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Policy Dialogue on the assessment and convergence of RES Policy in EU Member States

D4.4: Costs and benefits of RES in Europe

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PREFACE

DIA-CORE intends to ensure a continuous assessment of the existing policy mechanisms and to establish a fruitful stakeholder dialogue on future policy needs for renewable electricity (RES-E), heating & cooling (RES-H), and transport (RES-T). The core objective of DIA-CORE is to facilitate convergence in RES support across the EU and enhance investments, cooperation and coordination.

This project shall complement the Commission's monitoring activities of Member States (MSs) success in meeting 2020 RES targets and builds on the approaches developed and successfully applied in the other previous IEE projects.

The strong involvement of all relevant stakeholders will enable a more thorough understanding of the variables at play, an identification and prioritization of necessary policy prerequisites. The dissemination strategy lays a special emphasis on reaching European-wide actors and stakeholders, well, beyond the target area region.

PROJECT PARTNERS

N°	Participant Name	Short Name	Country Code
CO1	Fraunhofer Institute for Systems and Innovations Research	Fraunhofer ISI	DE
CB2	Vienna University of Technology, Energy Economics Group	EEG	AT
CB3	Ecofys Netherlands bv	Ecofys	NL
CB4	Eclareon GmbH	eclareon	DE
CB5	National Technical University of Athens	NTUA	GR
CB6	Lithuanian Energy Institute	LEI	LT
CB7	Centre for European Policy Studies	CEPS	BE
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1 Introduction

1.1 Policy context

The first decade of the new millennium was characterised by the successful deployment of RES across EU Member States – total RES deployment increased by more than 40%. The impressive structural changes in Europe's energy supply are the result of a combination of strong national policies and the general focus on RES created by the EU Renewable Energy Directives in the electricity and transport sectors towards 2010 (2001/77/EC and 2003/30/EC).

The pathway for renewables towards 2020 was set and accepted by the European Council, the European Commission and the European Parliament in April 2009. The related policy package, in particular the EU Directive on the support of energy from renewable sources (2009/28/EC), subsequently named RES Directive, comprises the establishment of binding RES targets for each Member State. The calculation of the particular targets is based on an equal RES share increase modulated by the respective Member State's GDP per capita. This provides a clear framework and vision for renewable technologies in the short to mid-term.

Despite the successful development of the RES sector over the last decade, substantial challenges still lie ahead. The EU Energy Roadmap 2050 gave first signals of renewable energy development pathways beyond the year 2020 and identified renewables as a "no-regrets" option. A binding EU-wide RES target of achieving at least 27% as RES share in gross final energy demand was adopted. This has to be seen as an important first step in defining the framework for RES post 2020. Other steps, like a clear concept for and agreement on the effort sharing across Member States have to follow.

1.2 Objective and structure of this report

This report includes **a comprehensive quantitative assessment of costs and benefits of RES deployment within the European Union** according to the cost-benefit concept developed in task 4.1 of this WP. Thus, following Breitschopf and Held (2014) the various costs and benefits of RES deployment will be divided into three categories: System related, actor-specific and macroeconomic effects as introduced subsequently.

The report is structured as follows: Chapter 2 describes overall methodological approach and specifies the scenarios of future RES developments within the EU that serve as basis for the accompanying assessment of costs and benefits done within this report.

Subsequently Chapter 3 analyses costs and benefits of RES in the 2020 and 2030 context with a particular focus on the need for and impact of RES cooperation (in the 2020 context) and with further country case insights in the 2030 perspective.

Chapter 4 focuses complementary aspects beyond the pure energy/policy model-based analysis, discussing macroeconomic impacts as well as the merit order effect related to RES deployment

Finally, Chapter 6 draws conclusions and presents key findings.

2 Method of approach

This chapter is dedicated to introduce the approach used for our assessment of RES-related costs and benefits as done from a forward-looking perspective.

More precisely, the following section provides definitions and distinctions between the assessment categories relevant for the present analysis. For more detailed insights into the respective categories, please also refer to the remaining deliverables of WP 4 of the DIA-Core project. Next to that, directly thereafter details on the methodology concerning the model-based prospective RES policy analysis is provided, informing on the models, key input parameter as well as the scenarios analysed within the prospective analysis of RES developments as well as of related costs and benefits.

