SEURECO

EmployRES

The impact of renewable energy policy on economic growth and employment in the European Union

Final report

Contract no.: TREN/D1/474/2006

Mario Ragwitz, Wolfgang Schade, Barbara Breitschopf, Rainer Walz, Nicki Helfrich
Fraunhofer ISI, Germany

Max Rathmann
Ecofys, the Netherlands

Gustav Resch, Christian Panzer, Thomas Faber, Reinhard Haas
Energy Economics Group (EEG), Austria

Carsten Nathani, Matthias Holzhey
Rütter + Partner Socioeconomic Research + Consulting, Switzerland

Inga Konstantinaviciute
Lithuanian Energy Institute (LEI), Lithuania

Paul Zagamé, Arnaud Fougeyrollas, Boris Le Hir
Société Européenne d’Économie (SEURECO), France

Karlsruhe, 27 April 2009

This report presents the approach and findings of the project EmployRES - Employment and growth impacts of sustainable energies in the European Union. The EmployRES project was supported by the European Commission, DG Energy and Transport, under contract TREN/D1/474/2006.

Partners in the EmployRES project are Fraunhofer ISI (Germany), Ecofys (the Netherlands), Energy Economics Group (EEG) (Austria), Rütter + Partner Socioeconomic Research + Consulting (Switzerland), Lithuanian Energy Institute (Lithuania), and Société Européenne d'Économie (SEURECO) (France).

The project consortium would like to thank the project officer Andrea Hercsuth for her support.

European Commission
DG Energy and Transport
Library (DM28, 0/36)
B-1049 Brussels
Fax: (32-2) 296.04.16
http://europa.eu.int/comm/dgs/energy_transport/forum/index_en.htm

Table of Contents

Figures

Tables

A Background, motivation and objectives of the study

Background

The Commission Communication ‘An energy policy for Europe’[1] clearly states the points of departure for a European energy policy as: ‘combating climate change, limiting the EU's external vulnerability to imported hydrocarbons, and promoting growth and jobs’.

The promotional effect of the increased diffusion of renewables on the first two objectives is largely undisputed. It has been clearly shown that renewables make an indispensable contribution to greenhouse gas reductions and to the increased security of supply in Europe.

There is, however, still uncertainty about the exact contribution of renewables to the third cornerstone: promoting growth and jobs in terms of the objectives of the Lisbon Strategy. As stated in the RES roadmap:[2]

> ‘Studies vary in their estimates of the GDP impact of increasing the use of renewables, some suggesting a small increase (of the order of 0.5%), and others a small decrease’.

While most policy makers believe that increased use of RES and job creation can go hand in hand, others assume that the distribution effects and the budget effects turn a large gross employment effect into a small or even a negative net employment effect.

The Renewable Energy Directive for 2020 was recently adopted by the European Parliament and the European Council. This Directive sets ambitious targets for each Member State with the aim of achieving a 20% share of renewable energy in Europe's final energy consumption by 2020. In order to reach this target, it is important to gain further understanding and awareness of the economic and employment benefits of renewables. The purpose of this study is to support an objective discussion on the effects of the enhanced deployment of renewable energies on growth and employment by contributing to a sound scientific basis.

Therefore this study aims to meet the need for scientifically robust information on the gross effects (direct and indirect) as well as on the net effects (including both conventional replacement and budget effects) of renewable energy policies in Europe. Furthermore, the

---

[1] Communication from the Commission to the European Council and the European Parliament - An energy policy for Europe {SEC(2007) 12} /* COM/2007/0001 final

[2] Communication from the Commission to the European Council and the European Parliament - Renewable Energy Road Map Renewable energies in the 21st century: building a more sustainable future, COM (2006) 848 final, Brussels, 10.1.2007.

future development of RES in Europe will take place against the background of a global market for RES technology. This global market and the potential share of European industries in it will play a critical role in the potentials for growth and employment.

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

Objectives and results

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

- To present an analysis of 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 be very transparent and to use a modelling system with a sound scientific basis in order to promote confidence in the quality of analysis.
- To facilitate an open and transparent review process with all the relevant stakeholders. This process allows all the stakeholders involved to share their views, incorporates these views in the analysis and thus facilitates a high level of acceptance of the results.
- 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 include:

- An analysis of the direct and indirect gross economic and employment impacts resulting from past and present RES developments for each of the 27 EU member countries and each of the RES technologies.
- A business-as-usual scenario, an improved policy scenario and a No policy scenario of the future deployment of renewables in the EU-27 up to 2030, and various sensitivity analyses of scenario assumptions and boundary conditions.
- An in-depth analysis of the future gross and net economic and employment impacts in the EU-27 up to 2030 resulting from the three scenarios described above based on a validated and transparent macroeconomic modelling approach.
- A stakeholder consultation and a peer review aimed at validation of the methodology, assumptions and results of the work ensured in two workshops.

B Project concept, modelling tools and structure of the report

The project involves intensive data analysis and economic modelling. The overall framework - in particular the links between various models - is described in this section. The inputs and results for each individual modelling step are presented in chapters 1 to 7.

The key rationale for the modelling approach is that it has to be tailored to the task in hand. In the past, there have been many studies of the economic effects of economy-wide measures, especially CO_2 taxation. In contrast to these studies, the effects of RES technologies are much more technology-specific. To achieve such a technology-specific analysis, the modelling approach must be based on a sound technological analysis and therefore follows a bottom-up approach: The cost and structural demand effects must be accounted for on a disaggregated level. Further, the additional export potential due to the technological competitiveness of EU countries must be accounted for rather than the economy-wide price changes. These requirements have important implications for the model choice: Economic models such as general equilibrium models, which are good at analysing changing relative prices on a macroeconomic level, are not suitable here. Instead, macroeconomic models are preferred as these can be easily linked to technological bottom-up models, and are able to model the changes in costs and demand.

Overview of the modelling system

The main idea is to combine diverse models to reflect the impacts on technologies and the economy as a whole. Therefore, a static input-output model that calculates the current value added of RES activities as well as employment effects is combined with a sector model that provides future investments and expenditures for RES according to selected RES policies. In the next step, the data are adjusted with respect to first mover advantages and then form the input to the macro models which calculate the economic effects. This sequence of models is roughly depicted in Figure 1. The detailed approach, the interfaces between models and the modelling steps are explained in the following sub-chapter.

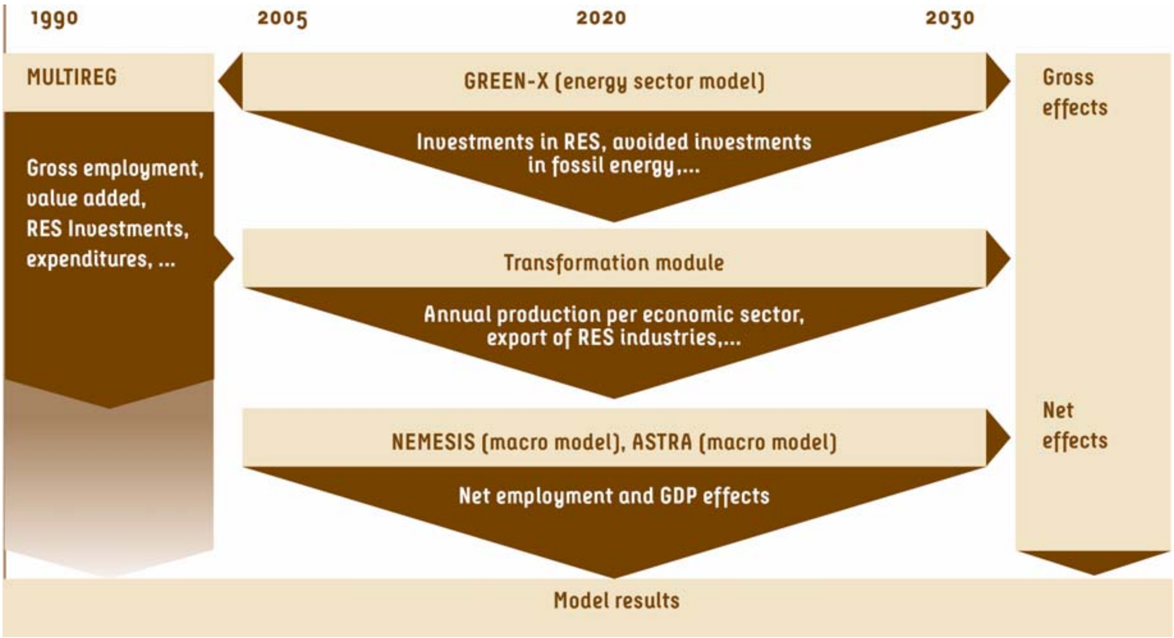


Figure 1: Modelling approach

The phases and interfaces in the project concept

To fully understand the method as well as the different models and their interdependence in this study, the project is illustrated in Figure 2 in detail. This should help guide readers through this report. The figure distinguishes between the models (green rectangles) and data sources (grey parallelogram) used for the project. It also shows 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 models used as input for another model.

The project is divided into four phases corresponding to the four dotted boxes in the figure below and the following four chapters in this report. The four phases/chapters are titled according to the main results produced in each stage. The different steps in producing these results are briefly described below and the numbers in the corresponding dotted box help to follow these steps. Details of the four phases are given in the following paragraphs.

Phase 1: Past deployment and cost of RES

RES deployment (i.e. capacity and production) and cost data are extracted from the GREEN-X database that already comprehensively illustrates the historical deployment and the present situation of the individual RES technologies by country.

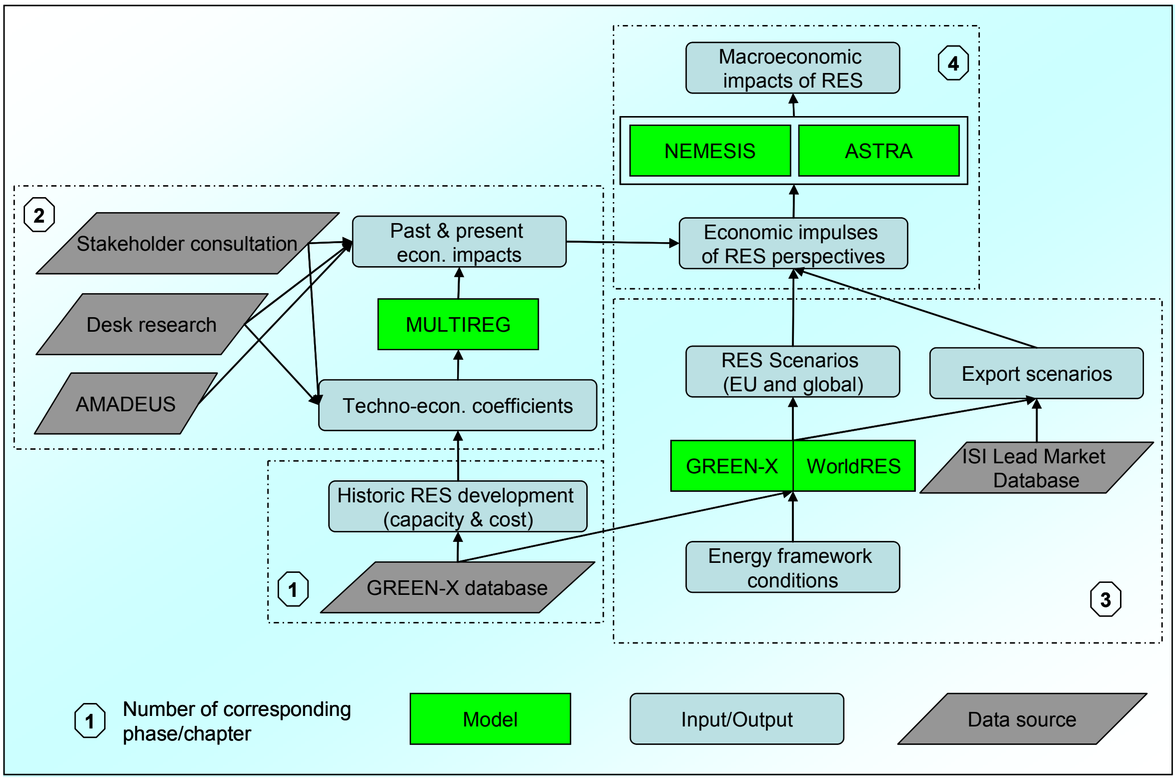


Figure 2: The overall modelling approach of the project

Phase 2: Past economic and employment impacts of RES deployment

In Phase 2, the gross economic and employment impacts of past and present RES deployment are calculated. They highlight the economic significance of the RES industry including the supplying industries. Two approaches can be distinguished, a modelling approach using the MULTIREG model, and a direct data collection approach based on the AMADEUS database and a stakeholder consultation.

Techno-economic coefficients are needed as input for the MULTIREG model that transform the historical development of expenditures for a certain RES technology 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 (Phase 1) are complemented by the following data obtained through desk research, expert interviews and a stakeholder consultation:

- cost structures of investment in the various RES technologies, their operation and maintenance and fuel supply,
- information on the regional supply patterns of cost components, especially the market shares of technology suppliers.

With the necessary adjustments, these data also serve to transform the impulses of RES deployment into data input for the macroeconomic models ASTRA and NEMESIS.

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.

MULTIREG is harmonised with the macroeconomic models NEMESIS and ASTRA to ensure methodological comparability between the results of the historical and the future gross effects.

The inputs and outputs of the MULTIREG model are complemented by results from the direct data exploration approach. The main idea behind this approach is to gather empirically based figures on the extent of employment and economic activity in RES-related sectors. This approach consists of two parts:

- Within the stakeholder consultation renewable energy branch organisations were asked to provide available empirical data on employment and economic impacts of RES.
- An exploration of the AMADEUS database[3] to extract data on companies engaged in RES–activities in order to obtain the size and structures of companies in RES.

Phase 3: Future renewable energy deployment and export scenarios

Scenarios on 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. Important data input for GREEN-X are, besides the applied support schemes for RES, the general energy framework conditions such as future energy demand and energy prices. Assumptions on the general energy framework conditions are harmonised with Commission views of future energy development based on official DG TREN projections. Based on these general assumptions, three main scenarios will be calculated for the future development of renew-

---

[3] MARKUS database for Germany

able energy sources until 2030 in the EU-27. The results of this modelling step serve as a main input for phase 4 of this project.

To estimate the future export opportunities of European RES industries to the rest of the world, a reliable scenario for the global deployment of renewable energy sources has to be used. In this project, the alternative scenario of the World Energy Outlook of the IEA is used and comprehensively prepared for the purposes of this study. The share of this global market which will be actually supplied by European companies is estimated in a subsequent step: Various studies on the economic effects of new technologies and innovations have demonstrated the importance of accounting for the induced foreign demand for the technologies. In the economic literature, this effect is known as the first mover advantage or lead market effect, and is behind the rationale of the Lisbon goals and European efforts to increase technological competitiveness. In order to come up with sound and reliable assumptions about the magnitude of such a first mover advantage, the technological competitiveness of the EU countries with regard to RES policies, and the supporting role of regulation in setting incentives for future innovations are considered (Walz 2006)[4]. The project draws on the extensive database at Fraunhofer ISI on "Indicators of Sustainability Innovations for Lead Markets" (ISI/LM), which covers indicators for 50 countries. It includes innovation indicators such as patent statistics or the revealed comparative advantage (RCA) for RES technologies. These data are combined with the evaluation of the innovation effects of RES support mechanisms in order to derive a methodologically sound estimation of future additional exports of RES technologies from the EU.

Phase 4: Future macroeconomic impacts of RES

The first part of phase 4 is critical for obtaining consistent input data for the macroeconomic models.

All the relevant economic mechanisms (as described in chapter B) must be accounted for in order to produce reliable results. This point is crucial, because many modelling approaches in the past only covered some of the economic mechanisms and therefore arrived at biased results. The following aspects are crucial for reliable results:

- The outputs of the Green-X model in terms of RES deployment and accompanying costs serve as input for the further macroeconomic analysis. These data are transformed to specify the additional cost and price effects for the economy, which have to be accounted for in the macroeconomic modelling.

---

[4] R. Walz, Impacts of strategies to increase RES in Europe on employment and competitiveness, Energy and Environment, 17, 6 (2006).

- The output of the Green-X model with regard to energy input and output is used to specify the induced changes in demand associated with the operation of RES technologies. A crucial factor is that these demand changes are specified with regard to import shares. Thus, the results are demand vectors for nationally produced goods and imported goods.
- The output of the Green-X model in terms of RES investments and avoided investments in conventional energy supply serves as input for the specification of the demand impulse. The use of specific techno-economic coefficients (see phase 2) allows a sectoral disaggregation of these demand effects. Furthermore, the specific direct employment effects from phase 2 are used as the basis for a forecast of the specific direct employment effects of operating RES-technologies in the scenarios.

In the second part of phase 4, the full macroeconomic modelling of the future economic and employment impacts of RES is done using two well-established macroeconomic modelling tools NEMESIS and ASTRA. Both models are real-world models which account for a broad spectrum of economic impulses of energy policy measures. A crucial point is that both models are able to integrate the impulses from additional exports. Thus, they have enough similarities to be used in one modelling approach and both of them are based on the same data input from GREEN-X.

Using two 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 advantages in modelling:

- Detailed cross-checking of results at different stages of the modelling exercise.
- Making use of a particular strength of 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 that exist in one model with results from the other model.
- Benefiting 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 Fraunhofer ISI from previous EU projects on the other hand.

The structure of the report

This report is divided into four main parts, A, B, C and D. While the first three covers the introduction, the theoretical approach, the modelling steps and structure of the report, the fourth part, part D, discusses in detail the models and results of the projects. It begins with chapter D 1 which describes past RES deployment and its costs. Then follows the past macroeconomic impacts presented by gross effects on employment and value added (D 2). Thereafter, the future potential (D 3) and future deployment (D 4) of renewable energy sources (RES) are discussed. Before the presentation of the future gross and net effects, the five scenarios used in the macro-economic models (D 5) are explained in detail. Finally we depict the future gross and net impacts on employment and GDP in D 6 and D 7, respectively. The comparison between the results of the two models and our conclusion for the study follows in chapter D 8 and 9.

C Theoretical approach: The impact of the promotion of renewable energy on employment and economic growth – economic mechanisms and first mover advantage

In order to provide a theoretical basis for the study, this chapter seeks to discuss and answer two central but rather complex questions in a simple way:

- Through which economic mechanisms do RES support schemes trigger various impacts on GDP and employment?
- What effects can be expected in countries which are the first movers or lead markets in RES?

The first question can draw on the discussion of the economic mechanisms triggered by climate policy measures (Walz/Schleich 2008), but has to account for some specifics of the RES technologies and support schemes. In general, RES support schemes set off diverse adjustment reactions among individual companies and private households which are then felt as structural effects on a sectoral and regional level. The sum of these adjustment reactions and their subsequent impacts then result in changed macroeconomic variables at the macroeconomic level. The various economic mechanisms describe which adjustment reactions and consequential effects are induced by climate policies. However, they are strongly influenced by the respective theoretical paradigm used. In line with the various schools of thought, we briefly describe these mechanisms in the following:

- Price and cost effects: impact of prices (energy costs) on industry and households.
- Structural demand effects: impact of demand on industry, household, trade.
- Multiplier and accelerator effects: impact of household and industry behaviour on other economic sectors.
- Innovation/productivity effects: impact of innovation or productivity on industry and households.

The second question refers to the discussion of lead markets: When do they emerge and what are the preconditions for their appearance? Lead markets are defined as regional markets with specific attributes that increase the probability that a locally preferred design becomes internationally successful, too (Beise and Cleff 2004). Export orientation, technological competitiveness, regulation and market context factors such as demand, prices, market structures etc. play an important role here. Hence, it is not price competition only, but quality competition that determines foreign trade successes. Especially trade with technology-intensive goods requires high innovation capability, learning effects and an early market presence. The factors that need to be taken into account when assessing the potential to become a lead market will be discussed in the last part of this chapter.

Figure 3 illustrates the economic mechanisms and questions considered in this study in a simplified way. It shows the impact of RES supporting policies on households and firms as well as the first mover advantage caused by the direct or indirect promotion of RES technologies via policy measures. Households, firms and trade react to price, quality and quantity changes. When this reaction is amplified by multiplier, accelerator and innovation effects, this in turn leads to an overall effect on demand and prices in the economic subsectors investment, operation and maintenance and consumption across all economic sectors. The sum of all the positive economic effects is termed the gross effect. Adding up the negative and positive effects gives us the economic net effect. The various effects are discussed in detail in the subsequent paragraph.

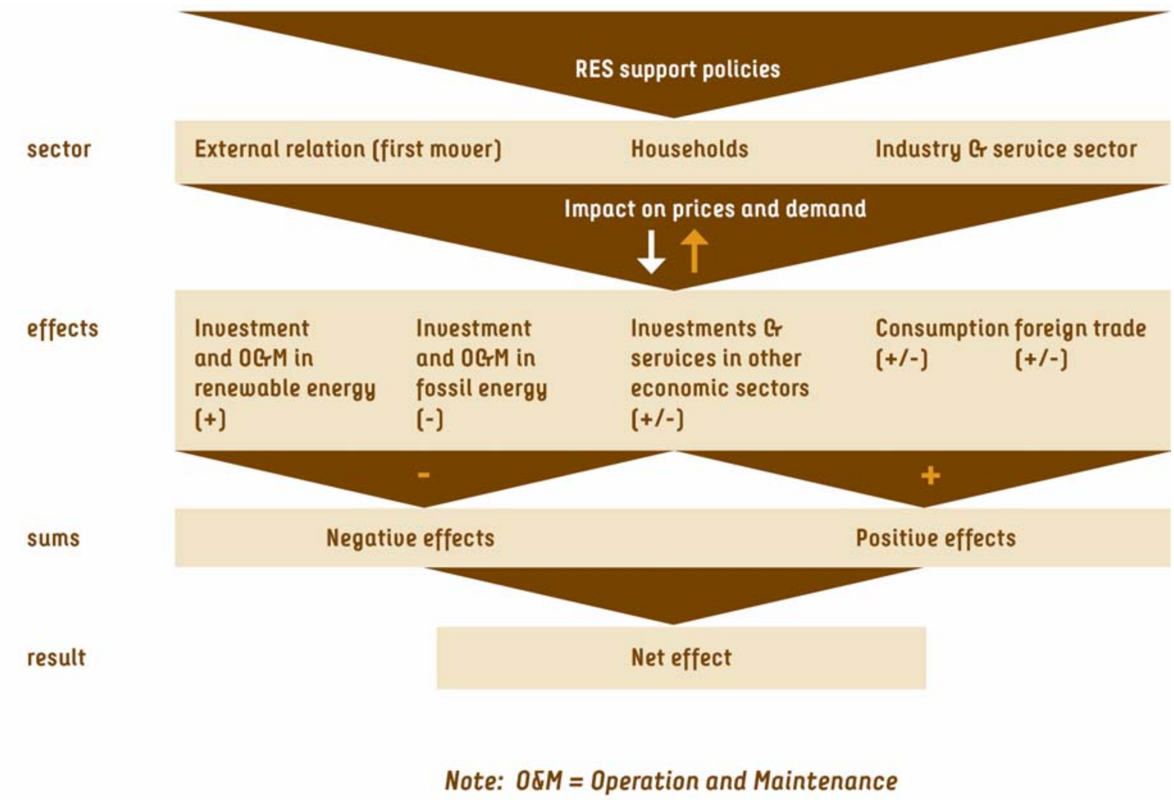


Figure 3: Simple illustration of the various economic mechanisms

Economic effects and adjustment mechanisms

The structural demand effect is depicted in Figure 4 as an example for the adjustment mechanisms and impulses. It shows the impulses deriving from the promotion of RES and illustrates where shifts in demand have various effects in the manufacturing and service sectors and at the household level (impulses via prices). Revenue and employment effects in this figure refer to a change in turnover or employment in the industry sector caused by structural demand effects in industrial and household sectors. Direct impulses occur in those industries which are directly involved in RES or fossil energy activities, while indirect impulses occur in industries which are only linked to RES and fossil energy activities through other industries. It is not really possible to illustrate the structural demand effect in isolation since the impulses sparked by prices, demand and innovation are interdependent and occur simultaneously.

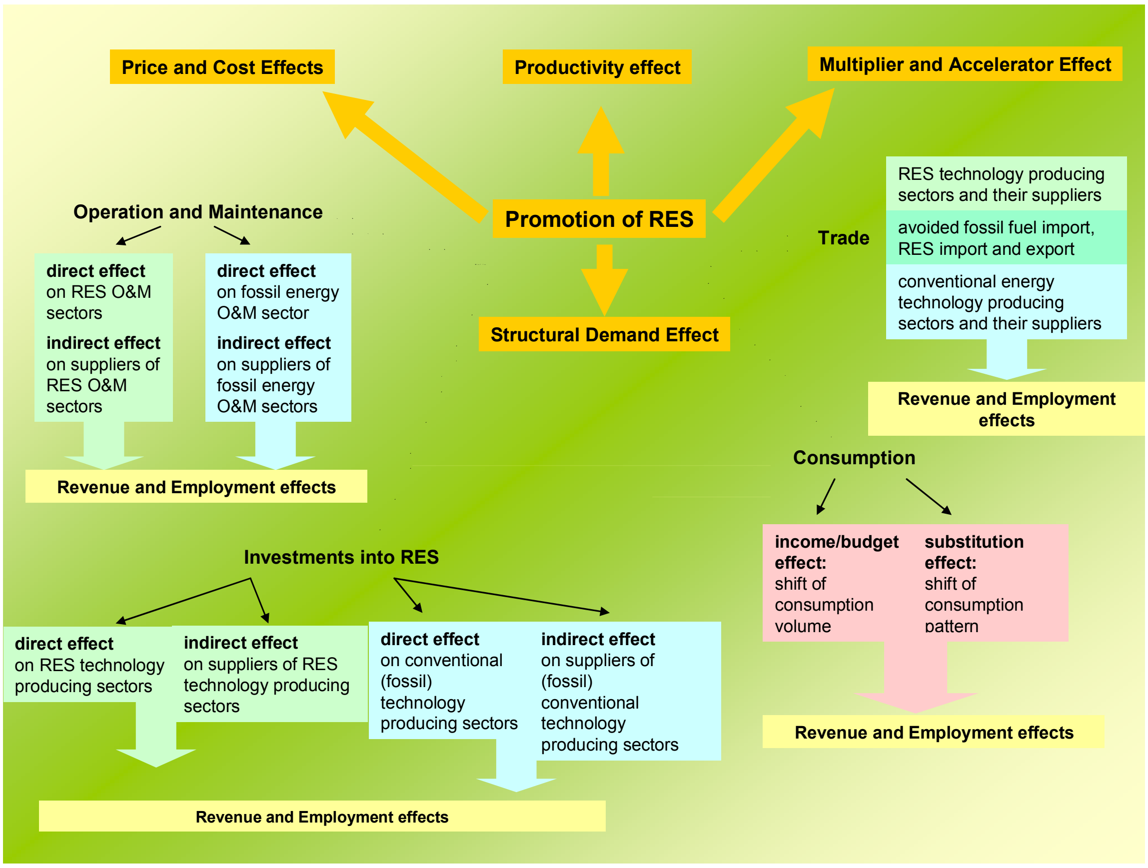


Figure 4: Economic effects and adjustment mechanisms

Table 1: 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.
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.
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
Income/budget effect	With the same income (nominal) less/more goods can be consumed due to a (energy) price change
Revenue effect	Changes in demand for RES or other investment or consumption goods affect revenues in (all) economic sectors
Employment effect	Changes in demand for RES or other investment or consumption goods affect employment in (all) economic sectors
Gross employment	The sum of positive, direct and indirect employment effects derived from investments in RES without taking negative employment effects in other sectors into account.
Net employment	The sum of positive and negative direct and indirect employment effects, taking negative employment effects in other sectors into account.

Price and cost effects

Price and/or cost effects are often mentioned as an important mechanism in how RES policies influence the economy. The primary cost factors in the general economic discussion are the costs of labour (wages) and capital. With regard to RES, another cost factor is the higher cost of supplying RES compared to conventional forms of energy. This cost increase triggers various supply-side effects. It leads to a reduction of the output due to higher costs and furthermore, to substitutions in favour of other production factors. This in turn might result in a lower demand for the production factor labour. If the market mechanism on the labour market leads to lower real wages, a new equilibrium with full employment is reached. If this is not the case, unemployment will result. Furthermore, an increase in costs entails disadvantages in international competition, leading to further pressure to lower real wages.

It is also relevant who has to bear these macroeconomic effects. If the increased cost burden falls on energy-intensive industries that are subject to strong international competition, the effects might be greater because the negative effect is aggravated by the loss of international competitiveness. If, on the other hand, the cost burden cuts into the monopolistic profits of utilities (because they are either unsuccessfully regulated or not subject to competition), the detrimental effects will be weaker.

If the cost burden falls on private households, i.e. if they have to pay higher prices for energy, they will modify their consumption pattern if possible to reduce their consumption level and by substituting other goods for energy. Depending on the price sensitivity of households' demand for consumption goods (elasticity), this impact might be stronger or weaker.

If the cost burden is to be borne by the public budget, the government will have to reduce other expenditures (public budget effect), or alternatively, the government will raise tax revenues in other areas and thus reduce the available budget of consumers or producers (leading to private budget effects). This leads to a crowding out of other investments or consumer spending. To sum up, compensatory effects occur within the structural adjustment mechanism and, in the case of higher costs (see section above), negative consumption effects have to be accounted for when analysing structural shifts of demand.

Thus, the macroeconomic effects depend on the support scheme and on the adjustment mechanisms in the economy which in turn depend on the relative supply and demand elasticities of the different economic agents.

In many studies of the economic effects of climate policies, the double dividend of CO_2 taxes has played a major role. However, this actually depends on the effects occurring because such a tax can replace other taxes which are associated with a higher excess burden. There has been an intensive debate about the double dividend effect centring on the magnitude of the so-called tax interaction and revenue recycling effect. However, RES support schemes in general are not associated with such a green tax reform. Thus, this specific effect does not play a role in this study.

Structural demand effects

In addition to changes in costs or prices, an increase in RES also leads to structural changes in the economy. Both positive and negative effects are to be found among the direct impulses of a RES policy. Implementing a RES policy requires additional investments to increase RES capacities and, in the case of biomass and biofuels, an increased demand for forest and agricultural products (direct positive impulses). At the same time, there is a drop in demand for both conventional energy carriers and conventional energy supply investments (direct negative impulses). In general, however, the costs for RES (which consist mainly of capital costs) are assumed to be higher than the capital and running costs for the conventional energy supply. Typically, a substantial share of the higher cost is transferred to the consumers. Thus, they have less income to spend on other consumption goods (private budget effect).

Since numerous inputs from other sectors are necessary to supply the respective demand, the direct positive and negative impulses are carried forward as positive and negative *indirect effects* according to the production linkages of the industries involved. Thus the different positive and negative impulses lead to a different structural composition of the overall economy.

The direct and indirect demand impulses are very much linked to technological changes and the RES support schemes. Therefore, they are described in more detail, distinguishing impulses in the area of investment, operation and maintenance, consumption of households, and trade.

In the study, the direct positive and negative impulses will be delivered by the analysis with the Green-X models. The macroeconomic models used will then be able to further account for the indirect effects of structural adjustments.

Structural investment impulses

Primarily, the promotion of RES affects all activities which are related to instalments of the RES generation facility. These include planning and financing, construction and manufacturing sectors. An increase in investments in RES power generation increases the demand in RES-related services and RES-technology producing sectors. Hence, an increased demand leads to an augmentation of the production in these sectors. We call these impulses on the RES-producing technology or service sectors direct positive investment impulses, since they are directly related to RES power generation and occur directly in the sector addressed by the policy. However, there are also policy impacts in sectors not directly, i.e. indirectly, related to RES power generation. The sectors that are indirectly affected by the policy are the suppliers of RES-technology producers or service providers like the steel producing sector, transportation sector, IT-service providers, etc. The increased production at suppliers of RES-technology producers induces higher revenues and employment in these indirectly affected sectors.

Besides the suppliers of the RES technology producing sector, we also have to take into account the effect of RES promotion on the fossil energy generation sector. Conventional investments in this sector will decrease since the generation of fossil energy will be replaced by RES. Hence, revenues and employment will decrease at conventional (fossil) energy technology producers and service providers as well as at the suppliers of technology producers. We consider this a direct negative investment impulse. Furthermore, this will also induce indirect negative investment impulses. In summary, we can state that sector revenues and employment and hence income will:

- increase among RES-technology producers and service providers (direct positive impulse)
- increase among suppliers of RES-technology producers and service providers (indirect positive impulse)
- decrease among fossil energy technology producers, service providers (direct negative impulse) and
- decrease among suppliers of fossil energy technology producers (indirect negative impulse).

Structural operation and maintenance impulses

After the instalment of the generation plant, the investment activities are completed and the radiated effects from investment will fade. But a certain number of employees are necessary for operation and maintenance of the RES generation facility. This results in higher revenues in this realm and subsequently in higher incomes. Hence, RES-related maintenance and operation activities reflect a direct positive impulse. Furthermore, there are indirect effects as well. The RES maintenance and operation sector causes demand for products and services in forward- and backward-linked sectors which in turn increases production and employment in these sectors. These we call indirect positive RES maintenance and operation impulses. Analogous to investment effects, there are negative direct and indirect impulses because the maintenance and operation sector of energy generation from fossil sources as well as in its forward-linked sectors will gradually be reduced. Overall, it is clear that sector revenues and employment and hence income will:

- increase among providers of RES maintenance and operation (direct positive impulse)
- increase among forward/backward-linked sectors of RES maintenance and operation providers (indirect positive impulse)
- decrease among maintenance and operation providers of fossil energy generation facilities (direct negative impulse)
- decrease among forward/backward-linked sectors of fossil energy facility maintenance and operation providers (indirect negative impulse).

Structural consumption impulses at the household level

Further, we consider the sector which benefits from the additionally generated revenues in the various economic sectors and which has to bear the higher energy prices: the household sector. The use of RES causes additional costs which are passed onto the households through higher prices for energy. Higher prices for RES reduce the real income of households. So, for the same (nominal) income, fewer goods can be consumed, real income has declined. We call this effect of prices changes a budget impulse, since it affects the available household budget for consumption. Therefore, a relatively larger part of household income will be spent on RES and is not available for other goods. So households have fewer funds for the consumption of other goods and use relatively more for RES consumption. Thus, the budget impulse triggers a substitution effect where money for consumption will be allocated (shifted) from other goods to the consumption of renewable energy as its price increases. All in all, through the budget impulse, the demand for other goods will decrease. Recapitulating, higher prices for RES reduces the consumption of households, their available (real) income declines (budget effect) and consumption is shifted from other goods to RE. However, if the additional investment, maintenance and operation for RES induce more employment, the households will have more money available for consumption (total income of household increases). This might compensate the negative price effect and increase consumption.

The argument so far has demonstrated the importance of the positive and negative demand impulses. It has been shown that it is the effect on the supply chain which influences the demand effects. These include the effects due to interlinkages between the production sectors.

Structural trade impulses

Trade of energy from fossil sources will decrease as generation from RES increases. Since fossil energy is mainly imported, imports will be avoided. Besides that, imports or exports of technology products and related intermediate inputs may increase (see chapter C). For energy-importing countries or regions, it is significant that a considerable share of the negative demand effects - namely the reduction in demand for imported energy - takes effect not domestically, but in the energy-producing countries. If a higher share of the RES investments or RES-typical inputs is produced domestically, a net increase in domestic production results. If, in contrast, a considerable share of the energy substituted by RES is produced domestically, and a considerable share of the RES investments has to be imported, then the result is a reduction in aggregated domestic demand. A comparison of the labour intensities[5] and the import shares[6] of the value chains of RES products provides a first impression of the probable structural effects on growth and employment. Briefly summarized, there are similar effects as for investments and M&O:

- increase in trade of RES (direct impulse)
- increase in exports of RES technology (direct positive impulse, first mover advantage) or increase in imports of RES technology (direct negative impact)

---

[5] shows how many persons are employed per Euro of total domestic production induced by the direct impulse

[6] shows which percentage of total production induced by the direct impulse is imported.

- increase in trade of backward/forward-linked products (indirect impulse)
- decrease of trade in fossil energy, fossil energy technology, and backward/forward-linked products (direct and indirect impulses).

Figure 5 gives a first impression of the order of magnitude of import shares of the value chain for impulses from different sectors and three EU countries. The mineral oil product chain has by far the highest share, while the total accumulated import of the value chain of electricity production is rather low. This reflects, among others, the important role of very capital-intensive nuclear power in France and Germany and the importance of German coal in electricity production. The import shares of the average consumption value chain are also quite low. The value chains of the sectors most likely to benefit from RES strategies, e.g. investments in equipment or the agricultural and forestry sector, tend to have import shares which are in-between the value chains of the sectors they will substitute (electricity and fuels). Given these results, a substitution of conventional electricity production and oil products by renewable energy has no clear effect with regard to import substitution and depends on the specifics of the RES strategy which influences the composition of technologies. Furthermore, this effect has to be accounted for in all of the EU member states.

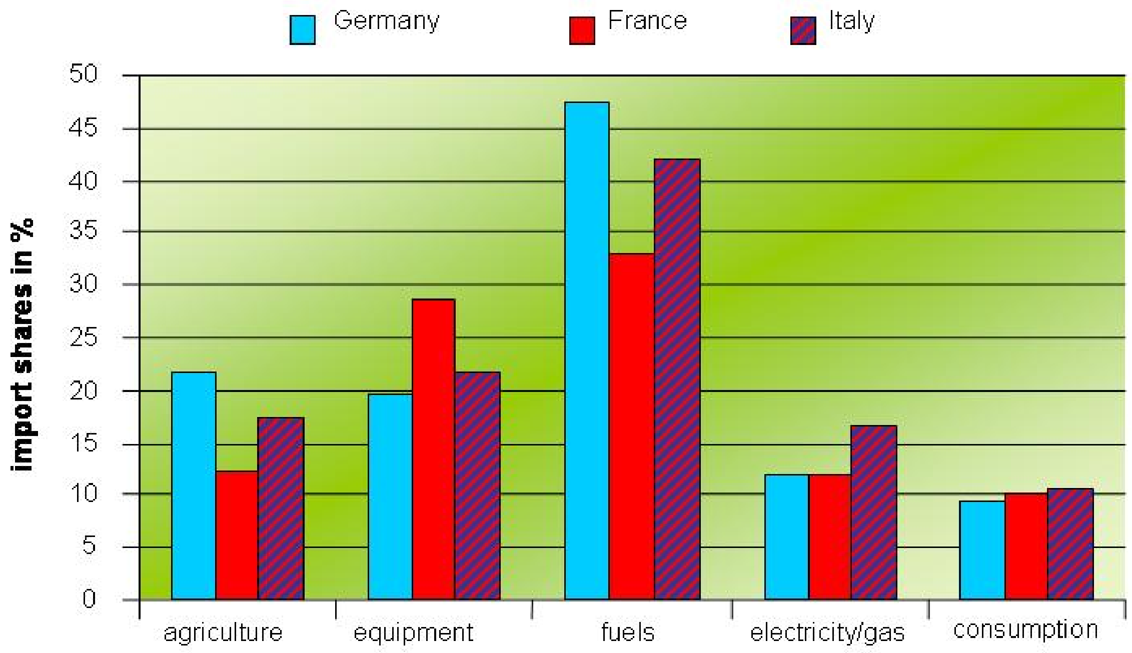


Figure 5: Import shares of the complete value chain of various goods

In addition to all the discussed structural demand effects, the labour intensity of the respective sectors plays a crucial role when assessing the potential impact on employment. An increase in employment occurs if the value chains of the sectors favoured by the RES policy have higher labour intensities than the value chains of the sectors favoured by the conventional energy supply. Typically, high labour intensities can be observed in the agricultural and forestry sectors (see Figure 6). These result in an above average labour intensity of the associated value chains. The value chain of fuels production has low labour intensity, followed by the value chain of conventional electricity production. The labour intensity of the investment sectors as well as of the agricultural sector is higher than the labour intensity of fuels and electricity production. Thus, it can be assumed that the substitution of the conventional energy supply by RES generally leads to an increase in labour intensity. However, if the additional cost of the renewable energy is very high, the value chain of consumption goods becomes increasingly important, because an ever larger share of consumption has to be sacrificed to cover the additional costs. The labour intensity of the value chain of consumption is greater than that for equipment. Thus, the higher the cost difference of renewable energies to conventional energy supply, the less prominent is the effect of structural change towards labour-intensive sectors because the reduction in consumption has a counterproductive impact on total employment.

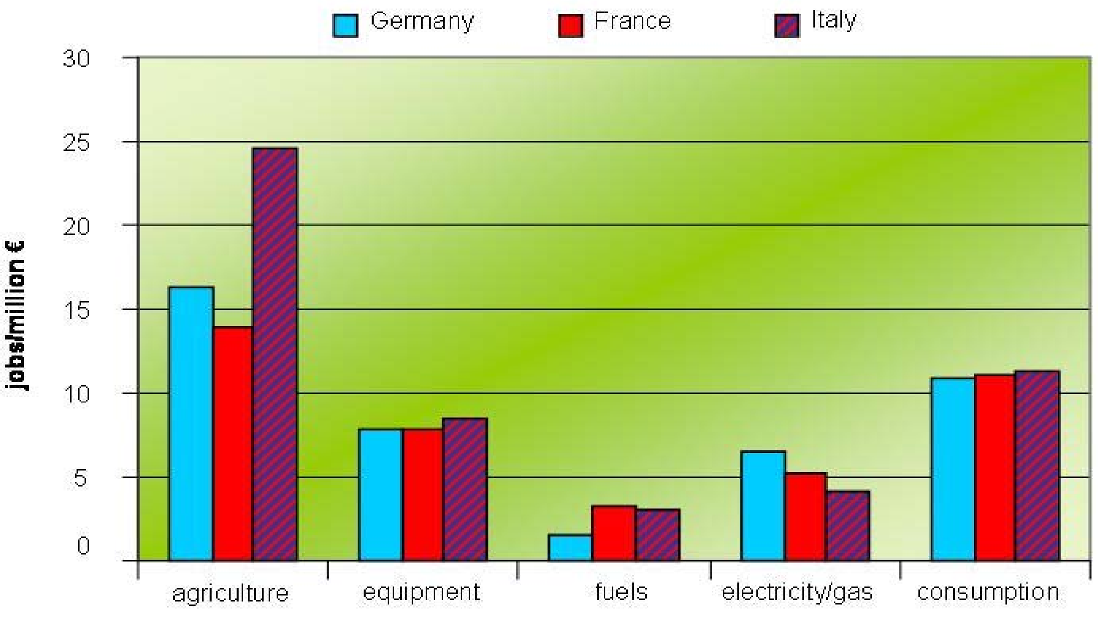


Figure 6: Labour intensity of the complete value chain of various goods

Income multipliers and accelerator effects

Demand-side effects are the cornerstone of the Keynesian model, which sees unemployment as caused by a deficit in aggregate demand. Assuming that the conditions for Keynesian unemployment are met, positive growth and employment effects are to be expected if RES policies result in an impulse which increases the effective demand for goods. Two effects have to be considered here:

- Income multiplier effects account for the spending of income generated by the production of the impulse.
- Accelerator effects account for the additional investments needed to provide the production capacity required for the additional goods.

The combination of these two effects can lead to a self-supporting increase in business activities triggered by such an impulse.

Especially the effects of shifts in income are interesting to look at. Households benefit from increased activities in RES but also suffer from decreased activities in fossil energy sources. An income reduction induces consumption cutbacks and, subsequently, the households' demand for all consumption goods declines, leading to a decrease in production in industry which in turn reduces revenues in the affected sectors. An increase in income has the opposite effect: Higher income induces a higher demand for consumption goods which translates into higher production and hence leads to higher revenues in the respective sectors resulting in high employment and hence income for households. This inducement of higher revenues in all sectors through increased investment activities in one sector is called a multiplier effect. An initial rise in spending can lead to an even greater increase in (national) income.

The accelerator effect refers to a similar mechanism but at the industry level. There, higher demand and hence rising revenues cause demand for investments in backward-linked industries. This increased demand in backward-linked industries in turn leads to higher production and revenues resulting in rising needs to invest, which leads to a growing demand of this industry for its own backward-linked industries and so on.

Income multiplier and accelerator effects depend on the economic conditions and the assumed reactions of the actors at the centre of the debate on Keynesian economics. An important assumption is that the demand from RES policies does not crowd out other segments of aggregate demand. Thus, some limitations have to be taken into account when considering this argument. The effect of Keynesian demand policy in the overlapping area of rational expectations and the internationalisation of goods and financial markets is substantially more complex than the mechanistic description above may suggest. Thus, the chances of success of a Keynesian demand policy have to be assessed within the context of empirically validated models.

In this study, empirically validated macroeconomic models are used which are capable of accounting for these effects based on the data input from the bottom-up analysis.

Productive effects of investments

Technical change in many cases is linked to previous investments. New systems incorporate technical change and bring about a modernisation of the capital stock. The production possibilities of a national economy increase over time due to the growth and renewal of the capital stock. It has to be asked which impacts the *diffusion of RES technologies* has on this process. Here it is decisive whether the RES technologies themselves show a productive effect in the sense of increasing the material goods output potential. Under the assumption of a constant total investment volume, the following two cases are conceivable:

- In the first case, it is assumed that RES technologies do not show any productive impact. Since the RES investments do not have any productive impacts themselves, under the assumption of a constant investment volume, the productive investments of companies are then crowded out. Thus, the increase in productivity is lower compared to the development in which all investments are used for productive technologies. To sum up, in case 1, the macroeconomic productivity increase would be diminished by such a "technological crowding out".
- In the second case, it is assumed that RES technologies also have a productive character. They thus simultaneously increase - in contrast to the first argument - the production possibilities of material goods. The crowding out of investments with productive effects derived under the ceteris paribus condition of a constant investment volume is then alleviated, or, in an extreme case, does not occur at all if climate protection investments result in the same increase in productivity as new productive investments.

The assumption of a constant investment volume can be abandoned if it is assumed that there is an increase in the investment volume, financed either by shifting demand from consumption to investments, or by an increased GDP. Under this assumption, this would be tantamount to a "technological crowding in" and an increased modernisation of the national economy would follow in its wake.

The effects of technical change induced by the RES support schemes depend very strongly on which of the two hypotheses with regard to the productive impact of climate protection technologies is given greater weight. The hypothesis of a non-productive effect of investments in environmental protection is probably valid for end-of-pipe solutions, which are added on to the production systems and tended to dominate environmental protection in the 1970s and 80s. On the other hand, it seems plausible that those investments which directly affect production, and which have become more important recently, have greater productivity-increasing effects than end-of-pipe systems. First empirical results indicate that climate protection investments do indeed have a productive effect as well (Walz 1999). However, it is also clear that the magnitude of this effect depends on the technology, and that, in general, a substantial increase in productivity is induced only by some of the climate protection investments.

First mover advantages

Besides price competitiveness, which is influenced by cost effects, foreign trade successes are also determined by quality competitiveness. Above all for technology-intensive goods, which include renewable energy technologies, high market shares depend on innovation ability and the achieved learning effects of a national economy and its early market presence. If there is a forced national strategy to increase the share of renewable energy, these countries tend to specialise early in the supply of the necessary technologies. If there is a subsequent expansion in the international demand for these technologies, these countries are then in a good position to dominate international competition due to their early specialisation in this field.

Being able to realise these kinds of first mover advantages requires other countries to follow suit. Given the growing demand for energy on the one hand, and the pressure to push for non-fossil fuels on the other, there is a high probability of this taking place. For first mover advantages to be realised, however, the domestic suppliers of climate protection goods have to be competitive internationally so that they and not foreign suppliers are able to meet the demand induced by the domestic pioneering role and so that they can actually profit from the demand in countries then following suit [29, 28]. Taking the globalisation of markets into account, this requires establishing competence clusters which 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. The following factors have to be taken into account when assessing the potential of countries to become a lead market in a specific technology:

- Lead market capability: It is not possible for every good or technology to establish a lead market position. One prerequisite is that competition is driven not by cost differentials alone, but also by quality aspects. This is especially valid for knowledge-intensive goods. In general, the technology intensity of renewable technologies can be judged as being above average or even (e.g. photovoltaics) high tech. Other important factors are intensive user-producer relationships and a high level of implicit knowledge. These factors are not easily accessible, difficult to transfer to other countries and benefit from local clustering. Two other important characteristics are high innovation dynamics and high potential learning effects. They are the key to a country forging ahead technologically also being able to realize solutions which are cost competitive. Previous results demonstrate that, by and large, these two prerequisites are fulfilled for renewable energy technologies.

- Competitiveness of industry clusters: Learning effects are more easily realized if the flow of (tacit) knowledge is facilitated by proximity and a common knowledge of language and institutions. Empirical results found strong evidence that the international competitiveness of sectors and technologies is greatly influenced by the competitiveness of interlinked sectors. By and large, renewable technologies have very close links to electronics and machinery. Thus, it can be argued that countries with strong production clusters in these two fields have a particularly good starting point for developing a first mover advantage in renewable energy technologies.
- The importance of the demand side can be traced back in the literature to the 1960s. There are various market factors which influence the chances of a country developing a lead market position (Beise/Cleff 2004). In general, a demand which is oriented towards innovations and readily supports new technological solutions benefits a country in developing a lead market position. Another factor is a market structure which facilitates competition. The price advantage of countries is very important which benefits those countries able to increase their demand fastest and thus most able to realize economies of scale and learning. If one looks at the diffusion rate of the various forms of renewable energy in different countries, it can be seen that European countries have been forging ahead recently. Furthermore, the political goals of the EU will bolster this advantage in future. Nevertheless, there are also other countries which have recently increased their diffusion rates. If large markets, such as the U.S., China, India or Brazil, increase their use of renewables, this will cause a huge rise in absolute numbers which might strengthen their price advantage.
- In addition to technological and market conditions, a lead market situation must also be supported by innovation-friendly regulation. This is especially true for sustainability innovations in infrastructure fields such as energy, water or transportation. In these fields, the innovation friendliness of the general regulatory regime, e.g. with regard to IPR or the supply of venture capital, must be accompanied by innovation-friendly sectoral and environmental regulation resulting in a triple regulatory challenge. Accounting for this factor is not easy. One promising approach is a heterodox one which uses the sectoral systems of innovation approach as guiding heuristics and combines this with the outcome of regulatory and environmental economics and the policy analysis approach of political science (Walz et al. 2008). The first empirical case studies for renewable energies show that a feed-in-tariff system might serve the functions of an innovation system well, especially if it supports a variety of technological solutions. Other paradigms contribute to this approach, e.g. transaction and evolutionary economics, which emphasise that the decisions, e.g. with regard to financing renewable energy technologies, follow a different paradigm (e.g. other valuation of financial risks, bounded rationality with regard to alternative suppliers of electricity). Furthermore, the policy analysis approach of political scientists emphasises the long-term character of political goals for renewable energy within the EU, or the comparatively important role of green policies for voters, which are key supportive context factors favouring innovations.

Since the Leontief Paradox and subsequent theories such as the Technology Gap Theory or the Product Cycle Theory, it has become increasingly accepted that international trade performance depends on technological capabilities. This has also been supported by recent empirical research which underlines the importance of technological capabilities for trade patterns and success. Thus, the ability of a country to develop a first mover advantage also depends on its comparative technological capability. If one country has performed better in the past with regard to international trade than others, it has obtained key advantages on which it can build future success. Thus, trade indicators such as shares of world trade, the Relative Export Shares (RXA) or the Revealed Comparative Advantage (RCA) are widely used to compare the technological capability of countries. Furthermore, a country has an additional advantage in developing future technologies if it has a comparatively high knowledge base. Thus, patent indicators such as the share of patents or the Relative Patent Advantage (RPA) are among the most widely used indicators to measure technological advantages.

D Detailed approach and results

1 Past deployment and cost of RES

The core objective of this working task is to provide a detailed depiction of RES development in the period 1990 to 2006, considering generation, installed capacities and costs of RES technologies in the European Union.

1.1 Approach, assumptions and input

Data and facts expressing the progress achieved in the different Member States include the amount of energy produced (electricity production, heat production, transport fuels) by RES as well as the installed capacity in the different sectors. The data on RES penetration, which are used in this project, strongly build on databases developed in earlier projects such as Green-X, TRIAS, FORRES 2020, OPTRES and PROGRESS. Therefore, the additional effort concentrated on the update of existing data as well as the adaptation of data to the specific needs of this project. This comprises in particular the data on installed capacities and past investment and operation costs of RES plants. The data have been derived on the level of the EU-27 and 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)

1.2 Result: Past deployment and cost of RES

This chapter 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 and Biofuels in the figures and tables are provided up to 2006 as this is the most recent year for which data for all countries and technologies were available at time of writing of this document. RES-H data are provided up to 2005. Generally, the figures will be given in terms of generation. Additionally the development of generation capacity is shown exemplarily for the case of wind onshore and biomass electricity. This section only serves to give the overall picture of the development of RES at European level. In the frame of this project all data are supplied on the Member State level for each of the technologies listed above.

Renewable electricity

Renewable energy sources play an increasingly important role in European energy supply. Electricity generation from renewable sources (RES-E) grew by ca. 30% from 371 TWh in 1997 to 477 TWh in 2006 in the EU-27. An overview of the historical development of electricity generation from renewable energy sources from 1990 to 2006 is presented in Figure 7. 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 years due in part to below average rainfall in some years, but also to continuous increases in deployment of other 'new' renewable energy sources such as wind and biomass. In 2006, hydropower represented only 64% of RES-E generation in the EU-27.

The contribution of RES-E to gross electricity consumption in the EU-27 in 2006 was 13.7%, only slightly higher than the figure of 12.8% in 1997 despite the positive developments in the RES-E sector, which can be explained by two reasons. First of all, the contribution of hydropower in 2006 was lower than in 1997 due to below average rainfall, which strongly affects the overall RES-E generation figure. Assuming normal climatic conditions, the contribution of RES-E as a share of electricity consumption in 2006 was 14.6%. Secondly, overall electricity consumption in the EU has grown by more than 15% since 1997, largely offsetting the newly realised deployment of renewable energy since then. If electricity consumption would have remained at 1997 levels, the actual contribution of RES-E in 2006 would have been 17%. Taking normal climatic conditions into account as well, the RES-E share in 2006 would have been 18.1% assuming 1997 levels for gross electricity consumption.

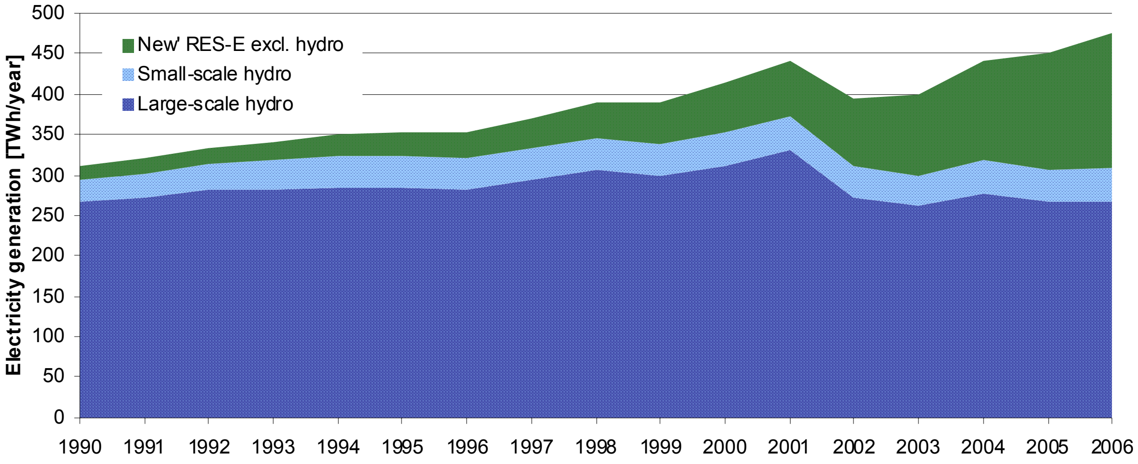


Figure 7: Historical development of electricity generation from RES-E in the European Union (EU-27) from 1990 to 2006

In order to avoid the influence of variable rain conditions on the picture, Figure 8 presents the development of electricity generation over the time period from all renewable sources except hydropower. A strong growth of several renewable energy sources over the last decade can be observed.

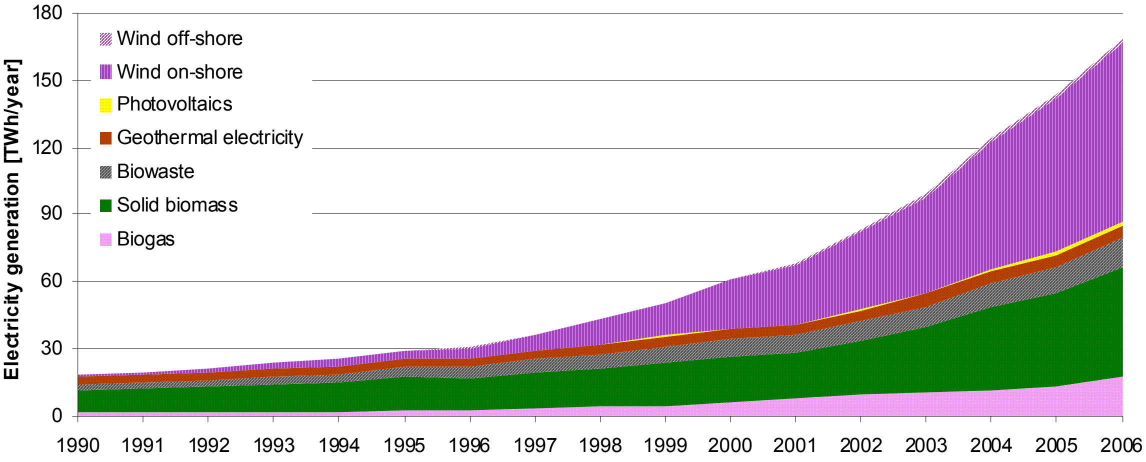


Figure 8: Historical development of electricity generation from RES-E without hydro power in the European Union (EU-27) from 1990 to 2006

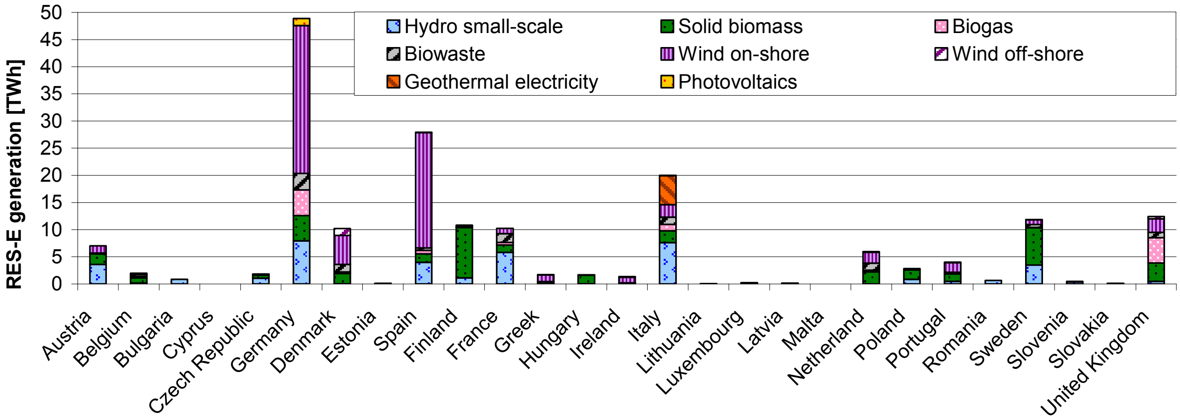


Figure 9: Breakdown of electricity generation from 'new' RES-E for 2006 by country

Electricity production from onshore wind equalled 79 TWh in 2006 compared to 7 TWh in 1997, which implies a spectacular average annual growth rate of 30% 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 coming years. In 2007, wind continued its impressive growth with additional new capacity of over 8,500 MW in the EU, resulting in an overall capacity of about 56,500 MW by the end of 2007. Also electricity generation from biogas has grown strongly, by 19% per year on average from 1997 to 2006. The highest average annual growth rate in this period has been realised by solar photovoltaics (PV), which grew on average by an impressive 56% over this nine year period, from 0.04 TWh in 1997 to 2.2 TWh in 2006. An overview of the development of each RES-E technology from 1997 to 2006 is provided in Table 2.

The average annual growth rate of RES-E excluding hydropower in the period 1997 to 2006 is 19%.

Table 2: Electricity generation from renewable energy sources in the EU-27 in 1997 and 2006

	1997 [GWh]	2006 [GWh]	Average annual growth 1997-2006 [%]	2006 normalised [GWh]
Biogas	3.49	17.30	19%	17.30
Solid Biomass	16.25	49.14	13%	49.14
Biowaste	5.48	12.92	10%	12.92
Geothermal electricity	3.96	5.69	4%	5.69
Hydro large-scale	294.96	266.72	-1%	297.09[7]
Hydro small-scale	39.00	41.35	1%	43.00
Photovoltaics	0.04	2.23	56%	2.23
Solar thermal electricity	0.00	0.00	-	0.00
Tide & Wave	0.57	0.52	-1%	0.52
Wind on-shore	7.26	79.48	30%	92.05
Wind off-shore	0.07	1.84	44%	2.53
Total RES-E	**371.07**	**477.19**	**3%**	**182.39**
Total RES-E excl. hydro	**37.11**	**169.12**	19%	**182.39**

Besides data on renewable energy generation, capacity data are of key relevance for studying the macroeconomic consequences of the 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 10 depicts the specific development of onshore wind power capacity in the EU-27 countries.

---

[7] Normalised figures for large scale and small scale hydropower refer to installed capacities of the year 2005.

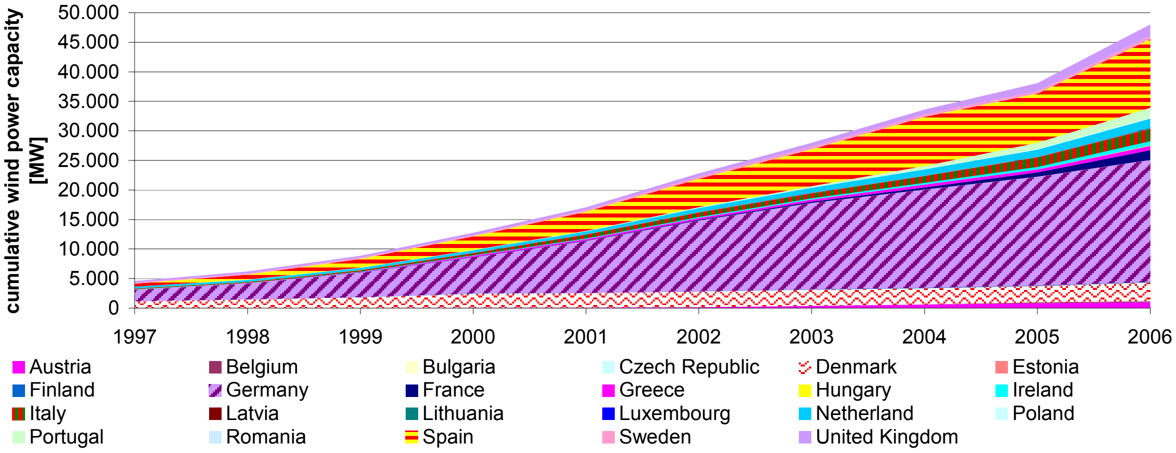


Figure 10: Historical development of cumulative installed wind capacity in EU-27 countries, (Source: EWEA, IEA Renewables Information 2006)

Biomass has the second largest percentage of renewable electricity generation in the EU-27. The biggest shares hold Sweden and Finland, whereby recently RES-E generation from biomass increased in Denmark, Italy and the United Kingdom, see Figure 11. Further increase of cumulative biomass capacity is expected due to large potentials in the new EU Member States.

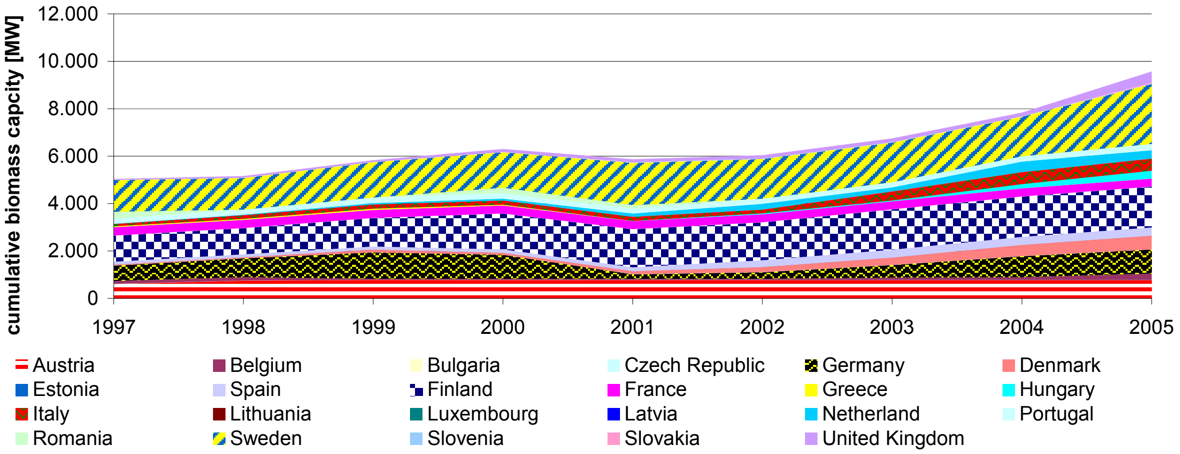


Figure 11: Historical development of cumulative installed biomass capacity in EU-27 countries (Source: Eurostat)

Renewable heat

Table 3 shows the generation of heat from renewable energy sources (RES-H) in the EU-27 in 1997 and 2005.

Table 3: Heat generation from renewable energy sources in the EU-27 in 1997 and 2005

	1997 [Mtoe]	2005 [Mtoe]	Average annual growth 1997-2005 [%]
Biomass heat	47.81	55.81	2%
Solar thermal heat	0.32	0.68	10%
Geothermal heat incl. heat pumps	0.72	1.58	10%
Total RES-H	48.86	58.07	2%

Overall progress made in the EU in heat generation from biomass is very modest: since 1997 heat output from biomass has grown by only 17% to 56 Mtoe in 2005, corresponding to an average annual growth rate in the period 1997-2005 of only 2% for the EU-27. Only three countries showed an average annual growth rate of biomass heat higher than 10%, i.e. Bulgaria (15%), Czech Republic (18%) and Slovak Republic (71%).

Solar thermal heat generation doubled from 0.3 Mtoe in 1997 to 0.7 Mtoe in 2005. In general, solar thermal heat has developed modestly, the overall EU growth rate in the period 1997-2005 being 10% per year. Only a few Member States have realised (slightly) higher average annual growth rates in this period, i.e. Germany (18%), UK (22%), Netherlands (18%), Italy (14%) and Spain (13%).

Geothermal heat generation was 1.6 Mtoe in 2005, including heat generation by heat pumps. The annual growth of geothermal heat generation corresponds to 12% on average in the period from 1997 to 2005. Average annual growth rates of around 30% or more have been realised by Sweden (+100%), Austria (48%) and Finland (28%).

Overall one can conclude that developments in the heat sector have been modest up to now and are clearly lagging behind growth rates realised in the electricity sector and – more recently – in the biofuels sector. It should be noted that the RES-E Directive has been in place since 2001 and the majority of Member States have formulated a clear framework for support of RES-E since then.

Biofuels

The Biofuels Directive of 2003 has meant an important stimulus to the creation of support frameworks for the production and consumption of biofuels in Member States, while RES-H has up to now been lacking a clear integrated support framework both at the European and national level.

An overview of the production of liquid biofuels in the EU-27 in 1997 and 2006 is provided in Table 4.

Table 4: Consumption of liquid biofuels in EU-27 in 1997 and 2006

	1997 [Mtoe]	2006 [Mtoe]	Average annual growth 1997-2006 [%]
Biofuels	0.41	5.38	33%

Biodiesel is dominating the European biofuel sector, with 72% of produced biofuels in 2006 being biodiesel and only 16% bioethanol. Accordingly, in most Member States biodiesel is the dominant biofuel production, except for Spain, Sweden, Finland, Hungary and the Netherlands where bioethanol is leading.

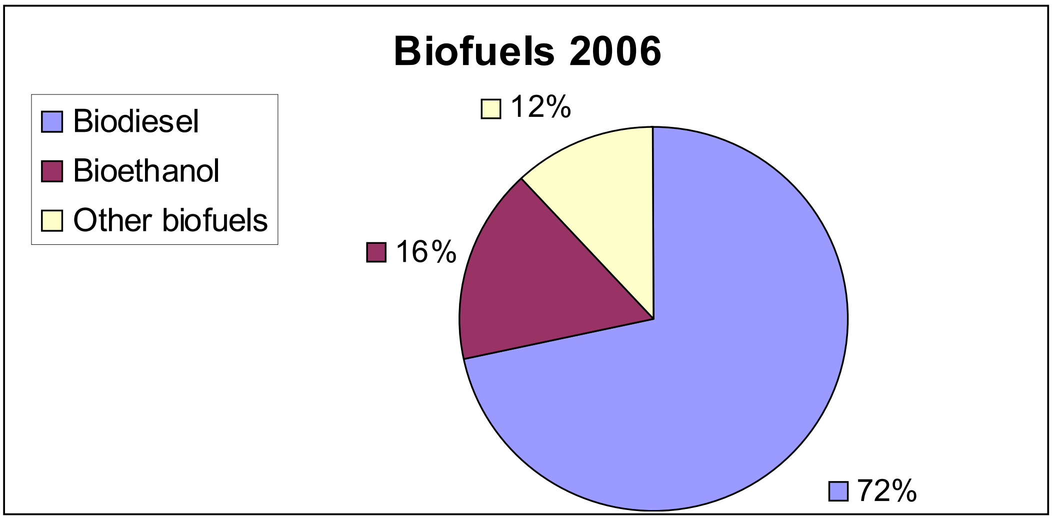


Figure 12: Breakdown of different types of biofuels in total EU-27 consumption in 2006

From 1997 onwards, biofuel production has grown with an annual growth rate of 33% on average. Adoption of the Biofuels Directive in 2003 has led to a strong enhancement in the formulation of biofuel support policies, resulting in new market opportunities. Especially since 2005 biofuel production has been taking off: EU biofuel production grew by

63% in 2005 and 2006, both biodiesel and bioethanol contributing to this expansion. However, there is still a long way to go as the contribution of biofuels to transport fuels in the EU-25 was only 1.1% in 2005 and 1.8% in 2006, which means the interim target of 2% by 2005 as formulated in the Biofuels Directive has not been met, although 2006 figures came close to the share targeted for 2005.

1.3 Assessment of economic parameters and costs for RES-E, RES-H and RES-T

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 2007 and encompass the electricity sector and the grid-connected heat sector. The assessment provides important parameters for the Green-X model and is, hence, consistent to the model's framework and settings.

