NET ZERO 2050

MEASURING PROGRESS TOWARDS CLIMATE NEUTRALITY

PART I: ASSESSING STRUCTURAL CHANGE THROUGH NET ZERO INDICATORS

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NET ZERO 2050

DISCLAIMER

This report has been commissioned by the European Climate Foundation (ECF). It is part of the Net-Zero 2050 series, an initiative of the ECF with contributions from a consortium of experts and organisations.

The Net Zero 2050 series of reports aims to start building a vision and evidence base for the transition to net zero emissions societies in Europe and beyond, by mid-century at the latest. The Paris Agreement commits us to making this transition, and long-term strategic planning shows that many of the decisions and actions needed to get us on track must be taken imminently. While most of the reports look in detail at the actions and transformations needed in different sectors, the overarching governance framework is also key to making sure that these steps are identified and taken.

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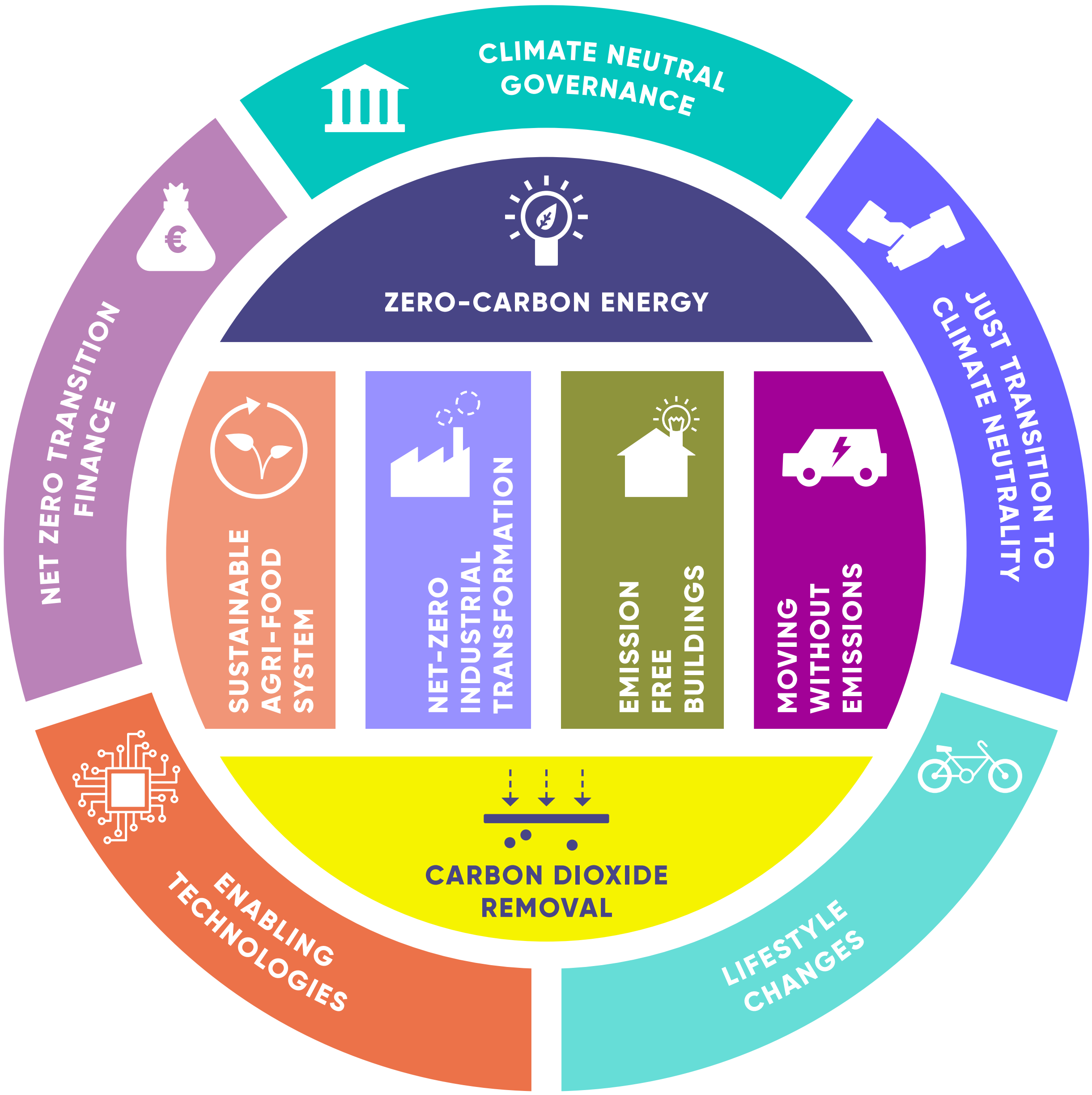
SUMMARY

Reaching climate neutrality requires changes in the way we organise our economies and conduct our daily lives. Net zero emission solutions often require integrated approaches across traditional sectors. Measuring progress towards climate neutrality needs to capture the complexity of the underlying transformation, to inform policy-making in a timely and sufficiently detailed fashion. This report presents a framework that can do this job. It is built on a set of indicators that can provide a systematic overview on the change happening (or not) in essential underlying processes. It could be applied for both reporting and planning purposes, at EU and national level alike.

TRACKING PROGRESS THROUGH ENABLERS FOR DIFFERENT ELEMENTS OF A NET ZERO FUTURE

This monitoring methodology is an attempt to develop a comprehensive tool for tracking progress towards the net zero emissions objective. Eleven “net zero elements” form the basis of this framework; they are pieces of a vision for the future, covering the greenhouse gas (GHG) emitting sectors as well as the cultural, governmental and economic structures that connect them (see Figure 1).

Figure 1: Elements for a climate neutral future



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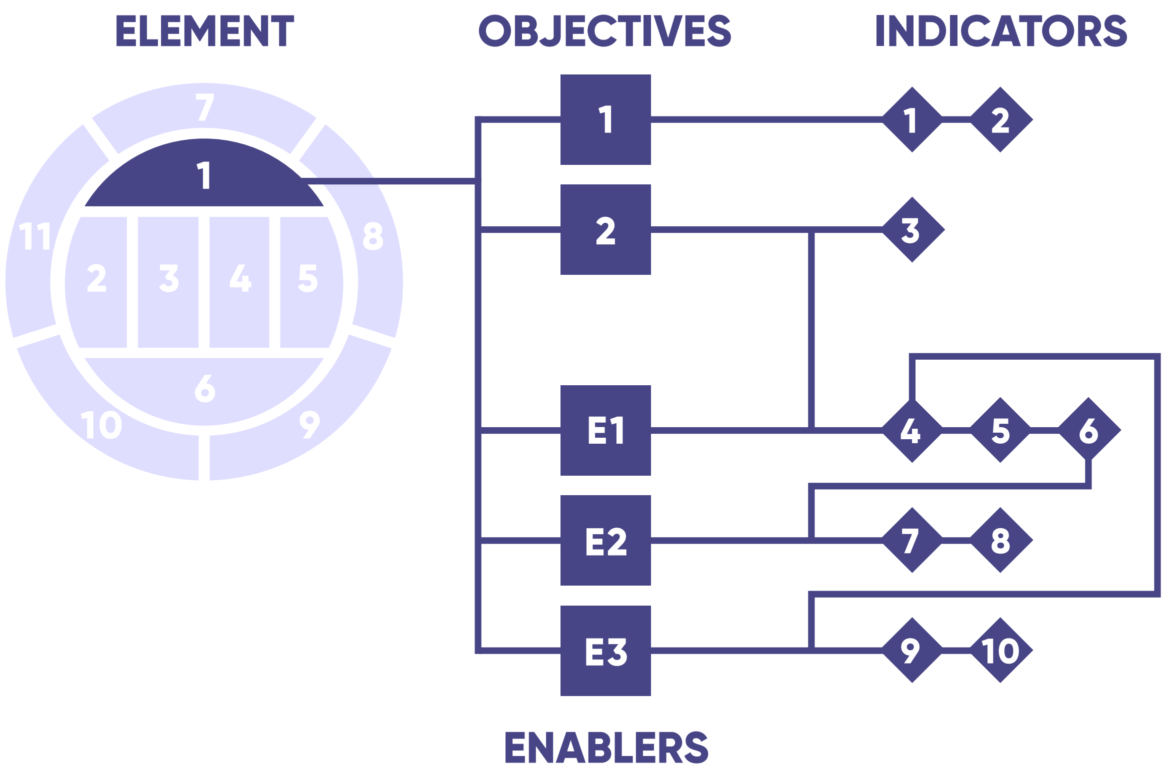
For each net zero element, we identified respective targets (where they currently exist), but also their essential drivers ("enablers") and corresponding indicators. For example, in the element "Moving without emissions", one of four enablers is to shift to "zero carbon fuels". One of four related indicators for the enabler is "number of vehicles per vehicle and fuel types". It provides information on the change in the vehicle fleet towards electric and hydrogen powered vehicles.

Standard progress measurement often relies on sectoral GHG emissions and energy consumption, which has its use at an abstract level but cannot provide real insight into underlying developments. Tracking enablers of change is essential to develop an understanding on the state of progress and to avoid blind spots. Without this level of detail, policy-making cannot be adjusted and improved to get on track – should a course correction be required.

Figure 2: Deriving indicators from net zero elements and their objectives and enablers



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Our approach for progress measurement is to compare past developments (historical data) for each indicator to the change that would be required for reaching net zero (using e.g. target values from the 1.5°C scenarios of the EU Long-Term Strategy or using expert judgemenet). The results are classified on a four-point scale including a qualitative description ("in line with net-zero"; "progressive but insufficient", "not supporting", "opposing") to clearly communicate the results in an easily understandable way. In addition, we propose to derive a composite value for each element that could be used to create a scoreboard with aggregate values for each element.

EARLY INDICATIONS OF STUMBLING BLOCKS – AND DATA GAPS

This report provides a detailed technical proposal for a monitoring methodology; however, it does not offer a comprehensive snapshot of the current state of progress by analysing the full set of indicators – instead it includes an example indicator for each element as "proof of concept". A preliminary analysis of selected indicators shows that progress is largely insufficient in most of the elements. While these example indicators only provide a glimpse of what the full set would reveal, the results provide a first hint at necessary policy adjustments addressing many sectors and policy fields to put the EU on track towards climate neutrality.

Our research has identified important gaps in data availability and a lack of harmonisation and centralisation in some areas. Moreover, for several indicators, there simply is no data available at present (e.g. for the elements sustainable finance and governance) suggesting the need for enhanced data collection in these areas. In addition, most cross-sectoral elements (especially lifestyle changes and just transition) lack clear targets and these need to be defined for better progress measurement. This is particularly important as some elements are presently not properly addressed in existing policy processes (lifestyle changes, just transition) or at an early stage (finance). This is a cause for concern as it could perpetuate blind spots and thus ignore important elements of the transformations that need to be achieved to realise the EU's net zero target.

NET ZERO INDICATORS CAN IMPROVE PLANNING AND REPORTING

The progress monitoring methodology we propose here has a potentially broad applicability and could be used to structure future Long-Term Strategies and sector specific roadmaps and it could be integrated into relevant planning and monitoring procedures (e.g. National Energy and Climate Plans). The concrete integration and use in relevant EU policy processes is analysed in Part II of this report.

We hope that this proposed methodology will serve as a welcome stimulus for debate about how all stakeholders in the EU can better judge whether we are on track towards climate neutrality and where and how adjustments are needed. It is also the authors' view that a common approach to planning for and tracking progress towards climate neutrality, integrated across relevant policy processes, could enhance administrative efficiency and real world impact.

INTRODUCTION

INDICATORS AND THE LONG-TERM OBJECTIVE

The long-term objectives and pathways in the Paris Agreement have helped generate a much stronger focus on the **transformational nature of the changes** required to tackle the climate crisis – and on what it means to reach net zero and net negative emissions. **This new focus has been aided by the drafting of 2050 strategies** at national and EU level, the adoption of climate neutrality as a new long-term goal for the European Union. This has been made the core objective of the European Green Deal and it has been enshrined in the EU Climate Law. The 2030 climate target for the EU has been strengthened as a result, one can argue.

Indicators in various forms are a common and important tool in EU policy-making, such as the indicator scoreboard in the EU Semester's macroeconomic imbalance procedure [1] or the monitoring of the Sustainable Development Goals (SDGs) [2]. They can be a powerful tool to help policy-making decisions according to the role they are given to play, the selection of indicators and how they are used [3].

Today, the most common metrics in energy and climate policy are direct measurements against formulated targets, e.g. in the form of a percentage reduction of greenhouse gases against 1990 level or the deployment of renewables relative to energy consumption overall. They measure fundamental components of the transformation towards climate neutrality at important but very general levels. To understand what is happening "under the hood" of economic sectors and how they are developing – and if this change is going in the direction of climate neutrality and at sufficient pace – needs additional information. To properly **understand if we are making progress towards our long-term climate objective** requires to complement existing metrics with a full and comprehensive set of other measurements. Deep decarbonisation scenarios and long-term strategies have the ability to reveal the necessary systemic changes needed to achieve climate mitigation objectives. They should be put to the task of identifying the underlying drivers to achieve net zero emissions by 2050 – drivers that should in turn serve as a basis to select and develop indicators able to guide and inform policy for the whole transition [4].

OBJECTIVE OF THIS REPORT

This work wants to provide a stronger focus on the transformational changes required over time and their individual triggers in the different fields of action so that it can contribute to making the path towards a climate neutral future more visible.

The work is divided into two parts. The part at hand provides a concept for a set of indicators that measures the ongoing and required transformation of the European economy compatible with net zero emissions and sustainable development objectives. The report offers a detailed technical proposal for how progress measurement could be done but it does not include a full and comprehensive progress measurement. While the focus lies on the European level, the proposed elements, most objectives and enablers and related indicators are also be suitable to measure progress in individual Member States.

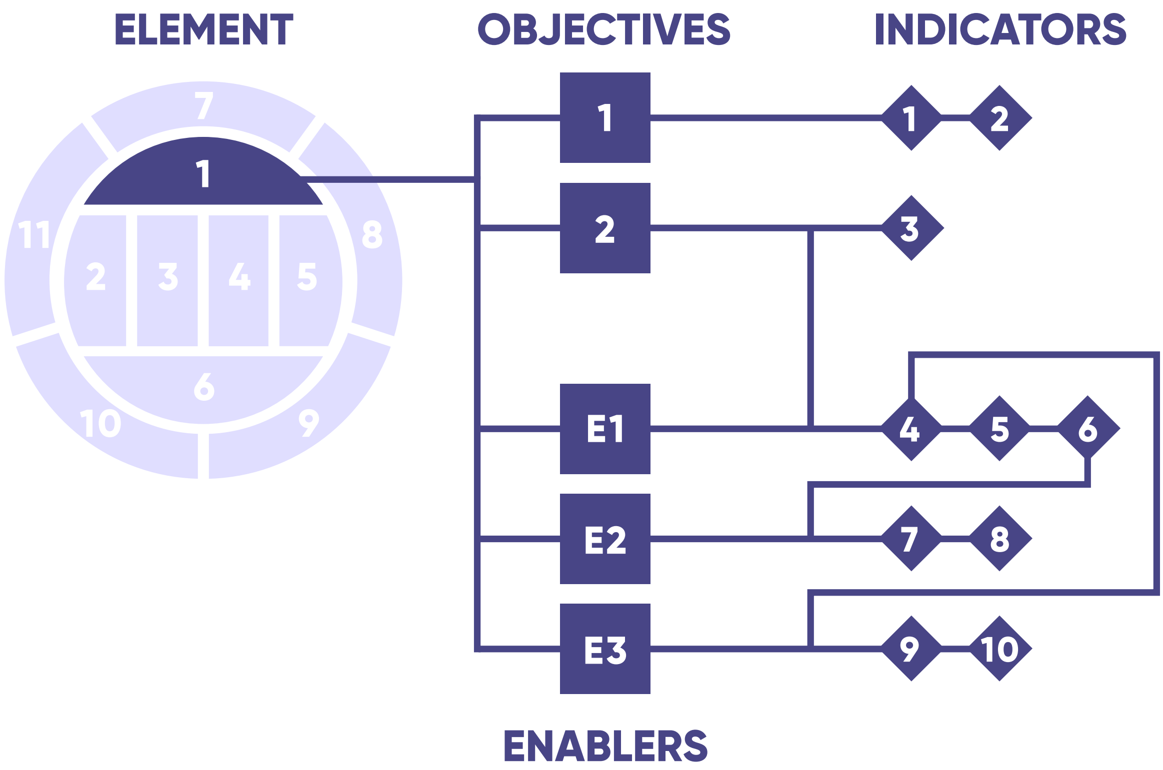
Part II "Integrating net zero indicators in EU governance processes" has analysed a suite of relevant policy processes to identify ways in which including net zero indicators can make the EU climate governance framework fit for the climate neutrality objective.

This report should be taken as a contribution, based on existing and ongoing research, to the debate on climate governance and mainstreaming into European policy. It is informed by a lot of existing thinking and aims to support a transparent debate and informed decision making on how to measure progress towards 2050 based on a sound understanding of drivers to the transformation.

OUR APPROACH: MEASURING STRUCTURAL CHANGE

The transition towards climate neutrality and net-negative emissions requires a drastic reduction of greenhouse gas emissions – this means we need to replace their source (e.g. fossil fuels, carbon-intense products and conventional practices) through zero emission, sustainable solutions. Such "deep decarbonisation" requires systemic changes that can be divided along the lines of the **sectors of the economy**. At the same time, some solutions require cross-sectoral approaches and **an integrated picture** (e.g. electrification of transport is only a solution where electricity generation is carbon neutral and the use of biomass for energy generation is only a solution where the cultivation does not negatively impact food supply, biodiversity and water availability). **Horizontal elements** are present in all sectors, such as financing, behaviour change and technological advances. Progress measurement should thus consider including such cross-cutting elements. In addition, the progress measurement towards climate neutrality should also support **communication of a vision** on the direction of travel for transformations to foster a transparent public debate [5] on the state of progress of the net zero transition through the use of easy-to-understand and descriptive indicators and a summary view on the advance in each element.

Figure 3: Progress measurement in elements uses indicators for objectives and enablers



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Elements for a climate neutral future: One of the main challenges in selecting indicators is to avoid "blind spots" in defining a suitable, comprehensive indicator set able to address all the different elements of a climate neutral future. To address this, we started by adopting the disaggregation proposed by the EU Long-term Strategy (EU LTS) on sectoral elements, such as industry, buildings or transport. Then, based on the identification of cross-sectoral challenges in the EU LTS and a literature review on deep decarbonisation challenges, we added horizontal elements, such as finance, enabling technologies or lifestyle changes which support the progress on decarbonisation in all sectors (see Chapter 3). In total, this has led to eleven "net zero elements". They are formulated in a way that denotes what function they would play in a climate neutral future – they form pieces of a vision in which the goal is reached.

Objectives and enablers: For each sectoral and horizontal element, we identified existing objectives as well as enablers for making progress within that element. The objectives include EU targets or target values derived from the EU LTS scenarios reaching net zero emissions in 2050 (as average values from the 1.5 Tech and 1.5 Life scenarios). The enablers were defined based on identified drivers and barriers of decarbonisation in the latest publications in the respective fields. The enablers represent essential changes needed in each policy field (= net zero element) to realise the function each of them has for a climate neutral future.

Indicators to measure progress in the elements: The progress towards the objectives and the development of enablers form the basis for the selection of indicators in our work. We checked a large range of publications and databases to find indicators that describe the respective objectives and enablers. In addition, we also discussed, cross-checked and complemented our analysis of elements including the objectives, enablers and related indicators with thematic experts, adding a form of informal peer review to the process.

The indicators can be used to measure progress using different methodologies. Our approach is to compare past developments to the change required for reaching net zero at a given point in time (see Chapter 4). However, the project's scope does not include progress measurement for all indicators– instead it includes an example indicator for each element to allow a first "proof of concept". Thus, this report does not offer a comprehensive snapshot of the current state of progress, but provides a detailed technical proposal for how this could be done.

The results for each element can be found in Chapter 5 which provides: 1) a short description of the element focussing on "what is included" and "why it is relevant for reaching net zero emissions"; 2) the relevant objectives and related indicators; 3) the dedicated enablers and related indicators; and 4) an illustrative progress measurement for one indicator.

A summary view on progress in each element: We finally put forth a short concept for a summary view on the progress in each element (Chapter 6). For this, one can use headline indicators or combined values for each element – we suggest using a composite value as these consider not only single indicator/s but a combination thereof and thus reflecting on both, the progress on objective and on enablers. This should support communication on where we stand in each element and where more action is required.