2.1 Classification for assessing costs and benefits of RES

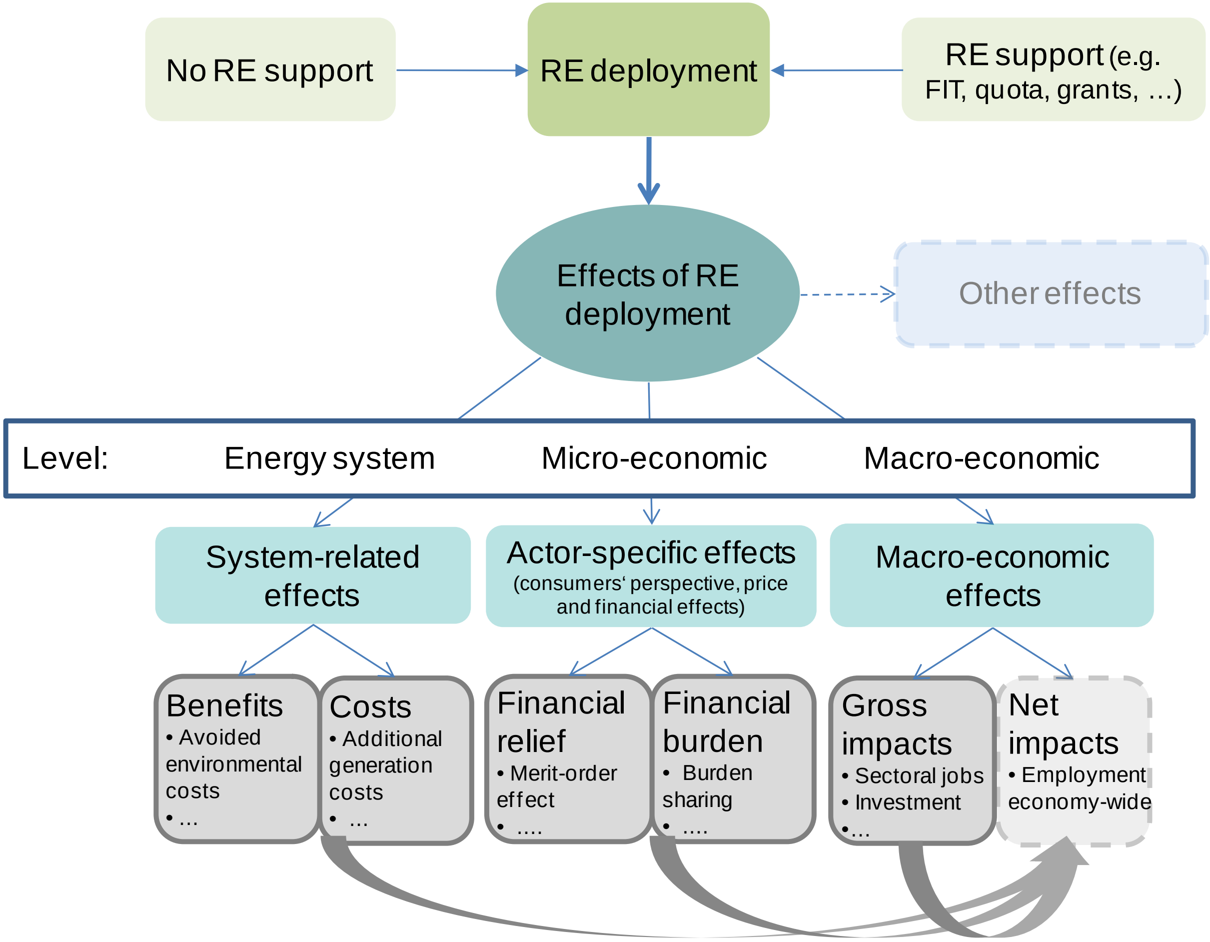

Figure 1: Categories of main effects related to RES deployment

Source: Breitschopf and Diekmann, 2011, adapted

This report includes a comprehensive quantitative assessment of costs and benefits of RES deployment according to the cost-benefit concept developed in task 4.1 of this WP. Following Breitschopf and Held (2014) the various costs and benefits of RES deployment will be divided into three categories: System related, actor-specific and macroeconomic effects as depicted in Figure 1.

While the DIA-CORE report D4.1 (Breitschopf and Held, 2014) gives an extensive overview on these effects, the following paragraphs serve to shortly outline the effects and put them into the perspective of the following analysis.

System-related effects occur at the system level of the energy system, i.e. where generation of electricity and heat, balancing of electricity, construction and maintenance of infrastructure or technology investments take place. It encompasses all benefits and costs of RES deployment. Direct costs include all costs that are directly related to electricity or heat generation such as installation, operation and maintenance of RE-technologies, indirect costs are caused by integrating RE into the existing generation system such as grid extension costs, balancing costs, etc. Benefits from RES-use arise e.g. as a result of avoided GHG emissions or fossil fuels. The main characteristics of system-related costs and benefits are that they represent additional costs or benefits of a RES-based generation system compared to a reference system based on nuclear and fossil fuels. Furthermore, system-related effects reflect the costs of input factors based on market prices (labor, capital, natural resources). Finally, these costs are identified from a system perspective without taking into account any policy-induced payments.

In contrast to system related effects, **actor-specific effects** reflect the burdens that are shifted from the system level to consumers and generators. These burdens accrue for selected economic agents or groups, at the micro-level. As the transfer mechanisms are determined by policies, they are sometimes called policy costs. They show to what extent the different economic agents have to bear the additional costs or benefits, i.e. they show who pays for deployment of RES and who receives benefits from said RES deployment. These distributional effects are the result of policies that determine how the system-related additional costs or benefits should be distributed among consumers and producers.

Macro-economic effects such as growth or employment are measured for the whole economy. There are gross effects, which refer to a single sector and show the effects in all industries that are directly related to for example RES deployment or generation such as manufacturing, operating, construction, research. Furthermore, there are net effects, which show the total effects on the economy. For the overall economy (all sectors), all positive and negative effects of RES-deployment should be included. To do this, macro-economic modeling is required that takes system-related costs and benefits as well as actor-specific effects of RES deployment into account and compares them with a reference situation (scenario or system) without RES use.

In the following, the costs and benefits of future RES deployment are assessed and macroeconomic gross effects of actual RES deployment are displayed. However, it should be clear that the different costs and benefits reflect only parts of the total impact of RES deployment on the economy. The main focus of the following analysis lies on the first category – system related effects. Furthermore, to provide a holistic view of the energy system, actor-specific as well as macro-economic effects of different levels of RES deployment are also presented as complementary analyses.

