Impacts of Biofuels and Renewable Energy

Data Collection Report

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Table of Contents

List of Tables

1 :: Objective

This CIRCULAR IMPACTS report presents the results of desk research conducted on issues of future scenarios for biofuels and renewable energy. The potential future of the EU energy economy reflects large-scale developments that are highly relevant for the future macroeconomic and environmental character of the EU and its Member States. This report includes a short description of the included studies on these topics and discussion of their findings. In this respect, the focus lies on macroeconomic impacts, i.e. GDP and employment. In the sections discussing these effects, we also briefly elaborate on the mechanisms driving them. We look into and discuss other impacts a well, such as changes in the use of fossil fuels, import dependence as well as emissions. The desk-research work summarised here is intended as a complement to the four case studies conducted within the CIRCULAR IMPACTS project.[1]

An EU-wide transition to an energy system powered by renewable resources is of particular importance for the transition to a circular economy. Considering the scarcity of fossil fuels and their impacts on the environment, as well as the great importance of the energy sector for the economy as a whole, strategies for increasing the share of renewable energy sources is a highly relevant policy discussion.

With respect to the concept of a circular economy, biological energy sources, such as biofuels, play a particularly significant role. First, they serve as a potential substitute for fossil fuels. Moreover, they are based on biological materials that are recognised in the context of circular economy for their renewability, biodegradability and compostability (European Commission, 2015). Furthermore, biological energy sources make up a large share of renewables used for power generation in the European Union, especially in the heating sector, and their importance is not expected to diminish in the upcoming years. According to the European Commission (2016a), bioenergy made up 60% of the EU 2014 final renewable-energy consumption, representing 88% of renewable energy used for heating, and its share in total energy demand is expected to grow.

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[1] The four case studies are: 1) recycling electric-vehicle batteries in the EU; 2) recycling phosphorus from manure; 3) carsharing in Germany; and 4) recycled concrete in France. The CIRCULAR IMPACTS project elected to use a desk-study approach to the renewable energy and biofuels topics, given the extensive and sophisticated modelling work done on energy-related scenarios for Europe.

The importance of renewable resources has gained increased recognition in the EU policy context. The European Union aims at a gradual phase-out of fossil fuels by setting RES deployment targets and implementing policies to facilitate their achievement. Some of the positive expected impacts driving these efforts are increased economic growth, job creation, diversification of energy supply and reduction of GHG emissions (European Commission, 2012). It is vital to assess if and to what extent further deployment of renewable energy contributes to these goals and what other positive impacts it might trigger. However, one must also keep in mind that further increase of the renewable share in the energy mix could have certain negative consequences as well. For example, the European Commission (2016a) has identified several potential risks related to the sustainability of bioenergy, including impacts on climate, biodiversity and soil quality. Understanding the broad spectrum of both positive as well as negative impacts is essential for an informed and transparent policymaking process.

With this in mind, this report aims at providing an overview of possible macroeconomic and other impacts that increasing the share of biofuels and other renewable-energy sources could have. Since several studies have been conducted on these topics already, the project team's work for this report took the form of desk research (as opposed to the case-study work done for other topic areas within CIRCULAR IMPACTS). The project team identified relevant studies in recent literature and collected their key findings into an integrated overview. Due to the importance of biological energy sources both in the EU renewable mix, as well as in the circular-economy framework, the team treated the impacts of these resources with particular interest.

Recently, Winkler et al. (2018) conducted a similar exercise to the one undertaken for this report. They compiled an overview of recent studies that analyse various impacts of increased RES deployment targets in the EU. The authors discuss a broader set of studies and corresponding impacts whereas the CIRCULAR IMPACTS project team intentionally limits the analysis to the publications that discuss macroeconomic impacts in the 2030 horizon. Additionally, the CIRCULAR IMPACTS project team paid particular attention to the potential role of biofuels in the identified literature. For those readers seeking additional information beyond that presented here, the report by Winkler et al. (2018) is highly recommended as a further source of evidence.

2 :: Data Sources

The project team identified several studies in the literature aiming at quantifying the impacts of increased deployment of renewable energy. However, in order to obtain an overview of impact assessments that are comparable with each other and specifically suite to the context of the CIRCULAR IMPACTS project, we decided to only include in the evidence base those papers and reports that analyse macroeconomic impacts on the EU scale and in the 2030 time horizon. Consequently, we eliminated from the analysis a large number of studies that, for example, focus on a single country or discuss a different timeframe. As a result, we narrowed the focus to three studies analysing the impacts of renewable-energy sources: Duscha et al. (2014), European Commission (2014) and European Commission (2016b); as well as one focusing specifically on bio-based applications: Smeets et al. (2014). All these studies were relatively recently and focus on a common time horizon of 2030[2], which makes the comparison of results more feasible and uses the sae time horizon as the four CIRCULAR IMPACTS case studies.

The impact assessments by the European Commission analyse the impacts of different elements of climate policy goals, not only regarding renewable energy, but also energy-efficiency policies and GHG-emissions targets. As the focus of this report lies on renewable energy, the project team has chosen for the analysis only these scenarios presented in the studies that include explicit increased RES deployment targets. The report on biomass applications (Smeets, et al., 2014) discusses four different bio-based applications only those three directly related to the topic of energy: biofuels, bioelectricity and biogas. The following subsections provide a concise description of each of the studies, including its context and estimated impacts, the analysed scenarios and the modelling tools used.