Economic data for RES-E

Table 10 gives an overview on the economic parameters and accompanying technical specifications on technological level by RES-E sub-category, referring to *new plants* installed in the year 2007. In case of (large- and small-scale) hydropower and wind onshore non-harmonised cost settings are applied, i.e. a country-specific[8] differentiation of investment- and where suitable also O&M-costs is undertaken, whilst for all other RES options harmonised cost settings are applied. In the latter case expressed ranges of the economic and technical parameter result from different plant sizes (small- to large-scale) and / or applied conversion technologies. Please note that all data – i.e. investment-, O&M-costs and efficiencies - refer to the default start year of the simulations in the Green-X model, i.e. 2007, and are expressed in €$_{2005}$.

---

[8] Especially in case of hydropower the range of investment costs differs largely between and within the countries. These capital costs are site-specific, depending on the plant-size and geographic conditions as well as on additional (country-specific) efforts (acceptance barrier, planning process, etc.). The applied country-specific settings are based on (Lorenzoni 2001).

Table 5: Overview on economic-& technical-specifications for new RES-E plant

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	2550 - 4290	115 - 140	0.28 - 0.34	-	25	0.1 - 0.5
	Agricultural biogas plant - CHP	2760 - 4500	120 - 145	0.27 - 0.33	0.55 - 0.59	25	0.1 - 0.5
	Landfill gas plant	1280 - 1840	50 - 80	0.32 - 0.36	-	25	0.75 - 8
	Landfill gas plant - CHP	1430 - 1990	55 - 85	0.31 - 0.35	0.5 - 0.54	25	0.75 - 8
	Sewage gas plant	2300 - 3400	115 - 165	0.28 - 0.32	-	25	0.1 - 0.6
	Sewage gas plant - CHP	2400 - 3550	125 - 175	0.26 - 0.3	0.54 - 0.58	25	0.1 - 0.6
Biomass	Biomass plant	2225 - 2530	75 - 135	0.26 - 0.3	-	30	1 - 25
	Cofiring	550	60	0.37	-	30	-
	Biomass plant - CHP	2600 - 4230	80 - 165	0.22 - 0.27	0.63 - 0.66	30	1 - 25
	Cofiring - CHP	220 - 550	85 - 115	0.2	0.6	30	-
Biowaste	Waste incineration plant	4300 - 5820	90 - 165	0.18 - 0.22	-	30	2 - 50
	Waste incineration plant - CHP	4600 - 6130	100 - 185	0.14 - 0.16	0.64 - 0.66	30	2 - 50
Geotherm. Ele.	Geothermal power plant	2000 - 3500	100 - 170	0.11 - 0.14	-	30	5 - 50
Hydro large-scale	Large-scale unit	850 - 3650	35	-	-	50	250
	Medium-scale unit	1125 - 4875	35	-	-	50	75
	Small-scale unit	1450 - 5950	35	-	-	50	20
	Upgrading	800 - 3600	35	-	-	50	-
Hydro small-scale	Large-scale unit	800 - 1600	40	-	-	50	9.5
	Medium-scale unit	1275 - 5025	40	-	-	50	2
	Small-scale unit	1550 - 6050	40	-	-	50	0.25
	Upgrading	900 - 3700	40	-	-	50	-
Photovoltaics	PV plant	5080 - 5930	38 - 47	-	-	25	0.005 - 0.05
Solar thermal electricity	Large-scale solar thermal plant	2880 - 4465	163 - 228	0.33 - 0.38	-	30	2 - 50
Tidal energy	Tidal (stream) power plant - shoreline	2670	44	-	-	25	0.5
	Tidal (stream) power plant - nearshore	2850	49	-	-	25	1
	Tidal (stream) power plant - offshore	3025	53	-	-	25	2
Wave energy	wave power plant - shoreline	2135	44	-	-	25	0.5
	wave power plant - nearshore	2315	49	-	-	25	1
	wave power plant - offshore	2850	53	-	-	25	2
Wind onshore	Wind power plant	1115 - 1295	33 - 36	-	-	25	2
Wind offshore	wind power plant - nearshore	1590	55	-	-	25	5
	wind power plant - offshore: 5…30km	1770	60	-	-	25	5
	wind power plant - offshore: 30…50km	1930	64	-	-	25	5
	wind power plant - offshore: 50km…	2070	68	-	-	25	5

Default ranges for fuel costs with respect to the various fractions of biomass are depicted in Table 6. These country-specific prices are mainly based on (EUBIONET 2003-2005). For biowaste as default a negative price of -4€/MWh was used, representing a revenue for the power producer, i.e. a 'gate fee' for the waste treatment. Again, these prices refer to the year 2007. Their future development is internalised in the overall model – linked to fossil fuel prices as well as the available additional potentials.

Table 6: Fuel price ranges for various fractions of solid biomass in EU countries excluding import

Solid biomass - Fuel cost			Fuel cost ranges (2005)
	Minimum	Maximum	Weighted average
(expressed in € per MWh primary energy)	[€/MWh-p]	[€/MWh-p]	[€/MWh-p]
AP1 - rape & sunflower	32.3	40.4	37.2
AP2 - maize, wheat (corn)	26.6	33.2	30.6
AP3 - maize, wheat (whole plant)	29.8	29.8	0.0
AP4 - SRC willow..	27.4	32.9	29.2
AP5 - miscanthus	27.1	34.1	30.0
AP6 - switch grass	17.9	31.9	25.9
AP7 - sweet sorghum	31.0	40.9	40.9
Agricultural procucts - TOTAL	**17.9**	**40.9**	**31.9**
AR1 - straw	12.2	14.7	13.4
AR2 - other agricultural residues	12.2	14.7	13.5
Agricultural residues - TOTAL	**12.2**	**14.7**	**13.4**
FP1 - forestry products (current use (wood chips, log wood))	17.8	22.3	20.6
FP2 - forestry products (complementary fellings (moderate))	19.1	23.8	21.7
FP3 - forestry products (complementary fellings (expensive))	25.8	32.3	29.4
Forestry products - TOTAL	**17.8**	**32.3**	**23.0**
FR1 - black liquor	5.6	7.7	6.0
FR2 - forestry residues (current use)	6.3	8.6	7.0
FR3 - forestry residues (additional)	12.5	17.1	13.9
FR4 - demolition wood, industrial residues	5.0	6.8	5.9
FR5 - additional wood processing residues (sawmill, bark)	6.3	8.6	6.9
Forestry residues - TOTAL	**5.0**	**17.1**	**6.9**
BW1 - biodegradable fraction of municipal waste	-3.8	-3.8	-3.8
Biowaste - TOTAL	**-3.8**	**-3.8**	**-3.8**
FR6 - forestry imports from abroad	16.0	16.8	16.8
Solid biomass - TOTAL	**-3.8**	**40.9**	**16.4**
… of which domestic biomass	**-3.8**	**40.9**	**16.4**

In order to give a better illustration of the current[9] economic conditions of the various RES-E options, electricity generation costs[10] are depicted in the following figures. Their calculation in Green-X is based on the economic and technical specifications as depicted in Table 5, extended by missing parameters such as full load hours and fuel prices (in case of biomass), representing the broad range of resource-specific conditions among the EU-15 countries.

For the calculation of the electricity generation costs, the **Green-X** tool differentiates between *long-run marginal generation costs* that are used for the simulation of investment decisions and *short-run marginal generation costs* which are the running costs that depict the operation decisions. These costs for the RES-E category are presented in Figure 13 and Figure 14. Thereby, for the calculation of the capital recovery factor two different settings are applied:[11] On the one hand, a default setting, i.e. a repayment time of 15 years, is used for all RES-E options – Figure 13 (left), and on the other hand, the repayment time is set equal to the technology-specific life time (right). The broad range of costs for several RES-E represents, on the one hand, resource-specific conditions as are relevant e.g. in the case of photovoltaics or wind energy, which appear between and also within countries. On the other hand, costs also depend on the technological options available – compare, e.g. co-firing and small-scale CHP plants for biomass (small scale CHP is contained in the cost band "solid biomass" shown below).

---

[9] As usual, costs refer to the starting year for model simulations, i.e. 2005 and, hence, are expressed in $€_{2005}$.

[10] Note that in the model ***Green-X*** the calculation of generation costs for the various generation options is done by a rather complex mechanism as described further in this report, respectively, 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.

[11] For both cases a default weighted average cost of capital (WACC) in size of 6.5% is used.

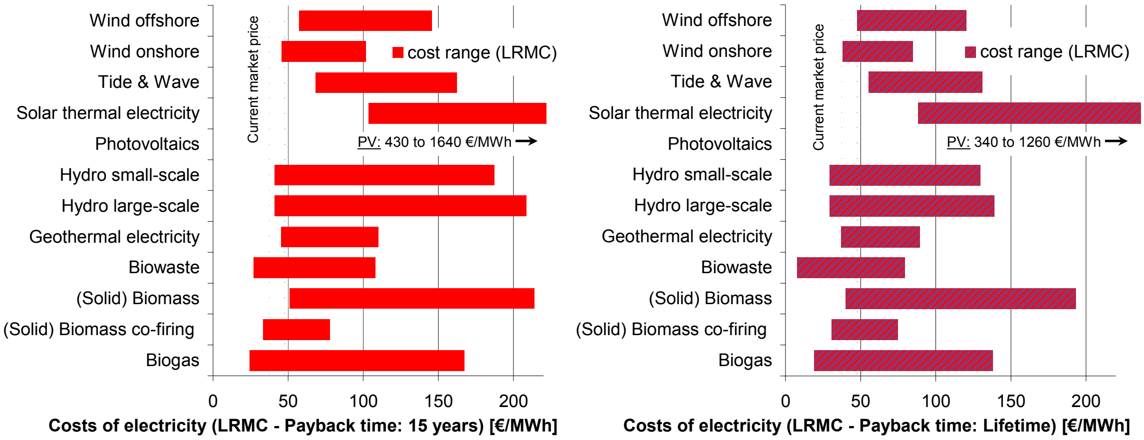


Figure 13: Long-run marginal generation costs (for the year 2005) for various RES-E options in EU countries – based on a default repayment time of 15 years (left: pay back = 15 years) and by setting the repayment time equal to lifetime (right: pay back = life time))

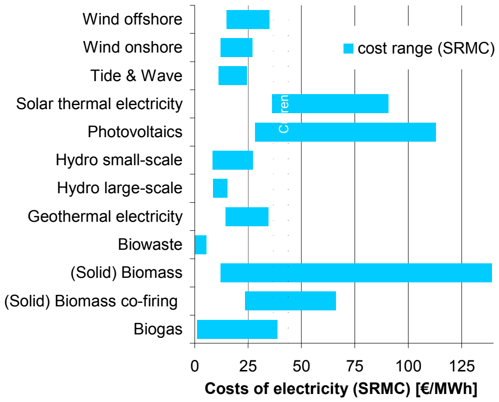


Figure 14: Short-run marginal generation costs (for the year 2002) for various RES-E options in EU countries

Figure 14 illustrates *short-run marginal generation costs*[12] by RES-E category. It is evident that for most RES-E options these short-run generation costs, i.e. the running costs, are low compared to conventional power generation based on fossil fuels. One exception in this context is biomass, where fuel costs and conversion efficiencies have a huge impact on the resulting running costs.

---

[12] Short-run marginal costs are of relevance for the economic decision whether to operate an existing plant or not.

The current situation, without consideration of expected technological change, may be described as follows: RES-E options such as landfill and sewage gas, biowaste, hydrothermal geothermal electricity, (upgrading of) large-scale hydropower plant or co-firing of biomass are characterised by from an economic point-of-view comparatively low cost and by, in contrast, rather limited future potentials in most countries. Wind energy and in some countries also small-scale hydropower or biomass combustion (in large-scale plant) represent RES-E options with economic attractiveness accompanied by a high additional realisable potential. A broad set of other RES-E technologies are less competitive at present, compare e.g. agricultural biogas and biomass – both if utilised in small-scale plants, photovoltaics, solar thermal electricity, tidal energy or wave power – although, future potentials are in most cases huge.

Economic data for RES-H

Table 7 gives an overview of economic parameters and accompanying technical specifications on technological level for grid- (i.e. district heating) and non-grid heating systems, referring to *new plant* of the database in accordance with the *additional realisable mid-term potential*.

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

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	350 - 380	16 - 17	0.89	30	10
	Medium-scale unit	390 - 420	17 - 19	0.87	30	5
	Small-scale unit	475 - 550	20 - 22	0.85	30	0.5 - 1
Geothermal - district heat	Large-scale unit	800	50	0.9	30	10
	Medium-scale unit	1200 - 1500	55	0.88	30	5
	Small-scale unit	2000 - 2200	57 - 60	0.87	30	0.5 - 1
Non-grid heating systems						
Biomass - non-grid heat	log wood	255 - 340	6 - 10	0.75 - 0.85*	20	0.015 - 0.04
	wood chips	340 - 610	6 - 10	0.78 - 0.85*	20	0.02 - 0.3
	pellets	390 - 530	6 - 10	0.85 - 0.9*	20	0.01 - 0.25
Heat pumps	ground coupled	900 - 1100	5.5 - 7.5	3 - 4[1]	20	0.015 - 0.03
	earth water	650 - 1050	10.5 - 18	3.5 - 4.5[1]	20	0.015 - 0.03
Solar thermal heating & hot water supply	Large-scale unit	400 - 420[2]	5 - 7[2]	-	20	100 - 200
	Medium-scale unit	540 - 560[2]	7 - 9[2]	-	20	50
	Small-scale unit	900 - 930[2]	13 - 15[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).

Economic data for RES-T (biofuels)

Table 8 gives an overview economic parameter and accompanying technical specifications on technological level for some selected RES-T plant, referring to *new plant* of the database. Please note that all data – i.e. investment-, O&M-costs and efficiencies - refer to the default start year of the simulations, i.e. 2005, and are expressed in €$_{2005}$.

Table 8: Overview on economic-& technical-specifications for new RES-T plant

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	210 - 860	10.5 - 45	0.66	-	20	5 - 25
Bioethanol plant (EtOH)	energy crops (i.e. sorghum and corn from maize, triticale, wheat)	640 - 2200	32 - 110	0.57 - 0.65	-	20	5 - 25
Advanced bioethanol plant (EtOH+)	energy crops (i.e. sorghum and whole plants of maize, triticale, wheat)	1130 - 1510[1]	57 -76[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	750 - 5600[1]	38 - 280[1]	0.36 - 0.43[1]	0.02 - 0.09[1]	20	50 - 750

Remarks: [1] In case of advanced bioethanol and BtL cost and performance data refer to 2010 - the year of possible market entrance with regard to both novel technology options.

2 Past economic and employment impacts of RES deployment

The dynamic evolution of RES deployment in Europe has led to the development of a cross-sectoral industry that centres around installation, operation and maintenance of RES facilities as well as the production of biomass fuels. The aim of this chapter is:

- to present the evolution of the RES industry in terms of its economic significance, or more concretely, to present its direct and indirect contribution to the gross domestic product and to employment in the EU Member States via the input-output model approach (MULTIREG) and
- to supplement the results from the input-output model by a direct data collection approach.
- Furthermore the transformation of technology specific data into (economic) sectoral data for use in macroeconomic models is presented.

Technically speaking the *gross* economic and employment impacts of the RES industry include the renewable energy industry itself and the industries indirectly depending 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. Conceptually, to estimate the economic significance of the renewable energy industry and its employment we distinguish here between two approaches: a supply side or direct data collection approach and a demand side or input-output (IO) model based approach.

In this study the IO model based approach is mainly used to analyse the past and present economic impacts of the renewable energy industry. The direct data collection approach is mainly used for validation purposes for the core part of the industry and might provide further development potential.

2.1 Using techno-economic data of RES technologies for macroeconomic analysis

In order to assess the economic impacts of RES deployment, it is necessary to translate the expenditures for installing and operating RES plants into economic activities or impulses, which can be fed into the economic models and are compatible with their sectoral classification. In this project these economic data are used as inputs in the model MULTIREG for the calculation of past and present economic impacts and - after the necessary adjustments - in the models NEMESIS and ASTRA for the assessment of future economic impacts. In this chapter this translation procedure is described in detail.

The costs for the deployment of RES technologies can be subdivided into four categories:

- costs for capacity increase,
- costs for replacement of existing capacity at the end of life,
- costs for operation and maintenance of RES facilities (without fuel use) and
- costs for fuel use, i.e. the use of biomass resources.

The costs for capacity increase and capacity replacement are summarized as investment costs.

Starting point are data from the Green-X model on 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 installation and operation of facilities (e.g. planning, manufacturing of the core technology, transportation and on-site installation) or that reflect 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 judgement.

For the assessment of the economic and employment impacts it is important to consider the regional origin of the goods and services that are related to the cost components. Some of them are provided in the country, in which the RES facilities are installed (e.g. planning or construction). Other goods are imported from other countries and lead to economic impacts in the countries of origin. Wind turbines for instance are installed in several countries, whereas their production is more concentrated in a few European countries and countries outside Europe. In order to take the specific regional distributions of activities into account, each cost component of a technology can be classified as "local" or as "global" in our analysis. A cost component classified as "local" is mainly supplied by the country of installation, with the average inter-country trade being taken into account. For a cost component classified as "global" (e.g. wind turbines or solar cells) an adequate distribution of supplying countries can be determined.

For the globally manufactured cost components of a RES technology we add up the costs across all countries (including the rest of the world) to gain a global demand for the related products. We then break down the global demand to the countries supplying these products. 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 expert opinion.

In a next step the production of each technology’s cost components is allocated to the corresponding economic sectors according to the sector classification used in the macroeconomic models.

Since also the cost components classified as „local“ are related to products actually traded across borders (services to a smaller degree than commodities), these trade shares are accounted for in the economic models according to the average trade patterns of the respective economic sectors. A cost component of a RES technology can be treated as a global cost component, if its actual trade pattern deviates strongly from the average trade pattern of the respective economic sector and the necessary data for determining the actual trade pattern is available.

The result of this procedure is - for each RES technology - a vector of production by economic sector and by country, which serves as an input to the economic models. The exact manner, in which this input is used, differs between the three economic models and is specified in the respective chapters, in which the models are presented.

In the following, this approach is depicted in Figure 15 and described in more detail for the example of photovoltaic installations.

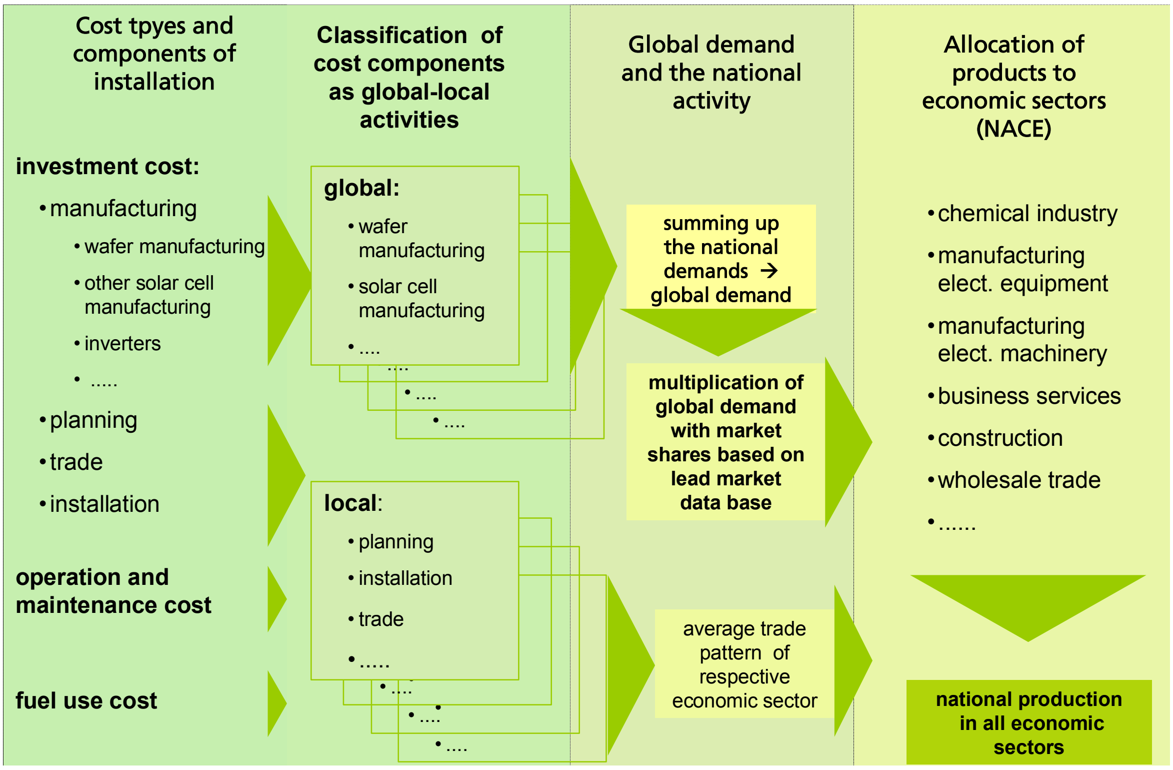


Figure 15: Overview and example of the classification and calculation of national investments of solar energy

Example: Photovoltaic installations

When analysing the cost structure of photovoltaic installations, one has to distinguish between two basic options, off-grid and grid connected installations. In the EU grid connected installations have a share of 95% of total installed capacity (Staiss, 2007). Among the grid connected installations decentralised rooftop installations clearly dominate the large-scale installations. Therefore the derivation of an average cost structure of PV installations focuses on grid-connected rooftop installations.

In terms of technology one has to distinguish between silicon-based PV systems and thin-film systems based on other materials, e.g. copper-indium-diselenide or cadmium-telluride. Since the latter are in a very early market phase, we concentrate on silicon-based PV systems.

Installation of photovoltaic modules for electricity generation includes the following components:

- planning
- PV modules,
- inverters,
- other installation components, summarised as the "balance of system" (BOS) and
- installation of the complete PV system.

The value chain for producing PV modules includes the following main steps:

- silicon production,
- wafer production based on silicon,
- production of solar cells,
- production of PV modules.

Estimating the average cost structure for these cost components has to rely on several information sources. Whereas there is a lot of information on specific costs and their development over time, information on cost structures and their development is far more restricted. Furthermore material costs can fluctuate strongly. Therefore the cost structures assumed in this study should be regarded as approximations.

Hirschl et al. (2002) have conducted an extensive survey of costs and cost structures of RES deployment in Germany. According to their analysis the average structure of total PV installation costs in Germany is the following:

PV modules:	72%
Inverter:	11%

- Other components: 8%
- Installation: 9%

Based on earlier work (Sprenger et al., 2003), we assume the cost breakdown of PV modules to be 60% for solar cells and 40% for other manufacturing. Wafer costs are assumed to cover half of the production costs of solar cells.

As in most bottom-up cost calculations, the costs refer to purchasers' prices (excluding VAT). For the use in macroeconomic analysis these have to be transformed into producers' prices, which means that trade and transport margins need to be subtracted. The installing company usually covers part of its cost with a trade margin on PV modules and inverters. According to Staiss et al. (2007) the range of these margins lies between 2% and 15% of the equipment price. Here we assume a margin of 7%, which is additional to the invoiced installation cost. Furthermore we assume a wholesale margin of 4% of the purchasers' price. The following table contains the cost breakdown used in our calculations and an allocation of the costs to the economic sectors used in the macroeconomic models. It also includes our classification as a global or local cost component.

Table 9: Structure of PV installation costs

Cost component	Share of total installation costs	Allocation to economic sector	NACE-Nr.	Classification
Planning	1%	Business services	74	local
Wafer manufacturing	19%	Chemical industry	24	global
Other solar cell manufacturing	19%	Manuf. of electronic equipment	32	global
Other solar module manufacturing	25%	Manuf. of electrical machinery, Manuf. of control equipment	31 33	global
Inverters	10%	Manuf. of electrical machinery	31	local
Other components	7%	Manuf. of metal products, Manuf. of electrical machinery;	28 31	local
Installation	15%	Construction	45	local
Wholesale trade margin	4%	Wholesale trade	51	local

Source: Own calculation based on Hirschl et al. (2002), Sprenger et al. (2003), Staiss et al. (2007)

Three important components of PV module manufacturing, wafers, solar cells and PV modules, are considered as "global" components, for which we specifically analyse the regional production patterns and the country market shares, respectively. Regarding solar cells and PV modules, our estimation of market shares is based on a detailed market survey published in the magazine *Photon International*, where global production is presented by country and manufacturer. For wafers our estimate is based on information from the technical literature. As a result we arrive at the following market shares for the year 2005 (Table 10). The results show that the market shares of EU countries vary between 26% and 31% of global production. Within the EU especially Germany and Spain have a strong position as manufacturing countries.

Table 10: Country market shares in global production of wafers, solar cells and PV modules in 2005

Country	Wafer production	Solar cells production	PV modules production
Germany	22%	19%	14%
Spain	6%	4%	8%
France		2%	1%
United Kingdom	3%	0%	0%
Other EU		1%	6%
Rest of the world	69%	74%	71%
Total	100%	100%	100%

Source: Photon International, own calculation

Similar analyses were performed for the other RES technologies considered in this project. The depth of the analysis depended on the relevance of the respective technologies. Figure 16 contains an aggregated overview of the investment cost breakdown by economic sector for the most important RES technologies.

Regarding the classification of cost components for other technologies, we identified two other cost components, for which it was necessary to consider specific regional production patterns and for which the necessary data is available: wind turbines and solar thermal collectors.

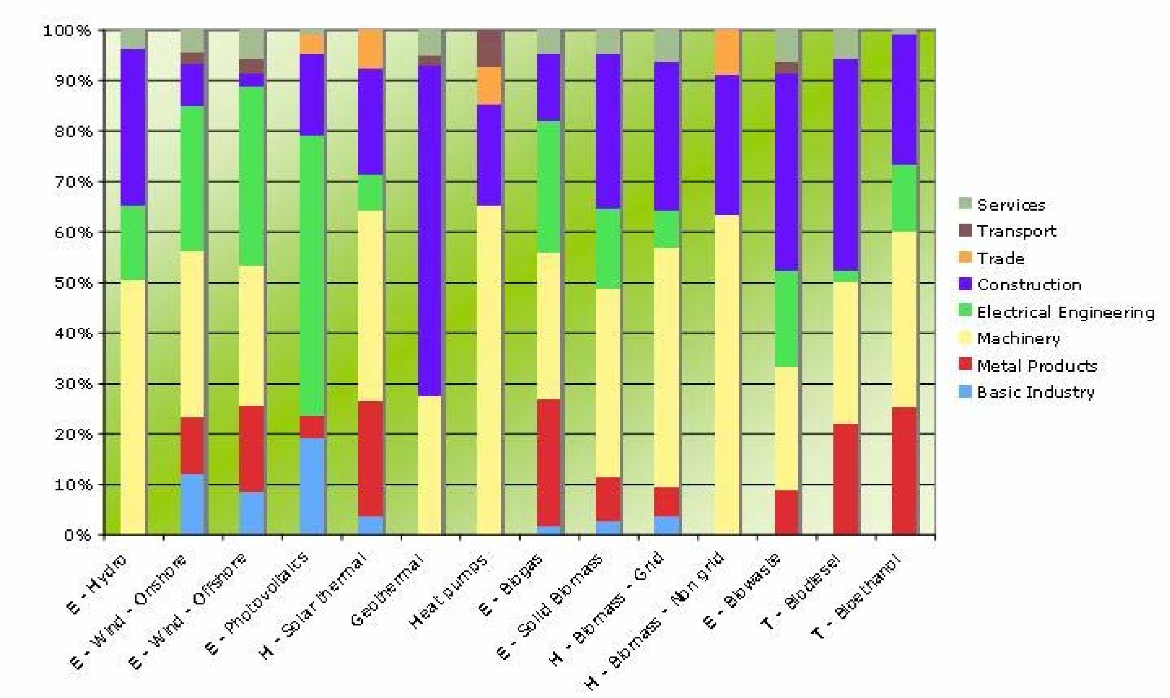


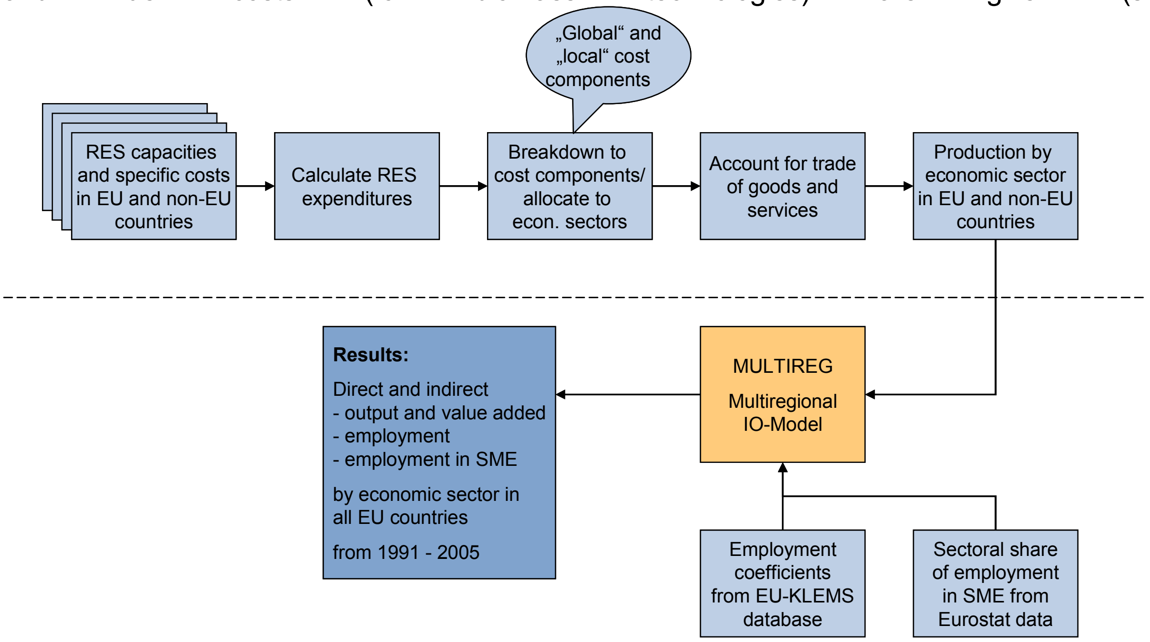
Figure 16: Overview of cost structures of investment in RES technologies by economic sector

2.2 The input-output model based approach with MULTIREG

The starting point for the 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 (O&M) 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).

2.2.1 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[13]. Furthermore specific investment costs, operation and maintenance costs and fuel costs (for biomass technologies) are given (see Figure 17). This capacity and cost data is available for the years 1990 to 2005. 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. The costs were converted from the price base year 2005, used in the Green-X model, to the base year 2000 as used in the MULTIREG model. 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. In some cases cost components do not lead to production activities (e.g. costs of wind parks for using land or the transfer component in insurance premiums). In accordance with conventions of national accounting, these cost components are not considered in the further economic modelling.

---

[13] Basically the countries represented in the MULTIREG model are considered (see Annex II).

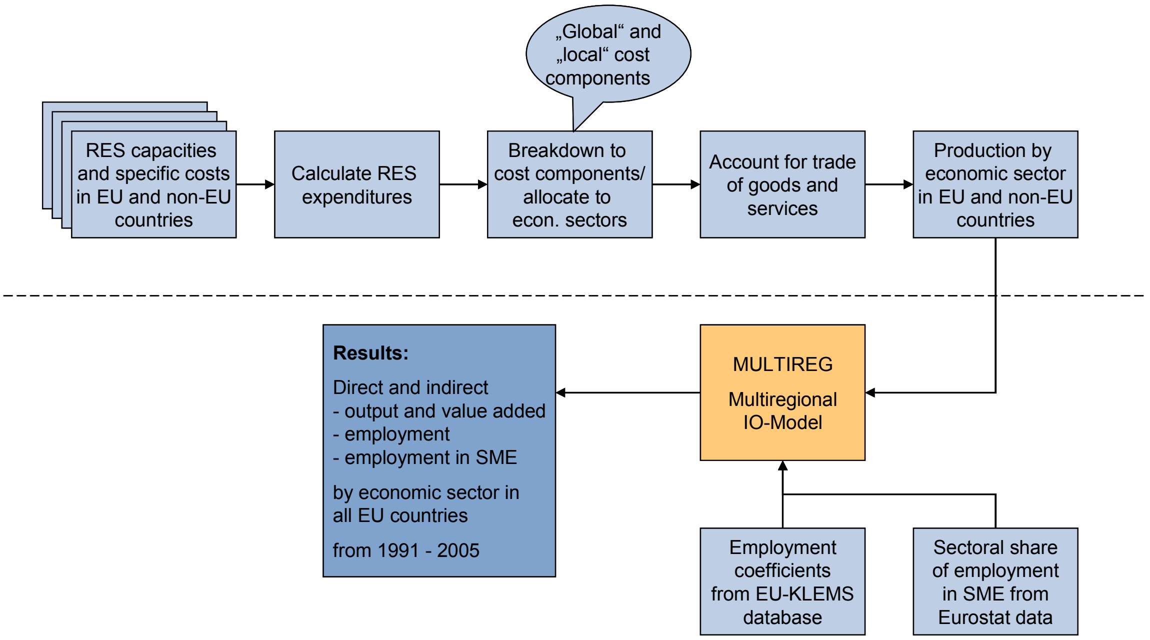


Figure 17: Overview of the modelling approach to calculate past and present economic and employment impacts of RES deployment

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.

In addition to the general economic and employment impacts, we also focus on the impacts on agriculture and forestry which often are located in less industrialised regions and employment in small and medium sized enterprises (SME). The impact on SME is calculated as an add-on to the calculation of employment impacts. Based on Eurostat data, the share of employed persons in SME (defined as enterprises with 250 or less employees) is determined for each economic sector in every EU member state. Since the available Eurostat database on enterprise size only covers the manufacturing industry and part of the service industry, we estimated the SME share for the missing industries[14].

---

[14] Among the missing sectors only the agricultural and forestry sector is relevant for our analysis. We estimate the SME share for this sector to be 95%.

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). In the study at hand an aggregation level of 41 sectors is used to incorporate trade with non-EU countries. 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. Furthermore it is extended with Eurostat data on the share of employment in small and medium enterprises (SME) in the economic sectors of the EU member countries to estimate the economic impact of RES deployment on SME. A more detailed presentation of the MULTIREG model can be found in the annex.

Remarks on the limitations of the analysis

Due to lack of data and data uncertainties the present analysis is subject to certain limitations, which are presented below. Due to these limitations the results are slightly underestimated and can thus be regarded to represent a lower boundary.

The following impact analysis includes the production of RES plants (e.g. wind power plants, hydro power plants or wood furnaces), their operation and maintenance and the supply of fuels used in biomass plants and facilities. Due to lack of necessary data, it excludes the second order impact of production facilities, in which the RES plant components are manufactured (e.g. production plants for wind turbines or solar cells). Even though studies on investment in the renewable energy sector contain partially useful information (e.g. UNEP et. al., 2007), the level of detail necessary to calculate the economic impacts by technology and by country is currently not available. In some RES sectors with large growth rates, e.g. the PV sector, current investment in production plants is substantial. Across all RES technologies the ratio of investment in production plants to the value of production output will probably be similar to the ratio of the investment goods sector, which typically is below 5%. This probably represents the level, by which this study underestimates the total impact due to the exclusion of production facilities.

Our analysis is done with a static input-output model with the base year 2000. Therefore changes of the general economic structure and of trade relations between 1990 and 2005 are not taken into account. During this time period trade relations have significantly intensified due to international specialisation, especially between Western and Eastern Europe.

Thus this study may overestimate trade for the year 1990 and underestimate trade for 2005. Yet, since the change of net trade is much smaller than the change of trade volume the impact of this simplification on economic output and employment results is not expected to be substantial. On the other hand, the more important development of labour productivities and of price levels over time has been taken into account in this study.

Generally the quality of data is good for capacities and costs of electricity generating RES technologies and of biofuels technologies. Data for heat generating technologies is less reliable, especially data for biomass heat generation. One important uncertainty concerns the supply of log wood to private households. It is unclear, which share of log wood is actually purchased on the market and which share is from privately owned forests or other supply channels. According to information from industry experts a substantial share is not purchased. Since reliable information is not available, we assume this share to be 50%.

Finally the impact of the use of heat generating RES technologies in countries outside the EU on EU exports could not be taken into account in this study since the necessary data on investment and heat generation are not available. This also leads to a slight underestimation of the total economic impact of RES deployment.

The following part of this chapter gives an overview of the main results regarding the economic impact of the renewable energy sector in the EU 27 countries. First an overview of the development of RES-related costs and the resulting gross economic impacts in the EU 27 over time is given. Then the results for 2005 are presented in more detail. All monetary values (e.g. gross value added) are expressed in prices of the year 2000.

2.2.2 Development of expenditures, gross value added and employment

As a starting point the development of expenditures for using RES (i.e. total cost, not additional cost compared to conventional energy supply) are presented in the figure below. In the EU 27 as a whole the expenditures have increased significantly from 29 billion € in 1991 to 61 billion € in 2005. While replacement costs, O&M costs and fuel costs have remained fairly stable over this period, costs of capacity expansion have increased substantially due to the various RES supporting policies in the EU Member States, reaching 30 billion € in 2005. 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 18 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 induced in the supplying industries. In total value added reaches 58 billion € in 2005 or 0.58% of total GDP in the EU 27 (Table 11).

The related development of total (i.e. direct and indirect) employment induced by RES deployment is shown in the following figure. Employment has grown from roughly 1 million employed persons in 1991 to 1.4 million in 2005 (equal to 0.64% of total employment in the EU). A comparison with the development of gross value added shows that employment has remained fairly stable until 2000 and has then grown, but less strongly than value added. This is a direct consequence of increasing labour productivity (the ratio of gross value added to employment) over time.

From the comparison of the two figures for value added and employment, it can be noted 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 clearly lower than in the sectors related to RES investment and operation.

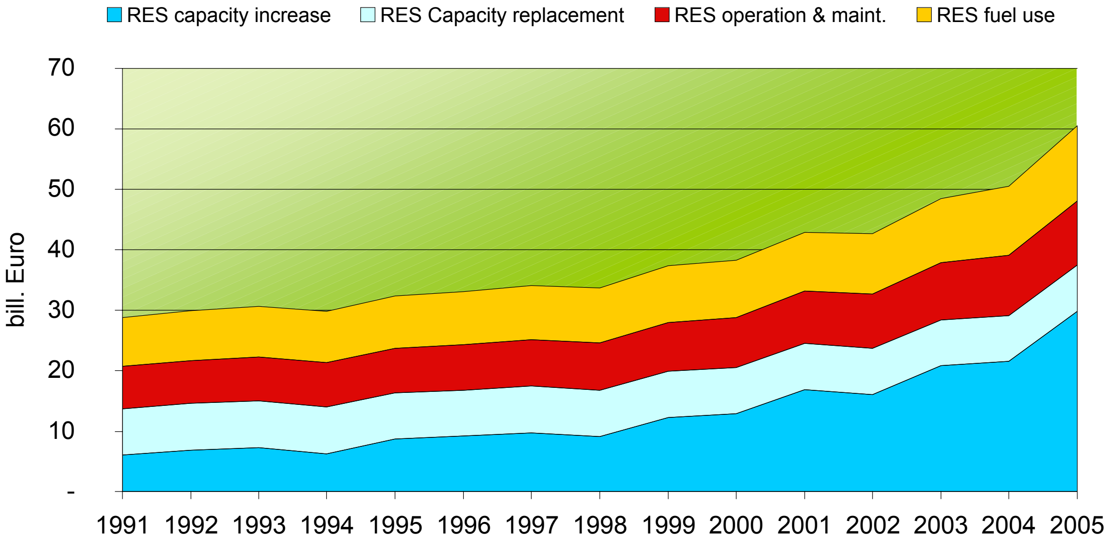


Figure 18: Development of expenditures for RES deployment 1991 – 2005

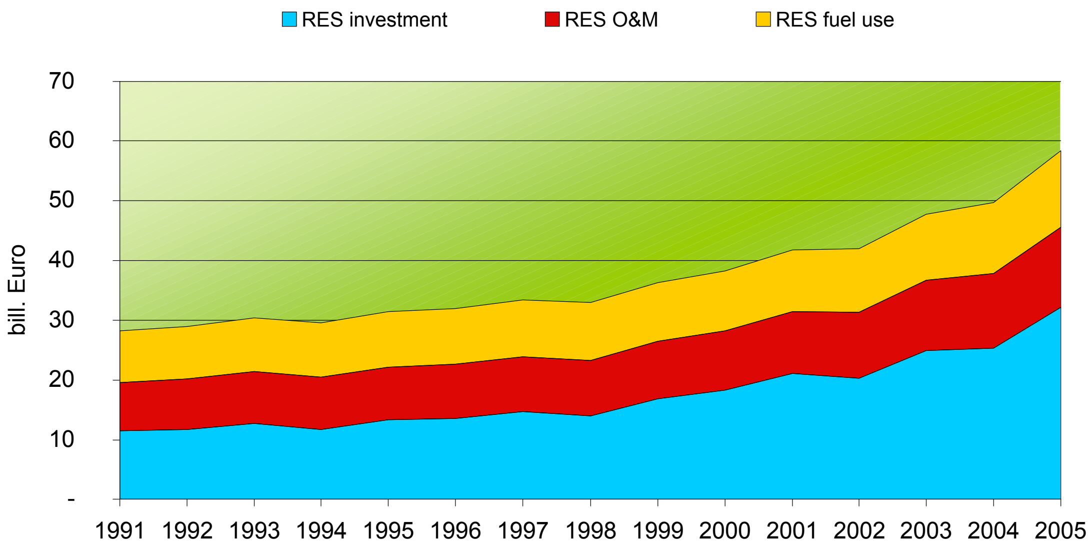


Figure 19: Development of total gross valued added induced by RES deployment between 1991 and 2005

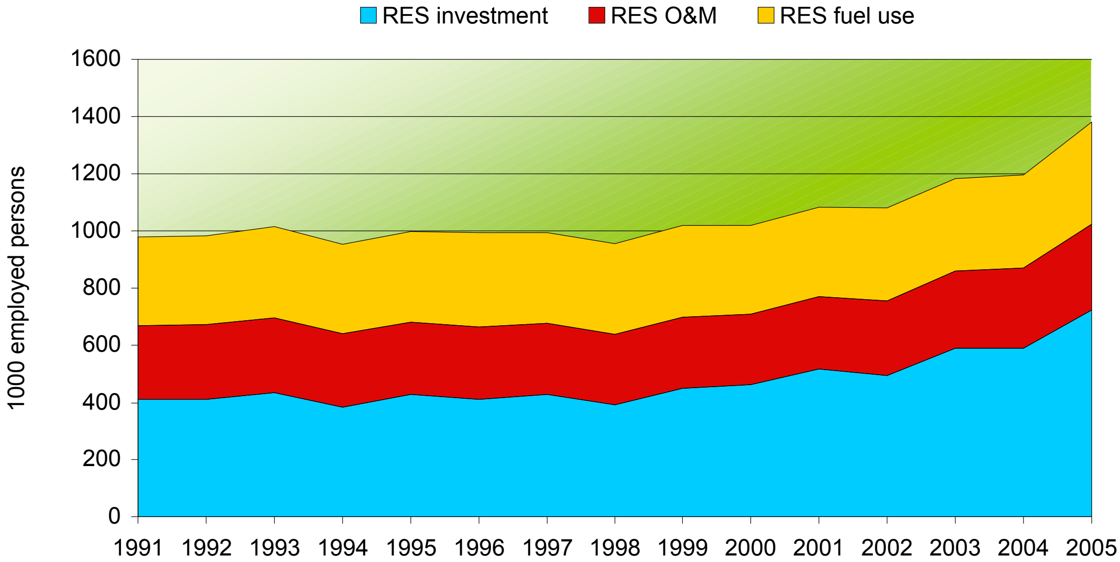


Figure 20: Development of total employment induced by RES deployment between 1991 and 2005

Table 11 gives an overview of the impacts in 2005, also indicating direct and total impacts. The direct gross value added generated by the renewable energy industry reaches 32 billion € in 2005, equalling 0.3% of total EU GDP. It employs roughly 800’000 persons or

0.4% of the total EU workforce. In both cases direct impacts equal approximately 55% of total impacts.

Table 11: Gross value added and employment induced by RES deployment in 2005

	Direct value added (mill. Euro)	Direct employment (1000 empl. persons)	Total value added (mill. Euro)	Total employment (1000 empl. persons)
RES investment	14'845	350	32'145	724
RES operation and maintenance	9'546	205	13'417	299
RES fuel use	7'491	220	12'768	358
Total	31'882	775	58'331	1'381
in % of EU total	0.32%	0.36%	0.58%	0.64%

At the member state level the economic relevance of the RES industry varies strongly among countries (Figure 21) and mainly reflects the differences in RES deployment regarding level and technology structure and differences in market shares of the supplying industries. Shares in GDP and total employment vary between next to zero in countries like Cyprus and Malta and almost 2.5% in countries like Finland, Sweden or Latvia, which partly are characterised by an extended use of biomass. The differences between the GDP and the employment shares reflect the relations between RES related labour productivities and average labour productivities in the respective countries

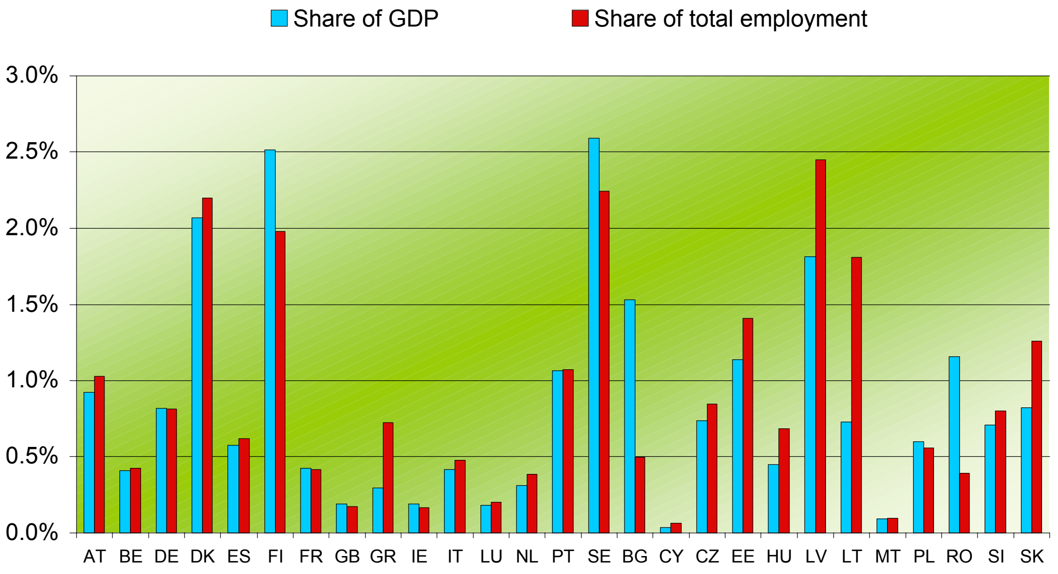


Figure 21: Significance of economic and employment impacts at the member state level

Gross value added in 2005

Figure 20 to Figure 23 present gross value added in 2005 by country from different perspectives. Figure 20 first shows for each country value added by expenditure category (investment, operation and maintenance, fuel use). Within the European Union, Germany, which also has the highest RES expenditures, has by far the largest share in total value added (28%). In Germany value added is to a high extent driven by RES investment. Other countries with major absolute impacts are France, Italy and Sweden. 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 22 contains the breakdown by country and RES technology. In most countries a large share of value added is realized with the use of biomass and hydro power. Whereas non grid-connected biomass use is important in countries like France, Finland, Austria and Poland, grid-connected biomass use has a strong position in Sweden as does biowaste in Italy. Hydropower is especially relevant for value added in Italy, France, Austria and Sweden.

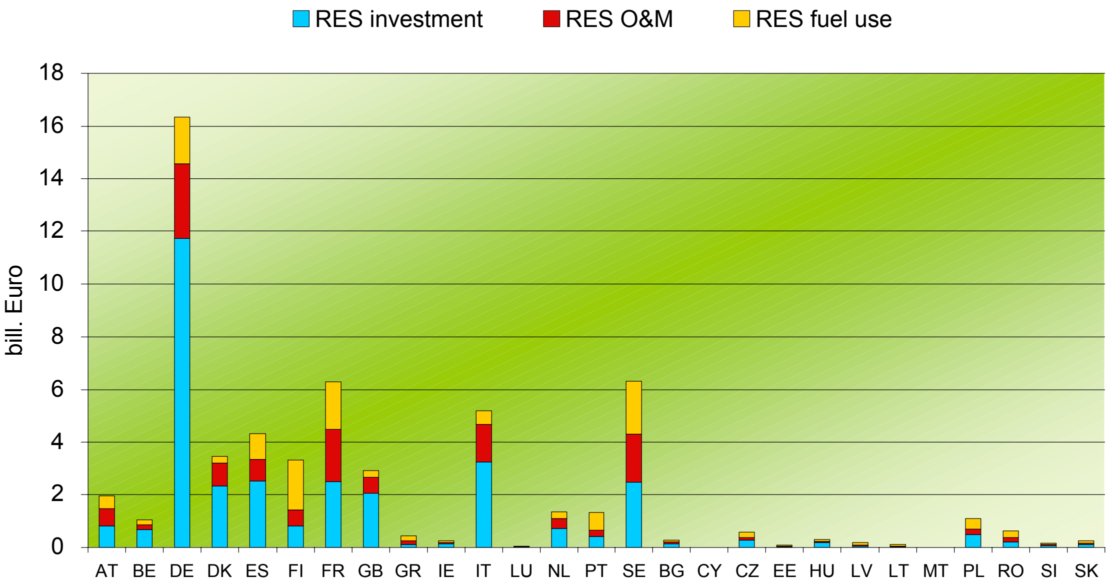


Figure 22: Total gross value added induced by RES deployment in 2005, by country and RES expenditure category

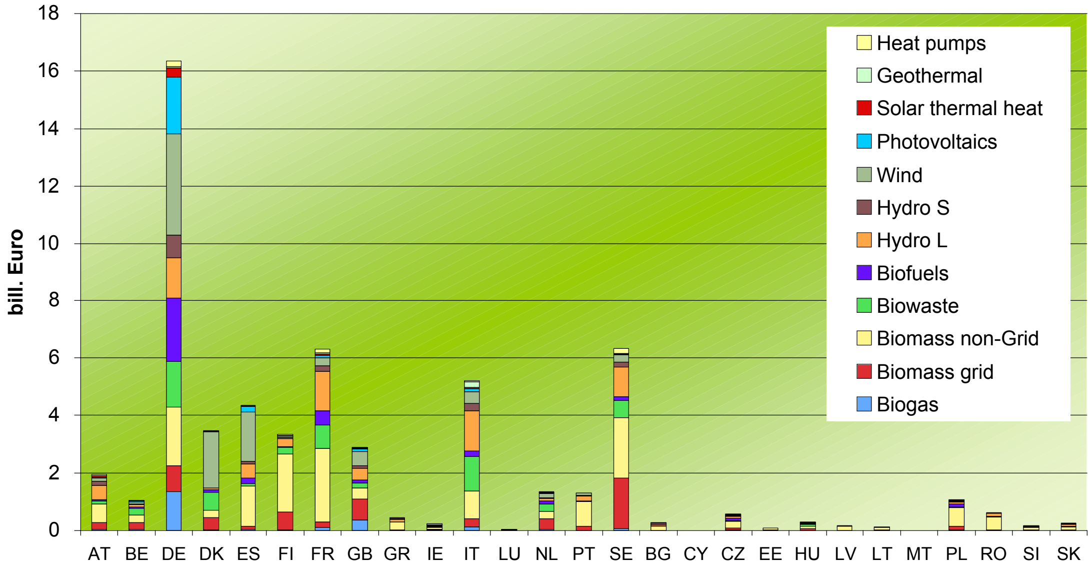


Figure 23: Total gross value added induced by RES deployment in 2005, by country and RES technology

Value added from wind power is largely concentrated in Germany, Denmark and Spain. In the photovoltaics sector, Germany - being by far the largest investing country in Europe – also has the largest PV manufacturers. It can be noted that PV-related expenditures in Germany only partly lead to value added in the same country, a significant share is used for imports from countries outside the EU, especially Japan, due to their large market share. Yet the German PV industry has been able to significantly increase its share in the global market since the mid nineties. The other RES technologies mostly have a minor economic impact.

An analysis of value added by economic sector shows that a broad range of sectors are active in directly or indirectly supplying the goods and services needed for the deployment of renewables (Figure 23). 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 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.

In a further perspective gross value added is shown in a breakdown by RES technology and expenditure category. Figure 24 highlights the large importance of the biomass technologies, especially of non grid-connected use of biomass (equalling 30% of the total impact, mainly for heating purposes). Here especially fuel use is responsible for a large share of value added. Other important technologies are wind power and hydro power. The relevance of photovoltaics is smaller, but growing rapidly.

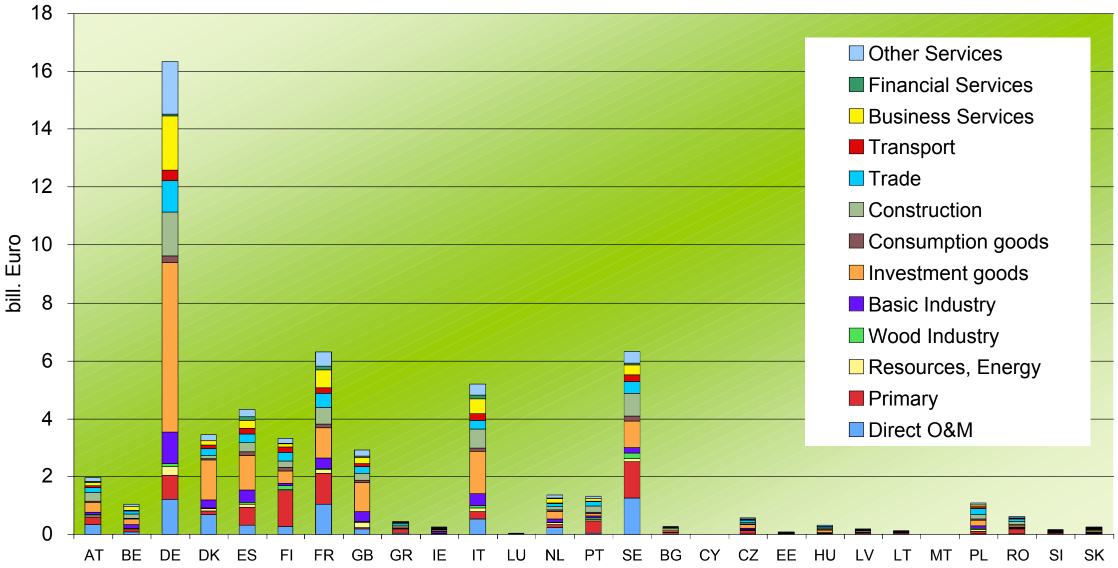


Figure 24: Total gross value added induced by RES deployment in 2005, by country and economic sector

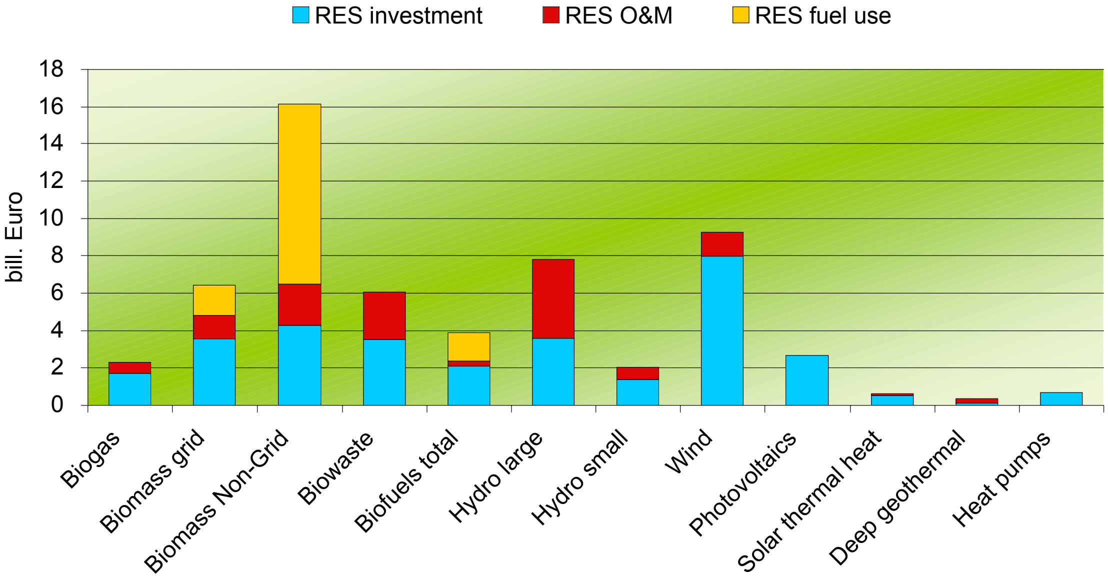


Figure 25: Total gross value added in the EU induced by RES deployment in 2005, by technology and expenditure category

Employment in 2005

The analysis of employment follows the analysis of value added presented above. Generally, differences from the results for value added are due to differences of labour productivity in the respective countries and economic sectors.

Figure 25 shows total employment induced in the EU by RES deployment. Compared to the figure before showing 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 also is characterized by a relatively low labour productivity. Due to these two effects, some Eastern European countries like Poland and Romania, that extensively use biomass resources, show substantial employment levels due to RES deployment. From the perspective of RES technologies, non grid biomass use accounts for the largest share with 450'000 employed persons (Figure 26). With the exception of biogas use, the other biomass technologies each contribute over 100'000 employed persons. The use of biogas induces approximately 50'000. The most important non-biomass technology in terms of employment is hydropower, where large and small power plants are responsible for 230'000 persons employed. Wind technology follows with 180'000 and photovoltaics with 55'000 persons employed.

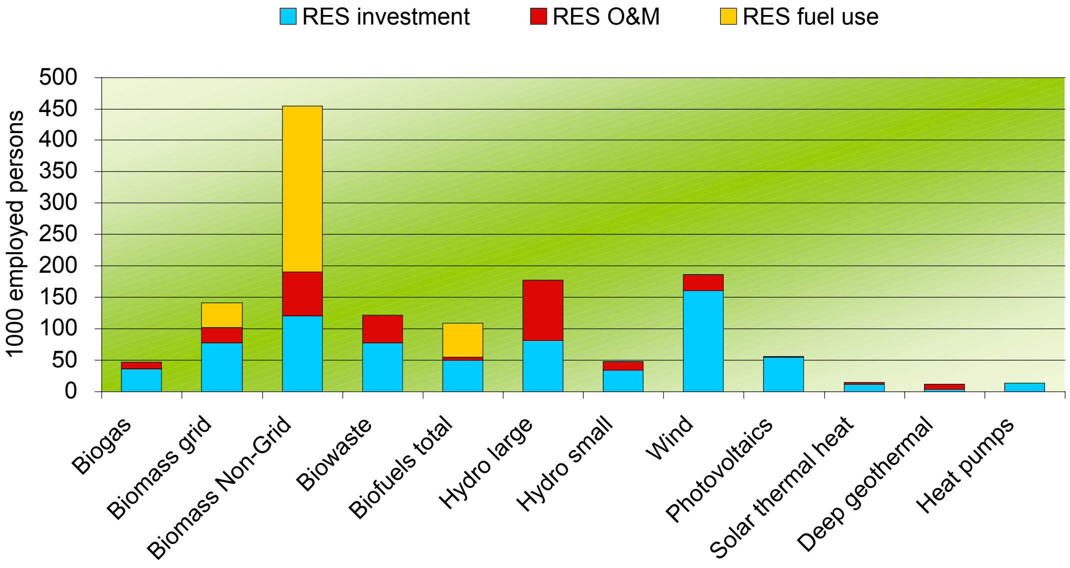


Figure 26: Total employment in the EU induced by RES deployment in 2005, by technology and expenditure category

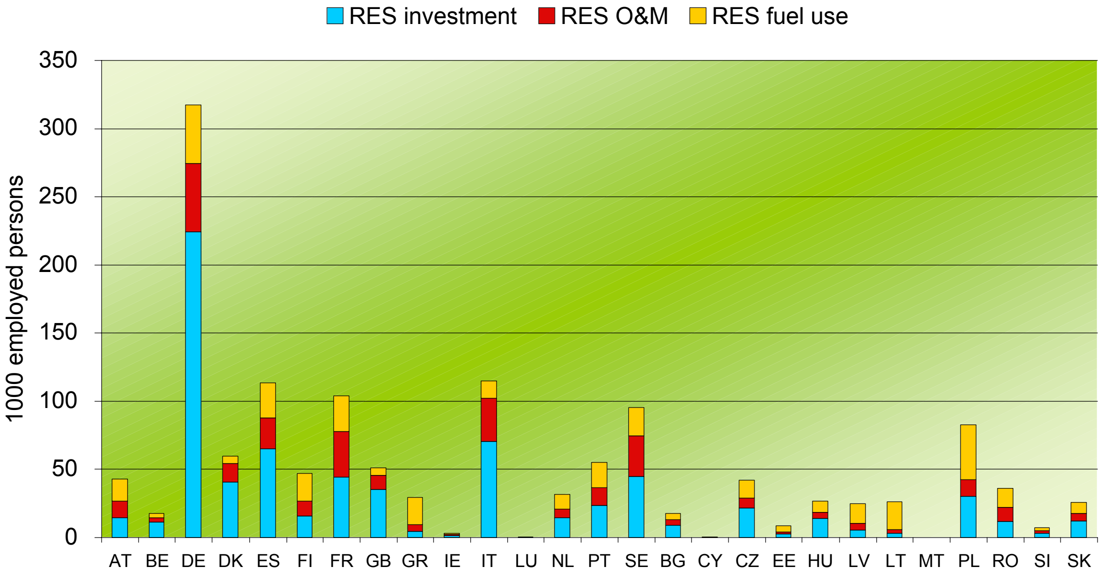


Figure 27: Total employment induced by RES deployment in 2005, by country and RES expenditure category

The contribution of the respective RES technologies to employment in the EU Member States is shown in Figure 27. In most countries biomass use has a high relevance for employment. Again wind technology is an important contributor to employment in Germany, Denmark and Spain and photovoltaics is relevant in Germany. Figure 28 finally shows employment by country and economic sector.

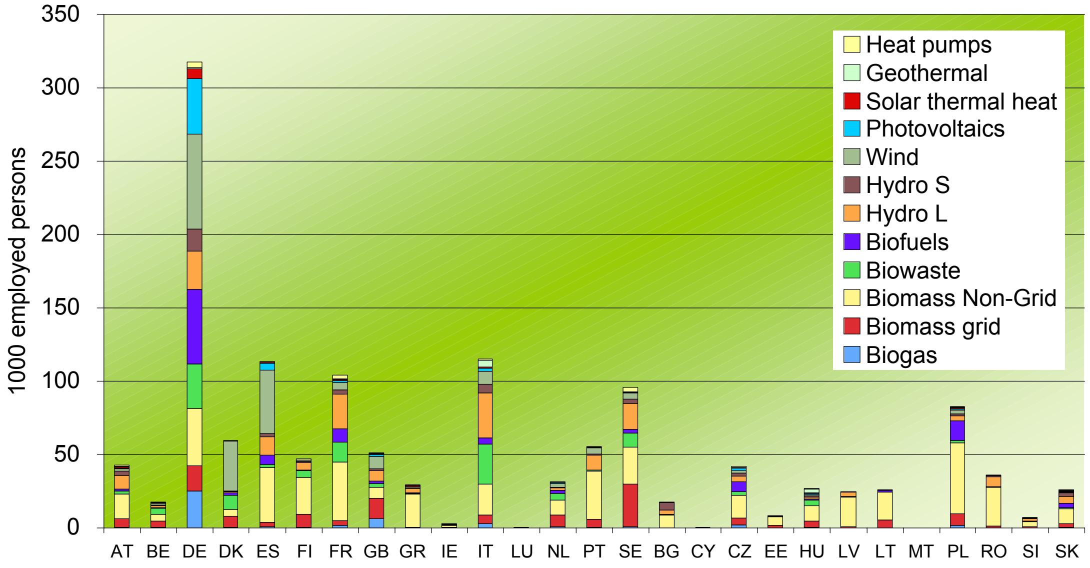


Figure 28: Total employment induced by RES deployment in 2005, by country and RES technology

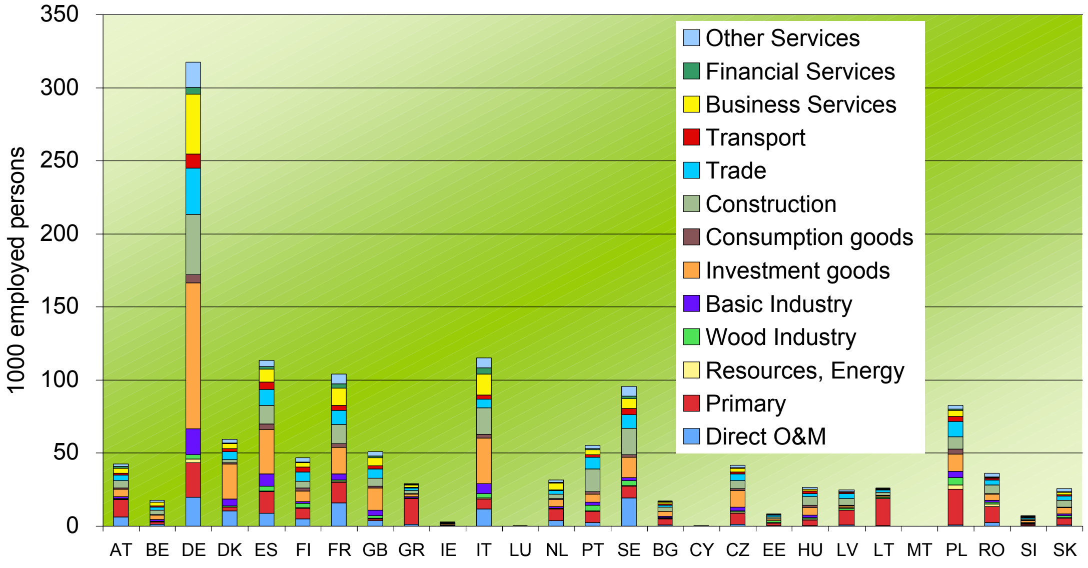


Figure 29: Total employment induced by RES deployment in 2005, by country and economic sector

Employment in small and medium enterprises (SME) in 2005

Our analysis shows that RES deployment induces a substantial share of employment impacts in small and medium enterprises in the EU. In total 900’000 jobs in SME can be attributed to RES deployment, equalling two thirds of the total employment impact[15]. The following figures present the results for employment in SME from different perspectives. Technologies that have an above average relevance for SME include non grid-connected biomass use, biofuels and deep geothermal energy use. These are technologies that to a larger extent trigger employment in sectors such as the primary sector, the wood industry or construction with high shares of small and medium enterprises.

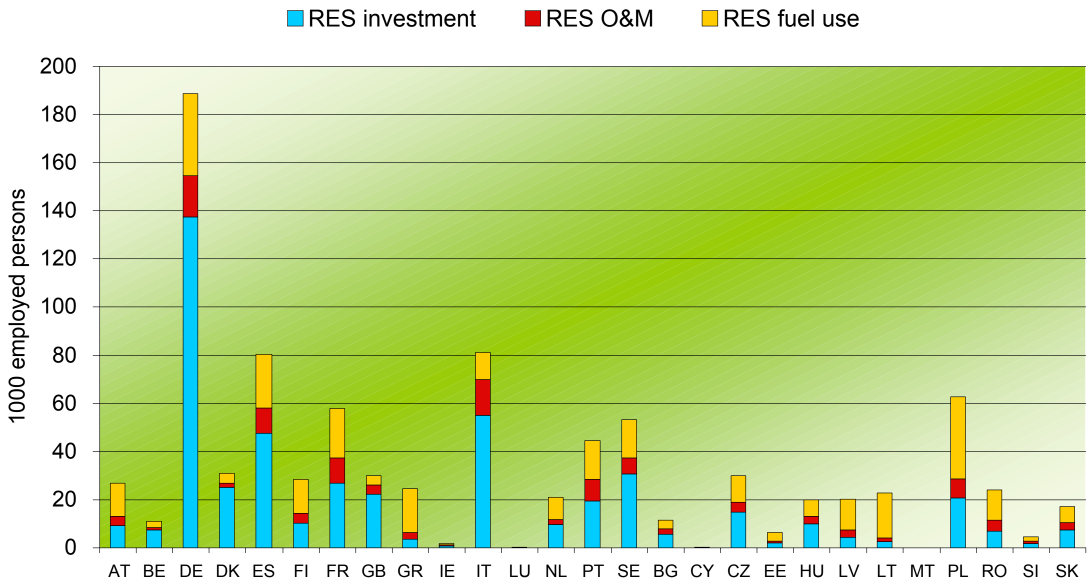


Figure 30: Total employment in SME induced by RES deployment in 2005, by country and RES expenditure category

---

[15] This result excludes personnel in direct operation of RES plants, for which the share of SME in the EU member states is not known. Therefore the results for employment in SME are slightly underestimated.

