Employment and growth effects of sustainable energies in the European Union

FINAL REPORT

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Glossary

Direct effects	Effects which are directly related to RES generation and RES technologies and occur directly in the sector addressed by the policy promotion
Employment effect	Changes in the demand for RES or other investment or consumption goods affect employment in (all) economic sectors
Gross effect	Provides the number of jobs and value added in the RE and the related upstream industries by taking into account positive direct and indirect effects
Impulse	Impulses induce economic activities. Relevant impulses for this study comprise expenditures for investment or fuel, trade and technology costs or policy induced energy prices, surcharges or household budget
Income/ budget effect	With the same income (nominal) fewer/more goods can be consumed due to a (energy) price change
Indirect effects	Effects in up/downstream sectors that are not directly (but only indirectly) related to the promotion of RES and that might occur with a time delay.
Induced effect type 1	Changes in demand for consumption goods due to income changes from changes in RET deployment
Induced effect type 2	Changes in consumption or production as a result of changes in energy prices due to RET deployment and support policies
Net effect	Shows the final economy wide impact on jobs and growth if all negative and positive direct, indirect and induced effects are taken into account
Revenue effect	Changes in demand for RES or other investment or consumption goods affect revenues in (all) economic sectors
Substitution effect	Money for consumption will be shifted from one good to another good, e.g. from travel to RES, due to the higher price of RES [Comment: would you please explain in a bit more detail. The current explanation gives the impression that the consumer in case of a relative price change will shift to a higher price good.]

List of Abbreviations

CET	Conventional Energy Technologies
O&M	Operation and Maintenance
RES	Renewable Energy Technologies
RES	Renewable Energy Sources

I Background, motivation and objectives of the study

Background

The Commission Communication “Renewable Energy: a major player in the European energy market” (EC 2012) clearly states the objectives for European energy policy: combating climate change, limiting the EU's vulnerability to imported hydrocarbons, and promoting growth and jobs: *“Renewable energy enables us to diversify our energy supply. This increases our security of supply and improves European competitiveness creating new industries, jobs, economic growth and export opportunities, whilst also reducing our greenhouse gas emissions.”*

The Energy Roadmap 2050 (EC 2011) reaffirms the strong role of renewable energy sources on the way to a low carbon European energy sector by 2050. “*Regardless of scenario choice, the biggest share of energy supply in 2050 will come from renewable energy. Strong growth in renewables is the so-called 'no regrets' option. However, despite the strong framework to 2020, the Roadmap suggests that growth of renewable energy will drop after 2020 without further intervention due to their higher costs and barriers compared to fossil fuels. Early policy clarity on the post 2020 regime will generate real benefits for investors in industry and infrastructure as well as for renewable energy investors directly.*” The European Energy Security Strategy (EC 2014), launched by the Commission in light of the Ukraine crisis, highlights the use of renewable energy sources as one way to increase energy production in the EU. *“There is a significant cost-effective potential for renewable electricity and renewable heating to further reduce natural gas use in a number of sectors by the end of this decade. [...] With technology cost reductions, many renewable energy sources are increasingly competitive and ready to join the market.*”

Given the high relevance of renewable energies in future energy scenarios and the high expectations regarding its potential benefits, it is important to gain a better understanding and awareness of the economic and employment impacts of renewables. This is of particular importance at a time when decisions need to be taken on the future role of renewable energy targets in the EU target system and on the European energy security strategy.

In order to promote the objective discussion of the growth and employment effects of an enhanced deployment of renewable energy sources (RES), a sound scientific basis is needed on the gross (direct and indirect) as well as the net effects (including negative effects like conventional replacement and budget effects).[1] Furthermore the future development of RES in Europe will take place against the background of a global market for

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[1] The detailed definition of gross versus net effects and direct versus indirect effects is given in section B.

RES technology. These global markets and the possible shares of European industries in these markets will play a critical role in the potential to create growth and employment.

This study aims to provide a sound scientific analysis of these issues.

Objectives and results

This study aims to present a complete analysis of the employment and economic growth impacts of renewable energies that encompasses past, present and future prospects. More specifically, the project's objectives are:

- To study the employment and economic effects of renewable energy deployment per renewable energy sector, per economic sector and per country.
- To support the development of a common understanding of the various gross and net employment and growth impacts of (an accelerated diffusion of) renewables.
- To analyse the impacts of renewable energy policies on the deployment of different renewable energy technologies, investments, costs and security of supply.
- To use a modelling system with a sound scientific basis and to ensure a high level of transparency in order to promote confidence in the quality of analysis.
- To facilitate an improved and common understanding of the balance between the costs and benefits of (an accelerated growth of) renewables.
- The results of this project as presented in this report include:
- An analysis of the direct and indirect gross economic and quantitative employment impacts resulting from past and present RES developments for each of the 28 EU member countries and each RES technology.
- A business-as-usual scenario and four different policy scenarios on the deployment of and support policies for RES technologies in the EU-28 up to 2050, and various sensitivity analyses of scenario assumptions and boundary conditions.
- An in-depth analysis of the future gross and net economic and quantitative employment impacts in the EU-28 up to 2050 resulting from the scenarios described above and based on a validated and transparent macro-economic modelling approach.

The structure of the report

This report consists of two major parts. The first part (Sections I-III) provides information on the theoretical framework and the methodology. Section II describes the macro-economic effects expected from RES deployment. Section III describes in more detail the modelling approach taken in this study to quantify the macro-economic effects and analyse the interdependencies. The second part (Section IV) presents the modelling results step by step. The report is compiled in such a way that Section IV can be read without a deeper understanding of the modelling approach (Section III), while Section III contains more details for interested readers and modellers.

II Theoretical approach: Economic impacts of RE support policies

Impacts on National Economies

The objective of this chapter is to elucidate the different economic effects of RET deployment and explain which costs and benefits are taken into account when we talk about net employment or net growth effects. Overall, net effects are the sum of all benefits and all costs of RET deployment. So, both the negative and positive effects of RET deployment should be taken into account when assessing net employment or growth impacts. This includes effects from avoided conventional energy technology (CET) use. To capture all the effects, we first analyse the potential impacts of RET or CET deployment on technology, the energy sector, the market and consumption (see Figure II-1).

RET (CET) deployment impacts different systems and sectors. Major effects on employment can be expected in the energy sector, the energy market and final energy consumers as well as the technology system.

- RET (CET) deployment impacts the energy sector, as generation technologies, supply security and stability as well as transport, distribution and marketing activities have to be adjusted to changing conditions. To measure or quantify these effects, expenditures for investments, operation and maintenance, fuel and other transactions are used. In sum, they reflect the effect of RET (CET) investments in the energy sector.
- The use of RET or RES (CET) also affects market prices as it changes the merit order of the power supply curve and the demand for fuels. Any shift in supply or demand results - under a functioning market mechanism – in a price change. However, as these price changes occur mainly on the wholesale market, they might not be fully passed on to final consumers.
- Besides price changes on the wholesale market, the final consumers of power or heat might pay a price supplement – a policy-induced levy or surcharge for RET deployment - which is supposed to cover the additional costs of RET use and eventually a margin for the power/heat provider. Some industries might be exempted from the levy or pay a lower amount. In other cases, the additional costs of RET deployment are financed through the public budget via subsidies or tax credits. This reduces the public budget so that either public services cannot be fully provided, or taxes have to be increased to compensate for public RE support. In the end, households and firms pay more taxes or fees to balance the shrinking budget.
- The use or deployment of RET (CET) has an impact on technologies/technological progress through learning by doing, learning by research and could lead to changes in production, technology costs, efficiency and trade. As this effect occurs over time, it is seen as a dynamic effect that should be taken into account when modelling future impacts.

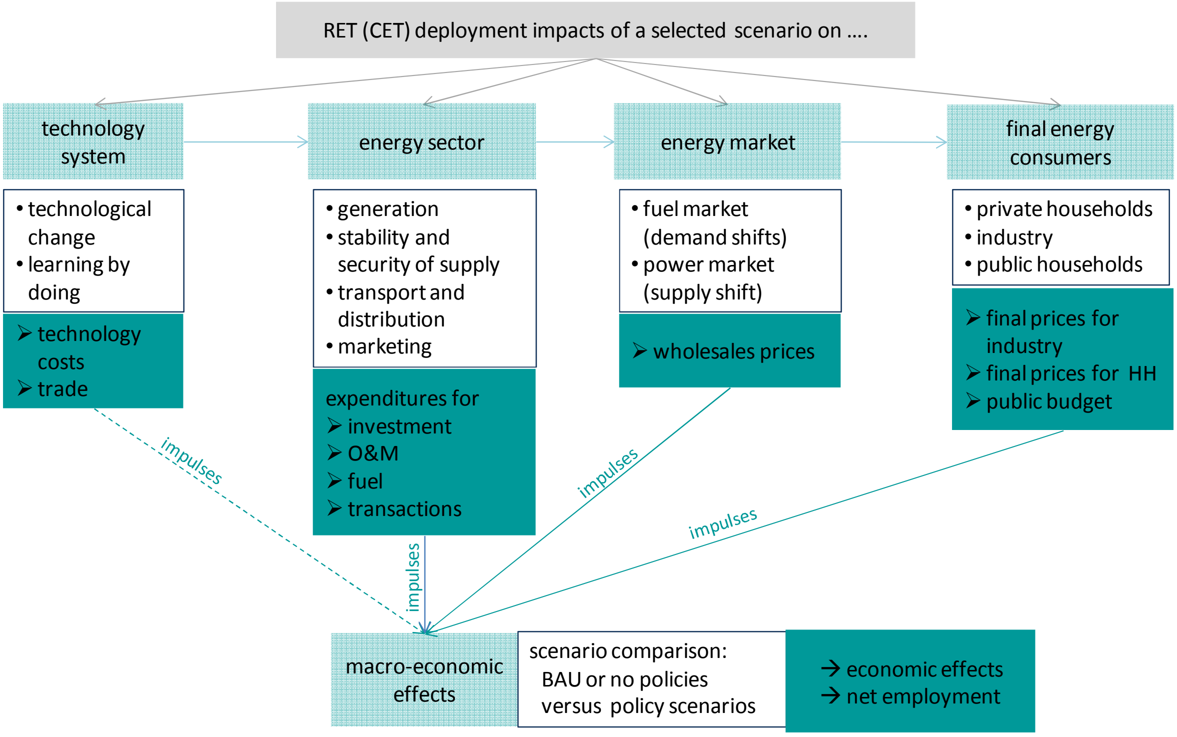

Figure II-1: Impacts of RET deployment on technology, the energy sector, market and consumption

Apart from these impacts, RET affects other economic areas as well, for example crowding out investments in areas outside the energy sector or changing land prices, etc. These impacts are not explicitly considered here as they are beyond the scope of the model.

To conduct a macro-economic impact analysis of RET deployment, scenarios should be developed that contain different but viable energy systems based on different RE shares and support policies for RE. Each energy scenario exerts different impacts on technology development, the energy sector, market and consumption and only a comparison of the macro-economic results of two of these scenarios shows the “net“effects of the respective RET use. The modelling of a viable energy system includes taking conventional energy technologies into account as well.

Impulses induce economic activities. They comprise:

- Expenditures for investment, O&M, fuel, transactions
- Trade and technology costs
- Policy induced energy prices, surcharges and public spending

To model the macro-economic impacts of different RET scenarios, **impulses** are needed that trigger economic activities in the model. Expenditures, costs and energy prices can be used as impulses. Figure II-2 shows the impulses that are taken into account as well as the main economic mechanisms that translate their effects into impacts on employment or growth. As we compare different energy systems, we always take into account impulses from conventional energy (CE) and RE based energy systems that address either the industry sector via the demand for technology components, services and fuels or via the costs for production and consumption goods. The main impulses can be classified into investment and price impulses. They include:

- Investment expenditures: this impulse is derived from the expenditures for domestic installations of plants minus the expenditures for imported equipment or components. This also includes expenditures for reinvestments and up-scaling. Technology costs take into account cost decreases due to increasing diffusion over time.
- Trade: export volume of RET (CET) equipment and services induced by global investments in RET (CET).
- Operation and maintenance (O&M) expenditures: expenditures necessary to operate and maintain generation including the costs for grid connection minus the imported O&M services.[2]
- Fuel expenditures: expenditures for fuel that is used domestically. This includes reductions in the use of fossil fuels due to the increases in RET and biofuels.
- Final consumer prices for households, services and industry: Apart from the impact of different generation technologies on wholesale prices, there are support policies for energies that are paid for directly by final consumers, i.e. they are obliged to pay the additional costs of selected (mainly RE) generation technologies via a levy on the electricity price. However, this levy not only compensates generators for the higher costs, but also allows for a profit margin (which in turn might increase income from capital). As in many countries selected industries pay a lower levy than households, the price effects should be differentiated by sector.
- Household budget spending (RE)[3]: The profit margins from support policies increase investor budgets. Depending on the investor structure, this is either the energy sector or private investors. Assuming that budget increases in the energy sector will also be redistributed to households via the shareholder value, we assume that these profits increase household budgets.

There are two main economic **mechanisms** that translate impulses into economic effects or impacts (see Figure II-2). First, the mechanism that is sparked by (domestic) invest-

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[2] Other costs that are not modelled explicitly include infrastructure costs (e.g. for the power grid or for storage) or transaction expenditures, e.g. for domestic services necessary to secure supply, match demand and sell.

[3] Also different financing mechanisms are possible such as the provision of interest subsidies, grants or tax credits by the government instead of the pay-as-you-go financing as applied e.g. in Germany. In that case, either a lower budget or an increase in taxes would be needed for financing.

ments in the energy technology and service industry triggers production and hence employment in this industry. These effects are called "**direct effects**" as they refer to jobs directly related to RET (positive direct effect) and to CET, as investments in these technologies may be crowded out / replaced by RET (negative direct effects in the CET industry). But changes in demand in these industries also affect activities (production) in upstream sectors[4]. These effects are called "**indirect effects**". Furthermore, income that is generated in these sectors increases demand for consumer goods and hence exerts an overall impact on all economic sectors. This effect is called **induced effect type 1** as it takes place "outside" the RET - and CET - related industries. Increases in the trade of energy technologies and services induced by global investments in RET and CET stimulate the same mechanism as domestic investments.

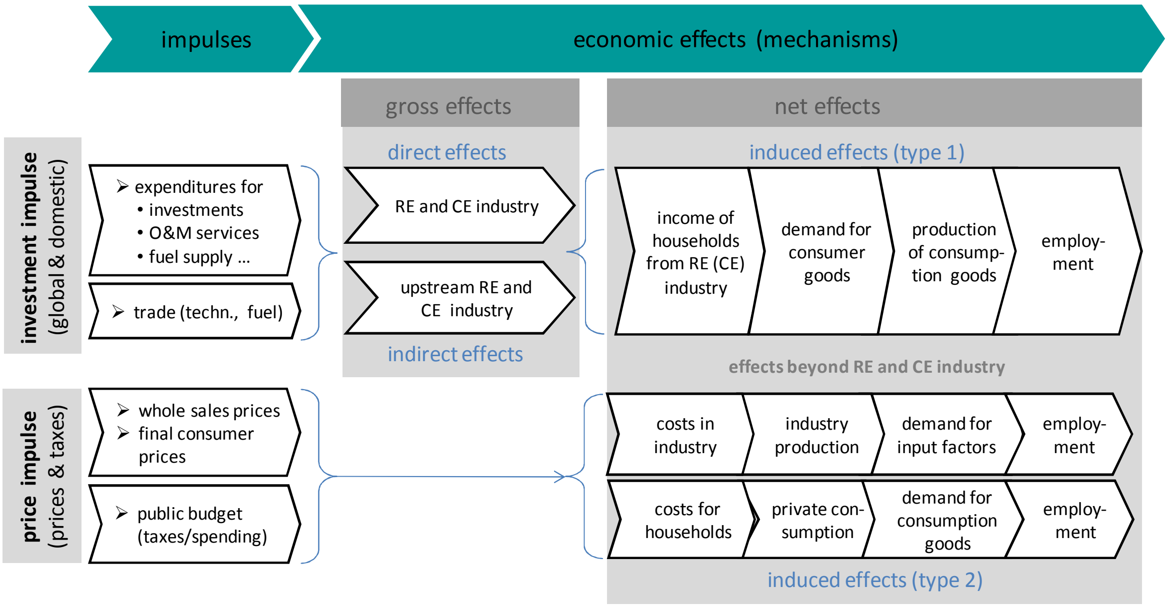

Figure II-2: Illustration of impulses, economic mechanisms and economic effects

Source: Breitschopf et al. 2013, adapted

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[4] For the definition of direct, indirect and induced effects, see Breitschopf et al., 2013.

Gross effect: provides the number of jobs and value added in RE and related upstream industries by taking into account positive direct and indirect effects.

Net effect: shows the final economy wide impact on jobs and growth if all negative and positive direct, indirect and induced effects are taken into account.

The second mechanism shows the economic reaction to price effects due to changes in taxes, levies or prices. In contrast to the stimulating effect of investments, price increases have a dampening effect on economic activities as they reduce the available budget of households for consumption (assuming no changes in the quantity of energy demand). Lower demand for consumer goods decreases production and hence income in these industries. Through multiplier effects this impact affects the whole economy over several periods. Similarly, industries facing higher energy prices either produce less, hence, reduce demand and income from these industries or sell their products at higher prices, which in turn reduces demand and thus their production.[5] Generally, a price increase has a negative effect and slows down economic activities, whilst a decrease of prices or costs stimulates economic activities. This effect is called induced effect type 2 as it is caused by energy consumption but begins “outside” the RET and CET industryand encompasses the whole economy. Both mechanisms are depicted in Figure II-2. Figure II-2 further stresses that **gross effects** only capture the impacts on RET (CET) – the grey block on the left - while **net effects** also include effects that occur beyond the RET (CET) industry – the right-hand block in Figure II-2.

The main economic effects of RET deployment that have a positive or negative impact on jobs are briefly described in Table II-1. Moreover, Table II-1 clearly illustrates that the effects of RET deployment are always compared to an energy system based on less RET and more CET. Consequently, as RET displaces CET, there is a negative effect in the CET industry (displacement). This effect is best captured by comparing the final effects of two RET/CET deployment scenarios. For example, the difference between the number of jobs under low and high RET deployment shows the net displacement effects on jobs. Please note that this study focuses on the number of jobs only. The quality of employment can vary widely from highly skilled jobs e.g. in the area of research and development to low-skilled workers, but the quality of the jobs linked to the RES scenarios analysed here is beyond the scope of this study.

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[5] Higher prices could also reduce companies’ profits leading to lower returns on equity.

Table II-1: Overview of positive and negative effects of RE as well as increase in RET and decrease in CET deployment

Positive effects → job increases	Negative effects → job losses	Type of effects
increase in investment in RET (RE industry and upstream industry)	displaced investment in conventional generation technology (CE industry and upstream industry)	direct & indirect
increase in O&M in RE generation (RE industry and upstream industry)	displaced O&M in conventional power generation (CE industry and upstream industry)	direct & indirect
increase in fuel demand (biomass) (RE industry and upstream industry)	decrease in fossil fuel demand (CE industry and upstream industry)	direct & indirect
increase in trade of RE technology and fuel (biomass) (RE industry and upstream industry)	decrease in trade of conventional technology and fossil fuels (CE industry and upstream industry)	direct & indirect
higher household income from employment in RE industry	lower household income from employment in CE industry	induced type 1
decreased electricity price for households and industry due to merit-order effect, CO_2 pricing, etc*	increased electricity price for households (budget effect) and industry (cost effect) due to additional generation cost of RE-based power generation	induced type 2

Source: Breitschopf et al. 2013

International Trade: Lead Markets

One prerequisite for an ambitious EU RES policy to have a positive impact on European trade is the ability to successfully market renewable energy technologies internationally. Due to the complex dynamics of trade in knowledge-intensive technologies, the effects of RES trade on national economies will be analysed in more detail. To this end, the European economies will be assessed with respect to their lead market potentials. Based on this assessment, different scenarios for national export shares will be defined, which will subsequently be used in the macro-economic modelling.

Globally successful technological innovations are commonly established first in one country or region before being adopted internationally (Quitzow et al. 2014). This can happen on the demand side in the form of a domestic market which adopts a technological innovation. This is then described as a lead market. Countries or entire regions such as the EU can also establish supply-based lead markets through dedicated policy action before the domestic demand for a technological innovation emerges. In bothcases the countries or regions which constitute or establish lead markets are said to have a “first mover advantage.”

Traditionally, it was thought that lead market suppliers originate mainly in traditional OECD countries. This concept has therefore strongly influenced European policy in the past and has focused research on activities related to lead markets (for the renewable sector, see Walz (2006), for the European Lead Market Initiative, see CSES and Oxford Research (2011), and for demand-led innovation policies, see Edler et al. (2012)). This concept is also one of the rationales behind European Flagship Initiatives such as "Resource Efficient Europe", which links increasing resource efficiency to securing growth and jobs for Europe, by stimulating innovation, improving competitiveness and opening up new export markets.

The Flagship Initiative on "Integrated Industrial Policy for the Globalisation Era. Putting Competitiveness and Sustainability at Centre Stage" underlines the importance of a strong manufacturing value chain for the EU. However, it also draws attention to the radically changing global business environment, with globalising value chains and emerging economies catching up with traditional ones. The globalisation of innovations along value chains (Pietrobelli and Rabelotti 2011), and the success of various emerging economies in building up innovation capabilities can also be seen for green technologies (Walz and Marscheider-Weidemann 2011). Therefore, the concept of lead markets from a demand and supply perspective has been broadened recently to include emerging economies (Cleff and Rennings 2012, Quitzow et al. 2014, Walz and Köhler 2014, Horbach et al. 2014, Köhler et. al. 2014).

If a policy focuses on realising an economic potential, the domestic suppliers of eco-innovations - and not foreign suppliers – must meet the demand. Taking the globalisation of markets into account, this requires the establishment of competence clusters which build on specific national competitive advantages and are difficult to transfer to other countries with lower production costs. These competence clusters must consist of high technological capabilities linked to a demand which is open to new innovations and horizontally and vertically integrated production structures (Quitzow et al. 2014; Walz and Köhler 2014). However, this concept is only applicable to technologies with certain characteristics, which act as obstacles to international relocation. A key prerequisite is that competition is not solely driven by cost differentials, but also by quality and/or performance aspects. Thus, especially goods which can be characterised as knowledge-intensive and with high innovation dynamics are suitable to form the basis for long-lasting first-mover advantages.

To a large extent, a number of environmental technologies, and especially renewable energy technologies are highly knowledge-intensive (Walz and Marscheider-Weidemann 2011; Walz and Eichhammer 2012), and are therefore likely to be successfully developed in lead markets. Furthermore, an analysis of the patent dynamics shows that energy technologies, and renewable energy technologies, in particular, are characterized by very high innovation dynamics (Figure II-3).

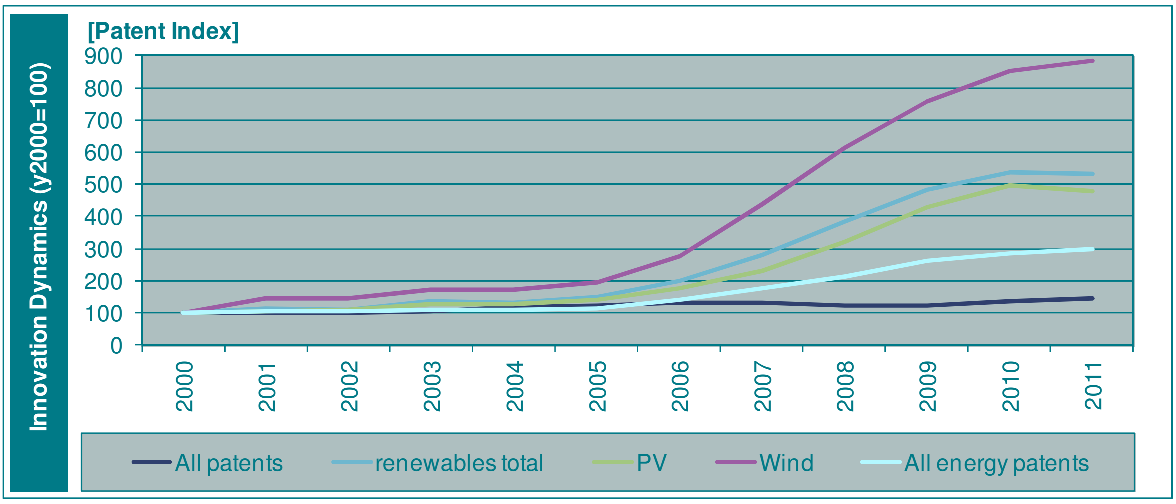

Figure II-3: Innovation dynamics for renewable energy technologies

Source: calculations of Fraunhofer ISI[6]

Comparative Lead Market Factors for RES technologies

The following factors have to be taken into account when assessing the potential of countries to be successful on international markets based on their innovation potential (see Quitzow et al. (2014) and Walz and Köhler (2014) for a discussion of indicators to measure these factors):

- Market conditions on the demand side
- Market conditions on the supply side
- System aspects of actors and their networks
- Technological competences
- Innovation friendliness of regulation.

Demand-based diffusion patterns of a technology may create price advantages for countries based on both economies of scale and learning (Beise-Zee and Cleff, 2004). It can also be expected that user-producer linkages increase if the technology diffuses through

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[6] Patent data are taken from the EPO Worldwide Patent Statistical Database (PATSTAT), version 13s. There are inconsistencies with earlier versions of the PATSTAT database which result in lower patent dynamics in some of the technologies.

the (home) market. Widespread diffusion therefore also leads to the improvement of future technological capability.

On the supply side, demonstration effects may create so called transfer advantages: If countries show a high level of successful technological applications, they will find it easier to export their products. Export advantages result to a large extent from similarities of preference. Thus, countries which take the preferences of a wide spectrum of countries into account when designing their technologies will enjoy an export advantage compared to countries which are oriented towards one particular market.

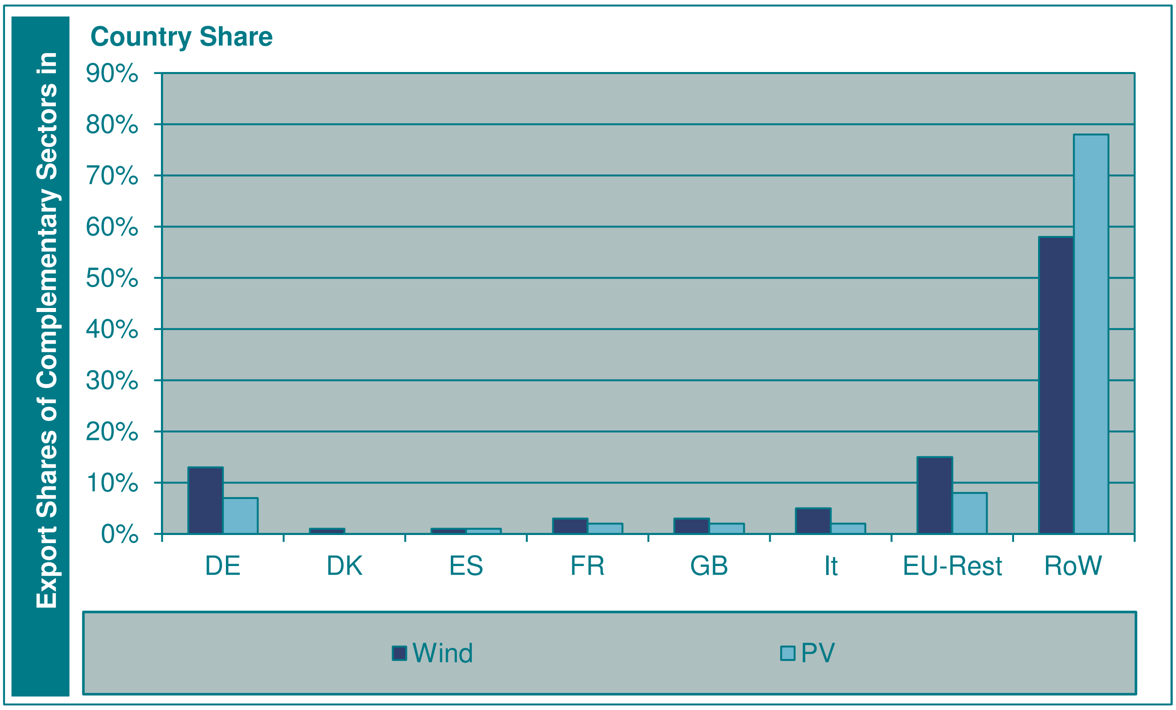

Figure II-4: Shares of EU countries/ regions and the rest of the world (RoW) in world exports in complementary sectors to wind energy technologies and PV in 2010

Source: Calculations of Fraunhofer ISI

Improving a country's competitiveness also depends on the structure of the innovation system. Apart from the number and qualifications of individual actors, functioning networks and coordination along the value chain are additional characteristics. It is widely accepted that innovation and economic success depend on how a specific technology is embedded into other relevant industry clusters, and how competitive these complementary sectors are. Figure II-4 gives an indication of the competitiveness in respective complementary sectors by looking at the export shares for EU countries/regions and the rest of the world. It becomes clear that the EU countries play an important role in complementary sectors of wind energy but have largely been overtaken by other parts of the world in complementary sectors of photovoltaics.

International trade performance also depends on technological capabilities (for a theoretical overview, see Dosi et al. 1990, Fagerberg 1995 or Wakelin 1997). Thus, indicators which measure technological capability are also important with regard to technological competitiveness. The empirical importance of these indicators for trade patterns has been analysed from the 1980s onwards, and repeated in various studies (for an overview, see Fagerberg et al. 2007 and 2010, and Schacht 2010)). Madsen (2008) underlines the importance of transnational patents. Thus, patent indicators such as share of patents or specialisation indicators such as the Relative Patent Advantage (RPA) are among the most widely used indicators to measure technological advantages. The data for the last available year clearly shows there are marked differences between wind energy technologies on the one hand and photovoltaics on the other. Europe is the leader in the first, but lags behind in the latter.

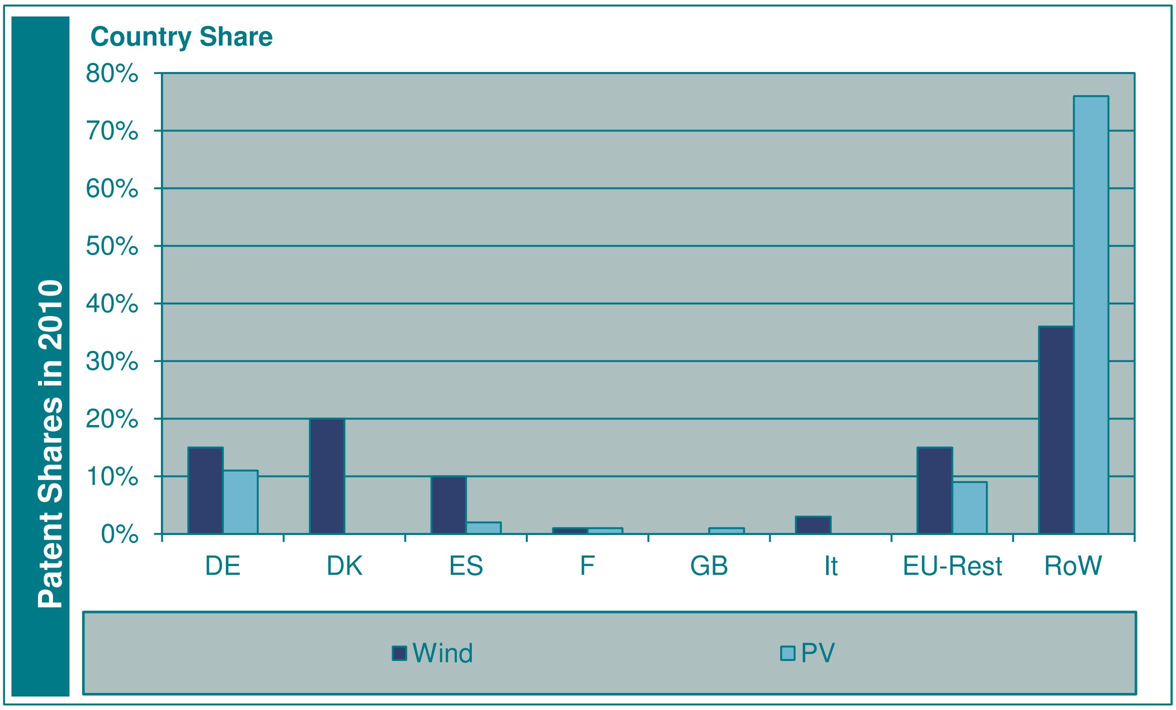

Figure II-5: Shares of EU countries/ regions and the Rest of the World (RoW) in patents in wind energy technologies and PV in 2010

Source: Calculations of Fraunhofer ISI

Regulation which is both innovation-friendly and sets an example for other countries to follow is another important factor (Beise-Zee and Rennings 2005; Walz 2007; Quitzow et al. 2014). This involves different aspects: First, demand depends heavily on the extent to which regulation leads to a correction of market failures such as the externalities of environmental problems (Rennings; 2000). Second, regulation should point the way to further innovations, and should be open to diverse technical solutions, which increases the chance that they fit the preferences of importing countries. Third, national regulation should set the standard for a regulatory regime which other countries are likely to adopt.

The lead market factors differ with regard to the availability of indicators to measure them (Walz and Köhler 2014). Thus, in addition to the assessment of lead market potential based on indicators, it will be necessary to factor in a qualitative dimension based on expert judgement.

III Methodology: concept & method of approach and key assumptions

III.1 Modelling Approach

The quantitative analysis of the macro-economic effects of RES deployment is based on the theoretical framework introduced above. Unlike other instruments such as CO_2 taxation or emission certificates, the effects of RES policies are much more technology-specific. To include these technology-specific aspects in the analysis, the modelling approach must be based on a sound technological analysis of the energy system. Typically, bottom-up approaches are used for this. At the same time, in order to quantify the macro-economic effects such as employment effects and economic growth, the interactions between different markets, different sectors and price effects typically found in macro-economic models also need to be modelled. On top of this, additional analyses of patent and trade data are necessary to account for additional export potential due to the technological competitiveness of EU countries.

Ideally, hybrid models are used comprising an energy sector module that models RET and CET generation under given policies, generates expenditures for the RET industry and final prices for consumers, contains input-output tables, public accounting and national accounts as well as a detailed trade module. However, macro-economic models and energy sector models with detailed RE policy impacts are usually not integrated. In this project, a modelling system consisting of bottom-up and top-down models is applied to quantify the impulses and model the mechanisms. The models are connected through external links so that many of the impulses will be “model”-exogenous. More specifically, impulses are calculated based on a bottom-up analysis in the sector model and used as exogenous input into the macro-economic models to quantify the economic effects.

There are specific challenges associated with entering such impulses as exogenous input to macro-economic models, because this interrupts certain economic cycles or links. For example, the final energy prices for consumers should be linked to the energy sector as revenue, while investments in RET as well as O&M should be linked to the energy sector as expenditures and to other industries or the private sector as revenue so that the remuneration of labour as well as income from/on investments can be redistributed accordingly.

This section describes the modelling framework used for this study. It provides descriptions of the model linkages and explains which impulses are fed into the macro-economic models Astra and Nemesis exogenously and how the missing links between the sectors and the economic models are handled. It also discusses some of the assumptions and simplifications made that deviate from optimal modelling.

The modelling system and phases in the project concept

The main idea is to combine diverse models to reflect the impacts on technologies and the economy as a whole. A static input-output model (MultiReg) is used to calculate the past and present value added of RES activities as well as employment effects. For the calculation of future effects, multiple models are linked: a sector model (Green X) provides future investments and expenditures for RES according to selected RES policies. These data are adjusted for imports and exports to and from the EU (ISI Lead markets tool) and then form the input to the macro models (ASTRA, NEMESIS), which calculate the economic net effects. For the calculation of the economic gross effects, again, the static input-output model (MultiReg) is applied. To fully understand the method as well as the different models and their interdependences in this study, the project's approach is illustrated in Figure C-1 in detail. This should help guide readers through this report. The figure distinguishes between the models (green rectangles) and data sources (grey parallelograms) used for the project. It also shows the inputs and outputs (turquoise rounded rectangles). These include outputs from different data sources which are used as inputs to the models, but also outputs from the models used as inputs to other models.

The project is divided into four main phases resulting in major outputs:

- Phase 1: Assessment of the past and present macro-economic impacts of RET
- Phase 2: Development of future RE deployment scenarios under different policy scenarios
- Phase 3: Transformation of future RE deployment scenarios into impulses for macro-economic modelling
- Phase 4: Modelling of the gross and net macro-economic impacts of future RE deployment

The different phases are described in detail below and the numbers help to follow the sequence of these steps.

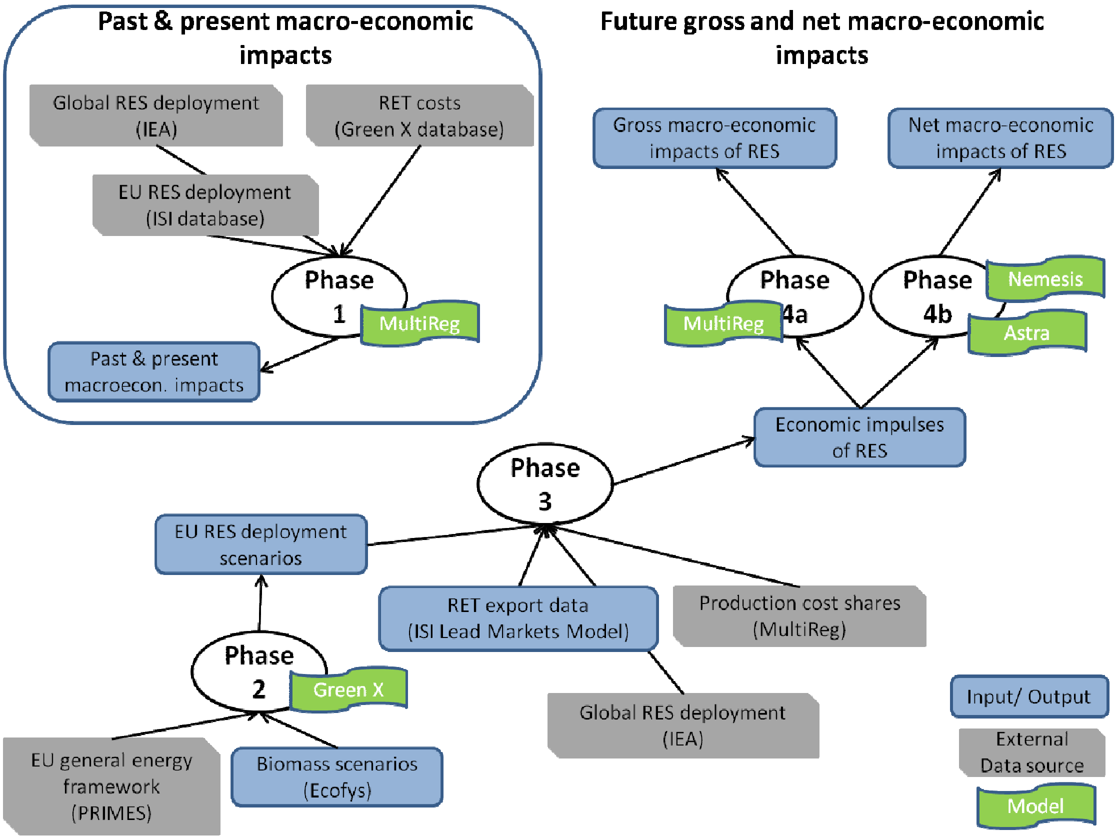

Figure III-1: The overall modelling approach of the project

Phase 1: Past and present macro-economic impacts of RES deployment

In Phase 1, the gross economic and employment impacts of past and present RES deployment are calculated. They highlight the economic significance of the RES industry including its supplying industries. The analysis is based on the MultiReg model, a static input-output model.

Figures on past and present RES deployment (i.e. capacity and production) and cost data are a major input for the analysis. Figures on RES deployment in the EU are taken from the ISI RES database which is based on data from Eurostat and EurObserver. In addition, global deployment data are taken from the IEA to calculate figures for the Rest of the World (RoW). All the data are technology- and country-specific. Where necessary, capacity data were estimated from production data by applying country and technology-specific full-load hours from the Green X database and calculating the average growth rates between 2005 and 2012. Technology-specific cost data on investments as well as operation and maintenance costs (O&M) and fuel costs are taken from the Green X database.

Techno-economic coefficients are needed as input to the MultiReg model that transforms the historical development of expenditures for a specific RET in a specific country into demand for products from different economic sectors. In order to be able to calculate these techno-economic coefficients, the past deployment and cost data from the Green-X database are complemented by the following data obtained via desk research and expert interviews:

- cost structures of investments in the various RET, as well as of operation and maintenance costs and fuel supply,
- information on the regional supply patterns of cost components, especially the market shares of technology suppliers.

The starting point is given by data from the Green X model on the specific costs per capacity or energy output unit for each year, country and RES technology.

For each technology the investment costs, O&M costs and fuel costs are divided into cost components that reflect the economic activities or goods and services needed for the installation and operation of facilities (e.g. planning, manufacturing of the core technology, transportation and on-site installation) or that reflect the different cost components of goods (e.g. the producer’s share, the transport and trade share in the purchaser’s price of wood pellets). The cost structures of the various RES technologies are derived from existing cost studies, other technical literature and expert judgements. In the next step, the production of each technology’s cost components is allocated to the corresponding economic sector according to the sector classification used in the macro-economic models. The result of this procedure is - for each RES technology - a vector of production by economic sector and by country, which serves as input to the economic models.

The MultiReg model – a static multi-country, input-output model - is used to calculate the direct and indirect economic and employment impacts of historical RES deployment.

Information from the MultiReg database is also used in Phase 3 for the transformation of Green X outputs on RET level and macro-model inputs on the sectoral level. This ensures methodological comparability between the results of the historical and of the future gross effects.

Phase 2: Future renewable energy deployment scenarios

Scenarios of future RES deployment are derived using the Green X model, a simulation model for energy policy instruments that has been successfully applied in this context in projects such as FORRES 2020, OPTRES and PROGRESS. Besides the applied support schemes for RES, important data input for Green X include the general energy framework conditions such as future energy demand and energy prices. Assumptions about the general energy framework conditions are harmonised with the European Commission's views of future energy development based on official EU impact assessment data for the 2030 energy and climate framework from the PRIMES model. Based on these general assumptions, five main scenarios were calculated for the future development of renewable energy sources in the EU-28 until 2050.

The RES scenarios contain – among others – information on:

- RES deployment by technology, country and year
- Investment costs for RES deployment by technology, country and year
- O&M costs for RES deployment by technology, country and year

The results of this modelling step serve as the main input to Phase 4 of this project.

Phase 3: Translation of future RES scenarios into impulses for the macro-economic models

In order to account for the relevant economic mechanisms (as described in chapter B) in the macro-economic modelling, the future RE scenarios developed in Phase 2 need to be translated into impulses for the macro-economic modelling. This point is crucial, because the impulses and how they are implemented in the macro-models determine the results to a large extent. The following information from the future RE scenarios are translated into impulses for the macro-economic models (see Figure III-2):

- Different investment impulses are calculated:
  - Sector-specific domestic investment due to RET based on investments in RET
  - Sector-specific avoided domestic investments for CET based on installed RET capacities and CET cost information
  - Sector-specific investments from exports for RET based on installed RET capacities, technology cost information and trade scenarios
- Two types of impulses are calculated for O&M costs:
  - Sector-specific O&M costs for RET based on installed capacities
  - Avoided O&M costs for CET based on installed RET capacities
- Impulses for fuel expenditures include:
  - Fuel expenditures for biofuels based on RES generation
  - Avoided fossil fuel expenditures due to RES generation
- Consumer price changes are calculated as follows:
  - Consumer price changes for heat and biofuels based on generation and additional generation costs for RET

  - Electricity price changes based on generation and policy support costs differentiated by consumers in order to account for the recuperation of RET support costs and reduced levies for industries
- Profit margins from support instruments for renewable electricity generation:
  - Profit margins in order to account for the profits from investments in renewable electricity generation for households

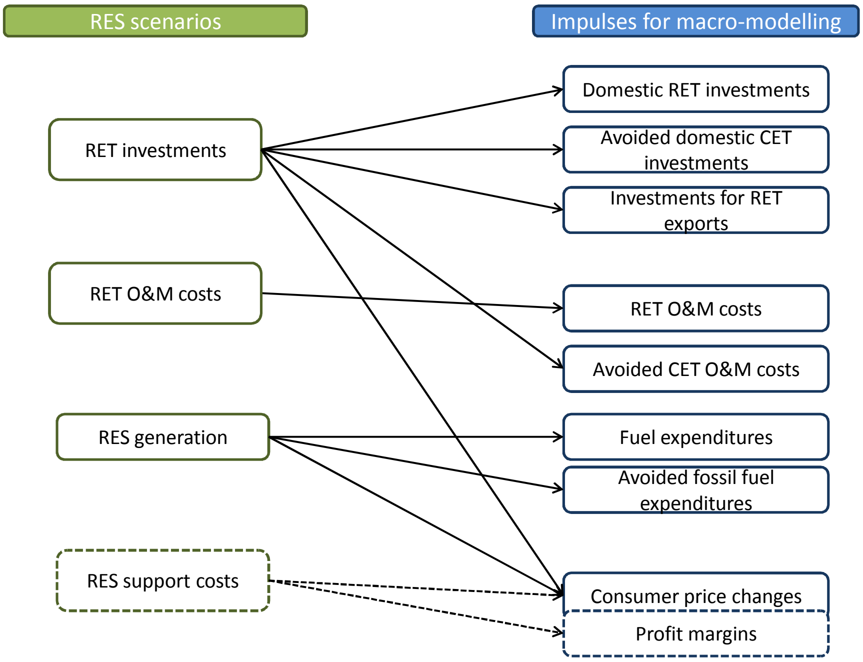

Figure III-2: Definition of impulses for the macro-economic models from RES scenarios

Further data processing is needed in two cases to extract impulses for the macro-economic modelling from the future RE scenarios: (i) calculation of domestic and export investment impulses and (ii) calculation of consumer price changes.

Calculation of domestic and export investment impulses

To determine the macro-economic effects from additional RET investments on the national level, additional investment per RE technology and country is further distributed to the different economic sectors. In addition, export shares are used to account for important trade relations. Based on estimates of the development of exports from the Rest of the World, these exports develop dynamically over time. For the conversion, a two-step approach is used (see Figure III-3). First, the investment for each RET is broken down into its main (cost) components. Second, investments for each cost component are further split up into investments into economic sectors. Data for the breakdown are taken from the MultiReg database (see also Phase 1).

To account for important import and export structures, two different kinds of cost components are distinguished: global and local cost components that represent the origin of the goods and services related to the cost components. A cost component classified as "local" is mainly supplied by the country of installation, taking the average inter-country trade into account. For a cost component classified as "global" (e.g. key components of wind turbines or solar cells) the specific distribution of supplying countries can be determined. Therefore, for global cost components, investment demand from all countries is aggregated into global investment demand. Global investment demand is met by global investment supply. Individual countries' shares in global investment supply are determined by the ISI lead markets tool (see Appendix). In cases where technology-specific market shares of suppliers are not available, we use proxies of related economic sectors (e.g. the machinery sector) or adaptations based on experts' opinions. Based on these shares, each country's domestic investment supply of global cost components is calculated.

In contrast to global cost components, the import and export shares for local cost components are not specifically calculated. Instead, investments in local cost components are further split up into different economic sectors. The export and import shares of these economic sector investments are determined in the macro-economic models themselves based on the average trade pattern of the respective economic sectors. The approach is depicted in Figure III-4.

A similar approach is used to calculate impulses for avoided conventional investments.

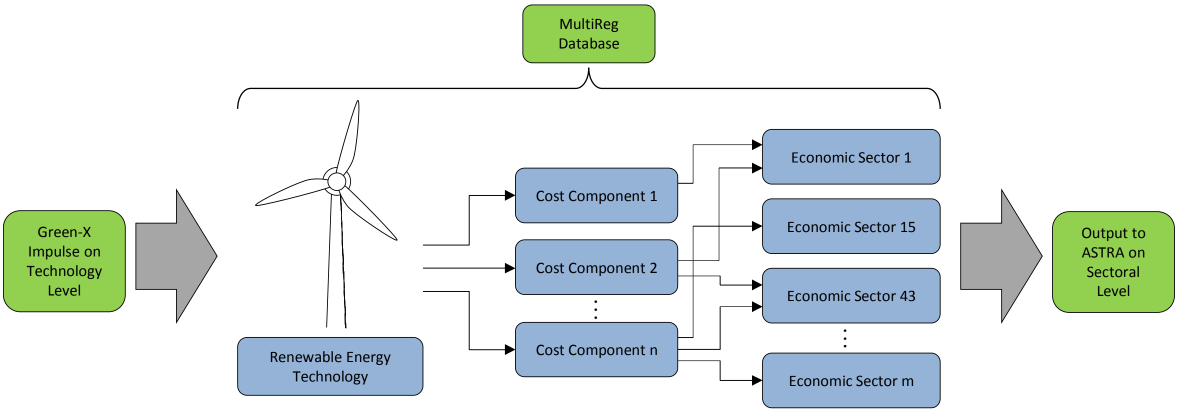

Figure III-3: Impulse transformation from Green X to ASTRA

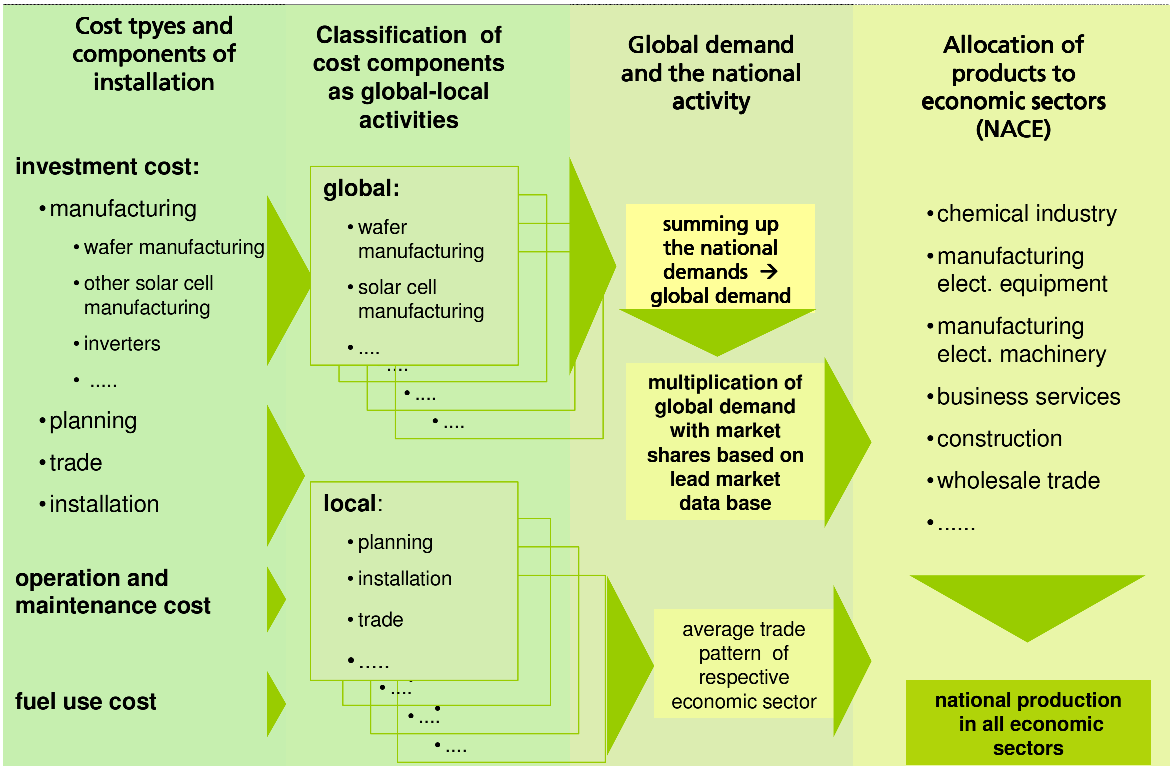

Figure III-4: Overview and example of the classification and calculation of national investments of solar energy

Calculation of consumer price changes and profit margins for renewable electricity investments

Financing RES support policies is levy-based, i.e. support costs are charged to consumers via the electricity, heat and biofuel prices. At the same time, it is assumed that profits from RES investments also go to households, i.e. we model a decentralized RES investment structure. Government budgets are not affected. Essentially, two different approaches are applied to calculate the price changes due to RET deployment. For heat and biofuels, price changes are calculated based on additional generation costs. This approach assumes that consumers only have to pay for the additional generation costs. Also, for heat and biofuels, differences between consumer groups are neglected, i.e. all consumers face the same absolute price increases.

In contrast, in the case of electricity, consumer price changes are calculated based on support policy costs. Support policy costs are higher than the additional generation costs and hence result in higher price increases. At the same time, the difference between the support policy costs and the additional generation costs creates a producer surplus. This producer surplus is returned to the households.

Electricity prices are also further differentiated by user groups. Certain industries are exempted or pay a reduced premium in many countries, so we assume that industry only pays 20% of the overall price increase[7] due to support policy costs. Households and the service sector have to cover the remaining costs for the electricity used, resulting in even higher electricity price increases for them.

The support policy costs required for each RET decrease over time, resulting in a decrease in support costs and hence smaller effects on consumer prices in the long run. However, as support costs are charged over a time period of 20 years, the prices react with a time lag.

Phase 4: Future gross and net economic impacts of RES

The total gross value added and employment related to the future deployment and use of renewable energy (also termed gross effects in this study) were estimated with the multinational input-output model MultiReg. The approach is similar to the one used for estimating the past and present value added and employment (see Phase 1). The calculations include the following steps:

- The starting points for each of the considered scenarios were the calculation of the demand for "local" cost components of investment expenditures, production of "global" cost components of investment expenditures in PV and wind technology, production of goods and services for the operation and maintenance of RES facilities and for the supply of biomass fuels. These data are available by RES technology, country and supplying industry. They stem from the calculations described in Phase 3. Production values of goods for biomass technologies in Eastern Europe were adjusted to reflect the lower level of labour productivity in these countries. Demand for "local" cost components was transformed into production by the supplying countries using average sectoral import shares from the MultiReg model.
- These production values were used as input to MultiReg to calculate the direct value added and employment in the respective industries as well as the indirect value added and employment in the supplying industries. To account for labour productivity improvements when calculating employment impacts, productivity growth rates to 2030 and 2050 were integrated into MultiReg from the ASTRA model.
- The results of these calculations include direct and total gross value added and employment, for each scenario by RES technology, country and supplying industry in the years 2030 and 2050.

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[7] Under the state aid guidelines for environmental protection and energy the European Commission decided that it will "consider the aid to be proportionate if the aid beneficiaries pay at least 15% of the additional costs without reduction (EC, 2014). The 20% chosen for the modelling is based on this Commission decision.

Phase 4b: Future net macro-economic impacts of RES

In Phase 4b, the full macro-economic modelling of the future economic and employment net impacts of RES is done using two well-established macro-economic modelling tools NEMESIS and ASTRA. Both tools are real-world models that account for a broad spectrum of economic impulses of energy policy measures. A crucial point is that both are able to integrate the impulses from additional exports. Moreover, both of them are calibrated on the same baseline and use similar impulses from Phase 3. Thus, both can be used to model the RET deployment effects in this project.

In particular, employment and economic growth are mapped in detail in both models. Sectoral employment is estimated endogenously considering wages, productivity and unemployment. In the NEMESIS model, wages react to policy measures and prices and sectoral employment changes together with changes of value added. IN ASTRA, the level of unemployment influences sectoral labour productivity, i.e. low unemployment rates drive improvements of labour productivity, while high unemployment rates slow down the progress of productivity. Sectoral productivity together with value added then determine the level of employment in each sector. The changes in value added in both models are driven by the total impacts of renewable policies, i.e. price increases, investment changes, changes in O&M costs and avoided fossil fuel imports and their sectoral repercussions through the input-output models of NEMESIS and ASTRA.

In general, RES investments are assumed to be funded by private investors (i.e. households) via loans. The revenues from the support schemes are used by the private investors to pay back their loans. Any remaining profits increase the household incomes.

Using both models, NEMESIS and ASTRA, has the main advantage of providing more reliable results than can be obtained from one model alone. This is reflected in the model philosophy behind the two models: The econometric NEMESIS model attaches a higher weight to neo-Keynesian effects. The ASTRA model integrates neoclassical production functions with the effects of changing structural demand. It uses system dynamics and thus can also incorporate non-linear effects from evolutionary economics. Thus, the differences in results between the models can be used as a sensitivity analysis to show the effect of emphasizing different economic mechanisms.

In addition, the parallel use of two models also has technical modelling advantages:

- Detailed cross-checking of results at different stages of the modelling exercise
- Making use of the model-specific representation of energy-related sectors: NEMESIS features a more detailed sectoral structure for the energy system; ASTRA a more detailed representation of the implications of RES-transportation technologies

- Filling in gaps in one model with results from the other (e.g. Croatia is only included in NEMESIS)
- Benefitting from past experience and the existing links between Green X and ASTRA on the one hand and the link between NEMESIS and technological bottom-up data provided by ISI from previous EU projects on the other hand

Despite these advantages, the differences between the two models still lead to differences in how the impulses from the RES scenarios are implemented.