2.1 Duscha et al. (2014)

The report by Duscha et al. (2014) presents the results of the project funded by the European Commission "Support Activities for RES modelling post 2020". The study provides science-based insights into the potential impacts of increased RES deployment on growth and employment as well as how this could be influenced by different policies. It provides an analysis of impacts expected in 2030 and 2050.

[2] Though 2030 is our focus, some studies discuss the 2050 time horizon as well.

The authors of the report consider scenarios differing with respect to renewable energy deployment targets in 2030 (30% and 35%) as well as with respect to policies implemented after 2020 to achieve these targets (SNP – "Strengthened National Policies" and QUO – "Harmonized Quota Scheme"). The scenarios are compared to the baseline case, which assumes phase-out of current EU RES policies after 2020 and results in RES-deployment of 26.4% in 2030.

The analyses combine several modelling tools. A sector model, Green-X, is used to explore potential RES deployment paths given the analysed policy scenarios. The obtained deployment scenarios are then translated into impulses for macroeconomic modelling. These impulses are in turn used for assessing the gross (MultiReg model) and net (NEMESIS and ASTRA models) macroeconomic impacts. The net impacts estimated in the study are the main interest for the purposes of this literature review. The two models used differ with respect to their underlying philosophies and the major advantage of applying both of them is the possibility to validate obtained results.

2.2 European Commission (2014)

Another study included in the literature base is an impact assessment published by the European Commission (2014). It evaluates potential climate-policy and energy-policy options for the period 2020-2030, including increased ambition regarding energy efficiency and targets for 2030 RES-deployment and GHG reductions. The analysis assesses, amongst other impacts, the environmental, macroeconomic and social impacts of the policy options, focusing on the impacts expected in 2030 and also providing a 2050 perspective.

The study considers several scenarios, differing with respect to targets for GHG reduction and RES deployment as well as varied ambitions for energy-efficiency measures. For the purpose of this task, however, the project team focused solely on the scenarios that identify specific RES targets. The impact assessment that was carried out considers two such cases, with targets of 30% and 35% respectively. Both of these scenarios are modelled under the so-called enabling conditions – such that the 2050 objectives for GHG-emissions will be achieved. The analysed policy scenarios are compared to the EU Reference Scenario 2013 (Capros, et al., 2013)[3]. The RES-deployment projected by the Reference Scenario in 2030 amounts to 24.4%.

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[3] EU Reference Scenario is the European Commission's tool that provides future projections of energy, transport and GHG emissions developments under current policies on the EU and Member States level. The developed projections serve as a benchmark for

The impact analysis is based on a number of modelling tools. It is mostly based on the PRIMES model. The macroeconomic analysis of the scenarios considering increased RES deployment targets, which is the main interest of this summary, was conducted using an adapted macro-econometric model E3ME. In the analysis of GDP and employment impacts, two cases are considered which differ with respect to the assumptions about the revenues from carbon pricing in the policy scenarios. In one case, these revenues are used to lower labour costs, whereas in the other case, they are transferred to consumers.

2.3 European Commission (2016b)

Another impact assessment published by the European Commission was conducted in 2016 in the context of revising the existing Renewable Energy Directive[4], which came into force in 2009. The impact assessment analyses potential policies aimed at achieving the EU-wide 2030 RES target of 27% agreed by the European Council in 2014 in a timely and cost-effective way. Similar to European Commission (2014), this impact assessment includes inter alia environmental, macroeconomic and social impacts.

Since the main objective of this impact assessment was to compare different policy options to achieve a pre-defined 2030 RES target of 27%, most of the analysed scenarios do not differ with respect to the renewable energy target (i.e. they assume 27%). Only one scenario examines a higher target of 30% and this case is considered in the project's evidence database. The macroeconomic impacts (GDP and employment change) are reported as compared to the EUCO27 scenario, which reflects the requirements for 2030 targets adopted by the European Council in 2014 (incl. RES deployment of 27%). For this reason, the team includes this scenario in the evidence base as the baseline.

The analysis is based mostly on PRIMES modelling, and macroeconomic impacts are assessed with the E3ME and GEM-E3 models. Additionally, within the macroeconomic modelling of this impact assessment, different cases were considered. In the case of the E3ME modelling, the differences in results between the cases ("partial crowding out" and

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assessing the impacts of possible policy options rather than being used as actual forecasts. The EU Reference Scenario is published as an updated version once every few years. The versions considered in this summary are the EU Reference scenario 2013, which includes policies adopted until late spring 2012, and EU Reference Scenario 2016, which includes policies adopted until December 2014 as well as amendments to three directives from early 2015.

[4] Renewable Energy Directive (2009/28/EC). Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=EN, accessed 26.02.2018

“no crowding out”) are not pronounced so we do not report them separately in this summary. In the case of the GEM-E3 modelling, the estimates differ between the analysed cases (“loan based” – borrowing is possible, “self-financing” – borrowing is not possible). Therefore, we discuss the results yielded for the both situations.

2.4 Smeets et al. (2014)

The aim of the study by Smeets et al. (2014) is to evaluate the macroeconomic impacts of using different bio-based applications (biofuels, biochemicals, bioelectricity and biogas) to replace their conventional equivalents. The study assesses the impacts for the EU in the 2030 time horizon.