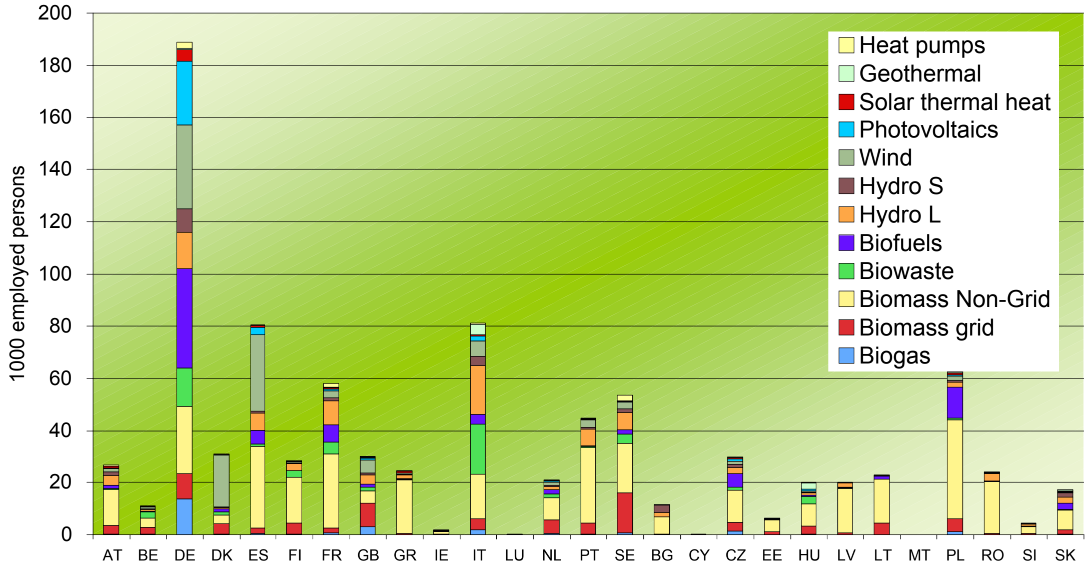


Figure 31: Total employment in SME induced by RES deployment in 2005, by country and RES technology

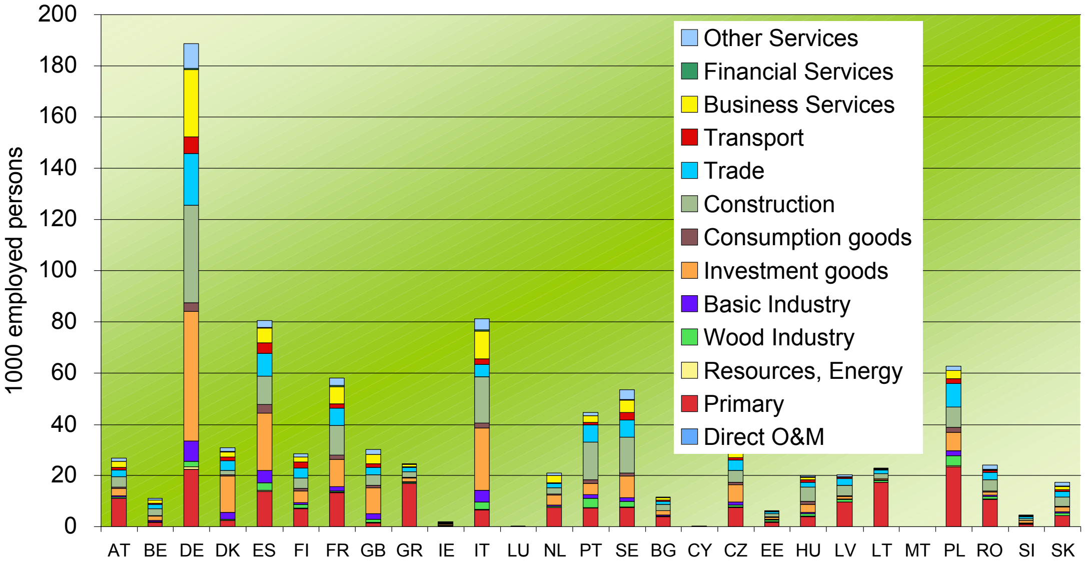


Figure 32: Total employment in SME induced by RES deployment in 2005, by country and economic sector

Economic impacts on agriculture and forestry

Agriculture and forestry have an important role in supplying the fuel for biomass technologies. In terms of economic impacts RES deployment generates gross value added of well over 9 billion € in the primary sector (equalling 15% of the total economic impact) and sustains around 210’000 jobs (15 % of total RES related employment). The share of the primary sector varies considerably among the EU member countries, depending on their respective profile of RES technologies and sectoral characteristics. It is generally higher in the new member states, but also some old member states such as Greece, Finland or Austria have significant shares.

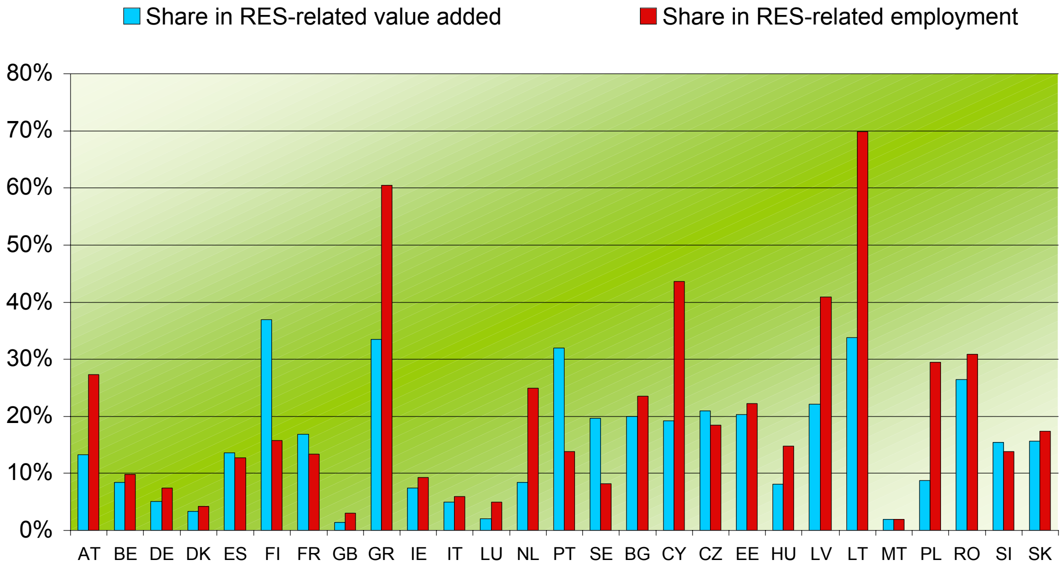


Figure 33: Share of gross value added and employment in the primary sector in total RES related impacts in the EU member countries

2.3 Direct data collection approach

Objective of direct data collection approach

The main idea behind the direct data collection approach is to gather empirically based figures about the extent of employment and economic activity in renewable energy (RE) related sectors. Further, we would like to supplement and compare the input-output model driven results from the MULTIREG model with empirical data.

The direct approach draws upon two paths:

- the stakeholder consultation, which should represent a supplement to the model's results
- an exploration of databases and other information sources to extract data on companies engaged in RES activities and to gather information on the number and structures of these companies for selected combinations of countries and technologies.

The data collection approach aims at directly identifying the enterprises that are active in the supply, operation and maintenance of renewable energy technologies and at determining their economic output and employment. The main task is to identify the associated enterprises in a comprehensive way. This can be done by analysing several sources which list enterprises active in the renewable energy field (e.g. membership lists of the respective enterprise associations, specialised data bases etc.). Determining their economic output (e.g. turnover) and employment is straightforward if an enterprise is only active in the renewable energy field. If a company has several fields of activity it is necessary to determine the shares related to the renewable energy field. Another difficulty is to determine the system boundary of the renewables industry. The further one moves up the supply chain, the more difficult it becomes to relate the enterprises' activities to the renewable energy field (e.g. manufacturers of "dual use goods", i.e. standard components used in renewable energy technologies that are also used for other purposes). The data collection approach generally includes parts of the value chain, but is not able to take indirect effects completely into account.

2.3.1 Stakeholder consultation

The desk research conducted in the context of the MULTIREG model produced a very sound overview on the available empirical data within the EU concerning the economic effects of RE. The stakeholder consultation was in this respect intended to

- ensure that all relevant existing data are indeed covered;
- validate the input data to the MULTIREG model and the output data of the MULTIREG model which are used as input to the two macroeconomic models.

These two objectives are achieved through a stakeholder workshop, a survey among stakeholders and personal contacts with stakeholders.

The stakeholder survey

About 80 renewable energy industry associations at the European and national level and about 30 machinery and electrical industry associations at the European and national level (key industries for RES technology production) were invited to provide empirical input data to the MULTIREG model. Of these organisations 10 RES branch organisations at

European level and 20 key RES branch organisations at national level have been contacted personally, partly for in-depth interviews to close data gaps, verify input data or to discuss first results.

RES branch organisations highly welcome this study on employment and growth effects and are very interested in having reliable data at their disposal. Certain data on the current employment figures on company level was used to cross check key input data to the MULTIREG model. However, so far most of the available data within the RES branch organisations are not sufficiently detailed in order to serve as input to the MULTIREG model.

The stakeholder workshop

Next to gathering and validating input data, the stakeholder workshop was also intended to present the overall project approach, i.e. input data, assumptions, the modelling approach and choice of scenarios, in order to gather comments on the approach in an early stage of the project where adaptations to the approach are still feasible.

This was achieved, and specifically detailed and valuable feedback was gained from participants involved in employment and growth studies covering the German RES industry and the European Wind industry.

Next to the organisations addressed during the stakeholder survey, the following organisations were invited to the stakeholder workshop:

- European level branch organisations for the supply of conventional electricity, heat, cogeneration and fuel sector (supply side); for energy consuming industry, business in general and the chambers of commerce (demand side)
- European Commission, IEA, OECD
- NGOs
- Academia

2.3.2 The AMADEUS database exploration

The database exploration approach represents an alternative way to get an overview on employment and economic data in the area of RE. Furthermore, for selected sectors and technologies, for which the completeness of the database appeared sufficient, it is used to support the outcomes of the MULTIREG model. Therefore, an ultimate objective is to build up a RES database on employment and other economic data.

Collecting data on companies or any organization involved in RES activities entails in particular two challenges: First, to properly identify companies or organizations that are engaged in RES activities and secondly, when they are identified, to group them into RES - technologies and get reliable economic data about them. A database providing comprehensive information on employment and other economic data, on RES - technologies and economic sectors, on the company's name and activities and covering all EU Member States is not available. However, there is a business service for financial affairs, which provides and delivers information on the creditworthiness and other financial data at the national and European level for financial intermediaries. One of these information services is Creditreform, which offers a database AMADEUS (and MARKUS for Germany) promising to provide all information needed apart from the clear identification of the RES - technology sector. As further source of information, we rely on data compiled from the world-wide-web, project partners and/or from RE-associations. This supply side oriented approach explores the applicability of these databases. Detailed information on the database can be found in the Box of ANNEX 1.

The figures on employment from the AMADEUS database exploration and from the modelling results of Multireg show a rather good match for Germany and Austria. This can be largely explained with a language bias since the research has been conducted mainly by researchers whose native language is German. Further aspects have to be kept in mind while using the results:

- the gross employment effects comprise direct and indirect employment effects of RE. However, given by our search strategy the RES-dataset from AMADEUS covers mainly direct employment in economic sectors like energy generation, construction of generation equipment, plants or machinery and business services directly related to energy generation.
- the identification of especially the manufacturing companies is not all comprehensive as they do hardly display the corresponding search keywords in their companies' name and many are not organized in the relevant associations.
- a possible false identification of companies since they show a keyword (e.g. solar) in their name but have no relation to RE
- the share of employees that are working in the field of RES technologies is not always indicated for large-scale enterprises dealing/operating with a variety of technologies and products (e.g. Siemens)
- in general, the identification via AMADEUS is not complete since AMAEDUS does not comprise all companies engaged in RE. The identification via world wide web neither encompasses all companies with RES activities, rather leads to a biased selection - a selection of the larger companies.
- The biomass sector reveals too low figures in the AMADEUS database.

The idea to derive a size structure of the companies involved in RES activities from our RES database is considered as applicable for Germany. This is because the identification process for Germany included data from information services that comprise also small enterprises, a search in the worldwide web and information from associations. In Table 26 of the Annex 1: AMADEUS and MARKUS - Additional/detailed results and information the share of small, medium and large enterprises in each technology field for Germany, based on our RES database are calculated. It shows that in most of the technology fields the small enterprises' share (in number) is clearly above 80%.

All in all, the supply oriented approach is a first trial/step to establish a RES database about companies involved in RES activities and to get an idea about employment related to RES technologies. It can be said that the procedure to identify the companies is the critical point in the process and needs further improvement.

3 Future potentials for RES in Europe

For a comprehensive investigation of the possible future development of RES it is of crucial importance to provide a detailed investigation of the country- and region-specific deployment potential and corresponding generation cost of all available RES technologies. The FORRES 2020 study recently made major effort to assess Europe's RES resource base in a comprehensive manner. Consequently, this project directly builds on these consolidated outcomes as presented in the Commission's Communication 'The share of renewable energy' (COM 2004(366)). The specific action undertaken within this study was to extent the previously derived data on realisable RES potentials as assessed in the 2020 time-horizon to include the long-term perspectives in the 2030 timeframe.

3.1 Classification of potential categories

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. In order to contribute to the comprehension of the derived data, we start with an introduction on the applied terminology:

- *Theoretical potential:* For deriving 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 can be produced from a certain energy resource from a theoretical point-of-view – of course, 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 – e.g. with increased R&D conversion technologies might be improved and, hence, the technical potential would increase;
- *Realisable potential:* The realisable potential represents the achievable potential assuming that all existing barriers can be overcome and all driving forces are active. The realisable potential is limited by assumed maximum market growth rates and planning

constraints.[16] Therefore, the realisable potential has to refer to a certain year – it becomes substantially higher the further one looks into the future.

- *Mid-term potential:* The mid-term potential is equal to the realisable potential for the year 2020.

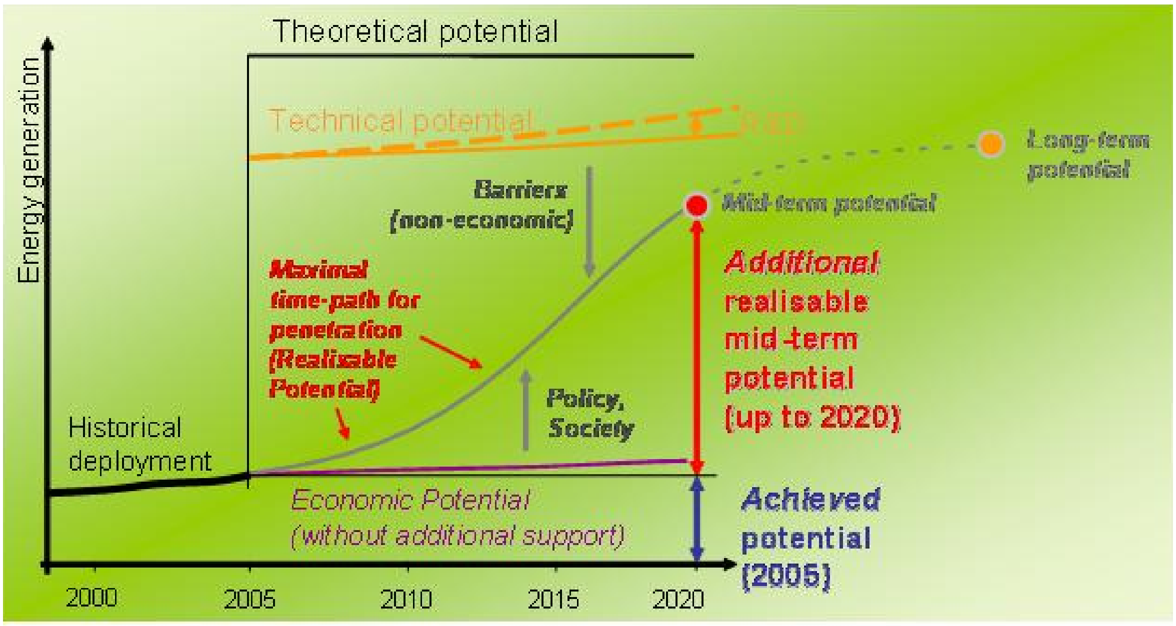


Figure 34: Methodology for the definition of potentials

Figure 34 shows the general concept of the realisable mid-term potential up to 2020, the technical and the theoretical potential in a graphical way.

Within the model ***Green-X***, 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

---

[16] Assumptions on maximum market growth rates and planning constraints are based on historic experience – i.e. at technology level a “best practice” evolution is preconditioned as observed in lead markets. Consequently, the realisable potential should not be misinterpreted as an absolute maximum: If policies, markets or technologies develop extraordinarily fast, the realisable potential given here can be exceeded.

- RES-T options include traditional biofuels such as biodiesel and bioethanol, advanced biofuels as well as the impact of biofuel imports

The potential supply of energy from each technology is described for each country 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 value in a given year depends on the value in the previous year and the (policy) framework conditions set.

Moreover, the availability of biomass and the allocation of biomass resources across sectors are crucial as this energy is faced with high expectations with regard to its future potentials. The total domestic availability of solid biomass by 2030 was set at 244 Mtoe/yr. Biomass data has been cross-checked with DG TREN, EEA and the GEMIS database[17]. In this context, Figure 35 indicates the dynamic evolution of the identified biomass primary potentials on EU27-level.

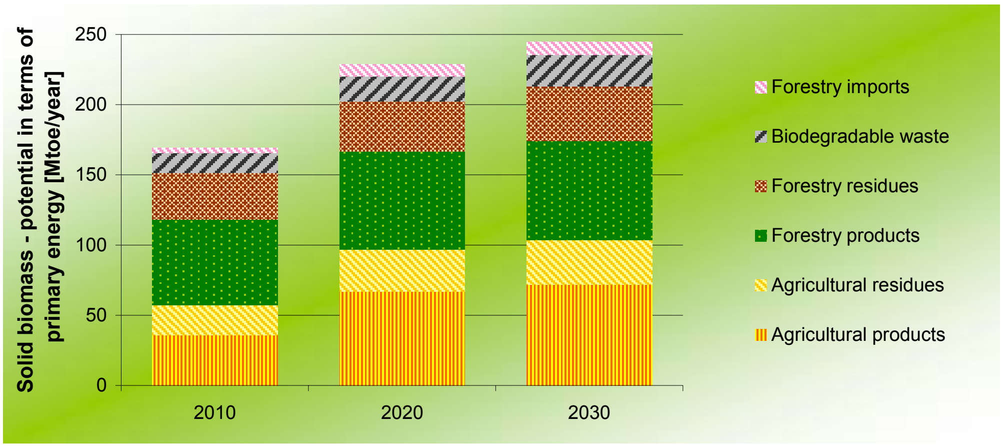


Figure 35: Biomass potentials in terms of primary energy for the years 2010, 2020, 2030

The allocation of biomass potentials in terms of primary energy to the various sectors and technologies is done within the Green-X model endogenously – based on feasible revenue streams under the scenario-specific assumed energy policy framework in place. For illustrative purposes in the subsequent sections where RES potentials are discussed sector by sector a draft sectoral pre-allocation of the primary biomass potentials is under-

---

[17] For example the recent EEA report "How much bio-energy can Europe produce without harming the environment?" gives 235 MtOE in 2020 for total biomass under the assumption of significant ecological constraints on biomass use.

taken. Consequently, scenario-specific deployment of electricity, heat or biofuels produced from biomass may exceed expressed potentials.

3.2 Comparison of realisable mid-term RES potentials (2020) to long-term RES potentials (2030)

In this section, according to the classification of the realisable potential the identified mid-term RES potentials (2020) are compared to the collected assessment on long-term potentials (2030).

As starting point, Figure 36 provides a comparison of the RES potentials at country level. Thereby, mid- (2020) and long-term (2030) potentials are depicted in relative terms, expressed as share on current (2005) gross final energy demand. This clearly depicts the importance of RES for energy supply, independent of the country size. Various countries posses significant RES potentials – e.g. in countries like Denmark, Estonia, Finland, Latvia, Lithuania, Portugal or Sweden the long-term potential is above 60% of current energy needs.

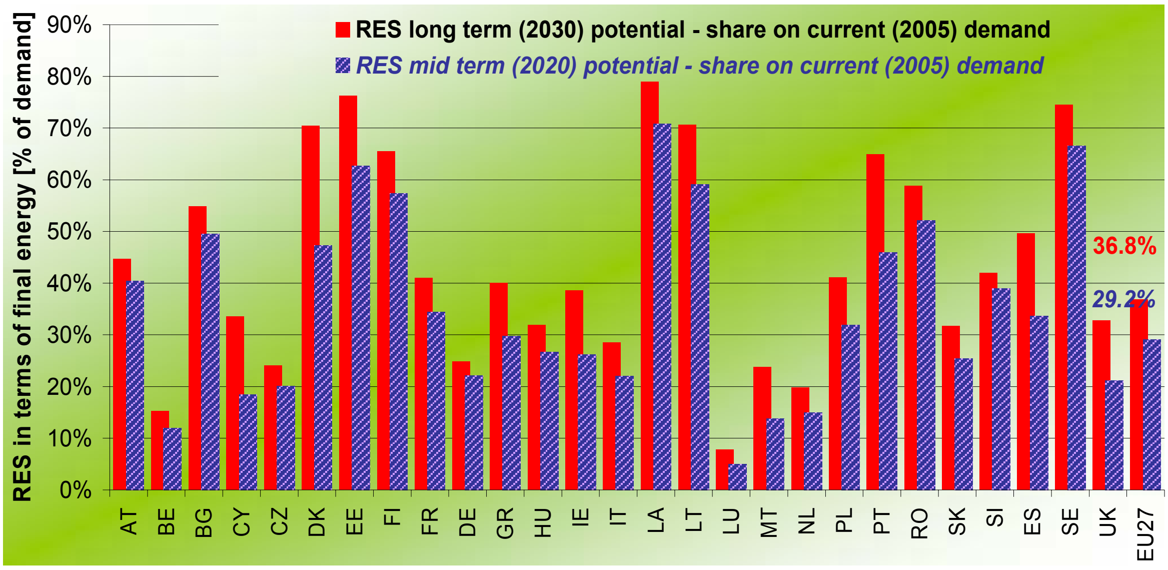


Figure 36: Comparison of mid-term (2020) and long-term (2030) realisable potential for RES in terms of gross final energy for all EU-27 Member States

As shown in Figure 36, the overall long-term RES potential up to 2030 at EU-27 level is 26% higher than the realisable mid-term potential in the 2020 timeframe, whereby differences are observable among the countries. At country level the strongest increase of the realisable RES potential in the period 2020 to 2030 occurs for Cyprus (87%), followed by Malta (71%), Luxembourg (57%), UK (54%), Denmark (49%), Ireland and Spain (both 47%). These are countries where novel RES options such as wind offshore, tidal stream, wave power or solar power – all technologies which are currently in an early phase of market deployment – hold a high share in the overall long-term RES potential.

In absolute figures, i.e. in terms of Mtoe electricity / heat / biofuels produced, the additional realisable potential of all EU-27 countries up to 2030 is 451 Mtoe – an increase of 94 Mtoe compared to the mid-term potential of 2020 or of 346 Mtoe in comparison to the achieved deployment as of 2005, respectively. Due to its country size France may contribute most in the mid- to long-run, with an additional potential of 51 Mtoe until 2030. Significant future potentials in absolute terms are also getting apparent in other large countries such as Germany (44 Mtoe), Spain (41 Mtoe) or the UK (49 Mtoe). Among the new Member States, high additional potentials until 2030 are identified for Poland (21 Mtoe) and Romania (11 Mtoe).

Remarkable is the shift of contribution among the three energy sectors. As presented in Figure 37, the potential contribution of the heat sector to final energy demand increases only slightly from 14% in 2020 to 14.8% in 2030, whereas the potential contribution of the electricity sector increases more substantially from 12% in 2020 to 16.6% in 2030. The potential contribution of the transport sector increases only marginally between 2020 and 2030.

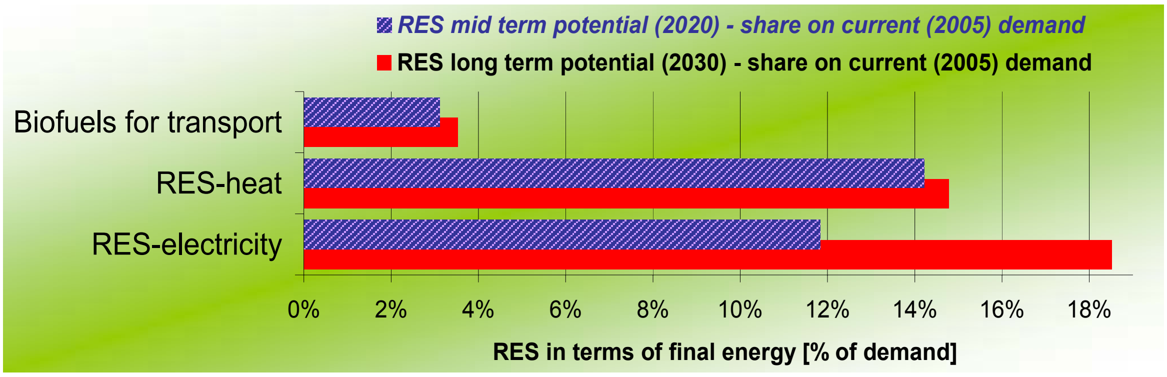


Figure 37: Sectoral breakdown of mid-term (2020) and long-term (2030) realisable potential for RES in terms of final energy at EU27 level – expressed in relative terms, as share on gross final energy demand

The strong increase of RES-E potentials beyond 2020 is mainly caused by the large additional realisable potential of wind offshore beyond 2020 and the increased availability of novel technology options such as photovoltaics or tidal & wave energy. In the case of photovoltaics almost a tripling of the realisable mid-term (2020) potential is indicated and for tidal and wave energy as well as solar thermal electricity even higher increases are assumed. However, wind onshore still provides the highest total potential among all RES-E options. In contrast, the large-scale hydro power and solid biomass potential remain almost stable beyond 2020. Figure 38 below presents an overview of the technology-specific contribution to the total realisable potential within the electricity sector, whereby mid- (2020) and long-term (2030) potentials are compared.

In contrast to above, with respect to the sectors of heat and transport the realisable mid-term potentials up to 2020 build to a large extent on bioenergy where no significant increase is assumed for the period 2020 to 2030.

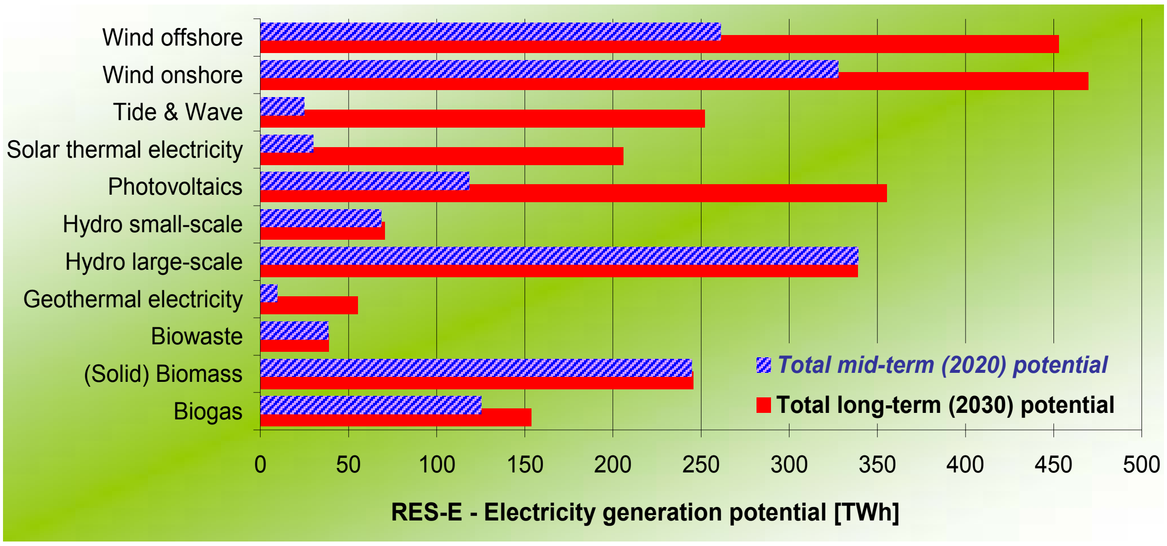


Figure 38: Total realisable potentials (2030) and achieved potential for RES-E in EU-27 countries on technology level

3.3 Realisable long-term (2030) potentials for RES in Europe

The following depiction aims to illustrate more closely to what extend RES may contribute to meet the energy demand within the European Union (EU-27) in the long-term (i.e. the year 2030) by considering the specific resource conditions and current technical conversion possibilities[18] as well as realisation constraints in the investigated countries. As explained before, *realisable long-term potentials* are derived, describing the possible RES contribution. Thereby, only the domestic resource base is taken into consideration – except for forestry biomass, where a small proportion of the overall potential refers to imports from abroad.[19]

We start with an overview on the overall long-term potentials in terms of (gross) final energy by country, followed by a detailed depiction of the individual sectors (electricity, heat, transport) and the corresponding RES technologies.

RES potentials in terms of gross final energy[20]

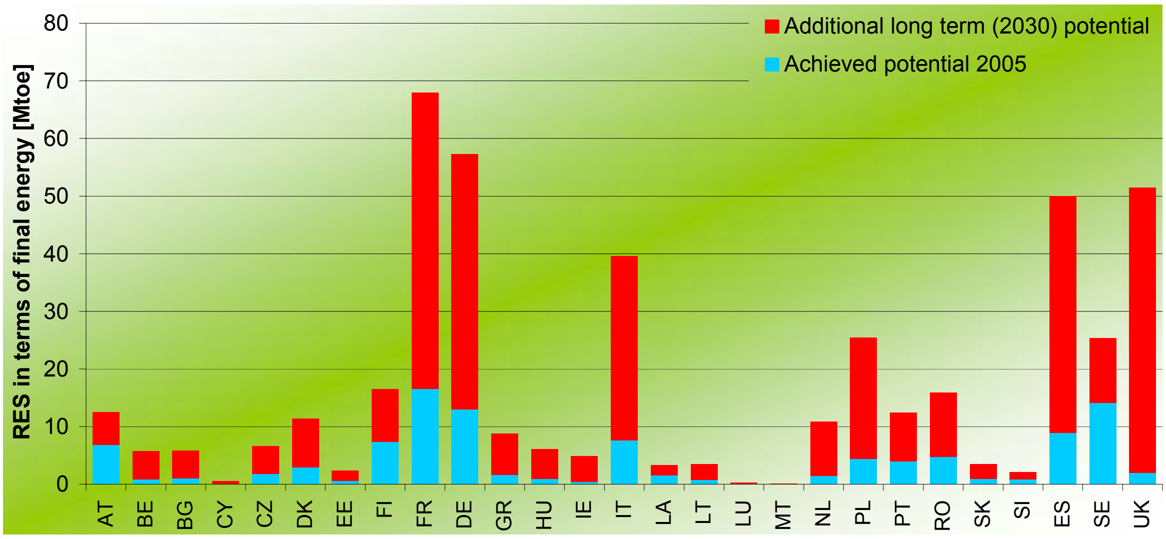


Figure 39: Achieved (2005) and additional long-term potential 2030 for RES in terms of gross final energy for all EU member states (EU27) – expressed in absolute terms

---

[18] The illustrated long-term potentials describe the feasible amount of e.g. electricity generation from combusting biomass feedstocks 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 mid-term potentials.

[19] Approximately 12.5% of the overall forestry potential or 30% of the additional forestry resources that may be tapped in the considered time horizon refer to such imports from abroad.

[20] Gross final energy is expressed in line with the definition given in the Renewable Energy Directive for 2020 as agreed by European Parliament and Council.

Summing up all RES options applicable at country level, Figure 39 depicts the achieved and additional long-term potential for RES in all EU member states. Potentials are expressed in absolute terms and the large Member States appear to have the largest absolute RES potentials, e.g. France, Germany, Italy, Poland, Spain, Sweden and the UK. Figure 40 offers a similar depiction in relative terms, expressing the realisable long-term potential as share on final energy demand.

The overall long-term potential for RES in the EU amounts to 451 Mtoe, corresponding to a share of 37% 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 potential 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 Denmark offer the highest additional potential compared to their current energy demand. However, in absolute terms the potential in both of these groups is rather small compared to other countries large in size or, more precisely, with large realisable future potentials.

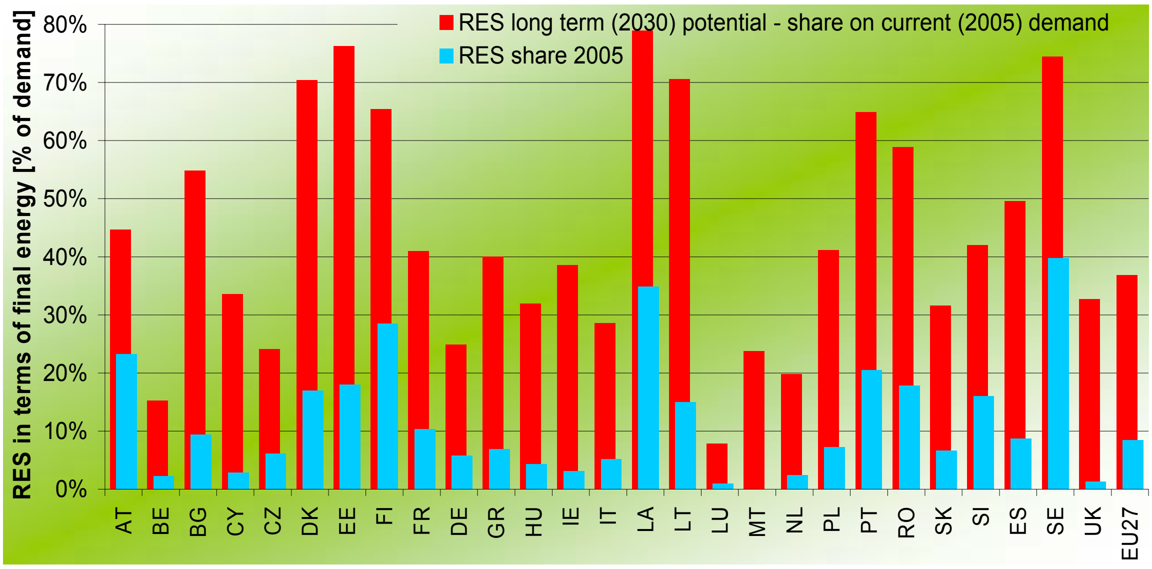


Figure 40: Achieved (2005) and total long-term (2030) potential for RES in terms of final energy for all EU member States (EU27) – expressed in relative terms, as share on final energy demand

The red and the turquoise bars in Figure 41 below are the same as in Figure 40, but Figure 41 additionally relates the total realisable long-term potentials (up to 2030) for RES to two different demand projections – a baseline and an energy efficiency scenario[21]. The impact of setting accompanying demand side measure to reduce demand growth is getting apparent: Even if the indicated realisable long-term potential for RES would be fully exploited up to 2030, only 29% of EU's overall final energy consumption could be covered, if the demand increases as expected under 'business as usual' conditions. In contrast, if a demand stabilisation would be achieved as preconditioned in the 'energy efficiency' case, RES may contribute to meet more than 38% of total demand in terms of final energy.

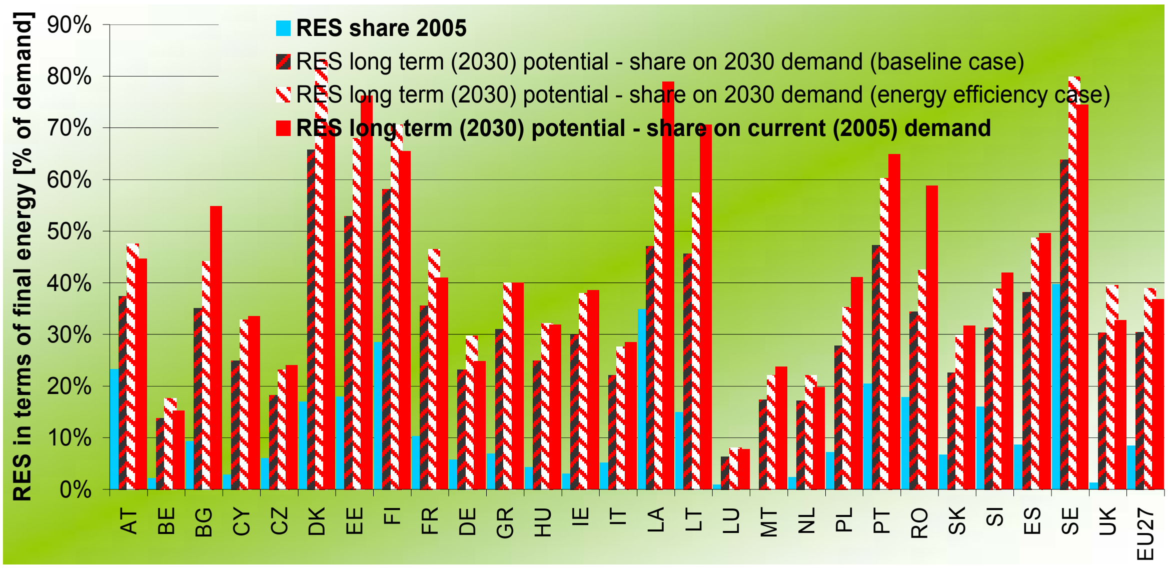


Figure 41: The impact of demand growth - Long-term (2030) potential for RES as share on current (2005) and expected future (2030) final energy demand

---

[21] In order to ensure maximum consistency with existing EU scenarios and projections, the demand projections are derived from PRIMES modelling:

- The European Energy and Transport Trends by 2030 / 2007 / Baseline
- The European Energy and Transport Trends by 2030 / 2007 / Efficiency Case (17% demand reduction compared to baseline)

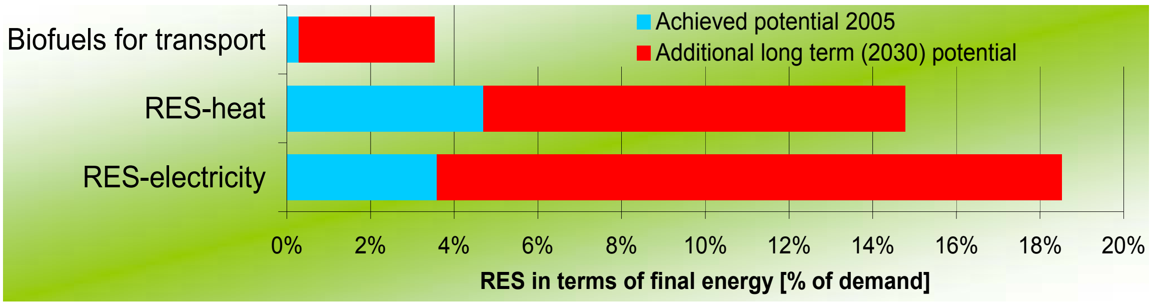


Figure 42: Sectoral breakdown of the achieved (2005) and additional long-term (2030) potential for RES in terms of final energy at EU27 level – expressed in relative terms, as share on final energy demand

Finally, a sectoral breakdown of the realisable RES potentials at European level is given in Figure 42. Both the electricity and the heat sector appear as possible large contributors to future RES targets, with the highest contribution among all energy sectors at present (2005) coming from RES heat. Although both sectors are significant in terms of current exploitation still large amounts appear feasible for the near to long future. The overall long-term potential compared to the current (2005) gross final energy demand is 18.5% for RES-electricity and 14.8% for RES-heat. The smallest contribution can be expected from biofuels in the transport sector, which offer, considering solely domestic resources, a potential of 3.5% on current gross final energy demand.

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[22] – 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 2030 – were assessed[23] taking into account the country-specific situation as well as overall realisation constraints.

---

[22] 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.

[23] A brief description of the potential assessment with regard to the underlying mid-term (up to 2020) potentials for RES-E is given e.g. in (Resch et al., 2006).

Figure 43 depicts the achieved and additional long-term potential for RES-E in the EU-27 at country level. For EU-27 countries, the already achieved potential for RES-E equals 510 TWh, whereas the additional realisable potential up to 2030 amounts to 2129 TWh (about 65% of current 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.

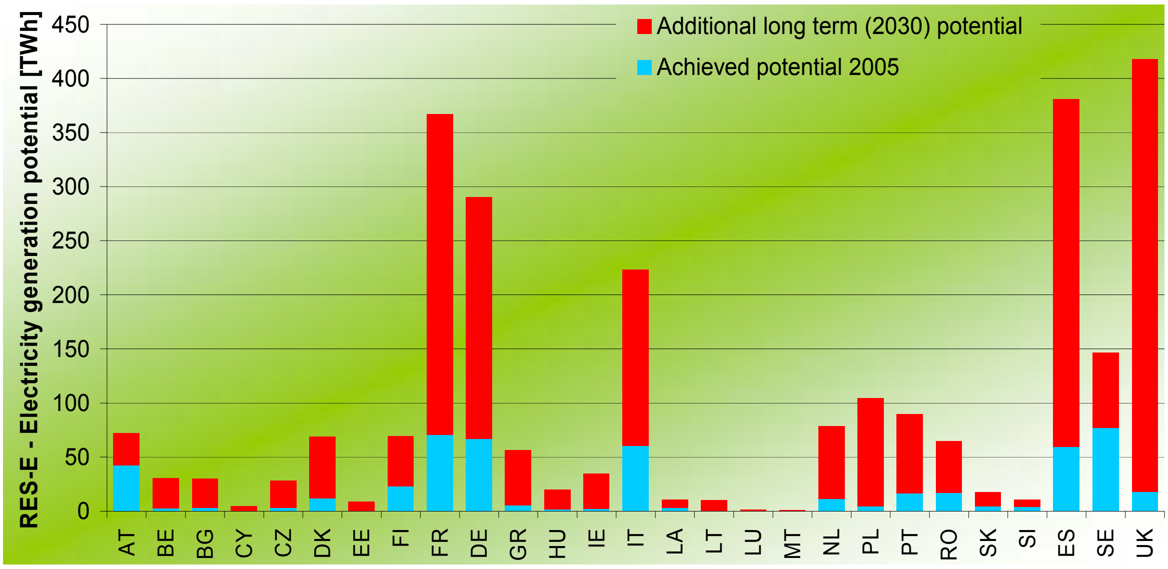


Figure 43: Achieved (2005) and additional long-term potential 2030 for electricity from RES in the EU-27 on country level

Next Figure 44 relates derived potentials to gross electricity demand. More precisely, it depicts the total realisable long-term potentials (up to 2030), as well as the achieved potential (2005) for RES-E as share of gross electricity demand in 2005 for all EU-27 countries as well as the EU-27 in total. Comparatively large additional potentials in order to cover major shares of the national electricity demand by RES are notable for Denmark, Ireland, Spain and the United Kingdom, 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 2030 in the EU-27, RES-E would cover about 80% of current gross electricity demand - whereas nowadays already installed RES-E plants possess the generation potential to meet about 16% of the electricity demand.

The red and the turquoise bars in Figure 45 below are the same as in Figure 44 above, but Figure 45 additionally relates the total realisable long-term potentials (up to 2030) for RES-electricity to two different demand projections – a baseline and an energy efficiency scenario. A strong impact of the electricity demand development on the share of renewables is noticeable: In a baseline demand scenario a RES-E share of 60% in the year 2030 would appear feasible – in an efficiency demand scenario 71%. As already discussed in the previous paragraph, if compared to current gross consumption, a share of even 80% would be feasible, showing that even the efficiency demand scenario takes an increasing absolute electricity demand into account.

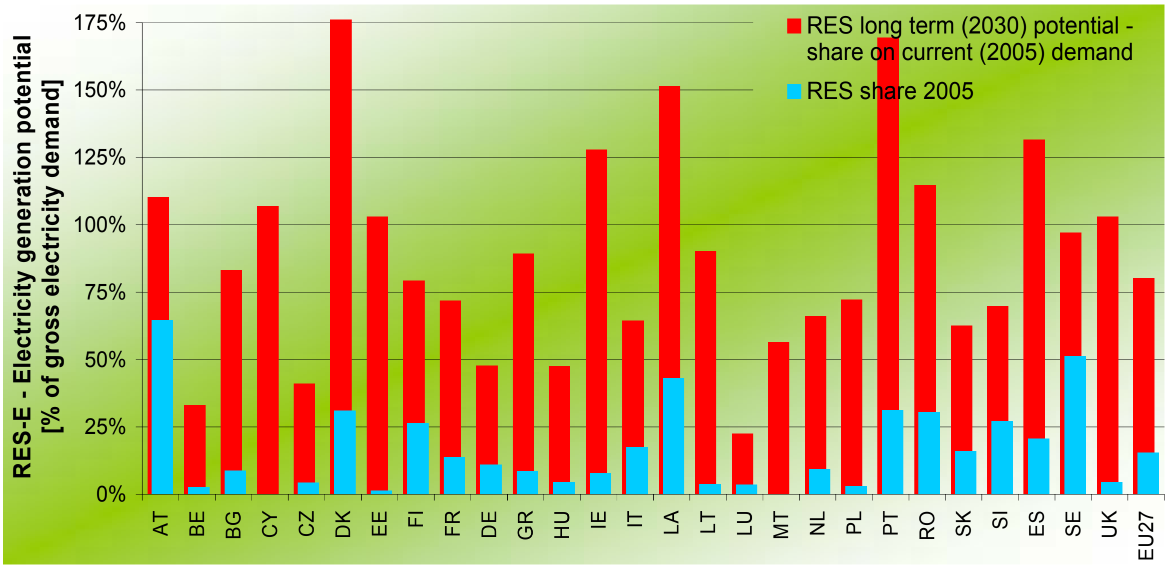


Figure 44: Total realisable long-term potentials (2030) and achieved potential for RES-E in EU-27 countries as share of gross electricity demand (2005)

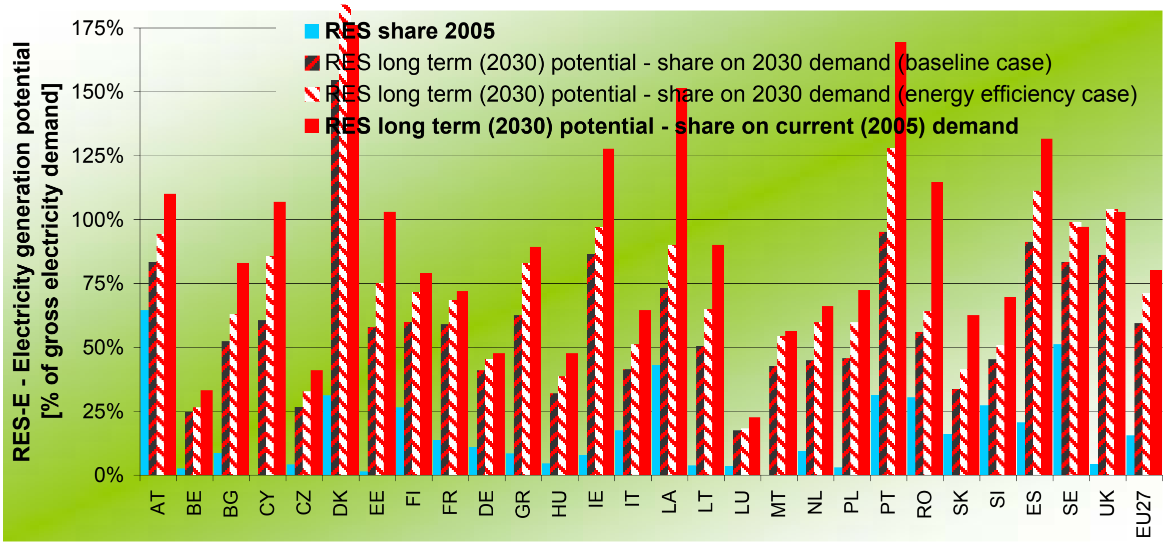


Figure 45: Total realisable long-term potentials (2030) and achieved potential for RES-E in EU-27 countries as share of gross electricity demand (2005 & 2030) in a baseline and an efficiency demand scenario

Figure 46, below, demonstrates the achieved as well as the additional realisable long-term potential up to 2030 on a technology level for the whole EU-27. The figure depicts a high penetration and a small additional realisable potential for hydropower, both small- and large-scale. Wind onshore and solid biomass are already well developed but still provide an enormous additional potential in order to meet future RES-E targets. Moreover, technologies like wind offshore, tide and wave and photovoltaics provide a large additional potential to be exploited up to 2030.

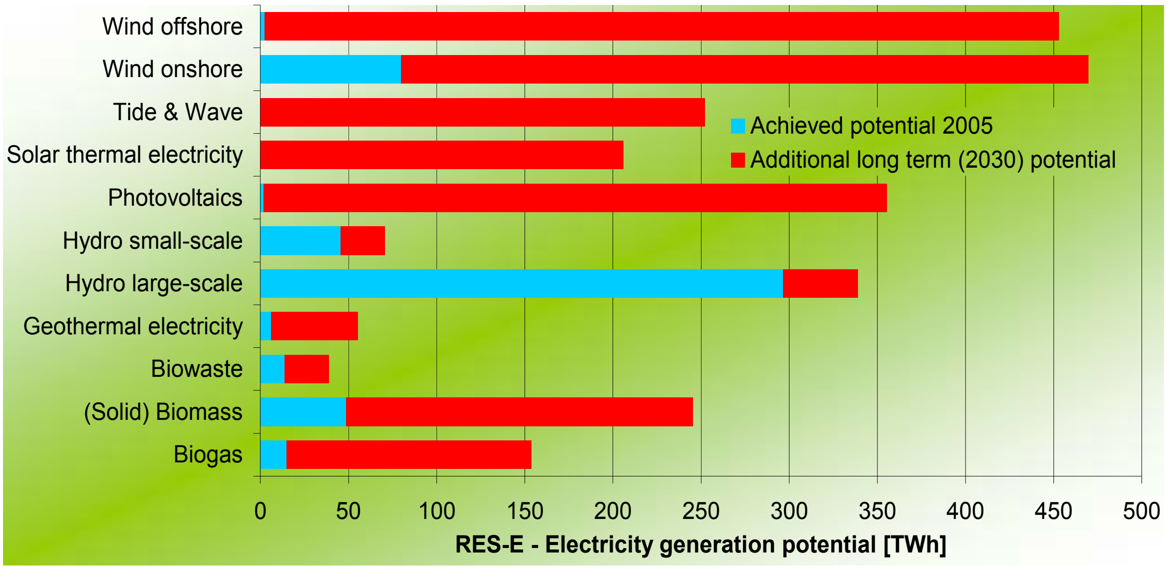


Figure 46: Total realisable long-term potentials (2030) and achieved potential for RES-E in EU-27 countries on technology level

Next, future perspectives are indicated at the country level. As already mentioned, hydropower dominates current RES-E generation in most EU countries, followed by wind, biomass, biogas and biowaste. Figure 47 shows the share of different energy sources in the *additional* RES-E long-term potential up to 2030 for the EU-15. The largest potential is found in the sector of wind energy (42%) followed by photovoltaics (17%), solar thermal energy (12%) and solid biomass (9%) as well as promising future options such as tidal & wave (7%).

Figure 48 provides the corresponding depiction for New Member States (NMS. In line with the EU-15, the largest potentials for these countries exist in the sectors of wind energy (32%) and photovoltaics (25%) followed by solid biomass (19%). Unlike the situation in the EU-15, the refurbishment and construction of large hydro plants holds significant potentials (5%). With regard to the current situation in the NMS, almost 88% of the renewable electricity is generated by hydro power plants and 10% by solid biomass, mainly cofired in thermal fossil fuel-based power plants, whereas only a minor part is provided by novel technologies like wind energy and biogas.

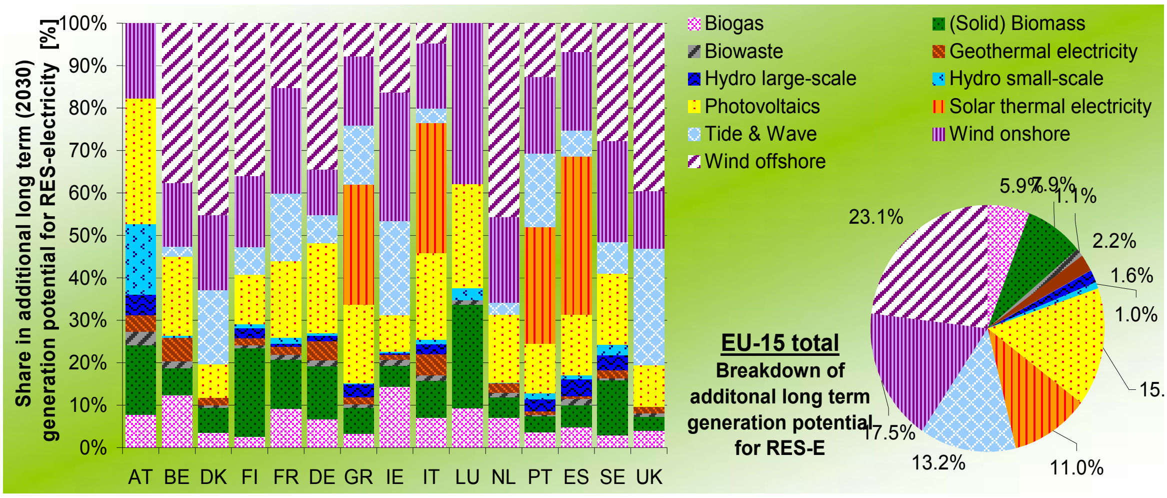


Figure 47: RES-E as a share of the additional realisable potential in 2030 for the EU-15 – by country (left) as well as for total EU-15 (right)

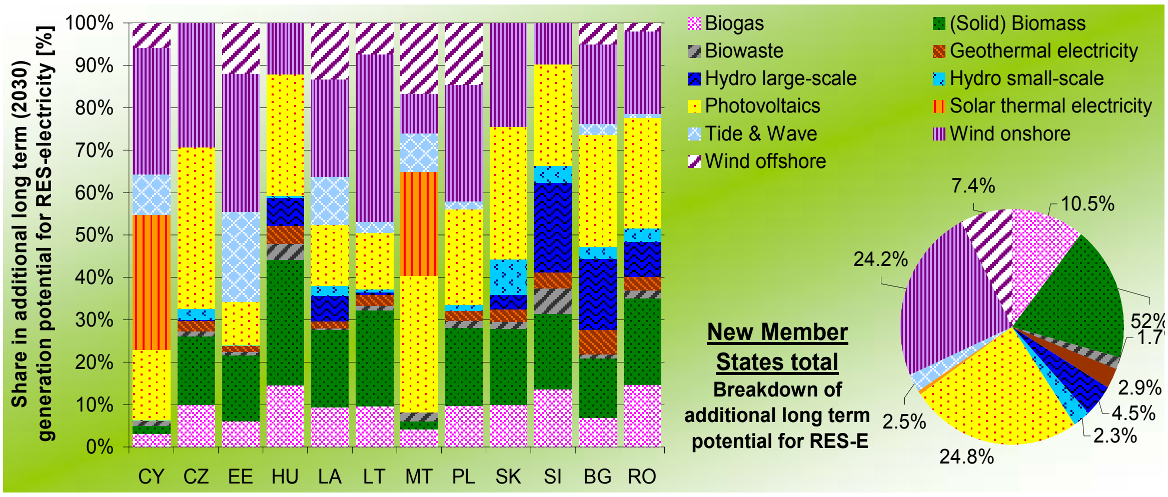


Figure 48: RES-E as a share of the additional realisable potential in 2030 for the NMS – by country (left) as well as for total NMS (right)

Heat sector

As shown in Figure 42, an ambitious development of renewables within the heat sector is possible and important. In order to estimate the additional realisable potential each Member State's technical potential and realisation constraints – i.e. non-economic barriers such administrative, technical, and social hindrances – were taken into account. The historical assessment is based on the same methodology as used for the electricity sector, i.e. building on a comprehensive data-collection (Eurostat, 2007; IEA, 2007) and statistical information gained on national level.

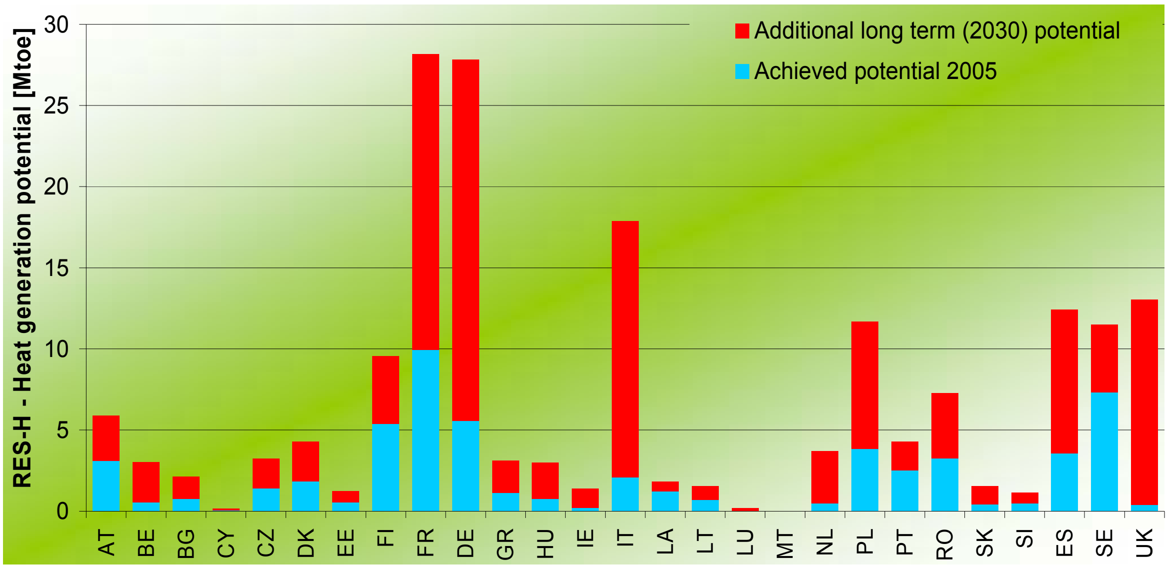


Figure 49: Achieved (2005) and additional long-term potential (2030) for heat from RES in the EU-27 on country level

In Figure 49 the achieved potential (2005) as well as the remaining additional potential for heat from RES-heat is presented at country level. Remarkable appears the large achieved potential in France, Sweden, Poland and Romania. Generally, a large additional potential is waiting to be exploited in the forthcoming years up to 2030. The achieved heat potential amounts to 57.5 Mtoe in the year 2005, whereof 44.1 Mtoe (about 77%) are generated in the former EU-15 countries. The additional realisable long-term potential up to 2030 is 124 Mtoe with a contribution of 21 Mtoe from New Member States.

Complementarily, Figure 50 presents the derived potentials in relation to current gross heat demand. In Member States like Finland, Sweden or Latvia the current (2005) RES share in overall heat demand and the total realisable RES heat potential up to 2030 are high, whereas in countries like Germany, Italy or Malta only a minor part of the long-term RES-H potential is exploited so far. At EU-27 level about one third of the total long-term RES-H potential is already used, covering 10% of the gross heat demand.

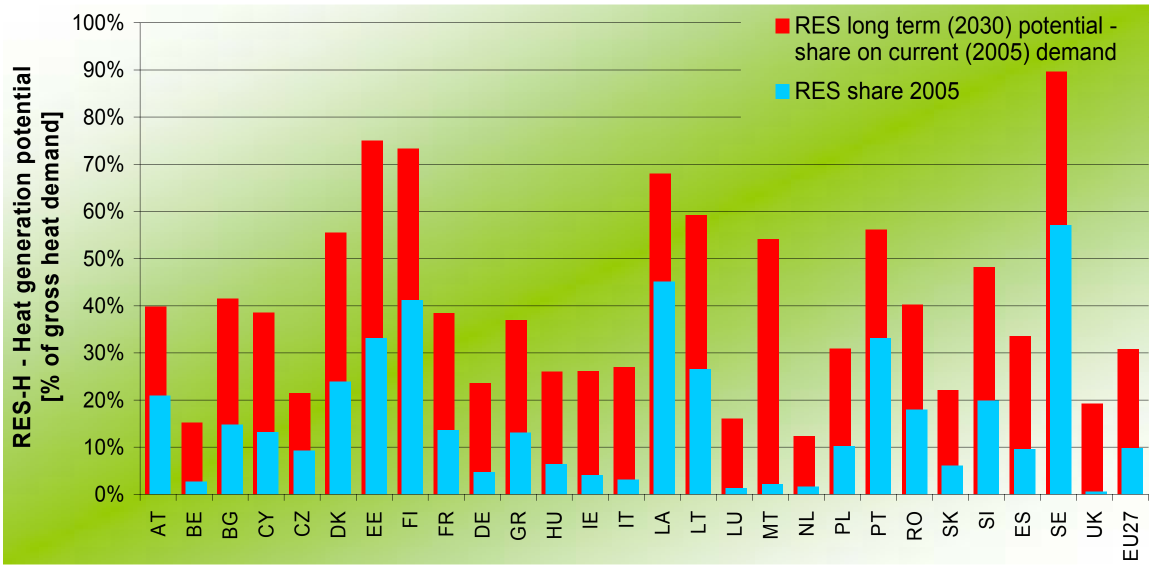


Figure 50: Total realisable long-term potentials (2030) and achieved potential for RES-H in EU-27 countries as share of gross heat demand (2005)

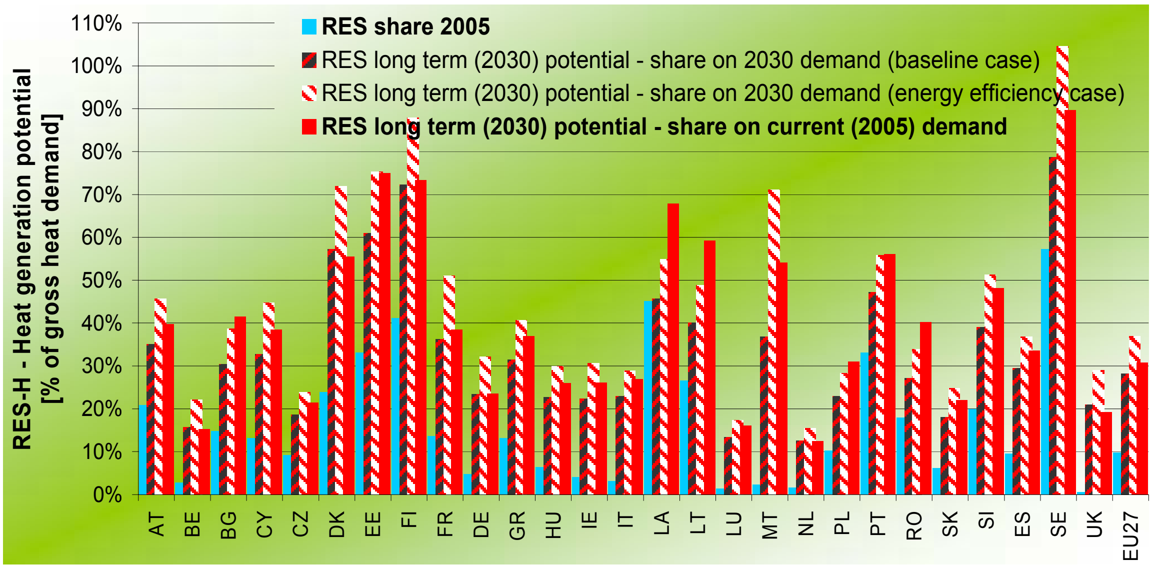


Figure 51: Total realisable long-term potentials (2030) and achieved potential for RES-H in EU-27 countries as share of gross heat demand (2005 & 2030) in a baseline and an efficiency demand scenario

The red and the turquoise bars in Figure 51 above are the same as in Figure 50, but Figure 51 additionally relates the total realisable long-term potentials (up to 2030) of RES-heat to two different total heat demand projections – a baseline and an energy efficiency scenario. The impact of the heat demand development on the share of renewables varies among the Member States, i.e. Malta, Estonia or Sweden show a large impact, whereas hardly any impact is notable for the Netherlands or Luxemburg. Generally, a baseline demand scenario leads to a maximal achievable RES-H share of only 28% in the year 2030, whereas in an efficiency demand scenario 37% of the EU-27's heat demand could be produced from renewables. As already discussed in the previous figure, this corresponds to a RES heat share of 30% in current (2005) gross heat consumption, meaning that in the efficiency scenario a reduction of the heat demand is projected up to 2030.

In principle in the renewable heat sector a distinction between non-grid connected heat (or decentralised heat), like solar collectors, heat pumps and decentral small-scale biomass heat, and grid-connected heat, such as geothermal heat and biomass heat from Combined Heat and Power (CHP) or District Heating (DH) plants is applied. With respect to the achieved potential, decentral biomass heat is by far the strongest developed technology, being dominated by log wood. In total terms, in the non-grid connected sector the total realisable long-term potential is already exploited by 37%, whereas in the grid-connect heat sector only 18% are realised yet, as indicated in Figure 52. Within the sector of grid-connected heat supply biomass heat represents the strongest developed technology at present, similar to non-grid heat. Generally, geothermal heat plants on the one hand, and solar collectors as well as heat pumps on the other hand play only a minor role so far, but offer a large long-term potential up to 2030.

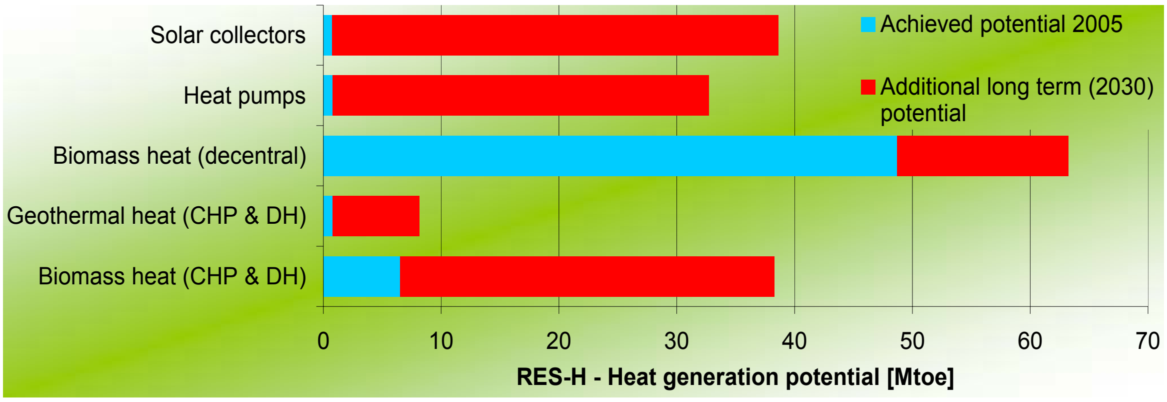


Figure 52: Total realisable long-term potentials (2030) and achieved potential for RES-H in EU-27 countries on technology level

In the following, the additional realisable RES-H potential is discussed in further detail at country and technology level. Decentral biomass heat dominates the current heat market, whereas solar collectors (32%) hold the major share of the additional realisable future potential in the former EU-15 countries, see Figure 53. Heat pumps (27%) and grid-connected biomass heat (24%) show a large potential, whereas non-grid connected biomass heat only possesses a significant future potential in Austria, Ireland, Luxemburg and the Scandinavian region among EU15 countries. Long-term future potentials for geothermal heat exist mainly in Denmark and Italy.

Corresponding to Figure 53, Figure 54 depicts the share of different RES-H options in the additional realisable RES-H potential up to 2030 for the NMS. In contrast to the EU-15, the largest potentials for these countries exist in the sector of grid-connected heat supply for solid biomass (35%). Unlike the situation in the EU-15, the potential for solar collectors (23%) is not equally distributed among the countries, but major shares are observable for Cyprus and Malta – due to their low potential for biomass heat. Heat pumps (21%) and non-grid biomass heat (14%) are also important in the NMS. With regard to the current situation in the NMS, 92% of the RES heat refers to solid biomass used in small-scale applications whereas hardly any contribution comes from novel technologies like solar collectors, heat pumps or geothermal heat.

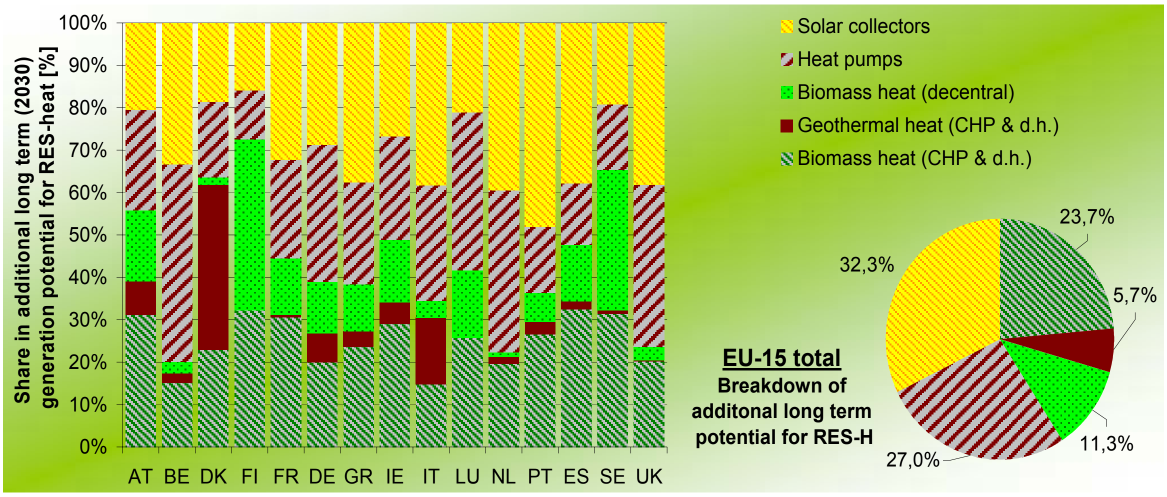


Figure 53: RES-H as a share of the additional realisable potential in 2030 for the EU-15 – by country (left) as well as for total EU-15 (right).

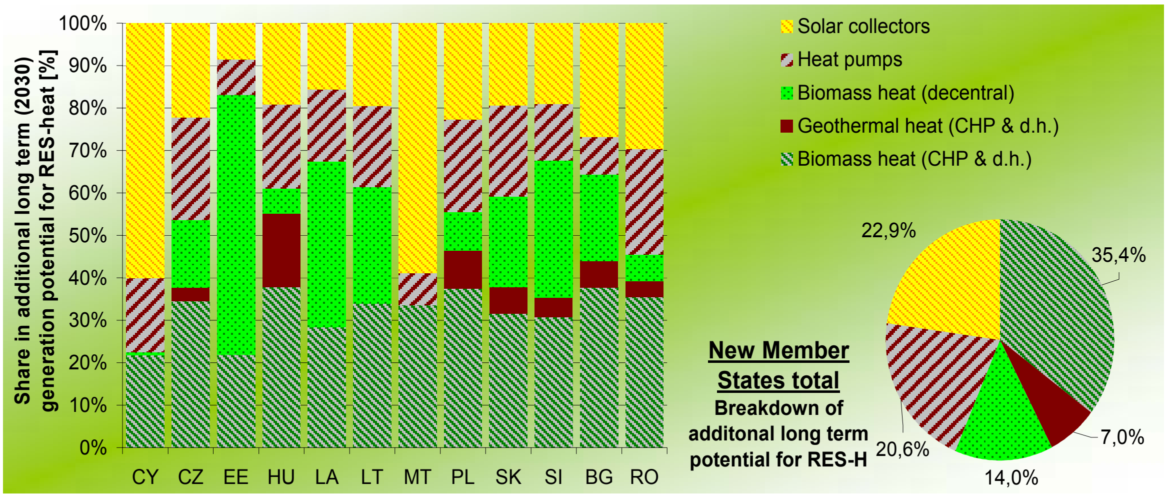


Figure 54: RES-H as a share of the additional realisable potential in 2030 for the NMS – by country (left) as well as for total NMS (right)

Transport sector

In order to meet the EU's ambitious 2020 RES targets of 20% in final consumption as well as the separate target of 10% in the transport sector by 2020 it is important to address the transport sector as well, since it offers a large additional potential compared to the currently achieved one. In order to estimate the additional realisable potential each Member State's technical potential and realisation constraints were taking into consideration. The historical assessment is based on the same methodology as in the electricity or heat sector, building on a comprehensive data-collection (Eurostat, 2007; IEA, 2007) and statistical information gained on national level.

In Figure 55 the achieved potential (2005) as well as the additional potential up to 2030 for biofuels in the transport sector is indicated on country level. It is remarkable that the renewable transport sector is by far the most poorly developed sector, since only Germany, France, Italy and Spain have a significant biofuel share at present. Nevertheless, large additional realisable long-term potential exist in most Member States, especially in France, Poland, Spain, the UK and Italy. The achieved biofuel potential amounts to 3.5 Mtoe in the year 2005, whereas 3 Mtoe (about 85%) refer to biodiesel. With respect to the additional realisable long-term potential up to 2030, the EU-27's domestic resource base amounts to 39.7 Mtoe.