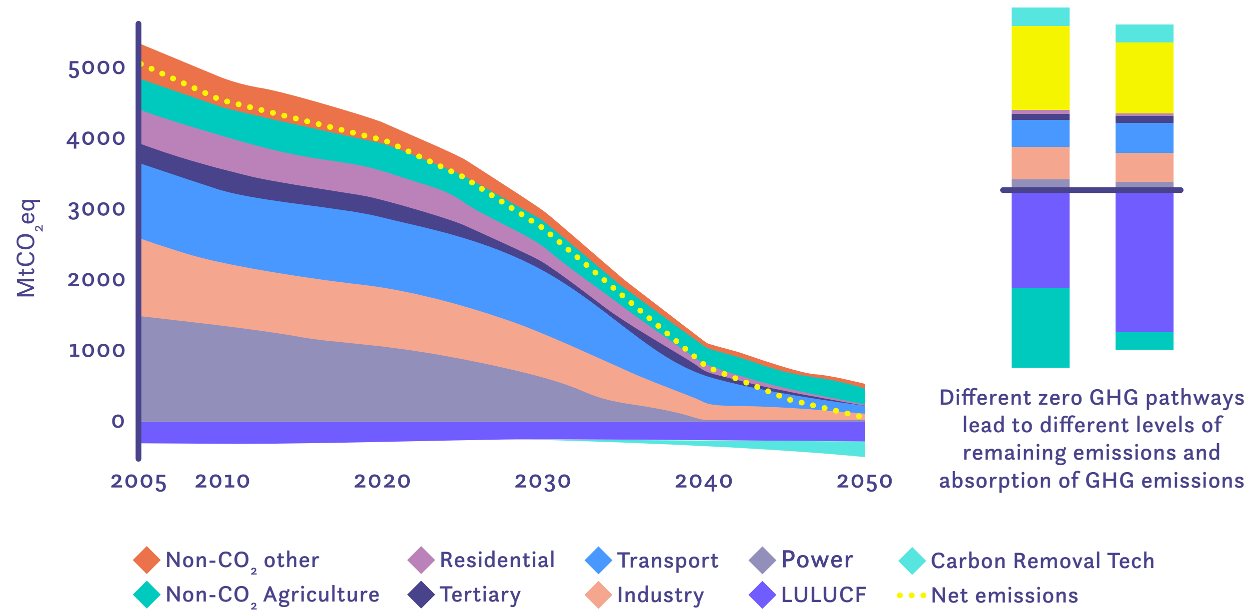
Some concluding findings from this work can be found in Chapter 7.

SELECTION OF ELEMENTS

The elements are the important fields of actions and they form the basis for deriving the indicators. The element selection is based on a literature review of long-term scenarios as well as on an external expert group meeting to identify relevant elements and what they comprise. The set of elements is depicted in Figure 3 with a short description of each element below of the figure. Their names have been defined to explain their role in a climate neutral future.

Existing long-term scenarios [6] illustrate GHG pathways to net zero as a sum of emissions from the different sectors (following the UNFCCC emission categories) including the Commission's "Clean Planet for All" communication (see Figure 2), which also acts as the EU Long-term Strategy (LTS). This **sectoral split** is commonly used, systematic and well understood, so we took this as a starting point, even though in a simplified manner, as we combined households and the services sector into "buildings". In addition, we combined natural carbon sinks and carbon removal technologies into one element – which acts as the counterweight to the emissions from the sectoral elements.

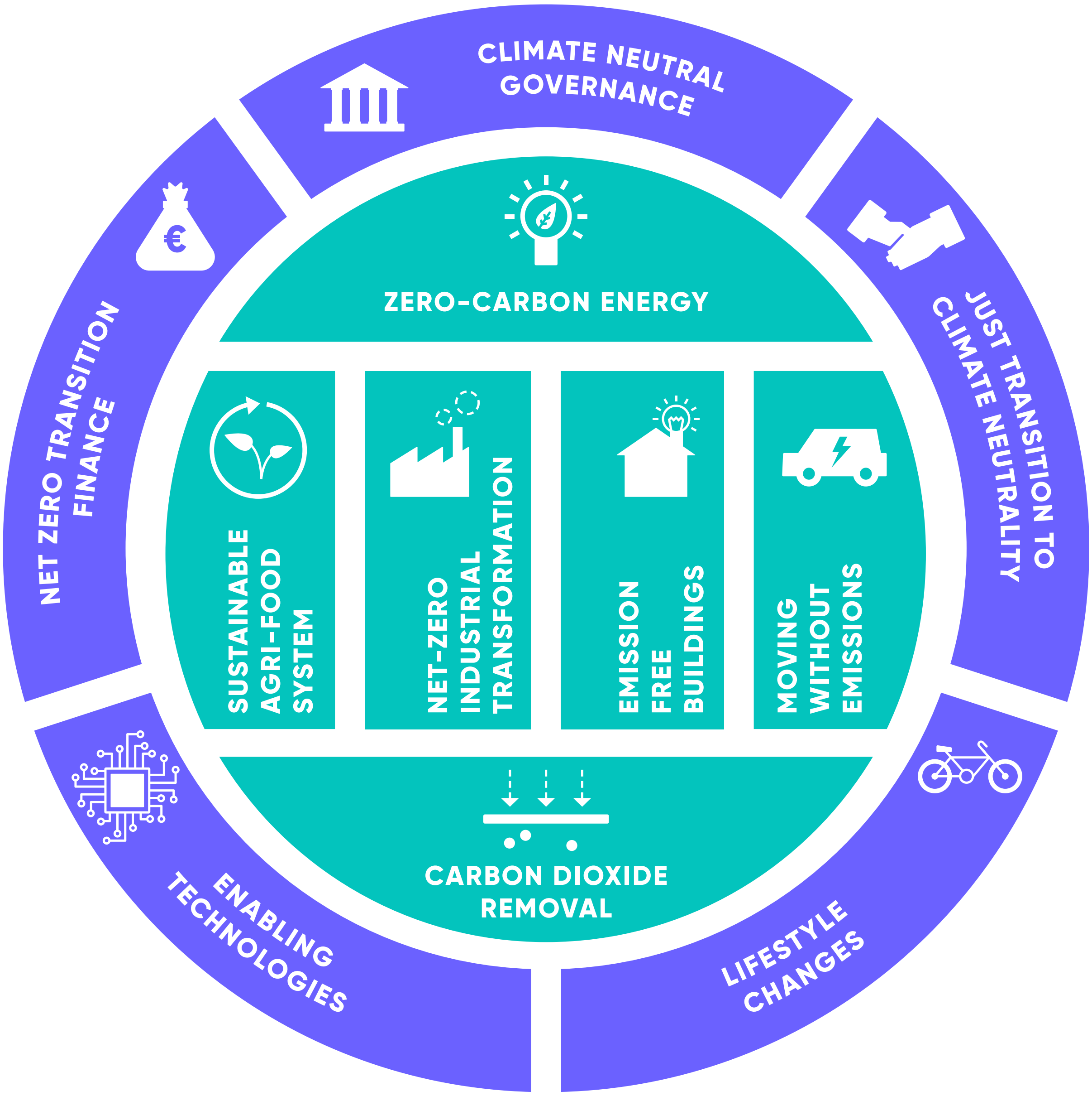
Figure 4: EU pathways to climate neutrality in 2050



Source: COM (2018): A Clean Planet for all.

To complement the sector elements, we included **horizontal elements** that are driving emission reductions and associated change in more than one sector. Going beyond the sectors with these horizontal elements **puts emphasis on cross-sectoral dimensions increasingly considered central in achieving net zero emissions** but which are less prominently featured in existing long-term scenarios and policy target definition. In total, we selected five horizontal elements: finance, technologies, lifestyle changes, a just transition and governance.

Figure 5: Overview and structure of selected elements



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SECTORAL ELEMENTS

1. **Zero carbon energy:** Describes the progress towards switching to renewables complemented by nuclear and fossil fuels equipped with CCS generating electricity, heat, hydrogen and synthetic fuels considering sector coupling and flexibility.
2. **Sustainable agri-food system and land-use:** Describes the progress towards a sustainable agri-food system and land-use reducing the use of pesticides and fertilisation, restoring ecosystems, preserving biodiversity and ensuring a healthy diet for all.
3. **Net zero industrial transformation:** Describes the progress towards a full shift to low or zero carbon industries with an improved material efficiency and circularity, an improved energy efficiency and a switch to zero carbon energy carrier.
4. **Emission-free buildings:** Describes the progress of moving towards zero emission building stocks with an improved material and energy efficiency throughout the lifetime while using zero carbon energy carrier.
5. **Moving without emissions:** Describes the progress towards emission free transportation services for passengers and freight which meets future mobility needs through modal shift and the use of zero carbon energy carriers.
6. **Carbon dioxide removal**: Describes the progress towards the conservation and development of natural carbon sinks and the uptake of carbon removal technologies in order to remove remaining emissions.

HORIZONTAL ELEMENTS

7. **Net zero transition finance:** Describes the progress towards net zero compatible finance and other sustainability objectives of investments undertaken by both private agents and public entities.
8. **Enabling technologies:** Describes the progress in allocating means and resources to R&D and into the uptake of key technologies necessary for reaching a net zero economy.
9. **Lifestyle changes:** Describes the progress in the collective and individual behaviours in the way people move, live, eat, work or consume that contribute to the transition to a net zero economy society across all sectors.
10. **Just transition to climate neutrality:** Describes the progress towards the reduction of vulnerabilities and energy poverty in the society and the inclusiveness in the society.
11. **Governance and political support:** Describes the progress towards a robust and inclusive governance system, enabling, determining and contributing to the required changes in all sectors and horizontal elements.

SELECTION AND USE OF INDICATORS

INDICATOR SELECTION

Selecting indicators is a complex and challenging task. To provide a reliable overview of progress towards climate neutrality, a set of indicators needs to combine a full and systemic overview of the state of decarbonisation of the economy and a focus on more specific but well-identified drivers [7]. In this study, we selected the indicators **based on the 11 elements identified and their objectives and enablers**. Thus, all selected indicators describe progress in at least one of the elements (see Figure 1). The indicator selection for each element is presented in Chapter 5 in the context of the objectives and enablers as well as in an overview table with corresponding data sources and target values at the end of each element chapter.

We included both rather common indicators as well as ones that go beyond the standard set to produce new insights or to shine a light on currently underrepresented aspects. For "new" or less common indicators, data availability may be limited or not existent at all. **Data availability is crucial but did not restrict the indicator selection** as new data gathering and indicator creation activities as well as new monitoring and reporting obligations can be set up to inform long-term policy making. In fact, one could argue that it is no surprise that new metrics are needed to measure some of the enablers for systemic change needed towards climate neutrality. The move to a climate neutral economy requires change on many levels, including in the way we look at the world and what data we extract to assess it. When deemed particularly important, we added the indicator indicating that data is not or only partly available.

We did not rank the indicators in the table and applied no weighting although indicators can be separated between "headlines" indicators that can serve to set high level policy targets and "auxiliary" indicators that help to capture the factors that are driving the results [8]. However, establishing a hierarchy, ranking and/or weighting would need additional research and should involve stakeholders to support the final selection.

To communicate the overarching progress within an element, we propose to derive one **composite value for each element**. The composite value can be derived from the combination of several individual indicators. The methodology should be made fully transparent and selection and weighting of individual indicators need to derive from an extensive consultation of stakeholders to ensure their value is recognised in policy debates. Although composite values implies an extra-layer of methodological definition, it could also better capture the multi-dimensional progress in the elements than a single indicator [9]. Using such a composite value is a good way to summarise the information of a longer list of indicators and consider overall progress on all of them. This approach is an alternative from tracking the progress of an element by singling out headline or key indicators as one example from a longer set, which is standard practise in policy monitoring [10] which has the value of clarity and can serve as a clear policy benchmark but often lead to overlook necessary underlying transformations by providing only a one-dimensional view on an element's progress. Although the combined value of an element can appear to be complex and less straightforward when compared to a headline indicator, a qualitative description of the combined value (as proposed in this study, see Table 1) helps to clearly communicate the results in an easily understandable way and allows for comparison between elements and over several years of progress measurement. As we only cover one example indicator in each element the **composite values could not be calculated.** This also means that the overview in Chapter 6 refers only to the respective example indicators. However, for one element ('Moving without emissions'), the indicator consists of three sub-indicators so that the methodology is applied in this context.

It is important to note that while indicators are a valuable tool to get a better grasp on a complex reality, they **need to be accompanied by an analysis in order to be interpreted in meaningful way**. On their own, they cannot give a comprehensive picture of the intricacies of complex societal, economic or political phenomena [11]. How they could be used in relevant EU governance processes is therefore an important aspect and subject of Part II of this report.

METHODOLOGY FOR PROGRESS MEASUREMENT

In this report, for the purposes of using the indicators for progress measurement, we **compare past developments against a trajectory that lead to the achievement of a target value**. This means that we use the past trend for classification and do not rely on e.g. policy scenarios. This has its advantage in being simple and available for all indicators with some historic data. However, the trend does not take into account any present or future policy decisions, technology advances etc. and it is based on a specific past period. Therefore, it can only provide an indication of the current direction of developments while it can never predict a final value in a specific year – in particular if one looks at more than a few years.

This analysis builds on the **short-term trend of the past five years**. For some indicators, however, it can be useful to make the assessment based on a long-term trend of e.g. 10-15 years – for example, when unusual events cause a strong trend distortion. In this context, we considered data since 2000 to review the short-term trend in the light of the long-term trend. We, however, did not analyse the reasons for the past development and for the differences in the short and long-term trend.

The **target values** are defined for 2050; interim targets are considered if useful, e.g. when there is a relevant EU 2030 target or when a 2050 value is meant to be achieved earlier. The target value is ideally 1) an EU quantitative target, followed by the average value of the LTS scenarios 1.5 Tech/1.5 Life, followed by 2) a quantitative target value provided by another official document or by a study or report, followed by 3) a quantitative target value provided by experts, followed by 4) a definition if the indicator should increase or decrease without aiming at a quantified 2050 value.

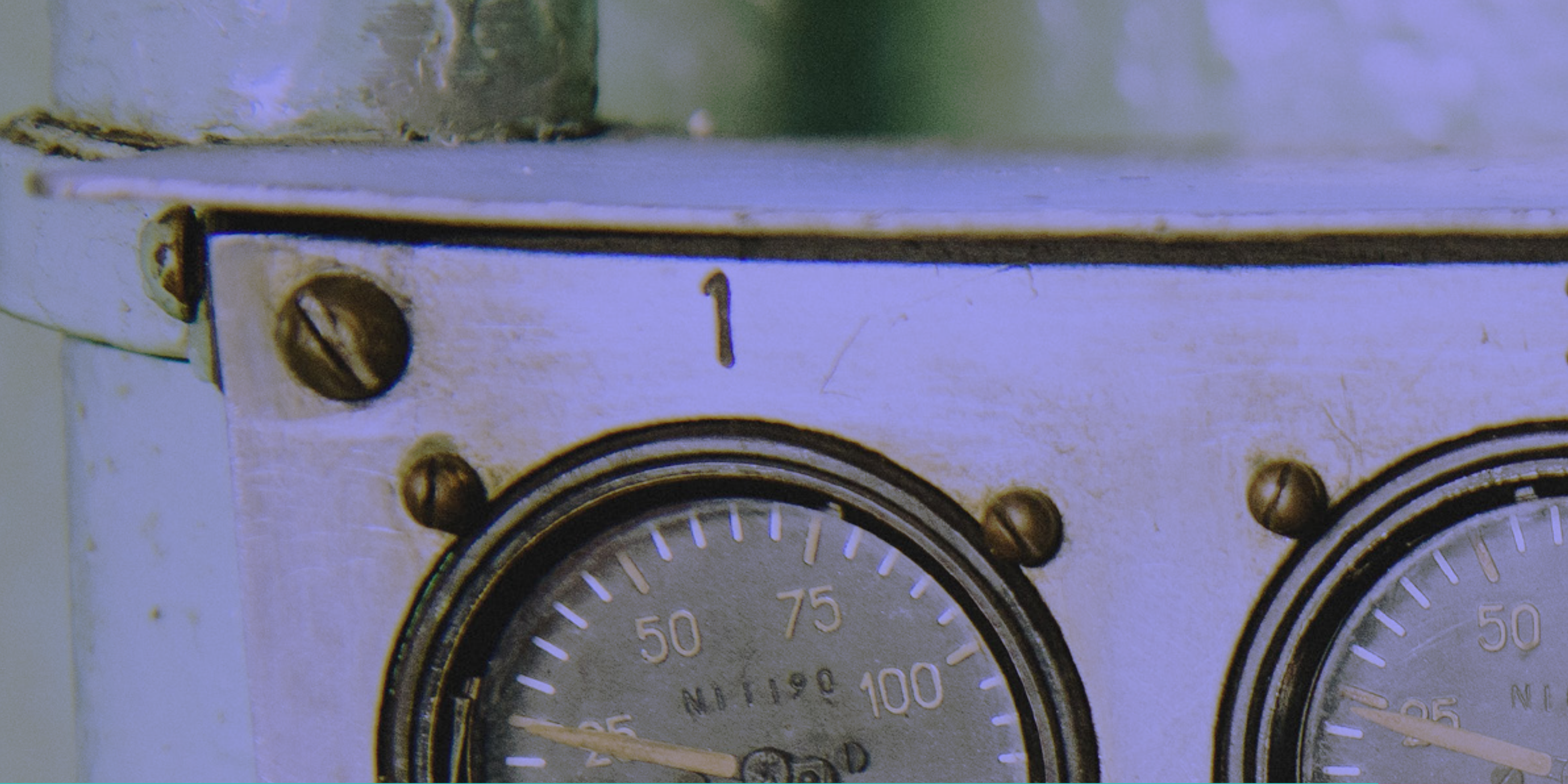
There are different approaches for classifying if progress is sufficient [12]. We use an approach derived from the methodology for monitoring the sustainable development goals (SDGs) in the EU [13]: **the methodology is based on the 'compound annual growth rate' (CAGR),** which is the average annual change between two data points. The annual change over a certain past period, i.e. the trend (= actual CAGR) is compared to the required change (= required CAGR) over the same period in the light of reaching specific target values – e.g. in 2030 and/or 2050. Where the target value is not quantified, the trend is compared to the desirable direction of change including the magnitude of change. The difference between the actual trend and required development can be classified into four categories (see Table 1). This methodology might not directly be applicable to the whole set of indicators as such. It may need adjustment for individual instances, e.g. when indicators measure presence or absence of a given aspect (this is the case for some indicators that measure the existence of government mechanisms).

Table 1: Classification of progress towards a target value

CLASSIFICATION			RANGE FOR QUANTIFIED TARGET VALUE	RANGE FOR DESCRIPTIVE TARGET VALUE
●●●●	4	In line with net zero emissions objective	Trend is at least 95 % of the required change	Trend is > 1 % in the right direction
●●●○	3	Progressive but insufficient for net zero emissions objective	Trend is 60 % - < 95 % of the required change	Trend is 0 % - 1 % in the right direction
●●○○	2	Not supporting the net zero emissions objective	Trend is 0 % - < 60 % of the required change	Trend is 0 % - 1 % in the wrong direction
●○○○	1	Opposing the net zero emissions objective	Trend is below 0 % of the required change	Trend is > 1 % in the wrong direction

Source: own representation with values taken from Eurostat SDG monitoring.

The **scoring also allows to classify a composite value for each element** using the same system as for the individual indicators. The composite value classification is thereby based on the arithmetic mean of the individual indicator scores. For this, the descriptive scoring system (“In line with net zero emissions objective” to “Opposing the net zero emissions objective”) is transferred to a semi-quantitative scoring (1-4) (see Table 1). The resulting average semi-quantitative score for the composite value can then be transferred back to the descriptive scoring system for easy representation of the progress in an element.



INDICATORS FOR MEASURING PROGRESS IN NET ZERO ELEMENTS

This chapter presents the **eleven elements including their objectives and enablers** in which the EU has to make progress in order to reach net zero emissions by 2050. For each element, we present suitable indicators to measure the required progress towards the objectives and the enablers. In addition, an illustrative progress measurement using one indicator from the element shows if there is sufficient progress (methodology described in Chapter 4). An overview table on all indicators in an elements provides further information also on the indicator databases and available target values for 2030 and 2050.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ZERO CARBON ENERGY

This element describes the progress towards switching to an energy system emitting almost no greenhouse gas (GHG) emissions which is a prerequisite for achieving net zero emissions by 2050 [14]. It requires a comprehensive substitution of the current use of fossil fuels by renewables. Renewable energy sources are crucial as their production emits (nearly) no carbon emissions; they deliver energy in the all forms (solids, gases, liquids and electricity), and they are applicable in all sectors. To some extent nuclear will still be used as well as fossil fuels predominantly used in industry in combination with carbon capture and utilisation or storage (CCUS) (where it also captures related process emissions). Securing energy supply will also require an increasing level of sector coupling and energy storage [15].