The impact of each of the discussed applications is analysed separately in one of the four scenarios. For each case, the authors assume that 1EJ of lignocellulose biomass is converted to a bio-based application in question, which in turn is used to replace the same amount of its conventional equivalent on an energy basis. Additionally, the authors consider two scenarios in which they analyse whether a biofuels-related result changes if the oil price rises or falls by 25%. The authors compare the scenarios developed in such a way to the baseline, which is a modelled projection of the developments until 2030 under relevant policies in place at the time of conducting the study.

The authors estimate the macroeconomic impacts of bio-based applications using two methods. Within the first approach, they evaluate the net change of production value, which serves as a proxy of direct macroeconomic effects. As an alternative, they evaluate the impacts using a computable general equilibrium model MAGNET. They also compare the results yielded by the two methods. The applied methodology allows them to capture intersectoral linkages and consequently analyse the effects on the sectoral level as well as for the whole economy.

3 :: Results

This section provides an overview and discussion of the results identified as the most important for CIRCULAR IMPACTS. Due to different benchmarks, tools and starting points used for modelling in the studies, they yield varying results that are not easily comparable. Drawing a single conclusion based on the studies' results is not feasible. However, one can observe a few general trends.

Table 1 summarises the results of the studies discussing RES deployment together with the main characteristics of the analysed scenarios.

Table 2 summarises the key implications of the various scenarios for issues related to bioenergy.

Table 1. Comparison of modelling results for 2030 renewable energy scenarios (macroeconomic results)

COMPARISON OF MODELING RESULTS FOR 2030 RENEWABLE ENERGY SCENARIOS

All data shown is for the year 2030 unless otherwise specified

SCENARIO DEFINITIONS	Duscha et al. (2014)					EC (2014)			EC (2016b)	
Scenario	Baseline	SNP-30	QUO-30	SNP-35	QUO-35	Ref 2013	GHG40/EE/RES30	GHG45/EE/RES35	EUCO27	EUCO3030
RES deployment (share of RES in gross final energy consumption)	26,3%*	30%	30%	35%	35%	24,4%*	30%	35%	27%	30%
GHG reductions (as compared to 1990 emissions level)	45%	40%	40%	45%	45%	32,4%*	40%	45%	40%	43,2%*
Energy efficiency (demand reduction compared to reference scenario in 2030)	n.a.	n.a.	n.a.	n.a.	n.a.	21,0%*	30,1%*	33,7%*	27%	30%
Energy efficiency 2050 (demand reduction compared to reference scenario in 2050)	33%	33%	33%	34%	34%	n.a.	n.a.	n.a.	n.a.	n.a.

**Asterisk indicates a modeled figure.*

MODELING RESULTS																					
Model used for macroeconomic impacts		n.a.	**NEMESIS**	**ASTRA**	**NEMESIS**	**ASTRA**	**NEMESIS**	**ASTRA**	**NEMESIS**	**ASTRA**	**E3ME[1]**	**E3ME[2]**	**E3ME[1]**	**E3ME[2]**	**E3ME[1]**	**E3ME**	**GEM-E3[3]**	**GEM-E3[4]**	**E3ME**	**GEM-E3[3]**	**GEM-E3[4]**
GDP	(Net) GDP effect (compared to BAU)	n.a.	0,40%	0,08%	0,34%	0,07%	0,80%	0,23%	0,78%	0,08%	n.a.	n.a.	0,46%	n.a.	0,53%	n.a.	n.a.	n.a.	0,53%	0,13%	-0,49%
Employment	(Net) employment effect (compared to BAU)	n.a.	0,32%	0,06%	0,30%	0,04%	0,67%	0,11%	0,68%	0,07%	n.a.	n.a.	0,09%	0,50%	0,09%	n.a.	n.a.	n.a.	0,18%	0,14%	-0,29%
	Net employment effect (1000 jobs)	n.a.	715	140	671	92	1497	242	1528	159	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Employment in 2030 (1000 persons)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	231.861	231.701	232.081	232.947	232.075	233.500	216.600	216.000	n.a.	n.a.	n.a.
CO2	Avoided CO2 emissions due to RE (Mio t/a)	1.515	1.701		1.709		1.967		1.972		n.a.		n.a.		n.a.	n.a.			n.a.		
	CO2 emission reductions vs 2005	n.a.	n.a.		n.a.		n.a.		n.a.		29%		37%		43%	n.a.			n.a.		
	Carbon intensity of power generation (per MWhe+MWhth)	n.a.	n.a.		n.a.		n.a.		n.a.		n.a.		n.a.		n.a.	0,179			0,157		
Energy imports	Avoided fossil fuel (imports) due to RE (bn EUR/a)	177,40	212,70		211,60		238,60		238,90		n.a.		n.a.		n.a.	n.a.			n.a.		
	Fossil Fuel Net Imports (bn EUR, average annual, 2011-30)	n.a.	n.a.		n.a.		n.a.		n.a.		461		439		434	n.a.			n.a.		
	Fossil Fuel Net Imports (bn EUR, average annual, 2021-30)	n.a.	n.a.		n.a.		n.a.		n.a.		n.a.		n.a.		n.a.	427			416		

1 - revenue from carbon pricing used to lower labour costs
2 - revenue from carbon pricing transferred to consumers
3 - loan-based case
4 - self-financed case

Macroeconomic effects of bio-based applications have been assessed by Smeets et al. (2014) who compare the impacts of producing 1EJ of biomass-based product and using it to substitute its conventional equivalent.
The net GDP effect evaluated with the MAGNET model amounts to 5,1bn US$ for biofuels, -3,0bn US$ for bioelectricity and -5,1bn US$ for biogas.
If a 25% higher or 25% lower oil price is assumed, net GDP effect of biofuel changes to 11,0 or 0,6bn US$ respectively.