2.1.1 Costs and benefits at the system level

Regarding system related effects, additional generation costs and avoided CO2 emissions will be estimated.

Additional generation costs quantify the change (typically an increase[1]) in heat or electricity generation costs due to an accelerated RES development. The additional generation costs in an RES based system arise from

- either the costs of (often more expensive) a RES generation technology that replaces a conventional generation technology or,
- especially in the heat sector, the costs of a combination of RES with a conventional technology that is non-intermittent and permanently available and, thus, ensures the required supply of heat. Combinations are for example solar thermal heat with gas firing, etc.

Generation costs are calculated on the basis of levelized costs of electricity or heat (LCOE). Cost components of LCOE include expenditures for investment, fuel, operation and maintenance of the generation plants that are installed with the purpose to provide energy.

To assess additional generation costs in the electricity sector, the LCOE are calculated for each generation plant and weighted according to their respective supplied quantity of power or heat in the system. The difference between the generation costs of the two systems (RES system – reference system) show the additional electricity generation costs at the system level. Similarly, to assess the additional annual generation costs for heating, all expenditures for investments (annuity of investment expenditures), fuel, maintenance and operation for all technologies of an RES based and a non-RES based system are added and compared.

The technologies considered here comprise the full list of RES-E and RES-H technologies, i.e. wind power, solar power, hydropower, geothermal power, solar- and geothermal heat, biomass technologies incl. biogas, solid and liquid biomass and biowaste.

Avoided emissions of greenhouse gases (GHG) and air pollutants are a major benefit of RES deployment. GHG emissions have a fundamental impact on climate change and, cause long-lasting global effects. To assess the avoided emissions at a system level, the generated amount of power or heat per technology should be known. Multiplications of technology specific emission factors with the amount of power generated by that technology lead to avoided emissions. The difference between the emission of an RE based and non RE bases system shows the benefit - the avoided emissions (damages) at

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[1] In principle the additional generation costs can also be negative, i.e. then the generation costs of RES are lower than of fossil based technologies.

the system level. Differentiating between technologies requires information on substitution factors, which show to what extent fossil energies are replaced by RES, and technology-specific emission factors, which indicate the direct and indirect emissions per kWh generated, and, finally the quantity of RE generated.

It is to note that, we do not assess the actual environmental costs of RES but the avoided emissions of GHG and airborne pollutions which accrue when using RES instead of fossil energy sources for power and heat generation. These avoided pollutants represent benefits that are calculated based on annual power and heat generation from RES, on emission and substitution factors

2.1.2 Policy and price effects

Policy costs: The deployment of RES has been supported by a variety of policy instruments ranging from price or cost-based support to quantity-based support. As the use of RES causes additional costs at the system level, these costs must be borne by someone. How these costs are financed is determined by policy support schemes. Financing of these RES promotion schemes relies on two main financing schemes, the consumer-based financing or budget-based financing[2].

Consumer-based financing refers to financing of RES deployment by final consumers without any support from public budgets. In a feed-in system the difference between feed-in tariffs (or premiums) paid to RES-E generators and the market wholesale prices at the respective time sums up to the policy support costs. In a quota system in which RES certificates are traded, the additional costs of RES deployment for actors are reflected in the certificate prices. To assess policy costs, i.e. the burdens for consumer, the traded certificate prices could be multiplied by the respective trade volume.

In the heat sector generators and consumers are in many cases identical. Thus, the micro-economic additional costs are the same as the system based additional generation costs, if no further support instruments are applied. In case **RES certificates** are traded, the certificate price reflects the additional burden per energy unit. Further support instruments (grants, interest subsidies, tax credits, etc.) are mainly co-financed by public sources and reflect a relief for generators but a burden for the public budget.

Merit-order effect: The generation of electricity from RE sources affects the market prices of power as the variable generation costs of most renewable energy power plants (all except biomass power plants) are close to zero. Hence, in an energy-only-market, where the marginal cost of the last operating generation plant sets the market price, the supply curve shifts to the right. This shift becomes larger, the more low-variable-cost RES enter the market. Thus, the market entry of RE generation technologies tends to lower market prices.

This price decreasing effect is called merit order effect, as the order of operating power plants changes with increasing RES-share. As this effect depends on the current load profile and available supply it can only be assessed with an energy sector model. The

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[2] Private households and firms will be indirectly affected as public spending for other activities decreases or taxes increase to compensate for RES related expenditures.

electricity market price of a system with RE and without (a few) RES should be modeled and compared. The difference between the price or traded volume with and w/o RES discloses the merit order effect, either as total (€) or specific effect in €/kWh.

2.1.3 Macro-economic effects

Gross effects: To assess the significance of RES in an economy gross effects are used. Gross employment reflects the jobs in RES related sector, without taking into account potential job losses in conventional sectors. The assessment is based on investments, fuel, maintenance and operation expenditures of RES plants and translates these impulses via input-output modeling or employment factors into employment.

Further macroeconomic effects are gross value added of RES use and reduced imports of fossil fuels. The latter are based on import shares and expected reduction in consumption of fossil fuels. The first shows the value generated by labor without taking into account lower value added in other sectors.

