CLIMATE CHANGE
38/2023

Final report

National Energy and Climate Plans: Evidence of Policy Impacts and Options for more Transparency

A Meta Study assessing Evaluations of selected Policies reported in the Danish, French, German, Slovenian, and Swedish Plan

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publisher:
German Environment Agency

German Environment Agency

Umwelt Bundesamt

CLIMATE CHANGE 38/2023

Forschungsplan of the Federal Ministry for
Economic Affairs and Climate Action

Project No. (FKZ) 3720 41 502 0

Report No. (UBA-FB) FB001166/ENG

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On behalf of the German Environment Agency

Imprint

Publisher
Umweltbundesamt
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06844 Dessau-Roßlau
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Report completed in:
April 2023

Edited by:
Section V 1.2 Strategies and Scenarios for Climate Protection and Energy
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Publication as pdf:
http://www.umweltbundesamt.de/publikationen

ISSN 1862-4359

Dessau-Roßlau, August 2023

Abstract: National Energy and Climate Plans: Evidence of Policy Impacts and Options for more Transparency

This study aims to contribute to the further development of the Member States' reporting to the EU with regard to the National Energy and Climate Change Plans (NECPs), especially with regard to the national progress reports, the NECP updates and a possible revision of the Governance Regulation.

The study was designed as a meta-analysis of the current state of knowledge regarding the methodology and impact of selected policies and measures (PaMs), following its appropriate preparation, by means of an analytical framework. The analysis was based on the example of the German NECP, taking into account the NECPs of Denmark, France, Sweden and Slovenia. In total, the authors examined a selection of 23 PaMs as well as ex-ante and ex-post evaluations that analysed the PaMs' impacts. The authors investigated, in particular, the methodology of ex-ante and ex-post evaluations, the contribution of selected PaMs to achieve the EU's climate protection and the energy transition targets adopted for 2030 as well as the socio-economic and further ecological impacts associated with the PaMs.

On this basis, the authors developed an in-depth understanding of the selected PaMs and the methodological and systemic uncertainties involved in their ex-ante and ex-post impact assessment. For this purpose, the authors discussed knowledge gaps, uncertainties, conflicts and synergies as well as political challenges, opportunities for action and obstacles to it. As a result, the authors have developed suggestions regarding the content requirements of NECP reporting as well as suggestions that can improve the transparency and traceability of evaluation methods and impact assessments of PaMs.

Kurzbeschreibung: Nationale Energie- und Klimapläne: Evidenz der Wirkung von Politikinstrumenen und Optionen für mehr Transparenz

Das Ziel dieser Studie ist es, einen Beitrag zur Weiterentwicklung der Berichterstattung der Mitgliedsstaaten an die EU mit Blick auf die nationalen Energie- und Klimaschutzpläne (NECPs) zu leisten, vor allem hinsichtlich der nationalen Fortschrittsberichte, der NECP-Updates und einer möglichen Revision der Governance-Verordnung.

Die Studie wurde als Metastudie konzipiert und umfasste die Aufbereitung des verfügbaren Wissensstands hinsichtlich Methodik und Wirkung ausgewählter Politiken und Maßnahmen (PaMs) mit Hilfe eines Analyserasters. Die Analyse erfolgte am Beispiel des deutschen NECPs unter Berücksichtigung der NECPs von Dänemark, Frankreich, Schweden und Slowenien. Die Autor*innen untersuchten eine Auswahl von insgesamt 23 PaMs sowie Ex-ante- und Ex-post-Evaluationen, welche die Wirkung der PaMs untersuchen. Die Autor*innen analysierten dabei insbesondere die Methodik von Ex-ante- und Ex-post-Evaluationen, die Beiträge der ausgewählten PaMs zum Erreichen des beschlossenen Klimaschutz- und Energiewendezielsystems der EU für 2030 sowie mit den ausgewählten PaMs zusammenhängende sozio-ökonomische und weitere ökologische Wirkungen.

Auf Basis dessen erarbeiteten die Autor*innen ein tiefgreifendes Verständnis der ausgewählten PaMs und den bei ihrer Ex-ante- und Ex-post-Wirkungsabschätzung auftretenden methodischen und systemischen Unsicherheiten. Zu diesem Zweck diskutieren die Autor*innen Wissenslücken, Unsicherheiten, Konfliktlinien und Synergien sowie politische Herausforderungen, Handlungsmöglichkeiten und -hindernisse. Als Ergebnis haben die Autor*innen Vorschläge bzgl. der inhaltlichen Anforderungen der NECP-Berichterstattung entwickelt sowie Vorschläge, die die Transparenz und Nachvollziehbarkeit von Evaluationsmethoden und Wirkungsabschätzungen von PaMs verbessern können.

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List of abbreviations

AECP	Agri-environmental and climate payments
ANEK	Action Plan for the Development of Organic Farming
APAE	Action Plan for the Aquatic Environment of Denmark
BAFA	Federal Office for Economic Affairs and Export Control
BBR	Building and Planning Building Regulations
BCIAT	Appel à projets national Biomasse Chaleur Industrie Agriculture Tertiaire
BEG	German Funding for Efficient Buildings Programme
BEHG	German Fuel Emissions Trading Act [Brennstoffemissionshandelsgesetz]
BMEL	German Federal Ministry for Food and Agriculture
BMF	Federal Ministry of FInance
BMU	German Federal Ministry for the Environment
BMWi	German Federal Ministry for Economic Affairs and Energy
CAP	Common Agricultural Policy
CAR	Climate Action Regulation
CH_4	Methane
CHP	Combined heat and power
CITE	French Energy transition tax credit
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalents
CPP	Climate Protection Programme 2030 of Germany
DHC	District heating and cooling
DKK	Danish krone
EEA	European Environment Agency
EED	Energy Efficiency Directive
EEWärmeG	German Act on the Promotion of Renewable Energies in the Heating Sector
EEX	European Energy Exchange
EFA	Ecological Focus Areas
ESD	Effort Sharing Decision
ESR	Effort Sharing Regulation
EU-ETS	EU Emissions Trading Scheme

EUR	Euro
F-gases	Fluorinated greenhouse gases
GDP	Gross Domestic Product
GGA	Green Growth Agreement of Denmark
GHG	Greenhouse gas
GOV-R	Governance Regulation
H&C	Heating and cooling
IPCC	Intergovernmental Panel on Climate Change
kg	Kilogramme
KIS	Agricultural Institute of Slovenia
kt	Kilotonnes
ktoe	Kilotonnes of oil equivalents
LULUCF	Land use, land use change and forestry
MAP	Market Incentive Program
MMR	Monitoring Mechanism Regulation
MS	European Member State
N	Nitrogen
N_2O	Nitrous oxide (laughing gas)
NEC	National emissions ceiling
NECP	National Energy and Climate Plan
NEHS	German national emissions trading system
NH_3	Ammonia
NRC	National Renovation Centre
PaMs	Policies and Measures
PJ	Petajoule (energy measuring unit)
RDP	Rural Development Programme
RED	Renewable Energy Directive
RES	Renewable Energy Sources
ROT	Renovation, conversion and extension deduction
SMEs	Small and medium-size enterprises
t	Tonne

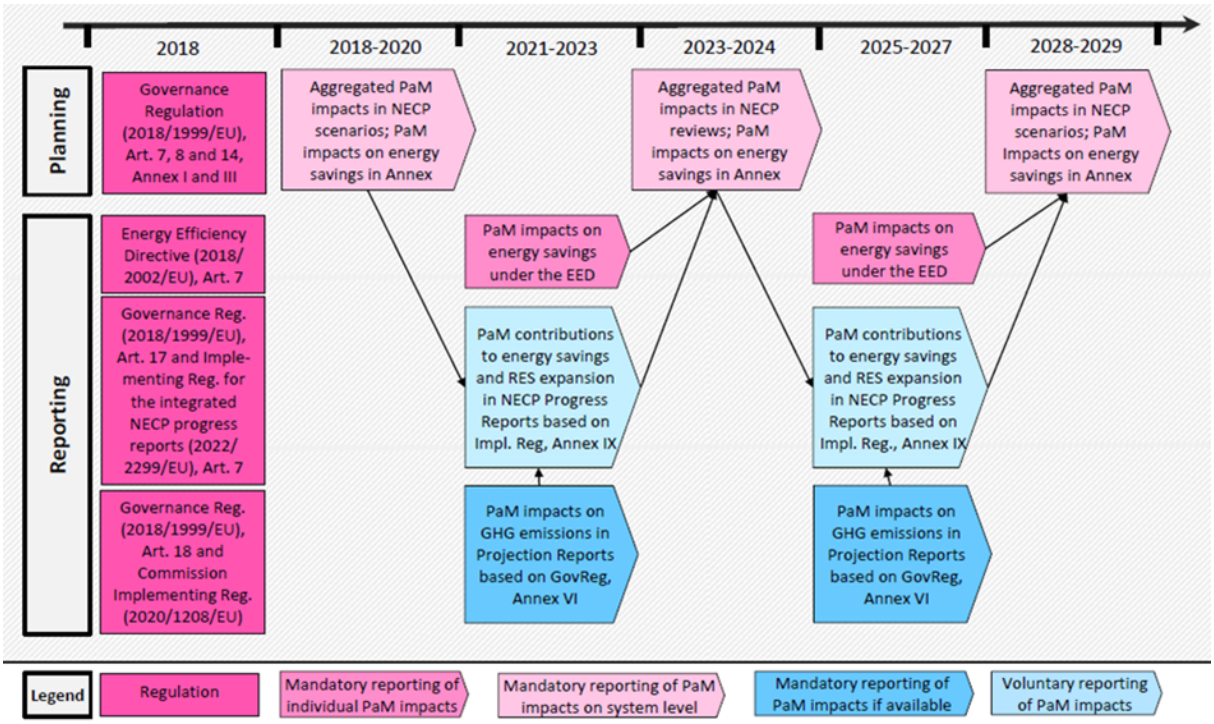
THG	Greenhouse gas
TWh	Terawatt hours (measuring units for energy)
UNFCCC	United Nations Framework Convention on Climate Change
Vzbv	Federation of German Consumer Organisations
WEM	With existing measures
WP	Work package

Summary

In its Governance Regulation (GOV-R), the European Union (EU) has set up a governance framework with key reporting obligations for all Member States (MS) that is intended to ensure that the EU meets its climate and energy targets for 2030. It includes a mechanism for monitoring the targets and plans of the MS (Integrated National Energy and Climate Plans - NECPs) and regulates the monitoring of actual progress in implementation. In the NECPs, MS have to present their national targets, contributions, strategies and policies and measures (PaMs) with respect to the five pillars of the Energy Union and back these with impact assessments. This includes the country-specific greenhouse gas (GHG) emission reduction targets as defined in the Effort Sharing Regulation (ESR), the increase in the share of renewable energies in gross final energy consumption as defined in the Renewable Energy Directive (RED), and the increase of energy efficiency as defined in the Energy Efficiency Directive (EED).

The GOV-R also includes instructions for integrated reporting on PaMs (Article 18.1(a)) and projections (Article 18.1(b)) with further detail provided by the Commission Implementing Regulation (EU) 2020/1208. So far, the reporting on PaMs was not linked to the NECPs; instead the information in the NECPs included projections for each of the five pillars of the energy union with existing and additional PaMs and descriptions of the underlying PaMs, but there was no obligation to show the effects on GHG emissions of single PaMs or groups of PaMs. In turn, there is the obligation that MS "shall report to the commission" (Article 18.1) "where available [...] *ex ante* [and *ex post*] assessments of the effects of individual or groups of policies and measures on the mitigation of climate change" in their PaM reports (Annex VI, c (v)). Moreover, MS will have to report certain impacts of their PaMs in the NECP progress reports, which are due in spring 2023. Figure 1 shows the current mandatory and voluntary stipulations for reporting PaM impacts under the GOV-R, in particular in the NECPs, the Progress Reports and the PaM reporting in the Projection Reports, and how these are linked.

Figure 1 **Overview of the reporting of PaM impacts with regard to energy and climate objectives across EU regulations (Summary)**



Source: own representation, Fraunhofer ISI

In the final Implementing Act on the NECP Progress Reports, which clarifies the reporting requirements and includes the reporting templates, the mandatory quantification and indicators refer to the operational level while reporting on the contributions to the overarching targets of GHG emission reduction, expansion of renewables and energy savings is voluntary. However, there is the mandatory requirement, albeit a qualitative one in our interpretation, to report the "[a]ssessment of the contribution of the policy or measure to the achievement of the Union's climate-neutrality objective […] and to the achievement of the long-term strategy […] (Regulation (EU) 2022/2299, Annex IX Table 1).

Objective and approach of this report

A major intention of introducing the GOV-R was to provide an integrated approach to planning and reporting on energy and climate policies, which was previously dispersed across several regulations. In particular, it linked the national planning in the NECPs to the reporting of policy impacts in the PaM reports via the NECP progress reports. Against this background, the objective of this report was to develop an in-depth understanding of the impact of the policy instruments that MS have included in their NECPs to reach their climate and energy targets. Key policy instruments from five selected NECPs were examined in four focus topics: carbon and energy pricing, renewable heating and cooling, energy-efficient buildings, and agricultural soils. The report shows the assessment of the expected impacts of these policy instruments and compared them with the findings of both ex-post and ex-ante evaluations. An additional objective was to gain insights into the methodological and systemic uncertainties when assessing the impact of policy instruments. The approach used was to analyse the information available in the literature regarding the impact of policy instruments in Denmark, France, Germany, Slovenia and Sweden (see Section 1.2). The selected PaMs are listed in Table 9.

In spite of the integrated approach of the Governance Regulation, the research process proved to be cumbersome, as the NECPs and the PaM reports were found to be still rather disjointed. In particular, the documents are made public via different platforms and in many cases are not accompanied by additional background information on the impacts of PaMs (see Section 2.1). Considerable efforts were therefore required to identify useful ex-post and ex-ante evaluations for the selected PaMs, if available at all (see Section 3.1). In total, evaluations for 23 different PaMs from our four topic areas were collected and analysed for this report. Overall, we assessed 50 evaluations, which represents an average of about two evaluations per PaM. Of these 50 evaluations, 23 were ex-post evaluations and 27 were ex-ante assessments. For three of the PaMs, no ex-post evaluation and for one no ex-ante assessment could be identified.

Regarding the content of the evaluations, 15 of the 23 ex-post and 17 of the 27 ex-ante evaluations quantify the GHG emission reductions of the respective PaMs. For energy savings, the numbers are 6 and 9, respectively, and for the impact on the increase in renewable energy, only 5 and 1. Overall, the availability of quantitative results is slightly better for the assessed ex-post evaluations than for the ex-ante assessments. With regard to socio-economic impacts of PaMs, only 6 evaluations provide quantitative assessments, 4 ex-post evaluations and 2 ex-ante assessments. From the ultimately quantitatively reviewed 41 evaluations, 24 have a direct reference to the respective NECP, i.e. that the numbers are either from the NECP or from directly cited official documents. About 30% of the evaluations with quantitative estimates were explicitly based on official guidelines (e.g. EU Better Regulation Guidelines or national guidelines). The findings of our assessment are provided in Section 3 for each of the four focus topics. The details of our assessment can be found in Annex A. Here, we summarise the contributions of specific PaMs to reach the national climate targets (see also Section 4.1.1 for the estimated emission reduction of each PaM).

Table 1 Overview of the selected PaMs (Summary)

Country	Carbon and energy pricing	Renewable heating and cooling	Energy-efficient buildings	Agricultural soils
Germany	CO_2 pricing in the heating and transport sector Energy and electricity tax	Heating networks systems 4.0 Market incentive programme (MAP)	Tax incentives for energy-related building renovations Federal funding for energy efficient buildings	Fertiliser ordinance Financial support for organic farming
Denmark	Mineral-oil Tax Act / Carbon tax Energy taxes / Carbon tax			Action Plan for the Aquatic Environment III Green Growth Agreement
France		Energy efficiency white certificates Heat Fund		
Slovenia		Obligatory share of heat from renewable energy sources, high-	Promoting energy efficiency and	Regional Development Programme with

Country	Carbon and energy pricing	Renewable heating and cooling	Energy-efficient buildings	Agricultural soils
		efficiency cogeneration and waste heat in district heating system Financial incentives for district heat production using renewable energy	renewable energy use in households Non-repayable investment financial incentives for energy rehabilitation of public sector buildings	Agri-Environmental Climate Payments (AECP) Upgrading agricultural policy - integrating climate policy and adapting to climate change
Sweden	Energy tax / Carbon tax		National Board of Housing, Building and Planning Building Regulations Local climate invest-ment programme (Climate Leap)	

Source: own representation, Fraunhofer ISI

Contribution of energy and carbon pricing

In general, the NECPs outline significant energy savings from energy and carbon pricing. Thus, these types of instruments may provide a major contribution to the 2030 climate target achievement of MS. But the energy savings are reported under the EED reporting obligation and tend to overestimate the effects in the context of the NECPs due to counterfactuals inappropriate for the NECPs. In addition, the stronger effects of taxes compared to ETS found in the literature should not lead to the conclusion that taxes are generally better suited to reduce CO_2 emissions. The very weak impact found in the ETS studies could be due to the fact that a large number of the studies focus on data from periods with low CO_2 prices in which, in addition, high amounts of free allocations were issued. More recent studies on the EU ETS focusing on the period from 2018 (higher prices and less free allocation) are not yet available. Although the impacts of energy and carbon pricing instruments measured in the scientific literature tend to be small, and the effects seem to be associated with energy efficiency improvements or fuel switch rather than transformation, these systems can still contribute to the transformation of the economy. Particularly in combination with support programmes that top up the market price (which is influenced by fossil fuel energy generators), price surcharges on fossil fuels can significantly reduce the necessary funding.

Contribution of PaMs in the field of renewable heating and cooling

The impact of PaMs to increase renewable heating and cooling shows a mixed picture across the PaMs and countries. Findings of the ex-post evaluation led to a positive assessment with regard to the performance of the German MAP, achieving around 70% of the annual target for the expansion of renewable H&C supply in the observation period. However, the ex-ante evaluation of the incentive scheme seems to overestimate the effect of the PaM on energy savings, while disregarding interaction effects. For the Heating Network Systems 4.0 program, the ex-ante evaluation outlines a broad range of the potential emission reduction depending on the funding amount. In France, the energy efficiency obligation scheme is likely to have led to considerably higher GHG emission reductions than the Heat Fund; in Slovenia as for the obligatory share of

heat from renewable energy sources, high-efficiency cogeneration and waste heat in district heating systems, no information is provided on the technologies and fuels used, so that it was not possible to make any further conclusions on the PaM's effectiveness. Their financial incentives for district heat production using RES likely fall short of meeting its targets. This is related to the PaM being undersubscribed and beneficiaries not making full use of the funds available.

Contribution of PaMs in the field of energy-efficient buildings

Energy savings and related emission reductions from the tax incentive and the federal funding for energy-efficient buildings in Germany are considered to be key PaMs but cannot reach the estimated energy savings of energy and carbon pricing. Still, the NECP and evaluations find that they can help to largely reduce GHG emissions. The two measures are not mutually exclusive and might, together, increase the number of investors, which means that the interaction between the two PaMs is seen as having a possibly positive effect. The evaluations for the Swedish PaMs showed that PaMs aiming at increasing energy efficiency in buildings could contribute to the goals, in particular in combination with the energy and carbon taxes. In the context of Slovenia, the evaluations found that the funding measures analysed were contributing to increasing energy efficiency in buildings, but also that the non-repayable investments were less effective than estimated before, possibly because challenges such as application for and access to the measure lowered the utilisation of the subsidies.

Contribution of PaMs in the field of agricultural soils

The analysis found that the reduction of fertiliser inputs through regulation and support programmes for improved management practices can lead to significant emission reductions. In Germany and Denmark, the focus is clearly on reducing N inputs to also reduce the related N_2O emissions and N leaching into waters. In Slovenia, the ex-ante evaluation however assumes a higher uptake of nitrogen by plants through improved agricultural techniques which leads to a reduction of N_2O emissions while still increasing the N input on agricultural land. Organic farming is promoted through area-based subsidies, which highly impact its expansion rate. When compared to the PaMs addressing a rational use of N fertilisers, organic agriculture shows a rather limited reduction of GHG emissions due to the rather low share of organic agriculture in total agricultural land. However, in all three countries ex-ante evaluations show an increase of land under organic farming. For both Germany and Slovenia, the ex-ante projections of the organic farming expansion rate exceed historical developments. At the same time, changing funding conditions and market fluctuations caused extreme fluctuations in the conversion rate for organic farming and evaluations mention the need for appropriate instruments, such as consumer information to ensure that there is sufficient demand for organic products, which becomes a greater challenge as the market share of organic farming increases.

The findings are synthesised across focus topics in Section 4. Here, we end with summarising the main conclusions and provide several suggestions how to increase transparency of NECPs with regard to PaM impacts.

How to improve the knowledge basis for transparent NECP updates

We found substantial knowledge gaps with regard to PaM impacts across all focus topics (see Section 4.2.3). Noting that our selection of PaMs was based on the availability of at least one ex-ante evaluation, we expect the overall knowledge gap to be even larger. Based on our findings, it is particularly important that there are several new types of PaMs in NECPs without ex-post evaluation, risking over-estimations in ex-ante evaluations. Consequently, we suggest to improve the knowledge basis for transparent NECP updates as follows:

- It is important that MS do ex-post evaluations of at least the main PaMs on a regular basis, with a focus on areas with limited progress, new types of PaMs, PaMs with the highest expected impacts and/or PaMs with particularly high administrative / implementing costs.
- GHG impacts should be made an integral part of agricultural evaluations, if this has not happened already.
- A centralised platform as already suggested by Fujiwara et al. (2019) would be a key step to increasing transparency and fostering a more informed selection and evaluation of policies.

While we acknowledge the progress made by the EEA catalogue and the PaM database in this regard (cf. EEA 2020a and EEA 2023), there is still substantial work needed to provide information in such a way that the link between evaluations, policies, NECPs and PaM reports becomes transparent.

How to increase transparency about the selection of policies and expected impacts in the NECPs

We found that the selection and design of PaMs in the NECPs was not fully grounded on evaluations. In this context, it became clear that NECPs rarely address barriers by accompanying PaMs, which puts the expected impacts at risk. In addition, NECPs generally do not sufficiently address uncertainties about PaM impacts, and in particular provide little information on net impacts and interactions with other PaMs. We also found significant uncertainties concerning the expected impacts from interactions between PaMs. Across all investigated PaMs, there was insufficient consideration of barriers to implementation or conflicts and synergies with other societal goals, which raises doubts about whether the ex-ante impact estimates can be realised (see Section 4.3). To improve the transparency of PaM selection and their role in the policy mix, we suggest to:

- Strengthen the role of NECPs in strategic planning of the policy mix towards 2030 by including information on the expected impact of single PaMs as well as the full policy mix.
- Enhance the NECPs with a better description of the role of specific existing and planned PaMs in the policy mix (such as to address barriers to implementation or conflicts with other societal goals).

The NECPs should also include the emission reduction estimates for the key PaMs that take into account the findings of ex-post evaluations.

How to increase transparency about uncertainties in the development and use of evaluations

Evaluations were based on various types of guidelines but did not often explicitly specify whether this was the case or not. Moreover, available ex-post evaluations were usually not linked to the preparation of NECPs and/or PaM reports. Differences in evaluations were often due to differences in the requirements of the relevant provisions and/or guidelines. This calls for a revision of certain guidelines for ex-post evaluations including the harmonisation of the reporting requirements under the EED and the Governance Regulation. To address uncertainties in a more transparent way, we suggest the following:

- Develop ex-post and ex-ante evaluations follow existing guidelines as much as possible.
- Integrate the requirement to measure the PaM contributions to the core objectives of energy and climate policy into all relevant policy evaluations and establish a consistent choice of baselines for such evaluations.
- Improve planning on the national level by using the same template for all ex-ante evaluations of PaMs, with mandatory reporting of available information and explicit coverage of the expected gross and net impacts as well as interactions with other PaMs.

- Ensure a clear description of PaMs including any potential changes over time and precise specification of the selected design parameters.
- The results of the evaluations should transparently communicate margins for input parameters and resulting corridors for the expected impacts.

How to foster more transparency by refining the integrated EU governance framework

The link between NECPs and policy evaluations was found to be rather weak across all areas. In this context, our results suggest that reporting requirements may be too limited. In particular, we have identified important gaps in reporting of PaM impacts with regard to energy and climate objectives across EU regulations: (1) There are no clear rules for harmonisation, in particular with regard to PaM names and baselines. (2) There is no explicit requirement to include PaM impacts from PaM Reports in NECPs and/or progress reports. (3) Reporting contributions to RES expansion (and energy savings other than EED Art. 7) is only voluntary. (4) There is no obligation to consider conflicts and synergies on the level of PaMs. Therefore, we suggest the following improvements to the EU governance framework:

- Enforce a high degree of harmonisation between NECPs, Progress Reports and PaM reports, in particular with regard to the aggregation and naming of included policies.
- Harmonise the baselines between NECPs, Progress Reports and PaM reports building on the requirements of the NECPs.
- If a MS keeps the PaM report separate from the NECP progress report, the progress report should clearly reference the PaM report and corresponding evaluations of PaMs.
- Make reporting the contributions of PaMs to RES expansion and energy efficiency mandatory if available.

Overall, we conclude that there is still room for improvement with respect to the integrated planning and reporting on PaMs envisioned by the GOV-R. We therefore recommend to carefully assess the issues we have raised here during the upcoming revision of the Governance Regulation and take into account options to enforce greater harmonisation between planning and reporting and increased transparency about the expected and achieved impacts of planned and established PaMs.

Zusammenfassung

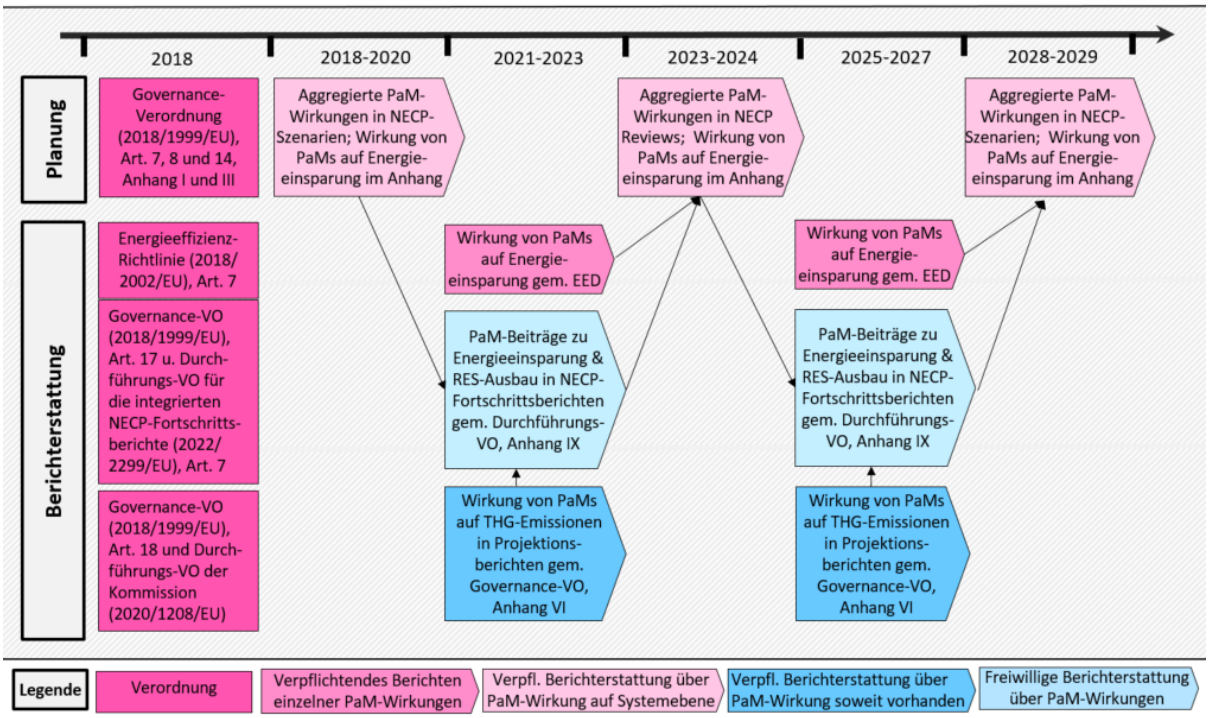
EU Governance-System für Energie- und Klimapolitik

Mit ihrer Governance-Verordnung (Engl.: GOV-R) hat die Europäische Union (EU) ein Governance-System geschaffen, welches die wichtigsten Berichtspflichten für alle Mitgliedstaaten (MS) regelt und sicherstellen soll, dass die EU ihre klima- und energiepolitischen Ziele für 2030 erreicht. Es umfasst Instrumente zur Überwachung der Einhaltung der Ziele und Pläne der MS (Integrierte Nationale Energie- und Klimapläne - NECPs) und regelt die Überwachung der tatsächlichen Fortschritte bei der Umsetzung. In den NECPs legen die MS ihre nationalen Ziele, Beiträge, Strategien und Politikmaßnahmen (Engl.: Policies and Measures, PaMs) im Hinblick auf die fünf Säulen der Energieunion fest und untermauern diese mit Wirkungsabschätzungen. Dies beinhaltet u. a. die länderspezifischen Ziele zur Reduzierung der Treibhausgasemissionen (THG) gemäß der Lastenteilungsverordnung (Engl.: ESR), den Ausbau der erneuerbaren Energien beim Bruttoendenergieverbrauch gemäß der Erneuerbaren-Energien-Richtlinie (Engl.: RED) und die Steigerung der Energieeffizienz gemäß der Richtlinie des Europäischen Parlaments und des Rates zur Energieeffizienz (Engl.: EED).

Die GOV-R enthält auch Anweisungen für die integrierte Berichterstattung über PaMs (Artikel 18.1(a)) und Projektionen (Artikel 18.1(b)). Weitere Informationen sind der Durchführungs-verordnung (EU) 2020/1208 der Kommission zu entnehmen. Bisher war die Berichterstattung über PaMs nicht mit den NECPs verknüpft; stattdessen enthielten die NECPs Projektionen für jede der fünf Säulen der Energieunion mit Beschreibungen der bestehenden und zusätzlichen PaMs, aber es bestand keine Verpflichtung, die Auswirkungen einzelner PaMs oder PaM-Gruppen auf die Treibhausgasemissionen aufzuzeigen. Dagegen verpflichten sich die MS (Artikel 18.1) in ihren PaM-Berichten „soweit verfügbar, […] Ex-ante-Bewertungen [und Ex-post-Bewertungen] der Auswirkungen der einzelnen Politiken und Maßnahmen oder Gruppen von Politiken und Maßnahmen auf den Klimaschutz […]“ aufzunehmen (Annex VI, c (v)). Darüber hinaus sind die MS verpflichtet, in den NECP-Fortschrittsberichten, die im Frühjahr 2023 vorzulegen sind, über bestimmte Auswirkungen ihrer PaMs zu berichten. Die finale Durchführungsverordnung (EU) 2022/2299 über die NECP-Fortschrittsberichte, welche die Anforderungen an die Berichterstattung verdeutlicht sowie die Berichtsformate und obligatorischen quantitativen Informationen und Indikatoren festlegt, bezieht sich auf die operationelle Ebene, während die Berichterstattung über die Beiträge zu den übergeordneten Zielen hinsichtlich der Verringerung der THG-Emissionen, des Ausbaus der erneuerbaren Energien und der Energieeinsparungen freiwillig ist. Es besteht jedoch die - wenn auch nach unserer Auslegung qualitative - Verpflichtung zur „Bewertung des Beitrags der Politik oder Maßnahme zur Verwirklichung des Unionsziels der Klimaneutralität […] und zur Umsetzung der langfristigen Strategie […]" (Durchführungsverordnung (EU) 2022/2299, Annex IX Tabelle 1).

Abbildung 2 zeigt die aktuellen Vorgaben für die verbindliche und freiwillige Berichterstattung über PaM-Auswirkungen im Rahmen der GOV-R, insbesondere in den NECPs, den Fortschrittsberichten sowie in der PaM-Berichterstattung der Projektionsberichte und wie diese miteinander verbunden sind.

Abbildung 2: Überblick über EU-Vorschriften bzgl. der Berichterstattung über PaM-Auswirkungen im Hinblick auf Energie- und Klimaziele (Zusammenfassung)



Quelle: Eigene Darstellung, Fraunhofer ISI

Ziel und Ansatz dieses Berichts

Ein wesentliches Ziel der Einführung der GOV-R war es, einen integrierten Ansatz für die Planung und Berichterstattung über die Energie- und Klimapolitik zu schaffen, die zuvor auf mehrere Verordnungen verteilt waren. Insbesondere verknüpft sie die nationale Planung in den NECPs mit der Berichterstattung über die Auswirkungen der Politik in den PaM-Berichten über die NECP-Fortschrittsberichte. Vor diesem Hintergrund war es das Ziel dieses Berichts, ein umfassendes Verständnis der Auswirkungen der politischen Instrumente zu entwickeln, welche von den Mitgliedstaaten in ihre NECPs aufgenommen wurden, um ihre Klima- und Energieziele zu erreichen. Untersucht wurden Schlüssel-Politikinstrumente aus fünf ausgewählten NECPs, unterteilt in vier Schwerpunktthemen: Kohlenstoff- und Energiebepreisung, erneuerbare Energien zur Erzeugung von Wärme und Kälte, energieeffiziente Gebäude und landwirtschaftlich genutzte Böden. Der Bericht stellt die Bewertung der erwarteten Auswirkungen dieser politischen Instrumente dar und vergleicht sie mit den Ergebnissen von Ex-post- und Ex-ante-Evaluationen. Ein weiteres Ziel war es, Einblicke in die methodischen und systemischen Unsicherheiten bei der Bewertung der Auswirkungen von Politik-Instrumenten zu gewinnen. Der Ansatz dieser Meta-Studie bestand darin, die in der Literatur verfügbaren Informationen über die Auswirkungen der Poltik-Instrumente in Dänemark, Frankreich, Deutschland, Slowenien und Schweden zu analysieren (siehe Abschnitt 1.2). Die ausgewählten PaMs sind in Tabelle 1 aufgeführt.

Trotz des integrierten Ansatzes der Governance-Verordnung erwies sich der Forschungsprozess als mühsam, da die NECPs und die PaM-Berichte nach wie vor recht unzusammenhängend sind. Insbesondere werden die Dokumente über verschiedene Plattformen veröffentlicht und sind in vielen Fällen nicht mit zusätzlichen Hintergrundinformationen zu den Auswirkungen der PaMs versehen (siehe Abschnitt 2.1). Es war daher schwierig, nützliche Ex-post- und Ex-ante-Bewertungen für die ausgewählten PaMs zu ermitteln, sofern diese überhaupt vorhanden waren

(siehe Abschnitt 3.1). Für diesen Bericht wurden Bewertungen von 23 verschiedenen PaMs aus unseren vier Schwerpunktthemen gesammelt und ausgewertet. Insgesamt wurden 50 Evaluationen untersucht, was im Durchschnitt etwa zwei Evaluationen pro PaM entspricht. Von diesen 50 Evaluationen waren 23 Ex-post-Evaluationen und 27 Ex-ante-Evaluationen. Für drei der PaMs konnte keine Ex-post-Evaluation und für eine PaM keine Ex-ante-Evaluation ermittelt werden.

Was den Inhalt der Evaluationen betrifft, so quantifizieren 15 der insgesamt 23 Ex-post- und 17 der insgesamt 27 Ex-ante-Evaluationen die THG-Emissionsreduktionen der jeweiligen PaMs. Sechs bzw. neun Evaluationen befassen sich mit der Auswirkung der PaM auf die Energieeinsparung, während nur fünf bzw. eine Evaluation die Auswirkung auf den Ausbau der erneuerbaren Energien betrachtet. Insgesamt ist die Verfügbarkeit quantitativer Ergebnisse bei den untersuchten Ex-post-Evaluationen etwas besser als bei den Ex-ante- Evaluationen. Was die sozioökonomischen Auswirkungen von PaMs betrifft, so liefern nur sechs Evaluationen quantitative Abschätzungen, wovon vier Ex-post und zwei Ex-ante-Evaluationen ausmachen. Von den letztlich 41 Evaluationen, die quantitativ überprüft wurden, haben 24 einen direkten Bezug zum jeweiligen NECP, d. h. die Zahlen stammen entweder aus dem NECP oder aus direkt zitierten offiziellen Dokumenten. Etwa 12 der Evaluationen mit quantitativen Abschätzungen stützten sich ausdrücklich auf offizielle Leitlinien (z. B. die EU-Leitlinien für eine bessere Rechtsetzung oder nationale Leitlinien). Die Ergebnisse unserer Bewertung für jedes der vier Schwerpunktthemen sind in Abschnitt 3 aufgeführt. Genauere Informationen zu unserer Bewertung finden sich in Anhang A, wo die Beiträge spezifischer PaMs zur Erreichung der nationalen Klimaschutzziele zusammengefasst sind (siehe auch Abschnitt 4.1.1 für den Beitrag einzelner PaMs zur Emissionsreduktion).

Tabelle 2: Überblick über die ausgewählten PaMs (Zusammenfassung)

Land	Kohlenstoff- und Energiebepreisung	Erneuerbare Energien für Wärme und Kälte	Energieeffiziente Gebäude	Landwirtschaftlich genutzte Böden
Deutsch-land	CO_2-Bepreisung im Wärme- und Transportsektor Energie- und Stromsteuer	Wärmenetzsysteme 4.0 Marktanreiz-programm (MAP)	Steuerliche Anreize für energetische Gebäudesanierungen Bundesförderung für energieeffiziente Gebäude	Düngeverordnung Finanzielle Unterstützung für ökologische Landwirtschaft
Dänemark	Mineralöl-steuergesetz / Kohlenstoffsteuer Energiesteuer / Kohlenstoffsteuer			Aktionsplan für die aquatische Umwelt III Vereinbarung über grünes Wachstum
Frankreich		Energieeffizienz-zertifikate ("weiße Zertifikate") Wärmefonds ("Fonds Chaleur“)		

Land	Kohlenstoff- und Energiebepreisung	Erneuerbare Energien für Wärme und Kälte	Energieeffiziente Gebäude	Landwirtschaftlich genutzte Böden
Slowenien		Obligatorischer Anteil von Wärme aus erneuerbaren Energiequellen, hocheffizienter Kraft-Wärme-Kopplung und Abwärme im Fernwärmesystem Finanzielle Anreize für die Fernwärme-erzeugung aus erneuerbaren Energiequellen	Förderung der Energieeffizienz und der Nutzung erneuerbarer Energien in Haushalten Nicht rückzahlbare finanzielle Investitionsanreize für die energetische Sanierung von Gebäuden des öffentlichen Sektors	Regionales Entwicklungs-programm mit Agrarumwelt- und Klimazahlungen (AECP) Modernisierung der Agrarpolitik - Integration der Klimapolitik und Anpassung an den Klimawandel
Schweden	Energiesteuer / Kohlenstoffsteuer		Nationale Behörde für Wohnungswesen, Bau und Planung Lokales Klima-Investitions-programm (Climate Leap)	

Quelle: Eigene Darstellung, Fraunhofer ISI

Beitrag von Energie- und Kohlenstoffbepreisung

Im Allgemeinen zeigen die untersuchten NECPs erhebliche Energieeinsparungen durch Energie- und Kohlenstoffbepreisung auf. Daher können diese Instrumenttypen einen wichtigen Beitrag zur Erreichung der Klimaziele der Mitgliedstaaten für 2030 leisten. Die im Rahmen der EED ausgewiesenen Energieeinsparungen überschätzen jedoch tendenziell die Auswirkungen im Zusammenhang mit den NECPs, da die kontrafaktischen Daten für die NECPs ungeeignet sind. Darüber hinaus sollten die in der Literatur festgestellten stärkeren Auswirkungen von Steuern im Vergleich zum EU-Emissionshandelssystem (ETS) nicht zu der Schlussfolgerung führen, dass Steuern generell besser geeignet sind, um CO_2-Emissionen zu reduzieren. Die in den ETS-Studien festgestellte sehr schwache Wirkung könnte darauf zurückzuführen sein, dass sich ein Großteil der Studien auf Daten aus Zeiten mit niedrigen CO_2-Preisen konzentrieren, in denen zudem hohe Mengen an kostenlosen Zuteilungen ausgegeben wurden. Neuere Studien zum EU-ETS, die sich auf den Zeitraum ab 2018 konzentrieren (höhere Preise und weniger kostenlose Zuteilungen), sind noch nicht verfügbar. Obwohl die in der wissenschaftlichen Literatur gemessenen Auswirkungen von Energie- und Kohlenstoffpreisinstrumenten eher mit inkrementellen als mit transformativen Maßnahmen in Verbindung gebracht werden, können diese Instrumente dennoch zur Transformation der Wirtschaft beitragen. Preisaufschläge auf fossile Brennstoffe können insbesondere in Kombination mit Förderprogrammen, die den Marktpreis aufstocken, die notwendigen Finanzmittel deutlich reduzieren.

Beitrag der PaMs zur Erzeugung von Wärme und Kälte aus erneuerbaren Energiequellen

Die Wirkung der PaMs zum Ausbau der erneuerbaren Energiequellen für die Wärme- und Kälteerzeugung zeigt ein gemischtes Bild über die verschiedenen PaMs und Länder hinweg. Die Ergebnisse der Ex-post-Evaluation führten zu einer positiven Wirkungsabschätzung des deutschen Marktanreizprogramms (MAP), das im Beobachtungszeitraum rund 70 % seines Jahresziels für den Ausbau der erneuerbaren Energien zur Wärme- und Kälteerzeugung erreichte. Die Ex-ante-Evaluation des Anreizsystems hingegen scheint die Auswirkung der PaM auf die Energieeinsparung zu überschätzen, da sie Wechselwirkungen außer Acht lässt. Für das Förderprogramm Wärmenetzsysteme 4.0 zeigt die Ex-ante-Evaluation eine breite Spanne an potenzieller Emissionsreduzierung auf, die je nach Höhe der Fördersumme variiert. In Frankreich dürfte das Energieeffizienzverpflichtungssystem zu wesentlich höheren THG-Emissionsreduktionen geführt haben als der Wärmefonds. Es war nicht möglich, Rückschlüsse auf die Wirksamkeit der PaM in Slowenien zu ziehen, was den obligatorischen Anteil von Wärme aus erneuerbaren Energiequellen, hocheffizienter Kraft-Wärme-Kopplung und Abwärme in Fernwärmesystemen betrifft, da keine Angaben zu den verwendeten Technologien und Brennstoffen gemacht werden. Die finanziellen Anreize für die Fernwärmeerzeugung aus erneuerbaren Energiequellen werden wahrscheinlich nicht ausreichen, um die Ziele Sloweniens zu erreichen. Dies hängt damit zusammen, dass die PaM nicht voll ausgeschöpft wird und die Fördernehmer*innen die verfügbaren Mittel nicht in vollem Umfang in Anspruch nehmen.

Beitrag der PaMs für energieeffiziente Gebäude

Die Energieeinsparungen und die damit verbundenen Emissionsminderungen durch steuerliche Anreize und die Bundesförderung für energieeffiziente Gebäude in Deutschland werden als wichtige PaMs angesehen, können jedoch schätzungsweise nicht die Energieeinsparungen durch Energie- und Kohlenstoffbepreisung erreichen. Der NECP und die Evaluationen zeigen jedoch, dass sie dazu beitragen können, die THG-Emissionen weitgehend zu reduzieren. Die beiden PaMs schließen sich nicht gegenseitig aus und könnten zusammen die Zahl der Investoren erhöhen, was bedeutet, dass die Interaktion zwischen den beiden PaMs eine möglicherweise positive Wirkung hat. Die Bewertungen der schwedischen PaMs zeigten, dass PaMs, die auf die Steigerung der Energieeffizienz in Gebäuden abzielen, insbesondere in Kombination mit der Energie- und Kohlenstoffsteuer, zur Erreichung der Ziele beitragen können. Für Slowenien ergaben die Bewertungen, dass zwar die analysierten Finanzierungsmaßnahmen zur Steigerung der Energieeffizienz in Gebäuden beitragen, aber auch die nicht rückzahlbaren finanziellen Investitionsanreize weniger wirksam waren als zuvor angenommen. Dies hängt möglicherweise damit zusammen, dass Herausforderungen bei der Beantragung der Gelder den Zugang zu den Subventionen verringerten.

Beitrag der PaMs für landwirtschaftlich genutzte Böden

Die Analyse ergab, dass die Verringerung des Düngemitteleinsatzes durch Vorschriften und Förderprogramme für verbesserte Bewirtschaftungsmethoden zu erheblichen Emissionsreduzierungen führen können. In Deutschland und Dänemark liegt der Schwerpunkt eindeutig auf der Reduzierung des Stickstoffeintrags, um die damit verbundenen N_2O-Emissionen und die N-Auswaschung in Gewässer zu verringern. In Slowenien wird bei der Ex-ante-Evaluation davon ausgegangen, dass die Pflanzen durch verbesserte landwirtschaftliche Techniken mehr Stickstoff aufnehmen, was zu einer Verringerung der N_2O-Emissionen führt, während gleichzeitig der Stickstoffeintrag auf den landwirtschaftlichen Flächen steigt. Der ökologische Landbau wird durch flächenbezogene Subventionen gefördert, die seine Ausbreitungsrate stark beeinflussen. Im Vergleich zu den PaMs, die sich mit Stickstoffdüngern befassen, zeigt der ökologische Landbau eine eher begrenzte Verringerung der THG-Emissionen aufgrund des eher geringen Anteils des ökologischen Landbaus an der gesamten

landwirtschaftlichen Fläche. Allerdings zeigen die Ex-ante-Evaluationen in allen ausgewerteten Ländern eine Zunahme der Anbauflächen im ökologischen Landbau. Sowohl für Deutschland als auch für Slowenien liegen die Ex-ante-Projektionen für die Expansionsrate des ökologischen Landbaus über den historischen Entwicklungen. Gleichzeitig führten veränderte Finanzierungsbedingungen und Marktschwankungen zu extremen Fluktuationen bei der Umstellung auf den ökologischen Landbau. In den Bewertungen wird auf die Notwendigkeit geeigneter Instrumente hingewiesen, um eine ausreichende Nachfrage nach ökologisch erzeugten Produkten zu gewährleisten.

In Abschnitt 4 erfolgt eine Synthese der Ergebnisse über alle Schwerpunktthemen hinweg. Hier fassen wir abschließend die wichtigsten Schlussfolgerungen zusammen und unterbreiten mehrere Vorschläge, wie die Transparenz von NECPs im Hinblick auf die Auswirkungen von PaMs erhöht werden kann.

Wie kann die Wissensbasis für transparente Aktualisierungen der NECPs verbessert werden?

Wir haben bei allen Schwerpunktthemen erhebliche Wissenslücken in Bezug auf die Auswirkungen von PaMs festgestellt (siehe Abschnitt 4.2.3). In Anbetracht dessen, dass unsere Auswahl der PaMs auf der Verfügbarkeit von mindestens einer Ex-ante-Evaluation basierte, gehen wir davon aus, dass die Wissenslücken insgesamt noch größer sind. Nach unseren Erkenntnissen ist es besonders wichtig, dass es in den NECPs mehrere neue PaM-Typen noch ohne Ex-post-Evaluation gibt, wodurch die Gefahr von Überschätzungen in Ex-ante-Evaluationen besteht. Daher schlagen wir vor, die Wissensbasis für transparente Aktualisierungen der NECPs wie folgt zu verbessern:

- Es ist wichtig, dass MS regelmäßig Ex-post- Evaluationen zumindest der wichtigsten PaMs durchführen und dabei den Fokus auf Bereiche mit begrenztem Fortschritt, neue PaM-Typen, PaMs mit den größten erwarteten Auswirkungen und/oder PaMs mit besonders hohen Verwaltungs-/Durchführungskosten setzen.
- Die Evaluierung der THG-Emissionsreduzierung sollte zu einem integralen Bestandteil von Evaluationen in der Landwirtschaft werden, soweit dies noch nicht geschehen ist.
- Eine zentrale Plattform, wie von Fujiwara et al. (2019) bereits vorgeschlagen, wäre ein wichtiger Schritt zur Erhöhung der Transparenz und zur Förderung einer besser informierten Auswahl und Bewertung von PaMs.

Wir erkennen zwar die Fortschritte an, die der EEA-Katalog und die PaM-Datenbank in dieser Hinsicht gemacht haben (vgl. EEA 2020a und EEA 2023), es sind jedoch noch erhebliche Anstrengungen erforderlich, um Informationen so bereitzustellen, damit die Verbindung zwischen Bewertungen, Politiken, NECP und PaM-Berichten transparent wird.

Wie kann die Transparenz bei der Auswahl der Politiken und der erwarteten Auswirkungen in den NECPs erhöht werden?

Wir stellten fest, dass die Auswahl und Gestaltung von PaMs in den NECPs nicht vollständig auf Evaluationen basierte. In diesem Zusammenhang wurde deutlich, dass in den NECPs nur selten Barrieren durch flankierende PaMs angegangen werden, was die erwarteten Wirkungen gefährdet. Darüber hinaus gehen die NECPs im Allgemeinen nicht ausreichend auf Unsicherheiten in Bezug auf die Wirkungen von PaMs ein und liefern insbesondere nur wenig Informationen über Nettowirkungen und Wechselwirkungen mit anderen PaMs. Wir haben auch erhebliche Unsicherheiten in Bezug auf die erwarteten Auswirkungen von Wechselwirkungen zwischen PaMs festgestellt. Bei allen untersuchten PaMs wurden Umsetzungshindernisse oder Konflikte und Synergien mit anderen gesellschaftlichen Zielen nur unzureichend berücksichtigt, was Zweifel daran aufkommen lässt, ob die Ex-ante-Wirkungsabschätzungen realisiert werden

können (siehe Abschnitt 4.3). Um die Transparenz bei der Auswahl von PaMs und ihrer Rolle im Policy-Mix zu verbessern, schlagen wir Folgendes vor:

- Stärkung der Rolle der NECPs bei der strategischen Planung des Policy-Mix bis 2030 durch Einbeziehung von Informationen über die erwarteten Wirkungen einzelner PaMs sowie des gesamten Policy-Mix.
- Verbesserung der NECPs durch eine bessere Beschreibung der Rolle spezifischer bestehender und geplanter PaMs im Policy-Mix (z. B. zur Beseitigung von Hindernissen für die Umsetzung oder von Konflikten mit anderen gesellschaftlichen Zielen).

Unter Berücksichtigung der Ergebnisse der Ex-post-Evaluationen sollten die NECPs auch Schätzungen der Emissionsreduzierung durch die wichtigsten PaMs enthalten.

Wie kann die Transparenz in Bezug auf Unsicherheiten bei der Entwicklung und Verwendung von Evaluationen erhöht werden?

Die Evaluationen stützten sich auf verschiedene Arten von Leitlinien, wobei jedoch häufig nicht ausdrücklich angegeben wurde, ob dies der Fall war oder nicht. Außerdem waren die verfügbaren Ex-post-Evaluationen in der Regel nicht mit der Erstellung von NECPs und/oder PaM-Berichten verbunden. Die Unterschiede in den Bewertungen waren häufig auf unterschiedliche Anforderungen in den einschlägigen Bestimmungen und/oder Leitlinien zurückzuführen. Dies erfordert eine Überarbeitung bestimmter Leitlinien für Ex-post-Evaluationen, einschließlich der Harmonisierung der Berichterstattungsanforderungen im Rahmen der EED und der Governance-Verordnung. Um Unklarheiten auf transparentere Weise zu beseitigen, schlagen wir Folgendes vor:

- Ausarbeitung von Ex-post- und Ex-ante-Evaluationen auf der Basis von bestehenden Leitlinien, soweit möglich.
- Integration der Anforderung in alle relevanten Politikevaluationen, die Beiträge der PaMs zu den Kernzielen der Energie- und Klimapolitik zu messen und Festlegung einer konsistenten Auswahl von Baselines für solche Evaluationen.
- Verbesserung der Planung auf nationaler Ebene durch Benutzung desselben Formats für alle Ex-ante-Evaluationen der PaMs mit verbindlicher Berichterstattung über verfügbare Informationen und expliziter Erfassung der erwarteten Brutto- und Nettowirkungen sowie der Wechselwirkungen mit anderen PaMs.
- Für eine klare Beschreibung der PaMs und eine genaue Spezifikation der gewählten Designparameter sorgen, einschließlich potenzieller Änderungen im Laufe der Zeit.
- Die Ergebnisse der Bewertungen sollten die Spielräume für die Eingangsparameter und die sich daraus ergebenden Korridore für die zu erwartenden Wirkungen transparent machen.

Wie lässt sich mehr Transparenz durch eine Verbesserung des integrierten EU-Governance-Systems fördern?

Die Verbindung zwischen den NECPs und den Politikevaluierungen wurde in allen Bereichen als eher schwach eingestuft. In diesem Zusammenhang deuten unsere Ergebnisse darauf hin, dass die Anforderungen an die Berichterstattung möglicherweise zu begrenzt sind. Insbesondere haben wir erhebliche Lücken in der Berichterstattung über die Auswirkungen von PaMs in Bezug auf die Energie- und Klimaziele in den EU-Verordnungen festgestellt: (1) Es gibt keine klaren Regeln für die Harmonisierung, insbesondere in Bezug auf PaM-Bezeichnungen und Baselines. (2) Es gibt keine explizite Anforderung, PaM-Wirkungen aus PaM-Berichten in NECPs und/oder Fortschrittsberichten aufzunehmen. (3) Die Meldung von Beiträgen zum Ausbau der

erneuerbaren Energien (und von Energieeinsparungen mit Ausnahme von EED Art. 7) ist nur freiwillig. (4) Es gibt keine Verpflichtung, Konflikte und Synergien auf der Ebene der PaMs zu berücksichtigen. Daher schlagen wir folgende Verbesserungen des EU-Governance-Systems vor:

- Durchsetzung eines hohen Maßes an Harmonisierung zwischen den NECPs, den Fortschrittsberichten und den PaM-Berichten, insbesondere im Hinblick auf Aggregation und Benennung der einbezogenen Politiken.
- Harmonisierung der Baselines zwischen NECPs, Fortschrittsberichten und PaM-Berichten auf Basis der Anforderungen der NECPs.
- Wenn ein MS den PaM-Bericht getrennt vom NECP-Fortschrittsbericht führt, sollte der Fortschrittsbericht eindeutig auf den PaM-Bericht und die entsprechenden Bewertungen der PaMs verweisen.
- Berichterstattung über die Beiträge von PaMs zum Ausbau der erneuerbaren Energien und zur Energieeffizienz, soweit vorhanden, verpflichtend machen.

Insgesamt kommen wir zu dem Schluss, dass die in der GOV-R vorgesehene integrierte Planung und Berichterstattung über PaMs noch verbesserungswürdig ist. Wir empfehlen daher, die hier aufgeworfenen Fragen bei der anstehenden Überarbeitung der Governance-Verordnung sorgfältig zu prüfen und Optionen für eine stärkere Harmonisierung von Planung und Berichterstattung sowie für eine erhöhte Transparenz über die erwarteten und erzielten Wirkungen geplanter und etablierter PaMs zu berücksichtigen.

1 Introduction

In the context of adopting the Paris Agreement in 2015, the European Commission (COM) set out the strategic principles of European climate protection and energy policy in its framework strategy for a crisis-proof Energy Union with a forward-looking climate protection strategy (COM/2015/080 final, EUR-LEX 2015). In a negotiation process that lasted until 2019, the COM, the EU Parliament and the Member States (MS) agreed on the legislative package "Clean Energy for All Europeans" (COM/2016/0860 final, EUR-LEX 2016), which puts these principles into a legal form together with the regulations on Effort Sharing (EU/ 2018/842 EUR-LEX 2018b) and Land Use, Land-Use Change and Forestry (EU 2018/841, EUR-LEX 2018a) as well as the Emissions Trading Directive (EC/2003/87, EUR-LEX 2003). Central components of the legislative package include the Governance Regulation (EU/2018/1999, EUR-LEX 2018e), the Renewable Energy Directive (EU/2018/2001, EUR-LEX 2018c) and the Energy Efficiency Directive (EU/2018/2002, EUR-LEX 2018d). Together, these set targets for 2030 of 40% reduction of greenhouse gases (GHG) emissions compared to 1990, 32.5% energy savings compared to a reference development (compare also EC 2016a) and 32% share of renewable energies in gross final energy consumption. In April 2021, the COM, the MS and the EU Parliament agreed on a European Climate Law (EU/2021/1119, EUR-LEX 2021f) which increased the 2030 target to a reduction of net GHG emissions by 55% compared to 1990. Draft revisions of the regulations on the i.a. Emission Trading Scheme (ETS) (COM/2021/551 final, EUR-LEX 2021c) as well as the Effort Sharing Regulation (COM/2021/555 final, EUR-LEX 2021e), the Renewable Energy Directive (RED) (COM/2021/557 final, EUR-LEX 2021b) and the Energy Efficiency Directive (EED) (COM/2021/558 final, EUR-LEX 2021d) were published as part of the Fit-for-55 package in July 2021 (COM/2021/550 final, EUR-LEX 2021a) and the REPowerEU package in Spring 2022 (COM/2022/108 final, EUR-LEX 2023a). A revision of the Governance Regulation (GOV-R) is planned for 2024 (EC n.d.a).

With the GOV-R, the EU has set up a governance framework with key reporting obligations for all MS. The aim was to better integrate the diverse obligations stipulated in the EED, the RED and the Monitoring Mechanism Regulation (MMR, Regulation EU/525/2013, EUR-LEX 2023b). Transparent, meaningful and well-founded reporting is essential for the validation of target achievement. Previous reporting had several shortcomings such as different interpretations of the obligations by MS and a partly narrow focus on reporting GHG emission reductions (Schoenefeld et al. 2018). In this respect, the GOV-R is an overarching legal act that is intended to ensure that the EU meets its climate and energy targets for 2030. It includes a mechanism for monitoring the targets and plans of the MS (Integrated National Energy and Climate Plans - NECPs), regulates the monitoring of actual progress in implementation, and determines respective timetables.

1.1 Policy impacts in the National Energy and Climate Plans

MS had to present their draft NECPs for the first time in 2018. After assessment by the COM, MS had to submit their revised NECPs by the end of 2019, taking into consideration the suggestions made by the COM. The plans were then reassessed (cf. EC 2020d) and published by the COM (cf. EC 2020c). The GOV-R also includes a timetable for future reporting and revisions in the context of the NECPs. By 30 June 2023, each MS must submit a draft update of its NECP to the COM and complete the update by 30 June 2024 (EU/2018/1999, EUR-LEX 2023b/EU, Art. 14 (1) and (2), EUR-LEX 2018e). In addition, MS shall submit a NECP progress report by 15 March 2023 and every two years thereafter (Regulation (EU) 2018/1999, Art. 17 (1) EUR-LEX 2018e)).

In the NECPs, MS have to present their national targets, contributions, strategies and policies and measures (PaMs) with respect to the five pillars of the Energy Union and back these with impact assessments. This includes the country-specific and binding non-ETS GHG targets (as defined in the Climate Action Regulation (CAR)/Effort Sharing Regulation (ESR)) and the energy targets - the increase in the share of renewable energies in gross final energy consumption (as defined in the RED II) and the increase of energy efficiency compared to a baseline development (as defined in the EED) – both of which are non-binding at national level. If the contributions of the MS are insufficient to achieve national and EU targets or their description does not meet the requirements of the GOV-R, the Commission can initiate additional actions (gap-filling mechanism) or recommend adjustments to the NECPs. However, their consideration or implementation is not obligatory for the MS (Treaty on the Functioning of the European Union (TFEU), Art. 288, EUR-LEX 2012; Regulation (EU) 2018/1999, EUR-LEX 2018e ; Official Journal of the EU 2019/C 297). Under Article 7 of the EED, MS are required to report the expected cumulated energy savings achieved by each of their energy efficiency PaMs. These estimates are to be included in the NECPs in an annex. However, the presented PaMs do not have to be fully consistent with those presented in the NECPs, and there is also no requirement to make any difference transparent.

The GOV-R also includes instructions for integrated reporting on PaMs (Article 18.1(a)) and projections (Article 18.1(b)) with further detail provided by the Commission Implementing Regulation (EU/2020/1208, EUR-LEX 2020). The instructions are in line with those in the preceding Monitoring Mechanism Regulation (MMR, EU/525/2013 EUR-LEX 2023b), which outlined the need for and stipulated consistent reporting of MS on emission projections and national PaMs and their impacts on GHG emissions. MS had to submit their reporting on projections (Article 14, MMR) and PaMs (Article 13, MMR) for the first time by 15 March 2015 and then every two years thereafter until 2019. In 2018, the MMR was substituted by provisions in the GOV-R and all report submissions from March 2021 are under the GOV-R. Under the MMR, the reporting on PaMs and on projections took place in two documents plus annexes in the form of tables. These are publicly available on the Eionet[1] in the Central Data Repository[2] under obligation "Greenhouse gas Monitoring Mechanism Regulation". As of 2021, reports on PaMs and projections (under the GOV-R) are available on Reportnet[3]. So far, the reporting on PaMs was not linked to the NECPs; instead the information in the NECPs included projections for each of the five pillars of the energy union with existing and additional PaMs and descriptions of the underlying PaMs, but there was no obligation to show the effects on GHG emissions of single PaMs or groups of PaMs (Articles 7 – 9). In turn, there is the obligation that MS "shall report to the commission" (Article 18 (1)) "where available […] *ex ante* [and *ex post*] assessments of the effects of individual or groups of policies and measures on the mitigation of climate change" in their PaM reports (Annex VI, c (v)). This missing link also results in some PaMs having different names/titles in the NECP and in the PaM reporting.

Moreover, MS will have to report certain impacts of their PaMs in the NECP progress reports, which are due in spring 2023. The final Implementing Act on the Progress Reports, which clarifies the reporting requirements and includes the reporting templates, was published on 6 September 2022[4] and adopted by the Commission on 15 November 2022 (EU/2022/2299)

1 The abbrevation stands for European Environment Information and Observation Network.

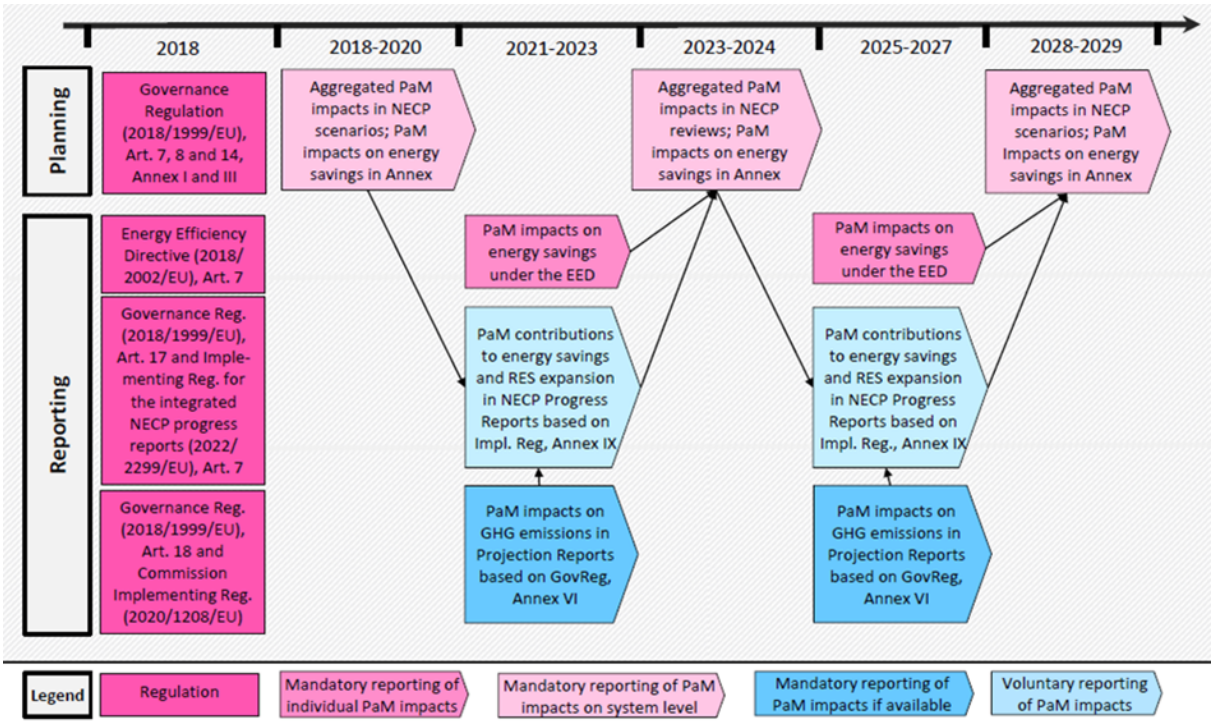
2 Eionet Central Data Repository. Available online at https://cdr.eionet.europa.eu/, last checked on 4 April 2023.

3 Repornet platform for reporting environmental and climate data to the EEA. Available online at https://reportnet.europa.eu/public/dataflows, last checked on 4 April 2023.

4 Comitology Register. Available online at https://ec.europa.eu/transparency/comitology-register/screen/documents/084049/1/consult?lang=en, last checked on 4 April 2023.

(EUR-LEX 2022). The template for reporting on PaMs is contained in "ANNEX IX Progress accomplished towards implementing the national policies and measures". The annex starts with mandatory reporting requirements, which include a description of the PaMs, their characterisation along certain dimensions as well as quantified objectives and progress indicators. While reporting such information is of course useful and important, the quantification and indicators refer to the operational level and not to the contributions to the overarching targets of GHG emission reduction, expansion of renewables and energy savings. However, there is the mandatory requirement, albeit a qualitative one in our interpretation, to report the "[a]ssessment of the contribution of the policy or measure to the achievement of the Union's climate-neutrality objective […] and to the achievement of the long-term strategy […]" (EU/2022/2299, Annex IX Table 1, EUR-LEX 2022). Concerning the contribution to the expansion of renewables and energy savings, there is a reporting template in the same annex, which asks for information quite similar to the data assessed in this report. Nevertheless, the reporting of such information is purely voluntary, thereby risking that no information is reported, as is currently often the case in the PaM reports. In addition, the reporting on PaMs and projections will feed into the NECP progress reports as of 2023 (EU/2018/1999, Article 17 (3), EUR-LEX 2018e), but the PaM reports can remain separate documents according to the Implementing Regulation for the NECP progress reports (EU/2022/2299, Article 7 (2), EUR-LEX 2022) shows the current mandatory and voluntary stipulations for reporting PaM impacts under the GOV-R, in particular in the NECPs and the progress reports, and how these are linked.

Figure 3 Overview of the reporting of PaM impacts with regard to energy and climate objectives across EU regulations



Source: own representation, Fraunhofer ISI

1.2 Objective of this report

The aim of the report is to provide an in-depth understanding of the impact of the energy and climate policy instruments[5] that the MS have included in their NECPs to reach their climate and energy targets. Therefore, this work assesses the expected impacts of selected key policy instruments and compares the impacts of different policy instruments addressing the same field. To this end, the expected impacts are compared to the findings of both ex-post and ex-ante evaluations. Here, *ex-post evaluations* are evaluations of historical impacts based on empirical evidence, while *ex-ante evaluations* are prospective estimates of impacts based on projections, models and/or justified assumptions. Prior to preparation of the NECPs, studies were made of EU energy and climate policy that had similar objectives (see in particular Fujiwara et al. 2019; Haug et al. 2010; Sandin et al. 2019). These studies found little systematic evaluation, and a lack of monitoring requirements (Haug et al. 2010) as well as too fragmented evaluation without sufficient coordination (Sandin et al. 2019). A specific goal of this report is therefore to examine whether the GOV-R has helped to overcome these shortcomings.

In order to achieve the objective, information from the literature regarding the impact of policy instruments in Germany and four other MS was analysed. The focus was on the contributions of policy instruments to achieving the former 2030 targets of 40% GHG emission reduction compared to 1990, 32.5% energy savings compared to a reference development and 32% share of renewables in gross final energy consumption, which was in force while the NECPs were prepared, as well as the recently agreed increase of the GHG emission reduction target to net 55% by 2030. We therefore concentrated on PaMs addressing carbon and energy pricing, the increase of energy efficiency, the expansion of RES as well as GHG emissions reduction in the agricultural sector. The work was structured in five work packages (WPs):

- WP 1 served to compile a literature database of relevant studies and research papers and to characterise and structure them as a basis for further work.
- WP 2 provided an analytical framework for a systematic evaluation of NECPs and ex-ante evaluations (WP 3) and ex-post evaluations (WP 4) of relevant policy instruments.
- WP 3 carried out a detailed evaluation of the NECPs of selected MS in relation to the policy instruments under consideration and their assumed impacts.
- Based on this, WP 4 compared the effects of policy instruments expected in the NECPs with suitable selected, already existing ex-post evaluations of policy instruments.
- WP 5 evaluated and discussed the results of WP 3 and 4 with regard to methodological consequences and substantive consequences in terms of achieving the national and EU energy and climate targets and the associated conflicts and synergies.

The results of the analyses are synthesised as follows:

- presentation of the impact of policy instruments and existing knowledge gaps;
- presentation of the methodological and systemic uncertainties when assessing the impact of policy instruments;
- presentation of conflicts and synergies in relation to the climate, energy, social and economic policy discussion on achieving the 2030 targets; and

[5] The terms measure, policy instrument and PaMs (policies and measures) are not used in a consistent manner in the literature. In this report, we consider measures to be the physical actions resulting in a contribution to climate and energy targets and policy instruments as the legislative acts triggering these measures. PaMs are considered a broader category, which aggregates the measures and their triggers.

- proposals for the further development of the NECP reporting processes and their relation to ex-ante and ex-post evaluations of policy instruments.

Particular emphasis is given to the comparison of selected PaMs in the German NECP to similar PaMs in other MS' NECPs. The remainder of this report is structured as follows. Section 2 presents the approach, the results of the literature research from WP 1 as well as the analytical framework developed for the evaluation of policy instruments in WP 2. Section 3 summarises the results from the review of policies in the selected NECPs as elaborated in WP 3 and WP 4. Annex A describes the application of the framework in detail, including the process of identifying and selecting the relevant PaMs. Section 4 synthesises the results with regard to their methodological and policy implications. Section 5 contains key conclusions and recommendations for increasing the transparency of PaM selection and their expected impacts in the NECPs.

2 Methodological approach and analytical framework

This section comprises (a) the selection of four NECPs in addition to the German NECP and related relevant focus topics to be analysed in detail; (b) the compilation of a literature database focusing on ex-ante and ex-post evaluations of policy instruments relevant to the NECPs and (c) the development of an analytical framework for the evaluation of PaMs given in the NECPs including a related guidance.

2.1 Selection of NECPs and related focus topics

A first systematic comparison of the NECPs[6] showed that, as a rule, it was not the impact of the individual PaMs or individual bundles of PaMs on GHG emissions, energy savings and the expansion of renewable energies that was presented, but rather the overall effect per sector. This is line with the content requirements for the NECPs according to GOV-R, which include an impact assessment on the system level with sectoral detail (see Section 1.1), but it means that the NECPs mostly do not allow deriving statements about the assumed impact of the measures. An exception is the energy saving effects according to Article 7 of the EED, which should be reported in an annex to the NECPs. The expected impact of PaMs with regard to the reduction of GHGs is, however, for the most part still reported by the MS in their PaM reports to the European Environment Agency (EEA)[7], which has shifted from the framework of the MMR to the corresponding one under the GOV-R. The PaM reports from 2019 and 2021 can therefore be used as an alternative source for the impact of PaMs. However, it should be noted that the resolution of the reported impact varies greatly between MS. In addition, MS also report certain effects of PaMs in their national progress reports under the RED II and the EED. Finally, a substantial number of scientific publications, national studies and databases provide additional insights.

This study is based on the evaluation of 23 PaMs selected from the German and four additional NECPs. The set of PaMs covered by a single NECP is usually larger. This means that only a limited subset of PaMs can be assessed for each NECP. In order to foster a useful overarching evaluation later on, the selection of the PaMs will focus on certain focus topics, which are meant to enable a comparison of the approaches in the various NECPs while also providing a broad overview of the NECPs. For the selected PaMs, concrete realisations in the form of policy instruments need to be identified in order to enable a later assessment of associated evaluations. Here, we describe the selection of both the NECPs and the focus topics and explain the deduction process of the relevant policy instruments.

2.1.1 Selection of relevant NECPs

The German NECP was selected by default, as one objective of the report is to compare the approach in the German NECP to others. The selection of further NECPs was carried out in two steps. In the first step, a list of six candidate NECPs was created based on an initial assessment of basic criteria. In the second step, this list was reduced to four NECPs based on a screening of the available literature on the NECPs and associated evaluations. This step included bilateral communication with national contact points for the development of the NECP. We very much appreciate the support and information provided by national contact points, which helped us a lot to understand the NECPs and to carry out the selection for this meta study.

[6] NECPs for all MS are available here: National energy and climate plans (NECPs) (europa.eu)

[7] PAM reports for all MS are available here: https://cdr.eionet.europa.eu/

In the first step, various criteria were considered in the selection process, in particular:

- Share of annual GHG emissions in total EU-27 emissions: This reflects the importance of the MS for the EU's climate targets.
- Upcoming EU Council Presidencies in the near future: This expresses the influence on the future design of the NECP process.
- Level of detail of NECPs and PaM reports: An evaluation of PaMs for which insufficient information is available yields little insight.
- Balanced geographical distribution within the EU: The starting points are diverse in different parts of the EU with regard to already implemented PaMs and the level of detail of planning for future PaMs.

Based on the above criteria, the MS listed in the following table were identified as particularly relevant for a more detailed screening.

Table 3: List of candidate NECPs considered

EU Member State	Share in EU-27 GHG emissions in 2020	Date of recent/upcoming EU Council Presidency	Level of detail of PaM report	Geographical location
Czechia	4%	1/2023	Medium to high	Central Europe
Denmark	1%	2/2025	High	Northern Europe
France	12%	1/2022	High	Western Europe
Germany	27%	2/2020	High	Central Europe
Slovenia	0.4%	2/2021	High	Central Europe
Spain	8%	2/2022	Medium	Southern Europe
Sweden	0,2%	2/2023	Low	Northern Europe

Sources: UBA (2022), EEA (2020b), European Council (2009)

In the second step, we looked more carefully at the available information and also considered the complementarity with regard to the German NECP in terms of national circumstances and policy instruments:

- The Czech 2019 PaM report is relatively detailed and consistent with the NECP. However, the general availability of relevant policy evaluations was found to be comparably low for Czechia in WP 1. Therefore, we decided not to select the Czech NECP for the further assessment.
- For the Danish NECP, evaluations informing its preparation were found to be available. Moreover, the advanced decarbonisation of heat supply was identified as a potential reference for comparison with the German NECP. These benefits made us select the Danish NECP in spite of the low level of detail of the Danish 2019 PaM report and the comparably low overall GHG emissions of Denmark.

- The French NECP and 2019 PaM report showed a high aggregation of key PaMs, resulting in a limited availability of relevant information on specific policy instruments. However, there is a high availability of evaluations of French policies. Moreover, France is the second largest emitter in the EU-27 (based on the GHG inventory data for 2020). In combination, we thus selected the French NECP for the detailed assessment.
- In spite of the low availability of evaluations of Slovenian policies, a set of evaluations informing the preparation of the NECP is available. Furthermore, the Slovenian 2019 PaM report is relatively detailed and consistent with the information in the NECP. Based on these considerations, we selected the Slovenian NECP for the further assessment.
- Spain is one of the largest emitters in the EU-27. In addition, there is a detailed evaluation of renewable electricity policies. However, PaMs are aggregated on a sectoral level both in the Spanish 2019 PaM report and the NECP. Moreover, the complementarity with the German NECP is relatively low due to the focus of evaluations on renewable electricity generation, which is also quite advanced in Germany.
- For the Swedish NECP, the strong focus on taxation of carbon dioxide emissions was identified as an important complement to the German NECP with its more diverse set of PaMs and the recently established fuel trading scheme. Therefore, we selected the Swedish NECP for the further assessment in spite of the low level of detail of the Swedish 2019 PaM report and the comparably low overall GHG emissions of Sweden.

In summary, the NECPs of Denmark, France, Slovenia and Sweden have been selected for the further assessment in addition to the German NECP. Key national 2030 targets from the five evaluated NECPs are presented in Table 4. While the ESR targets are quite similar for all NECPs except for Slovenia, the associated range of RES and energy efficiency targets is considerable.

Table 4: Key national 2030 targets in the evaluated NECPs

	Denmark	France	Germany	Slovenia	Sweden
GHG target under the ESR (comp. to 2005)	-39%	-37%	-38%	-15%	-40%
RES-E share in gross final energy demand	55%	33%	30%	27%	65%
Primary energy consumption vs. 2020	5%	-8%	-22%	-10%	-7%
Final energy consumption vs. 2020	4%	-8%	-5%	-8%	-2%

Sources: Danish Ministry of Climate, Energy and Utilities (2019), Federal Ministry for Economic Affairs and Energy] (BMWi) (2020), Ministère de la Transition écologique et solidaire (2020), The Government of the Republic of Slovenia (2020), Swedish Ministry of Infrastructure (2020)

2.1.2 Identification of investigated focus topics

As described in the introduction (see Section 1.1), an important issue of the assessment of the NECPs is the fact that the NECPs mostly provide information about the impacts of PaMs only aggregated on the level of sectors, but not on the level of individual or bundles of PaMs. For the German NECP, however, there is a certain partial set of PaMs, for which the assumed impacts of the PaMs or at least topical bundles is transparently provided in an ex-ante background study (see Harthan et al. 2020), namely those under the Climate Action Programme 2030. As this

programme was adopted in 2019, it contains PaMs that are newly established and have no long history of evaluations. Consequently, the PaMs corresponding to the Climate Action Programme 2030 can be considered particularly relevant for a review and comparison to similar PaMs in the NECPs of other countries. Accordingly, we compiled a list of focus topics based on the ex-ante assessment of the Climate Action Programme 2030, namely energy efficient buildings, renewable heating and cooling, CO_2 and energy pricing and agricultural soils.

For the other NECPs, the information about impacts of individual PaMs in the NECP is less transparent and scattered across various sources. However, the NECPs from the selected countries were rendered to be consistent with the PaM reports based on the information provided by national contact points, and the PaM reports provides quantitative information about the impact of individual PaMs for a certain subset of the PaMs covered by the NECPs (cf. EEA 2023). Therefore, the choice of focus topics for an assessment of corresponding evaluations was based on the information available in the 2019 PaM reports for the countries other than Germany. Given that the selection of NECPs considered the complementarity with the German NECP as a key criterion, this criterion was extended to complementarity with the identified German focus topics. To ensure relevance for the corresponding NECPs, the PaMs identified in the PaM reports were matched with PaMs described in the NECPs (cf. EC 2020c). In this way, we identified which of the selected NECPs to be seen as primary candidates for an in-depth analysis of the focus topics, and which NECPs to be used as back-up candidates in case of insufficient availability of required information in the primary candidates. Table 5 provides the resulting list of focus topics per country.

Table 5: List of focus topics per county for assessment of corresponding evaluations

Country	Energy-efficient buildings	Renewable heating and cooling	CO_2 and energy pricing	Agricultural soils
Germany	In-depth analysis	In-depth analysis	In-depth analysis	In-depth analysis
Denmark		Primary candidate for in-depth analysis	Primary candidate for in-depth analysis	Backup candidate for in-depth analysis
France	Backup candidate for in-depth analysis	Primary candidate for in-depth analysis	Backup candidate for in-depth analysis	Primary candidate for in-depth analysis
Slovenia	Primary candidate for in-depth analysis	Backup candidate for in-depth analysis		Primary candidate for in-depth analysis
Sweden	Primary candidate for in-depth analysis		Primary candidate for in-depth analysis	

Source: own represenatation, Fraunhofer ISI

In two cases, we had to replace a primary candidate with a back-up candidate due to insufficient availability of quantitative evaluations during the assessment, namely the Slovenian NECP was analysed with respect to the topic renewable heating and cooling instead of the Danish NECP, while the Danish NECP was analysed with respect to the topic agricultural soils instead of the French NECP.

2.1.3 Identification of relevant literature

The starting point for the assessment of the PaMs in the NECPs was a literature list that included ex-post and ex-ante evaluations of PaMs in the field of climate and energy policy. This literature database was meant to include literature that evaluated the effects of individual policy

instruments or topical bundles of instruments and focus less on evaluations of more aggregated bundles of PaMs, such as sectoral bundles. Moreover, a special focus lay on evaluations of PaMs that help to understand the NECPs of the MS.

While policy databases have been established by various actors such (e.g. by the IEA), there was no central database operated by an EU institution that systematically collected and compared evaluation results of climate and energy policies and analyses until recently. A first attempt in this regard has been made by the EEA (cf. EEA 2020a): they provide a catalogue of existing evaluations in the environmental sector (on individual measures, bundles of measures, programmes and projects), which is updated at regular intervals. The catalogue categorises evaluations based on their topic or sectoral focus and methodological approach, but does not provide evaluation results. In addition, the EEA provides the PaM database including related ex-ante GHG emission reductions per individual policy or measure, which MS report under the GOV-R and formerly under the MMR (cf. EEA 2023). The GOV-R (Annex VI) also asks for ex-post evaluation results for GHG emission reductions per individual policy or measure; however, this is no obligation and only a limited number of MS provide information on ex-post GHG emission reductions. An additional source for evaluations can be earlier meta-studies similar to ours (for instance Fujiwara et al. 2019 and Haug et al. 2010).

The starting point for the literature database were three sources provided by the German Environment Agency (UBA) to the project team (see Annex B.2). In addition, specific publications on specific PaMs of the NECPs have been added based on a literature search and information provided by the national contact points for the NECP preparation in the considered MS.

In a first step, all the mentioned lists of publications were analysed according to a set of selection criteria (see Annex B.2.1), which classified the sources as relevant or partially relevant. In a second step, the relevant and partly relevant publications were assigned to the topic areas relevant to this project and then assessed on the basis of further criteria (see Annex B.2.2). These criteria focus more on the content of the evaluation, *i.e.* the policy or measure, the sector targeted, the MS, the topic area (renewable energy, energy efficiency, etc.) or even the type of evaluation. These further criteria form the basis for categorising the literature and using filters for a literature search. In addition, for the relevant literature, the data list includes a brief description of the content of the sources. In addition, descriptive criteria were collected (see Annex B.2.3)

During the review of the NECPs and the assessment of the included PaMs, the literature database was constantly updated. This approach allowed gradually filling in existing gaps as well as to focus the literature list on the MS and PaMs that are relevant for the review carried out in this report.

Overall, a total of 317 publications are on the list representing neither a representative nor a comprehensive collection of literature in the topic field(s). During the work on WP 3 and 4, the project team added further publications that turned out relevant during the assessments.

Table 6 provides an overview of the number of publications per country and topic area whereby some publications cover more than one topic area or more than one country, so that the sum of the publications over the topic areas or over the countries does not provide any information about the number of all publications in the list.

In addition to Europe-wide publications, there is a focus on publications from Denmark, France, Germany and Sweden. The correlation with the selected NECPs is not surprising, as the national contact points for the NECPs were asked to provide literature relevant for their countries'

NECPs. Nevertheless, the Netherlands, Slovenia and the United Kingdom are also represented with a fairly high number. The best covered topic area is energy efficiency represented by 184 publications in the literature list, with a concentration of publications on the focus countries. The distribution of publications across the MS in the topic areas ETS/ESR and Renewable Energy is quite similar, with a total of 140 and 116 publications, respectively, with only nine publications in the area of renewable energy for France. The topic area of agriculture and F-gases is represented by only 83 publications in the literature list. In the focus countries France and Germany, this topic is also rather weakly represented with below ten publications. Overall, the coverage of the topics seems to be most balanced, mainly for Sweden and Denmark.

Table 6: Number of publications in the literature list per country and topic area

Country	Total per country*	Renewable Energies	Energy Efficiency	EU ETS and ESR	F-GHG, Agri-culture, etc.
Global	5	2	2	4	1
EU**	87	38	44	39	18
AU	1	0	1	0	0
BE	4	0	4	0	0
BG	1	0	1	0	0
CA	1	0	0	1	0
CZ	3	2	3	2	2
DE	35	17	21	13	7
DK	26	16	19	16	13
EE	2	0	1	0	1
ES	5	2	5	0	0
FI	7	1	3	3	0
FR	27	9	19	12	6
GR	3	0	2	0	0
IE	3	1	2	1	0
IS	1	1	1	0	0
IT	4	0	4	1	0
LT	1	0	0	0	1
LV	1	0	0	0	1
NL	16	0	7	6	3
PL	2	0	1	1	0
PT	1	0	0	0	0
SE	35	10	18	22	16
SI	18	10	10	10	9

Country	Total per country*	Renewable Energies	Energy Efficiency	EU ETS and ESR	F-GHG, Agri-culture, etc.
UK	14	2	11	3	2
Other	14	5	5	6	3
Total	**317**	**116**	**184**	**140**	**83**

* A publication can cover several topic areas, so that the sum of the publications of all topic areas can be larger than the total number per country. ** Includes publications analysing EU15, EU27 (UK or HR) and EU28. Source: own representation, Fraunhofer ISI

A larger share of the publications are ex-post evaluations (#139 in total) referring to an observation period in the past, in comparison to #89 ex-ante evaluations, which project potential future developments. Some publications may contain ex-post and ex-ante analysis. Publications that are not assigned to any of the categories are either databases, websites, or literature reviews that look at many evaluations, or the type could not be identified without a detailed check. In case of the focus countries, there is no concentration on ex-post evaluations, and for France and Sweden there are even more ex-ante evaluations available (see Table 7). However, at least two ex-ante and at least two ex-post publications per topic area are included in the literature list in the focus countries. Somewhat fewer ex-ante publications are found for Slovenia (only #2 or #3 per topic).

Table 7: Number of publications by topic area and ex-post/ex-ante assessment

Focus country	Ex-post Ex-ante	Renewable Energies	Energy Efficiency	EU ETS and ESR	F-Gases, Agri-culture, etc.
DE	Ex-post	13	15	9	4
	Ex-ante	7	6	6	4
DK	Ex-post	10	12	10	7
	Ex-ante	9	9	10	9
FR	Ex-post	4	10	7	2
	Ex-ante	6	10	6	5
SE	Ex-post	4	10	12	6
	Ex-ante	9	10	13	13
SI	Ex-post	8	8	8	5
	Ex-ante	2	2	3	3

Source: own representation, Fraunhofer ISI

Table 8 shows the number of publications across different sectors. "All" was indicated when (almost) all relevant sectors are looked at in the publications. This may be the case for CO_2 taxes, for example. Frequently, publications analyse not all but more than one sector, such as the building and transport sector. The publications have therefore always been classified in a way that highlights the focus of the analysis. Overall, publications that look at many or all sectors are most dominating in numbers. In addition, many publications focus on the building, electricity, industry or transport sectors. This is not surprising, as these are the most relevant sectors in terms of energy-related GHG emissions. Agriculture, land use, land use change and forestry

(LULUCF), and waste are other relevant sectors that are represented in the list but in a fewer number of publications.

Table 8: Number of publications in relevant sectors

Sector	Number*
All	72
Agriculture	33
Buildings	50
Education	1
Electricity	51
Energy	37
Financing	1
Forestry	5
Energy Grids/ Storage	2
Heat	14
Industry	57
LULUCF	12
Household appliances	3
Tertiary	7
Transport	56
Waste/ Wastewater	13

* Publications can cover more than one sector. Source: own representation, Fraunhofer ISI

The work of the bibliography was focused primarily on reviewing the existing lists and databases (see Annex B.2) and rating and categorising sources relevant to this project. It is noticeable that these lists and databases contained no or only few policy instruments or specific evaluations regarding agricultural policy.

Overall, the number of publications seems to be adequate as a starting point for the assessment of the impact of PaMs covered by the NECPs, especially in the focus countries.

2.2 Developing the analytical framework

An analytical framework was used to collect the relevant information for selected policy instruments from various ex-post and ex-ante evaluations. It includes information categories to collect information on the policy instrument, the evaluation methodology and the evaluation outcome in a structured way.

Evaluations of policy instruments vary in terms of their methodologies, data sources and coverage of impacts (see e.g. OECD 2019). The analytical framework should be able to capture the wide range of information provided in evaluations. At the same time, it should streamline information to enable the comparison of methodologies and expected impacts of instruments,

capture individual specifics from evaluations while also asking for a short and simple assessment if provided information is clear and comprehensible.

Identification of categories and criteria

For this study, we defined three categories to separate information about a) policy instruments, b) methodology of the evaluation and c) the results of the evaluation in terms of impacts of the instrument.

For each of the three categories, we defined criteria that describe specific aspects of the category summing up to 104 criteria in total. These criteria are split into further sub-criteria which in turn are specified using guiding questions. For a better understanding of the different sub-criteria, additional explanations and examples complement the framework.

The selection of criteria for category 1 on the policy instrument focused mainly on the information coverage suggested by the EEA policies and measures database. We excluded information that is easily derivable from other information we requested such as the IPCC emission category. The instrument classification is based on Bemelmans-Videc et al. (2007).

The selection of criteria for category 2 on the evaluation context and methodology is mainly based on the criteria provided in the EEA catalogue of policy evaluations. Here, we excluded the criterion on the used evaluation technique as evaluation generally use a set thereof, also depending on the evaluation criterion. We also found that the information is rather difficult to identify while it provides no to little insights. Instead, we added transparency of the methodology to better understand if evaluations clearly describe their methodologies as well as the "impact measurement and related assumptions" criterion which asks for information on the impact measurement in particular with respect to the reference case. The selection of criteria for category 3 on the outcome of the evaluation for the policy instrument is based on the better regulation guidelines of the EC (2021b) including the guidelines on impact assessment (Chapter III) and evaluation (VI). We also consulted the OECD best practice principles for regulatory policy (mainly OECD 2020a, 2020b) and the EEA catalogue on policy evaluations and its criteria (EEA 2016) and guidance on impact assessment in Germany (Böhret et al. 2000). For clarification of specific criteria, we referred to further literature (in particular Bemelmans-Videc et al. 2007; Böhret et al. 2000; Duval 2008; Serres et al. 2010).