Modelling in ASTRA-EC

The integrated assessment model ASTRA-EC is based on the System Dynamics methodology and has a modular structure. The modules represent individual systems which are connected by functional cause-and-effect relationships, including feedback loops. For Employ-RES II, micro-macro bridges have been built to connect the Green X / MultiReg inputs with the directly affected systems in ASTRA-EC (economy, trade and transport). The inputs from Green X / MultiReg are:

- RES investment and avoided conventional investment,
- RET exports and imports,
- Energy price changes due to RES deployment,
- RES O&M costs and avoided O&M costs for CET
- Avoided fossil fuels due to RES deployment,
- Additional domestic biomass production and biomass imports.

Figure III-5 depicts how these inputs enter the economy, trade and transport modules, where they directly influence the variables in the light grey boxes. For instance, energy price changes directly affect household consumption as well as the exchange of intermediate goods between production sectors. The altered exchange of intermediate goods has secondary effects on household consumption through the links between the modules and their individual components. Finally, fuel prices also have an effect on that part of consumption which is attributable to transport. Since ASTRA-EC has a detailed transport modelling capability, this effect is examined separately. Together, these effects trigger developments in other parts of the model. A more detailed description of ASTRA-EC and the propagation of impulses from the bottom-up inputs is provided in the appendix.

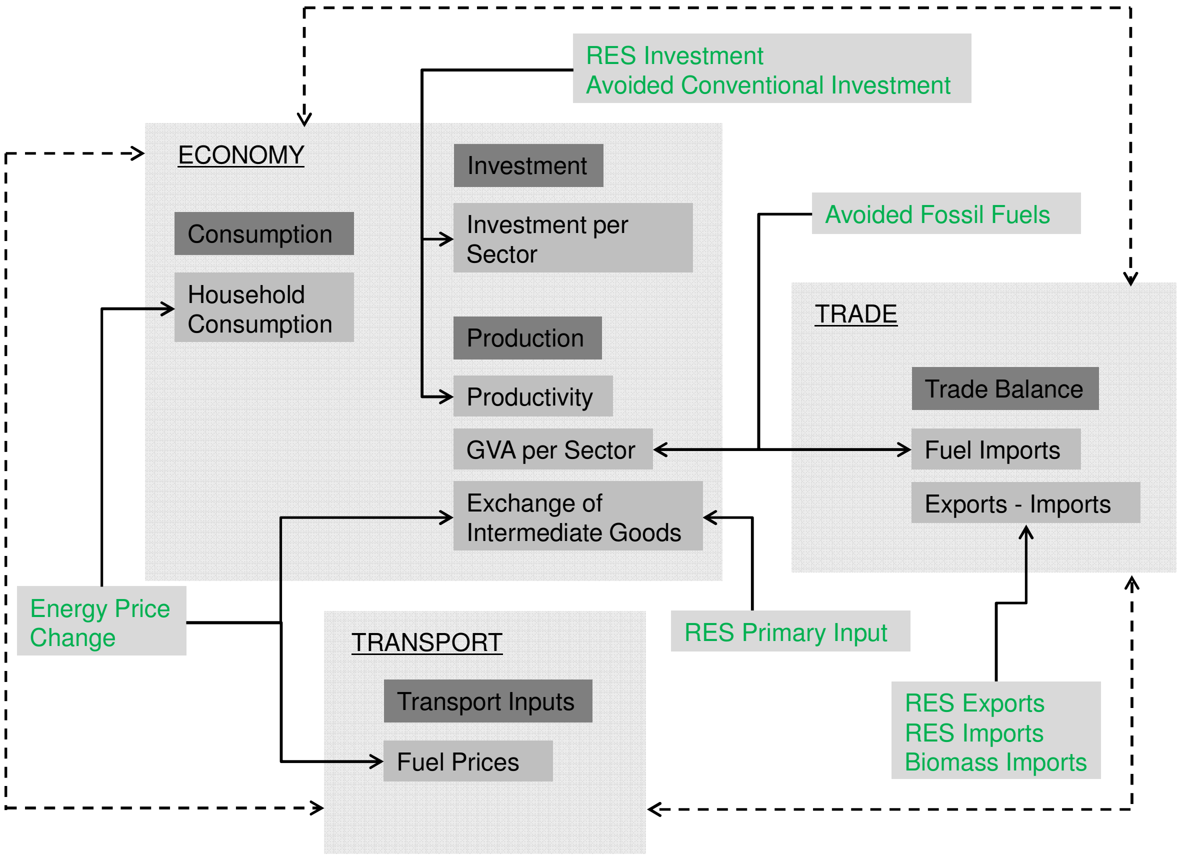

Figure III-5: Green X / MultiReg Inputs (green) into ASTRA-EC Modules (black)

Modelling in NEMESIS

The output of the Green X and MultiReg models used in the NEMESIS model features five main types of variables: investments, intermediate consumption, international trade, energy prices and profit margins from renewable electricity investments. For investments and intermediate consumption this can be either new expenditures due to RES developments or avoided expenditures due to the abandonment of other technologies.

In order to understand how these inputs were introduced into the NEMESIS model, it is important to first show how these variables are integrated in the state of the art of the NEMESIS model, particularly regarding investment and intermediate consumption demands.

State of the art of sectoral demands in NEMESIS

The domestic demand of a country is defined as the sum of the different national demand types (see Figure III-6): households' final consumption, firms' investments, intermediate consumption and government consumption.

For each sector, the main activity variable is the total demand in the considered sector. The demand in sector s is divided into two parts, domestic demand and net exports (exports minus imports). This total demand equals the output of sector s. Sectoral exports depend on the demands of other countries and relative prices, while imports follow the evolution of the country's national domestic demands and relative prices.

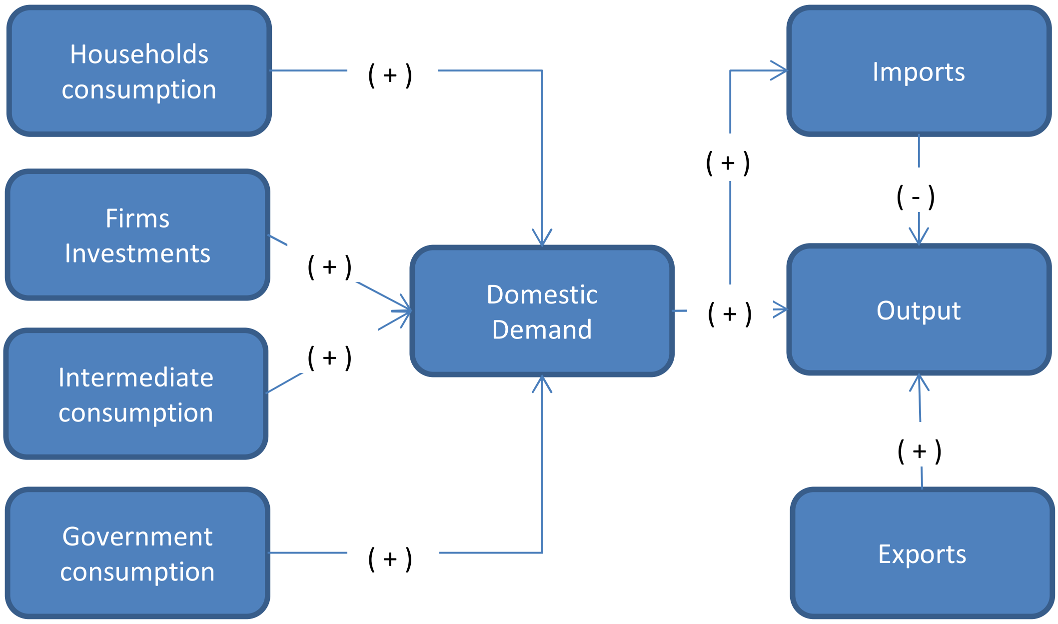

Figure III-6: State of the art of demands in NEMESIS

In order to integrate the impulses from Phase 3, some modifications are made to this system. To understand the modifications, it is important to realise that there are differences in the investment impulses that are incorporated differently in the NEMESIS model:

- For "global cost components", Phase 3 provides the share of investment produced domestically and the share of investment imported from other countries
- For "local cost components", Phase 3 provides each country's investment demand, but this is not further differentiated

The two types are implemented differently in the NEMESIS model. For the second case, the model has to allocate the net investment demand to national products and imported products, while in the first case the model takes this allocation as inputs. The treatment of intermediate consumption demands (such as O&M costs or avoided O&M costs and intermediate consumption for energy production) will be the same as for local components.

The treatment of intermediate consumption and demand for “local cost components”

The demand for intermediate consumption and for “local cost components” is introduced in the model in the same manner. Net demands (new demands related to RES technologies minus avoided demands related to conventional technologies) are added to the domestic demands. The allocation to national products or imported (and exported) ones is endogenously determined by the model itself (see Figure III-7). Thus, ceteris paribus, the imported share of these demands will be the same as the one in the model.

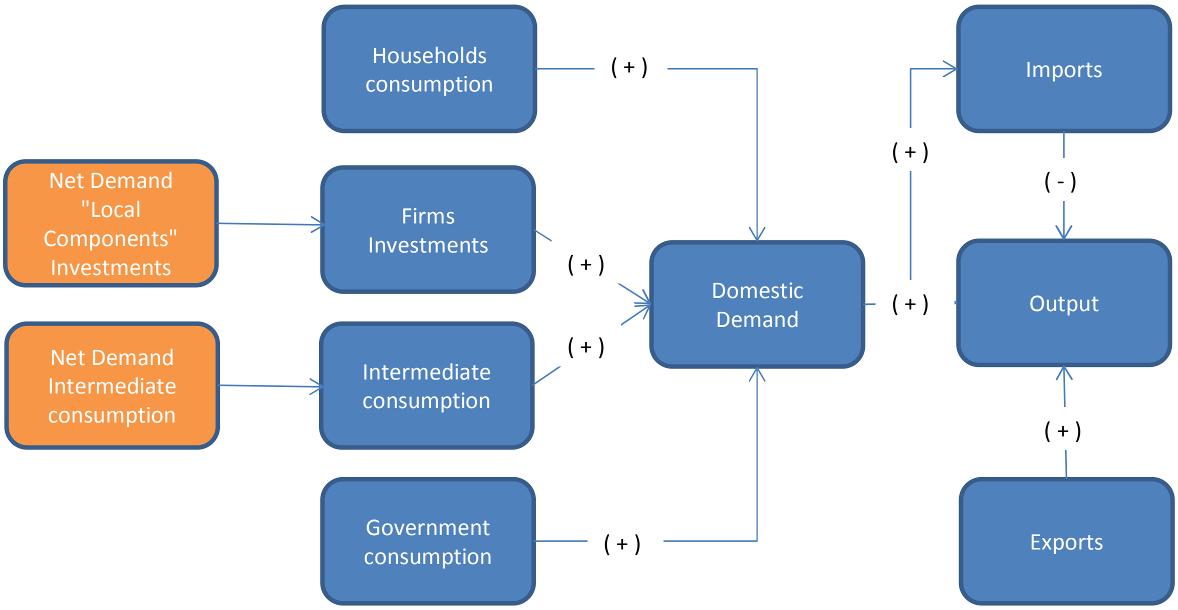

Figure III-7: Integration of intermediate consumption and "local cost components"

The treatment of the demand for “global cost components”

“Global cost components” should be treated differently insomuch as impulses taken from Phase 3 distinguish the amount of investment produced nationally, imported and exported. As a consequence, four new variables are added to the model:

- Total net global investment to be added to domestic investment
- Nationally produced global investment to be added to output
- Imported global investment to be added to imports
- Exported global investment to be added to exports

However, adding these four variables directly to the NEMESIS model would create double accounting. Indeed, net investment will increase domestic demand, but domestic demand affects both national output and imports. Hence, adding the specific allocation of RES investments (imported, exported and national) would cumulate the natural behaviour of the model in the allocation between national and imported products and the allocation received as inputs. To correct this, the net investment demand of “global components” should not be integrated in domestic demand. Therefore, the variables are modified as follows (see Figure III-8):

- Net investments are added to the demand for investment in order to have the correct GDP contributions.
- Net investments are subtracted from total domestic demand in order to avoid double counting.
- Finally, net demand nationally produced, imported and exported is added to national output, imports and exports respectively.

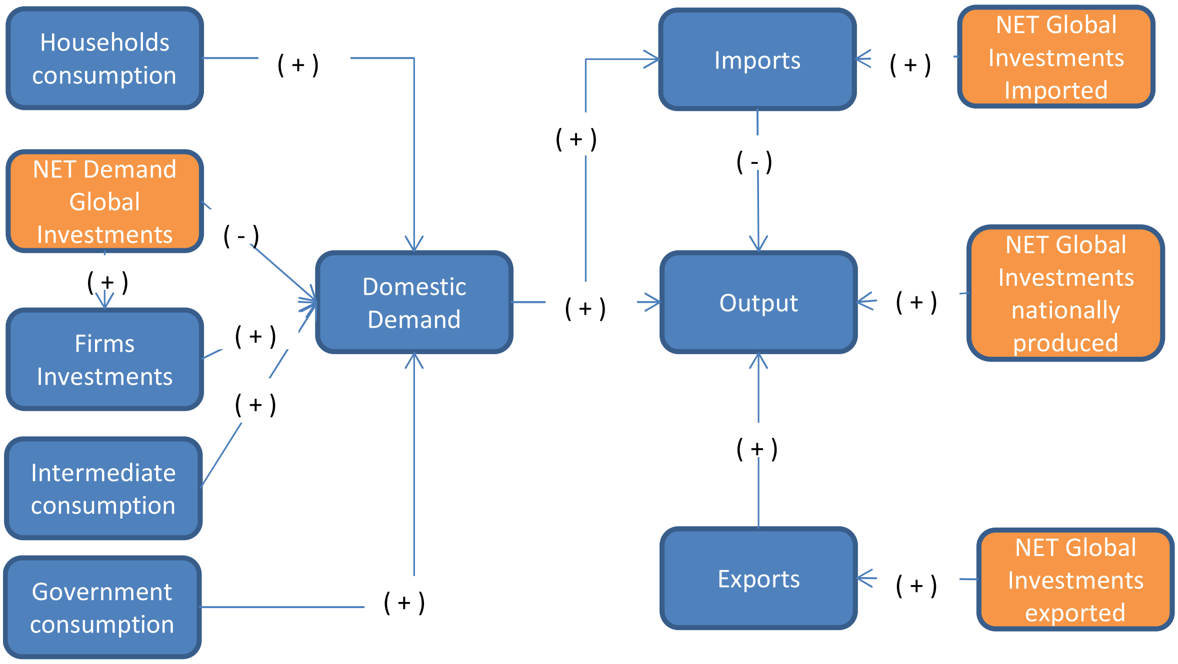

Figure III-8 : Integration of demand for “global cost components”

The effects of RET deployment on energy prices is introduced to the baseline scenario as a slack variable.

III.2 Scenario definition and key assumptions

The core objective of this working task is to provide a detailed depiction of the scenarios analysed within the project. The scenarios consist of three parts:

- the future RES opportunities up to 2050 within the European Union, considering deployment of RES technologies in EU Member States under different RES policy assumptions (see Section III.2.1),

- the assumed corresponding global RES deployment – i.e. more precisely the exploitation of RES technologies in the rest of the world (ROW) – (see Section III.2.2) and
- the related export opportunities for European economies (see Section III.2.3).

III.2.1 Scenarios of future renewable energy deployment in the EU

Specifics and constraints of the model-based policy analysis (Green-X modelling)

- ► Time horizon: 2010 to 2050 – Results are derived on an annual basis
- ► Geographical coverage: all Member States of the EU as of 2013 (EU 28)
- ► Technology coverage: all RES technologies for power and heating and cooling generation as well biofuel production. The (conventional) reference energy system is based on PRIMES modelling on behalf of the EC
- ► Energy demand and prices: baseline demand and price forecasts are taken from the recent Impact Assessment accompanying the Communication from the European Commission “A policy framework for climate and energy in the period from 2020 to 2030” (COM(2014) 15 final)
- ► Reference prices and market values: Sector- and country-specific reference prices are derived in accordance with the general energy scenarios used as overall demand and price references, complemented by market values for variable RES-E technologies to incorporate their specifics in an adequate manner
- ► RES imports to the EU: generally limited to biofuels and forestry biomass meeting the sustainability criteria – moreover, physical imports of RES electricity are also considered an option for RES target fulfilment that mainly becomes viable in the period post 2020.

The overall constraints and specifics of the model-based assessment of future RES deployment within the European Union are briefly summarised above. Complementary to that, before discussing the results, an overview is given below of the investigated scenario paths and cases as well as key assumptions.

Scenario definition

Different scenarios have been defined for the deployment and support of RES technologies in the EU. Obviously, the RES policy pathway for the years up to 2020 appears well defined given the EU RES directive 2009/28/EC and the corresponding national 2020 RES targets and accompanying National Renewable Energy Action Plans for the period up to then. Exploring RES development beyond 2020, however, means entering terrain characterized by a higher level of uncertainty – both with respect to the policy pathway and with regard to the potentials and costs of applicable RES technology options.

In its communication "A policy framework for climate and energy in the period from 2020 to 2030" (COM(2014) 15 final) in January 2014, the European Commission proposed targets for 2030 of reducing greenhouse gas emissions by 40% and achieving a 27% share of renewable energy in final consumption. In the accompanying impact assessment (SWD(2014) 15), further scenarios were analysed with respect to RES deployment and climate mitigation, characterised by RES shares of 30% and 35% by 2030, respectively. Thus, the scenarios defined for this study are closely aligned to these impact assessment scenarios.[8] The table below summarises the general settings of all scenarios assessed, indicating the policy concept and the ambition level with respect to renewable energy, energy efficiency and GHG emission reduction for 2030 and 2050, respectively.

The scenarios analysed combine two different characteristics: different ambition levels for RES deployment in 2030 in particular and different support policies for renewables from 2020 onwards. With respect to the underlying policy concepts the following assumptions are taken:

- In the "Strengthened National Policies (SNP)" scenarios, a continuation of the current policy framework with national RES targets (for 2030 and beyond) is assumed. Each country uses national (in most cases technology-specific) support schemes in the electricity sector to meet its own target, complemented by RES cooperation between Member States (and with the EU's neighbors) in the case of insufficient or comparatively expensive domestic renewable sources. In the SNP scenarios support levels are generally based on technology specific generation costs per country.
- In the case of the quota system, an EU-wide harmonized support scheme is assumed for the electricity sector that does not differentiate between different technologies. In this case the marginal technology to meet the EU RES-target sets the price for the overall portfolio of RES technologies in the electricity sector. The policy costs occurring in the quota system can be calculated as the certificate price multiplied by the RES generation under the quota system. These costs are then distributed in a harmonized way across the EU so that each type of consumer pays the same (virtual) surcharge per unit of electricity consumed.[9]

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[8] At the time of defining the scenario scope, the EU proposal of a 27% target for renewables by 2030 was not yet publicly available.

[9] In the same way as assumed for other support schemes the contribution of industry consumers will be limited to 20% of the relative levy and the remaining amount will be distributed among households and services.

Table III-1: Overview of Green-X scenarios

Scenario Name	Description	
Baseline scenario - reference demand	Continuation of current RES policies and achievement of the 2020 targets but no new targets for 2030 in line with the PRIMES reference scenario (i.e. gradual phase-out of RES support beyond 2020). Future demand development & CO_2 prices: PRIMES reference case (EC, 2013)	
Baseline scenario*	Continuation of current RES policies and achievement of the 2020 targets but no new targets for 2030 in line with the PRIMES reference scenario (i.e. gradual phase-out of RES support beyond 2020) Future demand development & CO_2 prices: Energy efficiency trend – i.e. 33% demand reduction (in accordance with policy cases) and a CO2 price in line with the PRIMES high efficiency scenario (GHG45EERES35)	
Policy case 1a (30% SNP)	Continuation of the current policy framework for RES beyond 2020 ("*Strengthened National Policies*")	2030: 30% RES target[10] (GHG: -40%) 2050: about 59% RES (EE: -33%)
Policy case 1b (30% QUO)	EU green certificate scheme for RES-E beyond 2020 ("*Harmonized Quota Scheme*")	
Policy case 2a (35% SNP)	Continuation of the current policy framework for RES beyond 2020 ("*Strengthened National Policies*")	2030: 35% RES target (GHG: -45%) 2050: about 62% RES (EE: -34%)
Policy case 2b (35% QUO)	EU green certificate scheme for RES-E beyond 2020 ("*Harmonized Quota Scheme*")	

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[10] At the time of definition of the scenarios, the EU proposal of a 27% target for renewables was not yet publicly available. Consequently, as moderate 2030 RES target a 30% (as RES share in gross final energy demand) was assumed.

Absolute RES deployment for 30% RES and 33.7% EE is very similar to 27% RES and 27% EE. Translated into a 27% EE-case the absolute RES figures analysed in this study correspond to RES-E shares of 23.9% for the baseline, 27.2% for the SNP/QUD-30, 31.8% for the SNP/QUD-35.

Note: * This case serves as a default baseline scenario for macro-economic modelling. Comparing scenarios with differing energy demand as done in this study can be misleading as it takes other differences into account such as differences in total generation capacity or changes in avoided fossil fuels as a result of energy efficiency measures.

Overview of key parameters[11]

In order to ensure maximum consistency with the existing EU scenarios and projections, the key input parameters of the scenarios presented in this report are derived from PRIMES modelling and the Green X database with respect to the potentials and costs of RES technologies (see Section B.2). Table III-2 shows which parameters are based on PRIMES and which have been defined for this study.

Table III-2: Main input sources for scenario parameters

Based on PRIMES	Defined for this study
Energy demand by sector	RES policy framework
Primary energy prices	Reference electricity prices
Conventional supply portfolio and conversion efficiencies	RES cost (*Green* X database, incl. biomass)
CO_2 intensity of sectors	RES potential (*Green* X database)
	Biomass trade specification
	Technology diffusion
	Learning rates

More precisely, the PRIMES scenarios used are:

- The latest reference case (EC, 2013)
- A climate mitigation scenario aiming at a 40% GHG reduction by 2030, assuming a 30% RES target by 2030 accompanied by (strong) energy efficiency measures to reduce demand growth (i.e. 33% reduction compared to reference by 2050).
- A climate mitigation scenario aiming at a 45% GHG reduction by 2030, assuming a 35% RES target by 2030 accompanied by (strong) energy efficiency measures to reduce demand growth (i.e. 34% reduction compared to reference by 2050).

Note that all scenarios have been developed for and are discussed in the Impact Assessment accompanying the Communication from the European Commission “A policy framework for climate and energy in the period from 2020 to 2030” (COM(2014) 15 final).

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[11] Please note that assumed RES potentials and costs are thoroughly discussed in Section B.1 of the Appendix to this report and consequently omitted in the subsequent description in this section.

Energy demand

Figure III-9 depicts the projected energy demand development at EU 28 level according to different PRIMES scenarios with regard to gross final energy demand (right) as well as gross electricity demand (left).

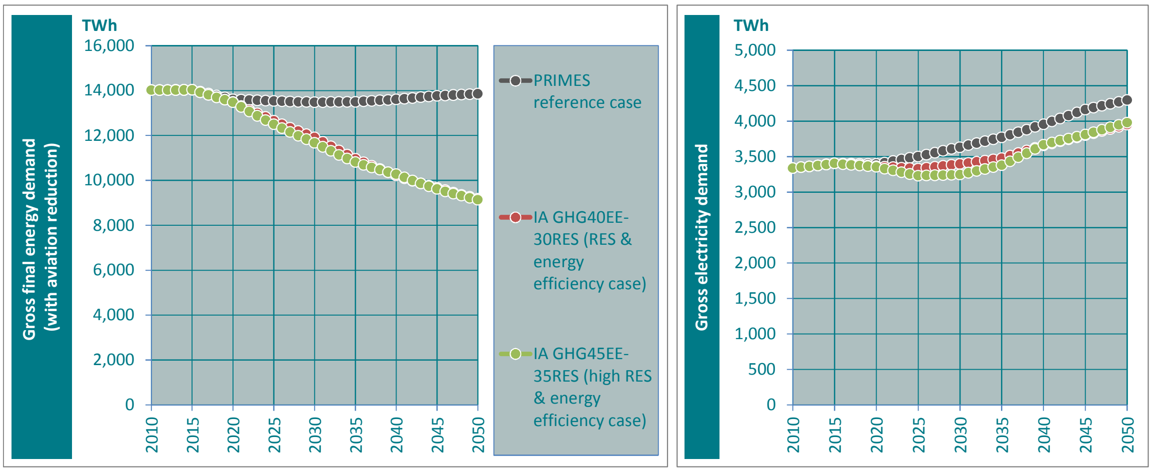

Figure III-9: Comparison of projected energy demand development at EU 28 level – gross electricity demand (left) and gross final energy demand (right). (Source: PRIMES scenarios)

A comparison of the different PRIMES demand projections at EU 28 levels shows the following trends: The *PRIMES reference case* as of 2013 (EC, 2013) draws a modified picture of future demand patterns compared to previous baseline and reference cases. The impacts of the global financial crisis are reflected, leading to a reduction of overall gross final energy demand in the short term, and moderate growth in later years towards 2020. Beyond 2020, according to the *PRIMES reference case* (where the achievement of climate and RES targets for 2020 is assumed) gross final energy demand is expected to stagnate and then moderately decrease. The decrease of gross final energy demand is even more pronounced in the other PRIMES cases where in addition to short-term (2020) also long-term (2050) EU climate targets have to be met. In these cases, policy measures supporting RES and energy efficiency were assumed to accompany purely climate policies (i.e. the ETS) – and both are regarded as key options for mitigating climate change.

For the electricity sector, demand growth is generally more pronounced. The distinct PRIMES cases follow a similar pattern and differences between them are moderate – i.e. all cases expect electricity consumption to rise strongly in later years because of cross-sectoral substitutions: electricity is expected to make a stronger contribution to meeting the demand for heat in the future, and similar substitution effects are assumed for the transport sector as well.

Conventional supply portfolio

The conventional supply portfolio, i.e. the share of the different conventional conversion technologies in each sector, is based on PRIMES forecasts on a country-specific basis. These projections of the portfolio of conventional technologies particularly influence the calculations done within this study on the avoidance of fossil fuels and related CO_2 emissions. As it is beyond the scope of this study to analyse in detail which conventional power plants would actually be replaced, for instance, by a wind farm installed in the year 2023 in a certain country (i.e. either a less efficient existing coal-fired plant or possibly a new highly-efficient combined cycle gas turbine), the following assumptions are made:

- Bearing in mind that fossil energy represents the marginal generation option that determines the prices on energy markets, it was decided to stick to the sector-specific conventional supply portfolio projections on a country level provided by PRIMES. Sector- as well as country-specific conversion efficiencies derived on a yearly basis are used to calculate the amount of avoided primary energy based on the renewable generation figures obtained. Assuming that the fuel mix is unaffected, avoidance can be expressed in units of coal or gas replaced.
- A similar approach is chosen with regard to the avoidance of CO_2 emissions, where the basis is the fossil-based conventional supply portfolio and its average country- and sector-specific CO_2 intensities that may change over time.

In the following, the derived data on aggregated conventional conversion efficiencies and the CO_2 intensities characterising the conventional reference system (excl. nuclear energy) are presented.

Figure III-10 shows the dynamic development of the average conversion efficiencies as projected by PRIMES for conventional electricity generation as well as for grid-connected heat production. Conversion efficiencies are shown for the PRIMES reference scenario (EC, 2013). Error bars indicate the range of country-specific average efficiencies among EU Member States. For the transport sector, where efficiencies are not explicitly expressed in PRIMES' results, the average efficiency of the refinery process used to derive fossil diesel and gasoline was assumed to be 95%.

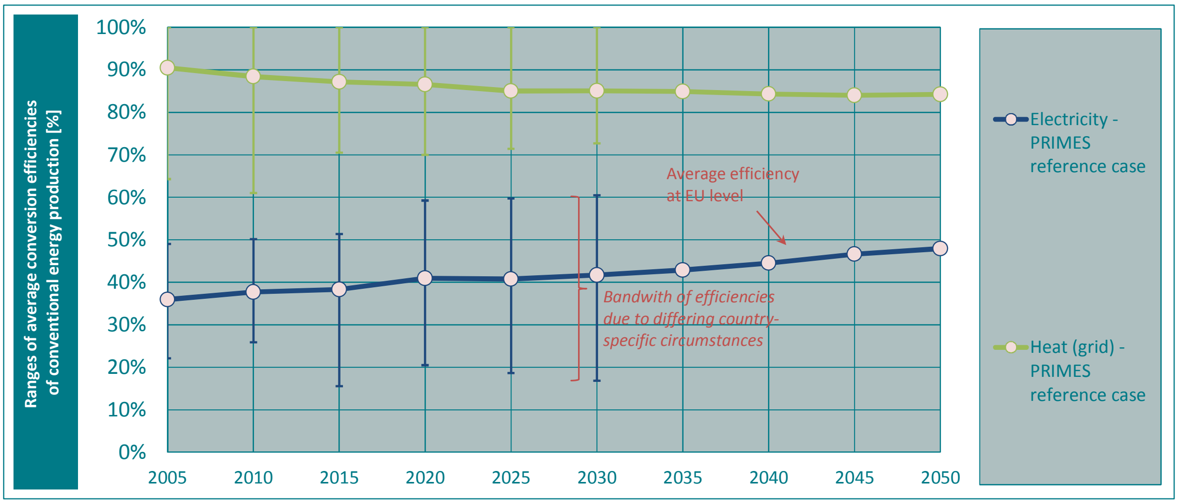

Figure III-10: Country-specific average conversion efficiencies of conventional (fossil-based) electricity and grid-connected heat production in the EU28

Source: PRIMES scenarios

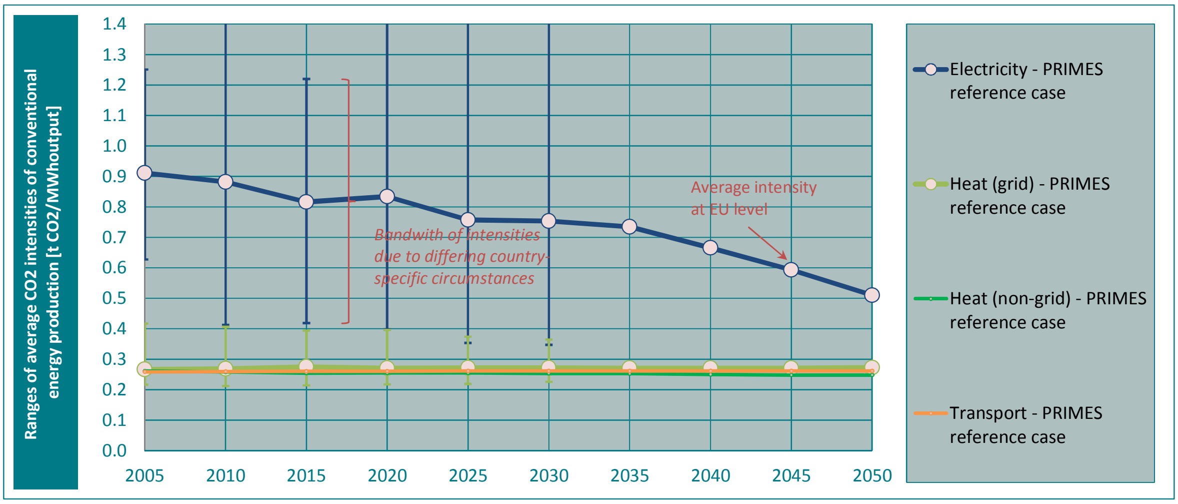

Figure III-11: Country-specific average sectoral CO2 intensities of the conventional (fossil-based) energy system in the EU28.

Source: PRIMES scenarios

The corresponding data on country- and sector-specific CO_2 intensities of the conventional energy conversion system according to the PRIMES reference scenario are shown in Figure III-11. Error bars again illustrate the variation across countries.

Fossil fuel and carbon prices

The country- and sector-specific reference energy prices used in this analysis are based on the primary energy price assumptions applied in the PRIMES scenarios as used for the Impact Assessment accompanying the Communication from the European Commission "A policy framework for climate and energy in the period from 2020 to 2030" (COM(2014) 15 final). As shown in Figure III-12, generally only one price trend is considered – i.e. a default case of moderate energy prices that reflects the price trends of the *PRIMES reference case*. Compared to the energy prices as observed in 2011, all the price assumptions appear comparatively low, even for the later years up to 2050.

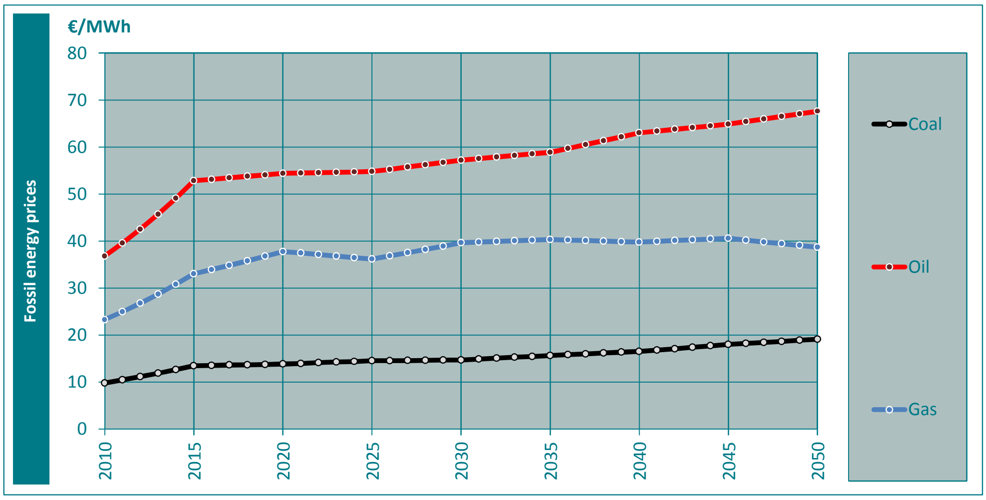

Figure III-12: Primary energy price assumptions in €/MWh

Source: based on PRIMES scenarios

The CO_2 price in the scenarios presented in this report is also based on recent PRIMES modelling, see Figure III-13. Actual market prices for EU Allowances have fluctuated between 6 and 30 €/t since 2005 but remained on a low level with averages around 7 €/t in the first quarter of 2012. In the model, it is assumed that CO_2 prices are directly passed through to electricity prices as well as to prices for grid-connected heat supply.

Increased RES-deployment has the effect of reducing CO_2 prices since it reduces the demand to cut CO_2 via alternative measures. This effect appears to be well covered in PRIMES scenarios, see for example CO_2 prices as shown in (COM(2014) 15 final) for climate scenarios with generally strong RES deployment in comparison with alternative cases where RES deployment is still significant but less pronounced.

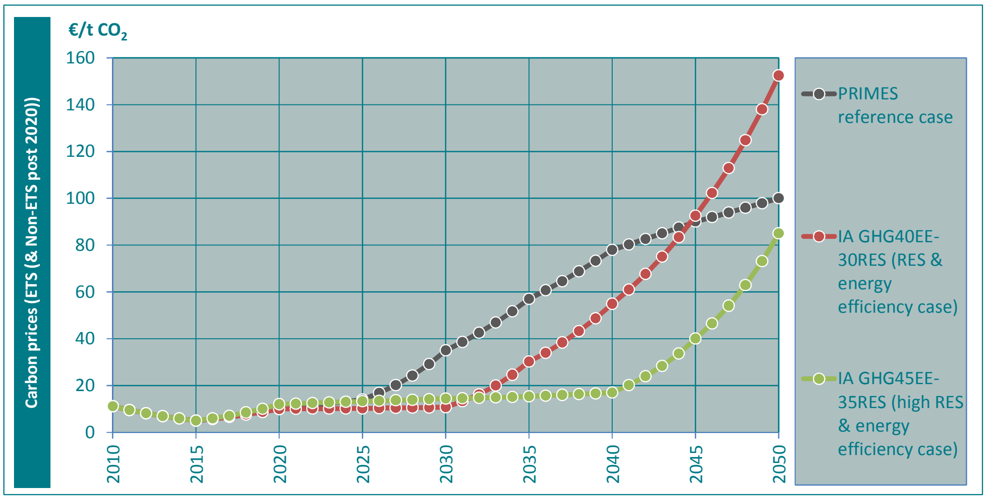

Figure III-13: CO_2 price assumptions in $€_{2010}$/ton

Source: PRIMES scenarios

<u>Interest rate / weighted average cost of capital - the role of (investor's) risk</u>

The model-based assessment incorporates the impact of risks to investors on RES deployment and corresponding (capital / support) expenditures. In contrast to the complementary detailed bottom-up analysis of illustrative financing cases as conducted e.g. in the RE-Shaping study (see Rathmann et al. (2011)), Green-X modelling aims to provide an aggregated view at the national and European level with fewer details on individual direct financing instruments. More precisely, the debt and equity conditions resulting from specific financing instruments are incorporated by applying different weighted average cost of capital (WACC) levels.

Determining the necessary rate of return is based on the weighted average cost of capital (WACC) methodology. WACC is often used as an estimate of the internal discount rate of a project or the overall rate of return desired by all investors (equity and debt providers). This means that the WACC formula[12] determines the required rate of return on a company's total asset base and is determined by the Capital Asset Pricing Model (CAPM) and the return on debt. Formally, the pre-tax cost of capital is given by:

$$WACC^{\text{pre-tax}} = g_d \cdot r_d + g_e \cdot r_e = g_d \cdot [r_{fd} + r_{pd}] \cdot (1 - r_{td}) / (1 - r_{tc}) + g_e \cdot [r_{fe} + \beta \cdot r_{pe}] / (1 - r_{tc})$$

---

[12] The WACC represents the necessary rate a prospective investor requires for investment in a new plant.

Table III-3: Example of value setting for WACC calculation

WACC methodology	Abbreviation/ Calculation	*Default* risk assessment		*High* risk assessment	
		Debt (d)	Equity (e)	Debt (d)	Equity (e)
Share equity / debt	g	70.0%	30.0%	67.5%	32.5%
Nominal risk free rate	r_n	4.1%	4.1%	4.1%	4.1%
Inflation rate	i	2.1%	2.1%	2.1%	2.1%
Real risk free rate	$r_f = r_n - i$	2.0%	2.0%	2.0%	2.0%
Expected market rate of return	r_m	4.3%	7.3%	5.4%	9.0%
Risk premium	$r_p = r_m - r_f$	2.3%	5.3%	3.4%	7.0%
Equity beta	b		1.6		1.6
Tax rate (tax deduction)	r_{td}	30.0%		30.0%	
Tax rate (corporate income tax)	r_{tc}		30.0%		30.0%
Post-tax cost	r_{pt}	3.0%	10.5%	3.8%	13.2%
Pre-tax cost	$r = r_{pt} / (1-r_{tc})$	4.3%	15.0%	5.4%	18.9%
Weighted average cost of capital (pre-tax)		**7.5%**		**9.8%**	
Weighted average cost of capital (post-tax)		*5.3%*		*6.8%*	

Table III-4: Policy risk: Instrument-specific risk factor

Policy risk: Instrument-specific risk factor (i.e. multiplier of default WACC)	
FIT (feed-in tariff)	1.00
FIP (feed-in premium)	**1.10**
QUO (quota system with uniform TGC)	**1.20**
QUO banding (quota system with banded TGC)	1.15
ETS (no dedicated RES support)	1.30
TEN (tenders for selected RES-E technologies)	1.20

Table III-3 explains how to determine the WACC for two example cases – a default and a high risk assessment. Within the model-based analysis, a range of settings is applied to accurately reflect the risks to investors. Risk refers to two different issues:

- A *"policy risk"* is related to the uncertainty about future earnings caused by the support scheme itself – e.g. refers to the uncertain development of certificate prices within a RES trading system and / or uncertainty related to earnings from selling electricity on the spot market. As shown in Table III-3, the range of settings used in the analysis with respect to policy risks varies from 7.5% (default risk) up to 9.8% (high risk). The different values are based on a different risk assessment, a standard risk level and a set of risk levels characterised by a higher expected / required market rate of return. 7.5% is used as the default value for stable planning conditions as given, e.g. under advanced fixed feed-in tariffs. The higher value is applied in scenarios with less stable planning conditions, i.e. in the cases where support schemes cause a higher risk for investors as associated with e.g. RES trading (and related uncertainty about future earnings on the certificate market). An overview of the settings used by the type of policy instrument or pathway, respectively, is given in Table III-4.

- A *"technology risk"* refers to uncertainty about future energy production due to unexpected production breaks, technical problems etc... Such problems may cause (unexpected) additional operational and maintenance costs or require substantial reinvestments which (after a phase-out of operational guarantees) typically have to be borne by the investors themselves. In the case of biomass, this also includes risks associated with the future development of feedstock prices. Table III-5 (below) illustrates the default assumptions applied to consider investors' technology risks. The expressed technology-specific risk factors are used as a multiplier of the default WACC figure. The ranges indicated for several RES categories reflect the fact that risk profiles are expected to change over time and that specific RES categories cover a range of technologies (and for instance also a range of different feedstocks in the case of biomass) and unit sizes. The lower boundary for PV or for several RES heat options also indicates a different risk profile of small-scale investors who may show a certain "willingness to invest", requiring a lower rate of return than commercial investors.

Table III-5: Technology-specific risk factor

Technology-specific risk factor (i.e. multiplier of default WACC)			
RES-electricity		*RES-heat*	
Biogas	1.00-1.05	Biogas (grid)	1.05
Solid biomass	1.05	Solid biomass (grid)	1.05
Biowaste	1.05	Biowaste (grid)	1.05
Geothermal electricity	1.1	Geothermal heat (grid)	1.05
Hydro large-scale	0.95	Solid biomass (non-grid)	0.95-1.00
Hydro small-scale	0.95	Solar thermal heat. & water	0.90
Photovoltaics	0.85-0.90	Heat pumps	0.90
Solar thermal electricity	1.1	*RES-transport / biofuels*	
Tide & wave	1.20	Traditional biofuels	1.05
Wind onshore	0.9-0.95	Advanced biofuels	1.05
Wind offshore	1.20	Biofuel imports	-

Please note that both policy and technology risks are considered as default in the assessment, leading to a different – typically higher – WACC than the default level of 7.5%. Additionally, the differences across Member States with respect to financing conditions as currently prominently discussed are considered in the model-based assessment. This leads to a higher risk profiling of investments in countries more strongly affected by the financial and economic crisis compared to more stable economies within Europe. Thus, *"country risks"* are assumed to be present in the near future, but financing conditions are assumed to converge in the period beyond 2020 – where the focus of this policy assessment lies – either driven by the RES policy approach itself (e.g. a harmonisation of RES support) or as a consequence of economic recovery and the continued alignment of financial procedures and procurements across the EU.

III.2.2 Scenarios of global RES deployment

The global RES development used in this study is based on the World Energy Outlook (WEO) 2013 of the International Energy Agency. The “New Policies Scenario” was used as the main scenario. Sensitivities were calculated for the Current Policies Scenario and the 450 ppm Scenario. Since these scenarios only cover the period until 2035, the development on a technology level was linearly extrapolated from 2035 to 2050. The globally installed capacity of RE technologies in the electricity sector (RES-E) is shown in Figure III-14.

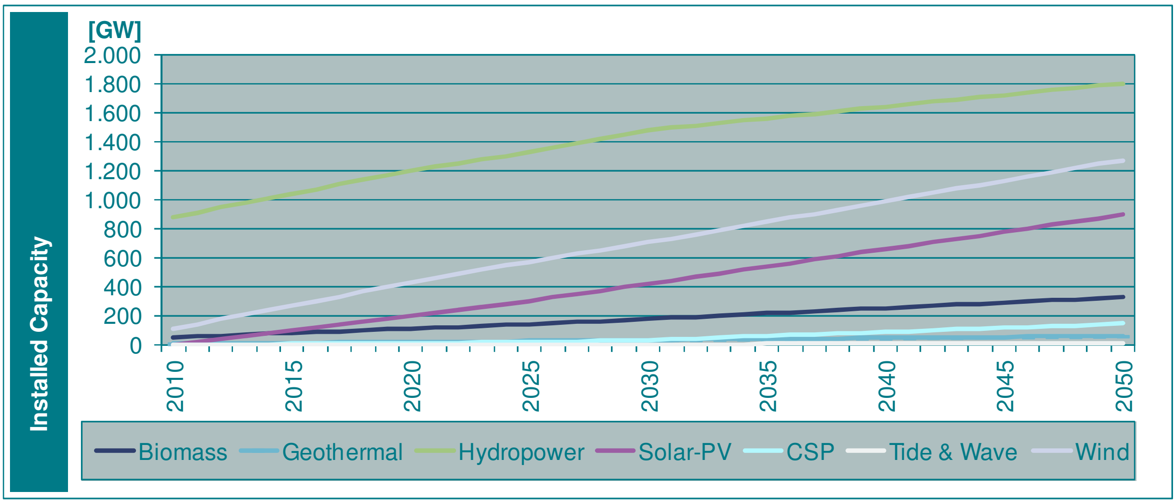

Figure III-14 : Globally installed capacity of RES-E in the “New Policy Scenario” of the WEO

III.2.3 Scenarios of export opportunities for European economies

It has been shown that especially wind energy technologies (on- and off-shore) and photovoltaics have considerable above average innovation dynamics. Thus, for these three technologies, the market share scenarios are explicitly built on the lead market considerations outlined above. For the other renewable technologies, the market shares and exports of the base year were projected according to the results of the macro-models for the underlying sectors, which are modelled endogenously in both ASTRA-EC and NEMESIS.

For the three technologies wind on-shore, wind off-shore and photovoltaics, detailed market share scenarios were developed. They follow the general scenario assumptions already outlined. The underlying forces which influence market shares in the BAU and the policy scenarios develop in a similar way for the EU countries and the Rest of the World. Therefore, the market share scenarios do not differ between the EU and the Rest of the World. However, there are obvious uncertainties, e.g. with regard to the relative improvement in the innovation system for renewable energy in the EU compared to the Rest of the World, or with regard to the comparative advantage in the regulatory system.

In order to develop the scenarios, lead market factors for the EU countries in comparison to the Rest of the World were used as a starting point. These are the market shares already achieved, the diffusion of the three RES technologies in the home market, the patent share and the export share of the complementary sector. The market share was projected for each year based on the indicator values for these variables for each year in the projected period. This dynamic projection has the advantage that the phase of changes in the world market share is consistent with the changes in the underlying drivers.

Pessimistic Scenario

For the pessimistic scenario, current world market shares were used as starting points. Combined with a pessimistic development of the aforementioned indicators, export shares were projected to the year 2030. As international innovation and market dynamics cannot reasonably be projected beyond this point, the market shares are then kept constant for the period 2030 to 2050.

In the pessimistic scenario, Europe's share in wind and photovoltaic technology exports declines considerably until 2030. This is due to the increasingly important role of emerging countries, which rapidly build up their technological capabilities. Although Europe will still play a role in international RET trade, other countries will become the main players.

In order to be on the conservative side we use the pessimistic scenario as the default option for the macro-economic calculations performed within the project.

More optimistic scenarios are possible for EU export shares, e.g. holding the current export shares constant until the year 2050. These reflect the possible effects of a conscious effort by European countries to defend their position in international RET trade. Two factors are vital for the success of such a strategy. One is strengthening the aforementioned lead market factors which originally put Europe in its RET leadership position. The other is a strengthened RET innovation and trade policy, which provides a basis for continued technological excellence as well as new market opportunities.

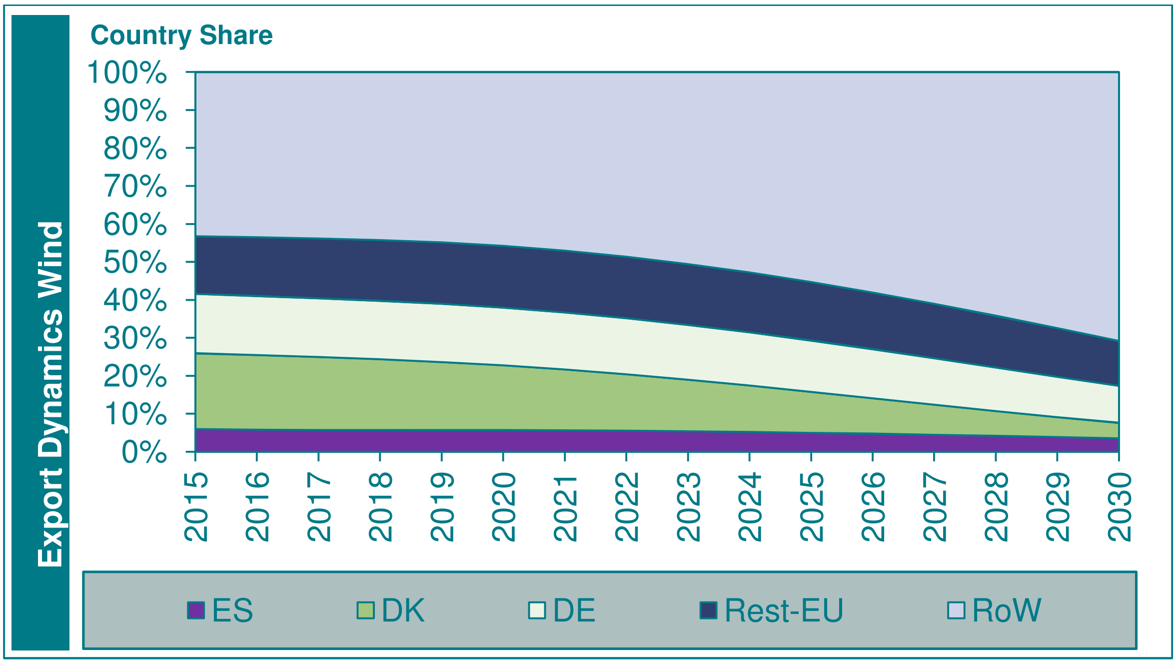

Figure III-15: Export Share Timeline of Wind Technology from 2015 to 2030 under the pessimistic scenario

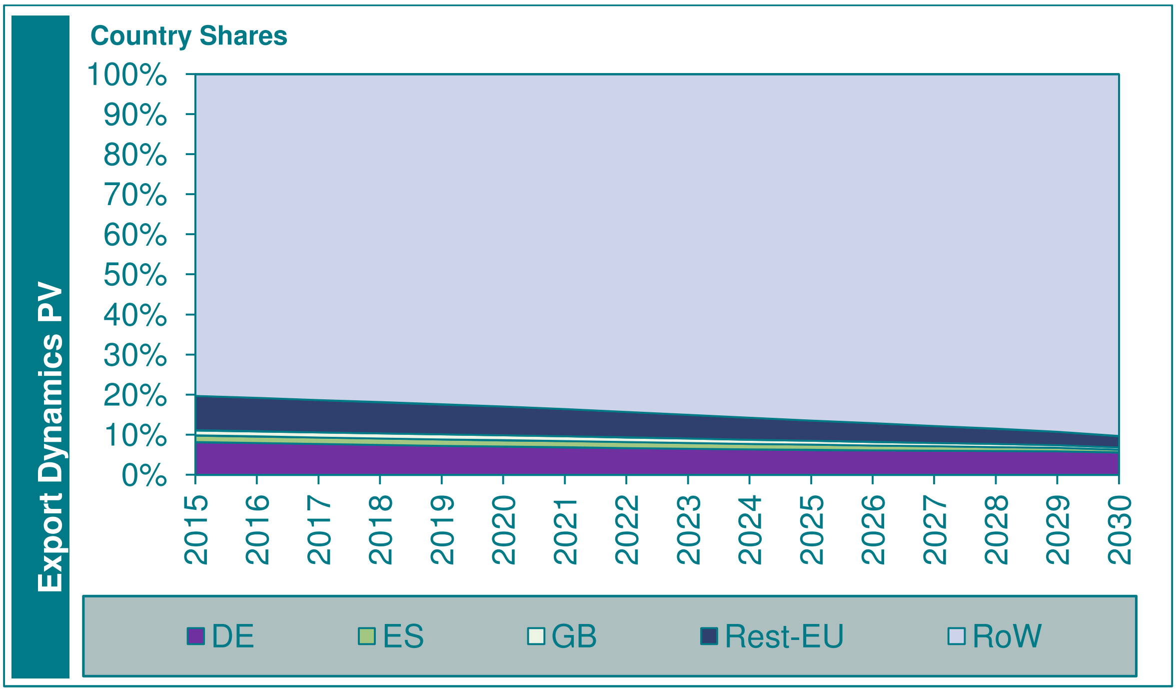

Figure III-16: Export Share Timeline of Photovoltaic Technology from 2015 to 2030

IV Results

The table on the next page contains the overview of key assumptions and results of this study. The first part contains assumptions about demand and prices, the second part the key results of the energy system modelling, the third part the trade relations for renewable energy technologies. The fourth part shows the macro-economic results in terms of gross impacts based on the MultiReg model as well as in terms of net impacts based on the NEMESIS and ASTRA models.

Key figures at European level (EU28)		Beginn of modelling	Baseline		SNP-30 (1a)		QUO-30 (1b)		SNP-35 (2a)		QUO-35 (2b)	
	Unit	2010	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050
Energy system characteristics (inputs)												
Gross final energy demand	TWh / a	14,015	11,675	9,137	11,910	9,175	11,910	9,175	11,675	9,137	11,675	9,137
Oil price	€$_{2010}$ / MWh	36.8	57.2	67.6	57.2	67.6	57.2	67.6	57.2	67.6	57.2	67.6
Reference (wholesale) electricity price	€$_{2010}$ / MWh	50.1	71.16	98.02	69.89	112.54	69.89	112.54	71.16	98.02	71.16	98.02
Reference heat price (grid)	€$_{2010}$ / MWh	41.8	60.32	75.79	59.50	90.38	59.50	90.38	60.32	75.79	60.32	75.79
Reference heat price (non-grid)	€$_{2010}$ / MWh	74.1	101.49	105.63	100.26	124.27	100.26	124.27	101.49	105.63	101.49	105.63
Reference transport fuel price	€$_{2010}$ / MWh	49.2	80.51	110.52	79.14	133.82	79.14	133.82	80.51	110.52	80.51	110.52
CO$_2$ price	€$_{2010}$ / ton CO$_2$	11.2	14.40	85.00	10.77	152.41	10.77	152.41	14.40	85.00	14.40	85.00
RE deployment, turnover and cost (Green-X)*												
Total RE deployment	TWh / a	1,746	3,070	4,011	3,579	5,400	3,579	5,420	4,083	5,643	4,084	5,627
RE share in gross final energy demand	%	12.5%	26.3%	43.9%	30.0%	58.9%	30.0%	59.1%	35.0%	61.8%	35.0%	61.6%
RE share in gross electricity demand	%	19.7%	45.1%	57.9%	51.1%	78.0%	51.1%	77.4%	61.9%	81.2%	62.1%	80.4%
RE share in gross heat demand	%	14.2%	27.0%	46.5%	30.0%	62.6%	30.0%	63.6%	34.1%	62.8%	34.0%	63.1%
RE share in transport fuel demand	%	4.8%	7.7%	15.5%	9.6%	21.7%	9.6%	22.4%	11.1%	25.6%	11.1%	25.6%
Average specific generation costs for new RES-E (in relation to 2010)	%	100%	53%	61%	61%	72%	64%	72%	78%	68%	73%	72%
Additional generation costs for RE	Bln. €$_{2010}$ / a	13.8	21.6	0.3	29.7	2.5	24.3	0.0	32.6	7.3	28.8	1.1
Avoided CO2 emissions due to RE	Mio t / a	778	1,515	1,699	1,701	2,117	1,709	2,152	1,967	2,428	1,972	2,444
Yearly capital expenditures for new RE	Bln. €$_{2010}$ / a	60.0	35.2	84.3	58.4	114.2	49.7	115.1	79.0	106.6	82.3	114.8
O&M expenditures for RE	Bln. €$_{2010}$ / a	19.3	31.3	32.0	37.9	47.2	37.0	46.0	44.2	52.0	43.5	49.8
Expenditures for biomass fuels	Bln. €$_{2010}$ / a	29.5	59.0	72.8	71.6	101.1	70.8	104.4	76.6	99.1	76.1	98.1
Avoided fossil fuel (imports) due to RE	Bln. €$_{2010}$ / a	58.2	177.4	225.9	212.7	305.7	211.6	305.9	238.6	324.5	238.9	322.0
Trade relations for RE												
EU share in global supply of RES technologies												
PV	%	20%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Wind	%	64%	29%	29%	29%	29%	29%	29%	29%	29%	29%	29%
Macroeconomic impacts of RE												
Gross value added (Multireg)	Bln. €$_{2010}$ / a	---	---	---	100	166	92	160	122	165	120	164
Gross employment (Multireg)	1000 jobs	---	---	---	1700	2230	1590	2210	2070	2240	2050	2260
NEMESIS												
Net GDP effect	% to BAU	---	---	---	0.40	0.28	0.34	0.32	0.80	0.50	0.78	0.74
Net employment effect	% to BAU	---	---	---	0.32	0.17	0.30	0.32	0.67	0.31	0.68	0.65
Net employment effect	1000 jobs	---	---	---	715	346	671	661	1,497	648	1,528	1,360
ASTRA												
Net GDP effect	% to BAU	---	---	---	0.08	0.27	0.07	0.31	0.23	0.41	0.08	0.62
Net employment effect	% to BAU	---	---	---	0.06	0.03	0.04	0.04	0.11	-0.15	0.07	-0.22
Net employment effect	1000 jobs	---	---	---	140	72	92	86	242	-327	159	-478

1 Past developments in the RES sector

1.1 Summary

The core objective of this chapter is to provide a detailed depiction of RES development in the period 1995 to 2011 considering generation, installed capacities and the costs of RES technologies in the European Union. Additionally, the main gross economic impacts of the RES sector are presented, including total value added by the RES sector as well as gross employment effects due to RES deployment.