2.2 Model-based prospective assessment of future RES developents and related costs and benefits

By use of a specialised energy system model (Green-X) a quantitative assessment was conducted to analyse RES prospects as well as the need for and impact of RES cooperation in the 2020 context, and to show pathways of possible RES developments up to 2030, indicating RES deployment at sector, at technology and at country level that can be expected under distinct policy concepts. Complementary to results on deployment, related impacts on costs and benefits are a key element of the RES policy analysis.

This chapter is dedicated to inform on the approach used and the assumptions taken. It also provides an introduction on the various scenarios assessed.

2.3 Specifics of the model-based assessment

- Time horizon: 2006 to 2030 – Results are derived on a yearly base
- Geographical coverage: all Member States of the European Union as of 2013 (EU-28)
- Technology coverage: limited to RES technologies for power and heat generation as well as biofuel production. The (conventional) reference energy system is based on PRIMES modelling – in particular the PRIMES reference scenario (as of 2013) was taken as reference.
- RES imports to the EU: limited to biofuels and forestry biomass – besides no alternative possibilities such as physical imports of RES-Electricity are considered for national RES target fulfilment.
- Flexibility options for national RES target fulfilment as defined in the RES directive: limited to “statistical transfer between Member States” and the option of (EU-wide) “joint support schemes” (by means of harmonised RES support). Although important from a practical viewpoint, the third principle intra-European flexibility option of “joint projects” as defined in the RES directive was neglected

since its incorporation into the modelling approach was not feasible due to the highly case-specific nature of related decision making processes.

2.4 The policy assessment tool: the Green-X model

As in previous research projects such as FORRES 2020, OPTRES or PROGRESS the ***Green-X*** model was applied to perform a detailed quantitative assessment of the future deployment of renewable energy on country-, sector- and technology level. The core strength of this tool lies in the detailed RES resource and technology representation accompanied by a thorough energy policy description, which allows assessing various policy options with respect to resulting costs and benefits. A short characterization of the model is given below, whilst for a detailed description we refer to www.green-x.at.

Box 1: Short characterisation of the Green-X model

The model Green-X has been developed by the Energy Economics Group (EEG) at the Vienna University of Technology under the EU research project "Green-X–Deriving optimal promotion strategies for increasing the share of RES-E in a dynamic European electricity market" (Contract No. ENG2-CT-2002-00607). Initially focused on the electricity sector, this modelling tool, and its database on renewable energy (RES) potentials and costs, has been extended to incorporate renewable energy technologies within all energy sectors.

Green-X covers the EU-27, and can be extended to other countries, such as Turkey, Croatia and Norway. It allows the investigation of the future deployment of RES as well as the accompanying cost (including capital expenditures, additional generation cost of RES compared to conventional options, consumer expenditures due to applied supporting policies) and benefits (for instance, avoidance of fossil fuels and corresponding carbon emission savings). Results are calculated at both a country- and technology-level on a yearly basis. The time-horizon allows for in-depth assessments up to 2030. The Green-X model develops nationally specific dynamic cost-resource curves for all key RES technologies, including renewable electricity, biogas, biomass, biowaste, wind on- and offshore, hydropower large- and small-scale, solar thermal electricity, photovoltaic, tidal stream and wave power, geothermal electricity; for renewable heat, biomass, sub-divided into log wood, wood chips, pellets, grid-connected heat, geothermal grid-connected heat, heat pumps and solar thermal heat; and, for renewable transport fuels, first generation biofuels (biodiesel and bioethanol), second generation biofuels (lignocellulosic bioethanol, biomass to liquid), as well as the impact of biofuel imports. Besides the formal description of RES potentials and costs, Green-X provides a detailed representation of dynamic aspects such as technological learning and technology diffusion.

Through its in-depth energy policy representation, the Green-X model allows an assessment of the impact of applying (combinations of) different energy policy instruments (for instance, quota obligations based on tradable green certificates / guarantees of origin, (premium) feed-in tariffs, tax incentives, investment incentives, impacts of emission trading on reference energy prices) at both country or European level in a dynamic framework. Sensitivity investigations on key input parameters such as non-economic barriers (influencing the technology diffusion), conventional energy prices, energy demand developments or technological progress (technological learning) typically complement a policy assessment.

Within the Green-X model, the allocation of biomass feedstock to feasible technologies and sectors is fully internalised into the overall calculation procedure. For each feedstock category, technology options (and their corresponding demands) are ranked based on the feasible revenue streams as available to a possible investor under the conditioned, scenario-specific energy policy framework that may change on a yearly basis. Recently, a module for intra-European trade of biomass feedstock has been added to Green-X that operates on the same principle as outlined above but at a European rather than at a purely national level. Thus, associated transport costs and GHG emissions reflect the outcomes of a detailed logistic model. Consequently, competition on biomass supply and demand arising within a country from the conditioned support incentives for heat and electricity as well as between countries can be reflected. In other words, the supporting framework at MS level may have a significant impact on the resulting biomass allocation and use as well as associated trade.

Moreover, Green-X was recently extended to allow an endogenous modelling of sustainability regulations for the energetic use of biomass. This comprises specifically the application of GHG constraints that exclude technology/feedstock combinations not complying with conditioned thresholds. The model allows flexibility in applying such limitations, that is to say, the user can select which technology clusters and feedstock categories are affected by the regulation both at national and EU level, and, additionally, applied parameters may change over time.

For specific purposes, e.g. within a detailed assessment of the merit order effect and related market values of the produced electricity for variable and dispatchable renewables, Green-X was complemented by its power-system companion – i.e. the HiREPS model – to shed further light on the interplay between supply, demand and storage in the electricity sector thanks to a higher intertemporal resolution than in the RES investment model Green-X.