All guidelines somewhat state that evaluations should cover "relevance", "effectiveness", "efficiency", "coherence". We consider all of these criteria. Thereby, a key focus of the analytical framework is on the "effectiveness" of the policy instrument. Here, it asks for details on the reference period, the estimated impacts on energy savings, expansion of renewables and reduction of GHG emissions for the overall evaluation period as well as for specific years to make results comparable. For all criteria, the analytical framework asks if the evaluation provides a conclusion (such as: Does the evaluation state if the policy instrument is relevant, effective, efficient, coherent?). Besides, the COM guidelines also refer to "EU added value" of a policy instrument, which we, however, excluded from the list. It asks for the changes that have happened due to the EU intervention and is thus not directly transferable to the country level. It also does not add relevant information to the criteria set which already ask for the link between the observed impacts and the policy instruments and any overlaps with other policy instruments.

In addition, we included socio-economic and environmental criteria, which we derived from the better regulation toolbox (EC 2021c) (including #29 on "employment, working conditions, income distribution, social protection and inclusion") and from the sustainable development goals (United Nations n.d.). We considered economic impacts (e.g. impacts on investment, Gross Domestic Product (GDP), competitiveness), social impacts (e.g. on employment and citizens' welfare) and on the

environment (e.g. on resource use, water, land, biodiversity etc.). In category 2 and 3, the analytical framework includes a request to the project experts to state on any concerns they may have with respect to the information provided in the evaluation. This gives them the chance to state any criticism on the methodology and/or results and may help in understanding differences in evaluation outcomes at a later stage.

The setup of the analytical framework was described in detail for its use by the evaluators and the set of criteria was subject to a test round with six evaluations (see Annex B.1).

2.3 Selection of policy instruments and application of criteria

Here, we describe how the considered policy instruments and associated evaluations were identified and how the selected evaluations were assessed.

2.3.1 Screening of the NECP with respect to the selected focus topics

The first step was to screen the selected NECPs with respect to the selected focus topics and to summarise how the NECP covers the focus topic, based on the following questions:

- Is the focus topic addressed explicitly by the NECP, for instance in a dedicated subsection?
- Is the information on the focus topic clustered or scattered in the NECP?
- Are there individual targets for the focus topic in the NECP, for instance a targeted share of renewable heat, and if so, which?
- Is there an overarching national strategy for the focus topic, for instance a buildings efficiency strategy?
- Is a general approach to the focus topic described?
- Does the NECP feature key policy instruments regarding the focus topic? Which ones?

2.3.2 Identification of the relevant PaMs and selection of the policy instrument(s) to be evaluated

Next, the relevant PaMs were identified for each focus topic. To this end, all PaMs from the NECPs and the 2019 PaM reports that were attributable to the focus topics were collected in one list per topic. In case there were PaMs relating to several focus topics, for instance both energy efficient-buildings and renewable heating and cooling, these were added to both lists noting the other relevant focus topics.

For the further evaluation, the two to three most relevant PaMs in each of the NECPs were selected to be considered in the further evaluation. The main selection criterion was the relative importance in the focus topic (based on the reported impact in the NECP if any or based on expected GHG emission reduction in the 2019 PaM report). If there was insufficient quantitative information readily available, the selection was based on qualitative information in the NECP (e.g. based on its prominent discussion therein) as well as the relevance for a comparison with the German NECP.

The PaM can refer to specific policy instruments (e.g. a feed-in tariff, a tax or a standard) or it refers to a broader action or measure. In the latter case, the relevant policy instruments were identified and the most relevant (bundle of) policy instrument(s) was chosen for the further evaluation based on the NECPs and/or the 2019 PaM reports if possible. Otherwise, additional country-specific information was evaluated.

2.3.3 Review of the scientific literature on impact of climate policies under the focus topics

Usually, impact assessments of policies are mostly based on grey-literature studies tied to the particular policy instruments. While this seems the most suitable approach, it is important to consider such assessments in the light of empirical findings on their verified and expected impacts in the scientific literature. In the next step, we therefore carried out a review of the scientific literature on policies under the focus topics, mainly considering the available literature reviews and cross-study comparisons. For CO_2 and energy pricing, there was a particular emphasis on the literature comparing the impacts of taxes to tradings schemes, while for energy efficient buildings and renewable heating and cooling, the emphasis was the main barriers (both financial and non-financial) to the realisation of the PaM impacts. More details are contained in Annex A.1.1, A.2.1 and A.3.1.

2.3.4 Selection of ex-ante and ex-post evaluations

In the next step, one ex-ante and one ex-post evaluation of each policy instrument was selected to be assessed in detail. The starting point for this was the literature database (see Section 2.1.3) but in most cases, there was a need to search for additional evaluations.

For the ex-ante evaluation, the following hierarchy of sources (in the order of importance) was used:

- NECP and/or background studies of the NECP,
- PaM reports and/or background studies of the PaM reports,
- any other ex-ante assessment of the exact policy instrument,
- any other ex-ante assessment of an earlier or an updated version of the policy instrument.

For the ex-post evaluation, if there was one evaluation that addressed the exact policy instrument in the given country (maybe in a former version), this ex-post evaluation was selected for the further analysis. However, this was not the case for some of the policy instruments. Instead, evaluations that at least deal with a similar policy instrument (meaning that it is the same type of instrument and addresses (almost) the same (sub)sector and target group/s) but in another country were identified. In the latter case, the best matching ex-post evaluation was selected and the analysis was complemented with the assessment of a second ex-ante evaluation if available.

2.3.5 Application of the analytical framework

Then, the categories and criteria developed above were applied to the selected ex-ante and ex-post evaluations. The findings about the expected contributions to the EU energy and climate target were compared and other findings from the assessment of the evaluations were summarised. In particular, the first iteration of the assessment addressed the following guiding questions:

- Is there a clear link between the assessed ex-ante evaluation and the NECP e.g. in the form that the NECP uses information from the evaluation (incl./excl. citation)?
- Is there a clear link between the assessed ex-post evaluation and the NECP e.g. in the form that the NECP uses information from the evaluation (incl./excl. citation)?
- Is it possible to assess the plausibility of the expected impacts based on the assessed evaluations?

In a second iteration of the assessment which included an additional literature review on synergies and conflicts with other EU objectives, the following further guiding questions were addressed:

- Do the evaluations address design issues and barriers identified in the scientific literature review and do the NECPs include accompanying PaMs to address these?
- Are main conflicts and synergies with other EU targets covered in the NECPs and the evaluations, respectively, and do the NECPs include accompanying PaMs related to these conflicts and synergies?

For CO_2 and energy pricing, the main EU objective considered in this context was the targeted just transition, with a focus on distributional impacts; for renewable heating and cooling, it was conflicts and synergies with the reduction of air pollution; for energy efficient buildings, it was cross-impacts with employment and labour markets; and for agricultural soils, it was conflicts and synergies with the improvement of water quality, employment and agricultural productivity.

3 Summary of the results from the review of policy impacts

This section provides an overview of the results from the application of the analytical framework to the selected NECPs and the related evaluation of policies for each of the four focus topics. The findings are synthesised across focus topics in Section 4. The selected PaMs are listed in Table 9.

Table 9 Overview of the selected PaMs

Country	Energy-efficient buildings	Renewable Heating and Cooling	Carbon and energy pricing	Agricultural soils
Germany	Tax incentives for energy-related building renovations Federal funding for energy efficient buildings	Heating networks 4.0[8] Market incentive programme (MAP)	CO2 pricing in the heating and transport sector Energy and electricity tax	Fertiliser Ordinance Financial support for organic farming
Denmark			Mineral-oil Tax Act / Carbon tax Energy taxes / Carbon tax	Action Plan for the Aqua-tic Environment III Green Growth Agreement
France		Energy efficiency white certificates Heat Fund [2009-2018]		
Slovenia	Promoting energy efficiency and renewable energy use in households Non-repayable investment financial incentives for energy rehabilitation of public sector buildings	Obligatory share of heat from renewable energy sources, high-efficiency cogeneration and waste heat in district heating system Financial incentives for district heat production using renewable energy		Regional Development Programme with Agri-Environmental Climate Payments (AECP) Upgrading agricultural policy - integrating climate policy and adapting to climate change
Sweden	National Board of Housing, Building and Planning Building Regulations Local climate invest-ment programme (Climate Leap)		Energy tax / Carbon tax	

Source: own representation, Fraunhofer ISI

[8] Since 15 September 2022, the PaM Heating Networks 4.0 has been replaced by the new federal funding for efficient heating networks (Bundesförderung für effiziente Wärmenetze; BEW).

The following subsection 3.1 provides an overview of the number and scope of evaluations identified in the project and summarise the findings for each of the focus topics. In subsections 3.2 – 3.5, we look at the focus topics in more detail. Each of the subsections includes a detailed summary table covering all the selected PaMs for the corresponding focus topic. We note that all of this is a concise summary of our extensive analysis provided in Annex A. The details of the application of the framework including the process of identification and selection of relevant PaMs and all the sources considered can be found in Annex A.

3.1 Overview of the number and scope of the identified ex-ante and ex-post evaluations

We start with the overview about number and content of evaluations assessed across all focus topics and then continue with a summary for each focus topic.

3.1.1 Overview on topics and Member States

In total, evaluations for 23 different PaMs from our four topic areas and from six different EU Member States were collected and analysed for this report. In terms of the type of PaM, of all the PaMs analysed in this report, 13 (57%) are active support policies, 3 (13%) are taxes and charges, 3 (13%) are command and control policies, 2 (9%) are tradable permits and 2 (9%) are quotas and obligations. Except for carbon and energy pricing, where taxes are the dominant instrument, active support policies are the most common PaM type in all other topics. Overall, we assessed 50 evaluations, which represents an average of about two evaluations per PaM. Of these 50 evaluations, 23 were ex-post evaluations and 27 were ex-ante assessments (see Table 10). For three of the PaMs, no ex-post evaluation and for one no ex-ante assessment could be identified. Reasons for a lack of evaluations in certain cases are discussed in Section 4.2.3.

Regarding the content of the evaluations, 15 (65%) of the ex-post and 17 (63%) of the ex-ante evaluations quantify the GHG emission reductions of the respective PaMs. For energy savings, the numbers are 6 (26%) and 9 (33%), respectively, and for the impact on the increase in renewable energy, only 5 (22%) and 1 (4%), respectively, of the analysed evaluations provide data. Overall, the availability of quantitative results is slightly better for the assessed ex-post evaluations than for the ex-ante assessments. With regard to socio-economic impacts of PaMs, only 6 evaluations (12% overall) provide quantitative assessments, 4 (17%) ex-post evaluations and 2 (7%) ex-ante assessments. Other issues such as cost-effectiveness, implementation costs, investments triggered, etc. are addressed in 9 (39%) of the identified ex-post evaluations and in 8 (30%) of the identified ex-ante assessments. From the ultimately quantitatively reviewed 41 evaluations, 59% (24) have a direct reference to the respective NECP, i.e. that the numbers are either from the NECP or from directly cited official documents. In the topic areas of energy and carbon pricing and agriculture, the share was significantly lower than in the other two topic areas, at 43% and 33% respectively. With regard to the quantitative estimates based on official guidelines (e.g. EU Better Regulation Guidelines or national guidelines), the share is about 30%, whereby official guidelines were used only in the topics renewable energy (56%) and energy efficiency (43%). In the topics of agriculture and energy and carbon pricing, the evaluations analysed are not based on official guidelines or it was not explicitly mentioned.

Looking at the differences between topic areas, comparably few of the assessed evaluations in the agricultural topic show quantitative results on the analysed aspects, whereas the coverage of the evaluations in the other focus topics is relatively similar. Not surprisingly, evaluations of RES PaMs coverage of RES expansion is above average, while energy efficiency PaMs consider energy savings more often. Table 10 summarises the results.

Table 10: Number of evaluations per topic and share of evaluations with certain content

	Energy and carbon pricing	RES Heating and Cooling	Energy-efficient buildings	Agricultural soils	Total
Ex-post (#)	**4**	**7**	**6**	**6**	**23**
- GHG emissions	75%	71%	67%	50%	65%
- Energy savings	25%	29%	50%	0%	26%
- RES expansion	0%	57%	17%	0%	22%
- Socio-economic impacts	25%	29%	17%	0%	17%
- Other impacts	50%	43%	50%	17%	39%
Ex-ante (#)	**7**	**8**	**6**	**6**	**27**
- GHG emissions	57%	63%	83%	50%	63%
- Energy savings	71%	13%	50%	0%	33%
- RES expansion	0%	13%	0%	0%	4%
- Socio-economic impacts	0%	25%	0%	0%	7%
- Other impacts	29%	25%	50%	17%	30%

Source: own calculation, Fraunhofer ISI

Table 10 shows the identified evaluations at the Member State level. Overall, we identified the most evaluations for Germany. This is not surprising since we considered German PaMs in each topic area, which was not the case for the other Member States. However, the share of ex-ante assessments with quantitative results was relatively low for Germany compared to the other four Member States considered. This is due to the fact that some German ex-ante assessments look at bundles of measures such like the climate protection programme, which means that the impacts of the individual PaMs cannot be identified. Only French evaluations quantitatively considered socio-economic impacts, except for two evaluations of German PaMs.

Table 11: Number of evaluations per Member State and share of evaluations with certain content

	France	Germany	Denmark	Sweden	Slovenia	Total
Ex-post (#)	**3**	**6**	**4**	**4**	**6**	**23**
- GHG emissions	67%	67%	100%	50%	50%	65%
- Energy demand	0%	50%	0%	25%	33%	26%
- RES expansion	33%	50%	0%	0%	17%	22%
- Socio-economic impacts	67%	33%	0%	0%	0%	17%
- Other impacts	67%	17%	75%	25%	33%	39%

	France	Germany	Denmark	Sweden	Slovenia	Total
Ex-ante (#)	**2**	**12**	**4**	**2**	**7**	**27**
- GHG emissions	100%	58%	75%	50%	57%	63%
- Energy demand	0%	50%	0%	50%	29%	33%
- RES expansion	50%	0%	0%	0%	0%	4%
- Socio-economic impacts	100%	0%	0%	0%	0%	7%
- Other impacts	100%	8%	75%	0%	29%	30%

Source: own calculation, Fraunhofer ISI

3.2 Carbon and energy pricing in Denmark, Germany and Sweden

Countries raise energy taxes on the final consumption of electricity, gas, coal, and petroleum products, which are mainly paid by private households as well as the service sector for housing and transport with exemptions for energy-intensive industries. The three selected countries have been levying energy taxes for many years and primarily intended to generate government revenues rather than implement climate protection policies. Complementary to energy taxes, this study also assesses evaluations related to the national emissions trading system (nationales Emissionshandelssystem, nEHS) in Germany and the CO_2 tax in Sweden.

The number of available assessments for PaMs reported in the Danish, German, and Swedish NECP is limited especially when focusing on the period between 2010 and 2030. Available scientific studies (see reviews by Green 2021; Lilliestam et al. 2021) preferably investigate energy and carbon taxes in the Nordic countries but often focus on the period before 2010, which prevent a comparison with the figures reported in the NECPs. Reasons for the limited literature may include data availability and the fact that countries originally raised energy taxes for other purposes than climate protection.

Table 12 provides an overview of all PaM evaluations considered under the topic energy and carbon pricing, summarising key assumptions, findings, and the comparative assessment. In summary, the present analysis has provided only limited mutual insights between the NECPs. In particular, the unavailable demand elasticities used for the calculations for Denmark and Sweden make a comparison of these analyses with the German analyses or with the scientific literature difficult. The evaluations of the nEHS also provide only limited information for assessing its role in the German NECP due to the different approaches.

Table 12: Overview of assessed PaM evaluations for the topic energy and carbon pricing

PaM	Evaluation(s)	Key findings	Systemic and methodological uncertainties:
Country: DE Name: Carbon pricing in the heating and transport sector Policy instrument(s): National emissions trading scheme (nEHS)	German NECP • Ex-ante assessment • Estimation based on elasticities	• 17,030 ktoe (2021-2030) reduction in energy consumption	• Elasticities may increase due to cheaper alternatives • Uncertainties regarding price and demand developments
	Harthan et al. 2020 • Ex-ante evaluation • Full modelling	• 3,700 kt CO_2 (2025) - 8,800 kt CO_2 (2030) reduction in GHG emissions • 143.3 ktoe (2025) - 549.3 ktoe (2030) reduction in energy consumption (Not including fuel consumption in the transport sector)	• Uncertainties regarding model assumptions • Crediting of reductions in the case of complementary policies unclear
	Bach et al. 2019 • Ex-ante evaluation • Estimation based on elasticities	• 83,000 kt CO_2 (2020-2030) reduction in GHG emissions • 31,050 ktoe (2020-2030) reduction in energy consumption	• Assumptions made in such a way that climate targets will be met. Does not correspond to the intended price path of the nEHS. • No supporting policies
	Swedish NECP* • Ex-post evaluation • Estimation for Swedish carbon and energy taxes based on elasticities and historical prices and consumption	• 10,224 ktoe (2014-2020) reduction in energy consumption	• No existing ex-post evaluations for the nEHS • Transferability of the Swedish results to Germany to a limited extent

PaM	Evaluation(s)	Key findings	Systemic and methodological uncertainties:
	Links with NECP: Prognos AG and Fraunhofer-Institut für System- und Innovationsforschung 2018 is referenced in the NECP, but the report is not publicly available, making it unavailable for use in the project context **Comparison:** Comparability between nEHS ex-ante estimation and ex-post energy/carbon tax estimation for Sweden hardly possible due to lack of background information and economic structure of Sweden **Barriers:** n.a. **Conflicts:** monetary burden on private households taken into account through the commuter allowance and the reform of the EEG levy **Synergies**: supports invest-ments in renewable energies and energy efficiency due to the higher costs of fossil fuels		
Country: DE Name: Energy and electricity tax Policy instrument(s): Energy and electricity tax	German NECP • Ex-ante assessment • Estimation based on elasticities	• 136,969 ktoe (2021-2030) reduction in energy consumption	• Elasticities may increase due to cheaper alternatives • Uncertainties regarding price and demand developments • Counterfactual unsuitable for calculating savings in comparison to 1990
	Institute for European Environmental Policy (2013) • Qualitative assessment	• No quantitative analysis	• No existing quantitative ex-post evaluations for the energy and electricity tax
	Links with NECP: Besides the NECP itself, no quantitative estimates were found **Comparison:** No ex-post assessment available **Barriers:** n.a. **Conflicts:** imposes a monetary burden on private households. No linked compensation mechanisms envisaged **Synergies:** supports invest-ments in renewable energies and energy efficiency due to the higher costs of fossil fuels		
Country: DK Name: Mineral-oil Tax Act Policy instrument(s): Tax on mineral oil products and CO_2-tax	Danish Energy Agency (2005) • Ex-ante assessment • Estimation based on elasticities	• 1,200 kt CO_2/year (2008-2012) reduction in GHG emissions	• Elasticities may increase due to cheaper alternatives • Uncertainties regarding price and demand developments • Counterfactual unsuitable for calculating savings in comparison to 1990 • Estimation quite old

PaM	Evaluation(s)	Key findings	Systemic and methodological uncertainties:
	Danish Energy Agency (2005) • Ex-post evaluation • Estimation based on elasticities	• 1,200 kt CO_2/year (2001) reduction in GHG emissions	• Historical elasticities tend to underestimate effect, as these are often estimated from energy price fluctuations. Permanent price surcharge usually causes stronger demand response • Elasticity estimation fails to take other influencing factors into account that can increase or reduce impacts
	Links with NECP: NECP does not show quantitative effects of the tax **Comparison:** Ex-post and ex-ante estimates are identical because the ex-post estimate was extrapolated. **Barriers:** n.a. **Conflicts:** imposes a monetary burden on private households. No linked compensation mechanisms envisaged **Synergies:** supports invest-ments in renewable energies and energy efficiency due to the higher costs of fossil fuels		
Country: DK Name: Energy taxes Policy instrument(s): Tax on natural gas, tax on coal, tax on electricity and CO_2 tax	Danish Energy Agency (2005) • Ex-ante assessment • Estimation based on elasticities	• 1,500 kt CO_2/year (2008-2012) reduction in GHG emissions	• Elasticities may increase due to cheaper alternatives • Uncertainties regarding price and demand developments • Counterfactual unsuitable for calculating savings in comparison to 1990 • Estimation quite old
	Danish Energy Agency (2005) • Ex-post evaluation • Estimation based on elasticities	• 1,500 kt CO_2/year (2001) reduction in GHG emissions	• Historical elasticities tend to underestimate effect, as these are often estimated from energy price fluctuations. Permanent price surcharge usually causes stronger demand response • Elasticity estimation fails to take other influencing factors into account that can increase or reduce impacts
	Links with NECP: NECP does not show quantitative effects of the tax **Comparison:** Ex-post and ex-ante estimates are identical because the ex-post estimate was extrapolated. **Barriers:** n.a. **Conflicts:** imposes a monetary burden on private households. No linked compensation mechanisms envisaged **Synergies:** supports invest-ments in renewable energies and energy efficiency due to the higher costs of fossil fuels		

PaM	Evaluation(s)	Key findings	Systemic and methodological uncertainties:
Country: SE Name: Energy and carbon taxes Policy instrument(s): Energy tax, carbon tax	Swedish NECP • Ex-ante assessment • Estimation based on elasticities	• 1,479 ktoe/year (2021-2030) reduction in energy consumption	• Elasticities may increase due to cheaper alternatives • Uncertainties regarding price and demand developments • Counterfactual unsuitable for calculating savings in comparison to 1990
	Swedish NECP • Ex-post evaluation • Estimation based on elasticities	• 10,224 ktoe (2014-2020) reduction in energy consumption	• Historical elasticities tend to underestimate effect, as these are often estimated from energy price fluctuations. Permanent price surcharge usually causes stronger demand response • Elasticity estimation fails to take other influencing factors into account that can increase or reduce impacts
	Links with NECP: NECP is evaluated source **Comparison:** Ex-post and ex-ante estimates are nearly identical because the ex-post estimate was extrapolated. **Barriers:** n.a. **Conflicts:** imposes a monetary burden on private households. No linked compensation mechanisms envisaged **Synergies:** supports invest-ments in renewable energies and energy efficiency due to the higher costs of fossil fuels		

* Due to the lack of an ex-post evaluation of the German scheme, the ex-post evaluation of carbon pricing in the Swedich NECP is used for comparison.

Source: own compilation, Fraunhofer ISI

3.2.1 Impacts on GHG emission reduction, energy efficiency and renewable expansion

The EED-based estimates reported in the NECPs promise significant energy savings from energy and carbon pricing; thus, these types of instruments may provide a major contribution to the 2030 GHG target achievement of MS. However, it is important to mention that the requirements of the EED for calculating the impact of taxes on energy consumption are designed in such a way that it always assumes a counterfactual with minimum EU tax rates. Such a counterfactual makes it difficult to assess the contribution of a measure to the GHG emission reduction target of an MS and may lead to overestimating the effects, as even in 1990 (the base year for the GHG emission reduction target), taxes in the considered MS were usually above the minimum rates. Calculations of ex-post estimates of the energy tax in Germany and calculations of ex-ante and ex-post estimates of the energy and CO_2 taxes in Denmark and Sweden use historical price elasticities of demand. These elasticities are often underestimated in relation to the impact of taxes, which may lead to an underestimation of the tax effect (see Section 3.2.3). The considered ex-post calculations use real data on energy consumption and energy prices, these must be estimated for the ex-ante calculations. In all considered MS, the ex-post estimates form the basis for extrapolated ex-ante estimations. Therefore, ex-post and ex-ante estimations are strongly correlated. In addition, due to the calculation methodology based on the EED and the uncertainties regarding the elasticities, the reported figures are of limited validity.

The rather weak impacts found in the ex-post scientific studies of energy and carbon pricing can hardly be compared with the figures from the NECPs because the observation periods were different and different methodologies were applied (see Section 3.2.3). In addition, the stronger effects of taxes compared to ETS (see Lilliestam et al. 2020) found in the literature cannot lead to the conclusion that taxes are generally better suited to reduce CO_2 emissions. The very weak impacts found in the ETS studies comes from a focus on data from periods with low CO_2 prices and a high number of freely allocated allowances. Both factors weakened the decarbonisation incentive for regulated companies considerably. More recent studies on the EU ETS focusing on the period from 2018 (higher prices and less free allocation) are not yet available.

Compared to the taxes, the ex-ante estimates for the nEHS, were more elaborate, with a particular difficulty in distributing the calculated effect of the entire German Climate Protection Programme among the individual PaMs. In the selected ex-ante assessment, only the effect that would be achieved by the nEHS without accompanying policies was attributed to it. That is, the effect that would be expected based on the price of the nEHS, energy demand, energy prices and elasticities. This leads to a rather conservative estimate of the effect of the nEHS, because the entire rest of the impact of the Climate Protection Programme is credited to the accompanying policies. Even if their effect as an individual measure would be smaller (combination of nEHS and accompanying policies leads to higher reductions than the sum of the individual consideration of nEHS and the accompanying policies). The comparison of the ex-ante estimates for the nEHS with ex-post evaluations of carbon taxes from other countries or with emissions trading systems from other countries seems to be of limited use: other emissions trading schemes covering the relevant sectors buildings and transport had too low prices in the past to make a robust comparison between ex-ante and ex-post. The comparison with carbon taxes in other European countries is difficult due to the different structures of significant influencing factors such as population density or the availability of public transport or the preferred use of different heating systems. In addition, factors such as income levels and income distribution can also have a strong influence on the results and thus limit comparability between MS.

Although the impacts of energy and carbon pricing instruments measured in the scientific literature tend to be small, and the effects seem to be associated with energy efficiency

improvements or fuel switch rather than transformation, these systems can still contribute to the transformation of the economy. Particularly in combination with support programmes, price surcharges on fossil fuels can significantly reduce the necessary funding gap in producers operating costs compared to a case without price surcharges (see Annex A.1 for more details).

3.2.2 Socio-economic impacts

Socio-economic impacts of energy and carbon pricing instruments were not reported in the NECPs reviewed in this report. In the scientific literature, empirical studies find no or weak effects of carbon taxes on GDP, GDP growth, or employment, tending to show slightly positive effects, whereas results from ex-ante modelling tend to show slightly negative effects (for an overview, see (Metcalf et al. 2020).

3.2.3 Systemic and methodological uncertainties

In our view, the available ex-ante estimates of energy taxes were carried out with limited effort in all three Member States and basically use almost identical methods. In the case of Denmark, values from 2001 were projected into the future by assuming the same values in terms of demand, energy prices and elasticities. In the Swedish NECP, where energy and carbon taxes are considered together, such an approach was also chosen, although the base year is 2020, which makes the projection of these values less critical with regard to the up-to-datedness. For the German calculation of the energy tax, the base year is not clear. As mentioned above, another source of uncertainty are the elasticities used. These were determined on the basis of historical data and could be too low, since new climate-friendly technologies cause the elasticities to rise. Furthermore, the elasticities measured in the past could also be too low, since the certainty about whether a price increase is permanent (rising carbon price) or possibly only temporary (normal energy price fluctuations) can strongly influence investment and demand behaviour (Edenhofer et al. 2019). For example, Andersson (2019) finds a three times higher elasticity to taxes than to energy price fluctuations. In the scientific literature (see reviews by (Lilliestam et al. 2021; Green 2021)), ex-post studies are no longer based on elasticities, but on econometric models especially on difference-in-differences approaches. Such approaches have the advantage that they are not based on an uncertain price elasticity calculated from the past, but explain changes in the dependent variable by a large number of explanatory variables and parameters. Uncertainties are inherent in such methods, in particular due to data quality and data availability (e.g. unobservable influences, exclusion of certain sectors). Nevertheless, such econometric models nowadays seem to provide more robust and reliable results than estimates based on elasticities. However, it must be mentioned that due to the simplicity, the data availability in national sources (except for elasticities) and the comparability of ex-ante and ex-post estimates, the extrapolated demand changes shown in the NECPs are quick and quite easy to understand, which is not always the case with scientific literature (although it is usually well documented and comprehensible upon request).

3.2.4 Conflicts and synergies with a just transition

Although there is clear evidence in the scientific literature (for a review see Ohlendorf et al. 2021) that low-income households may be at risk of not being able to pay for their living expenses and that certain population groups may be disproportionately affected by such tax systems, none of the NECPs reviewed in this report examines the impact of energy and carbon pricing on households, vulnerable households, or disproportionate burdens on individual groups. Although the German NECP presents compensatory measures, such as the reform of the EEG surcharge or the adjustment of the so called Pendlerpauschale (commuting allowance), the

exact effects of these measures are not presented. No specific compensatory measures introduced in response to energy or carbon taxes are mentioned in the NECPs of Sweden and Denmark.

3.3 Renewable heating and cooling in France, Germany and Slovenia

We have identified the most relevant PaMs for RES in H&C in Germany, France and Slovenia and analysed ex-ante and ex-post evaluations for each of them. In Germany, we analysed the Market Incentive Programme (Marktanreizprogramm, MAP) as well as the Heating Network Systems 4.0 programme (Wärmenetzsysteme 4.0). In France, we considered the Heat Fund and the energy efficiency obligation scheme (Certificats d'économies d'énergie, CEE). The two Slovenian PaMs looked at are the "Obligatory share of heat from renewable energy sources, high-efficiency cogeneration and waste heat in district heating systems" and "Financial incentives for district heat production using renewable energy sources". The availability, degree of detail and quality of ex-ante and ex-post evaluations differed considerably from country to country. In Germany, separate and independently conducted ex-ante evaluations commissioned before or early into the life of a PaM are common for significant renewable heat instruments (i.e. MAP, see Annex A.2.2.1), which is the ideal case. As for French PaMs, ex-ante and ex-post analyses are often included in the same document with ex-ante values being extrapolated from ex-post results. This was also the case for the two analysed French PaMs and comprehensive background studies to the 2017 PaM report for key PaMs. In the Slovenian case, the identification of comprehensive quantitative ex-ante evaluations proved to be challenging, so we had to fall back to the presumed PaM report effects without having access to the calculations done to obtain them. In terms of ex-post evaluations, the LIFE ClimatePath2050 project helped greatly to increase the number of available evaluations for Slovenia, which is why most of the evaluations used to analyse renewable H&C PaMs are deliverables of the said project. Given that they were not following established evaluation methodologies though, the quality and comprehensiveness of evaluations varied considerably and results were not always traceable.

To illustrate the variety of possible PaMs in the focus area, we looked at different types of PaMs, with financial incentives prevailing. A common topic for the assessed PaMs and their evaluations was the relatively weak links to the NECPs. While renewable H&C PaMs were duly described in all NECPs, information on their estimated impacts and wider benefits was mostly missing or merely provided in an aggregated manner (for a bundle of PaMs or even at sectoral level). It seems that the repository of existing evaluations was an underutilised resource in the writing process of the NECPs. Except for the German NECP, which directly refers to the conducted evaluations for the MAP, evaluation results were not picked up by the analysed NECPs to substantiate PaMs. In the French case, ex-ante and ex-post evaluations used the same scenario (WEM). It would be desirable for MS to be more explicit about conducted evaluations for PaMs and directly make links by referencing evaluations and their findings when writing their NECPs.

Table 13 provides an overview of all PaM evaluations considered under the focus topic renewable H&C, summarising key assumptions findings and the comparative assessment.

Table 13: Overview of assessed PaM evaluations for the topic renewable H&C

PaM	Evaluation(s)	Key findings	Systemic and methodological uncertainties:
Country: DE Name: Market incentive programme (MAP) Policy instrument(s): Market incentive programme (MAP)	Federal Ministry for Economic Affairs and Energy (2014): 3rd National Energy Efficiency Action Plan (NEEAP) • Ex-ante assessment • Quantitative assessment based on historic data from the Federal Statistical Office, literature review, expert support and stakeholder consultation • 1995-2008	• No energy saving contribution attributed to KfW part of the funding - estimated target contributions all result from BAFA funding • 1,815 ktoe reduction of energy consumption 2009-2020 • 1,720 ktoe reduction of final energy consumption 2009-2020	• Interaction effects with other instruments not considered, hence over- or underestimation of effects is possible • Evaluation only assesses energy savings • Not the most recent ex-ante evaluation, but the most comprehensive
	Zech et al. (2019) • Ex-post evaluation • Quantitative and qualitative assessment based on BAFA and KfW promotion statistics 2015-2018	• MAP performed well during the observation period • Annual target for expansion of renewable H&C supply was achieved by ca. 70% in 2018 • 303 kt CO2/year (2018) • 102 ktoe/year increase of RES consumption (2018)	• Interaction effects with other instruments not considered • Emissions factors from 2014 used (possibly out-of-date)
	Links with NECP: NEEAP - as a sector strategy - feeds into NECP. NECP refers to Zech et al. (2019). **Comparison**: Ex-ante and ex-post evaluation can only be compared to a limited extent as ex-ante analysis focuses strongly on energy savings. PaM report projections are higher than findings of the ex-post evaluation. **Barriers:** MAP not sufficiently known, high degree of complexity **Conflicts:** Decrease in support efficiency (avoided tonne of CO_2eq is getting more and more expensive). **Synergies**: n/a		

PaM	Evaluation(s)	Key findings	Systemic and methodological uncertainties:
Country: DE Name: Heating Network Systems 4.0 Programme [Wärmenetzsysteme 4.0] Policy instrument(s): Module I (feasibility study) and Module II (realisation) Country: UK Name: Heat Networks Investment Project (HNIP) Policy instrument(s): Heat Networks Invest-ment Project (HNIP)	Pehnt et al. (2017) • Ex-ante assessment • Quantitative and qualitative assessment, divided into three scenarios with different assumptions regarding the uptake of the PaM • 2009-2017	• Overall conclusion is that funding for district heating grids can lead to a high target contribution • Depending on the scenario GHG emissions savings between 1,940 and 7,930 kt CO_2	• PaM was amended in 2019, but evaluation is based on the originally proposed instrument • Results differ considerably depending on scenario selected
	BEIS (2018) • Ex-post evaluation • Mostly qualitative assessment of a similar PaM in the UK, the HNIP Programme, as no ex-post evaluation has yet been conducted for the PaM • 2015-2018	• No quantifications provided, but evaluation finds that HNIP encourages heat source replacement planning and promoting district heating network development	• No quantitative results available regarding projected GHG emissions reduction, energy savings or increase in RES
	Links with NECP: No direct link between evaluations and NECP **Comparison:** Ex-ante and ex-post evaluation cannot be compared directly as they evaluate different instruments and the ex-post evaluation is purely qualitative **Barriers:** Application processes perceived as cumbersome and complicated Signals for investment security not strong enough **Conflicts:** n/a **Synergies**: Stakeholder dialogue as accompanying measure		
Country: FR Name: Heat Fund [Fonds Chaleur] Policy instrument(s): BCIAT (national calls), regional calls	Direction Générale de l'Énergie et du Climat (2017) • Ex-ante assessment • Qualitative and quantitative assessment based on statistical data from ADEME • 2009-2017	• Annual emissions reductions gradually increase until 2022, then plateau until 2030, after which they gradually decline • 68,706 kt CO_2eq reduction of GHG emissions (2022-2030) • 27,873 ktoe increase of RES consumption (2022-2030)	• Several simplifying assumptions taken, but these are well explained and substantiated • No stakeholders involved in evaluation process

PaM	Evaluation(s)	Key findings	Systemic and methodological uncertainties:
	Direction Générale de l'Énergie et du Climat (2017) • Ex-post evaluation • Qualitative and quantitative assessment based on statistical data from ADEME • 2009-2017 (same data basis as used for ex-ante evaluation)	• 9,931 kt Co2eq reduction of GHG emissions (2009-2015) • 4,030 ktoe increase of RES consumption (2009-2015)	• Several simplifying assumptions taken, but these are well explained and substantiated • Interdependencies with other instruments might be underestimated
	Links with NECP: Links to NECP as evaluations are part of the French background study too the 2017 PaM report **Comparison:** Since the ex-ante evaluation is essentially a linear extrapolation the results of both evaluations go hand in hand **Barriers:** n/a **Conflicts:** interdependencies with other instruments possible but no detail provided **Synergies**: The evaluation also finds positive socio-economic effects of the PaM, such as an annual heating cost reduction, benefitting primarily lower income classes, an increase in jobs created as well as positive impacts on air quality		
Country: FR Name: Energy efficiency (white certificates) obligation scheme [Certificats d'économies d'énergie] Policy instrument(s): Energy efficiency (white certificates) obligation scheme [Certificats d'économies d'énergie]	Direction Générale de l'Énergie et du Climat (2017) • Ex-ante assessment • Qualitative and quantitative assessment based on data from the national registry "Emmy" • 2009-2017	• Annual emissions reductions first increase gradually, then sharply until 2021, and then decline at a slower rate • 18,830 kt CO2eq reduction of GHG emissions (2025)	• Assumptions taken are rather conservative
	Direction Générale de l'Énergie et du Climat (2017) • Ex-post evaluation • Qualitative and quantitative assessment based on data from the national registry "Emmy" • 2009-2017 (same data basis as used for ex-ante assessment)	• 19,529 kt CO_2eq reduction of GHG emissions (2006-2015)	• Rebound effect possible as shown in sensitivity analysis

PaM	Evaluation(s)	Key findings	Systemic and methodological uncertainties:
	Links with NECP: Links to NECP as evaluations are part of the French background study to the 2017 PaM report **Comparison:** Since the ex-ante evaluation is mainly a linear extrapolation of the ex-post evaluation, their results go hand in hand **Barriers:** lack of transparency and stability, complicated administrative processes **Conflicts:** mismatch in national and local priorities with the CEE not being sufficiently promoted at the territorial level **Synergies**: The evaluation also finds positive socio-economic effects of the PaM, such as positive effects on employment and innovation		
Country: SI Name: Obligatory share of heat from renewable energy sources, high-efficiency cogeneration and waste heat in district heating systems Policy instrument(s): Obligatory share of heat from renewable energy sources, high-efficiency cogeneration and waste heat in district heating systems	Slovenian PaM report (2019) • Ex-ante assessment • No detail provided on data used or assumptions taken	• 68 kt CO_2eq reduction of GHG emissions (2025) (aggregated for "Obligatory Share" PaM and "Financial Incentives" PaM) • 114 kt Co2eq reduction of GHG emissions (2030) (aggregated for "Obligatory Share" PaM and "Financial Incentives" PaM)	• Ex-ante effects are aggregated for both assessed Slovenian PaMs ("Obligatory Share" PaM and "Financial Incentives" PaM) • Methodology and assumptions not clear
	Merše et al. (2018) • Ex-post evaluation • Qualitative assessment and recommendations for improving the PaM's design	• New district heating systems are using 100% RES • No quantifications provided for GHG emission saving	• No quantitative values for ex-post provided
	• **Links with NECP:** PaM report projections used for ex-ante view. No direct links of the ex-post evaluation with the NECP. • **Comparison:** No comparison possible • **Barriers** PaM is very flexible and does not provide stringent targets • **Conflicts:** PaM can also be complied with by fossil-fuel based CHP plants • **Synergies**: n/a		

PaM	Evaluation(s)	Key findings	Systemic and methodological uncertainties:
Country: SI Name: Financial incentives for district heat production using renewable energy sources Policy instrument(s): Encouraging the development of district heating to RES systems within the Operational Programme for the Implementation of the EU Cohesion Policy, Financial incentives of the Eco Fund for the sustainable development of district heating systems	Slovenian PaM report (2019) • Ex-ante assessment • No detail provided on data used or assumptions taken	• 68 kt Co2eq reduction of GHG emissions (2025) (aggregated for "Obligatory Share" PaM and "Financial Incentives" PaM) • 114 kt Co2eq reduction of GHG emissions (2030) (aggregated for "Obligatory Share" PaM and "Financial Incentives" PaM)	• Ex-ante effects are aggregated for both PaMs • Methodology and assumptions not clear
	Česen et al (2020) • Ex-post evaluation • Qualitative and quantitative assessment based on statistical data of projects realised • 2016-2019	• PaM performed below expectations, but not clear why • 46.2 kt CO_2 reduction of GHG emissions (2016-2019) • 11.2 and 12.6 kt CO_2 annual reduction of GHG emissions (2017 and 2019 respectively)	• No quantitative values for ex-post provided
	Links with NECP: No direct links of the ex-post evaluation with the NECP **Comparison:** No comparison possible **Barriers:** n/a **Conflicts:** n/a **Synergies**: Positive side effects of the PaM are mentioned, such as creation of new jobs and increase in security of supply of energy		

Source: own compilation, Fraunhofer ISI

3.3.1 Impacts on GHG emission reduction, energy efficiency and renewable expansion

The ex-ante evaluation of the German MAP (BMWi 2014) focuses on the impact assessment of energy saved and does not cover any other aspects. In contrast, the ex-post evaluation (Zech et al. 2019) is more comprehensive covering also the increase of RES consumption and reduction in GHG emissions due to the instrument. We conclude that the ex-ante evaluation overestimates the effect of the PaM on energy savings, because of disregarding the synergy effects led by interaction with other instrument(s). The findings of the ex-post evaluation lead to a positive assessment with regard to the MAP's performance in the observation period achieving around 70% of the annual target for the expansion of renewable H&C supply. In terms of the second renewable H&C PaM investigated for Germany, Heating Network Systems 4.0, the ex-ante evaluation (Pehnt et al. 2017) focused on the PaM's contribution to reducing GHG emissions. The three elaborated scenarios, distinguished by the degree that the PaM is in demand by the target audience, estimate a range of 1,940 and 7,930 kt of CO_2 equivalents saved over the period from 2018 to 2030. Since the Heating Network Systems 4.0 program is a comparatively new instrument, no ex-post analysis is available so far, and consequently, no comparison with past emission reductions is possible. The conclusions that can be drawn from the analysis of a similar policy instrument (BEIS 2018b), the UK's HNIP scheme, are limited.

For France, the authors analysed the Heat Fund and the energy efficiency obligation scheme. The ex-ante and the ex-post analysis of the Heat Fund (DGEC 2017) correspond with one another, since the ex-ante analysis is a linear extrapolation of the ex-post evaluation . The ex-ante evaluated targets of the Heat Fund are avoided GHG emissions, avoided fossil fuels and increase of RES consumption. According to the ex-ante projections the annual emissions reductions gradually increase until 2022, then stay at the same annual level until 2030, and then gradually decline. Target contributions of the Heat Fund according to the ex-post evaluation amount to 9,931 kt CO_2eq avoided between 2009 and 2015, and an increase in RES consumption of 4,030 ktoe in the same period. The Direction Générale de l'Énergie et du Climat indicates and discusses weaknesses and simplifications of the analysis in the evaluation document. The picture is similar to the energy efficiency (white certificates) obligation scheme. Analogous to the Heat Fund evaluation, the ex-ante analysis is a linear extrapolation of ex-post values. The main national targets looked at are final energy savings and the reduction of GHG emissions. Total reduced GHG emissions between 2006 and 2015 amount to 19,529 kt CO_2eq.

In Slovenia, both examined PaMs are complementary and target district heating systems. The first PaM is an obligatory share of heat from renewable energy sources, high-efficiency cogeneration and waste heat in district heating systems. No ex-ante evaluation exists for the obligatory share, hence the authors considered the projections from the PaM reports instead. The ex-post evaluation (Merše et al. 2018) is purely qualitative, respectively focusing on different aspects, mostly on the degree to which the shares set out in the PaM are met by district heating systems across the country. Since, however, the evaluation provides no information on the technologies and fuels used, the authors cannot derive any further conclusions on the PaM's effectiveness in meeting the defined targets. The second PaM provides financial incentives for district heat production from renewable energy sources in the form of co-financing grants. Also, in this case, the authors were not able to identify any ex-ante evaluation. Consequently, projections from the PaM report were used instead. We concluded that the PaM is likely falling short of meeting its targets, however, this is also due to the PaM being undersubscribed and beneficiaries not making full use of the funds available. Therefore, the PaM's target contributions for the period between 2016 and 2019 are low and only amount to 46,2 kt CO_2.

Except for the German NECP, which refers to Zech et al. (2019), none of the other two NECPs explicitly take into account the results of the evaluations. In the Slovenian case the PaM report was used to quantify impacts on GHG emission reductions and also for France the background study for the PaM report was used for both the ex-ante and ex-post view, providing a detailed quantification.

3.3.2 Socio-economic impacts

Socio-economic effects only play a minor role in the assessed evaluations and do not take a prominent role in the respective sections of the NECPs.

The ex-ante analysis of the German MAP does not address socio-economic effects due to the focus on energy savings. The ex-post analysis is more comprehensive and also considers a number of additional aspects, such as cost efficiency and effects on innovation and competitiveness, all of which are considered to be positive. The evaluations of the Heating Network Systems 4.0 do not look at socio-economic impacts, but discuss besides others socio-economic barriers.

In France, the evaluation of the Heat Fund identifies a number of socio-economic effects and qualitatively discusses their underlying effects. For instance, the instrument is more beneficial for lower-income households than their better-off counterparts since it proportionately contributes to reduce heating bills. The Heat Fund also improves the French trade balance, increases the country's security of energy supply and creates new job opportunities. Evaluations for the French energy efficiency obligation scheme qualitatively report positive labour market effects as well as impacts on innovation.

Lastly, evaluations of the Slovenian financial incentives PaM state creation of jobs and a contribution to self-sufficiency by increasing local supply of energy as positive socio-economic effects.

3.3.3 Systemic and methodological uncertainties

With regard to the treatment of uncertainties, the ex-ante evaluations deemed most helpful were those that were clear and upfront about underlying assumptions and resulting limitations, e.g. as in the ex-ante evaluation from Pehnt et al. 2017 for the German Heating Network Systems 4.0 programme. The degree of detail of the utilised French ex-ante projections was relatively low, however, its high transparency made it easy to put results into perspective and assess their plausibility. In the case of the energy efficiency obligation scheme (Certificats d'économies d'énergie, CEE), a sensitivity analysis was included to show how results were susceptible to variance due to changes in assumptions.

In the Slovenian case, additional ex-ante and ex-post evaluations of the effectiveness of measures (contribution to target achievement) or a more detailed break-down of the calculations done for the 2019 PaM report including the used methodology would greatly increase the explanatory value of the analysis. With the available evaluations for PaMs addressing RES in H&C, an assessment of the plausibility of the ex-ante values from ex-post is only possible with strong limitations.

In the case of the German Heating Network Systems 4.0 PaM, we had to consider an ex-post evaluation for a similar PaM (focusing on HNIP in the UK), as mostly due to the novelty of the PaM, no ex-post evaluation is available yet. Also, in that case it would be beneficial to identify at least one or two additional evaluations from other countries dealing with similar instruments to complement the selected UK evaluation for the HNIP (if available). In the case of France, a

comparison with similar instruments from other countries might also help to put the French PaMs into perspective.

3.3.4 Conflicts and synergies with reducing air pollution and other targets

While the expansion of RES in H&C is overall positively contributing to the mitigation of GHG emissions and other pollutants, some sources used for H&C can have adverse effects on air quality. It is thus important to be aware of trade-offs and the interplay between different RES and indoor and ambient air pollution. These effects are especially important with regard to increases in the burning of (solid) biomass as well as transitioning district heating networks to RES and CHP (especially biomass). Conflicts and synergies with reducing air pollution and other targets are not systematically addressed at PaM level in the three considered NECPs, but all NECPs include some considerations on interaction effects as well as general projections and causal relationships.

3.4 Energy-efficient buildings

In this section, the most relevant PaMs concerning energy efficient buildings in the NECPs of Germany, Slovenia and Sweden were identified. We reviewed ex-post and ex-ante evaluations for all of them. Except for one PaM in Sweden, all are financial PaMs for funding refurbishments in buildings. Although the NECPs from Slovenia and Germany referred to the evaluations analysed in this report, the links were rather weak. If impacts were assessed in the NECPs, they were reported only in an aggregate manner. The requirement for the topic of energy efficiency in the NECPs, namely to provide a sufficiently ambitious national contribution for both primary and final energy consumption, which takes into account the need to increase, collectively, the level of efforts necessary to reach the Union's 2030 target, were addressed only partially in all three countries. All NECPs refer to the difficulties of conducting impact assessments for individual PaMs due to interaction with other PaMs and cross-sectoral impacts and refer to third party sources for impact assessments on individual levels. However, the three countries did not report interactions with other PaMs in their NECPs. For the Swedish PaMs, no evaluations assessing the impact of the PaMs on instrument level could be found. In the case of Germany, the ex-ante evaluation directly refers to a regularly conducted ex-post evaluation. Overall, the number of available evaluations is very limited, particularly in Sweden assessments are given on an aggregate level and usually the carbon and energy taxes are reported as accompanying instruments. This situation makes a comparison and a detailed analysis on instrument level impossible. It might be beneficial if, similar to the German ex-post evaluation for the federal funding for efficient buildings (German Funding for Efficient Buildings Programme, BEG), Sweden reports impacts at individual instrument level, includes net impacts and interactions and considers further effects, e.g. on employment.

Table 14 provides an overview of all PaM evaluations considered under the topic energy efficient buildings, summarising key assumptions, findings and the comparative assessment.

Table 14: Overview of assessed PaM evaluations for the topic energy efficient buildings

PaM	Evaluation(s)	Key findings	Systemic and methodological uncertainties:
Country: DE Name: Tax incentives for energy-related building renovations Policy instrument(s): Tax incentives for energy-related building renovations	Prognos et al. (2020) • Ex-ante assessment • Quantitative assessment based on KfW and BAFA promotion statistics	• 1,420 kt CO_2 (2020-2030) reduction of GHG emissions	• The ex-ante evaluation only assesses the gross impact without considering a baseline
	Domergue & Vermont (2018) • Ex-post evaluation • Quantitative and qualitative assessment	• 240 kt CO_2 (2015-2016) reduction of GHG emissions • 76.53 ktoe (2015-2016) reduction of final energy consumption	• Different scenarios are compared, but no explicit reference considering a deadweight effect is given
	Links with NECP: The NECP references Prognos et al. (2020), the NECP does not refer to the French PaM so there is no link between the ex-post evaluation and the NECP **Comparison:** The ex-ante and the ex-post evaluation cannot be compared in a systemic manner, since they refer to two different countries and PaMs **Barriers:** a possible skilled worker shortage is considered qualitatively, application and verification processes as a barrier are addressed **Conflicts:** the current tax system encourages renovations on a smaller scale than wanted **Synergies**: Financing through tax returns might seem more reliable and less complex than a funding scheme. Measures such as the federal funding for efficient buildings and the tax incentives complement each other. They are exclusive to one another and might, together, increase the number of investors.		
Country: DE Name: Federal funding for energy efficient buildings Policy instrument(s): Federal funding for efficient	Prognos et al. (2020) • Ex-ante assessment • Quantitative assessment based on KfW and BAFA promotion statistics	• 2,530 kt CO_2 reduction of GHG emissions (cumulative, 2020-2030)	• The ex-ante evaluation only assesses the gross impact without considering a baseline

PaM	Evaluation(s)	Key findings	Systemic and methodological uncertainties:
buildings (BEG) - individual measures for renovation products and CO_2-tax	IWU & Fraunhofer IFAM (2018) • Ex-post evaluation • model for calculating final energy savings • Evaluation is based on KfW statistics and the results of a survey of funding recipients asking for data on the buildings, the measures to be conducted and the condition of the building before renovation were evaluated	• 479.8 kt CO_2 reduction of GHG emissions (2017) • 23.2 ktoe increase of RES consumption (2017) • 137.8 ktoe reduction of primary energy consumption (2017) • 123.9 ktoe reduction of final energy consumption (2017)	• The ex-post evaluation only assesses the gross impact without considering a baseline
	Links with NECP: The NECP refers to both evaluations, the ex-ante evaluation is explicitly linked to the NECP as the key data used for the assessment of energy use and GHG emissions replicates the NECP scenario **Comparison:** the two evaluations complement each other, the ex-ante evaluation is based on the results of the ex-post evaluation **Barriers:** in the ex-post evaluation**,** a possible skilled worker shortage is considered qualitatively; application and verification processes as a barrier is addressed **Conflicts:** n/a **Synergies**: The federal funding for efficient buildings and the tax incentives complement each other. They are exclusive to one another and might, together, increase the number of investors.		
Country: SI Name: Financial incentives for energy efficiency and RES use in residential buildings Policy instrument(s): Financial incentives for	Vlada Republike Slovenje (2008) • Ex-ante assessment • all savings, except for CHP (combined heat and power), are estimated at final energy level; electricity savings are multiplied by a factor of 2.5 according to the provisions of ESD	• cumulative reductions of GHG emissions 486 kt CO_2 (2008-2016) • cumulative reductions of final energy consumption of 162.52 ktoe (2008-2016)	• Unclear whether GHG emissions reductions are annual or cumulative for the evaluation period. • A possible expansion of renewable energies was not taken into account. • Evaluation quite old.

PaM	Evaluation(s)	Key findings	Systemic and methodological uncertainties:
energy efficiency and RES use in residential buildings	Vlada Republike Slovenje (2015) • Ex-post evaluation • The GHG emissions reductions are derived from the reduction of final energy consumption which are assessed against the reference of the energy savings targets 2010-2012 and based on Eurostat statistics	• 41.1. kt CO_2 cumulative reductions of GHG emissions (2011-2021) • 22.41 ktoe cumulative reductions of final energy consumption (2011-2021)	• Additionality or other effects were not considered. • The data used are Eurostat statistics on final energy consumption, but the data is not made transparent.
	Links with NECP: The NECP references both the analysed evaluations **Comparison:** A comparison between the two is difficult because of the different evaluation periods. The assumptions made and used methodologies however seem to be consistent **Barriers:** The evaluation addresses diverse barriers in the building sector in general, but not directly in relation to the PaM. Possible barriers are administrative obstacles, lack of appropriate financial instruments, inadequate readiness and capacity of the sub-public sector to undertake large scale comprehensive energy renovations, the absence of more stable financial resources to carry out these renovations, as well as obstacles in the planning and coordination of activities, e.g. due to a lack of human capital **Conflicts:** na **Synergies**: na		
Country: SI Name: Non-repayable investment financial incentives for energy renovation of buildings in the public sector, aimed at increasing the share of projects implemented through energy contracting	Vlada Republike Slovenje (2008) • Ex-ante assessment • all savings, except for CHP (combined heat and power), are estimated at final energy level; electricity savings are multiplied by a factor of 2.5 according to the provisions of ESD	• cumulative GHG emission reductions of 225 kt CO_2, final energy consumption estimated to be reduced by 74.3 ktoe (2008-2016)	• no interaction, additionality, spillover, rebound or other effects were considered • Evaluation quite old.

PaM	Evaluation(s)	Key findings	Systemic and methodological uncertainties:
Policy instrument(s): Non-repayable investment financial incentives for energy renovation of buildings in the public sector, aimed at increasing the share of projects implemented through energy contracting	Stegar et al. (2020) • Ex-post evaluation • quantitative and qualitative assessment • The evaluation is based on internal data from the Public Sector Buildings Energy Refurbishment Project Office; no information is given on the data basis or the data collection processes.	• Energy savings as well as GHG emissions reductions are only available on an aggregate level for all instruments promoting energy efficiency in public buildings, including the savings generated by the carbon and energy taxes. • 357.2 kt CO_2 GHG emissions reductions (2007-2019) • final energy consumption was reduced by 113.65 ktoe (2007-2019) • the effectiveness of the instrument is considered to be low	• the ex-post evaluation only reports the savings in aggregated form • no reference case was used • no interaction, additionality, spillover, rebound or other effects were considered • no reason for the low effectiveness is reported
	Links with NECP: The NECP references both evaluations. **Comparison:** A comparison is not possible since the ex-post evaluation assessed energy savings and GHG emissions reductions only on an aggregate level for all instruments promoting energy efficiency in public buildings **Barriers:** Barriers such as administrative obstacles, lack of appropriate financial instruments, inadequate readiness and capacity of the sub-public sector to undertake large scale comprehensive energy renovations, the absence of more stable financial resources to carry out these renovations, as well as obstacles in the planning and coordination of activities, e.g. due to a lack of human capital are addressed in general concerning the implementation of PaMs for increasing energy efficiency in buildings **Conflicts:** n/a **Synergies**: n/a		

PaM	Evaluation(s)	Key findings	Systemic and methodological uncertainties:
Country: SE Name: National Board of Housing, Building and Planning Building Regulations (BBR) Policy instrument(s): National Board of Housing, Building and Planning Building Regulations (BBR)	Sweden's Environmental Protection Agency (2017) • Ex-ante assessment • Estimation of mitigation impact in Mt CO_2eq per year compared with 1990 instruments. • The impact of instruments in the residential and commercial/institutional buildings sector was estimated aggregated for Energy and Carbon Taxes, Mandatory energy labelling, the Ecodesign Directive and the law on energy performance certificates for buildings.	• No GHG emissions reductions were estimated on individual PaM level. • For both 2020 and 2030, GHG emissions reductions of 400 kt CO_2eq. were estimated for the bundle	• no evaluation on PaM level was found
	Sweden's Environmental Protection Agency (2017) • Ex-ante (post?) assessment • Estimation of mitigation impact in Mt CO_2eq per year compared with 1990 instruments. • The impact of instruments in the residential and commercial/institutional buildings sector was estimated aggregated for Energy and Carbon Taxes, Mandatory energy labelling, the Ecodesign Directive and the law on energy performance certificates for buildings.	• No GHG emissions reductions were estimated on individual PaM level. • For 2010, GHG emissions reductions of 1300 kt CO_2eq were estimated for the bundle, for 2015 1400 kt CO_2eq	• no evaluation on PaM level was found

PaM	Evaluation(s)	Key findings	Systemic and methodological uncertainties:
	Links with NECP: Seemingly, there is no relation to the NECP. **Comparison:** The same evaluation was used both for the ex-ante and the ex-post assessment. As such the methodological approach is the same and the ex-ante values are based on the ex-post values. **Barriers:** n/a **Conflicts:** n/a **Synergies**: n/a		
Country: SE Name: Climate Leap (Klimatklivet) Policy instrument(s): Climate Leap (Klimatklivet)	na	na	na
	Pädam et al. (2020) • Ex-post assessment • Net accounting, full additional reductions are estimated against gross savings.	• GHG emissions reductions of 115.67 kt CO_2eq were estimated (cumulative, 2016-2018) • Overall, energy efficiency measures contribute less than 1%, energy conversion in buildings about 5% to the overall GHG emissions reductions achieved through the instrument (1131.12 kt CO_2eq. per year, 808.77 kt CO_2eq. per year considering full additionality).	• additionality was assessed by means of a survey and interviews and then quantified; due to this approach, the values are highly characterised by individual estimations.
	Links with NECP: No links to the NECP are apparent. **Comparison:** No ex-ante evaluation was available, hence, no comparison was possible. **Barriers:** na **Conflicts:** na **Synergies**: na		

Source: own compilation, Fraunhofer ISI

3.4.1 Impacts on GHG emission reduction, energy efficiency and renewable expansion

The most relevant PaMs for energy-efficient buildings in Germany, Slovenia and Sweden are mostly PaMs providing financial incentives. The level of detail differs between the NECPs concerning the inclusion of ex-ante and ex-post evaluations as well as specific targets for individual PaMs. In Germany, ex-post evaluations for certain PaMs such as the Federal Government's CO_2 Building Modernisation Programme (CO_2-Gebäudesanierungsprogramm) are commissioned regularly and thus available for most years of their actual runtime. Furthermore, for the NECP and the preceding Climate Protection Programme 2030, thorough ex-ante evaluations for instruments were conducted. The authors hardly find any quantified evaluations of Slovenian PaMs instead of scenarios considering the whole energy system. Similarly, in Sweden evaluations estimating the impact of individual instruments instead of bundles of instrument or on sector level are rare in case of energy efficiency and energy-efficient buildings. In the evaluations authors stress that assessments on instrument level are difficult to conduct precisely as interactions as well as different effects cannot be considered sufficiently. Overall, the evaluations for the Swedish PaMs showed that PaMs aiming at increasing energy efficiency in buildings could contribute to the goals; however, the importance of the interaction with different PaMs, in particular the energy and carbon taxes, was highlighted. In the context of Slovenia, the evaluations found that the funding measures analysed in Section 3.3.3 were contributing to increasing energy efficiency in buildings, but also, that one of the PaMs (non-repayable investments, see Section 3.3.3.2) was less effective than estimated before.

While Sweden primarily relies on the energy and carbon taxes, the focus of the other countries' key renovation PaMs is promoting investment in energy efficiency measures, often also in RES. As of 2021, Germany introduced tax incentives (Steuerliche Förderung der energetischen Gebäudesanierung) as an additional instrument providing financial support. Besides important legal frameworks (i.e. the Buildings Energy Act, GEG), the tax incentive and the federal funding for energy-efficient buildings (BEG) are key German PaMs. Evaluations as well as the NECP find that they can help to largely reduce GHG emissions (see Annex A.3.4). Further possible positive side effects such as increased employment in Germany were assessed. Also, the interaction between the two PaMs is seen as having the possible positive effect to attract more possible investors and to enlarge the group to actually implement refurbishment measures.

In Slovenia, the energy efficiency PaMs target residential and public buildings separately. Germany and Sweden also categorise their building stock by building type but do not distinguish their PaMs in this respect. Furthermore, in Sweden cross-sectoral instruments play an important role; the energy and carbon taxes in particular are crucial for the most GHG-emission-intensive sectors and are also considered one of the most central instruments in the context of energy efficient buildings. Another cross-sectoral PaM is the Climate Leap, which is a crucial instrument for realising the Swedish GHG emission reduction targets, even if for energy efficiency it is only of relatively low importance.

3.4.2 Socio-economic impacts

Socio-economic impacts are rarely taken into account in the different evaluations. Where employment effects are considered, PaMs aiming at energy efficiency in buildings are an important factor to reduce unemployment. In the three NECPs, this assumption is adopted insofar as they all mention increasing job opportunities in construction, even if only marginally. In particular, the ex-post evaluation for the BEG in Germany provides detailed insights into employment effects. The authors showed that, against a baseline of 93.000 person-years, the

direct employment effects might amount to additional 85.000 person-years in 2017, the indirect employment effects to additional 33.000 person-years in 2017.

3.4.3 Systemic and methodological uncertainties

The reviewed evaluations do not always use a reference case and even when the evaluation is conducted relative to a reference case, this is not always clear. Bottom-up and top-down approaches are usually combined. Impact models are generally used to model the impact of an instrument, taking into account different impacts and with estimating first the gross impact and then the net impact. However, in most cases it is not clear how the results were achieved and the quality of the different evaluations varies widely. For instance, assumptions and sources of uncertainties in ex-ante evaluations are not always discussed, at least not in detail. The most informative ex-ante evaluation analysed is the impact assessment for the German tax incentives for energy-related building renovations and the federal funding for efficient buildings (Prognos et al. 2020). The methodology is described in detail and the estimations are critically discussed in the context of limitations and underlying assumptions. In the case of Slovenia, the ex-ante evaluation of financial incentives for energy efficiency and RES use in residential buildings lacks this level of detail. Thus, the results are less well traceable, in particular because further effects or analyses are conducted on an aggregated level. In terms of interaction, the approach seems plausible; however, impacts of the individual instruments are less easy to understand and their plausibility is hard to assess. In the case of Sweden, the authors could not find ex-ante evaluations with quantitative results for instruments for energy-efficient buildings (see Annex A.3.4).

Some examined ex-ante evaluations emphasise their limitations and particularly their dependence on assumptions (e.g. Prognos et al. 2020; Stegnar et al. 2020) . Limitations are that ex-ante evaluations analyse most effects (i.a. interaction effects and efficiency, except additionality effects), if considered for instruments instead of instrument bundles, rather qualitatively or not at all

Ex-post evaluations, if supported by thorough data, can provide additional information, in particular as there are fewer constraints on impact assessments and fewer uncertainties on other aspects (e.g. socio-economic aspects) . The data and the resulting estimates are valuable not only for understanding the impact and importance of an intervention in the past, but also for understanding possible future impacts. In the case of Germany's federal funding for energy-efficient buildings, this is highlighted by the use of ex-post evaluations for previous instruments, which have been merged into the federal funding scheme as of 2021. Earlier ex-post evaluations are reference cases for ex-ante estimates. Moreover, clearly documented methodologies are important for assessing validity and replicability. Also, the French ex-post evaluation Domergue et al. 2018, see Annex A.3.2.1 shows the importance of discussing different aspects, such as additionality but also cost-effectiveness and constraints on the evaluation. These aspects are assessed and discussed critically, which makes the evaluation more comprehensible to assess.

Particularly in Sweden, but also in the other evaluations, the overlap between the focus topics "Energy-Efficient Buildings" and "Renewable Heat" becomes apparent. They are not always easy to separate and many instruments target both. In the case of the Swedish cross-sectoral instrument "Climate Leap" , the contributions to energy savings and RES expansion are not analysed separately, while for all other Swedish PaMs, a clear distinction is possible in the analysis of the instruments. This overlap should be kept in mind when assessing impacts in the different dimensions.

3.4.4 Conflicts and synergies with labour markets

In summary, the NECPs and impact assessments provided very limited information on conflicts and synergies with labour markets. The NECPs provide different levels of detail, but also the evaluations analysed in this report were very different in terms of methodological approaches or the way in which the impacts of individual PaMs were reported (if assessments of individual PaMs were reported). In all the NECPs, the employment effects of the PaMs are mentioned in general terms. Labour market effects are rarely considered and not for individual PaMs, but for bundles of PaMs or the issue of energy efficiency or the implementation of PaMs in general. As such, conflicts such as a possible reduction in the workforce are rarely addressed. Possible employment effects of sustainability transitions and the adoption of new technologies are also addressed in general, but not directly related to specific PaMs. Possible accompanying instruments can be found implicitly or through empirical studies, but not in the NECPs themselves. Such information could be included in more detail way and with explicit references to individual PaMs.

3.5 Agricultural soils

All three considered countries, Germany, Denmark and Slovenia, include limited information in their NECPs on agricultural emissions, for both the focus topic “rational use of N fertilisers” and “increase of organic farming”. Their NECPs list few agricultural PaMs and do not contain quantitative data on GHG emissions reductions associated with the PaMs.

Based on the assessment of the three countries, it became clear that a general lack of information - including quantitative data - related to the rational use of N fertilisers and the increase of organic farming, made it hardly possible to check ex-ante estimates of GHG emission reductions against ex-post evaluations. The intensive literature research carried out in this project could not identify additional studies that could help overcome this information gap.

Nevertheless, both emission reductions in the agriculture sector and the sector’s potential contribution to negative emissions receive increasing attention. The European Commission is currently developing a Carbon Farming initiative that has the potential to make a significant contribution to the EU’s effort to tackle climate change by incentivising carbon removals (EC 2021a). This development is also reflected in the assessed evaluations, with more recent ones considering the climate-mitigation potential of PaMs and providing quantitative data on GHG emission reductions. Table 15 provides an overview of all PaM evaluations considered under the topic agricultural soils.

Table 15: Overview of assessed PaM evaluations for the topic agricultural soils

PaM	Evaluation(s)	Key findings	Systemic and methodological uncertainties:
Country: DE Name: Fertiliser Ordinance Policy instrument(s): Fertiliser Ordinance	Harthan et al. (2020) • Ex-ante evaluation • Estimates impact of Fertiliser Ordinance as part of broader effort to reduce nitrogen surpluses • Assumptions for Climate Protection Programme (CPP): Germany reduces nitrogen surplus from 98 kg N/ha to 70 kg/ha	• WEM: 3,300 kt CO_2eq + CPP: 500 kt CO_2eq (2030) reduction of GHG emissions. • Compared to 2016; with existing measures (WEM) taken from 2019 PaM report; additional impact from CPP.	• Uncertain whether the changed Fertiliser Ordinance will be sufficient to reduce the nitrogen surplus to 70 kg/ha N • Modelling uncertainties regarding reduction per ha calculated: the required reduc-tion might be higher in areas with high livestock densities.
	Velthof et al. (2010) • Ex-post evaluation of the Nitrates Directive (focus on EU level) • Modelling to calculate gaseous N emission for scenarios with and without Nitrates Directive • Nitrates Directive implemented in Germany by Fertiliser Ordinance	• 464 kt CO_2eq (2000) and 653 kt CO_2eq (2008) reduction of GHG emissions in Germany. • Same year without the Nitrates Directive.	• n.a.
	Links with NECP: NECP is based on Harthan et al. (2020). **Comparison:** Comparability of ex-ante and ex-post studies challenging due to evaluation of different periods. **Conflicts:** The CPP states that an upper limit for N fertilisation and stricter limitation of N in nitrate-polluted waters may lead to decrease in yields. **Synergies**: The CPP notes that reducing the nitrogen surplus and increasing N efficiency serves the aim of protecting waters, controlling air pollution and conserving biodiversity		

PaM	Evaluation(s)	Key findings	Systemic and methodological uncertainties:
Country: DE Name: Expansion of organic farming Policy instrument(s): Financial support for organic farming	Harthan et al. (2020) • Ex-ante evaluation • Assumptions of Climate Protection Programme (CPP): extrapolation of expansion rate over 2015-2018 (118,000 ha per year), leading to additional of 1.42 million ha converted to organic farming (18-20% of agricultural land)	• WEM: 400 kt CO_2eq + CPP: 900 kt CO_2eq (2030) reduction of GHG emissions • Compared to 2016; with existing measures (WEM) taken from 2019 PaM report; additional impact from CPP. • To secure and stabilise the increase in organic farming, at least 400 million EUR per year are needed, also beyond 2030 (in 2019, total spending was 300 million EUR).	• Reduction effect of organic farming mainly depends on cultivation intensity of farms that switch to organic farming. • There is overlap with PaMs that reduce the nitrogen surplus: lower fertiliser levels of conventional farming lead to lower emission reductions when this land is converted to organic farming. • Current goal of federal govern-ment is 30% of agricultural land under organic farming by 2030 (higher than assumed in ex-ante evaluation)
	Bonneval et al. (2016) • Ex-post evaluation of RDP programme (2007-2013) from Berlin/Brandenburg region • Regional focus	• Reduction of GHG emissions only available on regional level • In 2014, organic-farming measures made up around three-quarters of total GHG emission reduction achieved by agri-environmental measures on a yearly basis.	• Creation of a detailed model to estimate GHG emission reductions was deemed too complex and could not be carried out based on the available data. Flat-rate values to calculate reduction potential were used instead.
	Links with NECP: NECP is based on Harthan et al. (2020). **Comparison:** Comparability of ex-ante and ex-post studies challenging due to different geographical scope. Both point out overlap with reduced fertiliser use and used flat-rate values to calculate reduction potential. **Conflicts:** The CPP highlights that an increase of organic farming from 12% to 20% is expected to result in a production decline of 4.5 million tonnes of cereals per year. **Synergies**: The CPP states that organic farming employs 0.2 to 0.3 more workers per 100 ha compared to conventional farming.		

PaM	Evaluation(s)	Key findings	Systemic and methodological uncertainties:
Country: DK Name: Action Plan for the Aquatic Environment (APAE) III and Green Growth Agreement (GGA) Policy instrument(s): APAE and GGA with focus on N fertiliser reduction	Schelde et al. (2014) • Climate note that recalculates figures from Børgesen et al. (2013) into GHG emission reductions (here: ex-ante).	• 179 kt CO_2eq (2015) reduction of GHG emissions (GGA, only includes reduction from N_2O emissions). • Mainly through land-use change and reduced fertilisation. • Measured against a standard value of N inputs.	• Reduction figures closely related to results of Børgesen et al. (2013). • Børgesen et al. (2013) notes that the calculation of nitro-gen leaching at both regional and national level is subject to considerable uncertainty related to the models used and the input data.
	Schelde et al. (2014) • Climate note that recalculates figures from Børgesen et al. (2013) into GHG emission reductions (here: ex-post).	• 67 kt CO_2eq (2007 and 2011) reduction of GHG emissions (APAE III and GGA). • Measured against a standard value of N inputs	• Same as for ex-ante.
	Links with NECP: NECP does not provide any detail on impact of agricultural PaMs. Denmark references Schelde and Olesen (2014) in third Biennial Report under the UNFCCC. **Comparison:** Challenging to compare results of evaluations because assessed time periods do not line up with implementation periods of policy instruments. **Conflicts:** n.a. **Synergies**: n.a.		
Country: DK Name: Green Growth Agreement (GGA) Policy instrument(s): Green Growth Agreement (GGA) with focus on organic farming	Schelde et al. (2014) • Climate note that recalculates figures from Børgesen et al. (2013) into GHG emission reductions • Ex-ante and ex-post	• **Ex-ante**: 11.3-13.6 kt CO_2eq (2015) of reduction of GHG emissions by organic agriculture. • **Ex-post:** 11.3-13.6 kt CO_2eq (2007 and 2011) of reduction of GHG emissions by organic agriculture. • Measured against a standard value of N inputs.	• Reduction figures closely related to results of Børgesen et al. (2013). • Børgesen et al. (2013) notes that the calculation of nitro-gen leaching at both regional and national level is subject to considerable uncertainty related to the models used and the input data.

PaM	Evaluation(s)	Key findings	Systemic and methodological uncertainties:
	Børgesen et al. (2013) • Ex-ante and ex-post	• **Ex-ante**: expected increase of organic farming of 24,000-28,000 ha over 2012-2015. • Estimates reduction of 240-480 tonnes of N (2015) compared to 2011. • **Ex-post**: organic farming increased by 24,000 ha over 2007-2012.	• Expected increase is based on extrapolation of expansion rate over 2007-2011.
	Links with NECP: NECP does not provide any detail on impact of agricultural PaMs and does not list organic agriculture as a separate PaM. **Comparison:** 2019 PaM report outlines an annual emission reduction of 500 kt CO_2e by 2020 for the GGA. **Conflicts:** n.a. **Synergies:** Børgesen et al. (2013) points out they needed to adjust downward the reduction potential of organic farming due to a significant tightening of fertiliser legislation.		
Country: SI Name: Implemen-tation of premium farming methods that contribute to reducing nitrous oxide emissions Policy instrument: Agri-Environmental Climate Payments (AECPs)	Slovenia's Fourth Biennial Report • PaM: Rational use of N fertilisers • Based on increased N uptake of plants.	• 32 kt CO_2 (2025 and 2030) emission reduction compared to 2015. • Reduction remains stable from 2020 to 2035.	• Basis of assumptions not further explained
	Čufer Klep et al. (2019) • Ex-ante and ex-post (mid-term review)	• 8.0 kt CO_2eq (2017) reduction of GHG emissions compared to 2013 for the RDP (incl. but not only the AECPs).	• No evaluation available that focuses on the AECPs only. • Reduction related to introduction of low emission fertilisation techniques and greening of arable fields as part of the RDP.
	Links with NECP: NECP does not provide GHG emission reduction figures for agricultural PaMs but seems to rely on the same PaMs as the PaM report. **Comparison:** Direct comparison not possible due to different scope of reduction figures. **Conflicts:** n.a. **Synergies:** n.a.		

PaM	Evaluation(s)	Key findings	Systemic and methodological uncertainties:
Country: SI Name: Implementation of premium farming methods that contribute to reducing nitrous oxide emissions/ Upgrading agricultural policy - integrating climate policy and adapting to climate change Policy instrument(s): Financial support for organic farming	Action Plan for the Development of Organic Farming by 2027 (ANEK) • Strategy document that contains ex-ante and ex-post part	• Does not provide GHG emission reduction figures. • **Ex-ante**: continuation of current trend (2007-2019) would lead to 62.737 ha of organic farmland in 2027 (13% of total farmland). • Achieving 18% organic-farmland target by 2027 is equal to 85.500 ha.	• Calculations come from Ministry of Agriculture, Forestry and Food but little information to no information is provided on underlying assumptions.
	Action Plan for the Development of Organic Farming by 2027 (ANEK) • Strategy document that contains ex-ante and ex-post part	• Does not provide GHG emission reduction figures. • **Ex-post**: development of organic farming has fluctuated significantly over 2007-2020 (but 71% area increase over this period). • Over 2016-2020, growth of organic farming has slowed down considerably. • Share of conversion payments grew by around 11 percentage points over 2014-2020 compared to 2007-2013.	• Calculations come from Ministry of Agriculture, Forestry and Food but little information to no information is provided on underlying assumptions.
	Links with NECP: NECP does not provide GHG emission reduction figures for agricultural PaMs but seems to rely on the same PaMs as the PaM report. **Comparison:** Achieving Slovenian target of 18% of all agricultural land under organic farming by 2030 requires average expansion rate of 4.800 ha per year. Highest recorded increase (2012-2013) is 3.563 ha. **Conflicts:** n.a. **Synergies:** The ANEK underlines that introducing organic farming in water protected areas and in nature protected areas will receive particular attention and has set targets to this end.		

Source: own compilation, Ecologic

3.5.1 Impacts on GHG emission reduction

Rational use of N fertiliser

When compared to the national PaM reports, PaM names and descriptions appear to be similar or the same, so that one can assume that PaM emission reductions from the NECPs are aligned with the emission reductions from the PaM reports. For Germany, the ex-ante estimates from Harthan et al. (2020) are more than twice as high when compared to a continuation of the trend from the ex-post evaluation (Velthof et al. 2010). Both studies assume that the Fertiliser Ordinance is the most important policy instrument realising the reductions. However, the ex-ante study assumes that the Fertiliser Ordinance will significantly reduce the N input excess, which explains the difference with the ex-post evaluation. The ex-post evaluation assesses an earlier version of the Fertiliser Ordinance, which had a rather limited impact. The Danish PaM report does not outline any emission reductions for the respective PaM. This means it proves very difficult to check NECP consistency with other ex-ante or ex-post evaluations in the country. In Slovenia, the focus of the ex-post study is solely on fertilisation techniques and greening of arable land, whereas the ex-ante evaluation seems to include more actions (Čufer Klep et al. 2019; Žnidarčič et al. 2014)

Comparing emission estimates across PaMs and countries is even more challenging. The German PaM is an Ordinance providing specific fertiliser application rules, the PaM in Slovenia is a financial support measure to improve farming practices, and the PaM in Denmark is a combination of both. This means that in Slovenia, an additional policy instrument regulates the implementation of the Nitrates Directive, which is not part of the NECP or PaM report. Evaluation periods and reference years vary and progress on fertilisation practices is different in the countries. One could use cost estimates to compare, but these are not available, besides in an ex-post evaluation in Denmark (Børgesen et al. 2009). Another option could be assessing the reduction of N inputs. However, emission reductions can be realised through reducing fertiliser inputs, as well as through better farming practices that improve the uptake of nutrients while keeping the N input stable. The evaluations show that at least in Germany and Denmark, emission reductions came from reduced fertiliser inputs in the past, whereas the projections in Slovenia focus on N uptake by plants.

Increase of organic farming

The NECPs provide little qualitative and quantitative information on the expansion of organic farming. Only Germany includes organic farming as a separate PaM. Slovenia explicitly mentions it as part of another PaM and Denmark does not mention it at all except for setting a general target. This also means that a clear identification of the PaMs was rather difficult, because the "increase of organic farming" is often not clearly defined. It is clear, however, that area-based subsidies play an important role in the promotion of organic farming, which is why we focused our assessment on financial support.

Almost all evaluations provide at least some figures on the expected increase of organic farming, often expressed in hectares converted to organic farming. For both Germany and Slovenia, the ex-ante projections of the organic farming expansion rate exceed historical developments. The German ex-ante evaluation (Harthan et al. 2020) extrapolates the period 2015-2018, which saw a higher expansion rate compared to previous years, up to 2030. For Slovenia, the expansion rate up to 2027 would need to be, on average, consistently higher than the highest recorded increase over 2007-2020. However, it becomes clear from all evaluations that the development of organic farming is subject to fluctuations, which is related to changing funding conditions and market fluctuations.

The German (Bonneval et al. 2016; Harthan et al. 2020) and Danish evaluations (Schelde et al. 2014) provide the GHG emission reduction associated with an increase of organic farming; the GHG emission reduction is generally calculated based on the reduction of nitrogen fertiliser inputs on organic farmland when compared to conventional farmland (i.e., the N_2O emissions from the use of nitrogen fertilisers on former conventional agricultural land is reduced to zero if the land is converted to organic farmland). This also means that any changes of N inputs on conventional land (e.g. via legislation) also change the GHG impact of the conversion to organic agriculture, and vice versa. Some PaMs that relate to the rational use of N fertiliser (e.g., the GGA in Denmark) also include organic agriculture as a measure. This increases the complexity of estimating GHG emission reductions for specific instruments over a longer period.

3.5.2 Socio-economic impacts

Rational use of N fertiliser

Neither the German ex-ante evaluation of the CPP (Harthan et al. 2020), nor the ex-post evaluation of the Nitrates Directive (Velthof et al. 2010), discuss any socio-economic impacts. The Danish ex-ante and ex-post evaluation of APAE III (Børgesen et al. 2009) assess the total costs of the programme, as well as the cost-effectiveness of its individual measures. The Slovenian ex-ante and ex-post evaluation of the RDP (Čufer Klep et al. 2019; Žnidarčič et al. 2014) determine the total costs of the programme. However, none of the reviewed evaluations goes beyond discussing the costs of the programmes or measures that promote a more rational use of N fertiliser.

Increase of organic farming

The German ex-ante evaluation (Harthan et al. 2020) underlines that at least 400 million EUR per year will be needed to support the continuous expansion of organic farming and to reach 18-20% of agricultural land under organic farming by 2030. However, with the new 30% target by the German federal government – exceeding the 25% target set by the Farm to Fork Strategy – it is likely that even more funding will be needed compared to the estimated 400 million EUR per year. This will require an additional increase of funding compared to what the federal government, federal states and the EU spent on the conversion and retention of organic farming in 2019: around 300 million EUR (BLE 2021a). Although the German CPP includes some quantitative information on the socio-economic impacts of organic farming – namely a positive effect on employment but also: production losses – Harthan et al. (2020) only estimate the required investments. In comparison, the (regional) ex-post evaluation (Bonneval et al. 2016) mainly analyses environmental impacts, including biodiversity, water quality and the reduction of soil erosion. None of the Danish evaluations (Børgesen et al. 2013; Schelde et al. 2014) or the Slovenian ANEK (Slovenian Ministry of Agriculture, Forestry and Food 2021) include assessments on the socio-economic impacts of organic farming.

3.5.3 Systemic and methodological uncertainties

Rational use of N fertiliser

Harthan et al. (2020) note that they do not estimate the effects of changed Fertiliser Ordinance. Instead, they assume that Germany reduces its nitrogen surplus from 98 kg N/ha to 70 kg N/ha but they acknowledge that it is unclear whether the revised Fertiliser Ordinance will be sufficient to reach this target. Moreover, they highlight modelling uncertainties related to the reduction per hectare for nitrogen surpluses, considering that in areas with high livestock densities the required reduction might be higher and thus have a greater impact. The uncertainty of the extent to which nitrogen inputs are reduced on a hectare of land or the shift in

intensity of the management practice is also highlighted in two evaluations. These are the German ex-post evaluation (Bonneval et al. 2016) and the Danish ex-ante and ex-post evaluation (Børgesen et al. 2013), which are also used for analysing the focus topic "organic farming".

Increase of organic farming

Bonneval et al. (2016), the German ex-post evaluation, highlight that they use flat-rate values to estimate GHG emission reductions from hectares converted to organic farming since the creation of a detailed model to estimate these reductions is very complex and required data were not available. Accordingly, this meant that the amount of nitrogen saved by using less fertiliser had to be assessed, subsequently using average N reduction potentials of different measures, and finally calculating associated N_2O emissions and converting these into CO_2eq. Although relatively straightforward, this approach makes it difficult to account for regional differences. Similarly, Harthan et al. (2020) use an average reduction value per hectare.

The reduction potential of converting conventional farmland into organic farmland is also closely related to how fertiliser legislation develops over time. Børgesen et al. (2013) point out that they lowered the reduction impact of organic farming by almost halve (from 33 kg/ha N to 17 kg/ha N) between two evaluation periods, due to a significant tightening of fertiliser legislation over the same period of time. The tightened fertiliser legislation lowered the use of N fertilisers on conventional farmland, and thus, diminished the GHG emission impact of converting such land to organic farming. Harthan et al. (2020) also highlights the overlaps with measures to reduce the nitrogen surplus (and thus fertiliser levels) and organic farming. They took this overlapping effect into account when calculating the reduction effect of measures to reduce the nitrogen surplus.

The importance of sufficient funding for area-based subsidies related to organic farming becomes apparent in the evaluations; in Germany, the conversion rate over 2015-2018 was higher partially due to an increase in the premium, whereas in Slovenia lower payments led to farms leaving the organic farming programme. This means that to realise the GHG emission reduction potential of organic farming in the long-term, sufficient and stable funding over a longer period is required. As Harthan et al. (2020) note, changing funding conditions and market fluctuations caused extreme fluctuations in the conversion rate for organic farming. They also highlight the need for appropriate instruments, such as consumer information, to ensure that there is sufficient demand for organic products, which becomes a greater challenge as the market share of organic farming increases.

3.5.4 Conflicts and synergies

The rational use of nitrogen fertilisers and conversion to organic farming come with synergies for GHG emissions and water quality. These measures reduce nitrogen input on agricultural land and thus, related N_2O entering the atmosphere, as well as N leaching into water bodies. All evaluations considered in this study acknowledge the positive impact on water quality from rational use of N fertilisers and organic farming. On the one hand, this can result in reduced crops yields because of the importance of fertilisers for agricultural productivity. On the other hand, an increase in organic farming might lead to an increase in employment and contributes to climate change resilience to help minimise production losses through better adapted soil structures.

None of the evaluations refers to synergies and conflict in terms of employment and productivity. An exemption is the German CPP which outlines potential employment effects and production losses (see Annex A.4.5).

4 What is (not) known about the impacts of policies and measures in the NECPs

In this section, we synthesise the findings from the review of policy impacts reported in the NECPs and corresponding evaluations. First, we compile the findings about impacts across focus topics and discuss the uncertainties associated with the impacts in detail. After these technical considerations, we discuss what this means for the achievement of the NECPs' GHG, RES and energy efficiency targets in a qualitative way and consider barriers to the realisation of impacts as well as conflicts and synergies with other targets. Finally, we discuss implications for the revision of the German NECP and potential general improvements to the coverage of policy impacts in the NECPs and the NECP progress reports.

4.1 Impacts associated with climate and energy PaMs

In this subsection, we summarise the impacts on the three core objectives of energy and climate policy, namely GHG emission reductions, increase in energy efficiency and expansion of renewables, as well as socio-economic impacts associated with the specific policy instruments per country and in the different focus topics based on the results of the in-depth assessment presented in Section 3 and the Annex.

4.1.1 Contributions of policy instruments to GHG emission reductions

A core objective of most of the energy and climate policies reported in the NECPs is to contribute to the reduction of GHG emissions in the MS. For the sectors buildings, transport and agriculture, the GHG emission reduction target is given by the ESR with individual targets for the MS to reduce their emissions compared to 2005 (see Section 2.1.1). Therefore, we compared the evaluated PaMs based on their contributions to reducing the ESR/ESD[9] emissions of the corresponding MS, thereby making the impact comparable among MS. In the following, the results are summarised for each of the focus topics.

Energy and carbon pricing in Denmark, Germany and Sweden

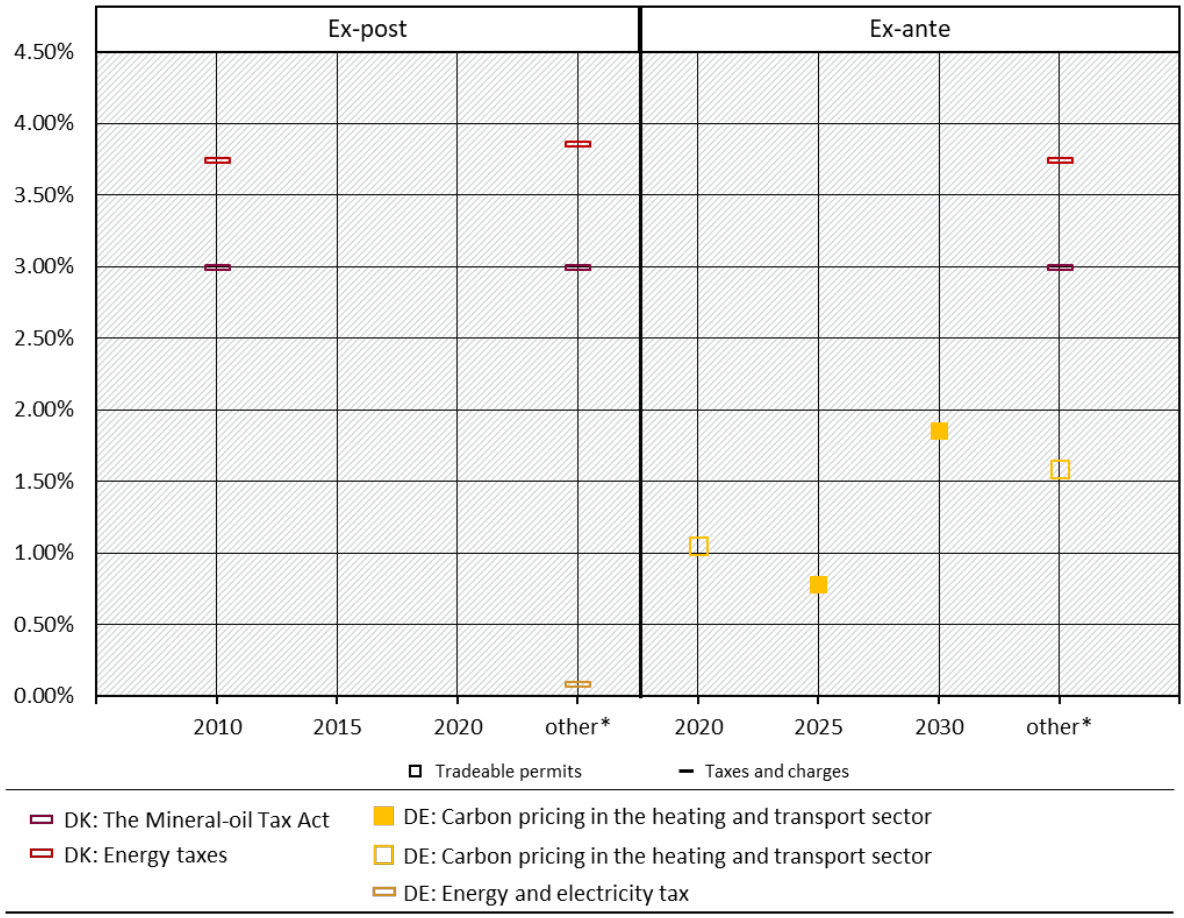
The annual target contribution of the individual energy and carbon pricing instruments is presented in Figure 4 for various years, expressed in % GHG emissions reduction compared to 2005 ESD emissions. For Denmark, both the ex-ante and the ex-post evaluations see a large contribution of Danish energy taxes to GHG emissions reduction of about 3% of the Danish 2005 ESD emissions. For Germany, the expected future contribution of the tradable permit scheme (nEHS) is lower, but also substantial across the ex-ante evaluations. The impact of the existing energy and electricity taxes in Germany was found be relatively small in the past. The Swedish evaluations only consider the resulting energy savings and not the expected GHG emission reductions, which is why no data are shown for Sweden in Figure 4. The same applies to ex-ante estimates of Germany's energy and electricity taxes.