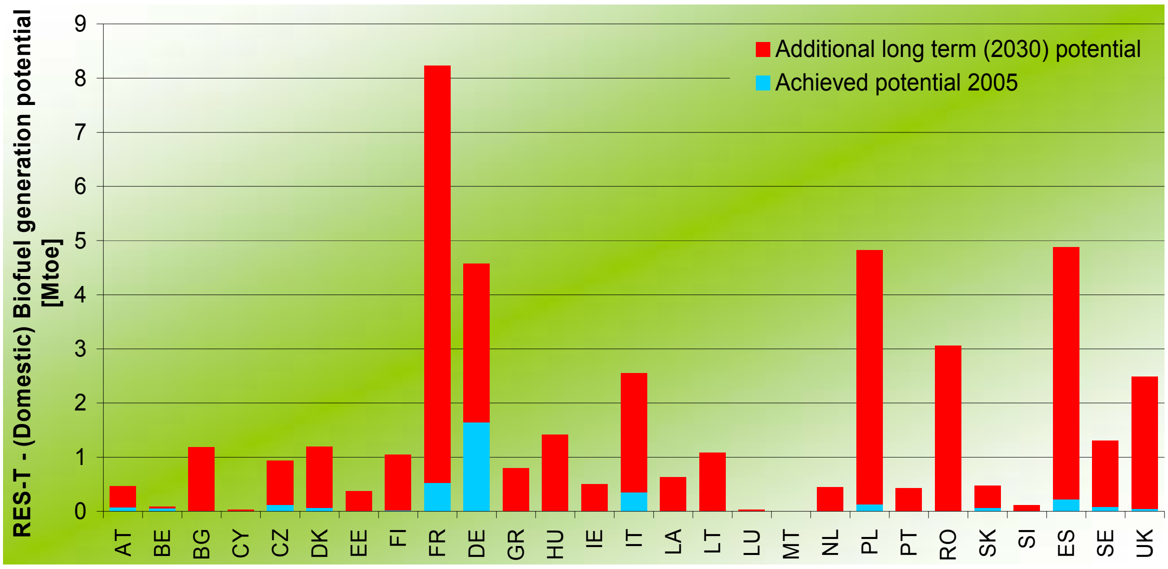


Figure 55: Achieved (2005) and additional long-term potential 2030 for biofuels in the transport sector in the EU-27 on country level

Below Figure 56 depicts for biofuels the relation of the additional realisable long-term potential as well as the already achieved potential (2005) to the gross transport fuel demand. As discussed above, France and Germany have a large long-term potential for biofuels, but taking their overall transport fuel demand into consideration this appears relatively small. Especially NMS have a large long-term potential compared to their current national demand; Lithuania 78%, Romania 75%, Latvia 64% or Bulgaria 47%. Regarding the achieved potential, only 1% of the current transport fuel demand throughout Europe is met by biofuels.

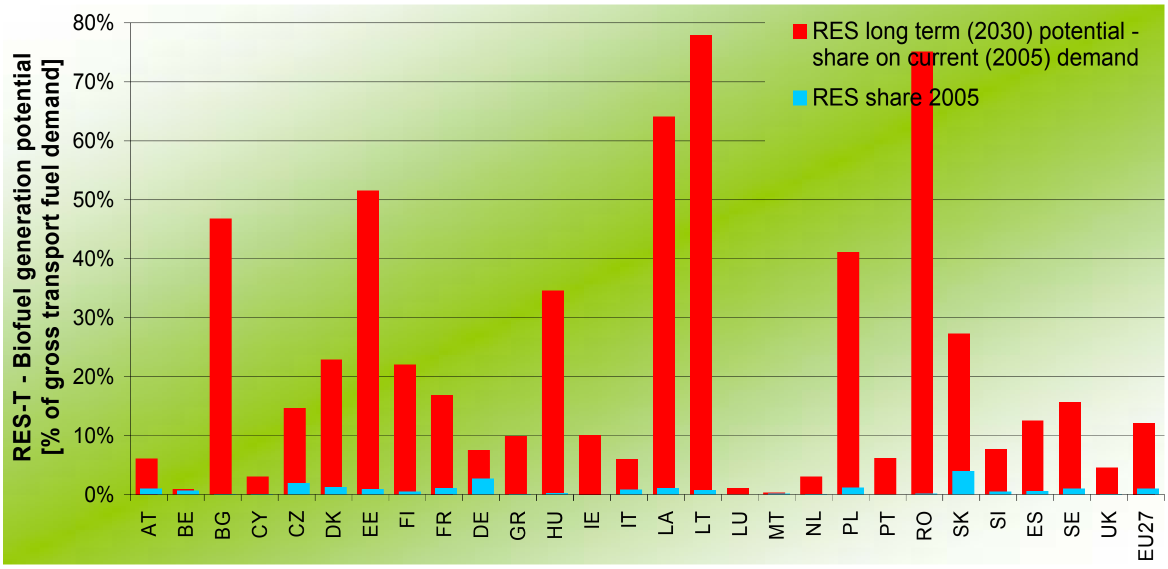


Figure 56: Total realisable long-term potentials (2030) and achieved potential for biofuels in EU-27 countries as share of gross transport fuel demand (2005)

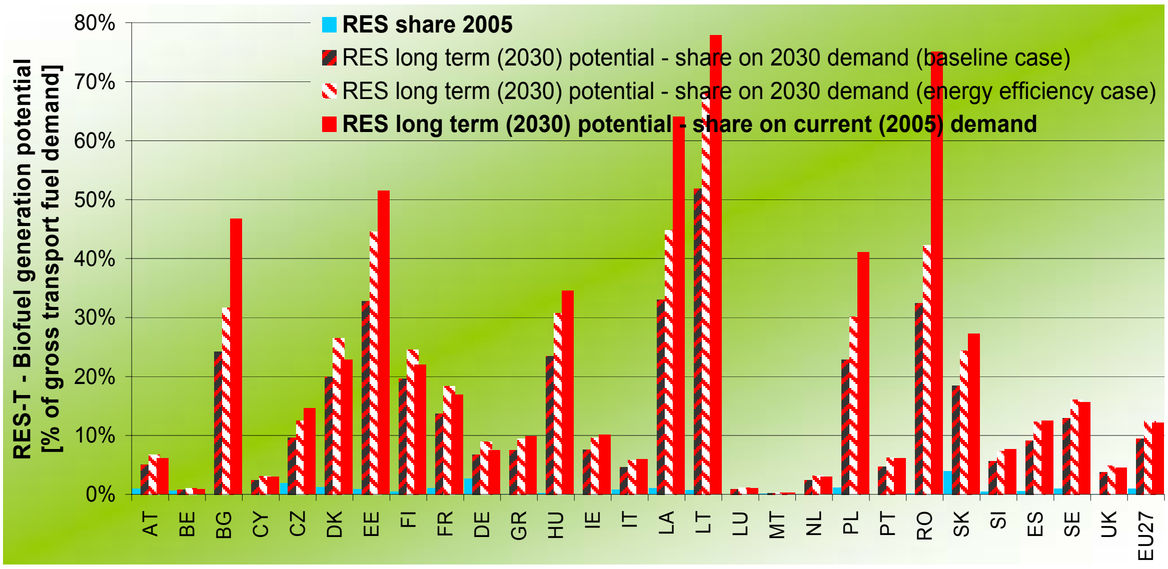


Figure 57: Total realisable long-term potentials (2030) and achieved potential for biofuels in EU-27 countries as share of gross transport fuel demand (2005 & 2030) in a baseline and an efficiency demand scenario

The red and the turquoise bars in Figure 57 Figure 41above are the same as in Figure 56, but Figure 57 additionally relates the total realisable long-term potentials (up to 2030) for biofuels to two different total transport fuel demand projections – a baseline and an energy efficiency scenario. Previously mentioned Member States that show a comparatively large realisable long-term potential are responding very sensitive to the development of the transport fuel demand, whereas hardly any impact is noticeable in countries with poor national long-term potentials, i.e. most of the former EU-15 countries. In general, applying the baseline demand scenario leads to biofuel share of only 8.7% in the year 2030, whereas according to an efficiency demand projection 11.4% of the transport fuel demand could be produced by biofuels. The importance of stabilising the demand for transport fuels is getting apparent in Figure 57.

4 Future renewable energy deployment

The core objective of this working task is to provide a detailed depiction of future RES opportunities up to 2030 within the European Union, considering deployment of RES technologies in EU Member States under different RES policy assumptions. Complementary to this, the assumed corresponding global RES deployment – i.e. more precisely the exploitation of RES technologies in the rest of the world (ROW) – and the related export opportunities for European economies are discussed then subsequently in section 5.

4.1 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 within among others the project FORRES 2020 and fulfils all requirements as set out in this tender with regard to the analytical framework for the assessment.

It covers geographically the EU-27, and can easily be extended to other countries such as Turkey, Croatia or Norway. It allows to investigate the future deployment of RES as well as accompanying cost – comprising capital expenditures, additional generation cost (of RES compared to conventional options), transfer cost due to applied supporting policies, etc. – at country- and technology-level on a yearly basis. The time-horizon was initially limited to 2020, which has been extended within this project to assess the perspectives up 2030. The modelling approach to describe supply-side generation technologies is to derive dynamic cost-resource curves by RES option, allowing besides the formal description of potentials and costs a detailed representation of dynamic aspects such as technological learning and technology diffusion.

Besides the detailed depiction of RES deployment and cost the model also allows to briefly investigate the impact of applying different energy policy instruments (e.g. quota obligations based on tradable green certificates, feed-in tariffs, tax incentives, investment subsidies) at country or at the European level. Sensitivity investigations for key input parameters such as non-economic barriers (influencing the technology diffusion), conventional energy prices or energy demand developments complement the policy assessment.

Investigated cases

First, an overview is given on the investigated scenario paths and cases. Please note that, geographically, all ***Green-X*** scenarios refer to the European Union as of 2008, comprising 27 member states. Results on RES deployment and accompanying parameters such as additional generation cost, transfer cost due to RES support etc. are derived on a yearly basis covering the time horizon 2006 to 2030. Obviously, the RES policy pathway for the years up to 2020 appears well defined given the new EU RES directive and the corresponding national RES targets for the year 2020. Exploring the RES development beyond 2020 means to enter a terrain characterized by a higher level of uncertainty – both with respect to the policy pathway as well as with regard to potentials and cost for applicable RES technology options. A simple decision was taken on the policy framework, where a continuation of the previously applied ambition level regarding RES support is preconditioned in the scenario calculation.

Thus, the model runs try to consider the spread of possible RES policy options within the EU as follows:

- **“No policy” case**: As reference for the subsequent macroeconomic assessment the virtual case of no further RES support until 2030 is calculated
- **BAU case**: RES policies are applied as currently implemented (without any adaptation) – business as usual (BAU) forecast.
- **Accelerated deployment policies (ADP):** Hereby it is assumed that the European RES policy framework will be improved with respect to its efficiency and effectiveness. These changes will become effective by 2011 in order to meet the agreed target of 20% RES by 2020. Improvements refer to both the financial support conditions (if necessary) as well as to non-financial barriers (i.e. administrative deficiencies etc.) where a rapid removal is also preconditioned. For the ambitious deployment path two variants have been conducted:
    - A **“policy” case** (default ADP) which assumes an improvement of RES support incentives for all EU member states. A continuation of national RES policies until 2030 is assumed, which will be optimised with regard to their efficiency and effectiveness. The further fine-tuning of national support schemes involves in case of both feed-in tariff and quota systems a technology-specification of RES support. The fulfilment of the target of 20% RES by 2020 is preconditioned at EU level as well as at national level. For the case that a Member State (MS) would not possess sufficient potentials, MS based trade (i.e. where MS posses the possibility to transfer their surplus to other MS) would serve as complementary option to fulfil given 2020 RES objectives. For the period beyond 2020 intensified cooperation between MS is preconditioned, meaning a step towards intensively coordinated RES support all over Europe and an enhanced sharing of corresponding costs and benefits.

- A **“least cost” variant** was conducted as an alternative policy variant where uniform RES support was preconditioned for all RES technologies all over Europe.

Noticeable, the macroeconomic assessment is based solely on the policy case, whilst the least cost case serves for a concise policy discussion.

Overview on key input parameters

Besides the comprehensive ***Green-X*** database for RES – which includes potentials and costs for RES-E within Europe on a country and technology level and assumptions with respect to future technological change and technology diffusion, etc. – the assumptions made regarding the applied policy instruments are discussed below in a concise manner.

In order to ensure maximum consistency with existing EU scenarios and projections, the key input parameters of the scenarios are derived from PRIMES modelling and from recent assessments of the European RES market (FORRES 2020, OPTRES, PROGRESS). Table 12 shows which parameters are based on PRIMES and which have been defined for this study. More precisely, the PRIMES scenarios used are:

- The European Energy and Transport Trends by 2030 / 2007 / Baseline
- The European Energy and Transport Trends by 2030 / 2007 / Efficiency Case (16% demand reduction compared to baseline)
- The PRIMES scenario on meeting both EU targets by 2020 – i.e. on climate change (20% GHG reduction) and renewable energies (20% RES by 2020) / 2008 (PRIMES target case)

Table 12: Main input sources for scenario parameters

Based on PRIMES	**Defined for this study**
Energy demand	Reference electricity prices
Primary energy prices	RES cost (based on FORRES 2020, PROGRESS)
Conventional supply portfolio and conversion efficiencies	RES potential (based on FORRES 2020, PROGRESS)
CO_2 intensities	Biomass import restrictions
	Technology diffusion
	Learning rates
	Weighted average cost of capital (WACC)

- Energy demand

  In general, it is hypothesized that improved RES policies are accompanied by an active energy efficiency policy (i. e. building on the *PRIMES efficiency case*) whereas no proactive demand side measures (DSM) are presumed in the case of a continuation of current RES support (BAU). To illustrate solely the impact of DSM, a sensitivity case is conducted in addition to the default scenarios.

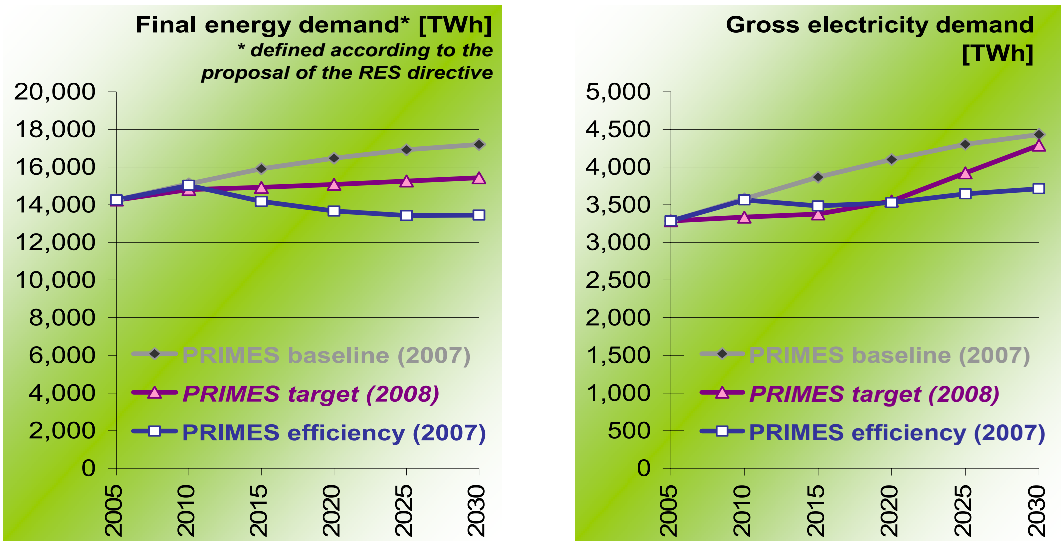


Figure 58: Comparison of PRIMES energy demand projections at EU27 level on (gross) final energy demand (left) & on gross electricity consumption (right)

Figure 58 illustrates the energy consumption parameters of the various PRIMES scenarios exemplarily for (gross) final energy (left) and gross electricity demand (right). Noticeable, in the *PRIMES efficiency scenario* a significant reduction of energy demand compared to the *PRIMES baseline scenario* is observable over the whole period. The PRIMES target scenario, which was not explicitly used within the final scenario elaboration, is characterised by moderate energy demand reductions at the aggregated level of (gross) final energy demand.

- Fossil fuel and reference energy prices

  With respect to conventional reference energy prices it is assumed that energy prices remain at the levels observed during the years 2007 and 2008 for the near future. Accordingly, the *PRIMES high energy price case* (as of 2007) represents the default setting for the overall assessment of RES prospects. In addition, a sensitivity case for both deployment paths is derived to illustrate the impact of low energy prices on RES deployment and the accompanying policy transfer costs.

  National reference energy prices used in this analysis are based on the primary energy price assumptions as used in the EU energy outlook (as of 2007). The PRIMES data provide two different scenarios on future fossil energy prices: a moderate and a high price case as shown in Table 13 and Table 14. Compared to current energy prices the price assumptions in the PRIMES scenarios are low for the later years up to 2030. In the high price case the oil price for instance goes up to 109 $ per barrel in 2030, which is still significantly below last years price peaks.

Table 13: Primary energy price assumptions in US$$_{2005}$/boe, moderate energy prices (sensitivity variant) (source: PRIMES scenario)

PRIMES default energy prices (sensitivity on low energy prices)	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
Oil	54.5	54.5	57.9	61.1	62.3	62.8
Gas	34.6	41.5	43.4	46.0	47.2	47.6
Coal	14.8	13.7	14.3	14.7	14.8	14.9

Table 14: Primary energy price assumptions in US$$_{2005}$/boe, high energy prices (default setting) (source: PRIMES scenario)

PRIMES high energy prices (reference price development)	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
Oil	54.5	76.4	88.1	100.0	101.1	109.1
Gas	34.6	59.1	67.4	77.0	78.3	84.7
Coal	14.8	19.2	21.7	24.0	24.0	25.8

Table 15: CO_2 energy price assumptions in €$_{2005}$/ton (source: own calculations)

	2005	**2010**	**2015**	**2020**	**2025**	**2030**
CO_2 price	20.0	20.0	27.1	34.2	39.2	44.2

The CO_2-price in the scenarios presented in this report is exogenously set as shown in Table 15, again similar to corresponding EU scenarios (as for example in the impact assessment of the Energy and Climate package of the EU). Actual market prices (for 2006 EU Allowances) have fluctuated between 7 and 30 €/t, with averages fluctuating roughly between 15 and 20 €/t. In the model, it is assumed that CO_2-prices are directly passed through to electricity prices. This is done fuel-specific based on the PRIMES CO_2-emission factors.

Increased RES-deployment can have a CO_2-price reducing effect as it reduces the demand for CO_2-reductions. As RES-deployment should be anticipated in the EU Emission Trading System and the CO_2-price in the Green-X scenario is exogenously set, this effect is not included, which represents a rather conservative approach.

Reference prices for the electricity sector are taken from the Green-X model. Based on the primary energy prices, the CO_2-price and the country-specific power sector, the Green-X model determines country-specific reference electricity prices for each year in the period 2006-2020. Reference prices for the heat and transport sector are based on primary energy prices and the typical country-specific conventional conversion portfolio. Default sectoral reference energy prices are illustrated in Table 16. More precisely, these prices represent the average at European level (EU-27) and refer to an energy demand development according to the PRIMES energy efficiency case and the PRIMES high energy prices as used as reference for the "Policy case". Note that heat prices in case of grid-connected heat supply from district heating and CHP-plant do not include the cost of distribution – i.e. they represent the price directly at defined hand over point.

Table 16: Reference prices for electricity, heat and transport fuels

in €/MWh output	2005	2010	2015	2020	2025	2030
(Wholesale) Electricity price	59.9	66.0	73.9	75.1	71.5	70.7
Heat price (grid)	33.0	38.0	46.9	53.6	57.4	60.6
Heat price (non-grid)	58.0	65.3	77.7	85.5	88.6	90.9
Transport fuel price	46.1	53.0	65.8	75.2	79.6	83.6

- Conventional supply portfolio
  The conventional supply portfolio, i.e. the share of the different conversion technologies in each sector, has been based on the PRIMES forecasts on a country specific basis. These projections on the portfolio of conventional technologies have an impact in particular on the calculations done within this study on the avoidance of fossil fuels and CO_2 emissions. As it is at least out of the scope of this study to analyse in detail which conventional power plant would actually be replaced by for instance a wind farm installed in the year 2014 in a certain country (i.e. either a less efficient existing coal-fired plant or possibly a new high-efficient combined cycle gas turbine), the following assumptions are taken:
  - Keeping in mind that, besides renewable energies, fossil energy represents the marginal generation option that determines the prices on energy markets, it was decided to stick at the country level to the sector-specific conventional supply portfolio projections as provided by PRIMES. Sector- as well as country-specific conversion efficiencies, derived on a yearly basis, are used to get a sound proxy to calculate from derived renewable generation figures back to the amount of avoided primary energy. Assuming that the fuel mix stays 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 yearly changing average country- and sector-specific CO_2 intensities of the fossil-based conventional supply portfolio form the basis.

- Technological change - future expectations

  Considering the assumptions of technology learning and cost reductions a brief overview is given here. For most RES technologies the future development of investment cost is based on technological learning. As learning is taking place on the international level the deployment of a technology on the global level must be considered. For the model runs global deployment consists of the following components:

  - Deployment within the EU 27 Member States is endogenously determined, i.e. derived within the model.
  - Expected developments in the 'Rest of the world' are based on forecasts as presented in the IEA World Energy Outlook 2007 (IEA, 2007).

  The consequences of the assumed technology learning rates and efficiency improvements regarding the cost reduction of RES are depict in Figure 59 to Figure 61, exemplarily for the electricity sector. It is distinguished between a pessimistic scenario ("low learning"), with relatively low expectations of future cost reductions – see Figure 59– and an optimistic case of "high learning" – see Figure 61 – and a moderate scenario, applying default assumptions with regard to future technological learning – see Figure 60. Remarkable is the negative development in the period 2007 to 2009 for most energy technologies, but probably mostly affecting the cost of wind turbines. This increase of investment cost is largely driven by the tremendous rise of energy and raw material prices as observed in recent years and expected to prolong in the near to mid future. However, still substantial cost reductions are expected for novel technology options such as photovoltaics, solar thermal electricity or tidal stream and wave power.

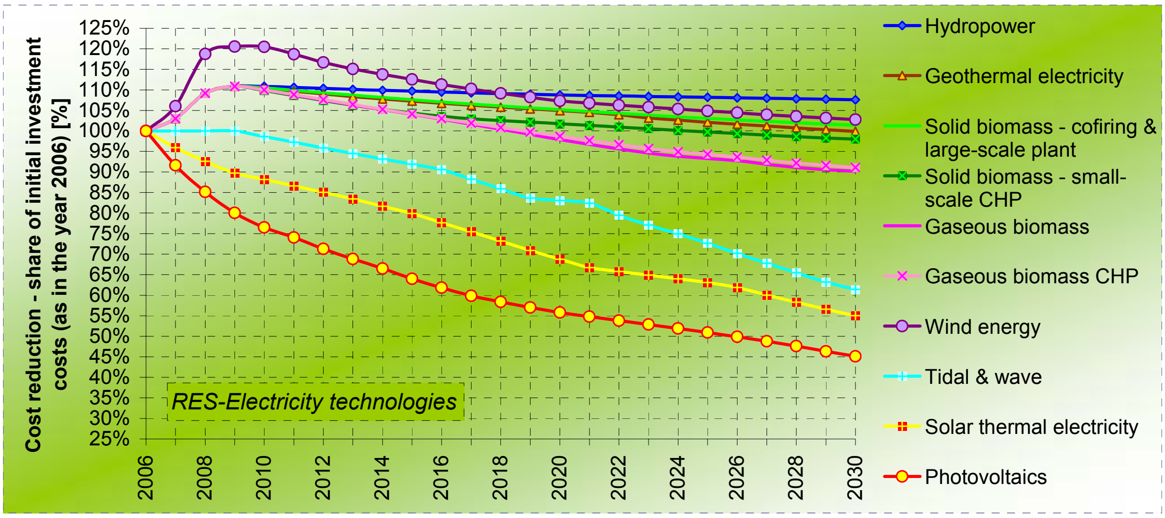


Figure 59: Cost reduction of RES-E investments as share of initial investment costs (2006) in a pessimistic scenario with regarding to technological progress (“low learning”) according to the “policy case” (default ADP)

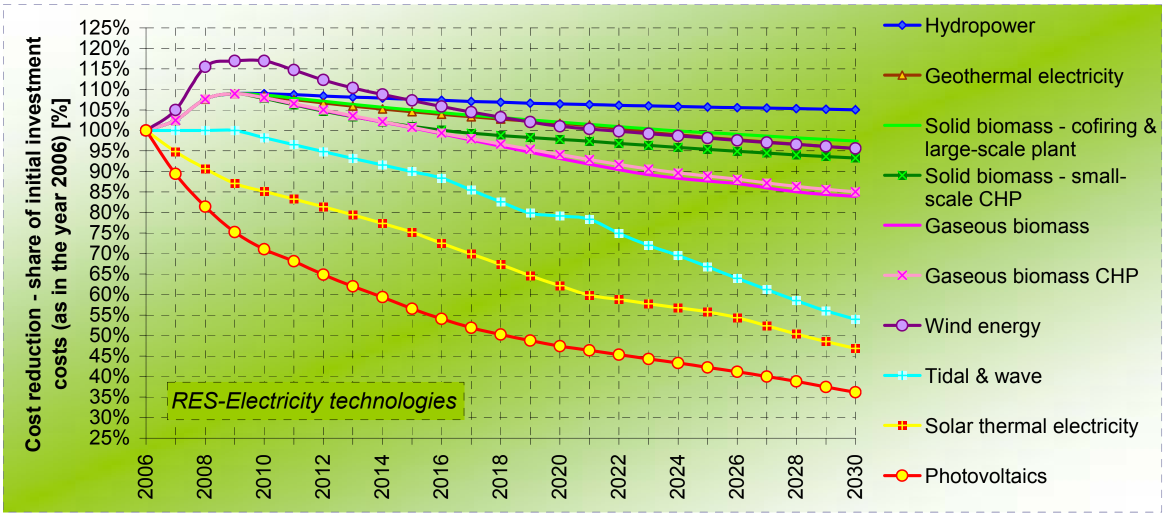


Figure 60: Cost reduction of RES-E investments as share of initial investment costs (2006) in a moderate scenario with regarding to technological progress (“moderate learning” (default setting)) according to the “policy case” (default ADP)

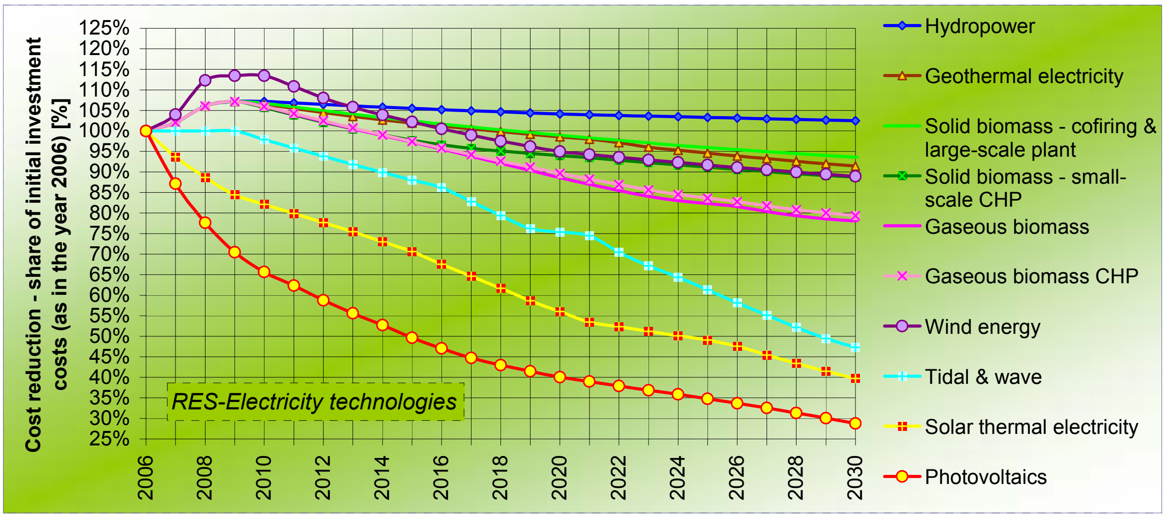


Figure 61: Cost reduction of RES-E investments as share of initial investment costs (2006) in a optimistic scenario with regarding to technological progress ("high learning") according to the "policy case" (default ADP)

Assumptions for simulated support schemes

A number of key input parameters are defined for each of the model runs referring to the specific design of the RES support instruments. These are described below.

- General scenario conditions
  The necessary consumer expenditures are heavily dependent on the design of the policy instruments. In the policy variants investigated, it is obvious that the design options of the various instruments are selected so that such expenditures are low. Accordingly, it is assumed that the investigated schemes are characterised by:
  - a stable planning horizon;
  - continuous RES policy/long-term RES targets;
  - a clear and well defined tariff structure / annual targets for RES technologies.

  In addition, the following design options are assumed for all the investigated scenarios, with the exception of the BAU scenario (i. e. currently implemented policies are maintained without adaptation up to 2020):
  - financial support is restricted to new capacity only and [24]
  - the guaranteed duration of financial support is limited. [25]

With respect to model parameters reflecting *dynamic aspects* such as technology diffusion and technological change, the following settings are applied:

- a stimulation of 'technological learning' is considered – leading to reduced investment and O&M costs for RES-E, increased energy efficiency over time;
- the removal of non-financial barriers and high public acceptance in the long term[26].

Next, the model settings and assumptions are described for each key type of support instrument separately. These assumptions refer to advanced support schemes as applied in the discussion of striving for an ambitious RES deployment path.

- Feed-in tariffs
  Feed-in tariffs are defined as technology-specific and settings are applied in order to achieve an overall low burden for consumers. In this way, tariffs decrease over time reflecting the achieved cost reductions on a technology level, but this annually adapted level of support refers only to new installations. More precisely, whenever a new plant is installed, the level of support is fixed for the guaranteed duration (15 years is assumed to be commonly applied in the case of generation-based support). A low risk premium (leading to a WACC of 6.5%) is intended to reflect the small degree of uncertainty associated with the design of this instrument.
- Quota obligations based on tradable green certificates / guarantees of origin (TGCs / GOs)
  Within the least-cost case referring to the ambitious deployment path a uniform trading system is studied in order to allow full liquidity and competition on the TGC / GO market.[27] Compared to the other support schemes, risk is assumed to be on a moderate to high level (leading to a WACC of 8.6%). Here, risk refers to the uncertainty about future earnings (on the conventional power / energy market as well as on the TGC / GO market).

---

[24] This means that only plants constructed after 2005 are eligible to receive the support given under the new schemes. Existing plants (constructed up to 2005) remain in their old scheme.

[25] In the model runs, it is assumed that the time frame in which investors can receive (additional) financial support is restricted to 15 years for all instruments providing a generation-based support.

[26] In the scenario runs, it is assumed that the existing social, market and technical barriers (e. g. grid integration) can be overcome in time. Nevertheless, their impact is still relevant as reflected in the BAU-settings (referring to the BAU scenario) compared to, e. g. the more optimistic view assumed for reaching a more ambitious target in 2020.

[27] More precisely, it is assumed that this common trading system neither includes technology-specific quotas nor any technology-specific weighting mechanism. Accordingly, it represents a policy scheme suited to supporting the most efficient RES-E options in a competitive environment.

4.2 Results of EU RES deployment scenarios

In this section results on the future RES deployment within the European Union are illustrated in a concise manner.

RES deployment

This section presents the main results on RES deployment obtained from the modelling calculations. As stated previously, three pathways of RES deployment are illustrated subsequently in a brief manner:

- a moderate RES deployment as occurring from a continuation of current RES support **(BAU**),
- an accelerated deployment path referring to the "**policy**" (default ADP), where improvements of the support conditions for RES are preconditioned for all EU countries, including also a removal of non-financial deficiencies and the implementation of feasible energy efficiency measures. Besides, for comparative reference
- a "no [RES] support" pathway is added for key outcomes, in the following referred to as **No policy**.

The projected RES deployment within each energy sector – i.e. electricity, heat and transport – can be analysed best by depicting deployment on sectoral level in relative terms – i.e. by indicating the deployment of RES-E, RES-H and RES-T as shares of corresponding gross demands. In this context, Figure 62 illustrates the development in the share of RES within each energy sector at EU level over time for the BAU-case and the "policy case" in line with the target of 20% RES by 2020. Below, Figure 63 provides a comparative depiction of the overall trend for all cases (incl. also the "No policy" pathway) by solely depicting the overall RES share on final (gross) energy consumption. As observable in the latter graph, no or insufficient (BAU) RES policies would allow only a moderate RES deployment, achieving a RES share of 11 ("no support") to 14% (BAU) in final (gross) energy consumption by 2020. A continuation of this trend is applicable for the period beyond 2020 where 14% ("no support") to 16% (BAU) appear feasible by 2030. In contrast to this, a proactive RES support ("policy case") may boost the RES deployment to at least 26% by 2030.

Next a closer look on the individual energy sectors is given. It can still be observed that RES-E shall contribute largely (34.6% of corresponding gross demand in the "policy case") to the achievement of the 20% RES target. For the period beyond 2020 this trend is projected to continue, achieving a RES share of 30% in gross final energy demand by 2030. A significant contribution to the target achievement is also expected to come from RES in the heat sector (21.7% by 2020 in the "policy case"), which requires an accelerated growth compared to the current trends (14.2% under BAU-conditions). The growth of

RES heat is expected to continue in the period beyond 2020, achieving 30% by 2030 in the “policy case” – to be compared with 17.2% under a BAU policy framework. According to the “policy case” the share of biofuels in transport fuel demand remains comparatively low in the first years, but later on is expected to rise continuously, reaching 8% in 2020 and 12.3% by 2030.[28]

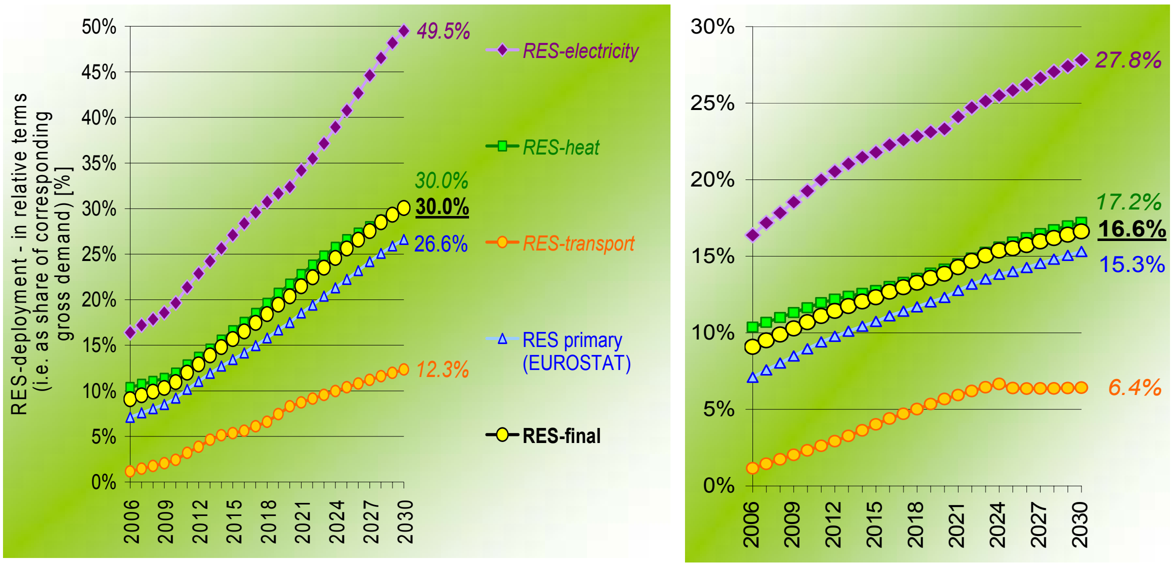


Figure 62: Deployment of RES-E, RES-H, RES-T and RES in total as shares of corresponding gross demands up to 2030 within the European Union (EU-27) in the “policy case” (left) & in the BAU case (right)

---

[28] This study compares biofuel production to the total transport fuel demand (excluding electricity), while the target setting in the biofuels directive is based on diesel and gasoline demand. Accordingly, 8.1% of total transport fuel demand as indicated for 2020 would correspond to 10% of the demand for diesel and gasoline.

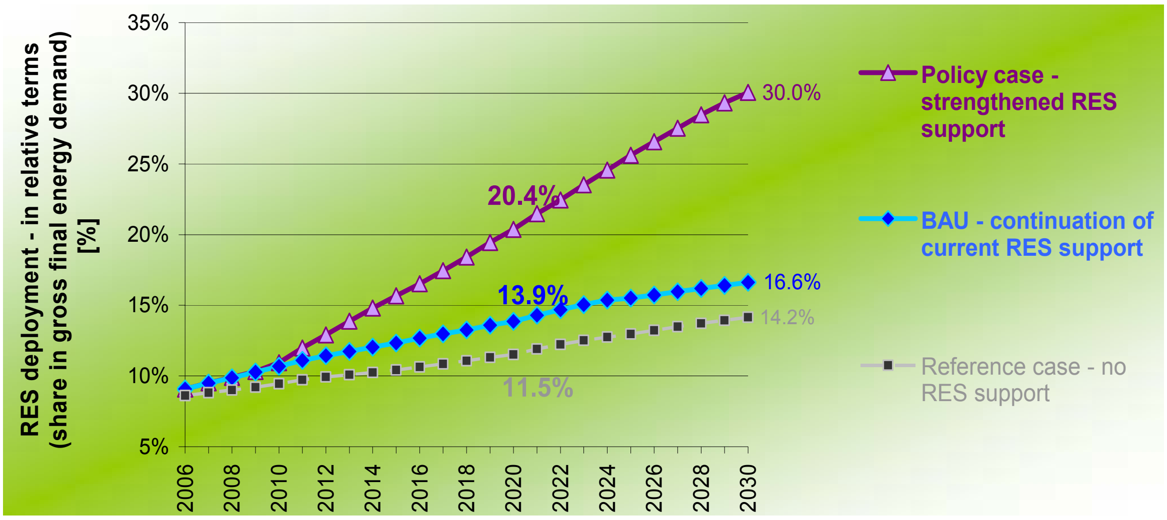


Figure 63: Comparison of the overall RES share in final (gross) energy consumption up to 2030 within the European Union (EU-27) for all investigated cases

The deployment of solely new RES plants (installed in the period 2006 to 2020) in the "policy case" (in line with the 20% RES by 2020 target) is shown in Figure 64 in terms of energy output[29] by sub-sector. To meet the 20% target, large increases are required in all three sectors. The results show that pro-active RES support will lead to a stimulation of RES-markets more or less equally among all sectors. Total generation from new RES installations in the period 2006 to 2020 achieves an impressive amount of 165.8 Mtoe by 2020 – representing more than two thirds of total RES output by 2020 or almost a doubling of current RES generation. However, this figure would have to rise by approximately 44 Mtoe if we fail to limit overall demand growth (*Less energy efficiency policies – baseline demand projection*). Beyond 2020 a continuation of this growth is observable, where new RES installations achieve 310.5 Mtoe by 2030 and comprise almost 90% of the overall RES deployment.

---

[29] According to the applied terminology energy output equals final energy in the cases of non-grid heat and transport, whilst for RES-E generation and grid-connected heat supply it refers to gross consumption.

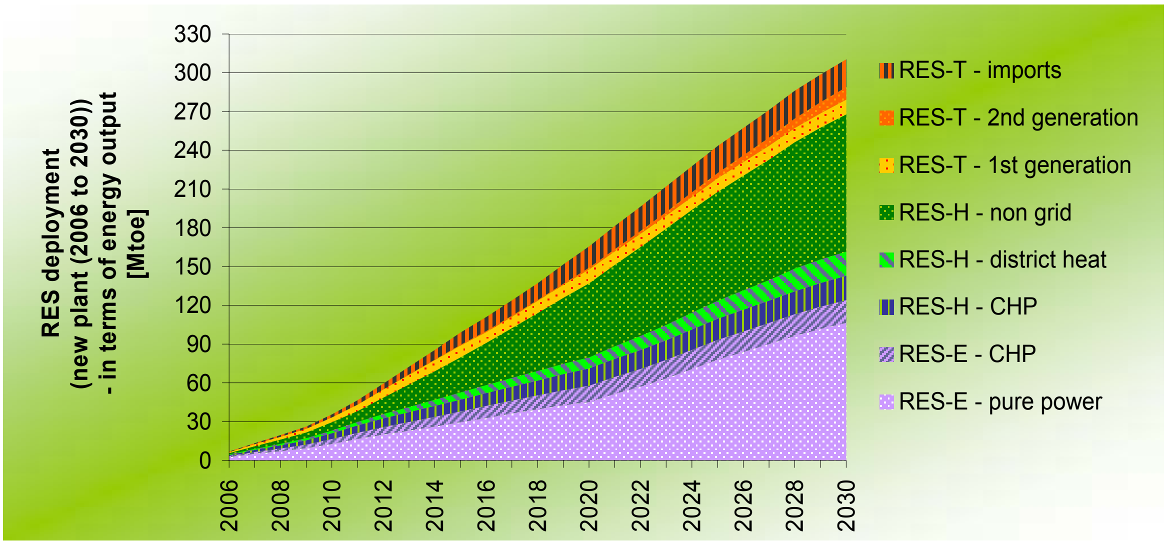


Figure 64: Deployment of new RES (installed 2005 to 2030) in terms of energy output until 2030 within the European Union (EU-27) in the “policy case”

The highest contribution in terms of primary energy and second highest in terms of energy output is projected for RES-E, especially for pure power generation options such as wind energy (all together covering 34% of total energy output of new RES installations (2006 to 2030) by 2030), but also RES-CHP acts as a major contributor (12% by 2030).

Besides RES-E, the non-grid heat market for RES, comprising residential and industrial biomass heating as well as solar thermal heating & hot water supply and heat pumps takes off fast if well supported. Among all sub-sectors it achieves the largest deployment in absolute terms, holding a share of 35% (34%) on total energy output of cumulative new installations by 2020 (2030). This underpins that the cost-effective achievement of RES targets requires an immediate strong growth of RES-H, which would need to be reflected by an appropriate policy framework.

In terms of growth rates biofuels for transport face a huge increase, but in absolute terms they will become an important contributor to achieve the 20% target only in the later years when also advanced conversion technologies such as lignocellulosic bioethanol are ready to enter the market. For the period beyond 2020 the growth of biofuels is assumed to continue.

Next an illustration of the projected penetration of RES on technology level is given, again exemplarily for the “policy case”. Table 17 lists the corresponding data in a detailed manner, indicating besides generation also technology-specific sectoral shares as well as average growth rates.

Table 17: RES penetration at detailed technology level in the “policy case” (2006-2030)

RES-E	**Electricity generation**							*Share of total RES-E [%]*			**Average yearly growth [%]**
	[Unit]	2006	2010	2015	2020	2025	2030	*2010*	*2020*	*2030*	**06-30**
Biogas	[TWh]	17	26	45	83	115	140	*4%*	*7%*	*8%*	**16.4%**
Solid biomass	[TWh]	57	97	152	182	199	211	*14%*	*16%*	*11%*	**9.8%**
Biowaste	[TWh]	14	23	30	34	36	38	*3%*	*3%*	*2%*	**7.5%**
Geothermal electricity	[TWh]	7	7	8	8	18	26	*1%*	*1%*	*1%*	**10.2%**
Hydro large-scale	[TWh]	302	316	323	326	327	330	*45%*	*29%*	*18%*	**0.6%**
Hydro small-scale	[TWh]	46	52	60	62	63	64	*7%*	*5%*	*3%*	**2.4%**
Photovoltaics	[TWh]	2	4	11	20	27	58	*1%*	*2%*	*3%*	**26.6%**
Solar thermal electricity	[TWh]	0	1	4	14	16	68	*0%*	*1%*	*4%*	**51.8%**
Tide & wave	[TWh]	0	2	4	6	21	57	*0%*	*1%*	*3%*	**47.3%**
Wind onshore	[TWh]	98	163	260	290	382	437	*23%*	*25%*	*24%*	**11.3%**
Wind offshore	[TWh]	4	9	47	117	281	407	*1%*	*10%*	*22%*	**39.8%**
RES-E total	**[TWh]**	**547**	**700**	**944**	**1,142**	**1,486**	**1,837**				**9.0%**
RES-E CHP	[TWh]	61	97	151	188	213	233	*14%*	*16%*	*13%*	**10.0%**
share on gross demand	[%]	**16.4%**	**19.6%**	**27.1%**	**32.4%**	**40.8%**	**49.5%**				

RES-H	**Heat generation**							*Share of total RES-H [%]*			**Average yearly growth [%]**
	[Unit]	2006	2010	2015	2020	2025	2030	*2010*	*2020*	*2030*	**06-30**
Biogas (grid)	[Mtoe]	1.5	1.6	1.7	1.9	2.1	2.2	*2%*	*2%*	*1%*	**2.7%**
Solid biomass (grid)	[Mtoe]	5.3	9.2	15.8	20.8	26.7	30.8	*13%*	*19%*	*21%*	**13.4%**
Biowaste (grid)	[Mtoe]	2.4	3.6	4.7	5.2	5.2	5.4	*5%*	*5%*	*4%*	**6.0%**
Geothermal heat (grid)	[Mtoe]	0.8	0.9	1.3	1.5	1.5	1.9	*1%*	*1%*	*1%*	**6.9%**
Solid biomass (non-grid)	[Mtoe]	49.7	53.8	58.4	65.7	68.4	69.4	*75%*	*59%*	*47%*	**2.4%**
Solar therm. heat.	[Mtoe]	0.8	1.6	4.2	8.3	12.7	15.0	*2%*	*7%*	*10%*	**23.4%**
Heat pumps	[Mtoe]	0.8	1.3	3.3	8.2	15.4	22.0	*2%*	*7%*	*15%*	**26.5%**
RES-H total	**[Mtoe]**	**61.3**	**72.0**	**89.4**	**111.6**	**132.1**	**146.7**				**6.4%**
RES-H CHP	[Mtoe]	7.1	10.7	15.5	18.2	20.2	21.7	*15%*	*16%*	*15%*	**8.3%**
RES-H distr. heat	[Mtoe]	2.9	4.7	8.0	11.2	15.4	18.6	*6%*	*10%*	*13%*	**14.2%**
RES-H non-grid	[Mtoe]	51.3	56.7	65.9	82.2	96.5	106.4	*79%*	*74%*	*73%*	**5.3%**
share on gross demand	[%]	**10.4%**	**11.9%**	**16.6%**	**21.7%**	**26.6%**	**30.0%**				

RES-T	**Biofuel generation**							*Share of total RES-T [%]*			**Average yearly growth [%]**
	[Unit]	2006	2010	2015	2020	2025	2030	*2010*	*2020*	*2030*	**06-30**
Traditional biofuels	[Mtoe]	3.7	6.8	9.9	11.4	10.4	11.3	*73%*	*39%*	*29%*	**8.3%**
Advanced biofuels	[Mtoe]	0.0	0.0	0.7	1.3	4.2	9.7	*0%*	*4%*	*12%*	-
Biofuel import	[Mtoe]	0.4	2.5	9.8	16.9	21.2	21.9	*27%*	*57%*	*59%*	**32.4%**
RES-T total	**[Mtoe]**	**4.1**	**9.3**	**20.4**	**29.7**	**35.8**	**42.9**				**18.2%**
share on gross demand	[%]	**1.1%**	**2.4%**	**5.4%**	**8.3%**	**10.4%**	**12.3%**				
share on diesel and gasoline demand	*[%]*	*1.4%*	*2.9%*	*6.5%*	*10.0%*	*12.5%*	*14.9%*				

Some of the most prominent conclusions drawn from this table comprise:

- The bulk of RES-E in 2020 will be produced by technologies that are currently already within or close to the market: Large-scale hydro (326 TWh/yr), solid biomass (182 TWh/yr), onshore wind (290 TWh/yr), offshore wind (117 TWh/yr), biogas (83 TWh/yr), small hydro (62 TWh/yr) and biowaste (34 TWh/yr) together will comprise about 96% of total RES-E production. However, this share will decline to 89% by 2030 – on the one hand, due to limitations on the potential side for several of these mature technology options and, on the other hand, due to a boost of novel RES-E options beyond 2020.
- However, also novel RES-E options with huge future potentials such as PV (20 TWh/yr by 2020), solar thermal electricity (14 TWh/yr by 2020) or tidal & wave (6 TWh/yr by 2020) enter the market and achieve a steadily growing share – if, as assumed, market stimulation is set in a proper manner. This trend is assumed to continue over the subsequent period up to 2030.
- In the heat sector solar thermal heat and heat pumps achieve a strong deployment, steadily growing over the whole investigated period, and finally account for about one sixth of RES-H generation by 2020. This share is assumed to increase further in the period beyond 2020.
- Biomass plays a crucial role in meeting RES targets. In the “policy case” co-firing of biomass refers to 62 TWh/yr in electricity production. Biomass will become even more important for the development of RES-H. In 2020 about 84% of total RES-H generation comprises biomass and biowaste. Besides co-firing and CHP also modern small-scale biomass heating systems are a major contributor. In the final years up to 2030 a saturation of the bioenergy growth is getting apparent due to limitations of domestic resources and the presumed limitation of alternative imports from abroad.
- In the “policy case” 78% of the domestic potential of solid biomass (173 Mtoe) is used and another 22 Mtoe is imported by 2020. Imports consist of 5 Mtoe forest products and residues and 16.9 Mtoe of biofuels.

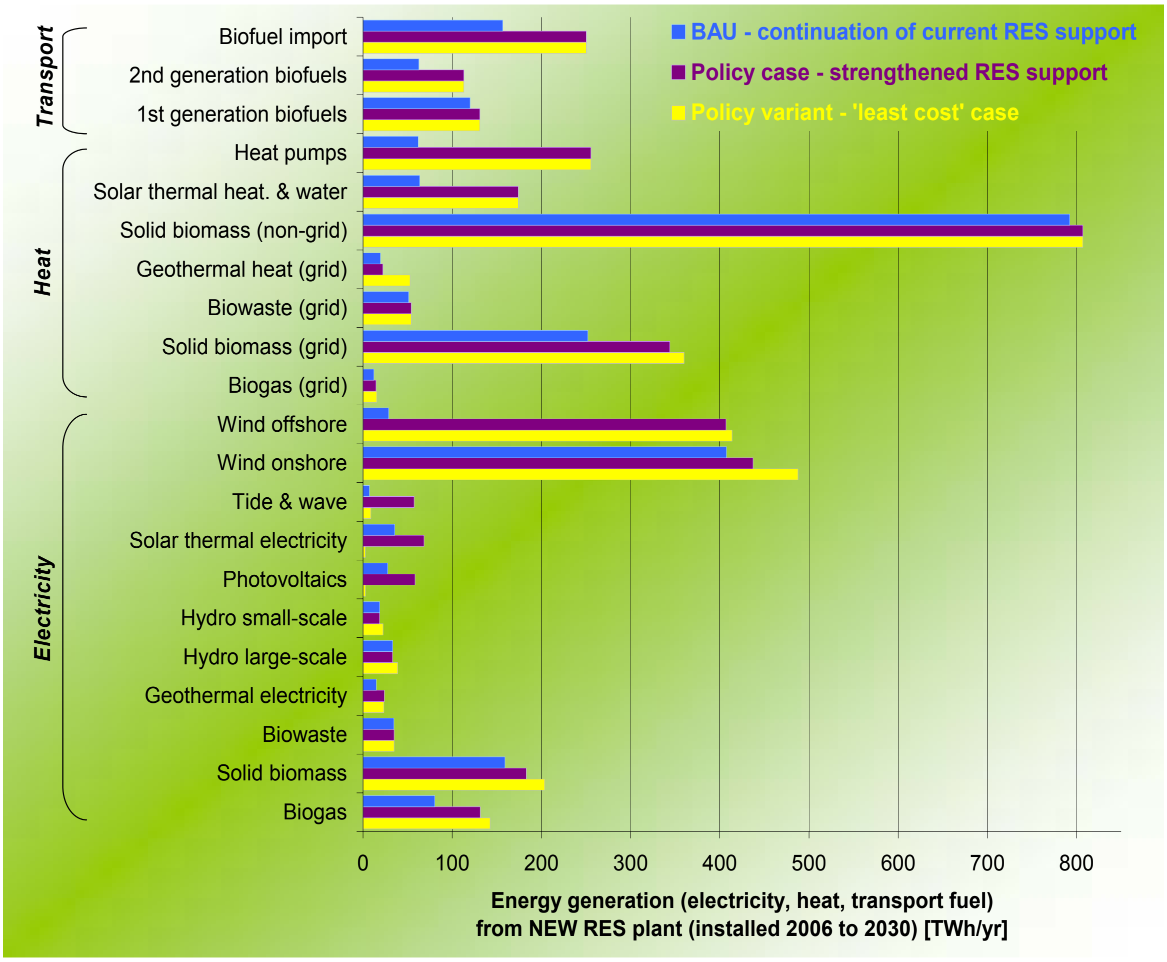


Figure 65: Scenario comparison: Technology-specific breakdown of energy generation (electricity, heat and transport fuels) from NEW RES plants (installed 2006 to 2030) by 2030 within the European Union (EU-27)

Finally, the impact of key policy choices on the technology specific RES deployment is getting apparent in Figure 65 offering a comprehensive comparison of the technology-specific RES deployment over the whole assessed period 2006 to 2030 for all investigated RES policy pathways. The following conclusions can be drawn from this depiction:

- Obviously, uniform RES support by means of a harmonised quota system with European wide trade would encourage a full exploitation of all least-cost options. As such e.g. solid biomass in the power sector and for grid-connected heat supply, wind energy (on- and offshore) and geothermal district heat would achieve a higher deployment as compared to all other policy options. To a less extent also hydropower and biogas would benefit from this policy choice.
- In contrast to above, novel RES technologies such as photovoltaics, solar thermal electricity and also modern small-scale biomass heat show a substantially reduced exploitation in case of a short-term least cost policy, whereby the latter technology option is

solely indirectly[30] affected by the decreased availability of biomass resources due to the increased demand of competitive energy uses.

- At first glance, several RES technologies appear robust on the applied policy framework. This refers to all biofuel technologies, heat pumps and solar thermal heat as well as hydropower, biowaste, geothermal electricity and tidal & wave power. Whilst the latter achieve in general only a low exploitation, the main reason for the robustness of several technologies for a decentralised heat supply is that these technologies are beyond the scope of this policy assessment – in other words, within all policy variants their support is assumed to be equal, consisting of a mixture of investment and tax incentives.
- Technology-specific RES support allows steering deployment simply and substantially. The use of a banding approach within a trading scheme or the direct definition of the support level in case of feed-in tariffs simplifies bridging the gap to the market for novel RES options. The impact of this is impressively illustrated in Figure 65. This allows for having the RES technologies ready when needed in the mid to long term.

Capital expenditure and induced technological progress

Table 18: Capital expenditure in new RES plants (2006 to 2030) in the BAU-case

Capital expenditure in NEW RES plant (installed 2006 to 2030)

	[Unit]	06-10	11-15	16-20	21-25	26-30	2006-2030 cum.	
RES-E - pure power	[Bill. €]	82.1	74.1	79.8	127.5	136.5	**499.9**	**55%**
RES-E&H - CHP	[Bill. €]	21.4	17.4	15.3	15.1	11.9	**81.0**	**9%**
RES-H - district heat	[Bill. €]	2.5	3.3	2.8	4.3	4.7	**17.5**	**2%**
RES-H - non grid	[Bill. €]	20.6	52.3	70.5	79.8	61.1	**284.3**	**31%**
RES-T - 1st generation	[Bill. €]	3.1	3.9	2.1	1.3	1.7	**12.1**	**1%**
RES-T - 2nd generation	[Bill. €]	0.0	1.2	3.2	2.6	2.3	**9.3**	**1%**
RES-total	**[Bill. €]**	**129.6**	**152.0**	**173.7**	**230.6**	**218.2**	**904**	

Significant investments are necessary to develop the new capacity. Table 18 (BAU-case - above) and Table 19 (“policy case” - below) depict a technology-specific breakdown of the cumulative investment requirements for RES plants installed in the investigated period 2006 to 2030. The cumulative capital expenditure for the BAU-case is in the order of 904 billion €, whilst 1,535 billion € are required in the “policy case” referring to an accelerated RES deployment in line with the 2020 RES target with an assumed continuation of this ambition level for the period beyond 2020.

---

[30] Decentralised heat is supported within all policy cases by a mixture of investment and tax incentives. Similar to a trading scheme by means of Guarantees of Origin, the investigated quota system is assumed to comprise solely electricity and grid-connected heat supply.

Table 19: Capital expenditure in new RES plants (2006 to 2030) in the “policy case”

Capital expenditure in NEW RES plant (installed 2006 to 2030)	[Unit]	06-10	11-15	16-20	21-25	26-30	**2006-2030 cum.**	
RES-E - pure power	[Bill. €]	86.0	143.7	131.6	232.7	316.0	**910.0**	**59%**
RES-E&H - CHP	[Bill. €]	23.3	25.4	20.4	15.1	11.7	**95.8**	**6%**
RES-H - district heat	[Bill. €]	2.7	4.7	4.5	6.2	5.4	**23.4**	**2%**
RES-H - non grid	[Bill. €]	25.5	80.6	130.0	134.6	106.0	**476.7**	**31%**
RES-T - 1st generation	[Bill. €]	3.3	5.0	2.0	0.3	2.5	**13.2**	**1%**
RES-T - 2nd generation	[Bill. €]	0.0	3.0	1.1	4.1	7.9	**16.1**	**1%**
RES-total	**[Bill. €]**	**140.7**	**262.6**	**289.5**	**393.1**	**449.4**	**1,535**	

It is obvious that these investments (within the EU and worldwide) will stimulate technological learning, leading to lower generation costs in the future. The highest decrease is projected for photovoltaics, followed by solar thermal electricity, and tidal & wave energy (see Figure 62 and Figure 60).

Benefits of increased RES deployment

Increased RES deployment reduces the demand for fossil fuels. As explained before, sector- and country-specific conversion efficiencies as projected by PRIMES for the future evolution of the conventional supply portfolio are used to obtain a sound proxy for calculating the amount of avoided fossil primary energy from derived renewable generation figures.

It is becoming apparent that renewable energy is an important element improving the security of energy supply in Europe. Even the figures for the moderate BAU-case as illustrated in Table 20 seem impressive: The total amount of avoided fossil fuels due to new RES capacities (installed in the period 2006 to 2030) equals 291 Mtoe in 2030. Assuming an unchanged conventional fuel mix, 42% of the reduction would refer to natural gas, followed by hard coal (29%), oil (22%) and lignite (6%). In the case of gas, this equals 20% of the *default* total EU gas consumption in 2020 or 24% of *default* gas import needs, respectively.[31] In monetary terms these figures correspond to reduced annual expenses for fossil fuels of 118 billion € from 2030 on.[32]

Obviously, savings also increase with higher RES deployment as expected in the “policy case”: In energy terms, the annual savings rise from 291 Mtoe to 478 Mtoe by 2030, and in monetary terms from 118 to 194 billion € (see Table 20 and

---

[31] Default figures refer to the adapted PRIMES projections – i.e. without additional RES deployment in the observed period 2006 to 2030.

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

Table 21).

Table 20: Avoided fossil fuels due to new RES plants (2006 to 2030) in the BAU-case

Avoided fossil fuels - due to NEW RES plant (installed 2006 to 2030)										
... in energy units - by fuel								*Share of total [%]*		
by year	[Unit]	2006	2010	2015	2020	2025	2030	*2010*	*2020*	*2030*
Avoided hard coal	[MtSKE]	5.4	24.9	48.9	70.5	103.7	120.6	***32%***	***28%***	***29%***
Avoided lignite	[MtSKE]	2.3	7.5	12.2	18.2	24.3	25.9	***9%***	***7%***	***6%***
Avoided oil	[Mtoe]	2.9	11.0	25.1	41.9	57.3	64.8	***20%***	***24%***	***22%***
Avoided gas	[Bill.m3]	6.2	28.0	60.2	93.0	135.7	163.1	***39%***	***40%***	***42%***
Avoided fossil fuels - total	**[Mtoe]**	**13.2**	**55.0**	**113.6**	**174.5**	**249.8**	**291.0**	**3,851**		
... in monetary terms - in total		2006	2010	2015	2020	2025	2030	**2006-2030 cumulative**		
Avoided fossil fuels - total	[Bill.€]	2.6	14.9	36.5	65.2	93.9	118.4	**1,398**		
... as share of GDP	[% of GDP]	**0.02%**	**0.12%**	**0.26%**	**0.42%**	**0.54%**	**0.63%**	*0.34%*		

Table 21: Avoided fossil fuels due to new RES plants (2006 to 2030) in the “policy case”

Avoided fossil fuels - due to NEW RES plant (installed 2006 to 2030)										
... in energy units - by fuel								*Share of total [%]*		
by year	[Unit]	2006	2010	2015	2020	2025	2030	*2010*	*2020*	*2030*
Avoided hard coal	[MtSKE]	5.4	26.7	68.0	87.4	152.4	184.7	***32%***	***23%***	***27%***
Avoided lignite	[MtSKE]	2.3	8.3	22.2	30.5	46.8	51.3	***10%***	***8%***	***8%***
Avoided oil	[Mtoe]	2.9	12.2	35.2	56.4	74.0	92.7	***21%***	***21%***	***19%***
Avoided gas	[Bill.m3]	6.1	29.5	76.8	163.9	226.3	290.4	***38%***	***47%***	***46%***
Avoided fossil fuels - total	**[Mtoe]**	**13.1**	**59.0**	**156.6**	**263.2**	**385.1**	**478.1**	**5,746**		
... in monetary terms - in total		2006	2010	2015	2020	2025	2030	**2006-2030 cumulative**		
Avoided fossil fuels - total	[Bill.€]	2.5	16.0	49.3	100.9	142.4	193.7	**2,091**		
... as share of GDP	[% of GDP]	**0.02%**	**0.13%**	**0.35%**	**0.64%**	**0.82%**	**1.04%**	*0.51%*		

Additional cost of increased RES deployment

- Additional generation cost

  Next, the overall cost of an increased RES deployment are presented in terms of *additional generation costs*, that is, the total costs of generation per energy output minus the reference cost of energy production per unit of energy output. To avoid underestimation of the resulting cost with regard to an enhanced RES-deployment, negative additional costs appearing at the technology level by country are not counted – i.e. set to zero.[33]

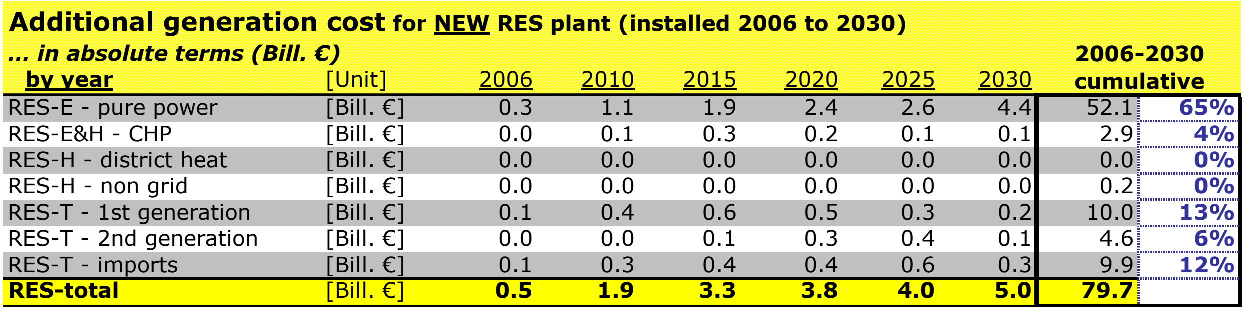
  Table 22 provides an overview of additional annual generation costs for the years 2006, 2010, 2015, 2020, 2025, and 2030 in the BAU case, and

---

[33] Negative additional cost appearing within one sector may compensate the additional cost in another, which leads to a misinterpretation of the overall associated societal transfer cost. Moreover, negative cost of conventional supply options are also not taken into account as conventional reference prices reflect the marginal cost and not the average. Consequently, to come up with a fair comparison it has been finally decided to neglect such cost.

Table 23 offers the corresponding listing for the “policy case”. The cumulative additional generation costs for the period 2006 to 2030 amount to 211 billion € in the “policy case”. This means that on average the additional generation costs are 8.4 billion € per year throughout this period. All other investigated scenarios show lower additional generation than the “policy case”: In the BAU-case, which is characterised by a 33% lower deployment of new RES, the yearly additional generation cost amount 3.2 billion € on average throughout the period 2006 to 2030. The “least cost” variant, characterised by a similar[34] overall RES deployment by 2030 as observed in the “policy case”, causes additional generation costs in size of 5.2 billion € on average.

Table 22: Additional generation cost for new RES plant (2006 to 2030) in the BAU case

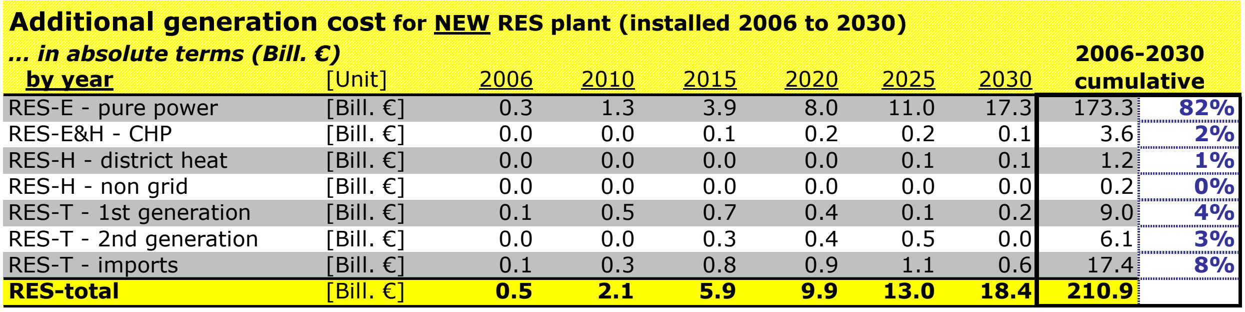


Additional generation cost for NEW RES plant (installed 2006 to 2030)

... in absolute terms (Bill. €)

by year	[Unit]	2006	2010	2015	2020	2025	2030	**2006-2030 cumulative**	
RES-E - pure power	[Bill. €]	0.3	1.1	1.9	2.4	2.6	4.4	52.1	**65%**
RES-E&H - CHP	[Bill. €]	0.0	0.1	0.3	0.2	0.1	0.1	2.9	**4%**
RES-H - district heat	[Bill. €]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0%**
RES-H - non grid	[Bill. €]	0.0	0.0	0.0	0.0	0.0	0.0	0.2	**0%**
RES-T - 1st generation	[Bill. €]	0.1	0.4	0.6	0.5	0.3	0.2	10.0	**13%**
RES-T - 2nd generation	[Bill. €]	0.0	0.0	0.1	0.3	0.4	0.1	4.6	**6%**
RES-T - imports	[Bill. €]	0.1	0.3	0.4	0.4	0.6	0.3	9.9	**12%**
RES-total	[Bill. €]	**0.5**	**1.9**	**3.3**	**3.8**	**4.0**	**5.0**	**79.7**	

Table 23: Additional generation cost for new RES plant (2006 to 2030) in the “policy case”



Additional generation cost for NEW RES plant (installed 2006 to 2030)

... in absolute terms (Bill. €)

by year	[Unit]	2006	2010	2015	2020	2025	2030	**2006-2030 cumulative**	
RES-E - pure power	[Bill. €]	0.3	1.3	3.9	8.0	11.0	17.3	173.3	**82%**
RES-E&H - CHP	[Bill. €]	0.0	0.0	0.1	0.2	0.2	0.1	3.6	**2%**
RES-H - district heat	[Bill. €]	0.0	0.0	0.0	0.0	0.1	0.1	1.2	**1%**
RES-H - non grid	[Bill. €]	0.0	0.0	0.0	0.0	0.0	0.0	0.2	**0%**
RES-T - 1st generation	[Bill. €]	0.1	0.5	0.7	0.4	0.1	0.2	9.0	**4%**
RES-T - 2nd generation	[Bill. €]	0.0	0.0	0.3	0.4	0.5	0.0	6.1	**3%**
RES-T - imports	[Bill. €]	0.1	0.3	0.8	0.9	1.1	0.6	17.4	**8%**
RES-total	[Bill. €]	**0.5**	**2.1**	**5.9**	**9.9**	**13.0**	**18.4**	**210.9**	

- Financial support / Consumer expenditures

  Next, the cost of meeting 20% RES are discussed by means of consumer expenditures – i.e. the necessary financial support for the future RES deployment discussed above.

---

[34] Differences in terms of RES deployment between both variants in line with the target of 20% RES by 2020 are however getting apparent: On the one hand, the “policy case” stipulates also an accelerated deployment of currently novel RES options (such as PV or solar thermal electricity), and, on the other hand, it is also characterised by an in total higher RES deployment in the near future.

Thereby, we focus solely on the 2020 time frame, where the policy framework is set with the new RES directive. Table 24 (“least cost”) and Table 25 (“policy case”) show the required consumer expenditure at EU-27 level due to the underlying (national) RES policies and the corresponding induced RES deployment. In this context, the consumer / societal expenditure due to the support for RES represent a net value referring to the direct costs of applying a certain support scheme.[35] More precisely, both tables illustrate solely the transfer cost dedicated to new RES plants (installed 2006 to 2020).Finally, Figure 66 provides a graphical illustration of both the additional generation cost as well as the required consumer expenditure for all investigated cases – including sensitivity variants – in the 2020 time frame (i.e. costs refer to new RES installations in the period up to 2020).

It is becoming apparent that when striving for an ambitious RES target a uniform support as preconditioned in the “least cost” case may lead to lower (additional) generation cost but results in higher consumer expenditures compared to the case of offering efficient & effective technology-specific RES incentives (“policy case”): 23 (“least cost”) compared to 16 billion € (“policy case”) are the required consumer expenses (on average per year throughout the period 2006 to 2020) if proactive energy efficiency measures accompany RES support (high energy efficiency – based on PRIMES efficiency case). If overall energy demand would rise as observed in the past (see sensitivity variants on low energy efficiency – based on PRIMES baseline case) the difference in terms of support cost between uniform and technology-specific support would rise, which underpins the importance of striving for efficient & effective technology-specific RES support. Therefore in the sense of the full costs of the policy the term "least cost" can be considered as misleading since the total costs of the policy are significantly higher for this uniform support scheme as compared to an efficient and effective technology specific RES support.