The RES sector is characterised by stable and continuous growth in recent years, which is especially dynamic in the electricity and heat sectors. Most Member States are on-track with regard to their interim targets as set in the Renewable Energy Directive (EC/28/2009). Renewable electricity generation has grown by about 50 TWh/a, renewable heat generation by about 1600 ktoe/a, and renewables in transport by about 1200 ktoe/a since 2007.

Table IV-1 gives an overview of the impacts on gross value added and employment in 2011, indicating direct and total impacts. The direct gross value added generated by the renewable energy industry reached €44.4 billion in 2011, which is equivalent to 0.3% of total EU GDP. The renewable energy industry employs roughly 990,000 persons or 0.4% of the total EU workforce. In both value added and employment, direct impacts account for approximately half of total impacts. Detailed results on the current economic impacts and breakdown per RES sector and Member State will be provided in this chapter.

Table IV-1: Gross value added and employment induced by RES deployment in 2011

	Direct value added (m Euro)	Direct employment (1000 EP)	Total value added (m Euro)	Total emplyoment (1000 EP)
RES investment	24 500	500	59 900	1 170
RES operation and maintenance	11 400	220	18 100	350
RES fuel use	8 500	270	16 100	440
Total	44 400	990	94 100	1 960
In % of EU total	0.3%	0.4%	0.7%	0.9%

1.2 Past deployment of RES

Section provides an overview of the development of renewable energy sources in the EU since 1997 in the sectors electricity, heat and transport fuels. Aggregated data for RES-E, RES-H and biofuels are provided up to 2011 in the figures as this is the most recent year for which data were available for all countries and technologies at the time of conducting the analysis within this project.[13] Generally, figures are given in terms of generation. Additionally, the development of generation capacity is shown exemplarily for the case of wind onshore. This section only serves to outline the overall RES development at European level. Within the scope of this project, all data are supplied on the Member State level for each of the technologies listed above.

The data on RES penetration shown in this report rely heavily on databases developed in earlier projects such as Green X, TRIAS, FORRES 2020, OPTRES and PROGRESS. The data are presented on the level of the EU-28 and for the following categories:

- **RES-Electricity (E) capacity and production data**: hydropower (large (>10 MW) and small (<10 MW)), photovoltaics, solar thermal electricity, wind energy (onshore, offshore), biogas (including landfill gas, sewage gas and gas from animal slurries), solid biomass, biodegradable fraction of municipal waste, geothermal electricity, tidal and wave electricity
- **RES-Heat (H) capacity and production data**: grid and non-grid connected biomass (including wood, agricultural products and residues), renewable municipal solid waste, biogas, solar thermal (grid and non-grid), geothermal (grid and non-grid - incl. ground coupled heat pumps),
- **RES-Transport (T)**: biodiesel, bioethanol, advanced biofuels (e.g. BTL)

Renewable electricity

Renewable energy sources are playing an increasingly important role in European energy supply. Electricity generation from renewable sources (RES-E) grew by ca. 79% from 371 TWh in 1997 to 664 TWh in 2011 in the EU-28. An overview of the historical development of electricity generation from renewable energy sources from 1997 to 2011 is presented in Figure IV-1. Hydropower is the dominant renewable energy source, representing about 90% of all RES-E generation in 1997, but its dominance has been slowly decreasing over the past few years due in part to below average rainfall in some years, but also to continuous increases in the deployment of other ‘new’ renewable energy sources such as wind and biomass. In 2011, hydropower represented only 46% of RES-E generation in the EU-28 also due to low precipitation.

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[13] Although 2012 historic figures were available at the end of the project, all gross macroeconomic analysis is based on 2011 figures. Therefore for the sake of consistency between RES deployment figures and macro-economic results for the past all results are presented up to the year 2011.

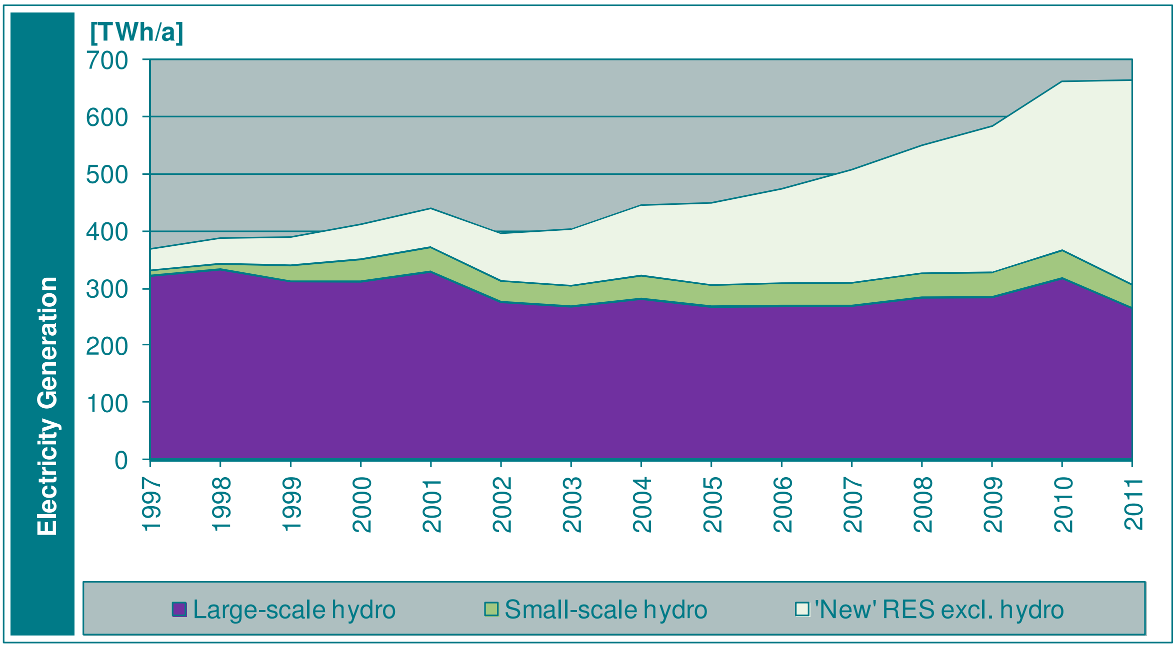

Figure IV-1: Historical development of electricity generation from RES-E in the European Union (EU-28) from 1996 to 2011

Source: Eurostat

In order to exclude the influence of variable rain conditions, Figure IV-2 presents the development of electricity generation over the time period from all renewable sources except hydropower. Strong growth in several renewable energy sources can be observed over the last decade.

Electricity production from onshore wind equalled 168 TWh in 2011 compared to 7 TWh in 1997, which indicates a spectacular average annual growth rate of more than 25% throughout this period. Offshore wind, though still relatively small in absolute terms, is starting to take off in several countries, and is expected to grow rapidly in the near future. In 2012, wind continued its impressive growth with an additional new capacity of over 11,500 MW in the EU, resulting in an overall capacity of about 105,600 MW by the end of 2012. Also electricity generation from biogas has grown strongly, by 18% per year on average from 1997 to 2011. The highest average annual growth rate in this period was realised by solar photovoltaics (PV), which grew on average by an impressive 65% over this nine year period from 0.04 TWh in 1997 to 44 TWh in 2011. The average annual growth rate of RES-E excluding hydropower in the period 1997 to 2011 is 17%.

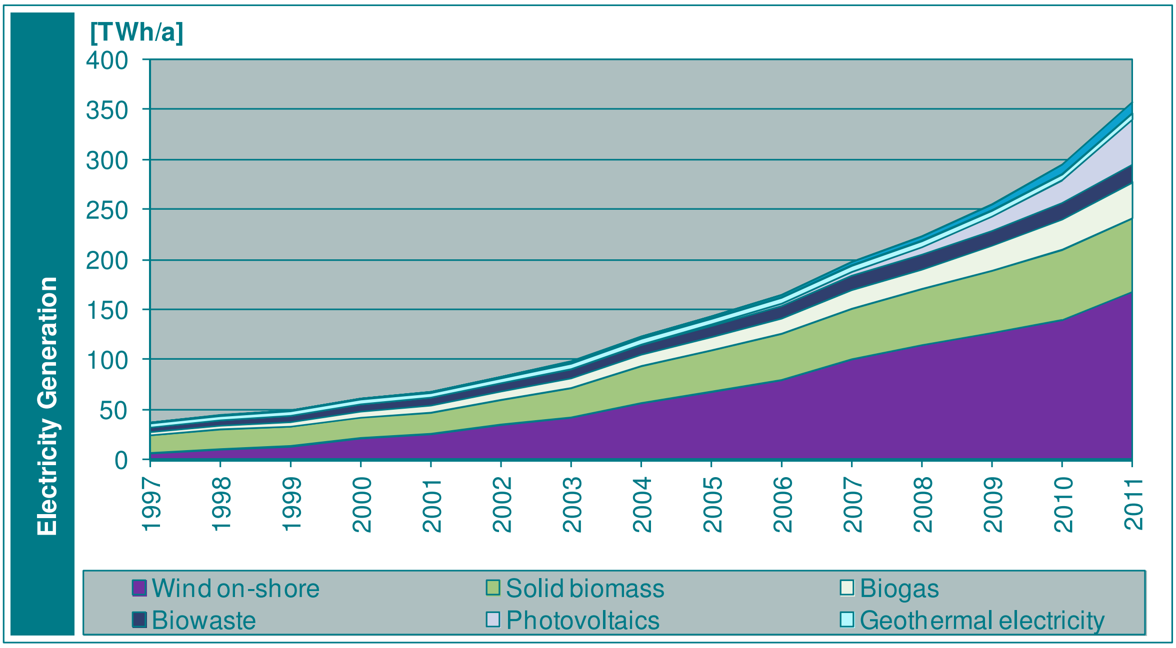

Figure IV-2: Historical development of electricity generation from RES-E without hydro power in the European Union (EU-28) from 1995 to 2011

Source: Eurostat

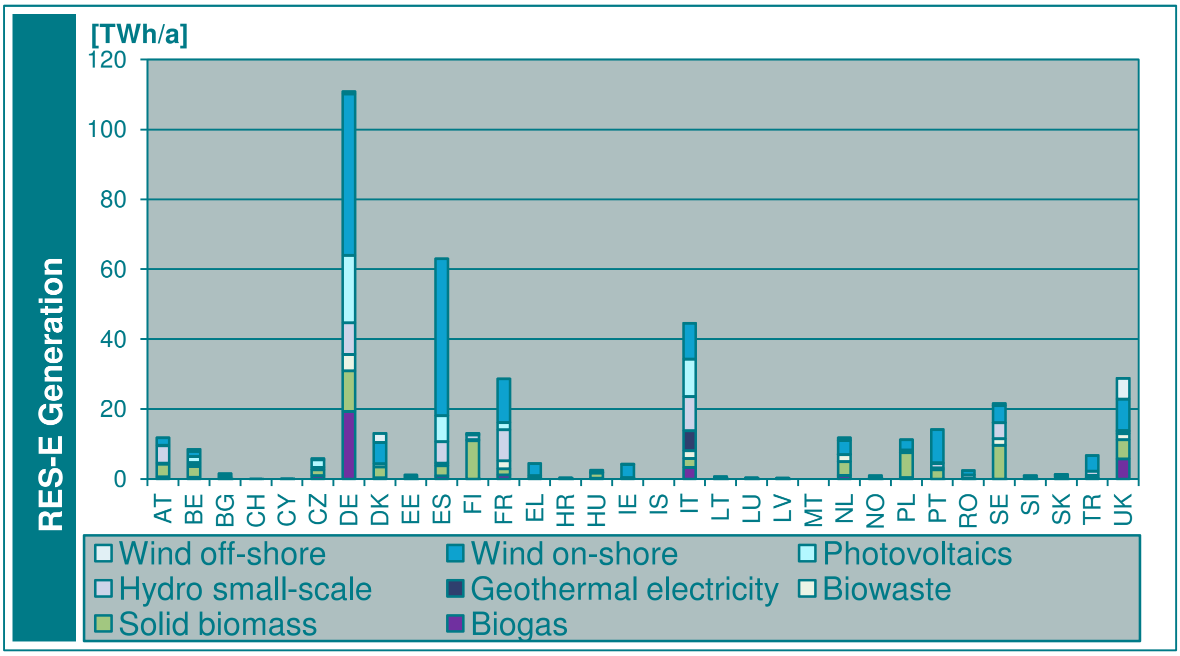

Figure IV-3: Breakdown of electricity generation from 'new' RES-E for 2011 by country

Source: Eurostat

Besides data on renewable energy generation, capacity data are of key relevance for studying the macro-economic consequences of renewable energy evolution. Therefore, the development of the installed capacity for two main new RES-E technologies is shown in the following. Onshore wind power has been the most successful RES technology in recent years. Figure IV-4 depicts the specific development of onshore wind power capacity in the EU-28 countries.

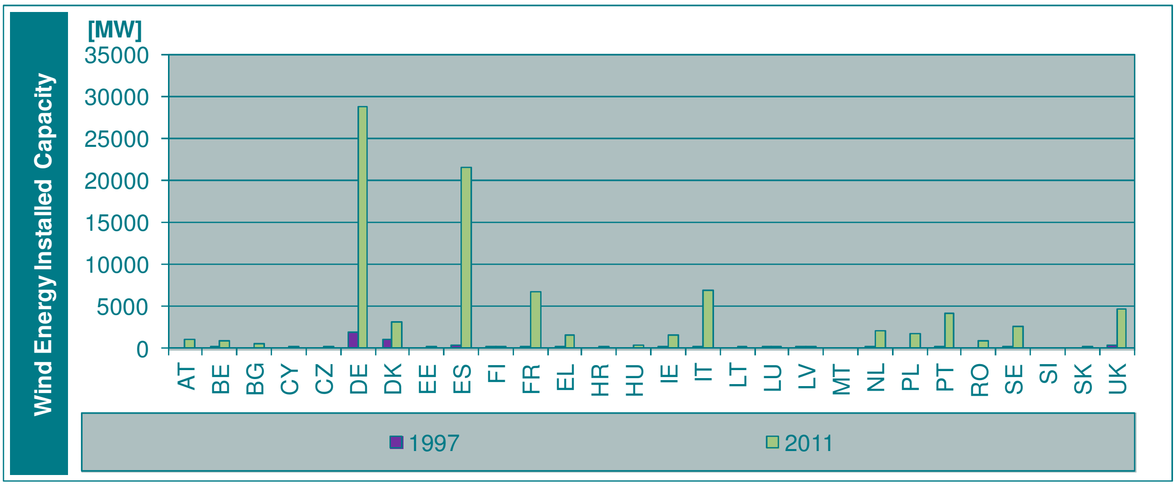

Figure IV-4: Historical development of cumulative installed wind capacity in EU-28 countries for the years 1997 and 2011

Source: Eurostat

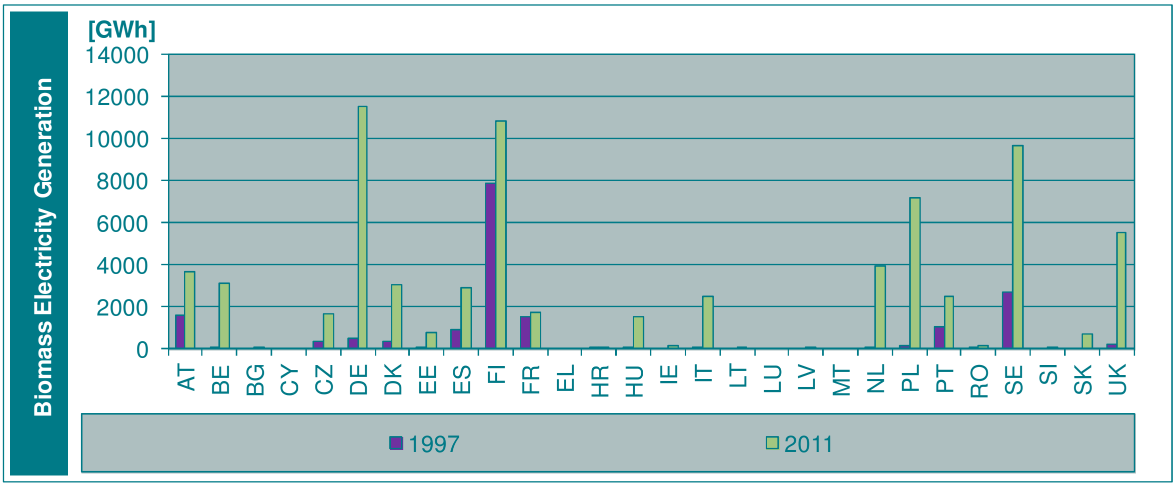

Figure IV-5: Historical development of electricity generation from biomass in EU-28 countries for the years 1997 and 2011

Source: Eurostat

Biomass has the second largest percentage of renewable electricity generation in the EU-28. The biggest shares are held by Finland, Germany and Sweden although RES-E generation from biomass has recently increased in Denmark, Italy, Poland and the United Kingdom, see Figure IV-5. Cumulative biomass generation is expected to increase further due to large potentials in the new EU Member States.

Renewable heat

Figure IV-6 shows the generation of heat from renewable energy sources (RES-H) in the EU-28 between 1995 and 2011.

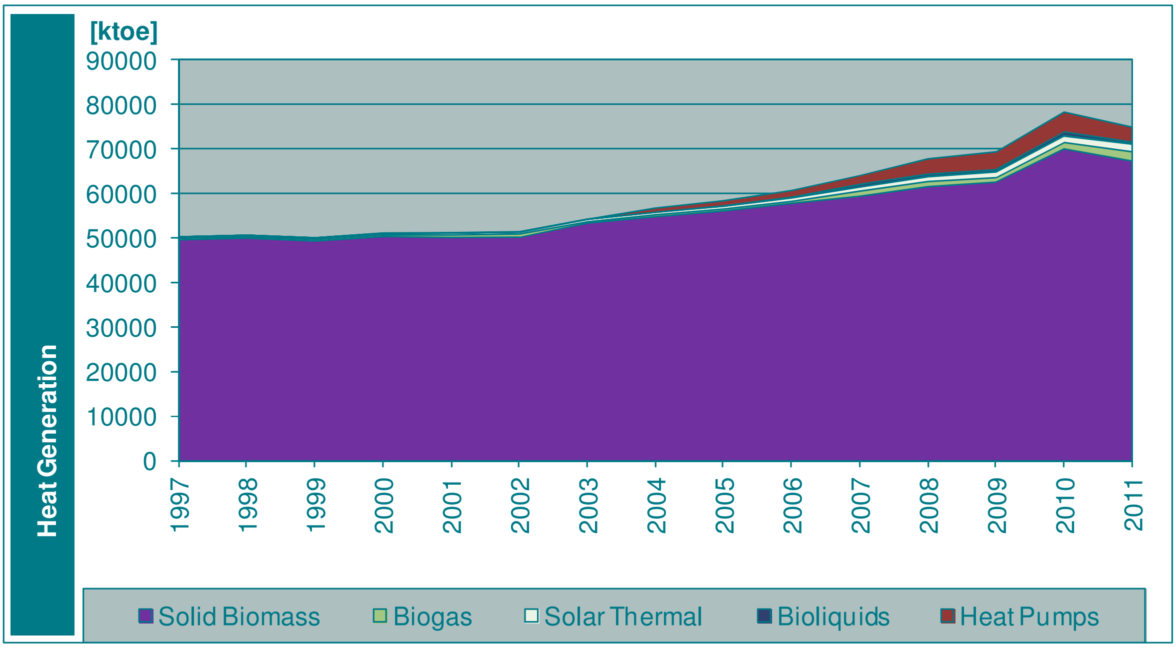

Figure IV-6: Historical development of heat generation from RES-H in the European Union (EU-28) between 1997 and 2011

Source: Eurostat

The overall progress made in the EU with heat generation from biomass is moderate: since 1997, heat output from biomass grew by 34% to 67 Mtoe in 2011, corresponding to an average annual growth of 2.1% in the period 1997-2011 for the EU-28. One should note, however, that the high level of overall deployment of biomass heating technologies makes it more difficult to reach high relative growth rates than for other technologies. Solar thermal heat generation increased by a factor of six from 0.28 Mtoe in 1995 to 1.69 Mtoe in 2011. In general, solar thermal heat has grown relatively steadily; the overall EU growth rate in the period 1995-2011 was 12% per year. Geothermal heat generation from heat pumps was 4.5 Mtoe in 2011.

Overall one can conclude that the heat sector has shown only moderate growth up to now and is clearly lagging behind the growth rates realised in the electricity sector.

Biofuels

The Biofuels Directive of 2003 was an important stimulus to creating support frameworks for the production and consumption of biofuels in EU Member States, as was the target and the measures set under the RES Directive for 2020. An overview of the RES consumption in transport in the EU-27 in 1995 and 2011 is provided in Figure IV-7.

Biodiesel dominates the European RES-T sector, accounting for 70% of RES transport consumption in 2011; bioethanol was only 19% and renewable electricity 8%.

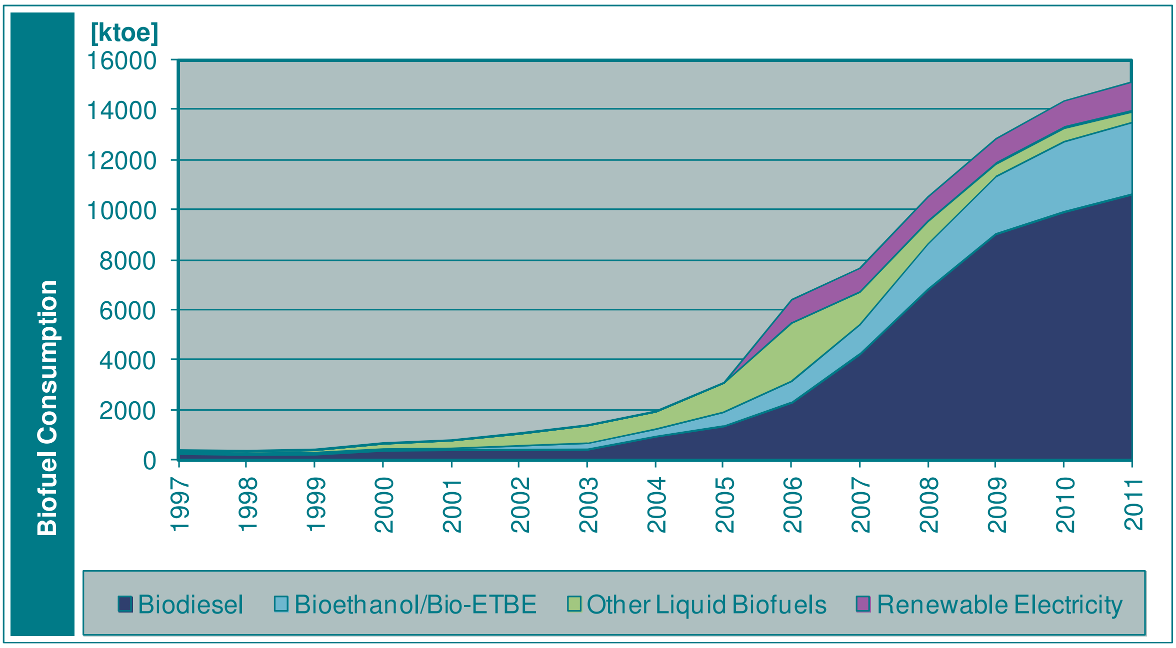

Figure IV-7: Historical development of RES consumption in transport in the European Union (EU-28) between 1995 and 2011

Source: Eurostat

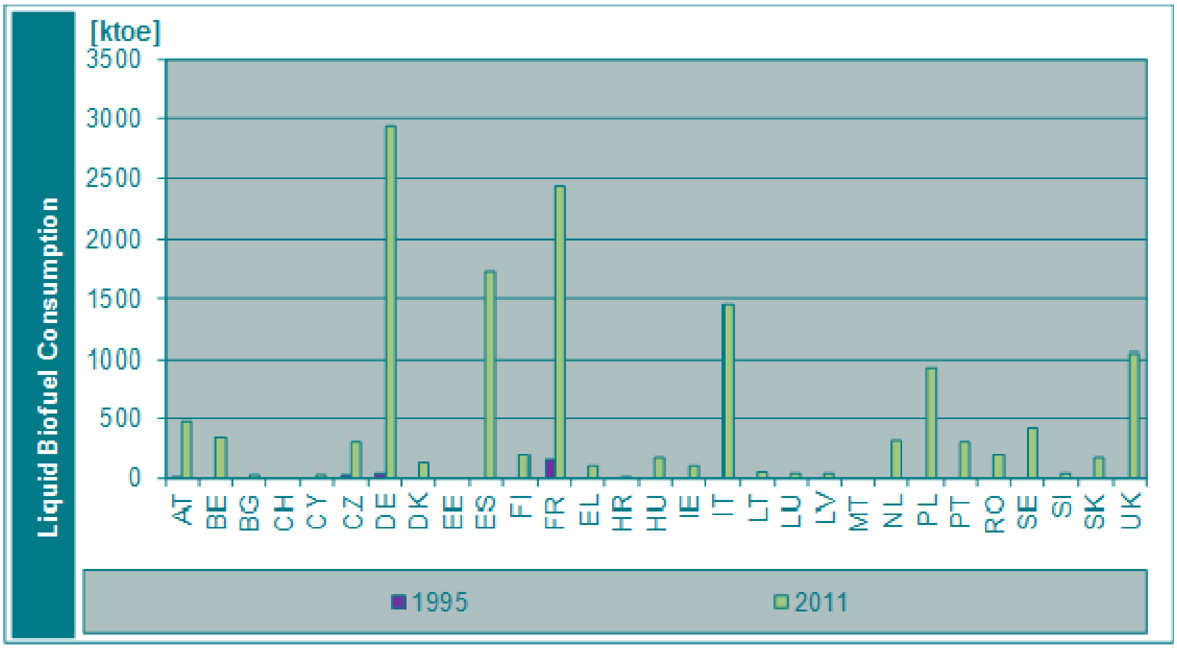

Figure IV-8: Historical development of biofuel consumption in transport in the European Union (EU-28) per Member State for the years 1995 and 2011

Source: Eurostat

1.3 Current growth effects of RES

The dynamic evolution of RES deployment in Europe has led to the development of a cross-sectoral industry focusing on the installation, operation and maintenance of RES facilities as well as the production of biomass fuels. This section describes the evolution of the RES industry in terms of its economic significance, or more concretely, pinpoints its direct and indirect contribution to gross domestic product. The associated employment effects will be presented in the subsequent chapter.

Technically speaking, the *gross* economic impacts (as well as the employment impacts) of the RES industry include the renewable energy industry itself and the industries depending indirectly on the activities of the renewable energy industry, either as suppliers of the intermediary inputs needed in the production process, or as suppliers of capital goods. In this perspective, the displacement of conventional energy generation and budget effects are not included. As presented in Section III.1, the results are based on an IO modelling approach.

Development of expenditures and of gross value added

As a starting point for calculating the gross value added induced by RES deployment, the development of expenditures for using RES (i.e. total expenditures, not additional expenditures compared to conventional energy supply) is presented in Figure IV-9. In the EU 27 as a whole, the expenditures increased significantly from €68 billion in 2005 to €129 billion in 2011. Expenditures for capacity expansion increased the most due to the various RES supporting policies in the EU Member States, reaching €80 billion in 2011. O&M expenditures and fuel expenditures also grew substantially, amounting to €20 and 22 billion, respectively, in 2011. Replacement expenditures remained fairly stable over this period at €6 to 7 billion. RES-related expenditures outside the EU are not included in the figure, but are considered in the model. They trigger exports from the EU and thus lead to economic impacts in the EU.

Gross value added induced by these expenditures shows a similar development. Figure IV-10 presents the development of total gross value added induced by expenditures for RES deployment, again allocated to investment expenditures (for capacity replacement and expansion), O&M expenditures and fuel expenditures. These values include direct value added generated in the RES-based industry as well as indirect value added triggered in the supplying industries. Gross value added grew from €53 billion in 2005 to €94 billion in 2011. This equals 0.7% of total GDP in the EU 27 (Figure IV-10).

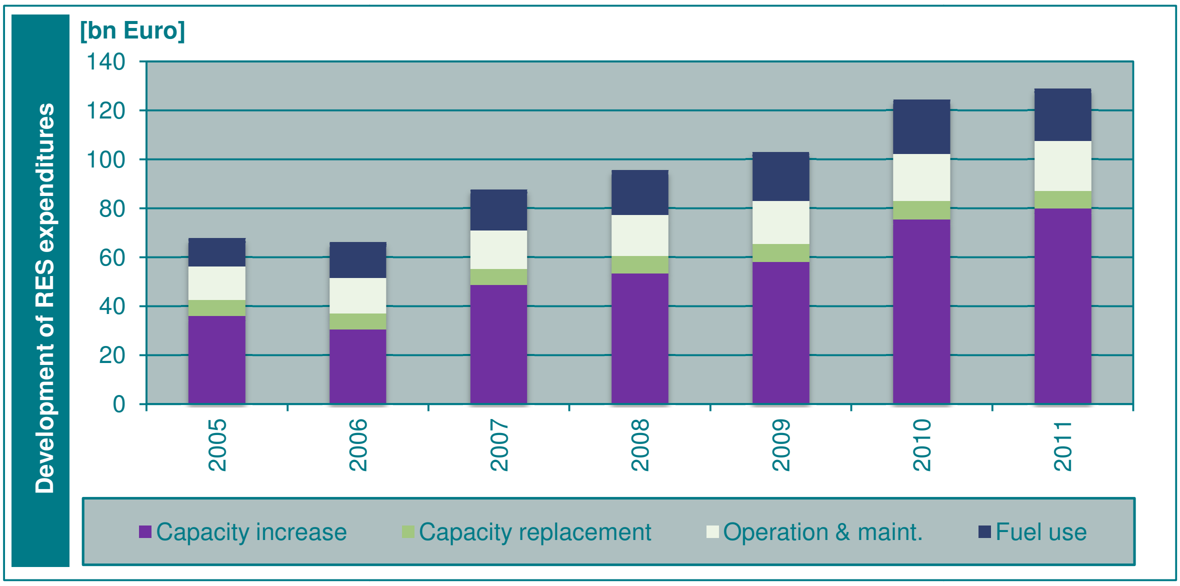

Figure IV-9: Development of expenditures for RES deployment 2005 – 2011

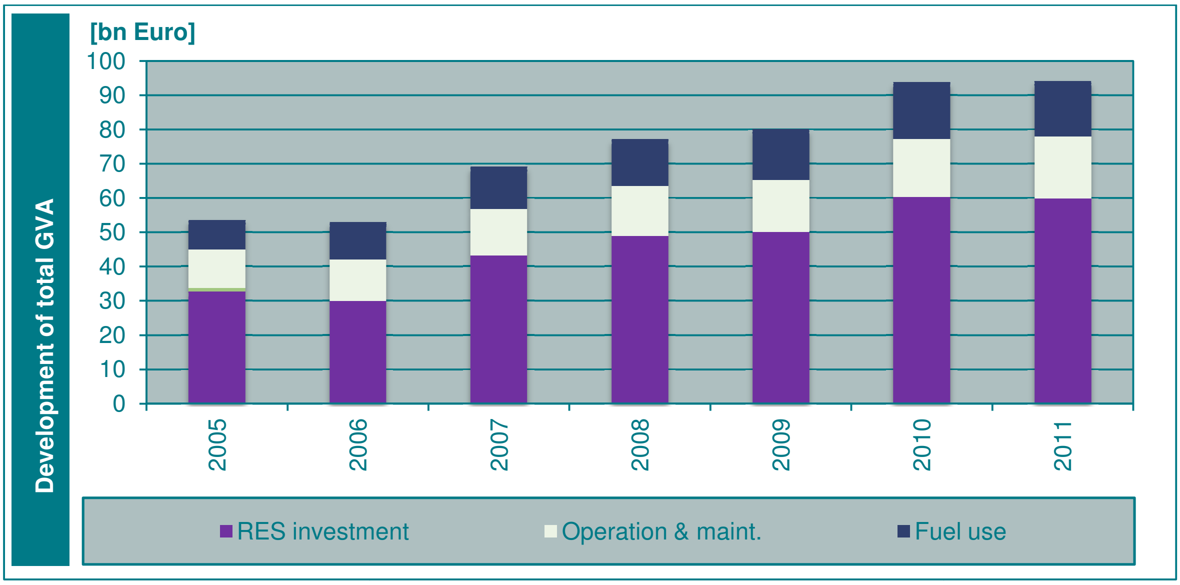

Figure IV-10: Development of total gross valued added induced by RES deployment between 2005 and 2011

Gross effects on gross value added in 2011

Figure IV-11 to Figure IV-14 present the gross value added in 2011 by country from different perspectives. Figure IV-11 shows the value added by expenditure category (investment, operation and maintenance, fuel use) for each country. Within the European Union, Germany and Italy, which also have the highest RES expenditures, have the largest share in total value added of the EU (28% and 16%). In both countries, the value added is driven by RES investment to a high extent, especially in PV plants. Other countries with major absolute impacts are France, Spain and the United Kingdom (GB). The contribution of the three expenditure categories varies between the different countries according to the RES technologies in use and their level of investment.

Figure IV-12 shows the breakdown by country and RES technology. In the above mentioned countries, a large share of the value added is due to the deployment of PV and wind technology as a direct consequence of strong support policies. Biomass technologies and hydropower make an important contribution in most countries, mainly influenced by their respective resource potentials and support policies. It can be noted that PV-related expenditures only partly lead to value added in the EU; an increasing share is used for imports from countries outside the EU since these have gained substantial market shares in PV cell and module manufacturing. This effect is dampened because the share of PV module costs in total PV system costs are decreasing due to the large cost reductions in PV modules.

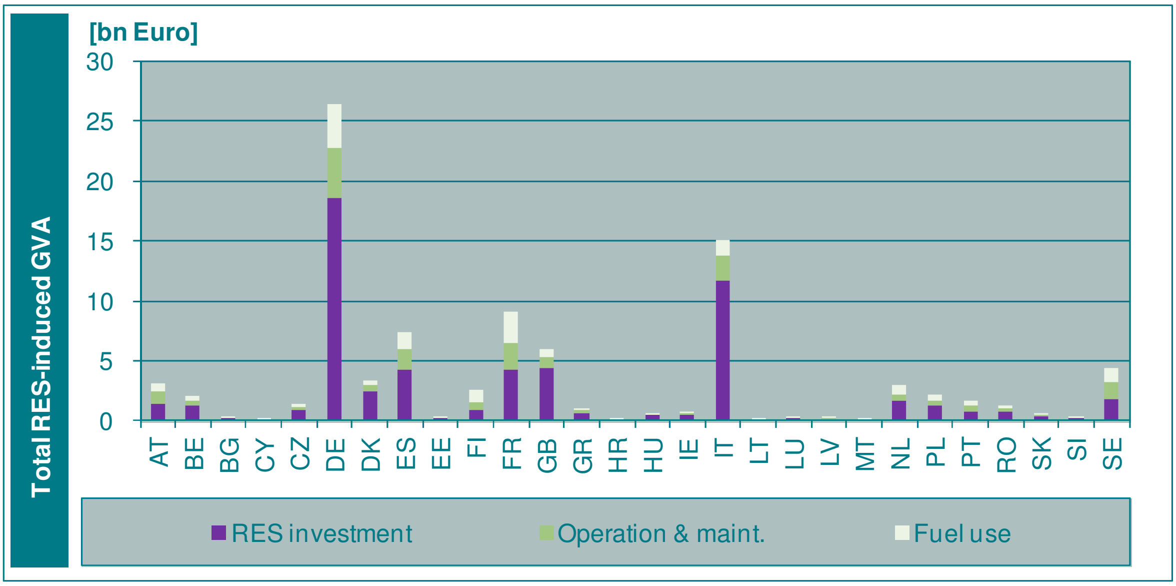

Figure IV-11: Total gross value added induced by RES deployment in 2011, by country and RES expenditure category

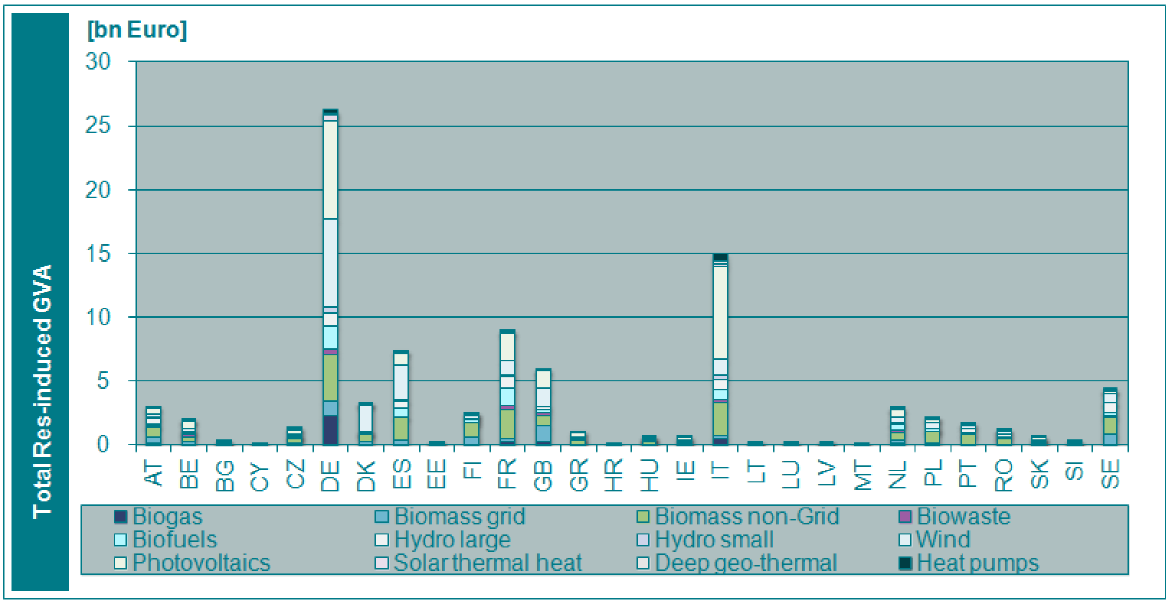

Figure IV-12: Total gross value added induced by RES deployment in 2011, by country and RES technology

An analysis of value added by economic sector shows that a broad range of sectors is active in directly or indirectly supplying the goods and services needed for the deployment of renewables (Figure IV-13). Countries with high investment expenditures see strong activity in the sectors supplying investment goods or in the construction sector (e.g. Germany or Denmark). In countries with a strong use of biomass resources (e.g. France or Sweden), agriculture, forestry and the wood industry are important. The figure also distinguishes value added related to the direct operation of RES facilities (e.g. hydropower plants or waste incineration plants). In addition to the primary and the manufacturing sectors, trade, transport and other service sectors are also significantly involved.

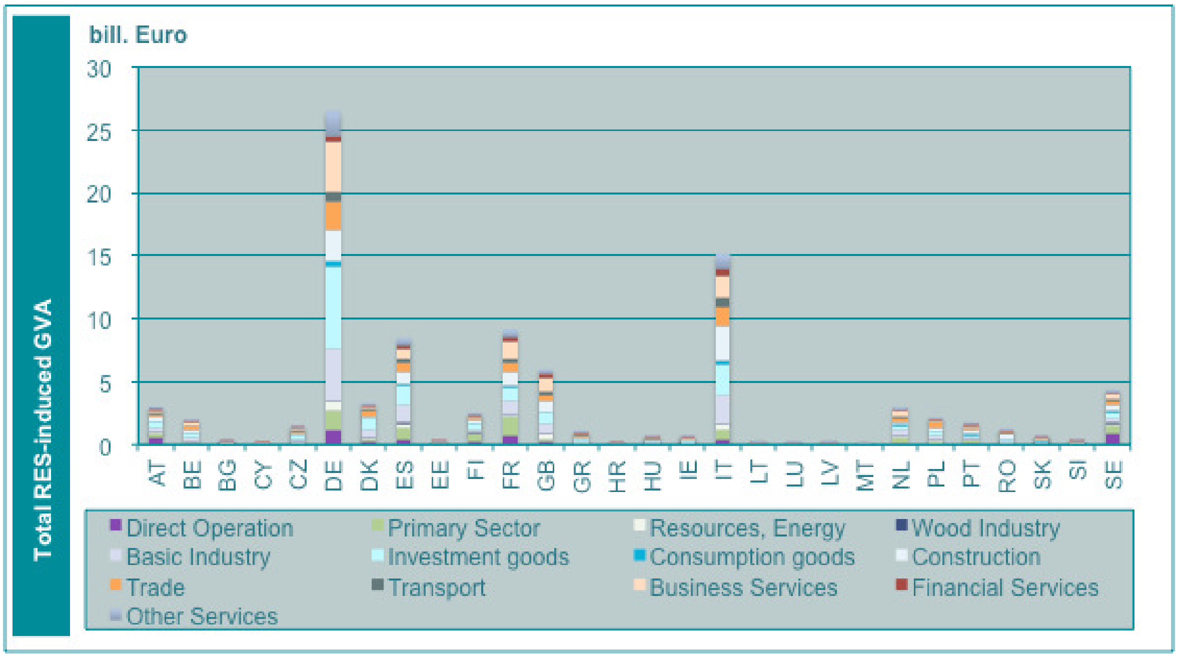

Figure IV-13: Total gross value added induced by RES deployment in 2011, by country and economic sector

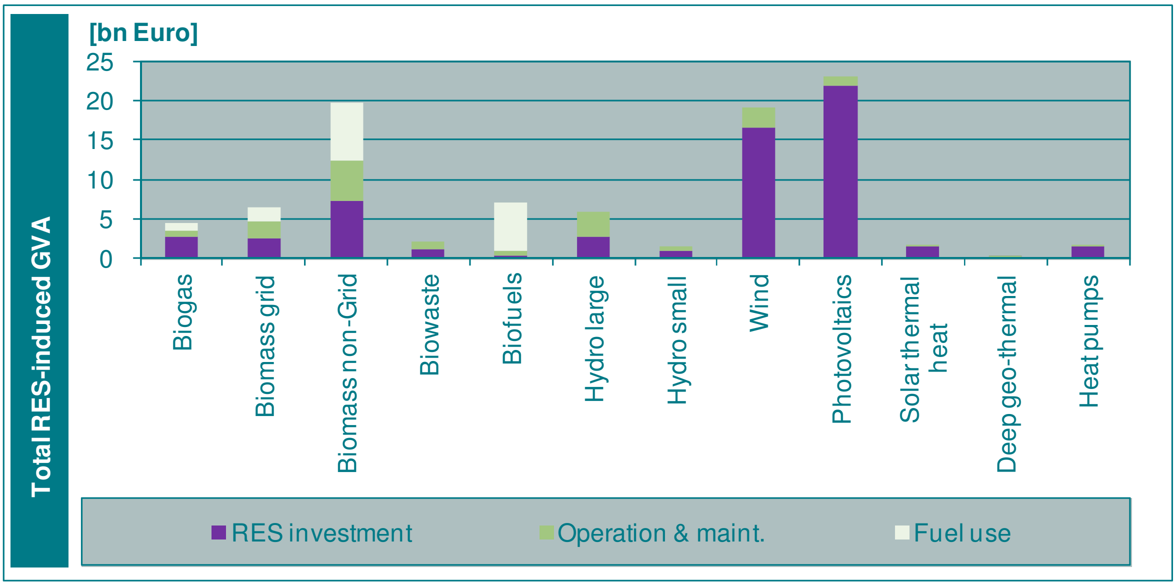

Figure IV-14: Total gross value added in the EU induced by RES deployment in 2011, by technology and expenditure category

In another perspective, the gross value added in the EU is broken down by RES technology and expenditure category. Figure IV-14 highlights the high importance of photovoltaics, wind and biomass technologies, especially the non-grid-connected use of biomass for heating purposes (equalling 23% of the total impact). In the case of PV and wind technology, investments in new plants are the main drivers of value added, whereas fuel use is responsible for a large share of value added in the case of biomass technologies. Value added from operation and maintenance activities is mainly relevant for hydropower and biomass use.

1.4 Current employment effects of RES

The development of total (i.e. direct and indirect) employment induced by RES deployment is depicted in Figure IV-11. Employment grew from roughly 1.2 million employed persons in 2005 to almost 2 million in 2011 (equal to 0.9% of total employment in the EU). A comparison with the development of gross value added shows that employment grew less strongly. This is a direct consequence of increasing labour productivity (the ratio of gross value added to employment) over time.

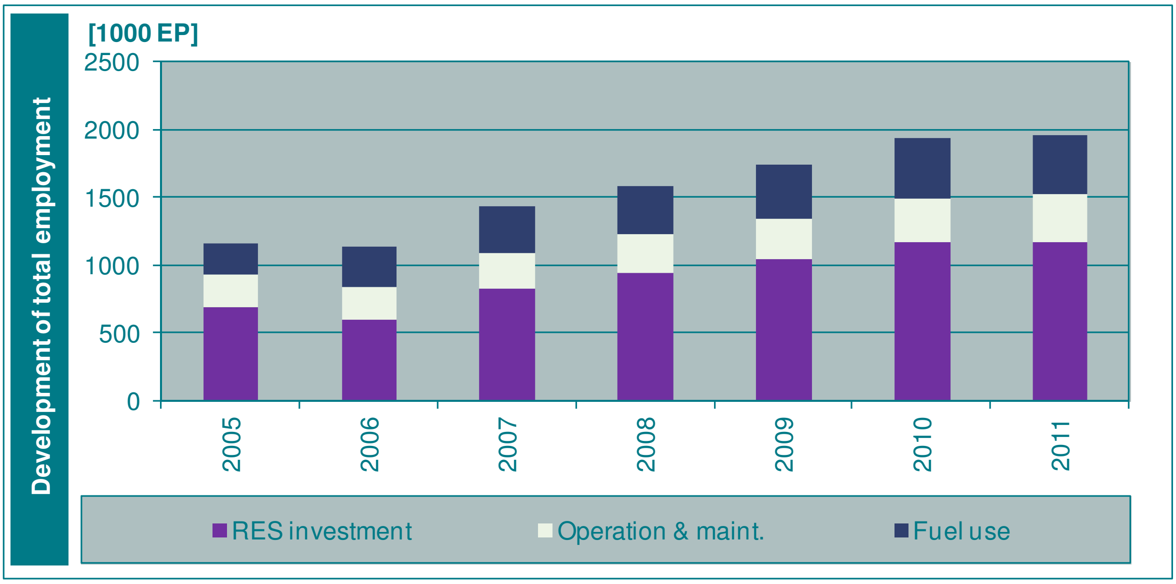

Figure IV-15: Development of total employment induced by RES deployment between 2005 and 2011

When comparing the two figures for value added and employment, it can be seen that biomass fuel use is responsible for a larger share in total employment than in total value added. This shows that labour productivity in the economic sectors related to fuel use (esp. agriculture and forestry) is lower than in those sectors related to RES investment and operation.

Employment in 2011

The analysis of employment follows the analysis of value added presented above. Generally, the deviations from the results for value added can be explained by labour productivity differences in the respective countries and economic sectors.

Figure IV-16 shows the total employment induced in the EU by RES deployment. Employment is largest in Germany with approximately 450,000 jobs, followed by Italy with almost 300,000 employed persons and Spain, France and the United Kingdom with between 100,000 and 150,000. Compared to Figure IV-14, which shows value added, employment is higher in the new Member States due to their significantly lower labour productivity. Furthermore, RES fuel use generally has a higher share in employment, since the connected primary sector is also characterized by relatively low labour productivity.

The contribution of the respective RES technologies to employment in the EU Member States is shown in Figure IV-17. Again, biomass use, PV and wind technology have high relevance for employment and the share of biomass technologies in employment is higher than their share in value added. Figure IV-18 shows employment by country and economic sector.

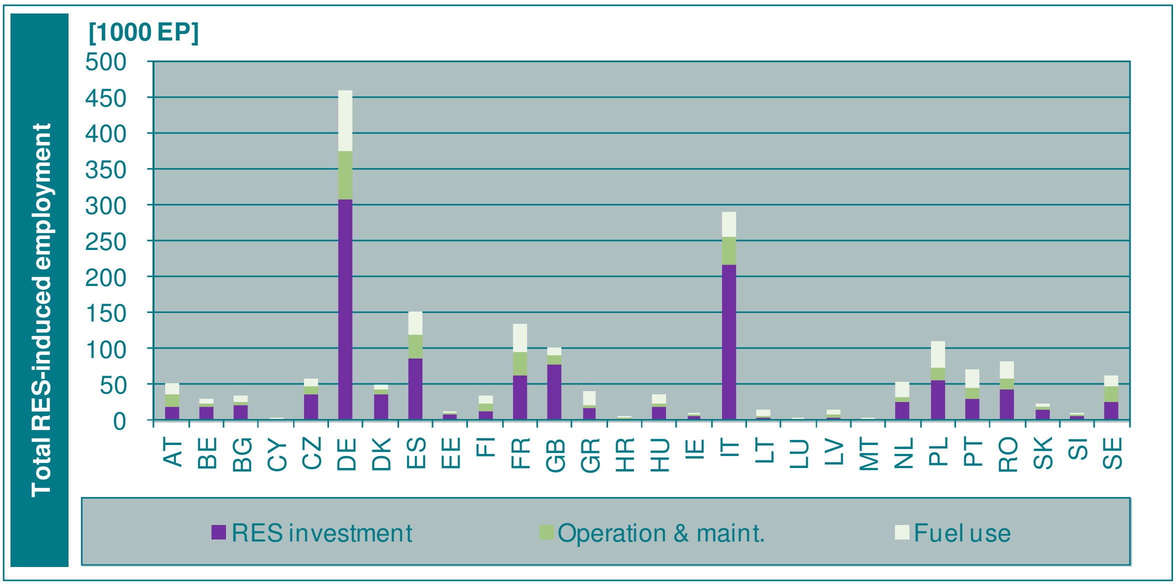

Figure IV-16: Total employment induced by RES deployment in 2011, by country and RES expenditure category

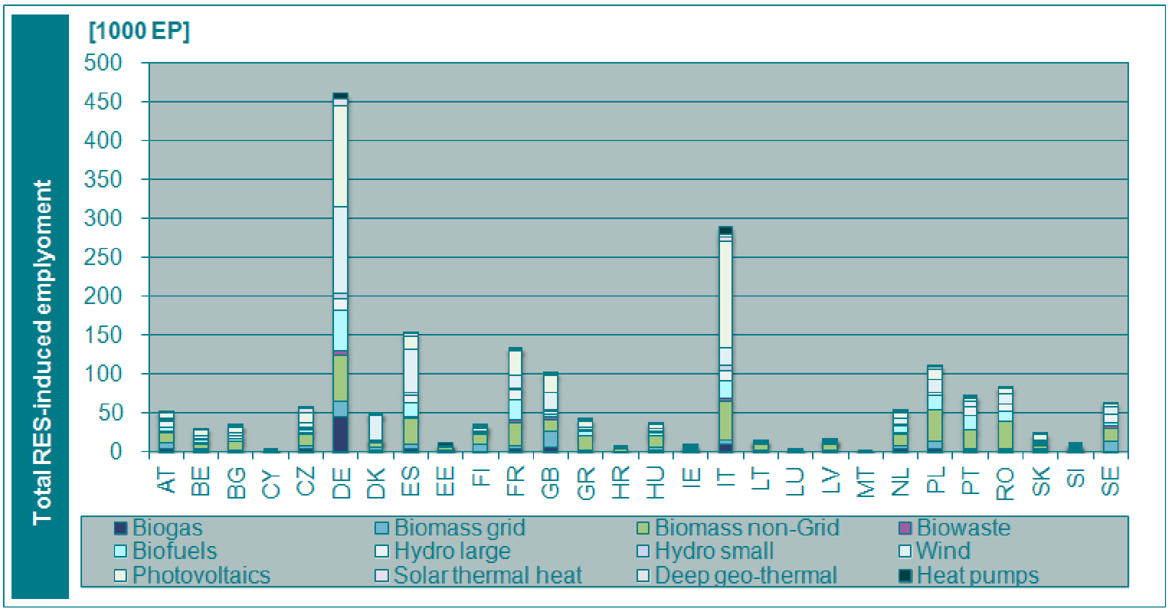

Figure IV-17: Total employment induced by RES deployment in 2005, by country and RES technology

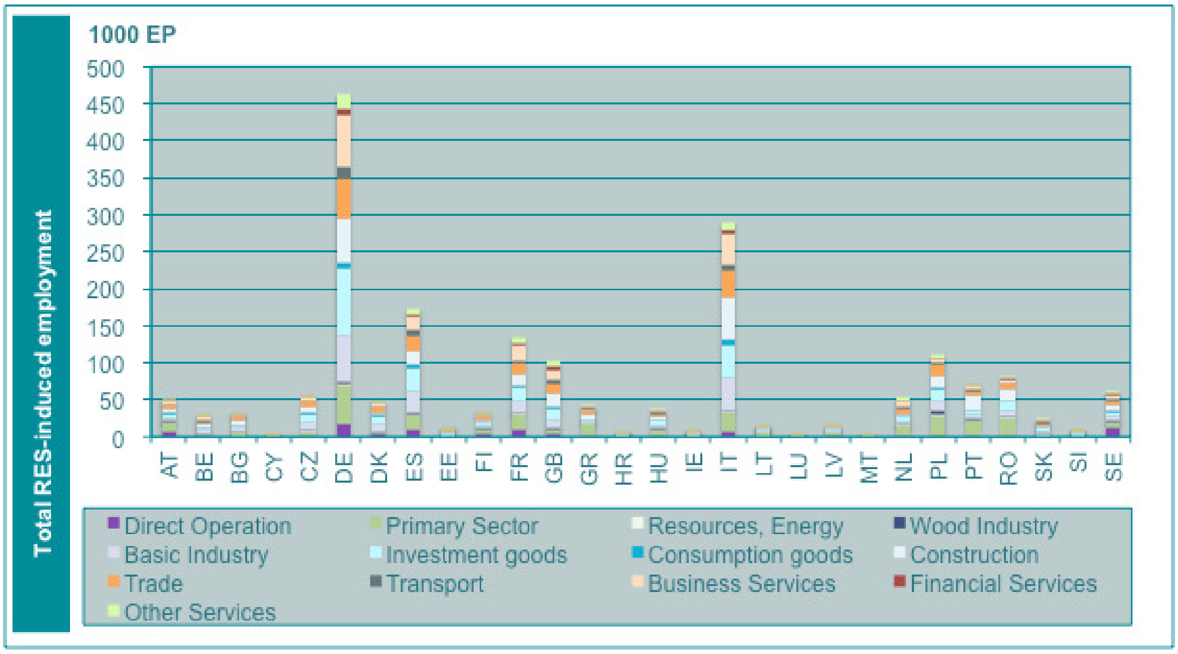

Figure IV-18: Total employment induced by RES deployment in 2005, by country and economic sector

From a RES technology perspective, non-grid biomass use accounts for the largest share of employment with 450,000 employed persons (Figure IV-19), followed by PV (440,000) and wind energy (350,000). Other important contributors are the other biomass technologies (except biowaste) and hydropower.

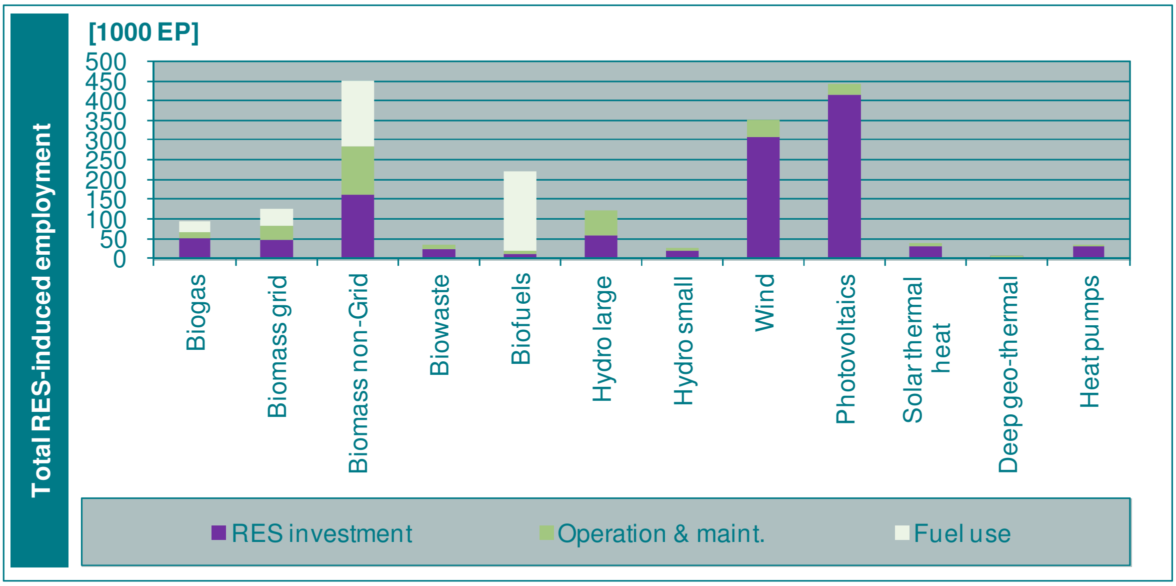

Figure IV-19: Total employment in the EU induced by RES deployment in 2005, by technology and expenditure category

2 Analysis of future RES policies

2.1 Summary

The core objective of this chapter is to provide a detailed depiction of RES deployment scenarios up to the year 2050. The main gross and net economic impacts of the RES sector are presented, including total gross value added by the RES sector and gross employment effects due to RES deployment. Additionally, net growth and net employment effects are discussed, taking into account additional RET deployment as well as reduced CET deployment.