The EED-based estimates reported in the Danish, Swedish and German NECPs promise significant energy savings from energy and carbon taxes and these types of instruments are therefore expected to make a major contribution to achieving the 2030 GHG target of MS. However, the ex-ante and ex-post estimates of the energy and CO_2 taxes in Denmark and Sweden and of the energy and electricity taxes in Germany were calculated based on historical price elasticities of demand. These elasticities were often underestimated, which may have led to an

[9] Pre-2020, the predecessor of the ESR, the Effort Sharing Decision (ESD), was in force. The ex-post reported emissions under the two schemes differ slightly. All percentage reductions shown in this report are based on 2005 ESD emissions from (EEA 2022)..

underestimation of the effect of the taxes (see Section 3.2.3). On the other hand, the EED allows the use of a counterfactual with the minimum EU energy tax rates in the calculations. This does not correspond to the baseline in the NECPs, so the impact of taxes may also have been overestimated (for more details, see Section 4.2.1). Whether overestimation or underestimation dominates depends on factors such as the tax level in the baseline and current price elasticities and was beyond the scope of this project. For the ex-post calculations of the Danish and Swedish energy and carbon taxes, real data on energy consumption and energy prices are used, which must be estimated or extrapolated for the ex-ante calculations. The ex-post and ex-ante estimates in the NECPs correlate strongly due to the extrapolations and the same underlying elasticities. It should be pointed out that the reported figures are of limited validity due to the calculation methodology based on the EED and uncertainties regarding elasticities.

Figure 4: Annual contribution of the energy and carbon pricing instruments to GHG emissions reduction in % of 2005 ESD emissions



Unfilled symbols = not NECP related; filled symbols = NECP related.* other: For studies with several observation years, the arithmetic mean is shown; for studies with one observation year not explicitly included in the figure, the value for that year is shown.

Source: own representation, Fraunhofer ISI based on EEA 2022 and the evaluations listed in Annex A.1

For the German nEHS, the ex-ante estimates were more detailed, but the individual effect of the nEHS was also estimated based on elasticities, which is a rather conservative approach, because synergies between different measures are not taken into account (see Section 3.2.1). In addition, factors such as income levels and income distribution can also have a strong influence on the results and thus limit the comparability of the nEHS with carbon taxes in other EU member states. The measured impacts of energy and carbon pricing instruments in the literature tend to

be smaller than in the ex-ante evaluations, and the effects seem to be associated with energy efficiency improvements or fuel switching rather than transformation (see Section 3.2.3). However, these systems can still contribute to the transformation of the economy. Particularly in combination with support programmes, price surcharges on fossil fuels can significantly reduce the funding gap in operating costs compared to a case without price surcharges. In addition, it cannot be concluded from the stronger effects of taxes documented in the literature (see Lilliestam et al. 2021) that taxes are generally better suited to reducing CO_2 emissions than the ETS. The very weak impacts found in the ETS studies result from focusing on periods with low CO_2 prices and high free allocations. Studies focusing on more recent periods with higher prices and less free allocation are not yet available.

RES Heating and Cooling (RES H&C) in France, Germany and Slovenia

For each of the three selected NECPs, evaluations for two policy instruments were considered. Except for the German NECP, neither of the other two NECPs explicitly addressed the results of the evaluations and no information on expected impacts was provided. However, for Slovenia and France, there was an implicit link between the evaluations and the NECPs. In the Slovenian case, the PaM report was used to quantify impacts on GHG emission reductions, and the French NECP used the background study of the PaM report for both the ex-ante and ex-post view, including detailed quantification. Originally, the Danish NECP was also a candidate for the detailed assessment because of Denmark's progressive RES H&C policies. However, the limited information in the Danish NECP, PaM reports and related studies led to its exclusion from this analysis.

The evaluations showed the assessed French policy instruments had the largest impact when compared to the ESR/ESD emissions. However, it is important to consider that no information on GHG impacts was available for some of the policy instruments in Germany and Slovenia. For both France and Slovenia, higher policy impacts can be observed for the ex-ante evaluations than for the ex-post evaluations. Moreover, in France, the tradable permits show a much larger impact than the active support policies (both ex-ante and ex-post). The results and the underlying reasons are discussed in more detail in the following paragraphs. The annual target contribution of individual RES H&C policy instruments is presented in Figure 5 for various years, expressed as a contribution to the ESR/ESD target in % GHG emission reduction compared to 2005.

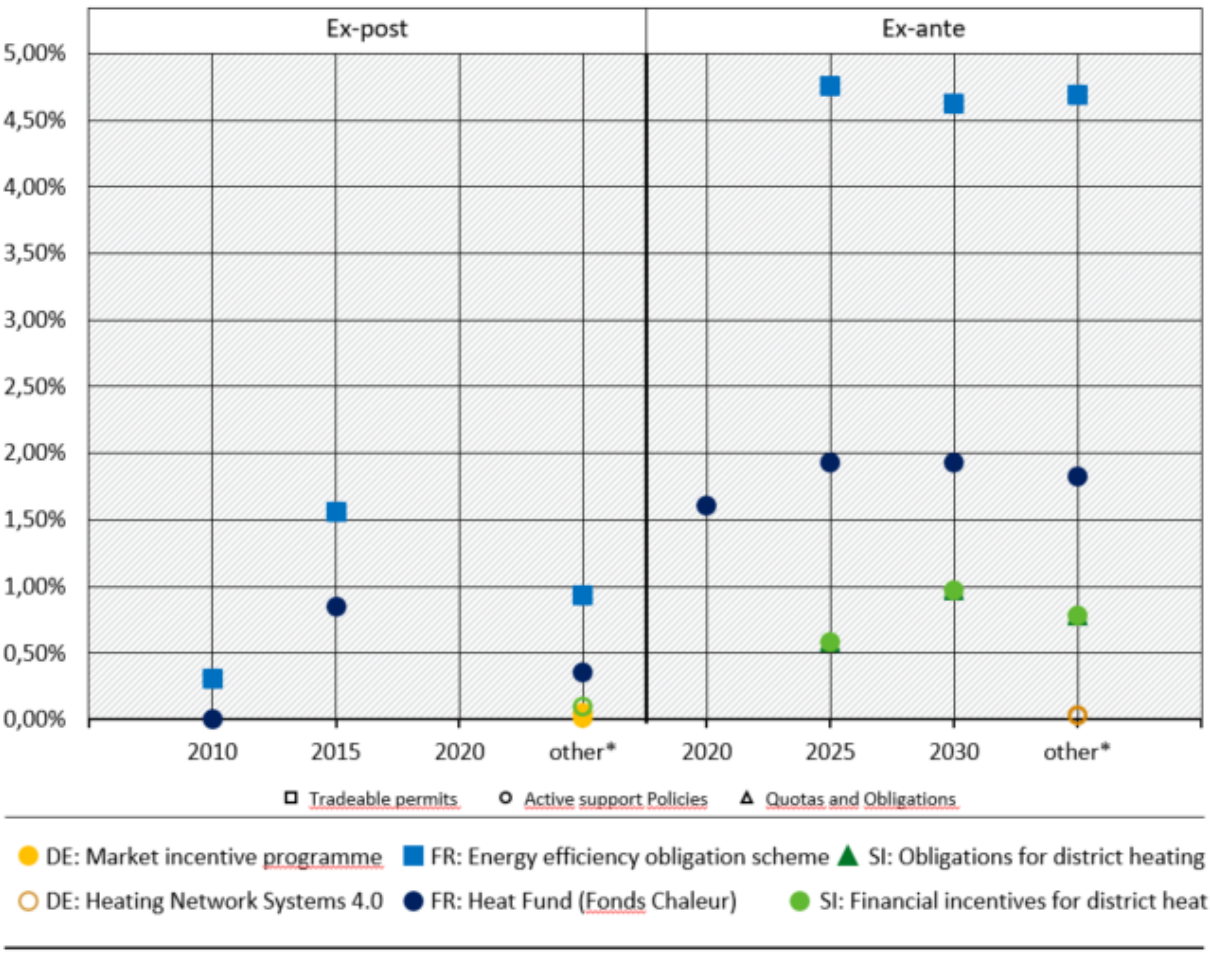
For France, the two analysed PaMs were the Heat Fund and the Energy Efficiency Obligation Scheme. The results of the ex-ante and the ex-post analysis are in line with one another, since the ex-ante analysis is based on linear extrapolation. The values of the ex-ante evaluation seem plausible in light of the ex-post results. Weaknesses and simplifications of the analysis are indicated and discussed in the evaluation document. The increasing impact here is not due to over-estimation, but simply to the accumulation of impact over time.

In the case of German RES Heating and Cooling measures, only the ex-ante evaluation of Heating Network Systems 4.0 considered the PaM's contribution to reducing GHG emissions. Depending on the scenario, the Heating Network Systems 4.0 programme is estimated to provide a moderate contribution by avoiding between 0.03% and 0.13% of ESR/ESD CO_2 emissions per year between 2018 and 2030. Since the Heating Network Systems 4.0 PaM is a new instrument, no ex-post analysis was available.

In Slovenia, the PaMs concern the obligatory share of heat from renewable energy sources, high-efficiency cogeneration and waste heat in district heating systems. However, as no information is provided on the technologies and fuels used, it was not possible to draw conclusions about the PaMs' effectiveness. The financial incentives for using RES to produce district heat only amounted to 0.10% of ESR/ESD CO_2 emissions between 2016 and 2019, and Slovenia is likely to

fall short of meeting its targets. This is related to the PaM being undersubscribed and beneficiaries not making full use of the funds available. The ex-ante estimation of the two PaMs was done in combination, which is why the figures in Figure 5 overlap.

Figure 5: Annual target contribution of RES H&C policy instruments to GHG emissions reduction in % of 2005 ESD emissions



Unfilled symbols = not NECP related; filled symbols = NECP related.

* other: For studies with several observation years, the arithmetic mean is shown; for studies with one observation year not explicitly included in the figure, the value for that year is shown.

Source: own representation, Fraunhofer ISI based on EEA 2022 and the evaluations listed in Annex A.2

Energy-Efficient Buildings in Germany, Slovenia and Sweden

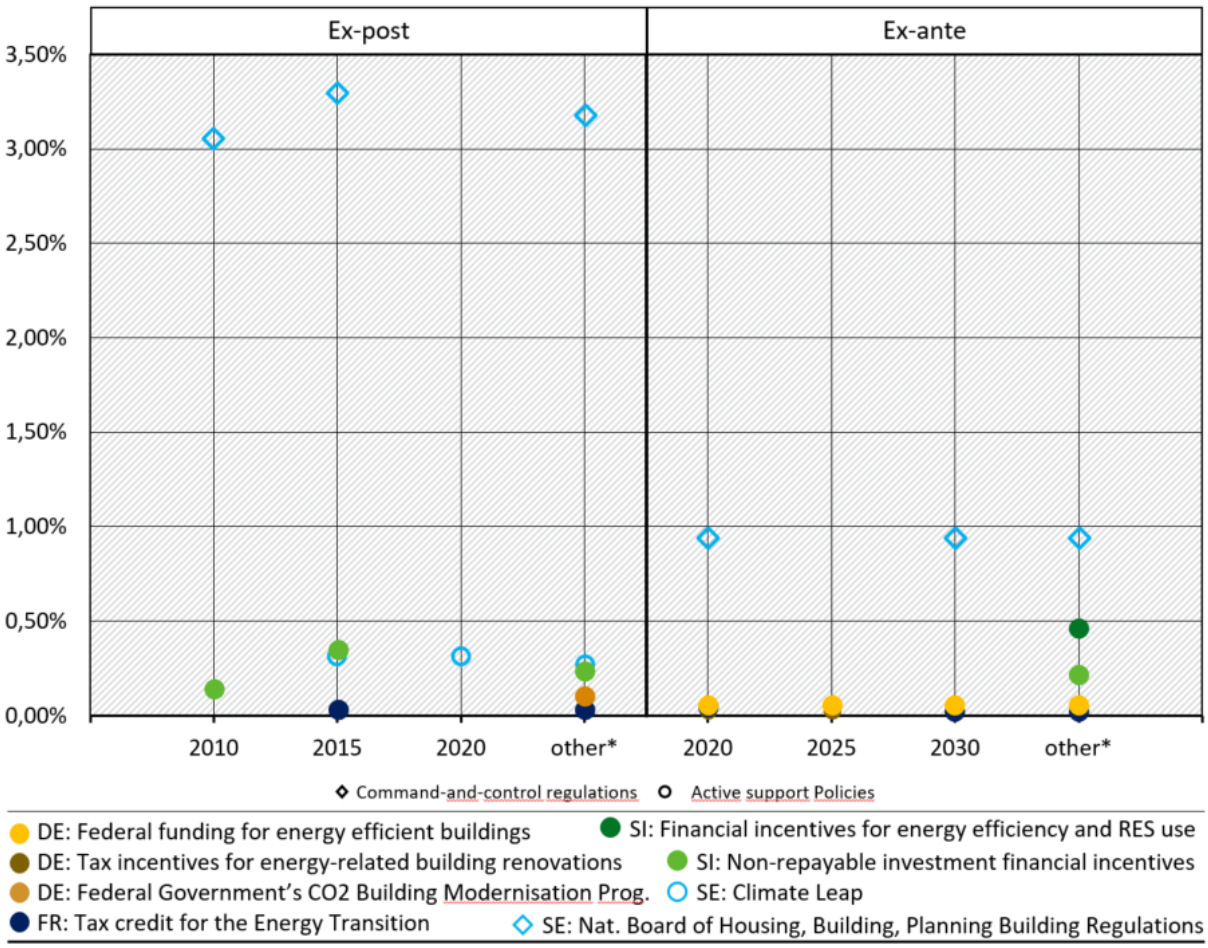
In addition to the MS considered, the evaluation of one French policy instrument was used for comparison due to the lack of ex-post evaluations. While Sweden primarily relies on energy and carbon taxes, other countries focus more on instruments promoting investments in energy efficiency measures, and often also in RES. In 2021, Germany introduced tax incentives as a complementary policy instrument to the federal funding for energy-efficient buildings (BEG). The assessed evaluations and the German NECP indicate that these two key policy instruments can make a considerable contribution to reducing GHG emissions. In Slovenia, the different PaMs are considered separately for buildings in general, residential buildings and public buildings.

Across MS, the evaluations show the largest contribution for the Swedish command-and-control building regulation (see Figure 6). The impacts of the German PaMs appear low in comparison. Active support policies are expected to have lower impacts based on the evaluations considered. The annual target contributions of all the individual policy instruments for the promotion of

energy-efficient buildings considered are presented in Figure 6 for various years, expressed as a contribution to the ESR/ESD target in % GHG emissions reduction compared to 2005 ESD emissions.

In the evaluations, the authors stress that precise assessments at instrument level are difficult, as interactions as well as different effects cannot be considered in sufficient detail. Overall, the evaluations of the Swedish PaMs showed that PaMs aimed at increasing energy efficiency in buildings could contribute to the goals, but also how important the interaction between different PaMs is, especially the interaction with energy and carbon taxes. Since the Swedish evaluations only considered the PaM bundle and not the individual PaMs, the estimated GHG emissions savings include, among others, the savings generated by the cross-sectoral carbon and energy taxes. Another cross-sectoral PaM is the Climate Leap, which is considered an important instrument for achieving GHG emissions reductions and realising the Swedish GHG emission reduction targets, even if it is only of relatively low importance for energy efficiency.

Figure 6: Annual target contribution of energy-efficient buildings instruments to GHG emissions reduction in % of 2005 ESD emissions



Unfilled symbols = not NECP related; filled symbols = NECP related.

* other: For studies that have several observation years, the arithmetic mean is shown; for studies with one observation year not explicitly included in the figure, the value for that year is shown.

Source: own representation, Fraunhofer ISI based on EEA 2022 and the evaluations listed in Annex A.3

For Slovenia, the evaluations found that the funding measures were contributing to increasing energy efficiency in buildings, but also, that one of the PaMs (non-repayable investments) was less effective than previously estimated, possibly because administration-related challenges

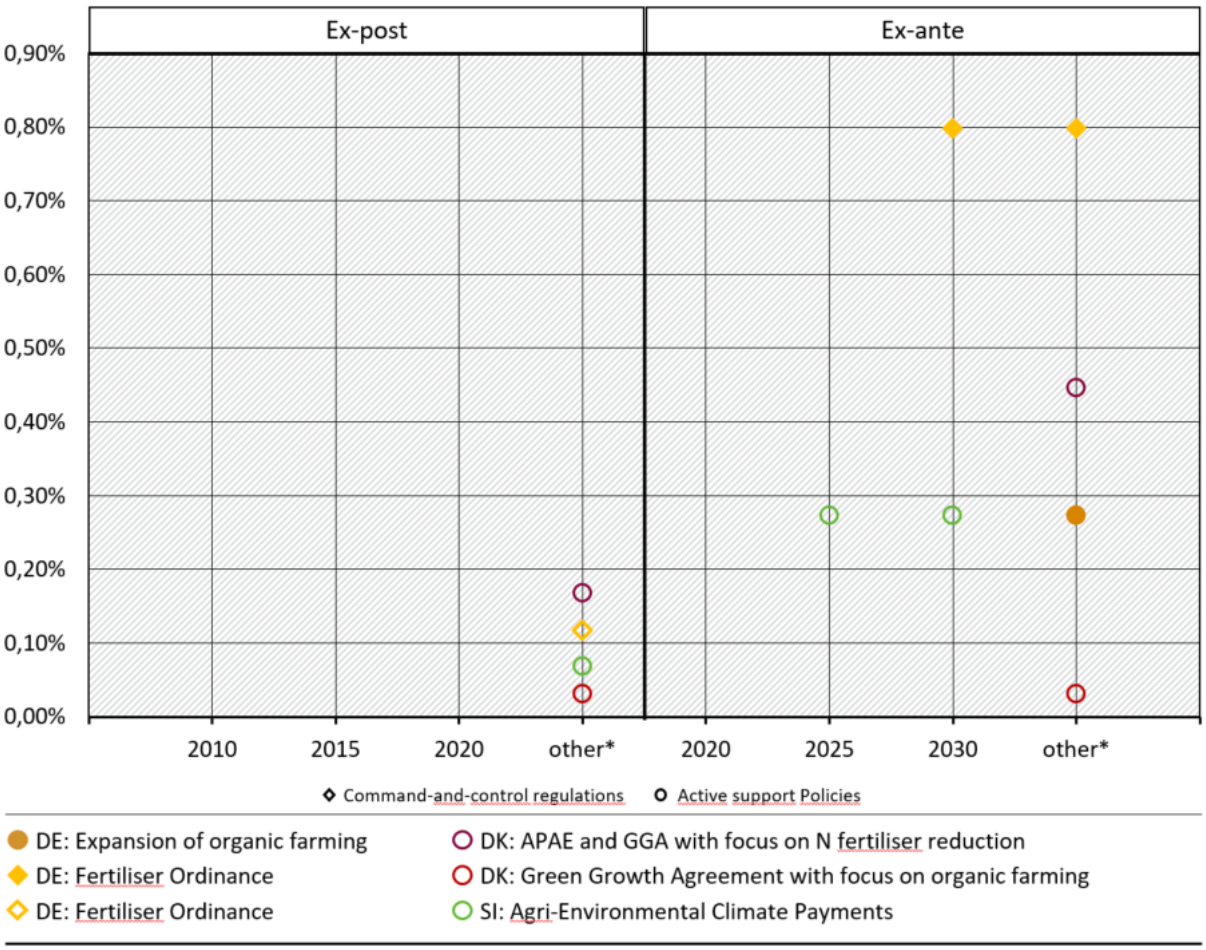
such as applying for and accessing the measure lowered its utilisation. Energy savings and related emission reductions from the tax incentive and the federal funding for energy-efficient buildings in Germany are considered to be key PaMs, but do not achieve the energy savings estimated for energy and carbon pricing (see Section 4.1.2). Still, the NECP and evaluations find that they can make a major contribution to reducing GHG emissions. The two instruments are not mutually exclusive and, together, might increase the number of investors, which means that the interaction between the two might have a positive effect.

Agricultural soils in Denmark, Germany and Slovenia

The NECPs of Denmark, Germany and Slovenia include information on PaMs to reduce GHG emissions related to agricultural soils, in particular to nitrogen fertilisers. The German PaM on N fertiliser is an ordinance with specific rules for applying fertiliser, the PaM in Slovenia is a financial support measure to improve farming practices, and the PaM in Denmark is a combination of both. This means that, in Slovenia, an additional policy instrument regulates the implementation of the Nitrates Directive, which is not part of the NECP or PaM report. The NECPs provided little qualitative or quantitative information on the expansion of organic farming. Only Germany includes organic farming as a separate PaM. Slovenia explicitly mentions it as part of another PaM and Denmark does not mention it at all except for setting a general target. It is clear, however, that area-based subsidies play an important role in the promotion of organic farming. There was some information on GHG emissions avoidance for at least one of the PaMs in all three MS. However, the Slovenian ex-ante evaluations do not include any quantification of the expected GHG emissions avoidance. In contrast to what was originally planned, we were not able to assess French agriculture PaMs due to too limited available information.

The annual target contribution of the individual agricultural policy instruments is presented in Figure 7 for various years, expressed as a contribution to GHG emissions reduction compared to the 2005 ESD emissions. The analysis found that the reduction of fertiliser inputs through regulation and support programmes for improved management practices can lead to significant emission reductions. In Germany and Denmark, the focus is clearly on reducing N inputs to also reduce the related N_2O emissions and N leaching into waters. In Slovenia, however, the ex-ante evaluation assumes a higher N uptake by plants due to improved agricultural techniques. This leads to a reduction of N_2O emissions despite the increased N use on agricultural land.

Figure 7: Annual target contribution of agricultural policy instruments to GHG emissions reduction in % of 2005 ESD emissions



Unfilled symbols = not NECP related; filled symbols = NECP related.

* other: For studies that have several observation years, the arithmetic mean is shown; for studies with one observation year not explicitly included in the figure, the value for that year is shown.

Note: Reductions refer to different base years. For a detailed description of the figures, see Annex A.4 and Section 3.5.

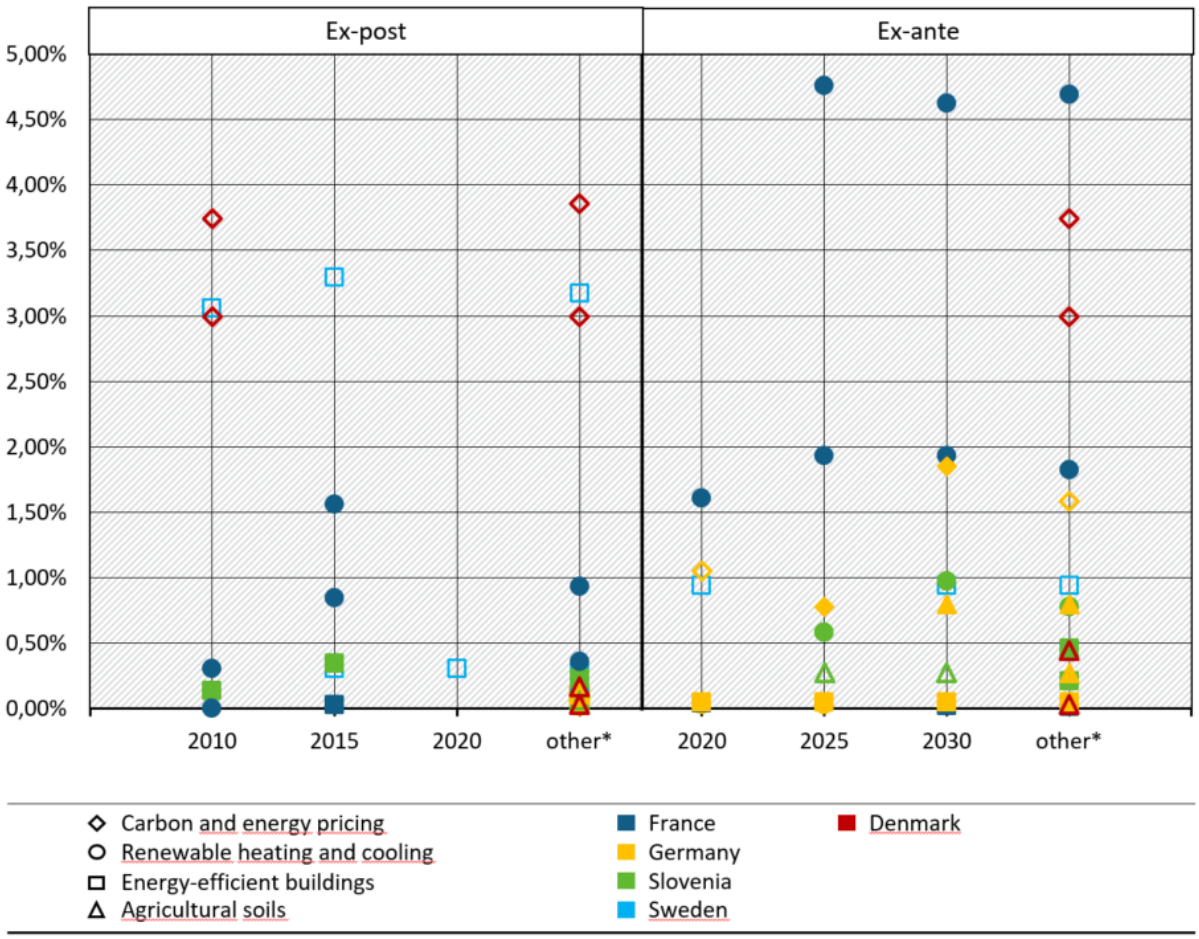
Source: own representation, Fraunhofer ISI based on EEA 2022 and the evaluations listed in Annex A.4

Organic farming is promoted through area-based subsidies, which have a high impact on its expansion rate. When compared to the PaMs addressing the more restricted use of N fertilisers, organic agriculture has a smaller effect on reducing GHG emissions due to the relatively small share of organic agriculture in total agricultural land. As organic agriculture does not use any synthetic fertilisers, some PaMs related to the efficient use of N fertiliser (e.g. in Denmark) also include organic agriculture as a measure. In addition, the impact of organic agriculture is measured against conventional farming, which means that its climate impact decreases as conventional farming increasingly adopts better practices. This makes estimating GHG emission reductions for specific instruments even more complex. However, ex-ante evaluations in all three countries show an increase in organically farmed land. For both Germany and Slovenia, the ex-ante projections of the expansion rate of organic farming exceed historical developments. At the same time, changes to funding conditions and market fluctuations have caused extreme fluctuations in the conversion rate for organic farming and evaluations mention the need for appropriate instruments, such as consumer information to ensure that there is sufficient demand for organic products, which becomes harder as the market share of organic farming increases.

GHG emission reductions in evaluations linked to the NECPs and/or PaM reports

We end this subsection by comparing the impacts of the assessed policy instruments on reducing GHG emissions across focus topics. Here, we examine the policy instruments that are di-rectly linked to the NECPs, e.g. via background studies, or linked to the PaM reports, see Figure 8.

Figure 8: Annual target contribution of evaluated policy instruments to GHG emissions reduction in % of 2005 ESD emissions



Unfilled symbols = not NECP related; filled symbols = NECP related.

* other: For studies that have several observation years, the arithmetic mean is shown; for studies with one observation year not explicitly included in the figure, the value for that year is shown.

Source: own representation, Fraunhofer ISI based on EEA 2022 and the evaluations listed in Annex A

The expected impacts in ex-ante evaluations tend to be higher than those observed in ex-post evaluations. However, this is often for plausible reasons, in particular due to the accumulation of effects or increased ambition of the instrument, e.g. a higher support volume. The largest impact by far, both ex-post and ex-ante, is found for the French Energy Efficiency Obligation Scheme, which is a tradable permit scheme targeting both energy efficiency and expansion of RES heating and cooling, thereby addressing a broad set of mitigation measures with a clear mechanism to realise the targeted impact.

There is no visible trend of higher or lower impacts across MS, type of instrument or focus topic, but the German policy instruments seem to have a relatively low impact. This is related to the fact that the baseline for the instruments in the German Climate Protection Programme is

considered relative to the baseline of the current policy mix. Moreover, most other MS focus on certain types of instruments and/or subsume policy impacts under certain key instruments, while the German NECP and the related evaluations cover a broader variety of instruments. Nevertheless, the large number of German instruments comes with the added risk of unclear interactions between them.

4.1.2 Contributions of policy instruments to further objectives

In this section, we take a look at the results of the review of policy impacts with regard to other objectives of energy and climate policies in the NECPs, in particular their contributions to energy savings as required under the EED and to the expansion of renewable energies as targeted in the RED. In addition, the information about socio-economic impacts that we found in the evaluations is summarised.

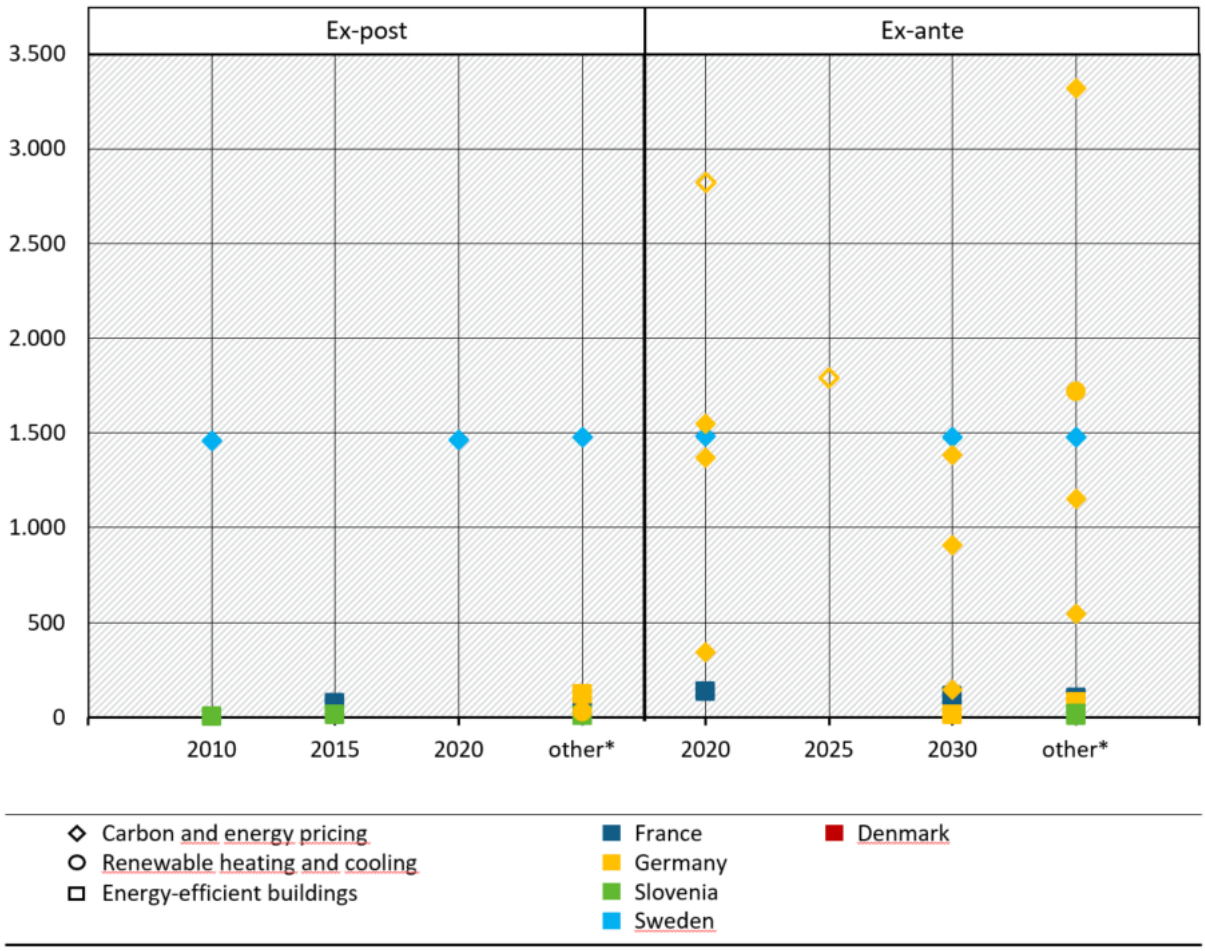
4.1.2.1 Energy efficiency and expansion of renewables

The quantitative information provided on energy savings and expansion of renewables was more limited than the information on GHG emission reductions. Therefore, we limit the considerations here to an overarching comparison across focus topics and countries.

The energy savings in the various focus topics and selected countries refer to different baselines and different sectors. Therefore, there is no suitable normalisation of impacts across countries and focus topics. We, hence, stick to the absolute emission savings here. However, the difference is the size of the countries and their energy demand need to be kept in mind when interpreting the results. This applies in a similar way to the expansion of renewables, where we consider the absolute uptake of renewable energy consumption.

The largest energy savings are expected for energy and carbon taxes in Sweden and the national emission trading scheme in Germany. While the former is in line with energy savings found in ex-post evaluations, there is no ex-post validation for the impacts expected in Germany yet due to the novelty of the instrument. For the Danish energy and carbon taxes, energy savings are not available. The energy savings for instruments under the focus topics energy-efficient buildings and RES H&C are mostly substantially smaller, which is related to their smaller scope. The findings on energy savings are summarised in Figure 9.

Figure 9: Annual energy savings by individual policy instruments in ktoe



Unit conversion: 1 ktoe = 11.63 GWh/11,630 MWh/11,630,000 kWh

Unfilled symbols = not NECP related; filled symbols = NECP related.

* other: For studies that have several observation years, the arithmetic mean is shown; for studies with one observation year not explicitly included in the figure, the value for that year is shown.

Source: own representation, Fraunhofer ISI based on the evaluations listed in Annex A

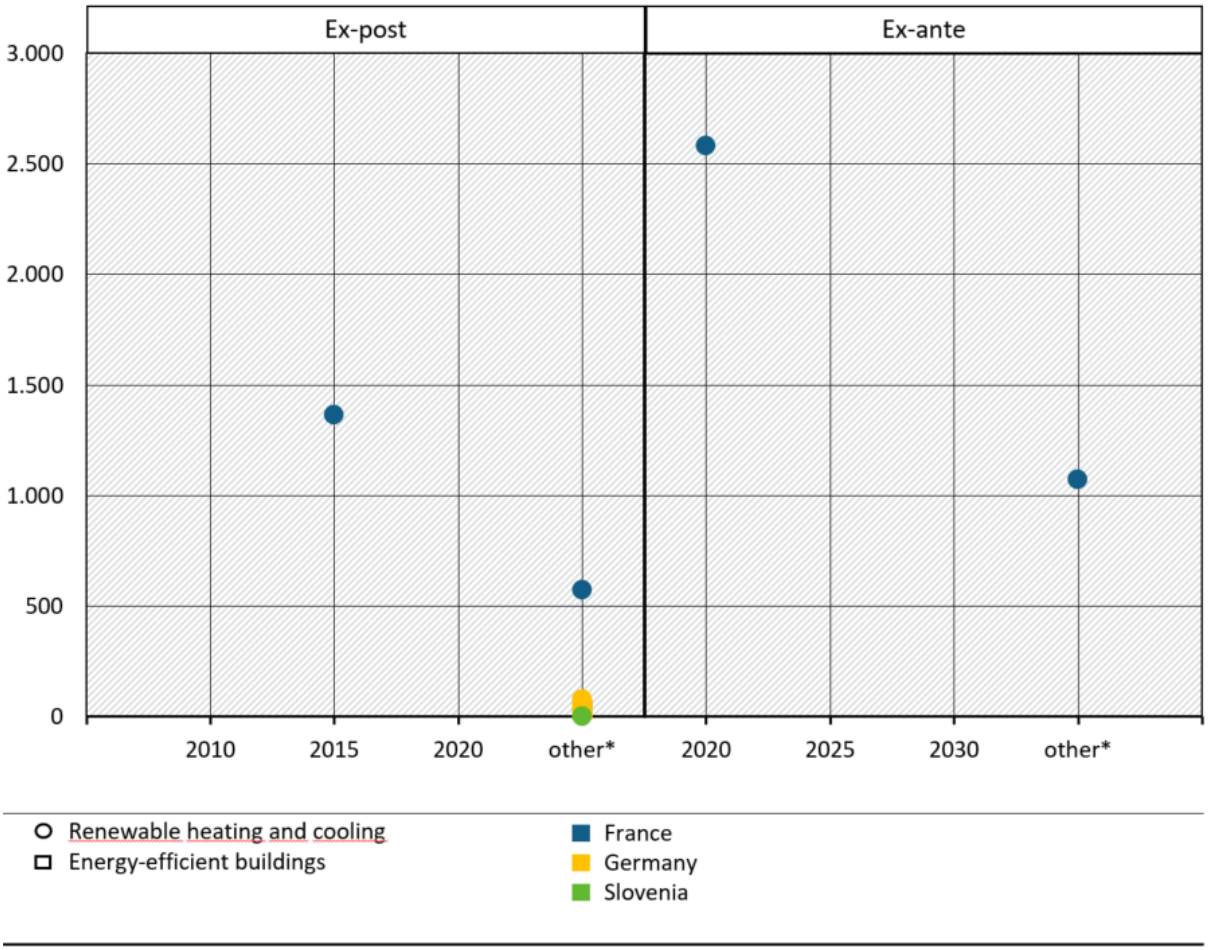
The contribution to the expansion of renewable energies is quantified only for very few instruments, mostly only in the ex-post evaluations under the RES H&C topic. The largest contribution is found for Heat Fund in France, for which an even higher impact is expected in the ex-ante evaluation. As far as provided, the contribution to expansion of renewables of all analysed instruments is limited. The findings on RES expansion are summarised in Figure 10.

4.1.2.2 Socio-economic impacts and costs

In this subsection, we summarise the findings about impacts on GDP, employment, investments and costs associated with the considered policy instruments per country and in the different focus topics. By obligation in Article 7 – 9 of the GOV-R, the NECPs include a system-wide impact assessment of the overall energy and climate policy mix with regard to impacts on GDP, employment and investments but no consideration of cost efficiency/effectiveness of planned policies is required. When it comes to the individual policy instruments, the picture is quite different. Socio-economic impacts of policy instruments are mostly not reported in the NECPs reviewed in this report. They are also rarely taken into account in the assessed evaluations and consider varying aspects depending on both the type of instrument and the evaluation. In some cases, quantitative impacts are reported, but qualitative assessments are more prominent.

Accordingly, the GDP impacts of individual policy instruments are rarely assessed. In France, the Heat Fund is said to have a positive effect on the French trade balance, as imports of fossil fuels are reduced. In the scientific literature (see literature review by Ohlendorf et al. 2021), empirical ex-post studies find no or weak effects of carbon taxes on GDP, GDP growth, or employment, tending to show slightly positive effects, whereas results from ex-ante modelling tend to show slightly negative effects.

Figure 10: Annual expansion of renewable energies by individual policy instruments in ktoe



Unit conversion: 1 ktoe = 11.63 GWh/11,630 MWh/11,630,000 kWh
Unfilled symbols = not NECP related; filled symbols = NECP related.
* other: For studies that have several observation years, the arithmetic mean is shown; for studies with one observation year not explicitly included in the figure, the value for that year is shown.
Source: own representation, Fraunhofer ISI based on the evaluations listed in Annex A

Distributional impacts are generally not considered, either. However, for carbon taxes there is clear evidence in the scientific literature (see Ohlendorf et al. 2021) that low-income households may be at risk of not being able to pay for their living expenses and that certain population groups may be disproportionately affected by such tax systems. Nevertheless, the German NECP includes some compensatory instruments such as the reform of the EEG surcharge and commuter allowances, but the impacts of these instruments are not assessed. The Heat Fund is expected to likely benefit lower-income households more than their better-off counterparts by contributing proportionately more to reduced heating bills according to the French background study to the PaM report.

As far as there is information on labor markets, the expected impacts are considered positive across all topic fields and evaluations. For RES H&C, the creation of additional jobs is described for both French instruments and the Slovenian direct support instrument but without quantification. Energy efficiency in buildings is also considered as an important factor to reduce unemployment, which is at least mentioned in the evaluated NECPs. In Germany, the Climate Protection Plan reports a positive effect on employment by organic farming, which is not addressed in the ex-ante evaluation. The most detailed consideration was found in the ex-post evaluation of the German Funding for Efficient Buildings Programme (BEG), which showed that, against a baseline of 93.000 person-years, the direct employment effects might amount to additional 85.000 person-years in 2017, the indirect employment effects to additional 33.000 person-years in 2017.

The information on costs and cost efficiency is also limited with some notable exceptions. The ex-post evaluation of the MAP in Germany find that the funding cost efficiency given by the amount of funding used per unit of CO_2eq of emissions avoided has decreased over time for a variety of reasons. The Danish and Slovenian ex-ante and ex-post evaluations assess the total costs of their agricultural programmes and partly the cost-effectiveness of its individual instruments. The most detailed assessment can be found in the ex-ante evaluation of the German organic farming instrument, which estimates that at least 400 million EUR per year will be needed to reach 18-20% of agricultural land under organic farming by 2030. Further socio-economic impacts mentioned in the evaluations across topic fields and countries included effects on innovation, and positive contributions to energy security and increasing the local supply.

4.2 Uncertainties of impacts

According to OECD (2014), important sources of uncertainty for ex-post evaluations are (1) the reference scenario describing what would have happened without the PaM, (2) additional assumptions when available statistics and data are not completely fit for purpose, (3) the output of any quantitative or qualitative method for gathering data as well as (4) rebound and free-rider effects, which are hard to assess but can have a significant effect on the effectiveness and efficiency of a PaM. In the context of ex-ante assessments of PaM impacts, Rich et al. (2014) distinguish (1) parameter uncertainty, i.e. uncertainty regarding whether a parameter value used in the assessment accurately represents the true value of a parameter, (2) scenario uncertainty, i.e. variation due to methodological and scenario choices, and (3) model uncertainty, i.e. limitations in the ability of models to reflect reality.

In general, uncertainty is a quite broad concept studied from different viewpoints in various disciplines (see e.g. Bilcke et al. 2011, Mirakyan et al. 2015). Moreover, various classifications and typologies for uncertainties have been developed (see e.g. Bilcke et al. 2011, Mirakyan et al. 2015, Walker et al. 2003). Hunter et al. (2013) focus on the imprecise specification of input data, which they call parametric uncertainty, and the limited ability of models to represent reality, which they call structural uncertainty. We build on this but prefer to separate more clearly between uncertainties that could be reduced by a different measurement or a more detailed model, which we call *methodological uncertainties* and uncertainties that are irreducible due to inherent uncertainties about the future, which are particularly relevant to ex-ante evaluations and we call *systemic uncertainties* here.

In the following subsections, we discuss in detail the methodological and systemic uncertainties related to ex-post and ex-ante evaluations as well as knowledge gaps that we identified in review of the NECPs. With respect to the uncertainties, the extent to which they can be reduced by adapting the methods and/or improving the data basis is examined. Regarding the knowledge gaps, possible reasons for their existence and options to close them are also addressed.

4.2.1 Methodological uncertainties of ex-ante and ex-post evaluations

Both the ex-ante and the ex-post evaluations of policy instruments face a variety of methodological uncertainties. In particular, each evaluation is based on an underlying impact model for estimating the effect of the policy instruments. While the assumptions in such impact models are usually based on empirical findings, there are various uncertainties about whether the impact model holds true under the exact conditions of the considered policy and what the relevant parameters for the calibration of the model are. While also the choice of these parameters can and should be informed by empirical findings, some uncertainty on the data in the exact context will always remain (Schlomann et al. 2022). Additional methodological uncertainties in ex-post evaluations come from the fact that in practice the impact can often be measured only on the basis of a sample of all relevant cases and only indirectly, for instance based on the funding spend on thermal insulation of buildings but not on the amount of energy savings realised, at least not for all buildings refurbished.

To deal with methodological uncertainties in ex-post-evaluations, a variety of guidelines has been established. Recently published guidelines on European level are for example the "Guidance document for ex-post evaluation of climate policies in Effort Sharing sectors" developed in a project of the European Commission for the EU Member States (Ricardo Energy&Environment et al. 2020) and . An example from Germany is the methodological guideline for evaluations of energy efficiency measures of the German Ministry of Economic Affairs [„Methodikleitfaden für Evaluationen von Energieeffizienzmaßnahmen des BMWi]" (Fraunhofer-Institut für System- und Innovationsforschung (Fraunhofer ISI) et al. 2020)[10]. These guidelines have different scopes and highlight different aspects.

For ex-ante evaluations tied to the preparation of NECPs and/or PaM reports, transparency and a careful treatment of uncertainties is also an important requirement. Important methodological uncertainties in ex-ante evaluations are related to the assumed parameters, to the scenarios considered and to the impact model used. In particular, methodological uncertainties stem from uncertainty about parameters being the same in the future as today and if impact models continuing to hold true. Moreover, the impact models for new kinds of instruments are usually based on the established models for similar types of instruments, but this analogy may still face important limitations. Various concepts how to deal with these limitations have been developed such as harmonisation of parameters between evaluations, transparency about the potential ranges in combination with sensitivity analyses, and model calibration based on ex-post evaluations (cf. EC 2021c). However, there are few best practice guidelines available for ex-ante evaluations (some aspects are covered in Azzini et al. 2020; EC 2021c; Rich et al. 2014). Recently, there have been some initiatives on providing guidance how to increase the transparency of ex-ante evaluations, in particular in the German context (see e.g. Matthes et al. 2021; Schlomann et al. 2022).

4.2.1.1 Methodological aspects of the assessed evaluations

Important methodological aspects of evaluations are the choice of the baseline, which considers the changes of energy demand and GHG emissions without the assessed policy, the assumed impact models, and the distinction between gross and net impacts, with the latter taking into account various factors reducing the gross impacts of the policy such as free-rider effects, spillover effects and interaction with other policies. All three aspects often depend on the guidelines used. As far as the evaluations have stated it, they were based on various types of

[10] For the sake of transparency, we point out that this guideline was authored by the same institution as the report at hand. The same applies to Schlomann et al. (2022) cited several times in this section.

national and European guidelines. Only very few were based on the Better Regulation Guidelines of the European Commission (cf. EC 2021b).

In terms of the baseline, not always a reference was used and even when the evaluation was conducted relative to a reference case, the latter was not always made transparent. For energy and carbon pricing instruments, it is important to mention that the requirements of the EED for calculating the impact of taxes on energy consumption are designed in such a way that they always assume a counterfactual with minimum EU tax rates (see Section 3.2.3). Such a counterfactual makes it difficult to assess the contribution of an instrument to the GHG emission reduction target of a MS and may lead to overestimating the effects, as taxes in the baseline scenario of the considered MS usually were above the minimum rates.

In terms of the assumed impact model, an important source of methodological uncertainty was the common use of elasticities. In the scientific literature (cf. Annex A.1.1), ex-post studies are no longer based on elasticities but on various types of more sophisticated econometric models, which seem to provide more robust and reliable results than estimates based on elasticities. However, due to the simplicity, the data availability in national sources (except elasticities) and the comparability of ex-ante and ex-post estimates, the extrapolated demand changes shown in the NECPs provide a certain transparency that the more sophisticated econometric models cannot provide. Impact-model-related uncertainties highlighted under the focus topic on organic farming (see Section 3.5.3) are the use of flat-rate values to estimate GHG emission reductions from hectares converted to organic farming, making it difficult to account for regional differences, and uncertainties related to the reduction per hectare for nitrogen surpluses, considering that in areas with high livestock densities the required reduction might be higher and thus have a greater impact. This uncertainty, related to what extent nitrogen inputs are reduced on a hectare of land/the intensity of the management practice that is being replaced, is also highlighted by a German ex-post evaluation (Bonneval et al. 2016) as well the Danish ex-ante and ex-post evaluation (Børgesen et al. 2013).

In terms of gross and net impacts of instruments, both were addressed with impact models in the evaluated ex-ante evaluations. However, assumptions and sources to uncertainties in ex-ante evaluations are not always discussed, at least not in detail. One good-practice example (see Section 3.4.3) is the impact assessment for the German tax incentives for energy-related building renovations and the federal funding for efficient buildings (Prognos et al. 2020). All three steps of the methodology are described in detail and all underlying assumptions, which are based on an ex-post evaluations and the details of the PaM design, are also well justified. The resulting estimations are critically discussed in the context of limitations. In the case of Slovenia, for instance, the ex-ante evaluation of the financial incentives for energy efficiency and RES use in residential buildings lacks this level of detail. Thus, the results are less well traceable, in particular because further effects or analyses are conducted on an aggregate level.

4.2.1.2 Conclusions on methodological uncertainties

In the evaluations we assessed, only gross impacts were considered in a lot of cases due to the complexity of assessing net impacts (compare the overview tables in Sections 3.2 - 3.5 to 3.5). If interactions with other policies were considered, this was mostly done by providing the impact only on the level of an instrument bundle. Moreover, the baselines were widely differing, for instance freezing the policy support at different point in times to compare changes or considering a counterfactual scenario based on a certain assumption depending on the guidelines used for the evaluation.

For a transparent ex-ante evaluation, two types of gross impacts and net impacts should be distinguished in the evaluation (see Schlomann et al. 2022). The non-adjusted gross impact is

the direct comparison of energy use and/or GHG emissions before and after the implementation of the policy instruments. The baseline-adjusted gross impact is the remaining impact after baseline savings relative to a reference development have been removed. To get to the net impact at the level of a single instrument, free-rider, structural effects and rebound effects need to be removed, while spill-over and follow-on effects have to be added. Free-rider effects are savings that would have occurred without the introduction of the instrument, structural effects are effects due to changing of relevant structural variables (e.g. weather conditions), and rebound effects are increases of energy use and/or GHG emissions due to lower unit costs. Spill-over and follow-on effects refer to effects not directly credited to the instruments and effects due to not yet fully realised actions, respectively. To get to the net impact on the level of an instrument bundle, the net impact of the single instruments has to be adjusted for their interactions (Schlomann et al. 2022).

Differences in the evaluations are often due to the context and the requirements by the contracting authority. This is a particular issue for ex-post evaluations, which are usually not tied to the preparation of NECPs and/or PaM reports but to other purposes, in particular evaluations of the usefulness of public spending. While this is of course an important purpose that should be considered, it is important to integrate the purpose of measuring the contributions of the policy instruments to the core objectives of energy and climate policy, too. This calls for a revision of certain guidelines and requirements for ex-post evaluations in view of the requirements of energy and climate policies. In particular, this applies to the requirements for ex-post evaluations under the EED, which require the use of a baseline that is not in line with the typical baselines for measuring the targets of the climate policies of the EU and its MS.

4.2.2 Systemic uncertainties of ex-ante evaluations

Independent of methodological uncertainties, an ex-ante impact assessment of a policy instrument will always face substantial limitations due to systemic uncertainties. This is strongly driven by the uncertain developments of the socio-economic and technological framework conditions, which may change the instrument's impact. Another important factor is the interaction with other policy instruments, may it be newly established, adjusted or even abandoned policy instruments.

4.2.2.1 Aspects of systemic uncertainties in the assessed NECPs and evaluations

According to our in-depth assessment of policy instruments from the NECPs and associated evaluations, quantitative ex-ante evaluations were able to provide useful insights on the potential impacts of policy instruments by making a range of well-funded assumptions on the development of key factors (compare the overview tables in Sections 3.2 - 3.5). Critical issues were the extrapolation of current trends and the choice of the base cases and base years. Another difficulty was that interaction effects with other instruments were often hard to consider and hence neglected, while in reality different policy instruments would influence one another. Thus, spill-over effects or the additionality of an instrument are hardly covered.

In various evaluations (e.g. Prognos et al. 2020; Stegnar et al. 2020), the limitations of ex-ante evaluations and particularly the dependence on assumptions made were highlighted, but still, the assumptions and the resulting uncertainties were often not discussed in detail. For instance, the ex-post effects of the energy tax in Denmark and Sweden were projected into the future, i.e. the ex-post evaluations formed the basis for the ex-ante estimates, however in a rather simple way. An important source of uncertainty is the use of historical elasticities, which might not reflect the availability of new technologies and the persistence of increasing prices. For example, Andersson (2019) finds that the elasticity to taxes is substantially higher than to energy price

fluctuations (see Section 3.3.3). Other sources of uncertainty include for example the assumed rate of actual energy savings for the evaluation of the French Energy Savings Certificate scheme. Here, standardised operation sheets are used to underpin the quantification, but the evaluation points out that there is likely a considerable gap between the expected performance of a technology as estimated in these sheets and the actual savings. It is pointed out that the effect might go into both directions, i.e. corresponding to either an over- or underestimation, but this is not further contextualised nor explained.

Also, interaction effects are often considered rather qualitatively. As for Germany, the ex-ante evaluation of the incentive scheme for renewable heating systems, the MAP, seems to overestimate the effect of the PaM on energy savings, while disregarding interaction effects. In the evaluations, authors stressed that assessments on instrument level are difficult to conduct precisely as interactions as well as different effects cannot be considered sufficiently. In several evaluations, also the overlap between the focus topics "Energy-Efficient Buildings" and "Renewable Heat" became apparent. This overlap should be kept in mind when assessing impacts in the different dimensions.

The ex-ante evaluations deemed most helpful in our assessment had clear and easy-to-find information about underlying assumptions and resulting limitations, even if the degree of detail was relatively low. A good-practice example is the ex-ante evaluation from Pehnt et al. (2017) for the Germany Heating Network Systems 4.0 programme. The evaluation is especially helpful in putting the PaM into perspective, describing adjacent PaMs and the wider systemic context. Assumptions for each of the three scenarios are listed transparently and consistently with the key results summarised in well-arranged tables. Ex-post evaluations were valuable not only for understanding the impact and importance an instrument had proven in the past but also for possible future impacts, especially when they used reliable data sources and considered interaction effects. If aggregation of effects of policy instruments could be avoided, a qualitative classification was helpful to (at least) make assumptions about potential additionality effects. For instance, the evaluated French RES H&C ex-post evaluations provided helpful information for understanding possible future impacts of the corresponding instruments, which made an assessment of the plausibility easier. These evaluations elaborated on the future effects of changes in fossil fuel commodity prices, most importantly oil prices, and how these were likely to affect the obtained results. These types of observations taking into account framework conditions would be even more helpful if performed in a quantitative manner, but can already serve as useful signposts if elaborated verbally.

4.2.2.2 Conclusions on systemic uncertainties

To deal with such systemic uncertainties, it is most important to address them explicitly and in a transparent way. In particular, this requires a precisely formulated description and a transparently communicated specification of the instrument, the use of margins for input and corridors for the resulting impacts. To increase the transparency of evaluations, Matthes et al. (2021) call for the use of binding predefined data in the definition of the reference system and for a reporting of inherent uncertainties in a transparent way to avoid biases in the results and their interpretation. As a consequence, the outcome will not be a single impact but include uncertainty ranges, which makes the further use more complex. This may require choosing a base case based on the developments and impacts considered most likely, but nonetheless the base case impact should not be communicated in isolation, i.e. without the associated uncertainties.

Moreover, Matthes et al. (2021) suggest to use standardised templates for the reporting of methods, input and output parameters and apply open-source tools whenever possible.

According to Schlomann et al. (2022), a suitable template for ex-ante assessments should explicitly ask for the considered baseline and framework conditions as well as for the specification of the gross and net impacts and the origin of the difference between the two. Even if some of the information is not provided in the end, it becomes transparent which effects have been considered and which not.

While systemic uncertainties are irreducible to a certain extent, a proper use of learnings from ex-post evaluations should inform ex-ante evaluations to take into account empirical findings, in particular on indirect and interaction effects. Ricardo Energy&Environment et al. (2020) present several suggestions how to improve ex-ante assessments based on ex-post evaluations, in particular (1) to harmonise the assumptions, outputs and inputs of ex-post evaluations and ex-ante projections, correcting for known differences, (2) to calibrate policy impacts in projections based on those estimated in the ex-post evaluations in past years, (3) to analyse sensitivities with regard to the most uncertain factors and (4) to align the time schedules of different reporting requirements. The latter aspect is taken up in more detail in the "Guidelines on how to integrate evaluation into the policy cycle" (Broc et al. 2019).

In addition, the IPCC developed a framework for judging the uncertainty of scientific results based on the amount, type and quality of available evidence and the agreement between different sources (Mastrandrea et al. 2011), resulting in a semi-quantitative rating of the uncertainty. To apply this framework to the evidence on PaM impacts across the EU could in principle be useful to provide an overview. However, it is likely to be too general to inform the selection and design of concrete PaMs taken up in the NECPs for several reasons. On the one hand, the assessment of whether national and/or EU targets will be reached requires a quantification of the expected ranged of PaM impacts. On the other hand, the uncertainty for a concrete PaM depends a lot on the exact specification of the PaM and other PaMs in place and may therefore substantially deviate from a more general assessment.

4.2.3 Knowledge gaps due to lacking ex-ante and ex-post evaluations

In the process of selecting the PaMs from the NECPs and identifying corresponding policy evaluations, we came across substantial gaps with regard to the availability and detailedness of ex-ante and even more of ex-post evaluations. This is already evident from the overview of the available evaluations and their scope in Section 3.1. However, it is important to point out here that the selection of PaMs included a check whether any ex-ante estimates of their impacts is available in the NECPs, PaM reports or associated documents, meaning that PaMs without such information were excluded. For instance, Danish RES H&C policies and French agriculture policies were not assessed in detail although originally planned due to the lack of sufficient evaluations. This demonstrates that the knowledge gap is even larger than suggested by the overview in Section 3.1.

4.2.3.1 Potential reasons for the knowledge gaps identified

There are several potential reasons for the knowledge gaps. A major reason for a lack of ex-post evaluations is the expansion of energy and climate policy in the recent years due to the increase of ambition, meaning that the pure number of policies has increased and keeps increasing. In particular, novel and unexplored types of policies enter the stage regularly. This means that it has obviously been not possible to carry out an ex-post evaluation for all the additional instruments yet. This is particularly relevant for the novel instrument types, since they can hardly be judged based on evaluations of other instruments. A further important reason for a lack of ex-post evaluations is that monitoring of the required data was and probably still is insufficient at least in certain areas (Haug et al. 2010), which may have been driven by

insufficient administrative capacities and resources (Sandin et al. 2019). The lack of ex-ante evaluations can also be related to a lack of capacity and resources, since a thorough ex-ante evaluation may require substantial capacity for data collection and analysis and trained experts. Nevertheless, obligations for providing such evaluations can be an important driver to provide them. So a lack of such obligations can also be a reason for unavailable ex-ante evaluations, at least in certain contexts (Haug et al. 2010).

The most elaborated use of ex-ante and ex-post evaluations was found to be established in the area of energy efficiency, where such evaluations are required in the context of the provisions under the EED (see Section 3.4). Nevertheless, there are some types of policy instruments with a limited number of evaluations also in the area of energy efficiency. Given the overlap of this area with RES heating and cooling as well as carbon and energy pricing policies, such evaluations are partly also available for policies in these two areas. Nevertheless, the number of available evaluations and the information on GHG emission reductions was also limited for all of the investigated carbon and energy pricing instruments (see Section 3.2). Reasons for the limited literature may include missing data and the fact that energy taxes as well as distributional accompanying instruments have hardly been used as a climate policy instrument so far. For emission trading schemes in the buildings and transport sector, the novelty of the instrument is the key factor to explain the lack of ex-post evaluations. According to Matthes et al. (2021), a lack of detailed data hampers a quantification of rebound effects in the transport and buildings sectors.

As the agricultural sector has been less in the focus of climate policy in the past, the availability of evaluations addressing GHG emission reductions is the lowest compared to the other focus topics of this study, which is in line with earlier findings (Fujiwara et al. 2019). The reviewed NECPs list few agricultural PaMs and do not contain quantitative data on GHG emissions reductions associated with the PaMs. In addition, also not all PaM reports outline emission reductions for the respective PaMs. Based on the assessment of the three countries, it became clear that a general lack of information - including quantitative data - related to the rational use of N fertilisers and the expansion of organic agriculture made it hardly possible to check ex-ante estimates of GHG emission reductions against ex-post evaluations (see Section 3.5). In several cases, the only available evaluations did not consider contributions to GHG emission reductions and focused on other environmental issues, such as nitrogen leaching or biodiversity. Where information on GHG emission reductions could be compared, there were considerable differences between the policy instruments evaluated ex-post and those considered in the ex-ante evaluation which also lead to substantial differences in the expected impacts.

4.2.3.2 Conclusions on closing knowledge gaps

Based on our assessments, the knowledge gaps are particularly urgent in the following areas:

- On the one hand, there are several new types of policy instruments becoming more and more relevant in the course of the transformation. This includes market-based approaches such as the extension of emission trading to additional sectors, which might even be established on the EU level, and instruments shifting the focus from scale-up to market diffusion (such as (carbon) contracts for difference) but also instruments supporting a just transition by addressing structural and distributional effects. While there are useful ex-ante evaluations for a lot of these instruments, their novelty leads to a substantial gap with regard to ex-post evaluations that needs to be closed quickly, in order to avoid the risk of over-estimations and to learn about how to set up such instruments in the most effective way. Assessing distributional impacts in detail may require the development of well-founded and applicable typologies of households and enterprises (Matthes et al. 2021).

- On the other hand, while there have been evaluations of policy instruments targeting agricultural soils in the past, these have mostly left out the impact on GHG emission reduction, as the focus of agricultural policy was a different one. The increasing importance of GHG mitigation in the agriculture sector in view of the EU's and MS net-zero targets renders it necessary to make the evaluation of GHG emission avoidance an integral part in the evaluation of agricultural policies.

In order to increase the evidence on the impacts of energy and climate policies and in particular of the NECPs, it is important to close the identified knowledge gaps quickly and substantially. Therefore, it is important that the MS conduct ex-post evaluation of at least the main relevant policies on a regular basis (cf. Broc et al. 2019). In this context it is important to understand which PaMs should be evaluated regularly and how often, taking into consideration the potential insights and related resources required for the evaluation. This can mean to focus evaluations on areas where not enough progress is happening to reduce emissions, on PaMs with particularly high administrative/implementing costs, for instance PaMs supporting building renovations, and/or on PaMs with the highest expected impacts, for instance energy and carbon taxes and cross-sectoral PaMs (see Section 4.1).

Of course, this will increase the MS' administrative burden and costs to a certain extent depending on the number of polices covered. However, evaluations can provide valuable insights into the impacts of specific PaMs to better understand which PaMs are most (cost-)effective (see Section 4.1.2.2). These insights can form the basis to decide on changes in design of a specific instrument or expansion of specific types of instruments that are deemed most (cost-)effective. This will also foster a more cost-effective spending of government funds. This may not only apply to direct support programmes but also to other instruments, since their effective design can also reduce the required volume of support programmes. Given the large financial volumes of support policies needed to achieve the energy and climate targets, it can be expected that the revenues from a more cost-efficient policy design will overcompensate the additional administrative costs of a regular evaluation of carefully selected key PaMs.

4.2.4 Barriers to the realisation of PaM impacts in the field of energy-efficient buildings and renewable heating and cooling

Our analysis shows that it remains mostly unclear if expected emission reductions of the PaMs outlined in the NECPs and evaluations have been assessed considering barrier to implementation. This puts expected GHG emission reductions at risks. While the scientific literature identifies a wide set of barriers for the implementation of PaMs, the investigated evaluations address such barriers only partially and to varying extents; in addition, the NECPs included accompanying PaMs to address the barriers only rarely (see Annex A.2.1 and A.3.1).

In particular, in the context of increasing efficiency and the use of renewable energies in buildings, a Swedish evaluation mentions the importance of the long-term planning horizon and a lack of knowledge concerning new technologies and processes (Pädam et al. 2020). Slovenian studies refer to administrative obstacles, lack of appropriate financial instruments, inadequate readiness and capacity of the sub-public sector to undertake large scale comprehensive energy renovations, the absence of more stable financial resources to carry out these renovations, as well as obstacles in the planning and coordination of activities, e.g., due to a lack of human capital (e.g., Stegnar et al. 2020). Some German evaluations pointed to the skilled worker shortage in relation to the development of funding cases and the landlord-tenant dilemma. The shortage of skilled labour force in the building sector was expected to increase in Germany, Slovenia and the EU in general due to an aging, primarily male workforce and changed requirements of skills (Czako 2020; Lutz et al. 2018; Stegnar et al. 2020). Conflicts could arise

due to missing knowledge and the unwillingness to proceed in an untraditional manner. A shortage of skilled workers was identified as a possible long-term bottleneck and instruments that aim to bring more staff and newer knowledge into the construction industry rather do not work in the short term manner (Berneiser et al. 2021). In all investigated NECPs, effects of the labour market including a possible low workforce were rarely considered and not for individual PaMs. Possible complementing instruments could be found implicitly or through empirical studies, but not in the NECPs themselves (see also Section 3.4.4).

To address such barriers, the provision of knowledge comprising basic energy literacy of users, technical/managerial experience and qualifications of intermediaries as well as availability and easy accessibility of target-group adapted information, e.g. via intermediaries, are key (see Annex A.2.1). In the German NECP, the landlord-tenant dilemma is addressed separately by the option of partially redistributing the CO_2-price from tenants to the building owner. The related Act on the Allocation of Carbon Dioxide Costs (Kohlendioxidkostenaufteilungsgesetz – CO2KostAufG) was adopted on 10 November 2022. Moreover, PaMs included in the German NECP aiming at increasing offers for information and counselling as well as PaMs using the role model function of public buildings might contribute to building owners' awareness and willingness to invest in refurbishments (see Annex A.2.1 and A.3.2.3).

As for PaMs requiring large-scale investments such as the remodelling of heating networks, there is generally a lack of instruments signalling long-term commitment and planning/investment security. This means that systemic approaches that foster inter-sectorial cooperation of actors are of importance for renewable H&C (Breitschopf et al. 2021).

4.2.5 Synergies and conflicts of climate action with other societal objectives

The investigated PaMs can have synergies or conflicts with EU objectives other than the energy and climate objectives. These are important to consider because conflicts with other policy objectives can lead to PaMs not being implemented, only being implemented incompletely or having to be implemented in a modified form. This can result in less impact than expected calling into question the achievement of expected GHG emission reductions (or the implementation risks to negatively affect other objectives). Synergies, in turn, can lead to support from other policy fields and their actors, which can result in upscaling of PaMs and related higher impacts.

In the literature, the following synergies and conflicts are relevant in the context of the investigated topic areas and PaMs:

- Potential conflicts with **providing affordable energy for all**: This is the case e.g., for energy and carbon pricing which can lead to disproportional impacts. This concerns particularly low-income households which may be at risk of not being able to pay for their living expenses as well as certain population groups which may be disproportionately affected by a pricing instrument (see Section 3.2.4). Support to renewable heating and cooling in buildings shows a rather mixed picture: the French heat fund probably benefits lower-income households more than better-off households, while the German MAP and tax incentives do not differentiate between different income levels and thus it cannot be excluded that economically better-off building owners are proportionally overcompensated (see also Section 4.2.4).
- Mainly synergies of the investigated PaMs with **job creation**: The potential in the building sector – including both energy efficiency and renewable energies in buildings – is well recognised in literature as related industries generally create more jobs than fossil fuel industries (see Annex A.3.6.1). An increase in organic farming can but does not have to lead to an increase in employment. Besides very little attention in the literature, available results

of existing studies differ on the employment effects and do not confirm the common view that organic farming always requires more labour than conventional farming (see Annex A.4.5.1).

- Mainly synergies with respect to **air and water quality**: The expansion of renewable heating and cooling as well as of a reduced fertiliser use is overall contributing to the reduction of pollutants. However, burning of (solid) biomass as well as transitioning district heating networks to renewable energy sources and CHP can have adverse effects on indoor and ambient air quality (see Annex A.4.5).
- Potential conflicts with a shift to organic farming and reduced fertilisation if **agricultural production** per hectare drops. Such reductions are around 20% on average when compared to conventional farming but can vary significantly (Ponti et al. 2012). However, organic farming increases the resilience against climate impacts and helps to minimise the related production losses in comparison to conventional agriculture. This means that sustainable agricultural practices may be better off in the long run (see Annex A.4.5).

Besides these findings in the scientific literature, conflicts and synergies of the investigated PaMs with other EU objectives have found to be addressed only exceptionally and not in a systematic manner in the NECPs (see Sections 3.2.4, 3.3.4, 3.4.4 and 3.5.4):

- None of the investigated NECPs examines the impact of energy and carbon pricing on households, vulnerable households, or disproportionate burdens on individual groups. The German NECP presents some compensatory instruments, but does not address the exact effects of these instruments.
- Expected employment effects through sustainability transitions and the adoption of new technologies as a result of PaMs are addressed in general, but not directly concerning a specific PaM with the exception that the German CPP outlines a positive impact on employment from organic farming but without providing a source or more information.
- The investigated NECPs include some considerations of interaction effects as well as general projections and causal relationships for air pollution but generally lack information on the positive impact of agricultural PaMs for water quality.
- None of the investigated NECPs nor the evaluations include information on production losses and related accompanying instruments. The German CPP provides some quantitative data on production losses related to organic farming but provides neither a source nor options to address the expected decrease.

The generally missing consideration of conflicts and synergies is a drawback as this means that it is unclear if and how conflicts and synergies have been taken into consideration in climate and energy planning, which also raises questions about if and how (planned) PaMs can be implemented and enforced. Eventually, this questions the expected PaM impacts and target achievement as other policy objectives influence climate policy making, the implementation of PaMs and the realisation of their impacts.

These findings are in line with the other studies, which find that there is a need to complement the assessment of effectiveness and cost efficiency by criteria related to just transitions (Matthes et al. 2021) and that synergies are seldom assessed in both ex-post and ex-ante evaluations (Ürge-Vorsatz et al. 2014). To a certain extent the use of cost-benefit analyses in evaluations fosters the consideration of co-benefits, but economic valuation faces shortcomings with respect to the monetisation of non-market goods and services, suggesting to stick to physical metrics in this context (Ürge-Vorsatz et al. 2014). In relation to synergies of energy efficiency, a tool to

measure multiple benefits based on quantitative indicators is available as part of the ODYSSEE-MURE project (Reuter et al. 2020).

4.3 Lessons for the German NECP

This subsection particularly looks at the German NECP (cf. BMWi 2020) and lessons learned for it considering also the assessment results of the four other investigated NECPs and related PaMs.

4.3.1 Expectation on target achievement

The German NECP scenario outlining the emission reductions with planned measures is the Climate Protection Programme (CPP) Scenario 2030. The NECP refers to another report that outlines the impact of the CPP (Harthan et al. 2020) with similar overall reductions. For the non-ETS emissions, the NECP outlines a reduction in the order of 35% for 2030 when compared to 2005 ESD emissions (own calculation using Table B27 and EEA (2021a)) which is not enough to reach the binding non-ETS target of 38% (see Regulation (EU) 2018/842). This means that the current and planned PaMs from the CPP are not sufficient. In this context, the NECP refers to additional PaMs being implemented but not considered in the scenario resulting in the expectation that "achievement of the overall target thus appears possible" (NECP, p.151).

This expectation can be questioned based on our findings, although we analysed only a subset of PaMs in key topic areas and had to use related evaluations as there were no GHG emission reductions of PaMs directly in the NECP. Still, it gets apparent that most GHG emission reductions estimates need further ex-post and ex-ante evaluations to be able to draw more reliable conclusions and some seem to be rather over-estimated or not effective enough to reach the 2030 climate target. This leaves the risk of unexpected underperformance of the PaMs and their respective expected contributions to target achievement in the NECP. For example, the German NECP provides energy savings of the German energy and electricity tax. Here, energy savings seem rather overestimated as energy demand reduction stimulated by other policies (e.g., the nEHS) and changes in elasticities are not taken into account. In addition, the reference case refers to the EU minimum tax rates and not to the baseline of the NECP (see Table 12).

The Commission's assessment of the final NECP of Germany (EC 2020a) highlights that the PaMs related to energy efficiency seem comprehensive in scope but their design is insufficient to achieve the primary energy reduction target as well as the energy saving obligation of Article 7 of the EED. For the Federal funding for efficient buildings, the NECP relates to an ex-ante evaluation (Prognos et al. 2020), which is based on an ex-post evaluation and the GHG emission reduction estimates seem plausible, although the assumptions are linked to uncertainties and accompanying measures are indispensable for reaching the funding cases and thus the energy efficiency target (see also Table 14). Still, the buildings sector was the only one to miss its sector target in 2020. Following, the suggested adaptation of policy was to increase the budget for the federal funding for efficient buildings, which can only under very improbable conditions lead to meeting the former target (besides the more ambitious new targets for the buildings sector introduced in mid-2021). This means that the PaM is not sufficiently effective, although it is important and successful. For the German tax incentive for energy efficiency improvements in buildings, the NECP shows the same energy savings as the 2019 PaM report; the 2021 PaM report reduced the reduction slightly, possibly due to barriers in implementation and possibly changed framework data. There is no ex-post evaluation available except for a similar instrument in France (which outlines comparable GHG emission reductions) (see also Table 14). Thus, further ex-post evaluations as well as ex-ante evaluations considering energy savings might be necessary in order to be able to draw more reliable conclusions.

For the German Fertiliser Ordinance, the NECP shows no impacts but relates to the ex-ante study (Harthan et al. 2020). The evaluation outlines the same GHG emission reduction of the instrument like the 2019 and 2021 PaM reports but compared to the ex-post evaluation of the Ordinance, the estimates are about more than twice as high (see also Table 15). An explanation can be the further development of the Ordinance, but it also means that ex-ante estimates cannot be supported by the ex-post findings. For the support of organic agriculture, the ex-ante evaluation (Harthan et al. 2020) indicates an emission reduction more than twice as high as in the 2019 PaM report. The new 2021 PaM report took over the higher emission reductions associated with a more rapid expansion of organic farming to reach the 20% of total agricultural land being organic farmland by 2030. In other words, the expected emission reduction is not a result of the analysis of the policy instrument, but the funding still needs updating to be able to fulfil the target (whereby it is unclear if funding alone can drive the required change) (see also Table 15).

For other PaMs, a conclusive assessment of the GHG reduction figures or energy savings in the NECP was not possible such as for the nEHS. For the MAP, the NECP only refers to an ex-post evaluation which raises few to no concerns regarding the results although GHG emission factors might be out of date. The ex-ante estimates available are considerably higher but do not directly relate to the NECP (see also Table 13). Funding of district heating grids can significantly contribute to reduction of GHG emissions but the estimates in ex-ante evaluations show considerable differences and no comparable ex-post evaluation is available for cross-checking with realised impacts (see also Table 13). The NECP contains no quantified impact. Also the Commission's NECP assessment highlights that the PaMs related to renewable energies "appear, at this stage, not enough to achieve the target, because there is too little detail on the effects of each measure" (EC 2020a).

In addition, there is evidence that the NECP as well as the investigated evaluations do not consider sufficiently interactions with other PaMs, barriers to successful implementation, and synergies and conflicts with other policy objectives (see Section 4.2.4 and 4.2.5). This means that the unfolding of the impacts might not happen as envisioned by the NECP resulting in a lower PaM impact.

4.3.2 Information needs for individual PaMs

The German NECP – like all other investigated NECPs – outlines the GHG emission development up to 2040 but does not contain emission reduction figures for single PaMs. Indeed, the GOV-R does not prescribe that NECPs need to outline this, but it is part of the NECP progress reports to be submitted in March 2023 or former PaM reporting under MMR (Regulation (EU) No 525/2013). Instead, the GOV-R asks Member States to describe their relevant PaMs in the NECPs in Section 3. Thus, the German NECP includes only a list of PaMs with very short descriptions, sorted by topic and unconnected to the scenarios or any instrument-specific emission reduction. This makes it difficult to assess the PaM's contributions to the achievement of the national 2030 climate targets (see Section 4.1.1). In addition, the NECP also misses a systematic consideration of barriers to implementation as well as synergies and conflicts with other societal goals (see Section 4.2.4 and 4.2.5). This might be a result of the rather short PaM descriptions which generally miss the positioning of the PaMs in the policy mix and notion of their broader impacts. If at all, these aspects are touched upon only with a broader scope and not for single PaMs.

Therefore, the German NECP (as well as the other NECPs) would benefit from information on GHG emissions reductions from key PaMs. This should at least include ex-ante estimates. Ex-post findings could further support and explain the ex-ante values. A description of the implemented

and/or planned changes to a PaM or of a new PaM help to outline the difference to a case of no changes. This would also help to check expected impacts against ex-post evaluations that might consider a former version of the PaM. Such information would create a better overview on the PaM contributions to the target achievement and it would allow comparing the estimates with other studies. This seems most important for PaMs without energy savings as these are not captured under the EED reporting.

In addition, it is of value to outline barriers and conflicts with societal objectives of specific PaMs including disproportional impacts, knowledge gaps of the target group, or skilled worker shortage. A follow-up step would be to also identify and outline if and how barriers as well as conflicts are addressed by the design or supporting PaMs. This type of information supports the identification of complementing PaMs that help to counteract the barriers and to find solutions for conflicts. At the same time, also synergies with other societal objectives should be considered so that Member States recognise such synergies and can consider them in the implementation of the NECPs. This means that related information such as the support of lower income households, the increase in employment and environmental benefits should be included in a more detailed way and with explicit references to individual PaMs. The Commission recommends giving due attention to energy poverty and include effort on removing accessibility barriers in buildings for persons with disabilities (EC 2020a).

In order to use the full potential of the NECP as a strategic planning document for climate and energy policy, it would be reasonable to step up the effort of describing the policy mix in more detail. This would include information on the (planned) PaM's consistency (i.e., PaMs are free of contradictions) and coherence (i.e., PaMs are interrelated or mutually reinforcing) in the policy mix to better understand how PaMs overlap, interact, or complement each other and to identify gaps. This increases the credibility and comprehensibility of the policy mix (see e.g., Del Río 2014; Rosenow et al. 2017). This being said, we suggest a combination of describing single PaMs and their expected impacts as well as describing the policy mix and its expected impacts with a view on GHG emission reductions but also more broadly. This broader understanding should then form the base for its subsequent improvements in terms of supplementing, replacing and expanding existing PaMs (see e.g., Howlett et al. 2014; Kern et al. 2017; Rogge et al. 2016). This gets even more important with the new 2030 EU climate goal requiring more action by the Member States.

4.3.3 Potential adoption of effective policies from other countries

There is no clear indication that Germany should consider adopting a PaM from one of the other investigated countries. On the one hand, it is rather difficult to pick out the PaMs with high effectiveness, because evaluations use different reference cases and relate to different years or periods. But even if, PaMs often complement each other, addressing different areas or target groups so that each has its justification. On the other hand, the learnings on design of and impact from PaMs in other countries is also limited due to the same reasons plus that PaMs are either very much the same or differ greatly. In addition, national circumstances are different, e.g., in terms of the existing policy mix but also characteristics of the building stock and related heat supply.

In the field of energy and carbon pricing, the investigated PaMs differ little from each other. Only the German nEHS is a somewhat different PaM compared to the typical taxes in the other MS. However, like taxes, the scheme also increases the price of energy. This means that all three MS in focus (DE, DK, SE) put a price on energy consumption comparably via EU ETS, energy tax and CO_2-tax/nEHS. Thus, it can be seen as a positive example for a widely applicable instrument and its high level of continuity providing long-term planning security. Room for improvement

remains in the area of tax rate and carbon price levels. The extent to which Germany can improve its energy and carbon pricing based on lessons from the other MS could not be clarified within the scope of this project, as information on the elasticities assumed in the assessments, but also on social compensation policies, was not available to a sufficient extent for all the MS considered.

In the field of energy efficient buildings, the Slovenian NECP similarly to the German NECP mostly relies on subsidies and on information PaMs. However, the designs of the PaMs differ, possibly due to the diverging socio-demographic framework as well as differences in the building stock. For instance, far more people in Slovenia live in houses instead of flats and rather own their home than rent it, especially compared to Germany (Eurostat 2022). This results in different needs and target groups for PaMs. The Swedish NECP heavily relies on the energy and carbon taxes, which drive energy savings and emission reductions. However, the design is different from the German nEHS and overall, the nEHS cannot be considered a main PaM for energy efficiency. The "white certificate schemes" in the French NECP (as mentioned above) has been discussed in Germany in detail and a possible design as well as the conditions that would need to be met are presented in detail in Schlomann et al. (2021). The perspective and aim in Germany versus France differ, which is why the learnings from the French scheme are limited in terms of design and impacts. Basically, in France the scheme is complementary to other PaMs, which e.g., help to overcome informational obstacles. In Germany, the PaM would instead stand alone and address gaps in the policy mix.

As for renewable heating and cooling, the French Heat Fund has considerable overlaps with the MAP, however, target groups somewhat differ due to the Heat Fund's focus on large and medium-size installations. It is difficult to compare both instruments' cost efficiency due to the fact that they support a large amount of different installations for various target groups. In any case, due to its high level of continuity, the Heat Fund has been described as offering good planning security and predictability to recipients, which seems to be one of the key features of its success. As described above, the transferability of learnings from the French "white certificates scheme" is limited at best as the German context differs considerably and so does the overall policy mix for renewable heating and cooling in both countries. Furthermore, white certificates in France go much beyond renewable heating and cooling and need to be discussed in a broader context. It is difficult to transfer learnings from the Slovenian RES H&C PaMs due to the already described large socio-demographic differences between the two countries as well as the narrow focus of the Slovenian PaMs on district heating only. Furthermore, the two Slovenian PaMs analysed cannot be regarded as best-practice examples and the evaluations suggest that they do not provide strong enough incentives.

4.4 Potential improvements of PaM reporting in the NECPs

In this section, we reconsider the current requirements for reporting of PaM impacts in the NECPs as well as under other parts of the GOV-R and EU regulation (see Figure 1 and the preceding text in the introduction), identify gaps in the current content requirements and provide recommendations for closing them.

As explained in detail before, the link between NECPs and policy evaluations was found to be rather weak across all areas. This can be explained by the fact that the provisions for NECPs in the GOV-R do not require the specification of the impacts of individual PaMs (except for energy efficiency instruments according to the EED) but focus on a comparison of the current instrument mix with the instrument mix planned to achieve the energy and climate targets on the system level (see Annex I of the GOV-R). This system-oriented approach allows to cover the interactions of policies in a more straight-forward way than an assessment of individual PaMs.

Nevertheless, it is important to understand the impacts of individual PaMs in detail, in order to provide evidence for the assumed impacts in the NECPs and their system-wide impact assessments. So strengthening the provisions with respect to reporting the expected contributions of single or bundle of PaMs in the NECPs as well as substantiating the proposed policies with evaluations can be seen as an important task for the future.

The missing link between the reporting on GHG emission reductions under Article 18 of the GOV-R as well as the NECPs and the NECP progress reports leads to substantial intransparency about the impact of PaMs implicit or explicit contained in the NECPs. A simple first step to improve transparency would be an obligation to include the latest PaM impacts reported under Art. 18 in the Annex of the NECPs similar to the energy savings from the EED reporting. A similar approach is foreseen for the NECP progress reports in Article 17 of the GOV-R. However, a more direct reference to the PaM reports both in the NECPs and the reporting of PaM impacts under the NECP progress reports would be even more transparent and thus preferable. This would in particular mean to use a harmonised naming of PaMs, to make transparent any changes to the PaMs compared to previous reports and to explicitly take up the information about the expected impacts and – as far as available – the impacts observed in the past.

Moreover, the limited obligations with regard to the reporting of PaM contributions in the NECP progress reports pose a hurdle for a stringent assessment of the foreseen updates of the NECPs, since it is difficult to identify which PaMs successfully contribute to achieving the MS energy targets outlined in the NECPs. This applies in particular to the contributions to RES expansion but despite the inclusion of cumulated energy savings based on the EED also to energy savings on an annual basis. In any case, it will be important to reflect the progress in the following update of the NECPs. In particular, harmonisation between the progress reports and the NECP updates seem an urgent matter. As mentioned above, PaM impacts are reported mostly only for PaMs related to energy efficiency based on the reporting requirements under the EED both in the current NECPs but – according to the Implementing Regulation – likely also in the NECP progress reports. However, the requirements of the EED are not aligned with the current PaM reports, for instance with regard to the baselines and the way impacts are reported. This calls for a harmonisation of requirements under the EED and the GOV-R. For tracking progress with regard to the NECPs, it is most helpful to set baselines based on the policy mix in place, when the first NECP was established. In order to assess the contributions to the 2030 targets, the reported PaM impacts should include the contributions to GHG emission reduction, energy savings and RES expansion in 2030 and beyond.

Finally, as explained in Section 4.2.4, there are substantial barriers to the realisation of PaM impacts, which concern policy fields not directly addressed in the NECPs, for instance the qualification of skilled workers. Moreover, conflicts and synergies with other policy objectives can be an important factor for achieving those of energy and climate policy. Currently, there is an obligation to address certain related policy targets such as improving air quality, but there is no requirement to address barriers, conflicts and synergies systematically. This can be seen as an important gap to be closed, both in the requirements of the NECPs itself and the NECP progress reports. One option to tackle this is to ask for a stringent consideration of the consistency and comprehensiveness of the overall policy mix, for instance based on the policy mix framework as established by Rogge et al. (2016), as described in detail in Section 4.3.2.

5 Conclusions and recommendations

A major objective of introducing the Governance Regulation was to provide an integrated approach to planning and reporting on energy and climate policies, which was previously dispersed across several regulations (see Section 1.1). In particular, it linked the national planning in the NECPs to the reporting of policy impacts in the PaM reports via the NECP progress reports. Against this background, the aim of this report was to develop an in-depth understanding of the impact of the policy instruments that MS have included in their NECPs to reach their climate and energy targets. To do so, selected key policy instruments from the NECPs were examined in four focus topics: carbon and energy pricing, renewable heating and cooling, energy-efficient buildings, and agricultural soils. The report assessed the expected impacts of these policy instruments and compared them with the findings of both ex-post and ex-ante evaluations. An additional objective was to gain insights into the methodological and systemic uncertainties when assessing the impact of policy instruments. The approach used was to analyse the information available in the literature regarding the impact of policy instruments in Denmark, France, Germany, Slovenia and Sweden (see Section 1.2).

In spite of the integrated approach of the Governance Regulation, the research process proved to be cumbersome, as the NECPs and the PaM reports were found to be still rather disjointed. In particular, the documents are made public via different platforms and in many cases are not accompanied by additional background information on the impacts of PaMs (see Section 2.1). Considerable efforts were therefore required to identify useful ex-post and ex-ante evaluations for the selected PaMs, if available at all (see Section 3.1). The most elaborate use of ex-ante and ex-post evaluations was found in the area of energy efficiency, where such evaluations are required in the context of the provisions under the EED. Since this area overlaps with RES heating and cooling as well as carbon and energy pricing policies, such evaluations are partly available for policies in these two areas as well. As climate policy has focused less on the agricultural sector in the past, the availability of evaluations addressing GHG emission reductions is the lowest here.

5.1 How to improve the knowledge basis for transparent NECP updates

We found substantial knowledge gaps with regard to PaM impacts across all focus topics (see Section 4.2.3). Noting that our selection of PaMs was based on the availability of at least one ex-ante evaluation of the exact policy instrument listed in the NECP, we expect the overall knowledge gap to be even larger. Based on our findings, it is particularly important that there are several new types of PaMs in NECPs (market-based and diffusion-focused PaMs, PaMs supporting a just transition) without ex-post evaluation, risking over-estimations in ex-ante evaluations. In addition, evaluations of agricultural PaMs mostly excluded GHG impacts in the past, but these PaMs are becoming increasingly important in view of the EU's and MS's net-zero targets. Several previous studies with similar objectives (in particular Fujiwara et al. 2019; Haug et al. 2010; Sandin et al. 2019) had similar issues with obtaining sufficient information. According to these studies, this was due to insufficient systematic evaluation, a lack of monitoring requirements (Haug et al. 2010) and too fragmented evaluation without sufficient coordination (Sandin et al. 2019). Fujiwara et al. (2019) also found very few evaluations for agricultural and land use PaMs and argued for stronger links between policy planning and evaluation results and for providing all the relevant information on a central platform.

Given this, we suggest to improve the knowledge basis for transparent NECP updates as follows:

- It is important that MS do ex-post evaluations of at least the main PaMs on a regular basis tied to the policy cycle (cf. Broc et al. 2019). In our view, such evaluations should focus on

areas with limited progress, on new types of PaMs, on PaMs with the highest expected impacts and/or on PaMs with particularly high administrative / implementing costs.

- GHG impacts should be made an integral part of agricultural evaluations, if this has not happened already.
- A centralised platform as already suggested by Fujiwara et al. (2019) would be a key step to increasing transparency and fostering a more informed selection and evaluation of policies.

While we acknowledge the progress made by the EEA catalogue and the PaM database in this regard (cf. EEA 2020a and EEA 2023), there is still substantial work needed to provide information in such a way that the link between evaluations, policies, NECPs and PaM reports becomes transparent.

5.2 How to increase transparency about the selection of policies and expected impacts in the NECPs

We found that the selection and design of PaMs in the NECPs was not fully grounded on evaluations. In this context, it became clear that NECPs rarely address barriers by accompanying PaMs, which puts the expected impacts at risk. In addition, NECPs generally do not sufficiently address uncertainties about PaM impacts, and in particular provide little information on net impacts and interactions with other PaMs. To address this issue in our assessment, our findings on the PaMs' impacts on GHG emissions are generally based on the assessment of other ex-post and ex-ante evaluations of PaMs with the same name and/or same description where such evaluations are available. We also found significant uncertainties concerning the expected impacts from interactions between PaMs, but also with socio-economic circumstances which may pose a barrier to implementation. The NECPs and evaluations did not address barriers, synergies or conflicts with other societal goals in sufficient detail so that impacts might be lower or might not occur as envisioned by the NECPs.

When looking at the focus topics, it can be concluded that, although the NECPs outline significant energy savings from energy and carbon pricing, which may therefore provide a major contribution to the 2030 climate target achievement of MS, the estimates originate from the EED reporting obligation and tend to overestimate the impacts relevant in the NECPs. Furthermore, ex-ante estimates of renewable heating and cooling PaMs seem rather too positive as they do not consider interaction effects and implementation barriers. PaMs for energy-efficient buildings cannot reach the estimated energy savings of energy and carbon pricing, but can still contribute to reducing GHG emissions, especially when combined with pricing PaMs. In the area of agricultural soils, regulation and financial support can reduce fertiliser inputs and encourage better practices including organic agriculture, but estimates are partly based on national targets and it remains unclear whether the PaMs are actually able to bring about the change needed to achieve the target. Across all investigated PaMs, there was insufficient consideration of barriers to implementation or conflicts and synergies with other societal goals, which raises doubts about whether the ex-ante impact estimates can be realised. Accordingly, it was challenging to assess the PaMs' contributions to the achievement of national climate targets in the context of the NECPs (see Section 4.3).