Source: own work based on results from Duscha et al. (2014), European Commission (2014), European Commission (2016b) and Smeets et al. (2014).

Table 2. Comparison of modelling results for 2030 renewable energy scenarios (bioenergy-related results)

COMPARISON OF MODELING RESULTS FOR 2030 RENEWABLE ENERGY SCENARIOS

All data shown is for the year 2030 unless otherwise specified

SCENARIO DEFINITIONS	**Duscha et al. (2014)**					**EC (2014)**			**EC (2016b)**	
Scenario	Baseline	SNP-30	QUO-30	SNP-35	QUO-35	Ref 2013	GHG40/EE/RES30	GHG45/EE/RES35	EUCO27	EUCO3030
RES deployment (share of RES in gross final energy consumption)	26,3%*	30%	30%	35%	35%	24,4%*	30%	35%	27%	30%
GHG reductions (as compared to 1990 emissions level)	45%	40%	40%	45%	45%	32,4%*	40%	45%	40%	43,2%*
Energy efficiency (demand reduction compared to reference scenario in 2030)	n.a.	n.a.	n.a.	n.a.	n.a.	21,0%*	30,1%*	33,7%*	27%	30%
Energy efficiency 2050 (demand reduction compared to reference scenario in 2050)	33%	33%	33%	34%	34%	n.a.	n.a.	n.a.	n.a.	n.a.

*Asterisk indicates a modeled figure.

MODELING RESULTS related to bioenergy										
RE share in transport fuel demand	7,7%	9,6%	9,6%	11,1%	11,1%	n.a	n.a	n.a	n.a.	n.a.
Expenditures for biomass fuels (bn €/a)	59,00	71,60	70,80	76,60	76,10	n.a	n.a	n.a	n.a.	n.a.
Avoided fossil fuels due to RES in transport by 2030 - increase compared to 2010 (bn EUR)	9,80	13,80	13,70	16,80	16,80	n.a	n.a	n.a	n.a.	n.a.
Demand biomass (Mtoe)	n.a.	n.a.	n.a.	n.a.	n.a.	178	192	223	n.a.	n.a.
Domestic production biomass feedstock (Mtoe)	n.a.	n.a.	n.a.	n.a.	n.a.	194	213	231	n.a.	n.a.
Net imports biomass feedstock (Mtoe)	n.a.	n.a.	n.a.	n.a.	n.a.	4	2	5	n.a.	n.a.
Bioenergy production (Mtoe)	n.a.	n.a.	n.a.	n.a.	n.a.	157	172	179	n.a.	n.a.
Net imports of bioenergy (Mtoe)	n.a.	n.a.	n.a.	n.a.	n.a.	21	20	32	n.a.	n.a.
Cropland are for perennials, including plantation wood (million hectares)	n.a.	n.a.	n.a.	n.a.	n.a.	7	10	12	n.a.	n.a.
RES-T share	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	18%	21%
Biofuels consumption (Ktoe)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	20.486	21.314
Biofuels consumption (% of gros final energy consumption - transport)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	8,00%	8,45%
Biofuels consumption (% of total RES consumption)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	7,03%	6,87%

Source: own work based on results from Duscha et al. (2014), European Commission (2014) and European Commission (2016b).

3.1 Renewable energy

3.1.1 GDP

In general, increased deployment of renewable energy sources seems to have a small but positive impact on GDP, reaching up to around 0.5% and 0.8% in case of 30% and 35% RES deployment targets, respectively. The estimate is negative in one case only, when the GEM-E3 model is used and no borrowing is possible.

Interestingly, the two models applied by Duscha et al. (2014) yield estimates of a different magnitude, although in both cases positive. The authors provide quite a thorough explanation of the modelling outcomes, also pointing out how different philosophies behind both models lead to a disparity in results. Discussing the results of the NEMESIS model, they explain that the positive net investment impulse and the rise in the use of domestic biomass triggered by RES policies lead to a demand increase, which is largely covered by domestic production. The authors recognise that the demand for fossil fuels is the most significant negative impulse. Since the EU depends mostly on fossil fuels imported from other countries, they notice the potential of RES policies to function as a cause of an import substitution effect in this regard, with a positive effect on GDP. Another important mechanism affecting the GDP are the additional costs related to RES deployment, which result in an increase in energy prices. On the other hand, Duscha et al. explain that redistribution of extra rents in the energy sector for consumer spending reduces this negative effect. The authors note that on the aggregate, the effects discussed above lead to a rise in domestic demand followed by income multiplier and accelerator effects. All those impacts interact in a way that the GDP effect is stronger if higher RES targets are considered, thus, the projected GDP growth is higher in the 35% RES deployment scenarios. The authors discuss also the results yielded by the ASTRA model. The GDP impacts in this case are lower because, as they explain, the model emphasizes more strongly the negative effects (e.g. higher costs of energy generation). Overall, this results in lower – although still positive – estimates of the expected GDP growth. Duscha et al. analyse also the results yielded under the assumptions of different policies regarding the RES targets implementation, represented by the QUO and SNP scenarios. They conclude that the outcomes of the two scenario types are comparable although they behave differently over time: the SNP scenarios lead to better results in the medium term and the QUO scenarios perform better if a longer timeframe is considered.