OBJECTIVES AND TARGETS

The EU's current 2030 target for renewables is a 32 % share in gross final energy consumption [16], which, however, has to increase in the light of the new climate target [17]. There is no target yet for 2050, but the in-depth analysis of the LTS shows that the EU has to shift its energy consumption to predominantly renewable energies (74 % of gross inland consumption excluding non-energy fossil fuel use) followed by nuclear (18 %) and fossil fuels partly in combination with CCS (9 %). GHG emissions from power generation must fall to 34.0 Mt CO_2eq by 2050. CCUS will be crucial for capturing these emissions as well as those from remaining industrial fossil fuel consumption and processes, and is in the order of 70 % of the potentially remaining emissions or 74 to 120 Mt CO_2eq [18] besides additional emission capture from biomass and direct air (see 'Carbon dioxide removal').

RELATED INDICATORS

- Share of renewable energies in gross final energy consumption (incl. sub-indicators for electricity, transport and heating & cooling) [%]
- CO_2 emissions from energy generation captured and used or stored [t CO_2]
- Carbon intensity of electricity generation [g CO_2eq/kWh]
- Electrification of the economy (incl. sub-indicators for sectors) [%]

ENABLERS

E1: SUPPORTING REGULATORY FRAMEWORKS

Renewables, synthetic fuels, energy storage and CCUS require a supportive regulatory framework taking into account the specifics of each technology. In general, administrative, planning and permitting procedures still need simplification and alignment with the objective of the shift to zero carbon energy; provisions need to facilitate market and network access; financial support is needed to ensure stable investment conditions and drive innovation and testing and market penetration of new clean technologies [19]. In addition, a sufficient carbon price sets the right incentive for short and long-term investments and dispatch decisions by improving renewable and low carbon energy production competitiveness vis-à-vis fossil fuels [20]. At the same time, the regulatory framework must ensure that energy remains affordable for citizens and companies (see "Just transition to climate neutrality").

RELATED INDICATORS

- Public money going to fossil-fuels [EUR]
- Support mechanisms for renewables (with sub-indicators for electricity, transport, heating & cooling) [N° of MS; scale]
- Additional energy related investment (with sub-indicators for grids, power plants, new fuels) [EUR]
- Levelised costs for battery storage, carbon capture [EUR/tCO_2], hydrogen [EUR/kgH_2]
- Share of EU financial support for zero carbon energy (EU budget, other programmes) [%]
- Price on carbon (with sub-indicators for different sectors/sources) [EUR/tCO_2eq]
- Share of households' expenditure on housing fuels for average and poor households [%]
- Differences in electricity prices for industry in the EU and globally [EUR/MWh]

E2: INFRASTRUCTURE TO ENABLE A SECURE TRANSITION

The shift to zero carbon energy requires the alignment of transmission and storage infrastructure to the needs of production and delivery of decarbonised energy carriers, CO_2, mobility and information. It requires the rededicating and upgrading of existing infrastructure, building new infrastructure and possibly decommissioning unnecessary systems [21]. For instance, future energy infrastructure will be digital and smart; it will exchange information between connected suppliers, storage options and users and distribute the provided energy safely and efficiently.

RELATED INDICATORS

- Curtailment of electricity generation capacities [hours]
- Infrastructure additions (incl. cross-border capacities) for electricity and gas networks [km; MW]
- Storage capacities for energy (for electricity, heat, gas) [TJ or m^3]
- Average outage duration for each customer (SAIDI) for electricity and gas [min]

E3: REDUCING TOTAL ENERGY CONSUMPTION

Energy efficiency, sufficiency and lifestyle changes are important contributors to achieving a zero carbon energy system by reducing the overall need for energy. In particular, halving energy consumption in the EU by 2050 while quadrupling energy generation from renewables can make specific other technologies unnecessary, such as nuclear and CCS. A limited reduction of energy consumption by only a third would require the quadrupling of the energy generation from renewables in addition to nuclear and CCS [22].

RELATED INDICATORS

- Primary and final energy consumption (incl. sub-indicators for final energy per fuel type, per sector) [% change to 2005 and/or PJ]
- More indicators in the related sectoral elements

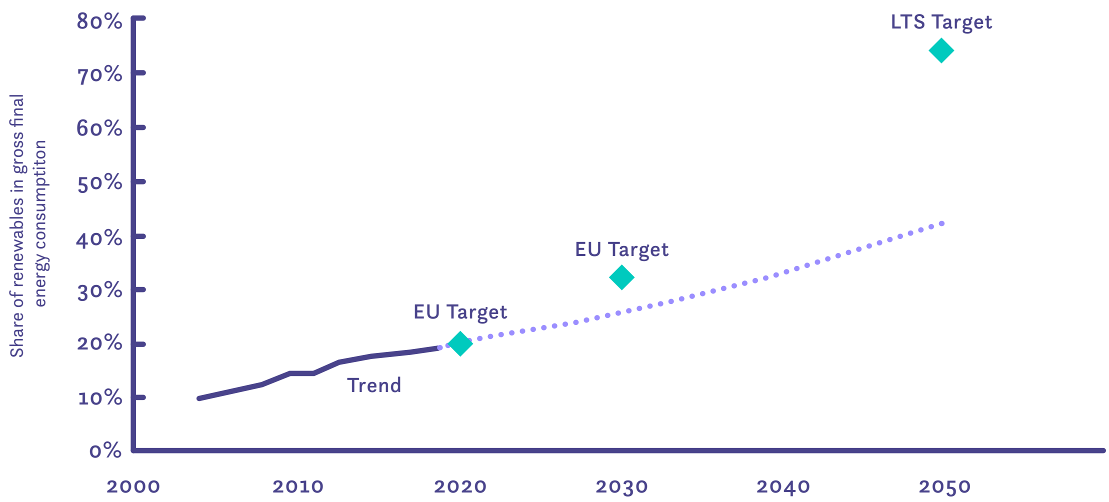
ILLUSTRATIVE PROGRESS MEASUREMENT

The *share of renewable energies in gross final energy consumption* measures the progress towards the objective of increasing the share of renewable energies to a level compatible with the net zero emission objective.

Two goals define the target trajectory: the current EU 2030 target of 32 % share of renewable energies, and the average value of the LTS scenarios 1.5 Tech/1.5 Life for 2050 of 74 % share of renewable energies.

The trend of the last 5 years for which data is available shows that the past developments are **progressive but insufficient for the net zero emissions objective**: the average annual increase was 2.5 % for the share of renewables. This is sufficient for reaching the 2020 renewables target but not for the 2030 target and the 2050 LTS target value. The annual growth rate should have been roughly a third higher at least 4 % to reach the targets. This means that an additional push is necessary to achieve the required transformation in the element.

Figure 6: Progress towards the deployment of renewables



Source: own presentation based on trend data from Eurostat [23] and target values from RED [24] and LTS [25]. The trend is 64 % of the required change to reach the 2030 and 60 % to reach the 2050 target value. For details on methodology, please see Chapter 4.2.

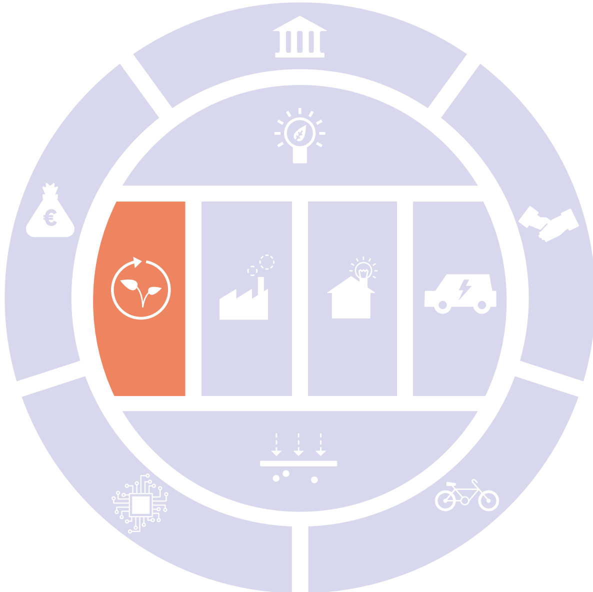
OVERVIEW OF INDICATORS AND RELATED DATA SOURCES AND TARGET VALUES

The following table sums up the indicators for measuring the progress on objectives and enablers including the existing data sources and available 2030 and 2050 target values.

Table 2: Indicators in element "Zero carbon energy"

REFERS TO	NAME OF INDICATOR [UNIT]	DATA SOURCE	SOURCE FOR TARGET VALUES
Objectives	**Share of renewable energies** in gross final energy consumption (incl. sub-indicators for electricity, transport and heating & cooling) [%]	Eurostat [26]	2030: RED; 2050: EU LTS
	CO_2 emissions from energy generation captured and used or stored [t CO_2]	No data yet. GHG inventory (crf. 1.C) [27]	EU LTS
	Carbon intensity of electricity generation [g CO_2 e/kWh]	EEA [28]	2030: EEA [29]
	Electrification of the economy (incl. sub-indicators for sectors) [%]	Eurostat [30]	EU LTS
Enabler 1 on supporting regulatory frameworks	**Support mechanisms for renewables** (incl. sub-indicators for electricity generation, transport, heating & cooling) [N° of MS; scale]	RES legal (database on policies; no scoring) [31]	Not available
	Additional energy related investment (with sub-indicators for power grid, power plants and boilers, new fuels) [EUR]	NECP (some years/ MS) [32], Bloomberg [33] (some MS)	EU LTS
	Share of **EU financial support for zero carbon energy** (EU budget and other programmes) [%]	EU budget [34]	Climate mainstreaming target but not available for 2050
	Public money going to fossil-fuels (fossil fuel subsidies) [EUR]	OECD [35]	E.g. G20 commitment [36]
	Price on carbon (with sub-indicators for different sectors/sources) [EUR/tCO_2eq]	EU ETS price [37]; Carbon taxes [38], Effective carbon rates for some countries [39]	Not available
	Share of **households' expenditure on housing fuels** for average and poor households [%]	Eurostat [40]	Not available
	Differences in **electricity prices for industry** in the EU and globally [EUR/MWh]	Eurostat [41]	Not available
	Levelised costs for emerging technologies (incl. e.g. battery storage, carbon capture [EUR/tCO_2] and hydrogen [EUR/kgH]	Individual studies [42], IEA (single study) [43]	Not available
Enabler 2 on infrastructure to enable a secure transition	**Curtailment** of electricity generation capacities [hours]	ENSOE [44]; available for some countries	Not available
	Infrastructure additions (incl. cross-border capacities) for electricity and gas networks [km; MW]	Possibly ENSO-E [45]; ENSO-G [46]	Electricity: 2040 in TYNDP [47]
	Storage capacities for energy (for electricity, heat, gas) [TJ or m^3]	Single studies	EU LTS
	Average outage duration for each customer (SAIDI) for electricity and gas [min]	CEER [48] ENSOE [49];	Not available
Enabler 3 on reduced energy consumption	**Primary and final energy consumption** (incl. sub-indicators for final energy per fuel type, per sector) [% change to 2005 and/or PJ]	Eurostat [50]	EU LTS

Source: own selection.



SUSTAINABLE AGRI-FOOD SYSTEM AND LAND-USE

This element describes the progress towards a sustainable agri-food system and land-use, which ensures a healthy diet for all while it also reduces GHG emissions, the use of pesticides and fertilisers, preserves biodiversity and contribute to ecosystem restoration. Combining these different priorities requires an attentive consideration of competition between different land-uses and agricultural practices. In addition, agricultural production could increasingly become a source of bioenergy and of biomaterials for decarbonizing construction and industrial activities on top of food. Reducing GHG emissions in the agri-food system requires changes in agricultural practices towards a greater use of agro-ecology and precision farming, dietary changes, the use of biomass resources in line with the preservation and increase of carbon sinks on farmland.

OBJECTIVES AND TARGETS

The agricultural sector will most probably retain residual emissions in a net zero economy due to the limited solutions to address emissions from biological processes involved. However, agricultural activities can also contribute to remove CO_2 present in the atmosphere and put it in carbon sinks such as soils. The Farm-to-Fork Strategy [51] aims at a 25 % of the EU's agricultural land under organic farming by 2030 while the Biodiversity Strategy [52] aims at legally protecting at least 30 % of EU's land area and reach 10 % of farmland under high-biodiversity landscape. By 2050, the LTS indicates that non-CO_2 agricultural emissions have to decrease by between 230 and 277 Mt CO_2eq, a reduction from 37 % to 39 % compared to 2005 levels in its 1.5°C TECH and LIFE scenarios. The reductions for N_2O (45 to 52 %) are expected to be higher than for CH_4 (28.7 % to 30 %).

ENABLERS

E1: FOSTER NEW ECO-AGRICULTURAL PRACTICES AND INNOVATION

The main source of non-CO_2 GHG emissions are the production of synthetic fertilizers enteric fermentation, management of agricultural soils and manure management [53]. The application of a number of technical options and the selection of management practices and the reduction of farmed animals and traded meat and feed can reduce these emissions [54]. In addition, using fewer fossil-based inputs (such as fertiliser and fuels) to produce the same crop, eggs, dairy or meat, generally improves the GHG efficiency of the agricultural system. New technologies like cultured meat could also further help to reduce emissions [55].

RELATED INDICATORS

- GHG emissions per farmland [tCO_2/ha]
- GHG emissions per unit of food production [tCO_2/kcal]
- Fertiliser inputs with sub-indicators for types[kg/ha]
- Consumption of pesticides [tons]
- Share of agricultural land with organic farming [%]
- Share of agricultural land with high-biodiversity landscape features [%]
- Traded meat and feed [tons]
- GHG emissions of agriculture (with sub-indicators for different emission sources) [tCO_2eq per year]

E2: REDUCING EMISSIONS AND INCREASING CARBON REMOVAL IN LAND USE

Improving agricultural practices as well as enhancing agro-ecosystem restoration and agro-forestation reduce emissions and can intensify carbon dioxide removal by natural sinks [56]. This includes options such as agro-forestry where crops and trees grow together as well as silvopastoralism and optimising grazing patterns that help to store carbon in pasture systems [57]. Rewetting of peatlands reduces emissions while allowing agricultural practices (i.e. paludiculture) [58]. Biomass cultivation for an increased use of sustainable biomaterials for long-lasting industrial products can also contribute to carbon removals if direct and indirect land use change impacts are fully taken into account.

RELATED INDICATORS

- GHG emissions of LULUCF (with sub-indicators for emissions and sinks and emission sources) [tCO_2eq per year]
- Average carbon sequestrated in top soil layer [% weight]
- Share of agricultural land under agroforestry [%]
- Share of farmed peatlands under partial-total rewetting and paludiculture [%]

E3: DIETARY CHANGES

Diet is part of lifestyle and linked to historical, economical and geographical determinants [59]. The current average diet in developed economies and Europe is not sustainable regarding its environmental footprint and its impact on health [60]. Reducing the consumption of animal products, salt, sugar and fat, and an increased consumption of fruits and vegetables are some of the most frequently proposed changes for European diets [61]. Achieving this requires a greater consideration of sustainable diet in all policies related to food and agriculture, trade flows and a changed food environment and education to induce changes in diet practices.

RELATED INDICATORS

- Diet carbon footprint [tCO_2/capita per year]
- Average per-person protein consumption from selected meat, fish, seafood, eggs and dairy products [kg/capita per year]

E4: REDUCE AND RE-USE FOOD WASTE

One third of the food produced for human consumption is estimated to be lost or wasted globally [62] representing annual GHG emissions of 186 $MtCO_2eq$ in Europe alone [63]. Packaging can increase the lifespan of products as well as improved food labelling and change in aesthetics requirements and consumer's education can reduce food thrown away although still edible. Systemic issues related to the functioning of the supply chain will need to be addressed to diminish food waste from farm to fork. In addition, collected food waste can be reused as feed, otherwise valorised or, as a last resort, used for energy production [64].

RELATED INDICATORS

- Food waste per capita [kg/capita]
- Amount of food waste [% of total food production or tons/year]

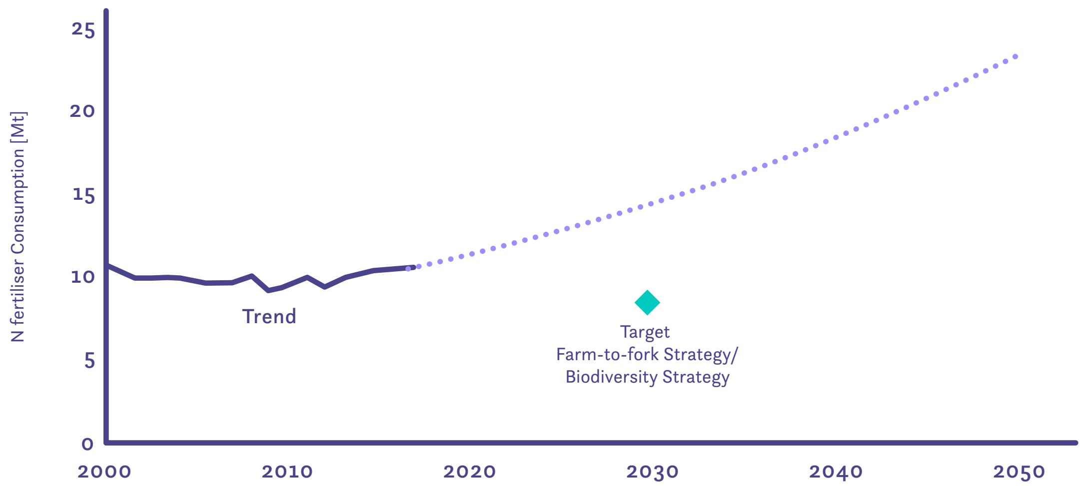
ILLUSTRATIVE PROGRESS MEASUREMENT

The indicator *fertiliser consumption* measures the progress of enabler 1 on fostering new eco-agricultural practices and innovation. We focus on the sub-indicator for *nitrogen consumption* specifically, as nitrous oxide is a potent GHG whose concentration has risen sharply in recent years, mainly driven by agricultural production [65].

The Farm-to-fork strategy [66] and the Biodiversity strategy [67] define a 20 % reduction in fertiliser consumption by 2030. There is no target available for 2050.

The trend of the last 5 years for which data is available shows that the past developments are **opposing the net zero emission objective**: While nitrogen consumption should have decrease by 0.6 % to reach the target, it increased on average by 2.4 % per year. This means that major inflection in agricultural practices is necessary to achieve the required transformation.

Figure 7: Progress in reducing nitrogen fertiliser consumption



Source: own presentation based on trend data from Eurostat [68] and the target value for 2030 from the Farm-to-Fork [69] Strategy and the Biodiversity Strategy [70]. The trend is -417 % of the required change to reach the 2030 target and the trend is 2.4 % in the wrong direction. For details on methodology, please see Chapter 4.2.

OVERVIEW OF INDICATORS AND RELATED DATA SOURCES AND TARGET VALUES

The following table sums up the indicators for measuring the progress on objectives and enablers including the existing data sources and available 2030 and 2050 target values.

Table 3: Indicators in element "Sustainable agri-food system and land-use"

REFERS TO...	NAME OF INDICATOR [UNIT]	DATA SOURCE	SOURCE FOR TARGET VALUES
Enabler 1 on fostering new eco-agricultural practices and innovation	**GHG emissions per farmland** [tCO_2/ha]	Eurostat [71] and national sources	Not available
	GHG emissions per unit of food production [tCO_2/kcal]	Can be calculated from Eurostat [72]	LTS
	Fertiliser consumption with sub-indicators for types [kg/ha]	Eurostat [73]	Farm-to-Fork [74] and Biodiversity strategy [75]
	Consumption of pesticides [tons]	Eurostat	Farm-to-Fork [76]
	Share of **agricultural land with organic farming** [%]	Eurostat [77]	Farm-to-Fork [78] and Biodiversity strategy [79]
	Share of **agricultural land with high-biodiversity landscape features**	In development	Biodiversity strategy [80]
	Traded Meat and Feed [tons]	WFO [81]	Not available
	GHG emissions of agriculture (with sub-indicators for different emission sources) [tCO_2eq per year]	EEA [82]	LTS
Enabler 2 on reducing emissions and increasing carbon removal through improved land use	**GHG net emissions of LULUCF** (with sub-indicators for emissions and sinks and for different emission sources) [tCO_2eq/year]	EEA [83]	LTS
	Average **carbon sequestrated in top soil layer** [% weight]	JRC-ESDAC [84]	Possibly new Soil Strategy [85]
	Share of **agricultural land under agroforestry** [%]	Eurostat [86]	Not available
	Share of **farmed peatlands under partial-total rewetting and paludiculture** [%]	Not available	Not available
Enabler 3 on dietary changes	**Diet carbon footprint** [tCO_2/capita]	Can be calculated from Eurostat [87], EFSA [88]	LTS
	Average per-person **protein consumption from selected meat, fish, seafood, eggs and dairy products** [kg/capita per year]	EEA [89]	Not available
Enabler 4 on reducing and re-using food waste	**Food waste per capita** [kg/capita]	WFO [90]	Not available
	Amount of food waste [% of total food production or tons/year]	WFO [91]	Possible proposal by end 2023 for 2030 [92]

Source: own selection.