To improve the transparency of PaM selection and their role in the policy mix, we suggest the following:

- The role of NECPs in strategic planning of the policy mix towards 2030 could be strengthened if they contained information on single PaMs as well as the full policy mix, as

this could be used to inform decisions about supplementing, replacing or expanding existing PaMs.

- The NECPs would particularly benefit from a better description of the role of specific existing and planned PaMs in the mix and their consistency, coherence, credibility and comprehensiveness. This should include an explanation of which PaMs are key, and which are accompanying and why (such as to address barriers to implementation or conflicts with other societal goals).

The NECPs should also include the emission reduction estimates for the key PaMs (whereby this information could also come from the PaM reports if the policies in the PaM reports are in line with those in the NECP). This should include ex-ante estimates that take into account the findings of ex-post evaluations.

5.3 How to increase transparency about uncertainties in the development and use of evaluations

Evaluations were based on various types of guidelines but did not often explicitly specify whether this was the case or not. Moreover, available ex-post evaluations were usually not linked to the preparation of NECPs and/or PaM reports but to other purposes, e.g. the effectiveness of public spending. In the current NECPs, PaM impacts were mostly reported based on the reporting requirements under the EED. However, these are not aligned with current PaM reports, e.g. with regard to the baselines. Differences in evaluations were often due to differences in the requirements of the relevant provisions and/or guidelines. This calls for a revision of certain guidelines for ex-post evaluations in view of the requirements of energy and climate policy. In particular, harmonisation of the reporting requirements under the EED and the Governance Regulation is urgently required.

To address methodological uncertainties in a more transparent way, we suggest the following:

- Both ex-post and ex-ante evaluations meant to inform national energy and climate policies should follow existing guidelines as much as possible, e.g. Ricardo Energy&Environment et al. (2020) and Matthes et al. (2021), and make use of the tools provided in the better regulation toolbox (cf. EC 2021c).
- Integrate the requirement to measure the PaM contributions to the core objectives of energy and climate policy into all relevant policy evaluations and establish a consistent choice of baselines for such evaluations, for instance building on the with-existing-measures scenarios used in the NECPs.

To address uncertainties beyond methodology improvements, we recommend:

- Improve planning on the national level by using the same template for all ex-ante evaluations of PaMs, with mandatory reporting of available information and explicit coverage of the expected gross and net impacts as well as interactions with other PaMs.
- A harmonised evaluation should be fostered by ensuring a clear description of PaMs including any potential changes over time and precise specification of the selected design parameters.
- The results of the evaluations should transparently communicate margins for input parameters and resulting corridors for the expected impacts.

5.4 How to foster more transparency by refining the integrated EU governance framework

The link between NECPs and policy evaluations was found to be rather weak across all areas. This can be explained by the fact that the provisions for NECPs in the GOV-R focus on a comparison of the current policy mix with the policy mix planned to achieve the energy and climate targets. This system-oriented approach allows covering the interactions of policies in a more straightforward way than an assessment of individual policies. Nevertheless, it is important to understand the impacts of individual policy instruments in detail, in order to provide evidence for the assumed impacts in the overarching impact assessment. In this context, our results suggest that reporting requirements may be too limited and voluntary reporting is of no use, which has been argued before in the context of RES targets (Veum et al. 2019). In particular, we have identified important gaps in reporting of PaM impacts with regard to energy and climate objectives across EU regulations: (1) There are no clear rules for harmonisation, in particular with regard to PaM names and baselines. (2) There is no explicit requirement to include PaM impacts from PaM Reports in NECPs and/or progress reports. (3) Reporting contributions to RES expansion (and energy savings other than EED Art. 7) is only voluntary. (4) There is no obligation to consider conflicts and synergies on the level of PaMs.

Therefore, we suggest the following improvements to the EU governance framework:

- Enforce a high degree of harmonisation between NECPs, Progress Reports and PaM reports, in particular with regard to the aggregation and naming of included policies, allowing deviations only due to actual changes in policies and requiring these to be made explicit.
- Harmonise the baselines between NECPs, Progress Reports and PaM reports building on the requirements of the NECPs, i.e. allowing for a comparison between current and planned policies.
- If a MS keeps the PaM report separate from the NECP progress report, the progress report should clearly reference the PaM report and corresponding evaluations of PaMs.
- Make reporting the contributions of PaMs to RES expansion mandatory if available. The same applies to contributions to energy efficiency, for which the required reporting is currently limited to cumulated savings.

Overall, we conclude that the objective of the Governance Regulation to establish an integrated framework for planning and reporting of national energy and climate policies has not yet been achieved to the extent desired. In particular, the harmonisation between the different planning and reporting requirements (cf. Schoenefeld et al. 2018) is still insufficient and strongly limits the transparency of interlinkages. We therefore recommend to carefully assess the issues we have raised here during the upcoming revision of the Governance Regulation and take into account options to enforce greater harmonisation between planning and reporting and increased transparency about the expected and achieved impacts of planned and established policy instruments.

6 List of References

Agency for ecological transition (2014): Bilan du fonds chaleur pour les années 2009 à 2014. Available at https://www.ecologie.gouv.fr/sites/default/files/bilan-fonds-chaleur-2009-2014-relance-et-nouvelle-dynamique-8383_0.pdf, accessed 16.05.2023.

Agency for ecological transition (2018a): Evaluation stratégique du Fonds Chaleur 2009-2017, accessed 20.09.2021.

Agency for ecological transition (2018b): Le Fonds Chaleur: Outil Majeur de la Transition Énergétique. Bilan 2009-2017, accessed 20.09.2021.

Andersson, J. J. (2019): Carbon Taxes and CO2 Emissions: Sweden as a Case Study. In: American Economic Journal: Economic Policy, 11 (4), pp. 1–30. https://doi.org/10.1257/pol.20170144.

ATEMA Conseil (2019): Evaluation du dispositif des Certificats d'Economie d'Energie. Rapport synthétique, accessed 20.09.2021.

Azzini, I.; Listorti, G.; Mara, T.; Rosati, R. (2020): Uncertainty and Sensitivity Analysis for policy decision making. An introductory guide. Luxembourg. https://doi.org/10.2760/922129.

Bach, S.; Isaak, N.; Kemfert, C.; Kunert, U. (2019): CO2-Bepreisung im Wärme- und Verkehrssektor: Diskussion von Wirkungen und alternativen Entlastungsoptionen. Endbericht des gleichnamigen Forschungsvorhabens im Auftrag des Bundesministeriums für Umwelt, Naturschutz und nukleare Sicherheit (BMU). Berlin. Available at https://www.diw.de/documents/publikationen/73/diw_01.c.676034.de/diwkompakt_2019-140.pdf, accessed 16.05.2023.

Bagaini, A.; Colelli, F.; Croci, E.; Molteni, T. (2020): Assessing the relevance of barriers to energy efficiency implementation in the building and transport sectors in eight European countries. In: The Electricity Journal, 33, p. 106820. https://doi.org/10.1016/j.tej.2020.106820.

Bemelmans-Videc, M. L.; Rist, R. C.; Vedung, E. (Eds.) (2007): Carrots, sticks & sermons. Policy instruments and their evaluation. New Brunswick, NJ: Transaction Publ. ISBN: 9780765805461.

Berneiser, J.; Burkhardt, A.; Henger, R.; Köhler, B.; Meyer, R.; Sommer, S.; Yilmaz, Y.; Kost, C.; Herkel, S. (2021): Maßnahmen und Instrumente für eine ambitionierte, klimafreundliche und sozialverträgliche Wärmewende im Gebäudesektor. Teil 1: Analyse der Herausforderungen und Instrumente im Gebäudesektor. Potsdam: Potsdam-Institut für Klimafolgenforschung.

Bilcke, J.; Beutels, P.; Brisson, M.; Jit, M. (2011): Accounting for methodological, structural, and parameter uncertainty in decision-analytic models: a practical guide. In: Medical decision making: an international journal of the Society for Medical Decision Making, 31 (4), pp. 675–692. https://doi.org/10.1177/0272989X11409240.

Biresselioglu, M. E.; Demir, M. H.; Demirbag Kaplan, M.; Solak, B. (2020): Individuals, collectives, and energy transition: Analysing the motivators and barriers of European decarbonisation. In: Energy Research & Social Science, 66, p. 101493. https://doi.org/10.1016/j.erss.2020.101493.

Böhret, C.; Konzendorf, G. (2000): Leitfaden zur Gesetzesfolgenabschätzung. Available at http://www.verwaltung-innovativ.de/SharedDocs/Publikationen/Presse__Archiv/leitfaden_zur_gesetzesfolgenabschaetzung.pdf%3F__blob%3DpublicationFile%26v%3D1, accessed 16.05.2023.

Bonneval; entera; AFC Management Consulting AG (2016): Ex-post-Bewertung des Entwicklungsplans für den Ländlichen Raum Brandenburgs und Berlins (EPLR) 2007 bis 2013. Available at https://eler.brandenburg.de/sixcms/media.php/9/BB_Ex-post-Bewertung_EPLR-07-13_Endbericht_20161219.pdf, accessed 16.05.2023.

Børgesen, C. D.; Nordemann Jensen, P.; Blicher-Mathiesen, G.; Schelde, K. (2013): Udviklingen i Kvælstofudvaskning og Næringsstof-overskud fra Dansk Landbrug for Perioden 2007-2011 [Trends in Nitrogen Leaching and Nutrient Surplus from Danish Agriculture for the Period 2007-2011]. Available at https://pure.au.dk/portal/files/68362856/dcarapporten31.pdf, accessed 16.05.2023.

Børgesen, C. D.; Waagepetersen, J.; Iversen, T. M.; Grant, R.; Jacobsen, B.; Elmholt, S. (2009): Midtvejsevaluering af Vandmiljøplan III [Mid-Term Review of the APAE III]. Available at https://pure.au.dk/portal/files/2841678/djfma142.pdf.pdf, accessed 16.05.2023.

Bourguignon, D. (2019): Briefing - EU fertilising products. Available at https://www.europarl.europa.eu/RegData/etudes/BRIE/2016/582010/EPRS_BRI(2016)582010_EN.pdf, accessed 16.05.2023.

Breitschopf, B.; Billerbeck, A. (2021): Overview of Heating and Cooling. Perceptions, Markets and Regulatory Frameworks for Decarbonisation. Deliverable 1.2: Report on results of the meta-study (Task 1): Factors governing decisions in H&C. Available at https://www.isi.fraunhofer.de/content/dam/isi/dokumente/ccx/2021/perception_final_deliverable_D1_Task_1.pdf, accessed 16.05.2023.

Broc, J.-S.; Oikonomou, V.; Dragovic, M. (2019): Guidelines on how to integrate evaluation into the policy cycle. Available at file:///C:/Users/waj/Downloads/epatee_integrating_evaluation_into_policy_cycle.pdf, accessed 03.06.2022.

Brucker Juricic, B.; Galic, M.; Marenjak, S. (2021): Review of the Construction Labour Demand and Shortages in the EU. In: Buildings, 11 (1), p. 17. https://doi.org/10.3390/buildings11010017.

Buildings Performance Institute Europe (2017a): Renovation strategy – addressing the barriers to deep renovation. Factsheet Germany.

Buildings Performance Institute Europe (2017b): Renovation strategy – addressing the barriers to deep renovation. Factsheet Slovenia.

Bundesamt für Justiz (Ed.) (2017): Verordnung über die Anwendung von Düngemitteln, Bodenhilfsstoffen, Kultursubstraten und Pflanzenhilfsmitteln nach den Grundsätzen der guten fachlichen Praxis beim Düngen 2. Available at https://www.gesetze-im-internet.de/d_v_2017/.

Bundesanstalt für Landwirtschaft und Ernährung (n.d.): Forschungs- und Entwicklungsvorhaben im Bundesprogramm Ökologischer Landbau und andere Formen nachhaltiger Landwirtschaft (BÖLN). Gefördert durch das Bundesministerium für Ernährung und Landwirtschaft aufgrund eines Beschlusses des Deutschen Bundestages im Rahmen des Bundesprogramm Ökologischer Landbau und andere Formen nachhaltiger Landwirtschaft. Available at https://www.ble.de/DE/Projektfoerderung/Foerderungen-Auftraege/BOELN/boeln_node.html, accessed 16.05.2023.

Bundesanstalt für Landwirtschaft und Ernährung (2021a): Bio boomt weiter – auch dank des Bio-Siegels. Available at https://www.bundesprogramm.de/aktuelles/detailansicht/?tx_news_pi1%5Bnews%5D=30

5&tx_news_pi1%5Bcontroller%5D=News&tx_news_pi1%5Baction%5D=detail&cHash=0eee899efa7471532dad63c7b96c712c, accessed 16.05.2023.

Bundesanstalt für Landwirtschaft und Ernährung (2021b): Zahlen zum Ökolandbau in Deutschland. Available at https://www.oekolandbau.de/landwirtschaft/biomarkt/oekoflaeche-und-oekobetriebe-in-deutschland/, accessed 16.05.2023.

Bundesfinanzministerium (2020): Subventionsbericht des Bundes. Available at https://www.bundesfinanzministerium.de/Content/DE/Standardartikel/Themen/Oeffentliche_Finanzen/Subventionspolitik/2020-03-01-Subventionsbericht.html, accessed 16.05.2023.

Bundesministerium für Ernährung und Landwirtschaft (n.d.): Umsetzung der ELER-Förderperiode 2014 bis 2020 für ländliche Räume in Deutschland. Available at https://www.bmel.de/DE/themen/laendliche-regionen/foerderung-des-laendlichen-raumes/eu-foerderung/eler-2014-2020-umsetzung.html, accessed 16.05.2023.

Bundesministerium für Ernährung und Landwirtschaft (2019a): Klimaschutzprogramm 2030 der Bundesregierung zur Umsetzung des Klimaschutzplans 2050. Available at https://www.bmel.de/SharedDocs/Downloads/DE/_Landwirtschaft/Klimaschutz/Klimaschutzprogramm2030.pdf;jsessionid=93E64C72C799FF3B432FF3DB4805BAD4.live922?__blob=publicationFile&v=3, accessed 16.05.2023.

Bundesministerium für Ernährung und Landwirtschaft (2019b): Stoffstrombilanz: Mehr Transparenz über Nährstoffe in landwirtschaftlichen Betrieben. Available at https://www.bmel.de/DE/themen/landwirtschaft/pflanzenbau/ackerbau/stoffstrombilanz.html, accessed 16.05.2023.

Bundesministerium für Ernährung und Landwirtschaft (2019c): Zukunftsstrategie ökologischer Landbau. Impulse für mehr Nachhaltigkeit in Deutschland.

Bundesministerium für Ernährung und Landwirtschaft (2020): Düngung. Available at https://www.bmel.de/DE/themen/landwirtschaft/pflanzenbau/ackerbau/duengung.html, accessed 16.05.2023.

Bundesministerium für Ernährung und Landwirtschaft (2021): Rahmenplan der Gemeinschaftsaufgabe „Verbesserung der Agrarstruktur und des Küstenschutzes“ 2021-2024.

Bundesministerium für Ernährung und Landwirtschaft (2022): Öko-Landbau stärken: Prozess zur Weiterentwicklung der Zukunftsstrategie ökologischer Landbau. Bundesanstalt für Landwirtschaft und Ernährung. Available at https://www.bmel.de/DE/themen/landwirtschaft/oekologischer-landbau/zukunftsstrategie-oekologischer-landbau.html, accessed 08.11.2022.

Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit (2019a): Nationales Luftreinhalteprogramm der Bundesrepublik Deutschland. nach Artikel 6 und Artikel 10 der Richtlinie (EU) 2016/2284 über die Reduktion der nationalen Emissionen bestimmter Luftschadstoffe sowie nach §§ 4 und 16 der Verordnung über nationale Verpflichtungen zur Reduktion bestimmter Luftschadstoffe (43. BImSchV). Available at https://www.umweltbundesamt.de/nlrp2019, accessed 16.05.2023.

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (2019b): Climate Action Programme 2030 - Measures to achieve the 2030 climate protection goals. Available at https://www.bmu.de/fileadmin/Daten_BMU/Pools/Broschueren/klimaschutzprogramm_2030_en_bf.pdf, accessed 16.05.2023.

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (2019c): Projektionsbericht 2019 für Deutschland gemäß Verordnung (EU) Nr. 525/2013. Available at https://cdr.eionet.europa.eu/de/eu/mmr/art04-13-14_lcds_pams_projections/projections/envxnw7wq/Projektionsbericht-der-Bundesregierung-2019.pdf, accessed 16.05.2023.

Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz; Repenning, J.; Emele, L.; Harthan, R. O.; Moosmann, L.; Blanck, R.; Böttcher, H.; Braungardt, S.; Bürger, V.; Görz, W. K.; Hennenberg, K.; Jörß, W.; Ludwig, S.; Matthes, F. C.; Mendelevitch, R.; Nissen, C.; Rausch, L.; Scheffler, M.; Schumacher, K.; Wiegmann, K.; Wissner, N.; Zerrahn, A.; Brugger, H.; Fleiter, T.; Rehfeldt, M.; Rohde, C.; Schlomann, B.; Yu, S.; Steinbach, J.; Deurer, J.; Osterburg, B.; Rösemann, C.; Gensior, A.; Stümer, W.; Rüter, S.; Fuß, R.; Tiemeyer, B.; Laggner, A.; Adam, S. (2021): Projektionsbericht 2021 für Deutschland. Gemäß Artikel 18 der Verordnung (EU) 2018/1999 des Europäischen Parlaments und des Rates vom 11. Dezember 2018 über das Governance-System für die Energieunion und für den Klimaschutz, zur Änderung der Verordnungen (EG) Nr. 663/2009 und (EG) Nr. 715/2009 des Europäischen Parlaments und des Rates sowie §10 (2) des Bundes-Klimaschutzgesetzes. Berlin: Öko-Institut; Fraunhofer-Institut für System- und Innovationsforschung; Institut für Ressourceneffizienz und Energiestrategien; Thünen-Institut. Available at https://www.oeko.de/fileadmin/oekodoc/projektionsbericht_2021_bf.pdf, accessed 16.05.2023.

Bundesministerium für Wirtschaft und Energie (2017): National Energy Efficiency Action Plan (NEEAP) 2017 for the Federal Republic of Germany. pursuant to Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, accessed 20.09.2021.

Bundesministerium für Wirtschaft und Energie (2019): Integrated National Energy and Climate Plan. Available at https://ec.europa.eu/energy/sites/default/files/documents/de_final_necp_main_en.pdf, accessed 16.05.2023.

Bundesministerium für Wirtschaft und Energie (2020): Integrated National Energy and Climate Plan.

Bundesministerium für Wirtschaft und Klimaschutz (2022): Energiedaten: Gesamtausgabe. Available at https://www.bmwk.de/Redaktion/DE/Artikel/Energie/energiedaten-gesamtausgabe.html, accessed 16.05.2023.

Cambridge Econometrics; ICF International; E3M-Lab; Warwick Institute for Employment Research (2015): Assessing the Employment and Social Impact of Energy Efficiency. Available at https://ec.europa.eu/energy/sites/ener/files/documents/CE_EE_Jobs_main%2018Nov2015.pdf, accessed 16.05.2023.

Česen, M.; Pušnik, M.; Urbančič, A.; Đorić, M.; Merše, S.; Čižman, J.; Staničić, D.; Petelin Visočnik, B.; Fatur, T.; Mali, B.; Kušar, G. (2020): Podnebno ogledalo 2020: Ostali sektorji. Končno poročilo. Poročilo C4.1, Vol. 3, Zvezek 5, accessed 20.09.2021.

Česen, M.; Pušnik, M.; Urbančič, A.; Đorić, M.; Merše, S.; Petelin Visočnik, B.; Fatur, T.; Mali, B. (2019): Podnebno ogledalo 2019: Ostali sektorji. Končno poročilo. Poročilo C4.1, Vol. 2, Zvezek 5, accessed 20.09.2021.

Chassein, E.; Roser, A. (2017): Boosting renewable energy in heating and cooling: Summary of best practices, success factors and recommendations based on literature, interviews and surveys in six case studies.

Chepeliev, M.; Osorio-Rodarte, I.; van der Mensbrugghe, D. (2021): Distributional impacts of carbon pricing policies under the Paris Agreement: Inter and intra-regional perspectives. In: Energy Economics, 102, p. 105530. https://doi.org/10.1016/j.eneco.2021.105530.

Colmenar-Santos, A.; Rosales-Asensio, E.; Borge-Diez, D.; Mur-Pérez, F. (2015): Cogeneration and district heating networks: Measures to remove institutional and financial barriers that restrict their joint use in the EU-28. In: Energy, 85, pp. 403–414. https://doi.org/10.1016/j.energy.2015.03.088.

Conseil général de l'environnement et du développement durable; inspection générale des finances; Conseil général de l'économie, de l'industrie, de l'énergie et des technologies (2014): Les certificats d'économies d'énergie: efficacité énergétique et analyse économique, accessed 20.09.2021.

Čufer Klep, P.; Skender, G.; Kržič, A.; Cunder, T.; Moljk, B.; Verbič, J.; Bedrač, M.; Travnikar, T.; Kožar, M.; Lugić, E.; Ostojić, A.; Pistotnik, M.; Mesić, Z.; Husnjak, S.; Kušan, V.; Žiža; Ivona; Jantol, N.; Sviben, S.; Kumar, M. (2019): Vrednotenje - Presoja dosežkov in vplivov Programa razvoja podeželja Republike Slovenije za obdobje 2014–2020 [Assessment of achievements and impacts of the Rural Development Programme of the Republic of Slovenia for 2014-2020]. Slovenian Ministry of Agriculture, Forestry and Food. Available at https://www.program-podezelja.si/images/SPLETNA_STRAN_PRP_NOVA/1_PRP_2014-2020/1_4_Spremljanje_in_vrednotenje/3_Vrednotenje/Vrednotenje_2019_PRP_2014-2020.pdf, accessed 16.05.2023.

Czako, V. (2020): Employment in the Energy Sector. Status Report 2020. Luxembourg: European Commission. https://doi.org/10.2760/95180.

Danish Energy Agency (Ed.) (2005): Danmarks udledning af CO2 - indsatsen i perioden 1990-2001 og omkostningerne herved. Bilagsrapport.

Danish government (2009): Grøn Vækst [Green growth]. Available at https://mfvm.dk/fileadmin/user_upload/FVM.dk/Dokumenter/Servicemenu/Publikationer/Groen_vaekst.pdf, accessed 16.05.2023.

Danish Ministry of Climate, Energy and Utilities (2017a): Denmark's Seventh National Communication and Third Biennal Report - Under the United Nations Framework Convention on Climate Change. Available at https://unfccc.int/sites/default/files/resource/3479620815_Denmark-BR3-NC7-1-NC7-DNK-Denmarks-NC7-and-BR3_1January2018.pdf.

Danish Ministry of Climate, Energy and Utilities (2017b): Denmark's Seventh National Communication and Third Biennial Report - Under the United Nations Framework on Climate Change. Available at https://unfccc.int/sites/default/files/resource/8057126_Denmark-NC7-BR3-2-NC7-DNK-Denmarks-NC7-and-BR3_1January2018-12MB.pdf, accessed 30.04.2021.

Danish Ministry of Climate, Energy and Utilities (2019a): Denmark's Integrated National Energy and Climate Plan (2019). Available at https://ec.europa.eu/energy/sites/ener/files/documents/dk_final_necp_main_en.pdf, accessed 16.05.2023.

Danish Ministry of Climate, Energy and Utilities (2019b): Denmark's update on the national system for policies and measures and projections, the low-carbon development strategy, climate policies and measures, greenhouse gas projections and LULUCF actions. Available at https://cdr.eionet.europa.eu/dk/eu/mmr/art04-13-14_lcds_pams_projections/pams/pams/envxlrppg/DK_PAMSandPROJECTIONS_UpdateMarch2019.pdf, accessed 16.05.2023.

De Klein, C.; Novoa, R. S.; Ogle, S.; Smith, K. A.; Rochette, P.; Wirth, T. C.; McConkey, B. G.; Mosier, A.; Rypdal, K. (2006): 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Chapter 11: N2O Emissions from Managed Soils, and CO2 Emissions from Lime and Urea Application. Available at https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf, accessed 16.05.2023.

Del Río, P. (2014): On evaluating success in complex policy mixes: the case of renewable energy support schemes. In: Policy Sciences, 47 (3), pp. 267–287. https://doi.org/10.1007/s11077-013-9189-7.

Department for Business, Energy & Industrial Strategy (2018a): Evaluation of the public sector energy efficiency loan scheme: Interim evaluation report. Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/730976/Public-sector-energy-efficiency_loan_scheme_evaluation_Interim_Report_Final.pdf, accessed 16.05.2023.

Department for Business, Energy & Industrial Strategy (2018b): Heat Networks Investment Project Evaluation: Pilot Project Evaluation Report.

Direction Générale de l'Énergie et du Climat (2017): Rapport de la France. En application de l'article 13.1 du règlement n° 525/2013 relatif à un mécanisme pour la surveillance et la déclaration des émissions de gaz à effet de serre. Actualisation 2017, accessed 20.09.2021.

Direction Générale de l'Énergie et du Climat (2019): Rapport de la France. En application de l'article 13.1 du règlement n° 525/2013 relatif à un mécanisme pour la surveillance et la déclaration des émissions de gaz à effet de serre. Actualisation 2019, accessed 20.09.2021.

Doelman, J. C.; Beier, F. D.; Stehfest, E.; Bodirsky, B. L.; Beusen, A. H. W.; Humpenöder, F.; Mishra, A.; Popp, A.; van Vuuren, D. P.; Vos, L. de; Weindl, I.; van Zeist, W.-J.; Kram, T. (2022): Quantifying synergies and trade-offs in the global water-land-food-climate nexus using a multi-model scenario approach. In: Environmental Research Letters, 17 (4), p. 45004. https://doi.org/10.1088/1748-9326/ac5766.

Domergue, S.; Vermont, B. (2018): Étude d'impact du crédit d'impôt pour la transition énergétique (CITE). Puteaux: Commissariat General au Developmenent Durable.

Đorić, M.; Urbančič, A.; Visočnik, B. P.; Merše, S.; Sučic, B. (2020): Climate mirror 2020 GHG Emissions and EU-ETS sector.

Duscha, V.; Lehman, S.; Ittner, S. (2021): Revision der EU-Klimaschutz-Verordnung - Zusammenfassung. Umweltbundesamt. Available at https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/fkz_3718411130_factsheet_iia-esd-20052028vorfinale_75200-4_clean_final20210802.pdf.

Duval, R. (2008): OECD Economics Department Working Papers. https://doi.org/10.1787/236846121450.

Edenhofer, O.; Flachsland, C.; Kalkuhl, M.; Knopf, B.; Pahle, M. (2019): Optionen für eine CO2-Preisreform. Available at https://www.sachverstaendigenrat-wirtschaft.de/fileadmin/dateiablage/Arbeitspapiere/Arbeitspapier_04_2019.pdf, accessed 16.05.2023.

EEA (2016): Environment and climate policy evaluation. Available at https://www.eea.europa.eu/publications/environment-and-climate-policy-evaluation, accessed 23.02.2023.

EEA (2020a): EEA catalogue of European environment and climate policy evaluations. Available at http://poleval-catalogue.apps.eea.europa.eu/, accessed 16.05.2023.

EEA (2023): EEA database on greenhouse gas policies and measures in Europe — European Environment Agency. Available at http://pam.apps.eea.europa.eu/?source=%7B%22track_total_hits%22%3Atrue%2C%22query%22%3A%7B%22match_all%22%3A%7B%7D%7D%2C%22display_type%22%3A%22tabular%22%2C%22sort%22%3A%5B%7B%22Country%22%3A%7B%22order%22%3A%22asc%22%7D%7D%2C%7B%22ID_of_policy_or_measure%22%3A%7B%22order%22%3A%22asc%22%7D%7D%5D%2C%22highlight%22%3A%7B%22fields%22%3A%7B%22*%22%3A%7B%7D%7D%7D%7D, accessed 16.05.2023.

Elektroinštitut MILAN VIDMAR, Department of the Environment (Ed.) (2019): Technical Support for Comprehensive Environmental Impact Assessment for Integrated National Energy and Climate Plan of the Republic of Slovenia.

Emele, L.; Harthan, R. O.; Moosmann, L. (2019): Projektionsbericht 2019 für Deutschland - Zusammenfassung in der Struktur des Klimaschutzplans. Teilbericht des Projektes „THG-Projektion: Weiterentwicklung der Methoden und Umsetzung der EU-Effort Sharing Decision im Projektionsbericht 2019 („Politikszenarien IX“)“. Available at https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2019-09-06_climate-change_33-2019_pb19-ksp2050_teilbericht-psz-ix.pdf, accessed 16.05.2023.

Engelken, M.; Römer, B.; Drescher, M.; Welpe, I. M.; Picot, A. (2016): Comparing drivers, barriers, and opportunities of business models for renewable energies: A review. In: Renewable and Sustainable Energy Reviews, 60, pp. 795–809. https://doi.org/10.1016/j.rser.2015.12.163.

Engelmann, P.; Köhler, B.; Meyer, R.; Dengler, J.; Herkel, S.; Kießling, L.; Quast, A.; Berneiser, J.; Bär, C.; Sterchele, P.; Heilig, J.; Bürger, V.; Braungardt, S.; Hesse, T.; Sandrock, M.; Maaß, C.; Strodel, N. (2021): Systemische Herausforderung der Wärmewende. Abschlussbericht. Dessau-Roßlau.

EUR-LEX.europa.eu (Ed.) (2003): Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC (Text with EEA relevance). 32003L0087. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32003L0087.

EUR-LEX.europa.eu (Ed.) (2012): Consolidated version of the Treaty on the Functioning of the European Union PART SIX - INSTITUTIONAL AND FINANCIAL PROVISIONS TITLE I - INSTITUTIONAL PROVISIONS Chapter 2 - Legal acts of the Union, adoption procedures and other provisions, Section 1 - The legal acts of the Union, Article 288 (ex Article 249 TEC). TFEU - 12012E288. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A12012E288.

EUR-LEX.europa.eu (Ed.) (2015): COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE, THE COMMITTEE OF THE REGIONS AND THE EUROPEAN INVESTMENT BANK A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy. COM/2015/080 final. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2015:80:FIN.

EUR-LEX.europa.eu (Ed.) (2016): MITTEILUNG DER KOMMISSION AN DAS EUROPÄISCHE PARLAMENT, DEN RAT, DEN WIRTSCHAFTS- UND SOZIALAUSSCHUSS, DEN AUSSCHUSS DER REGIONEN UND DIE EUROPÄISCHE INVESTITIONSBANK Saubere Energie für alle Europäer. COM/2016/0860 final. Available at https://eur-lex.europa.eu/legal-content/DE/ALL/?uri=COM:2016:860:FIN.

EUR-LEX.europa.eu (Ed.) (2018a): Regulation (EU) 2018/841 of the European Parliament and of the Council of 30 May 2018 on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework, and amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU (Text with EEA relevance). PE/68/2017/REV/1 - 32018R0841. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.156.01.0001.01.ENG.

EUR-LEX.europa.eu (Ed.) (2018b): Regulation (EU) 2018/842 of the European Parliament and of the Council of 30 May 2018 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement and amending Regulation (EU) No 525/2013 (Text with EEA relevance). PE/3/2018/REV/2 32018R0842. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32018R0842.

EUR-LEX.europa.eu (Ed.) (2018c): Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast) (Text with EEA relevance.). PE/48/2018/REV/1 - 32018L2001. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018L2001&qid=1682415507416.

EUR-LEX.europa.eu (Ed.) (2018d): Directive (EU) 2018/2002 of the European Parliament and of the Council of 11 December 2018 amending Directive 2012/27/EU on energy efficiency (Text with EEA relevance.). PE/54/2018/REV/1 - 32018L2002. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0210.01.ENG.

EUR-LEX.europa.eu (Ed.) (2018e): Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action, amending Regulations (EC) No 663/2009 and (EC) No 715/2009 of the European Parliament and of the Council, Directives 94/22/EC, 98/70/EC, 2009/31/EC, 2009/73/EC, 2010/31/EU, 2012/27/EU and 2013/30/EU of the European Parliament and of the Council, Council Directives 2009/119/EC and (EU) 2015/652 and repealing Regulation (EU) No 525/2013 of the European Parliament and of the Council (Text with EEA relevance.). PE/55/2018/REV/1 - 32018R1999.

EUR-LEX.europa.eu (Ed.) (2020): Commission Implementing Regulation (EU) 2020/1208 of 7 August 2020 on structure, format, submission processes and review of information reported by Member States pursuant to Regulation (EU) 2018/1999 of the European Parliament and of the Council and repealing Commission Implementing Regulation (EU) No 749/2014 (Text with EEA relevance). EU/2020/1208 - 32020R1208. Available at https://eur-lex.europa.eu/eli/reg_impl/2020/1208/oj.

EUR-LEX.europa.eu (Ed.) (2021a): COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS 'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality. COM/2021/550 final - 52021DC0550. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2021%3A550%3AFIN.

EUR-LEX.europa.eu (Ed.) (2021b): Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC of the European Parliament and of the Council as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652. COM/2021/557 final - 52021PC0557. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2021:557:FIN.

EUR-LEX.europa.eu (Ed.) (2021c): Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union, Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and Regulation (EU) 2015/757. COM/2021/551 final - 52021PC0551. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0551.

EUR-LEX.europa.eu (Ed.) (2021d): Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on energy efficiency (recast). COM/2021/558 final - 52021PC0558. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2021:558:FIN.

EUR-LEX.europa.eu (Ed.) (2021e): Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Regulation (EU) 2018/842 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement. COM/2021/555 final - 52021PC0555. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2021%3A555%3AFIN.

EUR-LEX.europa.eu (Ed.) (2021f): Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law'). PE/27/2021/REV/1 - 32021R1119. Available at https://eur-lex.europa.eu/eli/reg/2021/1119/oj.

EUR-LEX.europa.eu (Ed.) (2022): Commission Implementing Regulation (EU) 2022/2299 of 15 November 2022 laying down rules for the application of Regulation (EU) 2018/1999 of the European Parliament and of the Council as regards the structure, format, technical details and process for the integrated national energy and climate progress reports. 32022R2299. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32022R2299.

EUR-LEX.europa.eu (Ed.) (2023a): COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS REPowerEU: Joint European Action for more affordable, secure and sustainable energy. COM/2022/108 final - 52022DC0108. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A108%3AFIN.

EUR-LEX.europa.eu (Ed.) (2023b): Regulation (EU) No 525/2013 of the European Parliament and of the Council of 21 May 2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC Text with EEA relevance. 32013R0525. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013R0525.

European Commission (n.d.a): Energy Union and climate action – Review report on the Governance Regulation. Available at https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13799-Energy-Union-and-climate-action-Review-report-on-the-Governance-Regulation_en, accessed 16.05.2023.

European Commission (n.d.b): Farm to Fork strategy. Available at https://ec.europa.eu/food/horizontal-topics/farm-fork-strategy_de, accessed 16.05.2023.

European Commission (n.d.c): Fertilisers and freshwater quality. Available at https://water.jrc.ec.europa.eu/khwa/knowledge/fertilisers.html, accessed 16.05.2023.

European Commission (n.d.d): Sustainable use of nutrients. The common agricultural policy supports farmers in the safe and efficient use of nutrients. Available at https://ec.europa.eu/info/food-farming-fisheries/sustainability/environmental-sustainability/low-input-farming/nutrients_en, accessed 16.05.2023.

European Commission (n.d.e): The common agricultural policy at a glance. Available at https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance_en, accessed 16.05.2023.

European Commission (n.d.f): The Nitrates Directive. Available at https://ec.europa.eu/environment/water/water-nitrates/index_en.html, accessed 16.05.2023.

European Commission (2016a): Impact Assessment Accompanying the document Proposal for a Directive of the European Parliament and of the Council amending Directive 2012/27/EU on Energy Efficiency. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52016SC0405R(01)&qid=1684140011400, accessed 16.05.2023.

European Commission (2016b): Impact Assessment Accompanying the document Proposal for a Regulation of the European Parliament and of the Council laying down rules on the making available on the market of CE marked fertilizing products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009. Available at https://eur-lex.europa.eu/resource.html?uri=cellar:5aa49d31-ec29-11e5-8a81-01aa75ed71a1.0001.02/DOC_3&format=PDF#page=7, accessed 16.05.2023.

European Commission (2019): Organic farming in the EU. A fast growing sector. Available at https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/farming/documents/market-brief-organic-farming-in-the-eu_mar2019_en.pdf, accessed 16.05.2023.

European Commission (2020a): Assessment of the final national energy and climate plan of Germany. Available at https://ec.europa.eu/energy/sites/ener/files/documents/staff_working_document_assessment_necp_germany.pdf, accessed 16.05.2023.

European Commission (2020b): Factsheet on the 2014-2020 Rural Development Programme for Slovenia. Available at https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/key_policies/documents/rdp-factsheet-slovenia_en.pdf, accessed 16.05.2023.

European Commission (2020c): National energy and climate plans (NECPs). Available at https://energy.ec.europa.eu/topics/energy-strategy/national-energy-and-climate-plans-necps_en, accessed 16.05.2023.

European Commission (2020d): An EU-wide assessment of National Energy and Climate Plans. Driving forward the green transition and promoting economic recovery through integrated energy and climate planning. Brussels.

European Commission (2021a): Questions and answers on Nitrates Directive Implementation Report. Available at https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_5110, accessed 16.05.2023.

European Commission (2021b): Better Regulation Guidelines. Brussels. Available at https://commission.europa.eu/system/files/2021-11/swd2021_305_en.pdf, accessed 23.02.2023.

European Commission (2021c): Better Regulation Toolbox. Available at https://commission.europa.eu/system/files/2023-02/br_toolbox-nov_2021_en.pdf, accessed 16.05.2023.

European Council (2009): laying down measures for the implementation of the European Council Decision on the exercise of the Presidency of the Council, and on the chairmanship of preparatory bodies of the Council. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02009D0908-20091201&from=DE%20(07.05.2021)., accessed 26.04.2023.

European Environment Agency (2018): Briefing - Agricultural land: nitrogen balance. Available at https://www.eea.europa.eu/airs/2018/natural-capital/agricultural-land-nitrogen-balance, accessed 16.05.2023.

European Environment Agency (2019): Climate change threatens future of farming in Europe. Available at https://www.eea.europa.eu/highlights/climate-change-threatens-future-of, accessed 27.02.2023.

European Environment Agency (2020b): Climate change mitigation policies and measures in Europe. Available at https://www.eea.europa.eu/data-and-maps/data/data-viewers/climate-change-mitigation-policies, accessed 26.04.2023.

European Environment Agency (2021a): Greenhouse gas emissions under the Effort Sharing Decision (ESD). Available at https://www.eea.europa.eu/data-and-maps/data/esd-4, accessed 14.11.2022.

European Environment Agency (2021b): EEA greenhouse gases – data reviewer. Data viewer on greenhouse gas emissions and removals, sent by countries to UNFCCC and the EU Greenhouse Gas Monitoring Mechanism (EU Member States). Available at https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer, accessed 16.05.2023.

European Environment Agency (2022): ESD dataset for the time period 2005-2021. Available at https://www.eea.europa.eu/data-and-maps/data/esd-4, accessed 02.05.2023.

European Evaluation Network for Rural Development (2014): Getting the most from your RDP: Guidelines for the ex-ante evaluation of 2014-2020 RDPs. Available at https://enrd.ec.europa.eu/sites/default/files/guidelines_for_the_ex_ante_evaluation_2014_-_2020_rdps.pdf, accessed 16.05.2023.

European Network for Rural Development (n.d.): RDP analysis - M10.1 Agri-environment-climate commitments. Available at https://enrd.ec.europa.eu/sites/default/files/rdp_analysis_m10-1.pdf, accessed 16.05.2023.

European Parliament; European Council; European Union (Eds.) (2013): Regulation (EU) No 1305/2013 of the European Parliament and of the Council of 17 Ddecember 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005. Available at https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:347:0487:0548:en:PDF.

Eurostat (2022): Wohneigentumsquote in ausgewählten europäischen Ländern im Jahr 2020. Available at https://de.statista.com/statistik/daten/studie/155734/umfrage/wohneigentumsquoten-in-europa/, accessed 16.05.2023.

Federal Ministry for Economic Affairs and Energy] (2014): 3rd National Energy Efficiency Action Plan (NEEAP) 2014 for the Federal Republic of Germany: Pursuant to Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency.

Federal Ministry of Economics and Technology (2011): Second National Energy Efficiency Action Plan (NEEAP) of the Federal Republic of Germany: Pursuant to the EU Directive on Energy End-use Efficiency and Energy Services (2006/32/EC).

Femenías, P.; Mjörnell, K.; Thuvander, L. (2018): Rethinking deep renovation: The perspective of rental housing in Sweden. In: Journal of Cleaner Production, 195, pp. 1457–1467. https://doi.org/10.1016/j.jclepro.2017.12.282.

Forschungsgruppe Agrar- und Regionalentwicklung Triesdorf (2016): Ex post-Bewertung des Bayerischen Zukunftsprogramms Agrarwirtschaft und Ländlicher Raum 2007-2013 (BayZAL). Triesdorf. Available at https://www.stmelf.bayern.de/mam/cms01/agrarpolitik/dateien/ex_post_bewertung_bayzal.pdf, accessed 03.06.2022.

Fragkos, P.; Paroussos, L. (2018): Employment creation in EU related to renewables expansion. In: Applied Energy, 230, pp. 935–945. https://doi.org/10.1016/j.apenergy.2018.09.032.

Fujiwara, N.; van Asselt, H.; Böβner, S.; Voigt, S.; Spyridaki, N.-A.; Flamos, A.; Alberola, E.; Williges, K.; Türk, A.; Donkelaar, M. ten (2019): The practice of climate change policy evaluations in the European Union and its member states: results from a meta-analysis. In: Sustainable Earth, 2 (1), pp. 1–16. https://doi.org/10.1186/s42055-019-0015-8.

Garrett-Peltier, H. (2017): Green versus brown: Comparing the employment impacts of energy efficiency, renewable energy, and fossil fuels using an input-output model. In: Economic Modelling, 61, pp. 439–447. https://doi.org/10.1016/j.econmod.2016.11.012.

German Federal Government (2021): German Sustainable Development Strategy - Update 2021. Available at https://www.bundesregierung.de/resource/blob/974430/1940716/6a4acf041217d39bac6a81cce971381f/2021-07-26-gsds-en-data.pdf?download=1, accessed 16.05.2023.

Golmohamadi, H.; Keypour, R.; Mirzazade, P. (2021): Multi-objective co-optimization of power and heat in urban areas considering local air pollution. In: Engineering Science and Technology, an International Journal, 24 (2), pp. 372–383. https://doi.org/10.1016/j.jestch.2020.08.004.

Good, N.; Martínez Ceseña, E. A.; Mancarella, P.; Monti, A.; Pesch, D.; Ellis, K. A. (2016): Chapter Eight - Barriers, Challenges, and Recommendations Related to Development of Energy Positive Neighborhoods and Smart Energy Districts. In: Mancarella, P. (Ed.): Energy positive neighborhoods and smart energy districts - methods, tools. Elsevier Science Publishing Co, pp. 251–274. https://doi.org/10.1016/B978-0-12-809951-3.00008-9.

Green, M.; Maynard, R. (Eds.) (2006): The employment benefits of organic farming. Available at https://orgprints.org/id/eprint/10178/1/The_employment_benefits_of_organic_farming.pdf, accessed 16.05.2023.

Harthan, R. O.; Repenning, J.; Blanck, R.; Böttcher, H.; Bürger, V.; Cook, V.; Emele, L.; Görz, W. K.; Hennenberg, K.; Jörß, W.; Ludig, S.; Matthes, F. C.; Mendelevitch, R.; Moosmann, L.; Scheffler, M.; Wiegmann, K.; Brugger, H.; Fleiter, T.; Mandel, T.; Rehfeldt, M.; Steinbach, J. (2020): Abschätzung der Treibhausgasminderunsgwirkung des Klimaschutzprogramms 2030 der Bundesregierung. Teilbericht des Projektes „THG-Projektion: Weiterentwicklung der Methoden und Umsetzung der EU-Effort Sharing Decision im Projektionsbericht 2019 („Politikszenarien IX“)“. Dessau-Roßlau: Umweltbundesamt.

Haug, C.; Rayner, T.; Jordan, A.; Hildingsson, R.; Stripple, J.; Monni, S.; Huitema, D.; Massey, E.; van Asselt, H.; Berkhout, F. (2010): Navigating the dilemmas of climate policy in Europe: evidence from policy evaluation studies. In: Climatic Change, 101 (3-4), pp. 427–445. https://doi.org/10.1007/s10584-009-9682-3.

Häussermann, U.; Bach, M.; Breuer, L.; Döhler, H. (2020): Potenziale zur Minderung der Ammoniakemissionen in der deutschen Landwirtschaft. Berechnung der Minderungspotenziale von Maßnahmen im Bereich Landwirtschaft zur Reduktion der nationalen Ammoniakemissionen und Entwicklung von Szenarien zur Einhaltung der Reduktionsverpflichtungen der neuen NEC-Richtlinie (EU) 2284/2016. Available at https://www.researchgate.net/publication/347520304_Potenziale_zur_Minderung_der_Ammoniakemissionen_in_der_deutschen_Landwirtschaft_Berechnung_der_Minderungspotenziale_von_Massnahmen_im_Bereich_Landwirtschaft_zur_Reduktion_der_nationalen_Ammoniakemissi, accessed 16.05.2023.

Hermann, A.; Wiegman, K.; Wirz, A. (2020): Instrumente und Maßnahmen zur Stickstoffreduktion im Rahmen der Stickstoffstrategie Baden-Württemberg,

Hölscher, L.; Gehre, L. (2018): Denmark: Action Plans for the Aquatic Environment and Green Growth Agreement - Fact sheet. Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit; EUKI. Available at https://www.euki.de/wp-content/uploads/2018/09/fact-sheet-actions-plans-dk.pdf, accessed 16.05.2023.

Howlett, M.; Rayner, J. (2014): Patching vs Packaging in Policy Formulation: Assessing Policy Portfolio Design. In: Politics and Governance, 1 (2), pp. 170–182. https://doi.org/10.17645/pag.v1i2.95.

Hrovatin, N.; Zorić, J. (2018): Determinants of energy-efficient home retrofits in Slovenia: The role of information sources. In: Energy and Buildings, 180, pp. 42–50. https://doi.org/10.1016/j.enbuild.2018.09.029.

Hunter, K.; Sreepathi, S.; DeCarolis, J. F. (2013): Modeling for insight using Tools for Energy Model Optimization and Analysis (Temoa). In: Energy Economics, 40, pp. 339–349. https://doi.org/10.1016/j.eneco.2013.07.014.

ifo Institut (Ed.) (2022). *Materialengpässe am Bau gehen zurück*. Available at https://www.ifo.de/node/67302.

Institut für Ländliche Strukturforschung (2016): Ex post-Bewertung „Maßnahmen- und Entwicklungsplan Ländlicher Raum Baden-Württemberg 2007 - 2013 (MEPL II)“ nach der VO (EG) Nr. 1698/2005. Frankfurt am Main. Available at https://foerderung.landwirtschaft-bw.de/pb/site/pbs-bw-mlr/get/documents_E676108532/MLR.LEL/PB5Documents/mlr/MEPL/mepl_ii_extern/Ex%20post-Bewertung%20MEPL%20II_final.pdf, accessed 16.05.2023.

Institut Wohnen und Umwelt GmbH (2016): Gebäudedatenbank 2016. Available at http://wohngebaeudedaten2016.iwu.de/, accessed 16.05.2023.

Institut Wohnen und Umwelt GmbH; Fraunhofer-Institut für Fertigungstechnik und Angewandte Materialforschung (2016): Monitoring der KfW-Programme „Energieeffizient Sanieren“ und „Energieeffizient Bauen“ 2015.

Institut Wohnen und Umwelt GmbH; Fraunhofer-Institut für Fertigungstechnik und Angewandte Materialforschung (2018): Monitoring der KfW-Programme „Energieeffizient Sanieren“ und „Energieeffizient Bauen“ 2017. Darmstadt: KfW Bankengruppe.

Institute for European Environmental Policy (2013): Evaluation of 2011 energy tax reform. Available at https://ieep.eu/uploads/articles/attachments/7f522cac-a949-4a6d-b8fe-f4e6df644efc/ETR_study_by_IEEP_for_the_Swiss_Government_-_Final_report_-_21_June_2013.pdf?v=63664509831.

Jacobs, C.; Berglund, M.; Kurnik, B.; Dworak, T.; Marras, S.; Mereu, V.; Michetti, M. (2019): Climate change adaptation in the agriculture sector in Europe. Available at https://www.eea.europa.eu/publications/cc-adaptation-agriculture, accessed 16.05.2023.

Jacobsen, B. (2012): Analyse af omkostningerne ved en yderligere reduktion af N-tabet fra landbruget med 10.000 tons N - Medarbejdere på Institut for Fødevare- og Ressourceøkonomi (IFRO). Available at https://ifro.ku.dk/medarbejdere/?pure=da%2Fpublications%2Fanalyse-af-omkostningerne-ved-en-yderligere-reduktion-af-ntabet-fra-landbruget-med-10000-tons-n(de9f857b-1196-4476-9969-b1544231968d).html, accessed 16.05.2023.

Jacobsen, Brian, H. (2012): Analyse af omkostningerne ved en yderligere reduktion af N-tabet fra landbruget med 10.000 tons N - Medarbejdere på Institut for Fødevare- og Ressourceøkonomi (IFRO). Available at https://ifro.ku.dk/medarbejdere/?pure=da%2Fpublications%2Fanalyse-af-omkostningerne-ved-en-yderligere-reduktion-af-ntabet-fra-landbruget-med-10000-tons-n(de9f857b-1196-4476-9969-b1544231968d).html, accessed 16.05.2023.

Jo, H.; Park, J.; Kim, I. (2021): Environmentally Constrained Optimal Dispatch Method for Combined Cooling, Heating, and Power Systems Using Two-Stage Optimization. In: Energies, 14 (14), p. 4135. https://doi.org/10.3390/en14144135.

Kemmler, A.; Kirchner, A.; Maur, A. auf der; Ess, F.; Kreidelmeyer, S.; Piégsa, A.; Spillmann, T.; Straßburg, S.; Wünsch, M.; Ziegenhagen, I.; Schlomann, B.; Plötz, P.; Lutz, C.; Becker, L.; Fritsche, U. (2021): Energiewirtschaftliche Projektionen und Folgeabschätzungen

2030/2050. Gesamtdokumentation der Szenarien. Bericht im Auftrag des Bundesministeriums für Wirtschaft und Energie.

Kern, F.; Kivimaa, P.; Martiskainen, M. (2017): Policy packaging or policy patching? The development of complex energy efficiency policy mixes. In: Energy Research & Social Science, 23, pp. 11–25. https://doi.org/10.1016/j.erss.2016.11.002.

KfW Bankengruppe (2021): Die Effizienzhaus-Stufen für bestehende Immobilien und Baudenkmale. Maßstab für Energieeffizienz. Available at kfw.de/s/deiEWv0, accessed 23.07.2021.

Kirchmann, H. (2019): Why organic farming is not the way forward. In: Outlook on Agriculture, 48 (1), pp. 22–27. https://doi.org/10.1177/0030727019831702.

Kölling, A.; Elola-Calderó, T. (2012): Organic Agriculture. A Strategy for Climate Change Adaptation. Available at https://www.organicseurope.bio/content/uploads/2021/02/ifoameu_policy_climate_change_adaptation_dossier_201212_0_compressed.pdf?dd, accessed 16.05.2023.

Krajnc, N.; Domac, J. (2007): How to model different socio-economic and environmental aspects of biomass utilisation: Case study in selected regions in Slovenia and Croatia. In: Energy Policy, 35 (12), pp. 6010–6020. https://doi.org/10.1016/j.enpol.2007.08.006.

Kuckshinrichs, W.; Aniello, G. (2018): Wirkungen der KfW-Programme „Energieeffizient Bauen", „Energieeffizient Sanieren", „IKK/IKU – Energieeffizient Bauen und Sanieren" und „KfW-Energieeffizienzprogramm – Energieeffizient Bauen und Sanieren" auf öffentliche Haushalte im Förderjahr 2016. Kurzgutachten im Auftrag der KfW. Jülich: KfW Bankengruppe.

Kuhn, T. (2017): The revision of the German Fertiliser Ordinance in 2017. Available at https://www.researchgate.net/publication/319211355_The_revision_of_the_German_Fertiliser_Ordinance_in_2017, accessed 16.05.2023.

Langniß, O.; Schüller, M.; Wülbeck, H.-F.; Nast, M.; Pehnt, M.; Frick, S.; Drück, H.; Streicher, E.; Hartmann, H.; Reisinger, K. (2010): Evaluierung von Einzelmaßnahmen zur Nutzung erneuerbarer Energien im Wärmemarkt (Marktanreizprogramm) für den Zeitraum 2009 bis 2011,

Lilliestam, J.; Patt, A.; Bersalli, G. (2021): The effect of carbon pricing on technological change for full energy decarbonization: A review of empirical ex-post evidence. In: Wiley Interdisciplinary Reviews: Climate Change, 12 (1). https://doi.org/10.1002/wcc.681.

Lin, B.; Li, X. (2011): The effect of carbon tax on per capita CO2 emissions. In: Energy Policy, 39 (9), pp. 5137–5146. https://doi.org/10.1016/j.enpol.2011.05.050.

Mandley, S.; Wicke, B.; Junginger, H.; Vuuren, D.; Daioglou, V. (2022): Integrated assessment of the role of bioenergy within the EU energy transition targets to 2050. In: GCB Bioenergy, 14 (2), pp. 157–172. https://doi.org/10.1111/gcbb.12908.

März, S. (2018): Beyond economics—understanding the decision-making of German small private landlords in terms of energy efficiency investment. In: Energy Efficiency, 11 (7), pp. 1721–1743. https://doi.org/10.1007/s12053-017-9567-7.

Mastrandrea, M. D.; Mach, K. J.; Plattner, G.-K.; Edenhofer, O.; Stocker, T. F.; Field, C. B.; Ebi, K. L.; Matschoss, P. R. (2011): The IPCC AR5 guidance note on consistent treatment of uncertainties: a common approach across the working groups. In: Climatic Change, 108 (4), pp. 675–691. https://doi.org/10.1007/s10584-011-0178-6.

Material Economics (2021): EU Biomass Use in a Net-Zero Economy. A course correction for EU biomass.

Matthes, F.; Renn, O.; Mendelevitch, R.; Camier, C.; Kiesow, T. (2021): Orientierungshilfe „Good Practice“ für Ex-Ante-Evaluierungen von Klimaschutzmaßnahmen. Freiburg, Potsdam, Berlin.

Melvin, J. (2018): The split incentives energy efficiency problem: Evidence of underinvestment by landlords. In: Energy Policy, 115, pp. 342–352. https://doi.org/10.1016/j.enpol.2017.11.069.

Memmler, M.; Lauf, T.; Schneider, S. (2018): Emissionsbilanz erneuerbarer Energieträger - Bestimmung der vermiedenen Emissionen im Jahr 2017. Dessau-Roßlau. Available at https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2018-10-22_climate-change_23-2018_emissionsbilanz_erneuerbarer_energien_2017_fin.pdf, accessed 16.05.2023.

Memmler, M.; Schrempf, L.; Hermann, S.; Schneider, S.; Pabst, J.; Dreher, M. (2014): Emissionsbilanz erneuerbarer Energieträger. Bestimmung der vermiedenen Emissionen im Jahr 2013. Dessau-Roßlau. Available at https://www.umweltbundesamt.de/sites/default/files/medien/376/publikationen/climate_change_29_2014_schrempf_komplett_10.11.2014.pdf, accessed 20.09.2021.

Merše, S.; Urbančič, A.; Čižman, J.; Staničić, D.; Petelin Visočnik, B.; Janša, T.; Stegnar, G. (2018): Podnebno ogledalo 2018: Ukrep v središču - Spodbujanje sistemov daljinskega ogrevanja: Končno poročilo.

Mirakyan, A.; Guio, R. de (2015): Modelling and uncertainties in integrated energy planning. In: Renewable and Sustainable Energy Reviews, 46, pp. 62–69. https://doi.org/10.1016/j.rser.2015.02.028.

Mirasgedis, S.; Tourkolias, C.; Pavlakis, E.; Diakoulaki, D. (2014): A methodological framework for assessing the employment effects associated with energy efficiency interventions in buildings. In: Energy and Buildings, 82, pp. 275–286. https://doi.org/10.1016/j.enbuild.2014.07.027.

Müller, M. (2021): Germany’s skilled labour shortage is the worst since unification. KfW-ifo. Available at https://www.kfw.de/PDF/Download-Center/Konzernthemen/Research/PDF-Dokumente-KfW-ifo-Fachkr%C3%A4ftebarometer/KfW-ifo-Fachkraeftebarometer_2021_11_EN.pdf, accessed 16.05.2023.

Naturvårdsverket (2020): Lägebeskrivning for Klimatklivet. Stockholm.

Naturvårdsverket (2021): Lägebeskrivning för Klimatklivet. Stockholm.

Nieberg, H.; Kuhnert, H. (2007): Support Policy for Organic Farming in Germany. In: Landbauforschung Völkenrode, pp. 95–106.

Nielsen, O.-K.; Mikkelsen, M. H.; Hoffmann, L.; Gyldenkærne, S.; Winther, M.; Nielsen, M.; Fauser, P.; Thomsen, M.; Plejdrup, M. S.; Albrektsen, R.; Hjelgaard, K.; Bruun, H. G.; Johannsen, V. K.; Nord-Larsen, T.; Bastrup-Birk, A.; Vesterdal, L.; Møller, I. S.; Rasmussen, E.; Arfaoui, K.; Baunbæk, L.; Gunnleivsdóttir Hansen, M. (2012): Denmark's National Inventory Report 2012. Emission Inventories 1990-2010 - Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Available at https://www.dmu.dk/pub/sr19.pdf, accessed 16.05.2023.

OECD (2014): OECD Regulatory Compliance Cost Assessment Guidance. Paris: OECD Publishing. https://doi.org/10.1787/9789264209657-en.

OECD (2019): Better Regulation Practices across the European Union. Paris: OECD Publishing. https://doi.org/10.1787/9789264311732-en.

OECD (2020a): Regulatory Impact Assessment. OECD Best Practice Principles for Regulatory Policy. Paris: OECD Publishing. Available at https://ebookcentral.proquest.com/lib/kxp/detail.action?docID=6408761, accessed 16.05.2023.

OECD (2020b): Reviewing the Stock of Regulation. OECD Best Practice Principles for Regulatory Policy. Paris: OECD Publishing. Available at https://ebookcentral.proquest.com/lib/kxp/detail.action?docID=6638943, accessed 16.05.2023.

Oehlmann, M.; Rubel, C.; Klaas, K.; Nunes-Heinzmann, A.-C.; Schäppi, B.; Peter, M.; Angst, V.; Reutimann, J. (2021): Maßnahmenvorschläge für ein Aktionsprogramm zur integrierten Stickstoffminderung. Abschlussbericht. Im Auftrag des Umweltbundesamtes. Available at https://www.umweltbundesamt.de/sites/default/files/medien/5750/publikationen/2021-05-26_texte_78-2021_aktionsprogramm_stickstoff_fin.pdf, accessed 02.06.2022.

Ohlendorf, N.; Jakob, M.; Minx, J. C.; Schröder, C.; Steckel, J. C. (2021): Distributional Impacts of Carbon Pricing: A Meta-Analysis. In: Environmental and Resource Economics, 78 (1), pp. 1–42. https://doi.org/10.1007/s10640-020-00521-1.

Öko-Institut; Fraunhofer-Institut für System- und Innovationsforschung; Institut für Ressourceneffizienz und Energiestrategien (2020): Abschätzung der Treibhausgasminderungswirkung des Klimaschutzprogramms 2030 der Bundesregierung. Teilbericht des Projektes „THG-Projektion: Weiterentwicklung der Methoden und Umsetzung der EU-Effort Sharing Decision im Projektionsbericht 2019 („Politikszenarien IX“)“. Berlin: Umweltbundesamt.

Orsini, S.; Padel, S.; Lampkin, N. (2018): Labour Use on Organic Farms: A Review of Research since 2000. In: Organic Farming, 4 (1). https://doi.org/10.12924/of2018.04010007.

Osterburg, B.; Techen, A. (2012): Evaluierung der Düngeverordnung – Ergebnisse und Optionen zur Weiterentwicklung. Bundesministerium für Ernährung und Landwirtschaft. Available at https://literatur.thuenen.de/digbib_extern/dn051542.pdf, accessed 16.05.2023.

Pädam, S.; Malmström, C.; Noring, M.; Pyk, F.; Wallström, J. (2020): Effekter av Klimatklivet. Stockholm: Naturvardsverket.

Palm, J.; Reindl, K.; Ambrose, A. (2020): Understanding tenants' responses to energy efficiency renovations in public housing in Sweden: From the resigned to the demanding. In: Energy Reports, 6, pp. 2619–2626. https://doi.org/10.1016/j.egyr.2020.09.020.

Pehnt, M.; Nast, M.; Götz, C.; Blömer, S.; Barckhausen, A.; Schröder, D.; Miljes, R.; Pottbäcker, C.; Breier, H.; Nabe, C.; Lindner, S.; Dannemann, B. (2017): Wärmenetzsysteme 4.0. Endbericht: Kurzstudie zur Umsetzung der Maßnahme "Modellvorhaben erneuerbare Energien in hocheffizienten Niedertemperaturwärmenetzen".

Perez Dominguez, I.; Fellmann, T.; Weiss, F.; Witzke, H.; Barreiro, Hurle, J.; Himics, M.; Jansson, T.; Salputra, G.; Leip, A. (2016): An economic assessment of GHG mitigation policy options for EU agriculture (EcAMPA 2). Publications Office of the European Union.

Persson, J.; Grönkvist, S. (2015): Drivers for and barriers to low-energy buildings in Sweden. In: Journal of Cleaner Production, 109, pp. 296–304. https://doi.org/10.1016/j.jclepro.2014.09.094.

Polzin, F.; Nolden, C.; Flotow, P. von (2018): Drivers and barriers for municipal retrofitting activities – Evidence from a large-scale survey of German local authorities. In: Renewable and Sustainable Energy Reviews, 88, pp. 99–108. https://doi.org/10.1016/j.rser.2018.02.012.

Ponisio, L. C.; M'Gonigle, L. K.; Mace, K. C.; Palomino, J. (2015): Diversification practices reduce organic to conventional yield gap, 282.

Ponti, T. de; Rijk, B.; van Ittersum, M. K. (2012): The crop yield gap between organic and conventional agriculture. In: Agricultural Systems, 108, pp. 1–9.

Poux, X.; Aubert, P.-M.; Saulnier, J.; Lumbroso, S.; Treyer, S.; Loveluck, W.; Hege, É.; Schwoob, M.-H. (2018): An agroecological Europe in 2050: multifunctional agriculture for healthy eating. Findings from the Ten Years For Agroecology (TYFA) modelling exercise. Available at https://www.iddri.org/sites/default/files/PDF/Publications/Catalogue%20Iddri/Etude/201809-ST0918EN-tyfa.pdf, accessed 16.05.2023.

Prognos AG; Fraunhofer-Institut für System- und Innovationsforschung (2018): Mittel- und langfristige Weiterentwicklung des Instrumentenmixes der Energieeffizienzpolitik zur Umsetzung der Energiekonzeptziele - NAPE 2.0.

Prognos AG; Fraunhofer-Institut für System- und Innovationsforschung; GWS; Internationales Institut für Nachhaltigkeitsanalysen und -strategien (2021): Energiewirtschaftliche Projektionen und Folgeabschätzungen 2030/2050. Gesamtdokumentation der Szenarien. Basel: Bundesministerium für Wirtschaft und Energie.

Prognos AG; navigant; Öko-Institut; Deutsche Energieagentur; adelphi; Becker Büttner Held; Institut für Energie- und Umweltforschung Heidelberg gGmbH (2020): Kurzgutachten zu Maßnahmen zur Zielerreichung 2030 zur Begleitung des Klimakabinetts. Berlin: Bundesministerium für Wirtschaft und Energie.

Ramboll (2020): Social Impacts of climate mitigation policies and outcomes in terms of inequality final report. Available at https://ramboll.com/-/media/files/rm/rapporter/social-impacts-of-climate-mitigation-policies-and-outcomes-in-terms-of-inequality/eea_just_transition_final-report_31march21_revised-clean.pdf?la=en, accessed 16.05.2023.

Ratinen, M. (2019): Social embeddedness of policy actors. The failure of consumer-owned wind energy in Finland. In: Energy Policy, 128, pp. 735–743. https://doi.org/10.1016/j.enpol.2019.01.004.

Republic of Slovenia (2020): Slovenia's Fourth Biennal Report UNFCCC. Available at https://unfccc.int/sites/default/files/resource/4BR_2020_EN_SLOVENIA.pdf, accessed 16.05.2023.

Republika Slovenija (2014): Operational Programme for the Implementation of the EU Cohesion Policy 2014-2020. Ljubljana: Governmental Office for Development and European Cohesion Policy.

Reuter, M.; Patel, M. K.; Eichhammer, W.; Lapillonne, B.; Pollier, K. (2020): A comprehensive indicator set for measuring multiple benefits of energy efficiency. In: Energy Policy, 139, p. 111284. https://doi.org/10.1016/j.enpol.2020.111284.

Ricardo Energy&Environment; Öko-Institut; VITO - Vlaamse Instelling voor Technologisch Onderzoek; WUR - Wageningen University & Research (2020): Guidance document for ex-post evaluation of climate policies in Effort Sharing sectors. Available at https://eionet.devel4cph.eea.europa.eu/reportnet/docs/govreg/policies-and-

measures/guidance-document-for-ex-post-evaluation-of-climate-policies-in-effort-sharing-sectors.pdf/view, accessed 16.05.2023.

Rich, D.; Bhatia, P.; Finnegan, J.; Levin, K.; Mitra, A. (2014): Policy Action and Standard. An accounting and reporting standard for estimating the greenhouse gas effects of poli-cies and actions. Washington, D.C. Available at https://files.wri.org/d8/s3fs-public/Policy_and_Action_Standard.pdf, accessed 16.05.2023.

Rogge, K. S.; Reichardt, K. (2016): Policy mixes for sustainability transitions: An extended concept and framework for analysis. In: Research Policy, 45 (8), pp. 1620–1635. https://doi.org/10.1016/j.respol.2016.04.004.

Rosenow, J.; Kern, F.; Rogge, K. (2017): The need for comprehensive and well targeted instrument mixes to stimulate energy transitions: The case of energy efficiency policy. In: Energy Research & Social Science, 33, pp. 95–104. https://doi.org/10.1016/j.erss.2017.09.013.

Sandin, S.; Neij, L.; Mickwitz, P. (2019): Transition governance for energy efficiency - insights from a systematic review of Swedish policy evaluation practices. In: Energy, Sustainability and Society, 9 (1), pp. 1–18. https://doi.org/10.1186/s13705-019-0203-6.

Sayegh, M. A.; Danielewicz, J.; Nannou, T.; Miniewicz, M.; Jadwiszczak, P.; Piekarska, K.; Jouhara, H. (2017): Trends of European research and development in district heating technologies. In: Renewable and Sustainable Energy Reviews, 68, pp. 1183–1192. https://doi.org/10.1016/j.rser.2016.02.023.

Scarlat, N.; Dallemand, J.-F.; Monforti-Ferrario, F.; Nita, V. (2015): The role of biomass and bioenergy in a future bioeconomy: Policies and facts. In: Environmental Development, 15, pp. 3–34. https://doi.org/10.1016/j.envdev.2015.03.006.

Schelde, K.; Olesen, J. E. (2014): Klimaeffekt af kvælstofvirkemidler i dansk landbrug i perioden 2007-2015 [Climate impact of nitrogen inputs in Danish agriculture in the period 2007-2015]. Available at https://pure.au.dk/portal/files/96971705/Klimaeffekter_Nvirkemidler_2007_2015_100314.pdf, accessed 16.05.2023.

Schleich, J. (2004): Do energy audits help reduce barriers to energy efficiency? An empirical analysis for Germany. In: International Journal of Energy Technology and Policy, 2 (3), 226-239.

Schlomann, B.; Brunzema, I.; Kemmler, A.; Bürger, V.; Mendelevitch, R. (2022): Methodikpapier zur ex-ante Abschätzung der Energie- und THG-Minderungswirkung von energie- und klimaschutzpolitischen Maßnahmen. Kurzpapier im Rahmen des Vorhabens "Projektionen zu nationalen und europäischen Energie- und Klimazielen und zu Wirkungen von Einzelmaßnahmen und Maßnahmenprogrammen" im Auftrag des BMWK. BMWK.

Schlomann, B.; Rohde, C.; Bentele, S. (2021): Mögliche Ausgestaltung eines Energieeinsparverpflichtungssystems für Deutschland. Abschlussbericht. Available at https://www.umweltbundesamt.de/sites/default/files/medien/5750/publikationen/2021-02-26_cc_11-2021_energieeinsparverpflichtungssystem.pdf, accessed 16.05.2023.

Schoenefeld, J. J.; Hildén, M.; Jordan, A. J. (2018): The challenges of monitoring national climate policy: learning lessons from the EU. In: Climate Policy, 18 (1), pp. 118–128. https://doi.org/10.1080/14693062.2016.1248887.

Serres, A. de; Fabrice Murtin; Giuseppe Nicoletti (2010): OECD Economics Department Working Papers. OECD. https://doi.org/10.1787/5kmfj2xvcmkf-en.

Seto, K. C.; Davis, S. J.; Mitchell, R. B.; Stokes, E. C.; Unruh, G.; Ürge-Vorsatz, D. (2016): Carbon Lock-In: Types, Causes, and Policy Implications. In: Annual Review of Environment and Resources (Annu. Rev. Environ. Resour.), 41, pp. 425–452. https://doi.org/10.1146/annurev-environ-110615-085934.

Shmelev, S. E.; Speck, S. U. (2018): Green fiscal reform in Sweden: Econometric assessment of the carbon and energy taxation scheme. In: Renewable and Sustainable Energy Reviews, 90, pp. 969–981. https://doi.org/10.1016/j.rser.2018.03.032.

Slovenian Ministry of Agriculture, Forestry and Food (2021): Akcijski načrt za razvoj ekološkega kmetijstva do leta 2027 (ANEK). Available at https://skp.si/download/akcijski-nacrt-za-razvoj-ekoloskega-kmetijstva?ind=1640338092652&filename=ANEK-akcijski-nacrt-za-ekolosko-kmetovanje.pdf&wpdmdl=9385&refresh=626a260501d2c1651123717, accessed 16.05.2023.

Sorrell, S.; O'Malley, E. J.; Schleich, J.; Scott, S. (2004): The economics of energy efficiency. Barrieres to cost-effective investment. Cheltenham: Edward Elgar Publishing. ISBN: 1840648899.

Sovacool, B. K.; Demski, C.; Noel, L. (2021): Beyond climate, culture and comfort in European preferences for low-carbon heat. In: Global Environmental Change, 66, p. 102200. https://doi.org/10.1016/j.gloenvcha.2020.102200.

Sovacool, B. K.; Martiskainen, M. (2020): Hot Transformations: Governing Rapid and Deep Household Heating Transitions in China, Denmark, Finland and the United Kingdom.

Stavropoulos, S.; Burger, M. J. (2020): Modelling strategy and net employment effects of renewable energy and energy efficiency: A meta-regression. In: Energy Policy, 136, p. 111047. https://doi.org/10.1016/j.enpol.2019.111047.

Stegnar, G.; Staničić, D.; Urbančič, A.; Visočnik, B. P. (2020): Podnebno ogledalo 2020 Ukrep v središču – Energetska prenova stavb ožjega javnega sektorja. Končno poročilo LIFE ClimatePath2050 (LIFE16 GIC/SI/000043). Ljubljana.

Sweden's Environmental Protection Agency (2019): Sweden's fourth Biennial Report under the UNFCCC. Stockholm.

Swedish Ministry of Infrastructure (2020): Sweden's Integrated National Energy and Climate Plan. Available at https://ec.europa.eu/energy/sites/ener/files/documents/se_final_necp_main_en.pdf, accessed 16.05.2023.

The Danish Environmental Protection Agency (n.d.a): Action Plan for the Aquatic Environment III 2005-2009. Available at https://eng.mst.dk/trade/agriculture/nitrates-directive/action-plan-for-the-aquatic-environment-iii/, accessed 16.05.2023.

The Danish Environmental Protection Agency (n.d.b): Green Growth Agreement. Available at https://eng.mst.dk/trade/agriculture/nitrates-directive/green-growth-agreement/, accessed 16.05.2023.

The Government of the Republic of Slovenia (2020): Integrated National Energy and Climate Plan of the Republic of Slovenia. Available at https://www.energetika-portal.si/fileadmin/dokumenti/publikacije/nepn/dokumenti/nepn_5.0_final_feb-2020.pdf, accessed 16.05.2023.

Toleikyte, A.; Carlsson, J. (2021): Assessment of heating and cooling related chapters of the national energy and climate plans (NECPs). JRC Technical Report, accessed 23.09.2021.

Umweltbundesamt (2019): Nitrous oxide and methane. Available at https://www.umweltbundesamt.de/en/topics/soil-agriculture/ecological-impact-of-farming/nitrous-oxide-methane, accessed 16.05.2023.

Umweltbundesamt (2022): Treibhausgas-Emissionen in der Europäischen Union. Available at https://www.umweltbundesamt.de/daten/klima/treibhausgas-emissionen-in-der-europaeischen-union#hauptverursacher, accessed 26.04.2023.

United Nations (n.d.): THE 17 GOALS | Sustainable Development. Available at https://sdgs.un.org/goals, accessed 16.05.2023.

United Nations Climate Change (2020): SLOVENIA'S FOURTH BIENNIAL REPORT UNFCCC. Available at https://unfccc.int/sites/default/files/resource/4BR_2020_EN_SLOVENIA.pdf, accessed 16.05.2023.

United Nations Climate Change (2021): Report on the technical review of the fourth biennial report of Slovenia. Available at https://unfccc.int/sites/default/files/resource/trr4_SVN.pdf, accessed 16.05.2023.

Ürge-Vorsatz, D.; Sergio Tirado Herrero; Navroz K. Dubash; Franck Lecocq (2014): Measuring the Co-Benefits of Climate Change Mitigation. In: Annual Review of Environment and Resources (Annu. Rev. Environ. Resour.), (39), pp. 549–582. https://doi.org/10.1146/annurev-environ-031312-125456.

van der Schoor, T.; Scholtens, B. (2015): Power to the people: Local community initiatives and the transition to sustainable energy. In: Renewable and Sustainable Energy Reviews, 43, pp. 666–675. https://doi.org/10.1016/j.rser.2014.10.089.

Velthof, G. L.; Lesschen, J. P.; Webb, J.; Pietrzak, S.; Miatkowski, Z.; Kros, J.; Pinto, M.; Oenema, O. (2010): The impact of the Nitrates Directive on gaseous N emissions. Effects of measures in nitrates action programme on gaseous N emissions. Wageningen: Alterra Wageningen UR. Available at https://ec.europa.eu/environment/water/water-nitrates/pdf/Final_report_impact_Nitrates_Directive_def.pdf, accessed 16.05.2023.

Veum, K.; Bauknecht, D. (2019): How to reach the EU renewables target by 2030? An analysis of the governance framework. In: Energy Policy, 127, pp. 299–307. https://doi.org/10.1016/j.enpol.2018.12.013.

Vlada Republike Slovenje (2008): Nacionalni akcijski načrt za energetsko učinkovitost 2008–2016. Ljubljana.

Vlada Republike Slovenje (2015): National Energy Efficiency Action Plan 2014-2020. (AN URE 2020). Ljubljana.

Vlada Republike Slovenje (2017): National Energy Efficiency Action Plan 2020. (AN URE 2020). Ljubljana.

Vlada Republike Slovenje (2021): Dolgoročna strategija energetske prenove stavb do leta 2050. Ljubljana.

Walker, W. E.; Harremoës, P.; Rotmans, J.; van der Sluijs, J. P.; van Asselt, M.; Janssen, P.; Krayer von Krauss, M. P. (2003): Defining Uncertainty: A Conceptual Basis for Uncertainty Management in Model-Based Decision Support. In: Integrated Assessment, 4 (1), pp. 5–17. https://doi.org/10.1076/iaij.4.1.5.16466.

Wojdyga, K.; Chorzelski, M. (2017): Chances for Polish district heating systems. In: Energy Procedia, 116, pp. 106–118. https://doi.org/10.1016/j.egypro.2017.05.059.

Zaunbrecher, B. S.; Arning, K.; Falke, T.; Ziefle, M. (2016): No pipes in my backyard? In: Energy Research & Social Science, 14, pp. 90–101. https://doi.org/10.1016/j.erss.2016.01.008.

Zech, D.; Ullrich, S.; Wülbeck, H.-F.; Stuible, A.; Wapler, J.; Valenbreder, P.; Meyer, R.; Miara, M.; Hartmann, H.; Reisinger, K.; Werner, F.; Orozaliev, J.; Vajen, K.; Schuhmann, E.; Erler, R.; Heinrich, P.; Schröder, G. (2019): Evaluation des Marktanreizprogramms zur Förderung von Maßnahmen zur Nutzung erneuerbarer Energien im Wärmemarkt im Förderzeitraum 2015 bis 2018. Available at https://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/Berichte/evaluierung-marktanreizprogramm-2018.pdf?__blob=publicationFile&v=2, accessed 16.05.2023.

Žnidarčič, S.; Arko, K.; Mahnič, T.; Cserháti, G.; Kaszap, A.; Podmaniczky, L.; Podmaniczky, B.; Berényi, A.; Vincze, A.; Dobos, B. (2014): Predhodno vrednotenje Programa razvoja podeželja za Slovenijo 2014–2020 [Preliminary evaluation of the Rural Development Program for Slovenia 2014–2020]. Available at https://skp.si/program-razvoja-podezelja-2014-2020-do-2022, accessed 16.05.2023.

A Annex: Application of the analytical framework to the selected NECPs and related evaluations

This section comprises (a) the description of the selected focus topics and the selection of most relevant PaMs and associated policy instruments; and (b) the identification of suitable ex-ante and ex-post evaluations for the selected policy instruments and a summary of the results from the application of the analytical framework to the evaluations.

A.1 Carbon and energy pricing

The topic area of carbon and energy pricing includes policy instruments such as emissions trading systems (e.g. EU ETS or nEHS in Germany), but also carbon taxes and energy taxes. These pricing systems aim to reduce GHG emissions. In most cases, these measures cover several sectors. For example, the EU ETS covers electricity generation, the industrial sector and to some extent aviation. Carbon and energy taxes in many cases cover at least road transport and the building sector. Such pricing systems provide an incentive to develop low-emission or zero-emission technologies, encourage the use of renewable energies and incentivise energy savings. While carbon and energy taxes are policy instruments on the Member State level, the EU ETS is a European instrument. Particularly energy taxes have been in place in most Member States for several decades and their original objective was to generate fiscal revenues and incentivise energy savings, rather than to reduce GHG emissions. The EU only sets minimum tax rates on fuels, and Member States are free to increase them. Furthermore, in many Member States, large parts of industry are exempt from energy taxation.

A.1.1 Scientific insights in the impact of different carbon and energy pricing approaches

The scientific literature on the effects of energy and carbon taxes is extensive. Lilliestam et al. (2021) identify three main streams of scientific literature on energy and carbon pricing in economics: distributional effects, macroeconomic effects, and environmental effects (divided by effectiveness and cost). This section focuses on the literature on environmental effects; an overview of other effects, in particular distributional effects, is provided in Annex A.1.7.

An important point of discussion in the environmental effects literature is the assessment of pricing policies not only in terms of their impact on CO_2 emissions (absolute or per capita) in the relevant region, but also whether the instrument is suitable to achieve the long-term target of carbon neutrality. For example, carbon pricing may significantly reduce emissions due to fuel switching, operational or behavioural changes, but if investments in key low-carbon technologies are not incentivised, the long-term target cannot be achieved with the instrument.

Although the literature can be considered as numerous, the comparability of studies is rarely possible. Not only qualitative studies and company surveys might be difficult to compare with empirical studies, but even within empirical studies, comparability is limited. For example, studies are available partly at the company or country level. In terms of countries, different countries may have been considered, within a country, different sectors or time periods may have been considered, or a different methodology or data sets may have been chosen. All these factors make the comparability of studies problematic.

A.1.2 Availability and scope of studies

The two literature reviews by Lilliestam et al. (2021) and Green (2021) provide a sound overview of the existing research. It is apparent that the scientific literature focuses on ex-post studies. No ex-ante studies are listed. Furthermore, studies that focus on regions or time periods with very low CO_2 prices can be considered of limited relevance, because the effect of pricing in such cases would be very limited. Lillierstam et al. and Green therefore focus on regions and periods in which prices were higher.

Both studies provide table-like reviews of the literature, with Green focusing on CO_2 emissions, whereas Lillierstam et al. also look at investments in low/zero-carbon technologies and innovations. Both reviews show a focus in the literature on the impact of the EU ETS, Scandinavian taxes, and the carbon tax in the Canadian province of British Columbia. Far less literature is available for the U.S. Emissions Trading Schemes in California or the Regional Greenhouse Gas Initiative (RGGI), for the New Zealand ETS, the Tokyo ETS or CO_2 taxes in other European countries (e.g. France, UK (Climate change Levy, Carbon price support rate)).

A.1.2.1 Key results and barriers

Most of the studies cited in the two literature reviews show little or no effect of carbon pricing on GHG emissions. E.g. Lin et al. (2011) choose a difference-in-differences approach[11] to analyse the effects of carbon taxes in Finland, the Netherlands, Norway, Denmark, and Sweden. Their period of observation is 1981-2008 and the control group is all other EU member states that did not implement major energy or carbon tax reforms during this time. Their results show a significant reduction in GHG emissions for Finland only. The result shows that the growth of per capita emissions is reduced by about 1.7% due to the tax. For the other countries, they find no significant results and interpret that these countries give large tax exemptions, especially for industry. Shmelev et al. (2018) use a time series approach to study the effect of Swedish energy and carbon taxes. Their period of observation was 1961 to 2012, and their results show that the carbon tax alone had no effect on CO_2 emissions. However, the combination of carbon and energy taxes showed significant reductions of 11% per year for transport fuels. Their conclusion was that only both taxes together were high enough during the period of observation to cause a significant effect. Andersson (2019) analyses per capita emissions in the transport sector in Sweden. He also uses a difference-in-differences approach but with a synthetic control group and looks at the period 1960-2005. He finds that per capita emissions in the transport sector in Sweden are about 6.3% (in every year) lower than in the synthetic control group. Anderson's study is thus one of the few that measures strong negative effects of carbon pricing on emissions. In particular, studies that also looked at effects on investment and technological innovation show mainly no and in a few cases very weak effects for these two fields. According to Lillierstam et al., these results suggest that carbon pricing has most likely had an effect in the area of behavioural and operational change, the use of certain fuels (fuel switch) and incentivised efficiency measures. But it has not incentivised the necessary technology transformation through low/zero-carbon investment or innovation. Moreover, there is evidence for a small advantage of carbon taxes over emissions trading schemes in terms of the effect on emissions. This may be due to better planning certainty in terms of carbon prices for industrial companies, but could also be driven by the first two EU ETS periods, where the EU ETS was not yet fully developed.

[11] A difference-in-differences approach calculates the effect of an explanatory variable on a response variable by comparing the average change over time in the response variable for the treatment group to the change over time for the control group.

The reasons for the rather disappointing results seem manifold. First, in most regions, prices in emissions trading schemes or carbon taxes have been rather low during the observation periods, which is why the necessary transformation incentive could not be created. Second, in many regions, the industrial sector has been exempt from energy and carbon taxes or generous free allocations have been provided in emissions trading schemes, which has weakened the incentive effect (see Lin et al. (2011). While residential consumers have generally not been exempted with respect to heating buildings or motor fuel use, high abatement costs may have led to rather small effects in these two sectors. Third, a majority of the studies are more than 10 years old and thus look at time periods with not only rather low prices, but also time periods in which possible investments and innovations may not yet have been translated into emission reductions by the time of the study. In addition, other barriers such as uncertainty about the future leading technology (e.g., electric vehicle vs. fuel cell), the landlord-tenant-dilemma, or uncertainties about future carbon prices and possible subsidies could have hindered investment in new technologies.

A.1.2.2 Methodological approach in the scientific literature

As mentioned above, some of the studies used qualitative methods and interviews, but the focus of the studies was on quantitative analyses. The simplest (early) studies often use price elasticities to estimate the effects of carbon pricing (e.g., Rivers et al. 2015). More recent papers (e.g., Andersson 2019) criticise these approaches, as new studies (e.g., Andersson 2019, Chad Lawley et al. 2018, Di Xiang et al. 2019, Bernard et al. 2019) have found that responses to a carbon tax are significantly higher (2.5-7 times higher) than to other price fluctuations. In the literature, the reasons for this are not always analysed. However, the most commonly cited explanation is that a tax provides certainty about the price premium and it is not assumed that it will fall in the future, but rather that it will rise. This certainty provides a stronger incentive to invest in reduction measures than price fluctuations. More recent studies use more sophisticated econometric methods, depending on the data situation and scope. For example, Shmelev et al. (2018) use a time series model to estimate the impact of the Swedish carbon tax. Other studies employ panel data models (e.g., Hájek et al. 2019) or difference-in-differences approaches. Difference-in-difference approaches must be distinguished between real control groups (e.g., Lin et al. 2011) and synthetic control groups (e.g., Andersson 2019). Which of the econometric methodologies is preferable cannot be stated in general terms and depends, in particular, on the available data.

A.1.3 German NECP

Germany's NECP (BMWi 2020a) addresses energy taxes and carbon pricing in the heating and transport sectors, but also other fiscal measures such as the vehicle tax. Energy tax and carbon pricing are addressed in dedicated clustered subsections 3.1.1.i.2. and M16. The NECP does not formulate any specific targets to be achieved by the energy taxes. Instead, the NECP focusses on the various energy tax concessions and exemptions, whilst referring the reader to an evaluation of these instruments that is taking place at the time of writing of the NECP. The introduction of carbon pricing in the heating and transport sectors through a national emission trading scheme is assessed in more detail. The NECP briefly describes the methods used to estimate the cumulative savings that result from the energy and electricity taxes currently in place and from the introduction of carbon pricing in the heating and transport sectors. Table 16 provides an overview of the key PaMs in the area of carbon and energy pricing.

The selection of two PaMs to be analysed in more detail was based on the expected energy savings by 2030 indicated in the NECP. Within the PaMs of this topic area, CO_2 pricing in the buildings and transport sectors is assumed to generate the highest savings, followed by energy and electricity taxes. Thus, these two PaMs were selected for detailed analysis.

Table 16: Key PaMs under the focus topic "Carbon and energy pricing" in the German NECP

Name of PaM	Short description	Selected for evaluation?
Carbon pricing in the heating and transport sectors	CO_2 pricing for the transport and heating sectors implemented through a national emissions trading scheme	yes
Energy and electricity tax	Tax levied on the demand for electricity and other energy, comparable to excise duty.	yes
Introduction of low-carbon passenger cars to the roads	Promotion of low carbon passenger cars through purchase premiums for electric vehicles as well as a restructuring of the vehicle tax, which should be based on the GHG emissions of the vehicles.	no

Source: own compilation, Fraunhofer ISI

A.1.3.1 Carbon pricing in the heating and transport sectors

Carbon pricing in the buildings and transport sectors is implemented through the policy instrument of a national emissions trading system (nEHS). The primary objective of the nEHS is to regulate GHG emissions of all fossil fuel uses not regulated under the EU ETS including those from road transport, buildings and small-scale industrial facilities. It aims at ensuring the achievement of the non-ETS target of the Climate Protection Programme. The nEHS was introduced in Germany in 2021 and applies to the distributors of fossil fuels such as coal, natural gas and mineral oil. These distributors must purchase allowances according to the carbon content of the fuels they sell and surrender these allowances to the regulating authority at the end of each reporting year. The nEHS is laid down in the Fuel Emissions Trading Act (BEHG) (see Table 17), and the responsible ministry is the Federal Ministry for Economic Affairs and Climate Action (BMWK). Until the end of 2025, the nEHS will operate with a fixed price that increases annually. This means that there will be no cap on emissions in these years; instead, the regulated companies can buy as many allowances as they want given the fixed price. From 2026, a price corridor will apply, and only from 2027 onwards, market-based pricing and a predefined cap might be introduced. However, the EU Commission proposal to introduce a European ETS for building and road transport from 2026 onwards would substitute the national system.

Table 17: Relevant and selected policy instruments for carbon pricing in the German heating and transport sectors

Selected PaM	Associated policy instrument(s)	Legal basis
Carbon pricing in the heating and transport sectors	National emissions trading scheme (nEHS)	Brennstoffemissionshandelsgesetz (BEHG) [Fuel Emissions Trading Act]

Source: own compilation, Fraunhofer ISI

Evaluations of the nEHS

Besides the German NECP, there are four other relevant ex-ante evaluations on the nEHS (see Table 18: Harthan et al. 2020, Kemmler et al. 2021, Bach et al. 2019) and Prognos et al. 2018).

The primary ex-ante evaluation selected for an in-depth assessment is Harthan et al. (2020). It is a report commissioned by the German Environment Agency which is mentioned in the NECP and provides savings that are achieved only through CO_2 pricing in the sectors industry, buildings and transport. The other ex-ante evaluations are less applicable, as e.g. in Kemmler et al. (2021), it is not possible to consider individual measures, whereas in Bach et al. (2019), the price path of the nEHS does not correspond to the actual planned price path. Prognos et al. (2018) is referenced in the NECP, but the report is not publicly available, making it unavailable for use in the project context. To check the robustness of the ex-ante evaluation as well as of the NECP figures, we have analysed Bach et al. (2019) because this ex-ante evaluation present expected effect of the nEHS.

The nEHS is a newly introduced policy instrument and therefore no ex-post evaluations of it are available. Therefore, the plausibility of the ex-ante evaluations with historical experience can only be checked using ex-post evaluations of comparable instruments from other countries. Here, we selected the Swedish energy and carbon taxes and its evaluation in the Swedish NECP because it is relatively up-to-date. A CO_2 tax is more advantageous as a comparable PaM than another emissions trading system covering the relevant sectors, since the fixed price foreseen in the nEHS until 2026 makes it more like a tax and less like an ETS.