Table IV-2 gives an overview of the key scenario assumptions and key macroeconomic results for 2030 and 2050. The future RES scenarios aim at 2030 targets of 30% and 35%, with RES shares projected to reach 59% and 62% in 2050, respectively. Gross value added increases to 166 billion €$_{2010}$/a in 2050, and associated gross employment to 2.3 million jobs in the EU28 in 2050. The net results indicate GDP increases of up to 0.4% in the 30% target scenarios and up to 0.8% in the 35% target scenarios compared to the BAU scenario. GDP effects diminish over time. Net employment effects are estimated to total 0.7 million jobs in the 30% target scenarios and 1.5 million jobs in the 35% target scenarios.

Table IV-2: RES targets and projections on key macroeconomic indicators for 2030 and 2050

		30%		35%	
		2030	2050	2030	2050
Total RE deployment	TWh/a	3600	5400	4100	5600
Share in gross final energy demand	%	30%	59%	35%	62%
Gross Value added	bn €$_{2010}$/a	100/ 92	166/ 160	122/ 120	165/ 164
Gross employment	1000 jobs	1700/ 1600	2200	2100	2200/ 2300
Net GDP (NEMESIS)	%	0.4/ 0.3	0.3	0.8	0.5/ 0.7
Net employment (NEMESIS)	1000 jobs	700	300/ 700	1500	600/ 1400

Where two figures are provided, the first refers to the corresponding SNP scenario, the second to the corresponding QUO scenario.

2.2 Future RES deployment

This section and the next one illustrate the outcomes of the model-based assessment of future RES deployment within the European Union according to the RES policy pathways defined in Section III.2.1. The assessment conducted with the Green-X model aims to deliver a quantitative basis for the subsequent macro-economic modelling, describing the direct economic impacts associated with future RES deployment within the EU. The results concerning the capital, O&M, and fuel expenditures of RES, additional generation costs and support expenditures as well as savings related to fossil fuel (imports) serve as the basis for the subsequent macro-economic modelling. We briefly summarise these results below, complemented by a qualitative discussion based on key quantitative indicators. Most prominently, the resulting deployment and the corresponding support expenditures will be discussed. Note that this section focuses on RES deployment, while the subsequent one aims to provide complementary outcomes on related direct impacts – i.e. costs, expenditures and benefits.

Key results on RES deployment at the aggregated level

We start with an analysis of RES deployment according to Green-X RES policy cases conducted on the basis of corresponding PRIMES scenarios that have been developed for and are discussed in the Impact Assessment accompanying the Communication from the European Commission "A policy framework for climate and energy in the period from 2020 to 2030" (COM(2014) 15 final). More precisely, Figure IV-20 below shows the development of the RES share in gross final energy demand throughout the period 2020 to 2050 in the EU 28 according to the assessed Green-X and PRIMES scenarios. Noticeably, with the exception of the long-term trend under baseline conditions, a full alignment to PRIMES results could be achieved at the aggregated level (total RES deployment, EU28). We also point out that the different policy tracks aiming for 30% (SNP 30 and QUO 30) or 35% (SNP 35 and QUO 35) RES by 2030, respectively, converge by 2050.

Beyond the scope of this figure, a more detailed analysis that involves sector-specific results also indicates that comparatively similar trends are observable by 2030 for the EU28 at sector level. Stronger differences between PRIMES and Green-X are, however, apparent with respect to long-term trends (2050) – i.e. while in Green-X, there is higher RES penetration in the electricity sector and for heating & cooling, in PRIMES, biofuels for transport diffuse more strongly in the policy cases.

Figure IV-20: Comparison of the resulting RES deployment in relative terms (i.e. as share in gross final energy demand) over time in the EU 28 for all assessed cases (incl. PRIMES scenarios)

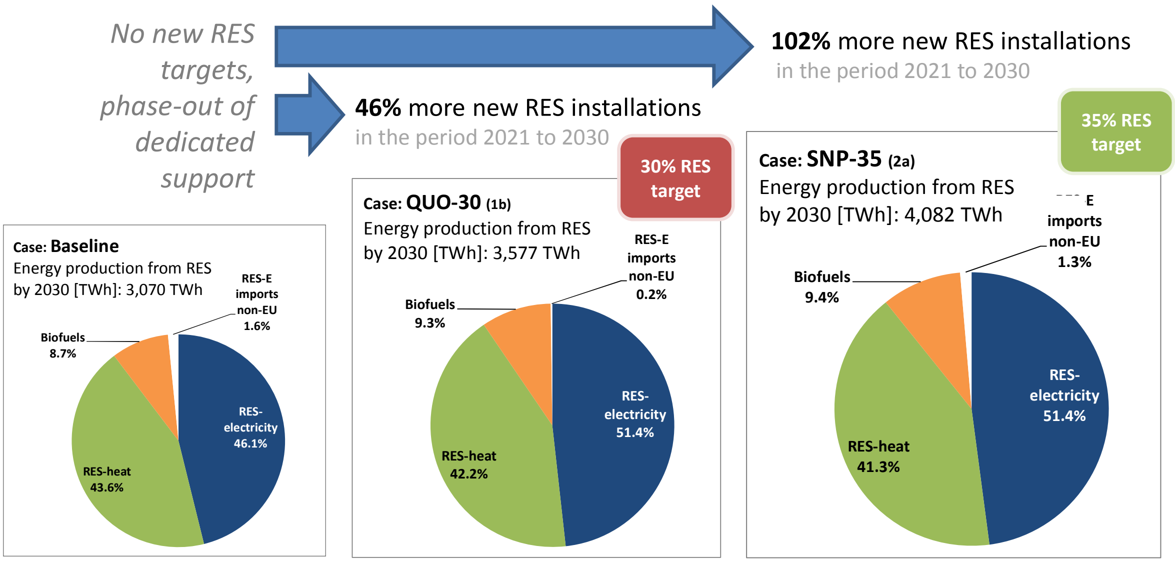

Figure IV-21: Sector-specific RES deployment at EU 28 level by 2030 for selected cases

Figure IV-21 takes a closer look at the sector-specific RES deployment at EU-28 level While sector-specific RES shares differ only to a small extent among the assessed cases, (strong) differences are apparent concerning the overall deployment of new RES installations: 30% RES by 2030 in comparison to the baseline means a 46% increase in the deployment of new RES installations, whereas a target of 35% RES by 2030 would imply doubling new installations in the same period 2021 to 2030 (102% more new RES by 2030 compared to the baseline). To achieve strong RES deployment as anticipated under the policy cases assuming 35% RES by 2030, imports of RES-electricity from non-EU countries play a major role: 1.2 to 1.3% of 2030 RES deployment, corresponding to 49 to 54 TWh that would be generated in North Africa, Turkey, the Balkan states or Norway and physically imported to the EU.

Details on RES in the electricity sector

Next, a brief overview of the results gained for RES in the electricity sector is given, indicating key indicators on RES deployment over time and at technology level: see Figure IV-22 to Figure IV-23.

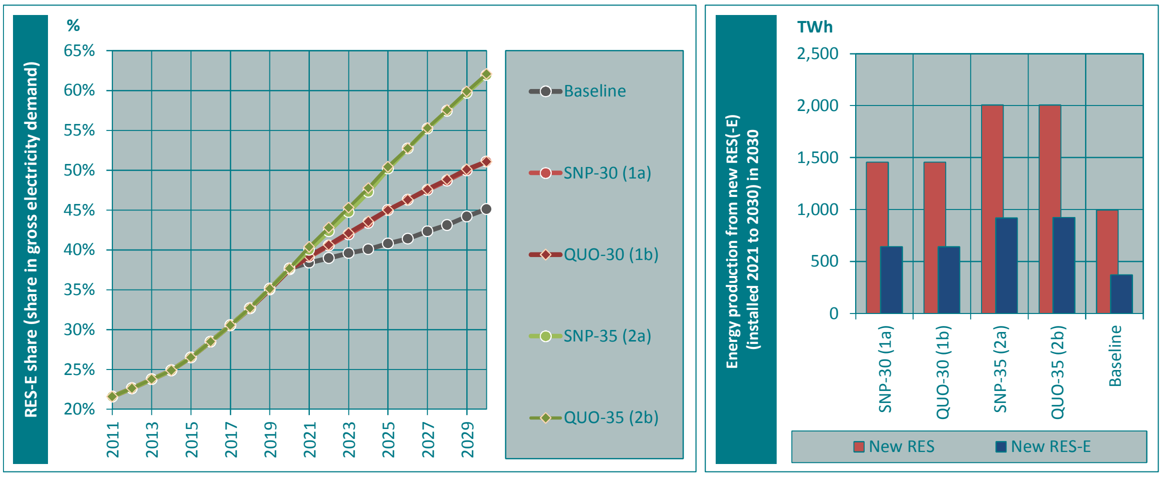

Figure IV-22: Comparison of the resulting deployment over time for all RES-E (left) as well as by 2030 for new RES-E and RES installations only (from 2021 to 2030) (right) in the EU 28 for all assessed cases.

More precisely, Figure IV-22 illustrates the feasible RES-E deployment for all assessed policy cases over time (left) as well as by 2030 (right), indicating the penetration of new RES-E installations within the observed time frame. It becomes evident that, without or with low dedicated support, RES-E deployment would increase modestly after 2020, reaching for example a share of 45.1% RES-E by 2030 in the baseline case. This indicates that the ETS on its own complemented by only moderate dedicated RES incentives does not provide sufficient stimulus for RES-E deployment to maintain a level of ambition consistent with the development until 2020. In contrast to the baseline case, the expected RES deployment in the electricity sector increases more substantially in all other policy variants by 2030, ranging from 51.1% (case 1a and 1b) to around 62% (case 2a and 2b). If total RES deployment is considered, a 26.3% RES share in gross final energy demand would be achieved under baseline conditions by 2030, while the targeted RES deployment volumes are reached in all other policy paths (i.e. 30% under 1a and 2b, and 35% in the cases 2a and 2b, respectively).

Figure IV-23: Technology-specific breakdown of RES-E generation from new installations by 2030 (top, incl. new installations from 2021 to 2030) and by 2050 (bottom, incl. new installations from 2021 to 2050) at EU 28 level for all assessed cases

Complementary to the above, Figure IV-23 provides a technology-breakdown of RES-E deployment at EU 28 level by 2030 (top) and by 2050 (bottom), indicating the amount of electricity generation by 2030 and 2050 that stems from new installations of the assessed period 2021 to 2030 (top) or 2021 to 2050 (bottom), respectively, for the analysed policy pathways. It is apparent that wind energy (on- & offshore), photovoltaics and biomass dominate the picture. Even in the baseline case, significant numbers of new installations can be expected, in particular for onshore wind energy. Differences are apparent among all the other cases that are a consequence of the targeted RES volumes (30% or 35% RES by 2030) or of the policy approach assumed to reach that target. An ambitious RES target (35% RES by 2030) generally requires a larger contribution of the various available RES-E options. Technology-neutral incentives as assumed under the policy variant with harmonised uniform RES-E support (QUO 35, case 2b) fail, however, to provide the necessary incentive to encourage more expensive novel RES-E options on a timely basis. Consequently, the deployment of CSP, tidal stream or wave power, but also to a certain extent offshore wind, may be delayed or even abandoned. The gap in deployment would be compensated by an increased penetration of low to moderate cost RES-E options, in particular onshore wind and biomass used for co-firing or in large-scale plants.

2.3 Direct impacts of future RES deployment: Costs, expenditures and benefits

The outcomes of Green-X modelling related to capital, O&M, and fuel expenditures of RES as well as to additional generation costs, support expenditures and savings related to fossil fuel (imports) serve as key inputs for the subsequent macro-economic modelling. These results are summarised below, complemented by a qualitative discussion based on key indicators. Since distributional effects are also very relevant for the macro-economic impacts, the resulting support expenditures will be discussed in more detail at the end of this section.

Indicators of costs, expenditures and benefits of RES

Indicators of the costs, expenditures and benefits of accelerated RES deployment in the European Union provide decision-makers with essential information as well as being the key inputs to the macro-economic modelling. In this context, Figure IV-24 summarises the assessed costs, expenditures and benefits arising from future RES deployment in the focal period 2021 to 2030 (upper graph in Figure IV-24) as well as in later decades (2031 to 2040 and 2041 to 2050). More precisely, these graphs show the *additional*[14] investment needs, O&M and (biomass) fuel expenditures and the resulting costs – i.e. additional generation cost, and support expenditures for the selected cases (all on average per year throughout the assessed period). Moreover, they indicate the accompanying benefits in terms of supply security (avoided fossil fuels expressed in monetary terms – with impact on a country's trade balance) and climate protection (avoided CO_2 emissions –expressed in monetary terms as avoided expenses for emission allowances). Other macro-economic impacts, like employment effects, will be discussed later on when analysing the results of the complementary macro-economic assessment.

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[14] *Additional* here means the difference to the baseline for all policy cases and indicators, indicating the additional costs or benefits accompanying the anticipated RES policy intervention.

Figure IV-24: Indicators on yearly average cost, expenditures and benefits of RES at EU 28 level for all assessed cases, monetary expressed in absolute terms (billion €) per decade (2021 to 2030, 2031 to 2040, and 2041 to 2050)

As shown in Figure IV-24, benefits such as fossil fuel or CO_2 emission avoidance depend mainly on the overall RES target and the related number of required new RES installations. Thus, they are more or less the same among all the assessed policy cases that aim to achieve the same overall RES target (i.e. 30% or 35% RES by 2030, and 59% or 62%

RES by 2050, respectively). When comparing case 1a with 1b, or case 2a with 2b, differences between the underlying policy concept are apparent in later years with respect to the resulting benefits: Path 1a (SNP 30) and 2a (SNP 35) show a higher avoidance of fossil fuels and of CO_2 emissions than the corresponding 1b (QUO 30) and 2b (QUO 35) in the period 2031 to 2050. These differences are again caused by disparities in intertemporal RES deployment – i.e. paths 1a and 2a show higher RES deployment in the interim period 2031-2040 than the corresponding cases of using a harmonised certificate scheme to support RES-E.

For investment needs and also for cost indicators (i.e. additional generation cost and support expenditures) a similar trend can be seen as discussed for benefits: Costs and expenditures depend to a large extent on the overall RES target that is aimed for – i.e. a stronger RES target (e.g. 35% RES by 2030 compared to 30% RES) leads to higher costs and expenditures. A comparison of the underlying policy concepts indicates that capital expenditures and additional generation cost are somewhat smaller in the case of a uniform quota scheme while, as also discussed above, support expenditures are significantly higher in magnitude compared to technology-specific incentives tailored to the national circumstances.[15]

Indicators of support expenditures for RES installations

Considering the importance of the distributional effects of energy and climate policy on the macro-economy this section takes a closer look at the support expenditures for renewable energies. Figure IV-25 complements the above depictions of RES deployment and overall economic impacts, indicating the resulting support expenditures for new RES installations in relation to the RES deployment in more detail. More precisely, Figure IV-25 compares overall RES deployment by 2030 with the corresponding support expenditures (on average per year for the period 2021 to 2030) for the selected policy pathwaysby depicting the RES share in gross final energy demand. This shows a relationship between an increase in RES-related support expenditures and an increase in RES deployment. Moreover, there are differences between the assessed policy variants for meeting the same RES target, specifically if strong RES expansion is anticipated:

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[15] It should be noted, however, that the total generation cost include all cost components of RES plants but do not consider costs for grid expansion, because this is a cost component belonging to the overall energy system. In odder words it is conceptually difficult to attribute a specific share of total grid expansion costs to the increasing share of RES-E or a higher concentration of RES-E in specific regions with low-cost resources. Therefore the advantage of least-cost resource allocation due to a harmonized quota scheme was somewhat overestimated due to the system boundaries used for the present analysis.

- For a target of 30% RES by 2030 both policy options, i.e. a more nationally oriented approach offering technology-specific incentives tailored to the specific needs (strengthened national policies (SNP 30), case 1a) and a harmonised approach offering uniform RES support via a uniform certificate trading regime (harmonised quotas (QUO 30), case 1b), show similar performance with respect to support expenditures.
- If a stronger RES target (35% RES by 2030) is targeted, policy options providing technology-specific incentives (SNP 35, policy case 2a) offer the possibility of achieving lower consumer/support expenditures compared to harmonised uniform RES support (QUO 35, policy case 2b). Since more costly RES technology comes into play to achieve a more ambitious RES target, technology-specific financial incentives are able to better align support to actual needs. Consequently, over-supporting mature RES technologies can be avoided, resulting in lower support expenditures at the aggregated level while simultaneously stimulating the deployment of currently more costly technology options. This leads to a more diverse portfolio of RES technologies by 2030 and 2050 under SNP 35 (policy case 2a) compared to QUO 35 (policy case 2b), see Figure IV-23.

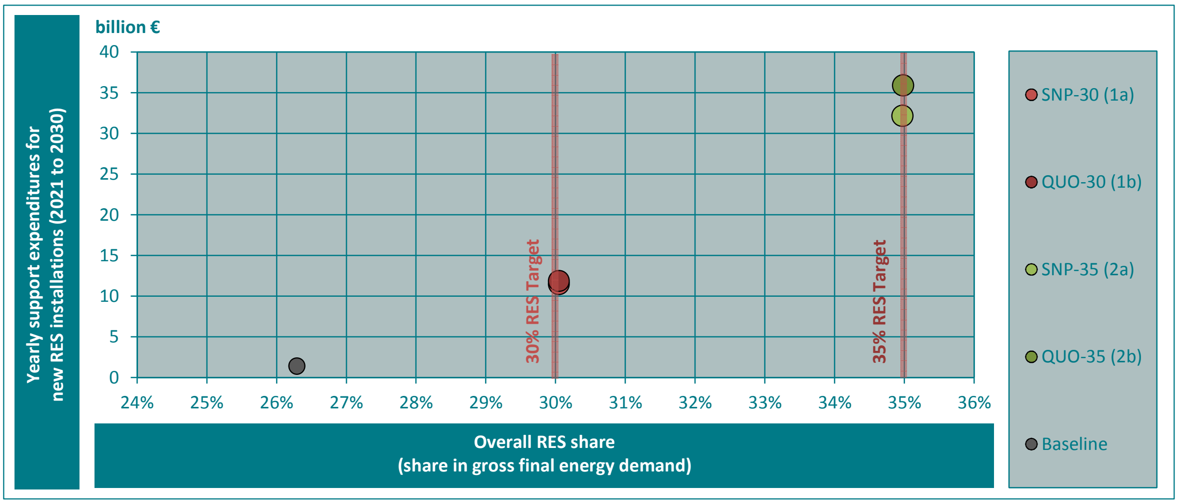

Figure IV-25: Comparison of the resulting 2030 RES deployment and the corresponding (yearly average) support expenditures for new RES (installed 2021 to 2030) in the EU 28 for all assessed cases.

Details on RES in the electricity sector

Next a closer look is taken at the financial impact of RES support in the electricity sector. The support expenditures for RES-E or policy costs from a consumer perspective are analysed in more detail. In this context, Figure IV-26 (left) provides a comparison of the dynamic evolution of the required support expenditures in the period 2011 to 2030 for all RES-E (i.e. existing and new installations in the focal period). Note that these figures represent an average premium at EU 28 level, while significant differences may occur at country-level, even in the case of harmonised support settings. Complementary to that, Figure IV-26 (right) shows yearly average support expenditures for new RES and RES installations in the period 2021 to 2030.

The same conclusion is reached as discussed previously for RES in general. Assuming a similar target has to be achieved, policy options providing technology-specific incentives allow lower consumer expenditures to be achieved compared to harmonised uniform RES support. If a more ambitious RES(-E) target is assumed, the differences between the two approaches are more pronounced.

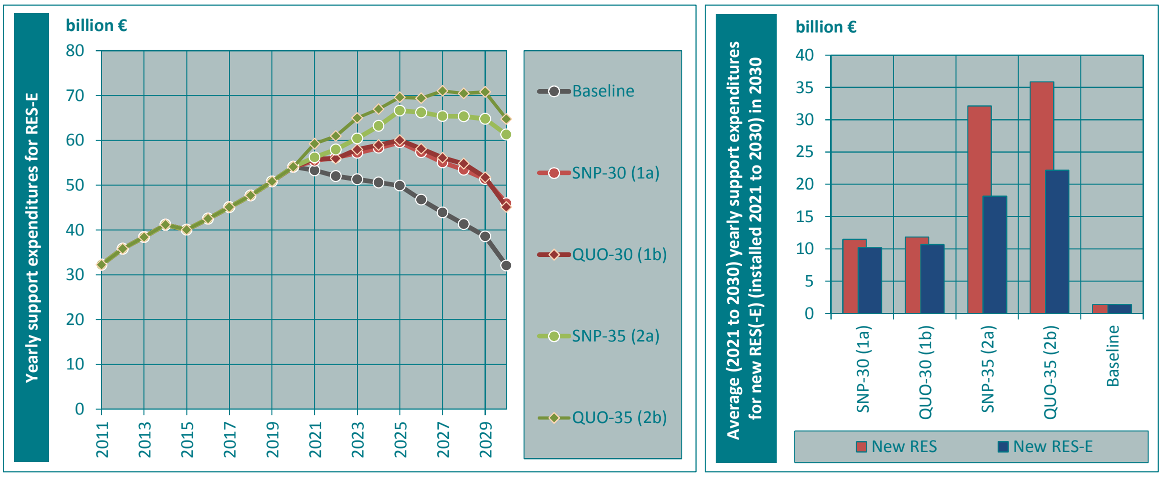

Figure IV-26: Comparison of the resulting yearly support expenditures over time for all RES-E (left) as well as on average (2021 to 2030) for new RES-E and RES installations only (from 2021 to 2030) (right) in the EU 28 for all assessed cases.

Finally, a brief look is taken at the period beyond 2030: Figure IV-27 shows the dynamic development up to 2050 of the necessary financial support per MWh of RES-E generation for new installations (on average). The values refer to the corresponding year. The amount represents the average additional premium on top of the power price (normalised for a period of 15 years) for a new RES-E installation in a given year from an investor's viewpoint; whilst, from a consumer perspective, it indicates the additional expenditure per $MWh_{RES\text{-}E}$ required for a new RES-E plant compared with a conventional option (characterised by the power price).

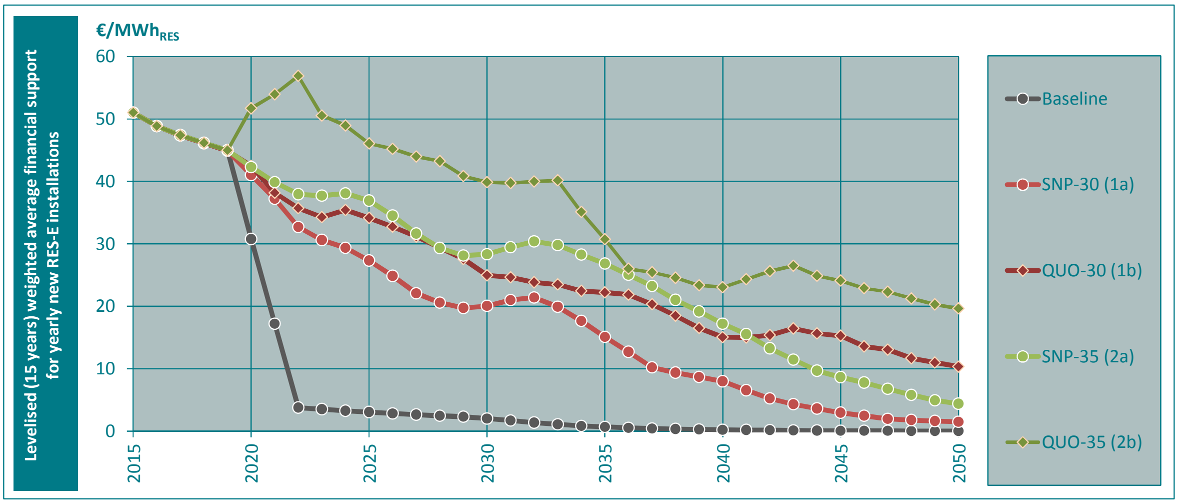

Figure IV-27: Comparison of financial support (premium to power price) for new RES-E installations at EU 28 level over time (2015 to 2050)

In general, a decline of the required financial support per MWh$_{RES\text{-}E}$ is apparent, but differences between the policy variants can be observed. Generally, the average support is higher under a technology-neutral scheme than if policy approaches offer incentives tailored to the specific needs. Most pronounced appears the decrease of financial support under baseline conditions: Under this scenario a phase-out of currently strong deployment incentives for RES-E is assumed in the period post 2020. This causes a sharp decline of the financial support for *yearly new* constructed RES-E installations while cumulative support expenditures decline moderately. As discussed previously, this has however a strong impact on the resulting RES-E deployment. The low support leads to a decline of investments in new RES-E by 55% to 62% in the period 2021 to 2030 compared to the policy cases 1a and 1b (where a 30% RES target is aimed for by 2030).

Sensitivity analysis of key input parameters

A sensitivity analysis has been conducted in order to indicate the robustness of the model results and to validate the scenario findings. While ultimately most assumptions could be tested, the sensitivity analysis focuses on two major points:

- Assumptions related to technological learning (future cost reductions) (i.e. +/-20% with respect to the default values for future learning rates of assessed RES technologies)
- Development of energy demand (indicating the role of accompanying energy efficiency measures)

This section presents the outcomes of this assessment, indicating affected RES deployment (in the case of changing demand assumptions) as well as changes in costs, expenditures and benefits.

Sensitivity on technological learning / future cost reductions

Figure IV-28 displays the outcome of modifications to the assumptions about technological learning. This graph shows for selected policy cases the change in costs (i.e. additional generation cost), expenditures (support and capital expenditures) and benefits (avoided fossil fuels and expenses for CO_2 emission allowances) compared to the default variant of moderate technological learning.

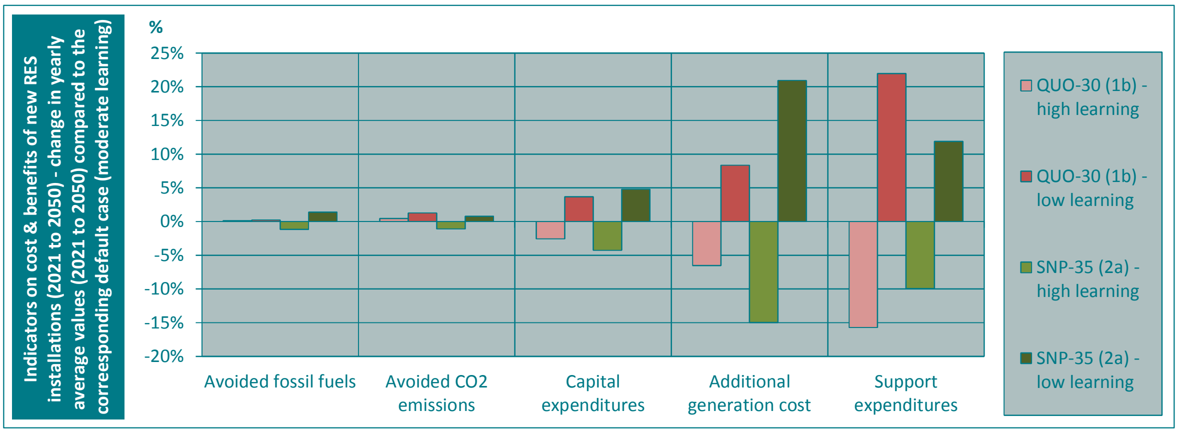

Figure IV-28 Sensitivity on technological learning: Indicators on yearly average (2021 to 2050) cost, expenditures and benefits of new RES (installed 2021 to 2050) at EU 28 level for all assessed cases, expressed are the changes compared to the corresponding default case (of moderate technological learning)

It can be seen that benefits are almost unaffected by changes in future cost reductions because the magnitude of overall RES deployment by 2030 and 2050, respectively, remains also unchanged. Slight changes can be observed with respect to capital expenditures: Higher learning leads to lower capital expenditures (i.e. -3% (case 1b) to -4% (case 2a)) while the opposite trend can be seen in the case of lower learning, leading to an increase of capital expenditures of 4% (case 1b) to 5% (case 2a). Strong deviations from the default case can be observed with respect to costs: Additional generation increases by 8% (case 1b) and by 21% (case 2a), respectively, in the case of lower learning, and vice versa if learning is stronger than anticipated in the default scenarios. The deviations are stronger if a strong RES deployment is targeted (as assumed under the policy case 2a (and 2b)). Surprisingly, support expenditures show the opposite trend: More significant changes can be seen if a moderate RES target is aimed for (as assumed under the policy case 1b). The magnitude of changes with respect to support expenditures ranges from -16% (case 1b under high learning) to 22% (case 1b if low learning can be achieved). One reason for this initially surprising trend may be the underlying policy concept – i.e. the harmonized quota scheme that offers uniform pricing to all RES options (case 1b) appears more sensitive to changes in the cost developments than the finely tailored technology-specific incentives (as assumed under case 2a)..

Sensitivity on future demand developments

The second sensitivity analysis assesses the consequences of a reduced role of energy efficiency in the future, where demand growth follows business-as-usual trends (as projected in the PRIMES reference case as of 2013 (EC, 2013). Compared to the default demand trend the reference case implies a 51% to 52% higher gross final energy demand by 2050. Consequently, this leads to an increase of the required RES deployment of similar magnitude if the same RES share has to be achieved by 2030 and 2050, respectively, see Figure IV-29.

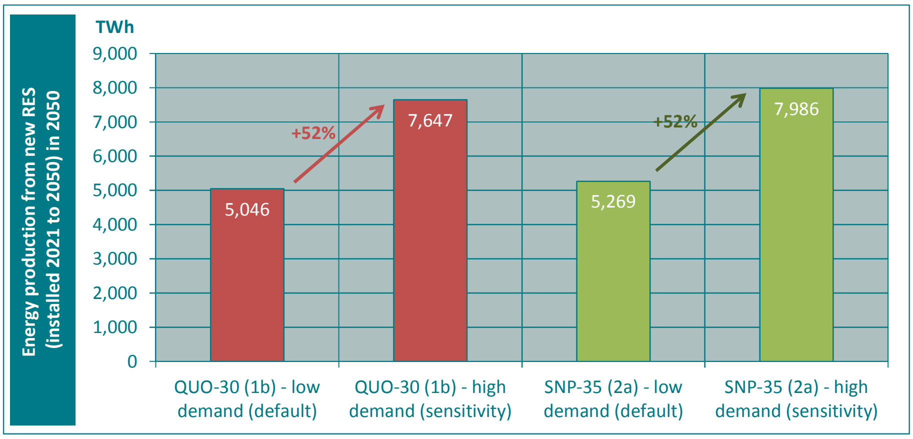

Figure IV-29 Sensitivity on future energy demand: Energy production from new RES (installed 2021 to 2050) in 2050 for selected assessed policy pathways

Figure IV-30 displays the consequences of changed assumptions about future demand development. Similar to the previous sensitivity analysis on technological learning, this graph shows for all assessed policy cases the change in costs (i.e. additional generation cost), expenditures (support and capital expenditures) and benefits (avoided fossil fuels and expenses for CO_2 emission allowances) compared to the default variant (of low energy demand / strong energy efficiency).

A stronger RES deployment in absolute terms results in an increase in RES-related benefits. Consequently, a high energy demand leads to an increase of fossil fuel avoidance as well as of CO_2 emission avoidance (but both only in absolute terms). A strong increase can also be observed for capital expenditures. However, the most pronounced increase can be observed for support expenditures, which rise by more than 200% in the cases 1a and 1b, while under the more ambitious RES target (35% RES by 2030) the increase remains comparatively moderate (75% to 90%).

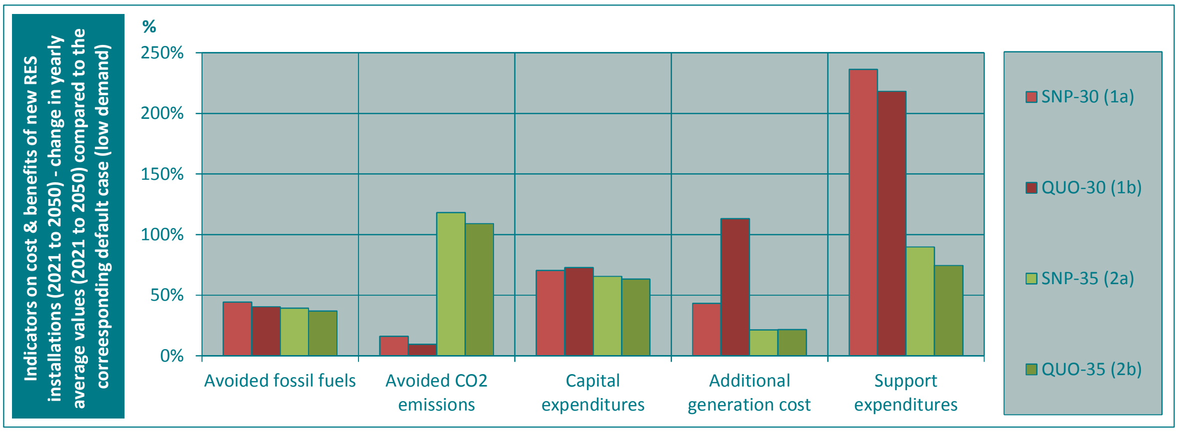

Figure IV-30 Sensitivity on future energy demand: Indicators on yearly average (2021 to 2050) cost, expenditures and benefits of new RES (installed 2021 to 2050) at EU 28 level for all assessed cases, expressed are the changes compared to the corresponding default case (of low energy demand / strong energy efficiency)

2.4 Effects on security of supply

A secure supply of energy represents a necessity for the well-being of European citizens and the European economy. In response to the political crisis in Ukraine that has started in early 2014 the European Commission has released an EU energy security strategy (COM(2014)330) on 28 May 2014. As top priority among five key areas with respect to medium- to long-term challenges the EC proposed action towards increasing energy efficiency and reaching the proposed 2030 energy and climate goals. This underpins the importance of increasing RES deployment as an effective measure to reduce the demand for fossil fuels and to decrease the need for related imports.

This section is dedicated to the possible future contribution of RES to a secure supply of energy in the EU. Before digging into details on future impacts arising from an enhanced RES deployment as anticipated in the assessed policy cases we take a closer look on the status quo of fossil energy use and related imports.

Figure IV-31 below shows the historic development of gross inland consumption (left) and net imports (right) of fossil fuels in the EU28 since the year 2000. While the gross inland consumption of fossil fuels decreased by 9% since the year 2000, the imports of these fuels increased by 11%. As a consequence the import dependency for fossil fuels increased from 60% in the year 2000 to 73% in 2012.

On the other hand imports are relatively concentrated on a few supplying countries as can be seen from Figure IV-32. This high concentration on very few countries causes substantial vulnerability issues for the EU economy. Therefore the further diversification of energy supply based on domestic sources combined with strengthened efforts to increase energy efficiency are gaining importance in EU energy policy.

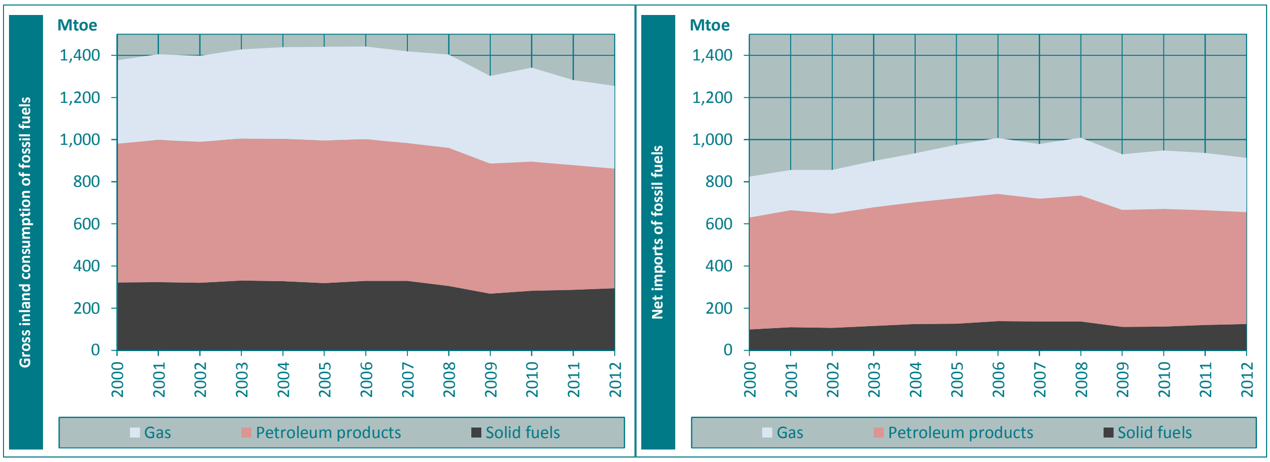

Figure IV-31: Historic development of gross inland consumption (left) and net imports (right) of fossil fuels in the EU28

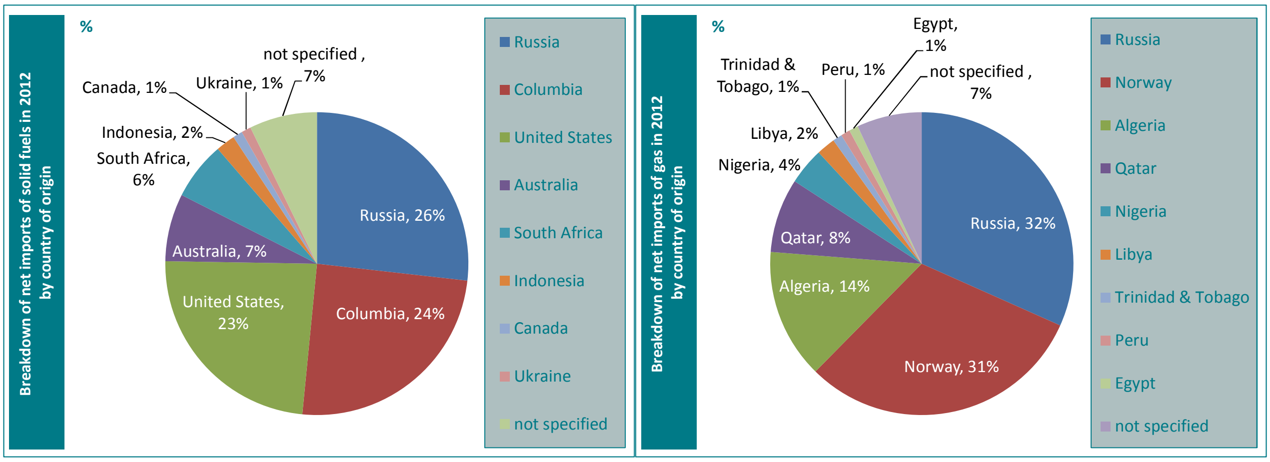

Figure IV-32: Breakdown of net imports of solid fuels (left) and of gas (right) in 2012 by country of origin

As explained before (see section III.2.1), sector- and country-specific conversion efficiencies as projected by PRIMES for the future evolution of the conventional supply portfolio are used to calculate the amount of avoided fossil primary energy from derived renewable generation figures. A monetary expression is then derived by using the projected price developments of fossil energy carriers at the international level.

Table IV-3 and Table IV-4 summarise the outcomes of the energy modelling conducted with the Green-X model related to the contribution of RES towards fossil fuel avoidance. More precisely, these tables show the amount of fossil fuels that can be additionally[16] replaced by use of domestic RES in forthcoming years, i.e. in 2030 (Table IV-3) and in 2050 (Table IV-4), respectively.

Table IV-3: Avoided fossil fuels due to RES by 2030 – increase compared to status quo (2010) at EU28 level according to assessed cases

Avoidance of fossil fuels due to RES by 2030 - increase compared to status quo (2010)	**Case: Unit**	**Baseline**	**SNP 30 (1a)**	**QUO 30 (1b)**	**SNP 35 (2a)**	**QUO 35 (2b)**
Expressed in energy units						
by sector						
Electricity	Mtoe	160.8	226.5	225.8	269.9	271.1
Heat	Mtoe	35.1	47.3	49.6	61.1	63.3
Transport	Mtoe	9.6	15.6	15.5	20.2	20.2
by energy carrier						
Coal	Mtoe	43.7	62.4	68.8	78.4	83.7
Oil	Mtoe	6.4	15.9	16.3	26.3	27.0
Gas	Mtoe	155.4	211.1	205.8	246.6	244.1
Total amount	**Mtoe**	**205.5**	**289.4**	**290.9**	**351.2**	**354.7**
Expressed in monetary terms						
by sector						
Electricity	billion €	82.5	107.9	105.8	124.0	123.2
Heat	billion €	27.0	32.7	33.8	39.6	40.6
Transport	billion €	9.8	13.8	13.7	16.8	16.8
by energy carrier						
Coal	billion €	11.8	15.0	16.1	17.8	18.7
Oil	billion €	16.2	22.5	22.8	29.4	29.9
Gas	billion €	91.2	116.9	114.5	133.3	132.1
Total amount	**billion €**	**119.2**	**154.5**	**153.4**	**180.4**	**180.7**
	% of GDP	0.7%	0.9%	0.9%	1.1%	1.1%

It is becoming apparent that renewable energy is an important element for improving the security of energy supply in Europe. Even the figures for the moderate Baseline case seem impressive: The total amount of avoided fossil fuels due to the increase in RES deployment compared to 2030 equals 205 Mtoe in 2030 and 325 Mtoe in 2050, respectively. Assuming an unchanged conventional fuel mix compared to PRIMES reference projections, 76% (73%) of the reduction in 2030 (2050) would refer to natural gas, followed by

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[16] *Additionally* shall mean here the increase compared to the status quo (as of 2010).

coal with 21% (22%) and oil with 3% (5%). In the case of gas, the 2030 (2050) baseline figure equals 36% (55%) of the current (2010) total EU gas consumption or 56% (88%) of current (2010) gas import needs, respectively. In monetary terms these figures correspond to reduced annual expenses for fossil fuels of €119 billion in 2030, increasing to €168 billion in 2050.[17]

Table IV-4: Avoided fossil fuels due to RES by 2050 – increase compared to status quo (2010) at EU28 level according to assessed cases

Avoidance of fossil fuels due to RES by 2050 - increase compared to status quo (2010)	**Case: Unit**	**Baseline**	**SNP 30 (1a)**	**QUO 30 (1b)**	**SNP 35 (2a)**	**QUO 35 (2b)**
Expressed in energy units						
by sector						
Electricity	Mtoe	274.0	409.4	411.6	445.9	439.1
Heat	Mtoe	34.2	67.9	73.5	69.1	76.6
Transport	Mtoe	16.5	31.2	32.7	37.0	36.9
by energy carrier						
Coal	Mtoe	72.3	105.6	121.4	116.5	126.7
Oil	Mtoe	14.8	38.2	40.8	47.6	48.4
Gas	Mtoe	237.6	364.7	355.6	387.9	377.4
Total amount	**Mtoe**	**324.8**	**508.5**	**517.8**	**552.0**	**552.6**
Expressed in monetary terms						
by sector						
Electricity	billion €	131.8	186.9	184.7	201.1	196.1
Heat	billion €	29.6	46.0	48.4	47.6	50.7
Transport	billion €	18.1	29.6	30.8	34.1	34.1
by energy carrier						
Coal	billion €	16.7	22.4	25.1	24.3	26.0
Oil	billion €	21.8	37.3	39.1	43.6	44.2
Gas	billion €	129.2	187.7	183.5	198.4	193.6
Total amount	**billion €**	**167.7**	**247.5**	**247.7**	**266.3**	**263.8**
	% of GDP	0.8%	1.1%	1.1%	1.2%	1.2%

Obviously, savings also increase with higher RES deployment as expected in the assessed policy cases, cf. Table IV-3 and Table IV-4: In energy terms, the annual savings in 2030 rise from 205 Mtoe (baseline) to about 290 Mtoe in the case of a 30% RES target, and to 351 to 355 Mtoe under a stronger RES target (i.e. 35% RES by 2030). In monetary

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[17] This also represents a possible saving with regard to the EU's trade balance as most fossil fuels are imported from abroad.

terms this equals an increase from €119 billion (baseline) to about €154 billion under a 30% RES target, rising to €180 billion in the case of a stronger RES target.

Corresponding results for 2050 are as follows: Fossil fuel savings rise from 325 Mtoe (baseline) to a around 508-518 Mtoe if a moderate 2030 RES target is followed (SNP 30 and QUO 30), and to about 552 Mtoe under stronger 2030 and 2050 RES targets (SNP 35 and QUO 35). In monetary terms this equals an increase of saved expenses for fossil fuels from €168 billion (baseline) to about €248 billion under a moderate 2030 RES target (SNP 30 and QUO 30). If a strong RES target (of 35% RES by 2030, and around 62% RES by 2050) is aimed for, monetary savings range from €264 to 266 billion by 2050 (SNP 35 and QUO 35).

Complementary to the above, a graphical illustration of additional savings resulting from an enhanced RES deployment (compared to baseline conditions) in the period beyond 2020 as anticipated in the assessed policy cases is given in Figure IV-33.

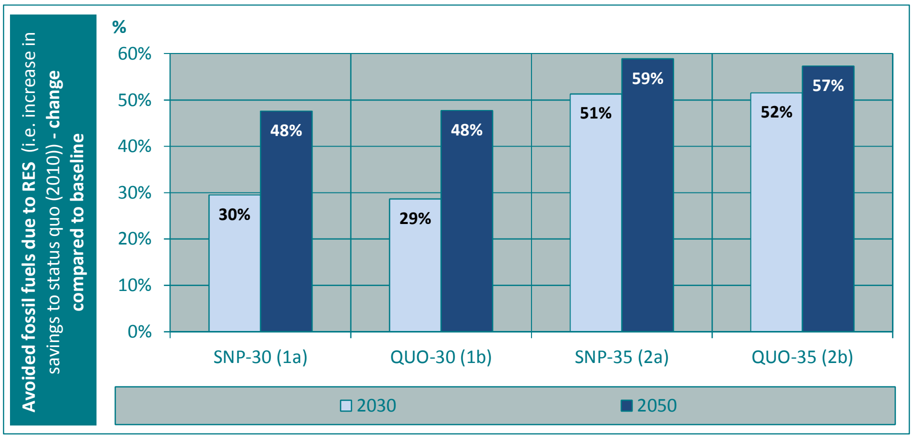

Figure IV-33: Avoided expenses for fossil fuels due to RES in 2030 and 2050 for the assessed policy cases, expressing the change in additional (i.e. increase to status quo (2010)) monetary savings compared to baseline

Below we put the outcomes as discussed above into further perspective, indicating the impacts arising from the enhanced RES deployment and accompanying fossil fuel avoidance on overall gross inland consumption and related imports of fossil fuels. Figure IV-34 shows the expected future gross inland consumption of fossil fuels for the assessed policy cases. The difference between the PRIMES reference path and the Baseline used in this study is dominated by the impact of energy efficiency targets, whereas the further reduction in gross inland consumption for the four policy cases is due to RES policies assumed.

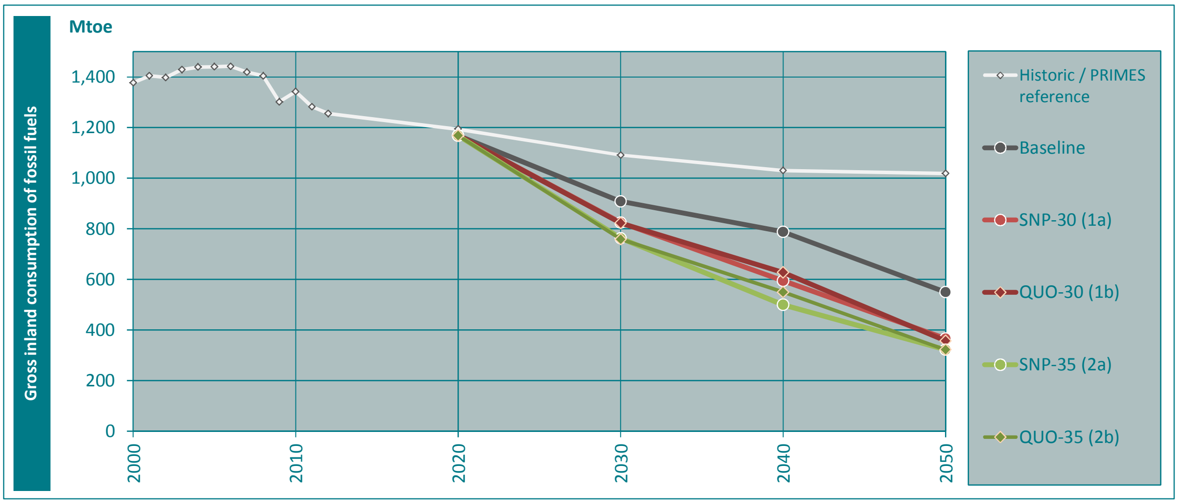

Figure IV-34: (Historic and) expected future gross inland consumption of fossil fuels according to assessed policy cases

In order to isolate the impact of RES policies Figure IV-35 shows the gross inland consumption of fossil fuels assuming the PRIMES reference demand for all assessed policy cases, which has been analysed in the frame of a sensitivity assessment. Due to the higher demand the absolute impact of the same relative RES targets (i.e. defined as share of demand) relative to Baseline increases. Following the methodology of Figure IV-34 Figure IV-36 shows the impact of the scenarios assessed on the net import of fossil fuels. As compared to current values energy imports can be reduced by about one third by 2030 and by two thirds by 2050.

Figure IV-35: Neglecting the impact of complementary energy efficiency: Expected future gross inland consumption of fossil fuels for the assessed policy cases in the case of high energy demand (sensitivity assessment)

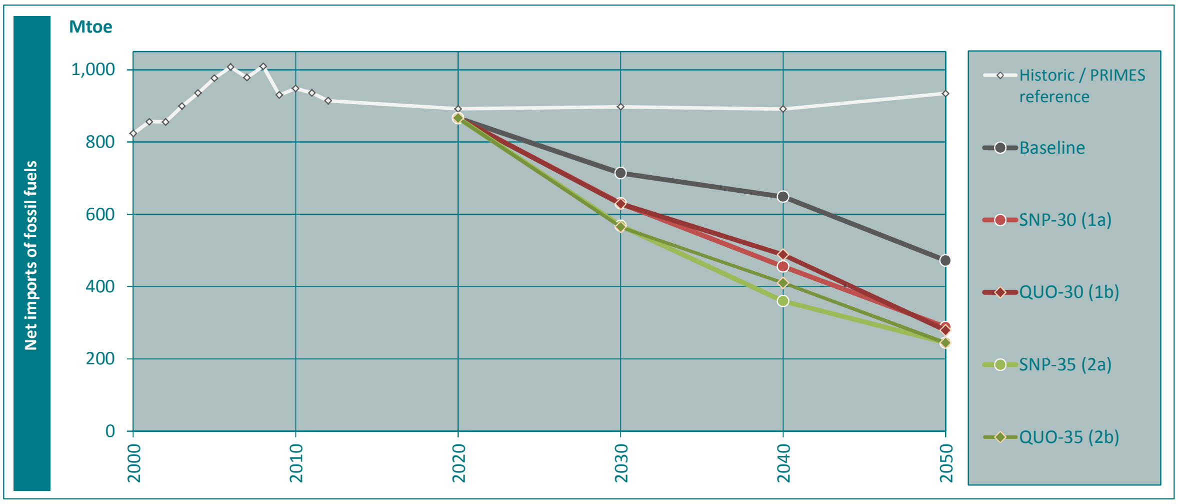

Figure IV-36: (Historic and) Expected future net imports of fossil fuels according to assessed policy cases

The following Figure IV-37 shows the results on expected future net imports by fossil fuel (i.e. for coal (left), oil (middle) and gas (right)) for the full spectrum of assessed policy cases. Within all policy scenarios imports of coal vanish until 2040 and gas imports can be mitigated to zero until 2050. Only for oil imports substantial quantities remain amounting to about three fifth of current imports.

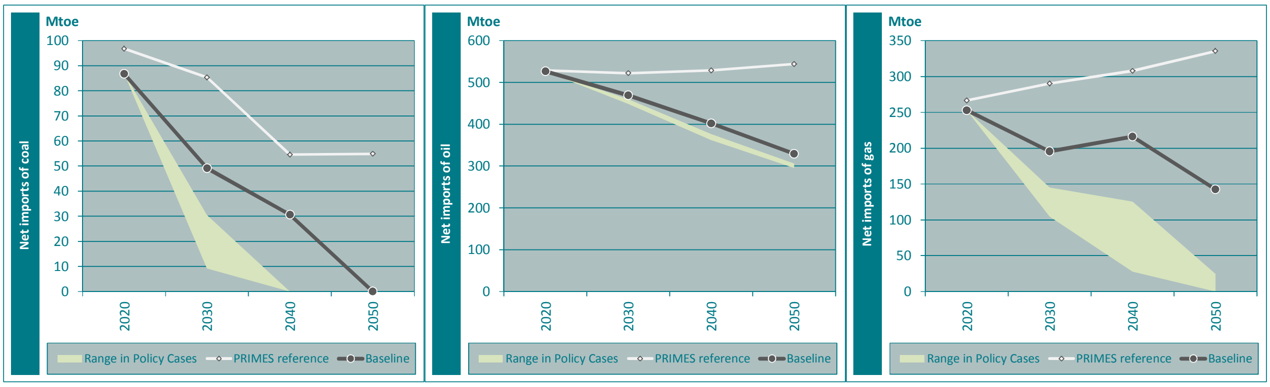

Figure IV-37: Details on expected future net imports by fossil fuel (i.e. for coal (left), oil (middle) and gas (right)) according to assessed policy cases

2.5 Effects on future growth

In line with the modelling approach presented in Section III.1, the impact of RES policies on Gross Value Added and GDP in 2030 and 2050 has been assessed based on the various scenarios outlined also in Section III.2. The analysis in this section focuses on the scenarios SNP30 and SNP35, which are compared to the BAU case. The modelling is based on the macro-economic modelling tools NEMESIS and ASTRA for net GDP effects and the MultiReg model for gross value added.

Gross value added due to RE deployment

In this chapter the development of total gross value added related to the deployment of RE technologies in the various scenarios until 2050 is shown. It comprises gross value added in the core RE industry and in supplying industries.

The following figure shows the development of value added in 2030 and 2050 compared to 2011, subdivided by type of activity (*investment* in RE facilities, *operation and maintenance* of existing RE facilities and *use of biomass fuels* in RE facilities). In the BAU scenario total value added will reach €75 billion, which is lower than the value in 2011. In the policy scenarios value added in 2030 reaches values between €90 and 100 billion in the 30% target scenarios and about €120 billion in the 35% target scenario. Value added in the SNP scenarios is slightly higher than in the quota scenarios due to higher RES expenditures.

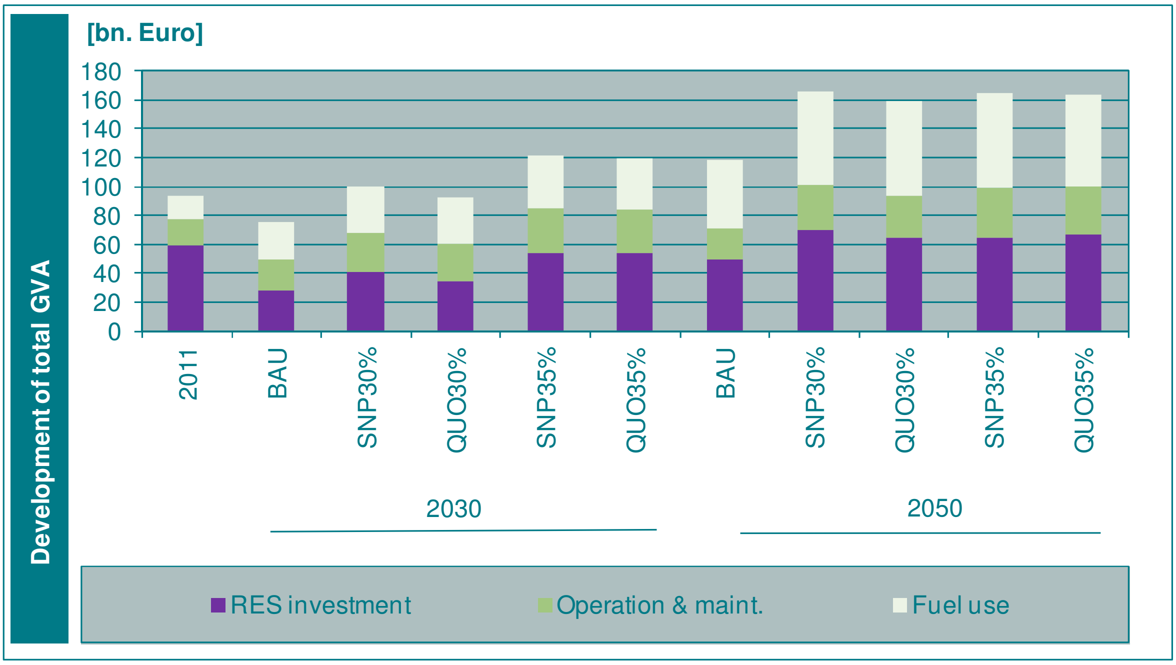

Figure IV-38: RES-related gross value added in the EU-28 by type of activity, 2011, 2030 and 2050

In the BAU scenario value added from investments in RE technologies is significantly lower than in 2011, whereas the larger base of existing facilities leads to higher value added from operation and maintenance and fuel use. In the policy scenarios both investment in new RE facilities as well as O&M and fuel use lead to increased value added compared to the BAU scenario.

In 2050 value added in the BAU scenario approximates €120 billion, whereas in the policy scenarios the respective values amount to between €160 and 170 billion. The differences between the policy scenarios are less pronounced than in 2030. In all scenarios fuel use plays a significant role in the increase of value added, especially for biofuels production.