In the analysis of macroeconomic impacts published by the European Commission (2014), the focus lies on the scenario analysing GHG reductions. However, the authors additionally report impacts of scenarios that include higher RES targets estimated with the E3ME model assuming that carbon pricing is used to lower labour taxation. These results indicate a positive change in GDP as compared to the reference. It is, however, not trivial to assess to what extent the increase in the RES target alone influences the results, as the analysed scenario combines it with GHG targets and increased EE measures, which can all potentially influence the estimates. It is worth mentioning that the change in the GDP in the GHG40EERES30 scenario is lower than in the GHG40EE scenario, which does not assume a specific RES target (not reported here). Overall, however, the authors note that increased levels of energy efficiency and renewables' deployment, which involves higher investments, can cause positive impacts on GDP.

In the more recent impact assessment published by the European Commission (2016b), two different models are used to evaluate the GDP impacts, which, interestingly, yield very different estimates. The modelling exercise using the E3ME model shows a positive GDP change in the EUCO3030 scenario, which assumes RES target of 30%. Like before, one needs to be careful in drawing conclusions about the direct impact of the RES target only, since the analysed scenarios (EUCO27 and EUCO3030) differ with respect to the GHG emissions and energy efficiency targets as well. However, the study finds that the EUCO3030 scenario leads to a higher GDP growth than another modelled case (EUCO30, not reported here), which assumes a 27% RES target (like EUCO27) and a 30% energy efficiency target (like EUCO3030). The authors explain this with additional investments related to renewable energy. A different picture emerges if the GEM-E3 model is used. Depending on the analysed case (loan-based or self-financing), it yields either lower positive or even negative GDP impacts of the EUCO3030 scenario than the previous model. The estimated effects are also less optimistic than the alternatively explored EUCO30 case. The authors explain this by the fact that due to new investments in RES, investments are shifted from other productive sectors. These missing investments are compensated for through higher prices and hence costs for electricity users, which means that the positive GDP effects are reduced. This affects the modelling results less under "loan-based" conditions because in this case the crowding out effect materialises after 2030. In the "self-financing" case, however, where borrowing is not possible, this leads to a negative impact on the GDP. The authors point out, however, that under the market conditions at the time of the study publication, RES investments were mostly financed through borrowing and that the correct interpretation of the results depends on the current options of financing investments.

3.1.2 Employment

One can draw a similar picture regarding employment impacts. The studies generally report a positive but not very pronounced change in employment as compared to the baseline caused by additional RES deployment. Again, the self-financing case in the Impact Assessment published by the European Commission (2016b) is the only one that shows a negative effect estimate.

Just as in the case of the GDP, the differences in the magnitude of estimates yielded by the NEMESIS and ASTRA models in Duscha et al. (2014) are very pronounced, with the

ASTRA-estimates considerably lower. While discussing the NEMESIS model, the authors explain the change in employment with the GDP effects triggered by RES policies. They note two reasons why the impact on employment is lower than the expected GDP change. First, they explain that the accelerator effects lead to increased investments in all sectors, which contribute to increased labour productivity, which in turn means that one needs less labour for producing the same GDP. Secondly, they point out that RES deployment triggers sectoral changes, which benefit less labour-intensive sectors so that overall labour intensity decreases. Consequently, the percent increase in GDP is greater than the percent increase in the number of created jobs. The ASTRA model yields less optimistic estimates of the employment effects. Duscha et al. explain this with developments over time, sectoral patterns and with the fact that employment effects are highly dependent on GDP effects, which in the case of ASTRA model are considerably lower. The authors observe a similar pattern of development over time of SNP and QUO scenarios as seen when analysing the GDP effects (i.e. SNP performs better in the medium and QUO in the longer term).

In the impact assessment by the European Commission (2014), the employment effects of the scenarios including specific RES targets differ depending on the assumed use of revenues from carbon pricing. The results suggest that in the case of revenue recycling to consumers, scenario with an increased renewable target corresponds to an increase in employment of 0.5% as compared to the reference scenario. The authors explain that the employment effects are even more visible on the sectoral rather than aggregate level, with new jobs created due to investments in renewable energy-power generation capacity and energy-efficient equipment and technology in sectors such as Engineering and Transport Equipment, Utilities or Construction. At the same time, the model predicts some negative changes in the extraction industries. Assuming revenue recycling to lower labour costs also results in positive employment effects. Interestingly, the impact on employment in the policy scenarios including RES targets is lower than in an alternative one, which only assumes a GHG reduction target under enabling conditions (not reported here). The authors explain it with lower carbon prices from EE and RES, which result in lower carbon taxation, so that less support is provided to lower the costs of labour. In the more recent Impact Assessment (European Commission, 2016b), just as in the case of GDP, the employment-related estimates differ depending on the applied model and assumptions regarding borrowing. The E3ME model yields positive but limited estimates of employment change for EUCO3030 as compared to EUCO27. On the other hand, this impact is very close to the alternative EUCO30 scenario (not reported here). It is therefore questionable, to what extent one can attribute the positive impacts to the increased renewables share. The results of the GEM-E3 model show a pattern comparable to the GDP impacts - they are in general less optimistic and in the “self-financing” case, even negative. This negative result again highlights the importance of considering investment-financing options while assessing the macroeconomic impacts.