Table 24: Transfer cost / Consumer expenditure due to RES support for new RES plants (2006 to 2020) in the “least cost” case

Transfer cost due to RES support for NEW RES plant (installed 2006 to 2020)

... in absolute terms (Bill. €)

by year	[Unit]	2006	2010	2015	2020	**2006-2020 cumulative**	
RES-E - pure power	[Bill. €]	1.5	3.7	5.4	15.7	8.3	**36%**
RES-E&H - CHP	[Bill. €]	0.5	1.0	1.4	8.1	3.5	**15%**
RES-H - district heat	[Bill. €]	0.1	0.1	0.0	4.2	1.4	**6%**
RES-H - non grid	[Bill. €]	0.6	1.2	5.4	11.0	5.9	**25%**
RES-T - 1st generation	[Bill. €]	0.3	0.8	4.7	1.0	2.2	**9%**
RES-T - 2nd generation	[Bill. €]	0.0	0.0	0.1	0.1	0.1	**0%**
RES-T - imports	[Bill. €]	0.1	0.4	3.7	1.4	1.8	**8%**
RES-total	[Bill. €]	**3.1**	**7.2**	**20.8**	**41.4**	**23.2**	

---

[35] E. g. in the case of a fixed feed-in tariff, its marginal value per MWh$_{RES\text{-}E}$ is calculated by subtracting the reference wholesale electricity price from the guaranteed support tariff.

Table 25: Transfer cost / Consumer expenditure due to RES support for new RES plants (2006 to 2020) in the "policy case"

Transfer cost due to RES support for NEW RES plant (installed 2006 to 2020)

… in absolute terms (Bill. €)

by year	[Unit]	2006	2010	2015	2020	**2006-2020 cumulative**	
RES-E - pure power	[Bill. €]	1.5	3.7	6.7	12.9	7.8	**48%**
RES-E&H - CHP	[Bill. €]	0.5	1.0	1.7	2.9	1.8	**11%**
RES-H - district heat	[Bill. €]	0.1	0.1	0.1	0.0	0.1	**0%**
RES-H - non grid	[Bill. €]	0.6	1.2	2.3	4.3	2.6	**16%**
RES-T - 1st generation	[Bill. €]	0.3	0.8	4.7	1.0	2.2	**13%**
RES-T - 2nd generation	[Bill. €]	0.0	0.0	0.1	0.1	0.1	**0%**
RES-T - imports	[Bill. €]	0.1	0.4	3.7	1.4	1.8	**11%**
RES-total	[Bill. €]	**3.1**	**7.2**	**19.3**	**22.6**	**16.4**	

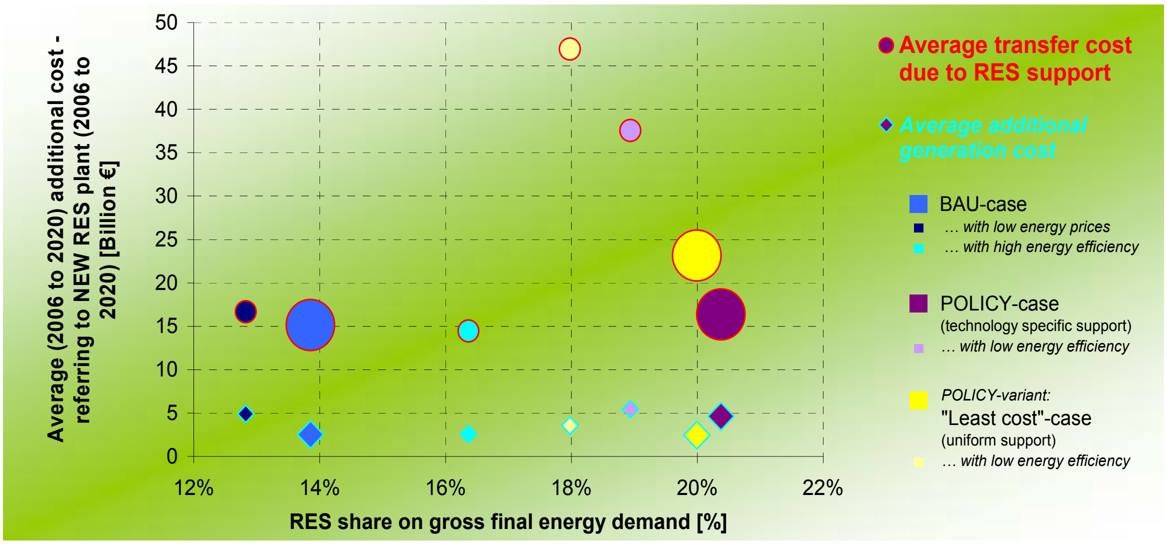


Figure 66: Comparison of (average) additional generation cost and (average) transfer cost / consumer expenditure for new RES plants (2006 to 2020) within the European Union (EU27) – for all investigated cases (BAU, "policy", "least cost" – including sensitivity variants)

Sensitivity calculations on fossil fuel prices and technology learning

Three sensitivity cases have been calculated to show the dependence of the three main indicators "additional generation costs", "capital expenditures", and "avoided fossil fuel imports" on the level of fossil fuel prices and the speed on technological learning. The results of these calculations are shown in Figure 67. For the sensitivity on fossil fuel prices the case of moderate fossil fuel prices instead of high prices has been used as shown in Table 13. In this case the additional generation costs increase substantially by more than a factor of two. On the other hand the capital expenditures as compared to the No policy scenario increase as well since less investments take place under the No policy scenario. The avoided fossil fuel imports in monetary terms are reduced due to the lower price of fossil fuels in this case. Summarising it can be assumed that this case of lower fossil fuel prices would substantially reduce the net macro-economic benefits of renewable energies as calculated in chapter 7. The two further sensitivities on the level of technological learning have less critical impacts on the overall figures. Lower learning would increase the additional generation costs as well as the capital expenditures by 15% and would hardly change the figures on avoided fossil fuel imports. Therefore the impact of the level of technology learning on the macro-economic results would be expected to be less significant as compared to the sensitivity on fossil fuel prices.

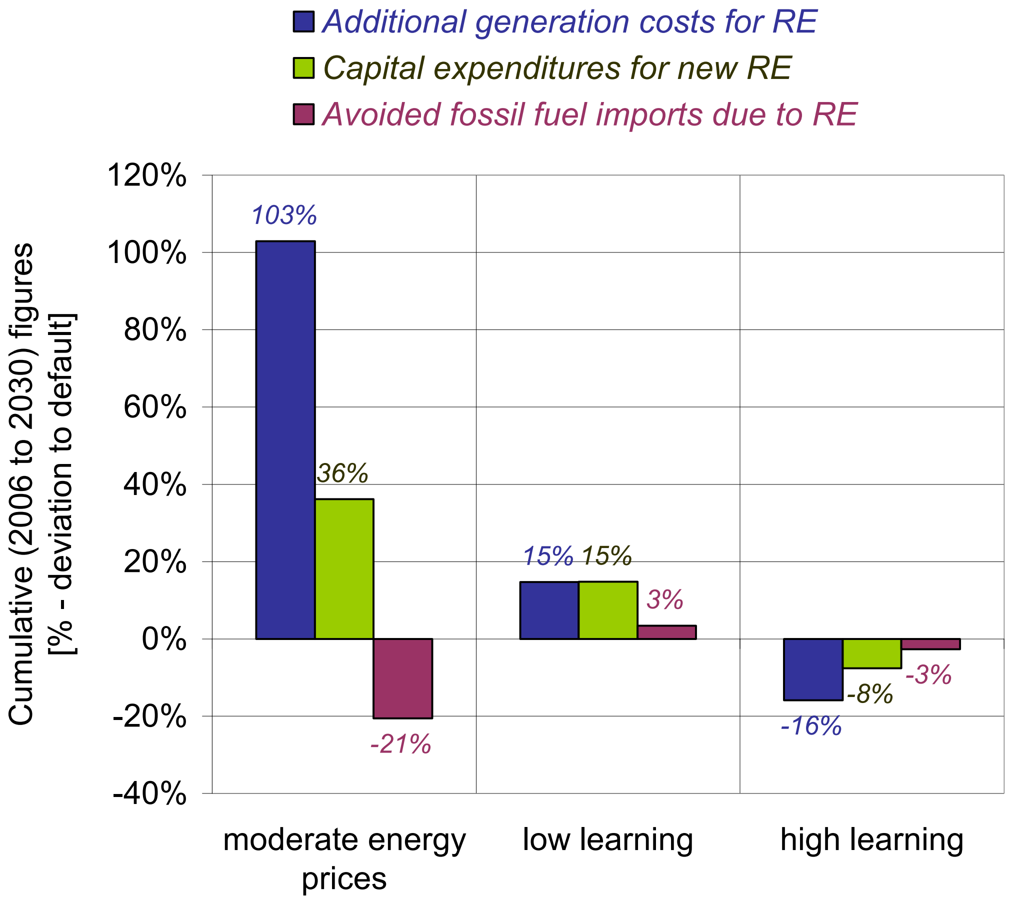


Figure 67: Sensitivity calculations on fossil energy prices and technological learning. Shown are the main indicators "additional generation costs", "capital expenditures", and "avoided fossil fuel imports" cumulatively 2006-2030

5 Scenarios on future global RES markets as basis for the macroeconomic modelling

Different scenarios are defined for the deployment of RES technologies in the EU and the rest of the world (ROW). These scenarios are then combined with different assumptions on the world market shares of European economies to form a sound basis for the subsequent macroeconomic modelling. Finally, a limited set of different overall scenarios describing future RES markets at global scale and within EU Member States are developed, which are outlined in section 5.3. Therefore, a combination of three major elements is needed to develop the scenarios:

- Deployment of RES technologies within the EU according to the Green-X scenarios No policy, BAU and ADP (see previous section 4);
- RES deployment in the rest of the world according to the IEA's reference and alternative policy scenario as published in the IEA world energy outlook (see section 5.1 below), and
- three projections on export opportunities for European economies as calculated by the ISI Lead Market Model, relying on export shares in complementary economic sectors, and patent shares (from the ISI Lead Market database) and on present world market shares from MULTIREG (see section 2).

The combination and extrapolation of these different settings provides the scenario basis for the macroeconomic models applied in this project. The opportunities for RES technology exports to global markets under the three policy cases for the EU and corresponding global energy projections are elaborated by means of conducting a qualitative and a quantitative assessment based on projected future global RES developments. Key inputs for this assessment are IEA's recent renewable energy projections which we briefly discuss in the following. The further assessment will also include an overview on the targets set and investment required from a worldwide perspective. Then, as illustrated in the subsequent section, European export opportunities are analysed on technology level, assessing the state-of-the-art and deriving likely future trends based on the ISI-Lead Market Model. For the EU policy cases we refer back to the description of the GreenX scenarios in chapter 4.

5.1 Global RES deployment based on the IEA world energy outlook

Prospects for RES technologies are presented in this study at a global level, illustrating the feasible deployment of these technologies by means of scenarios depending on the applied energy policies. These future projections as published in the latest IEA "World

Energy Outlook 2007"[36] were conducted with EEG's global RES modelling tool **World*RES***.[37] Two different cases will be presented subsequently which show the feasible RES deployment exemplarily for the electricity sector:

- A *reference scenario*, illustrating a conservative view of the future RES deployment based on the currently applied energy policy support and the corresponding observed framework conditions that often comprise several deficits for an accelerated RES deployment.
- In contrast to this, an *alternative policy scenario* aims to indicate the feasible RES deployment if support measures as currently in the pipeline of political decision making will become effective. This also comprises an improvement with regard to pending non-economic obstacles.

The following part illustrates the future deployment of RES-E generation according to these projections for selected countries / regions, at global scale as well as on technology level.

Figure 68 (below) provides a comparison of the future RES-E deployment up to 2030 in absolute terms by country / region. The left hand figure represents the deployment in the reference scenario while the right hand figure is based on the alternative policy scenario. Within the reference scenario the EU27 would maintain its leading role with regard to RES-E at global scale, whereas the contribution of Japan and Russia is comparatively small. Moreover the latter show only small increases within the regarded time period in comparison to other countries where a doubling of RES-E production is expected. On the other hand, the alternative policy scenario evolves stronger increases of electricity generation from renewable energy sources, especially in economically emerging regions such as China and India. Remarkable, China would then also take over the global lead by 2025. Comparing both scenarios, at global scale a higher renewable electricity exploitation of 1637 TWh can be observed in the alternative policy case.

---

[36] International Energy Agency (2007). World Energy Outlook to 2030 – 2007 edition. International Energy Agency, Paris, France.

[37] The projections of renewable energies of last year's "World Energy Outlook 2007" were derived in the separate model WorldRES, allowing assessments of the future deployment of renewable energies and the investment needs related to such deployment. This model has been developed for this purpose by the Energy Economics Group (EEG) at Vienna University of Technology in cooperation with Wiener Zentrum für Energie, Umwelt und Klima (WZE). This builds on previous work as done in a fruitful cooperation in the context of IEA's last years world energy outlook series.

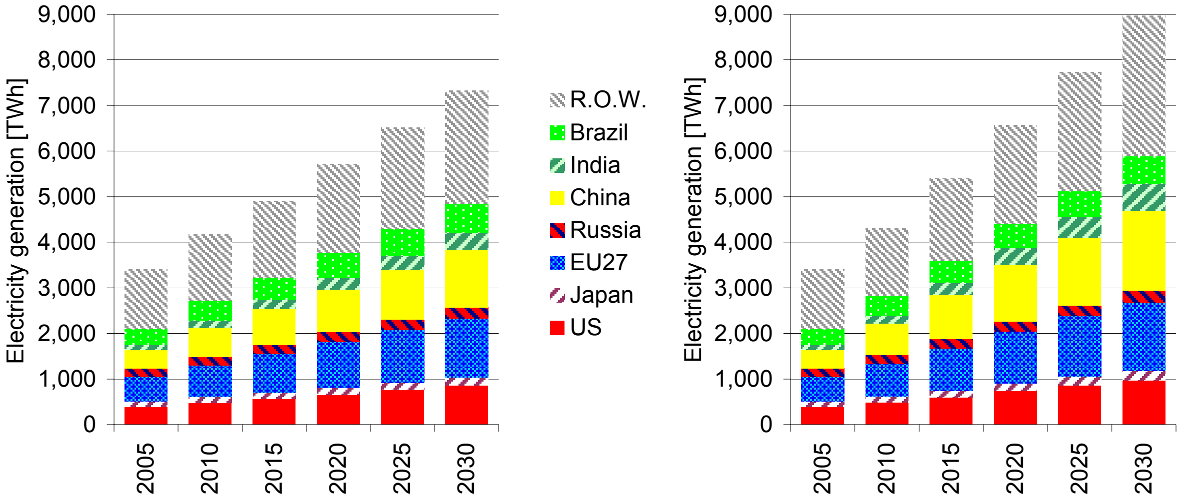


Figure 68: Comparison of the future RES-E deployment up to 2030 in absolute terms by country / region for both IEA scenarios – reference case (left) and alternative policy scenario (right) Source: Own investigations and (IEA, 2007)

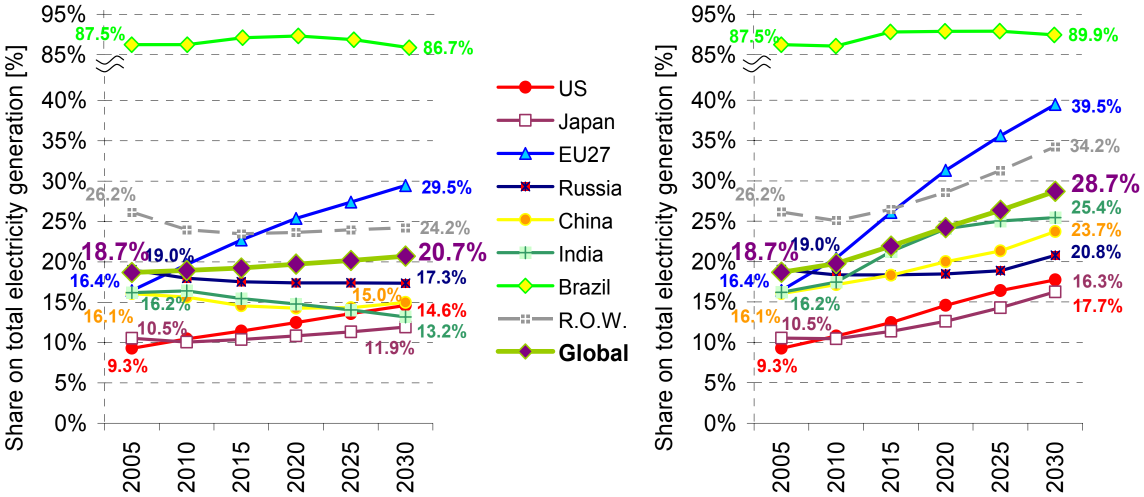
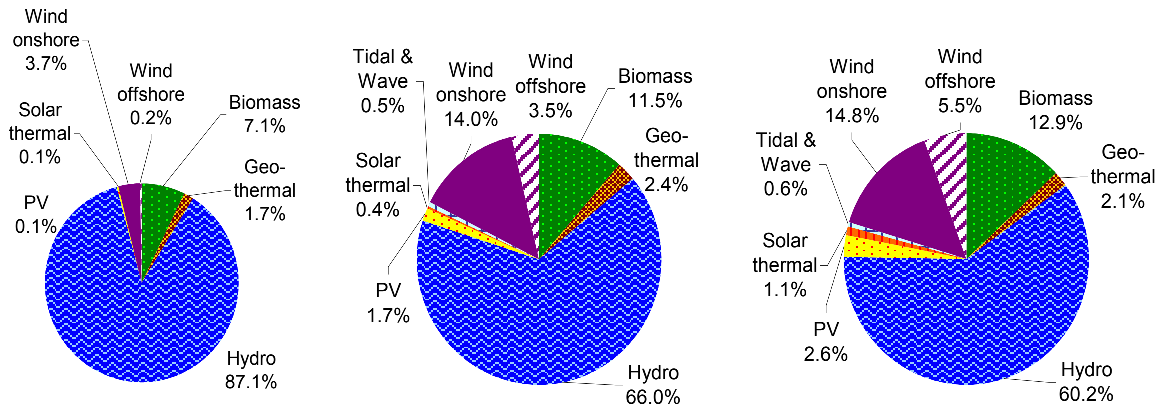


Figure 69: Comparison of the future RES-E deployment up to 2030 in relative terms (expressed as share on total electricity generation) by country / region for both IEA scenarios – reference case (left) and alternative policy scenario (right) Source: Own investigations and (IEA, 2007)

Figure 69 (above) shows a comparison of the future RES-E deployment up to 2030 in relative terms, indicating the RES-E share on total electricity generation by country / region. The left hand figure illustrates the deployment in the reference scenario while the depiction on the right refers to the alternative policy scenario. In the reference scenario industrialised countries / regions achieve an increase of the electricity generation from renewable energy sources in relation to its total electricity generation except the economically emerging countries where the RES-E share slightly declines. However, for Brazil a hold of their already high RES-E share is projected. Remarkable is the comparatively strong increase of the EU27 region from currently (2005) 16.4% up to 29.5% in 2030. In comparison, discussing the alternative policy scenario all investigated countries / regions show an increasing share of RES-E. Besides the EU27 region with the strongest increase up to 39.0%, also the US and Japan as well as the emerging economies China and India show strong increases of about 10%. At global scale, it can be expected that 28.7% of total electricity will be generated by using RES by 2030, corresponding to an increase from currently (2005) 18.7% by 10% within the assessed period of 25 years.



Total RES (2005): 3,401 TWh

Reference scenario
Total RES (2030): 7,332 TWh

Alternative policy scenario
Total RES (2030): 8,969 TWh

Figure 70: Technology-specific breakdown of the current (2005 – left) and of the expected RES-E deployment by 2030 at global scalefor both IEA scenarios – reference case (middle) and alternative policy scenario (right)
Source: Own investigations and (IEA, 2007)

Figure 70 (above) indicates the technology-specific breakdown of the current (2005 – left) and of the expected RES-E deployment by 2030 in the reference case (middle) as well as the alternative policy scenario on the right hand. Firstly, a strong increase of the total electricity generation by renewable energy sources in absolute terms is notable. As already stated in prior, currently among all RES-E technologies hydropower is strongly dominating the market, whereas wind, biomass and geothermal power only contribute with 12.7% in total to renewable electricity generation. In the reference scenario up to 2030 the diversity of RES-E technologies is growing since major shares of the hydro potential are already exploited. Besides hydro power (66.0%), wind onshore (14.0%) as well as biomass (11.5%) and wind offshore (3.5%) will play an important role. Additionally, geothermal, solar thermal and photovoltaics will also contribute to a larger extend compared to the current situation. Considering the alternative policy scenario, new renewables will contribute even larger in absolute as well as in relative terms due to the improvements of the support framework for these promising technology options. Although hydropower also deploys larger the share on total RES-E is expected to be smaller than in the reference case (60.2% in 2030). All “new” RES-E except geothermal electricity increase their share on total RES-E by 2030 more substantially compared to the reference case. Thereby, a significant amount of currently novel technology options including offshore wind (5.5%), photovoltaics (2.6%), solar thermal electricity (1.1%) and tidal & wave power (0.6%) is observable.

5.2 ISI Lead Market database as basis of the export projections for RES technology

5.2.1 Lead markets and RES technologies

Globally successful innovations have commonly been preferred first in one country or region before being adopted internationally according to Beise (Beise 997-1018). Countries in which these innovations have evolved can be described as lead markets. It is said they have a first mover advantage. A lead market is the origin of the diffusion of a newly developed technological solution. It is a market in which the demand for such a technology is higher than in other countries, in which firms can grow and realise cost advantages or technological leadership providing them an advantage on the international market for that technology.

Due to their special characteristics, lead markets provide the opportunity to keep those parts of an enterprise with a relatively high part of the value creation - like research and development - in one country in the long run. If environment policy contributes to the development of a lead market it fosters aims also pursued by industry policy.

In case of the successful diffusion of an environmentally sound technology, like renewable energy technology, additionally positive effects for the environment are created.

Lead market ability of RES technologies

One prerequisite that an ambitious EU RES policy can lead to additional exports is the lead market ability of RES technologies. A lead market ability is given if the technology fulfils the following three criteria:

- high knowledge-intensity: In general, the technology intensity of renewable technologies can be judged as being above average or even (e.g. photovoltaics) high tech (see Grupp 1998).

- high innovation dynamics: The patent dynamics for renewable energy technologies also shows an impressive push, which has been characterised by substantially higher patent growth rates than the average increase in patents (Figure 71). This holds especially for on- and off-shore wind energy technologies, which have experienced a patent growth even above the average of RES technologies, followed by photovoltaics.
- high potential learning effects: e.g. the latest Japanese Delphi study, reveals that above average learning effects are expected for renewable energy technologies.

They are the key criteria for a country that strives to forge ahead technologically and aims at solutions which are cost competitive.

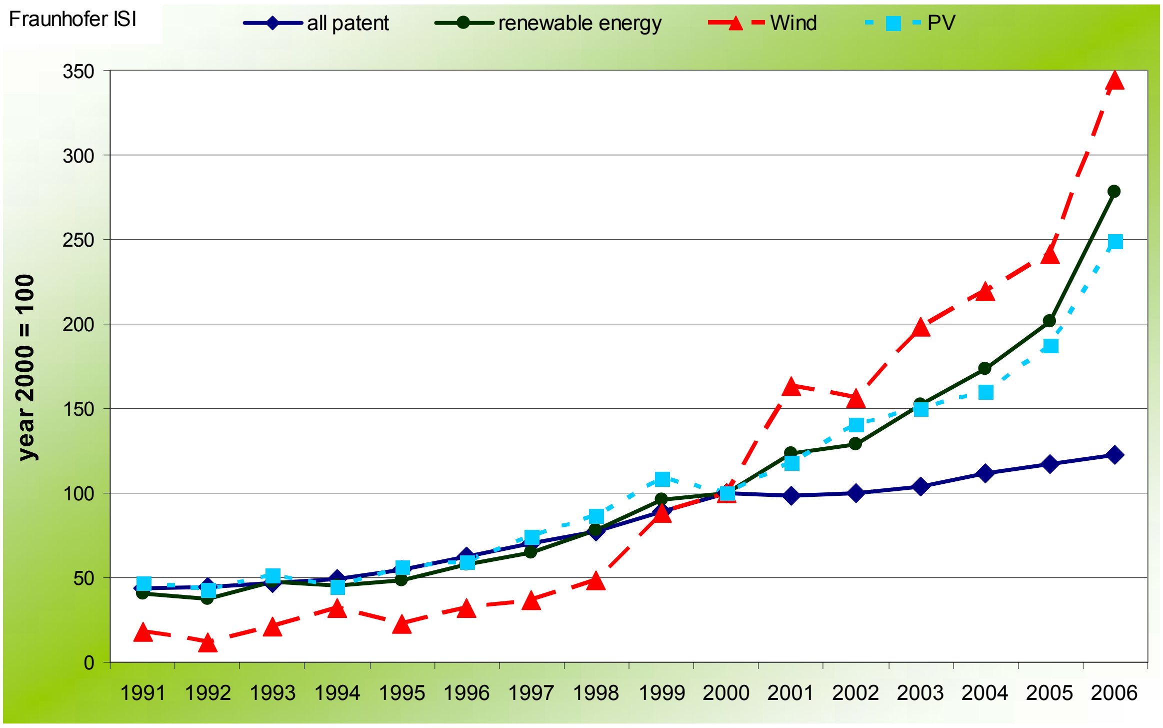


Figure 71: Innovation dynamics for renewable energy technologies
Source: calculations of Fraunhofer ISI

Comparative Lead Market Factors for RES technologies

It follows from the discussion of the lead market factors that the diffusion of the technologies is important for cost and price advantages. Thus, the diffusion pattern shown in the scenarios developed in this report also influence the cost advantages of countries based on both economies of scale and learning. Furthermore, it can be expected that user-producer linkages are increasing if the diffusion of the technology in the (home) market is increasing too. Thus, additional diffusion also leads to improvement of future technological capability. As can be seen for example for renewable electricity in Figure 68 the share of the EU-27 in the global diffusion of RES technology after 2006 is projected to account for roughly 20%.

The export and transfer advantages are difficult to assess with indicators. However, it can be assumed that already existing export success also backs these two factors. Thus, there is a path dependency in the market performance, with past success making it easier to obtain future success. Clearly, the market shares found in the past also continue to influence the market shares in the future.

It is widely held that innovation and economic success also depend on how a specific technology is embedded into other relevant industry clusters. Learning effects, expectations of the users of the technology and knowledge spillovers are more easily realized if the flow of this (tacit) knowledge is facilitated by proximity and a common knowledge of language and institutions. The results of Fagerberg (1995b) can be explained in this way. He found strong empirical evidence that the international competitiveness of sectors and technologies is greatly influenced by the competitiveness of interlinked sectors. By and large, renewable technologies have very close links to machinery and electronics. Thus, it can be argued that countries with strong production clusters in these two fields have a particularly good starting point for developing a first-mover advantage for renewable energy technologies, especially because success in these clusters also contributes to an export and transfer advantage. Figure 72 gives an indication of the competitiveness in these 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. If one looks at the export specialisation of the countries, measured by the revealed comparative advantage (RCA), it becomes clear that Japan and the US are also showing positive specialisation on these complementary sectors. For the different EU countries, both positive and negative specialisation can be found. Thus, for the EU as a whole, there is no clear comparative advantage with regard to competitiveness of complementary clusters.

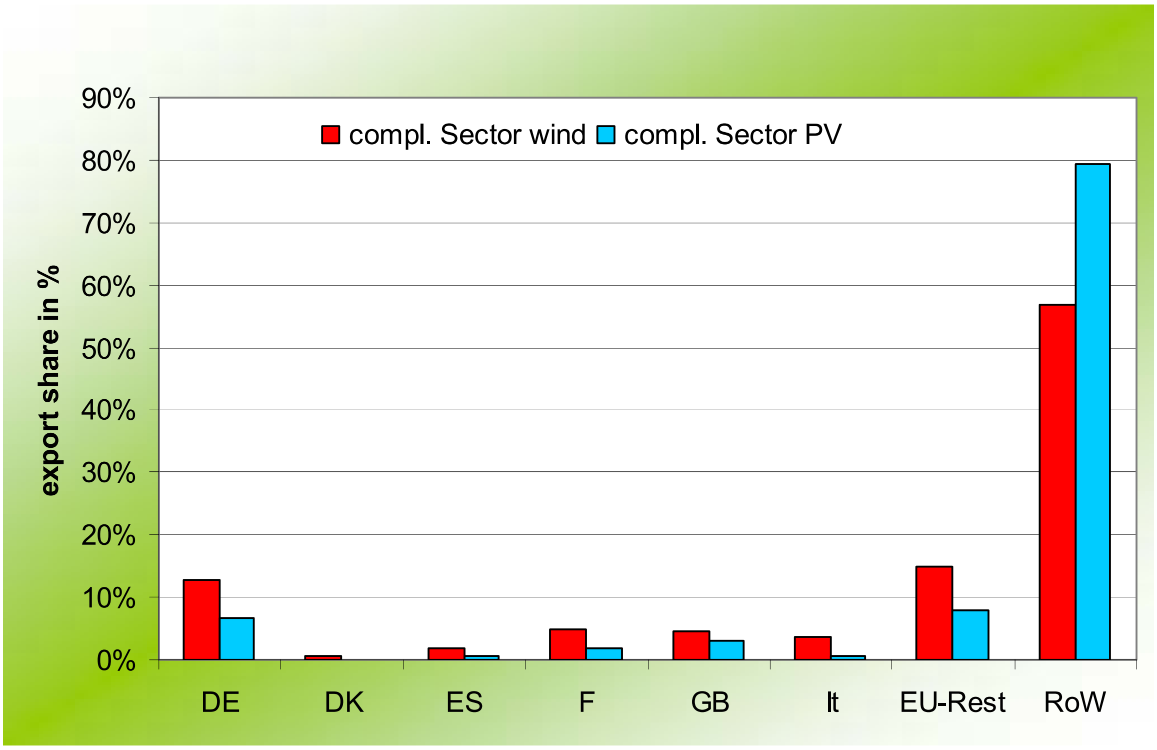


Figure 72: Shares of EU countries/ regions and the rest of the world (RoW) at world exports in complementary sectors to wind energy technologies and PV
Source: Calculations of Fraunhofer ISI

Since the Leontief Paradox and subsequent theories such as the Technology Gap Theory (Posner 1961) or the Product Cycle Theory (Vernon 1966), it has become increasingly accepted that international trade performance depends on technological capabilities (see, e.g. the overview in Fagerberg 1995a and Wakelin 1997). This has been supported by recent empirical research (e.g. Grupp/Münt 1998; Fagerberg/Godinho 2005; Blind/Frietsch 2005) underlining the importance of technological capabilities for trade patterns and success. Thus, the ability of a country to develop a first-mover advantage also depends on its comparative technological capability. A country has an additional advantage in developing future technologies if it has a comparatively high knowledge base. 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 clearly shows that there are strong differences between wind energy technologies on the one hand and photovoltaics on the other. Europe clearly is the leader in the first, but must catch up at the latter.

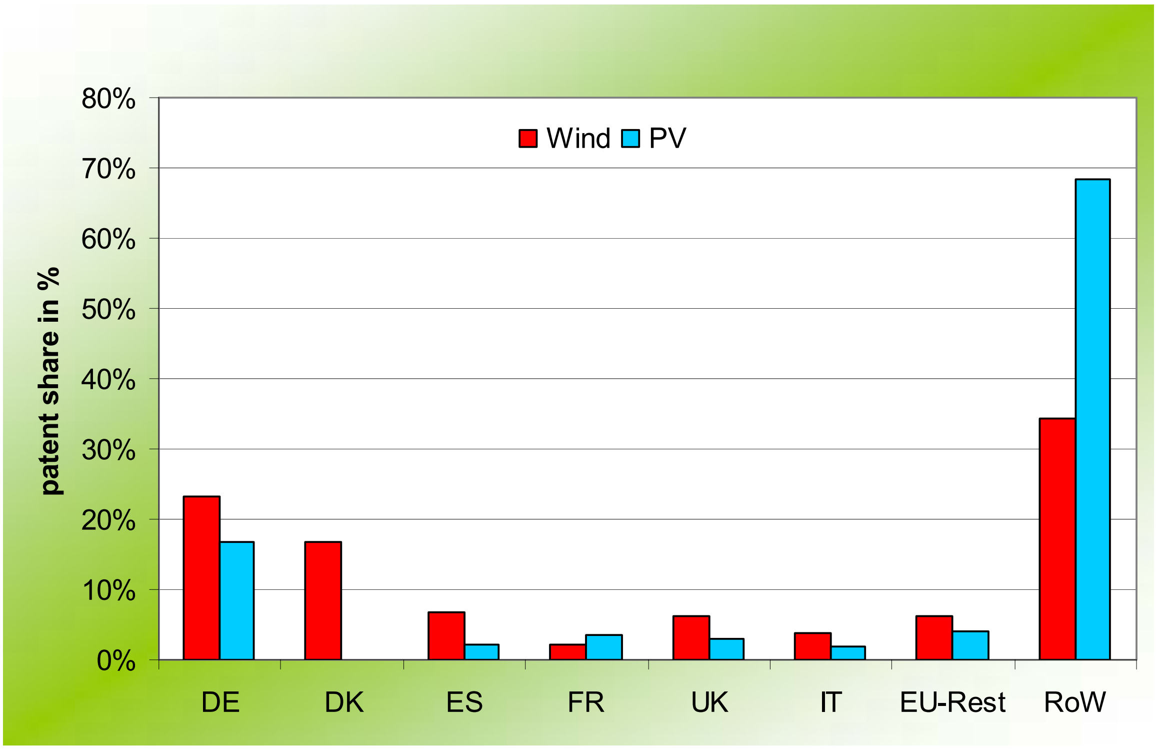


Figure 73: Shares of EU countries/ regions and the Rest of the World (RoW) at patents in wind energy technologies and PV in 2006
Source: Calculations of Fraunhofer ISI

A lead market situation must also be supported by innovation-friendly regulation and a well functioning innovation system for renewable energy technologies. There have been first attempts to measure the innovation friendliness of regulation (Walz et al. 2008). However, research in this direction is still very exploratory, and it is too early to build quantitative scenario analysis on them. Thus, especially these factors must be taken into account in form of a sensitivity analysis, e.g. distinguishing between optimistic and pessimistic cases.

5.2.2 Scenarios for world market shares for RES technologies

It has been shown that especially wind energy technologies (on- and off-shore) and photovoltaics have a considerable above average innovation dynamics. Thus, for these three technologies, the scenarios for market shares were explicitly built on the lead market considerations sketched out above. For the other renewable technologies, the market shares and exports of the base year, which are analysed in chapter 5, are projected according to the results of the macro-models for the underlying sectors, which are modelled endogenously in both ASTRA 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 story outlined in the construction of the scenarios as defined in section 5.3. As the underlying forces which influence the market shares develop in the BAU and the ADP scenario similar for both the EU countries and the Rest of the World, the market share scenario does not differ either. However, there clearly are 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. Therefore the market share scenarios distinguish between a more negative and more positive variant. In quantitative terms, it is assumed that the world market share of the EU versus the Rest of the world changes by ca. 12 percentage points between the pessimistic, the moderate and the optimistic scenario in 2030.

In order to develop the scenarios, comparative lead market factors for the EU countries – in comparison to the rest of the world – for the market share already achieved, diffusion of the three RES technologies in the home market, patent share and export share of the complementary sector were used as a starting point. Based on the indicator values for these variables for each year in the projected period, the market share were projected by expert opinion for each year. This dynamic projection scheme has the advantage that the phase of changes in the world market share is consistent with the changes in the underlying forces. Figure 74 and Figure 75 show the results for the example of wind on-shore for the EU-pessimistic and the EU-optimistic market share variant. Based on the calculations carried out here, it can be shown that the market shares develop in different directions. For on-shore wind energy, there is a catching up of the Rest of the World, e.g. by the US and Japan or emerging economies such as India (Suzlon) or China. For off-shore wind energy technologies, Denmark enjoys an early lead, which is eroded over time. However, the market shares for the first movers still remain rather considerable high. For photovoltaics, however, the underlying forces imply even a slight catching up of the European countries to the rest of the world, even though emerging economies (e.g. China) are pushing considerably into the market.

In order to interpret these results correctly it must be kept in mind that these shares are applied to a different market volume, which increases both over time and between the BAU and policy (ADP) scenario (for scenario definition see section 5.3). Thus, a constant market share translates into enormous increase in the absolute market value supplied by a country.

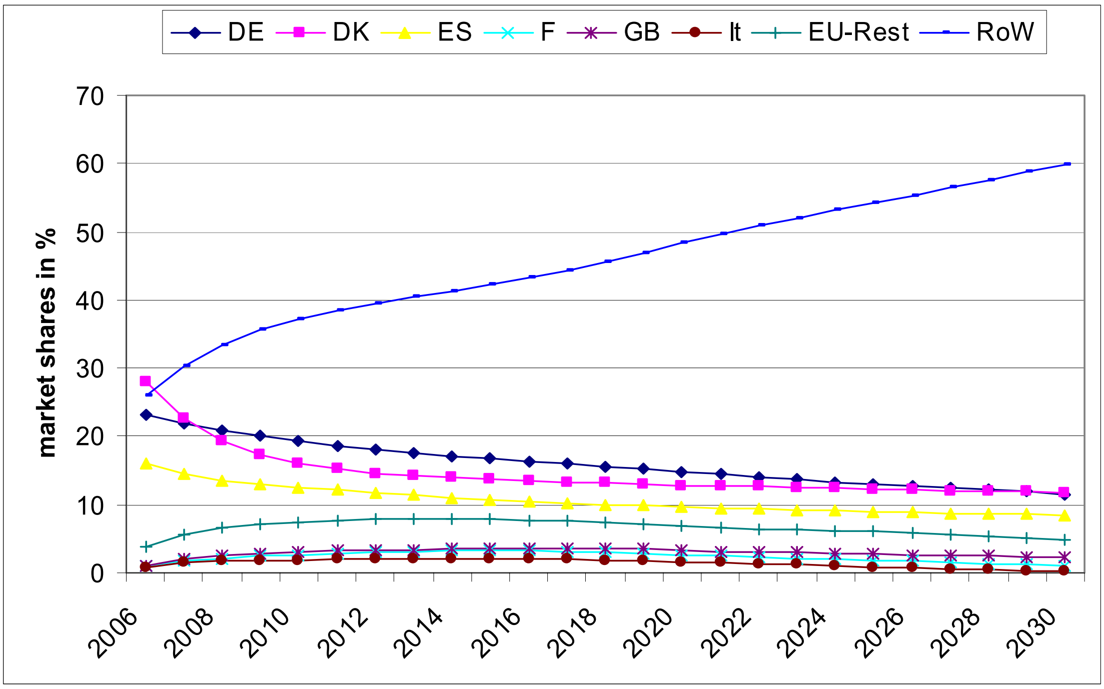


Figure 74: Market shares of EU countries and the Rest of the World (RoW) for on-shore wind energy technologies for the pessimistic scenario
Source: Calculations of Fraunhofer ISI

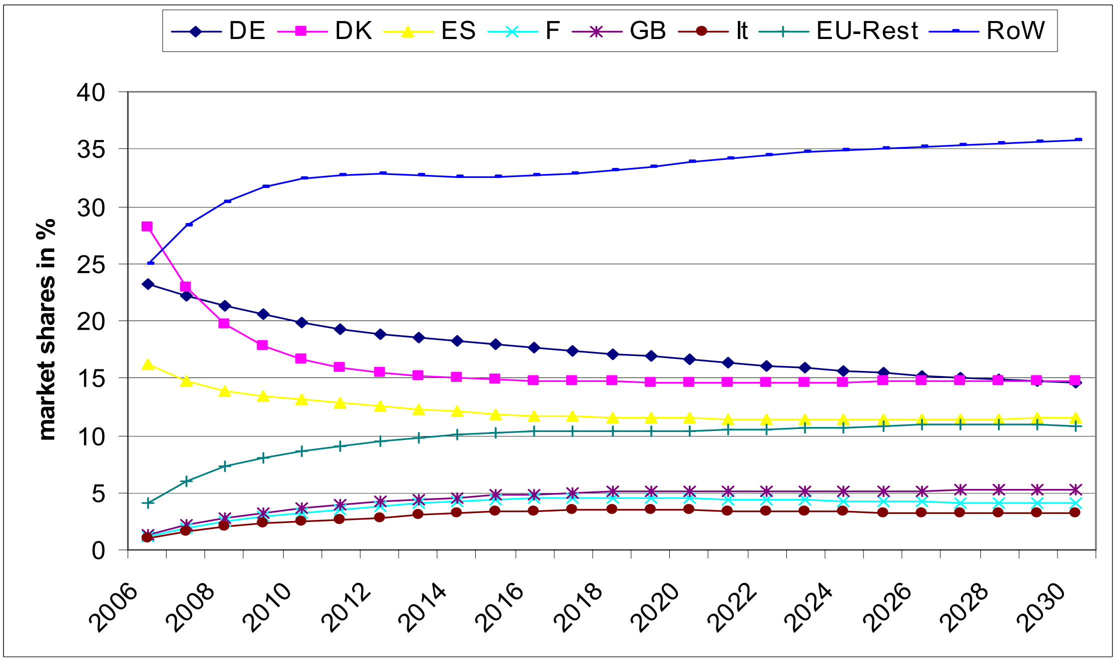


Figure 75: Market shares of EU countries and the Rest of the World (RoW) for on-shore wind energy technologies for the optimistic scenario
Source: Calculations of Fraunhofer ISI

5.2.3 Export projections for the final scenarios

The policy settings for renewable energies in the EU-27 and IEA projections on renewable energy sources discussed before are now combined with assessments on the export potential of European economies[38]. These assessments are based on an econometricl analysis and evaluation of the key input parameters for the characterization of lead markets, as discussed in the preceding section. Generally, three different scenarios for the export potential of European economies are defined (the graphical presentation of the market shares of the EU and the rest of the world in the global cost components of the technologies is shown in Figure 76):

- Pessimistic case: the world market share of European companies for global cost components of RES technology is reduced from ca. 69% in 2006 to ca. 31% in 2030.
- Moderate case: the world market share of European companies for global cost components of RES technology in 2030 is on average 12% points larger compared to the pessimistic case
- Optimistic case: the world market share of European companies for global cost components of RES technology in 2030 is on average 23% points larger compared to the pessimistic case

The current market share of the EU of around 70% shows a descending trend over time for all three cases. This is due to strong developments in other countries such as China, were production of wind turbines and photovoltaic modules has increased during the last years. This decrease in shares of the EU does not reflect a decline in market volume. Overall a strong increase in volume is anticipated such that the current market volume might be tripled in 2030.

---

[38] For the definition of local and global cost components of RES technologies see section 2. For some technologies, i.e. wind onshore, wind off-shore, photovoltaics, were the world market shares deviate significantly from the world market shares of the generic economic sectors, the future market shares are calculated based on a lead market methodology and given externally to the macroeconomic calculations. For all other technologies the exports and imports and therefore the world market shares are calculated endogenously in the macroeconomic models.

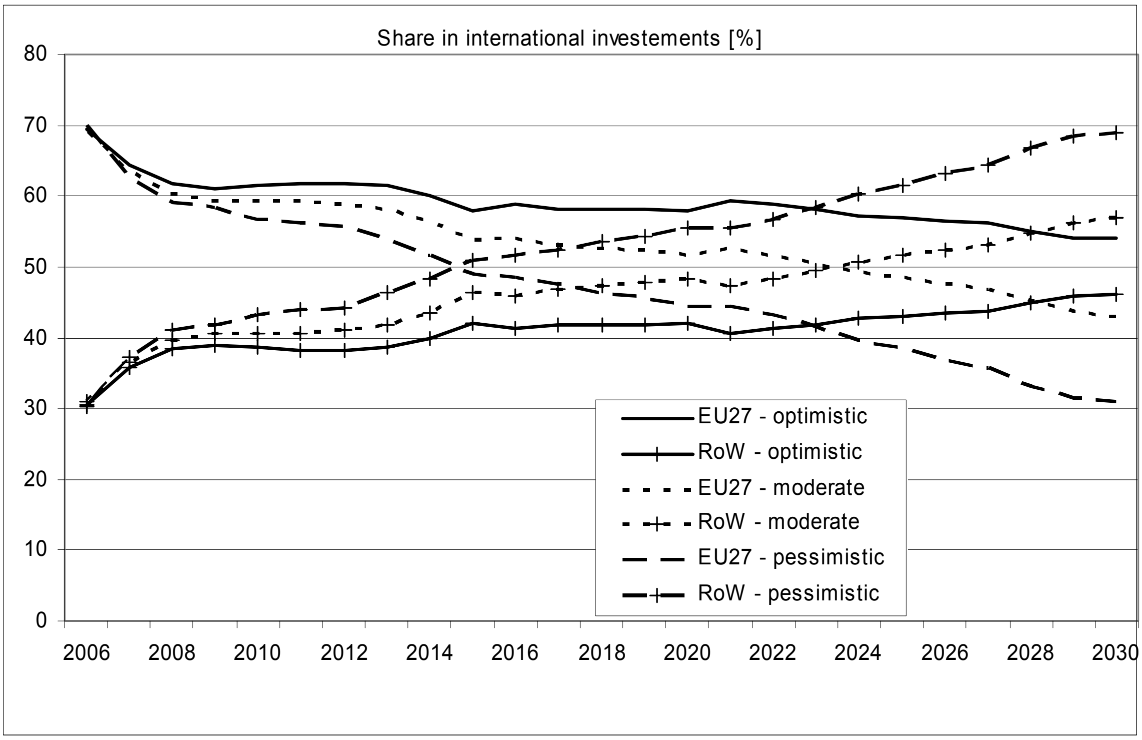


Figure 76: World market shares of the EU and the rest of the world (RoW) in the global cost components of RES technologies (weighted average of all technologies)

5.3 The scenario setting for the macroeconomic models

In a final step the two projections for the global RES development - the IEA world energy deployment reference and alternative scenario -, the three policy cases for the RES deployment in the EU No policy, BAU and Policy[39] modelled using the Green-X model and three scenarios for the global market share projections with pessimistic, moderate and optimistic export projections derived from the lead market data base and expert opinion are then combined as shown in Figure 77. Thereby for consistency reasons the more ambitious RES supporting policy cases on the EU level are combined with the more ambitious scenarios on the global level, i.e. EU BAU and IEA Reference as well as EU Policy and IEA Alternative scenario. This means a strong deployment of renewable energies on the EU level is more likely to occur if a strong development on the global level takes place.

In both cases, for EU- BAU and EU-Policy cases we have assumed two variants for the European world market share in global cost components: moderate and optimistic. Moderate and optimistic market share projections for the EU as a whole can only occur under a strong RES deployment, hence, under a corresponding EU- BAU or Policy case.

---

[39] A detailed definition of these scenarios is given below.

Only in the case, where there is a reference deployment at global level and no further policy in the EU the pessimistic case for the EU world market share was applied.

Therefore the **five main scenarios** to be analysed in this study are defined as follows:

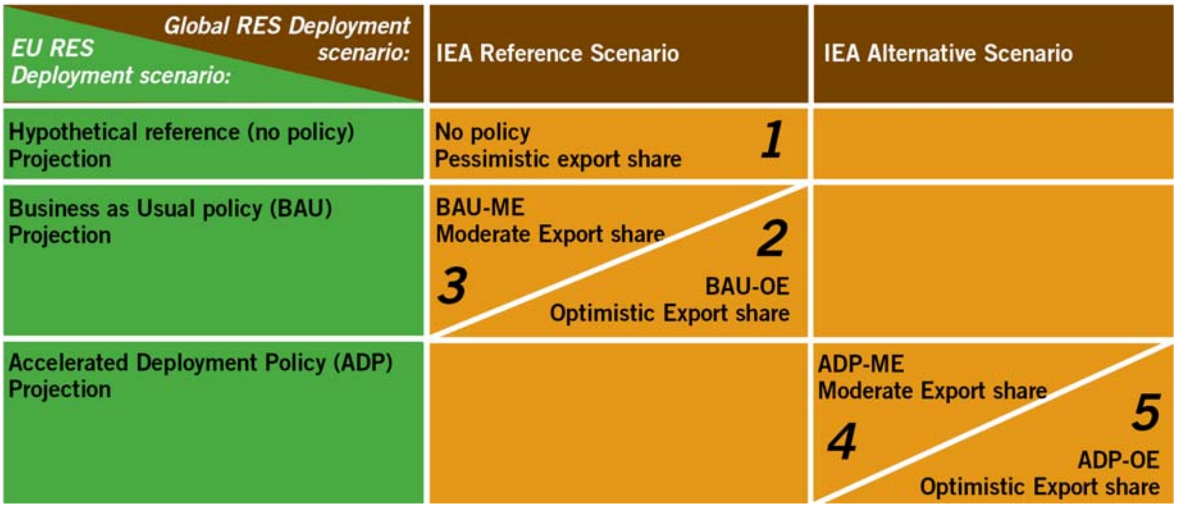
1) **No policy** - Pessimistic export share - all existing policies in Europe will be ceased to be applied while world wide no changes of the existing policies is anticipated. Therefore, the EU loses its technological competitiveness and the development of the export shares decreases steeply.

2) **BAU-ME** - Moderate export share (ME) - All existing RES policies will be continued (business as usual) until 2030 in the EU and world wide. Hence, exports in absolute numbers increase, but the EU's export share is declining over time.

3) **BAU-OE** - Optimistic export share (OE) - All existing RES policies will be continued (business as usual) until 2030 in the EU and world wide, leading to innovations within the EU and a slightly decreasing export share of the EU.

4) **ADP-ME** - Moderate export (ME) share - Accelerated deployment policies are assumed in the EU and world wide leading to innovations and a moderately declining EU export share.

5) **ADP-OE** - Optimistic export share (OE) - Accelerated deployment policies are assumed in the EU and world wide and hence and assumptions on export shares as under 3).



Global RES Deployment scenario: *EU RES Deployment scenario:*	IEA Reference Scenario	IEA Alternative Scenario
Hypothetical reference (no policy) Projection	No policy Pessimistic export share *1*	
Business as Usual policy (BAU) Projection	BAU-ME Moderate Export share *2* *3* BAU-OE Optimistic Export share	
Accelerated Deployment Policy (ADP) Projection		ADP-ME Moderate Export share *5* *4* ADP-OE Optimistic Export share

Figure 77: Combination of scenarios for EU and global RES scenarios and assumptions on European export shares (world market shares)

6 Future gross effects of RES

This section presents the **gross** macroeconomic effects of the different scenarios on the European economies, with the focus on employment and value added. The calculation of the gross effects is mainly based on input-output relations as given by the MULTI-REG model presented in chapter 2 in combination with the future evolution in labour productivity provided by the NEMESIS model and demand for RES technology based on the Green-X model.

For the definitions of the five main scenarios developed in this project and largely used in the subsequent sections, we would like to refer to the preceding chapter. To emphasise and point out the impacts of the different policies and export projections, we present the results on employment and GDP as differences from the scenario without and with RES promoting policies as follows:

- **BAU-ME – No policy:** scenario "Business as usual" (BAU) and moderate exports (ME) *versus* "No policy": gross employment under a scenario with current RES policy actions with a moderate export development minus gross employment of the scenario with no further policy support for renewables.
- **BAU-OE – No policy:** scenario "Business as usual" (BAU) and optimistic exports (OE) *versus* "No policy": gross employment under a scenario with current RES policy actions with a optimistic export development minus gross employment of the scenario with no further policy support for renewables.
- **ADP-ME – No policy:** scenario "Accelerated RES deployment policy" (ADP) and moderate exports (ME) *versus* No policy: gross employment of the scenario with accelerated policy actions under a moderate export development minus the gross employment of the scenario with no further policy support for renewables and hence pessimistic export expectations for RES technologies.
- **ADP-OE – No policy:** scenario "Accelerated RES deployment policy" (ADP) and optimistic exports (OE) *versus* "No policy"": gross employment of the scenario with additional policy actions under optimistic export expectations minus the gross employment of the "No policy" scenario.

The gross effects of RES use provide an impression of the size or economic relevance of the RES industry and the industries that depend on it as suppliers. The calculation of the gross effects therefore includes all RES-related economic activities and all currently available and future RES technologies. The calculation of the **future gross employment effect** is illustrated in Figure 78 below. It is based on

- the future development of investments, operation and maintenance and fuel use expenditures from the Green-X model per country, RES technology and scenario;

- translation of the future economic activities from Green-X in our five scenarios by taking into account the market shares and export projections
- the current labour coefficient for each RES technology and country from the MULTI-REG model;
- the changes of the labour coefficients over time per country, economic sector, RES technology and scenario from the macroeconomic model NEMESIS.

On this basis, the future gross employment effect can be estimated per country, RES technology, scenario and year up to 2030.

For the estimation of the future RES-policy impact on the value added, we used the results from the Green-X model and translated them into the five different scenarios by taking into account the market shares as well as the global and local trade and production pattern.

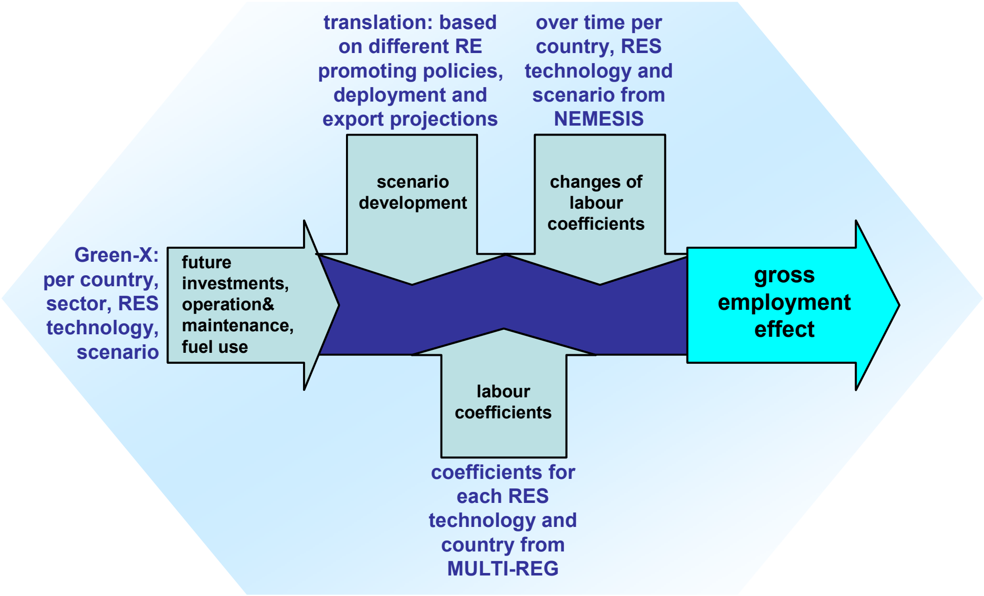
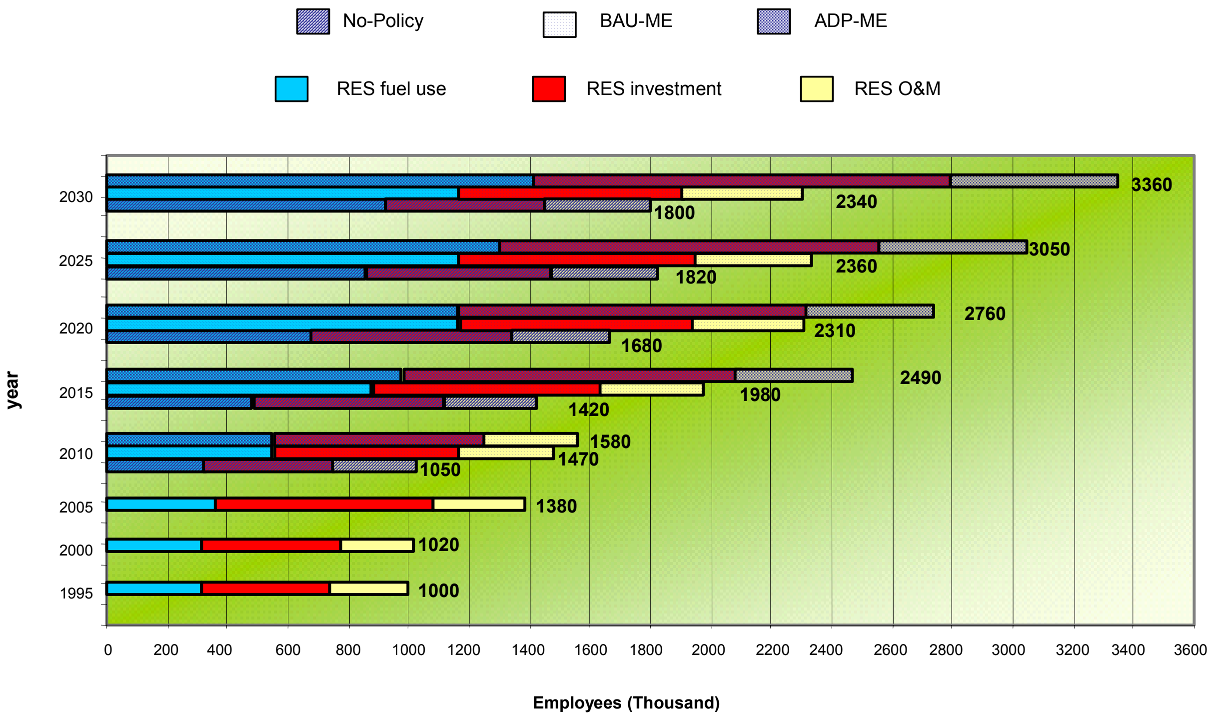


Figure 78: Calculation scheme for the gross effects

6.1 Gross effects on the EU 27 level

The gross effects depicted here are indicated by technologies or cost types, referring to the origin of the impulse. The cost type "investments" refers to employment caused by producing the generation technology and plant, "fuel use" refers to all the activities implied to provide biomass fuels while "operation and maintenance" includes all jobs (value added) related to run the generation facilities. Technologies are distinguished according to the generation technologies solar, wind, biomass, etc. and into the categories heat, electricity and transport.

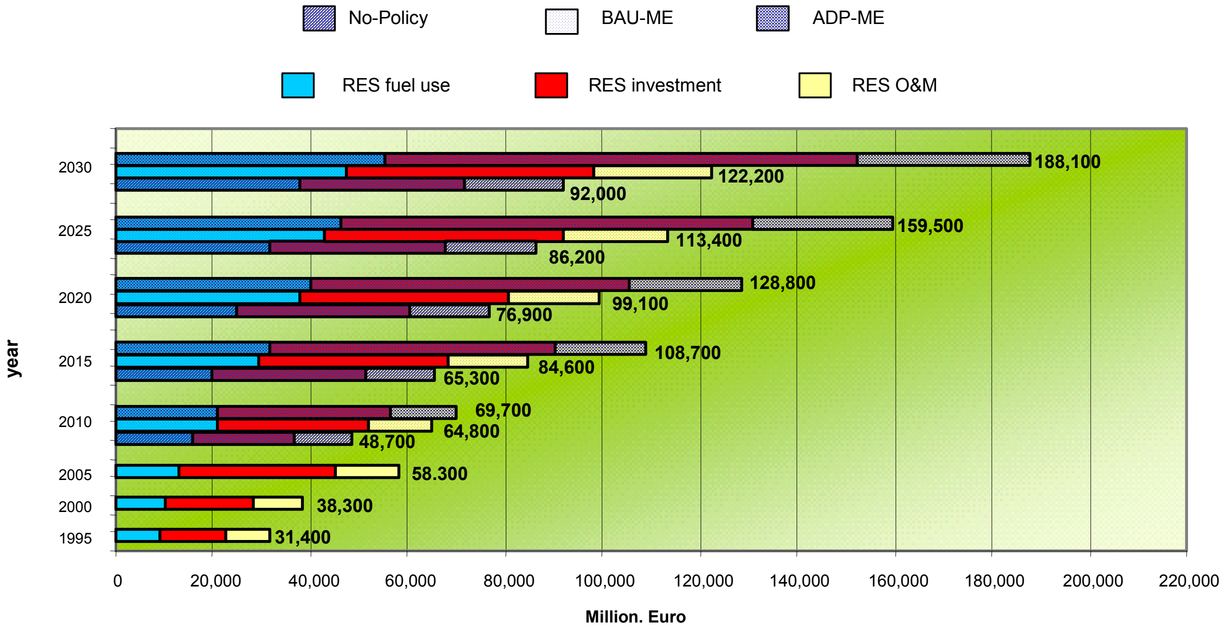
The gross effects on employment and value added in the EU27 are depicted in Figure 79 and Figure 80, respectively. The future effects in these two figures are shown for three of the five scenarios as described in the section before. The past gross effect is given by one value reflecting the historical development.



Source: own calculation (Rütter+Partner, EEG, Seureco, Fraunhofer ISI)

Figure 79: Development of gross employment under scenario "No policy" BAU-ME and ADP-ME in the EU 27, by cost types

The results show a clear increase in employment and value added under RES-promoting policies (BAU and ADP scenario). In the No policy scenario employment increases until 2025, but stays far below the employment in the BAU and ADP scenario. In the BAU scenario gross employment reaches a saturation point at around 2025, while it continues to grow significantly in the ADP scenario. Among the three cost types O&M plays a minor role, while investment and fuel use are the main carriers for employment. However, the impact of biomass fuel use on the results for value added and employment depends on the assumption about the ratio of commercial and non-commercial biomass production. In this study 50% of total biomass use in non-grid-connected small scale units is assumed to be non-commercial until 2010. The future non-commercial biomass use is assumed to correspond to the anticipated existing stock of non-grid biomass boilers that is decreasing. Nevertheless, fuel use sets off a relatively large employment effect in all scenarios. However, future employment growth under a strong RES supporting policy is strongly triggered by investments in RES technologies. As future biomass potentials are limited and innovative RES technologies are developing rapidly the (traditional) biomass sector looses in relative significance for employment over time.

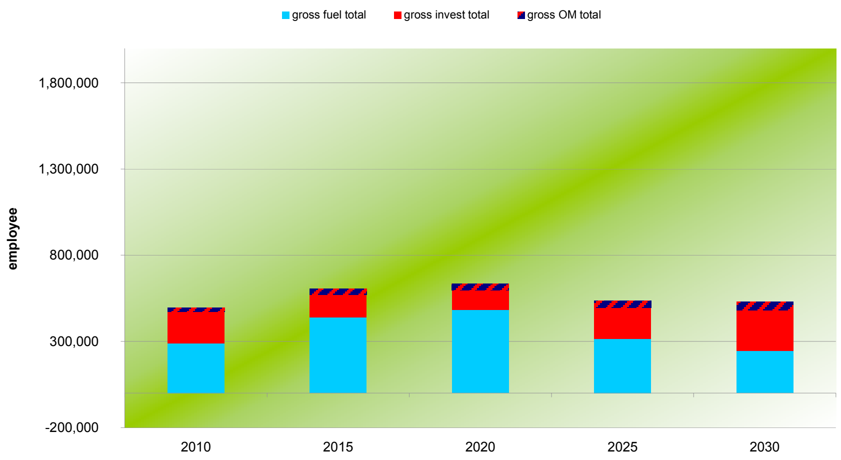


Source: own calculation (Rütter+Partner, EEG, Seureco, Fraunhofer ISI)

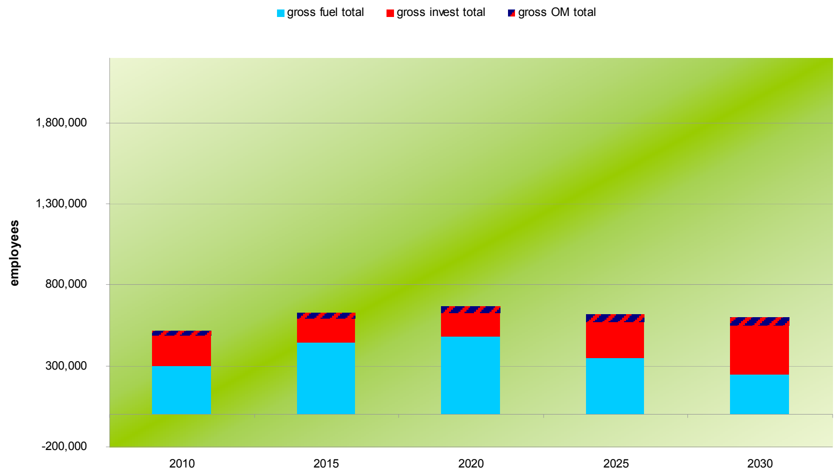
Figure 80: Gross effect on value added for the EU 27 by cost types

In contrast to the future development of employment, the value added continuously increases in all three scenarios, in particular under the ADP scenario owing to investments in RES-technologies, which in turn are directly triggered by the demand for RES technologies and generation plants. The RES policy targets taken into account in the different scenarios set off the demand for RES technologies. So, Figure 80 clearly illustrates the direct translation of policy targets into value added of an economy. The differences between the development of employment and value added under the three scenarios are due to the diverging labour productivities in the economic sectors and technologies. For example, biomass fuel is responsible for a larger share in total employment than in total value added since labour productivity in the agricultural and forestry sector is clearly lower than in other RES-related sectors. Therefore, employment will be low in sectors with a high productivity.

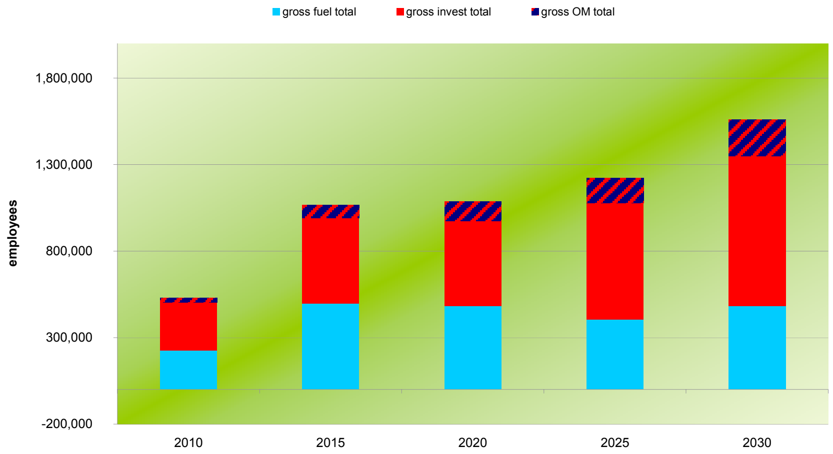
Difference between BAU-ME and No-policy EU 27 by cost types

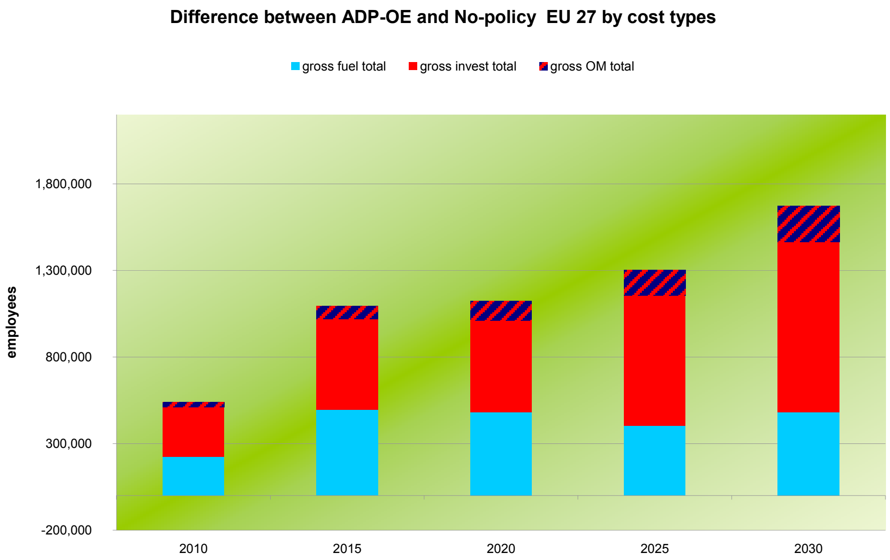


Difference between BAU-OE and No-policy EU 27 by cost types



Difference between ADP-ME and No-policy EU 27 by cost types

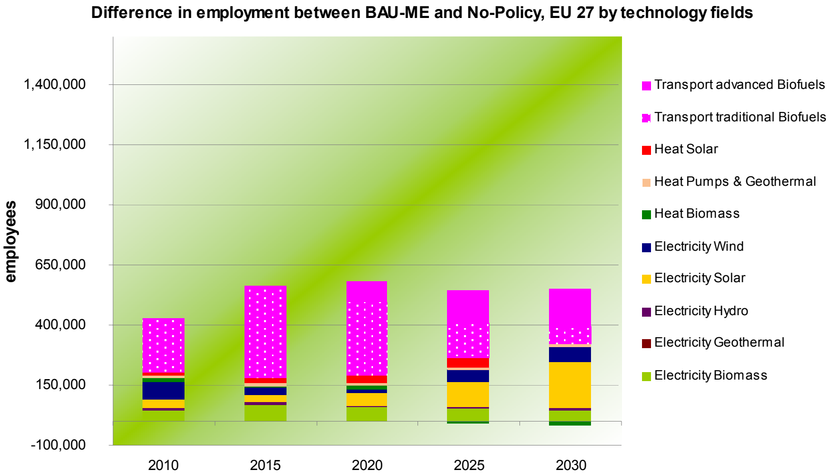


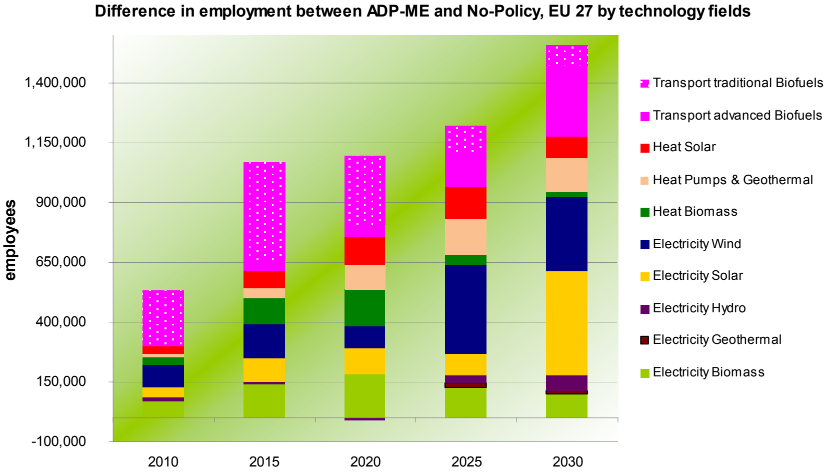


Source: own calculation (Rütter+Partner, EEG, Seureco, Fraunhofer ISI)

Figure 81: Differences in gross employment between the scenario "No policy" with the scenarios BAU-ME, ADP-ME and ADP-OE for the EU 27, by cost types

In Figure 81 and Figure 82 the differences of gross employment between the different policy scenarios (BAU and ADP) and the No policy scenario are depicted by RES-cost types and RES-technologies for the total EU-27. Both figures emphasise the increasing economic relevance of investments in knowledge-intensive RES technologies for gross employment under strong RES supporting policies. It can be clearly seen in Figure 81, that the main impulse for employment comes from the RES promoting policies and not so much from exports. The impact of policy on gross employment is rather large (ADP and BAU with respect to No policy) and reveals significant changes in the cost types investment and fuel use. Thereby, the difference between scenarios with moderate (ME) and optimistic export projections (OE) highlights just a positive impact of higher export expectations (ME and OE) on employment by the cost type investment.