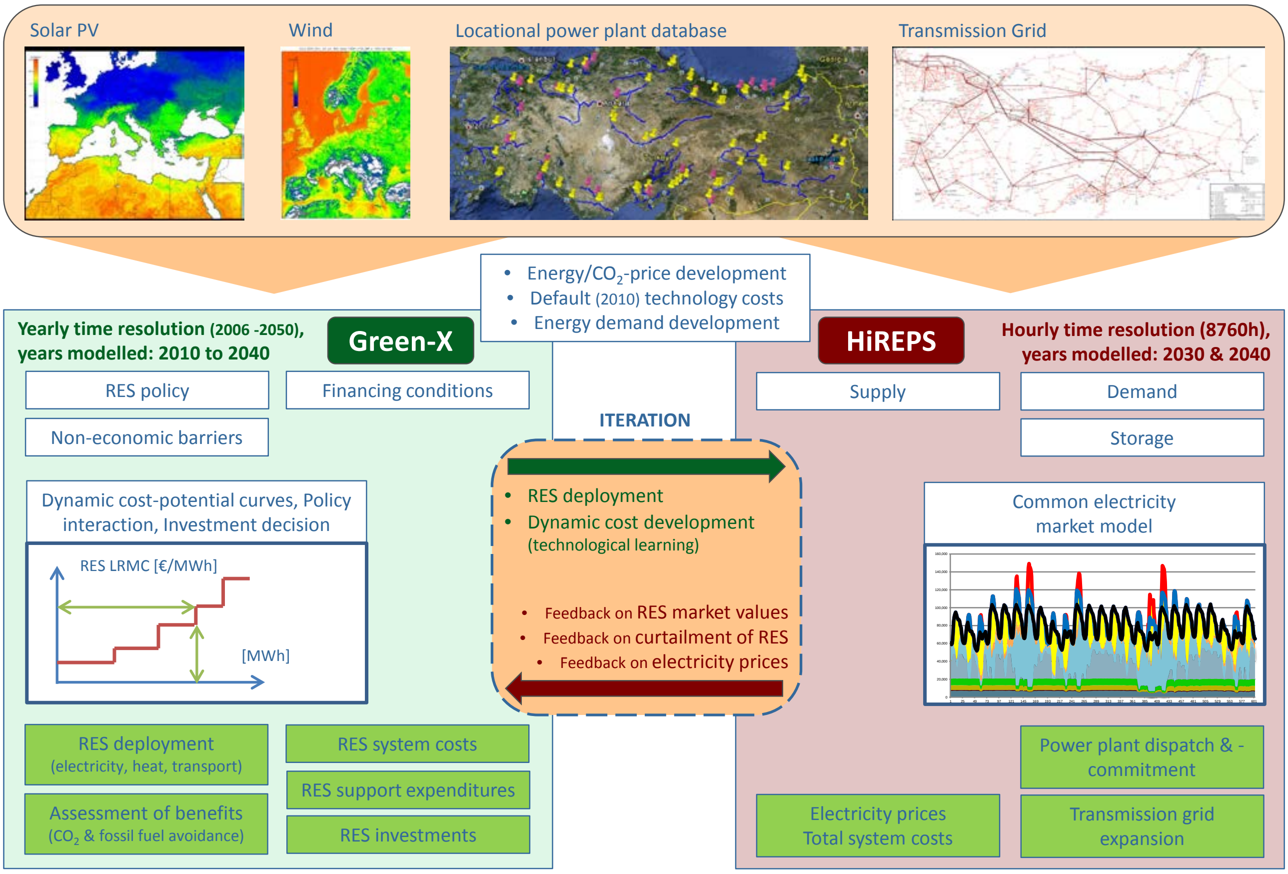

Figure 2: Model coupling between Green-X (left) and HiREPS (right) for a detailed assessment of RES developments in the electricity sector

Figure 2 gives an overview on the interplay of both models. Both models are operated with the same set of general input parameters, however in different spatial and temporal resolution. Green-X delivers a first picture of renewables deployment and related costs, expenditures and benefits by country on a yearly basis (2010 to 2030 (and up to 2050 for specific purposes)). The output of Green-X in terms of country- and technology-specific RES capacities and generation in the electricity sector for selected years (2020, 2030 (and 2050)) serves as input for the power-system analysis done with HiREPS. Subsequently, the HiREPS model analyses the interplay between supply, demand and storage in the electricity sector on an hourly basis for the given years. The output of HiREPS is then fed back into the RES investment model Green-X. In particular the feedback comprises the amount of RES that can be integrated into the grids, the electricity prices and corresponding market revenues (i.e. market values of the produced electricity of variable and dispatchable RES-E) of all assessed RES-E technologies for each assessed country.

2.5 Overview on key parameter

In order to ensure maximum consistency with existing EU scenarios and projections the key input parameters of the scenarios presented in this report are derived from PRIMES modelling and from the Green-X database with respect to the potentials and cost of RES technologies. Table 1 shows which parameters are based on PRIMES, on the Green-X database and which have been defined for this study. The PRIMES scenarios used for this assessment are the latest publicly available *reference scenario* (European Commission, 2013b) and a climate mitigation scenario building on an enhanced use of energy efficiency and renewables named “GHG40EERES30” as presented in the European Commission’s Impact assessment (SWD(2014) 15) related to its Communication on “A policy framework for climate and energy in the period from 2020 to 2030” (COM(2014) 15 final).