NET ZERO INDUSTRIAL TRANSFORMATION

This element describes the progress towards a climate neutral industry implying the realisation of several process and product changes including: the change of product characteristics and compositions to reduce emissions, the improvement of material efficiency and circularity and switch to carbon-free materials and processes; the reduction of required energy inputs and the shift to zero carbon energy including greater electrification and hydrogen; and the deployment of CCUS for unavoidable emissions. This implies significant effort given the lack of progress in past decades and the long investment cycles of the sector requiring the integration of long-term considerations in today's investment decisions. In addition, energy and trade intensive industries need a strong common approach to maintain a level-playing field within and outside the EU.

OBJECTIVES AND TARGETS

The in-depth analysis of the LTS shows that from 2015 to 2050 industrial CO_2 emissions from energy consumption need to fall by 95 % to reach 25 Mt CO_2 and process emissions by 75 % to reach 95 Mt CO_2. Energy intensity of industrial activity would fall by 54 %. The reduction of process emissions will depend on the realisation of process and product changes, as the CO_2 emission reduction potential differs depending on each industrial sector. For example, iron and steel production process emissions need to drop to almost zero by 2050 while the cement industry would halve its process emissions in the same period. Most of the remaining industrial emissions (125 Mt CO_2/year) would be captured and either stored underground or in materials [93]. Following the 2021 update of the European industrial strategy [94], green and digital transition pathways for several ecosystems will be produced starting from the end of 2021 and should provide more detailed climate objectives for industrial sectors.

ENABLERS

E1: CREATING LEAD MARKETS FOR INNOVATIVE TECHNOLOGIES

Innovative low-carbon industrial technologies often cannot compete with existing technologies when entering the market. Policy support can create lead markets oriented towards investment and market securing demand for low-carbon or reused materials. Such policies can take different forms and combine policy instruments such as market standards, investment support for pilot projects, green public procurement and other market pull policies like contracts-for-difference [95], subsidies or tax incentives. Lead markets can accelerate the diffusion of innovative climate-friendly technologies, increase economies of scale and awareness, and in general create a profitable business case [96].

RELATED INDICATORS

- Share of production from zero carbon industrial processes in gross industrial production and in energy intensive industrial production [% and/or tonne]
- Jobs created in zero carbon industrial processes in energy intensive industrial production [number of jobs]
- Annual investments in zero carbon industrial processes [EUR]

E2: UNLOCK VALUE CHAINS FOR MATERIAL EFFICIENCY AND CIRCULARITY

Improving the circularity of materials reduces emissions from primary and secondary production as it reduces the overall need for (raw) materials and improves the reusability and recycling of materials resulting in higher material efficiency. Circular economy including materials efficiency, new technologies and associated new business models in major value chains can reduce 58 to 171 Mt CO_2 by 2050 compared to the 530 Mt CO_2 emitted by the basic materials sectors in the EU in 2015 [97]. The level of circularity varies today across industries and many challenges remain to tap the existing potential – the most important being the securing of a sufficient level of material recuperation and the quality of the recycled/reused material [98].

RELATED INDICATORS

- Share of reused or recycled materials in basic material product demand [%]
- Ratio of primary to secondary production by industrial product [%]
- Value-added per tons in energy intensive industries [EUR/tones]
- GHG emissions per industrial output [tCO_2eq/tonne]
- Final energy consumption in industry per unit of value added [kWh/EUR value added]
- CO_2 intensity of gross final energy consumption in industry (sub-indicator for energy-intensive industry) [tCO_2/kwh]
- Energy and CO_2 cost as a share of value-added in industrial sector [%]

E3: ENSURE LOW-CARBON INDUSTRY COMPETITIVENESS BY INTEGRATING CLIMATE, TRADE AND INDUSTRIAL POLICY

Reducing emissions in the industrial sector often implies increasing investment costs and/or higher operational costs. Energy and trade-intensive industries might face competitive pressure from increased carbon and energy prices and are thus likely to find it difficult to increase investment in more efficient capital stock without measures to ensure a level playing field [99]. Integrating industrial, climate, energy and trade policy in the EU and with trade partners is a strong lever to help all industries to engage in the zero carbon transformation and preventing relocation of production in regions with less stringent climate policy.

E4: INFRASTRUCTURE TO ENABLE THE INDUSTRIAL TRANSITION

The shift to zero carbon industry requires the development of the adequate upstream infrastructure [100]. In particular, the development of hydrogen infrastructure, possibility of electrification, and CCUS infrastructure will be central to achieve deep decarbonisation in industrial production in Europe.

RELATED INDICATORS

- GHG emissions from final use of products [tCO_2]
- Cost ratio of low carbon vs. conventional processes [%]

RELATED INDICATORS

- Share of industrial sites having access to CO_2 storage [%]
- Share of industrial sites having access to hydrogen production and storage [%]
- Length or transport capacity of hydrogen and CCUS infrastructure network (with sub-indicators per infrastructure) [km or volumes per year]

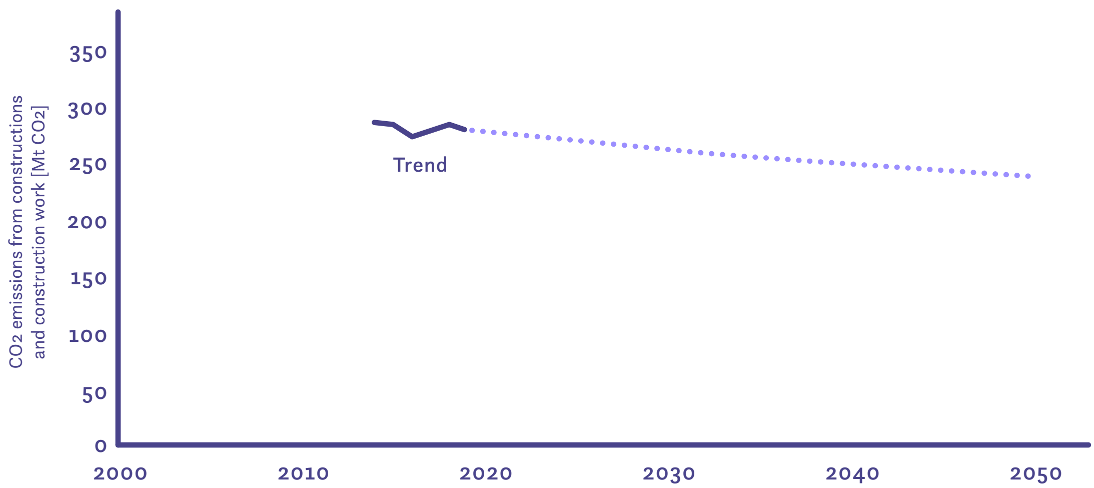
ILLUSTRATIVE PROGRESS MEASUREMENT

The indicator *GHG emissions from final use of constructions and construction products*, refers to the "embodied emissions" of materials used in the construction industry. It is the one with the highest carbon footprint linked to embodied emissions in materials. This indicator should be monitored for all final products to measure the progress of enabler 2 on unlocking value chains for material efficiency and circularity and enabler 3 on ensuring low-carbon industry competitiveness.

There is currently no target defined for this indicator, but embodied emissions should decrease in line with the Paris Agreement stipulating that all countries need to reduce their emissions by mid-century.

The trend of the last 5 years for which data is available shows that the past developments are **progressive but insufficient for the net zero emissions objective**: although emissions declined, the average annual decrease was only 0.5 %. This means that progresses in decarbonising heavy industry in Europe should be accelerated to achieve the required transformation in the element.

Figure 8: Progress on reducing embodied emissions in the construction sector



Source: own presentation based on trend data from Eurostat [101]. Trend is 0.5% in the right direction. For details on methodology, please see Chapter 4.2.

OVERVIEW OF INDICATORS AND RELATED DATA SOURCES AND TARGET VALUES

The following table sums up the indicators for measuring the progress on objectives and enablers including the existing data sources and available 2030 and 2050 target values.

Table 4: Indicators in element "Net zero industrial transformation"

REFERS TO...	NAME OF INDICATOR [UNIT]	DATA SOURCE	SOURCE FOR TARGET VALUES
Enabler 1 on creating lead markets for innovative technologies	Share of **production from zero carbon industrial processes** in gross industrial production and in energy intensive industrial production [% and/or tonne]	Not available	LTS
	Jobs created in zero carbon industrial processes in energy intensive industrial production [number of jobs]	Not available	LTS
	Annual investments in zero carbon industrial processes [EUR]	Not available	LTS
Enabler 2 on unlocking value chains for material efficiency and circularity	Share of **reused or recycled materials in basic material product demand** [%]	EEA [102]	Circular Economy Package (until 2030 [103]
	Ratio of primary to secondary production by industrial product [%]	Not available	LTS
	Value-added per tons in energy intensive industries [EUR/tones]	Not available	LTS
	GHG emissions per industrial output (including specific basic material production, like cement clinker, crude steel, aluminium etc…) [tCO_2eq/tonne]	Not available	LTS
	Final energy consumption in industry per unit of value added [kWh/EURvalue added]	Eurostat [104]	LTS
	CO_2 intensity of gross final energy consumption in industry (sub-indicator for energy intensive industry) [tCO_2/kwh]	Can be calculated from Eurostat [105]	LTS
	Energy and CO_2 cost as a share of value-added in industrial sector [%]	Not available	Not available
Enabler 3 on ensuring low-carbon industry competitiveness	**Cost ratio of low carbon vs. conventional processes** [%]	Not available	Not available
	GHG emissions from final use of products (with sub-indicators for different products) [tCO_2]	Eurostat [106]	LTS
Enabler 4 on infrastructure to enable the industrial transition	Share of **industrial sites having access to CO_2 storage** [%]	Not available	Not available
	Share of **industrial sites having access to hydrogen production and storage** [%]	Not available	Not available
	Length or transport capacity of hydrogen and CCS infrastructure network (with sub-indicators per infrastructure) [km or volumes per year]	Not available	Not available

Source: own selection

EMISSION-FREE BUILDINGS

This element describes the progress of moving towards emission-free building stocks which have an improved material and energy efficiency throughout their lifetime and which use mainly renewables to cover their remaining energy needs [107]. At present, buildings are responsible for 40 % of the total EU energy consumption and 36 % of energy-related CO_2 emissions [108]. Moving towards net zero emissions requires all new buildings to be nearly zero energy buildings (nZEBs). Renovations must be material-efficient, include high-performance thermal insulation and encompass the replacement of fossil fuelled heating systems, e.g. by heat pumps, renewable systems, green hydrogen or synthetic fuels or systems using waste heat. There is also a need for high efficient appliances and smart energy management systems to reduce energy needs. The diffusion of clean technologies depends on local circumstances such as the availability of renewables or infrastructure [109].

OBJECTIVES AND TARGETS

The EU requires that from 2021 onwards, all new buildings will be nZEBs [110]. Buildings undergoing major renovation have to achieve minimum energy performance requirements [111]. For 2050, the in-depth analysis of the LTS shows that 97 % of the building's stock needs to undergo a partial or deep renovation with an annual renovation rate of at least 3 %, whereby energy consumption declines by 56 % in residential buildings and by 37 % in commercial buildings. The largest decrease will come from heating and cooling (H&C) with residential buildings reducing their energy consumption by 68 % and commercial buildings by 55 %. Accordingly, residential buildings will emit 11.6 Mt CO_2eq (minus 96 % compared to 2018) and commercial buildings 19.4 Mt CO_2eq (minus 86 %) from onside use of fossil-fuels [112].

RELATED INDICATORS

- GHG emissions of buildings (incl. sub-indicators for building type, direct and indirect emissions) [tCO_2eq]
- Share of buildings with RES heating systems (incl. sub-indicators for type and rented or owner-occupied buildings) [%]
- Share of renewable energy in heating and cooling [%]
- Final energy consumption in buildings (incl. sub-indicators for building type, type of applications and energy carriers) [% change to 2005 and/or PJ]
- Total number of renovated buildings [number of buildings]; renovation rate (incl. sub-indicators for deep, medium, light renovations) [%]
- Embedded GHG emissions in buildings (incl. sub-indicators for life-cycle stages and for different building materials) [tCO_2eq/t material]

ENABLERS

E1: FACILITATING EMISSION-FREE BUILDINGS

The upscaling of emission free buildings and deep renovations using clean technologies and materials with a higher degree of circularity requires verifiable information that de-risks energy efficiency investments and engages relevant actors as well as sufficient workforce with the right skills to install clean technologies [113]. Therefore, distribution of information to professionals, capacity building and upskilling in regard to clean technologies for people working in the building sector, such as architects, engineers, heating installers and construction workers, is necessary [114]. In addition, there is a need for further R, D&D and the market penetration of innovative solutions [115].

RELATED INDICATORS

- Amount of One-Stop-Shops for energy renovation [OSS/capita]
- Share of people knowing about building renovation (incl. sub-indicators for professionals/public; on measures, benefits of renovation and support programmes) [%]
- Recovery rate of construction and demolition waste (incl. sub-indicators for recovery for same purpose, up- or downcycling) [% of construction and demolition mineral waste recycled]

E2: RAISING DEMAND FOR EMISSION-FREE BUILDINGS

Standards can guarantee a basic threshold of achievement towards environmental objectives and compensate for knowledge gaps. The economic viability of energy efficient technologies can be increased through financial support, which can spur private and commercial investments while also targeting specific market failures (e.g. landlord-tenant dilemma). Carbon pricing increases the costs for fossil-fuel based heating, cooling and electricity which improves the economic viability of low and zero carbon options. However, increasing fuel costs can lead to energy poverty requiring appropriate countermeasures (see element 10). The dissemination of information assures that the public knows about possibilities and benefits of clean technologies, thereby creating demand and acceptance [116].

RELATED INDICATORS

- Average cost of renovation (incl. sub-indicators for building type and renovation depth, before and after the use of grants) [EUR/m^2]
- Public money going to building renovation (EU budget and other programmes) [EUR]
- Investment in energy renovations (incl. sub-indicators for residential / commercial, rented / owner-occupied buildings and for type of renovation actions) [mEUR]
- Share of households' expenditure on housing fuels for average and poor households [%]
- Share of energy performance certificate (EPC) levels (A and B) (incl. sub-indicators for residential/commercial) or share of nearly zero energy buildings (NZEB) [% of total building stock]

E3: DIGITALISATION

Digital and smart energy-consuming appliances and services can react to consumer preferences and limit unnecessary energy uses and address technical failures. In addition, they can enable consumers to react to varying energy production and include self-production and energy storage systems (including e.g. batteries in electric vehicles), thus balancing demand and supply and helping with a cost-effective integration of renewables. Digital building logbooks can contain information about life-cycle energy consumption and GHG emissions providing information to the construction sector, building owners and consumers. Innovative home energy appliances also provide energy data for policymakers as well as the market allowing for targeted action and innovative solutions [117].

RELATED INDICATORS

- Coverage of households with smart meters [%]
- Smart readiness of buildings [A-G scale]

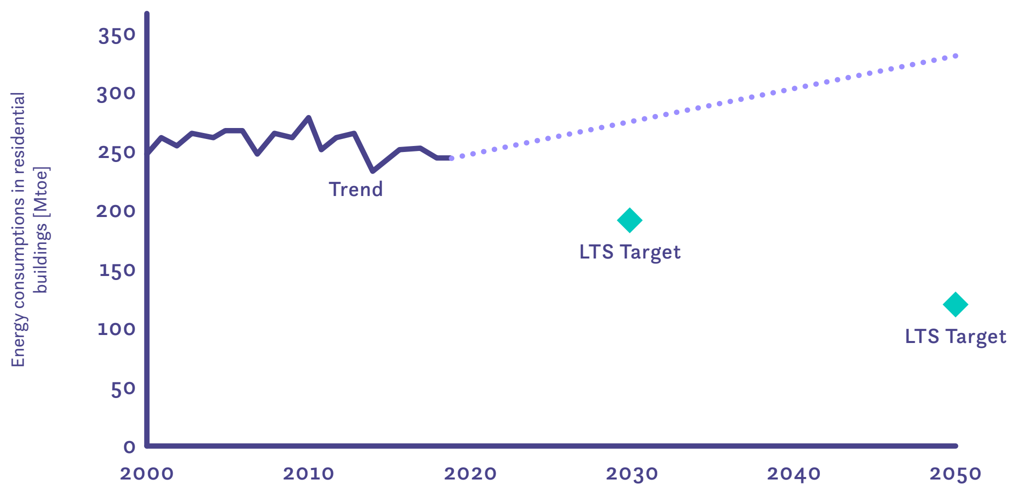
ILLUSTRATIVE PROGRESS MEASUREMENT

The indicator *final energy consumption in buildings* measures the progress towards the objective of reducing energy consumption to a level compatible with the net zero emission objective. Here, we present the sub-indicator *energy consumption of households*, which consist of energy used for space heating (63 %), water heating (14.8 %) as well as lighting and electric appliances (14.1 %) [118].

Two goals define the target trajectory: A 28 % reduction of final energy consumption until 2030 and a 55.5 % reduction until 2050 (in comparison to 2005). Both stem from the average value of the LTS scenarios 1.5 Tech and 1.5 Life.

The trend of the last 5 years of which data is available shows that the past developments are **opposing the net zero emission objective**: While the achievement of the 2030 and 2050 targets would have required an average annual decrease of energy consumption of 1 % and 2 %, respectively, energy consumption increased on average by 1 % in recent years. The long-term trend over the past 15 years is less pronounced but still going into the wrong direction: the energy consumption in residential buildings increased on average by 0.5 % per year. This means that a building modernisation need to be accelerated to reach a turnaround in the trend.

Figure 9: Progress on reducing energy consumption in residential buildings



Source: Own presentation based on data from Eurostat [119], target values are based on the LTS reduction targets for 2030 and 2050 [120]. The trend is -77 % of the required change to reach the 2030 and -51 % to reach the 2050 target value. For details on methodology, please see Chapter 4.2.

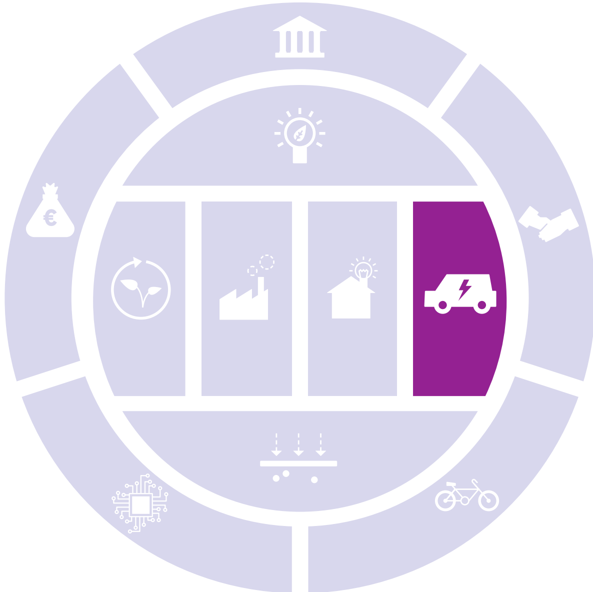
OVERVIEW OF INDICATORS AND RELATED DATA SOURCES AND TARGET VALUES

The following table sums up the indicators for measuring the progress on objectives and enablers including the existing data sources and available 2030 and 2050 target values.