3.1.3 Fossil fuels import dependency

In terms of import dependency, drawing an exact conclusion summarizing all studies is not feasible, as the authors discuss different indicators relating to fossil-fuel imports and relate them to different reference years. In general, however, one can observe that the increased deployment of renewable energy sources would decrease the EU's spending on the fossil fuel energy sources.

Duscha et al. (2014), for example, discuss avoided fossil fuel imports (annual). According to their modelling results, by 2030, they would amount to around 177bn € in the baseline scenario, around 212bn € in the cases of SNP-30 and QUO-30 scenarios and around 239bn € in the SNP-35 and QUO-35 scenarios. This corresponds to around 20% and 35% increase compared to the baseline in the 30% and 35% RES deployment scenarios, respectively. The authors stress that these impacts are due to the increased RES deployment only and they suggest that combining RES targets with ambitious energy efficiency measures, even stronger effects can be achieved.

European Commission (2014) reports fossil fuel net imports (average annual 2011-2030) to amount to 461bn € in the reference scenario. In the scenarios with higher GHG reductions and RES deployment targets, this value is expected to be up to around 6% lower (434bn € in the GHG45/EE/RES35 scenario). It is worth noting that the difference between the policy scenarios and the baseline increases significantly in the longer time horizon (2050). European Commission (2016b) expects the fossil fuel net imports (average annual 2021-2030) to amount to 427bn € in the EUCO27 scenario and to 416bn € (around 3% less) if a higher RES-deployment target is considered.

3.1.4 CO_2 emissions

Similarly, in terms of climate impacts, one cannot directly compare the studies because they use different measures to report the impacts on CO_2 reductions. Generally, the authors agree that the impact is positive.

Duscha et al. (2014) models avoided CO_2 emissions due to RES deployment (Mio t/a). The modelling results indicate that these numbers would be significantly higher in the case of increased RES deployment scenarios – some 12% higher in SNP-30 and QUO-30 scenarios and around 30% higher in SNP-35 and QUO-35 scenarios as compared to the baseline.

European Commission (2014) reports the modelled CO_2 emission reductions in terms of percentage change as compared to 2005. They estimate the CO_2 emission reductions to amount to 29% in the reference scenario, 37% in the GHG40/EE/RES30 scenario and 43% in the GHG45/EE/RES35 scenario. One must keep in mind that these two policy scenarios differ with respect to both RES and GHG reduction targets.

European Commission (2016b) does not report the overall impacts on the CO_2 emissions reduction. However, their results indicate that that in the EUCO3030 scenario, carbon intensity is significantly lower than in the EUCO27 case.

3.2 The role of bioenergy

The only one of the analysed studies that explicitly focuses on the impacts of biomass-based applications is the assessment by Smeets et al. (2014). Three of the analysed applications have a direct relation to energy: biofuel, bioelectricity and biogas. In the scenario considering biofuels, the authors find a positive net GDP effect of 5.1bn US$ and a multiplier effect greater than one (the effect is also positive in scenarios assuming different oil prices but its magnitude changes). In the other cases related to bioenergy, they find a negative impact on GDP (-3.0bn US$ and -5.1bn US$ for bioelectricity and biogas respectively). The authors explain that the changes in GDP are to a large extent driven by indirect macroeconomic effects, like changes in oil prices and wages induced by the switch to biomass-based products.

The other of the discussed studies do not provide particular estimates on macroeconomic impacts of increased deployment of bioenergy. They provide, however, several insights into how the role of bio-based energy sources among other renewables might develop and some other impacts that they may trigger. The rest of this section provides a brief summary of these points.

Duscha et al. (2014) describe some of the Green-X modelling results, which can be related to bioenergy. For example, they report the modelled share of renewable energy in transport-fuel demand, which equals 7.7% in the baseline scenario and grows to 9.6% and 11.1% when the RES general deployment increase to 30% and 35%, respectively. Additionally, they report the estimated annual expenditures for biomass fuels which range from 59.0bn €per year in the baseline scenario to 76.6bn € per year in the case of the SNP-35 scenario. Moreover, the authors estimate in monetary terms the avoidance of fossil fuels in the transport sector due to RES as compared to 2010, which grows together with the RES deployment targets. The authors are silent about the role of bioenergy in these savings. It is possible, however, that biofuels could play a role in this effect.

European Commission (2014) examines how their analysed policy options influence demand for biomass. They expect this demand to reach significantly higher levels in 2030 in scenarios with increased RES deployment targets. The Commission also finds that most of this additional demand is expected to be covered by increased domestic biomass production and only to a small degree by increase in biomass imports. This is expected to result in an increase in the area of cropland for perennials, which in turn might affect the trade in agricultural commodities. The Commission notes, however, that the net trade balance should not be highly affected due to the decrease in demand for 1st generation biofuels, which allows the use of land for other purposes.