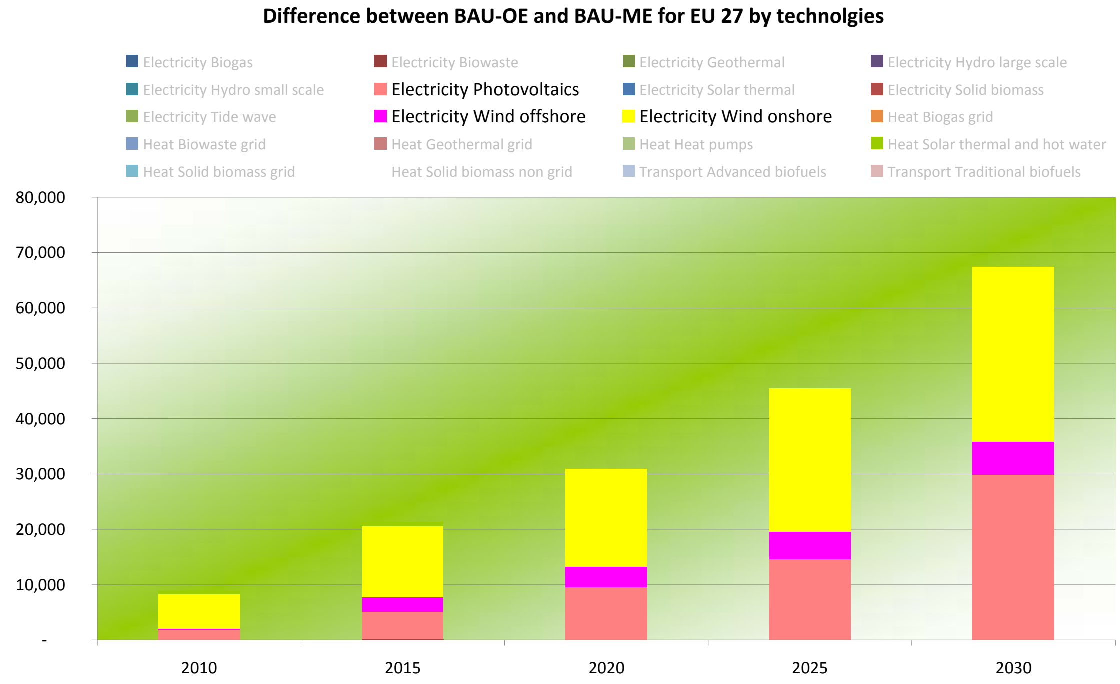

Difference in employment between BAU-ME and No-Policy, EU 27 by technology fields

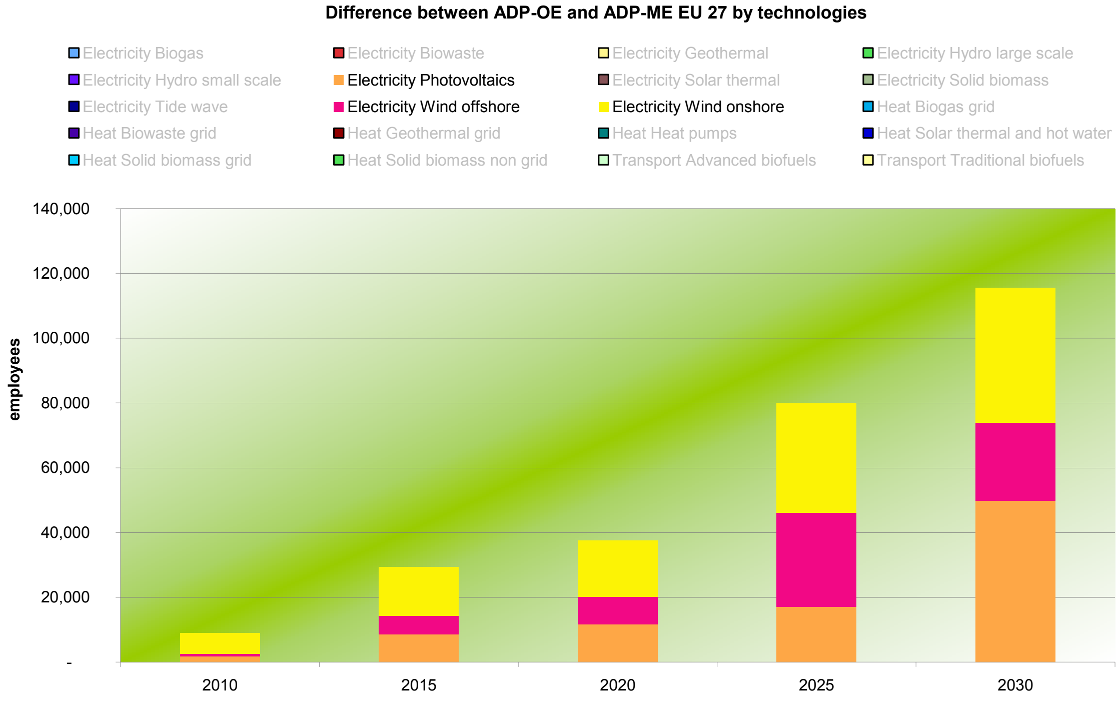

Difference in employment between ADP-ME and No-Policy, EU 27 by technology fields

Source: own calculation (Rütter+Partner, EEG, Seureco, Fraunhofer ISI)

Figure 82: Differences in gross employment between the scenarios BAU-ME and No policy as well as between ADP-ME and No policy for the EU 27, by technologies

Regarding the employment effects per technology (Figure 82), the results above are confirmed: current RES policies (BAU-ME) do not provide sufficient impulses to push future development of and employment in research and knowledge intensive technology while a strong RES promoting policy like ADP-ME triggers development and employment in knowledge intensive and innovative technologies in the future. A strong increase in RES technologies like wind power, photovoltaics and solar thermal electricity is responsible for roughly 50% of the gross employment increase in 2030 compared to a No policy situation. The technology pattern of RES deployment under this ADP-ME scenario reflects (and justifies) the high promotion and hence the additional generation costs for these knowledge intensive technologies, which are establishing successfully in the market and are contributing to export and technological competitiveness and hence to employment under the ADP scenario.





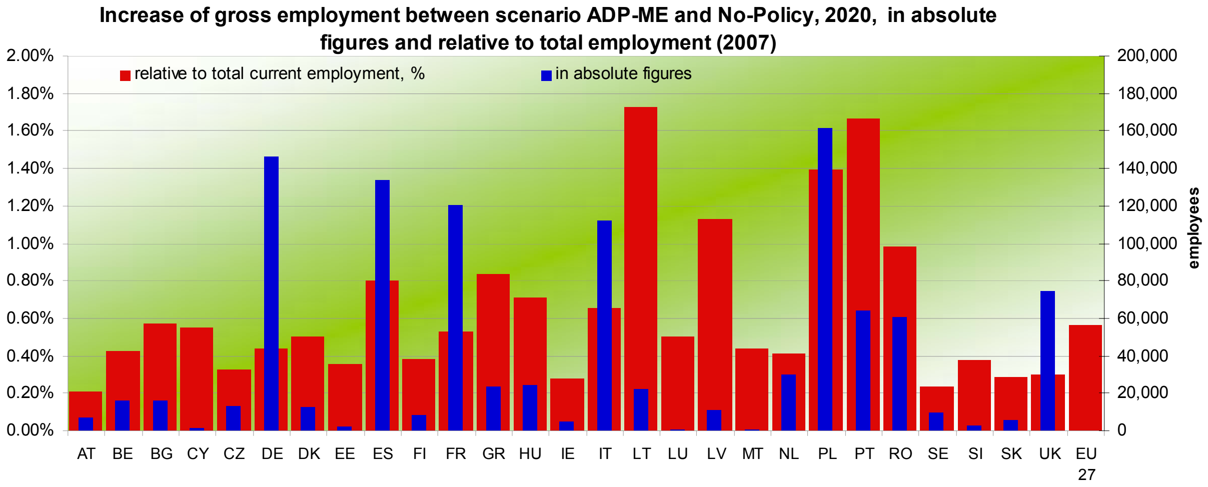
Source: own calculation (Rütter+Partner, EEG, Seureco, Fraunhofer ISI)

Figure 83: Differences in gross employment between the scenarios BAU-OE, and BAU-ME as well as between the scenarios ADP-OE and ADP-ME for the EU 27, by technologies

Figure 83 illustrates the differences between the optimistic (OE) and moderate export (ME) cases by technologies. This comparison just takes into account the global cost components. Under the BAU scenario and to a much stronger extent under the ADP scenario, the optimistic export projections lead to a stimulation of investments which in turn triggers employment in the fields of wind and solar power. In case of an optimistic export projection (OE) an additional increase of ca.120 thousand jobs can be expected for the ADP scenario in 2030. Increased exports due to investments in particular in knowledge intensive RES technologies are the main driver for this development.

6.2 Gross employment in EU member states

In Figure 84 the increase in gross employment is depicted for the individual Member States in absolute figures for 2020 and in relation to the employment in 2007. The relative impact is especially large for Eastern European countries while the impact in absolute figures is – as anticipated – strong in countries with a large population. All countries are benefiting from RES promotion according to their comparative cost/production advantages

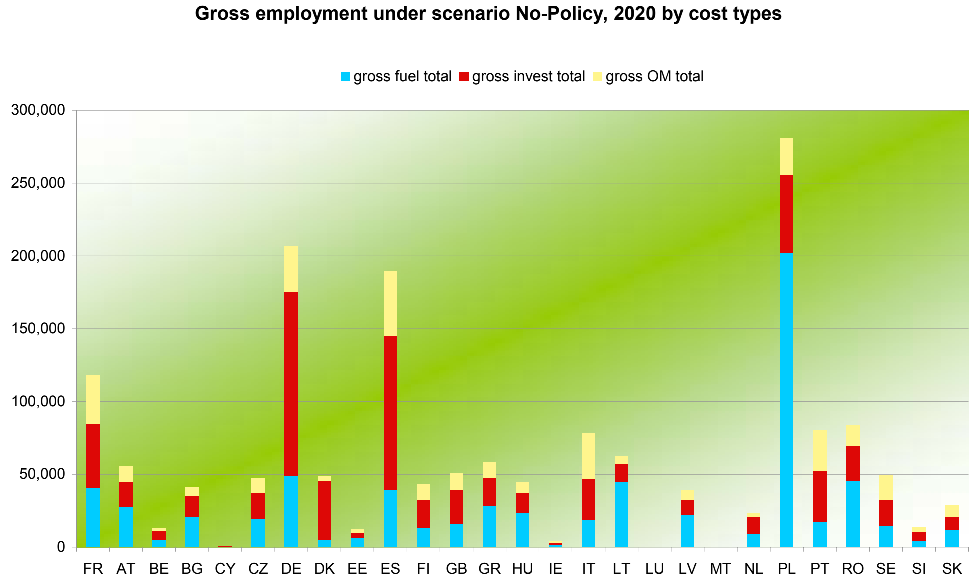


Increase of gross employment between scenario ADP-ME and No-Policy, 2020, in absolute figures and relative to total employment (2007)

Source: own calculation (Rütter+Partner, EEG, Seureco, Fraunhofer ISI)

Figure 84: Absolute differences in employment between the scenarios ADP-ME and No policy for 2020 by countries and in relation to total current employment (2007)

Although the gross employment effects are rather significant in relative terms for smaller countries, only the large absolute impacts permit a more detailed analysis by RES-cost types and RES-technologies. As Figure 85 shows under the No policy support for RES deployment, the employment effect is rather large in some Eastern European Member States due to fuel use while in particular in Germany and Spain the employment effect is mainly caused by investments.



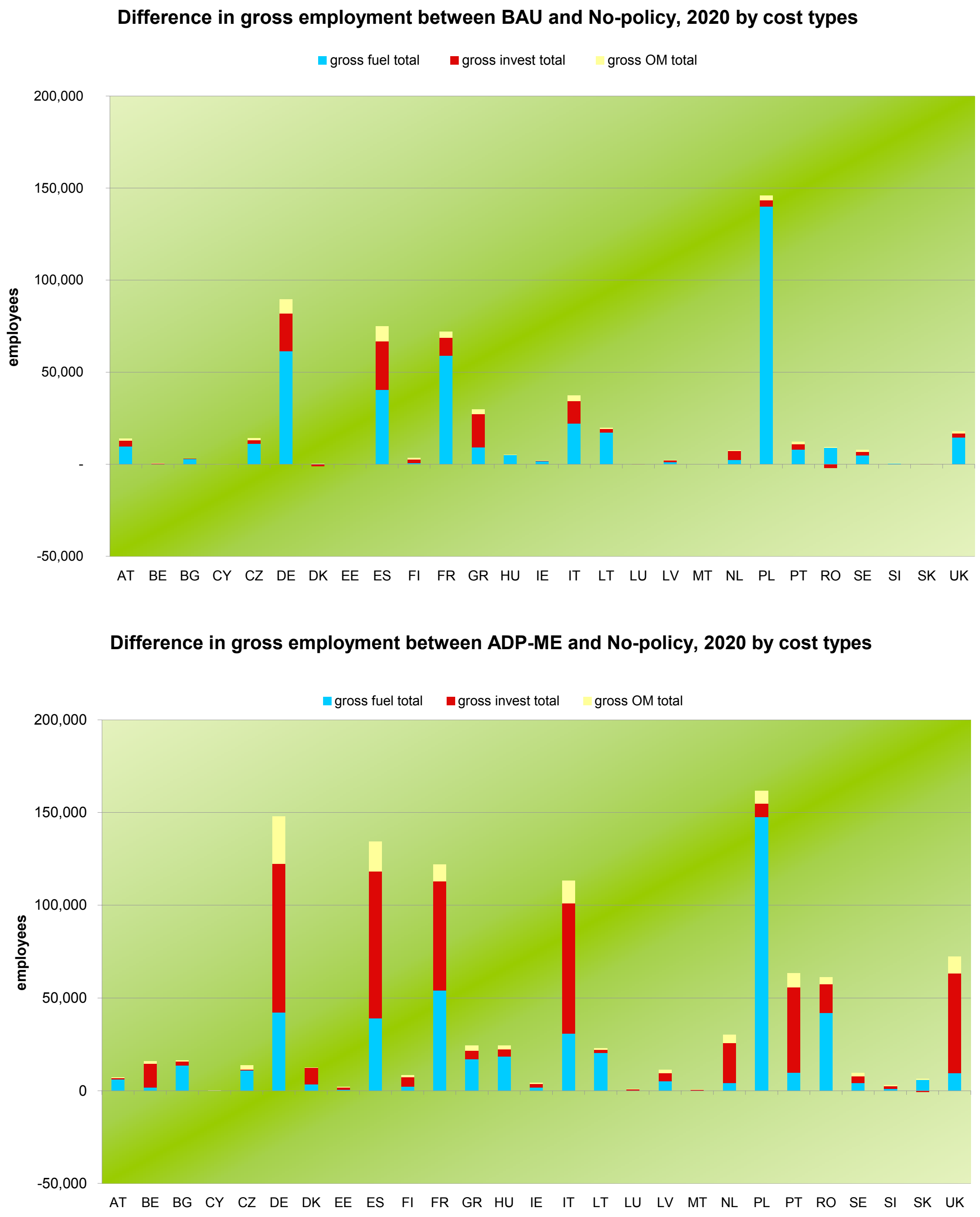
Source: own calculation (Rütter+Partner, EEG, Seureco, Fraunhofer ISI)

Figure 85: Gross employment under "No policy" scenario, by country in 2020

A comparison between the No policy and the BAU-ME scenario reveals the impacts of RES supporting policies (see Figure 86) on each Member State: under a moderate RES promoting policy (BAU-ME scenario) the increase in gross employment effect can be traced back mainly to fuel use. This is rather strikingly in absolute terms for large Member States such as Poland, Spain, Germany and France but in relative terms this is true for almost all EU countries. However, under a strong RES promoting policy the gross employment increase is in most Member States primarily due to investments. This is especially the case for countries like Germany, Spain, France, Italy, United Kingdom, Portugal, Belgium and the Netherlands while for other countries like Poland and Romania and some other East European countries fuel use has the highest impact on gross employment.

An illustration of the impact of No policy and policy (BAU, ADP) on gross employment for each Member State by technologies (Figure 87) gives the same message as at the EU level: More ambitious RES policy targets trigger investments and hence employment in knowledge intensive generation technologies while a less ambitious policy target provides impulses for employment via biofuels. This is – in absolute terms – very obvious for large countries but also true for smaller countries. In France, Poland and Germany, the employment "pushing" technologies are traditional biofuel, biogas and partly advanced biofuels under the BAU-ME scenario. Capital-intensive technologies such as photovoltaics and wind off- and onshore, solar thermal and heat pumps dominate in absolute terms under a strong RES promoting policy as in the ADP scenario in Spain, Germany, Italy and United

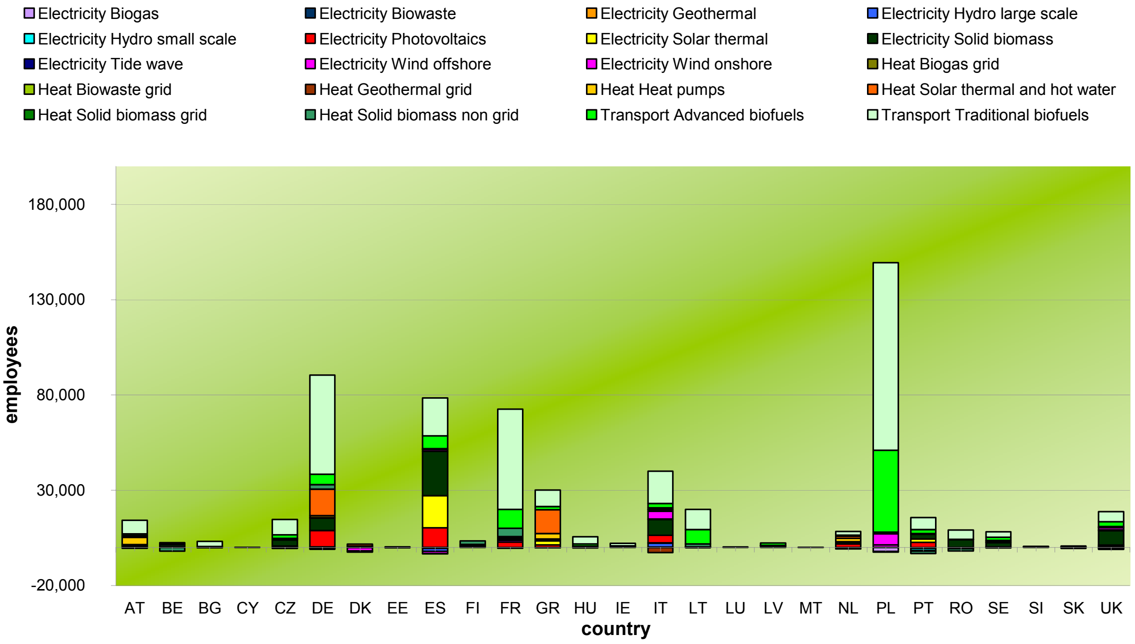
Kingdom (see Figure 87), but in also smaller countries like Belgium and the Netherlands. However, even under a No policy option wind power is a rather competitive technology.



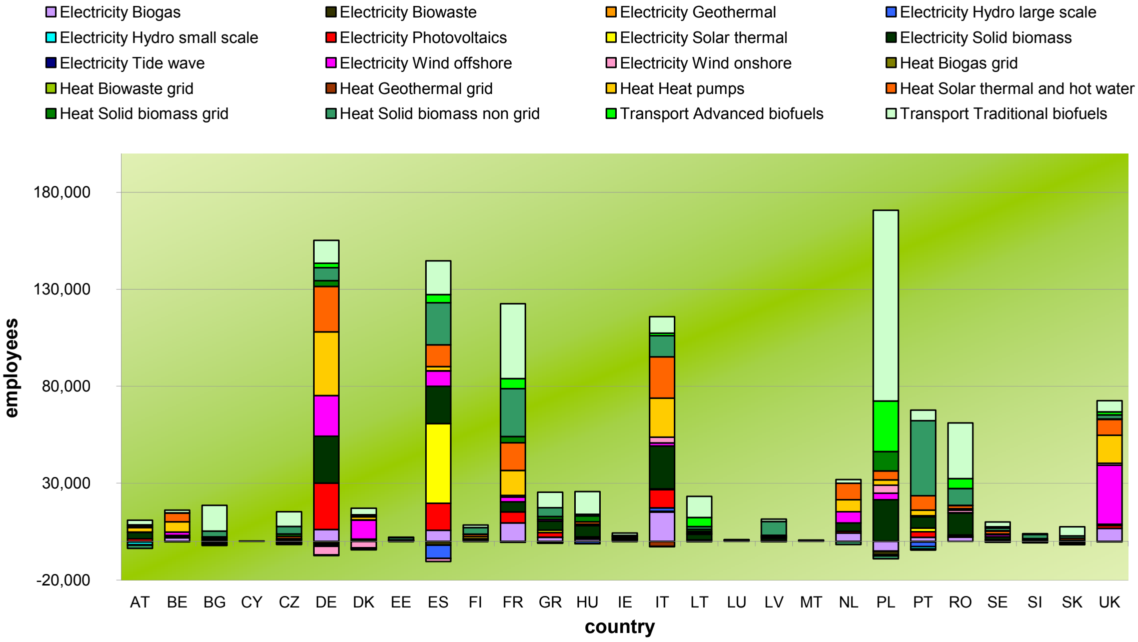
Source: own calculation (Rütter+Partner, EEG, Seureco, Fraunhofer ISI)

Figure 86: Differences in gross employment between the scenarios "No policy" with BAU-ME and ADP-ME for all European member states in 2020, by cost types

Difference in gross employment between BAU and No-policy by technologies, 2020

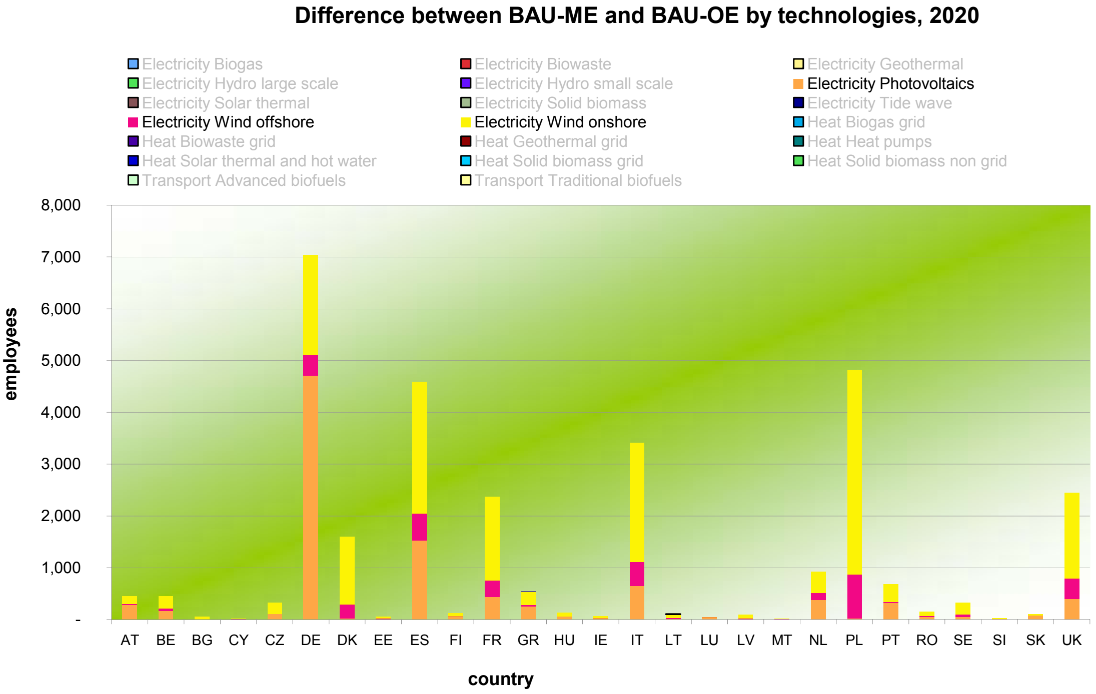


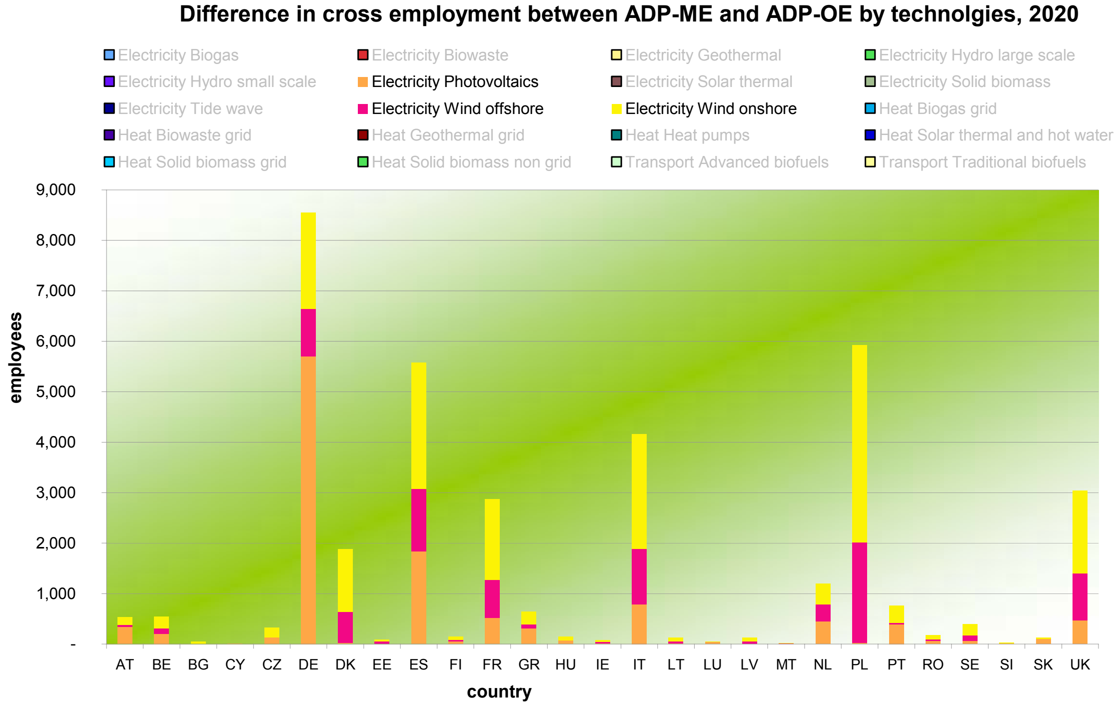
Difference in gross employment between ADP-ME and No-policy by technolgies, 2020



Source: own calculation (Rütter+Partner, EEG, Seureco, Fraunhofer ISI)

Figure 87: Differences in gross employment between the scenarios "No policy" with BAU-ME and ADP-ME for all European member states in 2020, by technologies





Source: own calculation (Rütter+Partner, EEG, Seureco, Fraunhofer ISI)

Figure 88: Differences in gross employment between the scenario BAU-OE and BAU-ME as well as between ADP-OE and ADP-ME for all European member states in 2020, by technologies

Figure 88 elucidates the impact of export opportunities on gross employment by depicting the differences in employment between a moderate export (ME) and optimistic export (OE) development in scenarios BAU and ADP. Germany, Poland, Spain, Italy, United Kingdom, France and partly Denmark and the Netherlands benefit in absolute terms from an optimistic export development. While Poland and Denmark have a large gross employment under an optimistic export development for wind, the other countries have some further advantages in photovoltaics. However, in comparison to the sum of the gross employment across all technologies the export impact on employment – and hence the employment effect itself - is rather small.

6.3 Conclusion for gross effects

Assuming an ambitious future policy framework for renewable energies in order to reach the 2020 RES targets for the EU the future employment in the sector of renewable energy sources can grow up to 2.8 Million employees in 2020 and 3.4 Million employees by 2030. Therefore the RES sector can become one of the very important sectors in terms of employment in Europe. As compared to the No policy scenario the most important technologies contributing largely to additional employment under the ADP scenario are wind energy, solar energy and liquid biofuels for transport. More optimistic assumptions on future world market shares for RES technologies have an important impact on the employment in the RES sector and could increase the number of employees by more than 120.000 above the figures under moderate export assumptions.

Furthermore the analysis on gross employment permits two main conclusions. First, current policies such as BAU-ME do not provide sufficient impulses to push gross employment in the long run rather it will top out in 2025 and will slightly decrease afterwards. Second, a strong RES policy support is needed to generate strong impulses via investments in rather knowledge-intensive RES-technologies and to trigger long lasting employment effects. The policy impact is sustainable since it provides impulses for further research and development in RES technologies, which in turn leads to a strengthening of technological competitiveness and hence an opening up of export markets.

A strong policy support arouses sizable employment effects in technology and knowledge-intensive RES-fields and in fuel production in absolute figures in populous member states such as Poland, Spain, Germany, France, Italy, UK, and Romania but also in small countries like Denmark, Belgium or the Netherlands. The impact of ambitious RES policy targets on gross employment might be even more significant due to spill-over effects from RES-technologies on other areas in the EU, which could push development and employment in the related economic sectors or technology fields.

7 Net economic impact and net employment effects

This section discusses the macroeconomic net effect of the different deployment policies and export projections on the European economies. The focus is on the net impact of RES deployment on the gross domestic product (GDP) and on employment. Whereas the gross effects are based on a rather simple calculation, the computation of the net effects builds on sophisticated macroeconomic modelling ensured by the models ASTRA and NEMESIS.

For the definitions of the five main scenarios developed in this project, which are largely used in the subsequent sections, we would like to refer to section 5.3. To emphasise the impacts of the policies and export projections, we present the results on employment and GDP as differences from the scenarios with and without RES promoting policies (BAU-ME – No policy, BAU-OE – No policy, ADP-ME – No policy and ADP-OE – No policy) as already described in section 6.

Translating the three policy cases and the world energy and export projections into five scenarios for the macroeconomic models entails two implications. The first is to transfer the data from RES-technologies into the economic sectors applied by the macroeconomic models (this builds on the work of the MULTI-REG model presented in Chapter 2) and the second is to translate the costs of the policies to support renewable energies into impacts on the price changes of commodities. RES-technology based data is transferred into the sectoral structure required by the macroeconomic models by applying transfer matrices as described in chapter 2. The macroeconomic models as well as their results are described in the subsequent sections.

7.1 Main inputs of the macroeconomic models

The inputs introduced in NEMESIS are the same as for the ASTRA model:

- National RES investment and avoided investment by economic sector
- Exports and imports (including avoided for both) by economic sector
- Operation and maintenance costs and avoided operation and maintenance costs by economic sector
- Fuel demand and avoided fuel demand
- Electricity price variation by broad categories (households, industry and services)
- Agriculture and forestry demands.

The inputs by economic sector are then allocated to the economic sectors in the model, and the increase of electricity price is translated into the different price equations of the different economic sectors and categories for households.

In order to have a clearer idea of the impulses implemented in the NEMESIS and ASTRA model we can calculate the ex-ante push as follows:

$$\begin{aligned} PUSH_{c,s} &= INVNATRES_{c,s} - INVNATavoid_{c,s} + FUEDEM - FUEDEMAV \\ &+ EXPRES_{c,s} - IMPRES_{c,s} + OPMAINRES_{c,s} - OPMAINavoid_{c,s} + AGRIRES \end{aligned}$$

With:

- $PUSH_{c,s}$ the ex-ante push in country c and sector s
- $INVNATRES_{c,s}$ the national investment in RES
- $INVNATavoid_{c,s}$ the investment avoided by RES deployment
- $EXPRES_{c,s}$ the exports of RES by country c and sector s
- $IMPRES_{c,s}$ the imports of RES
- $OPMAINRES_{c,s}$ the operation and maintenance cost induced by RES deployment
- $OPMAINavoid_{c,s}$ the operation and maintenance cost avoided by RES deployment
- $FUEDEM - FUEDEMAV$ fuel demand minus avoided fuel demand
- $AGRIRES$ the additional demands for agriculture and forestry sectors

RES deployment will have several direct or indirect impacts on European economies.

- Positive effects
  - At first, the investment push will act as a traditional Keynesian multiplier by increasing demand for the producing sectors, although countries benefit to a different extent from these new investments.
  - The operation and maintenance costs, that are often labour-intensive, are mainly of a national nature and all RES deploying countries will benefit from them.
  - The development of RES positively affects employment and growth in the agriculture and forestry sector. Most countries' agricultural and forestry sector stands to benefit, but to a varying degree depending on the significance of agriculture in the national economy.
- Negative effects
  - The avoided investments in conventional energy reduce the positive effect of the RES investments.
  - The development of RES implies an increase in energy prices (mainly for electricity); this price effect could have some limited effects on consumption, investment and on competitiveness.
  - The fuel demand will also decrease, penalising some energy sectors such as the “refined oil” and gas “distribution” sectors.

7.2 NEMESIS model

7.2.1 Model approach and key assumptions

The NEMESIS model is a sectoral, macro econometric model covering 30 production sectors and 27 consumption categories and all EU 27 countries plus Norway but without Cyprus and Bulgaria (due to a lack of data for these two countries). Each country is modelled separately and linked together through external trade. Each national economy is represented by three different agents: households, government and firms.

Each of the 30 production sectors of each country is modelled individually and receiving demands from consumers, government, firms and other countries. The production process of each sector (except agriculture) is represented by a nested Constant Elasticity of Substitution (CES) function covering 6 production factors (materials, intermediate energy, final energy, labour (highly skilled and low skilled) and investment). In the Employ-RES project, the agricultural module that details the agriculture sector was used in order to give a more precise representation of RES deployment impacts in the agriculture and forestry sectors.

Households receive wages and salaries from firms modelled by an augmented Philips curve. Households' final consumption is represented by a Rotterdam system with 27 consumption categories.

The government has revenues from taxes (VAT, excise duties, production taxes, social contributions, etc.) and on the expenditure side, social transfers (unemployed, retired population) and final consumption.

External trade is split between intra-European trade and trade with the rest of the world represented by ten different regions.

The strong interactions between sectors, agents (consumers, firms, government…) and countries through external trade are crucial when studying the potential impacts of structural policies such as RES deployment policies.

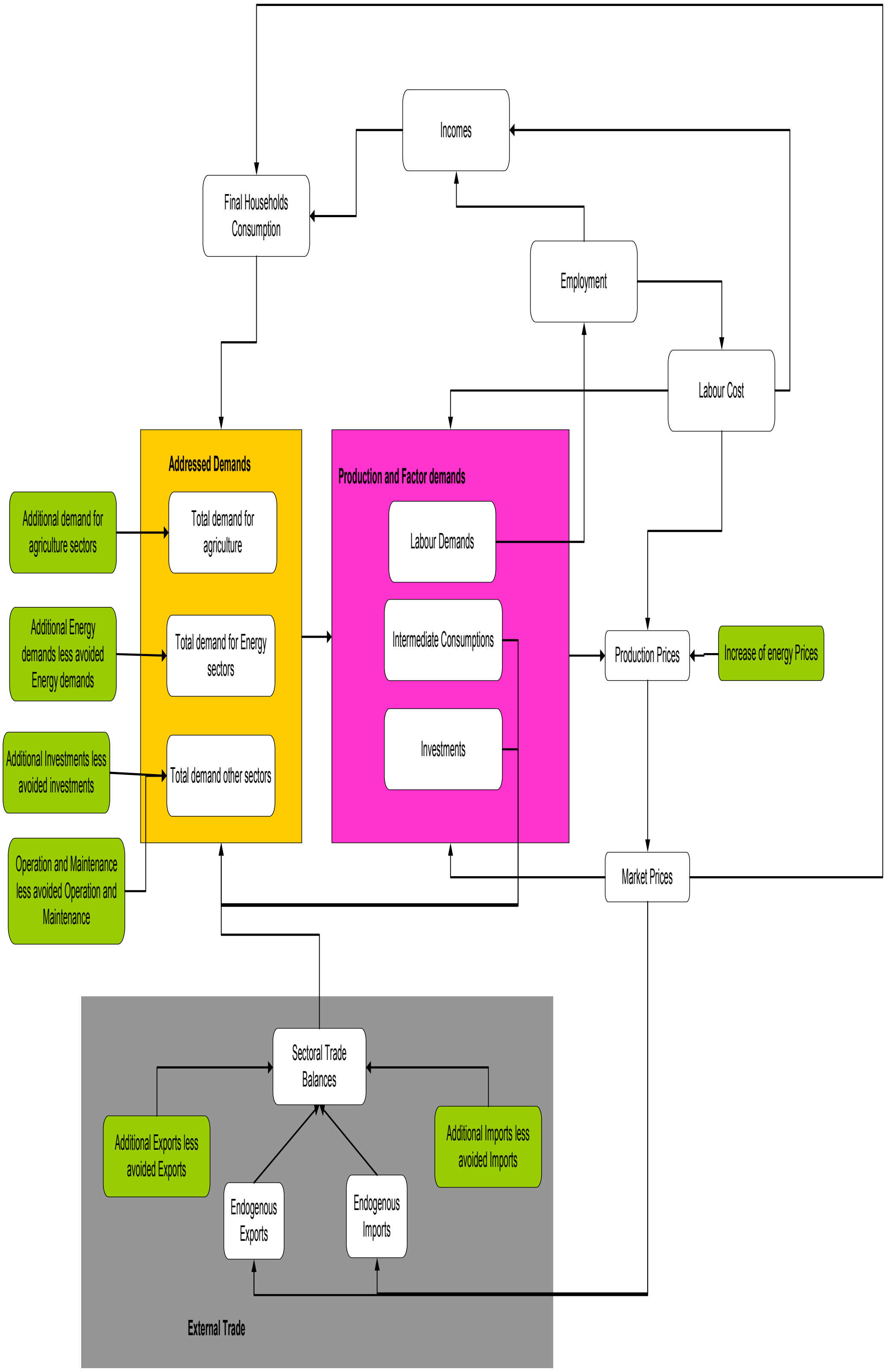


Figure 89: The NEMESIS model and its links with bottom-up models

Within the Employ-RES project, a bridge had to be constructed between the NEMESIS model, the Green-X and Multireg models. These interactions are shown in Figure 89 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 turm 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).

This section presents the main NEMESIS results of the different RES policies. The results of the NEMESIS model are highly dependent on the primary impulses received from the Green-X model. The main difficulty in interpreting such results is that the impulses introduced in the model are very dynamic, and as a consequence, the traditional behaviour and causality chains of the model are sometimes difficult to interpret.

The results of the NEMESIS model are presented as follows:

- The business-as-usual (BAU) scenario with moderate exports (ME) compared to the “No policy” scenario.
- The business-as-usual (BAU) scenario with optimistic exports (OE) compared to the “No policy” scenario.
- "Accelerated RES deployment policy" (ADP) with moderate exports (ME) compared to the “No policy” scenario.
- "Accelerated RES deployment policy" (ADP) with optimistic exports (OE) compared to the “No policy” scenario.

In order to present the results of the model more clearly, we will also portray the basic impulses introduced in the NEMESIS model for each scenario. The macro model results are presented at European level first, then at member state level and at a sectoral level.

7.2.2 Impulses for the policy scenarios

The objective of this study is to analyse and compare different RES policies scenarios. This section describes the methodology and scenarios used in the model to accomplish this objective.

We first define a “Business-as-usual” scenario (BAU), in which current policies are maintained and the economy develops in line with current trends. It should be noted that the BAU scenario is not the reference scenario in this study.

In the BAU scenario, the current policies that aim at promoting RES deployment are implemented, and both moderate and optimistic scenarios for future exports are assumed.

In the following sections, we analyse the results of BAU compared to the case in which all these policies are suppressed.

The reference scenario used is one which assumes no RES policies and which is referred to as the “No policy” (NP) scenario. The objective is to analyse the overall effect for EU member states of implementing policies supporting RES technologies.

In the NP case, all national investments in RES technologies cease, and all direct (investments) and indirect costs (operation and maintenance) will fall when compared to the BAU scenario. However, as the generation cost of RES is greater than that of traditional technologies, in most countries, the electricity price will also drop.

Finally, we also implement the "Accelerated RES deployment policy" (ADP) scenario. The objective here is to analyse the effect of reinforced RES deployment in European countries up to 2030. This ADP scenario is not compared to the BAU scenario, but to the NP scenario, because the BAU scenario already includes some RES deployment policies and comparing ADP with BAU would penalise countries that have already invested in RES deployment. In both the BAU and the ADP scenario, moderate and optimistic export expectations were assumed.

As shown in Figure 89, the implementation of RES policies in the NEMESIS model requires inputs from the GREEN-X and Multireg models; these include:

- Additional investments in RES technologies.
- Exports of RES technologies.
- Additional demand in agriculture.
- Additional operation and maintenance costs for RES technologies.
- Avoided imports of fossil energy.
- Imports of RES technologies.

- Avoided investment in conventional technologies.
- Avoided operation and maintenance costs for conventional technologies.
- Electricity price increase.

The first five inputs give positive impulses to the model while the final four have negative impacts. The total impulses in the NEMESIS model are presented in Figure 90 for Europe as a whole. For the BAU scenarios, the maximum impulse reaches 0.18% of the NP scenario GDP for the moderate export scenario and 0.21% when the export scenario is more optimistic. If a more ambitious RES policy is implemented, the total impulse increases up to 0.68% for the moderate export scenario, and reaches 0.73% for the optimistic export scenario.

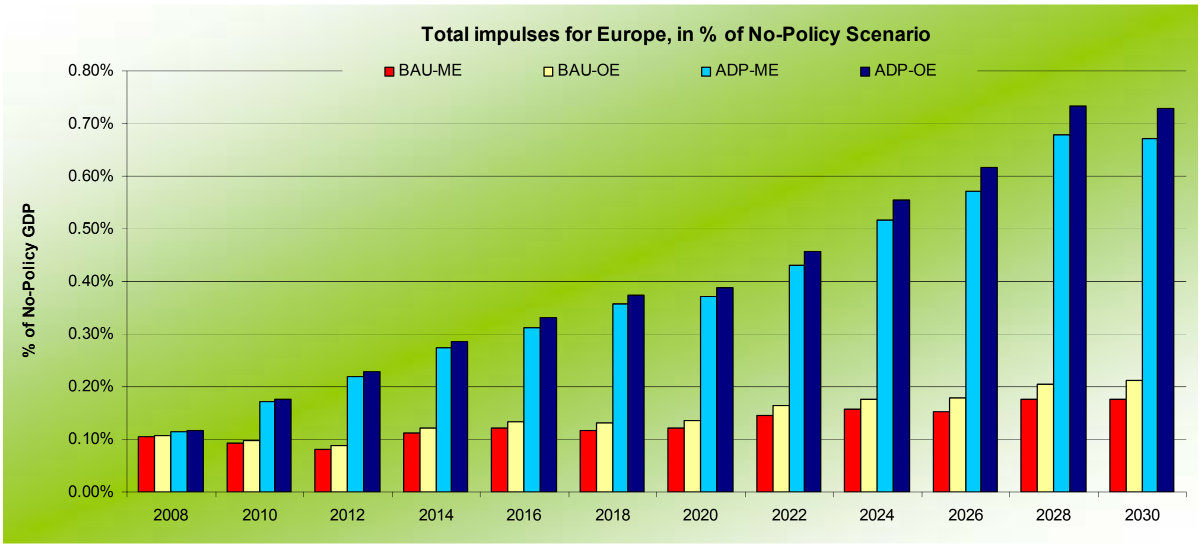


Figure 90: Total impulse in % of No policy GDP for Europe

The main source of the impulse differs widely between the scenarios. As shown in Figure 91 below, in the BAU-ME scenario, the additional demand in agriculture represents a large part of the total impulse, and for some years it constitutes the major share of the total impulse. The negative exports during the first years occur due to stronger exports in the NP scenario compared to the BAU scenario, as the demand for RES technologies in the rest of the world compared to Europe will be relatively stronger in the NP scenario.

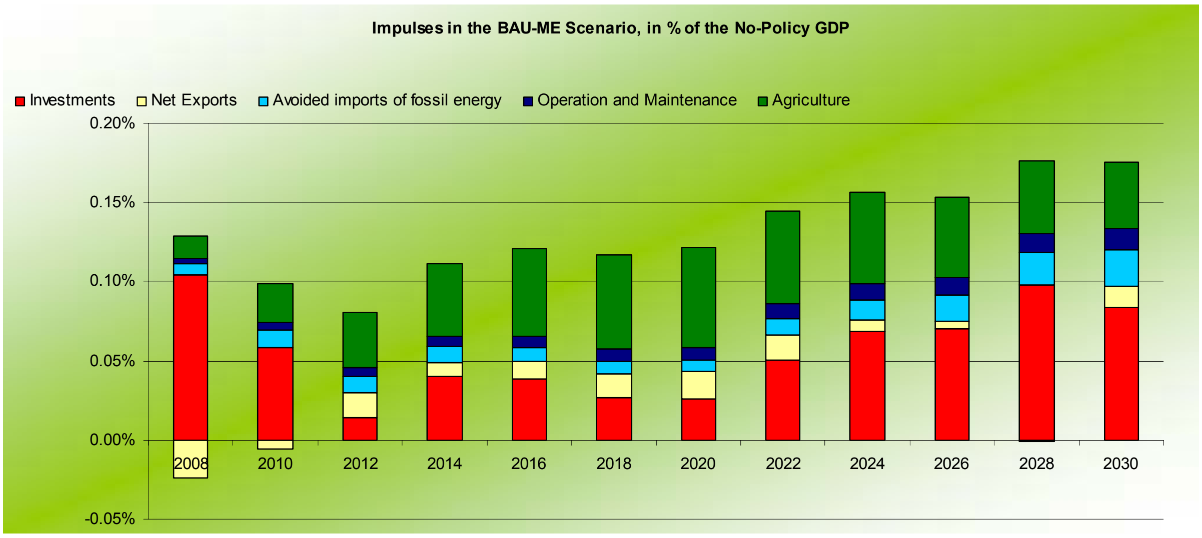


Figure 91: Decomposition of total impulse for Europe in the BAU-ME scenario, in % of NP GDP

In the accelerated deployment policy scenario, the decomposition of the total impulse (see Figure 92) is rather different; here, investment in RES technologies and energy savings are the most important sources of the impulse in the model. This difference in the structure of the total impulse implies that the implementation of both scenarios BAU and ADP in the NEMESIS model results in different sources of economic growth beyond the importance of the impulse.

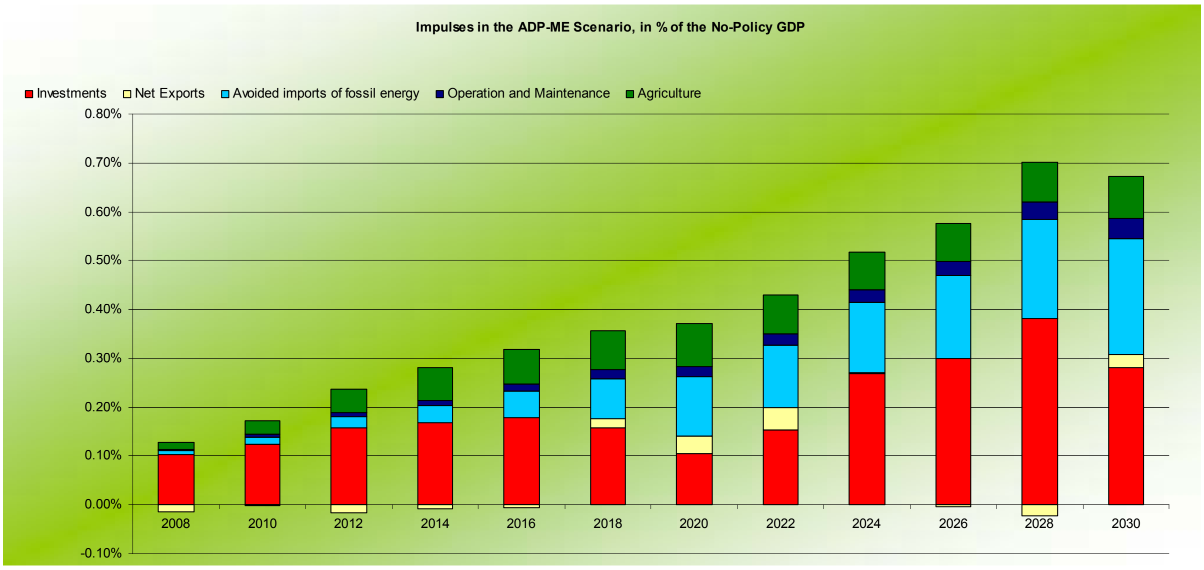


Figure 92 Decomposition of total impulse for Europe in the ADP-ME scenario, in % of NP GDP

At member state level, the differences in the source of economic growth are even more marked. In Denmark, for instance (see Figure 93), as one of the main RES technology producers, the main growth source is external trade, while national investments, agriculture and energy savings are much less important. The opposite is true for Hungary (see Figure 94), where national investments, the increased demand for agriculture and energy savings are the real drivers of Hungarian economic growth, and the external trade of RES technologies has a negative impact.

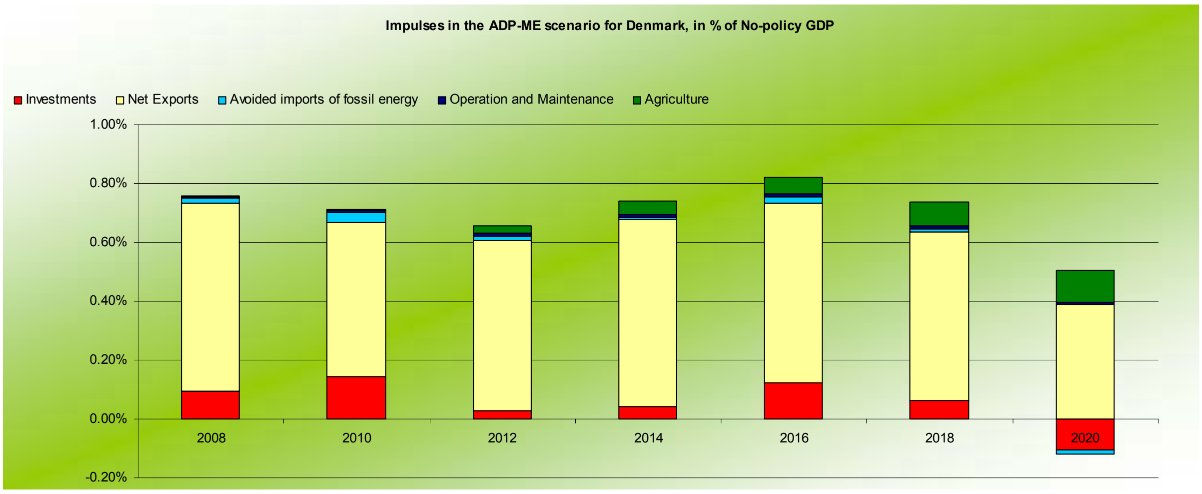


Figure 93: Decomposition of total impulse for Denmark in the ADP-ME scenario, in % of NP GDP

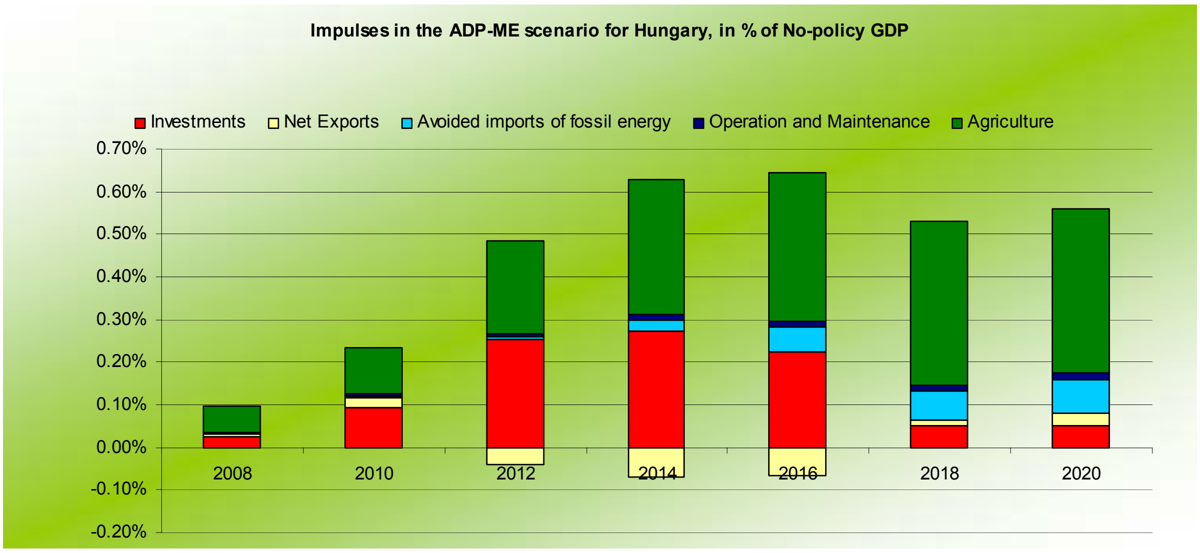


Figure 94: Decomposition of total impulse for Hungary in the ADP-ME scenario, in % of NP GDP

7.2.3 Results for the EU 27

This section presents the results of the NEMESIS model for the four scenarios implemented for Europe. The focus here is on the two major economic indicators of GDP and employment.

The impact of RES policies on GDP is positive in all the scenarios. By comparing the initial impulses presented above and the results on GDP one can note that the slack between BAU impulses (0.18% for ME and 0.21% for OE) and BAU GDP (0.14% and 0.20%) is smaller than for ADP scenarios, which shows impulses of 0.67% for ME and 0.73% for OE and GDP effects of 0.36% for ME and 0.44% for OE. This can be easily explained by the inflationary pressure resulting from the energy cost increase and from the pressure on the labour market that leads to wages increase. This inflationary pressure tends to limit GDP growth by decreasing competitiveness with respect to the rest of the world.

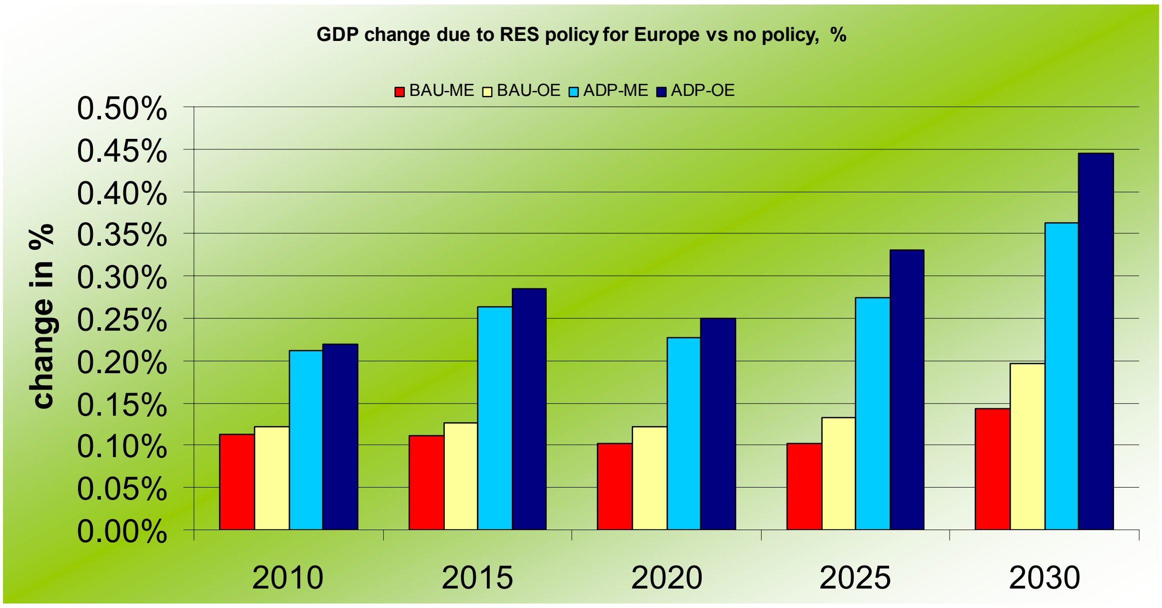


Figure 95: GDP change due to RES policy for Europe

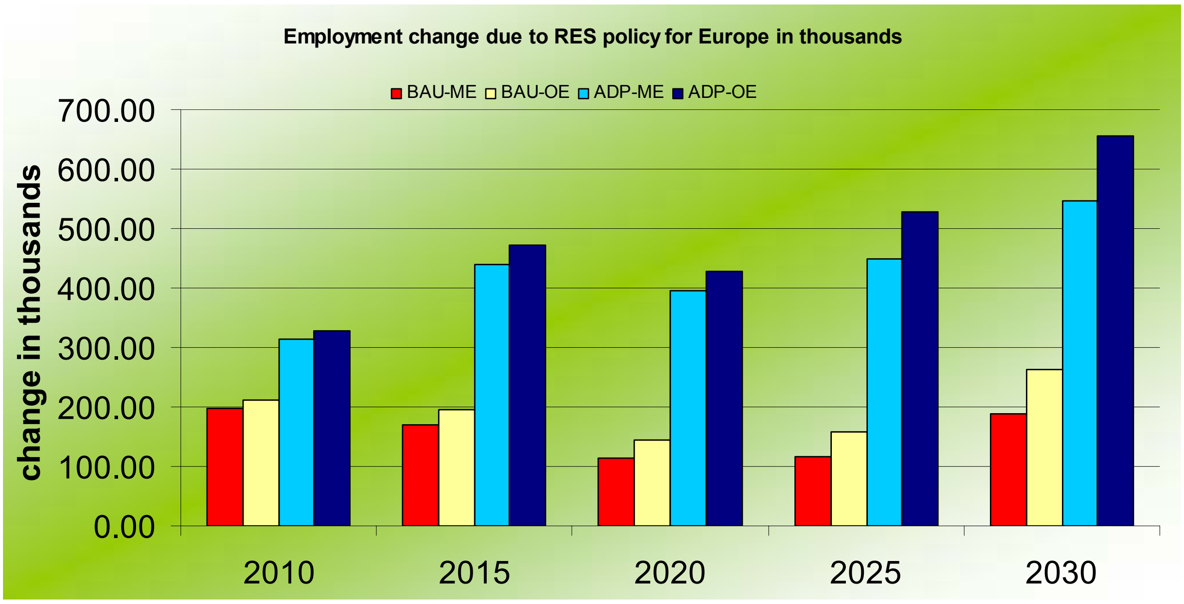


Figure 96: Employment change for Europe in thousands

In Figure 96 and Figure 97 we present the results on employment in absolute and relative terms, respectively. It is apparent that employment increases in all the scenarios, but to a smaller extent than GDP. In BAU scenarios, employment increases by 0.08% in the ME scenario and 0.12% in the OE one; this represents 187,000 and 262,000 new jobs created, respectively. In the ADP scenarios, the additional investments and demands bring about 0.24% increase in employment (545,000 jobs) in the ME scenario and 0.29% (656,000 jobs) in the OE one.

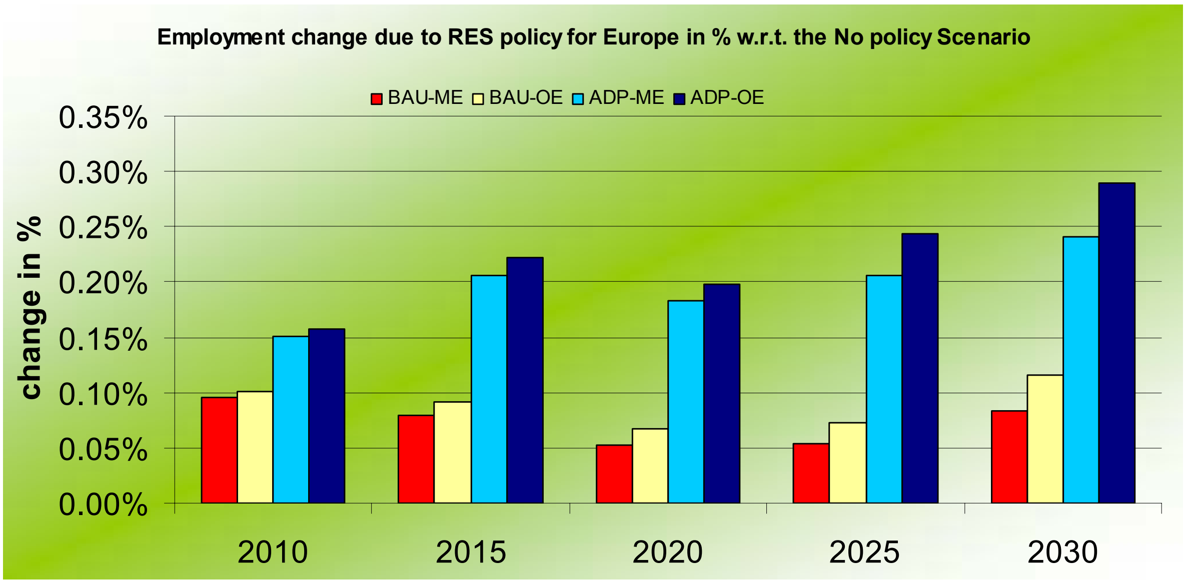


Figure 97: Employment changes for Europe in % relative to the No-Policy scenario

European GDP follows the total positive impulse generated in the model with a multiplier of 0.55 in the ADP scenarios in the moderate export assumption case and a multiplier of 0.6 in the optimistic case. The multipliers are smaller than one because of the increase in energy prices. In the BAU-ME scenario, we observe a rise to nearly 0.1% in 2010 of the GDP due to the increase in investment and consumption. After 2010, even if investment increases with respect to the NP scenario, the increase in GDP tends to be reduced. However the increased demand in agriculture keeps the GDP deviation at around 0.10%. Finally, increased investment at the end of the period has a positive effect on manufacturing and services, and GDP increases by 0.15% (24 billion constant 2000 Euros).

Figure 98 and Figure 100 show the production variations in percent of GDP (not the added value of the sectors) and Figure 99 and Figure 101 show employment variations (in thousands of jobs) of five sectors comprising agriculture and forestry, energy, manufacturing, construction and services under the four different scenarios for Europe.

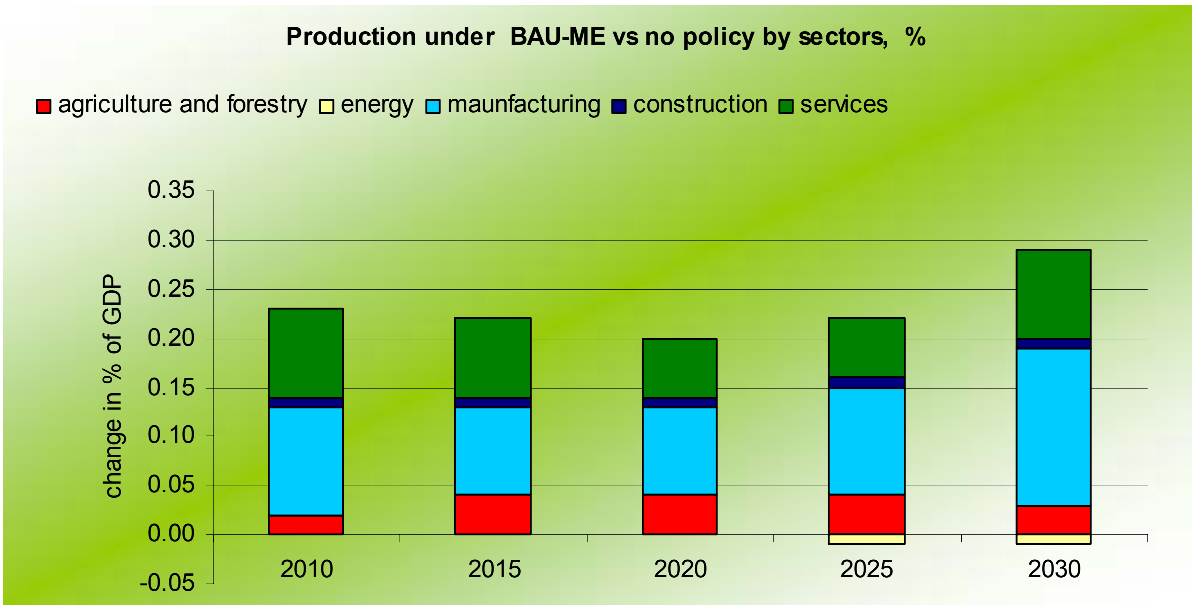


Figure 98: Production under BAU-ME vs. NP by sector, %

In the BAU-ME scenario, the main part of the employment rise is due to the increase in the demand addressed to the services, manufacturing and agricultural sectors. In 2030, there are 65,000 new jobs in the services, 73,000 in the manufacturing sector and 35,000 in agriculture.

Results for the scenario BAU-OE are a little better but qualitatively similar as we can see from the results in the annex.

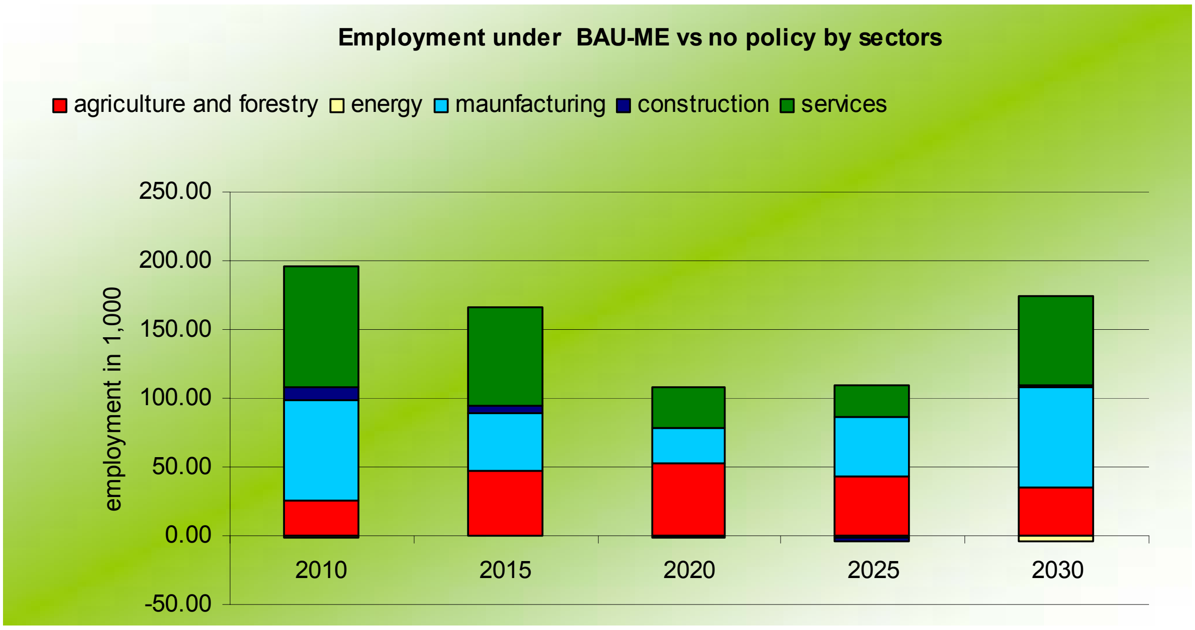


Figure 99: Employment under BAU-ME vs. NP by sector (in thousand jobs)

In the ADP-ME scenario, Europe as a whole enjoys a rise in GDP and employment; the positive effects of the investment push exceed the negative ones.

At the European level, as shown in Figure 100 and Figure 101, industrial (manufacturing) sectors are buoyed up by the extra investment; production increases by 0.45% of GDP in 2030 and 233,000 new jobs are created.

The agriculture and forestry sectors also benefit from the RES deployment policies; the production of the global agricultural sector increases by 0.06% of GDP in 2030 compared to the NP scenario, and employment increases by 65,000 new jobs.

The construction sectors increase by 0.02% of GDP, while all other services sectors increase by around 0.26% of GDP.

Only the energy sectors do not benefit from the RES deployment due to the decreased fuel demand (that affects the gas distribution and refined oil sectors), and the electricity sector is faced with a generation cost increase.

Similar to the BAU scenario, the results for the ADP-OE scenario are a little better than for ADP-ME but qualitatively similar.

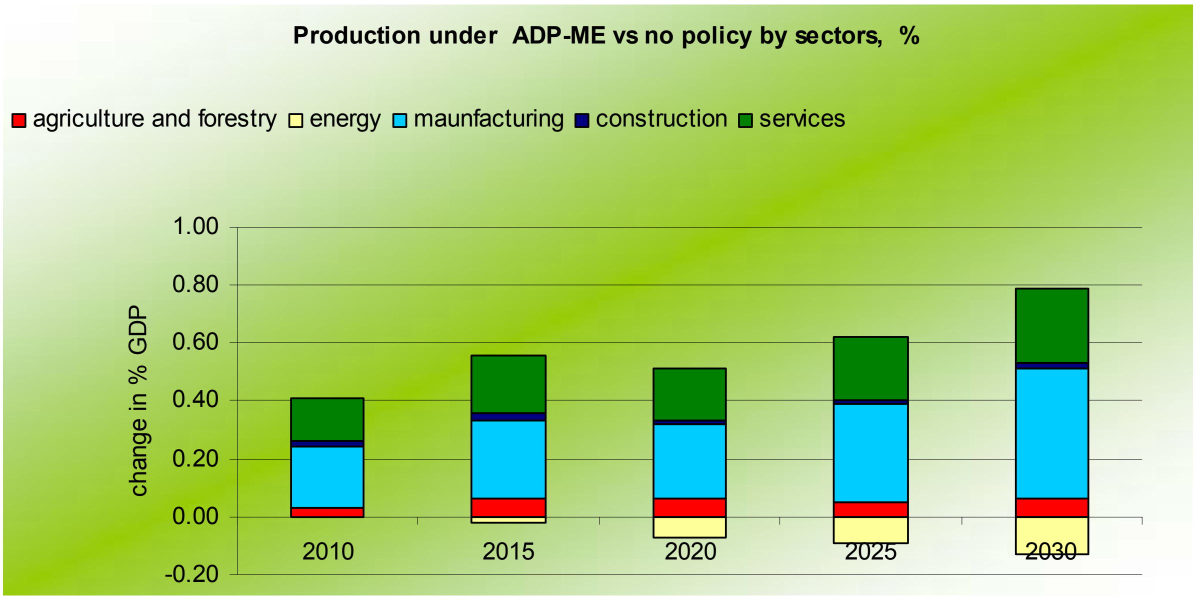


Figure 100: Production under ADP-ME vs. NP by sector, %

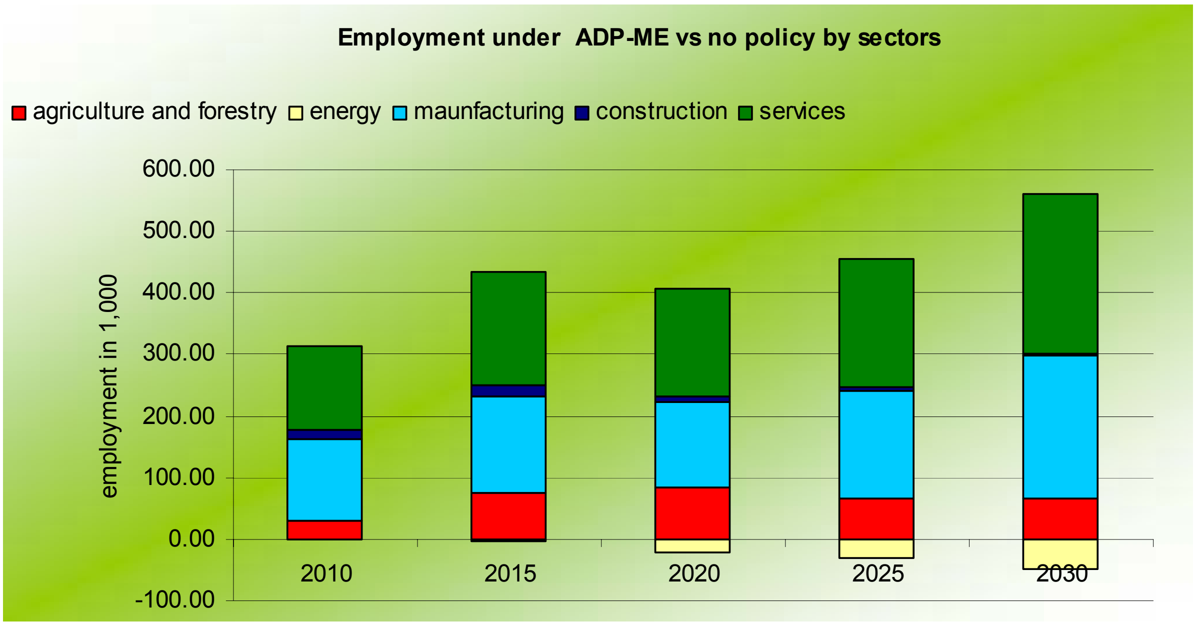


Figure 101: Employment under ADP-ME vs. NP by sector (in thousand jobs)

7.2.4 Results at member state level for the year 2020

This section describes the results of the NEMESIS model for GDP and employment at member state level for the four scenarios compared to the NP scenario. The impact of the RES policies on GDP differs from one country to another. These differences can easily be explained by some factors:

- The impulse strengths vary among member states.
- The timing of policy implementation also varies which is of crucial importance in dynamic models such as NEMESIS.
- As shown in 7.2.2, the composition of the initial impulse can vary widely.
- Finally, the initial conditions in each country also influence the policies' results.