Table 5: Indicators in element "Emission-free buildings"

REFERS TO...	NAME OF INDICATOR [UNIT]	DATA SOURCE	SOURCE FOR TARGET VALUES
Objectives	**GHG emissions of the building sector** (incl. sub-indicators for building type and for direct and indirect emissions) [tCO_2eq]	EEA & Eurostat [121]	EU LTS
	Share of **buildings with RES heating systems** (incl. sub-indicators for type and rented or owner-occupied buildings) [%] Share of **renewable energy in heating and cooling** [%]	Hotmaps data (not all years) [122], Eurostat [123]	EU LTS
	Share of **energy performance certificate (EPC) levels (A and B)** (incl. sub-indicators for residential/commercial) Share of **nearly zero energy buildings** (NZEB) [% of total building stock]	Zebra 2020 data tool [124], EU BSO (not all MS and years)	National plans for some countries [125]
	Final **energy consumption in buildings** (incl. sub-indicators for building type, for type of applications and energy carriers) [% change to 2005 and/or PJ]	Eurostat [126], EU Buildings Datamapper (not all years) [127]	EU LTS
	Total number of **renovated buildings** [number of buildings] **Renovation rate** (incl. sub-indicators for deep, medium, light renovations) [%]	EU-BSO (not all MS and years), Zebra 2020 data tool [128], individual studies [129]	EU Renovation Wave [130] 2030: IA55% [131] 2050: EU LTS
	Embedded GHG emissions in buildings (including sub-indicators for life-cycle stages and for different building materials) [tCO_2eq/t material]	Only individual studies [132]	Not available
Enabler 1 on facilitating emission-free buildings	Share of **households' expenditure on housing fuels** for average and poor households [%]	Eurostat [133]	Not available
	Amount of **One-Stop-Shops for energy renovation** [OSS/capita]	Registry in progress [134]	Not available
	Share of **people knowing about building renovation** (incl. sub-indicators for professionals/public; on measures, benefits of renovation and support programmes) [%]	Not available yet	Not available
	Recovery rate of construction and demolition waste (incl. sub-indicators for recovery for same purpose, up- or downcycling) [% of construction and demolition mineral waste recycled]	Eurostat [135]	Material recovery targets to be developed by COM until 2024 [136]
Enabler 2 on raising demand for emission-free buildings	Average **cost of renovation** (incl. sub-indicators for building type and renovation depth, before and after the use of grants) [EUR/m^2]	Partly Zebra 2020 data tool (not all MS and years) [137]	Not available
	Public money going to building renovation (EU budget and other programmes) [EUR]	EU budget [138], individual studies [139]	Not available
	Investment in **energy renovations** (incl. sub-indicators for residential / commercial, rented / owner-occupied buildings and for type of renovation actions) [mEUR]	Individual studies [140]; IEA [141]	LTS
Enabler 3 on digitalisation	Coverage of **households with smart meters** [%]	EU BSO [142]	Not available
	Smart readiness of buildings [A-G scale]	Methodology developed [143]	Not available

Source: own selection



MOVING WITHOUT EMISSIONS

This element describes the progress towards an emission-free transport system for passengers and freight which meets future mobility needs. At present, emissions from the transport system make up about one third of overall GHG emissions in the EU and are still on the rise. In order to reverse the trend and achieve high emission reductions, it is necessary to reduce mobility needs, to change modes of transport including more public and collective transportation and active mobility (walking and cycling) and to shift towards zero carbon transportation solutions based on electricity, synthetic fuels and hydrogen, and to increase efficiency [144].

OBJECTIVES AND TARGETS

The Sustainable and Smart Mobility Strategy [145] lays out the pathway for a 90 % reduction of transport emissions by 2050. It specifies milestones including at least 30 million zero-emission cars by 2030 and nearly all cars, vans and busses and all new heavy-duty vehicles being zero-emission by 2050. The LTS outlines the same emission reduction by 2050 when the remaining emissions of 90 Mt CO_2 come from airplanes (78 % of transport emissions) followed with a wide distance by heavy good vehicles (17 %) and inland shipping (3 %); emissions from private motorised and rail transport decreases to almost zero. This requires also a reduction by almost half of the energy consumption (-47 % from 2015 to 2050). Fuel use switches from almost 100 % diesel and petrol to electricity (26 % of transport energy consumption) followed by bio-based and synthetic fuels and gases (both 21 %), remaining fossil-fuels (16 %) and hydrogen (16 %) [146].

RELATED INDICATORS

- GHG emissions from transport (incl. sub-indicators for road, rail, water, air) [Mt CO_2eq]
- Energy consumption of transport (incl. sub-indicators for fuel types) [PJ]

ENABLERS

E1: ZERO CARBON FUELS

Electric vehicles (EVs), including e-bikes, cars, busses, vans and lorries, offer the possibility to keep parts of the private and commercial motorised transport while increasing energy efficiency and emitting no direct GHG emissions [147]. Vehicle batteries also offer an opportunity for electricity storage supporting distribution network security. Advanced biofuels and synthetic fuels can power conventional engines where long distances and/or fuelling stations are a challenge and in particular airplanes and ships. However, advanced biofuels compete with other land use options and are limitedly scalable and synthetic fuels require more electricity than EVs due to efficiency losses in their production [148]. Key drivers for this enabler are technological advances reducing the costs of new options as well as the availability of infrastructure.

RELATED INDICATORS

- Share of low-emission fuels (with sub-indicators for electricity, biofuels, synthetic fuels and hydrogen) [%]
- Average GHG emissions of new vehicles (incl. sub-indicators for vehicle types) [kgCO_2eq/km]
- Number of vehicles (incl. sub-indicators for vehicle types and fuel types)
- Electric charging points (incl. sub-indicators for different charging types) [number]

E2: INCENTIVISING THE MODAL SHIFT

A stronger focus on inter-modality in the design of transport systems, ensuring that public transport is convenient, secure and accessible and the existence of secure bike lanes and walkable areas can promote the shift from cars to walking, biking and public transport (see "Lifestyle changes"). In addition, financial incentives for e-bikes or affordable public transport, pricing of CO_2 emissions and air pollutants, road charges and reduced and expensive parking space in crowed cities or a ban of private cars in the inner city can drive the modal shift [149].

RELATED INDICATORS

- Modal split of passenger and freight transport (according to type) [%]
- Expenditure per capita on transport [EUR]

E3: URBAN AND TERRITORIAL PLANNING AND ITS IMPLEMENTATION

Adequate transport infrastructure based on clever urban and regional planning can shorten travel distances or reduce the need to travel. Adequate planning can improve the availability of infrastructure for low-carbon transport modes such as public and non-motorised and the connection between different transport modes [150]. Good planning also addresses congestion. New infrastructure and restructuring should aim for improved comfort and time savings in particular for non-motorised and public transport, and it should also improve accessibility of electric charging and to new fuel types.

RELATED INDICATORS

- Passenger transport (incl. sub-indicators for mode and purpose) [passenger-km]
- Freight transport (incl. sub-indicators for mode and type of goods) [tonne-km]
- Infrastructure updates and additions (incl. roads, rail, bike-lines etc.) [km and/or as EUR invested; related to population]
- Commuting travel time [average time of commute per minutes per day]
- Congestion and delays [hours spend in road congestion annually]

E4: DIGITALISATION

Digitalisation, if implemented in a sustainable manner, can lead to a reduction of the need for travel if e.g. people can work in their home office or management systems better coordinate and shorten the distances for services and deliveries [151]. It can also reduce congestion and delays in road and rail transport through better travel management [152].

RELATED INDICATORS

- Commuting travel time [average time of commute per minutes per day]
- Congestion and delays [hours spend in road congestion annually]

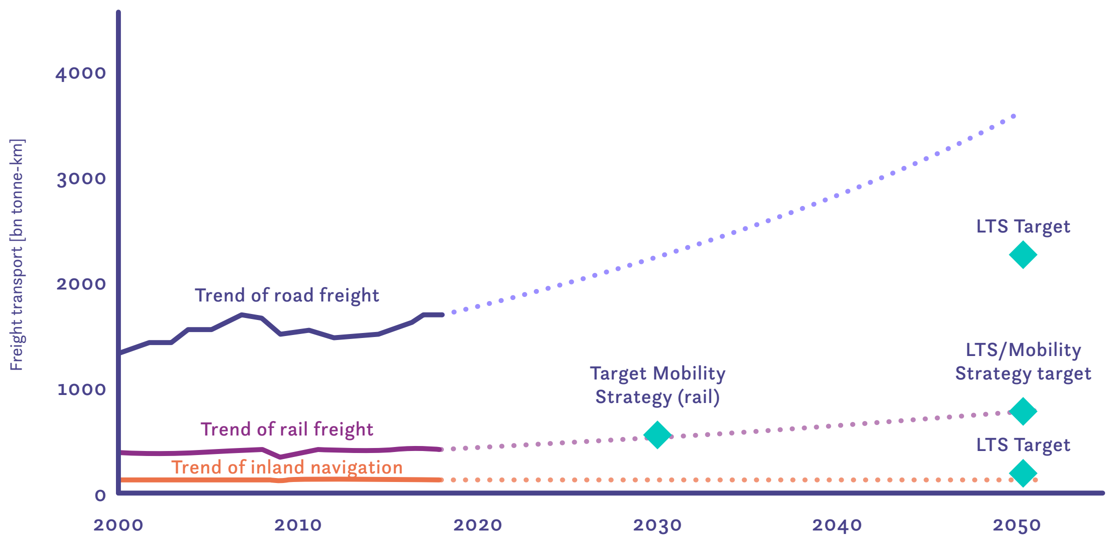
ILLUSTRATIVE PROGRESS MEASUREMENT

The *modal split in freight transport* helps to measure the progress of enabler 2 on incentivising the modal shift, which facilitates the transformation necessary for achieving the net zero emission objective. The indicator tracks the development of various modes of freight transportation including road, rail and inland waterways.

The LTS, the European Green Deal and the new Mobility Strategy of the European Commission ask for a shift away from the heavy dependency on motorised road transport towards a more balanced modal split of using road, rail and inland waterways. The target trajectory is based on the LTS and the Mobility Strategy with the latter providing very similar target values for 2030 and 2050 for rail freight transport.

The trend of the last five years for which data is available shows an increase in total freight. The average annual increase of road freight was 2.4 % which is more than twice as high when compared to the target trajectory of the LTS which stipulates an annual increase of maximum 1.1 %. Therefore, the development is **opposing the net zero emissions objective**. The recent trend in inland waterways is also **opposing the net zero emission objective** – however, here an average annual increase of 0.7 % would have been in line with the LTS target but it decreased by 2.4 % per year. In contrast, the progress in rail freight shows that the trend is **in line with net zero emission objective** as the trend equals the target trajectory. In summary, the indicator's assessment shows that more progress is needed in road and inland waterways freight while rail freight increases must continue to realise the required modal shift.

Figure 10: Progress on the modal shift in freight transport



Source: Own presentation based on data from Eurostat [153] (data for EU 28) using data on inland waterways for domestic navigation; target values are based on the LTS targets for 2050 [154]. The trend is -18 % (road), 100 % (rail), -339 % (inland waterways) of the required change to reach the 2050 target value. For details on methodology, please see Chapter 4.2.

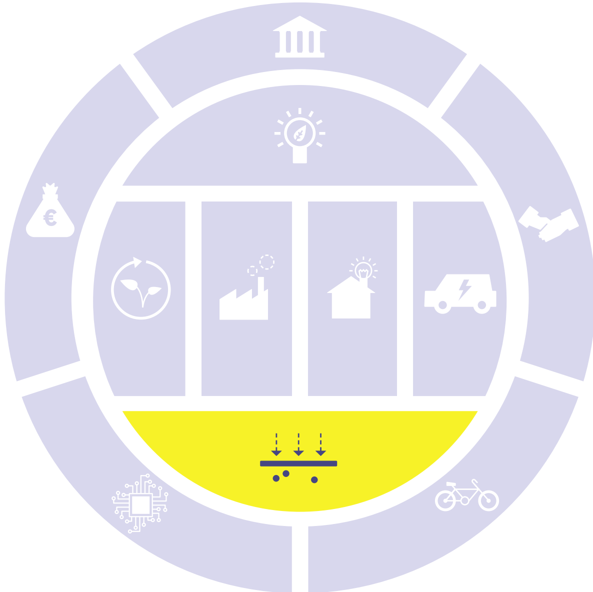
OVERVIEW OF INDICATORS AND RELATED DATA SOURCES AND TARGET VALUES

The following table sums up the indicators for measuring the progress on objectives and enablers including the existing data sources and available 2030 and 2050 target values.

Table 6: Indicators in element "Moving without emissions"

REFERS TO...	NAME OF INDICATOR [UNIT]	DATA SOURCE	SOURCE FOR TARGET VALUES
Objectives	GHG **emissions from transport** (incl. sub-indicators for road, rail, water, air) [Mt CO_2eq]	EEA [155]	Mobility Strategy, EU LTS
	Energy consumption of transport (incl. sub-indicators for fuel types) [PJ]	Eurostat [156]	EU LTS
Enabler 1 on zero carbon fuels	Share of **low-emission fuels** (with sub-indicators for biofuels, synthetic fuels and hydrogen) [%]	Eurostat [157]	EU LTS, RED [158]
	Average **GHG emissions of new vehicles** (incl. sub-indicators for vehicle types) [kgCO_2eq/km]	For cars: EEA [159]	EU targets [160]; Mobility Strategy
	Number of vehicles (incl. sub-indicators for vehicle types and fuel types)	Eurostat [161]	Mobility Strategy (for some modes), EU LTS
	Electric charging points (incl. sub-indicators for different charging types) [number]	EAFO [162]	National infrastructure targets for 2020/2025 [163]
Enabler 2 on incentivising the modal shift	**Modal split of passenger and freight transport** (according to type) [%]	Eurostat [164]	EU LTS
	Expenditure per capita on transport [EUR]	Eurostat [165]	Not available
Enabler 3 on urban and territorial planning and implementation	**Passenger transport volume** (incl. sub-indicators for mode and purpose) [passenger-km] **Freight transport volume** (incl. sub-indicators for mode and type of goods) [tonne-km]	Eurostat [166]; THETIS-MRV [167]	Mobility Strategy (for some modes of transport), EU LTS
	Infrastructure updates and additions (incl. roads, rail, bike-lines etc.) [km and/or as EUR invested; related to population]	Eurostat [168]	Not available
	Commuting travel time [average time of commute per minutes per day] [169]	European Working Conditions Survey [170]	Not available
	Congestion and delays [hours spend in road congestion annually] [171]	COM [172]	Not available
Enabler 4 on digitalization	**Commuting travel time** [average time of commute per minutes per day] [173]	European Working Conditions Survey [174]	Not available
	Congestion and delays [hours spend in road congestion annually] [175]	COM [176]	Not available

Source: own selection; some indicators appear in two enablers.



CARBON DIOXIDE REMOVAL

This element describes the progress towards enhanced carbon dioxide removal (CDR). CDR can compensate the residual GHG emissions from human activities [177], which is relevant in all 1.5°C scenarios of the IPCC [178]. Options for removing and storing CO_2 can be divided into natural sinks and carbon removal technologies (CRT). Natural sinks store CO_2 in the form of biomass on land and oceans and can be enhanced through ecosystem restoration, reforestation and improved forest management practices that also tackle the biodiversity crisis. CRTs include the use of biomass for energy generation coupled with carbon capture and storage (BECCS), direct air CO_2 capture and storage (DACCS), biochar, enhanced weathering, ocean alkalinisation and ocean fertilization. Those technologies store CO_2 in geological reservoirs or via chemical processes and differ widely when it comes to their maturity, potentials, costs, risks and benefits [179].

OBJECTIVES AND TARGETS

The EU requires that Member States at least remove their emissions within the land-use, land use change and forestry (LULUCF) sector over the period 2021 to 2030 reaching net zero emissions in that sector [180]. The rules relating to LULUCF are currently being renegotiated with the upcoming redesign of the climate policy architecture [181]. The Biodiversity Strategy [182] aims at protecting at least 30 % of EU's land area increasing the potential of ecosystems and soil as carbon sinks. In addition, the EU Commission works on a proposal to set restoration targets for degraded ecosystems, particularly those with a high potential for CDR [183]. By 2050, the LTS 1.5°C scenarios indicate that natural sinks should remove emissions from LULUCF and an additional 399 Mt CO_2eq. To achieve this goal, forest area need to expand to roughly 170 Mha, the area for grassland and shrub should remain relatively stable and the productive agricultural land need to slightly decrease to roughly 140 Mha. In addition, CRT (BECC and DACC with geological storage) should remove roughly 155.9 Mt CO_2eq [184].

RELATED INDICATORS

- Natural CO_2 removal of different land types [$MtCO_2$]
- CO_2 removal of CRT (incl. sub-indicators for types of removal technologies) [$MtCO_2$]
- Technical CO_2 storage (incl. sub-indicators for different storage options) [$MtCO_2$]

ENABLERS

E1: ENHANCING NATURAL CARBON SEQUESTRATION

Improving forest management and agricultural practices (see also element 2) as well as ecosystem restoration intensifies the sink function of soils and forests. Related activities should be coherent with and support biodiversity objectives. This requires an enabling environment to incentivise and scale-up related activities including comprehensive governance frameworks with suitable targets in concert with sufficient funding [185].

RELATED INDICATORS

- Restoration of ecosystems (incl. sub-indicators for different ecosystems) [Mha and/or %-increase, additional trees]
- Change in land coverage (incl. sub-indicators for types) [%-share; Mha]
- Soil organic carbon (SOC) in the topsoil [%-share; g C/kg; t C/ha]
- Annual felling [m^3/ha/year]) and net annual increment of forests [m^3/ha/year] (and their long term ratio) [-]

E2: INVESTMENT INTO RESEARCH, DEVELOPMENT AND DEMONSTRATION

Most CDR options such as BECC, DAC with underground and/or ocean storage of emissions need further research, because knowledge on the functioning and impacts is diffuse and incomplete or the options are not yet at the stage of market maturity [186]. Their availability and economic viability will determine which options and how much emissions can be securely stored by 2050. For soil organic carbon, research addresses monitoring and reporting of soil organic carbon change.

RELATED INDICATORS

- Costs of CCS [EUR/t CO_2]
- Legal framework for CCS [e.g. scoring system]
- Funding for R, D&D related to natural sinks and CRTs (EU budget, other programmes) [EUR]
- Legal framework for CCS [e.g. scoring system]

E3: ACCEPTANCE OF CARBON DIOXIDE REMOVAL

CDR options come with side-effects that may hamper their acceptance in the public and in politics, in particular of those directly affected. For example, growing biomass for BECCS is land-intensive, requires water and fertilisers and can impact food production and biodiversity; DACCS still come with high energy demand; transport and underground storage of CO_2 is still expensive and may leak emissions [187]. However, CDR options are considered as generally acceptable if they are understood as an addition to ambitious climate action [188]. Clear communication of reduction and of removal targets and an EU-wide policy frame that sets a clear scope for the use of CDR can help in this regard. CDR is then considered as necessary to reach net zero but not as excuse for specific actors to lower the ambition in emission reductions [189].

RELATED INDICATORS

- Share of population supporting CRT (incl. reasons for non-/support) [%]
- Contributions of GHG reductions and removals to an overall GHG net reduction target [% share]

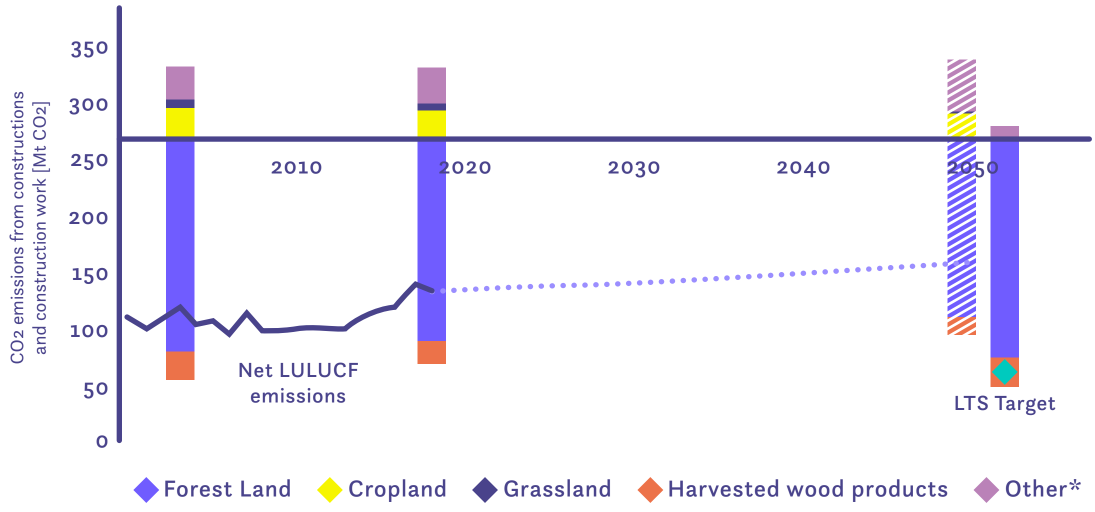
ILLUSTRATIVE PROGRESS MEASUREMENT

The indicator *natural CO_2 removal* helps to measure the progress towards the target of increasing natural sinks to a level compatible with the net zero emission objective. Data availability is limited so that trend and target trajectories presented here are net values, i.e. they account for carbon sinks as well as emission sources of the LULUCF sector.

The target trajectory is defined by the LTS scenarios 1.5 Tech and 1.5 Life: in 2050, LULUCF should be a sink for 399 Mt CO_2eq. Additionally, the LTS provides CO_2 target values for the different land types.

For the analysis, the long term trend over the last 15 years of available data was chosen instead of the 5 year time span due to short-term fluctuations that distort a meaningful assessment of the trends. The analysis shows that the past developments are **opposing the net zero emission objective**. The 2050 target value would have require a rising net sink function of 0.6 % per year but it decreased by 0.6 % per year. This means that action is needed in the LULUCF sector to increase the CO_2 removal e.g. by forests while reducing emissions from cropland and wetlands (see “Sustainable agri-food system and land-use”).

Figure 11: Progress on increasing carbon dioxide removal from LULUCF



**Settlements, wetland, other land and other LULUCF*

Source: own presentation based on trend data from the EEA [190] and target values based on the LTS [191]. Trend is -109 % of the required change for reaching the 2050 target value. For details on methodology, please see Chapter 4.2.