Although a target of 27% for energy efficiency has already been fixed for 2030, we show ranges with regard to the actual achievement of energy efficiency to cover both, a higher or substantially lower level of ambition in terms of energy efficiency policy: Under reference conditions an improvement in energy efficiency of 21% compared to the 2007 baseline of the PRIMES model is projected for 2030, whereas in the “GHG40EERES30” case, assuming a medium ambition level for energy efficiency, an increase to 30% is assumed.

Table 1: Main input sources for scenario parameters

Based on PRIMES	Based on Green-X database	Defined for this assessment
Primary energy prices	Renewable energy technology cost (investment, fuel, O&M)	Renewable energy policy framework
Conventional supply portfolio and conversion efficiencies	Renewable energy potentials	Reference electricity prices
CO_2 intensity of sectors	Biomass trade specification	
Energy demand by sector	Technology diffusion / Non-economic barriers	
	Learning rates	
	Market values for variable renewables	

2.5.1 Energy demand

Figure 3 depicts the projected energy demand development at EU 28 level according to the PRIMES reference scenario with regard to gross final energy demand (left) as well as gross electricity demand (right).

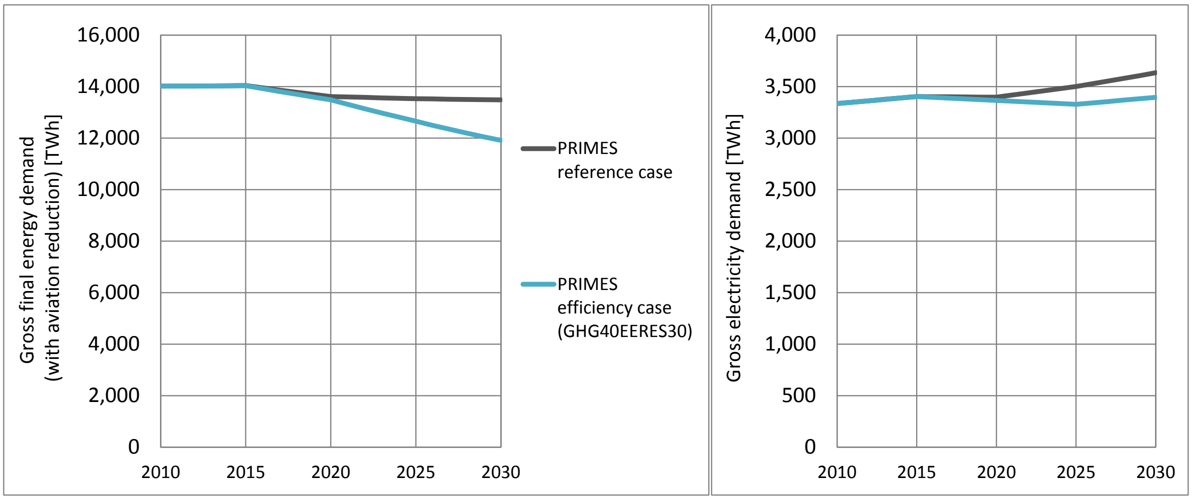

Figure 3: Comparison of projected energy demand development at European (EU-28) level – gross electricity demand (left) and gross final energy demand (right). Source: PRIMES scenarios (EC, 2013)

A comparison of the different PRIMES demand projections at EU 28 levels shows the following trends: The *PRIMES reference case* as of 2013 (EC, 2013) draws a modified picture of future demand patterns compared to previous baseline and reference cases. The impacts of the global financial crisis are reflected, leading to a reduction of overall gross final energy demand in the short term, and moderate growth in later years towards 2020. Beyond 2020, according to the *PRIMES reference case* (where the achievement of climate and RES targets for 2020 is assumed) gross final energy demand is expected to stagnate and later on (post 2030) moderately decrease. The decrease of gross final energy demand is even more pronounced in the PRIMES efficiency case where in addition to short-term (2020) also long-term (2050) EU climate targets have to be met. In this case, policy measures supporting RES and energy efficiency were assumed to accompany purely climate policies (i.e. the ETS) – and both are regarded as key options for mitigating climate change.

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

Complementary to the above, a closer look at the Member State level is taken next. Thus, Figure 4 provides a comparison of actual 2012 data and projected 2020 gross final energy demand by Member State. As applicable from this graph, for several countries (e.g. France, Germany, UK, Netherlands or Spain) projected gross final energy demand by 2020 is, in accordance with the overall trend at aggregated (EU) level, below current (2012) levels. For other Member States like Cyprus, Czech Republic, Greece or Poland PRIMES scenarios show a comparatively strong increase in demand compared to today.