Table 18: Available and selected ex-ante and ex-post evaluations for carbon pricing in the heating and transport sectors

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)*
Carbon pricing in the heating and transport sectors	**Harthan et al. (2020): Abschätzung der Treibhausgasminderungswirkung des Klimaschutzprogramms 2030 der Bundesregierung (Estimation of the greenhouse gas reduction effect of the Federal Government's Climate Protection Programme 2030)** Kemmler et al. (2021): Energiewirtschaftliche Projektionen und Folgeabschätzungen 2030/2050. Gesamtdokumentation der Szenarien (Energy industry projections and impact assessments 2030/2050. Overall documentation of the scenarios) **Bach et al. (2019): CO2-Bepreisung im Wärme- und Verkehrssektor: Diskussion von Wirkungen und alternativen Entlastungsoptionen (CO2 pricing in the heating and transport sectors: discussion of effects and alternative options)** (BMWi 2020): Integrated National Energy and Climate Plan Prognos et al. (2018):Mittel- und langfristige Weiterentwicklung des Instrumentenmixes der Energieeffizienzpolitik zur Umsetzung der	DEA (2005): Danmarks udledning af CO2 -indsatsen i perioden 1990-2001 ogomkostningerne herved, Bilagsrapport 3 (Denmark's CO2 emissions in the period 1990-2001 and their costs, Annex Report 3) **Swedish Ministry of Infrastructure (2020): Sweden's Integrated National Energy and Climate Plan**

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)*
	Energiekonzeptziele – NAPE 2.0 (Medium- and long-term further development of the instrument mix of energy efficiency policy to implement the energy concept targets - NAPE 2.0)	

The evaluations that were selected for an in-depth assessment are shown in bold font. * No ex-post evaluation for the PaM were available so that ex-post evaluations of similar PaMs in other MS were considered.
Source: own compilation, Fraunhofer ISI

Results from the ex-ante evaluation

The German Environment Agency coordinated the selected primary ex-ante evaluation on behalf of the BMU. The assessment was conducted by the Oeko-Institut, the Fraunhofer Institute for Systems and Innovation Research ISI and the Institute for Resource Efficiency and Energy Strategies. The report analyses the German Government's entire 2030 Climate Protection Programme and assesses its impact for the period from 2020 to 2035. The evaluation was not part of an organised regulatory review process, nor does it follow any specific guidelines. The assessments are quantitative and the methodologies used are described in detail in most cases. The authors model the overall effect of the Climate Protection Programme, and address individual PaMs and instruments. Interactions with other PaMs are also considered. In particular, interactions with PaMs that have an influence on the purchasing and usage costs of vehicles or heating systems are relevant in this case, as these have a direct influence on the demand for fossil fuels in the sectors covered by the nEHS. The reference scenario includes all relevant policies from before August 31st, 2018, but no relevant policies established after that date – this means that there is no carbon price in the relevant sectors in the reference scenario. The authors applied simulations using techno-economic bottom-up models, and short- and long-term price elasticities to estimate the CO_2 price effect. Data sources for these elasticities were publicly available scientific papers. The CO_2 price follows the prescribed path until 2025, is at the upper end of the corridor in 2026 and then increases in EUR 15 steps to EUR 200 until 2035.

The effect of CO_2 pricing on final energy consumption and on GHG emissions is indicated in the report. However, it should be noted that an individual measure analysis is not straightforward in this case, since other instruments in the affected sectors change the relative prices and thus only the interaction of this instrument with the CO_2 price leads to the desired reductions. In the document, therefore, only the effect that would be expected on the basis of the price elasticities and the assumed CO_2 price is attributed to the nEHS. The other emission reductions expected in the model are attributed to the supporting policies.

The results show a reduction in final energy demand in the three sectors of buildings, road transport, and industry of 143 ktoe in 2025 and 549 ktoe in 2030, corresponding to GHG emission reductions of 3,700 kt CO_2 in 2025 and 8,800 kt CO_2 in 2030 (see Table 19). Around 70% of these reductions are achieved in the transport sector, 16% in the buildings sector and 14% in the industrial sector.

Table 19: Target contributions of carbon pricing in the heating and transport sectors according to the NECP and the ex-ante evaluation 2020/21-2030

Evaluation	National targets and contributions	2021-2030	2025	2030	Reference case and year
NECP	Reduction of GHG emissions [kt CO_2]				
	Increase of RES consumption [ktoe]				
	Reduction of primary energy consumption [ktoe]				
	Reduction of final energy consumption [ktoe]	17,030	902.8	3,322.6	Reductions compared to a reference scenario without CPP
Harthan et al. (2020)	Reduction of GHG emissions [kt CO_2]		3,700	8,800	Reductions compared to a reference scenario without CPP
	Increase of RES consumption [ktoe]				
	Reduction of primary energy consumption [ktoe]				
	Reduction of final energy consumption [ktoe]		143.3*	549.3*	Reductions compared to a reference scenario without CPP
Bach et al. (2019)	Reduction of GHG emissions [kt CO_2]	83,000			Reductions compared to a reference scenario without CPP
	Increase of RES consumption [ktoe]				
	Reduction of primary energy consumption [ktoe]				
	Reduction of final energy consumption [ktoe]	31,050			

* Not including fuel consumption in the transport sector, which is not reported in Harthan et al. (2020).

Source: own compilation, Fraunhofer ISI

Overall, the reductions achieved by the CO_2 price in Harthan et al. (2020) are relatively small, which is due to the calculation method described, which tends to underestimate the effect of the CO_2 price. Only the reductions that would be achieved by the CO_2 price without supporting policies are attributed to the CO_2 price and all reductions that go beyond are attributed to the other policies. However, this estimation ignores the fact that without the CO_2 price, the supporting measures could never achieve the reductions attributed to them, but only the interaction of the various instruments would lead to these reductions. Therefore, it is not

surprising that the reductions in final energy consumption due to the carbon price reported in the NECP are about six times higher than the reductions reported in this evaluation.

Similar, albeit slightly higher, greenhouse gas reductions resulting from the nEHS can be found in the German 2021 PaM report. This is based on the Projection Report (2021) and shows the results of the three affected sectors (buildings, transport, non-ETS industry) separately. Overall, the 2021 PaM report estimates emissions reductions resulting from the nEHS in 2025 by 4,650 kt. CO2 in 2025 and 11,650 kt. CO2 in 2030.

Other effects, such as costs, cost-effectiveness or economic impact of the nEHS, are not analysed in the document at the level where attributable to individual policies such as carbon pricing.

The additional ex-ante report selected, Bach et al. (2019) was commissioned by the BMU and UBA and carried out by Deutsches Institut für Wirtschaftsforschung. The report quantitatively analyses the impact of the introduction of a nEHS, without following any specific guidelines. The evaluation method is highly detailed with elasticities and price assumptions provided. The CO2-price assumptions are higher than the prices that are implemented within the nEHS with 35EUR/t CO2 in 2020 and 180EUR/t CO2 in 2030. Dynamic, rebound and anticipatory effects were not considered. The report compares a scenario where the nEHS is implemented with a reference scenario without any additional carbon pricing. The estimated impacts are provided in comparison to the baseline quantities of 2017 and with price changes relative to 2019. The report estimates minimal and maximal final energy consumption reductions and carbon emission reductions with the short-term price elasticities used to calculate estimations of the minimal reductions and long-term price elasticities for the maximum reductions. The evaluation period is from 2020 to 2030. The report estimates that during this period, the final energy savings attributed to the nEHS are capped at 1.300 PJ with a maximum of 83 Mt CO2. Additional effects such as cost or economic impact were not considered.

The report concludes that, given the elasticities and price assumptions used, the emission reduction goals for the three sectors (heating, transport, household) in question will not be achieved by the implementation of the nEHS. The nEHS reduces emissions in the sectors but not sufficiently to achieve the sectoral goals set out in the Climate Protection Programme.

The study, however, uses CO_2-price assumptions higher than the actual nEHS CO_2-price, which means that the impact of the nEHS would probably lower using the correct prices for the assessment.

Results from the ex-post evaluation

We selected an ex-post evaluation of the Swedish energy and carbon taxes, which Sweden introduced in 1957 and 1991 respectively. The evaluation was carried out during the preparation of the NECP. It followed the minimum requirements of the guidelines from the Energy Efficiency Directive. The methodology that examines the change in final demand for fossil energy due to the taxes is described in the NECP. Other effects of the taxes are not examined or only marginally, for example, it is mentioned that double counting with other PaMs such as the "Voluntary agreement with the car industry" can occur. The counterfactual case is the application of the minimum EU energy taxes rates. The evaluation period covers seven years from 2014 to 2017, and the underlying elasticities used to calculate the counterfactual were calculated using data from 1976 to 2017 (a more detailed description of the evaluation of the Swedish CO_2 tax can be found in the NECP chapter on Swedish PaMs). Since Sweden is not comparable to Germany in many respects (population, energy sources, economy, etc.), it makes little sense to analyse the absolute reductions achieved by Swedish taxes (see Table 20) as part of a plausibility check of the evaluation of the German nEHS. For this reason, it seems more

useful to look at the underlying elasticities of demand for fossil fuels. The Swedish NECP references various sources for these elasticities, but these sources are not publicly available.[12]

Table 20: Target contributions of Swedish energy and carbon tax according to the ex-post evaluation

National targets and contributions	2014-2020	2010	2015	Reference case and year
Reduction of GHG emissions [kt CO_2]				
Increase of RES consumption [ktoe]				
Reduction of primary energy consumption [ktoe]				
Reduction of final energy consumption [ktoe]	10,224	…	1,462	Demand for fossil energy without CO_2 tax and with EU minimum energy tax rates.

Source: own compilation, Fraunhofer ISI

Comparison between the ex-ante and ex-post evaluations and with the NECP

In theory, evaluations of emissions trading systems (ETS) covering the building and transport sectors (e.g. New Zealand, California) are potentially suitable reference evaluations. However, such evaluations seem unsuitable, as the carbon price of these ETSs has remained significantly below the target fixed price of the nEHS and therefore presumably had substantially less impact on the GHG emissions of the covered sectors. Another caveat for a comparison with other ETSs is that the nEHS has no cap until 2026, so it is similar to a CO_2 tax. Therefore, it is more appropriate to use evaluations of CO_2 taxes. In this case, we can compare the elasticities of demand for fossil fuels used in the ex-ante evaluation of the nEHS with the elasticities measured in the ex-post evaluation of the CO_2 tax. However, this approach also provides drawbacks, as it is likely that technical progress, but also the policy instrument introduced together with the nEHS, change (increase) exactly these elasticities. The elasticities measured ex-post could therefore be significantly lower than the elasticities assumed ex-ante, without being fundamentally wrong and contradictive.

Our analysis showed that looking at the carbon price and analysing the effect as an isolated policy instrument is problematic, as only the interaction with complementary policies can achieve the desired reductions. The complementary policies lead to a shift in the relative prices of the available technologies in the respective sectors, which results in a lower CO_2 price being necessary to achieve the targets than in a scenario without complementary policies. Neither the complementary policies nor the CO_2 price alone could achieve such reductions, so attributing reductions to individual policy instruments is difficult and complicates plausibility checks. Especially since there are no comparable examples concerning the nEHS from the past so far. CO_2 taxes in other MS can also only be considered comparable to a limited extent, due to the

[12] Elasticities were requested from the Swedish Regeringskansliet. An answer was not available at the time of writing this report, so a more detailed analysis was not possible.

absence of complementary policies (esp. funding programmes) agreed in the 2030 climate change program.

Due to the difficulties listed above, it is not easy to provide a proper interpretation of the impacts of the nEHS on energy demand reported in the German NECP. The reductions are about six times higher than in Harthan et al. (2020). We could not fully clarify how these differences came about, because the calculation methods in the NECP are not described in enough detail. But it is very likely that it has to do with the distribution of the overall effect of the CPP among the individual PaMs. Harthan et al. (2020) only calculate the sole effect of the nEHS excluding accompanying policies, which we interpret as the lower end of the nEHS effect. The values from the NECP therefore do not seem to be implausible. Since the elasticities used to calculate the ex-post evaluation are not available, it is not possible to compare the demand elasticities underlying all calculations. Therefore, a conclusive assessment of the figures from the NECP regarding the nEHS was not possible.

A.1.3.2 Energy and electricity tax

The German state levies a tax (see Table 21) on various energy sources such as fuel oil, petrol, diesel, natural gas, LPG, CNG and electricity. It is therefore a typical energy tax as prescribed by the EU for its Member States (see Energy Taxation Directive: Council Directive 2003/96/EC). The tax should incentives energy savings and generate a source of revenue for the government. This fact might change in the future, as the EU Commission proposed an energy tax reform with tax rates based on the environmental and climate impacts of energy sources.

Germany, with the Ministry of Finance being responsible, introduced its first energy taxes in 1939 adjusting coverage and rates on a regular basis since then. The most recent amendment to the energy tax dates from June 2020. In principle, the energy and electricity tax address all sectors and energy users in Germany, with the industrial sector in particular benefiting from tax exemptions. The overall impact of the energy and electricity tax is presented below without discussion on individual sectors.

Table 21: Relevant and selected policy instruments for energy and electricity tax

Selected PaM	Associated policy instrument(s)	Legal basis
Energy and electricity tax	Energy and electricity tax	Energiesteuergesetz [Energy Tax Act]

Source: own compilation, Fraunhofer ISI

Evaluations of the energy and electricity tax

Besides the German NECP, we identified no other ex-ante estimation of the effect of the German energy and electricity tax. The lack of ex-ante estimates of the effect of the energy and electricity tax could be due to the fact that no concrete reform proposals for the period until 2030 were available for the tax when the NECPs were drawn up. In July 2021, the EU Commission's Fit-for-55 Package provided concrete reform proposals. However, no one in Germany has published ex-ante estimates based on this proposal at the time of writing this report.

For the ex-post evaluation, we used a study of the Institute for European Environmental Policy from 2013, which only provides a qualitative assessment. We could not identify any other ex-post evaluations. For an overview of the available ex-ante and ex-post studies, see Table 22.

Table 22: Available and selected ex-ante and ex-post evaluations for energy and electricity tax

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
Energy and electricity tax	**BMWi (2020): Integrated National Energy and Climate Plan**	**IEEP (2013): Evaluation of Environmental Tax Reforms: International Experiences. Annexes to Final Report**

The evaluations that were selected for an in-depth assessment are shown in bold font.

Source: own compilation, Fraunhofer ISI

Results from the ex-ante evaluation

The reader finds the approach of the selected ex-ante evaluation in the German NECP under M15. This evaluation was prepared for the NECP and is a quantitative evaluation of the energy savings induced by the German energy and electricity tax. The counterfactual is a Germany where the European minimum tax rates apply. Assumed are constant tax rates and a constant energy demand but real energy price increases and an inflation of 1.4%. Energy savings are calculated based on short-term elasticities; however, these are neither shown nor referred to. The energy statistics of the BMWK (2022) and the subsidy report of the Federal Government (BMF 2020) serve as the data basis. The estimates cover the years 2021 to 2030 and thus an observation period of 10 years. The approach seems to be in line with the requirements of the Energy Efficiency Directive. However, no further information is provided apart from this.

Table 23: Target contributions of Energy and electricity tax according to the NECP

Evaluation	National targets and contributions	2021-2030	2025	2030	Reference case and year
NECP	Reduction of GHG emissions [kt CO_2]				
	Increase of RES consumption [ktoe]				
	Reduction of primary energy consumption [ktoe]				
	Reduction of final energy consumption [ktoe]	136,969	13,851	11,510	Reductions compared to a counterfactual with minimal EU tax rates

Source: own compilation, Fraunhofer ISI

The NECP presents only final energy savings as result of the energy and electricity tax (see Table 23) while providing no information with regard to GHG emission savings, the increase in renewable energies or even the decrease in primary energy consumption. An estimation of GHG emissions could be made using emission factors, but seems hardly reliable without information on the energy mix. There is also no information on other effects, such as costs, the cost-effectiveness, or economic impact of the PaM.

Results from the ex-post evaluation

The Swiss Government commissioned the selected ex-post evaluation, which evaluates the impact of the Energy Tax Reform from 1999, it's launch year, until 2013. The evaluation assesses environmental, social, and economic impacts of the tax by evaluating numerous quantitative and

qualitative academic or governmental reports. The counterfactual is a scenario without the tax reform. We evaluate the assessment as an unstructured literature review. It is not stated what method was used to identify the relevant documents, nor is sufficient information provided about the sources that led to the evaluation's conclusions. The evaluation highlights the negative impact of tax derogations for the manufacturing industry on the mitigation of greenhouse gas emissions and the achievement of environmental goals. The highest environmental impact, according to the evaluation, is in the transport sector. However, due to increasing oil and gas prices in tandem to the tax increases, the evaluation was not able to provide an estimate of the reduction in transport fuels that result from the Energy Tax Reform alone. The assessment notes that in Germany transport fuel consumption decreased by 6.8% between 1999 and 2003, but was unable to ascertain to what extent this reduction was due to the Energy Tax Reform or to other factors.

In addition to the GHG emission reductions from the 1999 Energy Tax Reform, the study analysed other effects including job creation or impact on GDP. The study also cites Bach et al. (2019) who estimated the impact of the Energy Tax Reform on income distribution and estimated that low-income households were the most exposed to the tax reform with 1% of their income being affected, as compared to only 0.5% among the high-income households. Unemployed and pensioners were not exposed to net negative impacts as a result of the tax reform.

In addition to the assessment of ex-post sources, the IEEP study also presents findings from ex-ante sources. The study quotes Kohlhaas (2005) who expects a reduction in GHG due to the Tax Reform to be 3% by 2010 compared to the situation without the Tax Reform. With regard to economic impacts, Kohlhaas (2005) is also quoted as he states that the Tax Reform could have increased employment by 0.46% between 1999 and 2003 and GDP by 0.13% between 1999 and 2010.

Comparison between the ex-ante and ex-post evaluations and with the NECP

We consider the results of the ex-ante assessment shown here to be of limited robustness. In our view, the main weaknesses of the estimation are (i) it does not account for energy demand reductions stimulated by other policies (e.g. nEHS) , (ii) it does not analyse long-term elasticities, whichcan significantly change due to new technologies, (iii) it could not integrate the effects of EU energy tax reforms being a consequence of the proposals of the Fit-for-55 package, (iv) it does construct a baseline, in which Germany applies EU minimum tax rates and not actual historic energy tax rates in 1990 in order to estimate the contribution of the tax to the achievement of the 2030 GHG-targets. However, the application of historic tax rates is in line with the requirements of the Energy Efficiency Directive for calculating energy savings achieved by taxes. A comparison of the effect of the energy and electricity tax estimated in the NECP with figures from the PaM reports is also not possible, since the PaM reports do not include any figures for the tax as a whole, but only figures for specific reforms of the tax on energy. Comparisons with ex-post evaluations are also difficult, as no serious quantitative evaluations of the effect of the energy tax in Germany could be found.

We also consider the results of the ex-post assessment to be of limited robustness. The method of gathering and evaluating the literature was not provided and thus cannot be considered systematic and reliable. Secondly, it is not clear which sources were used for the specific statements. The assessment succeeds however in highlighting the difficulties in isolating the effects of the implementation of a new energy tax rate that are necessary to perform a valid ex-post evaluation. Indeed, since the tax increases occurred at a similar time to oil and gas price

increases, it is extremely difficult (and possibly impossible) to isolate the effects of just one factor.

Given the different nature of the ex-ante and ex-post assessments with the first being quantitative and the second qualitative, a direct comparison of the results of the studies may be misleading. Additionally, a different counterfactual scenario is used within the assessments with the EU minimum tax rates used in the ex-ante study and tax levels before the Energy Tax reform in the ex-post assessment.

A.1.4 Danish NECP

Denmark's NECP briefly addresses energy and climate taxes. The references to these taxes are scattered, with two short parts focusing explicitly on one of these taxes being the electrical heating tax (Section 3.1.2.i and 3.1.2.ii). There are not any targets associated with the taxes. The taxes are adjusted to contribute to the strategy related to the dimension Decarbonisation - Renewable Energy. The implications of carbon and energy taxes for achieving climate goals are briefly mentioned but neither discussed nor assessed empirically. With regards to energy and emission trading systems, the Danish NECP mentions no additional systems beyond the EU ETS.

The Danish NECP presents energy taxes as the instruments generating the highest savings. Consequently, we selected two PaMs to be analysed in more detail based on the expected energy savings by 2030 and on available information (see Table 24). Somewhat unstructured, these PaMs are listed in the NECP. For example, the mineral oil tax is considered separately, whereas the energy taxes on other energy sources such as gas, coal or electricity are grouped under one PaM. This approach can be explained by the fact that the mineral oil tax primarily targets transport, whereas the other energy taxes mainly cover the building sector. In addition to energy taxes, there is also a CO_2 tax and a tax on methane from natural gas fired power plants, which use as backup PaMs.

Table 24: Key PaMs under the focus topic "Carbon and energy pricing" in the Danish NECP

Name of PaM	Short description	Selected for evaluation?
Mineral-oil Tax Act	Tax levied on the demand on mineral oil products in the transport sector, comparable to excise duty.	Yes
Energy taxes	Tax levied on the demand on gas, coal and electricity, comparable to excise duty.	Yes
CO2 tax on energy products	CO2-tax levied on the demand on fossil energy.	Yes
Tax on methane from natural gas fired power plants	Methane-tax levied from natural gas fired power plants, - equivalent to the CO2 tax.	No

Source: own compilation, Fraunhofer ISI

A.1.4.1 Mineral-oil Tax Act and CO_2-tax

The Mineral-oil Tax Act (see Table 25) is a conventional excise tax in the sense of an energy tax on mineral-oil-based fuels. The tax exists in its present form (except for adjustments to the tax rates) since 1993, but mineral oil products have been taxed in Denmark since 1977. The primary

objective was not to reduce GHG emissions, but to achieve fiscal goals such as generating government revenue. In addition, the tax was also used as a control instrument. For example, the tax differentiated between diesel containing sulphur and diesel with a very low sulphur content, successfully driving sulphur-containing diesel out of the market. Leaded fuels were also pushed out of the market in this way. The responsible authority is the Danish Ministry of Finance, which states that the primary goal is not the reduction of GHG emissions, as this is what the CO_2 tax was introduced for, but other environmental and energy policy related targets.

Table 25: Relevant and selected policy instruments for Mineral-oil Tax Act and CO_2-tax

Selected PaM	Associated policy instrument(s)	Legal Basis
Mineral-oil Tax Act CO2-tax	Tax on mineral oil products CO2-tax	Mineralolieafgiftsloven [Mineral oil tax] CO2-afgiftsloven [CO2-Tax Act]

Source: own compilation, Fraunhofer ISI

Evaluations of the mineral oil tax

Although many official documents of the Danish Ministry of Energy, Utilities and Climate, such as the NECP and the Biennial Reports, denote the Mineral-oil Tax Act as an important PaM reference is only made to one quantitative ex-ante evaluation from the Danish Energy Agency from 2005 (DEA 2005). Since we could not identify any other evaluation of the Mineral-oil Tax Act in the official documents of the ministry, the selection of the ex-ante evaluation listed in Table 26 was without alternative.In addition to the ex-ante/ex-post evaluation from 2005, we could not identify any ex-post evaluation that quantitatively measures the effect of the Mineral-oil Tax Act on the consumption of mineral oil products (IEEP 2013 is a qualitative analysis). However, the selected ex-ante evaluation analyses the effect, that is to say the total tax revenue, of the Mineral-oil Tax Act in combination with the CO_2 tax.

Table 26: Available and selected ex-ante and ex-post evaluations for Mineral-oil Tax Act and CO_2 tax

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
Mineral-oil Tax Act	**Danish Energy Agency (2005): Danmarks udledning af CO2 -indsatsen i perioden 1990-2001 ogomkostningerne herved, Bilagsrapport (Denmark's CO2 emissions in the period 1990-2001 and their costs, Annex Report)** Danish Ministry of Energy, Utilities and Climate (2017): Denmark's Seventh National Communication on Climate Change Under the United Nations Framework Convention on Climate Change and the Kyoto Protocol and Denmark's Third Biennial Report Under the United Nations Framework Convention on Climate Change	**Danish Energy Agency (2005): Danmarks udledning af CO2 -indsatsen i perioden 1990-2001 ogomkostningerne herved, Bilagsrapport (Denmark's CO2 emissions in the period 1990-2001 and their costs, Annex Report)** Institute for European Environmental Policy (2013): Evaluation of Environmental Tax Reforms: International Experiences. Annexes to Final Report

The evaluations that were selected for an in-depth assessment are shown in bold font.

Source: own compilation, Fraunhofer ISI

Results from the ex-ante evaluation

The evaluation was conducted in 2005 as part of an official assessment of the Danish government's efforts to reduce GHG emissions during the period 1990-2001. The authors of the evaluation describe the quantitative methods in medium detail, but it is not clear whether they applied specific evaluation guidelines. The effect of the mineral oil and the CO_2 tax on demand for taxed petroleum products is examined, although the authors note that there may be double counting with other policies in the transport sector.

The ex-ante estimation is calculated using elasticities of demand, which the Danish Ministry of Transport provided, without referring to concrete numbers in the text and any online source. A request to the Danish Energy Agency remained unanswered. For the calculation, a constant energy demand and unchanging real prices are assumed. The demand for petroleum products without mineral oil and CO_2 tax serves as the baseline scenario. GHG emission savings are projected for the period from 2008 to 2012. Table 27 shows the annual GHG emission reductions attributed to the Mineral-Oil Tax Act and the CO_2 tax. It was calculated that approximately 1,200 $ktCO_2e$ would yearly be saved as a result of the tax. However, few other figures are provided in the document; for example, energy savings are not shown, which are key for the GHG emission reductions. Also, the absolute emissions of the taxed fuels are not shown, but only the difference of the scenario with tax and the baseline scenario, which means that no relative savings can be calculated.

Table 27: Target contributions of Mineral-oil Tax Act and CO_2 tax according to the ex-ante evaluation

Evaluation	National targets and contributions	2008-2012	2008	2012	Reference case and year
Danish Energy Agency (2005)	Reduction of GHG emissions [kt CO_2]	6,000	1,200	1,200	GHG emissions without Mineral Oil Tax Act
	Increase of RES consumption [ktoe]				
	Reduction of primary energy consumption [ktoe]				
	Reduction of final energy consumption [ktoe]				

Source: own compilation, Fraunhofer ISI

In addition, the study reports costs of about EUR 101 million for the year 2001. The costs consist of the effect of tax increases (less fuel sold, but higher tax rate), less tax revenue due to fewer cars sold (given the assumption that fewer people will buy a car if fuel becomes more expensive), and environmental costs resulting from the use of fossil fuels. The cost efficiency is given as about 775 DKK/tCO_2e. Compared to other measures in other sectors, which are also assessed in the report, the Mineral Oil Tax Act (incl. CO_2 tax) is relatively cost inefficient, but this may also be due to the fact that it targets in particular the transport sector, where abatement costs tend to be high.

Results from the ex-post evaluation

As mentioned above, the 2005 report presenting the ex-ante evaluation of the Mineral-Oil Tax Act and the CO_2 tax also includes an ex-post evaluation. This evaluation does not differ methodologically from the ex-ante assessment and refers to the year 2001 using statistical data on fuel demand and prices. The ex-ante evaluation simply extrapolates the statistical data . , which is why the ex-ante and ex-post figures do not differ with respect to GHG emissions reductions and are quantified with 1,200 $ktCO_2e$ in 2001 (see Table 28).

Table 28: Target contributions of Mineral-oil Tax Act and CO_2 tax according to the ex-post evaluation

National targets and contributions	2001			Reference case and year
Reduction of GHG emissions [kt CO_2]	1,200			GHG emissions without Mineral Oil Tax Act
Increase of RES consumption [ktoe]				
Reduction of primary energy consumption [ktoe]				
Reduction of final energy consumption [ktoe]				

Source: own compilation, Fraunhofer ISI

In terms of the cost to the government and the cost-effectiveness of the measure, the ex-post evaluation shows the same values as for the ex-ante estimation, since the approach is the same and the ex-post data were used for the ex-ante estimation.

In contrast to the results referenced in the NECP, the only scientific analysis of Danish energy and CO_2 taxes we know of by Lin et al. (2011) shows no significant effect of the taxes. In addition to the methodological difference (difference-in-difference approach used by Lin and Li and elasticity estimation in the official document), data differences may also have led to this discrepancy in results, but this could not be analysed further on the basis of the available information.

Comparison between the ex-ante and ex-post evaluations and with the NECP

In principle, the evaluation of the Mineral-oil Tax Act and the CO_2 tax was conducted using a common approach. Therefore, the ex-post evaluation seems to present reliable results, but concerns remain for the ex-ante estimation. It is surprising that there are no recent official ex-ante estimates (no quantitative estimate in the NECP), so that these relatively old figures are also found in the 2019 PaM reports. In particular, the assumption of constant demand for petroleum products seems questionable, as many additional measures have been taken to reduce energy consumption. Especially since the Member States were obliged to take action under the effort sharing regulation and the energy efficiency directive. The elasticities used could also be significantly higher today, as alternatives to individual transport and petroleum products are increasingly available in the transport sector. The concerns are therefore especially due to the age of the evaluation and the results do not seem to be reliable for today. Also, against

the background of the expected energy tax reform at the EU level as part of the Fit-for-55 package, the validity of the figures shown here appears to be very limited.

Since the Danish NECP does not specify any quantitative targets for the mineral-oil tax, we could not compare the analysed evaluation with the Danish NECP. Furthermore, a comparison with the German NECP was also not possible, since the evaluation of the Danish Mineral-oil Tax Act and CO_2 tax does not provide concrete numbers of the used elasticities. We were not able to resolve this incompatibility. Even though the calculation method of the Danish evaluation is similar to the methodological procedure for calculating the effects of the energy tax in the German NECP.

A.1.4.2 Energy taxes and CO_2-tax

In addition to the tax on mineral oil products, which is always shown separately in the NECP and 2019 PaM report, Denmark also has taxes on the other energy sources; coal, gas and electricity. These are summarised in NECP and the 2019 PaM report under G2 (former TD-1a): Energy taxes (see Table 29). These are common excise taxes, which exist in their current form since 1995. However, taxes have been levied on energy products in Denmark since 1977. While the tax on mineral oil is mainly relevant for the transport sector, the other energy taxes are mainly targeted on the building and industry sectors. The Ministry of Finance is in charge of the tax system and sets the tax rates.

Table 29: Relevant and selected policy instruments for Energy taxes and CO_2-tax

Selected PaM	Associated policy instrument(s)	Legal Basis
Energy taxes CO_2 tax	Tax on natural gas, tax on coal, tax on electricity CO_2 tax	Gasafgiftsloven, Kulafgiftsloven, Elafgiftsloven, [Gas Tax Act, Coal Tax Act, Electricity Tax Act] CO_2-afgiftsloven [CO_2 Tax Act]

Source: own compilation, Fraunhofer ISI

Evaluations of the Energy and CO_2 tax

We did not identify any further relevant quantitative evaluation for the energy taxes other than the document already examined for the Mineral-oil Tax Act, which also allows to check the effects of energy and CO_2 taxes. Therefore, this document was again used for detailed consideration in the following section (see Table 30).

Table 30: Available and selected ex-ante and ex-post evaluations for the Energy and CO_2 taxes

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
Energy taxes	**Danish Energy Agency (2005): Danmarks udledning af CO2 - indsatsen i perioden 1990-2001 ogomkostningerne herved, Bilagsrapport (Denmark's CO2 emissions in the period 1990-2001 and their costs, Annex Report)**	**Danish Energy Agency (2005): Danmarks udledning af CO2 - indsatsen i perioden 1990-2001 ogomkostningerne herved, Bilagsrapport (Denmark's CO2 emissions in the period 1990-2001 and their costs, Annex Report)** Institute for European Environmental Policy (2013):

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
		Evaluation of Environmental Tax Reforms: International Experiences. Annexes to Final Report

The evaluations that were selected for an in-depth assessment are shown in bold font.

Source: own compilation, Fraunhofer ISI

Results from the ex-ante evaluation

To calculate ex-ante the GHG emission reductions resulting from the energy and CO_2 taxes, the same methodological approach is applied as in the case of the Mineral-oil Tax Act. That is, demand elasticities (without further description) as well as energy demand and energy prices from 2001 are extrapolated for the period from 2008 to 2012. This results in an annual reduction of 1.5 (1.0) $MtCO_2e$, or a reduction of 7.5 (5.0) $MtCO_2e$ over 5 years (see Table 31). Since emissions from the use of electricity and district heating occur at the point of generation and not at the point of consumption, this viewpoint also plays a role for the energy tax. The consumption perspective considers the emissions avoided due to a reduction in consumption, regardless of the origin, i.e. emissions resulting from the generation of imported electricity, for example, are also taken into account. The generation perspective, on the other hand, does not consider these emissions, as they were not emitted domestically. In the following, we always name first the consumption perspective followed by the generation perspective in brackets.

Table 31: Target contributions of the Energy and CO_2 taxes according to the ex-ante evaluation

Evaluation	National targets and contributions	2008-2012	2008	2012	Reference case and year
Danish Energy Agency (2005)	Reduction of GHG emissions [kt CO_2]	7,500 (5,000)	1,500 (1,000)	1,500 (1,000)	GHG emissions without Energy taxes
	Increase of RES consumption [ktoe]				
	Reduction of primary energy consumption [ktoe]				
	Reduction of final energy consumption [ktoe]				

Source: own compilation, Fraunhofer ISI

Also, for the energy and CO_2 taxes, the cost-effectiveness of the measure is calculated using DKK/tCO_2e. This results in a value of 325 DKK/tCO_2e per year. This value is significantly lower than the value for the Mineral-oil Tax Act, which in turn may be related to the abatement costs and the associated different elasticities.

Results from the ex-post evaluation

The difference of the ex-post evaluation is again that statistical data for demand and energy prices were available for the year 2001. For this year, a reduction of 1.5 (1.0) $MtCO_2e$ due to the energy taxes was calculated (see Table 32).

Table 32: Target contributions of the Energy taxes according to the ex-post evaluation

National targets and contributions	2001			Reference case and year
Reduction of GHG emissions [kt CO_2]	1,500 (1,000)			GHG emissions without Energy taxes
Increase of RES consumption [ktoe]				
Reduction of primary energy consumption [ktoe]				
Reduction of final energy consumption [ktoe]				

Source: own compilation, Fraunhofer ISI

For the year 2001 onwards, , the ex-post and ex-ante values are the same, since the ex-ante calculation is an extrapolation of ex-post values . The 2019 PaM report presents the same value with respect to the energy production view, which amounts to 1,000 tCO_2e.

As in the case of the Danish mineral oil tax, we only have one scientific paper on energy taxes by (Lin et al. 2011), in which the authors find no significant effects of the tax. One possible reason is that the authors used different methodology and data.

Comparison between the ex-ante and ex-post evaluations and with the NECP

The concerns regarding the usefulness of the values are the same for energy and CO_2 taxes as for mineral oil taxes. In particular, the age of the evaluation makes a reliable estimate of the GHG emission reductions from the energy and CO_2 taxes questionable, since elasticities may have changed and energy demand and energy prices have certainly changed over the last ten years. The critical comments on the baseline scenario and the limited validity due to the upcoming EU energy tax reform also apply to energy taxes. Since the Danish NECP does not specify any quantitative targets for the energy tax, we could not compare the evaluation the Danish NECP.

A.1.5 Swedish NECP

The Swedish NECP explicitly addresses and evaluates energy and carbon taxes. A carbon tax based on the fossil content of the fuel and an energy tax on electricity, heating and motor fuel compose the tay system. The energy and carbon taxes are presented in Section 3.1.1.1 of the NECP and evaluated in a subsequent section (Section 3.2.1.1), with a third additional, more detailed section in the Annex 2. The taxes aim to contribute to the decarbonisation and energy efficiency strategies, without specifying any individual targets. The carbon and energy taxes are systematically assessed and evaluated in the NECP, with a comprehensive method using elasticities to calculate the estimated electricity and fuel (?) saved as a result of the taxes. The Swedish NECP does not mention additional energy and carbon trading schemes beyond the EU Emission Trading System.

The selection of the PaMs to be analysed in detail here, energy and CO_2 taxes, was relatively straightforward, as there are no other PaMs listed in the Swedish NECP besides these two taxes that are projected to have a significant impact on GHG emissions in Sweden (see Table 33).

Although the NECP mentions, for example, measures such as a CO_2-based vehicle tax, tax incentives for environmentally friendly vehicles, or even a tax on air travel. However, we expect these to have rather small effects.

Table 33: Key PaMs under the focus topic "Carbon and energy pricing" in the Swedish NECP

Name of PaM	Short description	Selected for evaluation?
Energy tax	Tax levied on the demand on energy sources like gas, coal or electricity, comparable to excise duty.	Yes
Carbon tax	CO2-tax levied on the demand on fossil energy sources.	Yes

Source: own compilation, Fraunhofer ISI

A.1.5.1 Energy and carbon taxes

We present the two taxes within one subchapter, since the selected evaluation examines the effects of energy and carbon taxes at once.

The Swedish state has been levying energy taxes on petroleum products since the 1920s and afterwards successively extended to other energy sources, e.g. electricity has been taxed since the 1950s. The energy tax, as it is still largely in force today, was introduced in 1957 and covers all energy sources (petroleum products, coal, natural gas and electricity), with reductions and exemptions for certain end users such as shipping, aviation, manufacturing, agriculture, forestry and aquatic industries. Since 1957, the responsible Ministry of Finance has mainly changed the level of taxation, The enforcement authority is the Swedish Tax Agency (see Table 34).

In addition to the energy tax, Sweden introduced a carbon tax in 1991, which, unlike the energy tax, only taxes the use of fossil fuels. The carbon content of the energy products determines the tax rates, which Sweden has successively increased since 1991 from the converted amount of around EUR25 to EUR120 today. Companies that are already subject to carbon pricing in the EU ETS are exempt from the tax. Tax reductions and exemptions are also in place for shipping, aviation, agriculture, forestry and aquatic industries.

Table 34: Relevant and selected policy instruments for the energy and carbon taxes

Selected PaM	Associated policy instrument(s)	Legal Basis
Energy and carbon taxes	Energy tax	lagen (1994:1776) om skatt på energi [Energy tax Act]
	Carbon tax	lagen (1994:1776) om skatt på energi [Energy tax Act]

Source: own compilation, Fraunhofer ISI

Evaluations of the energy and carbon tax

Table 35 shows available ex-ante and ex-post evaluations . Apart from the NECP and the qualitative analysis of the Institute for European Environmental Policy (2013), we could not trace any other recent evaluations that analyse the effect of the two taxes on energy demand or greenhouse gas emissions.

Table 35: Available and selected ex-ante and ex-post evaluations for the energy and carbon taxes

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
Energy and carbon taxes	**Swedish Ministry of Infrastructure (2020): Sweden's Integrated National Energy and Climate Plan**	**Swedish Ministry of Infrastructure (2020): Sweden's Integrated National Energy and Climate Plan** Institute for European Environmental Policy (2013): Evaluation of 2011 energy tax reform

The evaluations that were selected for an in-depth assessment are shown in bold font.
Source: own compilation, Fraunhofer ISI

The NECP includes ex-post and ex-ante evaluations, which comply with the minimum standards of the Energy Efficiency Directive, and describes their methodological procedure in detail, possible double counting of GHG emission reductions of different policies, especially in the transport sector, is pointed out, but not fully discussed. The baseline scenario is the Swedish economy, where the minimum energy and excise taxes (no carbon tax) set by the EU are applied. Evaluation use long- and short-term demand elasticities to calculate the effect of the two taxes on energy demand, based on a period from 1975 to 2017. However, these elasticities are not shown and the referenced sources do not show them either. A request to the competent Swedish authority remained unanswered up to the time of writing this report.

Results from the ex-ante evaluation

The ex-ante evaluation simply extrapolates the energy savings caused by the two taxes calculated for 2020 on the basis of statistical data of energy prices and energy demand to the next ten years until 2030. Thus, over the period from 2021 to 2030, the evaluation estimates total energy savings of 14.789 ktoe or annual savings of 1.479 ktoe (see Table 36) but does not show reductions in GHG emissions. Latter are difficult to calculate using emission factors without information on the energy mix. Overall, both taxes appear to be very effective, as the calculated reductions in energy demand exceed the Swedish targets. A comparison of the calculated values with other sources is not possible, as we could not research any further sources and the 2019 PaM report provides no figures on energy savings for the two taxes . At least the 2019 PaM report shows GHG emission declines that are driven by the carbon tax. Here, values of 19,000, 17,000, and 15,000 tCO_2e are given for the years 2020, 2025, and 2030, respectively. To what extent these values are related to the energy savings shown in the NECP could not be found out in more detail.

Table 36: Target contributions of the Energy tax according to the NECP and the ex-ante evaluation

Evaluation	National targets and contributions	2021-2030	2025	2030	Reference case and year
NECP	Reduction of GHG emissions [kt CO_2]				
	Increase of RES consumption [ktoe]				

Evaluation	National targets and contributions	2021-2030	2025	2030	Reference case and year
	Reduction of primary energy consumption [ktoe]				
	Reduction of final energy consumption [ktoe]	14,789	1,479	1,479	Demand for fossil energy without CO_2 tax and with EU minimum energy tax rates.

Source: own compilation, Fraunhofer ISI

Results from the ex-post evaluation

For the ex-post evaluation of the two taxes, the NECP considers the years 2014 to 2020. Compared to the ex-ante assessment, the same statistical data on energy prices and energy demand were used, but of course without the need for extrapolation. Besides this significant difference, the methodological approach is the same as for the ex-ante assessment. For the year 2015, the ex-post analysis results in slightly lower savings of 1.462 ktoe than for the year 2020. Over the entire 7-year period, savings of 10.224 ktoe were calculated (see Table 37).

Table 37: Target contributions of the Energy tax according to the ex-post evaluation

National targets and contributions	2014-2020	2010	2015	Reference case and year
Reduction of GHG emissions [kt CO_2]				
Increase of RES consumption [ktoe]				
Reduction of primary energy consumption [ktoe]				
Reduction of final energy consumption [ktoe]	10,224	…	1,462	Demand for fossil energy without CO_2 tax and with EU minimum energy tax rates.

Source: own compilation, Fraunhofer ISI

Further analysis on the two taxes is not performed in the NECP, neither ex-ante nor ex-post.

We can hardly compare the results from the scientific literature with the results from the NECPs for the following reasons: (i) the scientific studies used econometric analyses with a difference-in-differences approach, whereas the NECPs used simple estimations with elasticities, (ii) the period considered in the scientific studies (no data more recent than 2012) is significantly before the period considered in the NECPs (from 2014 onwards), (iii) in most cases the focus of the scientific studies is on specific sectors and not on the economy as a whole, and (iv) the estimates in the NECPs in particular lack background information (e.g. elasticities) to compare at least the measured coefficients from regression analyses with the assumptions behind the NECP calculations.

Comparison between the ex-ante and ex-post evaluations and with the NECP

Similar criticisms as in the evaluations of the Danish measures can also be raised for the Swedish evaluations. Although the extrapolation of energy prices and energy demand is less critical, since the base year in this case is 2020 and not 2001 as in the Danish case, doubts remain as to whether such assumptions are appropriate. Due to the fact that the tax reforms announced in the Fit-for-55 Package at the EU level are not taken into account, the validity of the ex-ante assessment does not seem very robust in the Swedish case either.

A.1.6 Overview of number of identified evaluations

Table 38: Number of evaluations per energy and carbon pricing PaM and content

MS	PaM [13]	Ex-post	GHG sh.	EE sh.	RES sh.	SEI sh.	Other share	Ex-ante	GHG sh.	EE sh.	RES sh.	SEI sh.	Other share
DE	1	0						3	67%	100%	0%	0%	0%
DE	2	1	100%	0%	0%	100%	0%	1	0%	100%	0%	0%	0%
DK	3	1	100%	0%	0%	0%	100%	1	100%	0%	0%	0%	100%
DK	4	1	100%	0%	0%	0%	100%	1	100%	0%	0%	0%	100%
SE	5	1	0%	100%	0%	0%	0%	1	0%	100%	0%	0%	0%
All		**4**	**75%**	**25%**	**0%**	**25%**	**50%**	**7**	**57%**	**71%**	**0%**	**0%**	**29%**

PaM = policy and measure, sh. = share, MS = Member State. DE = Germany, DK = Denmark, SE = Sweden, GHG = greenhouse gas emissions reductions, EE = increase of energy effciency, RES = increase of renewables share, SEI = socio-economic impacts

Source: own calculation, Fraunhofer ISI

Table 38 shows an overview of the identified evaluations under the energy and carbon pricing topic per PaM and MS. The table shows the number of identified ex-post and ex-ante evaluations and the share of evaluations reporting GHG emission reductions, energy consumption reductions, impact on renewable energy development, and socio-economic factors.

A.1.7 Conflicts and synergies of carbon and energy pricing with a just transition

Pricing on energy or on carbon emissions are instruments that fulfil the role of Pigouvian taxes. Such Pigouvian taxes aim to shift the costs from society to the polluter. From an economic point of view, such a tax is beneficial because it provides an incentive for polluters to reduce or stop their pollution. Polluters, however, usually price the additional costs into their products or services, so the real bearer of the tax is not the polluter but the end customers, who have to bear the tax through increased prices. If reduced consumption of the affected products is not an option for end customers (e.g. food) and alternative products are not available or very expensive or the polluter is the end customer (building heating/car driver), such a tax has a direct impact on the disposable income of individuals or households and thus also on welfare. In this context, it is important to ask whether certain groups of households are affected more than others, whether the tax is progressive (puts disproportionate burden on higher incomes), regressive (puts disproportionate burden on lower incomes), or proportional, and whether certain households may no longer be able to cover their living costs. It should be noted that a progressive tax generally leads to higher social acceptance, but progressivity does not preclude households at the lower end of the income distribution from being unable to cover their living expenses. The literature often cites the example of Nigeria's reform of diesel and petrol subsidies in 2012, which was highly progressive but was partially rolled back due to protests by the lowest-income households (Soile and Mu 2015, Lockwood 2015, Dorband et al. 2017). Before introducing energy and carbon taxes, policymakers should therefore be aware of the impact and possibly establish compensatory measures in parallel to reduce the burden on the most

[13] 1 = nEHS, 2 = Energy and electricity tax, 3 = Mineral oil tax and CO2 tax, 4 = Energy and CO2 tax, 5 = Energy and CO2 tax

vulnerable households. The big advantage of such taxes is that they generate income for the government, which can then be used for compensation measures.

A.1.7.1 Literature review of the potential conflicts and synergies

The literature on conflicts associated with the implementation of energy or carbon pricing is predominantly focused on the distributional effects and the impact of such instruments on different household types or income groups. In most cases, the scientific literature looks at the effect of the instrument on disposable income or the share of a household's carbon/energy tax expenditures in total household expenditures. However, data availability generally poses challenges to the scientific literature in this area because data protection regulations make it particularly difficult to obtain information on household income or information on household expenditures. The literature review by Ohlendorf et al. (2021) shows a strong concentration on U.S. regions, which may be due to data protection, since it is often easier to obtain the necessary and reliable data in the United States.

In the following, the key findings of the two meta-studies by Ramboll (2020) and Ohlendorf et al. (2021) are presented.

Evidence on Indirect Effects and Lifetime Income

The literature distinguishes between direct effects that hit households or available jobs in energy-intensive industries due to fuel price increases and indirect effects that arise from price increases of products downstream in the supply chain. Furthermore, analyses that do not only look at one point in time but perform lifetime income analyses have to be distinguished. Ohlendorf et al. (2021) find that lifetime income studies and indirect effects studies find progressivity of energy and CO_2 taxes in the majority of studies. According to (Chepeliev et al. 2021), these findings can be explained by the fact that non-food goods increase in price relatively more than food goods due to such taxes and because skilled wage premiums decrease.

Evidence on residential heating and electricity use

Ramboll's meta study (2020) finds mostly regressive results in the literature on the effect of energy and carbon taxes on residential heating and electricity use on household disposable income or expenditures. The most vulnerable groups are (i) households with persons of 60+ years or retired or unemployed, as they spend more time at home and are thus more directly affected by price increases, (ii) disabled and sick people, as they heat more and spend more time at home, (iii) women, as they also spend more time at home and in some cultures have higher barriers to participate in the labour market, (iv) households with many occupants, as they have to spend more on energy, and (v) households in rural areas, as they tend to live on larger housing surfaces. Evidence regarding the fact that low-income households in particular benefit from air quality improvement is low to nil. In general, studies find a stronger progressive effect of energy taxes in regions with higher income inequality than in regions with lower income inequality.

Evidence on fuel taxes on private means of transport

The majority of the studies reviewed in Ramboll (2020) and Ohlendorf et al. (2021) find a progressive effect of energy and CO_2 taxes on private means of transport. However, it is striking that in regions with higher GDP per capita, more studies find regressive effects. These findings may be explained by the biggest influencing factors, which are the reliance on the private car, the availability of bicycle infrastructure and public transport. In this context, (i) middle-income households are most affected, since low-income households often do not own a car and higher-

income households can rely more on alternatives (air transport, high-speed trains, etc.). (ii) In regions with little public transport, the results tend to be regressive. (iii) Large households are more affected, since the cost of a private car can be spread over several shoulders and decreases for multi-person households, whereas the cost of public transport per capita hardly decreases with household size. (iv) Employed persons are more affected than non-employed persons due to higher car use.

There is no significant evidence in the literature that fuel taxes affect employment or quality of life. Whereas, in terms of quality of life, the effect of increased air quality could be offset by the decreased mobility options.

Evidence on Energy taxes on employment, congestion charges and subsidies

The literature on the effects of energy taxes on employment is relatively small. A negative effect on households employed in energy-intensive industries is found. However, this effect disappears in a lifetime income analysis, since the number of jobs in the energy-intensive industry decreases, but at the same time, new jobs are created in the renewable energy sector.

In the field of congestion charges, the effect on the different household groups is strongly dependent on the design, e.g. whether the toll has to be paid regardless of the distance travelled (penalises short-distance drivers), which tends to lead to regressive findings.

With regard to the removal of subsidies on fossil fuels, the results predominantly show a progressive effect. This can be explained by the fact that subsidies are usually strongly driven by interest groups, most of which are representatives of higher income groups.

A.1.7.2 How the selected NECPs and the evaluated instruments address the conflicts and synergies

As mentioned above, the implementation of energy taxes, carbon pricing, or the removal of subsidies on fossil fuels may disproportionately affect certain household groups or may leave them unable to finance their daily living. Hence, it is essential that policymakers are informed about the impact of the policies and implement countermeasures when necessary.

German NECP

There is very little information on energy and electricity taxes in the German NECP. No analysis of the impact of the two taxes on vulnerable households can be found, or whether the taxes are progressive, proportional or regressive. Nor does the document mention any measures directly linked to the energy tax to reduce the burden on households. Only specific exemptions for industries are listed in Table B24, which are mainly aimed to preserve competitiveness or to avoid carbon leakage.

For the nEHS, there is also no analysis of the exact effect on private households, the most vulnerable households or whether the effect is regressive, proportional or progressive. However, in Section 3.1.1.i.2 of the NECP, which explains the nEHS, direct reference is made to Section 3.4.3.iv, which presents compensatory policy instruments. In Section 3.3.4.iv, in addition to more general instruments, the two instruments mainly attributed to the introduction of the nEHS can be found. On the one hand, electricity costs should be reduced by paying the EEG surcharge to a greater extent through the revenues of the nEHS. Secondly, the "Pendlerpauschale"[14] for employees with a working distance of more than 20 kilometres shall be

[14] Under German income tax law, the "Pendlerpauschale" (commuter allowance) reduces taxable income by the expenses incurred for traveling between the home and the first place of work.

adjusted. No impact assessment is presented in the NECP for any of these instruments. Harthan et al. (2020) present an estimate of the additional tax savings for households due to the commuter allowance. However, the number of working days, distance to work and income strongly drive the amount of reimbursement . For example, with a distance to work of 40 km, 20 working days and a marginal tax rate of 20%, one receives about 44EUR. A marginal tax rate of 40% roughly doubles the saving. Depending on the marginal tax rate, car drivers save about 5-16 cents per litre of petrol. These facts increase the attractiveness of long-distance commuting and, according to Harthan et al. (2020), lead to about 1.2 billion higher car mileage in 2025 compared to the reference scenario.

Another accompanying PaM might be the general PaM "Transfer payments", which the NECP describes it in one sentence. The PaM aims at maintaining the current benefits practice and cushion future energy cost increases, such as rising heating costs due to the introduction of a CO_2 price, through correspondingly higher subsidies for costs of accommodation and heating for recipients of transfer payments in a socially acceptable way (Prognos et al. 2020).

Danish NECP

The Danish NECP provides no analysis of the effects of energy and carbon taxes on households, the most vulnerable households, or whether the taxes have a regressive, proportional, or progressive effect.

In Section 3.4.3.iv Denmark clarifies that social policy has no focus or specific thematic field on energy. Households at risk of energy poverty are usually supported through measures that are not necessarily linked to energy prices, energy costs or the like. But the financial support is in some cases related to energy purposes. For example, vulnerable households can apply for heating supplement, special supplementary housing benefit, or additional cash support. Specifically related to energy and carbon taxes is only a so-called green check, introduced in 2010 to compensate low-income people for increased "green taxes." However, the exact design or an impact assessment is not presented in the NECP.

Swedish NECP

The effect of Swedish energy and CO_2 taxes on households, vulnerable households, or whether they have progressive, proportional, or regressive income effects is not considered in detail in the Swedish NECP. There are no measures directly linked to the two taxes which compensate undesirable social effects. Although the NECP refers to social aspects in several places (e.g. the particular vulnerability of women), the statements remain vague and do not refer directly to the taxes. Section 3.4.3.iv, which presents planned and existing policy instruments, also does not contain any specific instruments related to the taxes. In this section, similar to the German and Danish NECP, instruments to improve transparency and security of energy supply for citizens are presented.

A.2 Renewable Heating and Cooling

Overall, the decarbonisation of the heating and cooling (H&C) sector plays a crucial role in the EU's strategy towards carbon neutrality, with H&C in buildings and industry accounting for approximately 50% of the EU's energy consumption. That said, the share of RES in H&C and therefore the level of ambition varies considerably across EU Member States, meaning that Member States have set different targets in the H&C sector, which they strive to achieve with different policy instruments, measures and schedules. Policy instruments in the area of RES in H&C fall in the realm of the individual Member States, with sometimes considerable involvement

of the regional level. On EU level, the Renewable Energy Directive (RED II, 2018/2001/EU) envisages an increase in the share of RES in the H&C sector (Article 23). In addition, according to Article 24 of the RED II, Member States are obliged to increase the share of RES and waste heat in district heating and cooling (DHC) systems or enable third-party renewable or waste heat generators to access DHC networks. Besides, according to Article 14 of the Energy Efficiency Directive (EED, 2012/27/EU) Member States are obliged to conduct a comprehensive assessment on the potential of efficient cogeneration or district heating (i.e. for example a minimum share of RES) every five years with the next update due in 2025.

The topic area of renewable H&C comprises various types of instruments such as fiscal incentives or public finance (in the form of grants or loans), regulations (including e.g. minimum thresholds, obligatory standards or building codes) as well as other forms of incentives for the use of RES in the H&C sector (e.g. via strategies, action plans or the exemplary role of public entities). Measures include supporting the centralised supply of H&C with DHC networks, using cogeneration of heat and power (CHP) or incentives for the modernisation or installation of (renewable) decentralised heating systems, e.g. heat pumps, biogas, biomass or solar thermal plants. In addition to measures being either implemented in a central or decentral way, they are focused at different levels, such as household, plant or industry level, corresponding to different target groups, e.g. households/consumers, industry, small and mid-size enterprises (SMEs) etc. PaMs in this focus topic also frequently cover more than one sector, e.g. energy consumption in industries, households or public buildings or energy supply. In general, policies and measures supporting RES in H&C often overlap with energy efficiency policies. Thus, PaMs can have a direct effect by promoting RES in the H&C sector, but can also have an indirect effect on RES by increasing energy efficiency or total energy consumption in the H&C sector, or both effects (direct and indirect) may occur together. In terms of RES, solid biomass remains an important contributor to the decarbonisation of H&C, but its relative contribution is expected to decrease by 2030, while that of heat pumps and solar thermal is likely to increase in most countries (with significant differences across MS). DHC and CHP are becoming more widespread as well, however, it is important to point out that some Member States still rely heavily on fossil fuels as energy carrier for both (Toleikyte et al. 2021).

A.2.1 Scientific insights in socio-economic constraints, potential hurdles and target-group-related factors for policy instruments targeting renewable heating and cooling

Policy instruments targeting renewable H&C in the residential, commercial, industrial and public sector are embedded in a socio-economic context, meaning that the decision-making process of the relevant actors is governed by an interplay of social, environmental, regulatory, economic and cultural aspects. In general, decisions about the deployment of H&C technologies and systems are taken by a variety of individual and collective actors. Biresselioglu et al. (2020) cluster these actors into three key decision-making levels: formal social units, collective decision-making units and individual consumers (which may also act collectively by entering into joint contracts). Formal social units encompass actors with a high level of decision-making power, such as policy-makers at supra-national, national and regional/local level, regulatory authorities or H&C service providers that may exercise influence over energy choice and infrastructure decisions. In contrast, collective decision-making units such as H&C producer associations, industrial clusters, chambers of commerce or alike exercise little formal authority, but can act as crucial intermediaries between individual actors and formal social units. Finally, individual consumers are end-users of heat and cold and comprise households, companies of the industry and service sector, agricultural sites or public sector entities acting as consumers. They

may also constitute themselves in coalitions or associations with the aim of increasing their negotiation power.

In line with Breitschopf et al. (2021), the different (archetypical) actor types can be distinguished by the main motivations that they pursue. While individual actors in the residential sector generally strive to maximise their well-being and comfort level (potentially combined with altruistic motives), associations and companies tend to be rational economic actors, striving to generate profits in order to secure their continued existence. Policy-makers, authorities and communities can be assumed to pursue society's best interest. As such the public sector can take a front-runner position in setting examples installing innovative technologies.

Barriers impede the spread of renewable H&C. When it comes to those hurdles for renewable H&C instruments, these can either be of fundamental character, i.e. relating to human nature or technology-intrinsic factors, or secondary, i.e. due to anthropogenic institutions or systems, such as market design or regulation (Good et al. 2016). Another way of grouping barriers is dividing them into economic and non-economic ones, as suggested by (IEA 2018). Economic barriers include higher capital costs of renewable heat technologies for consumers, fossil heating fuels being too cheap because of not accounting for externalities, the general volatility of fossil fuel prices or the “landlord-tenant dilemma” where building owners not living in the property themselves have a low incentive to invest in renewable heat or to make energy efficiency improvements. Non-economic barriers on the other hand can be of technical (e.g. certain technologies not being feasible in certain buildings), regulatory (e.g. regulations that lead to complex procedures for plant approvals and funding permits, such as emission standards, connection obligations or spatial planning requirements), commercial (e.g. lack of supply chains for certain technologies), educational (e.g. lack of a suitably trained workforce) or informational nature (e.g. lack of heat data and statistics, such as outdated heat demand maps for planning of DHC networks). In the case of break-downs of existing appliances, consumers also tend to make expedited decisions, usually going with replacing the status quo (e.g. old oil-based boiler with new). These lock-in effects and path dependencies when having chosen / choosing a specific heating system are discussed by several authors, e.g. Zaunbrecher et al. (2016) or Sovacool et al. (2021). Due to the aforementioned effects, preferences and rationales of owners of already-built homes and owners of new builds also vary significantly. Renewable technologies can also be more space-consuming or cause disruptions, especially when being installed retrospectively. Low levels of familiarity with technologies, options for diversifying energy sources and switching to more environmentally-friendly ones as well as a general skepticism towards new technologies and innovations for example found by Sovacool et al. (2021) who look at household preferences across five European countries. Colmenar-Santos et al. (2015) conclude that with regards to DHC systems and cogeneration barriers persist across the EU with regulators not setting incentivising institutional and financial conditions for utilities to invest in DHC, and cogeneration and innovative business models being riskier and thus not sufficiently attractive for the supply side. Sayegh et al. (2017) come to a similar conclusion when looking at current trends and challenges in the heat market, underlining the importance of the right framework conditions at system level, including introducing more dynamics into the market by, for example, enabling consumers to financially participate in their local DHC network. As for the commercial and industrial sector, Cornelis (2020) concludes that small and medium-sized companies are often faced with a lack of competences and resources to implement new technologies in H&C. Larger companies often have other priorities than energy efficiency investments or may be faced with a lack of joint objectives and awareness. An important barrier is also the lack of sufficient example projects. Therefore, pilot and “lighthouse” projects may help to pave the way for further investments and animate others to follow suit.

Key enabling factors of low-carbon H&C have for instance been analysed by Galindo Fernández et al. (2016) who divide them into internal and external ones. External success factors mean the existence of an adequate policy and regulatory environment as well as (in)direct financial support mechanisms or instruments, focused local policy and coherence with urban planning as well as maturity of cooperation between all involved actors, e.g. authorities, regulators, installers, end users and energy advisors. Internal factors refer to the availability of local resources, e.g. geothermal or solar energy, a comprehensive approach to the development of low-carbon H&C projects, competitive prices, the ability to flexibly produce heat and cold and optimise supply, as well as innovation happening at all levels, i.e. technology, governance, regulation, etc. Other factors, including climatic conditions or numbers of users, have been identified as enablers but do not seem to be critical (Galindo Fernández et al. 2016). Chassein et al. (2017) group the existing types of enabling policies into command-and-control ("sticks"), incentive ("carrots") and knowledge-building ("tambourines") instruments. Command-and-control instruments are usually obligations put on new or existing building owners, heat/cold generators or end consumers, e.g. the ban of oil-based heating appliances. Incentive instruments on the other hand increase financial attractiveness of PaMs and are offered in the form of direct investment support, operating support, loans, or tax reductions. Knowledge-building instruments may take diverse forms such as informational campaigns, the (compulsory or voluntary) consultation of energy advisors or trainings for installers. Educational offers, e.g. courses, webinars, and trainings, for change agents such as installers, architects, planners etc. as well as qualification requirements and measures to ensure the availability of qualified personnel are of key importance as well.

Depending on the H&C technology in focus, different drivers may play a more or less pronounced role and decisions vary in complexity, e.g. long-term planning security for investors is more important when it comes to investing in DHC, but is less crucial for the deployment of decentral heat pumps or renewable heating system where at the side of final consumers basic energy literacy and understanding of the underlying technologies seem to be a significant issue (Breitschopf et al. 2021). As for the household level, there is a rich literature examining drivers for energy decisions, including factors of an institutional nature, individual preferences, values, societal norms, etc. and how they interact with one another. Many authors examine demographic aspects, environmental or economic concerns as well as behavioural aspects. Mahapatra et al. (2009) show that for homeowners the combination of investment subsidies and targeted marketing campaigns can have a high success rate in adopting renewable heating systems. Krikser et al. (2020) look at willingness-to-pay for German renters and home owners alike, focusing on district heating, and show that there are different consumer clusters. The largest cluster (more than 50%) has a strong preference for a local supplier, while not being very price-sensitive. The second largest consumer segment on the contrary is highly price-sensitive, and attaches less value to sustainability concerns and local supply. The third cluster is mainly driven by environmental concerns, shows insensitivity to price and does not have a pronounced preference for a local supplier. Zaunbrecher et al. (2016) also look at Germany and find that the source of energy is the most important factor influencing home owners' decisions, followed by network design considerations and security of supply (for DHC). If, however, prices reach a certain threshold these preferences change dramatically. They also conclude that the choice of one source of energy over another is highly country-specific as countries exhibit different availability, price structures and, connected to that, acceptance patterns.

Overall, one can group decision-making factors into factors at the macro, meso and micro level where the macro level relates to overarching contextual factors that do not necessarily have to relate to energy, e.g. societal norms, education, access to information, etc. (Breitschopf et al.

2021). The micro level groups individual aspects and preferences, such as habits, values, altruistic orientation. The meso level is in between and relates to factors concerning the energy system or energy-behaviour-related factors of the actor group in focus. Generally speaking, the factors governing decisions tend to be more complex when it comes to the deployment or fostering of larger systems, such as DHC, where institutional settings, market power and regulation come into play. Therefore, institutional frameworks that ensure transparency and long-term stability to underpin investment decisions are of key importance. Instruments that also finance early-stage feasibility studies in an integrated way may help to overcome inertia. In addition, coordination policies and actions across sectors and levels as well as willingness of actors to cooperate with one another are crucial as well.

In summary, three important factors for policy instruments addressing renewable H&C that stand out as relevant across all sectors are 1) the necessity of instruments signalling long-term commitment and planning/investment security (especially crucial for large-scale investments in DHC that have a longer pay-off period), 2) knowledge comprising basic energy literacy of users, technical/managerial experience and qualifications of intermediaries, and availability and easy accessibility of target-group adapted information, e.g. via intermediaries, 3) systemic approaches that foster inter-sectorial cooperation of actors (when it comes to DHC network roll-out it is, for example, crucial to factor in the preferences and views of users already in the planning process to ensure a better up-take)(Breitschopf et al. 2021).

A.2.2 German NECP

The focus topic renewable H&C is addressed in several sections of the German NECP, each time under the subsection "Renewable Energies" as part of the dimension "Decarbonisation". National targets are presented in Section 2.1.2 and policy measures are addressed in Section 3.1.2. Therefore, information on the focus topic is more or less clustered. The indicative sectoral trajectory for H&C is 14% in 2020, 20.5% in 2025 and 27% in 2030 (see Table 4 in Section 2.1.2). Strategies like the Long-Term Renovation Strategy or the national Energy Efficiency Strategy have an impact on renewable H&C, even though their main focus lies on energy efficiency. There are several measures in the NECP addressing RES in H&C. They are divided into incentives for encouraging the continued dissemination of RES-based heating technologies in buildings and the switch to increasingly decarbonised district heating networks. Key policy instruments in the building sector for renewable H&C are the New Buildings Energy Act and the new Federal funding for efficient buildings. Besides, a key policy measure for district heating is the federal funding programme for efficient district heating networks, called Heating Network Systems 4.0. Another key instrument is the Market Incentive Programme (MAP) supporting generation of heat from RES. The key PaMs for renewable H&C are listed in Table 39.

The two PaMs selected for a more detailed analysis in the context of this project were chosen based on their large relative contribution to GHG emissions reductions, but also due to their innovative character and the availability of evaluations. While the projected emissions reduction potential of the Heat Network Systems 4.0 programme is comparatively smaller than the emissions reduction of the CHP Act (KWK-Förderung), we decided to select it due to its importance for fourth-generation DHC networks. The Renewable Energies Heat Act (EEWärmG) PaM was also excluded from the selection due to large overlaps of the instrument with the energy efficiency focus topic.

Table 39: Key PaMs under the focus topic "Renewable Heating and Cooling" in the German NECP

Name of PaM	Short description	Selected for evaluation?
Market incentive programme for renewable energies in the heating market	Grants for efficient heat pumps, biomass and solar heating installations	yes
Heating Network Systems 4.0 Programme	Support scheme for lowEx district heating systems	yes
Federal funding for efficient buildings	Federal funding for efficient buildings including investment grants as well as an oil heating system replacement bonus	no
Renewable Energies Heat Act (EEWärmG)	Governs the use of renewable energy sources for heating in new buildings	no
Combined Heat and Power Act	Feed-in premium for combined-heat-and-power (CHP) electricity generation paid on top of the electricity price to increase overall fuel-efficiency	no

Source: own compilation, Fraunhofer ISI

A.2.2.1 Market Incentive Programme (MAP)

The MAP aims to strengthen the market penetration of renewable H&C technologies, selected heat storage systems and small, local district heating networks (residential and non-residential buildings). It was introduced under the Act on the Promotion of Renewable Energies in the Heating Sector (EEWärmeG) (see §§ 13-15 EEWärmeG) in September 2019. The MAP provides financial support, which consists of two parts administrated by the Federal Office for Economic Affairs and Export Control (BAFA) and the Credit Institute for Reconstruction (KfW) respectively. The BAFA funding focuses on investment grants for mainly smaller systems with capacity up to 100 kW in the field of solar thermal, biomass and heat pumps. The KfW funding, on the other hand, provides larger systems with investment subsidies for pro-rata repayment of low-interest loans in the field of solar collector systems, biomass systems, specifically efficient heat pumps, biogas pipelines, deep geothermal systems, local district heating networks and large heat storage systems for renewable heat. With regards to target groups, the MAP addresses a variety of stakeholders in both the residential and non-residential sectors, including households, companies, municipalities, municipal regional authorities and municipal special-purpose associations, members of the liberal professions, non-for-profit organisations and cooperatives. Since there is no distinction made between different income levels, it cannot be excluded that economically better off building owners are proportionally overcompensated leading to potentially unwanted distributional effects (Engelmann et al. 2021).

The MAP also shows a high complementarity and interrelationships with other instruments mentioned in the NECP, particularly in the building sector, including tax incentives for energy-related building renovations or the funding of serial renovation work. Even though complementarities between instruments are not explicitly mentioned, the following can be considered important accompanying instruments: energy consultations, offered for different stakeholder groups in both the residential and non-residential sectors and specific promotional

strategies aiming to address knowledge and awareness gaps in the commercial and industrial sectors.

As one of the national key PaMs for the expansion of renewable heat, the MAP was selected for further analysis due to its significant projected annual contribution to GHG emission reductions according to the 2021 PaM report for the year 2030 and 2035 of 12,400 kt CO_2 and 17,690 kt CO_2 respectively, see BMUV et al. (2021). Moreover, as of January 2021, the MAP has been transformed and included in the Federal Funding for Efficient Buildings Programme (BEG), the current central policy instrument for renewable heat in the building sector. Therefore, the MAP is considered a relevant policy instrument. Table 40 below shows an overview of the selected policy instrument and its legal basis.

Table 40: Relevant and selected policy instruments for the Market Incentive Programme

PaM	Associated policy instrument(s)	Legal basis
Market incentive programme for renewable energies in the heating market (both BAFA part and KfW part)	Market incentive programme for renewable energies in the heating market (both BAFA part and KfW part)	Act on the Promotion of Renewable Energies in the Heating Sector (§§ 13-15 EEWärmeG)

Source: own compilation, Fraunhofer ISI

As the MAP has been implemented for around 20 years, there are several ex-ante and ex-post evaluations available for this instrument besides the German NECP and PaM reports. They were commissioned by the Federal Ministry for Economic Affairs and Energy (BMWi)[15] as regular impact assessment. These assessments are the National Energy Efficiency Action Plan (NEEAP) for Germany (BMWi 2011; BMWi 2014; BMWi 2017), the evaluations from Langniß et al. (2010) as well as the evaluation from Zech et al. (2019). Table 41 provides an overview of the available ex-ante and ex-post evaluations for the MAP and the selected evaluations.

For the ex-ante evaluation, the 3rd NEEAP of Germany (BMWi 2014) was chosen for the analysis. The NEEAP analyses are not specified as a background document for the German NECP, however they are commissioned by BMWi and therefore considered as official documents. Although the selected 3rd NEEAP is not the most recent document, it is the most comprehensive quantitative ex-ante evaluation of this policy instrument with a high level of detail on methodology and results.

As for the ex-post evaluation, the latest analysis (Zech et al. 2019) was selected. This is a background document referred to in the German NECP under the measure "Energy efficiency in the economy – subsidy and credit" and the measure "Federal subsidy for efficient buildings". Moreover, the selected assessment provides a comprehensive evaluation for this exact policy instrument.

Table 41: Available and selected ex-ante and ex-post evaluations for the Market Incentive Programme

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
Market incentive programme for renewable energies in the heating market	BMWi (2011): 2nd National Energy Efficiency Action Plan	Langniß et al. (2010): Evaluation of the Market Incentive Programme supporting Measures

[15] Formerly called Federal Ministry of Economics and Technology.

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
	(NEEAP) of the Federal Republic of Germany. **BMWi (2014): 3rd National Energy Efficiency Action Plan (NEEAP) of the Federal Republic of Germany.** BMWi (2017): 4th National Energy Efficiency Action Plan (NEEAP) of the Federal Republic of Germany.	for the Use of Renewable Heat in the Funding Period 2009 until 2011 [Evaluation des Marktanreizprogramms zur Förderung von Maßnahmen zur Nutzung erneuerbarer Energien im Wärmemarkt im Förderzeitraum 2009 bis 2011.]. **Zech et al. (2019): Evaluation of the Market Incentive Programme for the Supporting Measures for the Use of Renewable Heat in the Funding Period 2015 until 2018 [Evaluation des Marktanreizprogramms zur Förderung von Maßnahmen zur Nutzung erneuerbarer Energien im Wärmemarkt im Förderzeitraum 2015 bis 2018.].**

The evaluations that were selected for an in-depth assessment are shown in bold font.
Source: own compilation, Fraunhofer ISI

Results from the ex-ante evaluation

As mentioned above, the selected ex-ante evaluation (BMWi (2014)) was commissioned by the national authority BMWi and followed the guidelines outlined in the EED. It provides a quantitative assessment along with a detailed description of the methodology. Methodologically, the evaluation combines a top-down and bottom-up approach of estimating and calculating energy savings. While the top-down approach allows for analysing a sector or area as a whole, the bottom-up approach can zoom in on individual measures or instruments. Using the bottom-up approach, the findings of an individual standardised case are extrapolated to the entirety of cases according to programme statistics. The same type of assessment has been conducted several times and the resulting evaluations were published individually for different observation periods. By means of extrapolation based on historic development data from 1995 to 2008 from the Federal Statistical Office (DESTATIS) as well as statistical data from AG Energiebilanzen e.V., the impacts on energy saving caused by the BAFA funding and the KfW funding have been assessed separately. Due to the replacement of low efficient generation plants with theoretically 100% efficient renewable generation facilities, the BAFA funding was estimated to lead to a primary energy saving of 1,815 ktoe and a final energy saving of 1,720 ktoe from 2009 to 2020. Assumptions on GDP development (lower than projected) and price development for EUA emissions certificates (2008: 22 EUR/tonne, 2020: 18.6–23.3 EUR/tonne) were made for the evaluation, which corresponded to the estimated reduction in final energy consumption of 220.7 Mtoe in 2008 to 194.3 Mtoe in 2020. Since the statistical data from AG Energiebilanzen e. V. suggest that primary energy consumption in trade, commerce and services increased over the observation period, no energy savings were assumed for the KfW part of the MAP. Besides the data source from DESTATIS, the assessment was based on further information from the literature and expert support from Prognos and Fraunhofer ISI. Moreover, national authorities were involved as stakeholders through written statements.

Based on the quantitative evaluation of primary and final energy savings, the BAFA funding was considered relevant for energy savings. From 2009 to 2013, its contribution to primary energy savings was estimated to be 1,218 ktoe and the contribution to final energy saving was estimated to be 1,146 ktoe, while from 2014 to 2020 the primary and final energy saving were predicted to be 597 ktoe and 573 ktoe respectively. On the contrary, the KfW funding was considered not relevant, since no energy saving contribution was predicted during the observation period through this programme. However, no interaction effects were considered in the evaluation and the impact of the instrument could thus be under- or overestimated. Besides, the same primary energy factor was applied throughout the evaluation period, which also influences the estimated impacts.

Since no energy savings contributions are attributed to the KfW funding based on the ex-ante evaluation, the estimated target contributions of the MAP result all from the BAFA funding, which are summarised in the Table 42 below.

Table 42: Target contributions of the Market Incentive Programme according to the ex-ante evaluation

National targets and contributions	2009-2020	2025	2030	Reference case and year
Reduction of GHG emissions [kt CO_2]	n/a	n/a	n/a	n/a
Increase of RES consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of primary energy consumption [ktoe]*	1,815	n/a	n/a	Projection based on historical development from 1995 to 2008
Reduction of final energy consumption [ktoe]*	1,720	n/a	n/a	Projection based on historical development from 1995 to 2008

* Aggregated values including BAFA funding and KfW funding. Values are converted from PJ.

Source: own compilation, Fraunhofer ISI

The selected ex-ante evaluation focuses on the impact assessment of energy savings. Other aspects (such as effectiveness of energy savings, expansion of renewables, GHG emission reduction, competitiveness and innovation) are not covered in the evaluation. Neither do the other available ex-ante evaluations (NEEAP) analyse other aspects except for energy savings, as they all follow the same reporting structure and guidelines. Nevertheless, some of these aspects, especially expansion of renewables, are important for the evaluation of the instruments in the RES in H&C sector.

Results from the ex-post evaluation

The ex-post evaluation from Zech et al. (2019) as also commissioned by the Federal Ministry for Economic Affairs and Energy as part of a regular impact assessment, which followed the guidelines under the Federal Budget Code (§ 7 BHO). The evaluation was conducted quantitatively and qualitatively along with a high detail description about the method applied. In essence, the evaluation is split in three analytical parts, evaluating the MAP's degree of target achievement, its effects and its economic efficiency. Targets and indicators are defined for each

of the three areas. The BAFA promotion statistics, the KfW promotion statistics and the UBA GHG emission reduction factors were used as data sources. The impact of the MAP for the observation period from 2015 to 2018 was assessed by comparison with the development of a reference conventional energy system. The leverage effect of the MAP together with the Renewable Energy Act (EEG) was considered for biogas plants. Moreover, constant economic conditions were assumed for the calculation of specific costs of heat. The national authority (BMWi) was involved in the evaluation through a written statement. The findings of the evaluation display that the annual target for the expansion of the renewable H&C supply of 146 ktoe was achieved by around 70% through the MAP in 2018 (expansion of 102 ktoe). In general, the evaluation concludes that the MAP performed well in the observation period by analysing four targets with respective indicators listed below:

- achievement of RES H&C expansion target,
- improvement of technology standard and innovation: qualitatively evaluated through increasing quality and performance of the plants and facilities,
- improvement of competitiveness: through decreasing specific heat production costs and a more diverse market structure, and
- establishment of a sustainable energy supply system: through energy savings, GHG emissions reduction and reduction of energy import dependency.

According to the evaluation, the final energy supplied by 713 MW newly installed BAFA-funded plants summed up to approximately 79 ktoe in 2018 (around 22% lower than in 2017). By applying the emission reduction factor from an UBA publication in 2014 (Memmler et al. 2014), these plants were estimated to contribute avoided emissions of 235 kt CO_2eq per year, which is lower than in the funding year 2017 (by approximately 25%). Most of the avoidance of GHG emissions from BAFA-funded plants is attributable to biomass plants. As for KfW-funded plants, 79 MW were installed in 2018 and the final energy supplied by these plants summed up to approximately 23 ktoe. The contribution of these plants was estimated to an avoided CO_2eq emission of 68°ktCO_2eq per year . As a result, RES in H&C reached around 102 ktoe in 2018 and achieved around 70% of the target, which aimed to reach a share of 14% for RES in the H&C sector by 2020. Therefore, the instrument was considered effective in terms of expansion of renewables. Regarding GHG emissions, a reduction of 303°ktCO_2eq in 2018 was estimated for the whole MAP. Corresponding declines (in comparison to 2017) in the subsidy effects were reflected in avoided GHG emissions (decrease approximately 23%). Nevertheless, the MAP was considered an effective instrument for GHG emission reduction.

As for energy savings, the bottom-up approach in the EED was applied for the calculation, especially for final energy savings. Additionally, for primary energy savings, energy-source-specific primary energy factors were assumed for the calculation. As a result, the BAFA funding was subjected to the primary energy savings of 22 ktoe and final energy savings of 26 ktoe in 2018, while the KfW funding contributed negatively (-0.086 ktoe and -0.172 ktoe respectively). The negative contributions to energy savings from the KfW funding were caused by the additional energy consumption due to the expansion of biogas CHP connected to the heating network. The MAP (both the BAFA and KfW instruments) was considered to be effective in terms of energy savings. It is to be noted that the evaluation of the effectiveness of energy savings was concluded, under the assumption that the instrument was implemented in a cost-effective way.

The aggregated target contributions of the MAP are summarised in Table 43 below.

Table 43: Target contributions of the Market Incentive Programme according to the ex-post evaluation

National targets and contributions	2018	2010	2015	Reference case and year
Reduction of GHG emissions [kt CO_2]	303	n/a	n/a	Comparison with conventional energy system
Increase of RES consumption [ktoe]*	102	n/a	n/a	Compared to 2017
Reduction of primary energy consumption [ktoe]*	22	n/a	n/a	Primary energy savings of a conventional energy system estimated with primary energy factors for non-renewable energy
Reduction of final energy consumption [ktoe]*	26	n/a	n/a	Comparison with conventional energy system (gross accounting)

* Aggregated values including BAFA funding and KfW funding; Values are converted from GWh

Source: own compilation, Fraunhofer ISI

The evaluation reveals that an investment amount of 2,486.2 million EUR was triggered by the BAFA funding during the observation period from 2016 to 2018 for renewable heating installations, of which 733.6 million EUR were invested in 2018. The KfW funding also triggered investments in renewable heating installations as well as heating networks, which summed up to 619.4 million EUR from 2016 to 2018 (167.6 million EUR in 2018). A cost-effectiveness analysis for GHG emission reductions was also conducted in the selected ex-post evaluation without considering ancillary effects. The cost efficiency of the MAP instrument reached 37 EUR/tonne CO_2-equivalent (CO_2eq) in 2018, whose value had raised in comparison to the previous years (2014: 13.4 EUR/tonne; 2015: 22 EUR/tonne; 2016: 28 EUR/tonne; 2017: 33 EUR/tonne). This indicates a decrease in efficiency of the policy instrument. This development was caused by the increased rate of support after the amendment of the MAP in 2015 and the additional funding granted through the Energy Efficiency Incentive Programme introduced in 2016. As a result, plants received higher amounts of support on average. Therefore, fewer plants benefited from the policy instruments, which further leads to less GHG emission reduction. As mentioned previously, the GHG emission reductions were estimated based on the emission reduction factor from an UBA publication in 2014 (Memmler et al. 2014). At the time this evaluation was conducted, a more recent update on the same series of publications (Memmler et al. 2018) was available. The credibility of the analysis depends strongly on the accuracy of these estimations. However, no background information was provided for the selection of the 2014 publication.

Lastly, the impact of the instrument on competitiveness was assessed by evaluating the specific heat production costs and the diversity of market structure. According to the selected ex-post evaluation, the specific heat production costs were reduced and the supplier market for heat pumps and biomass boilers are diversified with multiple manufacturers. The target of improving competitiveness is considered partially to completely achieved. As for the effects on innovation, the MAP's goal of increasing the quality and performance of systems in the reporting period was considered achieved. This results from the prerequisite for funding of applying new standards after the amendment of the MAP in 2015 and the introduction of the Energy Efficiency Incentive Programme, which creates incentives for innovative developments. In addition, the promotion of innovation is becoming more and more important in 2018, i.e. innovative technologies were increasingly supported in the framework of the programme.

Comparison between the ex-ante and the ex-post evaluation and with the NECP

In general, the selected ex-post and ex-ante evaluations can be compared to a limited extent, as the ex-ante analysis focused on the impact on energy savings only with other impacts not being considered.

By comparing to the primary and final energy saving contributions (2018: 22 ktoe and 26 ktoe respectively) analysed in the ex-post evaluation, the selected ex-ante evaluation seems to have overestimated the impact of the MAP on energy savings with the average annual energy savings of 71.65 ktoe during 2014 and 2020. This could result from the decreasing cost efficiency and the amendment of the MAP in 2015, which the ex-ante evaluation did not consider. Since the ex-ante evaluation focused on the impact on energy savings, no further plausibility analysis can be made for the other target contributions. Nevertheless, such ex-ante assessment is still considered valuable for assessing the impact of comparable policy instruments in the short-term, using assumptions based on historical and predictable developments. For the long-term impact assessment, it is considered not suitable, since it is difficult to estimate the long-term development of key assumptions.

As the background document of the German NECP, the ex-post evaluation has clearly stated the method and data sources, hence it is easily possible to assess the plausibility. The evaluation reflects multiple aspects of the instrument and raises few to no concerns regarding the results. The contribution on GHG emissions reduction was estimated based on emission factors drawn from the publication Memmler et al. (2014), which could be not up to date. This would challenge the accuracy of the analysis conducted based on these estimations. Reductions of GHG emissions were also projected in the PaM reports, which are much higher than the ex-post evaluation and hardly comparable due to the different methods applied. The projections from PaM reports considered only the direct emissions reduction from replacing fossil fuels, while the ex-post evaluation estimated the GHG emissions reduction technology-specifically. Although this evaluation was made based on certain estimations, such an ex-post assessment is useful to keep track of the different impacts caused by the policy instrument, and its effectiveness.

Due to the programme's continuity, ongoing amendments and its recent (2021) integration into the BEG, the MAP has been offering relative planning and investment stability to applicants. Although the programme has gained in attractiveness due to increased support rates, it is still not as widely known amongst potential applicants, most notably house and building owners. No concrete information measures are mentioned in the NECP and according to a position paper of the German Renewable Energy Federation (BEE) the lack of information measures led to the fact that the MAP was not sufficiently known among potential customers, dampening demand (BEE 2016). Also, the high degree of complexity of the provisions and application processes represented a hurdle and would need streamlining to reach more beneficiaries (Engelmann et al. 2021).

A.2.2.2 Heating Network Systems 4.0

The PaM Heating Network Systems 4.0 provides financial support for low-temperature district heating grids with a high share of RES. Funding is initially provided for feasibility studies with up to 60% of the eligible expenditure and a maximum funding amount of 600,000 EUR (Module I). In a further module, the implementation of a district heating network system 4.016 can be subsidised with up to 50% of the eligible expenditures in the investment project (Module II). In

[16] District heating network system 4.0 refers to 4th generation district heating networks with a clear definition in the funding announcements.

addition, measures for customer information in the area of the planned district heating networks 4.0 to increase the connection rate can be supported through a grant of up to 80% of the eligible costs and up to a maximum amount of 200,000 EUR (Module III). Expenditures by higher education institutions, research and science institutions incurred in the context of a non-economic activity in cooperation with an applicant in Module II may be funded up to a maximum grant amount of 1 million EUR (Module IV). The PaM seeks to address one of the central hurdles to the build-up of low-temperature district heating networks, which is a lack of investment security especially for smaller providers that are often deterred by large investment costs and uncertain revenues (see Annex A.2.1for more information on socio-economic constraints). The NECP also mentions accompanying instruments, supporting the transformation to a low-carbon heat supply, most notably the stakeholder dialogue "Heating networks in the context of the heating transition". Other PaMs can also be regarded as related, e.g. the CHP Act.

The support scheme Heating Networks 4.0 is a key PaM for expansion of renewable heat with a significant projected GHG emissions reduction contribution, amounting to 1,600 and 1,900 in 2030 and 2035 kt CO2eq per base year respectively according to the 2021 PaM report, and 1,001 and 1,507 kt CO2eq per base year respectively according to the 2019 PaM report. Long-term investments in low-temperature district heating networks are needed and the PaM provides a systemic framework for these investments, supporting both the planning as well as the realisation phase but also the outreach strategy and activation of all stakeholders. Module I and Module II are the parts most important for the objective to increase the share of low-temperature district heating networks with a high share of renewables. Besides, both modules were evaluated together in the available ex-ante evaluation. Therefore, Module I and Module II were selected as relevant policy instruments (see Table 44).

Table 44: Relevant and selected policy instruments for Heating Networks 4.0

PaM	Associated policy instrument(s)	Legal basis
Heating Network Systems 4.0	Module I - Feasibility study	Förderbekanntmachung zu den Modellvorhaben Wärmenetzsysteme 4.0 (BAnz AT 24.12.2019 B1)
Heating Network Systems 4.0	Module II - Realisation	Förderbekanntmachung zu den Modellvorhaben Wärmenetzsysteme 4.0 (BAnz AT 24.12.2019 B1)

Source: own compilation, Fraunhofer ISI

Table 45 lists all identified relevant evaluations, which we were able to identify during our earch for ex-ante and ex-post evaluations. These are the following documents: Pehnt et al. (2017), Harthan et al. (2020) and BEIS (2018a).

Pehnt et al. (2017) is an ex-ante evaluation conducted on behalf of the BMWi. Harthan et al. (2020) provides an estimate of the GHG emission reduction of the Climate Protection Programme 2030, which includes the continuation and extension of the PaM Heating Network Systems 4.0. However, as this estimate contains less information, we chose the ex-ante analysis from Pehnt et al. (2017) for further investigation. The selected study evaluates the PaM as originally proposed disregarding the 2019 amendment.

Besides, there has been no ex-post evaluation for the PaM published so far, as it is a rather young instrument (introduced in June 2017). Therefore, an ex-post evaluation of a similar PaM in the UK was selected. The document from the Department for Business, Energy & Industrial Strategy (BEIS) 2018 is an ex-post evaluation of the Heat Networks Investment Project (HNIP). The HNIP

provides support for new district heating networks in England or Wales, or expands existing district heating networks. HNIP has two stages: (1) Pilot: which was launched in October 2016 and announced funding recipients in April 2017. This offered grants and loans to local authorities and the wider public sector. (2) Main scheme: which will offer grants and loans to local authorities, public bodies, and private and third sector organisations. This part provided funding from April 2019 for up to three years. Therefore, the HNIP is similar to the PaM in focus, which justifies the selection of the evaluation.

Table 45: Available and selected ex-ante and ex-post evaluations for Heating Networks 4.0

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)*
Heating Networks 4.0	**Pehnt et al. (2017): Wärmenetzsysteme 4.0. Kurzstudie zur Umsetzung der Maßnahme „Modellvorhaben erneuerbare Energien in hocheffizienten Niedertemperaturwärmenetzen“. [Heating Networks 4.0. Short Study of the Implementation of the Measure "Pilot Programme Renewable Energies in Low-Temperature Heating Networks"].** Harthan et al. (2020): Abschätzung der Treibhausgasminderungswirkung des Klimaschutzprogramms 2030 der Bundesregierung Estimation of the greenhouse gas reduction effect of the Federal Government's Climate Protection Programme 2030	**UK: Department for Business, Energy & Industrial Strategy (2018b): Heat Networks Investment Project Evaluation.**

The evaluations that were selected for an in-depth assessment are shown in bold font. * No ex-post evaluation for the PaM were available so that ex-post evaluations of similar PaMs in other MS were considered.
Source: own compilation, Fraunhofer ISI

Results from the ex-ante evaluation

The selected ex-ante evaluation was conducted by several institutions (adelphi, Ecofy, PwC, Agentur für Erneuerbare Energie, dena and ifeu) with data from 2009-2017 and published in 2017. The evaluation was not part of an organised regulatory review process, nor does it follow any specific guidelines.