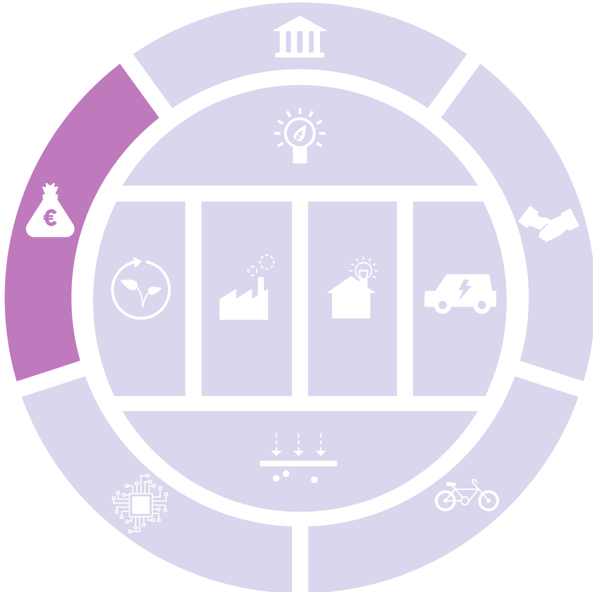
OVERVIEW OF INDICATORS AND RELATED DATA SOURCES AND TARGET VALUES

The following table sums up the indicators for measuring the progress on objectives and enablers including the existing data sources and available 2030 and 2050 target values.

Table 7: Indicators in element "Carbon dioxide removal"

REFERS TO...	NAME OF INDICATOR [UNIT]	DATA SOURCE	SOURCE FOR TARGET VALUES
Objectives	**Natural CO_2 removal of different land types** [$MtCO_2$]	EEA [192]	2030: LULUCF Directive 2050: EU LTS for LULUCF
	CO_2 removal of CRT (incl. sub-indicators for types of removal technologies) [$MtCO_2$]	No data yet. GHG inventory (crf. 1.C)	EU LTS
	Technical CO_2 storage (incl. sub-indicators for different storage options) [$MtCO_2$]	No data yet. GHG inventory (crf. 1.C)	EU LTS
Enabler 1 on enhancing natural sinks	**Restoration of ecosystems** (incl. sub-indicators for different ecosystems) [Mha and/or %-increase, amount of additional trees]	Partly EEA [193], GFRA [194]	Possibly new Regulation on restoration targets [195]
	Change in **land coverage** (incl. sub-indicators for types) [%-share; Mha]	EEA [196]; HRL VPP [under dev.] [197]; EEA [198]; GPD [199]	Biodiversity Strategy [200] Possibly new Soil Strategy [201]
	Soil organic carbon (SOC) in the topsoil [%-share; g C/kg; t C/ha]	JRC ESDAC [202]; EUSO [under dev.] [203], GFRA [204]	Possibly new Soil Strategy
	Annual felling [m^3/ha/yea]) and net annual **increment of forests** [m^3/ha/year] (and their long term ratio) [-]	Old data: EEA [205]; HRL VPP [under dev.]	Not available.
Enabler 2 on investment into R, D&D	**Costs of CCS** [EUR/t CO_2]	Individual studies [206]	Not available
	Legal **framework for CCS** [e.g. scoring system]	Scoring: Global CCS Institute [207]	Not available
	Funding for R, D&D of CRT (EU budget, other programmes) [EUR]	EU Budget [208]	Not available
Enabler 3 on acceptance of CDR	Share of **population supporting CRT** (incl. reasons for non-/support) [%]	Not available yet (possibly Eurobarometer)	Not available
	Contributions of GHG reductions and removals to an overall GHG net reduction target	EEA [209]	EU climate targets [210]

Source: own selection; for more indicators on the functioning of ecosystems, see MAES report.



NET ZERO TRANSITION FINANCE

This element describes the progress towards net zero compatible and sustainable finance and investments, which are also among the objectives in the Paris Agreement [211]. Transitioning to a net zero economy requires significant investments into low or zero carbon technologies, services and products and a phase out of investments contributing to GHG emissions. Climate finance has reached record levels, however it still falls far short of what is needed under a 1.5˚C scenario [212]. Private finance accounts for the bulk of investments; however, the public sector has a key role in providing regulatory stability and risk-sharing solutions in order to reduce the risk investors face and their financing costs. This requires a timely transformation of the financial sector to break the "Tragedy of the Horizon" [213] and to better take into account long-term societal needs. Reorienting finance will require innovation, new practices and metrics and new standards in order to embed climate in the everyday decision of financial actors. This reorientation will generate considerable cost savings, especially in operating costs [214], and will help strengthening financial stability explicitly integrating long-term physical and transition risks and intangible value creation factors in asset pricing [215].

OBJECTIVES AND TARGETS

The additional investments in the energy sector compared to the baseline for achieving the 2030 climate target of reducing net emissions by 55 %, have been estimated at between EUR 63 and 114 billion per year between 2021 and 2030 [216]. For the period thereafter from 2031 to 2050, reaching net zero would require between EUR 1,366 and 1,480 billion of annual investments corresponding to a rather limited additional EUR 176 to 290 billion per year compared to the baseline scenario [217]. More than 80 % of this investment corresponds to investments in demand sectors whereas only 17 % correspond to investments in the energy supply. The Green Deal investment plan [218] includes the idea to use public funds to leverage private funds and lower the capital costs for green investments. The EU taxonomy that will apply from 2021 [219] classifies sustainable economic activities according to six environmental objectives, among them climate mitigation. It could serve to set sustainable investments targets which should progressively reach 100 % for all economic activities by 2050 at latest.

RELATED INDICATORS

- Total amount of sustainable and unsustainable investments in all economic sectors [EUR]
- Investment gap [EUR]
- Share of sustainable and unsustainable investments in EU/MS GDP [%]

ENABLERS

E1: ORIENT PUBLIC FUNDS TOWARDS THE TRANSITION

Public funds and investments are necessary for achieving the transition towards net zero. Public authorities should adapt their own activities and direct their funds into net zero compatible technologies, products, processes, practices, services and infrastructure, thus supporting the market entry of climate friendly innovations into all economic activities [220]. Financial instruments using public money to leverage private funds can be a powerful tool to bring down the financing costs of innovations and infrastructure for the transition [221].

RELATED INDICATORS

- Share of public funds dedicated to climate action in EU and MS budget [% of overall funding]
- Green budget analysis of EU/MS budget (share brown / green; volume-based assessment, etc.)

E2: ENABLING REGULATORY FRAMEWORK

Regulatory measures, clarity and predictability are key to convince investors to switch to investments in the low carbon transition that will pay over a long period and bring down financing costs [222]. It includes a clear objective and strategic planning system of the contribution of each sector and predictable policy levers (e.g. regulation, subsidies, carbon pricing).

RELATED INDICATORS

- Average cost of capital for sustainable investments [%]

E3: ALIGN THE FINANCIAL SYSTEM WITH CLIMATE

Reorienting private capital towards more sustainable investments requires creating the necessary level of transparency in the financial market [223] and to foster lower capital costs for long-term investments, new entrants and innovative challengers [224]. Standards and certifications can define what is considered as a sustainable investment compatible with the net zero objective and improve disclosure requirements for companies and investors. In addition, climate and environmental risk assessments need to be mainstreamed in economic and financial decision-making and the valuation of assets [225] including the supervision of banks and financial institutions [226] while market-shaping financial regulations could be introduced [227].

RELATED INDICATORS

- Share of financial market assets labelled as Green / consistent with EU taxonomy (loans, primary market transactions, secondary market portfolios) [%]
- Coverage of banking stress tests considering climate risks [% overall bank assets]

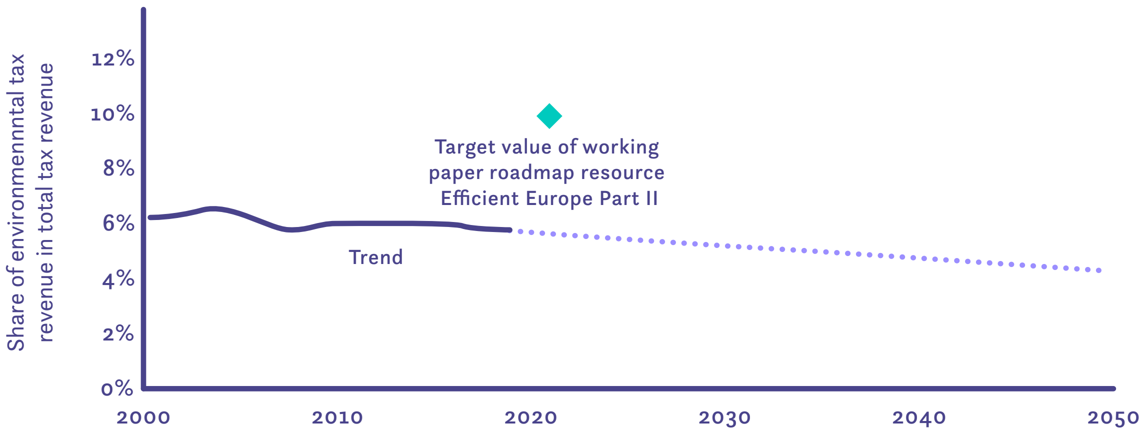
ILLUSTRATIVE PROGRESS MEASUREMENT

The *share of environmental tax revenue of total public revenue* measures the progress of the enabler 2 on enabling regulatory framework.

There is no official EU target for this indicator but the Commission Staff working paper for the Roadmap Resource Efficient Europe Part II [228] suggests that the share should increase to reach 10 % by 2020. We assume that the share should further increase up to 2050.

The trend of the last five years for which data is available shows that the past development **is opposing the net zero objective**: while the average annual increase of the share of environmental tax revenue should be 8.8 %, it decreased on average by 0.9 % per year. This means that a profound shift is necessary to achieve the required transformation towards a net zero compatible tax system.

Figure 12: Progress on an increased share of environmental tax revenue



Source: own presentation based on trend data from Eurostat [229] and target values from Commission Staff Working Paper – Analysis associated with the Roadmap Resource Efficient Europe Part II [230]. The trend is -10 % of the required change to reach the target value for 2020 and 0.8% in the wrong direction. For details on methodology, please see Chapter 4.2.

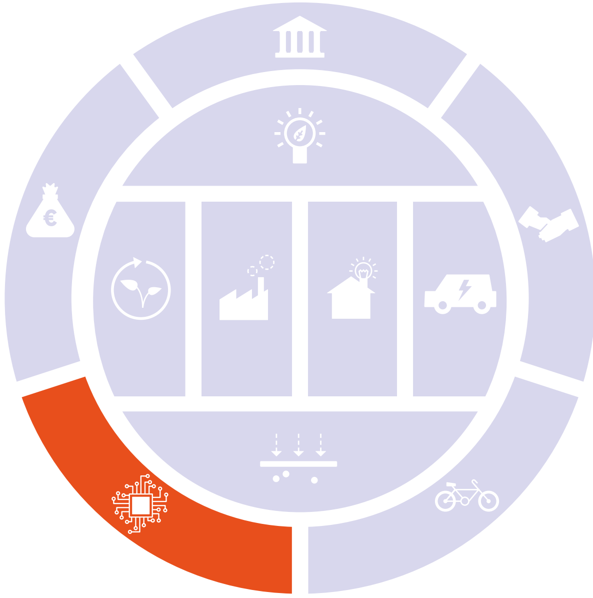
OVERVIEW OF INDICATORS AND RELATED DATA SOURCES AND TARGET VALUES

The following table sums up the indicators for measuring the progress on objectives and enablers including the existing data sources and available 2030 and 2050 target values.

Table 8: Indicators in element "Net zero transition finance"

REFERS TO...	NAME OF INDICATOR [UNIT]	DATA SOURCE	SOURCE FOR 2050 TARGET VALUES
Objectives and targets	Total amount of **sustainable and unsustainable investments** in all economic sectors [EUR]	Not available might be built on the EU taxonomy [231]	LTS
	Investment gap [EUR]	Not available	LTS
	Share of **sustainable and unsustainable investments in EU/MS GDP** [%]	Not available might be built on the EU taxonomy [232]	LTS
Enabler 1 on orienting public funds towards the transition	Share of **public funds dedicated to climate action** in EU and MS budget [% of overall funding]	European Commission [233]	2021-2027: 25 % 2050: not available
	Share of public funds detrimental to climate action in EU and MS budget [% of overall funding]	Not available	Not available
Enabler 2 on enabling regulatory framework	Average **cost of capital for sustainable investments**	Not available	Not available
	Share of **environmental tax revenue of public revenue** (i.e. total tax and social contributions revenue) [%]	Eurostat [234]	COM analysis for the Roadmap Resource Efficient Europe Part II [235]
Enabler 3 on aligning the financial system with climate	Share of **financial market assets labelled as Green** / consistent with EU taxonomy (loans, primary market transactions, secondary market portfolios) [%]	Not available	Not available
	Coverage of **banking stress tests considering climate risks** [% of overall bank assets]	Not available	Not available

Source: own selection



ENABLING TECHNOLOGIES

This element describes the progress in the uptake of key technologies necessary for reaching a net zero economy. A portfolio of technologies across all sectors have to support and enable the transition in all sectors and the society. Energy-related technologies to widely electrify end-use sectors; carbon capture, utilisation and storage (CCUS), hydrogen and hydrogen-related fuels and bioenergy represents half of the expected CO_2 emissions savings to reach net zero [236]. Other key decarbonisation technologies include new industrial production processes in chemical & plastics, cement or iron and steel industry [237], the use of biomaterials [238] or the application of digitalization for energy, transport system, industry [239] or farming [240]. Low carbon technology development can become a strong driver of climate ambition as policymakers increasingly recognize the potential to create industries and high-skilled and well-paid jobs [241].

OBJECTIVES AND TARGETS

The LTS underlines the importance of investments into new technologies and their deployment across different sectors. The 1.5-Tech scenario results in GHG emission reductions of 91 % below 1990 levels and would require net negative emissions later in the century [242]. The overall GHG emissions in the 1.5-Tech scenario reach 589 Mt CO_2eq that will need to be compensated by additional carbon dioxide removal (CDR) of 228 Mt CO_2eq in addition to natural sinks according to the LTS (see "Carbon dioxide removal") compared to a scenario centred on lifestyle changes.

ENABLERS

E1: FOSTER CLIMATE RELATED RESEARCH AND INNOVATION

Many low and zero carbon technologies still have a low readiness level and require more research, development and deployment before commercialisation. Europe is a scientific powerhouse with 30 % of all scientific publications and one fifth of global research expenditure however, the EU has a rather low R&I expenditures to GDP at around 2 % below its 2020 objective and only a small proportion of the 3 to 4 % of EU R&I investments go into the development of climate mitigation and adaptation technologies [243]. Increase funding of climate research and innovation ("R&I") from public and private capital, develop soft attractiveness factors for scientists, innovators, and foster innovative ecosystems linking different actors: universities, research institutions, public authorities and business [244]. In addition, decarbonisation solutions often requires different scientific disciplines, actors and sectors to work together, for example in energy system integration or in finding digitalised application to reduce GHG emissions in each sectors. A cooperative and targeted or mission-oriented approach of innovation to decarbonisation and sustainability can contribute to deliver cross-sectoral innovation [245].

RELATED INDICATORS

- R&D expenditure in the EU [EUR]
- Environmentally related public R&D budgets [% of total R&D]
- Renewable energy RD&D [% energy RD&D]
- Total and per sector climate change mitigation technologies patents [CCMTs]

E2: ACTIVE PUBLIC POLICY TO PROMOTE MASS DEPLOYMENT OF LOW AND ZERO GHG TECHNOLOGIES

Many innovative technologies are available but not at a price that can compete with existing technologies. Promoting their deployment by an active market-pull public policy can decrease their cost through economies of scale and learning-by-doing [246] as has been the case for renewable energy technology [247]. Deployment policies include price-based policies to reduce the existing cost differential between new and existing technologies through financial support and market rules and training and information [248]. These policies are regularly revised to take into account the technological progress and cost decrease and existing bottlenecks [249].

RELATED INDICATORS

- Countries with key net zero technology deployment policy (sub-indicators per key net zero technologies) [number]

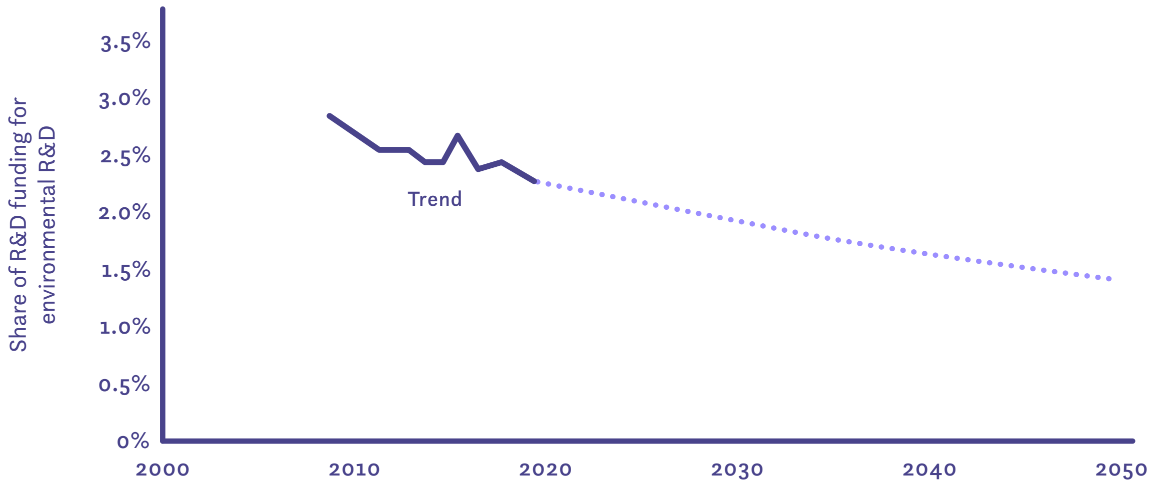
ILLUSTRATIVE PROGRESS MEASUREMENT

The *government budget allocation to environmental R&D* in total government budget allocated for R&D measures the progress of enabler 1 on fostering climate related research and innovation.

There is currently no target defined for this indicator, but the LTS indicates that public budget allocated to environmentally related R&D should increase.

The trend of the last five years for which data is available shows that the past developments are **opposing the net zero emissions objective** as the indicator decreased on average 1.5 % per year instead of the required increase. This means that research and development fund allocation should to a greater extent prioritise environment protection including climate mitigation.

Figure 13: Progress on an increased share of environmentally related R&D budget



Source: own presentation based on trend data from Eurostat [250]. The years 2007, 2009-2011 are estimates. Trend is 1.5% in the wrong direction. For details on methodology, please see Chapter 4.2.

OVERVIEW OF INDICATORS AND RELATED DATA SOURCES AND TARGET VALUES

The following table sums up the indicators for measuring the progress on objectives and enablers including the existing data sources and available 2030 and 2050 target values.

Table 9: Indicators in element "Enabling technologies"

REFERS TO...	NAME OF INDICATOR [UNIT]	DATA SOURCE	SOURCE FOR TARGET VALUES
Enabler 1 on fostering climate related research and innovation	**R&D expenditure** in the EU [EUR]	Eurostat [251]	To be defined, EU current objective is 3%
	R&D personnel [% of active population]	Eurostat [252]	Not available
	Government budget allocation to environmental R&D [% of total R&D]	Eurostat[253]	Not available
	Renewable energy RD&D [% energy RD&D]	OECD [254]	Not available
	Total and per sector **climate change mitigation technologies patent** [CCMTs]	IEA [255]	Not available
Enabler 2 on active public policy	Number of **countries with key net zero technology deployment policy** [sub-indicators per key net zero technologies]	Not available	Not available

Source: own selection

LIFESTYLE CHANGES

This element describes changes in collective and individual behaviours contributing to climate mitigation. Households' consumption represents directly or indirectly three quarters of CO_2 emissions associated with the way people move, live, eat, work or consume [256]. Our lifestyles choices depend on cultural norms and have always been gradually evolving. They determine the impacts of our society on the environment of our planet. Adopting climate-friendly lifestyles includes choosing low-carbon products and services, dietary changes [257], changes in mobility habits and housing. All these changes can significantly decrease overall GHG emissions. A transition to a net zero society [258] needs collective choices to increase the available options such as choice on infrastructure or durability of goods.

OBJECTIVES AND TARGETS

There is no EU target on lifestyle changes towards climate neutrality. However, the EU LTS shows that lifestyle changes, in particular dietary changes, can lead to a significant reduction of GHG emissions. As such, the overall emissions in the technology-driven scenario of the LTS (1.5 Tech) reach 589 Mt CO_2eq in 2050 whereas the overall emission in the scenario with a stronger focus on lifestyle changes (1.5 Life) reach 439 Mt CO_2eq or 25 % less with a share of the difference coming from continuing current dietary changes trend (-90 Mt CO_2eq) [259].