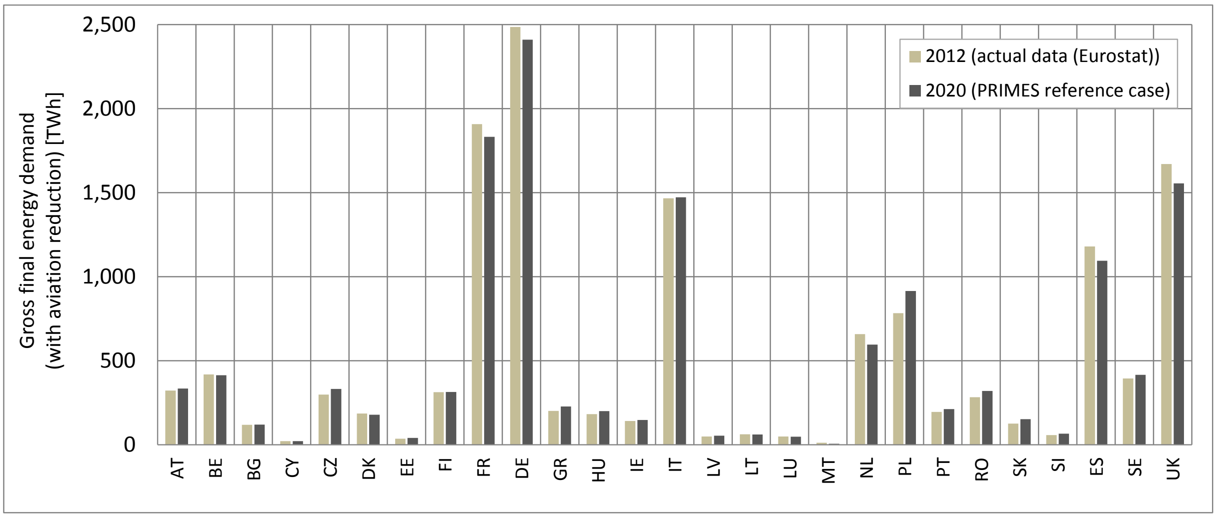

Figure 4: Comparison of actual 2012 and projected 2020 gross final energy demand by Member State. Source: PRIMES scenarios (EC, 2013)

2.5.2 Conventional supply portfolio

The conventional supply portfolio, i.e. the share of the different conventional conversion technologies in each sector, is based on PRIMES forecasts on a country-specific basis. These projections of the portfolio of conventional technologies particularly influence the calculations done within this study on the avoidance of fossil fuels and related CO2 emissions. As it is beyond the scope of this study to analyse in detail which conventional power plants would actually be replaced, for instance, by a wind farm installed in the year 2023 in a certain country (i.e. either a less efficient existing coal-fired plant or possibly a new highly-efficient combined cycle gas turbine), the following assumptions are made:

- Bearing in mind that fossil energy represents the marginal generation option that determines the prices on energy markets, it was decided to stick to the sector-specific conventional supply portfolio projections on a country level provided by PRIMES. Sector- as well as country-specific conversion efficiencies derived on a yearly basis are used to calculate the amount of avoided primary energy based on the renewable generation figures obtained. Assuming that the fuel mix is unaffected, avoidance can be expressed in units of coal or gas replaced.
- A similar approach is chosen with regard to the avoidance of CO2 emissions, where the basis is the fossil-based conventional supply portfolio and its average country- and sector-specific CO2 intensities that may change over time.

In the following, the derived data on aggregated conventional conversion efficiencies and the CO2 intensities characterising the conventional reference system (excl. nuclear energy) are presented.

Figure 5 shows the dynamic development of the average conversion efficiencies as projected by PRIMES for conventional electricity generation as well as for grid-connected heat production. Conversion efficiencies are shown for the PRIMES reference scenario (EC, 2013). Error bars indicate the range of country-specific average efficiencies among EU Member States. For the transport sector, where efficiencies are not explicitly expressed in PRIMES' results, the average efficiency of the refinery process used to derive fossil diesel and gasoline was assumed to be 95%.

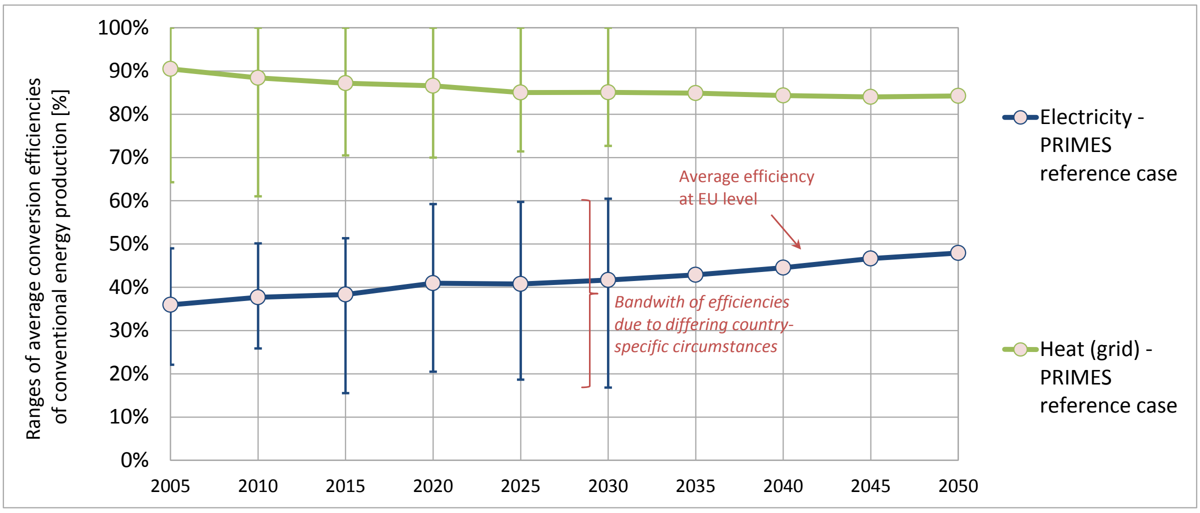

Figure 5: Country-specific average conversion efficiencies of conventional (fossil-based) electricity and grid-connected heat production in the EU28. Source: PRIMES scenarios (EC, 2013)

The corresponding data on country- and sector-specific CO_2 intensities of the conventional energy conversion system according to the PRIMES reference scenario are shown in Figure 6. Error bars again illustrate the variation across countries.