Figure IV-39 gives an overview of RE related gross value added by technology[18]. The decrease of value added in 2030 in the BAU scenario compared to 2011 is mainly due to much lower investments in PV technology, while the contribution of biomass is larger than in 2011. The relevance of PV (as well as solar thermal electricity) remains lower in all scenarios until 2050 than in 2011. Biomass technologies mainly drive the increase of value added until 2050, with an increased contribution of biofuels after 2030. Wind technology roughly keeps its substantial share in RE-related value added until 2050.

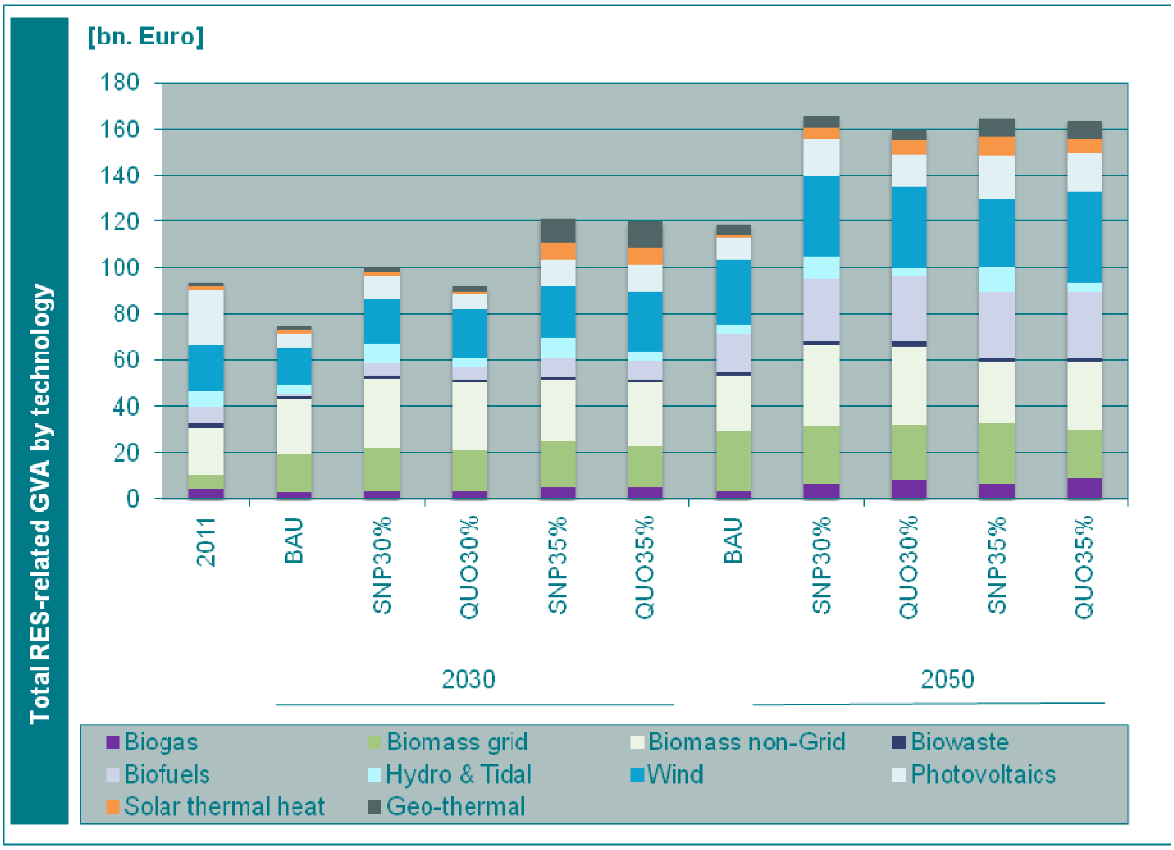

Figure IV-39: RES-related gross value added in the EU-28 by technology, 2011, 2030 and 2050

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[18] Note that the results for photovoltaics also include solar thermal electricity.

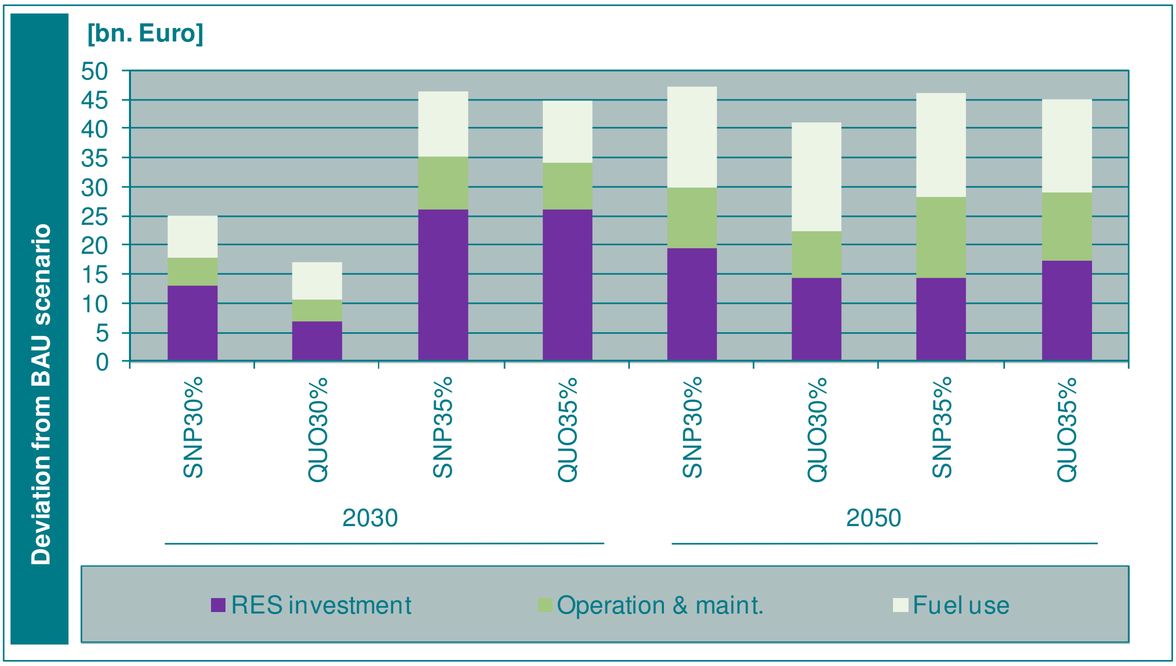

Figure IV-40: Differences in RES-related gross value added between policy scenarios and the BAU scenario in 2030 and 2050 by activity type

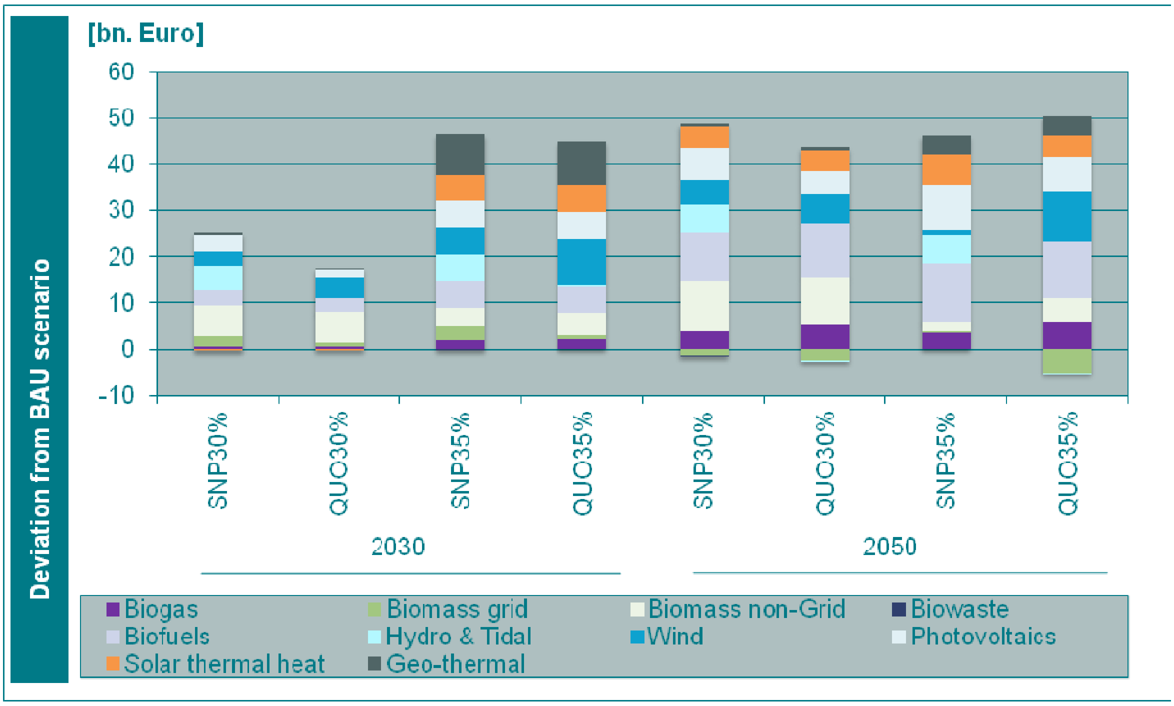

Figure IV-41: Differences in RES-related gross value added between policy scenarios and the BAU scenario in 2030 and 2050 by technology

Figure IV-40 focuses on the differences between policy scenarios and the BAU scenario in 2030 and 2050. In 2030 the less ambitious 30% scenarios lead to an increase in gross value added of 15 to 25 billion Euro. In the 35% scenarios value added grows by roughly €45 billion. This is mainly due to substantially larger investments in new RE facilities. In 2050 value added in the policy scenarios is between €40 and 50 billion higher than in the BAU scenario. The shares of the different activity types differ between the scenarios. Most important are increases in investment and fuel use. Figure IV-41 contains an overview of the differences between policy scenarios and the BAU scenario by technology. In addition to the above-mentioned, the increasing relevance of solar thermal heat and geothermal technology becomes apparent in this perspective.

Figure IV-42 shows the generation of RE-related value added in 2011 and the various scenarios until 2050 by country. The countries with the largest relevance in absolute terms are Germany, Spain, France, the United Kingdom and Italy.

Among these larger countries France, Italy and Spain experience significant relative growth of value added until 2050, whereas growth rates in Germany and Italy are smaller. Among the other countries the largest growth rates are seen for Eastern European countries, especially Croatia, Lithuania, Poland, Latvia, Romania and Bulgaria. According to the Green-X results these countries will profit from substantial investments in biomass technologies, esp. biofuel production between 2030 and 2050, which is mainly second generation biofuels.

Complementary to above, the relative deviation from the BAU scenario is then shown for each policy scenario and each EU country in Figure IV-43.

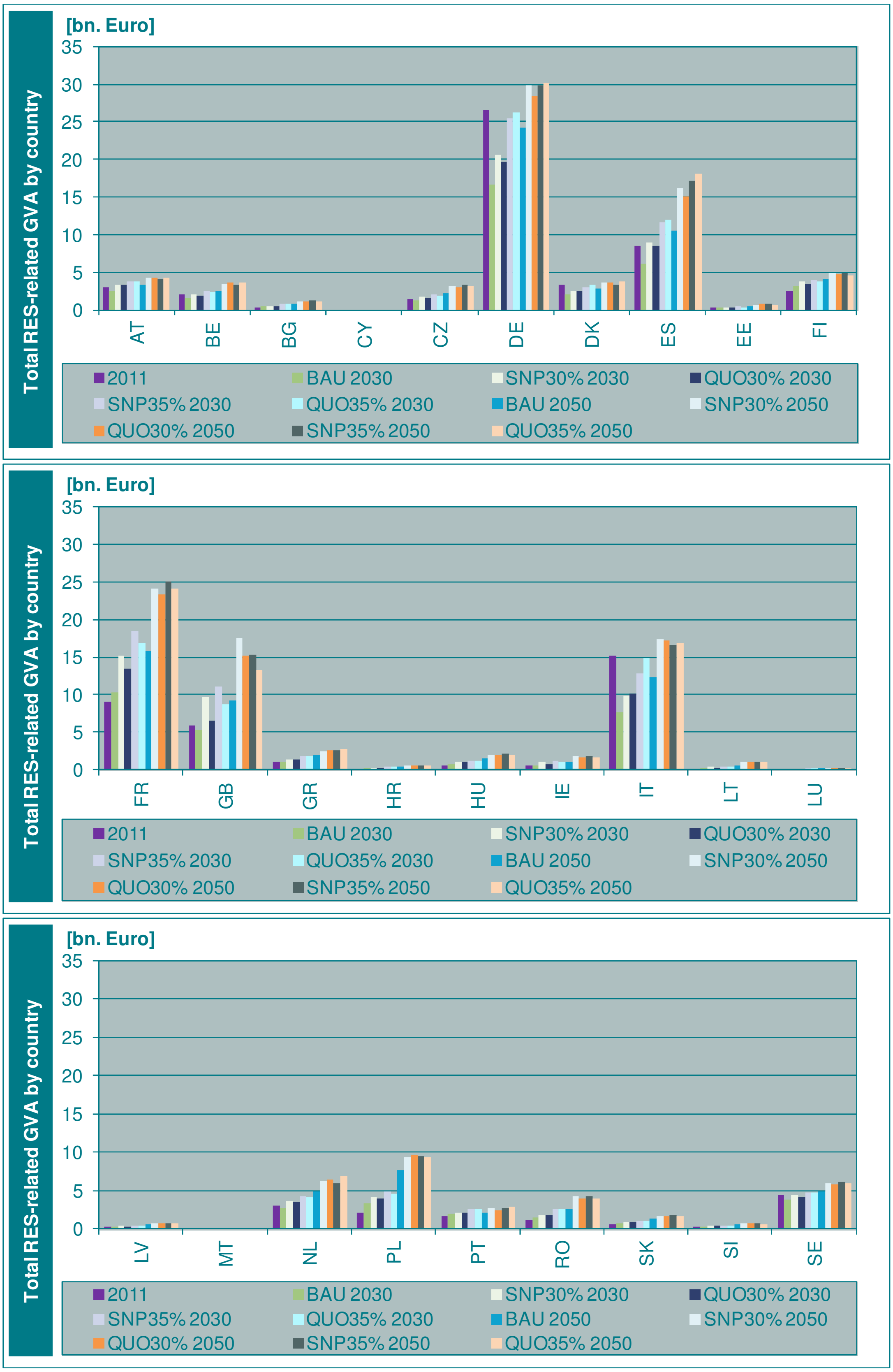

Figure IV-42: Gross value added by country in 2011, 2030 and 2050

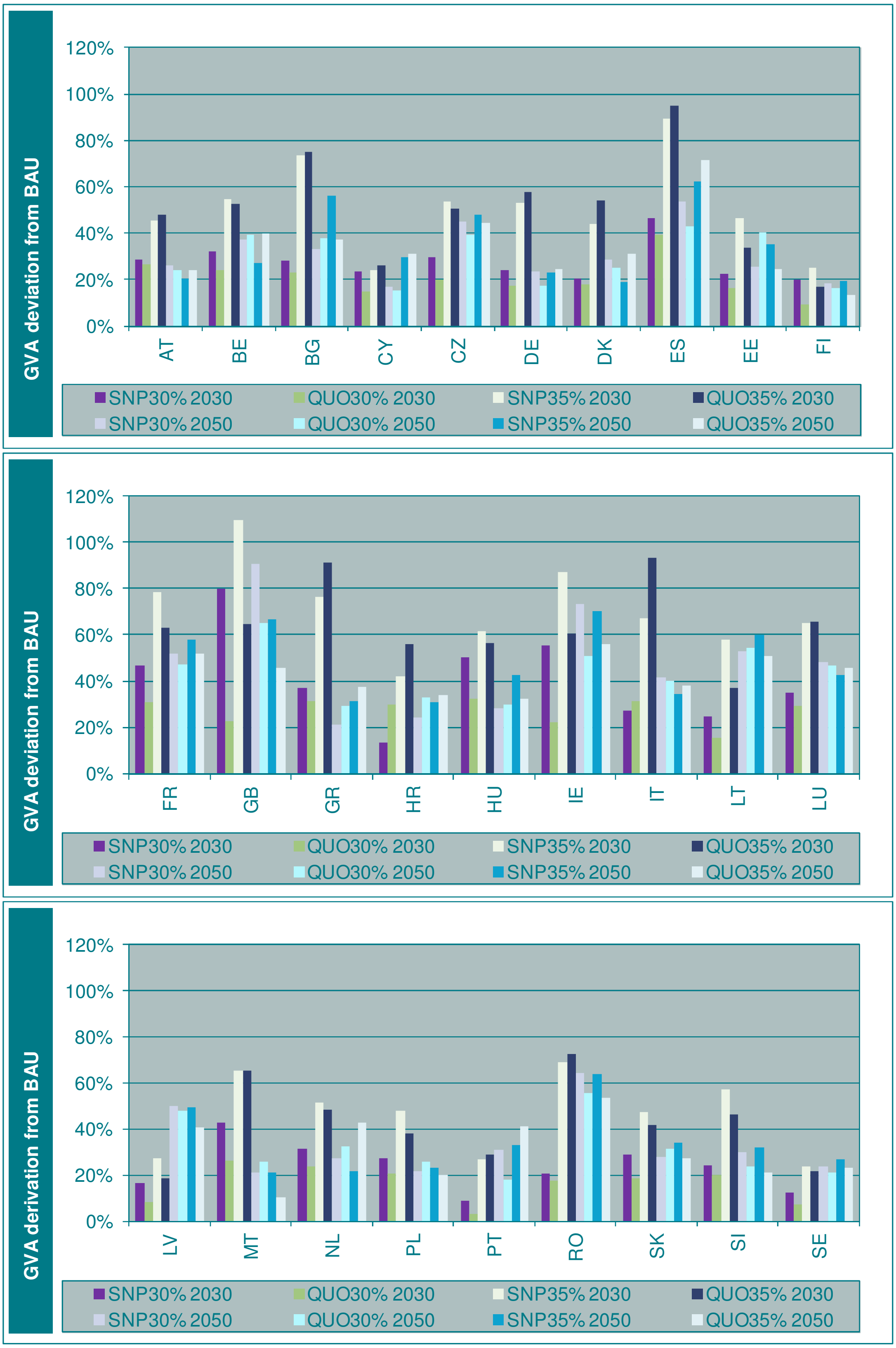

Figure IV-43: Relative deviation of gross value added from the BAU scenario by country in 2030 and 2050

Net effects on growth

Average effects on GDP

Figure IV-44 shows the impact of RES-policies on *net* GDP obtained with the NEMESIS model. The results show that RES policies will lead to moderate but positive GDP effects. On average, GDP will increase between 0.37% and 0.76% compared to BAU.

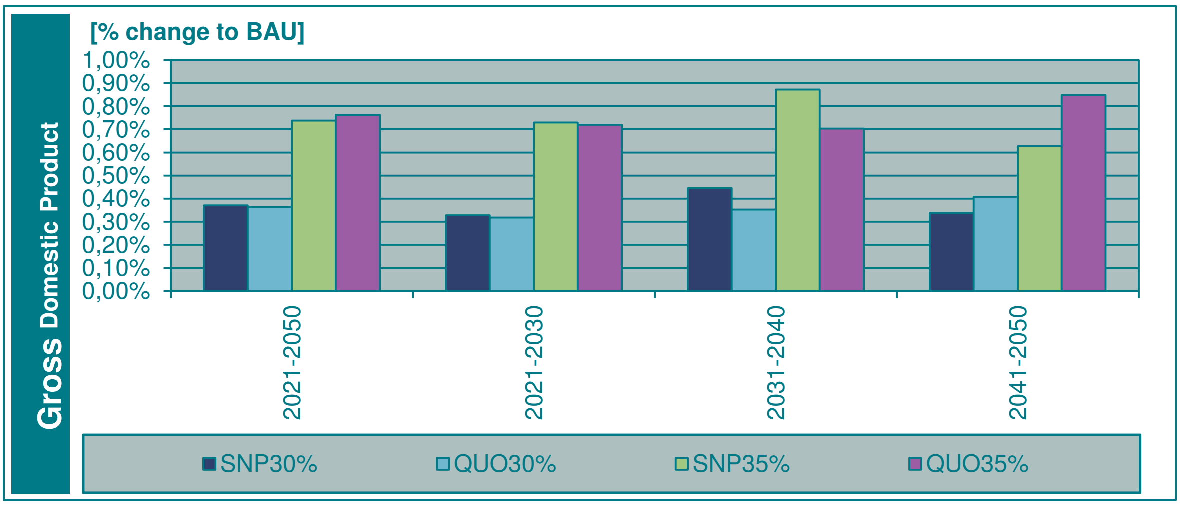

Figure IV-44: European GDP, % deviation, 10 years average on EU28 level based on NEMESIS

The positive development can be explained with the structure of the impulses. RES policies lead to a positive net investment impulse and increase in domestic biomass use, which increases demand. Substantial parts of this additional demand are provided by domestic production. Most important among the negative impulses are the demand for fossil fuels. However, as most of these fuels are imported from outside the EU, the reduction in demand for fossil fuels is transferred to outside the EU. Thus, RES policies can also be interpreted to cause an import substitution effect, which benefits domestic GDP.

The increase in RES also entails additional costs. The support expenditures, which include the increase in generation costs and the rents related to the policy instruments, lead to higher energy prices, which industry, service sectors and households have to cope with. However, the additional rents in the energy sector are redistributed and become available for consumer spending. Thus, the negative effect of support expenditures on demand is dampened. The interplay of these effects leads to an increase in aggregate domestic demand, which triggers further income multiplier and accelerator effects.

These effects are so strong that they dominate the outcome for both the 30% and the 35% target scenarios. The difference between the less and the more ambitious scenarios is a result of the different level of total RES deployment. The more ambitious scenarios require a higher RES deployment. Thus, the level of impulses compared to BAU is substantially higher in the 35% target scenarios. However, the generation costs of the 35% target scenarios are only moderately higher. In comparison, the amount of fossil fuels, which are imported, is substantially lower. Thus, the results obtained with NEMESIS also show a higher increase in GDP for the 35% scenarios.

Development of GDP over time

The development of GDP over time shows only small variations. With impulses growing at the beginning of the analysed time span, the increase in GDP is building up until 2030. The positive effect of RES policy on GDP continues for the following periods and for all scenarios analysed. However, there is a slightly different pattern for the SNP and quota scenarios: The increase in GDP for the SNP scenarios accelerate between 2030 and 2040. After 2040, the increasing dynamics of the impulses level off. The decrease in fossil fuel imports further drives an import substitution effect. However, the net increase of investments among the impulses decreases. Furthermore, the level of support expenditures, and among them the rents which are re-allocated towards consumption, decrease after 2040. Thus, the increase in positive impulses becomes less strong, and consequently the impact on GDP becomes lower. In the QUO scenarios the increase of GDP accelerates after 2040. There are various effects taking place: First, the level of investments does not slow down. This can be explained by the theoretical least-cost character of the scenario, which postpones more costly investments towards later time periods. Secondly, however, the high costs of these investments are still decreasing substantially, as the cost degression is also driven by deployment outside of the EU. Thus, the increase in generation costs is much smaller after 2040. Thirdly, the support expenditures are still growing substantially, due to the rents associated with the Quota. However, these rents are reallocated and drive consumption up. Taken together, this drives the expansionary effect of the impulses up and leads to an accelerated GDP increase.

In the short to medium term, SNP scenarios generate more GDP than the QUO scenarios, but in the long run the QUO scenarios imply a higher GDP increase then SNP ones. This can be interpreted as follows: in the short run the slightly higher costs of the SNP scenarios are overcompensated by higher investments. In the long run, however, the impact of RES policy on total costs of energy consumption becomes more dominant.

Development of GDP components

The development of GDP components is shown in Figure IV-2. The sum of percentage changes of GDP components is equivalent to the change in overall GDP in the scenario compared to BAU.

The level of consumption is increased in all scenarios. There are various factors driving this development. Among the impulses, higher energy prices for households limit the income available for spending on other goods on the one hand. On the other, the redirection of rents from the energy sector benefits consumer spending. Finally, there are income multiplier effects. Increasing investments generates additional income, which is available for spending. The consumption level is slightly higher in the QUO scenarios. This reflects that the generation costs are slightly higher in the SNP scenario. However, this outcome also hinges on the recycling of the increasing rents in the energy supply sector in the QUO scenarios towards consumption. The development over time of consumption shows the same pattern as GDP development. For the SNP scenarios, the growth in consumption is highest between 2031 and 2040, and levels off afterwards. In the QUO scenarios, consumption increases slightly towards 2050. This can be explained again with the redirection of rents from the energy sectors, which are growing especially in the later time periods in the QUO scenarios.

The level of investments also contributes to GDP growth in all four scenarios. The main driver is the investment impulses induced by RES deployment in the scenarios. Thus, the 35% target scenarios show considerably higher investment growth. However, the growth effects of GDP also induce additional investments in all sectors of the economy, which accelerate these effects. In the SNP scenarios, the investment impulses of RES deployment level off over time, with the induced investments from the accelerator effect partially compensating this development. In the QOU scenarios, the investment impulses are lower between 2030 and 2040, but increase afterwards. Thus, the overall level of investments increases towards 2050 in these scenarios.

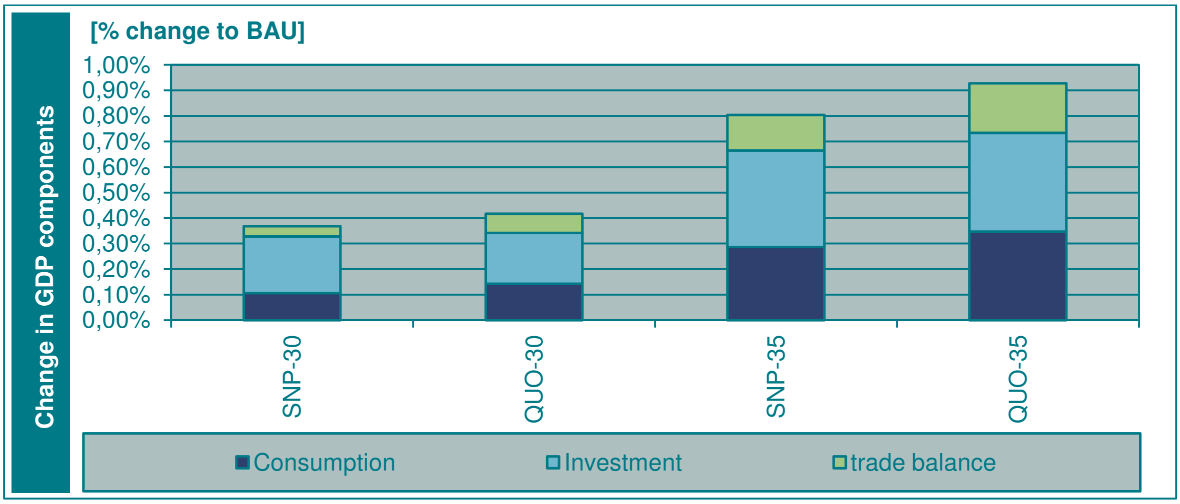

Figure IV-45: Contribution of GDP components to GDP growth, average 2021-2050 based on NEMESIS

Differences between countries

The impact of the RES policies on GDP differs from one country to another. These differences can be explained by various factors:

- The impulse strengthens in relation to national GDP, but also their timing varies among Member States. The total impulse in the SNP 30 scenario, for example, varies between 0.04% of ex-ante GDP for Malta to 2.76% of ex-ante GDP for Lithuania.
- The composition of the initial impulse is very different between the Member States. In the SNP 30 scenario, for example, the impulse of avoided fossil fuels represents almost 50% of the total impulse in Lithuania, while in Romania this share is only around 25%.
- Finally, the initial conditions of the Member States with regard to sectoral structure, external trade composition varies between the countries. Thus, even if the impulses would be identical in size, their impacts would differ between the countries.

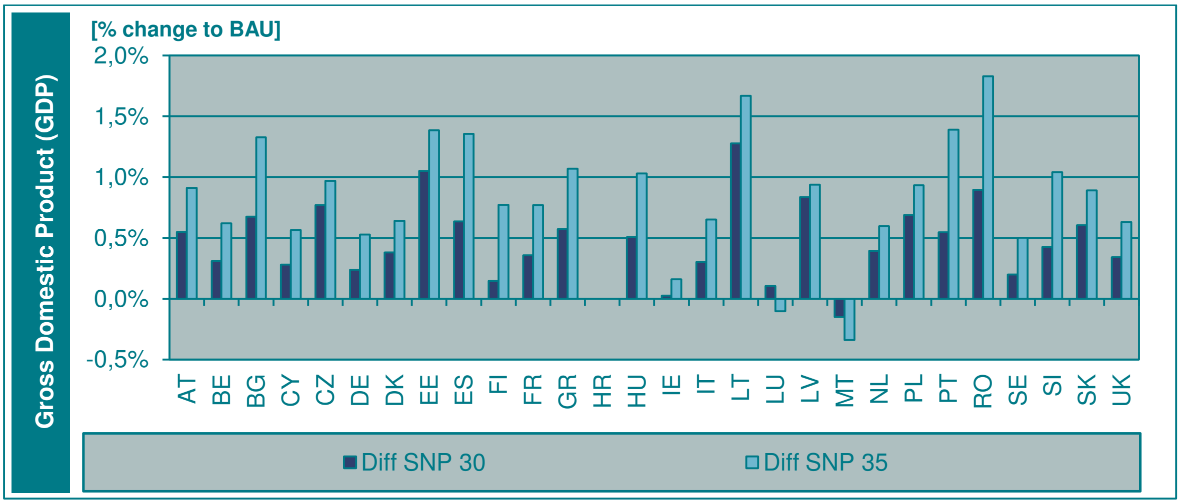

Figure IV-3: Member States GDP, % deviation compared to BAU, average 2021-2050 based on NEMESIS

GDP gains for the SNP 30 scenario are positive in all countries, except for Malta. The results range from -0.13% for Malta to +1.09% for Lithuania. Malta has the lowest ex-ante impulse, is a very small country and suffers of the very limited possibilities to supply nationally the additional demand that has to be imported alternatively. In Lithuania, the high share of avoided fossil fuel imports drives GDP growth. The SNP 35 scenario shows a similar pattern, however the deviations are stronger. In addition to Malta, Luxemburg shows a small decline in GDP. However, 9 Member States experience a GDP increase above 1%.

Sectoral differences

Not all sectors benefit from the increase in GDP to the same extent. Figure IV-4 shows the contribution of aggregated sectors to the growth of total production output compared to BAU. Compared to their overall size, the construction sector, and agriculture and forestry sector gain substantially. The recycling of the rents from the energy sector towards private consumption indirectly also benefits the service sectors. Thus, even though the service sector is not benefitting directly from the expansionary impulses so much, it is still participating substantially from the growth effects of the economies.

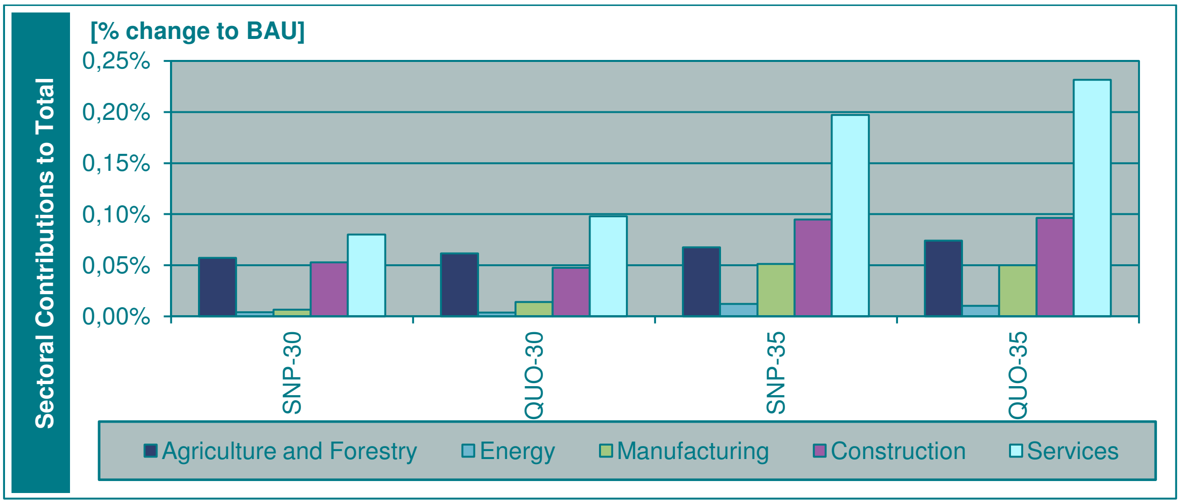

Figure IV-3: Contribution of production sectors to total output growth, average 2021-2050 based on NEMESIS

Sensitivity analysis with the ASTRA model

In addition to the NEMESIS model, the ASTRA model was used in order to analyse the effects of the impulses. The ASTRA model more strongly takes effects on the supply side such as increasing costs of energy generation into consideration. Furthermore, the ASTRA model shows as a lower elasticity of production inputs with respect to higher energy prices, whereas in the NEMESIS model sectors suffering from higher energy prices can substitute energy by other production factors more easily (by reducing energy demand due to energy efficiency). This reduces the pressure for the producing sectors to carry on energy price increases towards product prices. To sum up these effects, it can be expected that the negative impacts of increases in generation costs and energy prices on the economy are more strongly emphasised in the ASTRA model.

Nevertheless, the overall impacts of RES deployment show a comparable pattern to the NEMESIS results. The impact on GDP is positive for all 4 scenarios. Furthermore, the overall impact of the more ambitious 35%-target scenarios tends to be stronger than for the 30% target scenarios. Similar to the NEMESIS results, the SNP 35 scenario is showing stronger GDP increase as the QUO 35 scenario between 2031 and 2041, and lower GDP increase between 2041 and 2050.

However, there are some differences which can be attributed to the different model philosophy. ASTRA tends to attach higher weight to the supply side. Thus, the positive impulses from the investments tend to be more strongly counterbalanced by the higher generation costs the economy has to cope with. This results in two effects:

- The overall level of GDP increase tends to be somewhat smaller in the simulations with ASTRA. On average over the entire period, GDP will increase between 0.14% and 0.29% compared to BAU.
- The timing of GDP increase shows a different pattern between the ASTRA and NEMESIS model. ASTRA attaches higher weight to the development of generation costs and the supply side. Thus, the increase in GDP starts slower compared to NEMESIS. For all scenarios, there is a substantial reduction of additional generation costs in 2041-2050 compared to 2031-2040. Thus, compared to the NEMESIS results, the increase in GDP between 2041 and 2050 is substantially stronger than for time period 2031-2030. This also results in the observation that the GDP increase for the SNP scenarios is not levelling off towards 2050.

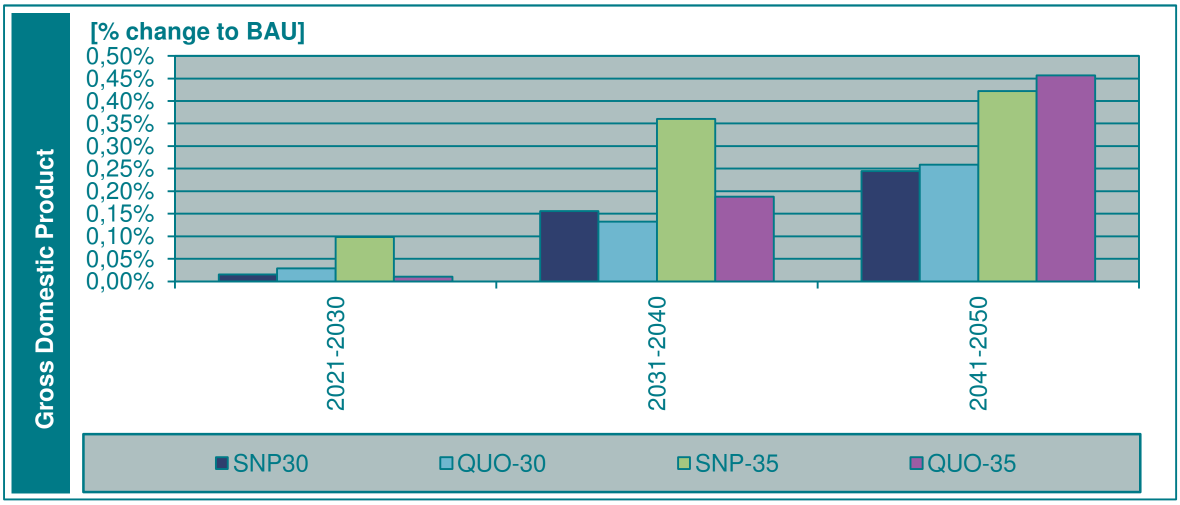

Figure IV-4: European GDP, % deviation, 10 years average on EU28 level based on ASTRA

The ASTRA model also shows a somewhat different impact on sectoral differentiation. The two sectors which most strongly benefit from RES deployment are Energy and Renewables as well as Construction. In the former case this is mostly due to the direct effect in the form of price increases for energy, which lead to an increase in monetary value of the production output. The Construction sector benefits relatively strongly from RES deployment. It is strongly connected to the investment impulse, and constitutes a sector with a very low import share, i.e. most construction is produced domestically. Even though it is burdened with the same energy price increase as all other industry sectors, the domestic investment impulse outweighs this effect.

The output from Industrial Machines, Metal Products and Plastics, which all belong to the Manufacturing category, also grows substantially. However, the other sectors included in Manufacturing do not benefit as strongly from the impulses. Furthermore, since the import shares are larger for these sectors, the remaining domestic investment impulses are rather small. However, the modelling assumes support costs are levied with a lower percentage on sectors from Manufacturing. Thus, the problem of rising energy prices is less pronounced. The sum of these effects leads to a moderate increase in production output of Manufacturing compared to BAU. The share of Manufacturing at total gross value added almost remains the same compared to BAU. It increases slightly for the SNP-scenarios, and diminishes slightly for the QUO-scenarios.

Agriculture and Forestry also experiences the direct effect in the form of energy price increases. This cannot be fully compensated for by price forwarding since demand in this sector is relatively inelastic. However, Agriculture and Forestry participates substantially from the expansionary impulses of RE deployment. In sum, the shares of Agriculture and Forestry increase in all four scenarios.

The Service sectors carry the highest price burden while at the same time not benefitting greatly from the investment impulse. Thus, these sectors are losing shares at total gross value added in all four scenarios. This effect is especially visible in the more ambitious target scenarios. However, when interpreting this development the classification scheme of the sectors, which follows an institutional logic, has to be kept in mind. A substantial part of the increase in the Energy and Renewables will be related to service type activities which support deployment of RES, such as new business models and organisational innovations. These are service type activities, which are, however, allocated to the Energy and Renewables sector. Thus, the decline in the institutional classification of Services cannot be interpreted that service type activities are reduced at the same level as shown in the graph.

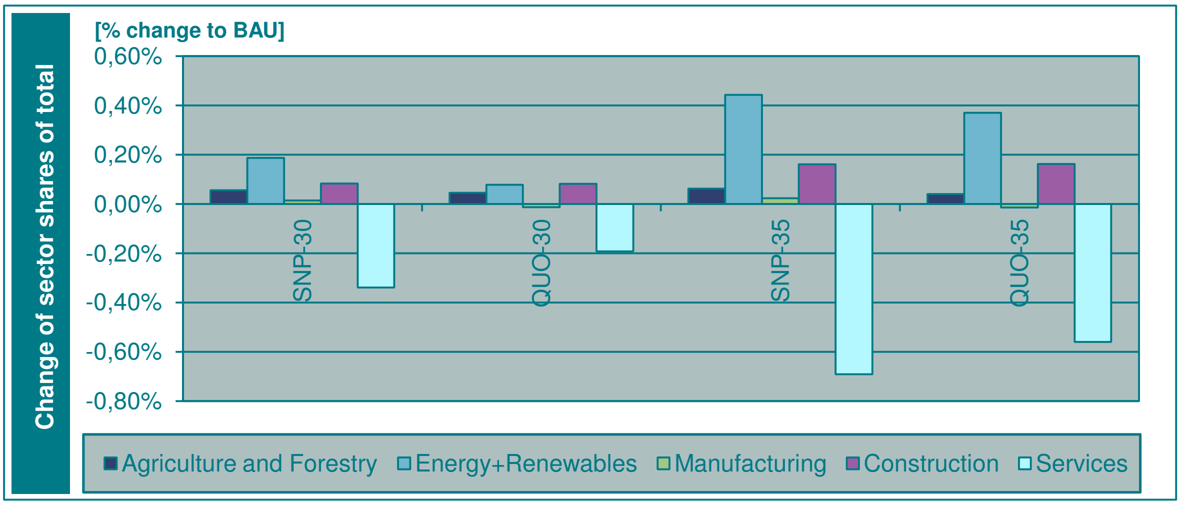

Figure IV-5: Change of sector shares at total gross value added in percentage points, average 2021-2050 based on ASTRA

Summary of net effects on growth

The effects of RES deployment policies are analysed for four scenarios. For each scenario, two models are used in order to show the influence of model specificities on the overall results. The following conclusions can be drawn from the analysis.

- All four RES deployment scenarios increase GDP on the EU-28 level moderately. For the different scenarios and models, the average results for 2021-2050 range between 0.14% and 0.76% compared to BAU.
- The more ambitious 35% scenarios show a higher increase in GDP, which is in general twice as high as for the comparable 30% scenario.
- In general, the differences between the SNP and QUO scenarios are small. A different pattern arises with regard to timing. In relative terms, the SNP scenarios perform better in the medium term, whereas the QUO scenarios tend to perform better towards the end of the analysed time horizon.
- There are differences between the results for the Member States, which can be explained by different levels of impulses resulting from RES deployment, and a different sectoral composition of the economies. However, in general, almost all Member States can expect a moderate GDP increase.
- The GDP increases with the NEMESIS model are on average double the size as in the sensitivity analysis performed with the ASTRA model. This can be explained with the higher importance which ASTRA devotes to supply side considerations. However, the differences are still moderate. On the other hand, the positive impact on growth would be higher if not the pessimistic export scenario but a more optimistic one had been used.
- The sectoral analysis shows that construction and agriculture is gaining. The two models show a somewhat different level of sectoral adjustment for services. In NEMESIS services benefit from the overall growth effect. The sectoral changes are somewhat more pronounced in ASTRA, with the service sector losing some of its share in overall production.

2.6 Effects on future employment

Gross employment due to RE deployment

In this chapter the development of total employment related to the deployment and use of RE technologies in the various scenarios until 2050 is shown. It comprises employment in the core RE industry and in supplying industries. Compared to the results for gross value added, the results for employment are mainly influenced by the development of labour productivity in the related industries. Since productivity will increase in the future, the same level of value added generates less employment in 2030 and 2050 compared to

2011. This effect is more pronounced in the new Member States in Eastern Europe, since labour productivity will increase more strongly in these countries than in Western Europe.

Figure IV-46 shows the development of employment in 2030 and 2050 compared to 2011, subdivided by type of activity (*investment* in RE facilities, *operation and maintenance* of existing RE facilities and *use of biomass fuels* in RE facilities). In the BAU scenario total employment will reach 1.3 million employed persons (EP), which is lower than the value in 2011. In the policy scenarios value added in 2030 reaches values between 1.6 and 1.7 million EP in the 30% target scenarios and about 2.1 million EP in the 35% target scenario. As with value added, employment is slightly higher in the SNP scenarios than in the quota scenarios.

In 2050 employment in the BAU scenario reaches 1.6 million employed persons, whereas in the policy scenarios the respective values range between 2.2 to 2.3 million employed persons. The differences between the policy scenarios are less pronounced than in 2030. Figure IV-47 gives an overview of RE related employment by technology[19]. Compared to the results for gross value added, biomass technologies have an even larger share in total employment. After 2030 biofuels substantially gain in importance, dominated by 2nd generation options. Due to the large relevance of agriculture and forestry in the biomass technology supply chain, labour productivity is lower than for other technologies. The share of biomass technologies in total employment increases from 47% in 2011 to between 60% and 70% in the different scenarios in 2030 and 2050. Compared to 2011 the contribution of photovoltaics to total employment decreases significantly, while the share of wind technology also tends to decrease, though less strongly.

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[19] Note that the results for photovoltaics also include solar thermal electricity.

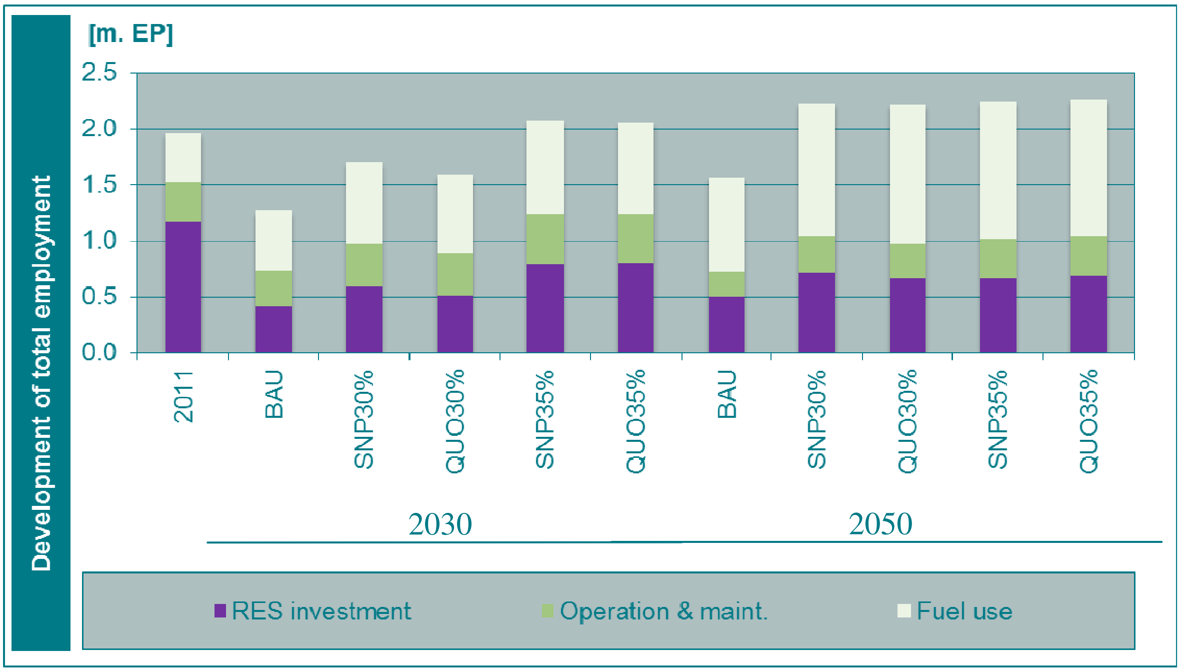

Figure IV-46: RES-related employment in the EU-28 by type of activity, in 2011, 2030 and 2050

Figure IV-48 and Figure IV-49 focus on the differences between policy scenarios and the BAU scenario in 2030 and 2050. In 2030 the less ambitious 30% scenarios lead to an increase of employment by 0.3 to 0.4 million employed persons compared to the BAU scenario. In the 35% scenarios RE-related employment is roughly 0.8 million EP higher than under BAU. This is mainly due to investments in new RE facilities and to stronger fuel use. In 2050 employment in the policy scenarios is between 0.6 and 0.7 million EP larger than in the BAU scenario. Here fuel use becomes the most important driver for employment. Figure IV-49 contains an overview of the differences between policy scenarios and the BAU scenario by technology. Almost all RES technologies experience growth compared to the BAU scenario. Notable exceptions are grid-connected biomass in 2050 and solar thermal heat in 2030. In 2030 solar thermal heat, biowaste and geothermal energy come into play in the more ambitious 35% scenarios. In 2050 the results confirm the role of biofuels as a driver of RE-related employment.

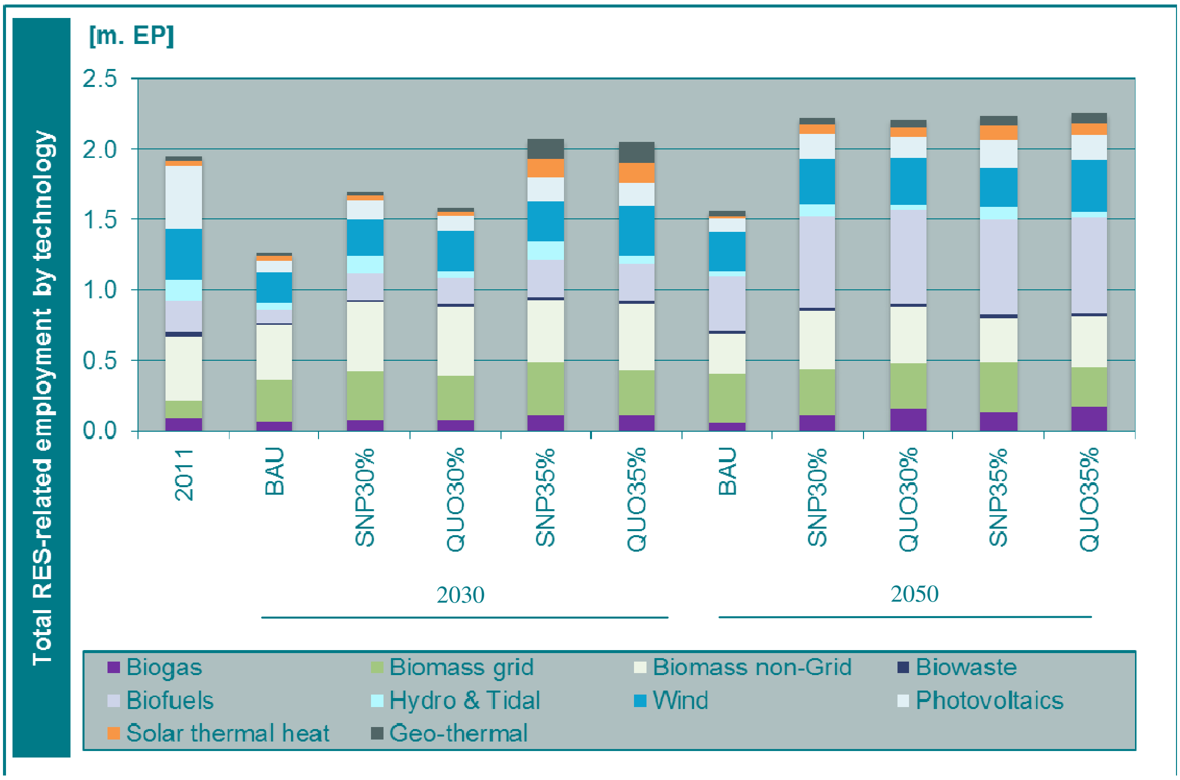

Figure IV-47: RES-related employment in the EU-28 by technology, in 2011, 2030 and 2050

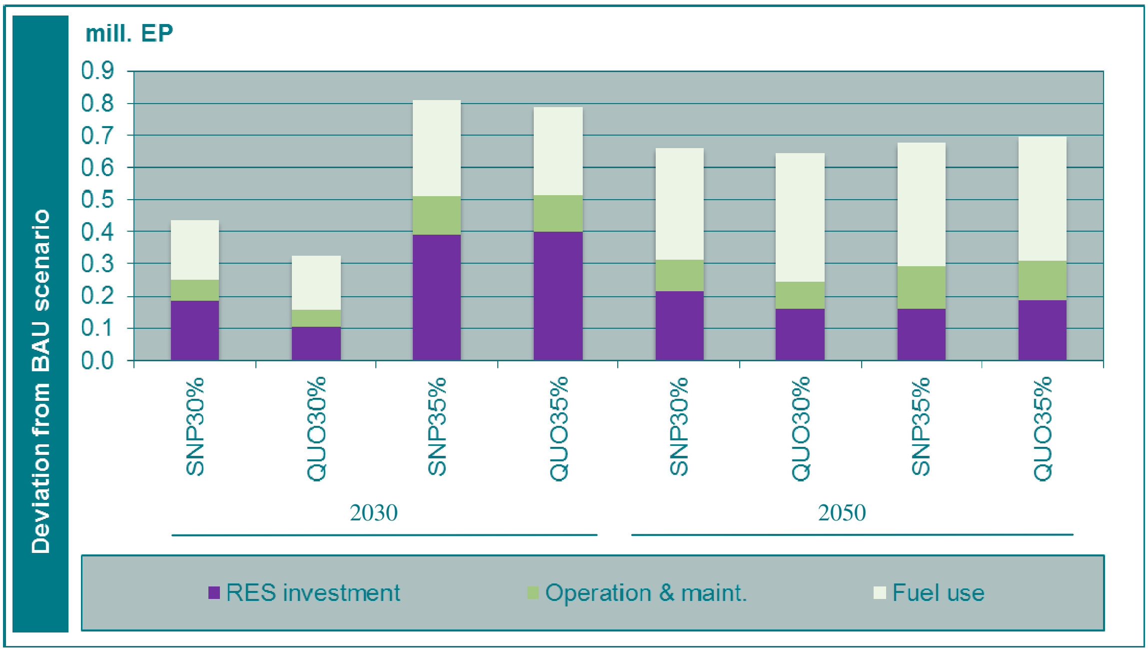

Figure IV-48: Differences in RES-related gross employment between policy scenarios and the BAU scenario in 2030 and 2050 by activity type

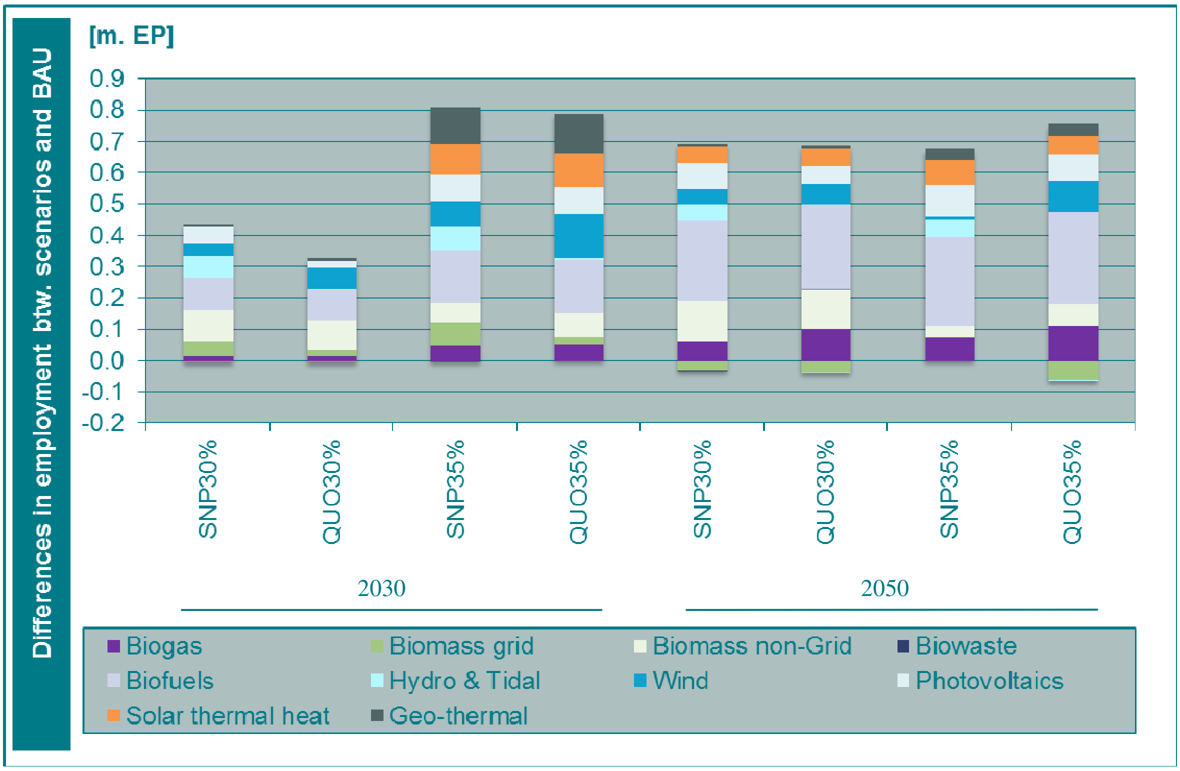

Figure IV-49: Differences in RES-related gross employment between policy scenarios and the BAU scenario in 2030 and 2050 by technology

Figure IV-50 shows the generation of RE-related employment in 2011 and the various scenarios until 2050 by country. In all scenarios RES deployment is more evenly distributed among the EU Member States than in 2011, when it was dominated by Germany and Italy. Therefore in these latter countries employment in 2030 and 2050 is lower than in 2011.

Countries in Eastern Europe that engage in substantial use of biomass and especially production of biofuels, gain strongly in RES-related employment. Their share in total employment is larger than in total value added due to low productivity of biomass technologies.

Complementary to above, the relative deviation from the BAU scenario is then shown for each policy scenario and each EU country in Figure IV-51.