ENABLERS

E1: RAISING COLLECTIVE KNOWLEDGE ON LIFESTYLE IMPACTS ON THE ENVIRONMENT

Sustainability is a growing concern for EU citizens that in majority accept the idea of lifestyle changes to respond to the environmental crisis [260] but often lack information on how their lifestyle affects the environment [261] and the capacity to change it. Raising collective knowledge includes the production of accessible information through education, training, communication and culture, increased citizen's participation in policy decisions. Public institutions, companies and figures can play an important role through leading by example and adopting consistent policies. Developing labels or regulating advertisement taking into account the environmental impact of goods and services contribute to raising awareness on environmental impacts of lifestyles and overcome the underestimation bias [262]. Collective knowledge will foster public engagement, orient collective and individual shifts consistent with the scale of the environmental crisis, and overcome cultural barriers to a low-carbon society [263].

RELATED INDICATORS

- Average consumption of goods per household [% of income]
- Material footprint of consumption(with sub-indicators per materials) [tonnes of raw materials]
- Waste per household [kg per capita]
- GHG footprint of consumption products and services [tCO_2eq]
- Diet carbon footprint [tCO_2/capita]
- Total calories consumption per capita per year [kCal per capita]
- Average per-person protein consumption from selected meat, fish, seafood, eggs and dairy products, EU [kg per capita]

E2: SYSTEMIC CHANGES THAT PROMOTE LOW-CARBON ALTERNATIVE SOLUTIONS

Lifestyle changes does not only depend on individual decisions and public policy can broaden individual choice through spatial planning and regulatory frameworks increasing the availability of low carbon alternatives [264]. On sustainable diet, this can take the form of regulations to generalise plant-based offer in catering outlets or train catering staff to address skill gaps [265]. On mobility, the investment in clean, reliable and secure mobility networks are necessary. For everyday mobility, bike lanes, public transportation and charging systems are key whereas long distance railway including night-train lines can provide an alternative to many flight lines [266]. Digital infrastructure and services easing remote working can also contribute to reduce mobility needs [267].

RELATED INDICATORS

- Average floor area per capita [m^2 per capita]
- Average cohabitation rate [avg. individuals per household]
- Average distance travelled per year [km]
- Modal split of passenger and freight transport (according to type) [%]
- Average distance travelled for holiday/ leisure (according to type) [km]
- Commuting travel time [average time of commute per minutes per day]
- Share of products covered with resource/ energy efficiency labels [%]
- Density of European urban areas [pop/km^2]

E3: ENHANCING ENVIRONMENTAL REGULATION AND ECONOMIC INCENTIVES

Environmental regulation and economic incentives can be powerful tools to change consumers and lifestyle choices. They include measures such as standards or bans, subsidies or support programs and environmental damages pricing. They have distributional impact and could even be regressive [268], so they should be complemented by additional measures or redistribution ensuring it doesn't lead to a reduced well-being by guaranteeing the access of basic services for all: energy, housing, transport, water and food.

RELATED INDICATORS

- Share of products covered with resource/ energy efficiency labels [%]
- Price on carbon (e.g. as effective carbon rates) [EUR/tCO_2eq]

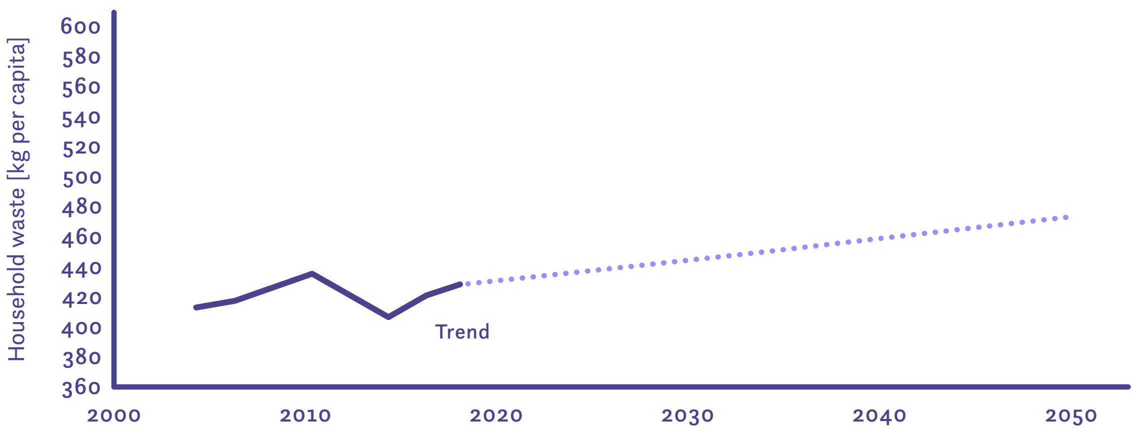
ILLUSTRATIVE PROGRESS MEASUREMENT

The *household waste* measures the progress of enabler 1 on raising collective knowledge on lifestyle impacts.

There is currently no target defined for this indicator, but the waste hierarchy stipulates that firstly, waste generation should be reduce at the source. This also means that household waste generation should decline up to 2050.

The trend of the last six years for which data is available shows that the past developments are **not supporting the net zero emission objective**: household waste volumes per capita increased on average by 0.3 % per year instead of showing a downward trend. This means that household consumption produces too much waste and there is a need for action.

Figure 14: Progress on reducing household waste



Source: own presentation based on trend data from Eurostat [269]. Data is just collected biannually, thus the graph depicts data for 2004, 2006, 2008, [..], 2018. Trend is 0.3% in the wrong direction. For details on methodology, please see Chapter 4.2.

OVERVIEW OF INDICATORS AND RELATED DATA SOURCES AND TARGET VALUES

The following table sums up the indicators for measuring the progress on objectives and enablers including the existing data sources and available 2030 and 2050 target values.

Table 10: Indicators in element "Lifestyle changes"

REFERS TO...	NAME OF INDICATOR [UNIT]	DATA SOURCE	SOURCE FOR TARGET VALUES
Enabler 1 on raising collective knowledge on lifestyle impacts on the environment	Average **consumption of goods per household** [% of income]	Eurostat [270]	Not available
	Material footprint of consumption (with sub-indicators per materials) [tonnes of raw materials]	Customs; Eurostat [271]	Not available
	Household waste [kg per capita]	Eurostat [272]	Not available
	GHG footprint of consumption products and services [tCO_2eq]	Customs; Eurostat [273]	Not available
	Diet carbon footprint [tCO_2/capita]	Can be calculated from Eurostat [274], EFSA [275]	LTS
	Total **calories consumption per capita** per year [kCal per capita]	Eurostat [276]	Not available
	Average per-person **protein consumption from selected meat, fish, seafood, eggs and dairy products**, EU [kg per capita]	EEA [277]	Not available
	Commuting travel time [278] [average time of commute per minutes per day] [279]	European Working Conditions Survey [280]	Not available
Enabler 2 on systemic changes that promotes low-carbon alternative solutions	Average **floor area per capita** [m^2 per capita]	Eurostat [281]	LTS
	Average **cohabitation rate** [avg. individuals per household]	Eurostat [282]	LTS
	Average **distance travelled per year** [km]	OECD [283]	LTS
	Modal split of **passenger and freight transport** (according to type) [%]	Eurostat [284]	LTS
	Average **distance travelled for holiday/leisure** (according to type) [km]	Not found	Not available
	Commuting travel time [285] [average time of commute per minutes per day] [286]	European Working Conditions Survey [287]	Not available
	Density of European urban areas [population/km^2]	Eurostat [288]	Not available
Enabler 3 on enhancing environmental regulation and economic incentives	**Price on carbon** (with sub-indicators for different sectors/sources) [EUR/tCO_2eq]	EU ETS price [289]; Carbon taxes [290], Effective carbon rates for some countries [291]	Not available

Source: own selection

JUST TRANSITION TO CLIMATE NEUTRALITY

This element describes the progress towards a just and inclusive transition to a climate neutral society, which is vital for ensuring the support and active participation of all actors of the society in climate action. A just transition requires the participation of citizens and stakeholders in strategy and policy definition processes to define what is considered as just taking into account existing economic environmental or social inequalities, such as gender inequalities. Policy levers for a just transition include actions to support citizens, companies, and regions through training, education, create new economic and social opportunities or distributional policies [292]. This is relevant particularly relevant for fossil fuel based industries, their employees and the regions where they are implemented but also for all economic activities, such as transportation or agriculture, that emit GHG emissions as they have to adapt or even disappear in a net zero society [293]. Economic activities linked to decarbonisation such as renewable energy, building renovation or nature conservation that will grow and require more trained workers in a net zero economy can become reconversion opportunities for affected workers and region [294]. The changes in economic activities will affect the required skills and the distribution of income and well-being throughout the society [295]. In addition, increased prices of essential goods and services, energy, food, housing and mobility will affect largely the most vulnerable citizens with limited means to reduce their necessary expenses by investing into efficient and low carbon products, vehicles or buildings [296]. Besides, a just transition also takes care that everyone experiences the benefits e.g. through improved outdoor and indoor air quality and temperatures, less noise, more beautiful cities and landscapes, and more comfort in living, working and travel.

OBJECTIVES AND TARGETS

The impact of the net zero transition on jobs, social aspects related to fuel expenses and interaction with sustainable development goals are explored in the LTS however, the pathways are not detailed on these dimensions. Helping a just and inclusive transition is part of the objectives of the EU Green Deal. The current revision of the European semester, integrating the sustainable development goals, especially the SDG 1 (no poverty), 8 (decent work and economic growth) and 10 (reduced inequalities) could lead to the definition of associated EU objectives.

ENABLERS

E1: MEANINGFUL CITIZENS' AND INTERMEDIATE BODIES' PARTICIPATION

Ensuring a just transition requires an inclusive deliberation on what is considered fair or just and how to implement the transition. Citizens' and intermediate bodies participation in transparent and inclusive planning and decision-making processes at all level of decisions (European, national, regional, local) is central to identify the levers and timing that will better combine the needs and aspirations of all members of the society.

RELATED INDICATORS

- Qualitative indicator on inclusiveness of policy processes [scoring]
- Existence of Citizen Assemblies for climate policy [number of MS]
- Public support for climate neutrality target [percentage of surveyed sample]

E2: A PROACTIVE STRUCTURAL PUBLIC POLICY

The net zero transition will necessarily cause the phase out of several economic activities, especially the ones linked to fossil fuels, and transform most of them. As a result, the EU will face a distributional and skills challenge in its transition to a climate neutral economy especially in regions where declining industries are concentrated [297]. Transitioning to a net zero future will require an active public policy [298] to organise and support financially the phase out of these activities, the development of alternatives and the retraining of workers to equip the workforce with the most adapted skills [299].

RELATED INDICATORS

- Employment rate (with sub-indicators for type of industry [% of population aged 20-64]
- Apprenticeships and/or students (with sub-indicators for type of industry [number or % share of total]
- Share of public budget to support regions in transition [% of total budget]

E3: ENSURING A JUST ENVIRONMENTAL PRICING

Pricing environmental damages allows to orient the decision of economic agents towards sustainability and net zero compatible decisions. However, it is affecting the relative prices of goods, especially essential goods (energy, food, housing, transport) and tend to impact relatively more vulnerable and budgetary constraint citizens in the absence of recycling revenues to benefit those groups [300]. Environmental pricing should be included in a broader social contract [301] that ensures fairness and guarantees the access to decent standards of living for all.

RELATED INDICATORS

- Income share of the bottom 40 % of the population (with sub-indicator by gender) [% of income]
- Per capita consumption emissions in EU MS by income groups [tCO_2/year]
- Risk of poverty and social exclusion (with sub-indicators cities and rural areas and gender) [% of population]
- Population unable to keep home adequately warm (sub-indicators for poverty status and gender) [% of population]
- Share of households' expenditure on electricity and gas and other housing fuels for average and poor households [%]
- Environmental tax revenues as a share of public revenue or GDP [%]

E4: AVAILABILITY OF LOW CARBON SOLUTIONS

Low carbon solutions such as highly efficient appliances, building renovation, public transportation or electric cars brings a lot of benefits for the society as a whole and the citizens with proven benefits for health and cost savings. However, these solutions require mobilising greater amount of capitals, a scarce resource for vulnerable citizens. Dedicated policies focussed on the availability of low carbon solutions for all citizens through standardisation, preferential financing conditions, subsidies, social innovation or other forms of public or shared provision of goods and services can foster a more inclusive transition [302].

RELATED INDICATORS

- Income distribution of deep energy retrofits beneficiaries [% of beneficiaries per decile]
- Income distribution of electric car users [% of users per decile]
- Air pollution exposure (with sub-indicators for local exposure) [% of population]

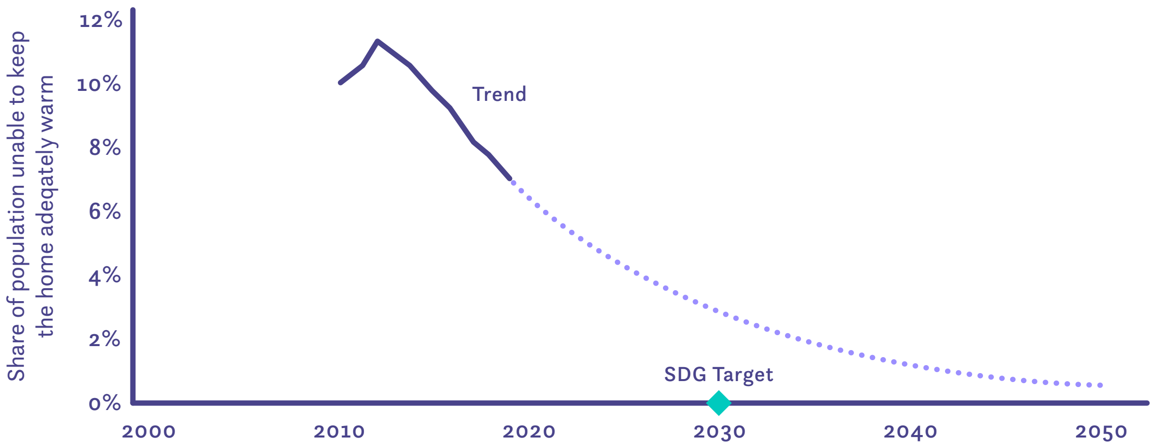
ILLUSTRATIVE PROGRESS MEASUREMENT

The indicator *share of population unable to keep their home adequately warm* measures the progress of enabler 3 on ensuring a just environmental pricing.

There is currently no target defined for this indicator, but SDG 7 calls for affordable and clean energy for all. This means that the share of people that are unable to keep their home warm should reach zero by 2030 in line with SDG 7 objective to ensure universal access to clean and affordable energy.

The trend of the last 5 years for which data is available shows that the past developments are **not supporting the net zero emissions objective**: while the required average annual decrease is 35.2 %, the share of the population unable to keep their house adequately warm only declined by 7.9 % per year in recent years. Actions for poverty alleviation and for renovating low energy efficient building, also where poor people live, are needed to help people to be able to pay for their energy needs.

Figure 15: Progress to decrease the share of population unable to keep their house adequately warm



Source: own presentation based on Eurostat [303]. The data has been estimated on the basis of survey data [304]. The trend is 22 % of the required change to reach the 2030 target. For details on methodology, please see Chapter 4.2.

OVERVIEW OF INDICATORS AND RELATED DATA SOURCES AND TARGET VALUES

The following table sums up the indicators for measuring the progress on objectives and enablers including the existing data sources and available 2030 and 2050 target values.

Table 11: Indicators in element "Just transition to climate neutrality"

REFERS TO…	NAME OF INDICATOR [UNIT]	DATA SOURCE	SOURCE FOR TARGET VALUES
Enabler 1 on meaningful citizen's and intermediate bodies' participation	Qualitative **indicator on inclusiveness of policy processes** [scoring]	Assessment of EU (and national) governance systems	Not available
	Existence of mechanism for continuing engagement with citizens on climate policy (such as **Citizen Assemblies**) [yes/no; for EU: both at EU level and in number of MS]	Not available yet [no recurring data available; individual study with partial data for 2019 value] [305]	Not available
	Public support for climate neutrality target [percentage of surveyed sample]	Eurobarometer survey data; possibly JRC Knowledge4Policy Composite Indicators [306]	Not available
Enabler 2 on a proactive structural public policy	**Employment rate** (with sub-indicators for fossil industry, clean industry, circular economy and other) [% of population aged 20-64]	Eurostat [307]	Possibly part of the European Semester
	Apprenticeships and/or students (with sub-indicators for fossil industry, green industry, circular economy and other) [number or % share of total]	Partly Eurostat [308]	Not available
	Share of **public budget to support regions in transition** [% of total budget]	European Commission [309] and national budgets	Not available
Enabler 3 on ensuring a just environmental pricing	**Income share of the bottom 40 % of the population** (with sub-indicator by gender) [% of income]	Eurostat [310]	Not available
	Consumption emissions by income groups [tCO_2/year]	Individual studies: Oxfam [311]	Not available
	Risk of **poverty and social exclusion** (with sub-indicators cities and rural areas and gender) [% of population]	Eurostat [312]	Possibly part of the European Semester
	Population unable to keep home adequately warm by poverty status and gender [% of population]	Eurostat [313]	Possibly part of the European Semester, 2030: SDG 7
	Share of **households' expenditure on electricity and gas and other housing fuels** for average and poor households [%]	Eurostat [314]	Possibly part of the European Semester
	Environmental tax revenues as a share of public revenue or GDP [%]	Eurostat [315]	COM analysis for the Roadmap Resource Efficient Europe Part II[316]
Enabler 4 on availability of low carbon solutions	**Income distribution of deep energy retrofits beneficiaries** [% of beneficiaries per decile]	Not available yet (possibly Eurobarometer)	Not available
	Income distribution of electric car users [% of users per decile]	Not available yet (possibly Eurobarometer)	Not available
	Air pollution exposure (with sub-indicators for local exposure) [% of population]	EEA [317]	Existing target values: New Air Quality Directive

Source: own selection

CLIMATE NEUTRAL GOVERNANCE

This element pertains to institutions and processes meant to help achieve net zero GHG emissions. As per the current understanding of climate governance [318], an effective system needs to include a set of key elements and fulfil core functions. It needs to provide clear long-term policy guidance (through targets) and continuously align short-term policy actions with long-term policy goals (across sectors) and measure progress on an ongoing basis. This implies regular policy planning cycles to improve and toughen up measures – based on regular monitoring data. An effective governance system must also create accountability for policy-makers through assignment of responsibilities and transparent evaluation procedures. Another critical component is ongoing political support and buy-in not only from decision-makers but also from stakeholders and the public – to increase both transparency and (perceived) legitimacy. This requires clear channels for public engagement and involvement by policy-makers (e.g. parliaments). In addition, many governance systems include dedicated institutions for independent scientific advice.

EU climate governance must fulfil these functions to guide Member States' actions and provide an interface to ensure the coordination of EU policies with the related processes and policies at the national level – to ensure that EU level targets are met. To do this, the EU has created an overarching climate governance architecture through a series of laws [319], which creates obligations for a variety of actors – including Member States, which draw up coherent short-term action plans and long-term strategies [320]. It also puts in place clear progress monitoring and review cycles and rules for public participation. Moreover, the proposed European Climate Law has expanded the existing system to include a dedicated check on progress towards neutrality (now a binding 2050 goal), an indicative carbon budget calculation and a new independent advisory body on climate policy. The European Green Deal [321] has added to the formal routines and procedures a set of additional sectoral and horizontal initiatives [322]. However, some gaps remain at EU level. Member States also have their own national climate governance systems which show a diversity of functionality and elements, some more detailed and with broader functionality than others [323]. For several governance functions, separate national arrangements are required in addition to EU-level requirements.

OBJECTIVES AND TARGETS

There are only a few concrete objectives on climate governance at the EU level – among them are the need to stimulate and coordinate Member State and EU level action, ensure the delivery of international commitments (and reporting) and provide a signal for the economy (see Art. 1 of the Governance Regulation). The preamble to the European Climate Law (ECL) states that the "Commission should (...) engage with all parts of society, (...), to enable and empower them to take action towards a climate-neutral and climate-resilient society" (recital 20 ECL). It also emphasises the importance of the Commission's role in monitoring progress regularly (recital 18), coordinating action at European level (recital 23 on the principle of subsidiarity) and basing policy on the most up-to-date scientific knowledge (recital 19) [324].

The Communication on the European Green Deal prioritises active public participation and "confidence in the transition" as paramount to policy acceptance (page 2). Furthermore, the launch of the European Climate Pact (under the Green Deal) bolsters this objective to enhance participatory processes, setting the lofty (albeit vague) goal of ensuring "democratic, science-based, hands-on, transparent...and long-lasting" action [325]. The EU Climate Law invites "Member States that have not already done so, (...) to establish a national climate advisory body." (Recital ECL).