In order to demonstrate these differences among member states, some individual countries that vary radically will be studied in more detail for each scenario. Denmark was selected, which is an RES technology producer, and Hungary, where the agricultural sector plays an important role in demand.

Business as usual (BAU) scenario with moderate exports (ME) compared to NP scenario

As shown in Figure 102 and Figure 103, the impact on GDP and employment of the BAU-ME scenario is positive in all countries except the United Kingdom. GDP growth varies between 0.3% for Lithuania and close to 0% for the United Kingdom. Lithuania, Poland, France, Hungary and the Czech Republic show the strongest impacts in this scenario. All these countries have rather strong impulses when compared with others and their energy prices are stable or increase slowly. Despite this, inflationary pressure is significant in some countries; this is the case, for instance, in Lithuania and Latvia because of the pessimistic demographic projections incorporated in the model (the population in these countries declines by 9% and 7%, respectively, between 2010 and 2030). Greece and Spain also show a strong initial investment impulse, but both countries are then penalised by the relative increase in their energy costs.

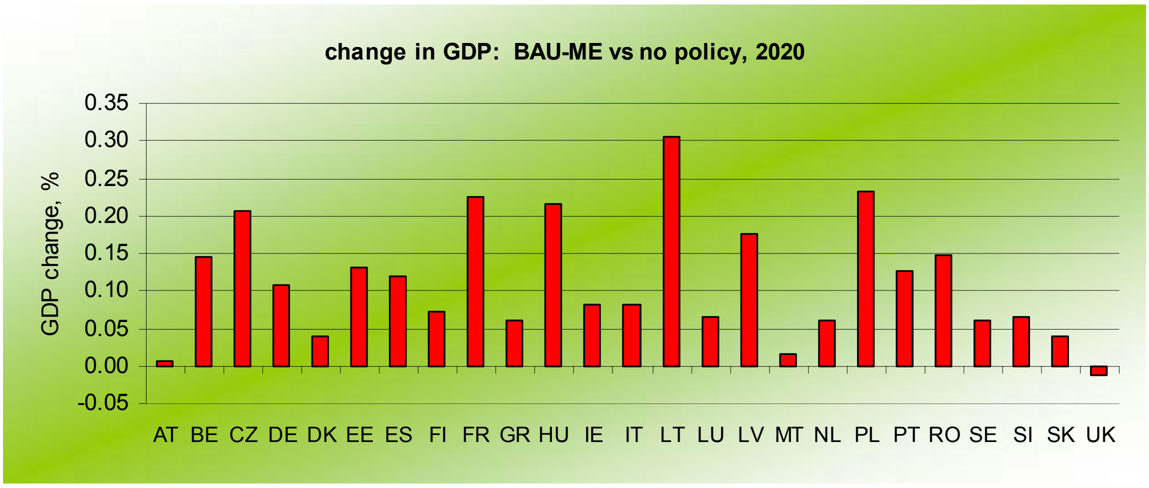


Figure 102: GDP changes in BAU-ME scenario for member states % deviation in compared to the No-Policy scenario

Regarding the impact of the scenario on employment, France, Germany and Poland are the biggest winners in terms of employment gains (in absolute terms), even if the employment gains in relative terms are rather small for Germany.

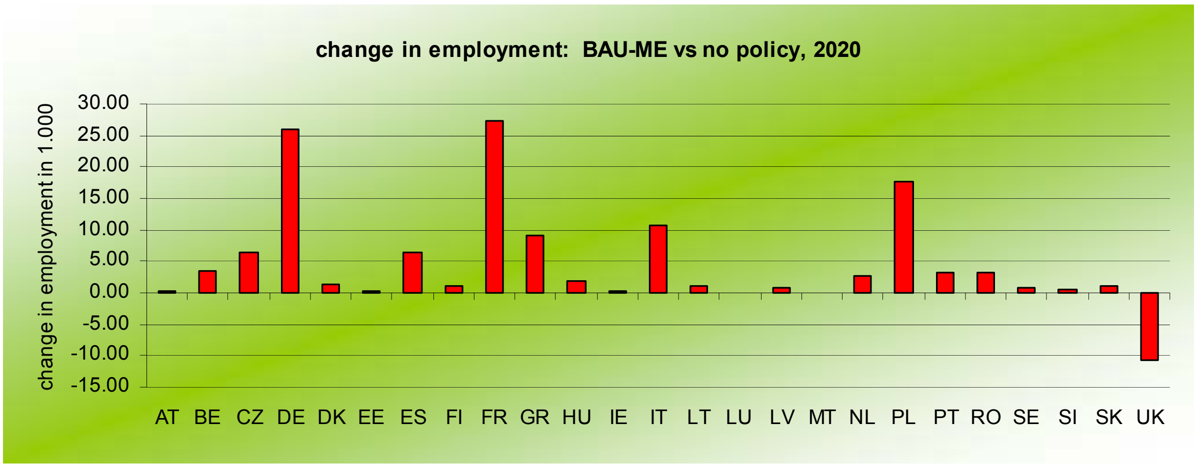


Figure 103: Employment changes in member states in thousands compared to the No-Policy scenario

The Hungarian case is very interesting in this scenario. The major part of its initial impulse is due to the growth in the demand for agriculture (see Figure 104). As a result, even though the investment in RES technologies is quite small, the overall impulse remains largely positive. The impact of the policy in Hungary (+0.21% GDP) is thus essentially due to the agricultural sector.

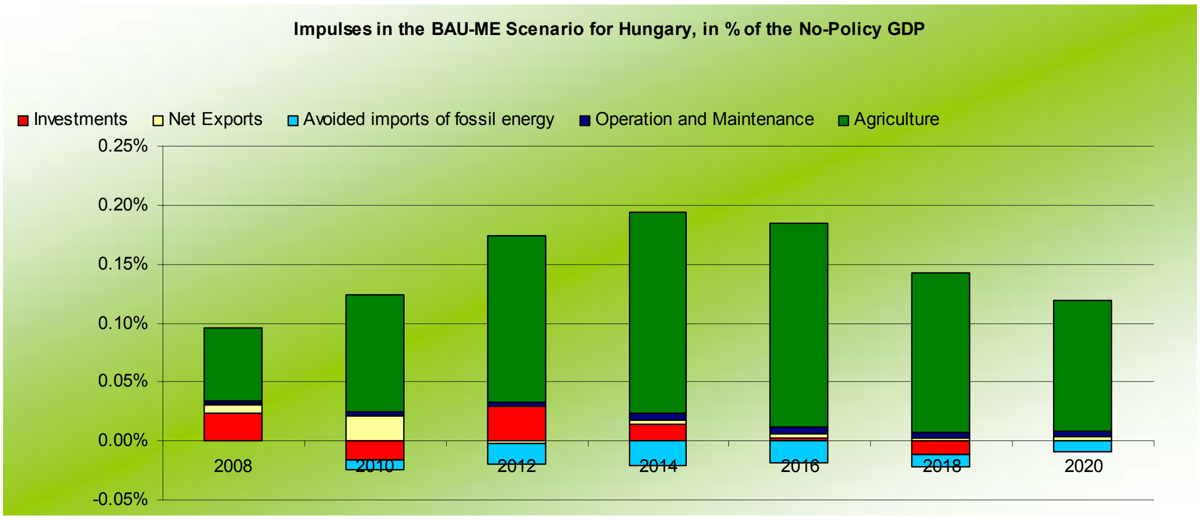


Figure 104: Impulses in the BAU-ME scenario for Hungary

The Danish case is the complete opposite. Denmark is one of the main producers of RES technologies. As a consequence, the investment in RES technologies in EU member states that occurs in the BAU scenario helps to push Danish exports. Hence, with respect to the NP scenario, the main result for Denmark is a strong rise in exports that represents almost all the impulse in the Danish economy. Other impulse sources are far less important here, the demand for agriculture remains close to zero while national investment does not exceed 0.10% of ex-ante GDP (see Figure 105).

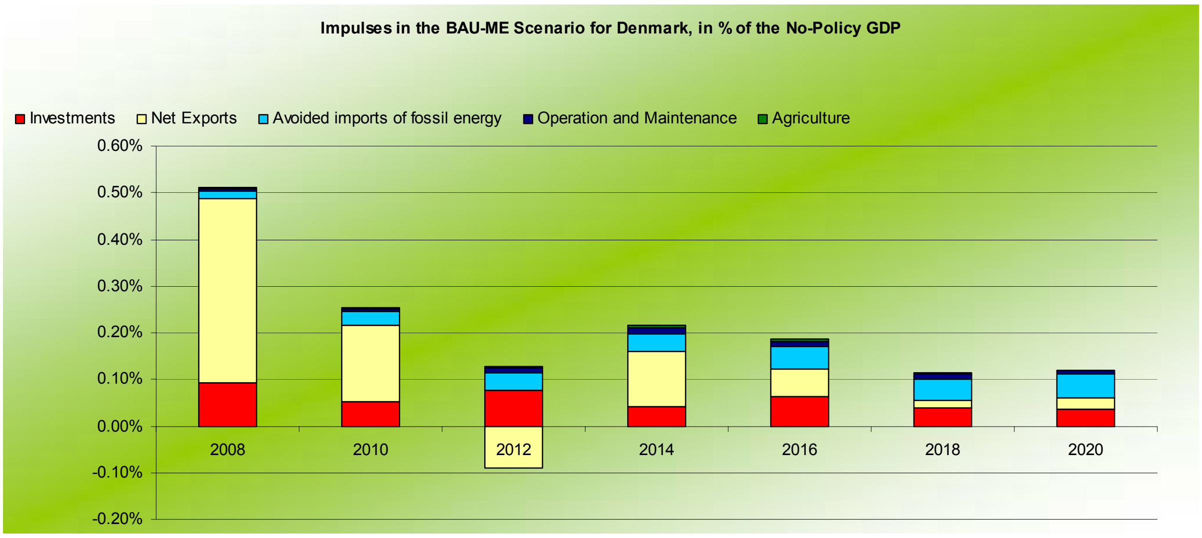


Figure 105: Impulses in the BAU-ME scenario for Denmark

Business as usual (BAU) scenario with optimistic exports (OE) compared to NP scenario

The differences between the BAU-ME and BAU-OE scenarios are rather small, and the gains in terms of GDP as well as in terms of employment are visible only for a few countries. Germany, Spain, Denmark and Poland see their GDP and employment increase when compared to the previous scenario.

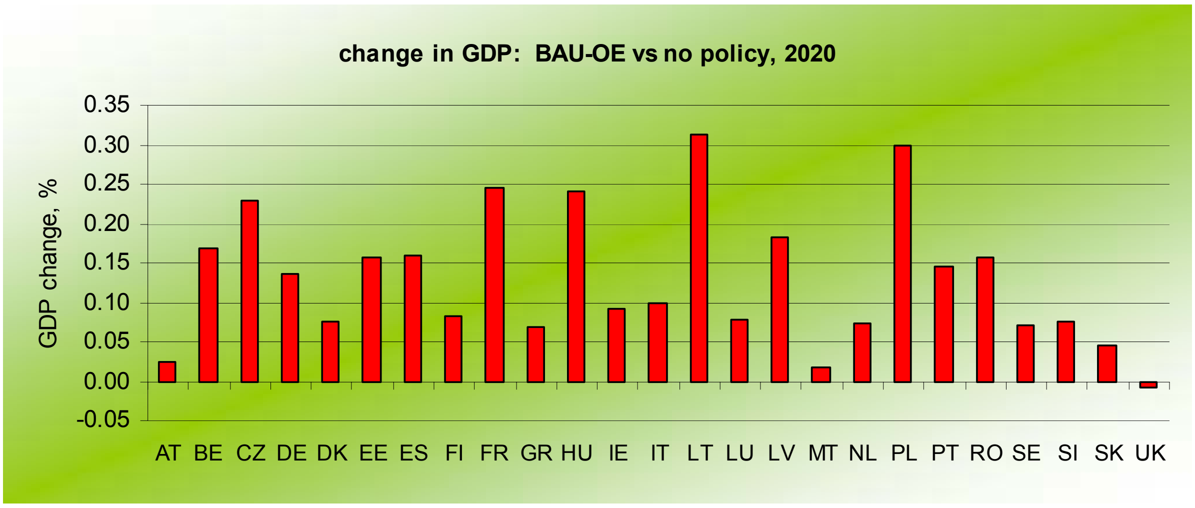


Figure 106: GDP changes in BAU-OE scenario for member states compared to the No-Policy scenario

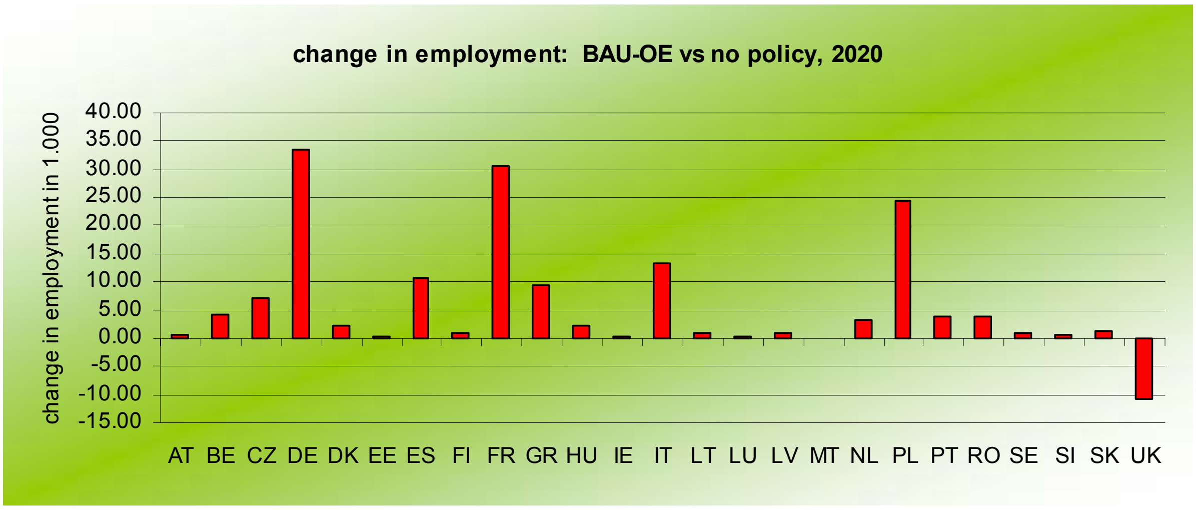


Figure 107: Employment changes in BAU-OE scenario for member states compared to the No-Policy scenario

"Accelerated RES deployment policy" (ADP) with moderate exports (ME) scenario compared to the NP scenario

Relative to their GDP, Romania, Portugal, Lithuania and Latvia experience a high total impulse in this scenario, while Greece and Austria exhibit the weakest one (see Figure 108). Regarding the electricity price increase due to the deployment of RES technologies, Germany, Spain, Netherlands and the UK install more expensive technologies (see Figure 109) with the consequence that this penalises their competitiveness and thus limits the positive effect of the investment push.

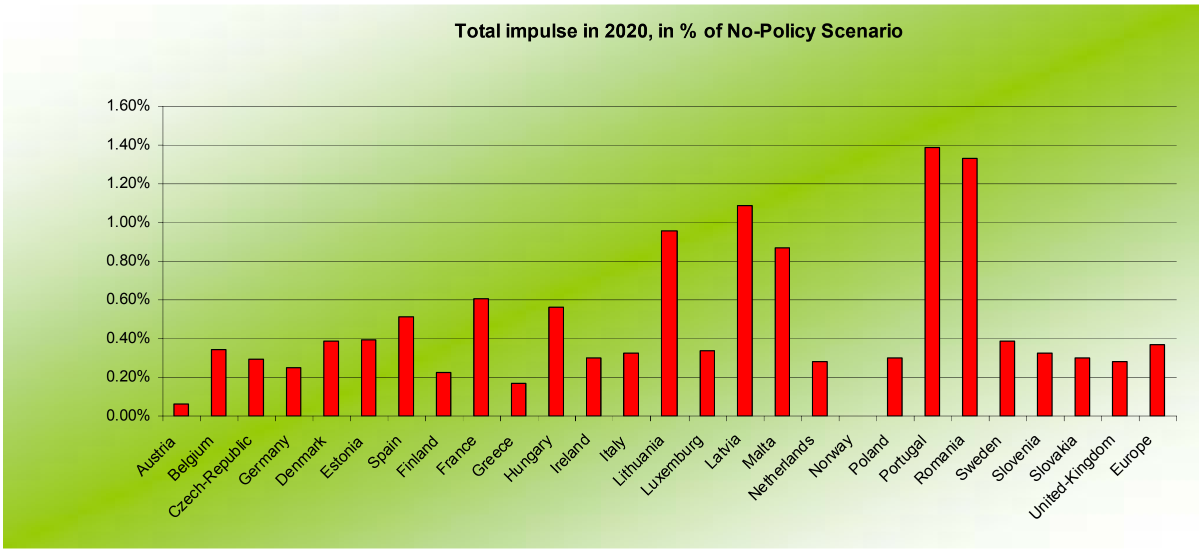


Figure 108: Total impulse in 2020 in ADP-ME scenario

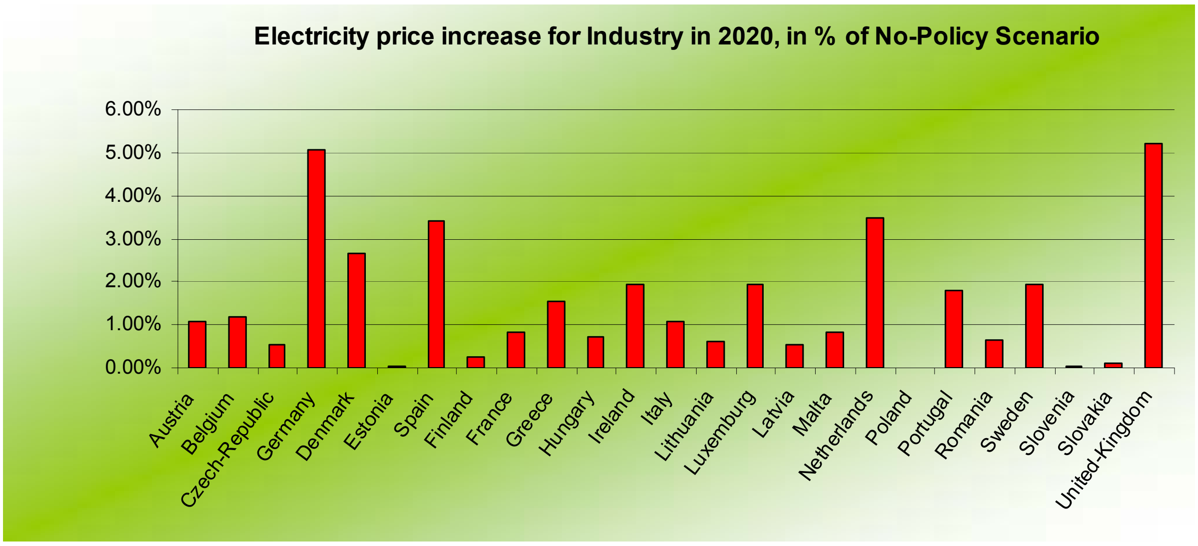


Figure 109: Electricity price change for industry in 2020 for ADP-ME scenario

Figure 110 and Figure 111 present the impacts of the ADP-ME scenario on GDP and on employment, respectively. The highest GDP gains occur in Hungary, Portugal and Romania, with 0.58%, 0.65% and 0.97%, respectively, when compared to the NP scenario.

In the UK, the total ex-ante impulse appears to be relatively small because even if national investment in RES increases, most of this has to be imported from other countries. Hence the positive effect of investment is compensated by the increase in imports. This small impulse is clearly marked on the simulation results; imports closely follow the evolution of investment, hence the deviation of GDP and employment with respect to the NP scenario remains close to zero.

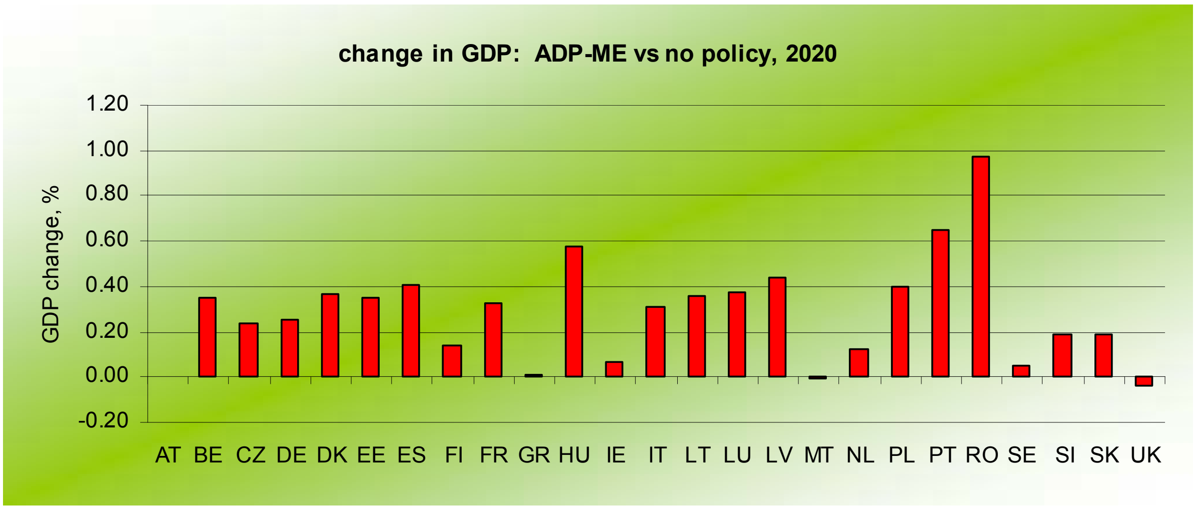


Figure 110: GDP changes in the ADP-ME scenario compared to the No-Policy scenario

Generally, employment changes follow the evolution of GDP but with less magnitude. Hence, in relative terms (Figure 112), the highest growth in employment is in Romania, Portugal and Denmark; in absolute terms, however, Germany, Spain, France, Italy and Romania create most of the new European jobs.

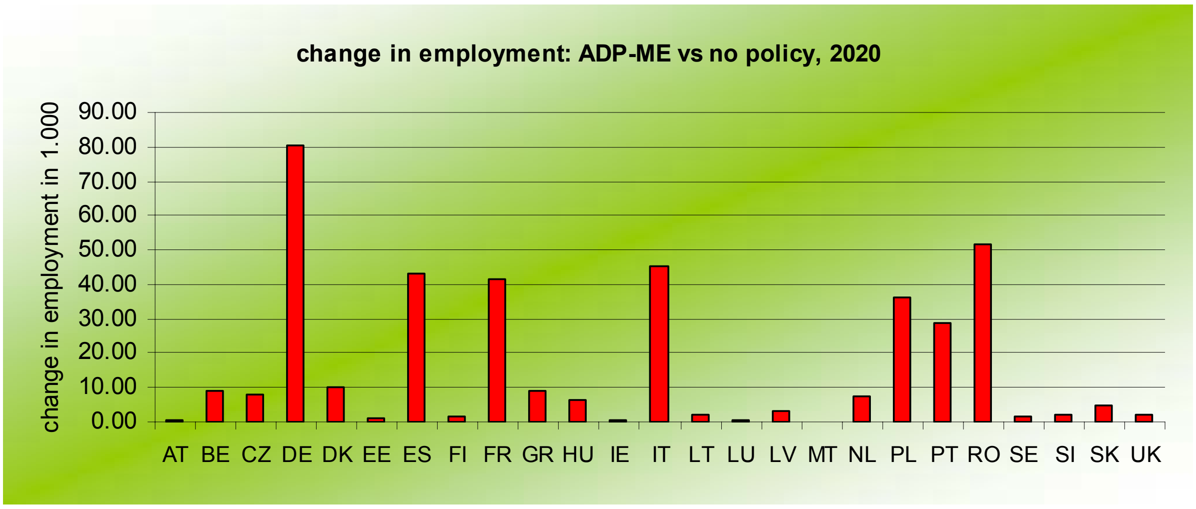


Figure 111: Employment changes in the ADP-ME scenario compared to the No-Policy scenario

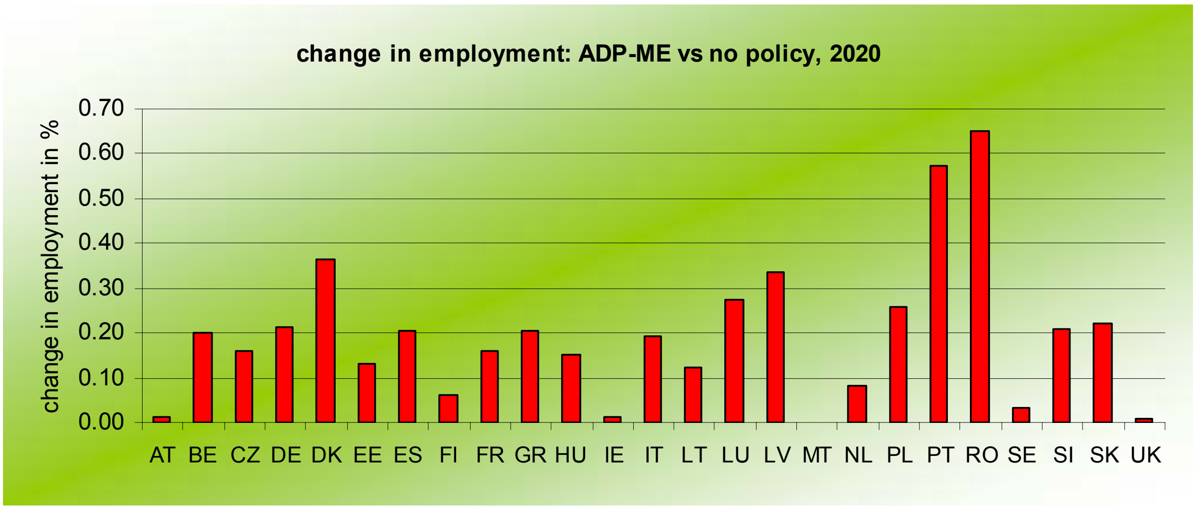


Figure 112: Employment changes in the ADP-ME scenario compared to the No-Policy scenario

Denmark has a unique position when compared to other European countries. As one of the main RES technology producers, exports are the primary impulse for GDP growth (see Figure 113). This additional demand in the Danish RES technology producing sectors then spreads to the rest of the economy by increasing firms' factor demands and employment. The increased level of employment enables wages and real incomes to rise which in turn leads to an increase in household consumption that sustains the gross domestic product.

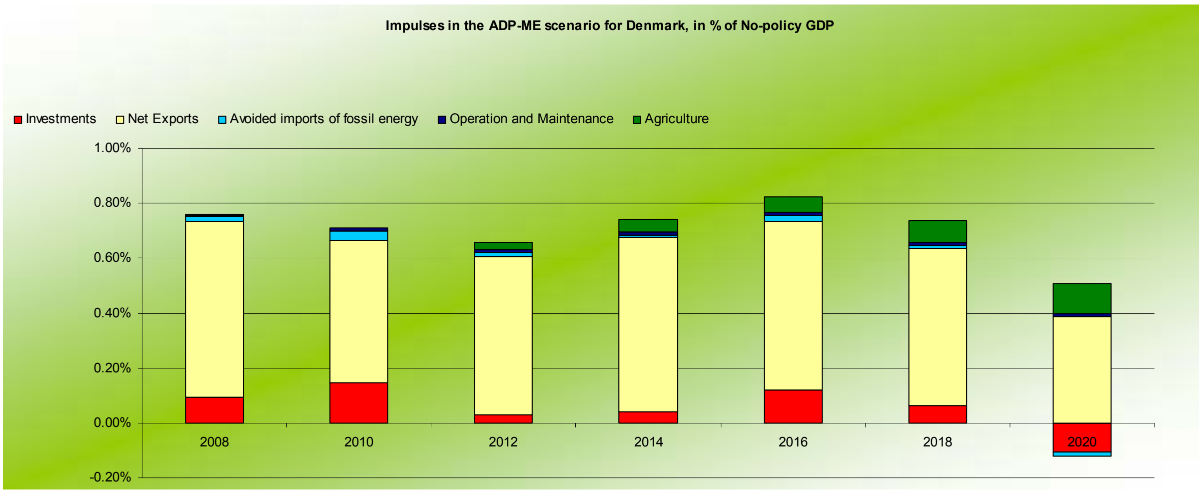


Figure 113: Impulse in the ADP-ME scenario for Denmark

In Hungary, the two major forces that result in GDP growth are national investments and the demand addressed to the agricultural sectors. Hence, in contrast to the Danish case, the channels through which economic growth occurs are mainly national.

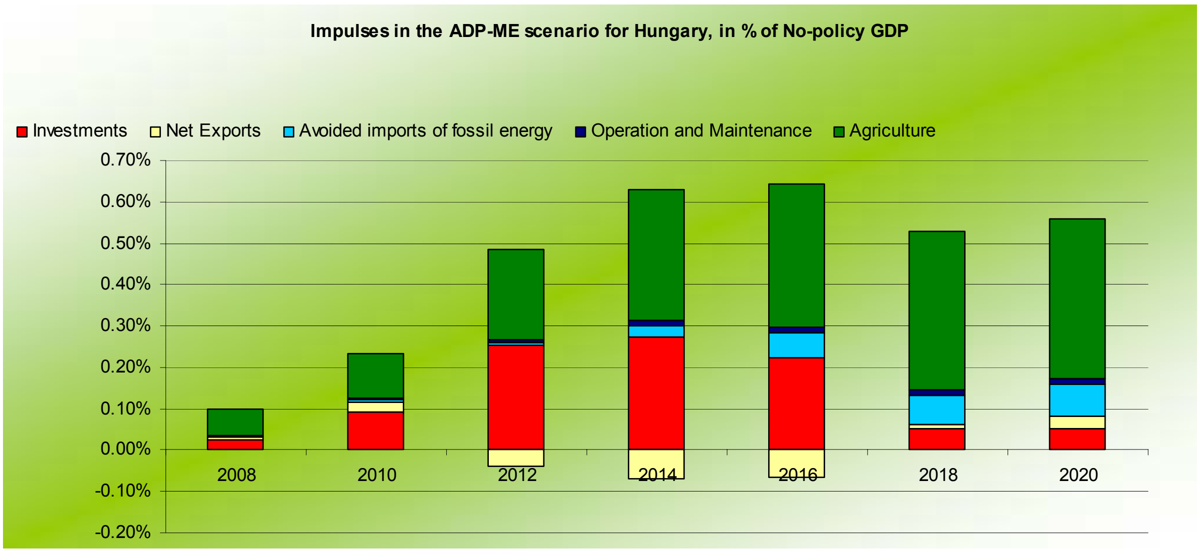


Figure 114: Impulse in the ADP-ME scenario for Hungary

"Accelerated RES deployment policy" with optimistic exports (OE)

We briefly present the impacts of the RES deployment policy with this exogenous modification of trade shares. Compared to the RES deployment policy presented above, only the impulse from exports and imports is modified, all other factors remain unchanged. This scenario will of course mainly have impacts in countries and industry sectors producing RES technologies. Globally, the differences between ADP-ME and ADP-OE are very small both with regard to GDP and employment.

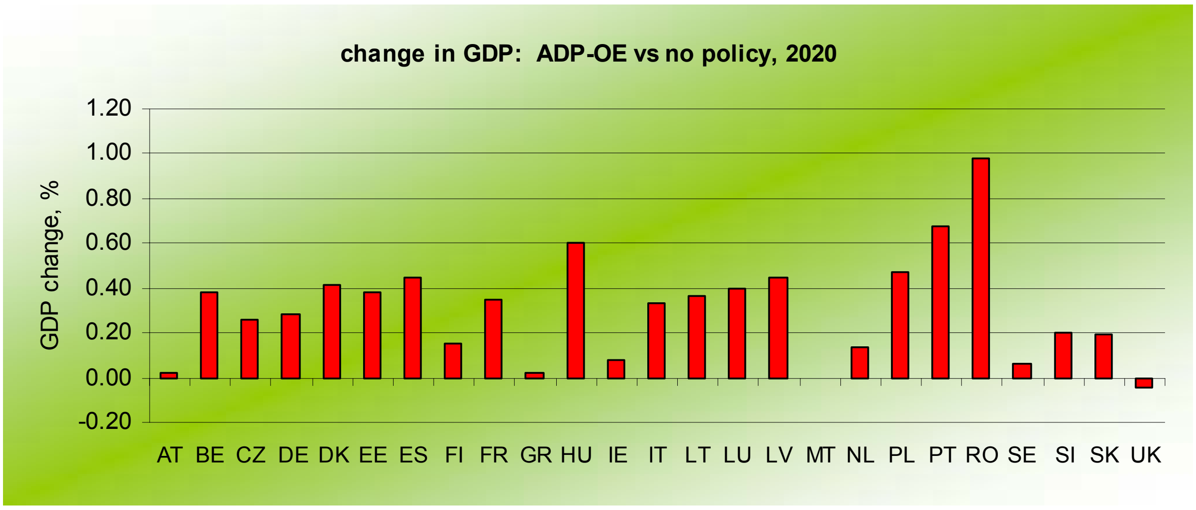


Figure 115: GDP changes in the ADP-OE scenario

7.3 ASTRA model

7.3.1 Model approach and key assumptions

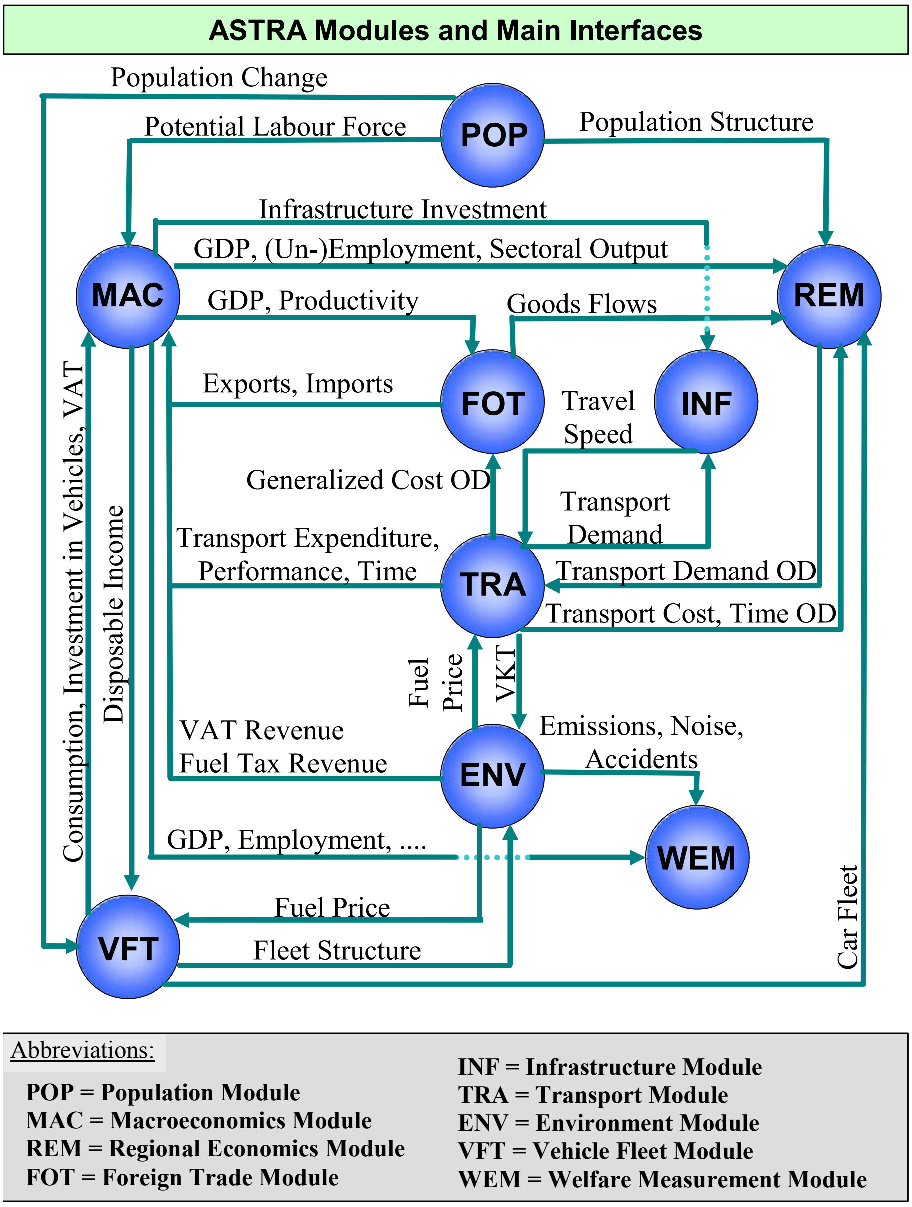
ASTRA stands for Assessment of Transport Strategies. The model has been continually developed since 1997 and is used for the strategic assessment of policies in an integrated way, i.e. by considering the feedback loops between the transport system and the economic system. Since 2004, it has been further 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).

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 and the model is calibrated for key variables for the period 1990 until 2003. The spatial coverage extends over the EU27 countries plus Norway and Switzerland. Each country is further disaggregated into a maximum of four functional spatial zones based on their settlement characteristics and classified into metropolis zones, high-, medium- and low-density zones. A detailed description of ASTRA can be found in Schade (2005) with extensions described in Krail et al. (2007).

The ASTRA model consists of nine modules that are all implemented within one Vensim system dynamics software file:

- Population module (POP),
- Macroeconomic module (MAC),
- Regional economic module (REM),
- Foreign trade module (FOT),
- Infrastructure module (INF),
- Transport module (TRA),
- Environment module (ENV),
- Vehicle fleet module (VFT) and
- Welfare measurement module (WEM).

An overview of the nine modules and their main interfaces is given in Figure 116. 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.



Source: Fraunhofer ISI

Figure 116: Overview of the ASTRA model modules

The economic models implemented in ASTRA 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 models 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.

The purpose of the model is to analyse long-term and strategic developments. Thus the model concentrates on describing the real economy and to a large extent neglects the short-term oscillations caused by the financial system. Two effects related to the financial markets are considered in ASTRA: (1) crowding out of private investment due to increased government debt and thus increased interest rates, and (2) dampening impact of inflation on real disposable income induced by higher energy prices. Both impacts were of minor importance in the EMPLOY-RES analyses as the policies do not involve significant government investments nor do energy costs increase to levels affecting inflation.

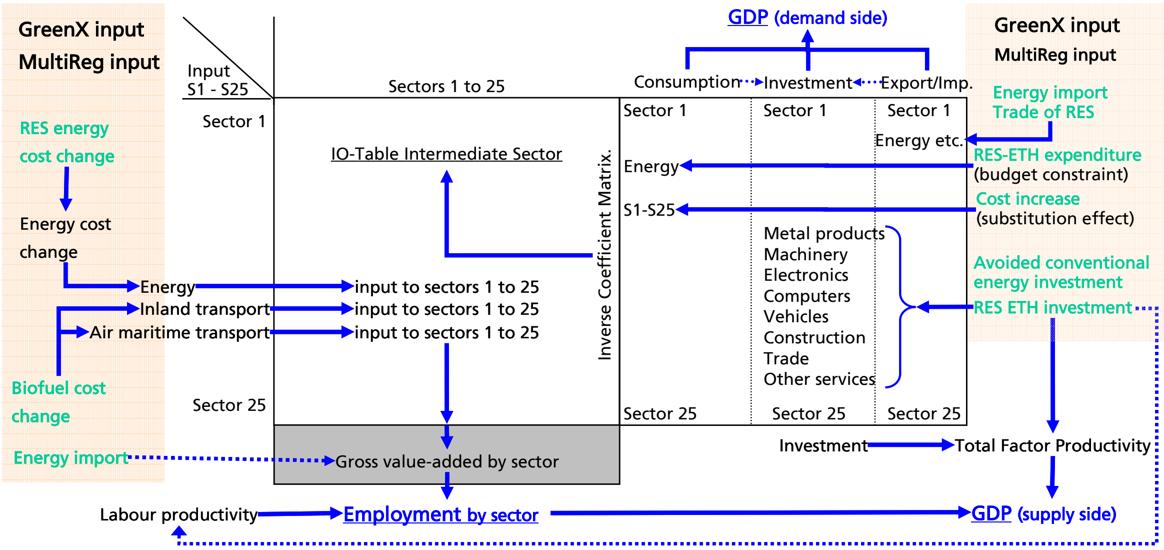
ASTRA incorporates the micro-macro-bridges from the bottom-up transport system models to the economy. For the EMPLOY-RES project, the micro-macro-bridges from the bottom-up energy system model to the economy also have to be established. This was achieved by linking ASTRA with the Green-X and MultiReg models. These linkages and their further take-up in the economic models of ASTRA are presented in Figure 117.

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 117 concentrates on presenting 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.



Source: Fraunhofer ISI

Figure 117: Inputs to ASTRA from the bottom-up analysis of RES policies from the GreenX and MultiReg models

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 model or the bottom-up inputs into ASTRA. 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.

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

7.3.1.1 Macro economy

The macroeconomics module (MAC) provides the national macroeconomic framework. The macroeconomics module 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, 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 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.

The micro-macro bridges form the sixth and final element comprising the MAC. These link micro- and meso-level models of ASTRA, for instance the transport module or the vehicle fleet module to components of the macroeconomics module. This means that expenditures for bus transport or rail transport of one origin-destination pair (OD) become part of the final demand of the economic sector for inland transport within the sectoral interchange model. This element also includes the linkages with bottom-up models, e.g. to include the changes of the energy system modelled by the GreenX model in EMPLOY-RES.

7.3.1.2 Trade

The Foreign Trade Module (FOT) is divided into two parts: trade among the EU29 European countries (INTRA-EU model) and trade between the EU29 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, 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 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 are added exogenously to the ASTRA trade model.

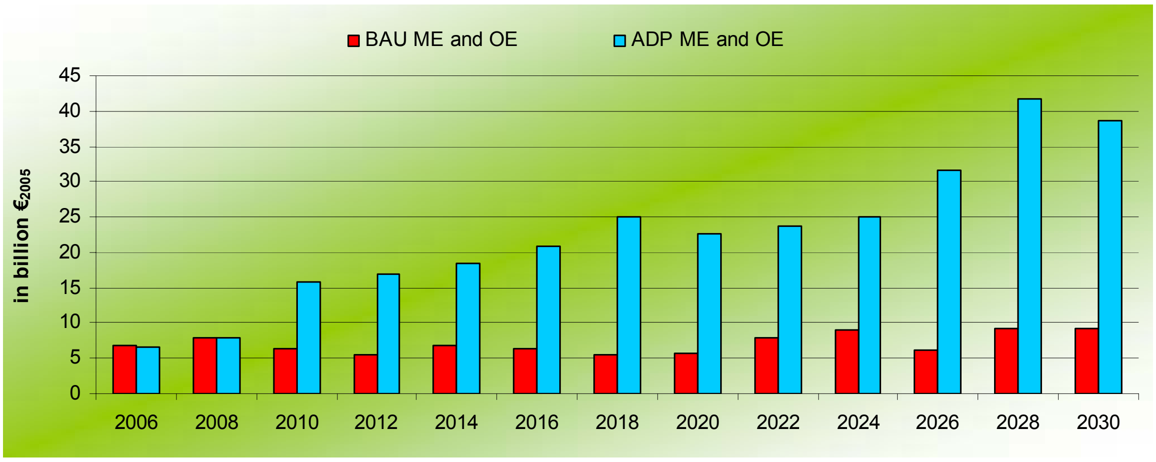
The resulting sectoral export-import flows of the two trade models are fed back into the macroeconomics module as part of final demand and national final use, respectively.

7.3.2 Impulses for the policy scenarios

Figure 117 shows the links with the bottom-up analyses in Green-X and MultiReg and ASTRA. The policy impacts implemented in the bottom-up models enter the macroeconomic models through these links. We call these impacts the impulses of the RES policy when they are transferred to the macroeconomic models. These impulses are presented in the following figures and comprise:

- Investment impulse consisting of the balance of additional RES investment and avoided conventional energy investment.
- Export impulse including the additional exports of global cost components of RES technologies.
- Energy import savings impulse representing the savings of fossil energy imports replaced by additional RES energy production.
- Energy cost impulse reflecting the energy cost increase induced by users having to pay for the additional RES investment.

The most important positive impulse is the investment impulse, i.e. the additional investment in RES installations. Without RES installation these investments would not have been made in the economy. They are financed by increasing the energy cost moderately. Both the additional investments and the energy cost increase are estimated by the bottom-up model Green-X and are transferred as impulses to ASTRA. Figure 118 illustrates the investment impulse that enters the ASTRA model in the two policy scenarios BAU and ADP and which is additional to the investments made under the NP scenario. This figure does not show the avoided investment, i.e. those investments in conventional energy plants which are not built because of the RES deployment. But the avoided investments are also estimated by Green-X and considered in NEMESIS and ASTRA. It can clearly be observed that the ADP provides the stronger investment impulse, i.e. induces more investment, which is also reflected in the fact that the electricity cost increase is greater (see Figure 121). In terms of additional RES investment, the moderate RES export (ME) and optimistic RES export (OE) scenario variants do not differ.

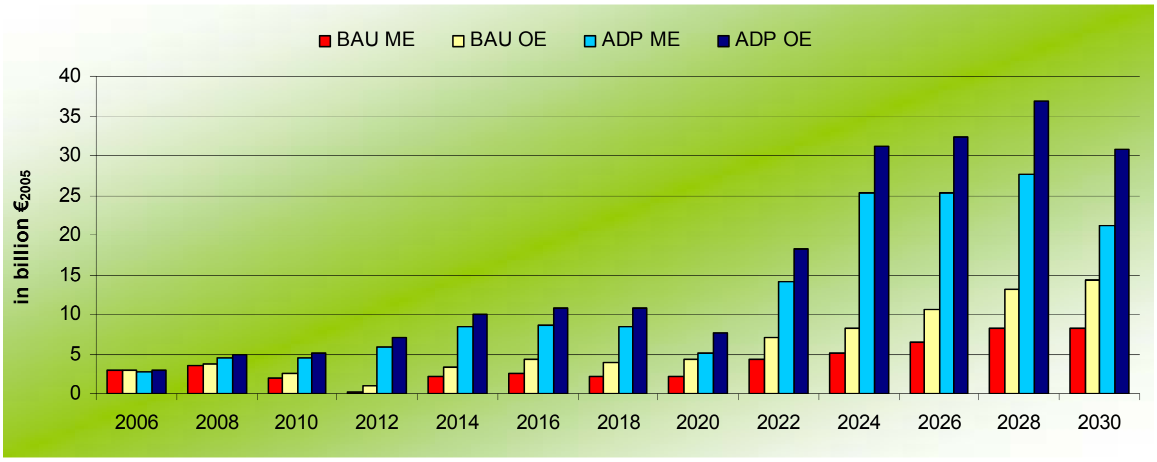


Source: ASTRA calculations with GreenX impulses

Figure 118: Investment impulse of RES-policy in EU27

A second economically stimulating impulse is the additional trade in RES generated by RES deployment. In this case, both a positive impulse, i.e. additional exports, and a negative impulse, i.e. additional imports, have to be considered in NEMESIS and ASTRA.

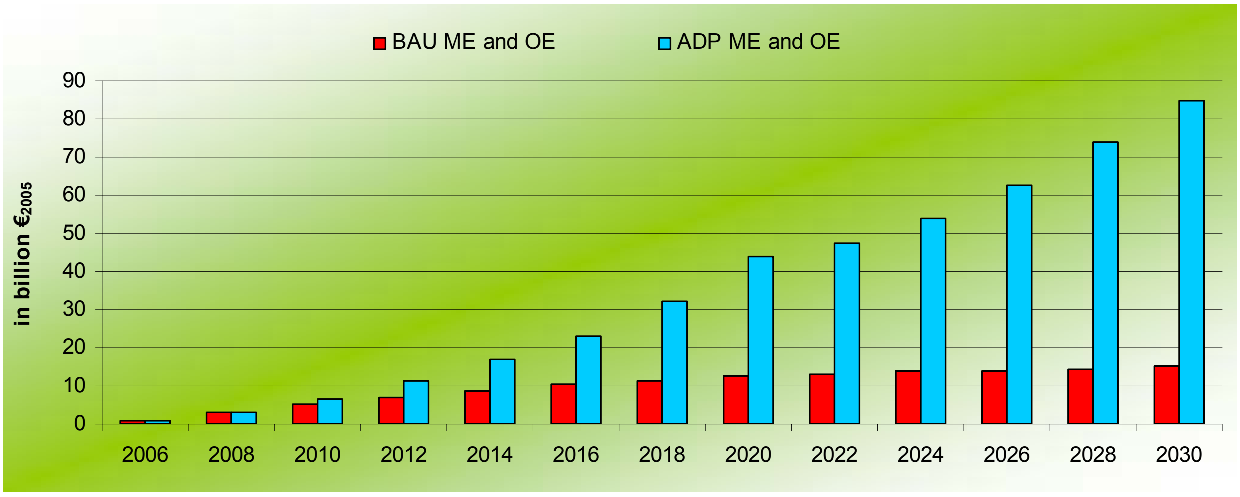
Figure 119 shows the exports of RES which are usually larger than the imports for the EU27 so that the balance which becomes active in macroeconomic terms is positive. It can also be observed that in both cases (BAU and ADP), the optimistic export variant (OE) reveals stronger exports than the ME variant, which reflects the scenario assumption of first mover advantages of the EU in ADP stimulating RES exports to the rest of the world. It should also be noted that the RES exports increase after 2020 in the ADP scenarios when the ambition to achieve a 30% RES share in energy production in the EU results in accelerated RES deployment.



Source: ASTRA calculations with GreenX impulses

Figure 119: Export impulse of RES technologies stimulated by RES-policy in EU27 – excluding secondary exports of local RES investment

Another positive economic stimulus emerges from the saved imports of fossil energy fuels, which is partially compensated by increased biomass imports used for energetic purposes. Figure 120 presents the energy import savings, which are four times higher in ADP than in BAU after 2020.

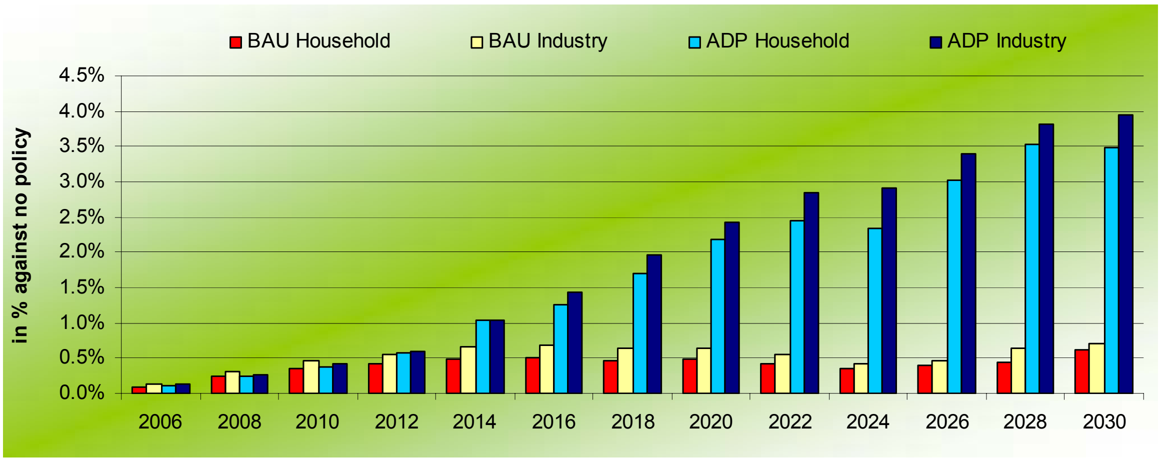


Source: ASTRA calculations with GreenX impulses

Figure 120: Energy import savings impulse of RES-policy in EU27

Though increased RES imports and avoided investment constitute two economically negative impulses, the strongest negative impulse is from the potential energy cost increase. Figure 121 shows averaged cost increases for the EU27 derived by weighting the percentage increases on country level with the country's GDP share in EU27 GDP. In the

BAU scenarios, the cost increase compared to the NP scenario remains moderate, at not much more than a maximum 0.5% increase. The largest increase in the cost of electricity on country level is +3% and +2% for Spain and the Netherlands, respectively. In the ADP scenario the cost increase becomes relevant around 2020, when it rises above 2%, leading to an increase of close to +4% in 2030 for the EU27. In Lithuania, the Netherlands, Spain and Poland, the increase reaches +6% or even higher.



Source: ASTRA calculations with GreenX impulses

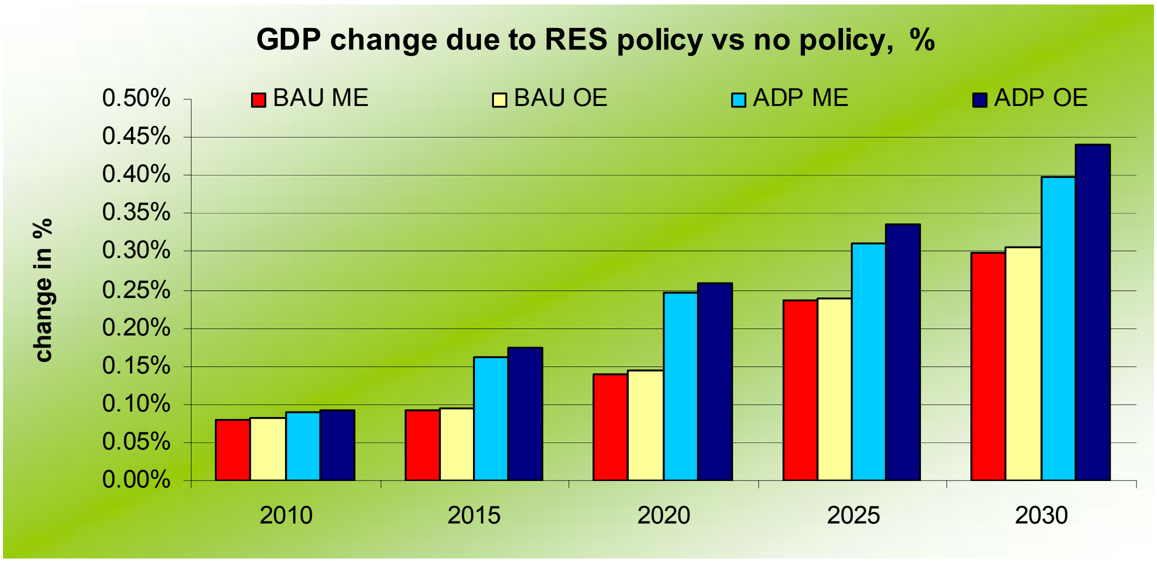
Figure 121: Electricity cost increase impulse for households and industry due to RES-policy in EU27

The structural differences of the NEMESIS and ASTRA models lead to a slightly different treatment of impulses in the two models. The RES investment impulse provided by the Green-X model as the INVRES variable is adopted as a whole into the output equation of NEMESIS, while in ASTRA it is split into the investment component and the export component, which both also enter the final demand and output equations, but differ in how they affect transport demand and productivity growth in the national economies. The treatment of RES investments that are locally produced and not traded also differs. NEMESIS treats them as final demand such that these generate trade indirectly after processing the input-output table, while ASTRA uses its trade model directly to assign the supply of the intermediate goods to the EU countries. Finally, the energy cost increase in NEMESIS affects the trade model and competitiveness, while in ASTRA it has more effect on consumption patterns and the input-output relations from the energy sector to the other sectors.

7.3.3 Results for the EU 27

This section compares the net economic effects across the four scenarios with the No policy scenario for the EU27. The comparison focuses on two major economic indicators, GDP and employment, and two important indicators, investments and exports.

Figure 122 presents the impact on GDP caused by RES policies. It can be noted that GDP increases in all scenarios and that the increase in the BAU scenarios amounts to about two thirds of that in the ADP scenarios. Given the fact that RES investments are much higher in the ADP scenarios the differences seem to be underestimated. However, one of the key findings of the ASTRA analysis is that beyond a certain threshold of energy cost increase, the positive impulses (e.g. RES investment and RES exports) are significantly compensated by the dampening impulse of the increased energy cost. The threshold in ASTRA only allows for rather limited energy cost increases due to the assumption of RES deployment without hampering economic development. This sensitive reaction is caused by a cautious parameterisation of how the energy cost increases affect the households via the prices of final goods and services and of how the energy sector, as part of the combined energy and water sector in ASTRA, would forward the cost increase to other sectors. A more moderate and less sensitive parameterisation would raise this threshold of harmless energy cost increases and thus lead to a stronger positive effect on GDP and, as will be discussed later on, also employment.

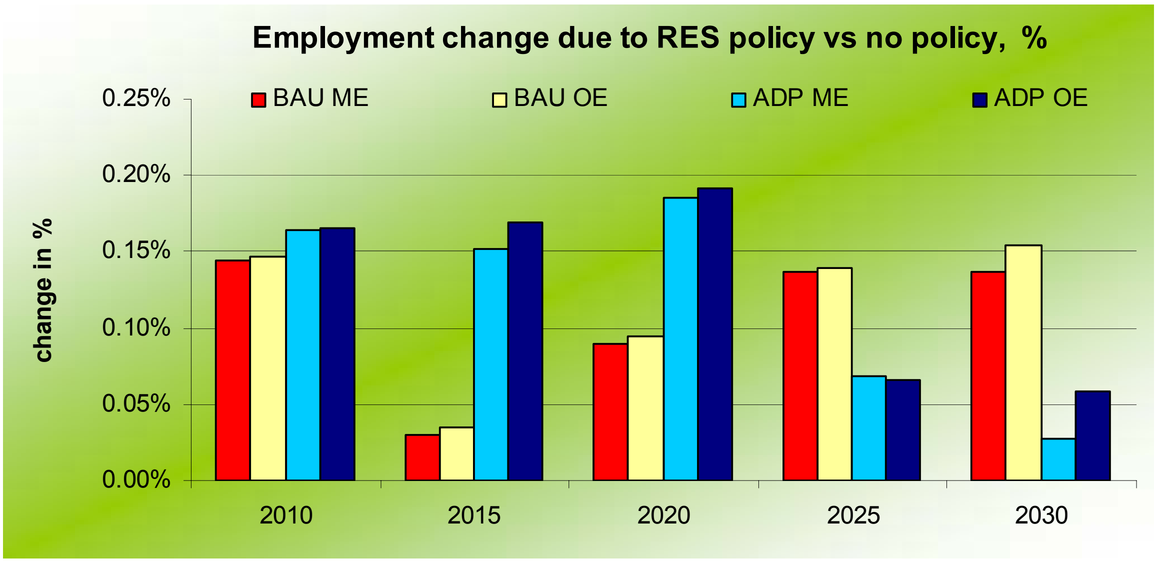


Source: ASTRA, own calculations

Figure 122: GDP change due to RES-policy in EU27

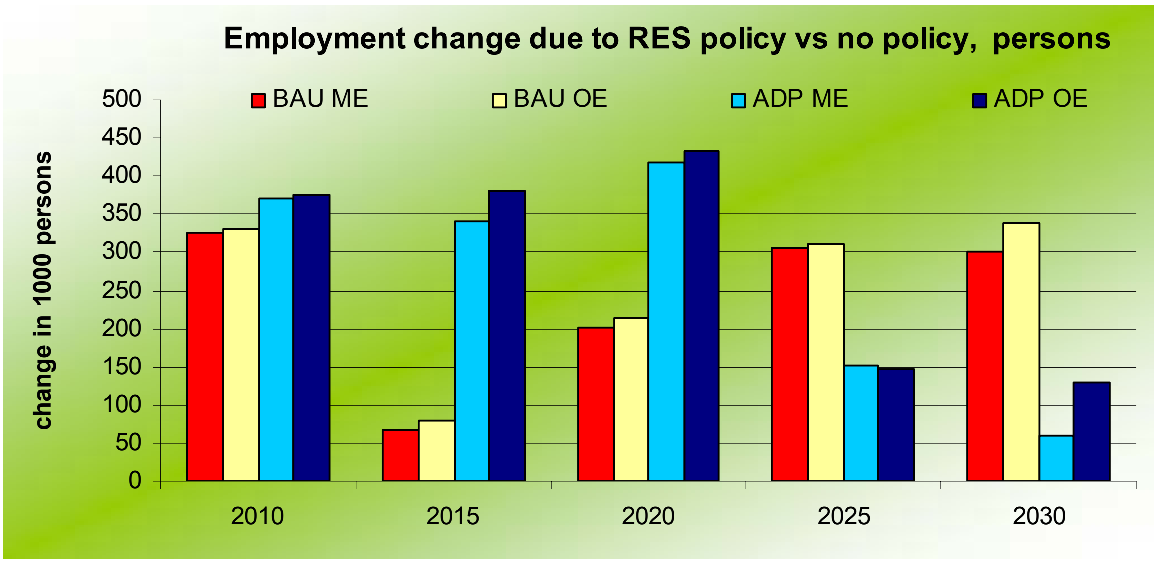
Figure 123 and Figure 124 present the impact on employment in relative and absolute terms for the scenarios. It can be observed that employment reacts much more sensitively to the interaction of RES investment, RES exports and energy cost increases. Until 2010 investment and exports increase in BAU and ADP scenarios, with a very moderate increase in energy cost, such that employment grows in all scenarios. After 2010 in the BAU scenarios, RES investment and exports decline while energy cost increases such that additional employment is reduced, e.g. because higher energy costs reduce consumption in non-energy sectors and also alter consumption patterns, which is not compensated by RES investment and RES trade. In the ADP scenario these positive impulses continue to grow and there is a slight growth in employment until 2020. However, after 2020, the energy cost increase passes above a relevant threshold and, despite further increases of RES investment, the growth in the number of jobs is reduced until 2030 and reaches about 60,000 additional employed persons in ADP-ME and 120,000 in ADP-OE in 2030.

For the BAU scenarios, the energy cost increase remains moderate after 2020 while the positive impulses continue to increase with the result that employment continues to grow in this scenario and there are more than 300,000 additionally employed persons in 2030.



Source: ASTRA, own calculations

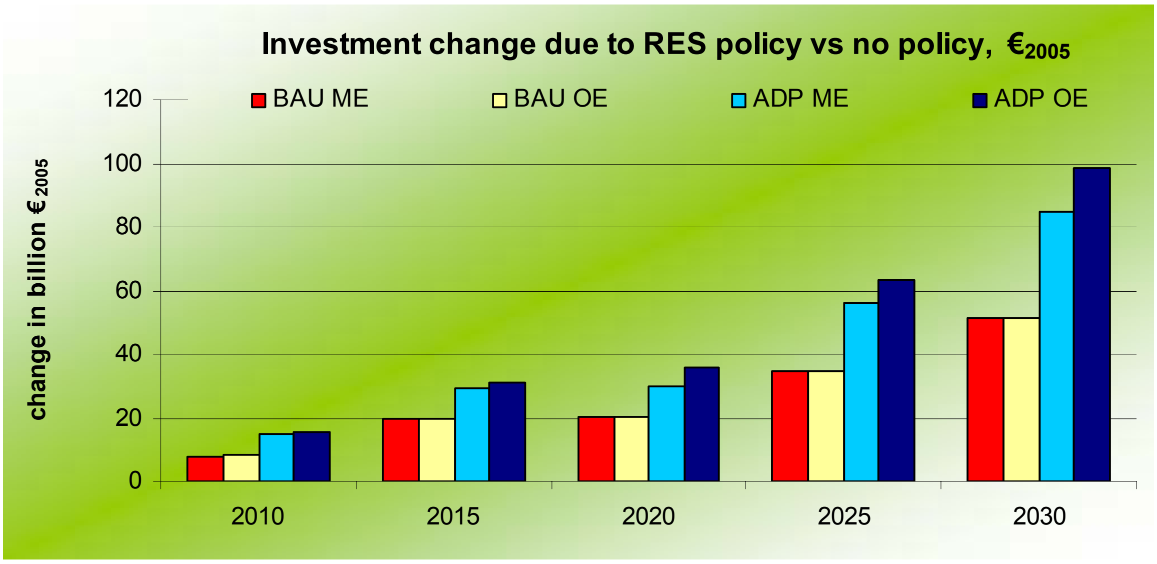
Figure 123: Employment change due to RES-policy in EU27



Source: ASTRA, own calculations

Figure 124: Absolute employment change due to RES-policy in EU27

Figure 125 shows the increase of total investment in the scenarios. In general the investment increase is significantly higher in the ADP scenarios than in the BAU scenarios. This investment increase differs from the additional RES investment shown in Figure 118 in the sense that they comprise the RES investments but also the induced investment caused by the second round effects of increased GDP and exports. Until 2010, induced investments are negligible, but by 2020 their share is between 40% and 70% of total investment increase and by 2030 between 65% and 80%. The pattern of changes in total investment closely mirrors the pattern of GDP growth in the scenarios, which again demonstrates the importance of investments for the economic impact of a policy.

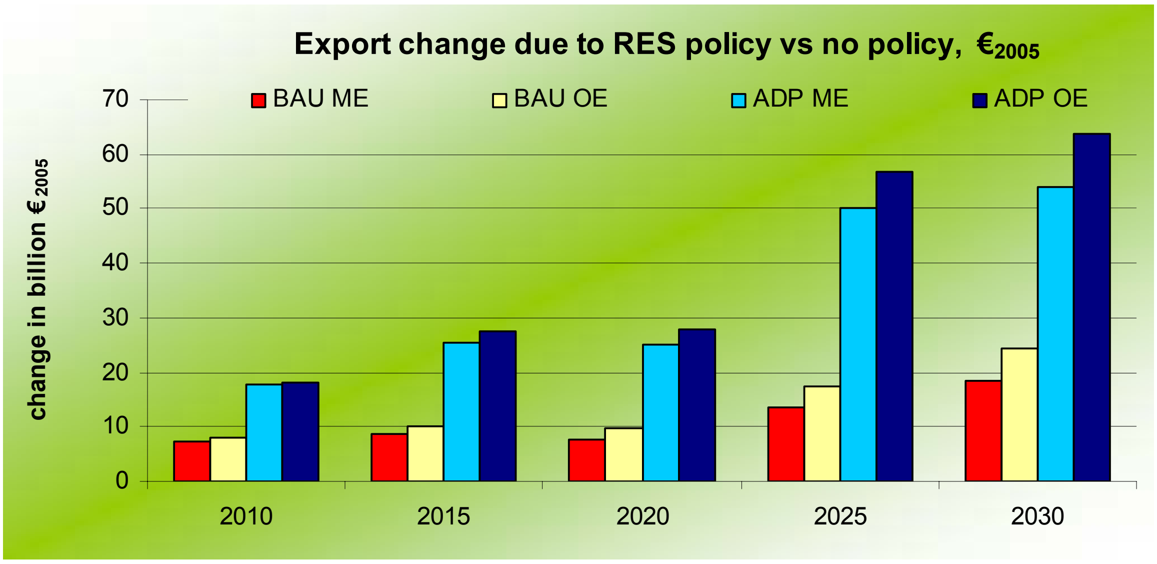


Source: ASTRA, own calculations

Figure 125: Absolute total investment change due to RES-policy in EU27

Figure 126 shows the impact of RES policies on the total exports of the EU27. These changes include the additional RES exports and the exports from second round effects of GDP growth and trade interactions of EU countries. The pattern in BAU and ADP scenarios is similar: Growth is very moderate up to 2020, followed by a decade of stronger growth, which is driven by both the additional RES exports due to the RES policies and the GDP growth induced by the policy. This results in increased imports of EU countries.

The impact of the first mover advantage - more optimistic RES export expectations (OE scenarios) - is clearly visible in the differences between the OE and ME scenarios. In 2020, the total difference is about 2 billion € in both scenarios and in 2030 between 6 billion € in BAU scenarios and 10 billion € in ADP scenarios.