Figure IV-50: Total RES-related employment by country in 2011, 2030 and 2050

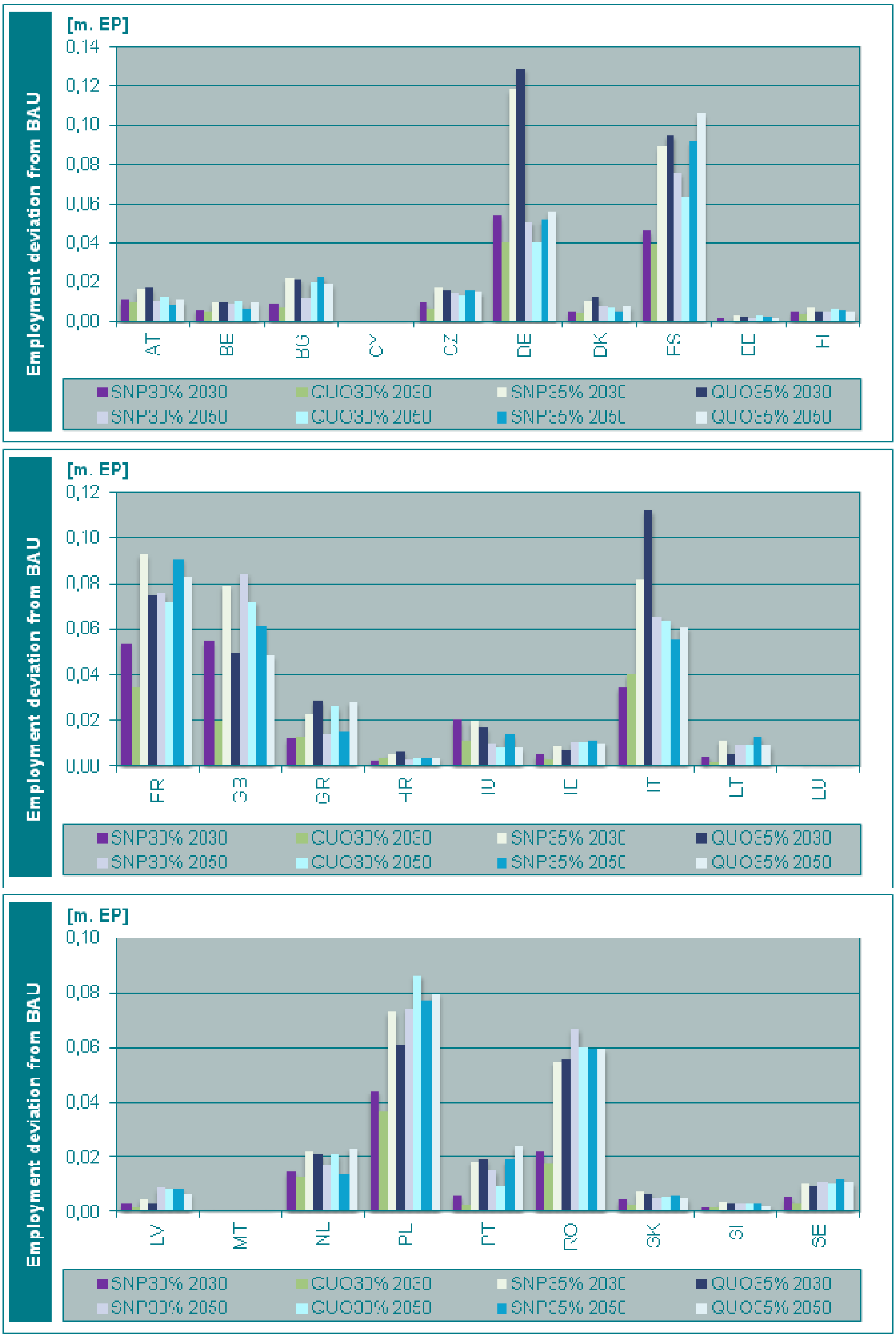

Figure IV-51: Relative deviation of total RES-related employment from the BAU scenario by country in 2030 and 2050

Net effects on employment

Average effects on employment

Figure IV-52 shows the impact of RES-policies on *net* employment obtained with the NEMESIS model. The results show that RES policies will lead to moderate but positive employment effects. On average, employment will increase between 0.28% and 0.64% compared to BAU. This is equivalent with an average increase of jobs in the EU between 600.000 and 1.400.000.

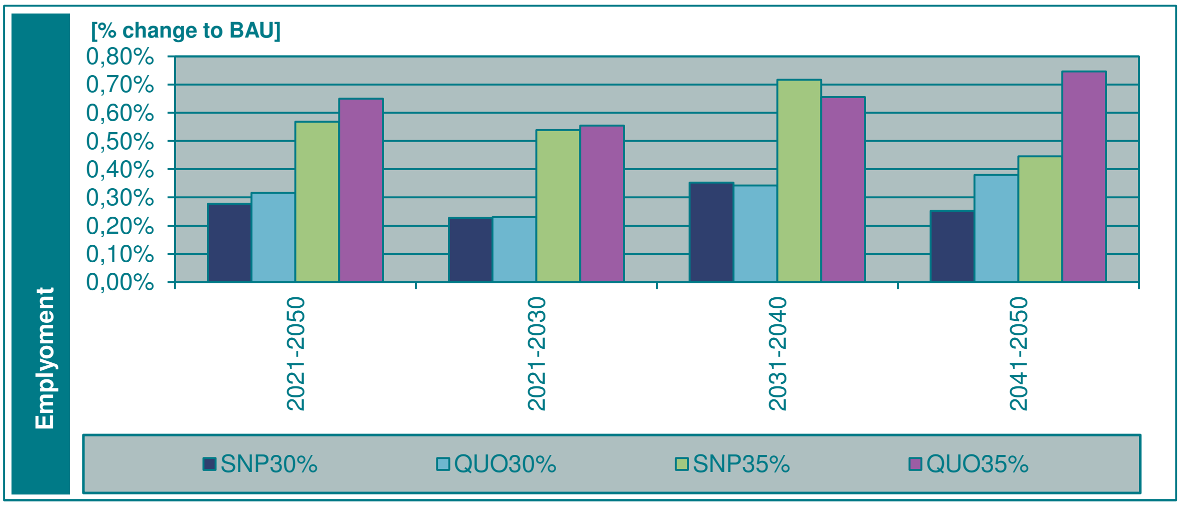

Figure IV-52: European Employment, % deviation, 10 years average on EU28 level based on NEMESIS

The positive development can be explained with the impacts of RES deployment on GDP. The main difference is that the average positive effects are slightly smaller than for GDP. This can be explained by two factors: First, the accelerator effects increase investments in all sectors. These investments contribute to an increase in labour productivity. Thus, the same amount of GDP can be produced with lower labour input. Secondly, the sectoral changes induced by RES deployment work towards benefiting sectors which are less labour intensive. Thus, the sum of all sectors becomes slightly less labour intensive, and the number of jobs needed increases less than GDP. Nevertheless, these mechanisms are not very strongly taking place within the NEMESIS model, and the resulting differences between GDP and employment development are small.

Development of employment over time

The development of employment over time shows only small variations. With GDP growing at the beginning of the analysed time span compared to BAU, the increase in employment is building up until 2030. The slightly different pattern for the SNP and QUO scenarios with regard to GDP can also be observed for employment: For the SNP scenarios, the increase in employment levels off after 2040. For the QUO scenarios, which show accelerating GDP increase after 2040, this translates also into higher growth of employment increase after 2040 compared to 2031-2040.

Differences between countries

As the impact of the RES policies on GDP differs from one country to another, there are also differences in the employment impacts. The average employment impacts for the SNP 30 scenario are positive in all countries, except for Malta in the SNP 30 scenario. The results show a variation from -0.02% for Malta to +0.80% for Romania. The SNP 35 scenario shows a similar pattern, however the deviations are stronger. On average, no country shows a decline in employment, and two Member States experience an employment increase above 1%.

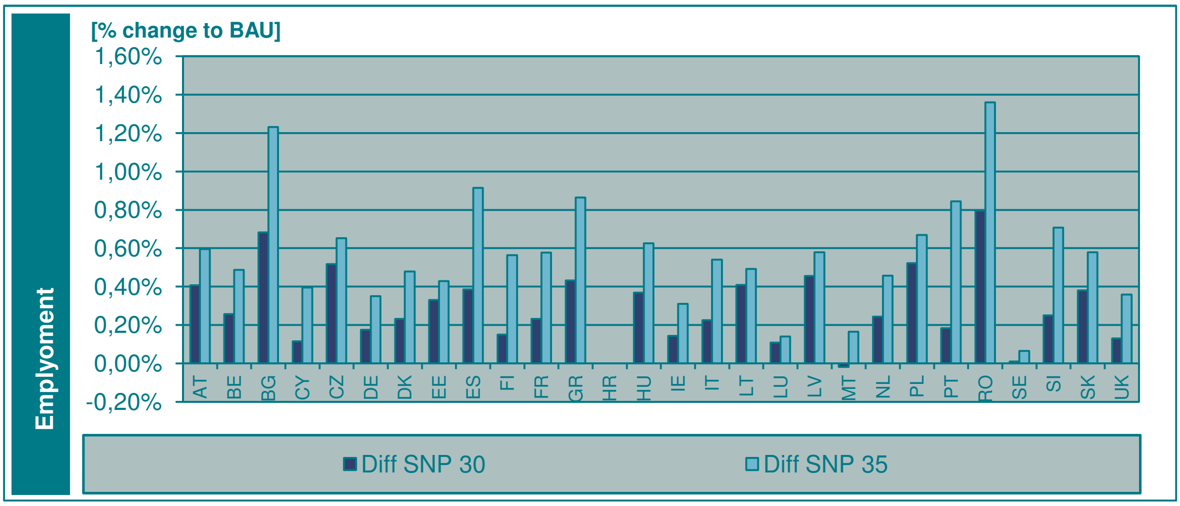

Figure IV-53: Member States employment, % deviation compared to BAU, average 2021-2050 based on NEMESIS

The differences between GDP development and employment development are more pronounced for some countries, and less for others. This can be explained by the interplay of different sector structures of the countries with different labour intensities of the sectors. Thus, if a country shows an economic structure which is strong in labour intensive sectors which are gaining, and weak in labour productive sectors which are losing production, it will show a better effect on employment than on GDP.

Sectoral differences

The development of employment among the sectors follows closely the sectoral shift of production. The Nemesis results show an increase in employment in all sectors, which is in line with the observation that each sector benefits from the overall growth of GDP. The increase in employment is especially strong in Services, which has a lower labour productivity. Thus, each unit of increase of production in this sector leads to higher employment increase than in a sector such as Manufacturing or Energy.

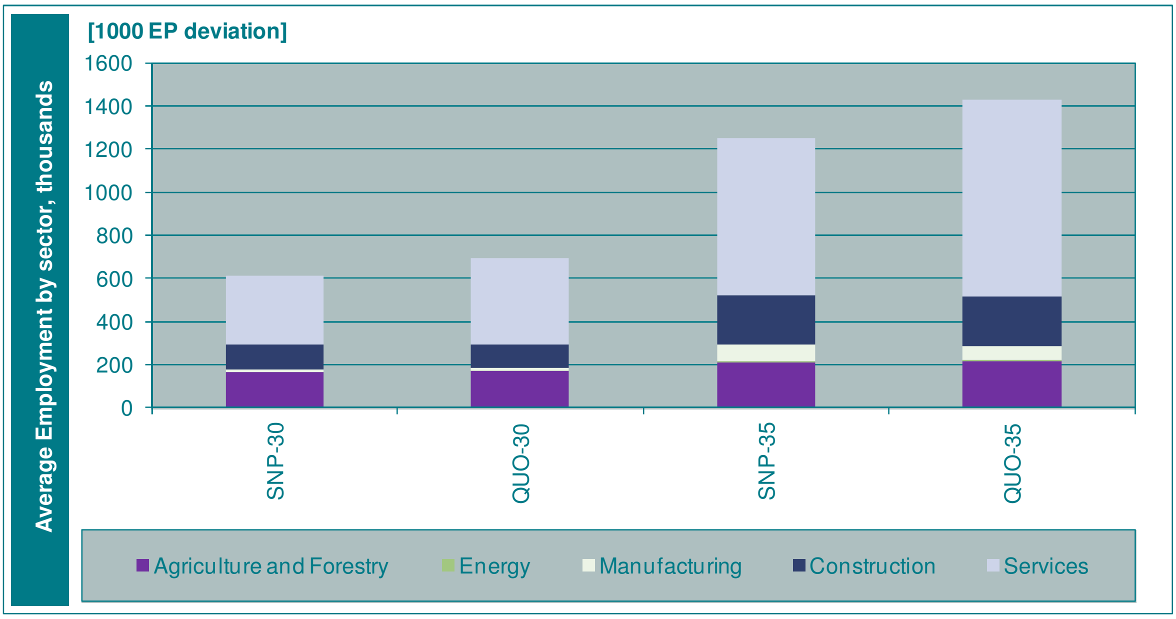

Figure IV-54: Average sectoral employment effects, on EU27 level, average 2021-2050 based on NEMESIS

Sensitivity analysis with the ASTRA model

In addition to the NEMESIS model, the ASTRA model was used in order to analyse the impact of attaching higher importance to effects on the supply side. Furthermore, ASTRA puts a specific emphasis on modelling sectoral changes. On average, the employment effects are between almost 0% and around 0,05% compared to BAU. Thus, the overall impacts of RES deployment are not as pronounced as in the NEMESIS model. In absolute terms, the average employment effects are almost zero in the QUO 35 scenario, and show an increase of 120.000 jobs per annum in the SNP 30 scenario.

The lower employment effects can be explained by a lower increase of GDP, as discussed in the previous chapter. However, the changes in sectoral pattern, and the development over time also play a role, which for example lead to the effect that the employment impact of both more ambitious scenarios becomes negative at the end of the analysed time horizon. There are two reasons for this. First, there is a shift in investments away from energy related investments towards production related investments in the industrial and commercial sector, which are induced by the accelerator effects. This not only increases GDP towards the end of the time horizon, but also drives up total factor productivity, which enables higher production with less labour input. Second, ASTRA shows a stronger sectoral shift. Especially the service sector is losing shares in the more ambitious scenarios (see below). As especially these sectors are very labour intensive, the change in sectoral composition creates a change towards a less labour intensive economy. The sectoral shift in the ASTRA model can also be interpreted as a lower elasticity of economic sectors with respect to higher energy prices, whereas in the NEMESIS sectors suffering from higher energy prices can substitute energy by other production factors and reducing energy demand (due to energy efficiency).

Figure IV-55: European employment, % deviation, 10 years average on EU28 level based on ASTRA

Sectoral differences

The results from ASTRA show that the pattern of sectoral employment is quite the same for all four scenarios. The sectors which most strongly benefit from RES deployment in terms of employment are Energy and Renewables, Agriculture, as well as Construction. However, the more ambitious scenarios clearly show a much stronger sectoral differentiation. Especially the sector Services is losing employment compared to the BAU scenario. Since the Services sector is especially labour intensive, the decrease in sectoral production share of service sectors translate into considerable decreases in employment in this sector.

There are two reasons that employment increases in Agriculture and Forestry. Firstly, the shares of this sector in total output increases. Secondly, it constitutes a special case as productivity effects play a large role in the development of employment. On the EU27 level, economies with established agricultural and biomass sectors gain from the biomass portion of RES deployment. This holds especially in the national policy scenarios in which biomass expansion in those countries is more pronounced than in the European harmonised quota scenarios. Since Agriculture and Forestry sectors in these countries tend to be more labour intensive than the European average, the increases in employment in those countries lead to an overall increase.

In the case of Energy and Renewables, there is a substantial increase in employment. However, the energy sector has already a high and increasing labour productivity, which works towards an increase in output not being fully translated into additional employment. On the other hand, it has to be accounted for that the increasing fraction of renewables, which are relatively more labour intensive and also include service type of activities, leads to a relative decrease in productivity. However, with increasing professionalization of these activities, it can be foreseen that the increase in labour productivity will be above average in this subsector, which reduces the employment effect. The increase in the Construction sector is triggered by the increase in output.

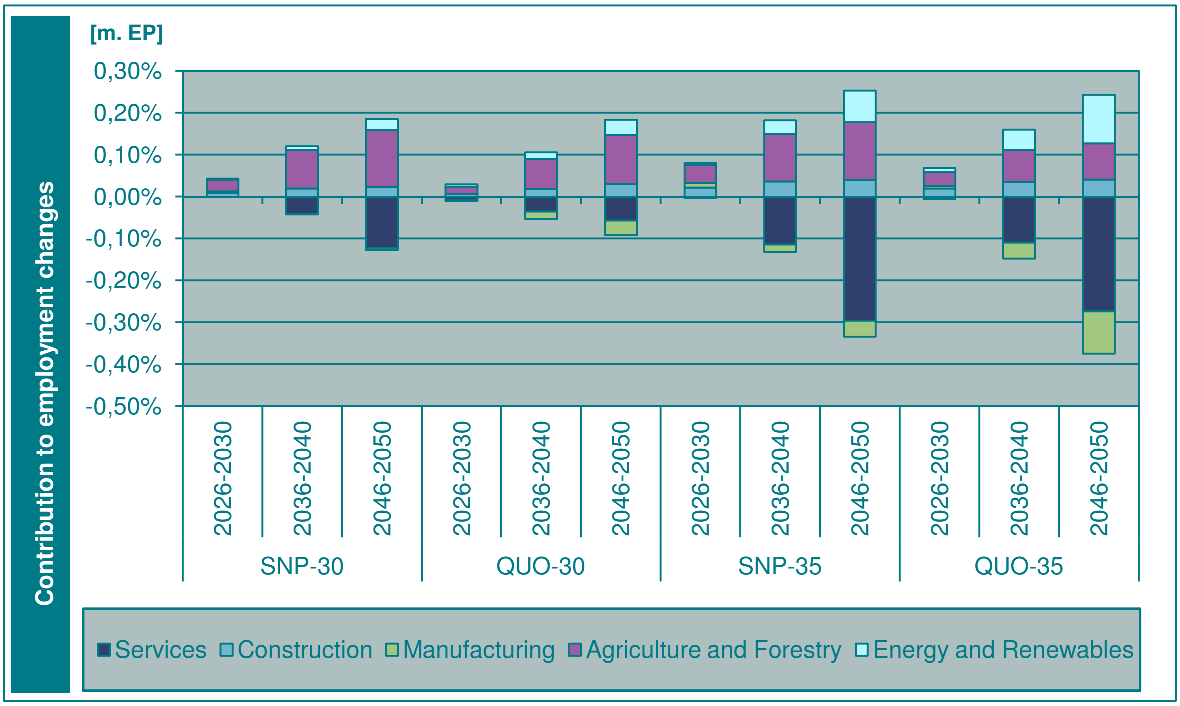

Figure IV-56: Average sectoral employment effects, on EU27 level based on ASTRA

Summary of net effects on employment

The effects of RES deployment policies are analysed for four scenarios. For each scenario, two models are used in order to show the influence of model specificities on the overall results. The following conclusions can be drawn from the analysis:

- All four RES deployment scenarios show moderately positive employment effects on the EU-28 level. For the different scenarios and models, the average results for 2021-2050 range between just above 0% and 0.64% compared to BAU. However, the positive impact on employment would be higher, if not the pessimistic export scenario but a more optimistic one had been used.
- The development of GDP is a key driver of employment. Thus, the difference between the GDP results for the Member States also translate into differences in employment. However, the composition of the economies with regard to importance of labour intensive versus non-intensive sectors also plays a role. In general, almost all Member States can expect a moderate increase in employment based on NEMESIS.
- The pattern of employment effects differ between the NEMESIS model and ASTRA. ASTRA shows lower levels of employment increase, which can be explained by the interplay of growth of productivity and stronger sectoral shifts away from labour intensive sectors. The latter can be explained by a lower elasticity of ASTRA with respect to energy prices.

The results also point towards the importance of embedding a RES deployment policy into a wider policy frame. The ASTRA model assumes that service sectors can forward energy price increases only to a lower extent, which leads to the effect that the level of real service demand is reduced. More positive effects on employment can be expected if the crowding out of consumer spending on services by higher energy costs is limited. The NEMESIS results are more in line with such a perspective, by assuming not only recycling of rents towards consumption, but also stronger potential to adapt to rising energy prices by factor substitution, which would benefit especially the service sectors and households. Thus, policies which support energy efficiency in these sectors would not only yield additional savings of energy, but could also contribute to achieve an outcome on the upper side of the spectrum of employment results shown by the two models.

3 Conclusions

The main conclusions of this study can be summarised as follows:

Current economic benefits of the RES sector are substantial

The relevance of the renewable energy sector has substantially increased since 2005, in terms of the share in overall energy consumption, installed capacities, value added as well as employment. New industries with a strong lead market potential have been created, which contribute a value added of about €94 billion or about 0.7% of the total GDP and an induced total employment of about 2 million relating to about 0.9% of the total workforce in Europe in 2011. This development is likely to accelerate if current policies are further improved in order to reach the agreed target of 20% renewable energies in Europe by 2020.

Positive gross and net GDP and employment impacts expected in case of ambitious RES targets for 2030

The gross value added of the RES sector may increase to about €100 (120) billion and employment in the RES sector would amount 1.6 (2.1) million persons by 2030 if a target of 30% (35%) in terms of the gross final energy is implemented. Despite the relatively strong growth in installed capacity as well as the total generation of renewable energies the gross contribution of the sector to the overall economy will only increase moderately due to technological progress and therefore decreasing specific costs and expenditures of RES technologies. Business as usual development will lead to a declining RES sector both in terms of value added (by about one fifth) as well as employment (by about one third) as compared to 2011 until 2030.

Despite the moderately higher generation costs of renewable energies the overall impact of ambitious renewable energy targets is positive due to the shift from a fossil fuel-based energy system to an investment focused one. Thereby the present study analysed the full macro-economic effects of renewable energy policies including the positive gross impacts within the RES sector as well as the negative impacts due to reduced value added of the conventional energy sector as well as considering budget effects caused by support payments for renewable energies. Net GDP change as compared to a business as usual scenario amounts to 0.1–0.4% (0.1–0.8%) of EU GDP and net employment change amounts to 90–720 thousand (160–1,500 thousand) jobs by 2030 if a target of 30% (35%) is implemented.

Future RES policies and targets will substantially contribute to securing energy supply and mitigating greenhouse gas emissions

Two objectives for increasing the share of RES are the reduction of CO_2-emissions and other environmental impacts and the increased security of energy supply due to a reduced dependency on imported fossil fuels. This study finds that compared to the status quo (2010) EU imports in fossil fuels can be reduced by €154 (180) billion until 2030 and by €248 (264-266) billion until 2050 if an ambitious RES target of 30% (35%) by 2030 is implemented. These figures represent solely the impact of increasing RES deployment – if combined with strong energy efficiency measures to decrease energy demand the overall impact may be significantly larger in magnitude: As compared to current values energy imports can be reduced by about one third by 2030 and by two thirds by 2050 in the case of an ambitious 2030 RES target of 35% combined with strong energy efficiency measures (i.e. a reduction of 34% in energy demand by 2050 compared to the EU's reference development path).

Furthermore the contribution of RES to the reduction of greenhouse gas emissions can be significantly increased. Compared to the status quo (2010), RES-related CO_2 avoidance can be increased by about 740 (920) million tons under baseline conditions in 2030 (2050). With dedicated RES support as anticipated in the policy cases this effect can be increased further by about 190 (455) million tons in 2030 and by 418-453 (729-745) million tons in 2050 in case of a 2030 RES target of 30% (35%).

Future policies and targets for renewables will be needed to provide investment certainty and driving technological innovation

Cost of renewable energy technologies have been reduced substantially in recent years leading to competitiveness with conventional alternatives in many cases. The focus of renewable energy policies will therefore shift from subsidising additional generation costs to de-risking investments by reducing costs of capital. Nevertheless, a certain fraction of the renewable energy technology portfolio will need financial support to incentivise technological learning. Additional generation costs for renewable energies will amount to €26 to 31 billion per year during the period from 2020 to 2030, depending on the target level and the degree of harmonisation. Therefore the additional costs of renewable energies are of the same order of magnitude as current subsidies for conventional fuels in Europe. These additional costs will almost vanish towards 2050 as technological progress continues and effective measures to assure least cost resource allocation are implemented.

Regarding the assessed policy options the study finds that the case of strengthened national policies (SNP) shows the larger macro-economic benefits in the mid-term until 2030 as compared to a harmonised quota scheme due to the development of a broader technology portfolio and stronger cost reductions of a broad spectrum of RES technologies. In the long term until 2050 the harmonised quota scheme shows the better macro-economic performance due to the dominating effect of least cost resource allocation of RES potentials across the EU.

Overall benefits until 2050 remain if generation costs of renewable energies can be reduced further, calling for policies that stimulate innovative technologies appropriately as well as for global action

Net GDP can grow by up to about 0.8% points and employment by up to 0.7% points until 2050 provided that cost increases due to renewable energy policies can be minimised and effective energy efficiency policies are implemented on the demand side. Currently the strong investment impulses - based on installations in Europe and exports to the rest of the world - dominate the economic impact of renewable energy policies and therefore lead to positive overall effects. In order to maintain this positive balance in the future it will be necessary to uphold and improve the competitive position of European manufacturers of RES technology and to reduce the costs of renewable energies by exploiting their full learning potentials. Therefore policies which promote technological innovation in RES technologies and lead to a continuous and sufficiently fast reduction of the costs will be of major importance. Besides the implementation of strong policies in the EU, it will be of key relevance to improve the international framework conditions for renewable energies in order to create large markets, exploit economies of scale and accelerate research and development.

Uncertainties about the future perspectives exist but mitigation options were used

As for any macro-economic modelling exercise also the results of this study are subject to uncertainties, which need to be treated properly. Thereby the kind of uncertainty analysis chosen has to suit the modelling problem studied. The main uncertainties of the modelling exercise of the EMPLOY-RES II project can be classified as follows:

(a) the inherent uncertainty about the future as for example given by the uncertainty about future energy demand, future energy prices, future policy framework for the support of renewable energy sources,

(b) the uncertainty of the way in which different economic mechanisms are implemented into the modelling system. The main economic impulses, such as investments or increased energy prices, can have very different impacts on the modelled economy depending on the precise manner, in which these mechanisms are implemented into the models,

(c) the uncertainty about how different national economies react to the impulses of additional renewable energy deployment. Depending on the characteristics of national economies (e.g. characterised by the level of labour productivity, share of overall investments in total GDP, trade balance) the impact of renewable energy policies might be very different.

These uncertainties have been considered in the EMPLOY-RES project by using different well accepted approaches. These methods include scenario analysis (to cope with uncertainties of type (a) above) as well as multiple model simulation (to cope with uncertainties of type (b) above). Furthermore, uncertainty of the type (c) is considered in the EMPLOY-RES study by running the scenarios defined in the analysis for each of the EU-28 countries and the two models used in the assessment separately. Additionally for a key input variables sensitivity analysis of the techno-economic modelling based on the Green-X model has been carried out in order to get a better understanding of how main impulses for the macro-economic analysis may change.

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V Appendix

A Conventional energy subsidies

Over the past few months there has been a heated discussion on energy prices and the effects of subsidies for renewable energy on these prices. Subjects such as competitive energy prices for industry and the levels of support for renewables in time of austerity dominate the debate on an EU 2030 policy framework. What is often forgotten or purposely left out of this debate is the fact that fossil fuels still receive significant governmental support in the EU. The total value of this support is not well-known and generally underestimated.

This section provides an overview and comparative review of methodologies and results from the literature. A comprehensive analysis and overview of results for the EU as a whole is largely non-existing. Existing studies either have a non-EU focus (e.g. G8/20 scope), although they include results for the different Member States, and there are studies that have looked at individual Member States. There is therefore added value in bringing these studies together and comparing them. This is the main aim of this section.

In the next subsection, we will discuss the various definitions of subsidies that exist, provide a classification of subsidies and provide examples that are specifically related to energy. We then discuss the main approaches and methodologies that are used for measuring and quantifying subsidies. In subsection A.3 we will review two main studies that have quantified subsidies for the different Member States and the EU as a whole. Results from these studies are presented, including their approach, scope and limitations. The studies are also compared. In subsection A.3 we shortly address individual Member State studies and compare their results.

A.1 Energy subsidies

This chapter provides a discussion of the various definitions of subsidies, their classification and typology as well as the most commonly used approaches to measure and quantify the value of subsidies for fossil fuels.

Definition

Subsidies are commonly understood as the direct financial support of governments. In this context a subsidy is the direct payment of a government to an organisation, producer or consumer with the purpose of improving particular circumstances or to stimulate certain activities. This definition is however rather restrictive and excludes other forms of government support or involvement that all have an influence on prices received by producers and paid by consumers. These may include tax measures, trade restrictions, purchase obligations and price conditions (EEA 2004).

The OECD (1998) uses a broad definition of subsidies as ‘any measure that keeps prices for consumers below market levels, or for producers above market levels or that reduces costs for consumers and producers’. This definition is comparable to WTO (1994) that defines a subsidy as ‘any financial contribution by a government, or agent of a government, that confers a benefit on its recipients’. There are several studies that use this broad definition of subsidies to also include government interventions and measures other than direct payments and transfers of funds from a government (agency) to beneficiaries.

So over the years the concept of a subsidy has been expanded to include different support measures and public resource transfers. In the literature, subsidies are also referred to by other terms, including (government) support measures, government interventions, (public) support, (public) assistance, state aid or grants; terms that are often used interchangeably.

Classification and typology

Apart from definitions of subsidies, various classifications and typologies of subsidies have been developed (c.f. ESM 2005, OECD 2013, World Bank 2010, GSI 2010, IMF 2013). There are many similarities between these and there is a shared understanding of the essential types of support that subsidies may comprise of.

The OECD (2013) defines two broad classes of subsidies or support measures: a) the transfer mechanisms and the statutory and b) formal incidence of the subsidy.

a) The transfer mechanisms: the mechanisms through which subsidies are channelled to recipients (i.e. the measures or instruments).

b) The formal incidence of a subsidy refers to who (or what) first receives the subsidy (the targeted recipients). This may refer to the consumption and production of energy as well as the point of impact (conditionality) of a subsidy. On the production side the point of impact may be the output returns, enterprise income, cost of intermediate inputs, labour, land and natural resources, capital and knowledge, and on the consumption side this includes the unit cost of consumption (e.g. of fuels or electricity) and household or enterprise income.

When the subsidies are classified as transfer mechanisms to producers and consumers, the OECD (2011, 2013) divides subsidies in five groups or subsidy types that are briefly discussed below.

Direct transfer of funds. Also referred to as direct subsidies. These are the most transparent and straightforward type of subsidy and refer to what people commonly understand by the term ‘subsidy’. These direct subsidies are most often visible, they can be quantified, and are often included in annual government budget statements. Direct transfer of funds may include direct government payments such as capital grants, production support (e.g. feed-in tariffs and premiums), government spending on R&D and deficiency payments[20].

Government tax revenue foregone. Tax revenue foregone refers to revenue foregone by the government (or other economic agents) due to changes in the tax code to reduce the tax liabilities of particular groups or of specific activities. Such deviations from benchmark tax structures may take the form of tax and duty exemptions, tax credits and investment tax deduction. Evidence shows that tax measures are often a more important source of subsidies than the direct transfer of funds (OECD 2013).

Energy tax measures or incentives may be related to a) consumption, b) to the inputs of production or c) the actual output/production of energy (OECD 2013, p.21).

a) *Tax measures related to final consumption*. These are often targeted at households and businesses, and provided through lower tax rates, exemptions and rebates on two main types of consumption taxes: value added tax (VAT) on energy consumption and excise taxes for certain groups of users or types of fuels/electricity.
b) *Tax expenditures related to energy as inputs to production*. These are targeted at fuels or electricity used as input to the final production of a particular good or service. They may include exemptions from excise taxes on fuels for certain types of businesses or economic sectors (e.g. agriculture, steel production, pulp and paper production, fishing or mining) and reductions in energy tax rates related to the energy intensity of a firm’s production processes.
c) *Tax expenditures related to energy production*. Such tax expenditures are targeted at the actual extraction and production of energy, including refining and transport and are usually conveyed through the corporate income tax system and consist of targeted measures to support fossil fuels through accelerated depreciation allowances for capital equipment and investment tax credits or resource-rent taxes, royalties and other fiscal instruments applied to resource extraction.

Government tax revenue foregone may also include modified fiscal or adjusted depreciation schemes that work on investments.

Tax measures are less transparent, less visible and are unlike direct subsidies, not always observed or published by governments in tax expenditure budgets. The size of such

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[20] A type of domestic support paid by governments to producers of certain commodities and based on the difference between a target price and the domestic market price or loan rate, whichever is the less.

measures therefore often needs to be estimated. In order to estimate how much revenue is foregone (i.e. how much would have been collected by a government under a different tax regime), a standard or benchmark needs to be established. Besides an estimation of the value of government revenue foregone (i.e. the size of a tax measure for that matter), the extent to which actors take advantage of it also needs to be established to arrive at a full pictures. In paragraph 0 we provide some of the most common quantification methods.

Other government revenue foregone. Besides tax revenue forgone, governments may also forego revenue by offering the use of non-depletable (e.g. land) or depletable assets (e.g. fossil-fuel resources) that are under their control and ownership, to a private company (or individuals) to exploit them for their own use or for sale – at prices that are below market prices. Through measures such as reduced resource rent taxes or royalty payments, governments may encourage more production or consumption than would otherwise be the case.

In addition to providing the private sector with access to domestic (fossil fuel) resources on concessional terms, governments may also provide access to government buildings, land and intermediate inputs (e.g. water or electricity) at below-market prices.

In order to estimate the monetary value of such transfers, the price that is actually charged for use of the assets or resources, needs to be compared with the price that would have been charged on the (international or ‘free’) market (e.g. through competitive bidding). There are different approaches or methods for quantifying other government revenue foregone.

Transfer of risk to government. This refers to the assumption of (some part of) the risk by governments that market players (e.g. energy producers) face. This may include a wide variety of measures, including loan guarantees, government participation in the equity of a project or company, government acting as an insurer of the last resort (e.g. in case of nuclear accidents or environmental disasters as a result of crude oil extraction), and government provision of military or police protection to strategic energy facilities or energy-transport corridors (OECD 2013).

The actual cost to government of any risk - reducing measure depends on the probability that it will incur costs (from, respectively, a loan default, an accident, or an attack), which may be anywhere from low to highly probable in any given year. Calculating the value of government assurance to its beneficiaries is therefore complex and controversial, and approaches and methods differ widely.

Induced transfers. Also referred to as income or price support. Induced transfers refer to government support that is (indirectly) provided to consumers or producers to keep the end-price of a good or service lower or higher than its actual market price, often through some sort of price support or price regulation. Induced transfers are subsidies that are provided through the market as a result of policies and regulation that raises or lowers prices. Measures may include regulated energy prices (e.g. though mandated feed-in tariffs and premiums), import tariffs, export subsidies, consumption mandates (e.g. biofuel blending mandate) and regulated land prices. In essence, measures create a gap between domestic prices and (international) benchmark or reference prices (i.e. the level of prices in the absence of the regulation).

In Table V-1 below the four common types or groups of subsidies are presented with examples related to energy.

Table V-1: Common types of subsidies and examples (adapted from GSI 2010 and OECD 2013)

Type	Examples
Direct transfer of funds	
	Direct payments linked to production volumes; deficiency payments
	Grants for the acquisition of capital or land: outright and reimbursable grants
	Subsidies to intermediate inputs
	Government-provided loans, including interest rate subsidies; loans, security or credit guarantees
	Government spending on R&D
	Wage subsidies
	Debt forgiveness
	Government-provided insurance or indemnification
	Caps or assumption of commercial liabilities; e.g., occupational health and accident, post-closure risks
Government tax and other government revenue foregone	
	Tax expenditure: reduced tax rates, tax credits, exemptions or deferrals; adjusted depreciation allowances; fiscal depreciation schemes
	Reduced royalty payments; reduced resource rents
	Under-pricing of government provided goods or services; Government-provided infrastructure or land
	Government transfer of intellectual property rights
Transfer of risk to government	
	Loan and credit guarantees

Type	Examples
	Assumption of accidents and calamity liabilities (e.g. in case of a nuclear fall-out)
	Third-party liability limit for producers
	Provision of security and protection
Income or price support (induced transfers)	
	Mandated feed-in tariffs; Portfolio standards; Consumption mandates; Priority grid connection and access
	Export or import restrictions, import tariffs and export subsidies
	Wage control
	Land use control
	Government procurement at above market rates
	Regulated consumer prices

Measurement and quantification of subsidies

Several approaches have been developed and used to quantify subsidies. This paragraph discusses three of the most common approaches: i) the price-gap approach, ii) the Producer Support Estimate (PSE) and the Consumer Support Estimate (CSE) and iii) the programme specific approach (OECD 2002, 2013, GIS 2011a). These approaches are summaries and discusses below, including their main strengths and limitations.

Price-gap approach

The price-gap approach is the most widely applied methodology for quantifying subsidies. It has been adopted and used by the OECD, the IMF, the IEA and the World Bank. The price-gap approach is based on a calculation of the gap between domestic energy and fuel prices and a reference or benchmark price. The price-gap is the amount by which an end-use price falls short of the reference price; its existence indicates the presence of a subsidy. Hence a price gap is calculated using the following (simplified) formula:

Price gap = Reference price – End-user price

The reference price for traded goods (particularly oil, natural gas and coal) is usually the international or the price established ‘at the border’, adjusted for transport and distribution costs, market exchange rates and national taxes. The reference price for non-traded energy commodities (such as electricity or in some cases also coal), is often based on the cost of domestic supply. In contrast to traded goods, it is not required to adjust the reference price for quality differences.

Practices differ widely in the choice of the reference price for non-traded commodities. In case of electricity, the IEA bases it on the estimated long-run marginal cost of delivering electricity to end-users, while the World Bank (2010) and the IMF (2013) for example base it on the estimated average cost of production (including necessary maintenance and replacement of depreciated capital), which is generally a lower benchmark for a pricing policy than the long-run marginal cost (OECD 2013, p.31).

Some of the main strengths and limitations of this approach are (also see text Box 1 below):

Strengths

- Can be estimated with relatively little data; useful for multi-country studies
- Good indicator of pricing and trade distortions

Limitations

- Sensitive to assumptions regarding efficient market and transport prices
- Understates full value of supports because it ignores transfers that do not affect prices

The price-gap method relies on a number of assumptions:

1) Identifying the appropriate cost: Many different measures of cost exist, including average cost, marginal cost and opportunity cost. Exporting countries with large energy endowments prefer to use cost of production as a benchmark. Furthermore, energy costs are highly variable, since not all commodities are widely traded.
2) Identifying the appropriate price: Although the price quoted in global markets is typically used as a measure of opportunity cost, international prices may be distorted by a variety of factors and can experience a high degree of volatility.
3) Price-gap estimates do not capture producer subsidies: Therefore, subsidy estimates based only on price- gap measurements tend to underestimate the total value of subsidies in countries.

Other limitations include exercising caution when interpreting or explaining market transfers (to consumers) and market price support (to producers) in any given year. In recent decades, U.S. dollar prices (especially for crude oil and petroleum products) have been highly volatile in international markets, as has the value of the U.S. dollar against other currencies. Combined, these two elements result in highly variable estimates of market transfers from one year to the next.

Box 1: Major challenges and limitations of the price-gap method

Source: Ecofys, adapted from OECD 2013, p.33

The PSE-CSE framework

The price-gap approach allows for an estimation of observed price distortions, but it misses the often substantial budgetary support that does not affect consumer energy prices but does influence the structure of supply. The so-called Producer Support Estimate (PSE) and the Consumer Support Estimate (CSE) framework provide insights into both. The approach combines the price- gap approach with subsidy measurements based on transfers from governments to both consumers and producers. It thereby combines direct financial transfers (including those benefiting producers through government assumption of risk) as well as transfers generated between producers and consumers (and vice-versa) as a result of government policies. The approach is also referred to as the integrated approach (GSI 2011). It is applied by the OECD (2011, 2013).

The **Producer Support Estimate (PSE),** measures the (annual) monetary value of transfers from consumers and taxpayers - to producers, measured at the producer property and arising from policy measures that support producers. This support is achieved by creating a gap between domestic market prices and border prices of products (often commodities) and in fewer cases also services. The PSE comprises both price-gap method indicators (measuring market price support to producers, MPS) as well as other transfers (such as actual budgetary transfers and revenue foregone by the government and other economic entities). The following (simplified) formula may be used to calculate the PSE:

$$PSE = MPS + BOT$$

Where,
PSE – Producer support estimate;
MPS – Market price support [to producers];
BOT – Budgetary and other transfers.

MPS is a price-gap indicator measured as: $MPS = (DP - BP)*PV$ where,
DP – Domestic price (usually measured at the factory gate, i.e. mine mouth, well head, refinery gate);
BP – Border price (reference price);
PV – Produced volume of good.

Consumer Support Estimate (CSE), measures the annual monetary value of transfers from taxpayers - to consumers, arising from policy measures that support consumers.

$$CSE = TCT - (TPC + OTC)$$

Where,
TCT – Transfers from taxpayers to consumers of a commodity;
TPC – Transfers from consumers to producers of a commodity (mirror image of MPS);
OTC – Other transfers from consumers of a commodity.

Transfers from taxpayers - to consumers of a product or commodity (TCT) are budgetary transfers to consumers (including tax concessions) that are designed to reduce the actual price they pay for a commodity or product such as energy (e.g. to compensate them for the higher energy prices they pay resulting from policies that support producer prices to favour a particular industry or to address energy poverty). TCT are obtained from information on budgetary or tax expenditure. The sum of the other two components (TPC + OTC) corresponds to price transfers from consumers that include transfers to both domestic producers and the government (providing some of the energy demand is met through imports subject to an import tariff).

Some of the main strengths and limitations of this approach are:

Strengths

- Integrates transfers with market supports into a more holistic measurement of support
- Separates effects on producer and consumer markets

Limitations

- Data intensive
- Little empirical producer subsidy equivalent / consumer subsidy equivalent: data needed primarily for fossil fuel markets

Programme specific approach

The programme specific approach[21] quantifies the value of specific government programmes to particular industries; aggregates programmes into overall level of support. In other words, the programme specific approach attempts to measure the value that is transferred to stakeholders from a particular government intervention.

The programme specific approach allows to capture the value of government measures that benefit (or tax) a particular sector, whether these benefits end up with consumers (as

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[21] Also referred to as programme aggregation approach

lower prices), producers (through higher revenues), or resource owners (through higher rents).

Some of the main strengths and limitations of this approach are:

Strengths

- Captures transfers whether or not they affect end-market prices
- Can capture intermediation value (which is higher than the direct cost of government lending and insurance)

Limitations

- Does not address questions of ultimate incidence or pricing distortions unless integrated into a macroeconomic model
- Sensitive to decisions on what programmes to include
- Data intensive: requires programme-level data.

A.2 Short review of existing EU studies and results

Over the last couple of years two major efforts have been undertaken to map the value of subsidies for fossil fuels at an EU-wide level, covering all or nearly all EU Member States. These are a study performed by the Organisation for Economic Co-operation and Development (OECD) in 2011 and updated and extended in 2013, and a study by the International Monetary Fund in 2013.

These studies are discussed in the following two paragraphs in terms of their scope and approach, their results as well as their limitations. First, the main differences between these two studies are further explored and discussed.

It is important to note that methodological differences and data gaps limit the comparability of subsidy figures across sectors (or within a sector). Also, the approaches used to estimate subsidies differ largely in the amount of data required to calculate them and in the degree to which budgetary payments and market transfers are measured accurately.

OECD

Scope and approach

The OECD has thus-far published two major reports that cover the EU (OECD 2011, 2013). While the 2011 version of the study did only include several (10) EU Member States, in 2013 the results of the study were updated and the scope extended to also include other Member States. In total, results for 26 Member States are available. Exceptions are Malta and Croatia.

The OECD distinguishes between subsidies that are related to energy consumption and those that are related to energy production. In total the study covers the following products/categories: petroleum, natural gas, coal and so-called general services support. The latter measures the value of transfers provided through policies that support producers or consumers collectively rather than as individuals (e.g. support for research, development, training, inspection, marketing and sectoral promotion). The 2013 study covers 2011 data.

The majority of support mechanisms identified in the inventory are tax expenditures, and are measured with reference to a benchmark tax treatment that is generally specific to the country in question. Tax expenditures are defined as “a relative measure of the amount by which tax revenues are lower as a result of some preference than they would be under the benchmark rules of the particular national tax system”.

The approach and methodology used by the OECD for estimating such tax expenditures is based on the price-gap approach and the PSE-CSE framework (see section 0).

Results

The OECD values the total of fossil fuel subsidies for the EU at €39 billion. By far the largest subsidies are related to the consumption of petroleum, in total valued at €25 billion, followed by subsidies related to the consumption of natural gas, nearly €5 billion. This is followed by €3.5 billion related to subsidies for the production coal and €2.6 billion for the consumption of coal. Subsidies related to the production of petroleum are estimated to be worth a little over 1 billion, the subsidies related to the production of natural gas are small, estimated at €0.1 billion.

The countries with the highest estimated shares of fossil fuel subsidies are Sweden (€9.75 billion - mainly diesel tax exemptions for transport), followed by Germany (€5.1 billion – particularly related to the production of coal and the consumption of natural gas). Also the subsidies in Denmark and Czech Republic are particularly high.

Note that the individual MS results need to be interpreted with care and that not all measures are included and the extent to which measures are included differ largely from country to country – thereby the picture is not complete (as can be seen from the blank cells in the table).

The full results are presented in Table V-2 below.

Table V-2: Value of fossil fuel subsidies in the EU according to the IMF (€billion, 2011 data)

	Petroleum		**Natural gas**		**Coal**		**General Services Support Estimate**	**Total**
	Production	Consumption	Production	Consumption	Production	Consumption		
Austria	0	0.109	0	0.213	n.a	0.1		**0.39**
Belgium	0.0	2.1	n.a	0.1				**2.14**
Bulgaria*		0.1		0.0				**0.07**
Croatia								
Cyprus		0.0						**0.02**
Czech Republic*		1.2		0.8	0.0	0.5	0.9	**3.39**
Denmark*		2.8				0.9		**3.74**
Estonia		n.a			0.0	0.0		**0.00**
Finland		1.5		0.1	n.a	0.2		**1.79**
France	0.1	2.4	0.0	0.3	n.a	0.0		**2.75**
Germany	0.3	1.7	0.0	0.5	1.9	0.2	0.3	**5.10**
Greece	0.2		0.0			0.0		**0.21**
Hungary*		0.0		0.0	0.0	0.0	0.0	**0.05**
Ireland					0.1			**0.08**
Italy		2.1		0.1				**2.12**
Latvia*				0.0				**0.01**
Lithuania*		0.0		0.1				**0.09**
Luxembourg		0.0						**0.00**
Malta								
Netherlands		0.2		0.1				**0.34**
Poland*	0.4				1.1	0.1	0.1	**1.66**
Portugal		0.1				0.0		**0.14**
Romania*		0.2			0.1		0.1	**0.35**
Spain		1.2			0.3	0.0	0.3	**1.87**

	Petroleum		Natural gas		Coal		General Services Support Estimate	Total
Slovakia		n.a		0.1	0.0	0.1	0.0	**0.17**
Slovenia		0.1		0.0	0.0	0.0	0.0	**0.14**
Sweden*		8.7		0.7		0.4		**9.75**
United Kingdom*	0.1	0.2	0.1	1.8	n.a	0.0	0.0	**2.18**
EU-28	**1.1**	**24.7**	**0.1**	**4.8**	**3.5**	**2.6**	**1.8**	**38.56**
EU-15	**0.7**	**23.1**	**0.1**	**3.8**	**2.3**	**1.9**	**0.7**	**32.60**

Source: OECD 2013. * National currencies are converted to EUR using average 2011 exchange rates. N.a. = not applicable.

Limitations

The OECD inventory has the following limitations:

- The study only includes federal measures in the extent to which governments report on the existence and value of support mechanisms: direct budgetary transfers and tax expenditures related to fossil fuels. Measures at the sub-national level in federal counties are only included on a selective basis.
- Other forms of support — notably those provided through risk transfers, concessional credit, injections of funds (as equity) into state-owned enterprises, and market price support — are not quantified.
- Externalities are not valued.
- Also not covered by this study are measures relating to energy-consuming capital, such as support to the manufacturing of motor vehicles designed to run on petroleum fuels, or to electricity producers.
- Finally, the extents to which measures of individual countries are included differ from country to country and depends the availability of data. One can therefore argue that for countries that are well organised administratively and are transparent in terms of data disclosure, figures are more complete.
- Although the OECD does indeed include subsidies at the producer-side, these are not always quantified due to lack of data.
- In text box 1 below, we provide a list of subsidies that are included by the OECD for the Netherlands.

Producer – side:

- Small Fields Policy: removes all uncertainties related to demand for gas from small gas fields.
- Aid for Exploration of Offshore Marginal Gas Fields This measure provides a deduction from the base for calculating royalty payments to gas companies that explore offshore marginal (i.e. insufficiently profitable) gas fields
- Both are however not quantified.

Consumer - side:

- Reduced Energy-Tax Rate in Horticulture: reduced tax rate for fuels used in the horticulture sector. In practice the reduced tax rate applies mainly to natural gas natural gas
- Energy-Tax Rebate for Religious Institution Users of buildings that are primarily used for public religious services or for philosophical reflection can apply for a 50% energy-tax rebate for both natural gas and electricity.
- Energy-Tax Rebate for Non-Profit Organisations: the 50% energy-tax rebate mentioned above also applies to the heating of buildings of non-profit organisations, including partial compensation for sport accommodations.
- Differentiated Tax Rate on Gas Oil: A differentiated tax rate applies to gas oil, depending on its use. A higher rate applies when it is used as transport fuel. A lower rate applies to uses other than as transport fuel, e.g. when used for heating or in off-road machinery.

Box 2: Subsidies and interventions that are included by the OECD for the Netherlands

IMF

Scope and approach

The IMF (2013) inventory covers the 28 Member States. The study comprises both consumer and producer subsidies. Subsidies are quantified using the price-gap approach (see section 0). In this context, consumer subsidies occur when the prices paid by energy consumers are below a benchmark price. Producer subsidies arise when prices received by suppliers are above this benchmark. In case energy products are traded internationally, this benchmark price is based on international prices, compared to energy products that are not internationally traded (e.g. electricity) where the benchmark is based on the so-called ‘cost – recovery price for the domestic producer. This includes a normal return on capital and distribution costs.

Besides differentiating between consumer and producers subsidies, IMF (2013) differentiates between a) pre-tax subsidies and b) post-tax subsidies.

a) **Pre-tax subsidies** occur when energy consumers pay less than the supply and distribution cost of energy - that is - subsidies measured as the difference between the value of consumption at world and/or domestic prices. Pre-tax subsidies include:
   - Consumer subsidies for gasoline, diesel and kerosene using the price- gap approach;
   - Consumer natural gas and coal subsidies using the price-gap approach;
   - Producer subsidies for coal (direct budgetary transfers).

b) **Post-tax subsidies** are the sum of pre-tax and tax subsidies (tax breaks and social and environmental costs). Post-tax subsidies include all policies that hold the after-tax price of energy below the level consistent with efficient taxation. The IMF defines efficient taxation as a system that applies uniform rates of consumer taxes like VAT across all goods, and also includes compensatory taxes to reflect externalities of energy use. Although the prices often extend to electricity and industrial energy, IMF focuses particular on consumer prices for petroleum products. Post-tax subsidies include:
   - Pre-tax subsidies (see above);
   - Tax breaks for fossil fuels, such as reduced VAT;
   - The failure to price (tax) negative externalities, such as the costs of climate change ($25 per tonne), local pollution, traffic congestion, accidents, and road damage.

While OECD (2013) does not account for externalities, the IMF study does indeed take these into account when calculating post-tax subsidies, albeit this concerns only rough estimates and based on other studies (including (OECD)). Externalities that are incorporated include i) the effects of energy consumption on global warming; ii) on public health through as a result of local pollution; iii) on traffic congestion and accidents, and iv) on road damage (p. 9).

The study values damages from global warming at a price of $25/ton CO2. This CO2 price also assumes that energy products are subject to the economy's standard consumption tax rate (an ad valorem tax) on top of the corrective tax. The estimates are based on VAT-rates for 150 countries in 2011.

Results

The IMF values the total of fossil fuel subsidies at nearly €64 billion for the EU-28 as a whole.

By far the largest subsidies are related to coal (€38 billion), followed by natural gas (€22 billion). Both consider mainly post-tax subsidies that include tax breaks and value the negative externalities related to these fuels. Post—tax subsidies for petroleum are valued at over €4 billion. Pre-tax subsidies for coal are valued at nearly €3 billion.

The countries with the highest shares of fossil fuel subsidies according to the IMF are Germany (nearly €16 billion), followed by the United Kingdom (€8 billion) and Poland (€8 billion). In all these cases, subsidies are particularly related to post-tax subsidies for coal and natural gas.

The full results are presented in Table V-3.

Table V-3: Value of fossil fuel subsidies in the EU according to the IMF 2013 (EUR Billion, 2012 data)

	IMF pre-tax					**IMF post-tax**				
	Petroleum	Electricity	Natural gas	Coal	**Total pre-tax**	Petroleum	Electricity	Natural gas	Coal	**Total post-tax**
Austria	0.00	n.a.	n.a.	n.a.	**0.00**	0.39	n.a.	0.36	0.48	**1.23**
Belgium	0.00	n.a.	n.a.	n.a.	**0.00**	0.00	n.a.	0.78	0.33	**1.11**
Bulgaria	0.00	n.a.	n.a.	n.a.	**0.00**	0.00	n.a.	0.10	0.84	**0.94**
Croatia	0.00	n.a.	n.a.	n.a.	**0.00**	0.00	n.a.	0.15	0.10	**0.24**
Cyprus	0.00	n.a.	n.a.	n.a.	**0.00**	0.10	n.a.	n.a.	0.00	**0.11**
Czech Republic	0.00	n.a.	n.a.	n.a.	**0.00**	0.00	n.a.	0.42	2.13	**2.55**
Denmark	0.00	n.a.	n.a.	n.a.	**0.00**	0.00	n.a.	0.19	0.43	**0.63**
Estonia	0.00	n.a.	n.a.	n.a.	**0.00**	0.01	n.a.	0.02	0.42	**0.46**
Finland	0.00	n.a.	n.a.	n.a.	**0.00**	0.00	n.a.	0.13	0.62	**0.75**
France	0.00	n.a.	n.a.	n.a.	**0.00**	0.00	n.a.	2.00	1.40	**3.40**
Germany	0.00	n.a.	n.a.	1.83	**1.83**	0.00	n.a.	3.65	12.01	**15.66**
Greece	0.00	n.a.	n.a.	n.a.	**0.00**	0.00	n.a.	0.17	0.92	**1.08**
Hungary	0.00	n.a.	n.a.	0.00	**0.00**	0.08	n.a.	0.58	0.30	**0.96**
Ireland	0.00	n.a.	n.a.	0.08	**0.08**	0.21	n.a.	0.21	0.36	**0.78**
Italy	0.00	n.a.	n.a.	n.a.	**0.00**	0.00	n.a.	3.63	1.74	**5.37**
Latvia	0.00	n.a.	n.a.	n.a.	**0.00**	0.00	n.a.	0.08	0.02	**0.11**

	IMF pre-tax					**IMF post-tax**				
Lithuania	0.00	n.a.	n.a.	n.a.	**0.00**	0.00	n.a.	0.12	0.03	**0.15**
Luxembourg	0.00	n.a.	n.a.	n.a.	**0.00**	1.49	n.a.	0.05	0.01	**1.55**
Malta	0.00	n.a.	n.a.	n.a.	**0.00**	0.005	n.a.	n.a.	n.a.	**0.005**
Netherlands	0.00	n.a.	n.a.	n.a.	**0.00**	0.00	n.a.	1.86	1.02	**2.88**
Poland	0.00	n.a.	n.a.	0.52	**0.52**	0.22	n.a.	0.70	6.82	**7.75**
Portugal	0.00	n.a.	n.a.	n.a.	**0.00**	0.00	n.a.	0.21	0.26	**0.46**
Romania	0.00	n.a.	n.a.	n.a.	**0.00**	0.00	n.a.	0.55	0.72	**1.27**
Spain	0.00	n.a.	n.a.	0.31	**0.31**	1.36	n.a.	1.36	1.78	**4.50**
Slovakia	0.00	n.a.	n.a.	0.01	**0.01**	0.00	n.a.	0.26	0.43	**0.68**
Slovenia	0.00	n.a.	n.a.	0.01	**0.01**	0.09	n.a.	0.03	0.18	**0.30**
Sweden	0.00	n.a.	n.a.	n.a.	**0.00**	0.35	n.a.	0.04	0.27	**0.66**
United Kingdom	0.00	n.a.	n.a.	n.a.	**0.00**	0.00	n.a.	4.07	3.90	**7.97**
EU-28	**0.00**	**n.a.**	**n.a.**	**2.76**	**2.76**	**4.30**	**n.a.**	**21.73**	**37.51**	**63.55**
EU-15	**0.00**	**0.00**	**0.00**	**2.22**	**2.22**	**3.79**	**0.00**	**18.71**	**25.52**	**48.02**

Source: IMF 2013. Originally the values are presented as a percentage of GDP and were transformed into billions of Euros by Ecofys on the basis of GDP figures from Eurostat. In Annex 1 the original values in as % of GDP are presented. N.a. = not applicable.

Limitations

- The study captures consumer subsidies that are implicit, such as those provided by oil-exporting countries that supply petroleum products to their populations at prices below those prevailing in international markets. The price-gap approach however does not capture producer subsidies that arise when energy suppliers are inefficient and make losses at benchmark prices.
- It is difficult to analyse subsidies using IMF data as the post-tax data combines 1) tax breaks such as ‘VAT’, which fits a narrow definition of subsidy, and 2) the failure to account for externalised social and environmental costs, which takes a broader definition of ‘subsidy’.
- Whilst the study recognises the importance of both consumer and producer subsidies, the evaluation of subsidies focusses mainly on consumer subsidies for fossil fuels.

- Pre-tax subsidies are limited to coal subsidies and not very common in most EU countries (except for a few emerging European economies). These data are drawn from IEA 2007 – 2011.
- Post-tax subsidies are presented for petroleum, natural gas and coal, not for electricity. Results are available for 28 Member States

In general the estimates provided by the IMF are likely to underestimate energy subsidies at the national level and should be interpreted with care:

- Data on producer subsidies are not available for all countries and products.
- Consumer subsidies for LPG are not included due to lack of data. This has a particular impact on more developing EU Member States and more rural regions that are not connected to the natural gas grid.
- Results for electricity, natural gas and coal are not fully comparable between countries as these are drawn from different sources and use different methodologies. These estimates also rely on assumptions regarding similar transportation and distribution margins across countries which are different in practice.
- The estimates of corrective taxes are made on the basis of studies for just a few countries and a common assumption regarding how these would vary with country income levels.