ENABLERS

E1: BUILT IN POLICY LEARNING

Strong climate governance must chart a path to climate neutrality, integrating options for a course correction if progress appears to falter along the way [326]. To this end, an integrated cycle of policy learning comprising four recurring phases is imperative: (1) planning towards the long-term goal (for and across sectors), (2) policy formulation (on the basis of long-term planning) and implementation, (3) progress monitoring of policy implementation and long-term transformation (i.e., climate neutrality), and (4) policy realignment and revision if actions are found to be insufficient. Ideally, this cycle of planning, policy implementation, review, and revision is formally established by a legislative instrument, such as framework law, and is closely connected to higher-level processes (i.e., those set in motion by the Paris Agreement).

RELATED INDICATORS

- Existence of a full formal climate policy learning cycle (target setting, strategic planning, policy formulation, progress monitoring) with action trigger. [yes/partially/no; for EU: both at EU level and in number of MS]
- A long-term climate strategy not older than five years with adequate level of detail [yes/partially/no; for EU: both at EU level and in number of MS]
- Regular and sufficiently detailed progress monitoring of necessary structural changes towards climate neutrality [yes/partially/no; for EU: both at EU level and in number of MS]
- Achievement of cohesion between short-term actions and long-term climate goals (net zero for the EU) [e.g., scoring system]

E2: DEDICATED INSTITUTIONAL ARRANGEMENTS

Effective climate governance should clearly assign individual functions to specific institutions (Ministries or dedicated agencies or other bodies. These include the policy learning cycle (see enable E1 above) and stakeholder and public engagement, as well as independent scientific advice. Furthermore, key concern in this regard is intra-governmental or intra-institutional coordination. Because the transformation to climate neutrality requires deep emission cuts in all sectors of the economy, a high degree of inter-departmental collaboration is needed to mainstream climate action between often times conflicting political, social, environmental and economic priorities. This can take the form of a lead institution (or individual) with overriding competencies or a formally established overarching coordination body on climate neutrality. At EU level this applies to all institutions individually and collectively – across policy areas. A prerequisite to fulfilling any dedicated duties is the capacity (in terms of financial and staff resources) to carry them out effectively.

RELATED INDICATORS

- Proliferation of framework climate laws with integrated policy cycle [yes/no; for EU: both at EU level and in number of MS]
- Quality of climate policy coordination mechanisms among EU institutions [e.g., scoring system]
- Existence of a dedicated institution for independent scientific advice on climate policy [yes/no; for EU: both at EU level and in number of MS]
- Formal and regular role for Parliament (national level or EU legislative body) [e.g., scoring system]
- Existence of dedicated institution for climate policy related stakeholder engagement [yes/no; for EU: both at EU level and in number of MS] (also for E3)

E3: POLITICAL AND SOCIETAL SUPPORT AND BUY-IN

A transition to net zero emissions can only occur if citizens and (private and public) interest groups are brought on board. Climate policy formulation should incorporate dialogue between different stakeholder groups and include channels for consultation. Ensuring a just transition (see “Just transition to climate neutrality”) will bolster buy-in by those most affected, but governance structures dedicated to participation and open dialogue can further the concept of a societal project by delivering information on climate change impacts and the clear benefits of taking action. A formal, active body or a dedicated recurring process for stakeholder exchange can further enhance accountability, especially if governmental authorities are required to engage with external criticism and recommendations. Clear follow-up to inputs from outside government lends legitimacy to consultations and outcomes. An active role for parliamentarians can also add to political engagement and buy-in. A detailed governance system should build in a specific function to achieve this.

RELATED INDICATORS

- Existence of dedicated institution for climate policy related stakeholder engagement [yes/no; for EU: both at EU level and in number of MS] (also for E2)
- Existence of mechanism for continuing engagement with citizens on climate policy (such as Citizen Assemblies) [yes/no; for EU: both at EU level and in number of MS]
- Public perceived legitimacy of participation channels for climate policy [percentage of surveyed sample]
- Public support for climate neutrality target [percentage of surveyed sample]

E4: REFLEXIVE INTERFACE FOR INTRA-EU COORDINATION

Climate neutrality needs to be achieved in the EU as a whole, but may require slightly different approaches and pathways in different countries and regions at different times. Due to varying national circumstances and starting points among Member States EU climate governance must aim to coordinate both national and EU-level actions in this context. This can be achieved through common but nationally adapted policies and measures in combination with supplementary EU policies, iterative processes and reflexive guidance. To identify how and where national efforts need to be coordinated regionally or at EU level, or where EU level measures are needed to unlock additional emission reduction potentials (or achieve these at lower costs), the EU needs to maintain and strengthen its existing internal dialogue facilities vis-à-vis climate neutrality and provide dedicated support for knowledge and capacity building. It also needs to strengthen and encourage coordination with the subnational level, which is key in many countries for the implementation of relevant programmes and investments.

RELATED INDICATORS

- Existence and quality of a mechanism for coordination between EU and MS – and MS-MS on climate neutrality policy planning and – and with subnational level [e.g., scoring system]
- Degree of follow-through with country-specific recommendations under EU climate governance processes (European Semester, NECPs, EU Climate Law) [e.g., scoring system]

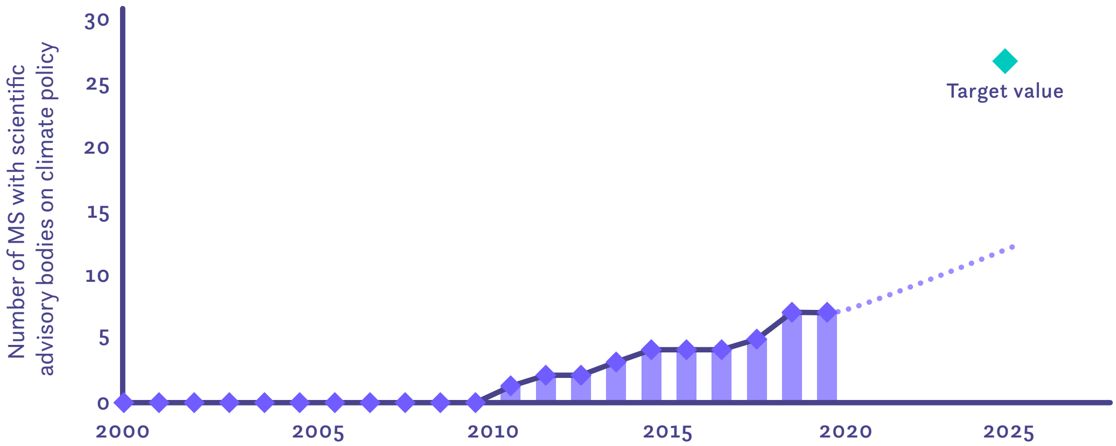
ILLUSTRATIVE PROGRESS MEASUREMENT

The indicator number of MS with a dedicated institution for independent scientific advice on climate policy-making measures the progress towards Enabler 2 on institutional arrangements.

The target value is defined by expert judgement but informed largely by signals from EU legislation, including the language in the EU Climate Law mentioned above, which encourages the creation of such bodies at a Member State level. By the year 2025, all of the EU member states should have a dedicated scientific advisory body on climate policy to inform policy making and ensure transparency.

The trend over the last five years for which data is available shows that the past developments are **not supporting the net zero emission objective**. The average annual increase should have been twice as high to be on track towards the target. While this is substantially off-target, the establishment of the EU level advisory body and a general dynamic in favour of the adoption of climate framework laws gives reason to believe that there could be a snowballing effect in terms of policy transfer between Member States, accelerating the current trend.

Figure 16 : Progress in MS in establishing a scientific advisory body for climate policy



Source: Own presentation based on an evaluation of national governance systems, only counting advisory bodies still in use. Target value is based on expert judgement. The trend is 56 % of the required change to reach the 2025 target value. For details on methodology, please see Chapter 4.2.

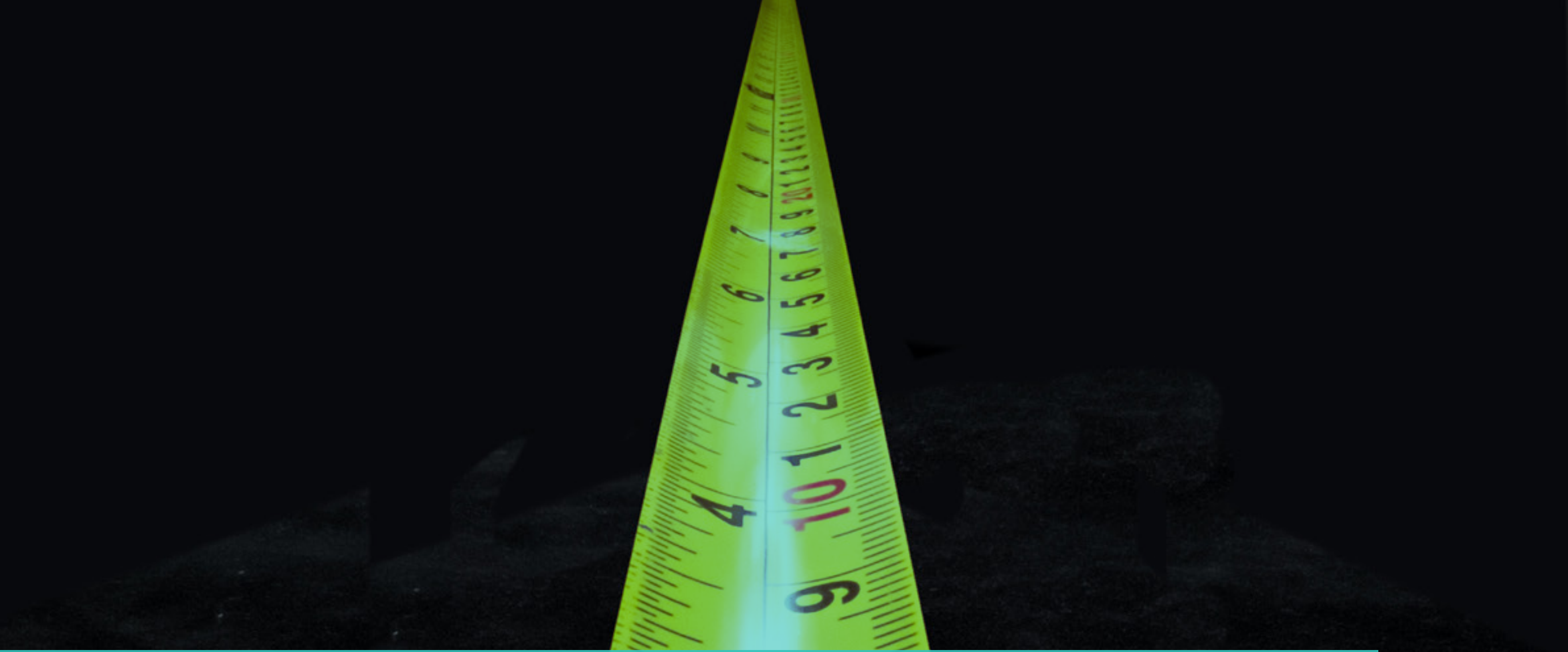
OVERVIEW OF INDICATORS AND RELATED DATA SOURCES AND TARGET VALUES

The following table sums up the indicators for measuring the progress on objectives and enablers including the existing data sources and available 2030 and 2050 target values.

Table 12: Indicators for measuring the progress on "Climate neutral governance"

REFERS TO...	NAME OF INDICATOR [UNIT]	DATA SOURCE	SOURCE FOR TARGET VALUES
Enabler 1 on built in policy learning cycle	Existence of a full formal climate policy learning **cycle (target setting, strategic planning, policy formulation, progress monitoring) with action trigger.** [yes/partially/no; for EU: both at EU level and in number of MS]	Not available yet (no recurring data available; individual study for 2020) [327]	Not available
	A **long-term climate strategy not older than five years with adequate level of detail** [yes/partially/no; for EU: both at EU level and in number of MS]	Not available yet [possible future individual studies or recurring evaluations]	Expert judgement (for 2020: EU Governance Regulation, Art. 15.1) [328]
	Regular and sufficiently detailed **progress monitoring of necessary structural changes towards climate neutrality** [yes/partially/no; for EU: both at EU level and in number of MS]	Not available yet (possible future individual studies or recurring evaluations)	Not available
	Achievement of **cohesion between short-term actions and long-term climate goals** (net zero for the EU) [e.g., scoring system]	Not available yet (no recurring data available; individual study 2020 value) [329]	Not available
Enabler 2 on institutional arrangements	Proliferation of **framework climate laws** with integrated policy cycle [yes/no; for EU: both at EU level and in number of MS]	Grantham Institute Climate Laws of the World Database and individual studies [330]	Not available
	Quality of **climate policy coordination mechanisms among EU institutions** [e.g., scoring system]	Not available yet (possible future individual studies or recurring evaluations)	Not available
	Existence of a dedicated institution for **independent scientific advice on climate policy** [yes/no; for EU: both at EU level and in number of MS]	Not available yet (no recurring data available; individual studies) [331]	Expert judgement based on language in the EU Climate Law (i.e., Art. 2b)
	Formal and regular role for **Parliament** (national level or EU legislative body) [e.g., scoring system][332]	Not available yet (no recurring data available; individual study for 2020 value) [333]	Not available
	Existence of dedicated institution for climate policy related **stakeholder engagement** [yes/no; for EU: both at EU level and in number of MS]	Not available yet (no recurring data available; individual study for 2020) [334]	Not available
Enabler 3 on political and societal support	Existence of mechanism for continuing engagement with citizens on climate policy (such as **Citizen Assemblies**) [yes/no; for EU: both at EU level and in number of MS]	Not available yet [no recurring data available; individual study with partial data for 2019 value][335]	Not available
	Public perceived legitimacy of participation channels for climate policy [percentage of surveyed sample]	Not available yet (possibly Eurobarometer survey)	Not available
	Public support for climate neutrality target [percentage of surveyed sample]	Eurobarometer survey data; possibly JRC Knowledge4Policy Composite Indicators [336]	Not available
Enabler 4 on reflexive interface for intra-EU coordination	Existence and quality of a mechanism for **coordination between EU and MS** – and MS-MS on climate neutrality policy planning and – and with subnational level [e.g., scoring system]	Not available yet (possible future individual studies or recurring evaluations)	Not available
	Degree of follow-through with country-specific recommendations under EU climate governance processes (European Semester, NECPs, EU Climate Law) [e.g., scoring system]	Not available yet (possible future individual studies or recurring evaluations of amendments to final or iterative plans and policy documents following EU consultation)	Not available

Source: own selection. Please note: progress measurement for this net zero element requires indicators that are not easily quantifiable and for which there are no obvious data sources. These will require elaboration through analysis of governance systems, structures and documents. Moreover, target values cannot be set based on modelling or technical studies but have to rely on expert judgement. Units are dichotomous in many cases (i.e., yes/no). Those marked as "descriptive" or with high, medium or low scale degrees must be determined qualitatively and crosschecked to ensure validity of measurement.



OVERVIEW OF PROGRESS TOWARDS CLIMATE NEUTRALITY

The presented indicator set helps to understand and communicate the transformational change that is required to achieve climate neutrality through change in each of the different elements. If implemented, it could generate **a comprehensive picture on the state of progress towards climate neutrality**. This would help inform policy-making, addressing current gaps and adjusting trends going in the wrong direction. A way of presenting indicator results is a dashboard [337] or scoreboard [338]. Creating a scoreboard for each element in a coherent and structured format allows to better integrate progress measurement into policy processes by focussing the policy debate on specific and important challenges of the transformation, increasing the probability of meaningful policy actions taken [339]. The selection of indicators should also be able to evolve over time according to the changing importance of drivers of change key topics of public concern.

Another possible visualisation of a more overarching view of progress would be a summary scoreboard using eleven composite values – one for each element. This aggregate assessment could show, in a simplified manner, in which parts of our economy and policy-making recent trends have been in line with the long-term objective and where additional effort is needed. The composite value could give a **systematic overview of progress** and allow for easy comparison amongst the elements but also with previous monitoring periods. As we only cover one example indicator in each element in this report, such summary composite values could not be calculated – in addition, selection and possible weighting of individual indicators should undergo a stakeholder review to ensure a well-selected indicator set (see also Chapter 4).

Notwithstanding these considerations, Figure 17 shows what a **potential summary scoreboard** could look like. It is based on the assessment of the one example indicator for each element that has been singled out in the respective sections. The scoreboard gives an overview of the progress of the sectoral as well as the horizontal elements and allows the viewer to grasp quickly which areas require future action.

Figure 17: Progress towards net zero emissions in the elements

ZERO-CARBON ENERGY	●●●○
SUSTAINABLE AGRI-FOOD SYSTEM	●○○○
NET-ZERO INDUSTRIAL TRANSFORMATION	●●●○
EMISSION FREE BUILDINGS	●○○○
MOVING WITHOUT EMISSIONS	●●○○
CARBON DIOXIDE REMOVAL	●○○○
NET-ZERO TRANSITION FINANCE	●○○○
ENABLING TECHNOLOGIES	●○○○
LIFESTYLE CHANGES	●●○○
JUST TRANSITION TO CLIMATE NEUTRALITY	●●○○
CLIMATE NEUTRAL GOVERNANCE	●●○○

CLASSIFICATION

●●●●	In line with net zero emissions objective
●●●○	Progressive but insufficient for net zero emissions objective
●●○○	Not supporting the net zero emissions objective
●○○○	Opposing the net zero emissions objective

Source: own presentation based on single indicators for each element. For details on methodology, please see Chapter 4.2.

The **preliminary analysis of selected indicators** shows that in most of the elements, the developments are either opposing or not supporting the net zero emission objective at present. While these example indicators only provide a glimpse of what the full set would reveal, the results provide a first hint at necessary policy adjustments addressing many sectors and policy fields to put the EU on track towards climate neutrality.

CONCLUSIONS

TRACKING PROGRESS TOWARDS NET ZERO NEEDS NEW TOOLS AND ADDITIONAL INFORMATION

Climate neutrality is an ambitious but necessary goal. Reaching it (and net negative emissions thereafter) requires a complex set of socio-economic changes. While the old business philosophy quote "you cannot manage what you do not measure" has its limitations, it is certainly true that **the EU needs to keep track of whether it is on the right path** – or risk missing the goal. This has to include but go beyond traditional GHG emission developments as a measurement.

A COMPREHENSIVE TOOL FOR TRACKING CLIMATE NEUTRALITY PROGRESS

The **progress monitoring methodology** we propose here is a first attempt to develop a comprehensive tool for tracking progress towards the 2050 net zero emissions objective. The "net zero elements" are the basis of this framework, they are pieces of a vision for the future, covering the GHG emitting sectors as well as the cultural, governmental and economic structures. The progress measurement in the net zero elements is happening not just through their respective targets, but also with regard to their essential drivers ("enablers"). The dedicated indicators track the progress towards the objectives and enablers providing a detailed view of the advancement of the net zero transition.

INFORM POLICY-MAKING AND AVOID BLIND SPOTS

The application of this climate neutrality monitoring methodology could inform policy-making processes at both the European and Member State level that influence our ability to avoid the climate crisis. This is particularly important as **some elements are presently not properly taken into account in policy processes** (lifestyle changes, just transition) or at an early stage (finance). This is a cause of concern as it could perpetuate blind spots and thus ignore important elements of the transformations that need to be achieved to realise the EU' net zero target.

The potential **applicability of the methodology is broad**. The notion of defining enablers itself would add depth to our understanding and could be used to structure future LTSs and sector specific roadmaps; and the indicators could be integrated into relevant planning and monitoring procedures. The concrete integration and use in relevant EU policy processes is analysed in Part II of this report, which covers the European Climate Law, the European Semester and the Recovery spending process, the 8th Environment Action Programme and more.

HARMONISING AND IMPROVING DATA AND INTRODUCING ADDITIONAL INDICATORS

The development of the net zero indicators has identified important gaps in **data availability**. While there is comprehensive data available for the indicators in some of the elements, most notably energy and mobility, in other elements data for relevant indicators is collected only for specific points in time, e.g. in studies analysing the respective aspect. In addition, data sources are sometimes fragmented even though similar data is gathered – this is, for example, the case for indicators in buildings and industry or for cross-sectoral elements such as lifestyle changes, just transition and finance. Those areas would benefit from a higher degree of harmonisation and centralisation. Moreover, for several indicators, there simply is no data available at present (e.g. finance and governance) and additional effort would be required to collect this data. Despite these limitations, Eurostat and the EEA already provide comprehensive datasets for some of the indicators and are moving in a direction of more holistic data gathering, which takes into account additional sustainability aspects.

Implementing the monitoring methodology would also require additional effort in defining 2030 and 2050 target values. Most cross-sectoral elements (especially lifestyle changes and just transition) lack clear targets – their definition would require resources and analysis. This is no surprise, considering the transformational nature of the climate neutrality objective.

Future developments, political decisions as well as new data sources may, of course, require additions or adjustments of the elements, their objectives and enablers and of the indicator set. Regardless, we hope that this specific methodology will serve as **a welcome stimulus for debate about how all stakeholders in the EU can better judge whether we are on track** towards climate neutrality and where and how adjustments are needed.

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NET ZERO 2050