In the study, minimum technical requirements for fundable district heating grids and a detailed design for the PaM are defined. Besides, the impact of the PaM is discussed. Moreover, the evaluation presents estimation of funding activities, CO_2 savings and funding volume with case studies (65 district heating networks), expert interviews (30), workshops (2), desk research, economic calculations and analysis of existing support measures. References are other PaMs, namely the Market Incentive Programme and the CHP law as well as a few support programmes on regional level. The assessments are quantitative and qualitative and the authors describe their methodologies in a medium degree of detail (i.e. several paragraphs to one page).

The estimations are divided into three scenarios, representing different demands of the funding programme. Scenario 1 is based on the following assumptions: 50 new construction networks of different sizes and structures, 60 subsidised plans for new networks, 15 large-scale optimisation measures for existing networks and 120 feasibility studies. In Scenario 1, the total amount of funding distributed reaches 482 million EUR, leading to an annual reduction of GHG emissions of 215 kt CO_2 and a total reduction until 2030 of 1,940 kt CO_2. Scenario 2 is based on the following assumptions: 175 new-build networks of different sizes and structures, 100 subsidised plans for new grids, 80 optimisation measures for existing grids and 230 feasibility studies. The total amount of funding distributed reaches 1,799 million EUR, leading to an annual reduction of GHG

emission of 858 kt CO_2 and a total reduction until 2030 of 7,930 kt CO_2. Finally, Scenario 3 is based on the following assumptions: 88 new-built grids, 36 subsidised plans for new grids, 85 optimisation measures for existing grids and 1,600 feasibility studies. In Scenario 3, 821 million EUR are spent, leading to an annual reduction of GHG emission of 380 kt CO_2 and a total reduction until 2030 of 3,520 kt CO_2.

In summary, the PaM's contribution to reducing GHG emissions is estimated at between 1,940 and 7,930 kt CO_2. These target contributions are also presented in Table 46.

Table 46: Target contributions of Heating Networks 4.0 according to the ex-ante evaluation

National targets and contributions	2018-2030	2025	2030	Reference case and year
Reduction of GHG emissions [kt CO2]	Scenario 1: 1,940 Scenario 2: 7,930 Scenario 3: 3,520	Scenario 1: 215 Scenario 2: 858 Scenario 3: 380	Scenario 1: 215 Scenario 2: 858 Scenario 3: 380	No expansion or modernisation of heating networks existing in 2017
Increase of RES consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of final energy consumption [ktoe]	n/a	n/a	n/a	n/a

Source: own compilation, Fraunhofer ISI

Results from the ex-post evaluation

The selected ex-post evaluation was conducted by the Department for Business, Energy & Industrial Strategy (BEIS) in the UK and published in 2018 (BEIS 2018b). The study was led by Risk Solutions and the Tavistock Institute for Human Relations. BEIS has commissioned a suite of independent process and impact evaluation activities to cover the full HNIP scheme (the pilot scheme and the main scheme). This involves a series of annual activity cycles with process, impact and economic evaluation. The selected evaluation is part of these activities and focused on the impact of the HNIP pilot scheme, following an initial evaluation of the pilot's process[17].

The selected evaluation was conducted in parallel with HNIP pilot and main scheme implementation. Until the publication of the evaluation in 2018, the HNIP Pilot attracted 25 applicants of which nine were successful. Two of these nine accepted applicants did not go ahead as the parties involved decided not to proceed with the projects. The remaining seven funded projects have proceeded.

The evaluation is theory-based and adopts a realist approach. Theories relating to six high-level research themes (HLT) are developed, tested, refined, confirmed or rejected through an iterative process of evidence collection. For this approach, three case studies, i.e. three funded projects, were selected from BEIS. The six HLT are:

[17] BEIS Research Paper Number 1 (February 2018). Heat Networks Investment Project Evaluation: Process evaluation of pilot; https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/699304/HNIP_EVALUATION_-_PILOT_PROCESS_REPORT_-_FINAL.pdf

- HLT1: Scheme technical design
- HLT2: Administrative design and delivery
- HLT3: Delivery of projects
- HLT4: Market sustainability
- HLT5: Delivery of scheme outcomes
- HLT6: Cost benefit of the scheme.

In order to collect evidence for the HLT case study, interviews, workshops and an e-survey with all project managers were conducted.

Table 47 shows that the evaluation does not include quantification regarding reduction of GHG emissions, increase of RES consumption, reduction of primary energy consumption or reduction of final energy consumption. However, the evaluation (i.e. testing of the HLT) shows that the HNIP is encouraging heat source replacement planning, as it helps cover a funding gap and reduces cost and technology risks to acceptable levels. In summary, the evaluation of the PaM provides evidence across the three case studies that the HNIP pilot shows clear signs of promoting and empowering district heating network development.

Table 47: Target contributions of HNIP according to the ex-post evaluation

National targets and contributions	2018-2030	2025	2030	Reference case and year
Reduction of GHG emissions [kt CO_2]	n/a	n/a	n/a	n/a
Increase of RES consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of final energy consumption [ktoe]	n/a	n/a	n/a	n/a

Source: own compilation, Fraunhofer ISI

Comparison between the ex-ante and ex-post evaluation and with the NECP

Our analysis showed that according to the ex-ante evaluation, funding of district heating grids can lead to a high target contribution, especially to the reduction of GHG emissions. However, the GHG emission reduction contributions differ widely (between 1,940 and 7,930 t CO_2) depending on the assumptions and total amount of funding. We could not conduct a quantitative comparison with the ex-post evaluation, since it does not provide a quantitative analysis and no other comparable ex-post evaluation is available. Nevertheless, in line with the high contribution, the ex-post evaluation demonstrates that the PaM can successfully influence and empower (low-temperature and renewable) district heating network development. In the NECP, the PaM Heating Network Systems 4.0 is described in Section 3.1.2.vi.1 and its importance is emphasised without quantification of its impact. A quantification of the PaM's projected GHG emission reductions is, however, provided in the 2019 and 2021 PaM reports. In 2019, GHG emissions of 1,001 kt CO2eqs are indicated for 2030 and of 1,507 kt CO2eqs for 2035. As for 2021, these numbers have been adjusted upwards to 1,600 (2030) and 1,900 (2035) kt CO2eqs

per base year. There is no direct link between the evaluations assessed here and the information in the NECP.

In terms of addressing hurdles and barriers, Pehnt et al. (2017) mention a number of potential issues that impede the PaM coming to full fruition, such as application processes being perceived as cumbersome and complicated and signals for long-term planning/investment security remaining too weak. Uncertainties also persist with regards to the further development of important accompanying instruments, such as the cogeneration act (KWKG), or the future role and assessment of alternative fuels such as hydrogen which could also play a role in the decarbonisation of district heating.

A.2.3 French NECP

The French NECP addresses the focus topic renewable H&C in several sections, each time under the subsection 'Renewable Energies' as part of the dimension 'Decarbonisation'. Renewable and recovered heating and cooling is explicitly addressed in Sections 2.1.2.1 and 3.1.2.1. The national Energy Code sets a target of 38% for the share of renewable energies in final heat consumption by 2030 (see Section 2.1.2.1). There is no strategy focusing on renewable heat, but the Long-Term Renovation Strategy has an impact on renewable heating, even though its main focus lies on renovation and energy efficiency. There are several measures in the NECP addressing renewable heat, even though only a few of them target renewable heat exclusively. Key instruments are the Heat Fund (Fonds chaleur), supporting production of heat from renewable energy in the tertiary, industry and collective housing sectors, the White Certificates scheme and the "MaPrimeRénov" energy renovation Programme for housing owners and co-owners.

Table 48 shows the relevant and selected French PaMs under the focus topic. Both PaMs were selected based on their large projected GHG emissions reduction as well as available information. While the Heat Fund is the central French PaM for renewable heat only, the White Certificates scheme is not a pure renewable heat PaM, but at the intersection of energy efficiency and renewable heat. Both selected PaMs are cross-sectoral.

Table 48: PaMs under the focus topic "Renewable Heat" in the French NECP

Name of PaM	Short description	Selected for evaluation?
Heat Fund	Scheme to support the production of heat from renewable resources and recovered energy	Yes
White Certificates/Energy efficiency obligation scheme	Scheme to incentivise energy efficiency using various mechanisms, including the trading of energy savings	Yes
Energy transition tax credit (CITE) - replaced by "MaPrimeRenov"	Tax credit mechanism for purchases of energy efficient equipment for primary residences, including high-efficiency boilers, thermal insulation works, heating regulation devices, heat pumps, etc.	No
Future environmental regulation on new buildings (ER 2020)	Regulation requiring all new buildings constructed after 2020 to reach zero net energy consumption	No

Source: own compilation, Fraunhofer ISI

A.2.3.1 Heat Fund

The Heat Fund (Fonds Chaleur), targeting the tertiary, industry, agriculture and collective housing sectors, is a key French PaM to support renewable heat (see Table 49). It is an active support policy, providing financial support for the planning, decision and production of heat, replacing fossil fuels by renewables. Introduced in 2008 through the Energy Transition Act (Loi relative à la transition énergétique pour la croissance verte, LTECV), the Heat Fund has been prolonged and progressively revised multiple times, extending its scope and compatibility with other PaMs. As of 2020, the annual budget of the Heat Fund was fixed at EUR 350 million and cumulated to about EUR 2.6 billion until 2020. The Heat Fund is managed by the French Environmental and Energy Agency (Agence de l'environnement et de la maîtrise de l'énergie, ADEME) and works through the provision of grants via national and local calls for tenders.

Two instruments characterise the Heat Fund, the annual BCIAT (Biomasse Chaleur Industrie Agriculture Tertiaire) call for projects aimed primarily at industry, and additional regional calls for projects addressing regional authorities and companies. Since these renewable support instruments are jointly evaluated, e.g. by ADEME, this means that studies treat the Heat Fund as one single instrument. This approach has also been chosen for the present report and both sub-instruments will be analysed jointly in the subsequent paragraphs as effects are not separated out. The central French instrument to promote renewable heating, the Heat Fund targets different types of actors, most notably industry, companies and public authorities, as well as technologies. In addition to the main beneficiary groups, the PaM also has effects on the wider sector, by mobilising local authorities, project designers, companies, equipment manufacturers, operators, biomass supply companies, and others which creates important spill-over effects and dynamics. Given its long history and continuity, it provides a relatively stable investment environment and planning security to potential beneficiaries. The prospect of stabilising the Heat Fund's budget at 350 million EUR annually can also be seen as an important signal to this end.

Table 49: Relevant and selected policy instruments for the Heat Fund

PaM	Associated policy instrument(s)	Legal Basis
Heat Fund (Fonds Chaleur)	Appel à projets national Biomasse Chaleur Industrie Agriculture Tertiaire (BCIAT) Appel à projets régional	Loi no 2015-992 du 17 août 2015 relative à la transition énergétique pour la croissance verte

Source: own compilation, Fraunhofer ISI

We list available and selected ex-ante and ex-post evaluations in Table 50. Our approach was to identify the most comprehensive ex-ante estimations included in any official document published on this PaM that show the biggest overlap with the NECP. The most recent and comprehensive ex-ante figures are included in the French 2017 background study on the PaM report (Direction Générale de l'Énergie et du Climat 2017). There is also a 2019 version of the same study available. Both the 2017 and the 2019 editions of the evaluation are equally closely related to the NECP as the PaMs they evaluate form part of the National Low Carbon Strategy which, together with the Multiannual Energy Planning, served as the basis of the NECP. As for ex-post evaluations, these are more readily available, even though not always of a rigorous quantitative nature. Out of all identified evaluations, the background study to the 2017 PaM Report was also selected due to it being the most comprehensive and recent quantitative assessment of the Heat Fund. The background study to the 2019 PaM report is of course more recent; however, it is not as detailed and comprehensive as the 2017 version, which considered

more evaluating categories. In terms of results and assumptions, the 2017 and the 2019 background study are similar, even though the 2017 evaluation finds a higher emissions reduction potential in the ex-ante perspective (while emission reductions plateau at 7,634 kt CO_2eq annually between 2022 and 2030 in the 2017 report, the 2019 study finds them to stabilise at 5,900 kt CO_2eq between 2020 and 2030). The 2021 PaM report does not show any changes as compared to 2019. The other evaluations conducted by ADEME were used to complement both the ex-ante and ex-post evaluation for certain aspects.

Table 50: Available and selected ex-ante and ex-post evaluations for the Heat Fund

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
Heat Fund (Fonds Chaleur)	**DGEC (2017): Rapport de la France En application de l'article 13.1 du règlement n° 525/2013 relatif à un mécanisme pour la surveillance et la déclaration des émissions de gaz à effet de serre. Actualisation 2017. [Report from France Pursuant to Article 13.1 of Regulation 525/2013 on a mechanism for the monitoring and reporting of greenhouse gas emissions-Update 2017]** DGEC (2019): Rapport de la France En application de l'article 13.1 du règlement n° 525/2013 relatif à un mécanisme pour la surveillance et la déclaration des émissions de gaz à effet de serre. Actualisation 2019. [Report from France Pursuant to Article 13.1 of Regulation 525/2013 on a mechanism for the monitoring and reporting of greenhouse gas emissions-Update 2019]	**DGEC (2017): Rapport de la France En application de l'article 13.1 du règlement n° 525/2013 relatif à un mécanisme pour la surveillance et la déclaration des émissions de gaz à effet de serre. Actualisation 2017. [Report from France Pursuant to Article 13.1 of Regulation 525/2013 on a mechanism for the monitoring and reporting of greenhouse gas emissions-Update 2017]** DGEC (2019): Rapport de la France En application de l'article 13.1 du règlement n° 525/2013 relatif à un mécanisme pour la surveillance et la déclaration des émissions de gaz à effet de serre. Actualisation 2019. [Report from France Pursuant to Article 13.1 of Regulation 525/2013 on a mechanism for the monitoring and reporting of greenhouse gas emissions-Update 2019 ADEME (2018a): Evaluation stratégique du Fonds Chaleur 2009-2017. [Strategic Evaluation of the Heat Fund 2009-2017]. ADEME (2014): Bilan du fonds chaleur pour les années 2009 à 2014. [Results of the Heat Fund for the years 2009 until 2014].

The evaluations that were selected for an in-depth assessment are shown in bold font.

Source: own compilation, Fraunhofer ISI

Results from the ex-ante evaluation

The ex-ante evaluation uses statistical data from ADEME for the years 2009 until 2015 regarding the number of supported projects under the fund and the amount of renewable heat generated thanks to it. The data basis is not described with great detail though and no stakeholders were involved during the evaluation process. As indicated in the report "Le Fonds Chaleur. Bilan 2009-2017" (ADEME 2018b), between 2009 and 2017, the Heat Fund supported almost 4,300 projects, the majority of them are in the area of solar heating, followed by wood and biomass and, ranked third, projects in the area of district heating networks.

The counterfactual scenario for the evaluation assumes that the Heat Fund does not exist and that all renewable heat supported by the Heat Fund is produced using fossil fuels. This

assumption is justified given the limited overlap of the Heat Fund with other instruments as well as by the low deadweight effect as the exact amount of aid provided under the Heat Fund is underpinned by rigorous economic analysis. The evaluation thus considers all the GHG emission reduction attributable to the Heat Fund. For the ex-ante view, the national targets evaluated are GHG emissions avoided, fossil fuels avoided and increase of RES consumption. According to the projections the annual emissions reductions gradually increase until 2022, then plateau until 2030, after which they decline gradually. This decline is based on the conservative assumption that the impact of an installation set up using the Heat Fund ceases at the end of its life span. Over the period from 2022 to 2030, a total GHG emission reduction of 68,706 kt CO_2eq[18] or annual emissions reductions of 7,634 kt CO_2eq are estimated. In terms of increase of RES consumption, the values are 27,873 ktoe[19] between 2022 and 2030 or 3,097 ktoe annually. After 2030, these values gradually decline reaching 1,734 ktoe of increase in RES consumption in 2035. Target contributions according to the ex-ante evaluation are also depicted in Table 51.

Table 51: Target contributions of the Heat Fund according to the ex-ante evaluation

National targets and contributions	2022-2030	2020	2035	Reference case and year
Reduction of GHG emissions [kt CO_2eq]	68,706	6,361	4,275	Heat production without Heat Fund
Increase of RES consumption [ktoe]	27,873	2,580	1,734	Heat production without Heat Fund
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of final energy consumption [ktoe]	n/a	n/a	n/a	n/a

Source: own compilation, Fraunhofer ISI

The ex-ante evaluation is based on linear extrapolation. As the main logic is that installations funded by the Heat Fund will generally replace natural gas, GHG emission reductions are calculated using the difference between the emission factor of gas and the emission factor of the renewable energy types used by the facilities under the Heat Fund, e.g. wood, geothermal, biomass, solar. To obtain the emission factor, the emission intensity of the fuel is divided by the typical energy efficiency of the facilities. It is estimated that most of the energy savings made due to the Heat Fund are attributable to the residential/tertiary sector (55%), with the rest taking place in the industrial sector. The contribution of agriculture is deemed negligible. A distinction between emissions avoided in the ETS and non-ETS sectors is not made, as the data does not allow for it.

Apart from the Heat Fund's effect on GHG emissions reductions, the evaluation mentions a number of additional effects of the Heat Fund, most notably socio-economic ones, even though these elaborations are not based on rigorous calculations but rather discussed in general terms. The Heat Fund is expected to reduce annual heating costs by approximately 5%, from which lower-income households benefit. In terms of the French trade balance, the Heat Fund is

[18] Calculated based on DGEC (2017) by adding up annual figures.

[19] Calculated based on DGEC (2017) by adding up annual figures.

expected to reduce dependence on imports of mostly natural gas, thereby rendering France more energy-independent. Also, a positive effect on jobs is indicated with the Heat Fund being estimated at having created approximately 4,900 jobs between 2009 and 2015, thereof 3,600 permanent ones in operation and supply, and 1,300 annual ones in construction and installation. 10% of these jobs are located outside of France. The evaluation also mentions other positive effects such as effects on sustainable forest management by having to adhere to minimum standards and impacts on air quality and pollution.

Results from the ex-post evaluation

As already indicated, the ex-post evaluation builds on the same data and calculation logic and assumes the exact same reference scenario. The main national targets evaluated are GHG emissions avoided and increase in RES consumption. Target contributions according to the ex-post evaluation are depicted below in Table 52. Between 2009 and 2015, annual emissions reductions increased steeply, rising from zero in 2009 and 2010 to 3,359 kt CO_2eq in 2018. The accumulated 2009-2015 reduction of GHG emissions attributable to the Heat Fund amounts to 9,931 kt CO_2eq[20]. The evaluation also quantifies avoidance of GHG emissions outside France (0.6 Mt CO_2eq in 2015, 1.1 MtCO_2eq in 2020, 1.4 Mt CO_2eq in 2025 and 2030, and 0.8 MtCO_2eq in 2035). As for expansion of renewable heat, the annual renewable heat production amounts to 2.4 million toe. For comparison, a different evaluation also conducted by ADEME, which evaluates a slightly different time period, points out that thanks to the Heat Fund nearly 2.2 million toe per year were produced, corresponding to nearly 25.1 TWh of renewable heat (ADEME 2018a).

Table 52: Target contributions of the Heat Fund according to the ex-post evaluation

National targets and contributions	2009-2015	2011	2015	Reference case and year
Reduction of GHG emissions [kt CO_2eq.]	9,931	482	3,359	Heat production without Heat Fund
Increase of RES consumption [ktoe]	4,030	196	1,363	Heat production without Heat Fund
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of final energy consumption [ktoe]	n/a	n/a	n/a	n/a

Source: own compilation, Fraunhofer ISI

Since the method, approach and data basis used are the same for both ex-ante and ex-post, there are also no major differences for other types of effects. Therefore, the additional effects described above apply for both the ex-ante and ex-post evaluation.

Avoided GHG emissions attributed to the Heat Fund first rise, then decline gradually, with a large plateau in between. The assumption that the effectiveness of Heat Fund installations drops at the end of their lifespan (approximated at 20 years) is reasonable. The shape of the curve will also be influenced by fluctuations in the price of carbon as well as technological progress in the

[20] Calculated based on Direction Générale de l'Énergie et du Climat (2017).

H&C sector and improvements in the mechanics of the Heat Fund itself, such as the ability to offset other financial aids. Future ex-ante projections will also have to take into account one important change in the Heat Fund: the obligation to make repayable advances for certain Heat Fund projects was eliminated in 2019 and replaced by subsidies. In the same year, ADEME reconciled the rules governing its grants with the EU guidelines by aligning them with the maximum levels of support for heat networks, which are more favourable for non-economic activities. The simplified extrapolation that we can see in the ex-ante values is plausible and informative. However, some factors such as interdependencies with other instruments might be underestimated. As of 2020, it is possible to combine the Heat Fund with another significant instrument, the Energy Efficiency (White Certificates) Obligation Scheme (see discussion on this PaM in Annex A.2.3.2) which should have important repercussions on both PaMs and will have to be taken into account in following evaluations.

Comparison between the ex-ante and ex-post evaluations and with the NECP

Overall, it can be said that even though the evaluation makes some simplifying assumptions, a plausible picture emerges that helps to put the PaM into perspective and enables the reader to assess its contribution in the overall framework of renewable heat PaMs. As the ex-ante and ex-post evaluations have been performed jointly and in the same document, they go hand in hand and there are no inconsistencies. The impact reported in the background study is of course also in line with the PaM reports, but provides further detail. The values of the ex-ante evaluation are plausible and the approach is well-substantiated, weaknesses of the analysis and evaluation approach are indicated and discussed. While the French NECP itself does not elaborate on the assumed impacts of PaMs and instruments, but aggregates impact at sectoral level, the background study on the PaM report is a helpful tool to comprehend the contributions and limitations of single PaMs reported in the NECP. Other than that, there is no strong link between the evaluations and the NECP. The evaluation does, however, state that it is in line with the official WEM (with existing measures) scenario, even though the scenario has been updated for the NECP.

A.2.3.2 Energy Efficiency (White Certificates) Obligation Scheme

The French PaM “Certificats d'économies d'énergie” (CEE) is an energy efficiency obligation scheme, commonly referred to as a “white certificates” scheme (see Table 53). White certificates describe tradable assets, issued by the regulating authority (ADEME) to energy suppliers or other eligible actors, which proof that a certain amount of energy has been saved as compared to a baseline. In France, the tradable unit for a CEE is “kWh cumac”[21] with one CEE corresponding to one kWh of final energy. The scheme is targeted at French energy suppliers that can realise energy savings via their clients: households, companies or local communities. Certificates are issued ex-ante, meaning that they are provided before the actual energy savings occur, and recorded in a national online register kept by the European Energy Exchange (EEX). The PaM is cross-sectoral with all end-use sectors being eligible. With regards to measures, a wide range of different measures contributing to energy savings and expansion of renewables is eligible, all of which are listed in the form of so called “sheets” in an official indexed catalogue which is regularly updated via decrees. The eligibility of additional measures is determined on a case-by-

[21] "Cumac" stands for "accumulée et actualisés", meaning "cumulated and actualized", hence "accumulated and discounted" (often abbreviated to "kWhc"). Under the CEE; energy savings are accounted for in final energy, cumulated over the lifespan of an installation and annually discounted by a fixed factor.

case basis. The scheme is highly concentrated with a large amount of certificates being issued in the buildings sector and, in particular, the residential sector.

The CEE scheme was established by the so-called POPE Act (Act n° 2005-781 of 13 July 2005 programming the orientations of energy policy), which outlines the scheme's basic principles. Subsequently, a number of decrees and sub-decrees were issued to define the specifics over time, such as administrative rules to adhere to or obliged entities. Targets are expressed in cumulative terms, i.e. in the final year of a three-year period. With the extended fourth period coming to an end in December 2021, the scheme will enter into its fifth four-year operational period, starting 1 January 2022 with a total savings obligation of 2400 TWh cumac. France is not the only European country having introduced a white certificates scheme. The UK, Italy or Poland have similar policies in place.

As already mentioned, the core focus of this selected PaM is energy efficiency. However, as can be seen from the official list of the eligible measures under the CEE, its scope includes a large number of renewable H&C measures, such as installation of different types of heat pumps, support of heat networks, solar water heating, pellet stoves or biomass boilers, with renewable heat measure even being one of the most popular categories of interventions. Thus, the CEE can be regarded as a key PaM also for renewable H&C. Another reason for selecting this PaM for further analysis is its high emissions reduction potential as well as the fact that it is a large, well-researched PaM with comprehensive data and evaluations available, which was not the case for many other French renewable H&C PaMs (with the exception of the Heat Fund).

As the CEE is a policy instrument in itself, no further sub-selection of subordinate instruments is possible and the PaM is regarded as a whole.

Table 53: Relevant and selected policy instruments for Energy Efficiency Obligation Scheme

PaM	Associated policy instrument(s)	Legal Basis
Energy Efficiency Obligation Scheme (Certificats d'économies d'énergie)	Energy Efficiency Obligation Scheme (Certificats d'économies d'énergie)	Loi n° 2005-781 du 13 juillet 2005 de programme fixant les orientations de la politique énergétique ("Loi POPE")

Source: own compilation, Fraunhofer ISI

Table 54 lists the available and selected ex-ante and ex-post evaluations for the PaM. The search for ex-ante evaluations proved to be difficult as these are not amply available. We thus took the approach of identifying the most comprehensive ex-ante estimations included in any official document published on the PaM. As the only official document containing an ex-ante evaluation, the French 2017 background study to the EEA was selected (DGEC 2017). This choice was made despite a newer document version being available, however, also for the CEE the 2017 version is more comprehensive than the 2019 version. The search for ex-post evaluations was more fruitful as the PaM has been the subject of a mandated evaluation process. Evaluations conducted were predominantly qualitative though ATEMA Conseil (2019) or not that recent CGEDD et al. (2014). The most comprehensive and recent quantitative assessment is contained in the background study to the 2017 PaM report as well due to the same reasons as for the Heat Fund (see A.2.3.1) and the 2019 background study being more recent, however, slightly less comprehensive. The 2021 PaM report does not show any changes as compared to 2019. To complement the information contained in that document, an additional evaluation, ATEMA Conseil (2019), was taken into consideration as well.

Table 54: Available and selected ex-ante and ex-post evaluations for Energy Efficiency Obligation Scheme

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
Energy Efficiency Obligation Scheme (Certificats d'économies d'énergie)	**DGEC (2017): Rapport de la France En application de l'article 13.1 du règlement n° 525/2013. Actualisation 2017. [France's Report. Pursuant to Article 13.1 of the Regulation No. 525/2013. 2017 Actualisation].** DGEC (2019): Rapport de la France En application de l'article 13.1 du règlement n° 525/2013. Actualisation 2019. [France's Report. Pursuant to Article 13.1 of the Regulation No. 525/2013. 2019 Actualisation].	**DGEC (2017): Rapport de la France En application de l'article 13.1 du règlement n° 525/2013. Actualisation 2017. [France's Report. Pursuant to Article 13.1 of the Regulation No. 525/2013. 2017 Actualisation].** DGEC (2019): Rapport de la France En application de l'article 13.1 du règlement n° 525/2013. Actualisation 2019. [France's Report. Pursuant to Article 13.1 of the Regulation No. 525/2013. 2019 Actualisation]. ATEMA Conseil (2019): Evaluation du dispositif des Certificats d'Economie d'Energie. [Evaluation of the instrument of Energy Saving Certificates]. CGEDD, IGF, CGEiet (2014). Les certificats d'économies d'énergie : efficacité énergétique et analyse économique. [Energy Saving Certificates: energy efficiency and economic analysis].

The evaluations that were selected for an in-depth assessment are shown in bold font.

Source: own compilation, Fraunhofer ISI

The ex-ante evaluation uses data from the national CEE registry Emmy, verified by the Pôle National des Certificats d'Économies d'Énergie, a special section of the administration responsible for the implementation of the CEE which belongs to the Directorate General of Energy and Climate (Direction générale de l'énergie et du climat). Experts from ADEME and different Directorates of the administration were consulted during the evaluation process to calibrate the methodology. The evaluation takes into account the following four periods of the CEE: 2006-2009, 2011-2014, 2015-2017 and 2018-2020, with the fourth period not yet being in progress at the time of the evaluation. A target of 925 TWh cumac has been set for 2018-2020. The evaluation estimates the future impact of former periods, with data on number of distributed certificates available for the first and second period and making assumptions for the third and fourth period. Based on the data available at the beginning of the third period, the share of distributed certificates to the residential sector in the third and fourth period is assumed at 50%.

The counterfactual scenario for the evaluation assumes that the CEE does not exist, thus considering that all the GHG emission reduction achieved is attributable to the CEE. The evaluation also takes into account that the CEE can be cumulated with other instruments, most notably the tax credit for energy transition (discontinued after 2017) or the zero-interest eco loan. It is thus necessary to identify its additionality, that is, determine which savings are solely attributable to the CEE and not to other instruments. Until 2017 the evaluation assumes that the effect of the tax credit for energy transition dominates in the residential sector as it offers a higher premium. Based on this, an additionally rate for the CEE is assumed which amounts to 20% in the presence of the tax credit for energy transition, the zero-interest eco-loan and the

social housing eco-loan, and 80% in their absence in the residential sector. This means that 20% of energy saving measures can be assumed to be triggered by the scheme if no interactions with other instruments are taken into account. In the non-residential sector, 100% of energy savings can be attributed to the CEE. For the ex-ante evaluation, national targets evaluated are reduction of final energy consumption and avoided GHG emissions using extrapolation. Increase of RES consumption and reduction of primary energy consumption are not looked at. According to the projections, the annual emissions reductions increase first gradually then sharply until 2021 due to accumulation of operations, then decline slowly. This decline is based on the conservative assumption that the impact of installations set up using the CEE only have a certain life expectancy (weighted average lifetime of operations assumed at 22 years) and are not renewed. Based on data collected during the first and second running period of the scheme, an average emission factor was calculated corresponding to 0.211 kt CO_2eq per kWh of energy saved thanks to the CEE. This factor is then extrapolated also to the third and fourth period of the scheme. A discount rate of 4% and a time lag of one year between installation of an operation and it becoming effective is applied across all periods. Numerical values, distinguished between periods, can be seen in Table 55.

Table 55: Target contributions of the Energy Efficiency Obligation scheme according to the ex-ante evaluation

National targets and contributions	2020-2035	2025	2030	Reference case and year
Reduction of GHG emissions [kt CO_2eq.] first and second period	n/a	6,490	5,950	Projection without CEE
Increase of RES consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of final energy consumption [ktoe] first and second period[22]	n/a	2,648	2,425	Projection without CEE
Reduction of GHG emissions [kt CO_2] first until fourth period	n/a	18,830	18,290	Projection without CEE
Reduction of final energy consumption [ktoe] first until fourth period[23]	n/a	7,670	7,455	Projection without CEE
Increase of RES consumption [ktoe]	n/a	n/a	n/a	n/a

[22] Converted from TWh.

[23] Converted from TWh.

National targets and contributions	2020-2035	2025	2030	Reference case and year
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a

Source: own compilation, Fraunhofer ISI

Overall, the ex-ante evaluation follows plausible but conservative assumptions. Interaction effects with other instruments, most notably the tax credit for energy transition are taken into account.

In addition to the CEE's effect on GHG emissions reductions and energy consumption, a number of other categories are invoked, even though there are no detailed justifications or explanations included in the evaluation document. Also, for further effects there is no distinction between the ex-ante and ex-post view. Such additional effects are (positive) employment effects (jobs being created in installation and manufacturing) or (positive) effects on innovation. It has to be said that these effects are hard to assess, as there is little detail provided on their mechanics and no rigorous investigation seems to have been conducted. The PaM is described as highly cost-efficient as costs are borne by the obligated parties. The cost for the State is limited to in-house administrative personnel, the commissioning of studies as well as a few other costs related to the running of the registry. The PaM, however, has a cost to energy suppliers, amounting to 26 EUR per avoided t CO_2eq.

As already indicated, the ex-post evaluation builds on the same data and has the same underlying reference scenario. The main national targets evaluated are final energy savings and the reduction of GHG emissions. Total reduced GHG emissions due to the CEE between 2006 and 2015 amount to 19,529 kt CO_2eq. Table 56 illustrates the calculated results of the ex-post evaluation.

Table 56: Target contributions of the Energy Efficiency Obligation scheme according to the ex-post evaluation

National targets and contributions	2006-2015	2010	2015	Reference case and year
Reduction of GHG emissions [kt CO_2eq]	19,529	1,224	6,190	Projection without CEE
Increase of RES consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of final energy consumption [ktoe][24]	n/a	498.71	2,519.35	Projection without CEE

Source: own compilation, Fraunhofer ISI

[24] Converted from TWh.

Limiting factors of the evaluation are the difficulty to estimate the additionality rate as well as the general assumption of fossil fuels as the reference case. The evaluation also admits that the additionality rate might depend on a deadweight effect (or free-riding) as well, i.e. operations receiving certificates that would have been carried out in any case. This effect, however, is mitigated by the scheme's design, which requires energy sellers to justify their incentive in carrying out the operations for which they claim certificates. Another important factor that could influence the results is a potential rebound effect, meaning that some beneficiaries might take advantage of their new installation's efficiency and increase their comfort levels and consume more energy, thereby diminishing the positive effects. The evaluation takes all of this into account by conducting a sensitivity analysis, which shows that the final results are highly dependent on the underlying assumptions.

Comparison between the ex-ante and ex-post evaluations and with the NECP

It can be concluded that despite a number of simplifying assumptions made by the evaluators, the emerging ex-ante projections are plausible and well-substantiated. Similar to the Heat Fund, the ex-ante and ex-post evaluation go well together as they have been conducted jointly and within the same document. Weaknesses and limiting assumptions of the evaluation are explained and discussed. Given that the CEE is a longstanding instrument and that the ex-ante evaluation was conducted in the mid-term further increases the evaluation's plausibility as real-life experience with the CEE can be used as a benchmark. In the next step, it might be helpful to compare the CEE projections to white certificate schemes operational in other European countries. The evaluations assessed are directly linked to the 2017 PaM report, however, not referred to in the NECP which does not provide information on the expected impact of the PaM in question.

As highlighted in ATEMA Conseil (2019) one central barrier of the PaM is its lack of transparency and stability. Beneficiaries refer to the system as "opaque" and improvements could be made regarding the availability and provision of data. The instrument's complexity and administrative procedures further complicate its implementation. Despite information and training being provided at regional level, the system seems to have not yet been comprehensively embraced by all local authorities which sometimes leads to a mismatch in national and local priorities with the CEE not being sufficiently promoted at the territorial level. Another shortcoming that is mentioned in ATEMA Conseil (2019) is that by its very nature the CEE favours the completion of individual works not taking a sufficiently systemic perspective, while it might be more efficient and also beneficiary to complete "bundles of interventions".

A.2.4 Slovenian NECP

The Slovenian NECP addresses the focus topic renewable heat under the subsection "Renewable Energies" as part of the dimension "Decarbonisation". As a target for 2030, the NECP sets a share of at least a 27% of renewables in final energy counting a share for heating and cooling of 41% (see Section 2.1.2). In the adoption of policy measures for renewables, special attention will be given to reducing bureaucracy and the appropriate integration of renewables into buildings, spatial planning and energy system and the process of siting all the necessary facilities. Besides, the Long-Term Renovation Strategy has an impact on renewable heating, and there are several specific measures in the NECP addressing renewable heat like financial incentives for energy efficiency and renewable energies in residential buildings. A mandatory share of renewables, combined heat and power and surplus heat in district heating systems is also mentioned.

Again, there is a considerable overlap between the focus topics renewable heat and energy efficiency, as many Slovenian energy efficiency PaMs also address renewable heat. This is the case for all grouped PaMs that promote energy efficiency and renewable energy use in different sectors, e.g. the public sector (PaM #58), households (PaM #52), industry (PaM #63) or in buildings in general (PaM #47). There is only a small amount of PaMs that exclusively focus on renewable heat, of which two were selected for further evaluation. The first one sets an obligation for district heating systems and sets a share for the source of energy that they use. The second one focuses on financial incentives for the construction or renovation of district heating systems. Compared with other PaMs, the aggregated projected GHG emissions reductions for both PaMs for year 2030 are relatively small, however, still significant. It is not surprising that both PaMs that focus exclusively on renewable heat centre around the topic of district heating systems as Slovenia has a long tradition of district heating. However, to have a more comprehensive picture on the renewable heat sector in Slovenia and related PaMs, the PaM "Financial incentives for energy efficiency and RES use in residential buildings" (see Section 4.3.2.1) is also considered in the concluding section, as it enables renewable heat via subsidies and soft loans provided by the Slovenian Ekofund (Ekosklad). The eligible renewable heating facilities include heat pumps, solar heating systems, biomass combustion plants or connections to district heating systems. All relevant PaMs for Slovenia are depicted in Table 57.

Table 57: PaMs under the focus topic "Renewable Heat" in the Slovenian NECP

Name of PaM	Short description	Selected for evaluation?
Obligatory share of heat from renewable energy sources, high-efficiency cogeneration and waste heat in district heating systems	Obligation for DH systems where at least 50% of the yearly amount of the heat distribution shall be produced from renewable energy sources or 50% shall come from waste heat or 75% from high-efficiency cogeneration or 50% from a mix of before listed sources.	Yes
Financial incentives for district heat production using renewable energy sources	Financial support for district heating using renewable energy in the form of co-financing grants. The target group of the scheme are businesses (large companies, SMEs and micro-businesses) and cooperatives.	Yes
Financial incentives for energy efficiency and RES use in residential buildings	Financial incentives to finance investments of a comprehensive energy renovation of buildings and the construction of almost zero energy buildings.	No
Promoting energy efficiency and renewable energy use in buildings in general	Financial incentives to promote energy efficiency and renewable energy use in buildings in general.	No
Promoting energy efficiency and renewable energy use in industry	Financial incentives to promote energy efficiency and renewable energy use in industry.	No

Source: own compilation, Fraunhofer ISI

A.2.4.1 Obligatory share of RES, CHP and surplus heat in district heating systems

This PaM was introduced in 2014 via an amendment to the Slovenian Energy Act EZ-1 (see also Table 58). The PaM is also anchored in the Renewable Energy Action Plan of the Republic of Slovenia for the period 2010-2020 (AN OVE 2020). As a key renewable heat PaM, it contributes to three national targets: increasing the use of RES, reduction of energy consumption and reduction of GHG emissions, decarbonising the district heating sector and "crowding out" fossil fuels. Consequently, it flanks the PaM "Financial incentives for district heat production using renewable energy sources", for which it is an accompanying regulation. The institutional body in charge of its implementation is the Slovenian Energy Agency with the Ministry of Infrastructure being the legislative body . The PaM targets heat distributors with a system power exceeding 10 MW and gives them a clear long-term goal, as they have to guarantee that heat is supplied from at least one of the following sources with respective required shares by 31 December 2020:

- At least 50% generated from RES,
- At least 50% generated from waste heat,
- At least 75% from high-efficiency CHP, or
- At least 50% from a mix of the above listed sources.

Given that only one of the criteria needs to be met, the PaM offers quite some flexibility. Operators that fall into one of the above categories are referred to as "energy-efficient district heating systems". The Slovenian Energy Agency publishes an annual list of all district heating units in compliance and non-compliance.

The PaM is a policy instrument in itself, hence no further selection took place.

Table 58: Relevant and selected policy instruments for the PaM Obligatory Share of Heat from RES, CHP and Waste Heat

PaM	Associated policy instrument(s)	Legal basis
Obligatory share of heat from renewable energy sources, high-efficiency cogeneration and waste heat in district heating system	Obligatory share of heat from renewable energy sources, high-efficiency cogeneration and waste heat in district heating system	Energetski zakon – EZ-1 (Uradni list RS, št. 17/14 z dne 7. 3. 2014)

Source: own compilation, Fraunhofer ISI

Table 59 summarises the available evaluations for the PaM. As it was not possible to find any ex-ante evaluations for the PaM, the alternative approach was to resort to the ex-ante assessment and effects implied in Slovenia's 2019 PaM report. No new projections were provided in the country's 2021 PaM report. A comprehensive background study and environmental impact assessment of the NECP is available, but it does not look into projected impacts on a PaM level (EIMV 2019).

With regards to ex-post evaluations, all retrieved evaluations of renewable heat PaMs were conducted in the context of the LIFE project ClimatePath2050 (Reference: LIFE16 GIC/SI/000043; "Slovenian Path Towards the Mid-Century Climate Target"), co-financed by the Ministry of Environment and Spatial Planning, focusing on GHG emission reductions in non -ETS sectors. Between 2018 and 2020, the project issued a so-called "Climate Action Mirror" every year, as well as accompanying reports on individual policy instruments and groups of instruments. In 2018, one of the reports focused on instruments promoting district heating in Slovenia (Merše et al. 2018). In 2019, a report on measures in the non-ETS sectors was

published, which includes an analysis of the two selected PaMs for Slovenia, "Obligatory share of heat from renewable energy sources, high-efficiency cogeneration and waste heat in district heating systems" and "Financial incentives for district heat production using renewable energy sources" (Česen et al. 2019). While none of the documents is covering the measures exhaustively, Merše et al. (2018) offers a good overview of the effects of the selected PaMs, even though mostly qualitative, and was thus selected for further analysis and complemented with a view in Đorić et al. (2020). All evaluations found are mid-term evaluations, as the instrument set a target of 31 December 2020 for all heat distributors to meet the obligatory shares, with a concluding evaluation of the instrument still pending. Given that the PaM targets a rather small group of actors (heat distributors only) that have to comply with it, there are no large-scale accompanying communication measures and end customers are also not involved in the process.

Table 59: Available and selected ex-ante and ex-post evaluations for the PaM Obligatory Share of Heat from RES, CHP and Waste Heat

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
Obligatory share of heat from renewable energy sources, high-efficiency cogeneration and waste heat in district heating system	**No ex-ante evaluation available: Slovenian 2019 PaM report considered in lieu thereof.**	**Merše et al. (2018): Podnebno ogledalo 2018, Zvezek 6: Ukrepi v središču - Spodbujanje sistemov daljinskega ogrevanja, končno poročilo. [The First Climate Action Mirror 2018 and Accompanying Reports, Part 6: The Measure in Focus - Promotion of District Heating, final report].** Česen et al. (2020): Podnebno ogledalo 2020, Zvezek 5: Ostali sektorji, končno poročilo. [The Third Climate Action Mirror 2020 and Accompanying Reports, Part 5: Other Sectors, final report]. Đorić et al. (2020): Podnebno ogledalo 2018, Zvezek 7: Emisije TGP in sektor EU-ETS, končno poročilo. [The Third Climate Action Mirror 2018 and Accompanying Reports, Part 7: GHG Emissions and EU-ETS Sector, final report].

The evaluations that were selected for an in-depth assessment are shown in bold font.
Source: own compilation, Fraunhofer ISI

Results from the ex-ante evaluation

As for the ex-ante evaluation, the effects assumed in the 2019 PaM report are limited to GHG emission reductions. The effects of the two district heating PaMs are aggregated and subsumed under the title of "Promotion of district heat from RES and CHP with high efficiency". The effects listed for GHG emissions reductions are 68 kt CO2eq in the year 2025, increasing to 114 kt CO2eq in 2030 and 143 kt CO2eq in 2035. This indicates an increasing effect of the two PaMs over time, with GHG emissions reduction potential rising over time. This is in line with the heat production scenarios for district heating included in the Slovenian NECP, which indicates a growing share of more energy efficient technologies, mostly CHP and heat pumps, alongside an increase of RES, to the detriment of fossil fuels. Due to lack of detail on the ex-ante projections and information on how they were derived, it is unclear, however, how this effect is composed, whether each PaM contributes to this effect and if so by how much. No other costs and benefits

of the PaM are calculated or indicated and the methodology of calculation is not explained. All target contributions can also be seen in Table 60 below.

Table 60: Target contributions of the PaM Obligatory Share of Heat from RES, CHP and Waste Heat according to the 2019 PaM report

National targets and contributions	Evaluation period/year	2025	2030	Reference case and year
Reduction of GHG emissions [kt CO_2e]	n/a	68	114	n/a
Increase of RES consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of final energy consumption [ktoe]	n/a	n/a	n/a	n/a

Source: own compilation, Fraunhofer ISI

Since the ex-ante projections for this PaM are aggregated with the effects for the "Financial incentives for district heat production using RES" PaM, it is difficult to assess in how far this effect can be traced back to either of them. The positive effect of the ” Obligatory share of heat” PaM would need to be attributed to the reduction of heat produced by fossil fuel-based units, increased use of RES and increased efficiency through CHP and the exploitation of waste heat.

In Slovenia's National Energy Action Plan 2010-2020, the PaM also figures as a key instrument, however, the expected result is not quantified but indicated as "increasing the share of RES in district heating". Given the variety of ways to comply with this PaM, it is a very flexible instrument and does not provide stringent incentives for the sub-goals.

Results from the ex-post evaluation

As for ex-post, no quantitative values are given in the evaluation, as shown in Table 61. Compliance of the PaM is being monitored on an annual basis, however, no comprehensive ex-post evaluation has taken place yet. The Slovenian Energy Agency is responsible for the monitoring of the PaM and publishes an annual list of heat system operators meeting at least one of the above criteria as well as those not meeting them. In 2016, 67% of all district heating systems were able to comply with at least one of the criteria set out in the PaM. This relatively high share is mostly attributable to the high proportion of CHP, which was close to 84% in district heating systems. From the point of view of reducing GHG emissions, the findings are not encouraging though. Fossil fuels were still dominating the fuel consumption structure in district heating systems with coal (55%) and natural gas (26%) being primarily used (Đorić et al. 2018). The picture did not look very different in 2018 where the share of municipalities with district heating meeting at least one of the PaM criteria had risen to 68%. 82.5% of all heat produced in district heating systems was produced in systems meeting at least one of the criteria outlined in Article 322 of the Energy Act, however, fossil fuels were still dominating. As also pointed out in Merše et al. (2018), the limited progress made against this PaM can mostly be attributed to the already good baseline.

As for other effects of the PaM described in Merše et al. (2018), progress has been made in the construction of new district heating systems where most are using 100% of RES. It is, however, not clear whether this is attributable to the PaM (only). The PaM also seems to be successful in increasing the share of CHP in smaller district heating systems (Merše et al. 2018).

Table 61: Target contributions of the PaM Obligatory Share of Heat from RES, CHP and Waste Heat according to the ex-post evaluation

National targets and contributions	Evaluation period/year	2010	2015	Reference case and year
Reduction of GHG emissions [kt CO_2]	n/a	n/a	n/a	n/a
Increase of RES consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of final energy consumption [ktoe]	n/a	n/a	n/a	n/a

Source: own compilation, Fraunhofer ISI

The ex-post evaluation focuses mostly on the degree to which the shares set out in the PaM are met by district heating systems across Slovenia. This alone, however, provides little information about GHG emission reductions or energy savings attributable to the PaM. As key data on amounts of renewable heat produced and GHG-intensity are missing, it is not possible to draw conclusions on the key national targets pursued by this PaM. Nevertheless, the ex-post evaluation gives some general information on the Obligatory Share's effectiveness and provides recommendations for improving its design, underlining the importance of ambitious long-term targets under this PaM. For the further analysis of the Obligatory Share outside of this report, it would be beneficial to look into similar PaMs in other countries, as the availability of evaluations for the exact PaM is scarce.

Comparison between the ex-ante and ex-post evaluations and with the NECP

Overall, it is not possible to draw conclusions on the plausibility of the ex-ante values of the PaM, as the degree of aggregation is too high and no quantitative values for ex-post are available. The PaM offers a high degree of flexibility to obligated parties, thus parties will choose the least cumbersome way to comply, which might not necessarily lead to an increase in RES. It could thus as well be possible that ex-ante projections might have overestimated the contributions of this PaM. In addition, no sanctions are indicated in case of non-compliance.

Also the NECP does not provide information on the expected impact of the PaM. The PaM expired on 31 December 2020 and no new target for obligatory shares in district heating has been set (yet). Following the Slovenian NECP, a new target should be set in 2021, in accordance with Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources (Renewable Energy Directive, RED II), i.e. to increase the share of RES and surplus heat by at least 1% annually. For the required long-term impact, it will be crucial to set sufficiently high shares by 2030 as well as less flexibility and give a long-term perspective to system operators and investors. The importance of clear medium and long-term goals and guidelines for heating and cooling is also stressed in the part of the NECP relating to multi-sectoral measures for

raising awareness and informing. Here it is stated that a comprehensive heating and cooling strategy shall be developed in 2021 (currently still pending), along with a heat map and tools for planning in 2022.

A.2.4.2 Financial incentives for district heat production using RES

The PaM is an active support policy in the form of financial incentives. It was introduced by the Slovenian Energy Act EZ-1 in 2007 and is still being implemented via multiple instruments. The responsible Ministry for the implementation of this PaM is the Slovenian Ministry of Infrastructure, which is in charge of designing and issuing the respective public tenders. The PaM is cross-sectoral and targets different groups of stakeholders via different instruments. Also, the funding of the PaM is coming from different sources, both national budget and EU funds.

The three key instruments are listed in Table 62 below and can be distinguished by their target groups, the scale of funding provided, eligible purposes and source of financing. Under EU cohesion policy, funding for the instrument is planned under the priority axis "sustainable consumption and production of energy and smart grids" (co-financed by national budget and cohesion funds). Eligible for co-financing (35% of total investment costs for large companies, 45% for medium-sized enterprises and 55% for small businesses and micro businesses) are investments in new RES district heating systems as well as the expansion or adaptation of existing district heating systems. Funding for the development of district heating systems using RES is also available under the Rural Development Programme (co-financed by national budget and the European agricultural fund for rural development EAFRD). Lastly, the Slovenian Eco Fund provides additional incentives. We selected the instruments "Encouraging the development of district heating to RES systems within the Operational Programme for the Implementation of the EU Cohesion Policy" and "Financial incentives of the Eco Fund for the sustainable development of district heating systems" for further analysis due to their importance and the availability of data and evaluations. While the Operational Programme for the implementation of the EU cohesion policy supports large-scale installations with the help of co-financed grants, the Eco Fund targets primarily households and offers them loans with favourable interest rates. The sub-instrument "Encouraging the development of RES district heating systems within the Rural Development Programme" targets small agricultural holdings and SMEs in rural areas (settlements of less than 5,000 inhabitants). The first call was published in 2020, but no data on it are available yet, hence it has not been selected for further analysis.

Table 62: Relevant and selected policy instruments for the PaM Financial incentives for district heat production using RES

PaM	Associated policy instrument(s)	Legal basis
Financial incentives for district heat production using renewable energy sources	Encouraging the development of DH to RES systems within the Operational Programme for the Implementation of the EU Cohesion Policy Encouraging the development of RES DH systems within the Rural Development Programme Financial incentives of the Eco Fund for the sustainable development of DH systems	Energetski zakon – EZ-1 (Uradni list RS, št. 17/14 z dne 7. 3. 2014)

Source: own compilation, Fraunhofer ISI

Table 63 summarises the available evaluations for the PaM. As it was not possible to find any ex-ante evaluations for the PaM, we had to rely on the ex-ante assessment and impacts given in Slovenia's 2019 PaM report. No new projections were provided in the country's 2021 PaM reporting. A comprehensive background study on the NECP is available (EIMV 2019), but it does not look into projected impacts on a PaM level. Also, there are no background studies of the Slovenian 2019 PaM reports available.

Ex-post evaluations were conducted in the framework of the LIFE project ClimatePath2050 (Reference: LIFE16 GIC/SI/000043) "Slovenian Path Towards the Mid-Century Climate Target". We selected Česen et al. (2020) as the most comprehensive and up-to-date ex-post evaluation for the PaM, however, Merše et al. (2018) is considered in addition, as it contains important observations and qualitative remarks on both instruments as well as the situation of the district heating sector in Slovenia in general.

Table 63: Available and selected ex-ante and ex-post evaluations for the PaM Financial incentives for district heat production using RES

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
Financial incentives for district heat production using renewable energy sources	**No ex-ante evaluation available: Slovenian 2019 PaM report considered in lieu thereof**	**Česen et al. (2020): Podnebno ogledalo 2020, Zvezek 5: Ostali sektorji, končno poročilo. [The Third Climate Action Mirror 2020 and Accompanying Reports, Part 5: Other Sectors, final report].** Merše et al. (2018): Podnebno ogledalo 2018, Zvezek 6: Ukrepi v središču - Spodbujanje sistemov daljinskega ogrevanja, končno poročilo. [The First Climate Action Mirror 2018 and Accompanying Reports, Part 6: The Measure in Focus - Promotion of District Heating, final report].

The evaluations that were selected for an in-depth assessment are shown in bold font.

Source: own compilation, Fraunhofer ISI

Results from the ex-ante evaluation

Comparable with the ex-ante evaluation, we considered Slovenia's 2019 PaM report, which shows a cumulated effect for all PaMs contributing to the promotion of district heating from RES and CHP with high efficiency. This means that the effects in terms of GHG emissions reductions are aggregated for the two PaMs discussed for the Slovenian NECP, "Obligatory Share of Heat from RES, CHP and Waste Heat" and "Financial incentives for district heat production using RES". It is thus not clear how much each of the two PaMs contributes to the projected emission reductions. Please see the text in Annex A.2.4.1 for further explanations and Table 65 for numerical results. No other costs and benefits of the PaM are calculated or indicated. The methodology of calculation is unclear.

Table 64: Target contributions of the PaM Financial incentives for district heat production using RES according to the 2019 PaM report

National targets and contributions	Evaluation period	2025	2030	Reference case and year
Reduction of GHG emissions [kt CO_2e]	n/a	68	114	n/a
Increase of RES consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of final energy consumption [ktoe]	n/a	n/a	n/a	n/a

Source: own compilation, Fraunhofer ISI

Results from the ex-post evaluation

Within the scope of the public tenders for RES district heating systems, four calls have already been published (2016, 2017, 2019 and 2021) under the PaM "Financial incentives for district heat production using renewable energy sources". By the end of 2019, applicants completed 14 projects and another four projects, which received a total of 5.9 million EUR, were in the process of implementation. Slovenia's 2020 PaM report projects the total increase in RES production of these 18 projects to the amount of 21.4 GWh. The first three calls made available a total of 3.9 million EUR of grants, which were not exploited. According to Česen et al. (2020), each of the projects completed in 2019 achieved an annual increase in energy production from RES amounting to 2.9 GWh and an annual CO_2 emission reduction of 0.8 kt CO_2. Between 2020 and 2021, applicants finalised another four projects, which are projected to lead to an annual increase in energy production from RES amounting to 2.5 GWh and CO_2 savings of 0.9 kt CO_2 per annum.

The second instrument, "Financial incentives of the Eco Fund for the sustainable development of district heating systems" is performing below expectations in terms of application numbers. In 2019, the instrument financed seven connections to district heating systems at household level with a total amount of 49,000 EUR and supported seven additional project applications from the public and business sectors with a total of 43,000 EUR. According to Česen et al. (2020), each of these projects achieved an annual increase in energy production from RES amounting to 1 GWh and an annual CO_2 emission reduction of 0.2 kt CO_2.

Table 65: Target contributions of the PaM Financial incentives for district heat production using RES according to the ex-post evaluation

National targets and contributions	2016-2019	2017	2019	Reference case and year
Reduction of GHG emissions [kt CO_2]	46.2	11.2	12.6	n/a
Increase of RES consumption [ktoe] [25]	12.65	3.01	3.61	n/a

[25] Converted from GWh.

National targets and contributions	2016-2019	2017	2019	Reference case and year
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of final energy consumption [ktoe]	n/a	… n/a	n/a	n/a

Source: own calculation and aggregation of data based on Česen et al (2020)

As for the public tenders for RES district heating systems financed under cohesion policy, the instrument is described as cost-efficient (15 EUR/tonne CO_2 abated). Additional positive side effects are mentioned, such as new jobs and the provision of local energy supply, but not described in detail (Merše et al. 2018).

Comparison between the ex-ante and ex-post evaluations and with the NECP

Given the aggregated nature of the ex-ante assessment as well as the large discrepancy in timeframes looked at, an assessment of the plausibility of the ex-ante evaluation is not possible. In order to compare values, one would at least need more detail on the ex-ante assessment, its underlying assumptions and the methodology used. Overall, the budget earmarked for this PaM has not been exploited in the first periods, the reasons for this should be analysed thoroughly as well. Another small limitation is that the ex-ante values are calculated in kt CO_2eq, while ex-post GHG emission reductions are given in kt CO_2 only. This, however, should not represent a big problem as it seems plausible that the ex-ante evaluation focused on CO_2 without considering any other types of emissions.

A.2.5 Overview of number of identified evaluations

Table 66: Number of evaluations per RES PaM and content

MS	PaM [26]	Ex-post	GHG share	EE share	RES share	SEI share	Other share	Ex-ante	GHG share	EE share	RES share	SEI share	Other share
DE	6	2	100%	100%	100%	0%	50%	2	0%	50%	0%	0%	0%
DE	7	0						2	50%	0%	0%	0%	0%
FR	8	1	100%	0%	100%	100%	100%	1	100%	0%	100%	100%	100%
FR	9	2	50%	0%	0%	50%	50%	1	100%	0%	0%	100%	100%
SI	10	1	0%	0%	0%	0%	0%	1	100%	0%	0%	0%	0%
SI	11	1	100%	0%	100%	0%	0%	1	100%	0%	0%	0%	0%
All		**7**	**71%**	**29%**	**57%**	**29%**	**43%**	**8**	**63%**	**13%**	**13%**	**25%**	**25%**

PaM = policy and measure, MS = Member State. DE = Germany, FR = France, SI = Slovenia, GHG = greenhouse gas emissions reductions, EE = increase of energy effciency, RES = increase of renewables share, SEI = socio-economic impacts

Source: own calculation, Fraunhofer ISI

[26] 6 = Market incentive programme, 7 = Heating network systems 4.0 programme, 8 = Heat Fund (Fonds Chaleur), 9 = Energy Efficiency obligation scheme (Certificats d'économies d'énergie), 10 = Obligatory share of heat from renewable energy sources, high-efficiency cogeneration and waste heat in district heating systems, 11 = Financial incentives for district heat production using renewable energy sources

Table 66 shows an overview of the identified evaluations under the Renewable H&C topic per PaM and MS. The table shows the number of identified ex-post and ex-ante evaluations and the share of evaluations reporting GHG emission reductions, energy consumption reductions, impact on renewable energy development, and socio-economic factors.

A.2.6 Conflicts and synergies of expanding renewable heating and cooling with the reduction of air pollution

A.2.6.1 Literature review of the potential conflicts and synergies

In general, it can be said that the mitigation of air pollution and the role that RES can play in it is a prolific field of research. Historically, however, the focus has been put on the developing world. This is illustrated by the large and still growing body of literature focusing on air pollution caused by heating and cooking in countries and regions where air quality continues to be a major concern and threat to health, investigating the role of conventional and renewable energy sources in the abatement of said pollution, see for example McGranahan & Murray (2003) for a comprehensive review on the (public) health effects and impacts of air pollution in the developing world as well as a literature review. As for the EU, this general pattern also holds true which means that areas with higher concentrations of pollutants are more likely to be studied than areas where air quality is less of a concern. Generally speaking, conflicts and synergies of expanding renewable heating and cooling with the reduction of air pollution do not play a major role in the literature on renewable heating and cooling in the European Union, but are addressed as side considerations. There is, however, a considerable literature discussing the health and environmental effects of biomass combustion in both households and industry as well as the significance of different types of biomass in the future European bioeconomy, see e.g. Scarlat et al. (2015) or Mandley et al. (2022). As for CHP and cooling, heating, and power (CCHP) systems, there is also a vast literature on health effects of various systems and fuels, with particular emphasis on urban environments as these tend to be close to densely populated areas. While the recently emerged literature on combined heat and power dispatch focuses on the economic performance of CHP plants and minimising their costs of operations, there is also an emergent strand of that literature that factors the minimisation of environmental and health effects into this complex optimisation problem by increasing the shares of RES, see e.g. Golmohamadi et al. (2021) or Jo et al. (2021).

The goal of reducing air pollution is seen as a driver of the uptake of renewable energy sources (e.g. Engelken et al. 2016), albeit it is usually seen as more of a co-benefit while the primary goal is to gain larger independency from fossil fuels and reduce GHG emissions (Sovacool et al. 2020). The general causal relationship assumed is a synergistic one, i.e. switching to renewable energy sources for heating and cooling contributes to decreasing GHG emissions all while increasing quality of air due to lower levels of other pollutants emitted. This holds especially true for geothermal and solar thermal energy as well as heat pumps which are most effective in curbing emissions and improving quality of ambient and indoor air. However, outcomes can be mixed as some renewable fuels have higher emissions factors with regards to specific pollutants than the fuel that they are replacing. This is particularly the case if the renewable energy source that replaces the combustion of fossil fuels for heating and cooling is biomass. In the European Union, growing levels of renewable energy sources in heating and cooling did contribute to a significant decrease in the emissions of sulphur oxides (SOx) and nitrogen oxides (NOx), while at the same time increasing primary particulate matter (PM) emissions, largely caused by the higher emissions due to the increase in the combustion of solid biomass (Breitschopf et al. 2021). These

trade-offs exist across the EU and are especially widespread at the household-level. They can be expected to be less prevalent for industry due to more stringent regulation, in turn leading to lower emission intensity factors (Breitschopf et al. 2021). Overall, the emissions of pollutants from households' biomass-based heating depend greatly on the type of heating system installed, its usage patterns as well as the type of biomass used.

When it comes to choosing renewable heating and cooling technologies, local attitudes, community acceptance and regional preferences play a major role and shape the way that associated costs and benefits are viewed (van der Schoor et al. 2015). A number of recent studies give insights into the various trade-offs as well as barriers and drivers in decision-making on renewable energy sources for heating and cooling at a local level and how these interact with air pollution concerns (e.g. Chassein et al. 2017). They show that the characteristics of the local area in question, such as population density, degree of urbanisation and availability of different types of resources, including biomass, matters greatly. Preferences for biomass, for instance, are often closely linked to local livelihood as shown for example by Krajnc et al. (2007) for selected forestry-dominated regions in Slovenia and Croatia. "Local" biomass is perceived differently as compared to non-endemic biomass, e.g. imported wood pellets. On a more general level, this is confirmed by (Zaunbrecher et al. 2016) who show that preferences for energy sources vary from country to country and also depend on local and regional availability and price patterns which in turn influence acceptance. The support for renewable energy over fossil fuels and socio-economic considerations might outweigh concerns over increases in local air pollution levels and decreases in air quality. This is for example of relevance when it comes to the significance of certain local value chains for the region's livelihood, the promotion of decentralised energy or heat supply or the establishment of local heat networks and maintaining a degree of self-sufficiency in heat production. These considerations are especially valid for biomass as a source for heating and the associated views will then not only permeate individual household decisions, but taken all together they will form the basis for the support or non-support of local communities towards distributed heating systems and the sources used to power it.

According to a study performed by Material Economics (2021) the future uses of biomass and bioenergy are likely to substantially differ from the currently incentivised short-term increases in RES shares in H&C (and power generation) and might instead occupy dedicated "niches". For example, the co-generation of heat and power may continue to play a certain role in specific areas, especially when it makes use of existing infrastructure, e.g. for DH, or is coupled with additional benefits and revenue streams, most notably waste disposal. In buildings, biomass-powered systems are likely to be crowded out by electrification, heat pumps, other renewable sources as well as the increased use of hydrogen and excess heat with positive effects on air quality. As for industrial uses of biomass-based heat, there might be a use-case in specific areas. For low-temperature heat, bio-based options might be a fit if they valorise waste streams. Alternatively, hybrid solutions where biomass could be used as a "fall-back option" to provide bridging solutions to counteract temporal spikes in electricity prices could be attractive. For high-temperature heat in industry, biomass might remain more competitive, depending on the costs of alternative options, such as hydrogen or direct electrification.

In addition to biomass, another vividly discussed subject in the literature is the upgrading and retrofitting of existing district heating and cooling networks as well as investing in the next generation of district heating systems. District heating systems exist in many different forms in the European Union, generally characterised by a great diversity with regards to technologies and sources of energy. In many countries, their potential to contribute to climate change mitigation and air pollution reduction is large and at present underexploited (Sayegh et al.

2017). Countries such as Poland have an enormous potential to reap as they have widespread district heating networks, dating from communist times, but still largely run on fossil fuels, predominantly coal (Wojdyga et al. 2017).

Overall, there is consensus that GHG emissions reduction and air pollution have to be addressed simultaneously and in an integrated manner. Policy-makers thus need to make informed choices, being aware of the trade-offs inherent to the various options and set incentives that tick all boxes.

A.2.6.2 How the selected NECPs and the evaluated instruments address the conflicts and synergies

Overall, none of the three NECPs addresses the mentioned conflicts and synergies at PaM level, but all NECPs include projections and general effects with regards to air pollutants and the increase of RES in H&C. As for the analysed evaluations, conflicts and synergies do not play a major role either, however, some of the evaluations do describe interdependencies between the PaMs and air pollution.

In the German NECP, conflicts and synergies with the reduction of air pollution are not addressed at the level of individual PaMs, but general effects of the existing as well as planned PaMs are described in Section 5.2 on macroeconomic and other aspects. Projections for individual air pollutants are shown in Section 5.1. The evaluations considered for the MAP and the Heating Networks 4.0 programme do not take into account conflicts and synergies with air pollution in a systematic way. Conflicts and synergies are, however, factored in at instrument and design-element level directly. In particular, the MAP lists a range of prerequisites to receive financial support for certain technologies to make sure that minimum standards in terms of air quality are complied with, most notably for biomass-powered installations. A list of heating systems and models, sorted by manufacturer, eligible to receive financial support can be consulted online[27]. In addition, the measurements for pollutants emitted have to be proven by an official confirmation issued by a chimney sweep.

Also the French NECP includes general considerations on the effects of the existing and planned PaMs on air pollution, pointing out the importance of avoiding potential adverse impacts, such as for example increased air pollution due to increased use of wood (see Section 1.1.2). While the French NECP does not address synergies and conflicts between the promotion of renewable energy sources for heating and cooling and air pollution in a specific section, it does address the issue for biomass in particular. As one of the central measures, a national awareness campaign to sensitivise the public regarding the existing trade-offs when it comes to the combustion of biomass is suggested. Also, the importance of emissions control is underscored as well as the need for updating emission factors for biomass-powered systems, including smaller industry-level boilers as well as biomass plants in district heating systems, to take into account new, improved filtering technologies that have been developed. The topic is also covered as part of the French national biomass strategy (Stratégie Nationale de Mobilisation de la Biomasse[28]) which was published in 2018. Furthermore, similar considerations also apply to wider bioenergy applications with the PaM of biomass co-generation auctions including air quality as part of the selection criteria. The evaluation of the Heat Fund mentions likely positive effects on reducing air pollution, however, this is not substantiated or stemmed from actual data.

[27] See www.bafa.de/DE/Energie/Heizen_mit_Erneuerbaren_Energien/Foerdervoraussetzungen/foerdervoraussetzungen_node.html (no longer applicable)

[28] See Stratégie Nationale de Mobilisation de la Biomasse.pdf (ecologie.gouv.fr)

Lastly, also the Slovenian NECP addresses the trade-off between instruments and goals with regards to the expansion of renewables and air pollution mostly when it comes to biomass. These are particularly also addressed in the annex regarding additional environmental mitigation measures and policies. For example, biomass utilisation is subject to being below the limits and targets stipulated in the Regulation on ambient air quality. The use of locally available biomass from wood shall be promoted for larger systems so as to allow for higher efficiency and lower emissions. In addition to those effects specific to biomass, general effects of the existing and planned PaMs on air pollution are covered in Section 5.2.2 regarding environmental and social effects. It is pointed out that meeting EU air quality requirements can be an obstacle to unfolding the full potential of biomass to contribute to Slovenia meeting its renewable energy targets. As for the evaluations of the two analysed Slovenian PaMs, air pollution is mentioned as a side consideration, but no detail is provided.

A.3 Energy-efficient buildings

The topic area of energy-efficient buildings is characterised by the two major components, which determine the energy and climate impact of buildings. The first component, which determines the useful energy demand, is the building envelope. The useful energy is provided by the second component, the heating system, which converts final energy into useful energy. The efficiency of this conversion process determines the final energy demand of a building.

Looking at new buildings, usually both dimensions are considered in an integrated approach in the planning process as required by the European Energy Performance of Building Directives (EBPD) and its national implementations. In addition to this integrated framework of the EBPD, the performance of the heating system is subject to the eco-design regulation, which sets minimum energy performance standards (MEPS) for the individual products.

PaMs targeting the energy efficiency of new buildings are usually in line with the integrated approach; e.g. funding schemes fostering energy efficient buildings cover both, the building envelope as well as the heating system to achieve an optimal result.

In the case of renovations, the integrated approach is less common. Renovation projects very often only cover one component of the building such as roofs, windows or heating systems.

For renovations, the PaMs reflect the different situation of the renovation market. Although there are measures with a broader focus, oftentimes they are targeted at individual measures; this occurs in particular when measures target the heating systems, as the implementation barriers are rather low in that domain.

A.3.1 Scientific insights in socio-economic constraints, potential hurdles and target-group-related factors for policy instruments targeting energy-efficient buildings

In the planning, implementation and adoption of policies aiming at energy efficiency in buildings, socio-economic factors largely set the framework for the decision-making progress. Policy-makers are socially embedded in such a manner that economic interests as well as the resident's willingness to adopt new measures due to soft factors such as personal values strongly impact how policies are designed (e.g. Bagaini et al. 2020; März 2018; Ratinen 2019). The gap between energy efficiency policies potential and effective achievement of using this potential for energy efficiency (eg. Schleich 2004; Sorrell et al. 2004) needs to be addressed by identifying barriers and drivers to adoption and include them in policy-making processes (Bagaini et al. 2020).

The most relevant actor groups in the field of energy efficiency in buildings are those deciding on and investing in refurbishments, policy-makers and those offering the needed services (Engelmann et al. 2021; Vlada Republike Slovenje 2017). Homeowners, owners of buildings, building managers, households and investors in general are important groups on the demand side. On the supply side, stakeholders involved in refurbishment processes, e.g. companies performing the renovations, and construction stakeholders (e.g. architects, engineers, technicians or site managers) should be addressed through the relevant PaMs in the topic of energy efficient buildings. Further important groups are actors who can be influential, such as teachers in training programmes and those who organise the education on construction and renovation. These actor groups need to be considered when designing PaMs in this topic field as they can be crucial to the implementation of concrete measures as well as to overcoming hurdles which can be directly related to the actors involved (Engelmann et al. 2021).

Energy-efficiency in buildings plays a major role in the heat transition, next to the use of renewable heating and cooling technologies (see chapter A.2). Engelmann et al. (2021) identify four different fields of action in the heat transition, namely a) an increased refurbishment rate and intensity, b) switch to RE-based heat supply systems (see chapter 3.2), c) ensuring the effectiveness of policies through effective adjustments with regard to their target compatibility and the relevant framework conditions and d) reducing social hardships (see also chapter 3.1.6). These fields of action represent the different dimensions that policies targeting energy-efficiency in buildings need to address.

Increasing the refurbishment rate as well as the refurbishment intensity (referring to the energy requirements for the refurbishment of buildings) is the aim of a variety of PaMs in Germany and other countries (BMWi 2020b). Ensuring these PaM's effectiveness, however, stands against a large number of factors currently impeding the heat transition and as such the effectiveness of PaMs and the adoption of energy efficiency in buildings. Such barriers can affect implementation processes on different levels. Bagaini et al. (2020) differentiate between economic, institutional and behavioural barriers. Economic barriers are related to accessing a credit or funding and to the risk of the investment. Institutional barriers can refer to guidelines in the governance, political obstruction and hurdles in policy coordination. Behavioural barriers refer to perception, awareness and information as well as to attitudes, e. g. because of a lack of trust or social group interactions. In the case of energy efficiency in buildings, economic barriers concerning planning and investment security are connected to different aspects, which are further discussed below.

One of the most important factors currently discussed is the shortage of qualified work force in construction and the refurbishment processes. While studies find that increasing sustainability and the adoption of new technologies create employment throughout the EU Brucker Juricic et al. 2021; Czako 2020; Fragkos et al. 2018 find skilled labour shortage to be an issue especially in the construction sector. In Germany, the shortage in 2021 is identified to be the worst in the past three decades and in all economic sectors (Müller 2021). In the context of the construction sector, a possible enabler could be a PaM addressing younger generations and encouraging entering the relevant professional fields. Other obstacles that add to the difficulties in implementing refurbishing measures for the relevant groups of actors are the lack of materials and resources, although the market for most materials is already recovering (Leiss et al. 2022), and the lack of technical knowledge concerning new technologies and methods (Berneiser et al. 2021). While the first is considered to be limited time wise, the latter is largely related to the shortage of new staff as well as education within the field. Education is often shaped by tradition and the knowledge the older professionals transfer into the business, which often proves to be a hurdle to entering new knowledge in the field (Engelmann et al. 2021). Also, Czako (2020) finds

a general mismatch of skills with offered skills and needed skills diverging. Hence a driver to match the hurdle could be to increase the technical knowledge, train building professionals and, as a result, reduce scepticism and insecurities towards new technologies, materials and processes (BPIE 2017a; Polzin et al. 2018). Another aspect to be considered is the complexity of application processes and processing periods which at times can be very long and complicated (Engelmann et al. 2021; Vlada Republike Slovenje 2017). Planning under such circumstances can be challenging both for investors and owners as well as for actors on the operational side.

Furthermore, limited payback expectations in general reduce the willingness to invest large amounts of money, in particular if private investors cannot assess whether the investment will pay off (Berneiser et al. 2021; Engelmann et al. 2021). Next to that aspect, homeowners often do not have the financial resources to invest in refurbishment measures (Hrovatin et al. 2018). Thus, an important possible enabler is the financial support through funding and subsidies, which needs to be easily accessible, and a calculability of the refurbishment's budget (BPIE 2017b; Polzin et al. 2018). These factors should be addressed when developing PaMs, particularly by providing more information on the financial benefits and the different funding options.

The design of policy measures is an institutional factor, but it can also directly cause or counteract economic obstacles. Overall, legal and administrative hurdles need to be considered, e.g., competencies of administrative staff (Vlada Republike Slovenje 2008), but also that financial incentives are partly only directed towards the purchase of established technologies (Engelmann et al. 2021; Vlada Republike Slovenje 2008). The tax incentives for energy-related building renovations in Germany (see in A.3.2.1) is a funding measure that can be used only for self-occupied property, meaning investing in the refurbishment of rental properties is less attractive. This aspect is closely linked to split incentives, due to which landlords tend to underinvest in energy efficiency measures in buildings and renters use more energy overall than people in self-used properties (Bagaini et al. 2020; Femenías et al. 2018; Melvin 2018). In this context, energy poverty, in particular on the tenant's side needs to be considered as well (Bagaini et al. 2020). Another aspect to consider is whether the PaM or the policy mix also provides the desired investment incentives or rather incentivises the financing of smaller-scale and low-cost measures, as Engelmann et al. (2021) found out for the tax incentives in Germany (see Annex A.3.2.1).

Last, behavioural aspects affect the implementation of energy efficiency measures in buildings. A lack of knowledge concerning possible energy efficiency measures, the own energy consumption as well as the actual status of a building can hinder the relevant actors of even thinking about or deciding for refurbishment measures (Berneiser et al. 2021; Palm et al. 2020; Persson et al. 2015; Vlada Republike Slovenje 2008). Another relevant behavioural aspect to bear in mind is the option of reduced energy savings relative to the refurbishment measures due to rebound effects. Rebound effects refer to an increased energy consumption due to reduced costs and increased energy efficiency in a building. This can e.g. concern a less energy efficient use of applications, the implementation of energy efficient applications, which would not have been used before or differently, less thoughtful ventilation habits after refurbishments in a building (Schleich et al. 2021; Aydin et al. 2017; adelphi et al. 2015; Schröder et al. 2018). These rebound effects can pose a large barrier to the success of energy efficiency PaMs. In a comparative analysis, adelphi et al. (2015) found the rebound effect in buildings to be estimated between 5% and 70% differing between the studies. The authors estimated energy efficiency gains in buildings to be reduced up to 20% by rebound effects.

Furthermore, possible lock-in effects are an overall aspect relevant to sustainability transitions. Seto et al. (2016) show the "carbon lock-in" as a form of path dependency based on the fact that

physical, economic and social restrictions in complex systems mutually reinforce each other and limit change. Concerning energy-efficiency in buildings, economies of scale and sunk costs in the form of high investment and fixed costs of fossil technologies create an incentive to continue using the established technology. This perpetuates conventional technologies. On the consumer side, such path-dependency can be reinforced due to information asymmetries. The more widespread the knowledge about how a technology works, the more inclined consumers are to adopt it. However, expectations about future developments determine user behaviour, so that technologies perceived as promising are more likely to be used. The resulting path dependencies make the diffusion of new technologies more difficult, but with a corresponding degree of diffusion, they can tip into the opposite direction (Seto et al. 2016).

A.3.2 German NECP

The German NECP addresses energy-efficient buildings explicitly in dedicated subsections clustered in the sections on energy efficiency (2.2, 3.2). Goals for energy efficiency in buildings are set in the Federal Government's Energy Concept, where Germany set the target of reducing GHG emissions by at least 55% in 2030 compared to 1990. In accordance with the long-term renovation strategy pursuant to Article 2a of the EU Directive on the energy performance of buildings, emissions in the building sector are limited to 67 Mt CO_2eq in 2030 (70 Mt CO_2eq before the amendment of the Climate Protection Act in 2021). Further goals are based on the overall national energy efficiency goal and the goal of increasing renewable energy in the heating and cooling sector. The latter goal is also related to the Energy Efficiency Strategy for Buildings, the national key strategy for the topic and wherein further targets are defined. Pursuant to Article 5 EED (2012/27/EU), at least 3% of the building stock not meeting the minimum requirements for energy performance must be renovated each year. Energy performance is set to be reduced to 2000 PJ of non-renewable primary energy consumption in 2030 as opposed to 4,400 PJ in 2008. The NECP report sets energy performance (non-renewable primary energy consumption) as the first indicator for energy efficiency overall. Further indicators might be configured or emerge as a result of the continuation of the buildings database of the Institute for Housing and Environment (IWU 2016) providing new approaches to the classification of energy performance certificates and the heating label. Out of 20 PaMs for energy efficiency in the NECP, 18 are directly linked to energy-efficient buildings (Section 3.2.ii).

The key PaMs for energy-efficient buildings are listed in Table 67. The two PaMs selected for more detailed analysis were based on their contributions to the reduction of GHG emissions and their prominence in the German climate policy. The tax incentives for energy-related building renovations and the federal funding for efficient buildings are two central instruments for incentivising renovations and aiming at higher energy efficiency standards in buildings as the amount of funding is also dependent on the implemented standards. The Building Energy Act, which is the new legal basis for energy-efficient buildings and renovations in Germany, is succeeding and merging different preceding laws[29]. It was implemented in November 2020 and is now the most crucial law for the focus topic. Another important PaM is the funding for serial renovation work to realise approaches to serial renovation, which were developed and tested in pilot projects beforehand. The instrument aims at higher standards of quality for renovations as well as shorter renovation times.

[29] The Building Energy Act (GEG) merges the Energy Saving Act (Energieeinsparungsgesetz, EnEG), the Energy Saving Ordinance (Energieeinsparverordnung, EnEV) and the Renewable Energies Heat Act (Erneuerbare-Energien-Wärmegesetz, EEWärmeG).

Table 67: Key PaMs under the focus topic "Energy Efficient Buildings" in the German NECP

Name of PaM	Short description	Selected for evaluation?
Tax incentives for energy-related building renovations	Tax reductions for renovation for home owners (in case of owner-occupation)	yes
Federal funding for efficient buildings/Federal Government's CO_2 Building Modernisation Programme	Federal funding for efficient buildings including investment grants as well as an oil heating system replacement bonus	yes
Buildings Energy Act (GEG)	Coordinated body of rules for the energy requirements for new and existing buildings and for the use of renewable energies for provision of heating and cooling in buildings.	no
Funding of serial renovation work	Support of the industrial prefabrication of facade and roof elements and standardised installation of systems technology	no

Source: own compilation, Fraunhofer ISI

A.3.2.1 Tax incentives for energy-related building renovations

The "Tax incentives for energy related building renovations" is a national key PaM for renovation. It is an active support policy which provides financial support to homeowners when investing in renovating their homes. It is an instrument in itself, hence, no further selection was necessary (see Table 68). It was implemented in 2021 by the Federal Ministry of Finance and can be used for investments already made as of 2020. It mainly addresses energy savings in residential buildings and CO_2 emissions reductions and targets private persons including households. Companies and public authorities are excluded from the PaM. Although still new, the tax incentive is considered to be an important instrument as it provides an easier way of financial returns compared to applying for a grant or a loan. 20% of the sum of the investments can be written off over three years via the tax return with a maximum of 40.000 EUR. Reimbursement thus follows from one year after the expenditure has been incurred. Owners face less insecurities about the subsidy and are not dependent on bureaucratic structures as opposed to measures providing a loan or grant.

Table 68: Relevant and selected policy instruments for the PaM "Tax incentives for energy-related building renovations"

Selected PaM	Associated policy instrument(s)	Legal basis
Tax incentives for energy-related building renovations	Tax incentives for energy-related building renovations	Energetische Sanierungsmaßnahmen-Verordnung - ESanMV (Energy-related Renovation Measures Ordinance)

Source: own compilation, Fraunhofer ISI

For the instrument, three evaluations were conducted so far (Öko-Institut et al. 2020; Prognos et al. 2020; Prognos et al. 2021). Only two of them actually assess the impact of the PaM in detail.

Since the instrument was implemented only in 2021, no ex-post evaluation could be conducted yet; instead, an ex-post evaluation for a similar instrument in France was used (namely Domergue et al. 2018). The "Energy transition tax credit" (CITE) is also a support policy providing financial support through tax reductions. As opposed to the German PaM it has been implemented in 2014 when it replaced another tax incentive instrument and is, as of 2021, substituted by a new instrument combining CITE and other instruments relevant to energy efficiency in the buildings sector.

The ex-ante evaluation refers directly to the NECP as the key data used for the assessment of energy use and GHG emissions reproduce the NECP scenario. The evaluation assesses the impacts of the different PaMs adopted in the German Climate Protection Programme 2030, on which the PaMs in the German NECP are based on; as such, the evaluation is explicitly linked to the NECP.

Table 69: Available and selected ex-ante and ex-post evaluations for the PaM "Tax incentives for energy-related building renovations"

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)*
Tax incentives for energy-related building renovations	**Prognos et al. (2020): Kurzgutachten zu Maßnahmen zur Zielerreichung 2030 zur Begleitung des Klimakabinetts. Short report on measures to achieve the 2030 target to accompany the Climate Cabinet.** Öko-Institut et al. (2020): Abschätzung der Treibhausgasminderungswirkung des Klimaschutzprogramms 2030 der Bundesregierung. Teilbericht des Projektes „THG-Projektion: Weiterentwicklung der Methoden und Umsetzung der EU-Effort Sharing Decision im Projektionsbericht 2019. Estimation of the greenhouse gas reduction impact of the German Federal Government's Climate Protection Programme 2030. Sub-report of the project "GHG Projection Prognos et al. (2021): Energiewirtschaftliche Projektionen und Folgeabschätzungen 2030/2050. Gesamtdokumentation der Szenarien. Bericht im Auftrag des Bundesministeriums für Wirtschaft und Energie. Energy industry Projections and Impact Assessments 2030/2050. Overall documentation of the scenarios. Report commissioned by the Federal Ministry for Economic Affairs and Energy (BMWi).	**France:Domergue et al. (2018): Étude d'impact du crédit d'impôt pour la transition énergétique (CITE). Impact study of the tax credit for energy transition (CITE).**

The evaluations that were selected for an in-depth assessment are shown in bold font. * No ex-post evaluation for the PaM were available so that ex-post evaluations of similar PaMs in other MS were considered.
Source: own compilation, Fraunhofer ISI

Results from the ex-ante evaluation

Prognos et al. (2020) evaluate the different measures of the Climate Protection Programme for reaching the 2030 targets. The Federal Ministry for Economic Affairs and Energy commissioned the assessment and is, as a service in accordance with the framework contract for advising Department II of the Federal Ministry for Economic Affairs and Energy, part of a regular impact

assessment. The evaluation does not follow any specific guidelines or protocol. The authors analyse the instruments quantitatively and qualitatively and describe their methods in great detail, explaining the different steps carried out and providing an overview of the models used and their characteristics. The evaluation period covers 11 years from 2020 to 2030.

The evaluation establishes a link between the observed impacts and the policy instrument and concludes that, based on the underlying assumptions, the tax subsidy results in annual CO_2 savings of 0.13 $MtCO_2eq$. Over the period 2020 to 2030, the savings add up to 1.42 $MtCO_2eq$ (see Table 70). The authors state that to meet these results, effective accompanying instruments are necessary to ensure that the assumed subsidy cases are actually achieved.

A deadweight effect is considered insofar as the tax incentive's contribution to the total savings are lower if it is modelled as part of a bundle of measures because it is assumed in the reference that some of the subsidised retrofits would take place anyway, but at a lower efficiency level. Rebound, substitution and leakage effects are not part of the analysis. By modelling the measures as part of a bundle and also qualitatively by considering different advantages and disadvantages, interactions with other measures have been assessed. Other effects that were considered are

- the additional source of funding and thus more budget introduced with the tax incentive (since the instrument is newly introduced and not an advanced version of an earlier instrument)
- tax psychological effects (tax reductions might help mobilise homeowners for whom grants and credits are not attractive)
- multiplier effect (mobilising more homeowners through new channels related to tax returns)
- a convenience factor is considered as making use of the tax incentive as application procedures as well as verification are considered to be easier than for existing investment support programmes
- the number of funding cases is seen as highly influenced by skilled worker shortage.

The authors describe the impact measurement, for which they use the gross accounting approach, and related assumptions in great detail. The evaluation happens in three steps (development of the total number of funding cases, distribution of funding cases among the various funding strands (BEG, tax incentive), CO_2 reduction effect and tax losses). The different effects that need to be considered are listed and justified. Qualitative explanations of different assumptions regarding individual instruments are given.

The authors rely on KfW and BAFA subsidy statistics as input data for the evaluation and provide a medium level of detail regarding the characteristics of the data base and a low level of detail with respect to the data collection process.

Contributions of the instrument to energy savings or the expansion of renewable energies are not assessed. The focus is on the reduction of GHG emissions, which are considered as cumulative reductions for the period between 2020 and 2030, based on constant annual reductions. Impacts of individual measures, such as renovation of the building envelope, are not considered. Only the impact of the instrument as whole is on the basis of the expected number of cases, assuming a constant number of cases per year.

Table 70: Target contributions of the PaM "Tax incentives for energy-related building renovations" according to the ex-ante evaluation

National targets and contributions	2020-2030	2025	2030	Reference case and year
Reduction of GHG emissions [kt CO_2]	1,420	130	130	Gross accounting
Increase of RES consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of final energy consumption [ktoe]	n/a	n/a	n/a	n/a

Source: own compilation, Fraunhofer ISI based on Prognos et al. (2020).

The ex-ante evaluation of the tax incentive includes a qualitative assessment of the relevance of the instrument to the current targets of the building sector in relation to other funding programmes. The instrument is considered to be able to mobilise homeowners who do not or cannot make use of existing support measures. Furthermore, the modernisation of heating systems today is considered to be a major determinant of emissions on 2050. This highlights the interactions between renewable heat and energy efficiency in buildings. In order to meet the targets for energy-efficient buildings, it is considered necessary to phase out support for fossil-fuel boilers (including in hybrid combination with a renewable energy system) in medium term, unless there is a decarbonisation option for fossil fuels in the next few years. This assessment implies that although the instrument is highly relevant, further changes in the conditions of the subsidies are needed to achieve the national targets.

The efficiency of the instrument is not assessed in the evaluation. Implementation and enforcement costs are considered quantitatively as corresponding to the reduced tax revenues to be expected. With 335 million EUR/a, the costs are a little higher than in the final adopted bill (Prognos AG et al. 2020). For the evaluation period of 2020 to 2030, cumulated costs of 3.7 billion Euro are expected. The evaluation does not mention any other categories.

For the evaluation the development of the funding cases for renovations in the building sector related to energy efficiency was updated based on the funding cases up to the year 2017., These funding cases had to be distributed to the two PaMs now providing subsidies for energy-efficiency related renovations in the building sector. Whereas preceding funding programmes are summarised in a new instrument ("Federal funding for efficient buildings") as of 2021, the tax incentives were newly introduced. In the evaluation, increased funding cases for different individual measures was assumed because of the increased funding budget for the federal funding for energy-efficient buildings (see Annex A.3.2.2) as well as the budget for the tax incentive and the amounts spent on different types of possible measures before. The assumptions were further supported by qualitative assumptions based on the effects described above. They are subject to considerable uncertainties, which must always be taken into account in ex-ante evaluations. In Prognos et al. (2020), the different considerations leading to the assumed numbers for each individual measure are explained in detail and as such can be considered to be comprehensible. Prognos et al. (2020) also assumed that homeowners will slightly prefer the tax incentive, because the simpler design of the tax incentive might at least in

some cases outweigh disadvantages such as the distribution of the costs over 3 years. Only when a higher funding rate is available by means of another instrument (the federal funding for efficient buildings), the authors assume a lower take-up of the tax incentives. As such, the assumed GHG emission reductions until 2030 seem plausible.

Results from the ex-post evaluation

Since the tax incentive for energy-related building renovations has only been implemented in 2021, no ex-post evaluation was available. For comparability, an ex-post evaluation of the similar instrument "Energy transition tax credit" (CITE) in France was analysed (Domergue et al. 2018). We conduct the comparison on a qualitative level, since the two are not identical and the conditions in both countries differ. A national authority commissioned the evaluation on an ad-hoc basis (General Commission for Sustainable Development[30]). It is unclear whether it followed any specific guidelines, but it was carried out under the supervision of the Green OAT Evaluation Board. It includes quantitative ex-post and ex-ante assessments, with the ex-ante assessment being a forward projection of the ex-post results. For the present analysis, only the ex-post assessment is considered.

The evaluation method is described in high detail and thus transparent and comprehensible. A link is established between the policy instrument and the observed impacts, namely reduced GHG emissions and energy savings. Additionality has been assessed by comparing scenarios with and without CITE. A rebound effect is considered, but not quantified, as it is only stated that it is taken into account by the model used for the impact assessment. Hence, it is unclear whether only direct or also indirect rebound effects are considered. As different scenarios are compared, in which CITE and other measures are differently considered, an interaction between different PaMs is considered at least indirectly. Furthermore, the evolution of energy prices is taken into account.