Regarding externalities and climate change (Pigouvian taxes):

- In order to avoid possible double counting, externalities from electricity generation are not measured – including negative externalities from nuclear power generation.
- Also, due to the lack of available evidence, externalities for other generation fuels are not measured.
- Transportation-related externalities (Climate change/CO2, local air pollution and include traffic congestion and accidents, and road damage have been quantified only for the UK.
- For CO2 emissions (from petroleum, coal and natural gas), the assumed value for global warming damages is set at $25 per ton of CO2 emissions (in 2010 dollars). This may undervalue the actual damage cost and is therefore a moderate value. The uncertainty about the social costs of climate change is however very large (Tol 2009) and estimates in the literature vary largely, ranging from $12 per ton (Nordhaus 2011), between $25 and $50 per ton[22] (Tol 2009), to $85 per ton (Stern 2006) (IMF 2013, p.45).
- Local air pollution and related health effects is assumed only for coal.

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[22] Average of results from various studies. $25/ton is the modal value while $50/ton is the mean value of these studies. A 3% discount rate is applied across the board.

The main differences between the OECD and IMF studies are discussed in the next section.

Main differences between OECD 2013 and IMF 2013

The total values of subsidies for fossil fuels are estimated by IMF (2013) to be in the order of €66 billion for the EU-28, while the OECD (2013) estimates are much lower and valued at around €39 billion. This is a difference of €27 billion. These differences can be largely explained by differences in their approaches and more specifically, on the following factors:

- The IMF study values externalities and 'corrects' for these in the establishment of benchmark prices (both at the consumer and producer side)[23]. The OECD does not include these externalities as far as they are not corrected for by national government measures themselves.
- This has a large effect on the overall results, particularly with regards to coal that has relatively high associated external costs. The OECD values total coal subsidies at €6.1 billion, compared to a significantly much higher figure from IMF: €40 billion. The IMF report does not allow for an extraction of the total estimated value of externalities in the EU, but a rough estimate leads to an estimation of about 50-70% of the total estimated value of subsidies that are related to the under-pricing of externalities.
- The OECD values the subsidies for petroleum much higher than IMF (€25 billion, versus €4 billion). Main reasons are:
    - Both studies use a price-gap approach as their main approach. IMF only focuses on consumer subsidies, not producer related subsidies. The OECD does include producer subsidies, but they are low compared to consumer subsidies.
    - Differences are also due to the use of different benchmark values, particularly for petroleum products.
    - Regarding natural gas: valued at €22 billion by IMF, compared to €9 billion by the OECD. Differences are due to the inclusion of externalities (IMF) and different benchmark values.
    - The OECD study does not include values for Croatia and Malta, while IMF does include these countries. However, this does only affects the total value of fossil fuel subsidies in the EU marginally.

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[23] This is also referred to in the literature as the marginal social cost. It is an estimate of the difference between a marginal social cost (that internalises the externalities) and the actual price paid for environmental damages.

A.3 Individual Member State studies

Over the last couple of years, several Member State studies have been conducted that quantify fossil fuel subsidies for individual countries. These include studies for Croatia, Germany, the United Kingdom and the Netherlands. The results from these studies, including their scope and methodology, are summarised in Table V-4 below and shortly discussed below. In Annex 2 the results of the country studies are presented with more detail.

Table V-4: Overview of results, scope and methodologies of EU Member State studies

	Value of fossil fuel subsidies (billion €)	Period covered	Scope	Methodology	External costs valued?	Source
Croatia	2.1 – 2.5[24]	2005 – 2009	Coal, natural gas, electricity, petroleum, district heating	Price-gap method, marginal societal cost	Yes	UNEP 2011
Germany	1.7	2012	Electricity (from coal, natural gas)[25]	PSE-CSE, programme specific, marginal societal cost	Yes	BWE 2013
United Kingdom	7.4[26]	2011	Coal, natural gas, electricity, petroleum[27]	Fossil fuels: figures taken from OECD (2011). Others: programme specific	No	Blyth et al. 2013
Netherlands	5.7	2010	Coal, natural gas, petroleum[28]	Programme specific, PSE-CSE, marginal societal cost	Yes	Ecofys 2012
Total value of fossil fuel subsidies (€billion)	**16.9 – 17.2**					

The country studies for Germany, the UK and the Netherlands all follow a partial – or full bottom-up approach, evaluating programme specific measures and instruments, including

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[24] Originally expressed as percentage of GDP (5 – 6%). Total value in €billions calculated, based on GDP figures from Eurostat.

[25] The study also includes renewable electricity valued at €10.4 billion and electricity from nuclear valued at €2.5 billion. Both are not included in total value in the table.

[26] Converted from GBP to EUR using average 2011 exchange rates

[27] The study also includes renewables valued at €3.5 billion EUR and electricity from nuclear valued at €2.7 billion. Both are not included in total value in the table.

[28] The study also includes renewables valued at €1.5 billion and electricity from nuclear valued at €15 million. Both are not included in total value in the table.

indirect subsidies and focussing on both the consumer and the producer side. The country study for Croatia however follows a more top-down approach by making use of the price-gap method.

The study for Croatia, Germany and the Netherlands all value external costs related to fossil fuels, while the UK study does not value negative externalities beyond the extent to which the existing measures in the country do.

In Table V-5 the results of the country studies are presented next to the results from the OECD and IMF studies. The differences are briefly discussed below.

Table V-5: Value of fossil fuel subsidies (billion €), comparison between country studies and OECD and IMF

	Country studies	IMF	OECD
Croatia	2.1 – 2.5	0.2	-
Germany	1.7 (only electricity)	17.5	5.1
United Kingdom	7.4[29]	8	2.2
Netherlands	5.7	2.9	0.3

From Table V-5 it becomes clear that the countries studies for the Netherlands and Croatia show higher values than the IMF and OECD studies. The UK study shows largely comparable figures with the IMF study but while the UK country study does not value externalities, the IMF study does.

The results for Germany cannot be compared to the OECD and IMD studies as the country study only focuses on electricity generation and not on other fossil fuel related products used for other purposes than electricity generation. The OECD and IMF study results do not include electricity.

There are various reasons for this and the differences need to be interpreted with care. The country studies:

- Tend to address a different and generally broader range of measures and interventions;
- Value externalities for more measures and use different benchmark prices (the UK study being the exception);

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[29] Converted from GBP to EUR using average 2011 exchange rates

- The studies for Germany, the UK and the Netherlands use broader concepts of support and more inclusive methodologies and follow a bottom-up approach (i.e. PSE-CSE/programme specific approach), compared to OECD and IMF that primarily use the price-gap approach.

A.4 Literature

Blyth et al. 2013. Written evidence commissioned by the Committee from Dr William Blyth, Oxford Energy Associates http://data.parliament.uk/writtenevidence/WrittenEvidence.svc/EvidencePdf/700. UK data.

Ecofys (2011) Government Interventions in the Dutch energy market

European Environmental Agency (EEA) (2004) Energy subsidies in the European Union: A brief overview

Global Subsidies Initiative (2011a) Subsidies and External Costs in Electric Power Generation: A comparative review of estimates. September 2011.

Global Subsidies Initiative (2011b) Subsidies to Liquid Transport Fuels: A comparative review of estimates. September 2011.

Green Budget Germany (2012) The full costs of power generation: A comparison of subsidies and societal cost of renewable and conventional energy sources

IEA World Energy Outlook 2011. Does not contain any EU countries/data.

IEA World Energy Outlook 2012. Only subsidies for renewables (p.233)

IEA World Energy Outlook 2013. Does not contain any EU data. Only a couple of pages on subsidies, but not covering Europe.

IISD (2012) Fossil fuel subsidies and government support in 24 OECD countries Summary for decision-makers 31 May 2012. 12 EU countries (G20) http://www.iisd.org/gsi/news/report-highlights-fossil-fuel-subsidies-24-oecd-countries

IMF (2013) ENERGY SUBSIDY REFORM: LESSONS AND IMPLICATIONS. Overview of post- Post-tax Subsidies for Petroleum Products, Electricity, Natural Gas, and Coal, 2011 for most EU countries (as a percentage of GDP). Pre-tax subsidies only available for Poland.

IMF (2013b) Case Studies on Energy Subsidy Reform: Lessons and Implications (only Poland)

KPMG. (2010). Taxes and incentives for renewable energy. KPMG.

OECD (2002) OECD Workshop on Environmentally Harmful Subsidies. A Stocktaking of OECD Work on Subsidies. Paris, 7-8 November 2002. http://www.oecd.org/site/agrehs/35218052.pdf

OECD (2011) Inventory of estimated budgetary support and tax expenditures for fossil fuels

OECD (2013) Inventory of Estimated Budgetary Support and Tax Expenditures for Fossil Fuels 2013 http://www.oecd.org/site/tadffss/

Oversees Development Institute (ODI) (2013) Time to change the game - Fossil fuel subsidies and climate

Tol (2009) The Economic Effects of Climate Change Journal of Economic Perspectives—Volume 23, Number 2—Spring 2009—Pages 29–51

UNDP (2011) Fossil Fuel Subsidies in the Western Balkans. December 2011. Contains data for Croatia.

World Bank (2010) Background Paper for the World Bank Group Energy Sector Strategy, ‘Subsidies in the Energy Sector: An Overview’, World Bank, July 2010

B Potentials and Costs of RES

B.1 Assessment of current economic parameters and costs for RES

The assessment of the economic parameters and accompanying technical specifications for the various RES technologies relies on a comprehensive literature survey and an expert consultation. All cost data represent a snapshot for the year 2010 and encompass RES within all energy sectors. The assessment provides important parameters for the Green X model and is, hence, consistent to the model's framework and settings.

Economic conditions of the various RES technologies are based on both economic and technical specifications, varying across the EU countries.[30] In order to illustrate the economic figures for each technology Table V-6 represents the economic parameters and accompanying technical specifications for RES technologies in the electricity sector, whilst Table V-7 and Table V-8 offer the corresponding depiction for RES technologies for heating and cooling and biofuel refineries as relevant for the transport sector. Note that all expressed data aim to reflect the current situation - more precisely, they refer to the year 2010 and are expressed in real terms (i.e. $€_{2010}$).

The Green X database and the corresponding model use a quite detailed level of specifying costs and potentials. The analysis is not based on average costs per technology. For each technology, a detailed cost-curve is specified for each year, based on so-called cost-bands. These cost-bands summarize a range of production sites that can be described by similar cost factors. For each technology a minimum of 6 to 10 cost bands are specified by country. For biomass, at least 50 cost bands are specified for each year in each country.

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[30] Note that in the model Green X the calculation of generation costs for the various generation options is done by a rather complex mechanism, internalized within the overall set of modelling procedures. Thereby, band-specific data (e.g. investment costs, efficiencies, full load-hours, etc.) is linked to general model parameters as interest rate and depreciation time.

Assessment of potentials and cost for RES in Europe – Method of approach

The Green X database on potentials and cost for RES technologies in Europe provides detailed information on current cost (i.e. investment -, operation & maintenance -, fuel and generation cost) and potentials for all RES technologies within each EU Member State. The assessment of the economic parameter and accompanying technical specifications for the various RES technologies builds on a long track record of European and global studies in this topical area. From a historical perspective the starting point for the assessment of realisable mid-term potentials was geographically the European Union as of 2001 (EU-15), where corresponding data was derived for all Member States initially in 2001 based on a detailed literature survey and an expert consultation. In the following, within the framework of the study “Analysis of the Renewable Energy Sources’ evolution up to 2020 (FORRES 2020)” (see Ragwitz et al., 2005) comprehensive revisions and updates have been undertaken, taking into account recent market developments. Consolidated outcomes of this process were presented in the European Commission’s Communication “The share of renewable energy” (European Commission, 2004). Later on throughout the course of the futures-e project (see Resch et al., 2009) an intensive feedback process at the national and regional level was established. A series of six regional workshops was hosted by the futures-e consortium around the EU within 2008. The active involvement of key stakeholders and their direct feedback on data and scenario outcomes helped to reshape, validate and complement the previously assessed information.

Within the Re-Shaping project (see e.g. Ragwitz et al., 2012) and parallel activities such as the RES-Financing study done on behalf of the EC, DG ENER (see De Jager et al., 2011) again a comprehensive update of cost parameter was undertaken, incorporating recent developments – i.e. the past cost increase mainly caused by high oil and raw material prices, and, later on, the significant cost decline as observed for various energy technologies throughout 2008 and 2009. The process included besides a survey of related studies (e.g. Krewitt et al. (2009), Wiser (2009) and Ernst & Young (2009)) also data gathering with respect to recent RES projects in different countries.

Box 3: About the Green X potentials and costs for RES in Europe

In the following the current investment cost for RES technologies are described alongside the data provided in Table V-6 and Table V-8, whereby a focus may be put on the description of some key technology options. Since the original development of the Green-X database in the year 2004, several updates and adjustments have become necessary due to cost dynamics of RES technologies. In many cases, there was a trend for an increase of investment costs in the years up to 2008, followed by a stagnation or decrease in subsequent years.

Firstly, explanatory notes are provided on the technology-specific investment costs as depicted in Table V-6:

- The current costs of biogas plants range from 1445 €/kW$_{el}$ to 5085 €/kW$_{el}$ with landfill gas plants offering the most cost efficient option (1445 €/kW$_{el}$ – 2255 €/kW$_{el}$) and agricultural biogas plants (2890 €/kW$_{el}$ – 5085 €/kW$_{el}$) being the highest cost option within this category;
- The costs of medium- to large-scale biomass plants only changed slightly and currently lie in the range of 2540 €/kW$_{el}$ to 3550 €/kW$_{el}$. Biomass CHP plants typically show a broader range (2950 €/kW$_{el}$ – 4885 €/kW$_{el}$) as plant sizes are typically lower compared to pure power generation. Among all bioelectricity options waste incineration plants have the highest investment costs ranging from 5150 €/kW$_{el}$ to 7695 €/kW$_{el}$ whereby CHP options show about 5% higher investment cost but offer additional revenues from selling (large amounts of) heat;
- The current investment costs of geothermal power plants are in the range of 2335 €/kW$_{el}$ to 7350 €/kW$_{el}$., whereby the lower boundary refers to large-scale deep geothermal units as applicable e.g. in Italy, while the upper range comprises enhanced geothermal systems;
- Looking at the investment costs of hydropower as electricity generation option it has to be distinguished between large-scale and small-scale hydropower plants. Within these two categories, the costs depend besides the scale of the units also on site-specific conditions and additional requirements to meet e.g. national / local environmental standards etc. This leads to a comparatively broad cost range from 870 €/kW$_{el}$ to 6265 €/kW$_{el}$ for new large-scale hydropower plants. Corresponding figures for small-scale units vary from 980 €/kW$_{el}$ to 6590 €/kW$_{el}$;
- In 2010 typical PV system costs were in the range 2675 €/kW$_{el}$ to 3480 €/kW$_{el}$. These cost levels were reached after strong cost declines in the years 2008 and 2009. This reduction in investment cost marks an important departure from the trend of the years 2005 to 2007, during which costs remained flat, as rapidly expanding global PV markets and a shortage of silicon feedstock put upward pressure on both module prices and non-module costs (see e.g. Wiser et al 2009). Before this period of stagnation PV systems had experienced a continuous decline in cost since the start of commercial manufacture in the mid 1970's following a typical learning curve. The new dynamic began to shift in 2008, as expansions on the supply-side coupled with the financial crisis led to a relaxation of the PV markets and the cost reductions achieved on the learning curve in the meantime factored in again. Furthermore, the cost decrease has been stimulated by the increasing globalization of the PV market, especially the stronger market appearance of Asian manufacturers.
- The investment costs of wind onshore power plants are currently (2010) in the range of 1350 €/kW$_{el}$ and 1685 €/kW$_{el}$ and thereby slightly lower than in the previous year. Two major trends have been characteristic for the wind turbine development for a long time: While the rated capacity of new machines has increased steadily, the corresponding investment costs per kW dropped. Increases of capacity were mainly achieved by up-scaling both tower height and rotor size. The largest wind turbines currently available have a capacity of 5 to 6 MW and come with a rotor diameter of up to 126 meters. The

impact of economies of scale associated with the turbine up-scaling on turbine cost is evident: The power delivered is proportional to the diameter squared, but the costs of labour and material for building a turbine larger are constant or even fall with increasing turbine size, so that turbine capacity increases disproportionally faster than costs increase. From around 2005 on the investment costs have started to increase again. This increase of investment cost was largely driven by the tremendous rise of energy and raw material prices as observed in recent years, but also a move by manufacturers to improve their profitability, shortages in certain turbine components and improved sophistication of turbine design factored in.

Table V-6: Overview on economic-& technical-specifications for new RES-E plant (for the year 2010)

RES-E sub-category	*Plant specification*	*Investment costs*	*O&M costs*	*Efficiency (electricity)*	*Efficiency (heat)*	*Lifetime (average)*	*Typical plant size*
		[€/kW_{el}]	*[€/ (kW_{el}*year)]*	*[1]*	*[1]*	*[years]*	*[MW_{el}]*
Biogas	Agricultural biogas plant	2890 – 4860	137 - 175	0.28 - 0.34	-	25	0.1 - 0.5
	Agricultural biogas plant - CHP	3120 – 5085	143 – 182	0.27 - 0.33	0.55 - 0.59	25	0.1 - 0.5
	Landfill gas plant	1445 - 2080	51 – 82	0.32 - 0.36	-	25	0.75 - 8
	Landfill gas plant - CHP	1615 - 2255	56 - 87	0.31 - 0.35	0.5 - 0.54	25	0.75 - 8
	Sewage gas plant	2600 - 3875	118 – 168	0.28 - 0.32	-	25	0.1 - 0.6
	Sewage gas plant - CHP	2775 - 4045	127 – 179	0.26 - 0.3	0.54 - 0.58	25	0.1 - 0.6
Biomass	Biomass plant	2540 - 3550	97 – 175	0.26 - 0.3	-	30	1 – 25
	Cofiring	350 - 580	112 – 208	0.35 – 0.45	-	30	-
	Biomass plant - CHP	2600 - 4375	86 – 176	0.22 - 0.27	0.63 - 0.66	30	1 – 25
	Cofiring – CHP	370 - 600	115 – 242	0.20 – 0.35	0.5 - 0.65	30	-
Biowaste	Waste incineration plant	5150 – 6965	100 - 184	0.18 - 0.22	-	30	2 – 50
	Waste incineration plant - CHP	5770 - 7695	123 – 203	0.16 - 0.19	0.62 - 0.64	30	2 – 50
Geothermal electricity	Geothermal power plant	2335 - 7350	101 - 170	0.11 - 0.14	-	30	5 – 50
Hydro large-scale	Large-scale unit	1600 - 3460	33 – 36	-	-	50	250
	Medium-scale unit	2125 – 4900	34 – 37	-	-	50	75
	Small-scale unit	2995 – 6265	35 – 38	-	-	50	20
	Upgrading	870 – 3925	33 – 38	-	-	50	-
Hydro small-scale	Large-scale unit	1610 - 3540	36 – 39	-	-	50	9.5
	Medium-scale unit	1740 - 5475	37 – 40	-	-	50	2
	Small-scale unit	1890- 6590	38 – 41	-	-	50	0.25
	Upgrading	980 - 3700	36 – 41	-	-	50	-
Photovoltaics	PV plant	2675 - 3480	30 – 39	-	-	25	0.005 - 0.05
Solar thermal electricity	Concentrating solar power plant	6135 -7440	136 - 200	0.33 - 0.38	-	30	2 – 50
Tidal stream energy	Tidal (stream) power plant - shoreline	6085 – 7100	95 – 145	-	-	25	0.5
	Tidal (stream) power plant - nearshore	6490 – 7505	108 – 150	-	-	25	1
	Tidal (stream) power plant - offshore	6915 - 8000	122 – 160	-	-	25	2
Wave energy	Wave power plant - shoreline	5340 – 5750	83 – 140	-	-	25	0.5
	Wave power plant - nearshore	5785 – 6050	90 – 145	-	-	25	1
	Wave power plant - offshore	7120 – 7450	138 – 155	-	-	25	2
Wind onshore	Wind power plant	1350 – 1685	30 – 36	-	-	25	2
Wind offshore	Wind power plant - nearshore	2850 - 2950	64 – 70	-	-	25	5
	Wind power plant - offshore: 5…30km	3150 – 3250	70 – 80	-	-	25	5
	Wind power plant - offshore: 30…50km	3490 - 3590	75 – 85	-	-	25	5
	Wind power plant - offshore: 50km…	3840 - 3940	80 – 90	-	-	25	5

Table V-7: Overview on economic-& technical-specifications for new RES-H plant (grid & non-grid) (for the year 2010)

RES-H sub-category	*Plant specification*	*Investment costs*	*O&M costs*	*Efficiency (heat)*[1]	*Lifetime (average)*	*Typical plant size*
		[€/kW$_{heat}$][2]	*[€/(kW$_{heat}$*yr)]*[2]	*[1]*	*[years]*	*[MW$_{heat}$]*[2]
Grid-connected heating systems						
Biomass - district heat	Large-scale unit	380 - 390	19 – 20	0.89	30	10
	Medium-scale unit	420 - 460	21 – 23	0.87	30	5
	Small-scale unit	500 – 580	24 – 27	0.85	30	0.5 - 1
Geothermal - district heat	Large-scale unit	820 – 840	50 – 52	0.9	30	10
	Medium-scale unit	1490 – 1520	55 – 56	0.88	30	5
	Small-scale unit	2145 – 2160	56 – 59	0.87	30	0.5 - 1
Non-grid heating systems						
Biomass - non-grid heat	log wood	390 – 430	12 – 15	0.75 - 0.85*	20	0.015 - 0.04
	wood chips	525 – 675	14 – 17	0.78 - 0.85*	20	0.02 - 0.3
	Pellets	510 – 685	11 – 15	0.85 - 0.9*	20	0.01 - 0.25
Heat pumps	ground coupled	735 – 1215	5.5 - 7.5	3 - 4[1]	20	0.015 - 0.03
	earth water	800 – 1195	10.5 - 18	3.5 - 4.5[1]	20	0.015 - 0.03
Solar thermal heating & hot water supply	Large-scale unit	660 – 680[2]	9 - 10[2]	-	20	100 - 200
	Medium-scale unit	760 – 780[2]	11 - 15[2]	-	20	50
	Small-scale unit	860 – 880[2]	15 - 17[2]	-	20	5 - 10

Remarks:

[1] In case of heat pumps we specify under the terminology "efficiency (heat)" the *seasonal performance factor* - i.e. the output in terms of produced heat per unit of electricity input

[2] In case of solar thermal heating & hot water supply we specify under the investment and O&M cost per unit of m^2 collector surface (instead of kW). Accordingly, expressed figures with regard to plant sizes are also expressed in m^2 (instead of MW).

Table V-8: Overview on economic-& technical-specifications for new biofuel refineries (for the year 2010)

RES-T sub-category	*Fuel input*	*Investment costs*	*O&M costs*	*Efficiency (transport)*	*Efficiency (electricity)*	*Lifetime (average)*	*Typical plant size*
		[€/kW$_{trans}$]	*[€/(kW$_{trans}$*year)]*	*[1]*	*[1]*	*[years]*	*[MW$_{trans}$]*
Biodiesel plant (FAME)	rape and sunflower seed	205 – 835	10 – 41	0.66	-	20	5 - 25
Bio ethanol plant (EtOH)	energy crops (i.e. sorghum and corn from maize, triticale, wheat)	605 - 2150	30 - 142	0.57 - 0.65	-	20	5 - 25
Advanced bio ethanol plant (EtOH+)	energy crops (i.e. sorghum and whole plants of maize, triticale, wheat)	1245 - 1660[1]	57 -74[1]	0.58 - 0.65[1]	0.05 - 0.12[1]	20	5 - 25
BtL (from gasifier)	energy crops (i.e. SRC, miscanthus, red canary grass, switchgrass, giant red), selected waste streams (e.g. straw) and forestry	825 - 6190[1]	38 - 281[1]	0.36 - 0.43[1]	0.02 - 0.09[1]	20	50 - 750

Remarks:

[1] In case of Advanced bio ethanol and BtL cost and performance data refer to 2015 - the year of possible market entrance with regard to both novel technology options.

For RES-H plants as displayed inTable V-7 the distinction between grid-connected and non-grid heating systems is important. Among the first category are biomass and geothermal district heating systems and among the latter one biomass non-grid heating systems, solar thermal heating systems and heat pumps. Depending on the scale investment costs for biomass district heating systems currently range between 380 €/kW$_{heat}$ and 580 €/kW$_{heat\ l}$ and for geothermal district heating systems between 820 €/kW$_{heat}$ and 2160 €/kW$_{heat}$. In case of non-grid biomass heating systems the investment costs differ depending on fuel type between 390 €/kW$_{heat}$ and 685 €/kW$_{heat}$. Heat pumps currently cost from 735 €/kW$_{heat}$ up to 1195 €/kW$_{heat}$ and for solar thermal heating systems depending on scale the specific investment costs reach from 660 €/kW$_{heat}$ to 880 €/kW$_{heat}$.

Table V-8 provides the current investment cost data for biofuel refineries. With regard to the fuel input / output different plant types are included in the database. Biodiesel plant (FAME) currently cost from 205 €/kW$_{trans}$ to 835 €/kW$_{trans}$, bio ethanol plants from 605 €/kW$_{trans}$ to 2150 €/kW$_{trans}$ and BTL plant from 825 €/kW$_{trans}$ to 6190 €/kW$_{trans}$. Please note that in the case of advanced bio ethanol and BtL the expressed cost and performance data represent expected values for the year 2015 - the year of possible market entrance with regard to both novel technology options.[31] While the investments costs of RES technologies as described above are suitable for an analysis at the technology level, for the comparison of technologies the generation costs are relevant. Consequently, the broad range of the resulting generation costs, due to several influences, for several RES technologies is addressed subsequently. Impacts as, variations in resource- (e.g. for photovoltaics or wind energy) or demand-specific conditions (e.g. full load hours in case of heating systems) within and between countries as well as variations in technological options such as plant sizes and/or conversion technologies are taken into account. In this context, for the calculation of the capital recovery factor a payback time of 15 years, which represents rather an investor's view than the full levelized costs over the lifetime of an installation, and weighted average cost of capital of 6.5% are used.[32]

As can be observed from Figure V-1, Figure V-2 and Figure V-3 the general cost level as well as the magnitude of the cost ranges vary strongly between the different technologies. It is thereby striking that RES-H options under favourable conditions are either competitive or close to competitiveness, while all RES-T options still are above the market price. Looking at RES-E options the situation is more diverse. The most conventional and cost efficient options like large hydropower and biogas can generate electricity below market

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[31] Expectations for 2015 are set in accordance with the GEMIS database of Oeko-Institute (cf. Oeko-Institute, 2009).

[32] A low WACC of 6.5% is used for this generic depiction in order to reflect the impact of a stable policy framework and/or revenue stream from an investor viewpoint.

prices. It is also noticeable that wind power (onshore) cannot deliver electricity at market prices even at the best sites. Of course, this proposition holds only for current market prices which have decreased substantially in the wholesale market in the near past. For most RES-E technologies the cost range at the EU level appears comparatively broad. In the case of PV or wind energy this can be to a lesser extent ascribed to (small) differences in investment costs between the Member States, but more crucial in this respect are the differences in resource conditions (i.e. the site-specific wind conditions in terms of wind speeds and roughness classes or solar irradiation and their formal interpretation as feasible full load hours) between the Member States. In the case of photovoltaics the broad cost range results also from differences in terms of application whereby the upper boundary refers to facade-integrated PV systems.

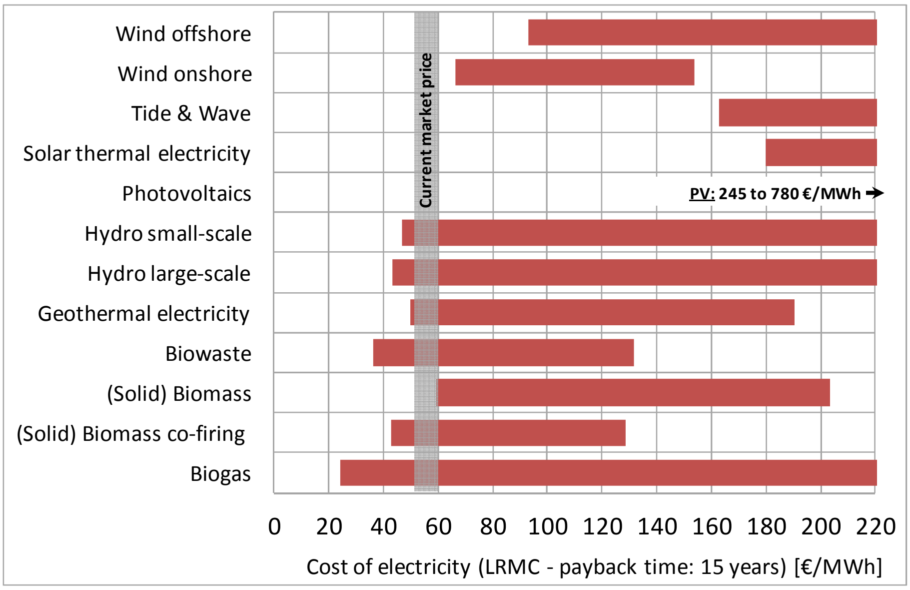

Figure V-1: Long-run marginal generation costs (for the year 2010) for various RES-E options in EU countries

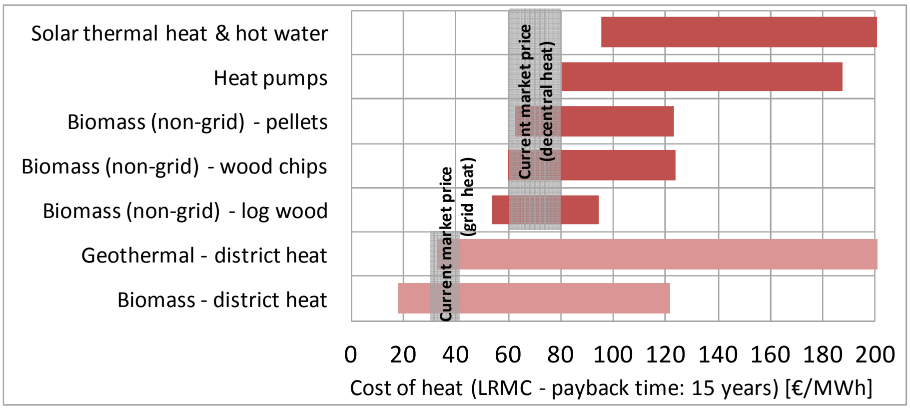

Figure V-2: Long-run marginal generation costs (for the year 2010) for various RES-H options in EU countries

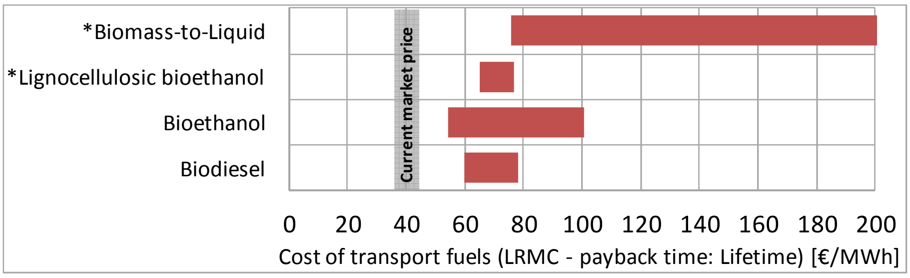

Figure V-3: Long-run marginal generation costs (for the year 2010[33]) for various RES-T options in EU countries

B.2 Future potentials for RES in Europe

Presently, a broad set of different renewable energy technologies exists. Obviously, for a comprehensive investigation of the future development of RES it is of crucial importance to provide a detailed investigation of the country-specific situation – e.g. with respect to the potential of the certain RES technologies in general as well as their regional distribution and the corresponding generation cost.

This section illustrates the consolidated outcomes of an intensive assessment process on Europe's RES potentials and accompanying costs that has been conducted within several studies in this topical area. This shall provide clarification on the pending question on the

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[33] In the case of lignocellulosic bio ethanol and BtL cost and performance data refer to 2015 - the year of possible market entrance with regard to both novel technology options. Please note that the relative low cost, in particular in the case of lignocellulosic bioethanol, take into account revenues stemming from the selling of electricity – a co-product for both advanced biofuel refinery technologies – on the electricity market.

possible contribution of RES to meet Europe's future energy demand in the long-term (up to 2050).

The derived data on realisable long-term (2050) potentials for RES fits to the requirements of the Green-X model, a specialised energy system model developed by TU Wien / EEG that allows to perform a detailed quantitative assessment of the future deployment of renewable energies on country-, sector- as well as technology level within the EU and its neighboring countries.[34] Within the course of this study Green-X will be used to conduct a quantitative assessment of different RES policy pathways up to 2050, indicating RES deployment at technology-, sector- and country- level as well as related costs, expenditures and benefits.

B.2.1 Classification of potential categories

We start with a discussion of the general background and subsequently present the status quo of consolidated data on potentials and cost for RES in Europe as applicable in the Green-X database. These figures indicate what appears to be realisable within the 2050 timeframe.

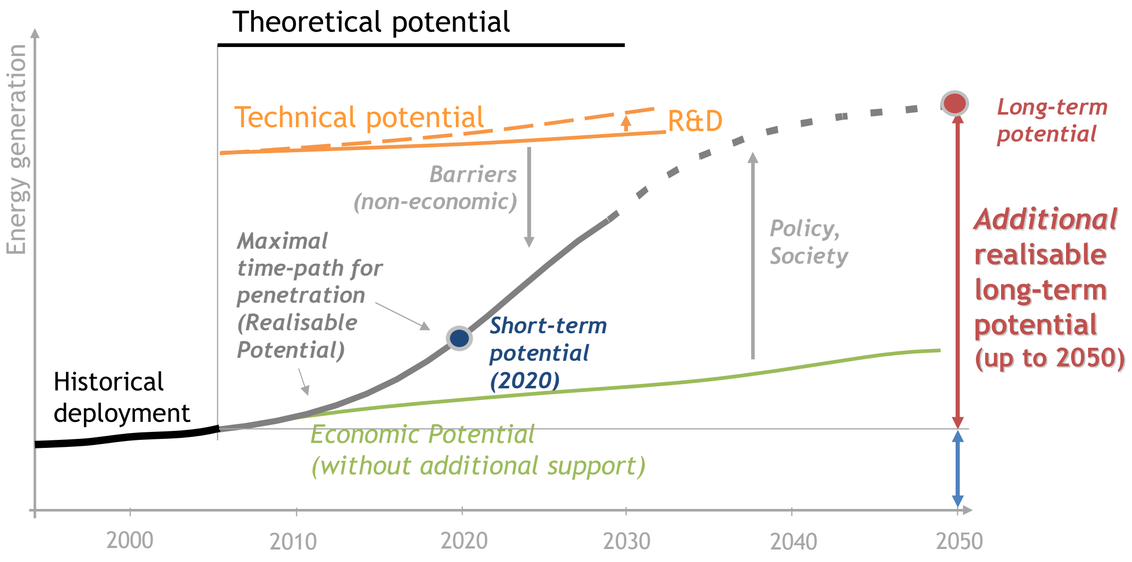

Figure V-4: Definition of potential terms

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[34] The core strength of this tool lies on the detailed RES resource and technology representation accompanied by a thorough energy policy description, which allows assessing various policy options with respect to resulting costs and benefits. For a detailed model description we refer to www.green-x.at.

The possible use of RES depends in particular on the available resources and the associated costs. In this context, the term "available resources" or RES potential has to be clarified. In literature, potentials of various energy resources or technologies are intensively discussed. However, often no common terminology is applied. Below, we present definitions of the various types of potentials as used throughout this report:

- *Theoretical potential:* To derive the theoretical potential, general physical parameters have to be taken into account (e.g. based on the determination of the energy flow resulting from a certain energy resource within the investigated region). It represents the upper limit of what could be produced from a certain energy resource from a theoretical point-of-view, based on current scientific knowledge;
- *Technical potential:* If technical boundary conditions (i.e. efficiencies of conversion technologies, overall technical limitations as e.g. the available land area to install wind turbines as well as the availability of raw materials) are considered, the technical potential can be derived. For most resources, the technical potential must be considered in a dynamic context. For example with increased R&D expenditures and learning-by-doing during deployment, conversion technologies might be improved and, hence, the technical potential would increase;
- *Realisable potential:* The realisable potential represents the maximal achievable potential assuming that all existing barriers can be overcome and all driving forces are active. Thereby, general parameters as e.g. market growth rates, planning constraints are taken into account. It is important to mention that this potential term must be seen in a dynamic context – i.e. the realisable potential has to refer to a certain year;
- *Realisable potential up to 2020:* provides an illustration of the previously assessed realisable (short-term) potential for the year 2020.
- *Realisable potential up to 2050:* provides an illustration of the derived realisable (long-term) potential for the year 2050.

Figure V-4 (above) shows the general concept of the realisable potential up to 2020 as well as in the long-term (2050), the technical and the theoretical potential in a graphical way.

B.2.2 The Green-X database on potentials and cost for RES in Europe – background information

The input database of the ***Green-X*** model offers a detailed depiction of the achieved and feasible future deployment of the individual RES technologies in Europe – in particular with regard to costs and penetration in terms of installed capacities or actual & potential generation. Realisable future potentials (up to 2050) are included by technology and by country. In addition, data describing the technological progress such as learning rates are available. Both serve as crucial input for the model-based assessment of future RES deployment.

Within the ***Green-X*** model, supply potentials of all main technologies for RES-E, RES-H and RES-T are described in detail.

- RES-E technologies include biogas, biomass, biowaste, onshore wind, offshore wind, small-scale hydropower, large-scale hydropower, solar thermal electricity, photovoltaics, tidal & wave energy, and geothermal electricity
- RES-H technologies include heat from biomass – subdivided into log wood, wood chips, pellets, and district heating -, geothermal heat and solar heat
- RES-T options include first generation biofuels such as biodiesel and bioethanol, second generation biofuels as well as the impact of biofuel imports

The potential supply of energy from each technology is described for each country analysed by means of *dynamic cost-resource curves*. Dynamic cost curves are characterised by the fact that the costs as well as the potential for electricity generation / demand reduction can change each year. The magnitude of these changes is given endogenously in the model, i.e. the difference in the values compared to the previous year depends on the outcome of this year and the (policy) framework conditions set for the simulation year.

Moreover, the availability of biomass is crucial as the contribution to energy supply is significant today and its future potentials is faced with high expectations as well as concerns related to sustainability. At EU 28 level the total domestic availability of solid and gaseous biomass (incl. energy crops e.g. for transport purposes) was assessed at 349 Mtoe/a by 2030, increasing to 398 Mtoe/a by 2050 – mainly because of higher yields assumed for the production of energy crops. Biomass data has been cross-checked throughout various detailed topical assessments with DG ENER, EEA and the GEMIS database. As biomass may play a role in all sectors, also the allocation of biomass resources is a key issue. Within the Green-X model, the allocation of biomass feedstock to feasible technologies and sectors is fully internalised into the overall calculation procedure. For each feedstock category, technology options (and their corresponding demands) are ranked based on the feasible revenue streams as applicable for a possible investor under the conditioned scenario-specific energy policy framework, which obviously may change year by year. In other words, the supporting framework may have a significant impact on the resulting biomass allocation and use.

B.2.3 Realisable long-term (2050) potentials for RES in Europe - extract from the Green-X database

The subsequent graphs and tables aim to illustrate to what extent RES may contribute to meet the energy demand within the European Union (EU 28) up to the year 2050 by considering the specific resource conditions and current technical conversion possibilities[35] as well as realisation constraints in the investigated countries. As explained before, *realisable mid-term potentials* are derived, describing the feasible RES contribution up to 2050 from a domestic point of view. Thus, only the domestic resource base is taken into consideration, excluding for example feasible and also likely imports of solid biomass[36] or of biofuels to the European Union from abroad. Subsequently, an overview is given on the overall long-term potentials in terms of final energy by country, followed by a detailed depiction as done exemplarily for electricity sector.

RES potentials in terms of (gross) final energy[37]

Summing up all RES options applicable at country level, Figure V-5 depicts the achieved (as of 2005) and additional long-term (2050) potential for RES in all EU Member States. Note that potentials are expressed in absolute terms. Consequently, large countries (or more precisely those Member States possessing large RES potentials) are getting apparent. For example, France, Germany, Italy, Poland, Spain, Sweden and the UK offer comparatively large potentials. To illustrate the situation in a suitable manner for small countries (or countries with a lack of RES options available), Figure V-6 indicates a similar depiction in relative terms, expressing the realisable mid-term potential as share on gross final energy demand.

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[35] The illustrated potentials describe the feasible amount of e.g. electricity generation from combusting biomass feedstock considering current conversion technologies. Future improvements of the conversion efficiencies (as typically considered in model-based prospective analyses) would lead to an increase of the overall long-term potentials.

[36] In comparison to this overview on RES potentials, as default, and also in the subsequent model-based assessment, the Green-X database considers imports of forestry biomass to the EU. Approximately 31% of the overall forestry potential or 12% of the total solid and gaseous biomass resources that may be tapped in the considered time horizon up to 2050 refer to such imports from abroad, assuming increasing potentials for imports in the period beyond 2030.

[37] (Gross) Final energy is hereby expressed in line with the definition as given in the Renewable Energy Directive (Directive 2009/28/EC) as adopted by the European Parliament and Council on 23 April 2009.

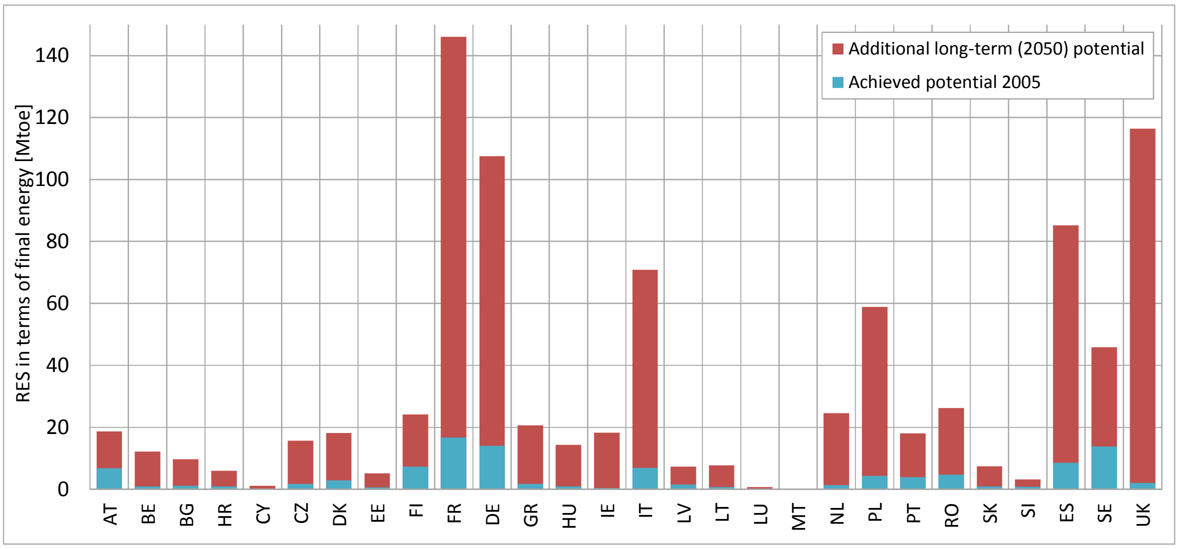

Figure V-5: Achieved (2005) and additional long-term (2050) potential for RES in terms of final energy for all EU Member States (EU 28) – expressed in absolute terms

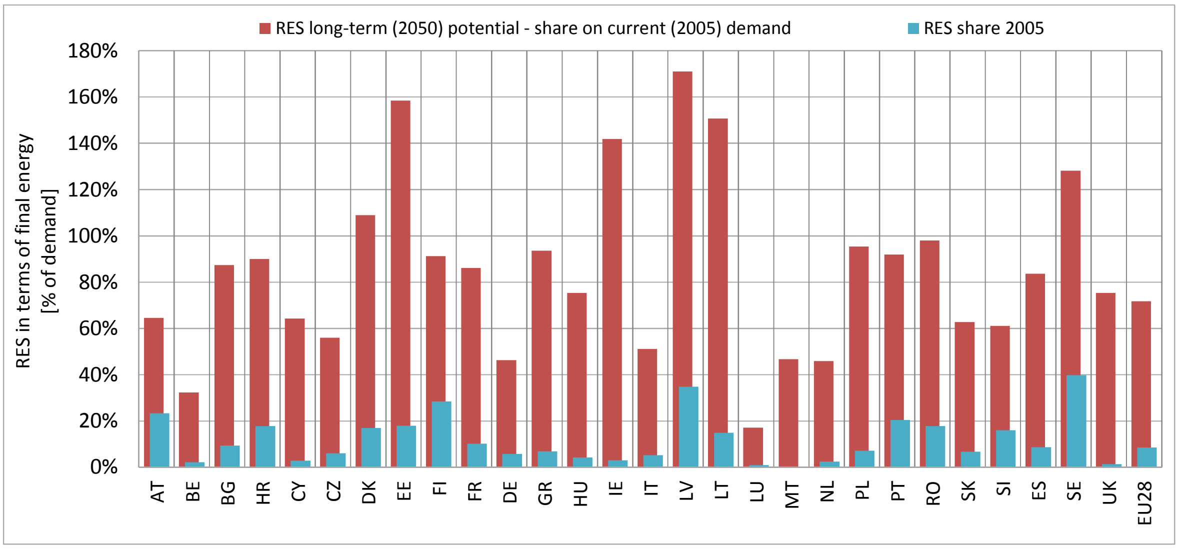

Figure V-6: Achieved (2005) and total long-term (2050) potential for RES in terms of final energy for all EU Member States (EU 28) – expressed in relative terms, as share on (gross) final energy demand

The overall long-term potential for RES in the European Union amounts to 890 Mtoe, corresponding to a share of 71.8% compared to the overall current (2005) gross final energy demand. In general, large differences between the individual countries with regard to the achieved and the feasible future potentials for RES are observable. For example, Sweden, Latvia, Finland and Austria represent countries with a high RES share already at present (2005), whilst Estonia, Lithuania and Ireland offer the highest additional potential compared to their current energy demand. However, in absolute terms both are relatively small compared to other large countries (or more precisely to countries with significant realisable future potentials).

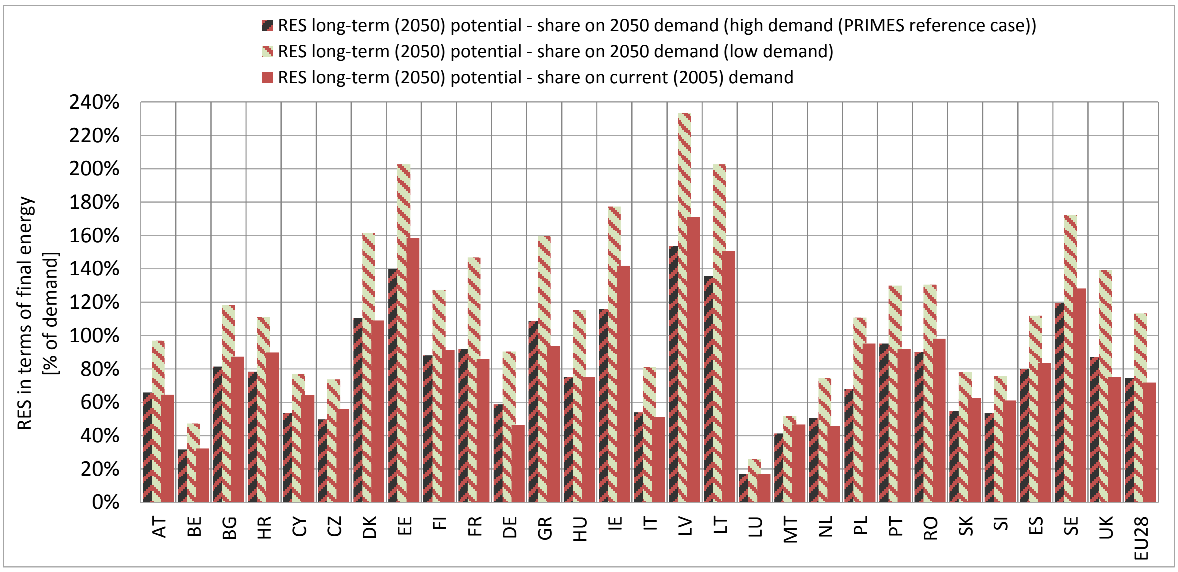

Figure V-7: The impact of demand growth - Long-term (2050) potential for RES as share on current (2005) and expected future (2050) (gross) final energy demand.

Above, Figure V-7 relates derived potentials to the expected future energy demand. More precisely, it depicts the total realisable long-term potentials at a country level [38] (up to 2050) for RES as share on final energy demand in 2005 and in 2050, considering two different demand projections – a reference and a high energy efficiency scenario taken from PRIMES modelling[39]. The impact of setting accompanying demand side measures to reduce demand growth is becoming apparent: the overall long-term potential for RES up

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[38] The total realisable mid-term potential comprises the already achieved (as of 2005) as well as the additional realisable potential up to 2030.

[39] In order to ensure maximum consistency with existing EU scenarios and projections, data on current (2005) and expected future energy demand was taken from PRIMES. In accordance with the subsequent model-based assessment the used PRIMES scenarios are:

- The latest reference case (EC, 2013)
- A *high energy efficiency scenario (EC, 2013) where a 34% demand reduction is achieved by 2030 compared to reference (scenario “45% GHG reduction and high energy efficieny”).*
- Note that both scenarios are discussed in the Impact Assessment accompanying the Communication from the European Commission “A policy framework for climate and energy in the period from 2020 to 2030” (COM(2014) 15 final).

to 2050 is in size of 71.8% compared to current (2005) gross final energy demand. A slight increase of the possible RES contribution by 2050 can be expected if demand trends as projected under “business as usual” conditions – i.e. 74.7% of EU’s overall final energy consumption could then be covered. In contrast to above, if for some sectors a partly significant decrease of energy demand would be achieved as preconditioned in the “high efficiency” case, RES provide a higher potential than the overall demand by 2050 (113% compared to gross final energy demand by 2050).

Finally, a sectoral breakdown of the realisable RES potentials at European level is given in Figure V-8. The largest contributor to meet future RES targets represents the electricity sector. The overall long-term potential for RES-electricity is 40.8% compared to the current (2005) final energy demand, followed by RES in heating and cooling, which may achieve (in case of a full exploitation) a share of 23.6% in total final energy demand. The smallest contribution can be expected from biofuels in the transport sector, which offer (considering solely domestic resources) a potential of 7.4% (on current final energy demand).

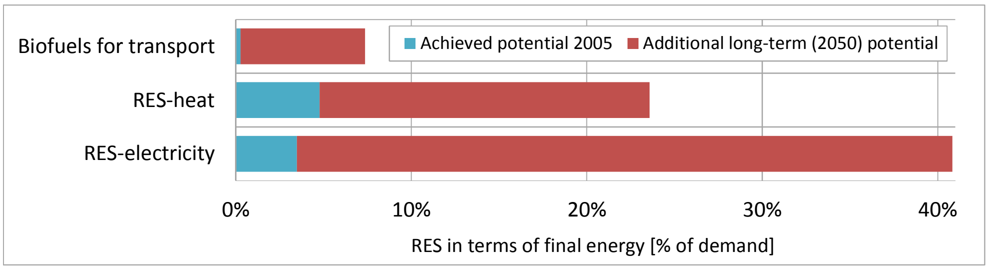

Figure V-8: Sectoral breakdown of the achieved (2005) and additional long-term (2050) potential for RES in terms of final energy at EU 28 level – expressed in relative terms, as share on current (2005) (gross) final energy demand

Long-term (2050) realisable potentials for RES in the electricity sector

Next, we take a closer look on the long-term prospects for RES at sector level, illustrating identified RES potentials in the 2050 time frame in further detail for the electricity sector. In the power sector, RES-E options such as hydropower or wind energy represent energy sources characterised by a natural volatility. Therefore, in order to provide an accurate depiction of the future development of RES-E, historical data for RES-E is translated into electricity generation potentials[40] – the *achieved potential* at the end of 2005 – taking into account the recent development of this rapidly growing market. The historical record was derived in a comprehensive data-collection – based on (Eurostat, 2007; IEA, 2007) and statistical information gained on national level. In addition, *future* potentials – i.e. the *additional realisable long-term potentials* up to 2050 – were assessed[41] taking into account the country-specific situation as well as overall realisation constraints, see section B.2.2.

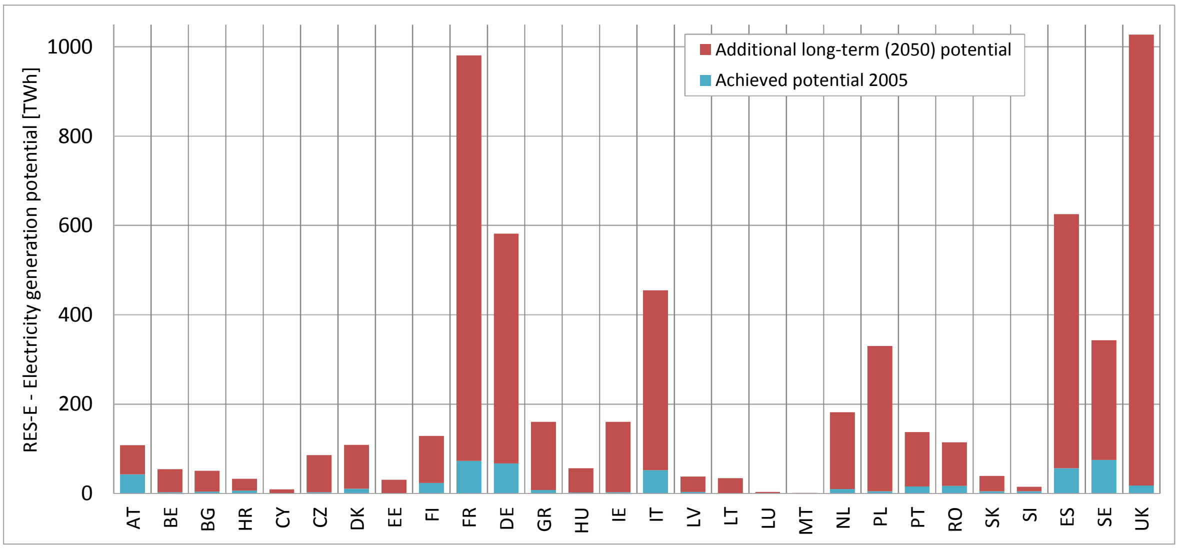

Figure V-9: Achieved (2005) and additional long-term potential 2050 for electricity from RES in the EU 28 on country level.

Figure V-9 depicts the achieved and additional mid-term potential for RES-E in the EU 28 at country level. For the 28 Member States, the already achieved potential for RES-E equals 504 TWh, whereas the additional realisable potential up to 2050 amounts to 5,385 TWh (about 163% of 2005's gross electricity consumption). Obviously, large countries such as France, Germany, Spain or UK possess the largest RES-E potentials in absolute terms, where still a huge part is waiting to be exploited. Among the new Member States Poland and Romania offer the largest RES-E potentials in absolute terms.

Consequently, Figure V-10 relates derived potentials to gross electricity demand. More precisely, it depicts the total realisable long-term potentials (up to 2050), as well as the

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[40] The electricity generation potential with respect to existing plant represents the output potential of all plants installed up to the end of 2005. Of course, figures for actual generation and generation potentials differ in most cases – due to the fact that in contrast to the actual data, potential figures represent, e.g. in case of hydropower, the normal hydrological conditions, and furthermore, not all plants are installed at the beginning of each year.

[41] A comprehensive description of the potential assessment is given e.g. in (Resch et al., 2006) from a methodological point of view.

achieved potential (2005) for RES-E as share of gross electricity demand in 2005 for all Member States and the EU 27 in total. As applicable from this depiction, significant additional RES potentials are becoming apparent for several countries. In this context especially notable are Portugal, Denmark and Ireland, as well as most of the new Member States. If the indicated realisable long-term potential for RES-E, covering all RES-E options, would be fully exploited up to 2050, almost twice of all our electricity needs as of today (178% compared to 2005's gross electricity demand) could be *in principle*[42] covered. For comparison, by 2005 already installed RES-E plants possess the generation potential to meet about 15% of demand.