Finally, the European Commission (2016b) reports the outcomes of modelling relating to energy-system indicators. For example, it expects the share of renewable energy in the transport sector to be higher in the EUCO3030 scenario (21%) as compared to the EUCO27 scenario (18%). They also state the estimated biofuels consumption. In the scenario with increased RES deployment, the authors expect it to amount to 21.314Ktoe, which is roughly 4% higher as compared to the EUCO27 case (20.486Ktoe). However, the share of biofuels consumption as the share of gross final energy consumption in transport is quite similar for both scenarios, with ca. 8% and ca. 8.45% in the EUCO27 and EUCO3030 scenarios respectively. In the both cases, the biofuels consumption as the percentage of total RES consumption is relatively similar, oscillating at around 7%, with this share a bit smaller in the EUCO3030 scenario.

Together with the above discussed Impact Assessment 2016, the European Commission conducted a study discussing the sustainability of bioenergy (2016a). This assessment evaluates different policy options with regard to bioenergy, focusing on solid and gaseous biomass used for power and heat. The study compares the baseline with policy options that aim at addressing some of the identified sustainability concerns related to bioenergy, such as, for example, impacts on biodiversity or biogenic greenhouse-gas emissions. The authors modelled the impacts of the policy options among others on supply and demand of biomass for energy, environment, economy, energy security and employment. The Commission did not identify the most favoured policy option. However, it provides an overview of how each of the discussed options can address the identified risks.

4 :: Summary Analysis

This summary analysis provides a general summary of the impacts of the increased RES deployment targets and bioenergy use discussed in the previous section. It focuses on the role of different drivers of these impacts and related policy consequences. Finally, it draws overall conclusions on the topics covered in this report.

4.1 Renewable energy

Based on the results of the analysed studies, one can conclude that the increased deployment of renewable energy sources is expected to have positive impacts in 2030 on the topics of interest: macroeconomic indicators, fossil-fuel imports and CO_2 emissions.

The macroeconomic impacts are in general positive but of a limited magnitude, which depends on the applied model and underlying assumptions. The change in GDP induced by higher RES deployment is positive in all but one case and it amounts to up to 0.8%. One observes a similar pattern in the case of employment effects, which are predominantly positive but amount to almost 0.7% at most.

The results of the above-discussed studies provide some policy insights. It seems that investments related to increased RES deployment play a significant role as drivers of these macroeconomic effects. However, not only their level plays a role. Duscha et al. (2014) state that since the costs of renewables has fallen significantly in the last years, the policies related to renewable energy will no longer focus on subsidising additional generation costs. Alternatively, they will focus on decreasing the risk of investments by reducing capital costs. The results of the impact assessment (European Commission, 2016b) suggest that macroeconomic effects depend also on the conditions regarding financing investments, with positive impacts in the loan-based case, but also negative impacts, if borrowing is not possible.

The study of Duscha et al. (2014) also provides some insights into how different policy options supporting RES deployment can influence macroeconomic effects over time. Their results indicate that in the 2030 timeframe, macroeconomic effects are more optimistic if strengthened national policies are applied, whereas in the longer horizon (2050), a harmonised quota system seems to be more beneficial. Duscha et al. suggest also that further reduction of RES generation costs is important for the benefits to hold until 2050. Therefore, they stress the importance of policies that support further innovation in RES technologies. They also recognise the necessity to improve international framework conditions for RES, which would “create large markets, exploit economies of scale and accelerate research and development”.

Another policy aspect, which seems to influence the macroeconomic effects, is the way in which revenues from carbon pricing are used: to benefit the economy as a whole (e.g. through lowering labour costs) or as transfers to consumers. This is visible in the impact assessment published by the European Commission (2014). While evaluating employment impacts or scenarios including RES targets they consider two cases differing with respect to the use of carbon pricing revenues and report a lower change in employment if revenue recycling to lower labour taxation is assumed, as compared to the other case. Additionally, under the assumption of revenue recycling to lowering labour costs, the modelled employment benefits are lower if a RES target is considered together with a GHG target and EE measures than otherwise. This reflects the importance of having carbon-pricing mechanisms in place and that they should be taken into consideration while climate policy options are evaluated.

4.2 The role of bioenergy

Since only one of the studies discussed in this review focuses specifically on macroeconomic impacts in the relevant time frame, the conclusions relating to bioenergy are more limited.

Smeets et al. (2014) discuss the impacts of replacing conventional fuels with biofuels, and bioelectricity. They find that only biofuels bring about a positive change in the GDP, whereas the other two energy sources do not. Therefore, it seems less reasonable to use biomass for bioelectricity and biogas production.

An important aspect of the significance of bioenergy is the corresponding role of biomass. Duscha et al. (2014) estimate that in the scenarios assuming a 35% RES target, the yearly expenditures for biomass fuels will grow to some 76bn € as compared to the 59bn € in the reference case. The European Commission (2014) finds a significant impact of increased RES targets of biomass demand. An important question from the policy point of view is how to satisfy this additional demand. The European Commission found that overall, this increase in biomass use will not have a large effect on the trade balance since it will mostly be supplied by domestic production. However, it could have an impact on the use of land for other purposes. Such possible effects must also be taken into consideration.

Other questions regarding bioenergy refer to their sustainability. Through their renewability they address the problem of finite reserves of fossil fuels. However, one must consider what environmental effects can be triggered increasing the amount of the Earth's surface used to produce bioenergy. The assessment by the European Commission (2016a) provides some insights into how different policy options can address common sustainability concerns related to bio-based energy sources.