The evaluation uses baseline adjusted gross accounting. Different scenarios are compared (scenario without the measure, reference scenario in which the instrument is abolished after two years), but no explicit reference considering a deadweight effect is given. While the evaluation period spans from 2015 to 2050, the ex-post data is assessed only for 2015 and 2016. The authors applied a simulation model for the estimation of energy savings (Res-IRF Model of CIRED) and conducted target group surveys, which provided reliable data on the characteristics of energy classes and household profiles and behaviour. Unfortunately, the data basis and data collection are described only in low detail. A national authority, the Green OAT Evaluation Council[31], was involved in the evaluation process. The council's study team had the role of a reviewer and commented the results of the evaluators.

The instrument is found to be highly relevant for reducing energy use and GHG emissions in the buildings sector and thus for reaching French energy efficiency targets. Energy savings are assessed quantitatively. Although it is not clarified whether primary or final energy savings are assessed, the context and the national targets make it probable that the evaluation considers final energy consumption. In the evaluation for 2015 a reduction of 76.53 ktoe in final energy consumption is estimated, the energy reduction for both 2015 and 2016 is declared as 151.33 ktoe, which would mean slightly less savings in 2016 (74.8 ktoe). The GHG emission reductions for 2015 and 2016 are estimated to have been 120 kt CO_2eq in each year, thus 240 kt CO_2eq for both years (see Table 71).

[30] Commissariat Général au Développement Durable

[31] Conseil d'évaluation de l'OAT verte, OAT verte = green government debt securities.

Table 71: Target contributions of the PaM "Energy transition tax credit" according to the ex-post evaluation

National targets and contributions	2015-2016	2010	2015	Reference case and year
Reduction of GHG emissions [kt CO_2]	240	n/a	120	Counterfactual scenario with the instrument inactive
Increase of RES consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of final energy consumption [ktoe]	151.33	n/a	76.53	Counterfactual scenario with the instrument inactive

Source: own compilation, Fraunhofer ISI based on CGDD (2018).

Furthermore, implementation and enforcement costs have been considered as the actual costs as appearing in public statistics, amounting to 3.4 billion EUR for 2016 to 2017 (as they are considered to come into effect a year later with the tax revenues). Thus, the annual costs were 1.7 billion EUR. By using a cost-effectiveness analysis, the efficiency of the instrument was assessed without taking into account ancillary effects. The cost efficiency of energy savings is estimated to be at 20 EUR/MWh. The result is not rated as efficient or not though. The efficiency of GHG emissions reductions is estimated to be 240 EUR/t CO_2eq. The evaluation does not specify how effective the instrument is concerning GHG emissions reduction.

Moreover, the evaluation assesses the impact on air quality with results showing positive effects. The reduction of fine particles emissions is 22.5 kt (11.5 kt when the discount rate of 4.5% per year is applied) and the reduction of nitrogen oxides emissions is 7.5 kt (4.2 kt in discounted value) in the course of the evaluation period. In undiscounted and cumulative terms, this emission reduction represents approximately 13% and 27% of the nitrogen oxides and fine particles emissions produced by households in 2016 respectively (Domergue et al. 2018).

Comparison between the ex-ante and the ex-post evaluation and with the NECP

A conclusion about the plausibility of the ex-ante evaluation based on the ex-post evaluation is to be taken with caution, since the national targets and contexts differ, also in terms of accompanying measures. Final energy savings cannot be compared, as the ex-ante evaluation does not assess them. The GHG emissions reductions though show similarities. Domergue et al. (2018) estimate a reduction of 120 ktCO_2eq for 2015 and 2016 each. Prognos et al. (2020) expect annual reductions between 2020 and 2030 to be 130 ktCO_2eq. The methodologies seem comparable; both evaluations applied models, comparing different scenarios with and without the instrument. Both studies also used official statistics to find out whether the target groups of both instruments, i.e. households and private individuals, make use of the instruments. . However, in France, 65% of the citizens own houses whereas Germany has one of the highest rates of tenants in Europe (Statista 2020). Furthermore, in Germany investors can write off up to 20% (40,000 EUR being the upper limit) of the investment (Prognos AG (Prognos) et al. 2020) , compared to up to 30% in France (8,000 EUR being the upper limit per person and 16,000 EUR per couple) (Domergue and Vermont 2018; Prognos AG et al. 2020). Bearing in mind these differences and taking into account different sets of instruments, a comparison is difficult.

Considering that the tax incentive in Germany is a new instrument and changes in the funds provided for different measures in the buildings sector are probable, fluctuations in the emissions reductions are probable. Still, the estimated reductions seem plausible; firstly, in Germany the tax incentives and the federal funding for efficient buildings are complementary instruments. Secondly, higher investments, possibly aiming at higher efficiency levels in buildings, are funded in Germany. Seeing that also the federal funding for energy efficient buildings alone will not be able to reach the national GHG emissions reduction targets and the evaluators already stated that additional instruments would be necessary, the tax incentive is an important instrument on the way to reaching the targets. Still, those two will not be sufficient and it is clearly stated that additional instruments will be necessary (Prognos AG et al. 2020). Barriers to the realisation of the expected PaM impacts are addressed in Annex A.3.2.3.

In the German NECP, the cumulative final energy savings due to the tax incentive were expected to amount to 127.11 PJ (3,035.97 ktoe) for the period from 2021 to 2030, with 3 PJ (71.65 ktoe) in gross accounting and 2 PJ (47.77 ktoe) in net accounting per year. The values are in accordance with the 2019 PaM report. A comparison with the 2021 PaM report is given by adding up the former programmes, KfW, MAP and APEE, and comparing the sum with the sum of the estimated reductions from the federal funding for efficient buildings (3.3.2.2.) and the tax incentive. Although the values are similar, the values lie slightly below the 2019 estimations. This might be due to barriers in implementation and possibly changed framework data used in the assessment for the 2021 PaM report.

The ex-ante evaluation did not assess energy savings, but only GHG emissions reductions. However, seeing that the ex-ante estimations seem plausible when compared to the ex-post evaluation (even though if only for a similar French instrument), the annual estimations might be regarded as plausible. In that context, further ex-post evaluations as well as ex-ante evaluations considering energy savings might be necessary in order to be able to draw more reliable conclusions. Still, it is clear that the tax incentives for energy-related building renovations is part of a set of instruments with complementary impacts. As in terms of the funding process and amount of funding it can be more attractive than already existing PaMs, it may help mobilising more citizens to invest in renovations. Overall it contributes to the targets. However, the impacts expected in the NECP may not be achieved without the use of other instruments.

A.3.2.2 Federal funding for efficient buildings

The Federal Ministry for Economic Affairs and Energy implemented the federal funding for efficient buildings (BEG) in 2021, which integrates various previously separate funding strands: the existing funding scheme for renewable energies of the Market Incentive Programme (MAP), for energy efficiency in buildings of the Federal Government's CO_2 Building Modernisation (EBS) programme, of the Energy Efficiency Incentive Programme (APEE) and the Heating Optimisation Programme (HZO). The PaM is an active support policy that provides financial assistance in form of grants or loans through KfW and BAFA. It primarily addresses energy savings and expansion of renewables and CO_2 emissions reductions. The instrument targets industrial energy consumption, households and the public sector and as such companies (industrial, commercial, services, farmers), private individuals, e. g. households or members of the homeowner's associations, municipalities and other eligible parties such as non-profit organisations.

The design of the federal funding for efficient buildings facilitates the application for grants and credits and has a greater volume of funding than its predecessors. It is a key instrument for renovation in Germany and is already supposed to receive a considerable increase in funds. First

reports show that in the first year, it has been very well received (Expertenrat für Klimafragen 2021). Since the launch year of the PaM is 2021, we chose the "KfW programmes to financially support ambitious energy standards for new buildings and renovations" for the comparison of ex-post and ex-ante results with a focus on individual measures for renovations. The KfW programmes were part of the preceding federal government's CO_2 building modernisation programme the and is partly equivalent to the individual measures for renovation of the federal funding for efficient buildings (Table 72).

Table 72: Key policy instruments for the PaM "Federal funding for efficient buildings"

PaM	Associated policy instrument(s)	Legal basis
Federal funding for efficient buildings (BEG)	Federal funding for efficient buildings (BEG) - individual measures for renovation	Guideline for federal funding for efficient buildings - Individual Measures (BEG EM)[32]
Federal Government's CO_2 Building Modernisation Programme	KfW programmes to financially support ambitious energy standards for renovations	Energy Saving Order (EnEV)/Buildings Energy Act (GEG)

Source: own compilation, Fraunhofer ISI

Three ex-ante evaluations were conducted with respect to the instrument so far, (namely Prognos AG et al. 2020; Prognos AG et al. 2021; Öko-Institut et al. 2020). Only two of them actually assess the impact of the PaM in detail. As the instrument has just been implemented, the chosen ex-post evaluation assesses the impact of the "KfW programmes to financially support ambitious energy standards for new buildings and renovations", one of the instruments that was integrated into the the BEG. KfW commissioned on an annual basis ex-post evaluations in order to assess the impact of the instrument (IWU et al. 2016, 2018; Kuckshinrichs et al. 2018). We decided to further analyse IWU et al. (2018) because the study uses 2017 data like Prognos et al. (2020) for the baseline of its ex-ante evaluation. The ex-ante evaluation is explicitly linked to the NECP as the key data used for the assessment of energy use and GHG emissions directly relate to the NECP scenario. The evaluation assesses the impacts of PaMs decided upon in the German Climate Protection Programme 2030, which are also part of the PaM portfolio reported in the German NECP.

Table 73: Available and selected ex-ante and ex-post evaluations for the PaM "Federal funding for efficient buildings"

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
Federal funding for efficient buildings	**Prognos et al. (2020): Kurzgutachten zu Maßnahmen zur Zielerreichung 2030 zur Begleitung des Klimakabinetts. [Short report on measures to achieve the target 2030 to accompany the Climate Cabinet.]** Öko-Institut et al. (2020): Abschätzung der Treibhausgasminderungswirkung des Klimaschutzprogramms 2030 der Bundesregierung. Teilbericht des Projektes	-

[32] Guideline for Federal Funding for Efficient Buildings - Individual Measures, see https://www.bmwi.de/Redaktion/DE/Downloads/F/foerderrichtlinie-beg-em.pdf?__blob=publicationFile&v=4.

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
	„THG-Projektion: Weiterentwicklung der Methoden und Umsetzung der EU-Effort Sharing Decision im Projektionsbericht 2019". [Estimation of the greenhouse gas reduction impact of the German Federal Government's Climate Protection Programme 2030. Sub-report of the project "GHG projection: Further development of methods and implementation of the EU Effort Sharing Decision in the 2019 projection report".] Prognos et al. (2021): Energiewirtschaftliche Projektionen und Folgeabschätzungen 2030/2050. Gesamtdokumentation der Szenarien. Bericht im Auftrag des Bundesministeriums für Wirtschaft und Energie. [Energy industry projections and impact assessments 2030/2050. Overall documentation of the scenarios. Report commissioned by the Federal Ministry for Economic Affairs and Energy.]	
Federal Government's CO_2 Building Modernisation Programme	-	**IWU and Fraunhofer IFAM (2018): Monitoring der KfW-Programme "Energieeffizient Sanieren" und "Energieeffizient Bauen" 2017. [Monitoring of the KfW "Energy-efficient refurbishment" and "Energy-efficient construction" programmes 2017.]** Kuckshinrichs and Aniello (2018): Wirkungen der KfW-Programme „Energieeffizient Bauen", „Energieeffizient Sanieren", „IKK/IKU – Energieeffizient Bauen und Sanieren" und „KfW-Energieeffizienzprogramm – Energieeffizient Bauen und Sanieren" auf öffentliche Haushalte im Förderjahr 2016. [Effects of the KfW programmes "Energy-efficient construction", "Energy-efficient refurbishment", "IKK/IKU - Energy Efficient Construction and Rehabilitation" and "KfW Energy Efficiency Programme - Energy-efficient construction and rehabilitation" on public budgets in the 2016 promotional year.] IWU and Fraunhofer IFAM (2016): Monitoring der KfW-Programme

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
		"Energieeffizient Sanieren" und "Energieeffizient Bauen" 2015. [Monitoring of the KfW "Energy-efficient refurbishment" and "Energy-efficient construction" programmes 2015.]

The evaluations that were selected for an in-depth assessment are shown in bold font.
Source: own compilation, Fraunhofer ISI

Results from the ex-ante evaluation

Prognos et al. (2020) evaluate the different measures of the Climate Protection Programme for reaching the 2030 targets. The Federal Ministry for Economic Affairs and Energy commissioned the evaluation as a repetitive service in accordance with the framework contract for advising its Department II. The evaluation does not follow any specific guidelines or protocol and conducts a quantitative and a qualitative analysis of the instruments. The authors describe the method in great detail, including the working steps as well as referencing an overview of the used models and their characteristics. The evaluation period spans 11 years from 2020 to2030.

The evaluation establishes a clear link between the observed impacts and the policy instrument, based on underlying assumptions which are explained in detail.

A deadweight effect is considered insofar as the instruments' impact is assessed as compared to the funding year 2017 with the assumption that the measure had not been implemented, less renovations would have been realised or the efficiency standards would have been lower. Rebound effects have not been considered. However, the interaction with other instruments, namely the tax incentive for energy efficient buildings, has been assessed.

The impact of the instrument is measured relative to a baseline that takes into account anticipatory effects and deadweight (net accounting), with the reference scenario being based on the policy measures introduced by the end of 2017 and updating current trends (2017 evaluation based on the MAP, KfW and BAFA funding cases in 2017). The impact measurement and the related assumptions are described in high detail. Three steps characterise the evaluationin order to appraise the development of funding cases and efficiency levels of renovations (development of the total number of funding cases based on how attractive the two different options (funding vs. tax incentives) are, distribution of funding cases among the various funding strands (federal funding for efficient buildings, tax incentive), CO_2 reduction effect and tax losses).

The input data used for the evaluation are KfW and BAFA promotion statistics. The data basis and data collection process are described only in low detail. No stakeholders were involved in the evaluation process.

The ex-ante evaluation of the PaM does not consider the relevance of the instrument regarding current targets for the building sector. Furthermore, contributions of the instrument to energy savings or the expansion of renewable energies are not assessed. The focus lies on the reduction of GHG emissions with an average of annual CO_2 savings of 620 ktCO_2eq. Over the period 2020 to 2030, the savings add up to 6,820 ktCO_2eq (gross accounting). Compared to the funding year 2017, the additional savings amount to 230 kt CO_2eq per year and 2,530 kt CO_2eq cumulated over the period from 2020 to 2030 (net accounting) (see Table 74).

Table 74: Target contributions of the PaM "Federal funding for efficient buildings" according to the ex-ante evaluation

National targets and contributions	2020-2030	2025	2030	Reference case and year
Reduction of GHG emissions [kt CO_2]	2,530	230	230	Funding frozen at the 2017 level
Increase of RES consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of final energy consumption [ktoe]	n/a	n/a	n/a	n/a

Source: own compilation, Fraunhofer ISI based on Prognos et al. (2020).

The effectiveness of the GHG emissions reduction has been assessed qualitatively. Prognos et al. (2020) argue that, with the goal of a nearly climate-neutral building stock at the average level of EH 55[33], the focus should be on implementing and incentivising packages or roadmaps that achieve at least this level (including through consistent implementation and application of iSFPs[34]), which is still not the case with the current status of the federal funding for efficient buildings.

In addition to the GHG emission reductions, the evaluation assesses the costs of the instrument with estimated 1.25 billion EUR per year amounting to 13.75 billion EUR for the period from 2020 to 2030. No other categories were considered in the evaluation.

Results from the ex-post evaluation

The chosen ex-post evaluation (IWU & IFAM 2018) and follows the evaluation guideline "Kurzverfahren Energieprofil"[35] of the Institute for Housing and Environment (Institut Wohnen und Umwelt - IWU). The assessment was conducted quantitatively and qualitatively and the method is described in high detail.

The evaluation establishes a clear link between the observed impacts and the instrument, focusing on primary and final energy savings and reduced GHG emissions. The authors do not assess deadweight, rebound, substitution, and leakage effects or and no interactions with other instruments.

The evaluation uses no reference but describes its procedure in great detail, which consists of modelling (gross accounting) final energy savings, use of KfW statistics and of a survey asking funding recipients about data on the buildings, implemented renovation measures and the condition of the building before renovation. The relevance of the instrument concerning current problems and needs was not assessed.

[33] The KfW Efficiency House 55 (EH55) must not exceed an annual primary energy demand of 55% and Transmission heat loss of 70% compared to the reference building, whose technical charactersitics are defined by the Buildings Energy Act (GEG) ((KfW Bankengruppe 2021)).

[34] The individual renovation roadmap (individueller Sanierungsfahrplan, iSFP) is an instrument for energy consulting for residential buildings and when using it, applicants for the BEG can receive further funding ((Prognos et al. 2020)).

[35] English: Short procedure energy profile.

Both primary and final energy savings for the year 2017 were assessed with a reduction of GHG emissions of 479.8 kt CO_2eq. Furthermore, evaluation estimates primary energy savings of 137.8 ktoe and final energy savings of 123.9 ktoe for 2017. Savings through increased RES energy consumption were estimated to equal 35.2 ktoe (see Table 75).

Table 75: Target contributions of the "KfW programmes to financially support ambitious energy standards for renovations" according to the ex-post evaluation

National targets and contributions	2017	2010	2015	Reference case and year
Reduction of GHG emissions [kt CO_2]	479.8	n/a	n/a	Gross accounting
Increase of RES consumption [ktoe]	35.2	n/a	n/a	Gross accounting
Reduction of primary energy consumption [ktoe]	137.8	n/a	n/a	Gross accounting
Reduction of final energy consumption [ktoe]	123.9	n/a	n/a	Gross accounting

Source: own compilation, Fraunhofer ISI based on IWU & IFAM 2018.

Furthermore, employment effects were assessed quantitatively as compared to 93.000 person-years in 2010. The evaluation provides different job categories where the employment effect takes place: self-employed vs. employed, rural vs. urban and sector specific effects. The direct employment effects assessed amount to additional 85.000 person-years in 2017, the indirect employment effects are additional 33.000 person-years in 2017.

Comparison between the ex-ante and the ex-post evaluation and with the NECP

A direct link exists between the German NECP and the analysed evaluations, since it refers to these evaluations. The ex-ante evaluation is based on the analysed ex-post evaluation, the two complement each other. The estimations in the ex-ante evaluation seem plausible. The annual GHG emissions reductions are average values based on the estimated cumulated savings for the period from 2020 to 2030 and fluctuations are probable, especially given the increased funding, which is to be expected for the instrument. Still, the assumptions are linked to uncertainties, which Prognos et al. (2018) consider qualitatively, stating that accompanying measures are indispensable for reaching the funding cases and thus the energy efficiency targets. As the German Climate Protection Act was amended in mid-2021, updating the annual GHG emission reduction targets per sector, it is even more uncertain whether the two instruments will meet the more ambitious targets.The buildings sector has been the only one to miss the targets in 2020 and thus had to present an immediate action programme presenting supplementary measures to guarantee reaching the targets in the following years. The suggested measure was to increase the budget for the federal funding for efficient buildings, although this can only under very improbable conditions lead to meeting the former target, let alone the new targets for the buildings sector. Knowing this and seeing that in the evaluations the assessors made similar observations, the PaM is not sufficient, although it is important and successful.

A.3.2.3 Barriers in the ex-ante and the ex-post evaluations

While the ex-post evaluations analysed in Annexes A.3.2.1 and A.3.2.2 did not mention any of the barriers identified in A.3.1,the ex-ante evaluations took some of them into account. Prognos AG et al. (2020), assesses the development and barriers to the implementation of the total number of funding cases with respect to the tax incentives and the federal funding for efficient buildings. Prognos et al. (2020) have pointed to the skilled worker shortage in relation to the development of funding cases for both PaMs, without providing quantitative values though. The authors also referred to application and verification processes and highlighted that processing the tax subsidy via the tax return might be easier for building owners than applying for funding through financial incentive PaMs.

Another aspect to consider is that Germany has one of the lowest home ownership rates in Europe (Eurostat 2022). Thus, addressing split incentives, the landlord-tenant-dilemma (see Annex A.3.1) and targeting refurbishments in rental properties is crucial to increasing overall refurbishment rates (Femenías et al. 2018). The tenants, however, face rising rents, even if the refurbishments do not lead to sunk energy costs. In that context, energy poverty and social hardships need to be addresses as well. In the German NECP, these aspects are separately addressed by the option of partially redistributing the CO_2-price as a means to not only incentivise tenants to adapt energy efficient behaviour but also landlords to invest in energy efficiency in buildings. The related Act on the Allocation of Carbon Dioxide Costs (Kohlendioxidkostenaufteilungsgesetz – CO2KostAufG) was adopted on 10 November 2022.

In terms of institutional and behavioural barriers, some accompanying PaMs included in the NECP can support the PaMs discussed above. Such PaMs are the independent consultancy services provided by Federation of German Consumer Organisations (vzbv), federal funding for energy consulting for residential buildings (on-site consulting, individual renovation roadmap), federal funding for energy consulting for non-residential buildings owned by municipalities/charitable organisations as well as the exemplary role of federal buildings. These PaMs, which aim at increasing the provision of information and counselling, as well as PaMs using the role model function of public buildings might contribute to building owners' willingness to invest in refurbishment.

A.3.3 Slovenian NECP

The Slovenian NECP includes a specific sub-section on energy-efficient buildings, which is grouped under the section on energy efficiency. The goal is to reduce final energy use in buildings by 20% by 2030 compared to 2005 and ensure a reduction of GHG emissions in buildings by at least 70% by 2030 compared to 2005. These targets are consistent with the key targets of the energy efficiency dimension, including the improvement of energy and material efficiency in all sectors, the improvement of energy efficiency by at least 35% by 2030 compared to the 2007 baseline scenario, limiting final energy consumption to 54.9 TWh (4,717 ktoe). The national overarching strategy the NECP refers to is the long-term strategy to encourage investment in the energy-efficient renovation of buildings, which sets out significant energy reduction targets for the building stock. A short paragraph in the NECP summarises the approach to assess the performance of energy-efficient buildings. A review of 17 existing instruments is supplemented by three additional planned instruments. The Slovenian NECP differentiates between “promoting energy efficiency and renewable energy use” in buildings in general as well as in households and in public sector buildings.

The two selected PaMs are relevant for residential and public buildings (see Table 76). They provide financial incentives without many restrictions, while other funding schemes are subject to more conditions or more general.

An example of a more general Slovenian funding scheme is Energy Contracting, an important instrument which the Slovenian state wants to extend from the public sector to other sectors in order to further increase the number of building renovations. The energy efficiency aid scheme for vulnerable groups aims at increasing the availability of financial incentives for renovations for poor households. Another PaM is an economic regulation instrument, which provides a legislative framework for obtaining approval for the implementation and crediting of energy renovation projects for multi-household buildings.

Table 76: Key PaMs under the focus topic "Energy Efficient Buildings" in the Slovenian NECP

Name of PaM	Short description	Selected for evaluation?
Financial incentives for energy efficiency and RES use in residential buildings	Promotion of the energy renovation of buildings (thermal insulation of facades, thermal insulation of lofts, replacement of windows) and the construction of low-energy and passive buildings	yes
Non-repayable investment financial incentives for energy renovation of public sector buildings aimed at increasing the share of energy contracting projects	Grants to stimulate investments in the energy-efficient renovation of public buildings	yes
Energy Contracting (EPO)	To achieve a higher volume of energy-efficient renovations according to the EPO, appropriate financial products and other support measures must be developed	no
Household energy efficiency support scheme for vulnerable population groups	Grants and incentives for renovations and energy efficiency improvements for vulnerable groups	no
Financial instruments for the renovation of multi-owner buildings	Co-shaping financial products based on the identified market needs (in the field of multi-apartment buildings)	no

Source: own compilation, Fraunhofer ISI

A.3.3.1 Financial incentives for energy efficiency and RES use in residential buildings

The PaM "Financial incentives for energy efficiency and RES use in residential buildings"[36] is part of the instrument bundle "Promoting energy efficiency and renewable energy use in buildings in households" and a national key PaM for renovation of residential buildings. It is an active support policy providing financial incentives. The legal basis for the instrument is the Slovenian Energy Act, which was passed in 2014 and is the primary Energy Efficiency Law in Slovenia (Table 77). The PaM was implemented in 2008 and renewed in 2020 with changing the

[36] Original: Finančne spodbude za energetsko učinkovitost in rabo OVE v stanovanjskih stavbah.

amount of funding. It predominantly addresses energy savings and the expansion of renewables in relation toresidential buildings and households/private persons.

Table 77: Relevant and selected policy instruments for the PaM "Financial incentives for energy efficiency and RES use in residential buildings"

PaM	Associated policy instrument(s)	Legal basis
Financial incentives for energy efficiency and RES use in residential buildings	Financial incentives for energy efficiency and RES use in residential buildings	Energy Act[37] (EZ-1)

Source: own compilation, Fraunhofer ISI

The main source of ex-post evaluations is the National Energy Efficiency Action Plan and different versions and assessments of it (namely (Republika Slovenija 2014; Vlada Republike Slovenje 2008, 2015, 2017, 2021), from which two evaluations were relevant for our purpose. The National Energy Efficiency Action Plans form the basis of the PaMs regarding the Energy Efficiency Dimension and energy efficient buildings in the Slovenian NECP. The Action Plan from 2008 has introduced many of the instruments later implemented, such as the "Financial incentives for energy efficiency and RES use in residential buildings". Apart from that we found only few other evaluations , of which only one ex-ante evaluation assessed the impact of the PaM instead of the effect of an instrument bundle or on the sector level (see Table 78).

We selected the aforementioned ex-ante evaluation, although it dates back to 2008, because it is the only one considering impacts on instrument level – but not on the level of individual measures - and hence allows conclusions on a less aggregate level than others. For reasons of comparability, we singled out the ex-post evaluation providing an aggregate assessment on instrument level.

Table 78: Available and selected ex-ante and ex-post evaluations for the PaM "Financial incentives for energy efficiency and RES use in residential buildings"

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
Financial incentives for energy efficiency and RES use in residential buildings	**Vlada Republike Slovenje (2008): Nacionalni akcijski načrt za energetsko učinkovitost 2008–2016. [National Energy Efficiency Action Plan 2008-2016.]** Republika Slovenija (2014): Operational Programme for the Implementation of the EU Cohesion Policy 2014-2020. Ljubljana: Governmental Office for Development and European Cohesion Policy. Vlada Republike Slovenje (2021): Dolgoročna strategija energetske prenove stavb do leta 2050. Ljubljana.	**Vlada Republike Slovenje (2015): National Energy Efficiency Action Plan 2014-2020 (AN URE 2020).** Vlada Republike Slovenje (2017): National Energy Efficiency Action Plan 2020. (AN URE 2020). Ljubljana.

[37] Energetski zakon

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
	[Long-term strategy for the energy renovation of buildings up to 2050. Ljubljana.]	

The evaluations that were selected for an in-depth assessment are shown in bold font.

Source: own compilation, Fraunhofer ISI

Results from the ex-ante evaluation

The Slovenian government commissioned the ex-ante evaluation, which follows the Eurostat methodology for reporting on energy savings. In a quantitative assessment, all savings, except for CHP (combined heat and power), are estimated at final energy level. Electricity savings are multiplied by a factor of 2.5 according to the provisions of the ESD. While the methodological basis is mentioned, the evaluation technique is described not very detailedl.

The evaluation establishes a link between the observed impacts and the policy instrument by assessing the final energy savings due to the implemented measure. Deadweight effect, rebound effects or interactions with other measures were not considered.

The evaluation period is between 2008 and 2016, covering 9 years. The impact of the instrument on final energy consumption was measured against a baseline (baseline adjusted gross accounting), which is the average annual final energy consumption in the last five-year statistical period prior to the implementation of the Effort Sharing Directive.

4261 GWh (366.38 ktoe) of final energy savings were aimed at for the period from 2008 to 2016 with interim targets of 1184 GWh (101.81 ktoe) of final energy savings from 2008 to 2010, as specified in the evaluation as well. Final energy savings were evaluated quantitatively with cumulated annual values of 1.8 ktoe given, which would amount to 1,890 GWh or 162.52 ktoe for the entire evaluation period 2008-2016. GHG emission reductions were estimated to be 54 kt CO_2eq per year amounting to 486 kt CO_2eq in the evaluation period (see Table 88)[38]. A possible expansion of renewable energies was not taken into account.

Table 79: Target contributions of the PaM "Financial incentives for energy efficiency and RES use in residential buildings" according to the ex-ante evaluation

National targets and contributions	2008-2016	2010	2015	Reference case and year
Reduction of GHG emissions [kt CO_2]	486	54	54	Derived from the reduction of final energy consumption.
Increase of RES consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a

[38] We assume that this is correct as it seemed plausible in the context of the other estimated values - however, as at one point, the reduced GHG emissions are given for the evaluation period whereas at another point the evaluation calls them annual GHG emission reductions, we cannot be entirely sure if the assumption is correct.

National targets and contributions	2008-2016	2010	2015	Reference case and year
Reduction of final energy consumption [ktoe]	162.52	18.1	18.1	The reference is the average annual final energy consumption in the last five-year statistical period prior to the implementation of the ESD for which official data are available (2001-2005).

Source: own compilation, Fraunhofer ISI based on Vlada Republike Slovenje (2008).

Furthermore, implementation costs were reported to be 33 million EUR; although no period was explicitly stated, the evaluation period from 2008 to 2016 can be assumed to be correct. No annual costs were given and the methodology and the data basis for the assessment are not transparent.

Results from the ex-post evaluation

The chosen ex-post evaluation is the National Energy Efficiency Action Plan 2014-2020, published in 2015 and evaluating policies relevant for reaching national energy efficiency targets (namely Vlada Republike Slovenje 2015). It followed the Eurostat methodology and the methods for determining final energy savings according to ESD. The evaluation method is described in high detail. The evaluation was part of a regular assessment and includes both ex-post and ex-ante estimations in a period from 2010 to 2016. The evaluation was conducted quantitatively and established a clear link between the instrument and the energy savings resulting from it. The impact measurement was conducted relative to a baseline, given by the energy saving targets for the evaluation period from 2010 to 2012. The data used were Eurostat statistics on final energy consumption.

Final energy savings were estimated to be34.91 ktoe from 2008 to 2012 as opposed to reduction targets of 39 ktoe for the same period. For the evaluated years 2011 and 2012, GHG emissions were reduced by 41.1 kt CO_2eq and 22.41 ktoe of end-energy savings were achieved (Table 84).

Table 80: Target contributions of the PaM "Financial incentives for energy efficiency and RES use in residential buildings" according to the ex-post evaluation

National targets and contributions	2011-2012	2010	2015	Reference case and year
Reduction of GHG emissions [kt CO_2]	41.1	n/a	n/a	Derived from the reduction of final energy consumption.
Increase of RES consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a

National targets and contributions	2011-2012	2010	2015	Reference case and year
Reduction of final energy consumption [ktoe]	22.41	n/a	n/a	Energy savings targets 2010-2012, based on Eurostat statistics.

Source: own compilation, Fraunhofer ISI based on Vlada Republike Slovenje (2015).

In 2011-2012, the total grants amounted to 41 million EUR, supporting approximately 29 thousand investment projects with a total value of 235.7 million EUR.

Comparison between the ex-ante the ex-post evaluation and with the NECP

The results seem comprehensible, but some information for clarity are missing and as no additionality seems to have been considered and other effects were not addressed either, other evaluations may be needed to verify the results. As the ex-post evaluation has only a duration of two years including energy savings and GHG emission reductions, an actual comparison with ex-ante estimates is to be interpreted with caution. Furthermore, both evaluations did not address uncertainties directly. The ESD does address them, but not in a manner that forces evaluators to analyse uncertainties. Overall, it may be that the ex-ante evaluation overestimated savings. The estimations in the evaluations cannot be compared to the PaM reports of 2019 and 2021 in a conclusive manner as the PaM reports provide the estimated GHG emissions reductions only for a bundle of PaMs. However, the estimations in the PaM reports seem consistent. Slight differences are probably due to a change in the allocation of individual PaMs to the bundles. In the NECP, the implementation of the instrument is considered to be continued and updated from 2021 to 2030, so a realistic assessment of the results is important for further decisions. Hence, more ex-ante as well as ex-post evaluations might be helpful. Barriers to the realisation of the expected PaM impacts are addressed in Annex A.3.3.3.

A.3.3.2 Non-repayable investment financial incentives for energy renovation of public sector buildings

The instrument named "Non-repayable investment financial incentives for energy renovation of public sector buildings, aimed at increasing the share of energy contracting projects " is a national key PaM regarding energy-efficient buildings. It provides financial support for the renovation of public buildings. The instrument was initialised in 2008 when it was called an instrument for buildings in the tertiary sector, whereas in 2015 its scope was reduced to buildings only in the public sector. The Slovenian Ministry for the Environment and Spatial Planning is responsible for the PaM.

It mainly addresses energy savings and CO_2 emission reductions. As its target area is the public sector, the instrument addresses public authorities. The financial incentives are aimed at energy-related renovation of buildings owned and used by municipalities, and the public sector. Comprehensive energy renovation in the public sector is also possible for buildings, for which individual measures or partial energy renovations have already been carried out in the past. In this context, eligible buildings are those, which do not reach the prescribed level of energy efficiency and additional measures would bring them up to the prescribed level of energy efficiency and use of RES according to the Regulation on the Efficient Use of Energy in Buildings (PURES) and other relevant guidance.

The instrument is part of an instrument set targeting energy efficiency in public buildings and a key PaM in this context (Table 81). It aims to ensure the continuity of grants to stimulate investments in the energy renovation of public buildings as well as encouraging project preparation, also in the context of promoting energy contracting. As such, it is seen as enabling more renovations through more funding and also helping public institutions lead by example in terms of energy efficiency schemes.

Table 81: Relevant and selected policy instruments for the PaM "Non-repayable investment financial incentives for energy renovation of buildings in the public sector, aimed at increasing the share of projects implemented through energy contracting"

PaM	Associated policy instrument(s)	Legal basis
Non-repayable investment financial incentives for energy renovation of buildings in the public sector, aimed at increasing the share of projects implemented through energy contracting	Non-repayable investment financial incentives for energy renovation of buildings in the public sector, aimed at increasing the share of projects implemented through energy contracting	Energy Act

Source: own compilation, Fraunhofer ISI

We identified only one ex-ante evaluation of the PaM (namely Vlada Republike Slovenje 2008). In other evaluations the instrument is either not mentioned or its impact is not assessed separately. The only ex-post evaluation evaluating the instrument is a report within a project presenting the main findings of the monitoring of the implementation of greenhouse gas (GHG) emission reduction measures for 2019, in this case for the building sector (namely Stegnar et al. 2020). No other evaluations could be found.

Table 82: Available and selected ex-ante and ex-post evaluations for the PaM "Non-repayable investment financial incentives for energy renovation of buildings in the public sector, aimed at increasing the share of projects implemented through energy contracting"

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
Non-repayable investment financial incentives for energy renovation of buildings in the public sector, aimed at increasing the share of projects implemented through energy contracting	**Vlada Republike Slovenje (2008): Nacionalni akcijski načrt za energetsko učinkovitost 2008–2016 (national energy efficiency action plan for the period 2008-2016).** .	**Stegnar et al. (2020): Podnebno ogledalo 2020 Ukrep v središču – Energetska prenova stavb ožjega javnega sektorja (Climate mirror 2020 Action in centre – Energy renovation of narrow public sector buildings).**

The evaluations that were selected for an in-depth assessment are shown in bold font.

Source: own compilation, Fraunhofer ISI

Results from the ex-ante evaluation

The Slovenian government commissioned the ex-ante evaluation follows the Eurostat methodology for reporting on energy savings. In a quantitative assessment, all savings, except for CHP (combined heat and power), are estimated at final energy level by multiplying electricity savings by a factor of 2.5 according to the provisions of the ESD, which shows the ratio between the primary energy required and the final electricity consumption. While the methodological

basis is referenced, the evaluation technique is described only in low detail. The evaluation establishes a link between the observed impacts and the policy instrument by assessing the final energy savings due to the implemented measure. Deadweight effect, rebound effects or interactions with other measures have apparently not been taken into account .

The evaluation period is between 2008 and 2016, spanning 9 years. The impact of the instrument was measured relative to a baseline (baseline adjusted gross accounting). The impact for 2008 until 2016 is assessed against the reference final energy consumption according to the ESD, which is the average annual final energy consumption in the last five-year statistical period prior to the implementation of the Directive for which official data are available. Savings in the public sector are part of the savings in the category "others"; the average annual energy savings from 2001 to 2005 in that case are 631.42 ktoe.

Final energy savings were evaluated quantitatively with cumulated annual values of 8.25 ktoe given, which would amount to 74.3 ktoe for the entire evaluation period 2008-2016. GHG emission reductions were estimated to be 25 ktCO_2eq per year amounting to 225 kt CO_2eq over the 9-year evaluation period. A possible expansion of renewable energies was not taken into account.

Table 83: Target contributions of the PaM "Non-repayable investment financial incentives for energy renovation of buildings in the public sector, aimed at increasing the share of projects implemented through energy contracting" according to the ex-ante evaluation

National targets and contributions	2008-2016	2010	2015	Reference case and year
Reduction of GHG emissions [kt CO_2]	225	25	25	n/a
Increase of RES consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of final energy consumption [ktoe]	74.3	8.25	8.25	The reference final energy consumption is the average annual final energy consumption in the last five-year statistical period prior to the implementation of the ESD for which official data are available (2001-2005).

Source: own compilation, Fraunhofer ISI based on Vlada Republike Slovenje 2008.

Furthermore, implementation costs of 44 million EUR were reported; although no period was explicitly stated, the evaluation period from 2008 to 2016 can be assumed to be correct. No annual costs were given and the methodology and the data basis for the assessment are not transparent. The evaluation projects that the instrument provides the stimulus for the renovation of an additional floor space of 162,000 m^2. Moreover, it expects that a floor space of 350,000 m^2 of low-energy buildings and 70,000 m^2 of passive buildings is renovated in the course of the evaluation period between 2008 and 2016 No other aspects were considered.

The estimated results are comprehensible based on the given information, but since many aspects were not considered, concerns remain about their validity. The authors give no reference and do not assess the efficiency of the instrument. In this context, the plausibility of the evaluation cannot be confirmed without doubts.

Results from the ex-post evaluation

Stegnar et al. (2020) assess the impact of the instrument qualitatively and quantitatively in an ex-post evaluation. The evaluation of existing instruments related to the energy renovation of buildings in the public sector is carried out along six dimensions of action: relevance, impact, effectiveness, long-term impact, flexibility and predictability. The evaluation technique is not clear and elaborated only in low detail.

A link between the observed effects and the instrument is established. The quantitative results (i.e. energy savings and CO_2 emissions reductions) for the dimensions impact and effectiveness are not reported, only a qualitative assessment for these dimensions is given in the evaluation. Instead, energy savings as well as CO_2 emissions reductions are reported on an aggregated level, over all dimensions, for renovations of public buildings, based on the programmes the renovations were carried out under. Grants were available from the Operational Programme for the Development of Environmental and Transport Infrastructure 2007-2013 (OP ROPI) and subsequently from the Operational Programme for the Implementation of the European Cohesion Policy 2014-2020 (OP ENPI). Quantitative assessments were given for these periods,

respectively. The evaluation is based on internal data from the Public Sector Buildings Energy Refurbishment Project Office, but no information is given on the data basis as well as the data collection processes. No stakeholders seem to have been involved.

The relevance of the instrument was assessed separately, stating that it makes an important contribution to the energy renovation targets for buildings in the sub-public sector, i.e. buildings owned and used by central or sub-central governments, as well as to the targets for reducing energy use in the service sector and for reducing energy-related GHG emissions in buildings. As the need for energy renovation in public buildings is high and the sector is generally under-financed, the instrument is considered to be highly relevant.

Stegnar et al. (2020) present energy savings as well as GHG emissions reductions are only available on an aggregate level. All instruments promoting energy efficiency in public buildings resulted in annual energy savings of 5.32 ktoe from 2007-2013 and 12.74 ktoe per year from 2014-2019 (end of February 2019). GHG emissions were reduced by 16.4 kt CO_2eq per year from 2007 to 2013 and by 40.4 kt CO_2eq per year from 2014 to 2019 (end of February 2020). No reference case seems to have been used.

Table 84: Target contributions of the PaM "Non-repayable investment financial incentives for energy renovation of buildings in the public sector, aimed at increasing the share of projects implemented through energy contracting" according to the ex-post evaluation

National targets and contributions	2007-2019	2010	2015	Reference case and year
Reduction of GHG emissions [kt CO_2]	357.2	16.4	40.4	No reference case seems to have been used.
Increase of RES consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of final energy consumption [ktoe]	113.65	5.32	12.74	No reference case seems to have been used.

The quantitative values represent the target contributions of all instruments promoting energy efficiency in public buildings.

Source: own compilation, Fraunhofer ISI based on Stegnar et al. (2020)

Further categories were assessed quantitatively and presented qualitatively on instrument level. The effectiveness of the instrument is considered to be low. The impacts achieved in the sub-public sector buildings are behind the planned ones. The finished energetically renovated floor space of public buildings for the period from 2014 to 2019 is equivalent to only 45% of the target for the mentioned period under the ENPI OP, or 1.2% instead of the target of 3% of floor space under Article 5 of the EED. No reasons for the low effectiveness are given. The flexibility of the instrument is partly considered. Its implementation in combination with energy contracting has encountered a number of obstacles in the public sector. In responding to the problems that have arisen, the instrument has proved to be less flexible, as the necessary changes to speed up project implementations have not yet been made. However, from the point of view that the energy renovation of buildings allows for a wide range of different measures to be carried out the instrument is considered to be flexible.

Comparison between the ex-ante and the ex-post evaluation and with the NECP

The ex-ante evaluation directly refers to the NECP, stating that recommendations for improving the implementation of the actions in the funding programme are already largely included in the national NECP and that the instruments' further implementation is secured in the NECP. Overall, comparing the two evaluations proves difficult, as the ex-post evaluation provides a quantitative impact assessment only on aggregate level. Furthermore, the ex-ante evaluation was conducted in 2008 for the period 2008-2016 as opposed to the time frame of the 2020 ex-post evaluation, which are the years from 2007 to 2019. Still, considering the aggregated estimations of the ex-post evaluation, the estimations in the ex-ante evaluation may have been too high. The ex-post evaluation stresses that the actual impact is at least partly below the expected impact. Other evaluations might help to validate this impression and more quantified evaluations, ex-post as well as ex-ante would be necessary overall in order to be able to draw concrete conclusions about the plausibility of the evaluation. Also, comparing the estimations in the evaluations to the PaM reports from 2019 and 2021 in a conclusive manner proves difficult as the PaM reports provides the estimated GHG emissions reductions only for a bundle of PaMs (Promoting energy efficiency and renewable energy use in public sector buildings). In the latest PaM report, this category is incorporated in a general category (Promoting energy efficiency and renewable energy use in buildings in general). Slight changes in the estimations between 2019 and 2021 might be due to this allocation of individual PaMs.

A.3.3.3 Barriers in the ex-ante and the ex-post evaluations

The ex-ante evaluation that was analysed for both PaMs in Slovenia directly addresses diverse barriers to increasing energy efficiency in general, but not directly in the context of any of the PaMs. The barriers identified in Annex A.3.1 are also all listed in the respective evaluation (Vlada Republike Slovenje 2008). However, over ten years later Stegnar et al. (2020) referred to the same barriers in their ex-post evaluation, analysed in the context of the non-repayable investment financial incentives (Annex A.3.3.2). The authors refer to administrative obstacles, lack of appropriate financial instruments, inadequate readiness and capacity of the sub-public sector to undertake large scale comprehensive energy renovations, the absence of more stable financial resources to carry out these renovations, as well as obstacles in the planning and coordination of activities, e.g. due to a lack of human capital (Stegnar et al. 2020). Ultimately, it remains unclear whether barriers could be removed successfully. The evaluation by Stegnar et al. (2020) points to the possibility that the barriers remain, even though it is not clear to what extent.

A.3.4 Swedish NECP

The Swedish NECP elaborates the topic “Energy efficient buildings” in a subsection of the energy efficiency dimension but does not express specific targets for energy-efficient buildings. A national long-term renovation strategy is announced for 2020. In the NECP, Sweden has set a general target for the reduction of energy intensity in terms of energy supplied in relation to GDP. This is a cross-sectoral target to reduce energy intensity by 20% between 2008 and 2020. Energy consumption must be 50% more efficient by 2030 than it was in 2005. Furthermore, it is stated that the cumulative energy savings obligation for 2014-2030 is 47.6 GWh and for 2021-2030 28.6 GWh. The cross-sectoral energy and carbon taxes are considered to be the most important PaMs in Sweden's climate and energy efficiency policy. Five other existing PaMs

relevant to energy efficient buildings and one that is being phased out were listed and explained, such as building regulations.

The Energy and Carbon Tax is not addressed in this section, as it is analysed in the context of the focus topic "Carbon and energy pricing" in Section 4.13.1. Moreover, it is a cross-sectional PaM, which is why evaluations of that tax do not focus on energy-efficient buildings and energy savings or GHG emissions reductions in the buildings sector.

Another cross-sectoral PaM is the Planning and Building Act (2010:900), providing the legal framework for land-use planning. It also establishes requirements for buildings, containing the National Board of Housing, Building and Planning Building Regulations (BBR). The BBR is the key PaM for energy-efficient buildings in Sweden and contains specific requirements concerning energy management and sets limits for energy consumption of buildings. Another financial instrument in form of a tax reduction is the Renovation, Conversion and Extension Deduction (ROT), which does not primarily focus on energy efficiency or GHG emissions reductions, but on the labour costs for house repairs, maintenance, conversions and extensions. The NECP describes the ROT as a PaM supporting energy efficiency goals because it incentivises energy-efficient renovations. Furthermore, the National Renovation Center (NRC) provides further training for and distributes information to actors in the building industry in order to make existing buildings more sustainable. Besides, the Energy Labelling Regulation and Energy Declarations were listed as important instruments for Housing and Services and chosen as possible back-up PaMs to analyse, whereas instruments aiming at informing and networking were not considered for analysis.

Furthermore, the cross-sectoral PaM called Klimatklivet (Climate Leap) is an initiative providing subsidies for local and regional measures to reduce greenhouse gas emissions for all sectors not included in the EU-ETS. However, the focus is not on energy-efficient buildings but defined more broadly, also covering RES as well as the transport and the healthcare sector.

Table 85: Selected and backup PaMs under the focus topic "Energy-Efficient Buildings" in the Swedish NECP

Name of PaM	Short description	Selected for evaluation?
National Board of Housing, Building and Planning Building Regulations (BBR)	detailed regulations for new buildings and alterations to existing buildings	yes
The Renovation, Conversion and Extension Deduction (ROT)	The tax deduction for renovation, conversion and extension applies to the labour costs for house repairs, maintenance, conversions and extensions.	no
The National Renovation Centre (NRC)	Provides further training and distributes information to actors in the building industry, to enable them to carry out renovations efficiently	no
Klimatklivet (Climate Leap)	Cross-sectoral PaM, financial incentive programme for local and regional investments in climate protection measures	yes

Name of PaM	Short description	Selected for evaluation?
Energy and Carbon Taxes	Cross-sectoral PaM which incentivises energy efficiency imporvements in buildings through higher energy costs	no

Source: own compilation, Fraunhofer ISI

A.3.4.1 National Board of Housing, Building and Planning Building Regulations (BBR)

The building regulations is a command-and control regulation, setting the requirements and limits for energy consumption of buildings. It was implemented in 2010 within the responsibility of the National Board of Housing, Building and Planning (Boverket). It primarily focuses on energy savings and the expansion of renewables and addresses GHG emissions reductions. The PaM targets all owners of buildings. We chose this PaM because it provides the basis for renovations of buildings in Sweden and thus is the principal instrument for energy-efficient buildings. The building regulations include stricter requirements for new electrically heated buildings (since 2009) and for new buildings with other heating systems (since 2012), such as requirements for specific energy use and average thermal transmittance.

Table 86: Relevant and selected policy instruments for the "National Board of Housing, Building and Planning Building Regulations"

PaM	Associated policy instrument(s)	Legal basis
National Board of Housing, Building and Planning Building Regulations (BBR)	National Board of Housing, Building and Planning Building Regulations (BBR)	plan- och bygglagen (Planning and Building Act)

Source: own compilation, Fraunhofer ISI

As the energy and carbon taxes are considered the key PaM in Sweden for GHG emission reductions as well as for energy efficiency, most evaluations do not assess the impact of individual instruments. The Swedish NECP does not provide impact assessments on instrument level (Swedish Ministry of Infrastructure 2020). Sweden's Fourth Biennial Report under the UNFCCC (Sweden's Environmental Protection Agency 2019), which does not establish a link to the NECP, provides quantitative assessments of the BBR, but only on an aggregate level together with other instruments (the energy and carbon taxes, mandatory energy labelling, the Ecodesign Directive and the law on energy performance certificates for buildings). However, as these instruments are the key instruments for energy-efficient buildings in Sweden and no individual assessments were available, the target contributions of the bundle are important to look at anyways.

Table 87: Available and selected ex-ante and ex-post evaluations for the PaM "National Board of Housing, Building and Planning Building Regulations"

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
National Board of Housing, Building and Planning Building Regulations (BBR)	**Sweden's Environmental Protection Agency (2019): Sweden's Fourth Biennial Report under the UNFCCC.**	**Sweden's Environmental Protection Agency (2019): Sweden's Fourth Biennial Report under the UNFCCC.**

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
	Swedish Ministry of Infrastructure (2020): Sweden's Integrated National Energy and Climate Plan.	

The evaluations that were selected for an in-depth assessment are shown in bold font.
Source: own compilation, Fraunhofer ISI based on Sweden's Environmental Protection Agency (2019).

Results from the ex-ante evaluation

The evaluation is part of a regular assessment under the United Nations Framework Convention on Climate Change. It is a quantitative assessment projecting GHG emission reduction on energy system level, thus, no direct link between the instrument and the impact becomes apparent. The evaluation method is described in high detail, explaining the different steps and models used for estimations for the energy sector and different parts of it. The projections on energy use in residential as well as commercial/institutional sectors are based on assumptions on future temperature conditions, population trends, stock of housing and commercial premises, energy prices, investment costs, technological development and economic development. Economic development for the evaluation period was based on the estimations of the National Institute of Economic Research. The trends in fossil fuel prices are the 2015 prices provided by the European Commission. The projection is based on normal production conditions. Changes in the assumptions due to future climate effects have not been taken into consideration (Ministry of Environment 2017). The evaluation was conducted against the mitigation impact of instruments implemented in 1990.

The evaluation provides an estimate of the aggregated GHG emission reductions (400 kt CO_2eq in 2020 and 2030) of the energy and carbon taxes, mandatory energy labelling, the ecodesign directive and the law on energy performance certificates for residential, public authority and commercially used buildings but no information about energy savings or RES use.

Table 88: Target contributions of the PaM "National Board of Housing, Building and Planning Building Regulations" according to the ex-ante evaluation

National targets and contributions	2015-2035	2020	2030	Reference case/year
Reduction of GHG emissions [kt CO_2]	n/a	400	400	Estimate of mitigation impact in Mt CO_2eq per year compared with 1990 instruments.
Increase of RES consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of final energy consumption [ktoe]	n/a	n/a	n/a	n/a

Source: own compilation, Fraunhofer ISI based on Sweden's Environmental Protection Agency (2019).
The values in the table represent aggregate target contributions of a bundle of instruments for improving energy-efficiency in buildings.

No further categories are considered in the ex-ante evaluation. The evaluation method is comprehensible and the assumptions are clear, thus the results seem plausible. Considering the aggregate level of the impact assessment, however, the impact of the single instrument is not clear. Since the carbon and energy taxes, respectively, are considered to be the most important instrument for GHG emissions reductions as well as for energy efficiency, and the other instruments included in the impact assessment are key PaMs for energy efficient buildings as well, an individual assessment based on the ex-ante evaluation is not possible.

Results from the ex-post evaluation

For ex-post evaluations, only the Fourth biennial UNFCCC report assessed the impact of the building regulations quantitatively on the level of the bundle of instruments instead of the energy system level. Again, the evaluation was carried out for energy and carbon taxes, mandatory energy labelling, the Ecodesign Directive, the law on energy performance certificates for buildings and the building regulations together with no distinction between the impacts of the individual instruments.

The evaluation is part of a regular assessment under the United Nations Framework Convention on Climate Change. It is a quantitative assessment projecting emission reductions on energy system level, thus, no direct link between the instrument and the impact becomes apparent. The evaluation method is described in high detail, explaining the different steps and models used for estimations for the energy sector and different parts of it. The assessment of the impact of the instruments are based on the available data provided by the responsible Ministry. The evaluation was conducted against the mitigation impact of instruments implemented in 1990.

The evaluation provides an estimate of the aggregated GHG emission reductions (1,400 $ktCO_2eq$ in 2010 and 1,300 $ktCO_2eq$ in 2015) of the energy and carbon taxes, mandatory energy labelling, the ecodesign directive and the law on energy performance certificates for residential, public authority and commercially used buildings but no information about energy savings or RES use.

Table 89: Target contributions of the PaM "National Board of Housing, Building and Planning Building Regulations" according to the ex-post evaluation

National targets and contributions	2015-2035	2010	2015	Reference case and year
Reduction of GHG emissions [kt CO_2]	n/a	1,300	1,400	Estimate of mitigation impact in Mt CO_2eq per year compared with 1990 instruments.
Increase of RES consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of final energy consumption [ktoe]	n/a	n/a	n/a	n/a

Source: own compilation, Fraunhofer ISI

No further categories seem to have been considered. The evaluation has been conducted using different impact models with all available data. The interaction within the broad range of instruments introduced in the Swedish climate strategy has been considered in order to avoid negative effects.

Comparison between the ex-ante and the ex-post evaluation and with the NECP

The estimated GHG emissions reductions seem plausible, as interactions between the instruments were considered and the evaluation method is traceable and transparent. Since the assessment was conducted on an aggregate level, the effect of a single instrument cannot be analysed. The ex-post impact is considerably higher than the impact expected for 2020 and 2030, which may be attributable to two PaMs within the bundle (including the law on energy performance certificates for buildings), which were implemented only in 2009 and 2010 respectively and, thus, may have had a higher impact in 2010 and 2015. Also, in the PaM reports no estimations are reported for the BBR . Considering that the building regulations are a key PaM and the main regulatory basis for energy management in buildings and their energy classes, the instrument at least seems to have contributed largely to the GHG emissions reductions in the buildings sector. Overall, the considered instruments together contribute to the GHG emissions reductions in the buildings sector in Sweden.

The ex-ante estimations are a forward projection of the assessed values for the preceding years under consideration of many aspects. However, a deadweight effect, rebound or other effects seemingly have not been considered. Barriers to the realisation of the expected PaM impacts are addressed in Annex A.3.4.3 and A.3.3.3.

A.3.4.2 Klimatklivet

The Climate Leap - Local Climate Investment Programme (Klimatklivet) is a Swedish national key PaM for climate protection. It subsidises investments in regional and local initiatives to reduce GHG emissions (including methane). It is a cross-sectoral PaM and although it also subsidises energy efficiency as well as energy conversion in buildings (the latter aspect is part of the focus topic Renewable Heat in this report), energy efficiency projects make only a very small part of the overall granted subsidies. The preceding Local Investment Programme ran from 1998 to 2002. Climate Leap was implemented in 2015 and was adapted in 2019; due to the decision about a new, lower budget, a new regulation was adopted for Klimatklivet excluding information measures from receiving funds and moving the support for non-public charging structure for electric vehicles to a separate regulation. The Swedish Environmental Protection Agency is responsible for the instrument which predominantly addresses GHG emissions reductions, focusing on CO_2. Private persons are not part of the target group but industry, companies, public authorities can apply for subsidies. Different action fields help categorising the measures to be conducted.

We focus our analysis on measures improving energy efficiency and with respect to energy conversion in buildings. Although the latter is rather a part of the focus topic "Renewable Heat", the two are not mutually exclusive and in the present case considering both allows to present a more complete picture for impacts concerning energy-efficient buildings

Table 90: Relevant and selected policy instruments for Climate Leap

PaM	Associated policy instrument(s)	Legal Basis
Climate Leap (Klimatklivet)	Climate Leap	Klimatlag 2017:703

Source: own compilation, Fraunhofer ISI

Only one ex-ante evaluation of a preceding programme, the Local Investments Programme which ran from 1998 to 2002, could be found. Ex-post Evaluations are regularly commissioned by the Swedish Environmental Protection Agency. Naturvårdsverket (2021) is the most recent one and assesses impacts in the period from 2015 to March 2021. However, it is less comprehensive and less detailed than Pädam et al. (2020), and the reported impacts do not disaggregate impacts in the buildings sector or energy efficiency in buildings, hence, we chose the Pädam et al. (2020).

Table 91: Available and selected ex-ante and ex-post evaluations for the PaM Climate Leap.

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
Climate Leap	n/a	**Pädam et al. (2020): Effekter av Klimatklivet.[Effects of the Climate Package.]** Naturvårdsverket (2021): Lägebeskrivining for Klimatklivet 2021. [Situation description for Klimatklivet 2021.] Naturvårdsverket (2020): Lägebeskrivining for Klimatklivet 2020. [Situation description for Klimatklivet 2020.]

The evaluations that were selected for an in-depth assessment are shown in bold font. * No ex-post evaluation for the chosen PaM were available so that ex-post evaluations of similar PaMs in other MS were considered.
Source: own compilation, Fraunhofer ISI

Results from the ex-post evaluation

The Swedish Environmental Protection Agency commissioned the ex-post evaluation and quantitatively and qualitatively assesses the impacts as well as the efficiency of the instrument for the period between 2016 and 2018. The evaluation method as well as data basis and data collection are described in high detail. A link between the impact and the instrument is clearly established. In contrast to rebound effects additionality was assessed by means of a survey and interviews and then quantified. Interaction with other PaMs – although not explicitly energy efficiency PaMs – was assessed, as the Climate Leap is legally required to support measures that provide the largest lasting reduction in GHG emissions, which means that the most cost-effective measures in reducing GHG emissions should be supported.

Measures for energy efficiency were estimated to contribute to reductions of GHG emissions with 4.505 kt CO_2eq per year. Considering full additionality of 50% though, this contribution reduces to 2.253 kt CO_2eq. For energy conversion in buildings, 57.891 kt CO_2eq of GHG emissions reductions per year were estimated, considering full additionality of 63% reduced to 36.304 kt CO_2eq. Overall, energy efficiency measures contribute less than 1%, energy conversion in buildings about 5% to the overall GHG emissions reductions achieved through the instrument (1131.12 kt CO_2eq per year, 808.77 kt CO_2eq per year considering full additionality).

Table 92: Target contributions of the PaM Climate Leap according to the ex-post evaluation

National targets and contributions	2016-2018	2016	2018	Reference case and year
Reduction of GHG emissions [kt CO2]	115.67	38.56	38.56	Net accounting, full additional reductions are estimated against gross savings.
Increase of RES consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of final energy consumption [ktoe]	n/a	n/a	n/a	n/a

The values in the table represent the added values for the categories energy efficiency and energy conversion in buildings.
Source: own compilation, Fraunhofer ISI based on Pädam et al. (2020).

Furthermore, the costs of subsidies for energy efficiency and energy conversion measures amounted to 38.08 million EUR during the evaluation period for a total of 328 granted measures, of which 10 were energy efficiency measures. The efficiency of the GHG emissions reductions were not assessed for energy efficiency or energy conversion measures.

Overall, the results seem plausible as they are based on statistical data of the evaluated years and the methodological approach is transparent.

Comparison between the ex-ante and ex-post evaluations and with the NECP

No ex-ante evaluation is available. Although references to them were found and the 2019 PaM report provided possible sources, we could only identify one document, which did not consider energy efficiency and which did not differentiate between the diverse categories. Other documents could not be accessed, although they are referenced. As no ex-ante evaluation is available, a comparison is not possible. In the ex-post evaluation, no link to the NECP was established.

The NECP does not provide information on the expected impact of the PaM in question, so neither on an aggregated level, nor specifically for energy-efficient buildings, implications for assumed impacts are possible based on the evaluation. By analysing another ex-post evaluation, comparability may be gained. Also, the values provided in the PaM reports of 2019 and 2021 do not suggest a high impact of the PaM. In the latest PaM report, instead of 1,400 kt CO_2eq GHG emissions reductions by 2030 as previously estimated in 2019, reductions of only 800 kt CO_2eq by 2030 are reported. This might be due to the restructuring and less budget provided for the PaM. However, this leaves the question about the effectivity of the PaM. Still, the results from the ex-post evaluation provide important information for further political decisions and it becomes apparent, that measures for improving energy efficiency in buildings are rarely funded. Energy conversion in buildings has a far higher share. A strict separation between these two is not necessary in the present case. Considering that many energy conversion measures in buildings also contribute to energy efficiency targets, the overall impact of the Climate Leap instrument for improving energy-efficiency in buildings is considerable, although only a small share of the overall funding is directly assigned to energy efficiency.

A.3.4.3 Barriers in the ex-ante and the ex-post evaluations

The ex-ante and ex-post evaluations for the respective PaMs in Sweden do not address any of the barriers identified in Annex A.3.1 in detail or systematically. The ex-post evaluation of the Kilmatklivet mentions the importance of the planning horizon in the context of renewable heat, which is closely related to energy efficiency in buildings. In the context of biogas, the role of knowledge and a lack of knowledge concerning new technologies and processes is highlighted. However, again, no link to energy efficiency is made. The Fourth Biennial UNFCCC Report (Sweden's Environmental Protection Agency (2019), analysed as both the ex-ante and the ex-post evaluation of the BBR (A.3.4.1), does not mention any of the barriers in a systematic way. The energy and carbon taxes are mentioned as an important cross-cutting PaM which also affects final energy consumption and GHG emissions of buildings and thus indirectly helps to increase energy efficiency.

A.3.5 Overview of number of identified evaluations

Table 93: Number of evaluations per Energy efficiency PaM and content

MS	PaM [39]	Ex-post	GHG share	EE share	RES sh.	SEI sh.	Other share	Ex-ante	GHG share	EE share	RES sh.	SEI sh.	Other share
DE	12	0						1	100%	0%	0%	0%	100%
DE	13	1	100%	100%	100%	100%	0%	1	100%	100%	0%	0%	0%
SI	14	1	0%	100%	0%	0%	100%	2	50%	50%	0%	0%	50%
SI	15	1	100%	100%	0%	0%	100%	1	100%	100%	0%	0%	100%
SE	16	1	100%	0%	0%	0%	0%	1	100%	0%	0%	0%	0%
SE	17	2	50%	0%	0%	0%	50%	0					
All		**6**	**67%**	**50%**	**17%**	**17%**	**50%**	**6**	**83%**	**50%**	**0%**	**0%**	**50%**

PaM = policy and measure, sh. = share, MS = Member State. DE = Germany, SI = Slovenia, SE = Sweden, GHG = greenhouse gas emissions reductions, EE = increase of energy effciency, RES = increase of renewables share, SEI = socio-economic impacts

Source: Own calculation, Fraunhofer ISI

Table 93 shows an overview of the identified evaluations under the energy-efficient buildings topic per PaM and MS. The table shows the number of identified ex-post and ex-ante evaluations and the share of evaluations reporting GHG emission reductions, energy consumption reductions, impact on renewable energy development, and socio-economic factors.

[39] 12 = Tax incentives for energy-related bulding renovations, 13 = Federal funding for energy efficient buildings/Federal Government's CO2 Building Modernisation Programme, 14 = Financial incentives for energy efficiency and RES use in residential buildings, 15 = Non-repayable investment financial incentives for energy renovation of buildings in the public sector, aimed at increasing the share of projects implemented through energy contracting, 16 = National Board of Housing, Building and Planning Building Regulations, 17 = Climate Leap (Klimatklivet)

A.3.6 Conflicts and synergies of increasing the energy-efficiency of buildings with the job creation and qualification

A.3.6.1 Literature review of the potential conflicts and synergies

Overall, employment effects are a research topic in the context of sustainability transitions and in particular in the buildings sector with regard to energy efficiency and renewable energy supply of residential and non-residential buildings. The potential for increased employment has been discussed in research in detail already (CE et al. 2015; Fragkos et al. 2018; Garrett-Peltier 2017; Mirasgedis et al. 2014; Stavropoulos et al. 2020). Different studies found that industries around energy efficiency and renewable energies create more jobs than fossil fuel industries, although with varying values and spans depending on the methodology (Stavropoulos et al. 2020).

Mirasgedis et al. (2014) found that, with regard to energy efficiency refurbishments in buildings, estimated employment benefits increase the higher the unemployment rate. In general, employment effects are particularly beneficial in the construction sector. Current European policies such as the EPBD have the potential for creating jobs (Czako 2020), still, Næss-Schmidt et al. (2018) estimated that in the context of energy efficiency improvement actions, employment increases will only be short-term. In the long run, labour force from other economic sectors could be attracted by increased wages, but the authors do not expect significant effects. Overall, workers will need more and more specific knowledge and be able to adapt to changes on the labour market (Czako 2020). Fragkos und Paroussos (2018) propose a policy framework considering new requirements on the labour market in economic sectors that are more and more changing towards sustainability. The potential for creating employment opportunities also via increasing energy efficiency in buildings needs to be supported by policies that increase labour market participation and improve skills and knowledge required for the installation of new technologies as well as the use of new materials and processes (Czako 2020; Fragkos und Paroussos 2018).

The increasing shortage of a skilled labour force in Germany, Slovenia and the EU in general counters the potential of increasing employment through implementation of energy efficiency measures in buildings (Lutz et al. 2018; Czako 2020; Stegnar et al. 2020). This is found to be the result of an aging, primarily male workforce and changed requirements of skills (Czako 2020). Conflicts can arise due to missing knowledge and the unwillingness to proceed in an untraditional manner. A shortage of skilled workers has been identified as a possible long-term bottleneck (Berneiser et al. 2021). The Covid-19 pandemic has affected the construction and installer businesses less than other branches since the order situation remains very good (Schirner et al. 2021). Nevertheless, the challenge of a skilled workforce shortage might remain in the long term and instruments that aim for attracting more staff and newer knowledge into the construction industry rather do not work in the short term (Berneiser et al. 2021). In the context of energy efficient buildings, but also for renewable energies and other topics, this factor needs to be addressed through PaMs in order to improve the implementation and impact of policies and measures.

A.3.6.2 How the selected NECPs and the evaluated instruments address the conflicts and synergies

The evaluated instruments and the NECPs of Germany, Slovenia and Sweden do not systematically examine employment effects. In the Slovenian and Swedish NECPs, possible employment effects are only marginally mentioned.

The German NECP considers the effects of the energy transition on the labour market. While the effects are not quantified in the NECP, it lays a focus on the potentials and also the status in the transformation towards a carbon neutral system. It acknowledges that the job market changes and skills and requirements shift. Indirectly, to avoid long-term shortage of skilled workers access to the labour market for the whole employable population needs to be improved. The NECP refers to a study showing signs of a shortage of skilled workers in occupational groups with a possible connection to the energy transition, such as technical professions and particularly construction professions (Lutz et al. 2018). These are relevant groups for the implementation of measures, which improve the energy-efficiency of buildings, however, no clear trend can be discerned for all occupational groups within that category: the shortage of skilled workers varies depending on the occupational sector, the level of requirements and the region. The German NECP does not mention any PaM, which directly addresses this issue. It is mentioned however that a forward-looking education policy and the immigration of skilled workers can counteract the problem.

In Germany, the tax incentives for energy-related building renovations and the federal funding for efficient buildings are closely linked as both have similar aims and provide funding for the implementation of energy efficiency measures in buildings. While the ex-post evaluation for the French tax incentives PaM did not consider any employment effects, IWU et al. (2018) looked into employment effects in detail (see Annex A.3.2.2) without taking into account a possible skilled workforce shortage. The authors concluded that the PaM could directly result in additional 85,000 person- years in 2017. The ex-ante evaluations analysed in Annex A.3.2.1 and A.3.2.2 did not assess employment effects.

The Slovenian NECP quantitatively assesses employment effects in general and briefly addresses the potential to increase employment in the context of renewable energy. However, energy-efficient buildings and possible employment effects are not directly linked in the NECP. Also, increased material and labour costs are assumed to be gradually increasing until 2040.The current high material prices and skilled workforce shortages show a more rapid change attributable to global economic development. Concerning the assessed PaMs, the NECP refers to sources which consider both increasing employment as a chance as well as skilled labour shortages as an obstacle to the implementation of PaMs for increasing energy efficiency in buildings (Vlada Republike Slovenje 2015; Stegnar et al. 2020).

In this context a possible accompanying PaM is aiming at ensuring the quality of energy renovation projects in the public building sector and has been implemented as of 2021. The PaM includes a structured stakeholder process, certification as well as education and training with respect to new technologies in order to reduce information asymmetries. No PaM in the focus topic of energy efficient buildings directly targets any of the conflicts or synergies or addresses the hurdles and related target groups.

Similarly, the Swedish NECP very broadly mentions increasing employment in companies and sectors with low emissions intensity or that offer sustainable solutions due to climate change, new technologies and processes. However, the topic is not directly linked to energy efficiency of buildings. Moreover, no PaMs in the NECP directly address labour and employment in general.

CO_2- and energy taxes seem to be the main PaM in Sweden in general; in the context of energy efficiency of buildings, interaction with important PaMs aiming at increasing refurbishment rates and the willingness to implement refurbishment measures and hence, indirectly, on employment, should be kept in mind.

A.4 Agricultural soils

The agriculture sector is very sensitive to climate impacts, but also an emitter of GHGs (Jacobs et al. 2019). In 2019, 12% of all EU GHG emissions came from agriculture (EEA 2021b). Although the EU reduced its agricultural GHG emissions by 20% between 1990 and 2019, annual emissions stabilised at around 460 Mt CO_2eq since 2010 (EEA 2021b). GHG emissions from agricultural activities include methane (CH_4), which primarily comes from animal husbandry, farm manure management, and digestate from biogas plants, as well as nitrous oxide (N_2O) which comes from fertilisation, manure management and also from digestate from biogas plants (Duscha et al. 2021). A second major source of emissions after animal husbandry is the application of synthetic fertilisers and animal manure to **agricultural soils**, which accounts for 39% share of agricultural emissions in 2019 (EEA 2021b) with emissions mainly originating from the use of mineral nitrogen fertilisers and organic nitrogen from animal manure (Perez Dominguez et al. 2016). Key options to address these emissions include a rational use of fertilisers and the shift to more sustainable management practices, such as cover cropping, improved crop rotations with inclusion of legumes, improved nutrient planning, as well as systemic approaches such as organic farming.

The "**rational use of nitrogen fertilisers**" includes both synthetic (inorganic) and organic fertilisers, but since the former account for up to 80% of the EU fertiliser market's value (EC 2016b), they are generally more prominently featured. In the EU, nitrogen fertilisers are most widely used, compared to e.g. phosphorus- or potassium fertilisers (Bourguignon 2019). In addition to the direct release of N_2O when fertilisers are applied, the production process of nitrogen fertilisers is also very energy-intensive and reliant on fossil fuels (UBA 2019). However, synthetic fertilisers have allowed for a huge increase in European agricultural productivity. The European Commission estimates that fertilisers were responsible for approximately 60% of the registered yield increases in the last 50 years (Bourguignon 2019).

Another important sub-topic of agricultural soils is "**increase of organic farming**". Organic farming completely refrains from using synthetic fertilisers, but rather relies on complex crop rotations and mixed crop-livestock systems to manage nutrients and maintain soil fertility. By reducing reliance on external inputs, using nutrients from manure, and through increased use of legumes and temporary grasses in crop rotations, organic farming allows for more closed nutrient cycles at farm level, therefore also reducing emissions from soil management, especially if the management includes reduced soil disturbance.

The **EU policy framework** in the agricultural sector is primarily based on **the Common Agriculture Policy (CAP)**. The CAP provides direct payments as income support, payments in the case of difficult market situations and payments to support rural development (EC n.d.e). . The aims of the CAP include ensuring a stable supply of affordable food and to safeguard EU farmers to make a reasonable living, but also to help tackle the climate crisis and improve sustainable management of natural resources (EC n.d.e). For the programming period 2023-2027, the CAP is based on nine objectives, one of which is "climate change action"(EC n.d.e). With this new programming period, organic farming can be supported under eco-schemes under the first Pillar, as well by the Rural Development Programmes under the second Pillar. In addition, through the second Pillar of the CAP, the EU provides additional funding via agri-

environmental and climate payments (AEC) to farmers and land managers in Member States that voluntarily commit to applying one or more specific agri-environmental and climate practices in their farming activities.

The **Nitrates Directive** has been in place since 1991 and "aims to protect water quality across Europe by preventing nitrates from agricultural sources polluting ground and surface waters and by promoting the use of good farming practices"(EC n.d.f). This includes the requirement for Member States to establish Codes of Good Agricultural Practice, which should cover measures limiting the periods when nitrogen fertilisers can be applied and measures limiting the conditions for fertiliser application, among others. These Codes help farmers to protect their land and the environment from pollution but are non-binding. Even though the Nitrates Directive focuses on reducing local nitrate pollution of waters, it has also contributed to reducing GHG emissions from the agriculture sector by requiring balanced nitrogen fertilisation (Velthof et al. 2010). Member States manage CAP payments under specific national programmes and implement the Nitrates Directive through national legislation.

The **Farm to Fork Strategy** is part of the European Green Deal and aims to make food systems fair, healthy and environmental-friendly (EC n.d.b). The Strategy lays down the objective that at least 25% of the EU's agricultural land is under organic farming by 2030. Other objectives for 2030 include reducing nutrient losses by 50%, while ensuring there is no deterioration in soil fertility, which will reduce the use of fertilisers by at least 20%, as well as lowering pesticide use by 50% and reducing the overall EU sales of antimicrobials for farmed animals and aquaculture by 50%. Organic farming can contribute to achieving these objectives.

A.4.1 German NECP

A.4.1.1 Rational use of nitrogen fertilisers

Germany's NECP includes a subsection on the reduction of nitrogen surpluses (Chapter 3.1.1.i.3.), which is part of the section on agricultural PaMs but provides little detail by only giving a rough overview of the different planned initiatives. However, it mentions the national target related to fertiliser use, which is to reduce the nitrogen surplus on utilised agricultural area to 70 kgN/ha by 2030, in line with the objectives of the German Sustainability Strategy. It also states that Federal States have a responsibility regarding fertiliser legislation. The NECP does not describe a general approach towards nitrogen use in Germany.

As a key PaM, the German NECP presents changes to the Düngeverordnung [Fertiliser Ordinance] as the main approach to reducing nitrogen surpluses in the agriculture sector. It has a clear focus on fertiliser use and on reducing nitrate leaching, including associated nitrogen emissions. Furthermore, the NECP mentions 1) the Stoffstrombilanzverordnung [Ordinance for Material Flow Balance], 2) the nutrient management programme and 3) digitalisation. Considering that these additional three PaMs have no quantitative GHG emission reduction contribution in the Climate Protection Programme (BMU 2019b) and are not specifically listed in the PaM report (BMU 2019c), the following section focuses on the Fertiliser Ordinance. Table 94 provides a short description of the key PaMs under the focus topic "rational use of nitrogen fertilisers" in the German NECP.

Table 94: Key PaMs under the focus topic "rational use of nitrogen fertilisers" in the German NECP

Name of PaM	Short description	Selected for further evaluation?
Düngeverordnung [Fertiliser Ordinance]	The Fertiliser Ordinance specifies the requirements for good fertiliser application practice and regulates how to reduce risks associated with fertilisation including such as nutrient losses. Changes to the Fertiliser Ordinance should further reduce nitrogen surpluses, including ammonia and nitrous oxide emissions.	yes
Stoffstrombilanzverordnung [Ordinance for Material Flow Balance]	The aim of the Ordinance for Material Flow Balance is to map nutrient flows on farms in a transparent and verifiable manner. An evaluation takes place until the end of 2021, followed by a refinement of the rules.	no
Bundesprogramm Nährstoffmanagement [Nutrient management programme]	The nutrient management programme offers financial support for projects that increase resource efficiency and improve groundwater protection. Focus is on the promotion of new manure technologies and the expansion of manure storage facilities.	no
Digitalisation	Digitalisation as part of additional climate protection measures.	no

Source: own compilation, Ecologic based on (BMEL 2019b, 2020; BMWi 2019; German Federal Government 2021)

The **Fertiliser Ordinance ("Düngeverordnung")** is Germany's most important policy instrument for reducing nitrogen surpluses and regulating fertiliser use. It lays down the rules on the application of fertilisers, soil additives, cultivation substrates and plant auxiliaries in accordance with the principles of good-fertilising practice (BfJ 2017). It also regulates how to abate risks associated with fertilisation, such as nutrient losses. Germany implemented the Fertiliser Ordinance in 1996 to comply with the European Nitrates Directive. The German Federal States are responsible for the implementation and systematic enforcement of the Fertiliser Ordinance (BMU 2019b).

Germany amended its national Fertiliser Ordinance in 2017, "[…] to adapt it to new professional requirements for improving the effectiveness of fertilisation and reducing environmental pollution" (BMEL 2020). However, in 2018, the European Court of Justice ruled that Germany failed to meet its obligations under the Nitrates Directive. As a result, the Federal Ministry of Food and Agriculture (BMEL) further tightened the rules in the Fertiliser Ordinance, for example by introducing an improved compulsory system of fertilisation records for each parcel (German Federal Government 2021). The new requirements entered into force in April 2020. Table 95 provides an overview of the relevant and selected policy instruments for the Fertiliser Ordinance.

Table 95: Relevant policy instruments for the Fertiliser Ordinance

Selected PaM	Associated policy instrument(s)	Legal basis
Fertiliser Ordinance	Fertiliser Ordinance	Fertiliser Ordinance

Source: own compilation, Ecologic

Evaluations of the Fertiliser Ordinance

The great majority of evaluation studies are ex-ante and do not exclusively evaluate the impact of the Fertiliser Ordinance. They discuss the reduction of nitrogen surpluses on a more general level and in different contexts (e.g. meeting the requirements of the NEC Directive), in some cases consisting of a catalogue of technical measures that are available to this end.

The selected ex-ante evaluation (Harthan et al. 2020) is the study mentioned in the German NECP, which evaluates the GHG emission reduction potential of the German Climate Protection Programme 2030, including its individual PaMs.

The ex-post evaluation (Osterburg et al. 2012) seems to be the only available (extensive) study that evaluates the Fertiliser Ordinance on the national level. However, it does not evaluate its climate impact and does not link to either the German NECP or the Climate Protection Programme 2030. To partially close this information gap, we also included an ex-post evaluation of the EU Nitrates Directive (Velthof et al. 2010).

The 2019 and 2021 PaM reports (BMU 2019c; BMUV et al. 2021) – also referred to as projection reports – were used to compare the ex-ante and ex-post estimates.

Table 96 provides an overview of the available and selected ex-ante and ex-post evaluations for the Fertiliser Ordinance.

Table 96: Available and selected ex-ante and ex-post evaluations for the Fertiliser Ordinance

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
Fertiliser Ordinance	**Harthan et al. (2020). Abschätzung der Treibhausgasminderungswirkung des Klimaschutzprogramms 2030 der Bundesregierung [Estimation of the greenhouse gas reduction effect of the German government's Climate Protection Programme 2030]** Kuhn (2017)The revision of the German Fertilisation Ordinance in 2017: Analysing economic and environmental impacts at farm-level Hermann et al. (2020). Instrumente und Maßnahmen zur Reduktion der Stickstoffüberschüsse [Instruments and measures to reduce nitrogen surpluses] BMU (2019a). Nationales Luftreinhalteprogramms gemäß Art. 6 und Art. 10 der Richtlinie (EU) 2016/2284 über die Reduktion der nationalen Emissionen bestimmter Luftschadstoffe sowie gemäß §§ 4 und 16 der 43. Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes [National Clean Air Programme pursuant to Art. 6 and Art. 10 of Directive (EU) 2016/2284 on the reduction of national emissions of certain atmospheric pollutants and pursuant to Sections 4 and 16 of the 43rd Ordinance on the Implementation of the Federal Immission Control Act] Häussermann et al. (2020). Potenziale zur Minderung der Ammoniakemissionen in der deutschen Landwirtschaft	Osterburg et al. (2012): Evaluierung der Düngeverordnung – Ergebnisse und Optionen zur Weiterentwicklung [Evaluation of the Fertiliser Ordinance - Results and Options for Further Development] **Velthof et al. (2010): The impact of the Nitrates Directive on gaseous N Emissions. Effects of measures in nitrate action programme on gaseous N emissions.**

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
	Oehlmann et al. (2021). Maßnahmenvorschläge für ein Aktionsprogramm zur integrierten Stickstoffminderung [Proposed measures for an action programme for integrated nitrogen reduction] **BMU (2019c). Projektionsbericht 2019 für Deutschland gemäß Verordnung (EU) Nr.525/2013 [Projection report 2019 for Germany according to Regulation (EU) No.525/2013]** **BMUV et al. (2021). Projektionsbericht 2021 für Deutschland gemäß Artikel 18 der Verordnung (EU) 2018/1999 des Europäischen Parlaments und des Rates vom 11. Dezember 2018 über das Governance-System für die Energieunion und für den Klimaschutz, zur Änderung der Verordnungen (EG) Nr. 663/2009 und (EG) Nr. 715/2009 des Europäischen Parlaments und des Rates sowie §10 (2) des Bundesklimaschutzgesetzes [Projection Report 2021 for Germany pursuant to Article 18 of Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the governance system for the Energy Union and for climate protection, amending Regulations (EC) No 663/2009 and (EC) No 715/2009 of the European Parliament and of the Council, and Section 10 (2) of the Federal Climate Protection Act]**	

Source: own compilation, Ecologic. The evaluations that were selected for an in-depth assessment are shown in bold font.

Results from the ex-ante evaluation

The ex-ante evaluation "Estimation of the greenhouse gas reduction effect of the German government's Climate Protection Programme 2030" uses the same methodology as the PaM report for Germany from 2019 and related update from 2021. It uses a forward-looking baseline against which it assesses the GHG emission reduction potential of the German Climate Protection Programme 2030's (as of 29 January 2020) individual measures. There is a brief description on assumptions and parameters for the reference scenario as well as for the agricultural projections.

The study includes six agricultural bundles of policy instruments, of which one is the "Senkung der Stickstoffüberschüsse einschließlich Minderung der Ammoniakemissionen und gezielte Verminderung der Lachgasemissionen [und] Verbesserung der Stickstoffeffizienz" [Reduction of nitrogen surpluses including reduction of ammonia emissions and targeted reduction of nitrous oxide emissions and improvement of nitrogen efficiency] (in the following: "reduction of nitrogen surpluses and emissions"). The latter bundle includes inter alia the improvement and further development of the Fertiliser Ordinance. However, it also includes other measures in that area such as the further development of the Ordinance of Material Flow Balance and increasing the proportion of gas-tight stored manure from cattle and pig farming to 70%.

The ex-ante evaluation shows a reduction of 3.8 Mt CO_2eq – mainly N_2O from agricultural soils – by reducing nitrogen surpluses, as part of a total reduction of 8.9 Mt CO_2eq from all agricultural measures. These figures relate to the reduction realised by 2030 in the reference scenario

complemented by the Climate Protection Programme when compared to 2016. The reduction of the additional effort stipulated by the Programme merely accounts for 0.5 Mt CO_2eq and relates to reducing the nitrogen surplus to 70 kg N/ha, mainly through reduced and improved fertiliser use. The changes to the Fertiliser Ordinance are "one of the main drivers" of realising the reductions, most of which already materialise in the reference scenario.

However, in fact the ex-ante evaluation does not estimate the effects of a changed Fertiliser Ordinance, because no draft was available due to the additional requirements by the European Commission. Instead it uses GHG emission reduction estimates for the Climate Protection Programme based on the assumption that Germany reduces its nitrogen surpluses from currently 98 kg N/ha (mean value of the overall balance 2015-2017) to 70 kg N/ha (on an annual average between 2028 and 2032), the goal which was set in the German Sustainability Strategy (German Federal Government 2021). So instead of assessing the design of the policy instrument, the ex-ante evaluation merely projects that Germany will reach its goal of reducing its nitrogen surplus. The ex-ante evaluation acknowledges that it is uncertain as to whether the changed Fertiliser Ordinance (as well as the measures under the NEC Directive) will be sufficient to meet this goal. In addition, there are modelling uncertainties regarding the reduction per hectare calculated for nitrogen surpluses, since in areas with high livestock densities the required reduction might be higher and thus have a greater impact. Table 97 shows the target contributions of the "reduction of nitrogen surpluses and emissions" including the Fertiliser Ordinance according to the ex-ante evaluation.

Table 97: Target contributions of the "reduction of nitrogen surpluses and emissions" including the Fertiliser Ordinance according to the ex-ante evaluation

National targets and contributions	2016-2030	2025	2030	Reference case and year
Reduction of GHG emissions [kt CO_2e]	n/a	n/a	WEM: 3,300 CPP: 3,800 (WEM plus 500)	Compared to 2016; With existing measures (WEM) taken from 2019 PaM report; additional impact from Climate Protection Programme (CPP)

Source: own compilation, Ecologic based on (Harthan et al. 2020)

The ex-ante evaluation focuses exclusively on the GHG emission reduction potential and does not consider additional categories, such as costs, investments, employment or any other socio-economic effects of changing the Fertiliser Ordinance. The official Climate Protection Programme 2030 discusses this briefly and only qualitatively, in the broader context of reducing nitrogen surpluses. It states that the planned upper limit for N fertilisation based on determining fertiliser needs and the stricter limitation of N fertilisation in nitrate-polluted areas may lead to a decrease in yields, which should be viewed critically and closely monitored. At the same time, it states the environmental advantages as reducing the nitrogen surplus and increasing N efficiency serves the purpose of protecting waters, controlling air pollution and conserving biodiversity (BMEL 2019a).

Results from the ex-post evaluations

The Federal Ministry of Food, Agriculture and Consumer Protection commissioned the ex-post evaluation "Evaluierung der Düngeverordnung – Ergebnisse und Optionen zur Weiterentwicklung" [Evaluation of the Fertiliser Ordinance - Results and Options for Further Development]. The evaluation includes discussions and analysis of the working group on the

evaluation of the Fertiliser Ordinance. This working group included representatives from federal ministries and federal state ministries as well as experts from various institutions. Sub-working groups focused on the individual regulations of the Fertiliser Ordinance in six areas. The ex-post evaluation defines individual weaknesses and criticisms of the Fertiliser Ordinance and proposes options for further development in the areas of fertilisation planning, site and soil condition specific restrictions, application times (except soil condition) and storage time (blocking periods, application after harvesting of the main crop and straw fertilisation), application technology and training, nutrient comparisons - methods and balances and application ceilings. The ex-post evaluation does not analyse the impact of the Fertiliser Ordinance on GHG emissions.

For each of the options for further development, the ex-post evaluation provides a description and analyses generally the following issues: the effect on the nutrient supply of plants, impacts of each option, regional effects, impact on the environment, effect on implementation and reference to other schemes. It describes the impact on the environment mainly based on scientific literature in combination with expert judgement. The impact on nitrogen and phosphorus inputs and associated GHG emissions is occasionally mentioned in qualitative form or as a potential. The ex-post evaluation does not consider the impact of changing the Fertiliser Ordinance as a whole.

We found no ex-post evaluation calculating the GHG emission reduction impact of the Fertiliser Ordinance. However, an ex-post evaluation of the EU Nitrates Directive (Velthof et al. 2010), implemented in Germany by the Fertiliser Ordinance, provides the reduction of N_2O emissions in kt N for the period from 2000 to 2008 with and without the Nitrates Directive. The study used the MITERRA-EUROPE model to calculate gaseous N emissions and gathered data from literature and statistical databases (e.g. Eurostat and FAO-stat), comparing the results of scenarios with and without the implementation of the Nitrates Directive.

For Germany, Velthof et al. (2010) shows a reduction of 0.95 kt N in 2000 and 1.34 kt N in 2008 due to the implementation of the Nitrates Directive. These reductions are equal to 463 kt and 653 kt CO_2eq for 2000 and 2008, respectively.[40] Moreover, its implementation reduced N leaching by 26.4 kt N in 2000, and 35.3 kt N in 2008. Table 98 shows the target contributions of the Nitrates Directive in Germany according to the ex-post evaluation.

Table 98: Target contributions of the Nitrates Directive in Germany according to the ex-post evaluation

National targets and contributions	2000 -2008	2000	2008	Reference case and year
Reduction of GHG emissions [kt CO_2eq]	n/a	463	653	Same year (2000; 2008) in a counterfactual scenario without the Nitrates Directive
Increase of RES consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of final energy consumption [ktoe]	n/a	n/a	n/a	n/a

[40] We calculated the related CO_2-equivalents by transferring N to N_2O (*44/28) and a global warming potential of 310 for the time horizon of 100 years.

Source: own compilation, Ecologic based on (Velthof et al. 2010)

Velthof et al. (2010) states that generally the use of N in amounts that exceed plant needs can lead to a variety of problems directly related to human health and ecosystem vulnerability. These include decreased species diversity and acidification of non-agricultural soils, pollution of ground water and drinking water, eutrophication of surface water and a decrease in natural diversity, global warming and impacts on human health due to ozone and particulate matter. The study, however, only calculates total N leaching to ground and surface waters and does not calculate the related GHG emissions.

Comparison between the ex-ante and ex-post evaluations and with the NECP

The NECP does not provide any detail about the impact of the Fertiliser Ordinance, or any other PaM in the agricultural sector. As a result, it proves difficult to compare the NECP to any evaluation. However, the overall development of the agricultural emissions seems in line with the PaM report of the German government under the MMR from 2019 (BMU 2019c). This PaM report outlines an **emission reduction** from the Fertiliser Ordinance and related measures of 2,519 kt CO_2eq in 2030 when compared to the baseline, which assumes no change in fertiliser use since 2016. The new 2021 PaM report (BMUV et al. 2021) shows almost the same emission reduction of 2,515 kt CO_2eq in 2030. The ex-ante study (Harthan et al. 2020) estimates a higher reduction of the existing design of the PaM – 3,300 kt CO_2e by 2030 when compared to 2016 – as well as that additional effort to improve fertiliser use by further developing the Fertiliser Ordinance leads to an additional reduction of roughly 500 kt CO_2e in 2030 when compared to the reference of no changes to the Fertiliser Ordinance in 2016. However, Harthan et al. (2020) also included the Ordinance for Material Flow Balance as part of the PaM, which the 2021 PaM report lists separately with a reduction of 880 kt CO_2eq in 2030. This means that both studies outline almost the same GHG emission reduction.