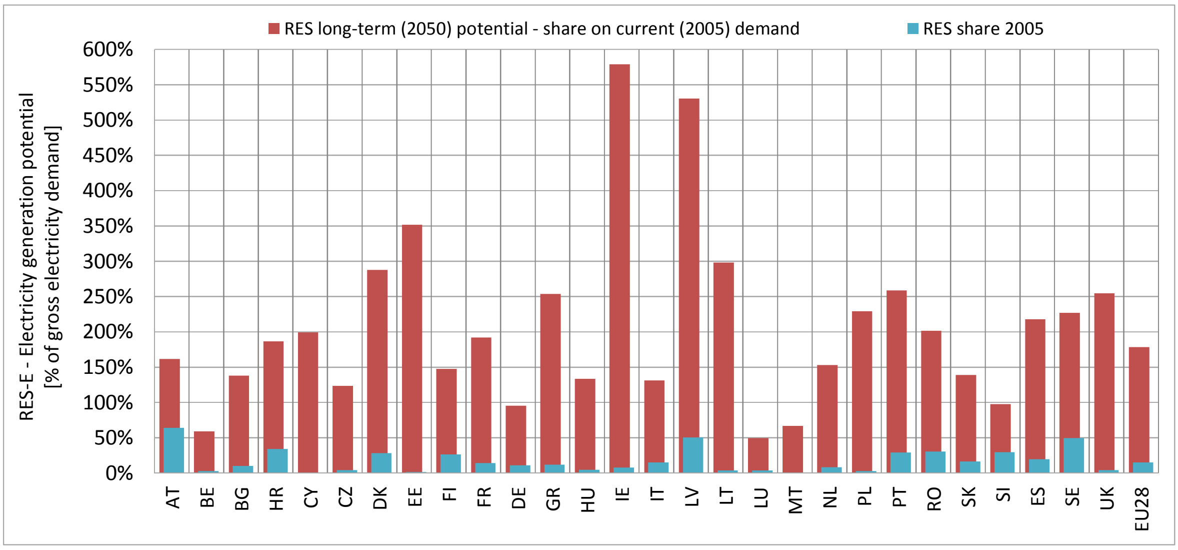

Figure V-10: Total realisable long-term potentials (2050) and achieved potential for RES-E in EU 28 countries as share of gross electricity demand (2005).

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[42] In practice, there are important limitations that have to be considered: not all of the electricity produced may actually be consumed since supply and demand patterns may not match well throughout a day or year. In particular this statement is getting more and more relevant for variable RES like solar or wind where curtailment of produced electricity increases significantly with increasing deployment. This indicates the need for complementary action in addition to the built up of RES capacities, including grid extension or the built up of storage facilities.

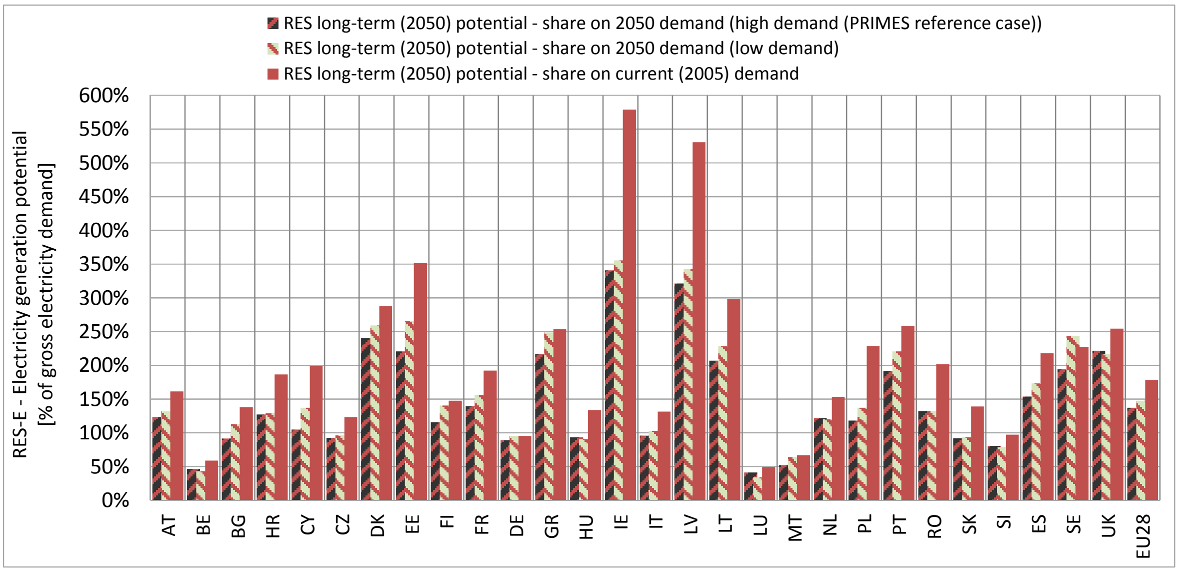

Figure V-11: Total realisable mid-term potentials (2030) and achieved potential for RES-E in EU 27 countries as share of gross electricity demand (2005 & 2030) in a reference and an efficiency demand scenario.

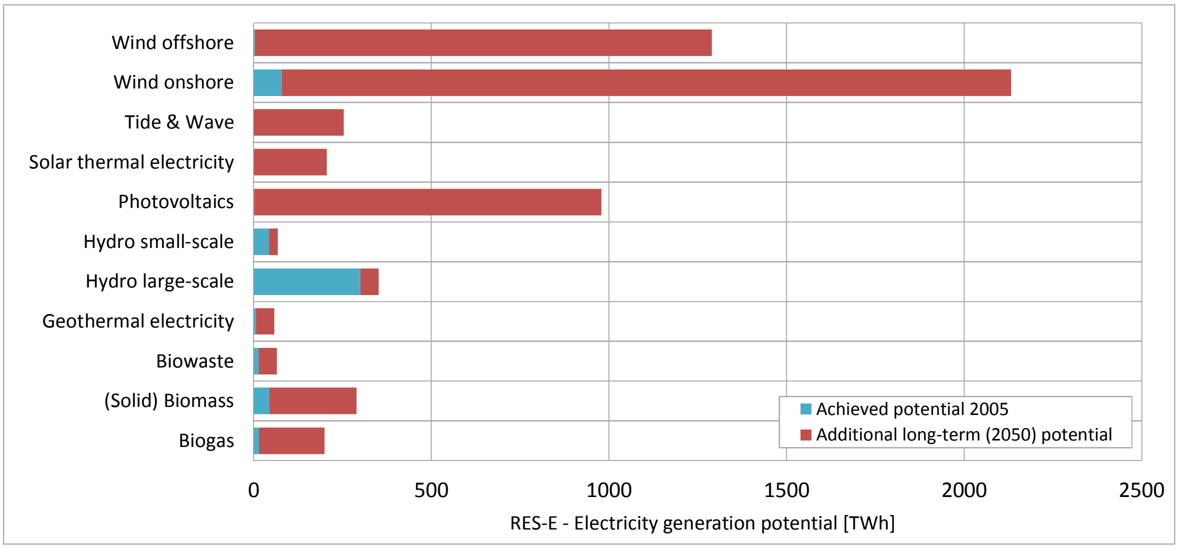

Figure V-12: Total realisable mid-term potentials (2030) and achieved potential for RES-E in EU 27 countries on technology level.

Additionally, the above-mentioned relations of the total realisable mid-term potential (2030) to the gross electricity demand are addressed in Figure V-11 with respect to different scenarios on the future development of the electricity demand. A strong impact of the electricity demand development on the share of renewables is noticeable: In a reference demand scenario (according to PRIMES (cf. NTUA, 2013)), a total achievable RES-E share of 137% in the year 2050 would appear possible, whereas in a high efficiency demand scenario (NTUA. 2013), 148% of the expected future electricity demand by 2050 could be generated by renewables. As already discussed in the previous figure, if the total realisable mid-term potential for RES-E was fully exploited up to 2030, 178% of current (2005) gross consumption could be covered, meaning even the efficiency demand scenario takes an increasing electricity demand into account – partly since cross-sectoral substitution effects are expected to come into play (i.e. electricity is expected to contribute stronger to meeting the demand for heat in future years, and similar substitution effects are assumed for the transport sector.

B.3 Potential for biomass imports to the EU

In this quick assessment, we have collected insights in the future potential import of bioenergy to the EU, in the form of liquid biofuels (or their feedstock) for transport application as well as solid biofuels for the production of heat or power. We have not developed a separate model, but rely on a few recent literature sources.

Note that the projection of the potential global biomass production depends on many assumptions, as biomass production is intertwined with many sectors. Scenarios typically come in pairs to address the full bandwidth in possible agricultural and industrial technology development, growth of population and change of diet, and developments in other biomass using sectors. The biomass for energy potential could be very large if other sectors would create more room, especially if livestock would be intensified and reduced. However, most scenarios, including the underlying assume a business as usual development for exogenous parameters outside the influence of bioenergy users.

Note further that while this quick assessment presents two scenarios on liquid biofuels and one on solid biofuels, the scenarios are not complementary but overlap. Any demand for solid biofuels will use agricultural space which reduces the potential supply of liquid biofuels. While a total supply could be expressed, it will not be easy to correct e.g. the liquid biofuels supply curve for a certain use of solid biofuels, amongst others because different assumptions have been made with regard to sustainability.

B.3.1 Total global bioenergy potential

The WWF Energy Report [WWF, 2011, The Energy Report, 100% renewable energy by 2050] assessed, amongst others, the total potential of rather sustainable biomass between 2000 and 2050 – meeting standards more strict than stipulated in the Renewable Energy Directive. Its scenario takes into account improvements in crop production such as yield increase, a modest intensification of livestock production to free up grazing land, and some energy efficiency improvements in other sectors. The scenario is rather optimistic in nature and could serve as an upper limit of what could be achieved, although less strict sustainability requirements would lead to an even larger potential.

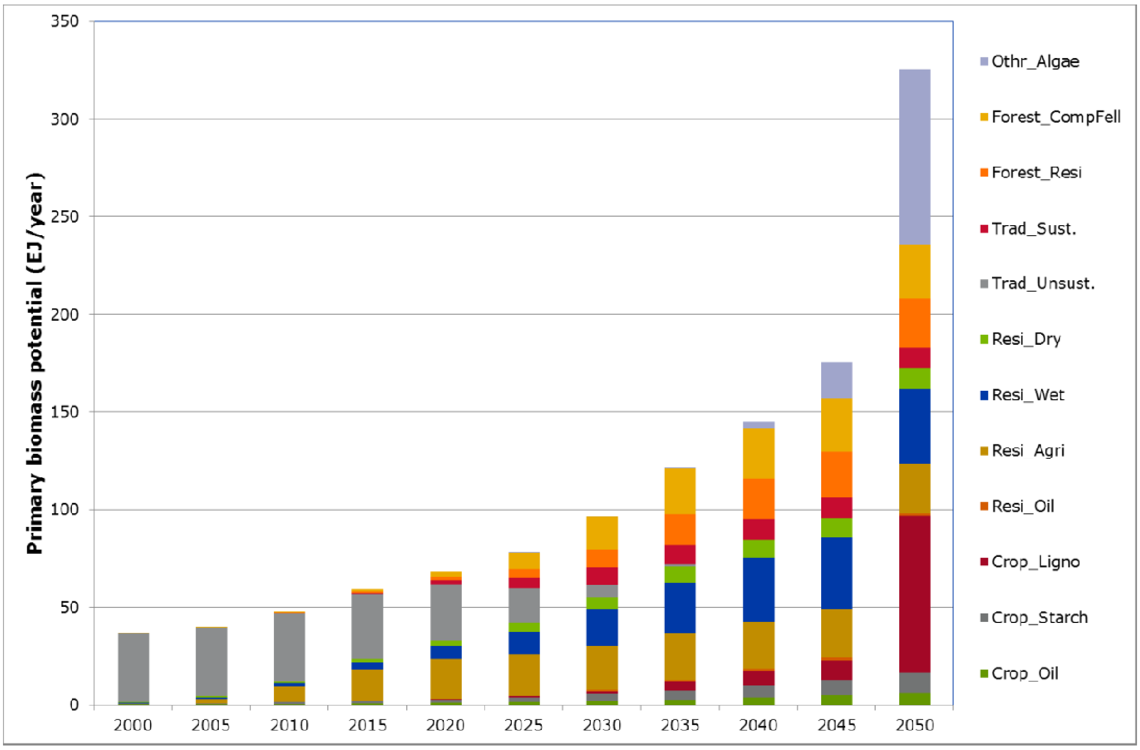

Figure V-13: Global sustainable primary bioenergy potential

Source: WWF 2011

Note that two important feedstock sources of bioenergy suddenly grow very fast between 2045 and 2050, namely lignocellulose energy crops and algae. Their development curve is very slow for a long time and as a result of many assumptions, suddenly becomes steep at this point in time.

Two recent studies evaluated the potential supply of liquid and solid bioenergy to the EU by 2030, both are discussed in more detail below:

- The E4tech study projects as a maximum, an availability of 40 Mtoe (final energy) of liquid biofuels to the EU by 2030 (sum of import and domestic potential): This equals 1.7 EJ;
- The Re-Shaping scenario analysis [forthcoming] projects a potential import of 36 Mtoe (primary energy) of solid biomass from the rest of the world to the EU. This equals 1.5 EJ.

These potentials take into account the demand for energy in the rest of the world. Still, the resulting potential seems very low in comparison to the primary feedstock potential projected by the WWF Energy Report. Or vice versa, the WWF Energy Report potential seems extremely high. For the current quick assessment, we will start from the E4tech and Re-Shaping study and extrapolate the results to 2050, following growth patterns in line with the WWF projection (while accounting for obvious restrictions for some feedstocks if/where necessary). The extrapolation will not lead to results comparable to the WWF Energy Report, but restrictions accounted for in that study will be taken into account.

B.3.2 Scenarios for the import of biofuels to the EU up to 2050

Liquid biofuels – without ILUC regulation

Without ILUC regulation, biofuels in the EU market after 2020 will meet the sustainability requirements that have been stipulated by the Renewable Energy Directive. They will have a GHG performance of at least 60% emission reduction and not be produced from land that was high in carbon and/or biodiversity prior to 2008.

Recently, E4tech [2013, A harmonised auto-fuel biofuel roadmap for the EU to 2030] assessed the potential global supply of liquid biofuels economically available, technically and environmentally suitable for the EU market for 2020 and 2030. They apply three categories:

(1) biofuels produced from conventional crops, limited by feedstock availability;

(2) biofuels from waste streams, agricultural and forestry residues, lignocellulose energy crops, microbial oils and microalgae, for which the supply is constrained by the rate plants can be built;

(3) biofuels produced from conventional crops but using advanced conversion technology. The potential is constrained by both feedstock availability and plant build rates.

E4tech further applies four scenarios that differ in technological advancement, environmental context, and global demand. We use their scenario A, which is the most progressive in results especially because a high export capacity from the ROW to EU is assumed and a low demand from competing markets apart from food/feed. Note that this scenario A assumes a low conversion efficiency and puts conservative limits on conversion capacity. So, the potential could still be higher.

E4tech explores the total availability from EU production and imports. Here, we are only interested in imports.

The E4tech assessment only reaches to 2030. For 2040 and 2050 we have applied a growth pattern in line with the growth potential as predicted in the WWF Energy Report, but starting from the 2030 point as found by E4tech. For 2010, we have applied a best guess on the current situation. The results are given in the next graph.

This extrapolation does not account for some important technological developments that mature after 2030. By starting from the E4tech 2030 values, some regions that would flourish after 2030 are not represented. Algae are expected to have a much larger role after 2030, but that role can hardly be justified by current techno-economic advancement.

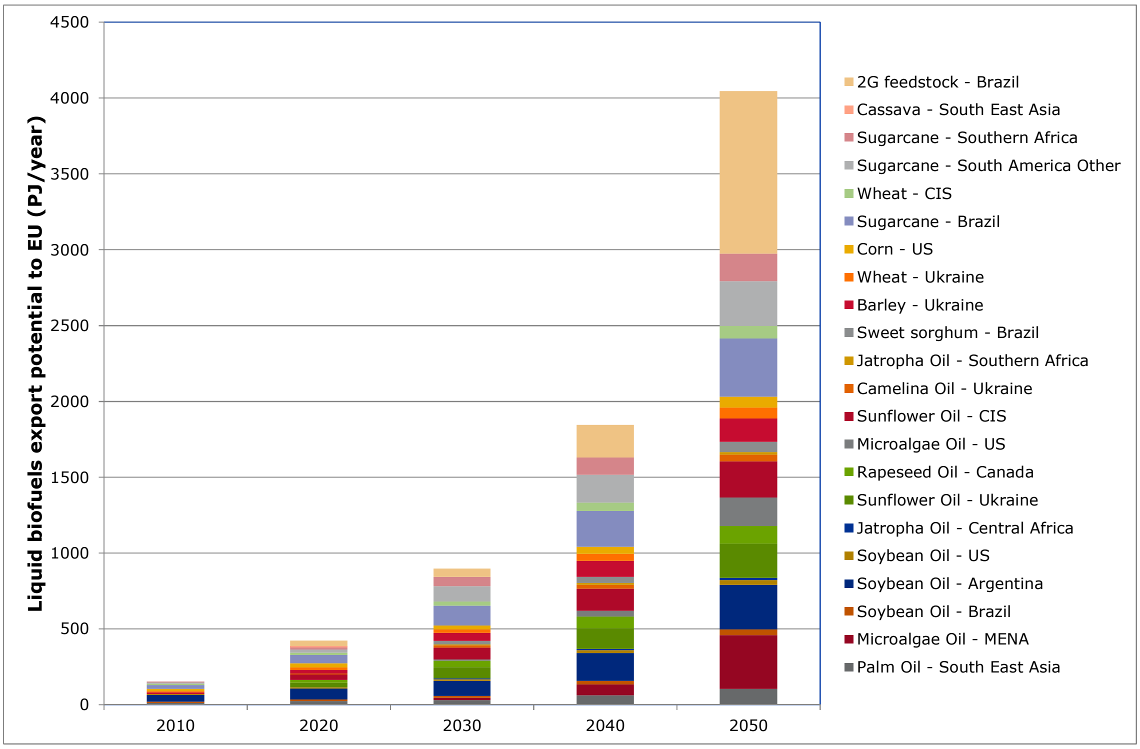

Figure V-14: Liquid biofuels export potential to the EU, up to 2050

Liquid biofuels – with ILUC regulation

In order to limit the ILUC effect from biofuels, the EC has proposed to cap the contribution from food crops at 5%. This should be seen as a very coarse temporary measure, not really addressing the potential ILUC impacts, which would differ per crop-fuel supply chain.

Improved insights in ILUC are necessary to allow for a crop-fuel specific ILUC factor, this may be possible after 2020. At the same time, the ILUC debate has sparked a development of ILUC free bioenergy production (e.g. WWF-Ecofys LIIB concept), and developments outside of the bioenergy sector could reduce the ILUC effect and create more room for bioenergy production (e.g. REDD+ and country specific moratoria on deforestation).

For the purpose of the current assessment, we assume that the contribution from crop based biofuels will be limited to 5% of the 2020 10% renewable energy target. Almost all biofuels from the previous section fall in this category, except for biodiesel produced from algae and bioethanol from lignocellulose.

However, this limit on use does not limit the supply. In fact, it increases the competition between suppliers to fill a smaller market share, so it could even be argued that this measure leads to using only the cheaper biofuels from the first part of supply curves.

The EC proposal does not foresee to give additional incentives to ILUC free biofuels, as for example produced via the LIIB approach. If LIIB would be stimulated, it is expected that the initial costs will be larger, however, the advantage of using less land, increasing yields of main and/or co-products may have broader macro-economic advantages in the 2030 - 2050 period that are yet impossible to project.

Feedstock costs

Some feedstock for biofuels have come available at negative costs, e.g. used cooking oil and tallow. However, the incentive systems in EU Member States, following from the renewable energy directive, and elsewhere have driven the raw material prices up. The current price level is unrelated to costs, but follows from the attractiveness for the biofuels market (driving prices up), while accounting for the value of more mainstream alternatives (especially rapeseed biodiesel) and the difficult feedstock quality of waste oils (limiting the technical conversion options).

Most feedstocks have a positive price, which follows from the production costs plus some margin for farmer and other players along the supply chain.

Agricultural production costs decrease over time. Over the past century food prices fell by an average of 1% per year.

Production costs differ per region. While some studies have calculated case specific biofuel production costs, often with the purpose of demonstrating a great potential, most of these studies take current land and labour costs as a starting point, which would certainly not hold when the large projected potentials in e.g. Africa would be developed. Also, the international market may change considerably over the coming decades. While removing trade barriers could lead to more equal production costs around the world (and phase out of some too expensive production in the EU), a consumers' wish for better socio-economic/environment conditions could increase the price of some country-crop combinations.

All in all, it is almost impossible to give a projection of future cost developments for biofuels. A 2009 E4tech study for DECC explores the bioenergy potential that could be delivered for less than some 5 Euro per GJ. They find that the minimum production costs for agricultural crop based bioenergy (i.e. biofuels) is about 2 €/GJ. For 5 €/GJ, about 25 PJ could be produced in 2010, 150 PJ in 2030.

GHG performance

The potential for biofuels discussed above assumes that all biofuels should meet a 50% GHG emission reduction threshold in 2020 (with some meeting 60%). All biofuels should meet the 60% threshold in 2030 and beyond. This is in line with the EU renewable energy directive.

The renewable energy directive, in its Annex, includes a list of default GHG emission reduction scores for a broad range of crop-fuel combinations. Note that the typical/default values and the accompanied calculation methodology does not (attempt to) give the real GHG performance. For example, the co-production of electricity is not appreciated (does not lead to improved score). The methodology and default factors are for only the administrative purpose of pragmatically distincting between biofuels.

For information, the scores from the Renewable Energy Directive, for major crop-fuels that have a sufficient typical GHG performance beyond 2020 (> 60%) are given in the table below.

Table V-9: Typical GHG emission reduction from major crop-fuels

	Typical GHG emission reduction
Sugar beet ethanol	61%
Wheat ethanol (with straw to CHP)	69%
Sugar cane ethanol	71%
Palm oil biodiesel (with methane capture)	62%
Waste vegetable or animal oil	88%
Sunflower HVO (a biodiesel type)	65%
Palm oil HVO (a biodiesel type)	68%
Lignocellulose ethanol	About 80%
Lignocellulose based diesel	About 90%

Solid biomass import potential

Again, the WWF Energy Report demonstrated that the global potential for 2050 is far larger than what could reasonably be developed in the 2030 timeframe covered by the Re-Shaping projections.

The Re-Shaping projections have been extrapolated following the growth pattern (percentage per decade) found in the Energy Report 2050 projections.

Figure V-15 shows an optimistic scenario for the import potential of solid biomass to the EU. The 2050 import potential (20.000 PJ) is much higher than what is needed in the EU. North and South America are the most important regions delivering the solid biomass streams to the EU.

Figure V-16 gives a conservative scenario for the import potential of solid biomass to the EU. Solid biomass import in 2050 reaches just over 2.000 PJ (around 1/10 of the import potential in the optimistic scenario). A number of assumptions limit the growth of the solid biomass import streams to the EU:

- Delayed development of energy plantations in South America, because pulp/paper price is more attractive than energy;
- Solid bioenergy from Canada / US decreases after 2020 because the local demand grows, and;
- No sustainable expansion in South America after 2030 (too much carbon loss from dLUC)

In this optimistic scenario, the role of North and South America is strongly decreased, because of in land consumption of biomass. On the other hand, there is a stronger role for Russia and Ukraine.

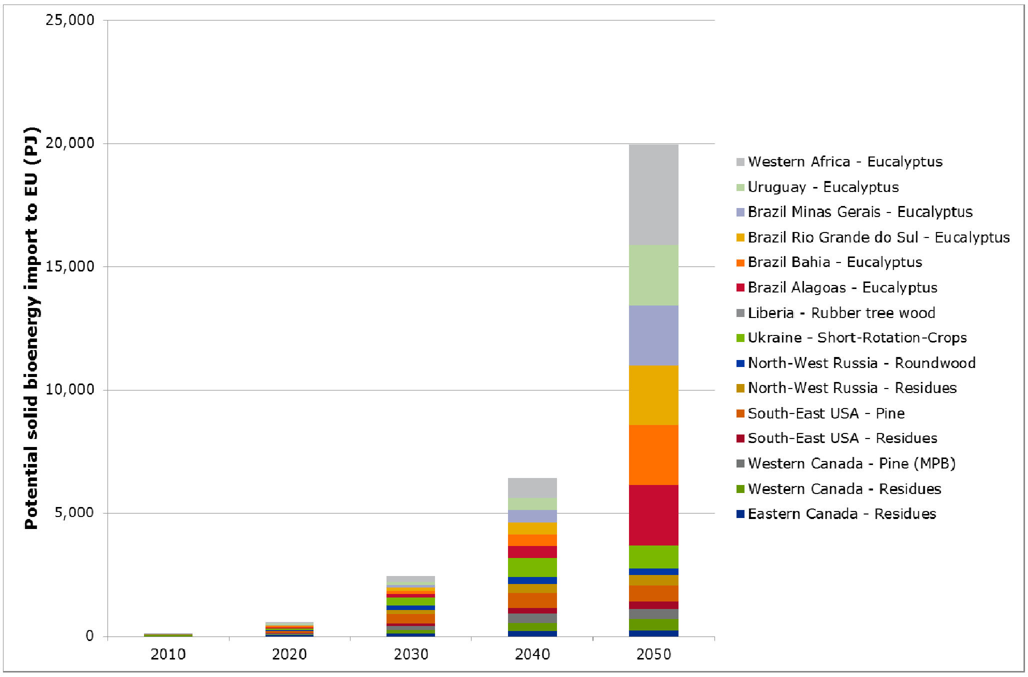

Figure V-15: EU import potential for solid bioenergy (optimistic scenario)

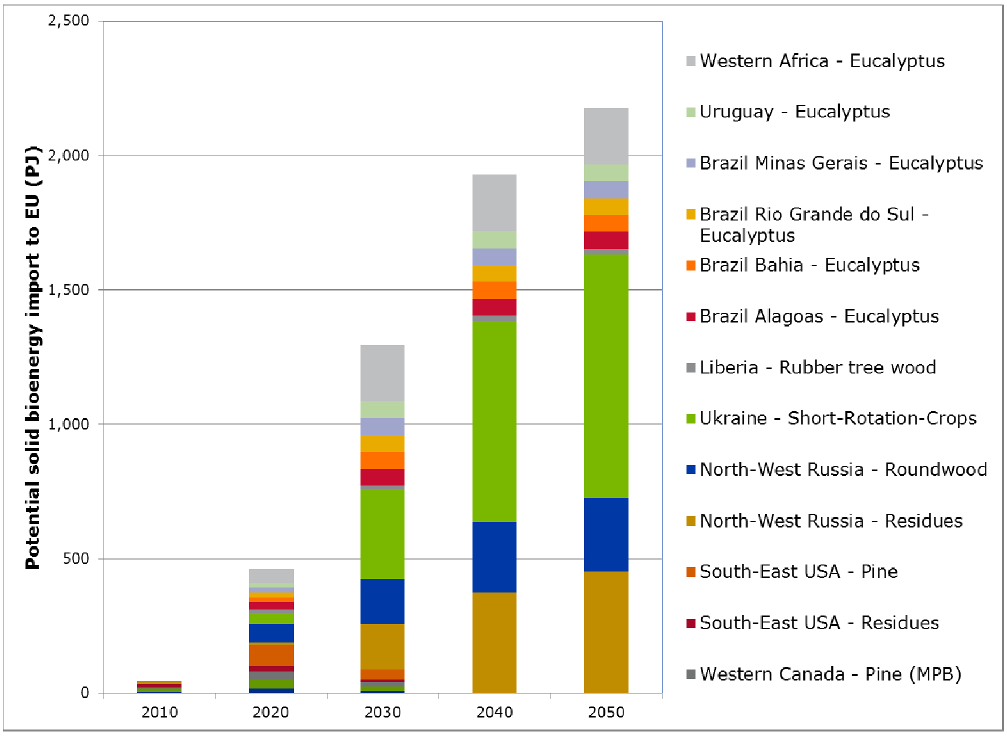

Figure V-16: EU import potential for solid bioenergy (conservative scenario)

C Model descriptions

C.1 Green X

The Green X database on potentials and cost for RES in Europe – background information

The input database of the Green X model offers a detailed depiction of the achieved and feasible future deployment of the individual RES technologies in Europe – in particular with regard to costs and penetration in terms of installed capacities or actual & potential generation. Realisable future potentials (up to 2030 / 2050) are included by technology and by country. In addition, data describing the technological progress such as learning rates are available. Both serve as crucial input for the model-based assessment of future RES deployment. Note that an overview on the method of approach used for the assessment of this comprehensive data set is given in Box 4.

Approach, assumptions, inputs and brief description of Green X model

The Green X model is used for a detailed quantitative assessment of the future deployment of renewable energies within the European Union on country-, sectoral- as well as technology level. A short characterisation of the model is given below, whilst a detailed description is included in the Annex of this report.

Short characterisation of the *Green* X model

The Green X model is used in this study to perform a detailed assessment on the future deployment of renewable energies in the European Union. The Green X model is a well known software tool with respect to forecasting the deployment of RES in a real-world policy context. This tool has been successfully applied for the European Commission within several tenders and research projects on renewable energies and corresponding energy policies, e.g. FORRES 2020, OPTRES, RE-Shaping, EMPLOYRES, RES-FINANCING and has been used by Commission Services in the “20% RE by 2020” target discussion. It fulfils all requirements to explore the prospects of renewable energy technologies:

- It currently covers geographically the EU-27 (all sectors) as well as Croatia, Switzerland, Norway (limited to renewable electricity) and can easily be extended to other countries or regions.

- It allows investigating the future deployment of RE as well as accompanying generation costs and transfer payments (due to the support for RE) within each energy sector (electricity, heat and transport) on country- and technology-level on a yearly basis up to a time-horizon of 2030 (2050).

The modelling approach to describe supply-side generation technologies is to derive dynamic cost-resource curves by RE option, allowing besides the formal description of potentials and costs a suitable representation of dynamic aspects such as technological learning and technology diffusion.

It is perfectly suitable to investigate the impact of applying different energy policy instruments (e.g. quota obligations based on tradable green certificates, (premium) feed-in tariffs, tax incentives, investment subsidies) and non-cost diffusion barriers.

Within the Green X model, the allocation of biomass feedstock to feasible technologies and sectors is fully internalised into the overall calculation procedure, allowing an appropriate representation of trade and competition between sectors, technologies and countries. Moreover, Green X was recently extended to allow an endogenous modelling of sustainability regulations for the energetic use of biomass.

Within Green X a broad set of results can be gained for each simulated year on a country-, sector and technology-level:

- RE generation and installed capacity,
- RE share in total electricity / heat / transport / final energy demand,
- Generation costs of RE (including O&M),
- Capital expenditures for RE,
- Impact of RE support on transfer costs for society / consumer (support expenditures),
- Impact of enhanced RE deployment on climate change (i.e. avoided CO2 emissions)
- Impact of enhanced RE deployment on supply security (i.e. avoided primary energy)

Green X database:

The input database of the Green X model provides a detailed depiction of the past and present development of the individual RES technologies - in particular with regard to costs and penetration in terms of installed capacities or actual & potential generation. Besides also data describing the technological progress such as learning rates is available which serves as crucial input to further macroeconomic analysis.

Box 4: The Green X model & database

C.2 MultiReg

The starting point for the input-output (IO) model based approach is the expenditure for renewable energy use, i.e. for installation of new plant capacities, end-of-life replacement of existing plant capacities and for operation and maintenance of the existing plants. The expenditures are allocated to cost components and finally to economic activities, i.e. to the supply of goods and services needed to install new capacities or to operate existing capacities. In order to capture the indirect economic impacts triggered by the supply of the necessary goods and services usually input-output models are used. Demand side analysis is more comprehensive than supply-side analysis, since it includes all the indirect economic activities related to RES use. On the other hand it is less specific, since to some extent the use of input-output models implies the use of average sector production structures. To enhance specificity it is possible to combine IO analysis with techno-economic coefficients for the considered technologies (e.g. number of employees needed to operate a hydro power plant). It is also possible to use specific data from supply side analysis. Here it is necessary to give care to the compatibility of the data (e.g. in terms of system boundaries).

Assumptions, model description and specification

The IO model based approach starts with data on capacity development and annual capacity increase of the various RES technologies in the EU 27 countries and in selected countries of the rest of the world[43]. Furthermore specific investment costs, operation and maintenance costs and fuel costs (for biomass technologies) are given (see

Figure V-17). This capacity and cost data is available for the years 2005 to 2011. The cost of capacity replacement is a part of the total investment cost and was calculated for each year as the cost of replacing the capacities reaching the end of their economic lifetime in that year. The development of specific costs was derived from the Green X database. Based on this data the annual investment costs, operation and maintenance costs and fuel costs are calculated.

In the case of some technologies, a part of the O&M costs are personnel expenditures for operating the plants. Value added and employment related to these direct operation costs are calculated directly by using country specific average values for labour costs and labour productivities. These cost components are not allocated to economic sectors, but to a separate activity “operation of RES facilities”. In some cases cost components do not lead to production activities (e.g.

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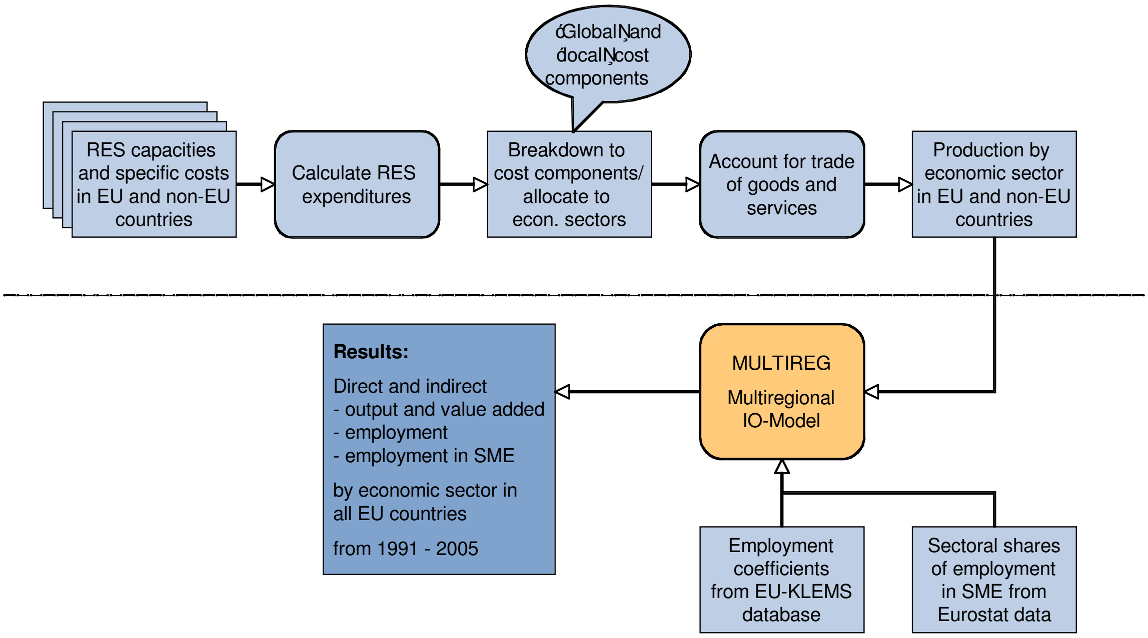
[43] Basically the countries represented in the MultiReg model are considered

costs of wind parks for using land or the transfer component in insurance premiums)[44]. In accordance with conventions of national accounting, these cost components are not considered in the further economic modelling.

As described in the chapter above, the costs are subdivided into cost components and then allocated to economic sectors, thus deriving for each RES technology a vector of production by country and by economic sector.

This vector is the basis for calculating gross value added as the direct economic impact indicator and direct employment. In order to calculate indirect economic and employment impacts related to the deployment of RES technologies, the above mentioned vector of production is introduced as an additional final demand into the model MultiReg, which then gives the induced economic output, gross value added and employment in all EU member countries and all industries as a result. In this calculation imports and exports between countries are accounted for at all levels of the supply chain.[45]



Results:

Direct and indirect
- output and value added
- employment
- employment in SME

by economic sector in all EU countries

from 1991 - 2005

Figure V-17 Overview of the modelling approach to calculate past and present economic and employment impacts of RES deployment

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[44] Some cost components relate to productive activities, but are considered as financial transfers. They may have an influence on income, but do not impact value added and employment in the economy.

[45] Expenditures for RES deployment are modelled as additional final demand to calculate gross effects. This methodological simplification may cause a slight overestimation of effects, which is negligible in the case of RES technologies.

The MultiReg model

MultiReg is a static multi-country input-output (IO) model that covers all EU Member States and their main trade partners as well as trade between these countries with high sectoral detail (up to 59 sectors at the NACE 2-digit level). The model allows capturing economic interdependencies between industries of a country as well as across country boundaries. This ability to include effects across country boundaries is an essential feature for this study due to the high level of economic integration within Europe and with countries outside the EU. For this study the MULTIREG model is extended with sectoral employment data from the KLEMS database (working hours, employment, labour productivity, labour costs) to calculate employment impacts.

Box 5: The MultiReg model

C.3 NEMESIS

Model approach and key assumption of NEMESIS

NEMESIS general overview

The NEMESIS model is based on detailed sectorial models for each of the EU 27 (Croatia, is on-going). Each model starts from an economic framework which is linked to an energy/environment module. The construction and the description of macro-economic pathway established by the NEMESIS model could be viewed as a "hybrid", *i.e.* "bottom-up" forces resulting from sectorial dynamics and interactions and "top-down" ones coming from macro-economic strength (labour force, international context, financial aspects, etc.). The sectorial interactions come not only from input/output matrix but also from more innovative exchange matrix: knowledge spillovers matrix based on patent data and fed by R&D investments.

Mechanisms

On the supply side, NEMESIS distinguishes 30 production sectors. Production in sectors is represented with CES production functions with 5 production factors: capital, low skilled labour, high skilled labour, energy and intermediate consumption. Interdependencies between sectors and countries are finally caught up by a collection of convert matrices describing the exchanges of intermediary goods, of capital goods and of knowledge in terms of technological spillovers, and the description of substitutions between consumption goods by a very detailed consumption module enhance these interdependencies. Furthermore, the energy/environment module computes (*i*) the physical energy consumption by ten different products through CES functions and (*ii*) CO_2 emissions.

On the demand side, representative households' aggregate consumption is dependent on current income, population structure, etc. Consistent with the other behavioural equations, the disaggregated consumption module is based on the assumption that there exists a long-run equilibrium but rigidities are present which prevent immediate adjustment to that long-term solution. Altogether, the total households aggregated consumption is indirectly affected by 27 different consumption sub-functions through their impact on relative prices and total income, to which demographic changes are added

For external trade, it is treated in NEMESIS as if it takes place through two channels: intra-EU, and extra-EU trades. The intra- and extra-EU export equations can be separated into two components, income and prices. The stock of innovations in a country is also included in the export equations in order to capture the role of innovation (quality) in trade performance and structural competitiveness.

The overall main mechanisms of the NEMESIS model are presented in Figure V-18.

Main Output

Beyond economic indicators as GDP, prices and competitiveness, employment and revenues, NEMESIS energy/environment Module gives detailed results on energy demand by source and sector, on electricity mix and on CO_2 and GHG. The inclusion in the model of detailed data on population and working force, allows also the model delivering many social indicators as employment by sectors and skills, unemployment by skills, etc.

Main Uses

NEMESIS can be used for many purposes as short and medium-term economic projections; analysing Business As Usual (BAU) scenarios and economy long-term structural change, research and innovation policies, energy supply and demand, environment and more generally sustainable development. NEMESIS is regularly used to study BAU as well as alternative scenarios for the EU in order to reveal future economics, environmental and societal challenges (projections of sectorial employment, short and medium-term economic path, long-term economic path, etc). It is also used for policies assessment in terms of research and innovation (Horizon 2020, FP7, 3% GDP RTD objective, etc), environment and energy policies (European climate mitigation policies, nuclear phasing-out in France, etc).

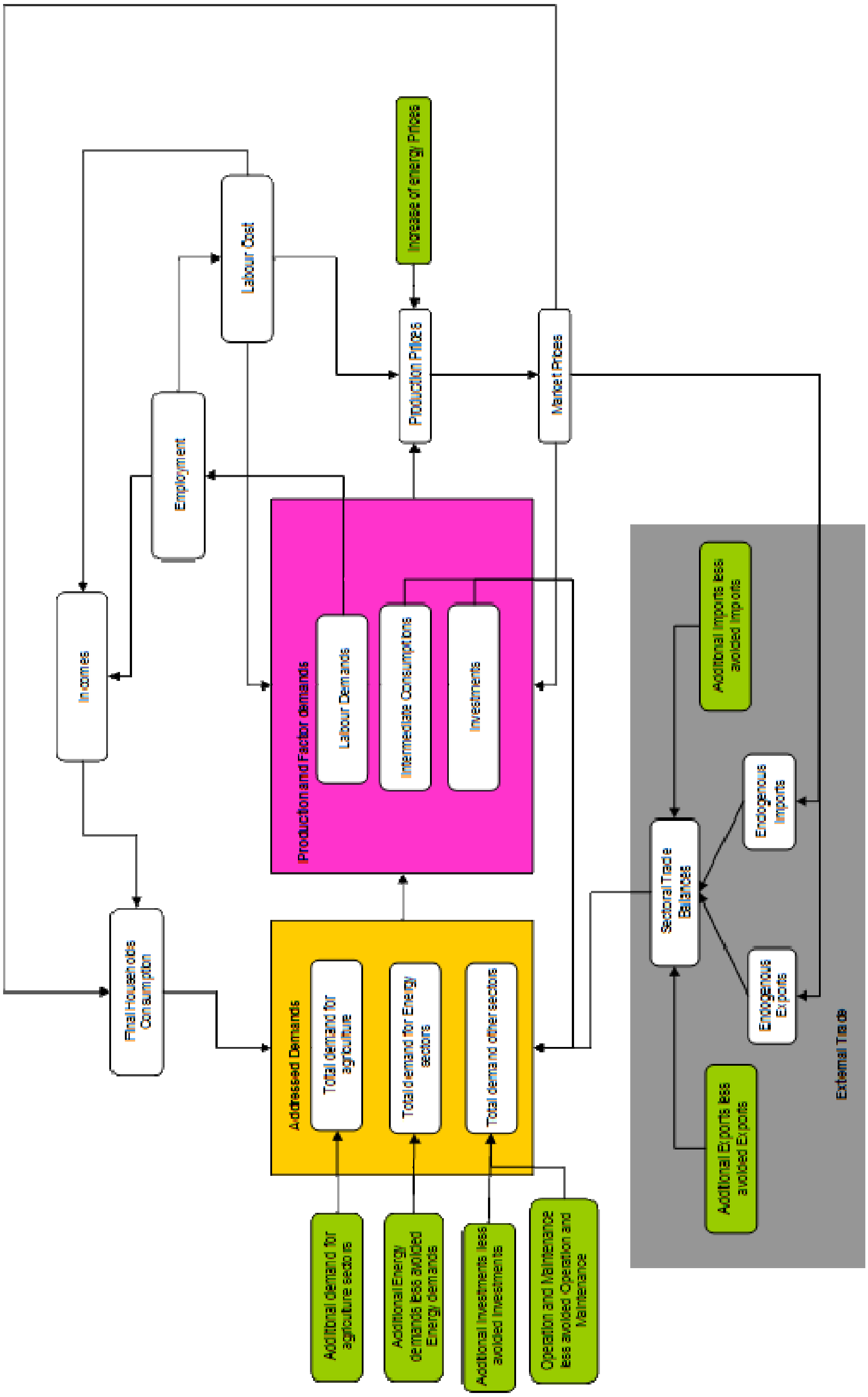

Figure V-18: The NEMESIS model and its links with bottom-up models

Within the Employ-RES II project, a bridge had to be constructed between the NEMESIS model, the Green X and MultiReg models. These interactions are shown in Figure V-18 above. The deployment of RES technologies will impact the NEMESIS model in many ways that can be separated into direct and indirect effects.

Direct effects

At first, the additional investment demands for RES from the Green X output will act the part of a traditional Keynesian multiplier, increasing the demand in national production sectors mainly for sectors producing investment goods. This positive effect will be reinforced by the additional operation and maintenance due to RES deployment. This deployment will also benefit the agriculture and forestry sectors due to the increasing biomass demand. Regarding the energy sectors, the development of RES technologies will lower the demand for conventional fuels.

However, the development of RES technologies will also result in decreased investment in conventional technologies as well as reduced operation and maintenance for these technologies, hence limiting the initial positive effects.

The direct impact of RES deployment on external trade can be split into two different effects. The first concerns the imports and exports of the global components of RES technologies that are produced by only a few countries. This global component trade is exogenous in the NEMESIS model. The second effect concerns the trade of local components of RES technologies; this part remains endogenous in the model.

Finally, RES deployment will have an impact on the electricity price, increasing the production cost.

Indirect effects

The additional demand in some production sectors will radiate throughout the whole economy in two different ways. At first, in order to produce this demand, firms will have to increase their production factor demands (investment, intermediate consumption), which in turn will lead to a second round effect. Moreover, the increased labour demand will increase households' final consumption in two ways: first by increasing employment, and second, depending on the initial national conditions, by increasing wages and salaries.

The increase in national demand will also be exported to other European economies through external trade.

The total effect of the deployment policies in the different Member States will depend on their starting conditions such as,

- existence of sectors producing RES technologies,
- initial conditions on the labour market,
- the agriculture and forestry sector's potential to produce biomass,
- the external trade structure,
- national competitiveness,
- the different elasticities of substitution between the production factors,
- the substitution elasticities in the different consumption categories for households.

The total effect of the deployment policies also depends on the assumption about the evolution of external trade. The study integrates two different assumptions about external trade in each scenario: one with a moderate assumption (ME) and another with an optimistic assumption (OE).

C.4 ASTRA-EC

Main model approach and key assumptions

ASTRA-EC stands for Assessment of Transport Strategies. The model has been continually developed since 1997 and is used for the strategic assessment of policies in an integrated way, i.e. by considering the feedback loops between technological changes and the economic system. Since 2004, it has been further extended by a number of studies and linked with energy system analysis, e.g. to analyse the economic impacts of high oil prices (Schade et al. 2008) and of the German climate strategy (Jochem, Jäger, Schade et al. 2008). Astra was also used within the Integrated European Project "ADAM".

The model is based on the System Dynamics methodology, which, similar to NEMESIS, can be seen as a recursive simulation approach. It follows system analytic concepts which assume that the implemented real systems can be conceived as a number of feedback loops that are interacting with each other. These feedback loops are implemented in ASTRA-EC and the model covers the time period from 1995 until 2050. The spatial coverage extends over the EU27 countries, plus Norway and Switzerland. A detailed description of ASTRA-EC can be found in Schade (2005) with extensions described in Krail (2009) and in the internet[46].

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[46] www.astra-model.eu

An overview on the modules and their main linkages is presented in Figure V-19. From the figure, it is apparent that modules are not independent, but linked together in manifold ways. A short description of the modules and their main links is provided below followed by a closer look at the two modules most relevant for EMPLOY-RES II.

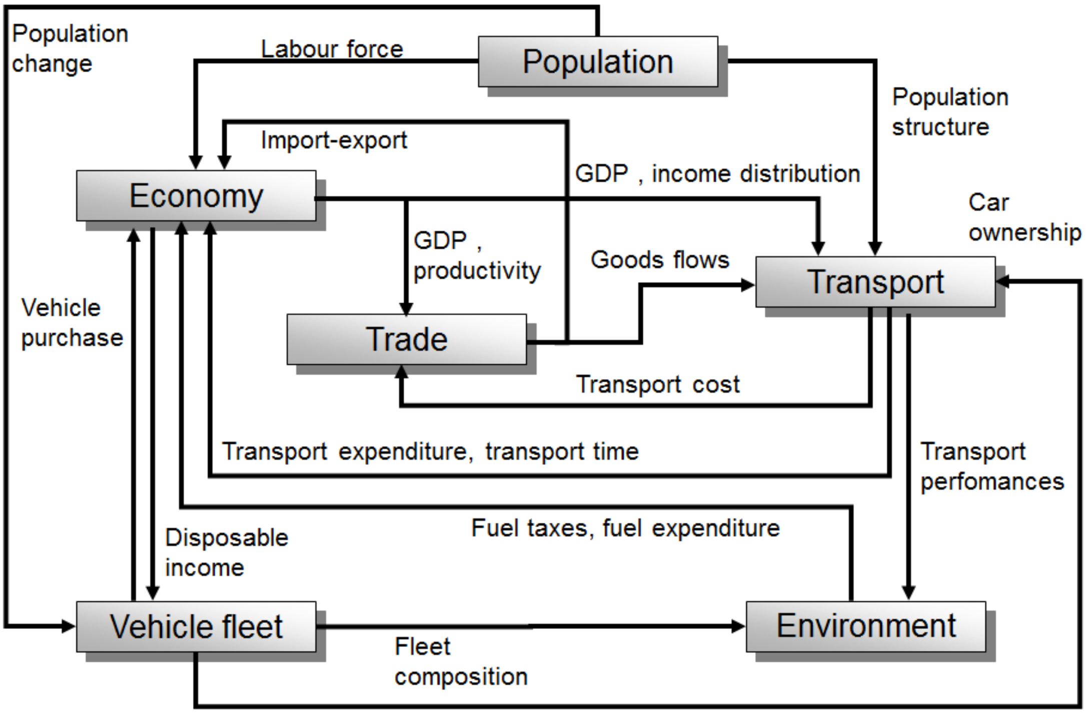

Figure V-19: Overview of the ASTRA-EC modules

Source: TRT / Fraunhofer ISI

The economic modules implemented in ASTRA-EC reflect the view of the economy as constructed of several interacting feedback loops (e.g. income – consumption – investment – final demand – income loop, the trade – GDP – trade loop etc.). These feedback loops are comprised of separate modules which do not refer to only one specific economic theory. Investments are partially driven by consumption following Keynesian thought, but exports are added as a second driver of investment. Neoclassic production functions are used to calculate the production potential of the 29 national economies. Total factor productivity (TFP) is endogenised following endogenous growth theory by considering sectoral investment and freight travel times as drivers of TFP.

Relevant Modules for EMPLOY-RES II

The following two sections briefly describe the modules/models relevant for the economic analysis applying ASTRA-EC in EMPLOY-RES II.

Economy

The macro-economic module (MAC) provides the national macro-economic framework and is made up of six major elements. The first is the sector interchange model that reflects the interactions between 25 economic sectors of the 29 national economies. Demand-supply interactions are considered by the second and third element. The second element, the demand side model, depicts the four major components of final demand: consumption, investments, exports-imports and government consumption.

The supply-side model reflects the influence of three production factors: capital stock, labour and natural resources as well as the influence of technological progress that is modelled as total factor productivity. Endogenised Total Factor Productivity (TFP) depends on sectoral investments, freight transport times and sectoral labour productivity changes weighted by sectoral value added. Investments are involved in a major positive loop since they increase the capital stock and total factor productivity (TFP) of an economy which leads to a growing potential output and GDP that in turn drive income and consumption which feeds back into an increase of investments again. However, this loop may also be influenced by other interfering loops that could disrupt the growth tendency:

1. In ASTRA-EC, the existence of the ‘crowding out’ effect is accepted so that increasing government debt could have a negative impact on investment.
2. Exports, e.g. influenced by RES policy, energy and transport cost, could also change, which in turn would affect investments.
3. Different growth rates between the supply side (potential output) of an economy and the demand side (final demand) change the utilisation of capacity. If demand grows slower than supply, utilisation would be reduced which would also have an effect on investment decisions. Ultimately, investments could decrease.
4. Substantial changes of energy prices could cause inflation, thus reducing real disposable income.

The employment model constitutes the fourth element of MAC based on value-added as the output from the input-output table calculations and labour productivity. The fifth element of MAC describes government behaviour. As far as possible government revenues and expenditures are differentiated into categories that can be modelled endogenously by ASTRA-EC and one category covering other revenues or other expenditures. Categories that are endogenised include VAT and fuel tax revenues, direct taxes, import taxes, social contributions and revenues of transport charges on the revenue side as well as unemployment payments, transfers to retired persons and children, transport investments, interest payments on government debt and government consumption on the expenditure side. This element also includes the linkages with bottom-up models, e.g. the changes of the energy system modelled by Green X in EMPLOY-RES II.

Trade

The Foreign Trade Module (FOT) is divided into two parts: trade among the 29 European countries (INTRA-EU model) and trade between the 29 European countries and the rest-of-the world (RoW) that is divided into nine regions (EU-RoW model with Oceania, China, East Asia, India, Japan, Latin America, North America, Turkey, Rest-of-the-World). Both models are differentiated into bilateral relationships by country pair and sector.

The INTRA-EU trade model depends on three endogenous and one exogenous factor. World GDP growth exerts an exogenous influence on trade. Endogenous influences are provided by: GDP growth of the importing country of each country pair relation, the relative change of sector labour productivity between countries and the averaged generalised cost of passenger and freight transport between countries. The latter is chosen to represent an accessibility indicator for transport between countries. In EMPLOY-RES II, the RES trade of selected technologies (e.g. wind turbines) stimulated by the policies is fed in exogenously into the trade model as the trade patterns of these RES technologies differ significantly from the modelled sectoral trade, e.g. of the machinery sector, while for other technologies (e.g. boilers for biomass), the trade patterns are derived directly from the ASTRA-EC model.

The EU-RoW trade model is mainly driven by the relative productivity between the European countries and the rest-of-the-world regions. Productivity changes together with GDP growth of the importing RoW-country and world GDP growth drive the export-import relationships between the countries. RES exports stimulated by ambitious RES policies in Europe and estimated by the lead market model in EMPLOY-RES II are added exogenously to the ASTRA-EC trade model.

The resulting sectoral export-import flows of the two trade models are fed back into the macro-economic module as part of final demand and national final use, respectively.

Treatment of RES-Deployment

For the EMPLOY-RES II project, the micro-macro-bridges from the bottom-up energy system model to the economy have to be established. This is achieved by linking ASTRA-EC with the Green X and MultiReg models. These linkages and their further take-up in the economic models of ASTRA-EC are presented in Figure V-20.

Broadly speaking, the impacts from the energy system and thus from RES policies can be divided into those on (1) consumer demand, (2) the production of goods and services, and (3) the trade balance of the 29 economies. Consumer demand is directly affected by the higher energy prices via the budget effect (more money spent on energy and thus less money for other sectors) and the substitution effect (prices of goods and services change differently as a reaction to higher energy prices and, depending on energy content and elasticities, the sectoral consumer demand will be restructured, i.e. if energy prices increase, more energy-intensive goods and services will be substituted by less energy-intensive ones).

The production of goods and services reacts in two ways: first, the adaptation of the energy system estimated by Green X leads to additional investments in RES energy technologies and to avoided investments in conventional energy technologies. Second, changes of energy prices affect the exchange of intermediate goods in the input-output-table. The latter impact is then felt on the value-added of each sector, employment and finally the GDP from the supply side, while the direct impacts on the consumer side and to some extent also the additional demand for investment goods also affect the GDP on the demand side.

Thirdly, the direct impacts on the trade balance have to be considered. These are twofold: First, reductions of energy imports in the energy sector have a positive impact on the demand side of GDP, as well as increase the value-added of the energy sector. Second, trade of RES technologies within the EU and from the EU to the rest of the world alter the national trade balances.

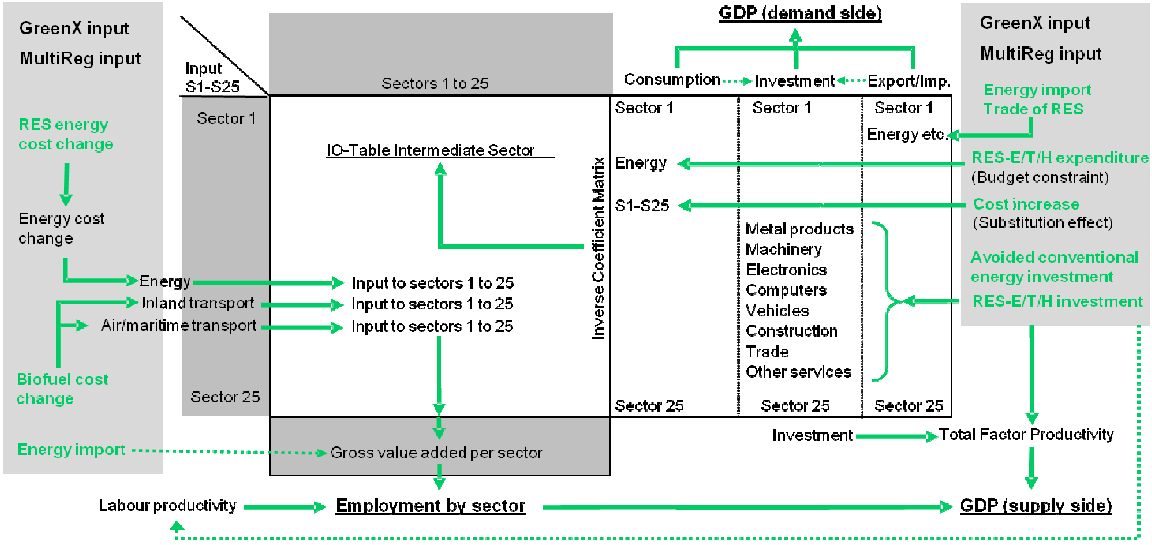

Figure V-20: Inputs to ASTRA-EC from the bottom-up analysis of RES policies from the Green X and MultiReg models

Source: Fraunhofer ISI

Figure V-20 illustrates the bottom-up inputs of the energy sector from the Green X and MultiReg models that provide the micro-macro bridges from the energy sector to the macro economy.

The economic outcome of the RES policies in the different countries depends on the countries' specific characteristics with respect to renewable technologies and their specific economic characteristics which are reflected in the ASTRA-EC model or the bottom-up inputs into ASTRA-EC. Among the important characteristics are:

- The existence of a domestic industry producing renewable technology.
- The potential to produce biomass.
- The competitiveness to export renewable technology.
- The existing energy system and cost of energy in a country.
- The elasticity of consumers and industry in responding to energy price changes.
- The level of (un-)employment which affects the reaction of the labour market.
- The productivity effect of investments in renewables compared with the productivity effect of other investments.
- The inter-industry structure, in particular the input-output relations of the energy sector and the major sectors producing renewable technologies, i.e. machinery, electronics, construction, computers and metal products.
- The trade relationships among EU countries, i.e. growth in one EU country can lead to growth in other countries via imports.