4.3 Conclusion

The aim of this report was to gather and summarise the findings of previous studies that analysed the impacts of increased renewable-energy deployment targets in the European Union until 2030. We focused the analysis on the results related to the GDP and employment effects but we also examined the changes expected with regard to the dependency on fossil-fuel imports and CO_2 emissions. We paid particular attention to the results related to bio-based energy sources. The studies discussed in this review were motivated by different aims; they also analysed different scenarios, applying various models, assumptions and targets. Therefore, drawing a single numerical conclusion from results yielded by them is not possible. On the other hand, comparing them provides useful insights, since they underline and draw attention to different aspects of energy policy.

In the majority of cases, scenarios assuming increased RES deployment targets display numerous benefits as compared to the baselines. In general, the macroeconomic effects are not very strong – for both GDP and employment, they are generally positive, but below 1%. These impacts might be subject to different policies in the areas of, for example, investments or carbon pricing. The studies also show that in general, higher deployment of renewable-energy sources can bring about positive changes with respect to the import-dependence on fossil fuels and can reduce CO_2 emissions.

As with regards to bioenergy, we discussed the macroeconomic impacts modelled in the study by Smeets et al. (2014). Their analysis leads to the conclusion that while replacing conventional energy with biofuels is expected to have a positive GDP impact in 2030, this is not the case for bioelectricity and biogas, which under the model assumptions appear to not be competitive with their conventional equivalents.

5 :: References

Capros, P., De Vita, A., Tasios, N., Papadopoulos, D., Siskos, P., Apostolaki, E., . . . Witzke, H. (2013). *EU Energy, Transport and GHG Emissions Trends to 2050: Reference Scenario 2013.* Luxembourg: Publications Office of the European Union.

Capros, P., De Vita, A., Tasios, N., Siskos, P., Kannavou, M., Petropoulos, A., . . . Kesting, M. (2016). EU Reference Scenario 2016. Energy, transport and GHG emissions Trends to 2050. Luxembourg: Publications Office of the European Union.

Duscha, V., Ragwitz, M., Breitschopf, B., Schade, W., Walz, R., Pfaff, M., . . . Boitier, B. (2014). *Employment and growth effects of sustainable energies in the European Union. Final report.* Karlsruhe.

European Commission. (2012). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Renewable Energy: a major player in the European energy market, COM(2012) 271 final.* Brussels.

European Commission. (2014). *Impact assessment accompanying the document, A policy framework for climate and energy in the period from 2020 up to 2030, SWD(2014) 15 final.* Brussels.

European Commission. (2015). *Closing the loop – An EU action plan for the Circular Economy, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2015) 614 final.* Brussels.

European Commission. (2016a). *Impact Assessment, Sustainability of Bioenergy, Accompanying the document Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable resources (recast), SWD(2016) 418 final, part 4/4.* Brussels.

European Commission. (2016b). *Impact Assessment accompanying the document, Proposal for a directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (recast), SWD(2016) 418 final, part 3/4.* Brussels.

Rizos, V., Tuokko, K., & Behrens, A. (2017). *Circular economy: An exploration of definitions, economic processes and macroeconomic impacts.*

Smeets, E., Vinyes, C., Tabeu, A., Van Meijl, H., Brink, C., & Prins, A. (2014). *Evaluating the macroeconomic impacts of bio-based applications in the EU.* European Union.

Winkler, J., Breitschopf, B., Ragwitz, M., Mistre, M., Cail, S., & Harmelink, M. (2018). *Renewable energy directive target. Study for the ITRE Committee.* European Commission.

In the course of this desk research, several additional studies were reviewed for inclusion. Though deemed not directly relevant for the specific aims of this CIRCULAR IMPACTS report, they are perhaps of relevance to researchers seeking to understand the current and future linkages amongst renewable energy, bioenergy and macroeconomic outcomes. Table 3 highlights some of the key studies and includes the regions covered and the time frames addressed.

Table 3: Overview of some additional studies reviewed for inclusion in this desk study

			Region				Time frame				
Title	**Author**	**Year**	EU	US	Global	Other	2010	2020	2030	2050	other
Economic Effects of Renewable Energy Expansion: A Model-Based Analysis for Germany	Blazejczak, J., et al.	2014				X			X		
Green Jobs? Economic impacts of renewable energy in Germany	Lehr, U., Lutz, C.	2012				X			X		
Renewable Energy and Employment in Germany	Lehr, U., et al.	2008				X			X		
Employment effects of selected scenarios from the Energy Roadmap 2050	Cambridge Econometrics	2013	X							X	
Smart Energy Europe: The technical and economic impact of one potential 100% renewable energy scenario for the European Union	Connolly, D., Lund, H., Mathiesen, B.V.	2016	X							X	
The Impacts of Biofuels Targets on Land-Use Change and Food Supply: A Global CGE Assessment	Timilsina, G. R., et al.	2010			X			X			
Unintended Environmental Consequences of a Global Biofuels Program	Melillo, J.M., et al.	2009			X					X	
Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Generate?	Kammen, D.M., Kapadia, K., Fripp, M.	2004	X	X				X			
Renewable Energy Benefits. Measuring the Economics.	IRENA	2016			X				X		
Putting renewables and energy efficiency to work: How many jobs can the clean energy industry generate in the US?	Wei, M., Patadia, S., Kammen, D.M.	2010		X					X		

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