The ex-post evaluation of the Nitrates Directive (with the Fertiliser Ordinance implementing the Directive in Germany) shows a similar reduction as the additional impact of the CPP with 463 to 653 t CO_2eq (for the years 2000 and 2008 compared against a scenario without the Directive) (Velthof et al. 2010). However, Harthan et al. (2020) estimate a much higher reduction of 3,300 t CO_2eq by 2030 when compared to 2016 which is – even if the trend from the ex-post evaluation would continue – more than twice as high. While all ex-ante and the ex-post studies assume that the Fertiliser Ordinance is the most important policy instrument realising the reductions, the ex-ante studies (PaM report and Harthan et al.) assume that the N input excess is significantly reduced. This explains the difference to the ex-post evaluation, which evaluates an early version of the Fertiliser Ordinance.

A.4.1.2 Organic farming

The German NECP notes that "increasing the area devoted to organic farming is also a climate measure". It outlines that the federal government will optimise existing legal and financial support and further develop legislation with the aim of promoting particularly environmental friendly methods, including organic agriculture.

Germany had a 20% organic agriculture target for 2030, which was laid down in the German National Sustainability Strategy. However, in 2021 – two years after Germany submitted their NECP – the new federal government raised this target to 30% with the coalition agreement for 2021-2025. The "Zukunftsstrategie ökologischer Landbau" [Strategy for the Future of Organic Farming] supports the target achievement with 24 measures divided into five fields of action

(BMEL 2019c); the measures have been further developed over the past years to address the new target (BMEL 2022).

The European Agricultural Fund for Rural Development provides financial support for organic farming through Regional Development Programmes (RDPs; 13 RDPs in total exist in Germany), which requires national co-financing (BMEL n.d.; EC n.d.b). The federal government participates through the "Gemeinschaftsaufgabe zur Verbesserung der Agrarstruktur und des Küstenschutzes" [Joint Task for the Improvement of Agricultural Structures and Coastal Protection], in short GAK, in the promotion of organic farming. As part of support area 4, which is named "Market- and site-adapted as well as environmentally sound land management including contract-based nature conservation and landscape management", this includes the promotion of organic farming and other particularly sustainable whole-farm practices. The GAK describes here, among others, what it considers to be organic farming, the eligibility requirements, as well as the type and size of support payments. It does the same for low-emission and water-friendly application of manure, which is listed separately (BMEL 2021).

The German NECP lists a total of four PaMs for increasing organic farming (see Table 99), which are all interrelated. Most are mainly financial in nature, whereas one – the "Consolidation and further development of research promotion for organic farming" – clearly focuses on research to promote organic farming. Financial support in the form of area-based payments for existing organic farmland and for conversion is of considerable significance from the perspective of most organic farmers (Nieberg et al. 2007). This is confirmed by the ex-ante evaluation of the CPP (Harthan et al. 2020), which points to the importance of area-based subsidies as well as creating sufficient demand for organic products.

Table 99: Key PaMs under the focus topic "increase in organic farming" in the German NECP

Name of PaM	Short description	Selected for further evaluation?
Expansion of support for organic farming	Expanding the financial support to maintain organic farming. Together with the support for maintenance, the government reserved roughly 1.2 billion EUR for organic farmland under the Regional Development Programme for 2014-2020.	yes
Provision of the necessary subsidies for conversion in the federal state budgets and at the federal level	Ensuring that the financial support for organic farming can be provided.	yes
Implementation of the 'organic farming strategy' to generate additional stimulus for growth along the entire value creation chain (indirect funding).	Published in 2017, the Strategy for the Future of Organic Farming aims to boost the growth of the organic farming and food sectors. Currently, it contains 5 lines of action and 24 action strategies.	No

Name of PaM	Short description	Selected for further evaluation?
Consolidation and further development of research promotion for organic farming, e.g. in the form of the BÖLN programme (Federal Programme for Organic Farming and Other Forms of Sustainable Agriculture).	The BÖLN promotes research on organic farming and disseminates results into practice.	No

Source: own compilation, Ecologic based on (BLE n.d.; BMEL 2019b, 2020; BMWi 2019; German Federal Government 2021)

The German PaM report and CPP both include the "increase of organic farming" with estimated GHG emissions but do not distinguish between specific policies. Therefore, we selected "financial support of organic farming" as a policy instrument by subsuming the two selected PaMs from Table 99.

Table 100: Relevant policy instruments for financial support for organic farming

Selected PaM	Associated policy instrument(s)	Legal basis
Financial support of organic farming	Financial support of organic farming	EU: Rural Development Programme National level: Gesetz über die Gemeinschaftsaufgabe "Verbesserung der Agrarstruktur und des Küstenschutzes" [Act on the Joint Task "Improvement of the Agricultural Structure and Coastal Protection"]

Evaluations of financial support for organic farming

The selected ex-ante evaluation (Harthan et al. 2020) is the study mentioned in the German NECP, which evaluates the GHG emission reduction potential of the German Climate Protection Programme 2030, including its individual PaMs. In addition, ex-ante GHG emission reduction figures are available from the 2019 and 2021 PaM reports (BMU 2019c; BMUV et al. 2021).

We could not identify an ex-post evaluation on the national level. However, many ex-post assessments that focus on the RDP are available on the level of the German federal states, mainly over programming period 2007-2013. Considering that Bavaria, Baden-Württemberg and Berlin/Brandenburg are the federal states with the highest share of organic farming (BLE 2021b), we briefly assessed the RDP evaluations from these states. We selected the ex-post evaluation for Berlin/Brandenburg because it contains most relevant qualitative and quantitative information on organic farming.

Table 101: Available and selected ex-ante and ex-post evaluations for financial support of organic farming

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
Financial support	**Harthan et al. (2020). Abschätzung der Treibhausgasminderungswirkung des**	ART (2016). Ex post-Bewertung des Bayerischen Zukunftsprogramms

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
of organic farming	**Klimaschutzprogramms 2030 der Bundesregierung [Estimation of the greenhouse gas reduction effect of the German government's Climate Protection Programme 2030]** BMU (2019c). Projektionsbericht 2019 für Deutschland gemäß Verordnung (EU) Nr.525/2013 [Projection report 2019 for Germany according to Regulation (EU) No.525/2013] BMUV et al. (2021). Projektionsbericht 2021 für Deutschland gemäß Artikel 18 der Verordnung (EU) 2018/1999 des Europäischen Parlaments und des Rates vom 11. Dezember 2018 über das Governance-System für die Energieunion und für den Klimaschutz, zur Änderung der Verordnungen (EG) Nr. 663/2009 und (EG) Nr. 715/2009 des Europäischen Parlaments und des Rates sowie §10 (2) des Bundesklimaschutzgesetzes [Projection Report 2021 for Germany pursuant to Article 18 of Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the governance system for the Energy Union and for climate protection, amending Regulations (EC) No 663/2009 and (EC) No 715/2009 of the European Parliament and of the Council, and Section 10 (2) of the Federal Climate Protection Act]	Agrarwirtschaft und Ländlicher Raum 2007-2013 (BayZAL) [Ex post evaluation of the Bavarian Programme for the Future Agriculture and Rural Areas (2007-2013)] IfLS (2016). Ex post-Bewertung „Maßnahmen- und Entwicklungsplan Ländlicher Raum Baden-Württemberg 2007 - 2013 (MEPL II)“ [Ex post evaluation "Action and Development Plan Rural Areas Baden-Württemberg 2007 - 2013 (MEPL II)" **Bonneval et al. (2016). Ex-post-Bewertung des Entwicklungsplans für den Ländlichen Raum Brandenburgs und Berlins (EPLR) 2007 bis 2013 [Ex-post evaluation of the development plan for the rural areas of Brandenburg and Berlin (EPLR) 2007 until 2013]**

Results from the ex-ante evaluation

The study on the “Estimation of the greenhouse gas reduction effect of the German government's Climate Protection Programme 2030” (for more information on the methodology and assumptions see the previous section) includes a bundle of agricultural policy instruments, which is named “Ausweitung der ökologisch bewirtschafteten Fläche” [Increase of organic farming], which encompasses the expansion of support, promotion of marketing and research for organic agriculture. With the implementation of the Climate Protection Programme, Harthan et al. (2020) extrapolate the expansion rate of area under organic farming over 2015-2018 (118.000 ha per year). This implies an additional of 1.42 million ha converted to organic farming by 2030 compared to the reference scenario, which corresponds to 18% of current agricultural land. The study indicates that this share can reach 20% if the current downward trend of the total land used for agriculture continues.

The ex-ante evaluation considers the mitigation effect of organic agriculture through reducing N_2O, which is realised by the abandonment of mineral fertiliser use on the additional organic farmland, as well as the CO_2 emissions reduction from the use of urea and the GHG emission reduction effect due to lower harvest residues related to lower yields associated with organic farming. The study indicates that there are overlaps with the PaMs aiming to reduce the nitrogen surplus, since lower fertiliser levels realised in conventional farming leads to lower emission reductions when this land is converted to organic farming. It states that this effect has been considered for the nitrogen reduction measures. Moreover, the study points out that the reduction effect of organic farming primarily depends on the cultivation intensity of farms that convert to organic farming and that they used an average reduction value per hectare to this end.

The ex-ante evaluation shows a total reduction of 1.3 Mt CO_2eq from an increase in organic farming by 2030 compared to 2016, of which 0.4 Mt CO_2eq are realised in the reference scenario and an additional reduction of 0.9 Mt CO_2 from additional measures in the Climate Protection Programme. It also notes that past developments have shown that the conversion rate for organic farming is subject to extreme fluctuations, which are the result of changing funding conditions and market fluctuations. To secure and stabilise the increase in organic farming area, additional funds for area-based subsidies of more than 400 million EUR per year are needed according to the study, also beyond 2030. It also notes that the long-term provision of these subsidies is risky for the EU and for the federal states of Germany as co-financiers; on the demand side, it should be ensured that organic products can be sold in sufficient quantities and at adequate prices, which becomes a greater challenge as the market share of organic farming increases. This also comes with an additional need for appropriate instruments to stimulate demand (e.g., consumer information) as well as the entire trade and processing chain.

Similarly, the Climate Protection Programme 2030 (BMU 2019b) states that no clear trend can be established over recent years regarding the expansion of organic farming area; in 2013 and 2014 the increase was 1% and 0.3%, respectively, whereas in 2016 and 2017 the increase was around 15% and 10%. Conversion rates were low between 2010 and 2014, but the total organic farming area grew between 2015 and 2018, in part because of an increase in the premium.

Accordingly, the ex-ante evaluation assumes an expansion rate of area under organic farming based on a period (2015-2018) in which the rate was higher compared to previous years. It also becomes clear that the availability and amounts of subsidies will be decisive for the extent to which an increase in organic farming will materialise (BLE 2021a).

The emission reduction estimate of the ex-ante study (Harthan et al. 2020) is higher compared to the impact outlined in the new 2021 PaM report (BMUV et al. 2021), the latter being 629 kt CO_2eq in 2030. The emission reduction in the 2021 PaM report is based on the CPP's assumption that 20% of agricultural land will be under organic farming and is compared to a counterfactual scenario in which this share reaches only 14%. With a 415 kt CO_2eq reduction by 2030, the results from the 2019 PaM report (BMU 2019c) are similar to the reference estimate of Harthan et al. (2020).

Table 102: Target contributions of the "increase in organic farming' according to the ex-ante evaluation and the PaM report

National targets and contributions	2016-2030	2025	2030	Reference case and year
Reduction of GHG emissions [kt CO_2eq]	n/a	n/a	WEM: 400 CPP: 1,300 (WEM plus 900)	Figures from ex-ante evaluation. Compared to 2016; With existing measures (WEM) taken from 2019 PaM report; additional impact from Climate Protection Programme (CPP).

Source: Emele et al. (2019), Harthan et al. (2020)

Next to the GHG emission reduction, the ex-ante evaluation highlights minimum required investments of 400 million EUR annually to ensure a continuous increase in organic farming and points out the overlap with reducing nitrogen surpluses. However, it does not discuss additional impacts related to an increase in organic farming. In comparison, the official Climate Protection Programme 2030 briefly discusses a range of environmental, social and economic impacts. This includes positive employment effects; the CPP highlights that organic farming employs 0.2 to 0.3 more workers per 100 hectares compared to conventional farming. Other benefits are the preservation of biodiversity and positive effects on human health. The CPP, however, also

explains that an increase in the share of organic farming from 12% to 20% is expected to result in a production decline of 4.5 million tonnes of cereals per year. It also points out the overlap with measures to reduce the nitrogen surplus and that organic farming should primarily be promoted to implement environmental objectives related to biodiversity and water protection.

Results from the ex-post evaluation

Berlin and Brandenburg have a joint rural development plan. The study "Ex-post evaluation of the development plan for the rural areas of Brandenburg and Berlin (EPLR) 2007 until 2013" assesses the overall programme implementation, results and impacts. This includes (but is not limited to) the following topics: growth and labour productivity in rural areas, labour productivity in agriculture and forestry, employment, biodiversity, water quality, climate protection and quality of life. It describes the different measures, the used methodology and data reliability. The focus of the assessment here is on the part of the ex-post evaluation that addresses organic farming.

The total budget for the RDP was 1.35 billion EUR, which was increased in 2009 to 1.5 billion EUR. In total, the European Agricultural Fund for Rural Development provided 1.25 billion EUR and national co-financing made up the remaining part of the budget. Agri-environmental measures – of which organic farming is a part (Code 214) – accounted for around 20.4% of the total programme expenditures over the period 2007-2013.

Organic farming is further distinguished between the promotion of arable land, permanent green land, outdoor vegetable cultivation and permanent crops. For organic farming, the complete abandonment of synthetic fertilisers and low N-balance surpluses are considered, as well as the reduction potential of lower livestock densities, a higher proportion of livestock housing systems with solid manure, higher humus contents in arable soils and lower purchase of feedstuffs. The ex-post evaluation states that organic farming compared to conventional farming leads to lower emissions of 1.75 t CO_2eq per hectare across the board (including farmlands and animal husbandry); organic-farming measures on average led to yearly reduced GHG emissions of 204 kt CO_2eq in Berlin and Brandenburg from 2007 to 2013. Together with other agri-environmental measures that foster reduced N input, the total reduction is estimated at 215.2 kt CO_2eq on a yearly basis and total savings over the total programming period of 1,577 kt CO_2eq. In 2008-2009, 93,964 hectares were under organic farming compared to 111,931 ha in 2014 (increase of approx. 19%). This 19% increase is reflected in the associated N and GHG emission reductions, which were also around 19%. In 2014, organic farming measures made up around three-quarters of total GHG emission reduction achieved by the agri-environmental measures on a yearly basis.

In this context, the ex-post evaluation states that the creation of a detailed model to estimate GHG emission reductions is very complex and cannot be carried out based on the available data. Therefore, it uses flat-rate values and the amount of nitrogen saved by using less fertiliser was assessed with subsequently using average N reduction potentials of different measures, and finally calculating associated N_2O emissions and converting these into CO_2eq.

For issues such as biodiversity, water quality and soil quality, the ex-post evaluation mainly looks at how many hectares are managed with relevant agri-environmental measures. For example, under "areas with successful land management measures contributing to the improvement of water quality", it lists a total of 116.244 hectares for organic farming (approx. 41% of all areas that contribute to better water quality). The ex-post evaluation notes that most area targets were achieved (or almost) in this regard. However, it also notes that achieving area targets does not immediately translate into high impact because measures applied on a larger scale generally place lower demands on management and have a less specific effect. The ex-post

evaluation highlights that organic farming on arable land made the greatest contribution to the improvement of soil quality.

Comparison between the ex-ante and ex-post evaluations and with the NECP

The NECP does not provide any detail about the impact of financial support of organic farming, or any other PaM in the agriculture sector. Accordingly, it proves challenging to compare the NECP to any evaluation. However, the NECP uses the information from the ex-ante study (Harthan et al. 2020) considered here, which shows that the implementation of the CPP will lead to a significant additional impact from organic farming equal to 900 kt CO_2eq. This is based on an extrapolated expansion rate (118,000 ha per year) for organic farming resulting in a share of 18-20% of all agricultural land in 2030. As the ex-ante evaluation points out, this would require a significant increase in annual available funds for area-based subsidies, also beyond 2030. The 2019 PaM report outlines emission reductions of 415 kt CO_2eq per year by 2030 for an increase in organic farming, which is slightly higher compared to the WEM scenario of the ex-ante evaluation (400 kt) (see Table 102). The new 2021 PaM report took over the higher emission reductions associated with a more rapid expansion of organic farming to reach the 20% of total agricultural land being organic farmland by 2030. To reach the federal government's 30% target of agricultural land under organic farming by 2030, the expansion rate would need to be even higher. This would lead to additional GHG emission savings but would increase the required financial support accordingly.

The ex-ante and ex-post evaluations point out that organic farming overlaps with reduced fertiliser use, since the impact of converting conventional farmland into organic farmland is smaller when fertiliser levels are already down. How much GHG emission reductions an increase of organic farming can achieve is closely interlinked with the previous management intensity of the converted areas. Both evaluations use average, fixed values to calculate the reductions per hectare.

Harthan et al. (2020) indicate that additional funds for area-based subsidies of more than 400 million EUR per year are needed, also beyond 2030, to secure and stabilise the increase in organic farming area. Expected impacts of such increasing the share of organic agriculture include an increase in employment: the German CPP highlights that organic farming employs 0.2 to 0.3 more workers per 100 hectares compared to conventional farming. However, production losses are also to be expected in the order of 4.5 million tonnes of cereals per year if the share of organic farming in total agricultural land increases from 12% to 20%. For issues such as biodiversity, water quality and soil quality, the ex-post evaluation mainly looks at how many hectares are managed with relevant agri-environmental measures.

A.4.2 Danish NECP

A.4.2.1 Rational use of nitrogen fertilisers

The Danish NECP does not have a subsection on nitrogen fertiliser use nor any information or individual targets on this focus topic. Relevant PaMs include rather overarching action plans and political agreements, including the Action Plan for the Aquatic Environment I+II+III and its successive Green Growth Agreement, the Action Plan for Sustainable Agriculture, as well as a general measure on reducing emissions of ammonia. However, most PaMs are expired. Current relevant agreements include the Political Agreement on a Food and Agricultural Package and the Agreement on Nature. In addition, as part of the additional PaMs section the Danish NECP states

that the government reached an agreement to allocate DKK 2 billion (approx. 267 million EUR)[41] in the period 2020-2029 to "[...] reduce greenhouse gas emission from agriculture as much as possible". Table 103 provides a short description of the key PaMs under the focus topic "rational use of nitrogen fertilisers" in the Danish NECP.

Table 103: Key PaMs under the focus topic "rational use of nitrogen fertilisers" in the Danish NECP

Name of PaM	Short description	Selected for further evaluation?
Action Plans for the Aquatic Environment I+II and Action Plan for Sustainable Agriculture (expired)	The Action Plans for the Aquatic Environment I+II and the Action Plan for Sustainable Agriculture had the goal to reduce agriculture's nutrient losses to the aquatic environment. They included requirements regarding closed periods for applying slurry, ensuring a better utilisation of manure, minimum slurry storage capacity, mandatory work-in of manure into the soil shortly after application and winter green fields.	No
Action Plan for the Aquatic Environment III (expired)	The Action Plan for the Aquatic Environment (APAE) III ran from 2005-2009 and consisted of broader efforts to reduce agricultural impacts on the aquatic environment and nature. APAE III represented the Danish Nitrate Action Programme and was a follow up to APAE I (1987-1998) and APAE II (1998-2004).	Yes
Green Growth Agreement (expired)	The Green Growth Agreement (2009-2010) takes on a broader perspective compared to the APAEs. Its aim was to ensure that a high level of environmental, nature and climate protection went hand in hand with modern and competitive agriculture and food industries. The Green Growth Agreement was introduced due to the lack of the GHG emission reduction from APAE III, and focused more on financial incentives as opposed to regulatory standards.	Yes
Green Growth Agreement 2.0 (expired)	The Green Growth Agreement (GGA) was reinforced in 2010 by the Green Growth Agreement 2.0. In 2015, the Political Agreement on a Food and Agricultural Package replaced the Green Growth Agreement.	No

Source: own compilation, Ecologic based on (Danish Ministry of Climate, Energy and Utilities 2017b, 2019a; EPA n.d.a, n.d.b; Hölscher et al. 2018)

The selected APAE and the follow-up Green Growth Agreement have a clear focus on fertiliser use and reducing nitrate leaching, including associated nitrogen emissions. Although the PaMs are expired, they are still listed in the Danish NECP and PaM report albeit without providing GHG emission reduction figures. However, Denmark's Third Biennial Report under the UNFCCC states that the Action Plans for the Aquatic Environment, as well as the Action Plan for Sustainable Agriculture, have led to emission reductions of nitrous oxides and that since 1990,

[41] Assumed exchange rate of 1 EUR = 7,5 DKK

most changes in their emission from the agriculture sector are the result of these action plans (Danish Ministry of Climate, Energy and Utilities 2017b).

Starting in 1987, the Danish government implemented a series of action plans and agreements that regulated farming practices, with the goal "[…] to reduce agriculture's nutrient losses to the aquatic environment" (Danish Ministry of Climate, Energy and Utilities 2017b). Nitrogen leaching can lead to eutrophication due to the excessive build-up of nutrients in water bodies. This results in increases of weeds and algae and lower levels of oxygen, which in turn has a negative impact on biodiversity (EEA 2018).

There are three Action Plans for the Aquatic Environment (APAE): APAE I (1987-1998), APAE II (1998-2004) and APAE III (2005-2009). They included requirements related to closing periods for applying slurry, ensuring a better utilisation of manure as well as minimum slurry storage capacity, mandatory incorporation of manure into the soil shortly after application and winter green fields (Danish Ministry of Climate, Energy and Utilities 2017b).

APAE II introduced additional measures, such as re-establishment of wetlands, afforestation, agreements on environment friendly agricultural measures, establishment of organic farming on an additional 170,000 ha, improved utilisation of fodder, reduced animal density, use of catch crops, more stringent fertilisation norms and increased efficiency of use of nitrogen in manure. The overall goal was to reduce nitrogen leaching by 100,000 t N per year (Danish Ministry of Climate, Energy and Utilities 2017b).

APAE III set targets with regard to nitrogen (a 13% reduction of nitrogen leaching in 2015 compared to 2003), phosphorus (halving the phosphorus surplus in 2015 compared to 2001/2002) (EPA n.d.a), sensitive natural areas and slurry odour, and focused in particular on the use of catch crops, afforestation, agro-environmental measures and tightening the requirements for the use of manure. It also contained research initiatives on slurry odours and the reduction of emission from nutrients (Danish Ministry of Climate, Energy and Utilities 2017b).

In 2009, the Danish government implemented the Green Growth Agreement (GGA). The GGA included the targets from APAE III, but focused more on financial incentives as opposed to regulatory standards, with additional measures mainly directed at increasing farming efficiency and providing financial support to produce biomethane (Hölscher et al. 2018). In 2010, the government reinforced the GGA with the Green Growth Agreement 2.0 (Danish Ministry of Climate, Energy and Utilities 2017b). The APAEs and GGA were legally binding and constituted the Danish national implementation of the Nitrates Directive (starting with APAE II) (Hölscher et al. 2018).

Considering that the Danish NECP does not further distinguish individual policy instruments for APAE III and the GGA, and evaluations generally assess action plans as a whole, the PaM is also the policy instrument. Table 104 provides an overview of the relevant and selected policy instruments for APAE III and the GGA.

Table 104: Relevant and selected policy instruments for APAE III and the GGA

Selected PaMs	Associated policy instrument(s)	Legal basis
Action Plan for the Aquatic Environment (APAE) III and the Green Growth Agreement (GGA)	Action Plan for the Aquatic Environment (APAE) III and the Green Growth Agreement (GGA)	Action Plan for the Aquatic Environment (APAE) III and the Green Growth Agreement (GGA)

Source: own compilation, Ecologic

Evaluations of the Action Plan for the Aquatic Environment (APAE) III and the Green Growth Agreement (GGA)

The Danish evaluations assess broader nitrogen-reduction programmes whereby they outline the impacts of individual measures. The evaluations are frequently mid-term reviews that contain an ex-post and ex-ante part.

The mid-term review of APAE III (Børgesen et al. 2009) is extensive and the only one that has a clear focus on this policy instrument. In addition to this study, Denmark used the results of the climate note (Schelde et al. 2014), which transfers information amongst other on N inputs and leaching from a follow-up evaluation of the APAE III and GGA (Børgesen et al. 2013) into GHG emissions. It is referenced in the Third Biennial Report under the UNFCCC (Danish Ministry of Climate, Energy and Utilities 2017a). None of the studies -which both include an ex-post and ex-ante part – are listed in the Danish NECP. Table 105 provides an overview of the available and selected evaluations for the Action Plan for the Aquatic Environment III and the Green Growth Agreement.

Table 105: Available and selected ex-ante and ex-post evaluations for the Action Plan for the Aquatic Environment III and the Green Growth Agreement

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
APAE III and GGA	**Børgesen et al. (2009). Midtvejsevaluering af Vandmiljøplan III [Mid-Term Review of the APAE III]** **Schelde et al. (2014). Klimaeffekt af kvælstofvirkemidler I dansk landbrug i perioden 2007-2015 [Climate impact of nitrogen inputs in Danish agriculture in the period 2007-2015]** Jacobsen (2012). Analyse af omkostningerne ved en yderligere reduktion af N-tabet fra landbruget med 10.000 tons N [Analysis of the costs of further reducing N losses from agriculture by 10,000 tonnes of N] Jacobsen, Brian, H. (2012). Analyse af landbrugets omkostninger ved implementering af vandplanerne fra 2011 [Analysis of the costs to agriculture of implementing the 2011 water plans] **Danish Ministry of Climate, Energy and Utilities (2019b). Denmark's update on the national system for policies and measures and projections, the low-carbon development strategy, climate policies and measures, greenhouse gas projections and LULUCF action**	**Børgesen et al. (2009). Midtvejsevaluering af Vandmiljøplan III [Mid-Term Review of the APAE III]** **Schelde et al. (2014). Klimaeffekt af kvælstofvirkemidler i dansk landbrug i perioden 2007-2015 [Climate impact of nitrogen inputs in Danish agriculture in the period 2007-2015]**

Source: own compilation, Ecologic. The evaluations that were selected for an in-depth assessment are shown in bold font.

The Faculty of Agricultural Sciences at the University of Aarhus conducted the mid-term review of the APAE III, which includes an ex-post (2003-2007) and ex-ante (2010-2015) assessment, as well as a separate economic review. Generally, the data basis and data collection are described with high detail, and the study contains an elaborate background note, which provides more information on how e.g. the modelling was done. Since APAE III constituted the Danish Nitrate Action Programme, mid-term evaluations were planned in 2008 and 2011 in accordance with Article 5 of the Nitrates Directive (EPA n.d.a). The economic mid-term review, which is included

as a separate part, was conducted by the Institute of Food and Resource Economics at University of Copenhagen (FOI) in cooperation with The National Environmental Research Institute under the University of Aarhus (NERI). It assesses the total costs of APAE III and the cost-effectiveness of its individual measures with a focus on 2005-2009. Results were presented in DKK and converted into EUR using an exchange rate of 1 EUR = 7.5 DKK.

The Danish Agrifish Agency requested the National Centre for Food and Agriculture (Schelde et al. 2014) to calculate the climate effect of nitrogen use in Danish agriculture over the period 2007-2015. This includes calculations for 2007-2011 and estimations for 2012-2015. This climate note mainly converts the results from Børgesen et al. (2013), which evaluated nitrogen use in relation to APAE III and the GGA, into CO_2eq. To this end, it uses a set of emission and calculation factors from Nielsen et al. (2012), which were also used in Denmark's 2012 National Inventory Report. As a result, the climate note is relatively brief and does not provide much detail on the methodology or assumptions used. Instead, it references previous studies.

Results from ex-ante evaluations

The mid-term review (Børgesen et al. 2009) looks at the period up to 2015. It does not provide GHG emission reduction figures but estimates the APAE III measures and the general development of the agriculture sector would lead to a reduction of 5,000 t N leaching over the period 2004-2015, which is considerably less compared to the anticipated reduction of 18,000 t N leaching for the programme.

The study states that large price fluctuations have made it difficult to predict developments, and accordingly, the projections come with a high degree of uncertainty. The economic mid-term review considers costs divided by those born by the public and those by industry. Costs are estimated at EUR 80-133 million over the period 2010-2015 with industry expected to pay EUR 33-89 million and public funding covering the rest (including EU financing).

The climate note (Schelde et al. 2014) focuses on the estimation of GHG emission reductions of the GGA. The ex-ante estimates are for 2012-2015 and assume that the GGA leads to a reduction of 337 kt CO_2eq per year, with 179 kt CO_2eq being N_2O emission reductions followed by increased carbon storage. The reduction of N_2O comes from reduced fertilisation due to the implementation of different measures, of which the following realised the highest reduction:

a) Reduction of arable land for infrastructure and natural land without fertilisation with 25% transferred to nature: this leads to reduction of the average standard of 146 kg N/ha to 0 kg N/ha and reduces N_2O emissions in the order of 45.7 kt CO_2eq.

b) Organic agriculture: this reduces nitrogen fertilisation by 58 kg N/ha and reduces N_2O emissions in the order of 11.3-13.6 kt CO_2eq (see also Annex A.4.2.2).

c) Establishment of peripheral zones: this reduces nitrogen fertilisation by 100 kg N/ha and N_2O emissions in the order of 43.9-55.0 kt CO_2eq.

This means that the GGA was expected to reduce N_2O emissions mainly through land use change leading to a reduced need for fertilisation. Table 106 shows the target contributions of the GGA according to the ex-ante evaluation.

Table 106: Target contributions of the GGA from reduced N_2O emissions according to the ex-ante evaluation

National targets and contributions	2015	2025	2030	Reference case and year
Reduction of GHG emissions [kt CO_2e]	179	n/a	n/a	Measured against a standard value of N inputs
Increase of RES consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of final energy consumption [ktoe]	n/a	n/a	n/a	n/a

Source: own compilation, Ecologic based on Schelde et al. (2014)

Results from ex-post evaluations

The mid-term review (Børgesen et al. 2009) assesses progress made to the following APAE III targets for 2015: a 13% reduction in nitrogen leaching compared to the year 2003; halving the phosphorus surplus compared to 2001-2002 levels and the establishment of an additional 50,000 ha buffer strips to reduce runoff. The mid-term review notes that there has not been a statistically significant reduction in the production of manure, a decrease in the consumption of fertilisers or lower levels of nitrogen leaching in the period 2003-2007, which ensured GHG emission reductions in the previous programmes. In other words, APAE III did not lead to significant GHG emission reductions by 2015. The phosphorus surplus had been reduced by about 6,500 tonnes (from 2001-2007), which corresponds to a reduction of approx. 23%. Accordingly, it is estimated that the objective of reducing the phosphorus surplus by 25% by 2009 is achieved. The establishment of 50,000 of hectares of new peripheral zones for rivers and lakes would be far from being met. The mid-term review also discusses progress to other objectives laid down in APAE III.

The costs amounted to 27 million EUR annually over the period 2005-2009, with yearly 22 million EUR for reducing nitrogen losses and 5 million EUR for reducing phosphorus losses. In total, the costs equalled 135 million EUR over the period. Of this, industry bore approximately 25% of the costs, the public sector the remaining 75%. The assessment also includes a cost-effectiveness analysis for each of the APAE III measures. A total reduced nitrogen leaching of 1,700 t N combined with annual costs at around 9.3 million EUR led to an average cost-efficiency of 5.50 EUR per kg N. This figure was twice as high as expected.

The climate note (Schelde et al. 2014) shows GHG emission reductions from the GGA of 190 kt CO_2eq per year over the period 2007-2011, of which 67 kt CO_2eq per year consisted of N_2O emission reductions and more than 100 kt CO_2eq per year came from carbon storage. The reduction of N_2O comes from reduced fertilisation due to the implementation of different measures, of which the following realised the highest reduction:

d) Reduction of arable land for infrastructure and nature with 25% transferred to natural land without fertilisation: this leads to reduction of the average standard of 146 kg N/ha to 0 kg N/ha and reduced N_2O emissions in the order of 11.2 kt CO_2eq (as was assumed for the ex-ante measure)

e) Increase of catch crops and energy crops: this leads to a reduction of fertiliser inputs of the average standard by 20kg N/ha for catch crops and 26 kg N/ha for energy crops and reduces N_2O emissions in the order of 12.6 kt CO_2eq.

f) Nitrogen quota: this leads to a reduction of 75 kg N/h, saves 873 t N for 11,600 ha and reduces N_2O emissions in the order of 8.9 kt CO_2eq per year.

g) Organic agriculture: this reduces nitrogen fertilisation by 58 kg N/ha and reduces N_2O emissions in the order of 11.3-13.6 kt CO_2eq (also considered as ex-ante measure) (see also Annex A.4.2.1).

This means that the GGA reduced N_2O emissions mainly through reduced fertilisation of agricultural soils because of other crops or practices. Table 107 shows the target contributions of APAE III and the GGA to reduced N_2O emissions according to the ex-post evaluation.

Table 107: Target contributions of APAE III and the GGA from reduced N_2O emissions according to the ex-post evaluation

National targets and contributions	2007	2011	2015	Reference case and year
Reduction of GHG emissions [kt CO_2e]	67	67	n/a	Measured against a standard value of N inputs
Increase of RES consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of final energy consumption [ktoe]	n/a	n/a	n/a	n/a

Source: own compilation, Ecologic based on Schelde et al. (2014)

Comparison between the ex-ante and ex-post evaluations and with the NECP

The NECP does not provide any detail about the impact of specific PaMs in the agricultural sector. However, the 2019 PaM report outlines an emission reduction of 500 kt CO_2eq in 2020 for the GGA as a whole.[42] It refers to a report by the Danish government (Danish government 2009) which shows that the expected annual emission reduction of the GGA (compared to a reference case without GGA) is 700 kt CO_2eq, with 520 kt CO_2eq coming from nature and environment initiatives and 180 kt CO_2eq from the generation of green energy. The reduction of N inputs (via the nitrogen regulation system) is expected to contribute 430 kt CO_2eq per year. These figures are considerably higher than the ex-ante estimation of Schelde et al. (2014), which projected a reduction of 179 kt CO_2eq from reduced N_2O emissions per year over the period 2012-2015 due to new and improved policy measures.

Nevertheless, it proves challenging to compare the results of the two selected evaluations, since the time periods they assess do not match up with the implementation periods of APAE III and the GGA. The mid-term review (Børgesen et al. 2009) found that APAE III did not lead to significant GHG emission reductions over the period 2003-2007. This prompted the Danish government to set up the GGA in 2009, as a follow-up action plan to address the problems that led to the underperformance of the APAE III (Danish Ministry of Climate, Energy and Utilities 2017a). The GGA was more successful in this regard: the evaluation of the GGA (Børgesen et al.

[42] The new 2021 PaM report does not include emission reduction for this programme anymore.

2013) and related GHG calculations from (Schelde et al. 2014) indicate a total GHG emission reduction ex-post of 190 kt CO_2eq per year (N_2O emission reductions: 67 kt CO_2e per year) over the period 2007-2011.

The results for nitrogen leaching show that the ex-post results of the evaluation of the GGA (Børgesen et al. 2013) support the ex-ante estimates of the mid-term review of APAE III (Børgesen et al. 2009): both evaluations provide similar values, but also found that leaching was more excessive and far from meeting the reduction objectives. The mid-term review of APAE III projected a reduction of only 5 kt N leaching over the period 2004-2015, which is far below the targeted 18 kt. The evaluation of the GGA noted a total reduction of only 4.7 kt – 6.0 kt N leaching over the period 2007-2011.

A.4.2.2 Organic farming

The Danish NECP includes a target for organic farming: "Increase organic foods targets and strengthen initiatives against food waste. The Government will increase the ambition for more organic foods in Denmark, starting with an aim to double organic farming acreage, the export of organic foods and the consumption of organic foods in Denmark by 2030, and to implement initiatives to reduce food waste." However, no separate PaMs are listed for organic agriculture and no further information is provided. Table 108 shows the key PaMs under the focus topic "increase in organic farming".

Table 108: Key PaMs under the focus topic "increase in organic farming" in the Danish NECP

Name of PaM	Short description	Selected for further evaluation?
Green Growth Agreement (expired)	The Green Growth Agreement (2009-2010) takes on a broader perspective compared to the APAEs (also see Table 103Table 113). Its aim was to ensure that a high level of environmental, nature and climate protection went hand in hand with modern and competitive agriculture and food industries. The Green Growth Agreement was introduced due to the lack of the GHG emission reduction from APAE III, and focused more on financial incentives as opposed to regulatory standards.	yes

Source: own compilation, Ecologic based on (Danish Ministry of Climate, Energy and Utilities 2017a, 2019a; EPA n.d.a, n.d.b; Hölscher et al. 2018)

The Green Growth Agreement (2009–2010) contained financial support for organic farming and investments at farm level (Hölscher et al. 2018). The mid-term evaluation of APAE III (see Annex A.4.2.1) states that the support for organic agriculture was not included as an instrument in APAE III. Therefore, we selected the Green Growth Agreement as the key PaM.

Considering that the Danish NECP does not further distinguish individual policy instruments for the GGA, and evaluations generally assess complete action plans, the PaM is considered the policy instrument. Table 109 provides an overview of the relevant and selected policy instruments for the GGA.

Table 109: Relevant policy instruments for the Green Growth Agreement

Selected PaM	Associated policy instrument(s)	Legal basis
Green Growth Agreement (GGA)	Green Growth Agreement (GGA)	Green Growth Agreement (GGA)

Evaluations of the Green Growth Agreement

The climate note Schelde et al. (2014) and Børgesen et al. (2013), which constitutes the basis for the climate note, are ex-post and ex-ante assessments. Both studies include organic farming as a separate measure. Therefore, we selected these two studies here.

Table 110: Available and selected ex-ante and ex-post evaluations for the Green Growth Agreement

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
Green Growth Agreement	**Schelde et al. (2014). Klimaeffekt af kvælstofvirkemidler i dansk landbrug i perioden 2007-2015 [Climate impact of nitrogen inputs in Danish agriculture in the period 2007-2015]** **Børgesen et al. (2013). Udviklingen I Kvælstofudvaskning Og Næringsstofoverskud Fra Dansk Landbrug For Perioden 2007-2011 [Trends in Nitrogen Leaching and Nutrient Surplus From Danish Agriculture For The Period 2007-2011]**	**Schelde et al. (2014). Klimaeffekt af kvælstofvirkemidler i dansk landbrug i perioden 2007-2015 [Climate impact of nitrogen inputs in Danish agriculture in the period 2007-2015]** **Børgesen et al. (2013). Udviklingen I Kvælstofudvaskning Og Næringsstofoverskud Fra Dansk Landbrug For Perioden 2007-2011 [Trends in Nitrogen Leaching and Nutrient Surplus From Danish Agriculture For The Period 2007-2011]**

Source: own compilation, Ecologic. The evaluations that were selected for an in-depth assessment are shown in bold font.

Results from the ex-ante evaluation

Børgesen et al. (2013)provides the basis of the GHG impact estimates for the climate note (Schelde et al. 2014). The former study estimated that the area of organic farming increases by 24.000-28.000 ha over 2012-2015. By 2020, it expected an increase in the share of organic farmland of around 9% compared to 2007, slightly below the Danish government's goal of 10%. The target meant to double the share of organic farmland in total farmland between 2007 and 2020.

The climate note (Schelde et al. 2014) focuses on the estimation of GHG emission reductions based on the findings of Børgesen et al. (2013). Ex-ante estimates are for 2012-2015 and assume that the GGA leads to a reduction of 337 kt CO2eq per year, with 179 kt CO2eq being N2O emission reductions. Organic agriculture reduces nitrogen fertilisation by 58 kg N/ha and thus contributes a reduction of N2O emissions in the order of 11.3-13.6 kt CO2eq per year (for an overview of measures of the GGA, see Annex A.4.2.1). Table 111 shows the expected GHG emission reductions of organic agriculture under the GGA according to the ex-ante evaluation.

Table 111: Target contributions of the "organic agriculture" according to the ex-ante evaluation

National targets and contributions	2015	2025	2030	Reference case and year
Reduction of GHG emissions [kt CO_2e]	11.3-13.6	n/a	n/a	Measured against a standard value of N inputs

Source: own compilation, Ecologic based on Schelde et al. (2014)

Børgesen et al. (2013) indirectly establishes the impacts of APAE III and GGA on water quality by evaluating reduced nitrate leaching of individual measures and assessing nitrogen inputs in Danish agriculture. The study estimates that the increase of organic farmland leads to a further reduction of total leaching of 240-480 tonnes of N in 2011 compared to 2007.

Results from the ex-post evaluations

Børgesen et al. (2013) shows that the organic farmland has increased by 24,000 ha over the period 2007-2011, which correspond to an average increase of around 4,800 ha per year. In 2007, the total organic area and in-conversion areas was equal to approx. 145,000, compared to 170,000 in 2011 (increase by 17%).

Børgesen et al. (2013) points out that the mid-term evaluation of APAE II (not further discussed here) used a reduction impact of organic farming of 33 kg N/ha, but that this needed to be adjusted downward to 17 kg N/ha for the mid-term evaluation of APAE III, mainly due to a significant tightening of fertiliser legislation, lowering the use of N fertilisers on conventional farmland and thus also the associated impact of a conversion to organic farmland.

The climate note Schelde et al. (2014) shows the GHG emission reductions from the GGA over the period 2007-2011, in the course of which organic agriculture reduced fertilisation by 58 kg N/ha and related N_2O emissions in the order of 11.3-13.6 kt CO_2eq per year (also considered as ex-ante measure) (for an overview on measures of the GGA see Annex A.4.2.1). Table 112 shows the target contributions of organic agriculture under the GGA according to the ex-post evaluation.

Table 112: Target contributions of "organic agriculture" according to the ex-post evaluation

National targets and contributions	2007	2011	2015	Reference case and year
Reduction of GHG emissions [kt CO_2e]	11.3-13.6	11.3-13.6	n/a	Measured against a standard value of N inputs
Increase of RES consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	n/a
Reduction of final energy consumption [ktoe]	n/a	n/a	n/a	n/a

Source: own compilation, Ecologic based on Schelde et al. (2014)

Comparison between the ex-ante and ex-post evaluations and with the NECP

The NECP does not provide any information on the impact of specific PaMs in the agricultural sector and does not list organic agriculture as a separate PaM. However, the PaM report outlines

an annual emission reduction of 500 kt CO_2eq in 2020 for the GGA. This figure includes the savings achieved by organic farming. Schelde et al. (2014) outline an ex-post GHG emission reduction estimate for organic agriculture under the GGA of around 11.3-13.6 kt CO_2eq annually over 2007-2011, which they used for the ex-ante estimation up to 2015 as well.

A.4.3 Slovenian NECP

A.4.3.1 Rational use of nitrogen fertilisers

The Slovenian NECP provides limited information on agricultural PaMs. The overarching strategic document is the Resolution aša hrana, podeželje in naravni viri po 2021 [Our Food, Rural and Natural Resources after 2021], which defines the basic framework for the operation of agriculture, food and rural areas and is used as a foundation for strategic planning beyond 2021 and does not contain specific actions for N fertiliser reductions.

Under the topic of "Increasing the efficiency of animal breeding and shares of minimum releases and the promotion of a more efficient nitrogen cycle in agriculture", only one out of four PaMs focusses on nitrogen fertilisers that is "incentives for the implementation of premium farming methods that contribute to reducing nitrous oxide emissions". Table 113 provides a short description of the key PaM under the focus topic "rational use of nitrogen fertilisers" in the Slovenian NECP.

Table 113: Key PaM under the focus topic "rational use of nitrogen fertilisers" in the Slovenian NECP

Name of PaM	Short description	Selected for further evaluation?
Implementation of premium farming methods that contribute to reducing nitrous oxide emissions	Promoting intensive fertilisation – through the use of financial incentives – with low ammonia releases as part of a future Rural Development Programme	yes

Source: own compilation, Ecologic based on The Government of the Republic of Slovenia 2020

The NECP does not provide any additional information on the PaM "**Implementation of premium farming methods that contribute to reducing nitrous oxide emissions"** besides that it is a financial incentive and should promote intensive fertilisation with low ammonia releases.[43] The NECP also indicates that the PaM is part of the Rural Development Programme (RDP).

The PaM report of Slovenia (Republic of Slovenia 2020) seems to refer to the same PaM although it is called "rational fertilisation of agricultural plants with nitrogen" as both PaMs focus on financial incentives for better use of nitrogen fertilisers with low GHG emission releases. According to the PaM report, the PaM aims for a more efficient use of mineral and livestock manure. With reduced use of nitrogen, agricultural productivity can be maintained or even increased, while reducing the direct N_2O emissions from agricultural land and related indirect N_2O emissions predominantly from N leaching (Republic of Slovenia 2020).

[43] Ammonia (NH_3) can be directly used as a nitrogen fertiliser or further processed to enrich soils.

Both the Slovenian NECP and PaM report refer to the RDP as a source of finance, and more specifically, to the Agri-Environmental Climate Payments (AECPs) under the RDP. AECPs are an important form of payment for farmers and other land-managers. The aim of the payments is "[…] to preserve and promote the necessary changes to agricultural practices that make a positive contribution to the environment and climate", going beyond the relevant mandatory standards. Its inclusion in national/regional RDPs is obligatory (European Parliament et al. 2013). MS most frequently mention the preservation of biodiversity as the key rationale for the AECPs. They also often cite the preservation of natural resources and landscapes, as well as mitigating climate change, as important objectives. The reduction of fertiliser use supports these objectives through lower GHG emissions and N leaching (European Network for Rural Development n.d.).

In Slovenia, farms that apply for AECPs need to have a programme of activities and need to keep track of the use of mineral and livestock manure. Farmers need to develop fertilisation plans based on soil analysis if they use mineral fertilisers. These general conditions are supplemented by specific requirements to further improve the efficiency of fertiliser use, related to e.g. crop rotation, fertilisation based on analysis of mineral nitrogen in soil, low-emission fertilisation practice or the greening of arable land (Republic of Slovenia 2020). Over the period 2014-2020, Slovenia allocated EUR 207 million to AECPs, making it budget-wise one of its four biggest RDP measures (EC 2020b). Table 114 provides an overview of the relevant and selected policy instrumen ts for the PaM "Implementation of premium farming methods that contribute to reducing nitrous oxide emissions".

Table 114: Relevant and selected policy instrument for the PaM "Implementation of premium farming methods that contribute to reducing nitrous oxide emissions"

Selected PaM	Associated policy instrument(s)	Legal basis
Implementation of premium farming methods that contribute to reducing nitrous oxide emissions	Agri-Environmental Climate Payments (AECP)	Regulation (EU) No 1305/2013 of the European Parliament and of the Council of 17 December 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005

Source: own compilation, Ecologic

Evaluations of AECPs

There is no evaluation that focuses on the Slovenian AECPs only. Instead, we found two evaluations of the RDP which also address AECPs – one being an ex-ante and one a mid-term evaluation (Čufer Klep et al. 2019; Žnidarčič et al. 2014). The selected evaluations therefore only assess the contribution of AECPs in the context of establishing the effectiveness of the much broader RDP, thereby only providing limited information on the former. Both evaluations do not link to the Slovenian NECP. Table 115 provides an overview of the available and selected ex-ante and ex-post evaluations for AECPs.

Table 115: Available and selected ex-ante and ex-post evaluations for AECPs

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
AECPs	**Žnidarčič et al. (2014). Predhodno Vrednotenje Programa razvoja podeželja za Slovenijo 2014–2020. [Preliminary evaluation of the Rural Development Programme for Slovenia 2014–2020]** **UNFCCC (2020). Slovenia's Fourth Biennial Report UNFCCC** **PaM reporting (2021)***	**Čufer Klep et al. (2019). Presoja dosežkov in vplivov Programa razvoja podeželja Republike Slovenije za obdobje 2014–2020 [Assessment of achievements and impacts of the Rural Development Programme of the Republic of Slovenia for 2014-2020]**

Source: own compilation, Ecologic. The evaluations that were selected for an in-depth assessment are shown in bold font.
* While Slovenia has delivered updated PaM data to the EEA, there is no updated PaM report available in Reportnet.

Results from the ex-ante evaluation

The Slovenian Ministry of Agriculture and the Environment commissioned KPMG to conduct the ex-ante evaluation of the RDP, as prescribed by Article 3 of the Strategic Environmental Assessment Directive (European Evaluation Network for Rural Development 2014). The goal of the ex-ante evaluation is to assess the (strategic) relevance, internal and external coherence and effectiveness of the measures introduced under the Slovenian RDP 2014-2020, as well as its alignment with the Europe 2020 strategy and the EU's Rural Development Policy. It contains a very detailed description of the consulted documents and the different steps the evaluators took to carry out the assessment.

The ex-ante evaluation estimates that about 260,000 ha will be under AECPs between 2014 and 2020. The expected total public funding used to this end is approximately EUR 210.7 million. However, the evaluation establishes qualitatively that the AECPs make a direct contribution to climate mitigation, but it remains unclear to what degree; it does not provide any GHG emission reduction figures.

Besides the climate impact, the ex-ante evaluation establishes that the total agricultural area in the base year is 613,298 ha. It estimates that until 2020, 250,000 ha (41%) thereof will be contracted to contribute to biodiversity and 218,000 ha (36%) to improve soil management. It proves challenging to identify the individual contribution of the AECPs, since the figures relate to the fourth RDP (2014-2020) priority: "Restoration, conservation and improvement of ecosystems related to agriculture and forestry" as a whole.

The ex-ante evaluation contains a qualitative assessment of the AECPs and identifies some points for potential improvement. It notes that the current version of the measure imposes several obligations, which comes with the risk of excessive administrative duties during implementation, as well as the risk of measure becoming too fragmented and complicated. The introduction of an advanced, more effective application system is mentioned as a general way to reduce administrative burdens/reduce complexity and fragmentation.

The 2020 PaM report of Slovenia (Republic of Slovenia 2020) indicates that the rational use of N fertilisers will lead to an increase of urea and tilling of manure on fields and better techniques for slurry manure application. In general, fertiliser use was at 44.4 kg N/ha in 2015 and will increase in Slovenia, but the PaM will limit the increase to less than 2% per year. However, the N uptake in plants increases, which reduces the associated GHG emissions. The resulting GHG emission reduction is 32 kt CO_2eq in 2020, which remains stable until 2035. Table 116 shows the target contributions of AECPs according to the ex-ante evaluation. The new 2021 PaM report

takes over this assumption and outlines an emission reduction of 34 kt CO_2eq. for the same years.

Table 116: Target contributions of the rational use of N fertilisers according to the ex-ante evaluation

National targets and contributions	2014 – 2020	2025	2030	Reference case and year
Reduction of GHG emissions [kt CO_2e]	n/a	32	32	Compared to 2015
Increase of RES consumption [ktoe]	n/a	n/a	n/a	
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	
Reduction of final energy consumption [ktoe]	n/a	n/a	n/a	

Source: own compilation, Ecologic based on (Republic of Slovenia 2020)

Results from the mid-term evaluation

The Ministry of Agriculture, Forestry and Food commissioned Deloitte, along with the Agricultural Institute of Slovenia (KIS) and Oikon as subcontractors, to conduct the mid-term evaluation of the RDP, which covers the period of 2014-2018. The evaluation assesses to what extent the RDP 2014-2020 has helped to achieve the CAP objectives and the Europe 2020 Strategy, for which purposes it addresses a variety of questions that are related to the six priorities of the RDP. There is a clear description of the evaluation method and data basis.

The mid-term evaluation is to a large extent not able to quantify the impact on GHG emissions of both the RDP and the AECPs, because the contribution of measures to climate-change mitigation is described qualitatively by beneficiaries in most cases. AECPs are merely presented as a "programmed action with secondary contribution". The mid-term evaluation indicates that overall the RDP has made a significant contribution to reducing N_2O and ammonia (NH_3) emissions, but failed to design appropriate operations and requirements to reduce methane emissions from farmed animals.

More specifically, the RDP supported 40% of all agricultural land. The study estimates direct N_2O emission reductions for the introduction of low emission fertilisation techniques and greening of arable fields after harvesting the main crop through winter of 6,630 t CO_2eq in 2017 when compared to 2013. In addition, both actions result in the reduction of 272 t NH_3 over the same period, which translates into a reduction of indirect N_2O emissions of 1,325 t CO_2eq.[44]. Table 117 shows the sum of the direct and indirect N_2O reduction of the RDP according to the ex-post evaluation.

Table 117: Target contributions of the RDP (*) according to the ex-post evaluation

National targets and contributions	2014-2018	2017	2030	Reference case and year
Reduction of GHG emissions [kt CO2e]	n/a	approx. 8.0	n/a	Compared to 2013
Increase of RES consumption [ktoe]	n/a	n/a	n/a	

[44] The IPCC suggests calculating indirect N_2O emissions from NH_3 using an emission factor of 0.01 ((De Klein et al. 2006)).

National targets and contributions	2014-2018	2017	2030	Reference case and year
Reduction of primary energy consumption [ktoe]	n/a	n/a	n/a	
Reduction of final energy consumption [ktoe]	n/a	n/a	n/a	

Source: own compilation, Ecologic based on (Čufer Klep et al. 2019) (*) We use the figures for the RDP as there is no information available for the individual contribution of AECPs

The mid-term evaluation notes that total public expenditure for the AECPs amounted to EUR 111.9 million (from 2014-2018) supporting a total of 14,533 (2015), 20,590 (2016), 27,390 (2017) and 27,549 (2018) of agricultural holdings and beneficiaries. In 2018, the RDP supported a total of 354,796 ha – a slight increase compared to 2016 – with 139,977 ha being supported by both AECPs and organic-farming payments, amounting to a total of 8,474 contracts. For the same two measures, 1,053 days of training were organised, which were attended by 29,868 participants.

In addition, the study estimates a reduction in excess nitrogen in water bodies from 69 kg N/ha in 2013 to 42 kg N/ha in 2016. It also states that the AECPs have the potential to reduce the intensity of decline related to farmland bird populations, but that this will be challenging to establish because of other (more important) factors external to the RDP, including e.g. intensive agricultural practices, habitat loss or fishing and poaching.

Comparison between the ex-ante and mid-term t evaluations and with the NECP

The NECP does not provide GHG emission reduction figures for a single agricultural PaM but seems to rely on the same PaMs as the PaM report. The PaM report expects an ex-ante emission reduction, which remains stable until 2035 when compared to 2015 for the RDP as a whole, from limited increases in fertilisation but better plant uptake equalling 32 kt CO_2eq by 2020. The starting point are N inputs of 44.4 kg N/ha in 2015, which remain more or less stable (under the assumption that agricultural land remains the same and an increase of 2% fertiliser inputs) (UNFCCC 2021). According to the ex-post evaluation, the emission reduction was only around 8 kt CO_2eq in 2017 when compared to 2013. When comparing the emission reductions, the ex-ante estimate seems quite high, but the study considers RDP financing including organic agriculture, while the emission reduction estimate in the mid-term evaluation is calculated for better fertilisation techniques and greening of arable land as part of the RDP. This means that a direct comparison is not possible.

More generally, the ex-ante evaluation of the RDP projected that between 2014 and 2020, the AECPs supported 260,000 ha. The mid-term review indicated that in 2018, 139,911 ha was under AECPs and organic-farming payments. With only two years remaining on the RDP programming period, this initial projection seems to have been too optimistic. This would require at least a doubling of the land supported by AECPs over 2019-2020, also considering the figure from the mid-term review included organic-farming payments. This is also reflected in the payments: the ex-ante evaluation forecasted a total of EUR 210.7 million of public funding for the AECPs over the whole RDP programming period. In 2018, only around half (53%; EUR 111.9 million) thereof was spent. This roughly corresponds to the aforementioned more limited uptake of AECPs than anticipated.

A.4.3.2 Organic farming

In the Slovenian 2020 PaM report, organic farming is included under the PaM "rational use of N fertilisers". We assume that the name of this PaM changed under the NECP to "incentives for the implementation of premium farming methods that contribute to reducing nitrous oxide emissions". There is no additional information on organic farming in the NECP, besides the statement that Slovenia is more successful on this than the EU average.

The Slovenian NECP also lists an "additional measure", which is called "Upgrading agricultural policy - integrating climate policy and adapting to climate change" and is considered an economic instrument (financial incentives). One of the listed activities under this PaM is "to formulate a policy to promote sustainable organic farming and to reduce the environmental burden and the consumption of natural resources [in 2021]". This PaM is not listed in the PaM report. However, because it specifically highlights organic farming it was included as a key PaM.

Table 118: Key PaMs under the focus topic "increase in organic farming" in the Slovenian NECP

Name of PaM	Short description	Selected for further evaluation?
Implementation of premium farming methods that contribute to reducing nitrous oxide emissions	Promoting intensive fertilisation – through the use of financial incentives – with low ammonia releases as part of a future Rural Development Programme.	yes
Upgrading agricultural policy - integrating climate policy and adapting to climate change	This includes a wide variety of activities with deadlines, such as formulating a policy to promote sustainable organic farming and to reduce the environmental burden and the consumption of natural resources (in 2021), as well as to reinforce market cooperation between organic producers and revitalise interest in local food production and processing to shorten the food supply chain [2021-2030].	yes

Source: own compilation, Ecologic based on The Government of the Republic of Slovenia (2020)

The Slovenian NECP and PaM report do not list specific policy instruments under the PaMs but state that they want to promote organic farming. As a result, we selected "financial support for organic farming" as the policy instrument by subsuming the two selected PaMs from Table 118.

Table 119: Relevant policy instruments for upgrading agricultural policy - integrating climate policy and adapting to climate change

Selected PaM	Associated policy instrument(s)	Legal basis
Financial support for organic farming	Financial support for organic farming	EU Rural Development Programme and national implementation

Source: own compilation, Ecologic

Evaluations of financial support for organic farming

In 2021, the Slovenian Ministry of Agriculture, Forestry and Food published the Action Plan for the Development of Organic Farming by 2027 (ANEK), which although not officially an evaluation, contains both an ex-post (2007-2020) and ex-ante part (up to 2030) but without providing the impact on GHG emissions. We selected the ANEK due to a lack of other relevant

evaluations; e.g., the PaM reports (2019 and 2021) do not outline any emission reduction from support for organic farming either.

Table 120: Available and selected ex-ante and ex-post evaluations for financial support for organic farming

PaM	Available ex-ante evaluation(s)	Available ex-post evaluation(s)
Upgrading agricultural policy - integrating climate policy and adapting to climate change	**Akcijski načrt za razvoj ekološkega kmetijstva do leta 2027 (ANEK) [Action Plan for the Development of Organic Farming by 2027 (ANEK)]**	**Akcijski načrt za razvoj ekološkega kmetijstva do leta 2027 (ANEK) [Action Plan for the Development of Organic Farming by 2027 (ANEK)]**

Source: own compilation, Ecologic

Results from the ex-ante evaluation

The ANEK does not provide any information on GHG emission reductions related to organic farming but includes other relevant quantitative information. Slovenia aims to achieve a minimum of 18% (currently 11%) organically farmed land in total agricultural land by 2027, as well as a 10% minimum share of organic farms (currently 5.4%) of the total number of farms. The ANEK states that if Slovenia were to reach this target, it would also be close to achieving the objective of the Farm to Fork strategy on having 25% of agricultural land under organic farming by 2030.

The ANEK presents three scenarios for the development of organic farming:

1. A continuation of the current trend with an extrapolation of the trend from 2007-2019 up to 2027, which would increase organic farmland by 1.630 ha per year and lead to a total of 62.737 ha of organic farmland in 2027 or roughly 13% of total farmland.
2. Achieving 18% of agricultural land under organic farming by 2027, equal to around 85.500 ha. This means that approximately 4.800 ha per year (or three times the value of the current trend) needs to be converted into organic farmland.
3. Achieving 25% area under organic farming by 2030.

To put this into perspective, the highest yearly increase of organic farmland in Slovenia took place between 2012 and 2013 and amounted to 3.563 ha. The ANEK indicates that the scenarios and accompanying calculations come from the Slovenian Ministry of Agriculture, Forestry and Food but provides little to no information on the underlying assumptions. It also does not state what support mechanism and related funding would be needed to realise the scenarios.

The ANEK points out that Slovenia aims to be among the Member States with the most developed organic farming and will devote additional attention and financial resources to achieve this. It presents ten key priority areas of organic farming, of which one constitutes "organic farming in relation to the environment and climate change" and states that organic farming is still underdeveloped in sensitive natural areas: water protected areas (11% of farmland), nature protected areas (17%) and Natura 2000 sites (17%). The ANEK highlights that particular emphasis will be placed on introducing organic farmland in water protected and in nature protected areas; it includes the goal for 2027 of increasing the share of organic agricultural land in water protected areas to 25% and in nature protected areas (including Natura 2000 areas) to at least 30%.

Results from the ex-post evaluations

The ANEK states that in Slovenia the development of organic farming has fluctuated significantly over the 2007-2020. However, the overall area under organic farming grew by 71% over this period. From 2007-2009, there was stagnation, followed by noticeable growth until 2015. However, over 2016-2020, the growth has significantly slowed down. It also explains that attracting new organic farms is a challenge, considering that the share of farms in conversion was 9% in 2020, compared to 36.5% in 2013.

Many farms discontinued organic farming in 2014 and 2020. The ANEK notes that the key reasons for exit mainly related to the termination of the implementation phase of the "Organic Farming" measure under the RDP 2014-2020, the reduction of financial support for grasslands, marketing problems and not achieving adequate yields or incomes, and the age of farm operators. The ANEK explains that under the 2014-2020 RDP, organic farmers could combine AECP (e.g., for farm and business development) and organic farming payments on the same area, provided the requirements for receiving payments would not overlap.

Regarding funding, Slovenia (like some other Member States) makes the distinction between financial support for the maintenance of and the conversion to organic farming practices and methods. Over 2007-2013, total payments for maintenance and conversion accounted for around 50.7 million EUR and 7.8 million EUR, respectively. Over 2014-2020, these figures changed to around 35.5 million EUR and 9.5 million EUR, for maintenance and conversion respectively. Accordingly, the share of payments for conversion as part of the total payments for organic farming grew by around 11 percentage points between the two programming periods.

Comparison between the ex-ante and ex-post evaluations and with the NECP

The NECP does not provide any GHG emission reduction figures for organic farming. The ANEK also does not refer to such figures but mainly discusses the development of organic farming in terms of supported hectares or as share of the total agricultural land. The 2019 and 2021 PaM reports estimate a steady reduction of 32 kt and 34 kt CO_2eq per year, respectively, over the period 2020-2035 for the PaM "Rational use of N fertilisers", under which all measures aimed at reducing nitrogen fertiliser use are grouped, including AECPs and organic farming payments.

Slovenia aims at reaching an 18% share of all agricultural land under organic farming by 2027, requiring a tripling of the average expansion rate over 2007-2019. This would likely increase the reductions associated with the PaM "Rational use of N fertilisers", although it remains unclear to what degree. The ANEK underlines that introducing organic farming in water and in nature protected areas will receive particular attention and has set targets to this end.

A.4.4 Overview of number of identified evaluations

Table 121 shows an overview of the identified evaluations under the agricultural soils topic per PaM and MS. The table shows the number of identified ex-post and ex-ante evaluations and the share of evaluations reporting GHG emission reductions, energy consumption reductions, impact on renewable energy development, and socio-economic factors.

Table 121: Number of evaluations per agricultural PaM and content

MS	PaM[45]	Ex-post	GHG share	EE sh.	RES sh.	SEI sh.	Other share	Ex-ante	GHG share	EE sh.	RES sh.	SEI sh.	Other share
DE	18	1	0%	0%	0%	0%	0%	1	100%	0%	0%	0%	0%
DE	19	1	0%	0%	0%	0%	0%	1	100%	0%	0%	0%	0%
DK	20	1	100%	0%	0%	0%	100%	1	0%	0%	0%	0%	100%
DK	21	1	100%	0%	0%	0%	0%	1	100%	0%	0%	0%	0%
SI	22	1	100%	0%	0%	0%	0%	1	0%	0%	0%	0%	0%
SI	23	1	0%	0%	0%	0%	0%	1	0%	0%	0%	0%	0%
All		**6**	**50%**	**0%**	**0%**	**0%**	**17%**	**6**	**50%**	**0%**	**0%**	**0%**	**17%**

PaM = policy and measure, sh. =share, MS = Member State. DE = Germany, DK = Denmark, SI = Slovenia, GHG = greenhouse gas emissions reductions, EE = increase of energy effciency, RES = increase of renewables share, SEI = socio-economic impacts

Source: Own calculation, Fraunhofer ISI

A.4.5 Conflicts and synergies of soil-related mitigation measures

In this section, we consider the impacts of a rational use of N fertilisers and organic farming on water quality, agricultural production, and employment.

A.4.5.1 Literature review of the potential conflicts and synergies

Improved water quality

Nutrients are essential for crop production, but their excessive application through fertilisation can be a major source of air, soil and water pollution, which in turn has negative impacts on human health, biodiversity and the climate (EC n.d.d, 2021a). Nitrate leaching occurs when nitrates and organic nitrogen compounds from fertiliser and manure use are washed away – due to e.g., rain or irrigation – into surface and groundwater. As a result, water bodies are progressively enriched with nutrients, which can lead to excessive plant and algae growth. In turn, this reduces oxygen levels, destroying aquatic life and biodiversity, besides damaging recreational and economic activities (EC n.d.c). This process is also referred to as eutrophication.

In this context, the Nitrates Directive from 1991 has the specific aim to reduce water pollution caused by nitrates used in agriculture and establishes a clear link between excessive fertiliser use and water pollution. All EU countries transposed the Directive into national law.

Doelman et al. (2022) show some of the dynamics of reducing the nitrogen surplus in practice. They use two different models – MAgPIE and IMAGE – to quantify synergies and trade-offs in the global water-land-food-climate (WLFC) nexus over the period 2015-2050. The combined effect

[45] 18 = Fertiliser Ordinance, 19 = Financial support of organic farming, 20 = Action Plan for the Aquatic Environment (APAE) III and Green Growth Agreement (GGA), 21 = Green Growth Agreement (GGA), 22 = Implementation of premium farming methods that contribute to reducing nitrous oxide emissions, 23 = Upgrading agricultural policy - integrating climate policy and adapting to climate change

of improved nitrogen use efficiency and dietary changes more than halves the agricultural nitrogen surplus in both models (-51% and -61%).

Production losses

There is quite some literature that investigates production losses associated with organic farming versus conventional farming. After analysing a meta-dataset of 362 publications, Ponti et al. (2012) conclude that organic yields of individual crops are on average 80% of conventional yields, but that there is significant variation. Ponisio et al. (2015) reported similar results. Based on an analysis of 115 studies, they found that organic yields are 19.2% lower compared to conventional yields.

More recently, Kirchmann (2019) reported that organic yields are 35% lower compared to conventional farming, which would require 50% more arable land to fill the production gap (based on Swedish national statistics). Moreover, the European Commission highlights that, especially wheat yields from organic farming may be significantly lower, ranging between 40% (Germany) and 85% (Italy) of conventional yields and indicates that yield gaps strongly relate to factors such as location, agriculture practice management and type of crop (EC 2019).

However, as the Ten Years for Agroecology (TYFA) modelling exercise confirms, a shift to a less-meat intensive diet could compensate for production losses as a large share of agricultural land is used to produce feed. The TYFA scenario is based on the widespread adoption of agroecology, the phasing-out of vegetable protein imports and the adoption of healthier diets by 2050. This provides healthy food for Europeans while maintaining export capacity, reduces Europe's global food footprint, leads to a 40% reduction in GHG emissions from the agricultural sector and regains biodiversity and conserves natural resources, despite a production drop of 35% by 2050 when compared to 2010 (in Kcal) (Poux et al. 2018). In this context, Doelman et al. (2022) also highlight that food measures, such as reduced meat consumption and less food waste, constitute a clear synergy with all other nexus dimensions (water, land and climate). In addition, organic farming increases the resilience of farms against climate impacts. Changing climate patterns – in the form of shifts in local climatic conditions as well as an expected increased occurrence of extreme weather events such as droughts and floods – already had and will even more have devastating effects for agricultural yields (EEA 2019). Organic agriculture helps to minimise the related production losses in comparison to conventional agriculture. For example, crops rotation and the use of organic fertilisers help to better soil structures, which reduces water erosion due to heavy rain fall and improves the water supply during droughts. Farmers can also reduce economic risks through crop and income diversification (Kölling et al. 2012).

Increased employment

There is some mixed evidence on the employment impacts of organic agriculture. Green et al. (2006) found that if all UK farmers adopted organic farming, this would result in 93,000 additional on-farm jobs. They concluded that organic farming provides 32% more jobs per farm than equivalent non-organic farms. In 2018, Orsini et al. (2018) reviewed the available scientific literature published since 2000 on labour use on organic and conventional farms. They conclude that labour use on organic farms has received very little attention in the literature, as well as that the results of existing studies differ and do not confirm the common view that organic farming always requires more labour than conventional farming. Instead, labour use seems to be linked to farm type. , Orsini et al. (2018) also indicate that there is limited research on whether the organic farming sector provides better opportunities in terms of job prospects, wages and employment of women.

A.4.5.2 How the selected NECPs and the evaluated instruments address the conflicts and synergies

The three assessed NECPs do not discuss the above identified (non-exhaustive) synergies and conflicts of reducing nitrogen input: improved water quality, production losses and increased employment. This reflects how little information generally is available on agricultural PaMs.

Water quality

Most evaluations (Børgesen et al. 2013; Harthan et al. 2020; Velthof et al. 2010) indirectly assess impacts on water quality by investigating how the nitrogen balance is affected (e.g., calculating reductions of N input, N leaching, N surplus etc.), without explicitly establishing the link to water quality. However, in some cases, (qualitative) information on water quality is included in addition to these calculations (Bonneval et al. 2016; Børgesen et al. 2009). Velthof et al. (2010) also provide a general qualitative description of the effects of excessive N use. The German ex-post evaluation for organic farming (Bonneval et al. 2016) analyses the N savings of agri-environmental measures and includes water quality as an evaluation criterion. In the context of water quality, the study also identifies how many hectares are managed with relevant agri-environmental measures. A similar approach is taken by the Slovenian mid-term evaluation of the RDP (Čufer Klep et al. 2019). The Slovenian Action Plan for the Development of Organic Farming 2027 (Slovenian Ministry of Agriculture, Forestry and Food 2021) does not include an assessment of impacts on water quality, but underlines that introducing organic farming in water protected areas and in nature protected areas will receive particular attention to realise the potential of organic farming in this regard.

Production losses

The German CPP (BMEL 2019a)provides some quantitative data on production losses related to organic farming (production decline of 4.5 million tonnes of cereals annually with an 8 percentage point increase of organic farming) and more generally states that reducing the nitrogen surplus may lead to yield decreases. The CPP does not provide the source for this figure. The ex-ante evaluation that assesses the GHG emission reduction potential of the CPP (Harthan et al. 2020) did not consider production losses associated with reducing the nitrogen surplus (or any compensation measures). Also, none of the Danish or Slovenian evaluations assess production losses for the focus topics.

Employment

The German CPP mentions a positive impact on employment from organic farming (0.2 to 0.3 more workers per 100 hectares compared to conventional farming), but again does not state the source of this figure and does not provide more information. None of the German, Danish or Slovenian evaluations assess employment effects for the focus topics.

B Annex: Literature research

B.1 Context and objective

The objective of work package 1 was to create a literature database that includes ex-post and ex-ante evaluations of policies and measures in the field of climate and energy policy. In particular, the literature list should include literature that evaluates the effects of individual measures and focus less on evaluations of entire bundles of measures (evaluations that look at bundles of measures are not categorically excluded; if these evaluations show the impact of individual measures separately, such evaluations would be relevant.). Moreover, a special focus lies on evaluations of policies and measures that help to understand the National Energy and Climate Plans (NECPs) of the MS. The list should not only be a pure list of literature containing typical criteria such as the author or the year of publication, but is supposed to provide a brief overview of the content of the publication. In particular, the list should contain filtering options using specific indicators so that users can quickly and conveniently find literature that is relevant to them in the list.

The purpose of the list serves two targets, on the one hand, the list will be provided to the client and they can use it for example to search for the effect of specific policies, on the other hand the literature list will also be used by the consultant in the following work packages when analysing policies and measures, thus possibly reducing the need to search for more literature in the following work packages. In the course of the project, the literature list will always be supplemented by further relevant literature, so that a final list will be available at the end of the project. A preliminary list is provided to the client together with this report.

So far, there is no central database that systematically collects and compares evaluation results of climate and energy policies and analyses. A similar approach can be found at the EEA (cf EEA 2020a). They provide a catalogue of existing evaluations in the environmental sector (on individual measures, bundles of measures, programmes and projects), which is updated at regular intervals. The catalogue categorises evaluations based on their topic or sectoral focus and methodological approach, although no evaluation results are listed and analysed. The catalogue can therefore only serve as a starting point for the literature research.

The result of the work package is an Excel-based literature list with a maximum of 300 sources, which is made available in a literature management programme (Citavi). The Excel sheet allows filtering according to relevant criteria and thus enables quick access to relevant literature, while Citavi provides several use features such as selection by key words, authors, time etc. and access to the study as a pdf file.

B.2 Methodology

The starting point of the WP were three sources provided by the German Environment Agency (UBA) to the project team:

- A draft bibliography prepared by UBA with 184 publications.
- A literature list prepared in the course of the project “Capacity building to facilitate implementation of the effort sharing legislation, with focus on ex-post evaluation and policy

lessons learned" financed by the European Commission with 95 publications[46] (Biblio Evaluation ExPost EffortSharing).

- The draft literature database of the EEA with 495 publications (Catalogue of available evaluations of European environment and climate policies).

In addition, the project team and UBA asked MS for further, specific publications on relevant measures of the NECPs. These publications were also considered in this work package. We very much appreciate the support and information provided by the European Environment Agency, which helped us a lot to identify relevant evaluations for this meta study.

In a first step, all the mentioned lists of publications were analysed according to a set of selection criteria (see Annex B.2.1) which classified the sources as relevant or partially relevant. For example, publications without a focus on energy or climate policy, publications that evaluate bundles of measures as a whole rather than the impact of individual measures, or publications that do not focus on policies in EU Member States were rated as not relevant. Based on this, a large number of publications could be classified as not relevant, so that only 395 publications were rated as relevant or partly relevant. The non-relevant publications were transferred to a separate list with a brief justification.

In a second step, the relevant and partly relevant publications were assigned to the topic areas relevant to this project and then evaluated on the basis of further criteria (see Annex B.2.2). These criteria focus more on the content of the evaluation, *i.e.* the policy or measure, the sector targeted, the Member State, the topic area (renewable energy, energy efficiency, etc.) or even the type of evaluation. These further criteria form the basis for categorising the literature and using filters for a literature search. In addition, for the relevant and partially relevant literature, the data list includes a brief description of the content of the sources.

In addition, the project team will include further publications identified in the course of work package 3 and 4 so that the literature list is constantly updated. In order not to exceed the maximum number of 300 publications, new publications will substitute less relevant publications. Especially after the final selection of PaMs to be analysed in work package 3 and 4, the project team will search for additional relevant publications and add those to the list. This approach allows to gradually fill in existing gaps as well as to focus the literature list on the MS and PaMs that are relevant for this project.

B.2.1 Selection criteria

The selection of literature was based on various criteria, encompassing mandatory and non-mandatory criteria. Although non-mandatory criteria were not decisive for the selection of the publication, they affected the final selection as sources that complied with these criteria were given preference over sources that did not.

Mandatory criteria to be fulfilled

- **Topic**: The publication must be relevant for climate and energy policy. It has to deal at least with one of the four topics of the project (renewable energy, energy efficiency, EU ETS/ESR, F-GHG, Agriculture, waste/resource, sinks). Publications can cover more than one topic.

[46] Information on the project and the literature list was provided by UBA but is not publically available anymore.

- **Specific policy instruments**: Relevant publications must look at specific policy instruments or instrument bundles targeting the same type of measures and not take a general overarching perspective or evaluate only sectoral bundles of instruments.
- **Geographical coverage**: The focus must be on EU Member States. However, highly relevant publications for which no comparable European evaluations are available could be included if they are policies or measures that have already been implemented in Europe but have not yet been evaluated.

Further selection criteria

- **Date of publication**: As a general rule, newer publications were preferred to older publications and only very relevant publications from before 2010 were included.
- **Observation period**: The same applies here as for the date of publication. A more recent observation period for the same policy instrument was preferred over an older period.
- **Language**: In general, English and German publications were analysed. However, particularly relevant publications in national languages were included upon availability and translated into English with the help of the eTranslation Service of the European Commission.

B.2.2 Categorisation criteria

The categorisation criteria serve to enable users of the list to quickly search and filter for specific literature and to get an initial overview of the results.

- **Geographic coverage**: Which countries and/or geographical areas are in focus?
- **Sectoral coverage**: Which sectors are analysed (e.g. transport, residential, industry etc.)?
- **Type of policy instrument**: What is the type of policy instrument used with respect to the policy mechanism (regulation, fiscal, etc.) and the sector addressed (e.g. transport, renewable heat)? If possible, the specific name of the policy instrument has been entered in this field.
- **Type of evaluation**: Is it an ex-post observation or an ex-ante estimation?

Only if possible (based on the abstract)
The following criteria were only collected if they were evident based on a brief look at the publication or if they were evaluated at all in the publication.

- **Target contributions**: What is the contribution to the achievement of the target? E.g. what GHG emission reductions, energy savings or renewable shares are achieved?
- **Socio-economic impacts**: What socioeconomic impacts are observed? For instance, was the impact on employment, vulnerable groups, or disposable household income also analysed?
- **Other relevant impact categories**: What other relevant effects of the measure are observed? Were effects on, for example, particulate matter pollution, noise or odor pollution, or other indicators not directly relevant to climate or socioeconomics also analysed.

B.2.3 Descriptive criteria

In addition to the selection criteria and the categorisation criteria that were collected to specifically search for evaluations, descriptive criteria (metadata) were also collected, which are typically listed in a literature list.

- **Title**: Publication title
- **Author**: Shows all authors of the evaluation
- **Type of source**: Specifies if publication is a report, scientific literature, database, etc.
- **Publisher**: Names the publisher
- **Link to source**: Provides download link to the publication, if available online.
- **Source of publication found**: Where was the publication found? Underlying literature lists, forwarded by Member States, Internet research, expert etc.
- **Accessible for free**: Indicates whether the publication is freely accessible or chargeable.
- **Brief description**: Summary of content in a few sentences based on abstract.

C Annex: Analytical framework

C.1 Categories and criteria covered by the analytical framework

Table 122 provides an overview on the three categories with their criteria and sub-criteria.

Table 122: Categories and criteria covered by the analytical framework

Category 1: Key information on the measure	
General info on the policy instrument	Country
	Name of the policy instrument
	Short description of the policy instrument
	Type of policy instrument
Implementation of the policy instrument	Legal basis
	State of implementation
	Period of implementation
	Updates and changes to the policy instrument
	Responsible body
Coverage of the policy instrument	Objective of the policy instrument
	Type of GHGs addressed
	Target area / sector
	Target group

Category 2: Information on the evaluation and its methodological elements	
Document info	Source
	Commissioner of the evaluation
Methodology	Consideration of standards and guidelines
	Evaluation type
	Evaluation method
	Transparency of evaluation technique and method
Impact measurement and related assumptions	Link between impact and intervention
	Deadweight and anticipatory effect
	Substitution and direct rebound
	Leakage and indirect rebound
	Interactions with other PaMs
	Further assumptions

Category 2: Information on the evaluation and its methodological elements	
	Measurement of impact
	Transparency of impact measurement and assumptions
Period under review	Evaluation period
Input data	Data sources and tools
	Transparency of evaluation data
Stakeholder involvement	Aim, variety and process of stakeholder involvement

Category 3: Evaluation outcome for the policy instrument	
Relevance of the policy instrument	Background information on relevance
	Outcome of the evaluation
	Concerns
Info on evaluation and reference period	Evaluation period
	Reference case
Energy savings	Check if considered
	Reference case
	Energy savings attributable to the policy instrument
	Effectiveness of energy savings
Expansion of renewable energies	Check if considered
	Reference case
	Expansion of renewables attributable to the policy instrument
	Effectiveness of the expansion of renewables
GHG emission reduction	Check if considered
	Reference case
	GHG emission reduction attributable to the policy instrument
	Effectiveness of GHG emission reductions
Implementation and enforcement costs	Check if considered
	Costs from the implementation and enforcement of the policy instrument borne by public authorities
Administrative costs	Check if considered
	Costs from administrative requirements borne by the target group
Compliance costs	Check if considered
	Costs from compliance borne by the target group

Category 3: Evaluation outcome for the policy instrument	
Other costs	Other costs
Efficiency (incl. cost-effectiveness) of energy savings, expansion of renewables or GHG emission reductions	Check if considered
	Consideration of co-benefits and negative side-effects
	Efficiency of energy savings
	Efficiency of the expansion of renewables
	Efficiency of GHG emission reductions
	Concerns
Ability to cope with uncertainties	Dynamic efficiency
	Stability
	Flexibility
	Concerns
Coherence	Coherence with national policy instruments
	Coherence with EU policy instruments
	Concerns
Social acceptance and participation opportunities	Check if considered
	Social acceptance
	Social participation
	Economic participation
	Concerns
Investments	Check if considered
	Reference case
	Investments triggered by the policy instrument
	Concerns
Employment	Check if considered
	Reference case
	Evaluation results for the employment effects
	Evaluation results for the direct employment effects
	Evaluation results for the indirect employment effects
GDP	Check if considered
	Reference case
	Impact on GDP
	Concerns

Category 3: Evaluation outcome for the policy instrument	
Competitiveness and innovation	Competitiveness
	Innovation
	Concerns
Resource use and environmental impacts	Evaluation results for the use of different resources and for the impact on the environment
	Concerns
Impacts on citizen welfare	Evaluation results for the impacts on citizens welfare (direct and indirect effects)
	Concerns
Interaction with other MS and the EU	Goals, interests, conflicts and potential trade-offs with other MS
	Goals, interests, conflicts and potential trade-offs with the EU
	International collaboration and/or conflicts
	Concerns
Transferability to other MS	Transferability to other MS
	Concerns
Any other evaluation results	What other topic does the evaluation cover?
	Additional topics covered?

Source: own compilation, Ecologic

C.2 General setup of the analytical framework

The analytical framework is implemented in the form of an excel-sheet to allow easy handling by different experts in the following work packages. It has two parts: 1) title and index, 2) information collection sheet (with supportive material (exchange rates) and hidden sheet for drop-down menus).

The title and index sheet (1) includes a short introduction to the project, the analytical framework and an index of the categories and their criteria. It also refers to the additional guidance document that provides a step-by-step guidance on how to fill-in the information collection sheet (2).

The information collection sheet (2) provides the analytical framework with its three categories, 104 criteria and further sub-criteria. The three categories are:

1. **Information on the policy instrument** (color code: orange): It includes information such as the name, target group, legal basis and type of the policy instrument.
2. Information on the **evaluation and its methodological elements** (blue): It includes information about the evaluation and its methodology such as if it is forward or backward looking (ex-post / ex-ante), data sources and the reference case.
3. **Evaluation outcome** for the policy instrument (green): It includes information about the estimated costs and impacts and effects of the policy instrument such as compliance costs,

impacts on GHG emissions, GDP or employment, as well as evaluation results related to e.g. coherence and transferability.

The information collection sheet is structured as follows. Column B-G in the excel-sheet provide the instructions (see Table 123):

- Each **category** [identified by colour-code] includes various **criteria** [column B] (e.g. *GHG emission reduction*) which are split into **sub-criteria** [column C] (*e.g. Effectiveness of GHG emission reductions*).
- Each sub-criterion contains one or more **information request** [column D]. It includes a description of what is needed or a question (*e.g. Does the evaluation analyse the effectiveness of the measures in terms of GHG emission reductions?*). Some of the requests come with an additional **guidance** [column E] that gives further details or definitions (e.g. *An effectiveness analysis considers how successful the measure has been in achieving or progressing towards its objectives…*).
- For each of the information requests, we provide guidance on the reply options [column F & G]. The answer can be 1) a defined answer provided in a drop-down, 2) a defined answer with free entry where one should select words from "reply options", 3) free entry. In principle, each sub-criterion includes a combination of defined answers and free entry. While the defined answers help us to analyse the information, the free entry allows for collecting specific information from the evaluation necessary to understand context or restrictions.
- The table separates criteria with bold lines, sub-criteria with thin lines and explanations with dotted lines.

Table 123: Structure of the information collection sheet

Column B	Column C	Column D	Column E	Column F	Column G
Criteria with category colour-code	Sub-criteria	Requested information	Further guidance	Type of answer	Reply options
Name of criteria	Name of Sub-criteria	Explanation of what needs to be filled in and/or question to better explain the required input	Explanations and examples to describe the criterion or needed information	"Defined (drop-down)" "Defined (free entry)" "Free entry"	Description of the defined reply options

Source: own compilation, Ecologic

Experts fill in the collected information starting in column H with the first evaluation, column I for the second evaluation etc. If an evaluation includes an ex-post and ex-ante assessment, two columns need to be filled-in to separate ex-post and ex-ante results for the same policy instrument. The category 1 information can in this case be copied to the next column; the category 2 information need to be adjusted to reflect on the ex-post and ex-ante part of the evaluation; the category 3 information should be specific to the ex-post or ex-ante evaluation results.

The experts fill in the information on the policy instrument, the evaluation methodology and the impacts of the policy instrument according to the evaluation. For the category "Information on

the policy instrument", they can also consult other documents than the evaluation. For the other two categories, they should only use the respective evaluation. It is very likely that no evaluation will provide information for all lines. Therefore, some answers directly tell the expert to jump to the next criterion or sub-criterion when one sub-/criterion is not covered in the evaluation (e.g. *"no (please move to the next criterion)"*). Where experts do not have information, they can leave the cell empty or fill in: " / ". Where the evaluation clearly states that the sub-/criterion is not applicable, expert should write "not applicable".

Expert should fill in the information as stated in the evaluation – they should not provide their own assessments or judgements on the policy instrument based on the evaluation. However, to capture any concerns regarding the evaluation results, each criterion includes a section on concerns. There, the expert filling-in the evaluation results should highlight if the results are comprehensible or if there are any concerns with respect to the evaluation result.

C.3 Test round of analytical framework

The analytical framework with its set of criteria was subject to a test round with six evaluations. It included ex-post as well as ex-ante assessments of policy instruments in the fields of energy efficiency, renewable energies, fossil fuel pricing (ETS/ESR) and agricultural GHG emissions, see Table 124.

Table 124: Policy instruments and evaluations in the test round

	Energy efficiency	Renewables	ETS/ESR	Agriculture
Selected policy instrument	Local climate investment programme (Climate Leap) (Sweden)	Le fonds chaleur 2009-2018 (France)	TD-1b: Mineral-oil Tax Act (Denmark)	Agri-Environment-Climate Payments (AECP) (part of RDF under the CAP) (Slovenia)
Selected ex-ante evaluation	Naturvårdsverket (2020): Lägesbeskrivning för Klimatklivet	Rapport de la France - En application de l'article 13.1 du règlement n° 525/2013 relatif à un mécanisme pour la surveillance et la déclaration des émissions de gaz à effet de serre - Actualisation 2019	DEA (2005): Danmarks udledning af CO2 -indsatsen i perioden 1990-2001 ogomkostningerne herved, Bilagsrapport	Žnidarčič et al. (2014). Predhodno vrednotenje Programa razvoja podeželja za Slovenijo 2014–2020

	Energy efficiency	Renewables	ETS/ESR	Agriculture
Selected ex-post evaluation	No ex-post evaluation available for the policy instrument. *Substitute ex-post evaluation:* Hirzel et al. (2019): Evaluierung und Weiterentwicklung des Energie-effizienzfonds (Projektnr. 63/15) im Auftrag des Bun-desministeriums für Wirtschaft und Energie (BMWi). Abschlussbericht – Langfassung" (Germany)	Rapport de la France - En application de l'article 13.1 du règlement n° 525/2013 relatif à un mécanisme pour la surveillance et la déclaration des émissions de gaz à effet de serre *Additional ex-post evaluation:* Zech et al. (2019): Evaluation des Marktanreizprogram ms zur Förderung von Maßnahmen zur Nutzung erneuerbarer Energien im Wärmemarkt im Förderzeitraum 2015 bis 2018 (Germany)	DEA (2005): Danmarks udledning af CO2 -indsatsen i perioden 1990-2001 ogomkostningerne herved, Bilagsrapport	Evaluation Assessment of achievements and impacts of the RDP of the Republic of Slovenia 2014-2020

Source: own compilation, Ecologic

We conducted the test to see if the analytical framework is useful for information collection and compilation and to identify gaps, inconsistencies and irrelevant criteria. It included the analytical framework implemented in an excel-table, a guidance document to the test round and the table as well as a feedback sheet to collect relevant notes and feedback. All participants in the test round also participated in a meeting to discuss the lessons learned.

The outcome of the test round confirmed the relevance of the criteria set and led only to minimal adjustments of the sub-criteria descriptions. The feedback from experts indicated that the main categories make it easy to find and assign the needed information but that a general overview of the categories and their criteria might be helpful. Therefore, the index has been added to the intro page of the excel-sheet.

The test round also showed that it was not easy to find an ex-post and ex-ante evaluation for each of the selected policy instruments. In the case of the "Agri-Environment-Climate Payments (AECP)" in Slovenia, the respective evaluations assessed the instrument only as part of the Rural Development Programme, which contains a relatively large set of policy instruments. We could not identify an ex-post evaluation for the "Fonds chaleur" of France.

In addition, the examined evaluations showed some limitations with respect to the expected evaluation results. The evaluation of the "Agri-Environment-Climate Payments (AECP)" in Slovenia provided no information on the GHG emission reduction for the specific instrument but included evaluation results for the use of different resources and for the impact on the environment. The "Fonds chaleur" in France focusses on the expansion of renewable energies but the ex-ante evaluation gave no indication on renewable capacity or energy production increases but referred only to the saved GHG emissions. The evaluation of the energy efficiency instrument "Climate Leap" in Sweden had no information on energy savings and the evaluation of the "Mineral-oil tax" in Denmark provided an estimate for the GHG emission reduction effect

but no quantified assessment of the impact on energy consumption. Due to the missing information on energy savings and the expansion of renewable energies, we added two further ex-post evaluations on the "German Energy Efficiency Fund" and the "Market Incentive Program" to test the relevant criteria in the evaluation framework.