Source: ASTRA, own calculations

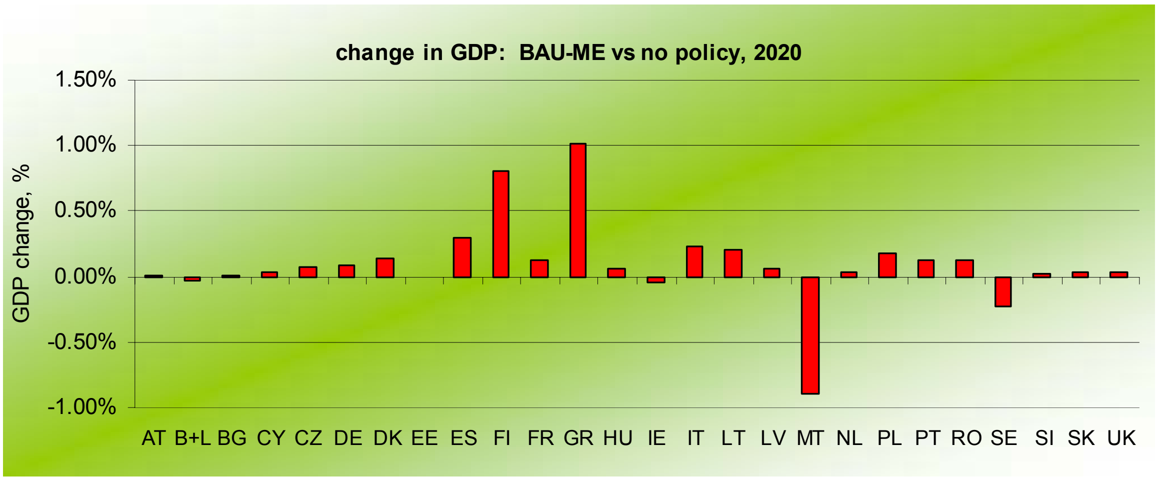
Figure 126: Absolute total export change due to RES-policy in EU27

The basic conclusion from ASTRA about the impact of RES policies on the EU27 level is that these policies would enable a moderate economic growth accompanied by at least temporary employment increase until 2020. In the long run, the employment impact depends on the energy cost increase and the sensitivity of the economic agents to such energy cost increases. The ASTRA model in the parameterisation of EMPLOY-RES takes a conservative view with high sensitivity to cost increases. A more optimistic view assumes lower sensitivity which would imply higher employment gains due to RES policies.

7.3.4 Results at member state level for the year 2020

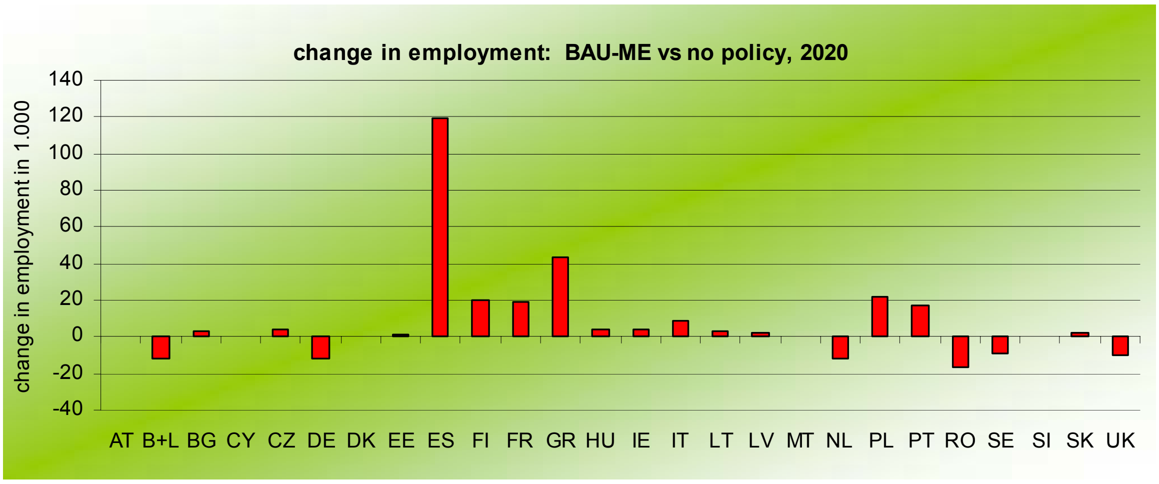
This section describes the results for GDP and employment on country level for the four scenarios in comparison with the No policy scenario. The individual country results depend on the interplay of a number of important factors and the impacts on GDP and employment differ, i.e. there is no linear correlation between GDP and employment. The reason is that although both are connected, the major drivers of the two variables differ. For GDP, the most relevant driver is the additional investment in relation to total GDP, while for employment, energy cost changes above a certain threshold are of greater importance. This already allows a simple pre-specification of expected country results. Countries with high additional RES investment but low additional generation will experience growth in both GDP and employment, which is stimulated directly by the investment and indirectly by second round effects of GDP and income growth. However, countries with high additional RES investment but high additional generation costs face a comparably high energy cost increase. This may stimulate substantial growth in GDP, but not in employment, which will compensate for the direct employment effects caused by the investments. In such a case, a sectoral shift of employment can be expected in favour of sectors producing RES technologies for example and away from more energy-intensive sectors or sectors with higher elasticities to price changes. A further indicator that can play a decisive role for the economic results is the relation of RES investment to total investment activity in a national economy. In countries with weak general investment activity, RES investment can amount to about 5% of total investment.

Figure 127 and Figure 128 present the GDP change and employment change caused by the BAU-ME policy in the different EU Member States (Belgium and Luxemburg are treated as one region B+L in ASTRA). The GDP change is provided as percentage change relative to the No policy scenario, while the employment change is given in absolute numbers of additional or reduced employed persons compared with the No policy scenario. GDP is increased in nearly all countries. The strongest positive GDP impact can be observed for Greece, Finland and Spain. The first two countries belong to the group with the highest RES investment impulse compared with total investment in these countries, but in both countries the investments go into RES technologies with cheap production cost such that energy cost remain nearly stable such that the major dampening impact of RES policy is absent. In Spain the situation differs in a sense that here the RES investment impulse is already significant in relation to GDP but the positive impact is dampened by the strongest energy cost increase, which for industry reaches about +2.5% for electricity in 2020. Looking at the absolute numbers of employment, the larger country size of Spain leads to the fact that in Spain employment is increased strongest by about 120 thousand persons in 2020, followed by the increase in Greece, France and Finland. Countries like Germany or United Kingdom, which due to a generally high level of investments and relatively large cost increase already under the BAU scenario remain close to neutral in GDP and employment effects in this scenario.



Source: ASTRA, own calculations

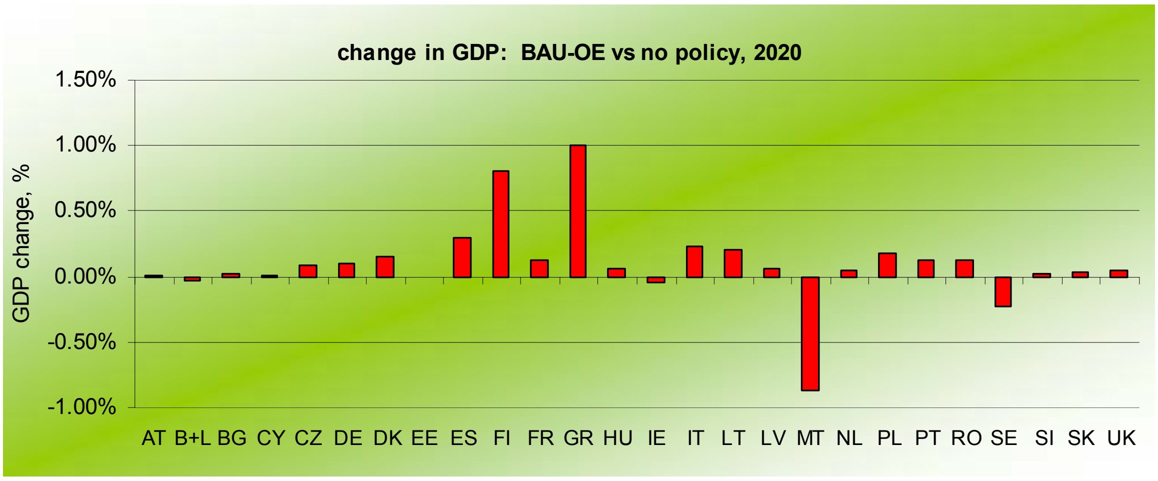
Figure 127: GDP change by country due to BAU-ME policy



Source: ASTRA, own calculations

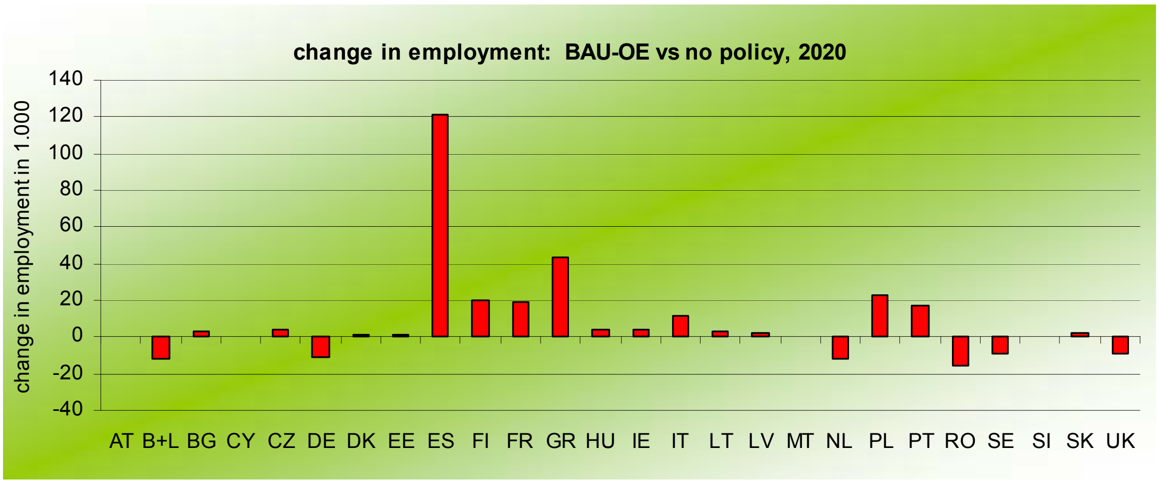
Figure 128: Employment change by country due to BAU-ME policy

Figure 129 and Figure 130 display the results for the BAU-OE scenario with increased RES exports to the rest of the world. The differences in ASTRA are minor and can hardly be detected in the figures. The largest increase in RES exports is expected for Germany. Stronger increases are also expected for Spain, Denmark, UK, Italy and Poland. These are also the countries benefiting (regarding GDP and employment) from the additional RES exports with Germany and Denmark reacting strongest with their GDP and Italy and Spain with their employment until 2020.



Source: ASTRA, own calculations

Figure 129: GDP change by country due to BAU-OE policy

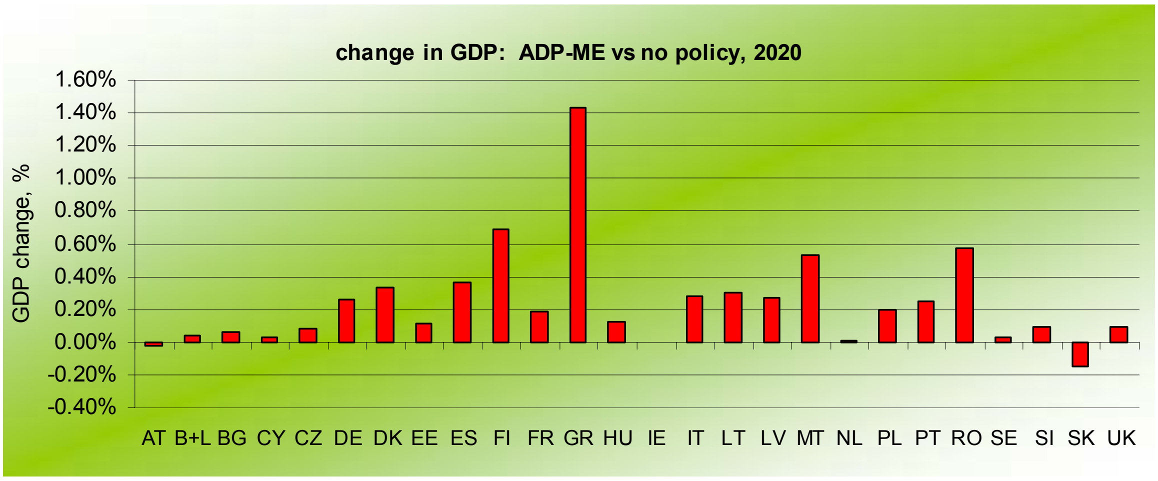


Source: ASTRA, own calculations

Figure 130: Employment change by country due to BAU-OE policy

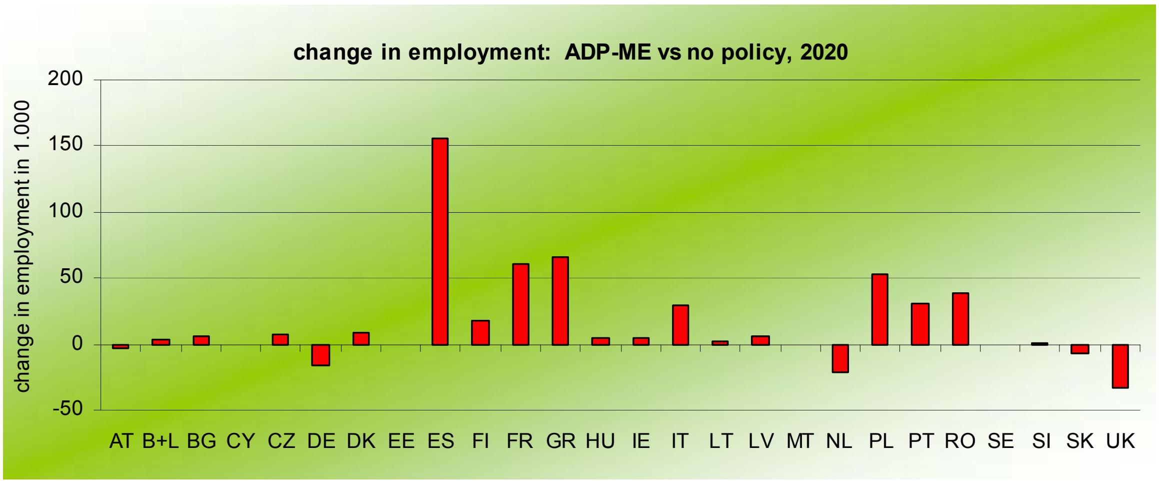
Figure 131 and Figure 132 present the results for the ADP-ME scenario. In this scenario several countries increase their level of ambitions to deploy RES technologies until 2020 and until 2030. In relation to their GDP Romania, Portugal, Spain and the three Baltic countries reach high levels of RES investment. In relation to their national investment also Bulgaria, Finland, Greece and Ireland initiate significant RES investment programs. In absolute terms of course the largest countries Italy, Spain, France, UK and Germany increase RES investment strongest. In general, the net effect on GDP is most positive in those countries, which stimulate significant RES investment but at low additional generation costs such that energy cost remain mostly stable and do not dampen the GDP increase. This is in particular the case for Greece, Finland and Romania, those countries that reveal the strongest GDP impulse. Although they invest highly in RES, Portugal and

Spain also install more expensive technologies so that, overall, energy cost increase and GDP growth remain moderate despite the investment push.



Source: ASTRA, own calculations

Figure 131: GDP change by country due to ADP-ME policy



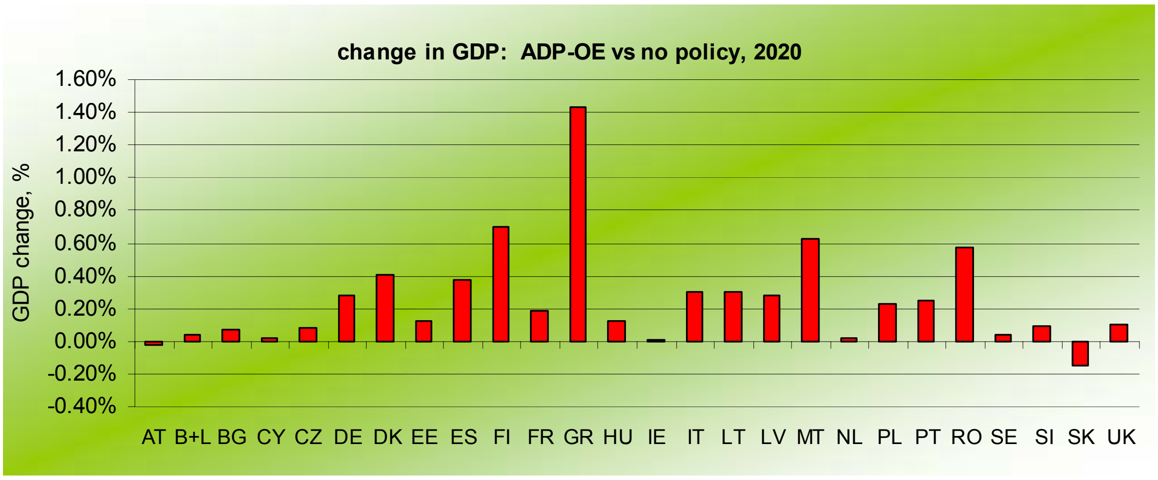
Source: ASTRA, own calculations

Figure 132: Employment change by country due to ADP-ME policy

Looking at employment again for Spain the highest employment gain is observed. France is gaining employment because the energy cost increase remains very low, such that even a minor investment impulse plus second round effects induced by growth in France and other EU countries raises the employment level.

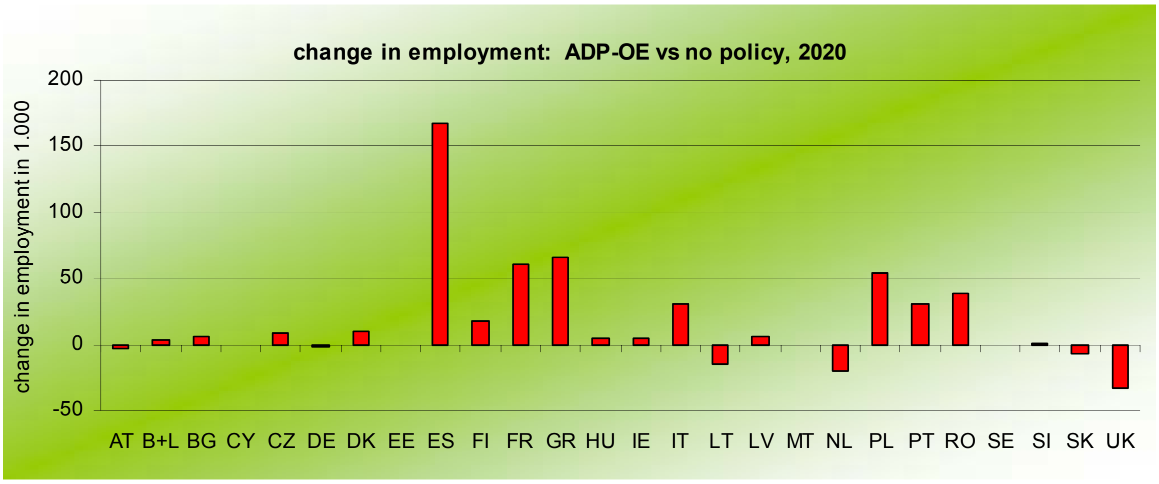
Looking at those countries that observe limited employment losses, UK, Netherlands and Germany, one can observe in Figure 109 that these mark the countries with the highest energy cost increase in 2020 with more than +4% in UK and Germany. Only Spain faces a similar high level of cost increase, but with additional RES investment that are about 3 to 4 times higher (in relation to GDP) than in the three other countries, such that the investment push dominates the dampening effect of increased cost. The general observation across scenarios is that energy cost increases of below a few percent compared to No policy would cause only negligible negative effects on the economic development of an EU country.

Figure 133 and Figure 134 display the economic impacts of the ADP-OE scenario, i.e. the scenario assuming an even stronger first mover role of the EU leading to additional RES exports to the rest of the world. Again the differences to the ADP-ME scenario remain very small. Most of this additional RES exports are supplied by the six largest EU countries plus Denmark, which has built-up a very competitive industry for a number of RES technologies. Accordingly the strongest absolute GDP impact is observed for Germany, Spain, Italy and Denmark, though the relative gain is largest for Denmark.



Source: ASTRA, own calculations

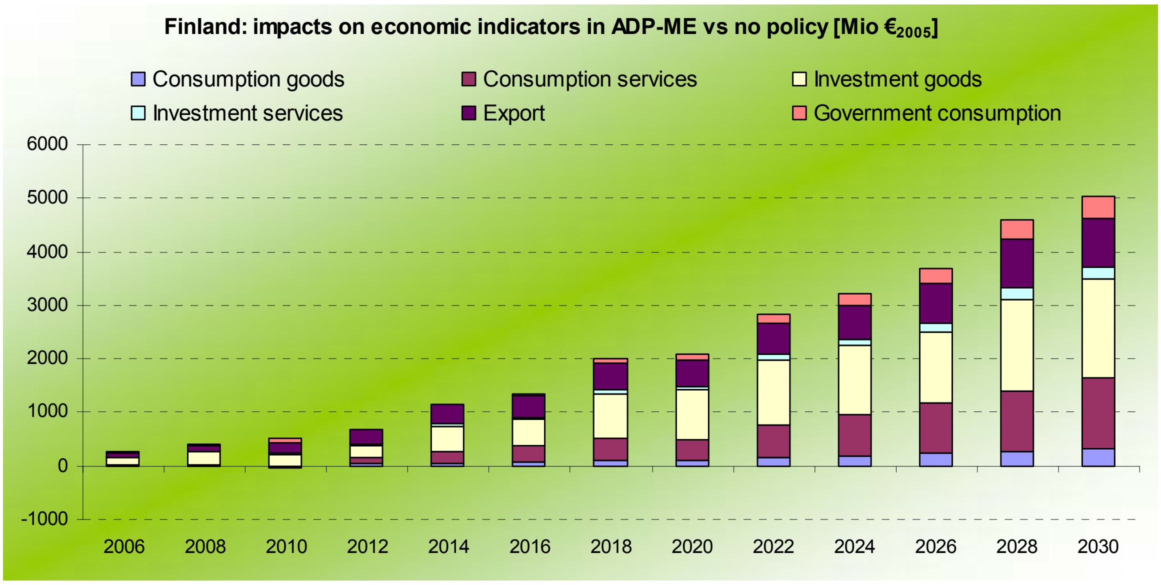
Figure 133: GDP change by country due to ADP-OE policy



Source: ASTRA, own calculations

Figure 134: Employment change by country due to ADP-OE policy

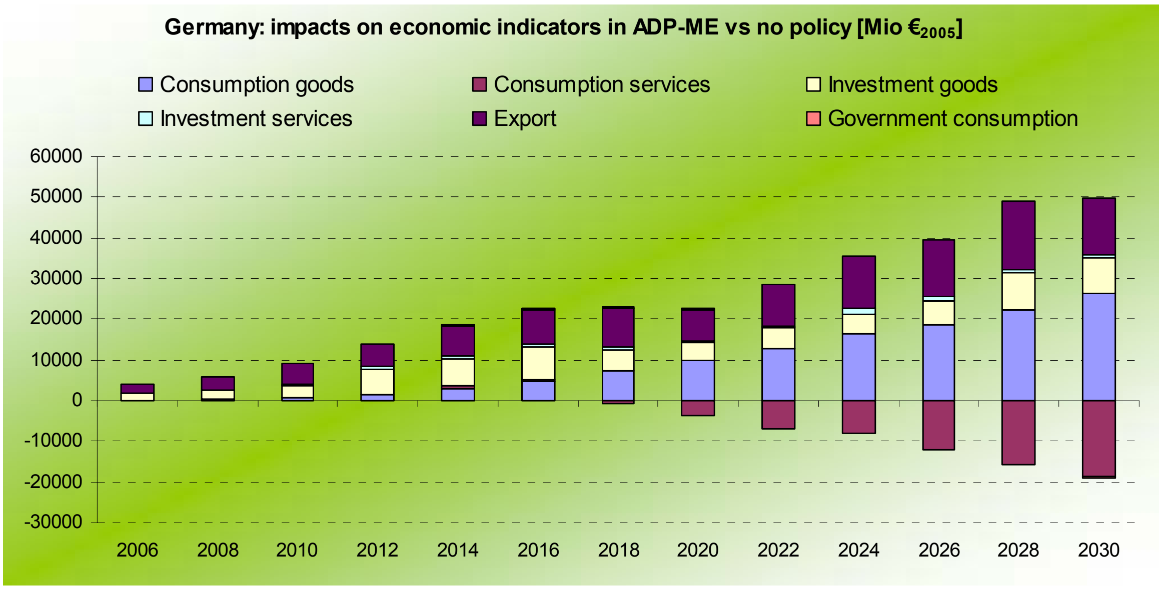
The following Figure 135 and Figure 136 exemplify the different economic development patterns of countries for which only a moderate energy cost increase is observed in ASTRA due to RES policy compared with countries that face stronger cost increases. In Finland (Figure 135) the energy cost increase remains moderate such that the stimulating impulses, in particular the investment impulse, can enfold over time without a major dampening direct effect of the policy. Here we observe that until 2010 RES investment, as part of aggregate investment in goods, and RES exports, as part of export, drive economic growth. After 2010 second round effects start to enfold, which can be observed by the growth in expenditures for consumption of services that occurs because GDP and disposable income grow and larger share of this additional income is spent for consumer services. After 2020 even government consumption can be increased due to the higher GDP in Finland. Also exports continue to increase due to the European trade interactions, such that other growing EU countries import more from Finland increasing the Finish exports, which is another type of second round effects of the RES policy.



Source: ASTRA, own calculations

Figure 135: Changes of major economic indicators in Finland in ADP-ME policy

Looking at the German development in Figure 136 the development in the first years is very similar to Finland: RES trade and RES investment stimulate exports and goods investment. However, around 2018 the energy cost increase significantly, which has two effects: households have to spent more for energy, which makes consumption of goods increasing as energy is aggregated in this representation into private consumption of goods, and private consumption of services is reduced continuously. In particular, this effect contributes to the close to neutral development of net employment effects in Germany in particular as the services sectors on average are more labour intense than the goods sectors.



Source: ASTRA, own calculations

Figure 136: Changes of major economic indicators in Germany in ADP-ME policy

7.3.5 Conclusion

The basic conclusion that can be drawn from the ASTRA model analysis is that RES policies are able to stimulate moderate economic growth in European countries. There might also be positive effects on employment, but these strongly depend on the rise in energy cost caused by the increased use of RES technologies. Therefore a thorough analysis of which RES technology best fits each country in terms of the specific production cost is a pre-requisite for a successful renewable policy. For the same reason, it is also important to capture learning effects which can help to drive down the production costs of RES technologies through increased deployment of RES technologies.

In general, it could be shown that moderate energy cost increases resulting from RES policies can be compensated by economic growth effects so that it is not necessary for RES technologies to have the same production costs as conventional technologies in the early phase of their development.

8 Comparison of the model results and conclusions about the economic effects

As presented in some detail in the preceding sections, the net effects of RES policies on the economy were analysed based on the models NEMESIS and ASTRA. In both models, the investments become part of the sectoral final demand and the indirect effects of investments spread throughout the economy. The main indicators selected to present the net effects of the RES policy were the gross domestic product (GDP) and employment. In this section, the results of these two models are compared for both of these indicators and for the two main scenarios BAU-ME and ADP-ME. The comparison is done for the EU-27 as well as on the level of individual Member States[40]. The differences in the model results reflect the differences in the implementation of the economic mechanisms in each model as well as the detailed implementation of the various impulses in NEMESIS and ASTRA. In this respect the analysis of these differences reflects the uncertainties of the modelling approach. A modelling analysis like the one presented here contains different forms of uncertainty. The most important are the uncertainty connected with the input data (e.g. on the costs of RES technologies), the inherent uncertainty about the future (e.g. future energy prices) and the uncertainty of the modelling system. The latter can be examined based on the analysis presented in this chapter.

One of the main conclusions of the individual section of NEMESIS and ASTRA was that GDP would be slightly stimulated by the RES policies. Figure 137 shows the impact of the policies BAU-ME and ADP-ME on the development of the GDP for the EU-27 for both models NEMESIS and ASTRA. The main effects on GDP can be summarised as follows:

- Current RES policies (BAU-ME) in EU member states result in an increase of GDP by 0.11% - 0.14% by 2020 and by 0.15 % - 0.30% by 2030.
- More ambitious policy assumptions (ADP) result in an even stronger increase of the GDP by 0.23% - 0.25% in 2020 and 0.36% - 0.40% in 2030 for the case of a moderate development of exports (ME) of RES technologies.
- The results for ASTRA and NEMESIS are generally consistent; there are only larger differences for 2030 in the BAU scenario. Both models deliver only positive results for each scenario and target year. In the short term, i.e. until 2010, the NEMESIS model projects more positive development, while in the longer term the ASTRA model generates higher GDP growth.

---

[40] Since the ASTRA model aggregates Belgium and Luxemburg into one region and the NEMESIS model does not contain Bulgaria, the comparison is shown only for the sum of Belgium and Luxemburg and is not shown for Bulgaria.

- The difference between the NEMESIS and the ASTRA model for the target years 2020 and 2030 remains below 70% of the average of the results of both models.
- One striking difference between both models concerns the different temporal dynamics: Whereas the result of the NEMESIS model is fairly constant for the BAU scenario and increases only slightly over time for the ADP scenario, the annual growth of the GDP impact is much larger in the ASTRA model. The reason might be a stronger emphasis of positive second round effects in the ASTRA model, while the NEMESIS model assumes more Keynesian behaviour. Investment influences economic growth more in the short term, while the multiplier effect tends to be reduced in the long term due to inflationary pressure. This effect is reinforced here by the increase in electricity prices. Therefore the stronger growth of the ASTRA model may be based on induced positive secondary effects which accelerate the original impulses received by the model.

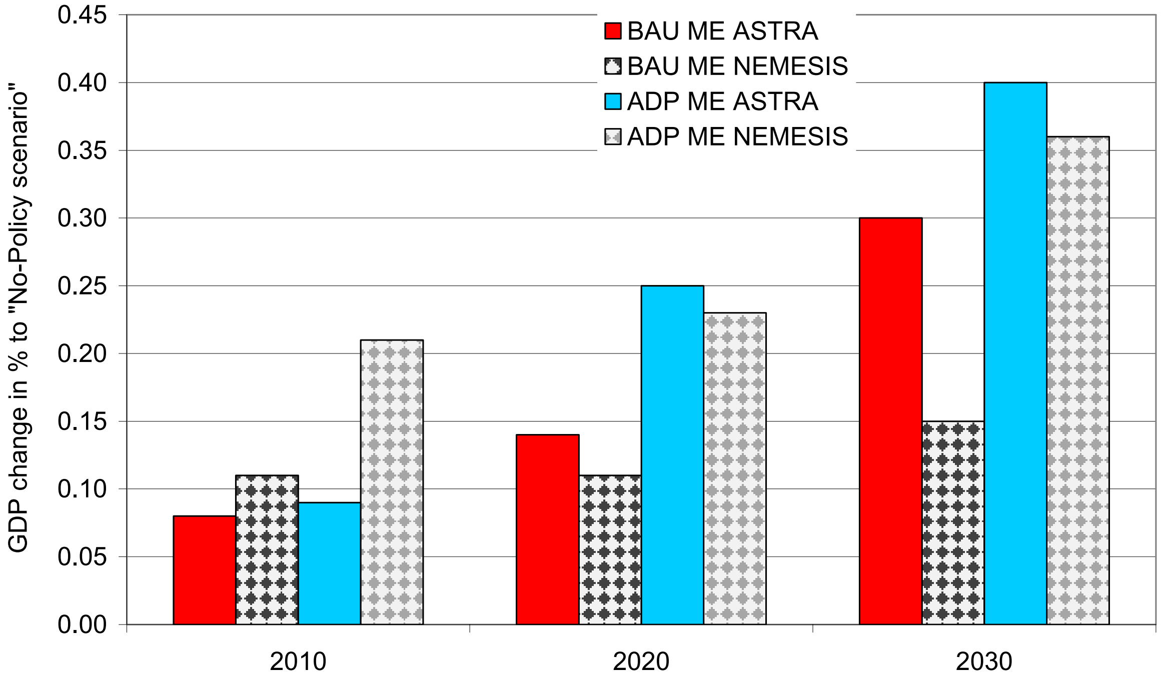


Figure 137: GDP impact of RES policy for the scenarios BAU and ADP with moderate export assumptions

With regard to employment, the basic conclusion of both models is that jobs would also be slightly stimulated by RES policies, but that the effects would be more moderate than the effects on GDP. Figure 138 shows the impact of RES policies on employment development for the EU-27. The main results can be summarised as follows:

- Business as usual RES policies (BAU-OE) in EU member states combined with moderate export expectations have a roughly constant positive effect on employment with 115,000 – 201,000 new jobs in 2020 and 188,000 – 300,000 jobs in 2030.

- The ADP scenario combined with moderate export expectations leads to a slightly higher increase in averaged employment of 396,000 – 417,000 new jobs by 2020 and 59,000 – 545,000 by 2030. In general, the models generate comparable results apart from those for 2030.
- The shifts in demand between different economic sectors as well as the moderate energy cost increase in the ADP scenario result in the additional employment caused by RES policies not continuing to grow compared to the GDP. In the ASTRA model the stronger impact of the energy cost increase after 2026 significantly dampens the growth in employment.
- The effect on employment depends heavily on the energy cost increase. If there are significant cost increases, these may hamper job creation. This is more obvious in the ASTRA model results for employment in the last years of the modelling period, while the impact on GDP was less significant.

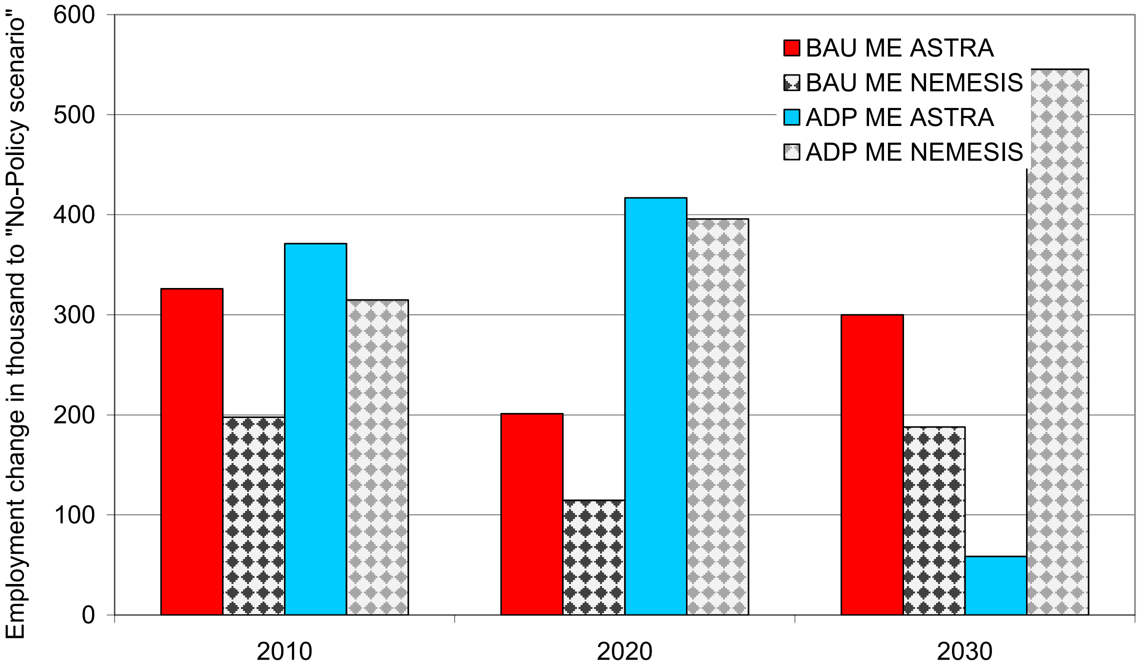
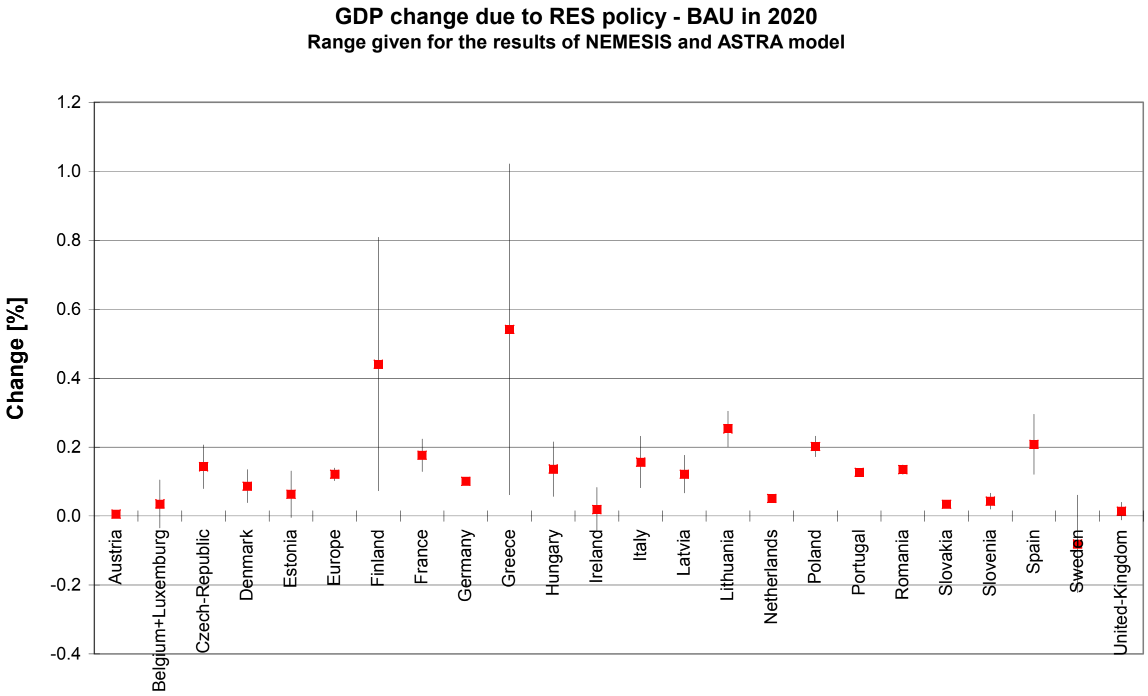


Figure 138: Employment impact of RES policy for the scenarios BAU and ADP with moderate export assumptions

In general, the NEMESIS and the ASTRA model arrived at comparable conclusions concerning the probable slightly positive effect of the RES policy on economic growth and employment in the EU. This is particularly valid for the investment impulse, which generates the strongest positive stimulus in both models. The difference between the models, which becomes apparent especially in the case of the additional employment after 2020, is mainly due to the different impact of rising energy costs on the overall economy. In NEMESIS, the increase in electricity cost enters the production costs and thus the output prices. At first this will lead to a slight decrease in competitiveness of those countries faced by high energy price increases. This will be less marked in other countries, depending on their external trade structure (intra EU vs. external EU). The second effect for firms will be that some factor substitution occurs in production in order to save energy. This energy saving will slightly benefit the production factor of labour. The effect on household consumption seems to be less marked than in the ASTRA model, even if the electricity price increase, the increase in employment and in wage and salaries maintain real disposable incomes and electricity demand decreases slightly. In ASTRA, the energy costs have to be compensated for mainly by changes in the marginal consumption of households. This leads to sectoral shifts of consumption away from labour-intensive sectors. Thus, the stronger impact of increased energy costs on employment in ASTRA is mainly caused by sectoral shifts of consumption. In this respect the results of the ASTRA model can be considered to give a more conservative view of the possible impact of renewable energies on employment. Thus, the results of the two models show the possible range of impacts of strong renewable energy policies on the economy.

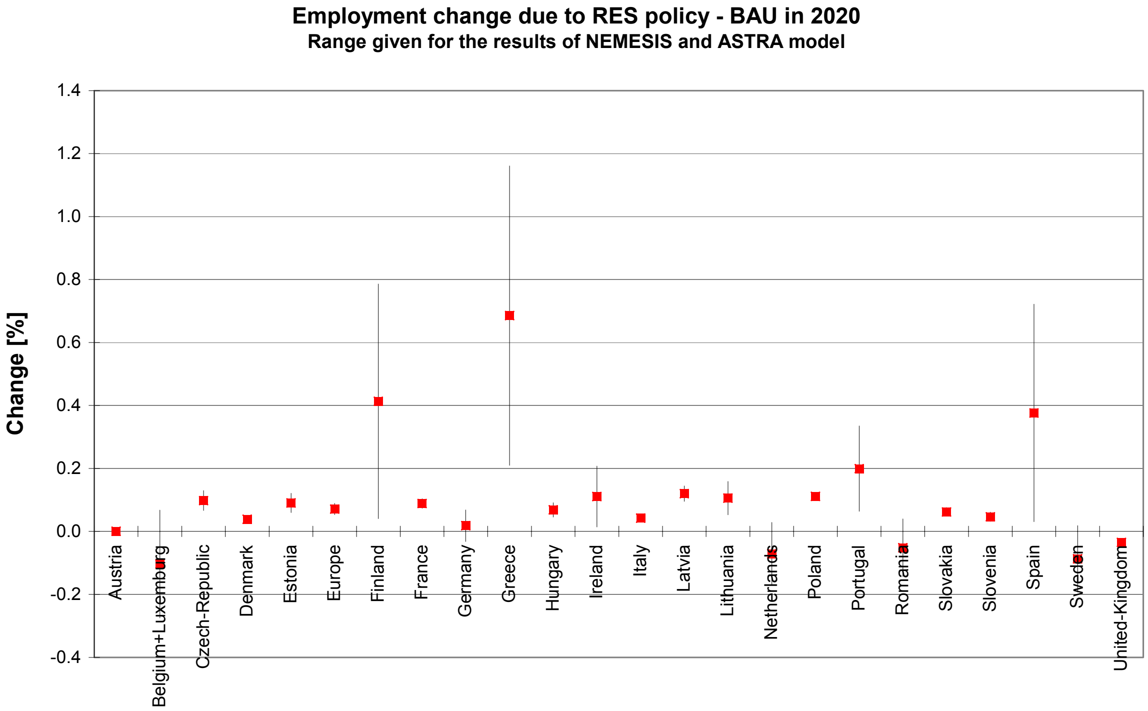
At country level, the impacts depend on both the country-specific economic system, which is not exactly the same in both models, and the impulses fed into the models. Some countries may be more positively stimulated than others, because (1) the investment and trade impulse is significant in relation to their GDP, (2) the investment impulse is significant in relation to their general investment, or (3) the energy price increase remains moderate because only RES technologies with low additional generation cost are deployed due to country-specific conditions.

The differences between both models on a country level for the scenario BAU-ME in 2020 are shown in Figure 131 and Figure 140. The results are clearly rather similar except for Finland, Greece, Ireland, Spain and Sweden. Differences between the models are very small, especially for the larger countries of France, Germany, the Netherlands, Poland and the UK. The larger differences in the two countries Finland and Greece can again be attributed to the importance of second round effects: The indirect investments caused by the investment push due to renewable energies has a stronger weight in the ASTRA model. For Greece this can be explained as follows: Although the initial impulse due to RES deployment is only moderate as a share of Greece’s GDP, it is actually significant in terms of total investments (about 5% of global investments in 2030). This strong impulse in terms of overall investments initiates strong indirect effects in the ASTRA model which are less important in the NEMESIS model. In the NEMESIS model, because the Greek investment goods sector is rather small when compared to the rest of the economy, it cannot meet the additional demand, and this has to be mainly imported (at least in the short run). A similar pattern can be observed for Finland.



Source: NEMESIS, ASTRA, own calculations

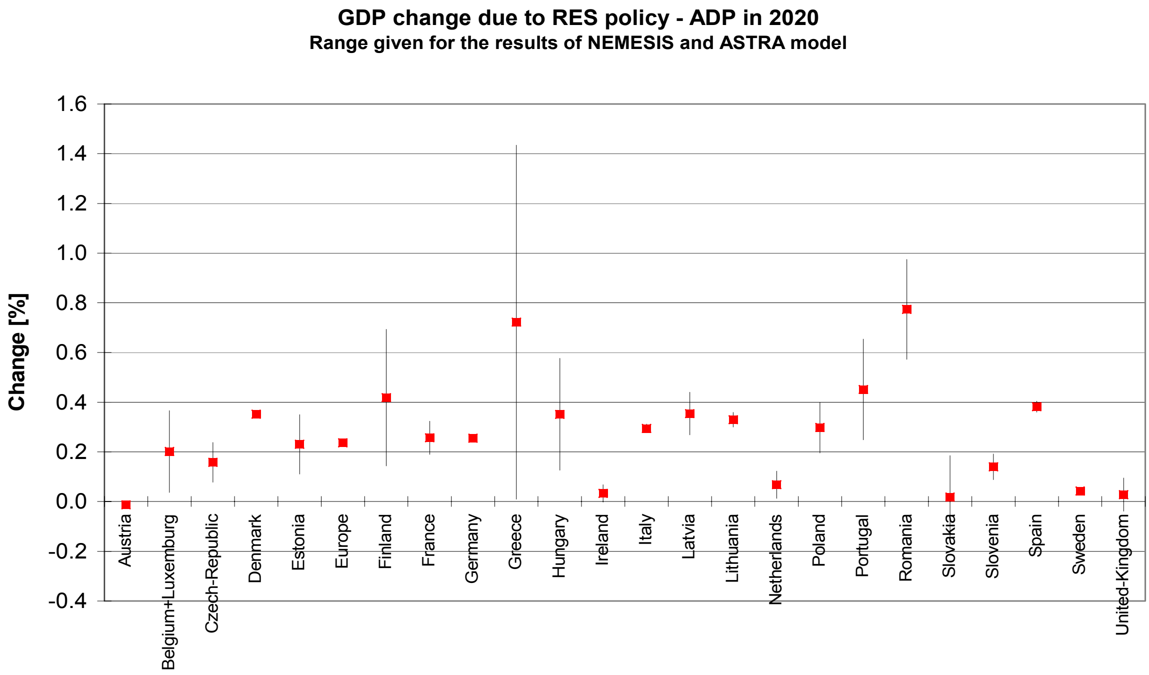
Figure 139: GDP change by country due to BAU-ME policy in 2020 - ranges give the results of the two models NEMESIS and ASTRA



Source: NEMESIS, ASTRA, own calculations

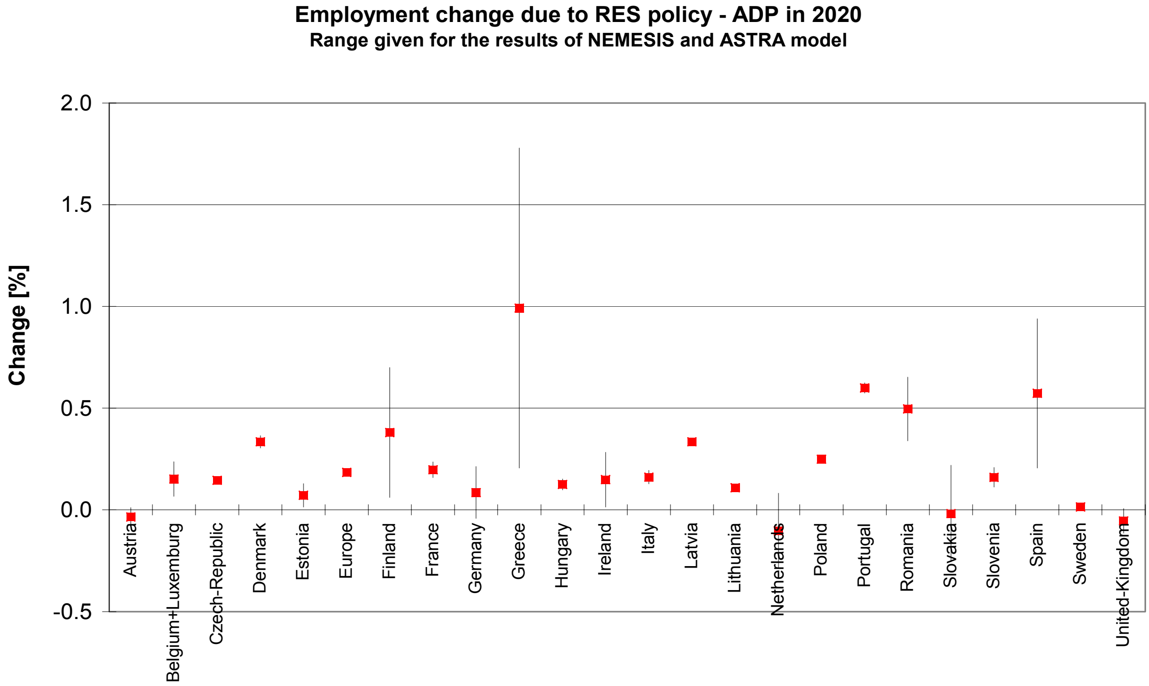
Figure 140: Employment change by country due to BAU-ME policy - ranges give the results of the two models NEMESIS and ASTRA

The differences between both models on a country level for the scenario ADP-ME in 2020 are shown in Figure 141 and Figure 142. As in the case of the BAU scenario it can be seen that there are similar results for each model except for Belgium and Luxemburg, Finland, Greece, Hungary, Portugal and Slovenia. Again, especially for the larger countries of France, Germany, Italy, Poland, Spain and UK, the differences are relatively small. The explanation for the larger differences in Finland and Greece is similar to that for the BAU-ME scenario.



Source: NEMESIS, ASTRA, own calculations

Figure 141: GDP change by country due to ADP-ME policy - ranges give the results of the two models NEMESIS and ASTRA



Source: NEMESIS, ASTRA, own calculations

Figure 142: Employment change by country due to ADP-ME policy - ranges give the results of the two models NEMESIS and ASTRA

9 General conclusions of the study

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

Increased confidence in the economic impacts of RES

This study contributes the first detailed analysis of the full macroeconomic effects of renewable energy deployment at EU level. It analyses the past, present and future impacts of renewable energy policies in the EU on employment and the economy, looking at the gross effects (direct and indirect) as well as the net effects (including both conventional replacement and budget effects). In this respect it fills important knowledge gaps regarding the overall economic implications of renewable energy policies in Europe.

The current high economic benefits of the RES sector can be increased in future …

It finds that the renewable energy sector is already a very important one in terms of employment and value added. New industries with strong lead market potential have been created, which contribute about 0.6% to total GDP and employment in Europe. This development is likely to accelerate if current policies are improved in order to reach the agreed target of 20% renewable energies in Europe by 2020.

…if support policies are improved to stimulate innovative technologies appropriately

Despite the large gross figures in terms of employment and value added, net figures are significantly smaller due to replaced investments in conventional energy technologies as well as due to the dampening effect of the higher cost of renewable energies compared with conventional alternatives. 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.

The benefits of RES for securing supply and mitigating climate change can go hand in hand with economic benefits

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. It is often mentioned that these two key energy policy objectives – security of supply and environmental sustainability – should be pursued without sacrificing the third one - economic sustainability. It is therefore doubly beneficial that increasing the share of RES not only does no harm to the economy, but can even contribute to it in a positive way by creating jobs and increasing GDP.

Besides the CO_2-price in the EU Emission Trading System, the economic value of RES in terms of their contribution to environmental protection and security of supply are not included in the analysis. If these so-called external costs and benefits were included, the economic benefits of RES would probably be even higher.

Uncertainties on 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 significant uncertainties, which need to be treated properly. Thereby the kind of uncertainty analysis chosen has to suit to the modelling problem studied. The main uncertainties of the modelling exercise of the EMPLOY-RES project can be classified as follows:

(a) the inherent uncertainty about the future as for example given by the uncertainty on 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 in the modelling system. The main economic drivers, 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 in the models,

(c) the general uncertainty of the overall modelling assumptions, intermediate results and model interactions,

(d) the uncertainty on 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), multiple model simulation (to cope with uncertainties of type (b) above) as well as stakeholder involvement (to cope with uncertainties of type (c) above). Furthermore uncertainty of the type (d) is considered in the EMPLOY-RES study by running the scenarios defined in the analysis for each of the EU-27 countries and the two models used in the assessment separately. Additionally for 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 the sensitivity on the main impulses for the macro-economic analysis on these parameters.

Annex 1: AMADEUS and MARKUS - Additional/detailed results and information

Box: Information about the database AMADEUS and MARKUS

AMADEUS is an extensive database containing financial information on over 5 million public and private companies from a total of 34 European countries. The data are provided by Creditreform International which is the umbrella association that unites independent Creditreform country offices in 20 European countries. The purpose of the national organizations is to provide information on companies to insurances, financial institutions, corporations, research institutes, consultants and other companies. The Creditreform International is a large information provider with more than 175 offices throughout Europe. At present it operates through Creditreform country offices directly on-site in 20 Middle and East European Countries. In markets where it is not directly present, Creditreform International cooperates with partners like BIGNet which is the umbrella organization for financial information providers from Europe (western part) and the USA. According to Creditreform International, inclusion criteria are applied for the AMADEUS database to prevent any bias in coverage towards countries where information is more readily available.

The database MARKUS is the national equivalent to AMADEUS in Germany and Austria. It provides data on 950.000 private and public legal and individual persons from Germany and Austria. The provided information contains data on financial activities, creditworthiness, liquidity and company structure. The data sources are public accessible registers such as commercial registers, annual reports, voluntary disclosure and information from one or more parties. The corresponding analytical and selective software and electronic data access is provided by the Bureau van Dijke for both databases.

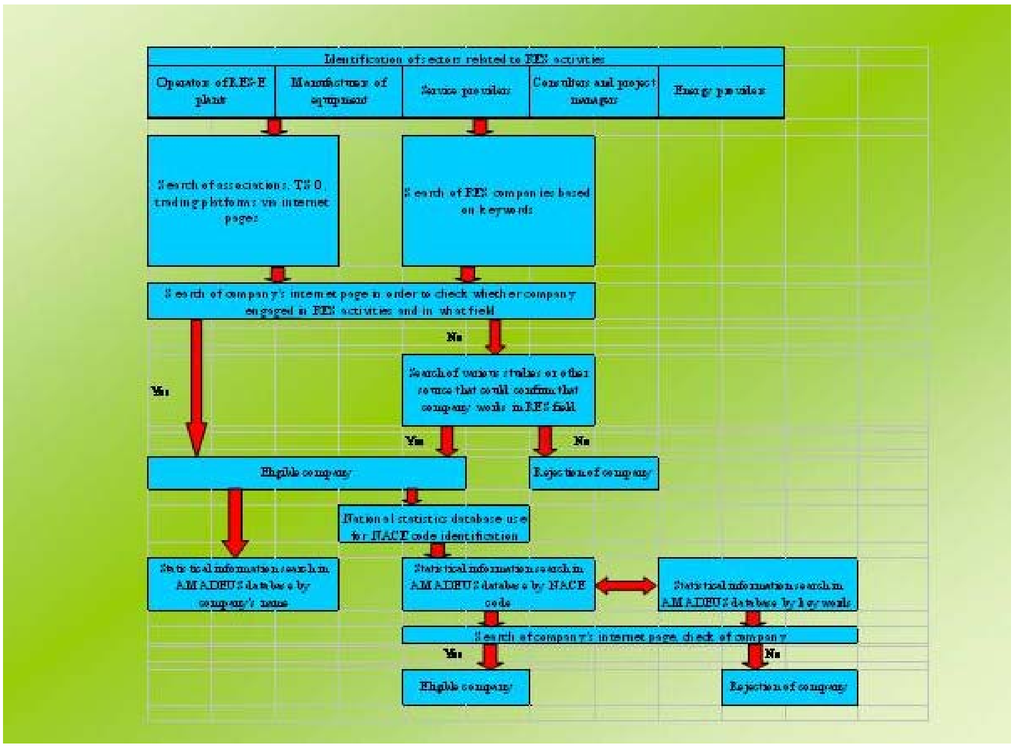


Figure 143: Procedure to identify the companies in E-MS for the data set (LEI)

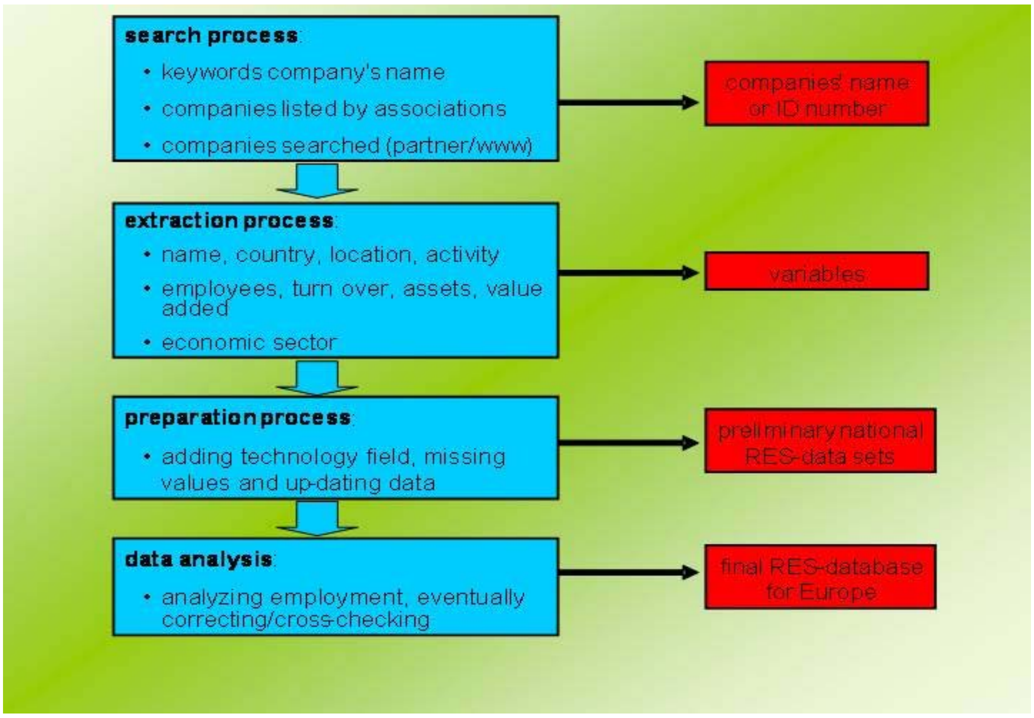
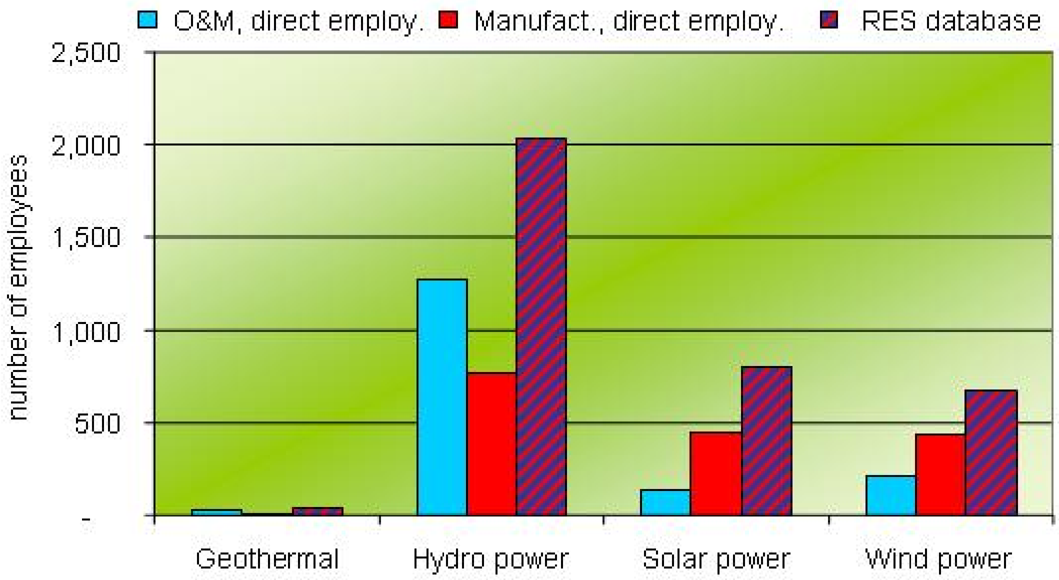


Figure 144: Procedure to compile the data set for W-MS and Germany (Fraunhofer ISI)

Table 26: Size structure of German companies with RES activities in the RES database

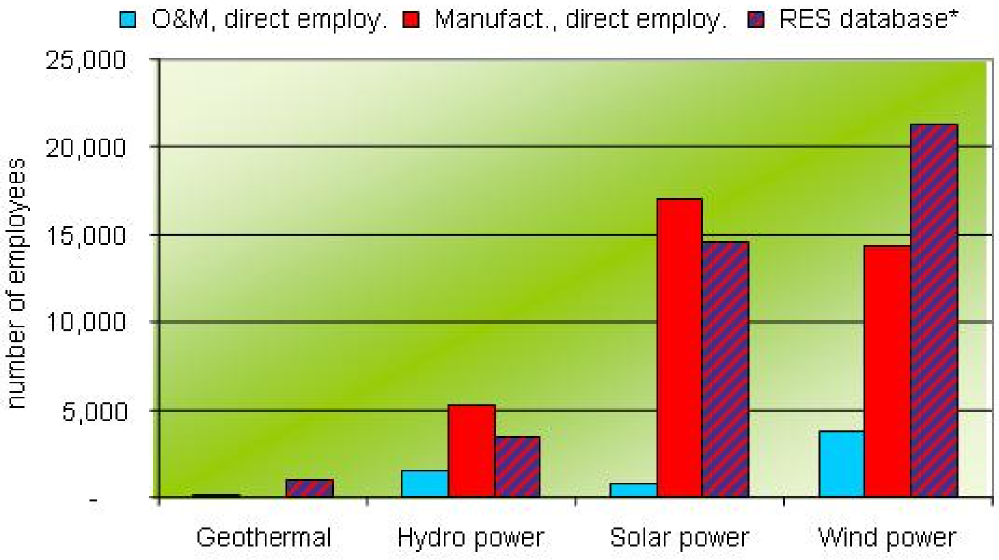
Bioenergy	**Windpower**	**Hydropower**	**Solar energy**	**Geothermal**	**RES**	**employees**
shares						**firm size**
2007						
91%	91%	82%	54%	87%	77%	**0 - 9**
6%	6%	12%	33%	9%	18%	**10 - 49**
2%	2%	3%	10%	3%	4%	**50 - 249**
1%	1%	3%	3%	1%	1%	**>249**
100%	100%	100%	100%	100%	100%	**sum**
2006						
89%	91%	78%	58%	76%	77%	**0 - 9**
7%	6%	12%	30%	19%	18%	**10 - 49**
3%	2%	3%	8%	4%	4%	**50 - 249**
1%	1%	7%	5%	1%	1%	**>249**
100%	100%	100%	100%	100%	100%	**sum**
2005						
80%	91%	82%	52%	69%	75%	**0 - 9**
13%	5%	11%	33%	24%	19%	**10 - 49**
5%	2%	4%	11%	6%	5%	**50 - 249**
2%	1%	4%	4%	2%	1%	**>249**
100%	100%	100%	100%	100%	100%	**sum**

Source: own calculation (Fraunhofer ISI)



Source: own calculation (Fraunhofer ISI, Rütter+Partner)

Figure 145: Employment figures from the RES database and Multireg, Austria 2005



* RES correction by Multireg-technology shares

Source: own calculation (Fraunhofer ISI, Rütter+Partner)

Figure 146: Employment figures from the RES database and Multireg, Germany 2005

Annex 2: Overview of the multiregional Input-Output-Model MULTIREG

MULTIREG is a multiregional input-output (IO) model that was developed at the ETH Zurich. It generally allows economic interdependencies to be analysed across country borders. MULTIREG was originally developed to determine the embodied energy balance of Switzerland and has since then been extended and applied to various research questions involving international trade.

It is a static Leontief input-output model that covers most of the developed countries of the world and many of the larger developing countries. Transactions within the economy are captured in typical input-output tables. Trade between countries is represented explicitly by commodity and by trade partners. Furthermore data on sectoral employment, energy use and CO_2 emissions are integrated.

The database of the MULTIREG model includes IO tables published by Eurostat for the EU member countries and OECD IO tables for the other countries. International trade is represented by the bilateral trade database of the OECD. Employment data, including employment in small and medium enterprises, are based on Eurostat statistics.

Generally MULTIREG covers all EU member countries, the EFTA countries and the most important Non-European trade partners (see table). Countries, for which no IO tables are available, are modelled by using IO tables of similar countries.

The sectoral level of disaggregation can be tailored to the research question. With a few exceptions, 59 sectors at the NOGA 2-digit level can be distinguished for the European countries and 48 sectors for the other countries. The model base year is the year 2000.

In the EMPLOY-RES project this model is used to capture economic and employment impacts that are triggered across country boundaries. This is an essential feature due to the high level of economic integration in Europe.

Countries covered in the MULTIREG model

European countries	Portugal
Switzerland	Romania
Austria	Slovakia
Belgium	Slovenia
Bulgaria	Spain
Czech Republic	Sweden
Denmark	United Kingdom
Estonia	
Finland	Non-European countries
France	Australia
Germany	Brazil
Greece	Canada
Iceland	China
Ireland	India
Italy	Indonesia
Latvia	Japan
Lithuania	Mexico
Luxemburg	New Zealand
Malta	South Korea
Netherlands	Taiwan
Norway	United States
Poland	

Annex 3: Macroeconomic model specifications and results

Time profile outputs of the Green-X model provided as scenario parameters for the macroeconomic models:

- National RES investment and avoided investment by economic sectors
- Exports and imports (including avoided for both) by economic sectors
- Operation and maintenance costs and avoided Operation and maintenance costs by economic sector
- Fuel demands and avoided fuel demands
- Electricity prices variation by broad categories (Households, industry and services)
- Agriculture and Forestry demands

Parameters for the macro models after translation

- investment demand per country and technology and sector
- O&M demand per country and technology and sector
- fuel demand per country and technology and sector
- avoided investment demand per country and technology and sector
- avoided o m demand per country and technology and sector
- avoided imports due to investments per country and technology and sector
- avoided imports of fossil fuels per country and technology and sector
- imports due to investments per country and technology and sector
- avoided exports per country and technology and sector
- exports per country and technology and sector
- investment demand international satisfied national per country and technology and sector

Annex 4: References

Beise, M.; Cleff, T. (2004) Assessing the lead market potential of countries for innovations projects. Journal of International Management 10 (4), 453-477

Beise, M. (2004) Lead Markets: country-specific drivers of the global diffusion of innovations, Research Policy 33 (2004): 997-1018.

CONCAWE (2003), Well-to-wheel analysis of future automotive fuels and powertrains in the European Context, Well Tank Report, Brussels, 2003. Available at: http://ies.jrc.cec.eu.int/Download/eh

Energy Research Centre of the Netherlands ECN (2003). An overview of biofuel technologies, markets and policies in Europe, 2003, Available at: http://www.ecn.nl/docs/library/report/2003/c03008.pdf

ESTO, IPTS, (2003), Trends in vehicle and fuel technologies: Scenarios for Future Trends" Ed. Luc Pelkmans (VITO), Panayotis Christidis, Ignacio Hidalgo, Antonio Soria. Report EUR 20748 EN, 2004. Available at; http://www.jrc.es

ESTO, IPTS, (2003). Biofuel production potential of EU-candidate countries – Final Report, EUR 20835, 2003, Available at: http://www.jrc.es/home/publications/publication.cfm?pub=1120;

European Commission, DG Energy and Transport (2003), European Energy and Transport Trends to 2030, January 2003. Available at: http://europa.eu.int/comm/dgs/energy_transport/figures/trends_2030/index_en.htm

European Commission (2003), Directive 2003/30/EC of the European Parliament and the Council of 8 May 2003 on the promotion of the use of biofuels and other renewable fuels for transport (OJ L 123, 17.5.2003, p.42)

European Commission (2003) Directive 2003/96/EC of the Council of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity (OJ L 283, 31.10.2003, p.51)

European Commission (2001), Green Paper towards a European strategy for the security of energy supply. Available at http://europa.eu.int/comm/energy_transport/doc-principal/pubfinal_en.pdf

European Commission (2001), White Paper: European Transport Policy 2010: Time to Decide. http://europa.eu.int/comm/energy_transport/library/lb_texte_complet_en.pdf

European Commission, DG Energy and Transport (2004). Promoting Biofuels in Europe: Securing a cleaner future for transport. Available at: http://europa.eu.int/comm/energy/res/publications/doc/2004_brochure_biofuels_en.pdf

Energy scientific and technological indicators and references (2005), DG for Research and Sustainable Energy Systems, EUR 21611. ISBN: 92-894-9169-8

Friedrich S. (2004), A World wide review of the commercial production of Biodiesel – A technological, economic and ecological investigation based on case studies, Band 41, Institut fuer Technologie und Nachhaltiges Produktmanagement, Vienna 2004.

Hamelinck, C. (2004), Outlook for advanced biofuels, PhD Dissertation June 2004, Utrecht University, Department of Science, Technology and Society, Netherlands. ISBN: 90-393-3691-1

Henke, J., Klepper, G., Schmitz, N. (2004): Tax Exemption for Biofuels in Germany: Is Bio-Ethanol Really an Option for Climate Policy? Kiel Institute of World Economics 2004.

International Energy Agency IEA (2004). Biofuels for Transport. An international perspective. Paris, France, April 2004. ISBN 92-64-01512-4.

IEA, CADETT, (1998), Mini-review of Energy from Crops and Crops Residues. UK, January, 1998.

IPTS, (2002). Techno-economic analysis of Bio-diesel production in the EU: a short summary for decision-makers, EUR 20279, 2002. Available at: http://www.jrc.es/home/publications/publication.cfm?pub=990

IPTS, (2002). Techno-economic analysis of Bio-alcohol production in the EU: a short summary for decision-makers, EUR 20280, 2002, http://www.jrc.es/home/publications/publication.cfm?pub=991

IPTS, (2003). Biofuel production potential of EU-candidate countries – Addendum to the Final Report, EUR 20836, 2003. Available at: http://www.jrc.es/home/publications/publication.cfm?pub=1121

IPTS, (2004).The introduction of alternative fuels in the European transport sector: Techno-economic barriers and perspectives - Extended summary for policy makers. IPTS, Ed. Soria Antonio, et al.

Kaltschmitt, M., Hartmann, H. (2001). Energie aus Biomasse, Grundlagen, Techniken und Verfahren (In German). Springer Verlag 2001, ISBN: 3-54-64853-4.

Ryan, L.; Convery, F.; Ferreira, S.: Stimulating the use of biofuels in the European Union: Implications for climate change policy. Working Paper, University College Dublin, 2004.

Sustainable Energy Ireland (SEI) (2004), Liquid Biofuel Strategy for Ireland study prepared by Hamelinck Carlo; Van den Broek, Richard; Toro, Felipe; Ragwitz, Mario; Rice, Bernard. Available at: http://europa.eu.int/comm/energy/res/legislation/doc/biofuels/member_states/2004_liquid_strategy_study_ireland.pdf

Toro, F. (2004). Techno-Economic Assessment of Biofuel Production in the European Union. Master Thesis, Karlsruhe, TU Freiberg, 2004.

United Nations Environmental Programme (UNEP) et al. (2007): Global Trends in Sustainable Energy Investment 2007. Paris.

Walz, R.; Schleich, J. (2008): The economics of climate change policies. Macroeconomic effects, structural adjustments and technological change. Springer, Heidelberg 2008.

Walz, R.; Ragwitz, M.; Schleich, J. (2008): Regulation and innovation: the case of renewable energy, DIME Working papers on Environmental Innovation No.2, April 2008.

Wyman, Charles E., Handbook on Bioethanol: Production and Utilization. Applied Energy Technology Series, Taylor & Francis 1998, ISBN: 1-56032-553-4.