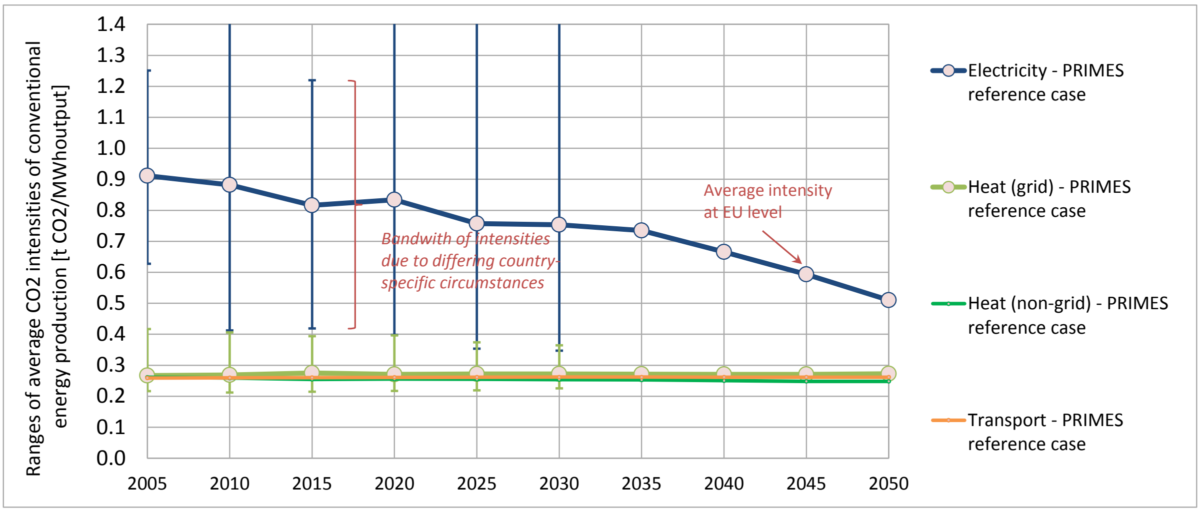

Figure 6: Country-specific average sectorial CO2 intensities of the conventional (fossil-based) energy system in the EU28. Source: PRIMES scenarios (EC, 2013)

2.5.3 Fossil fuel and carbon prices

The country- and sector-specific reference energy prices used in this analysis are based on the primary energy price assumptions applied in the latest PRIMES reference scenario that has also served as a basis for the Impact Assessment accompanying the Communication from the European Commission "A policy framework for climate and energy in the period from 2020 to 2030" (COM(2014) 15 final). As shown in Figure 7 generally only one price trend is considered – i.e. a default case of moderate energy prices that reflects the price trends of the *PRIMES reference case*. Compared to the energy prices as observed in 2011, all the price assumptions appear comparatively low, even for the later years up to 2050.

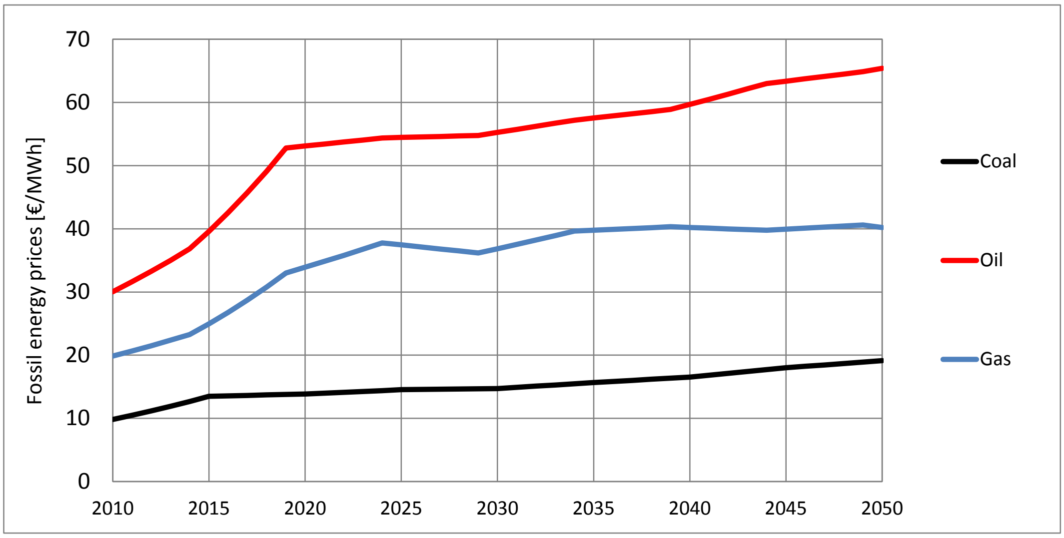

Figure 7: Primary energy price assumptions in €/MWh. Source: PRIMES scenarios (EC, 2013)

The CO_2 price in the scenarios presented in this report is also based on recent PRIMES modelling, see Figure 8. Actual market prices for EU Allowances have fluctuated between 6 and 30 €/t since 2005 but remained on a low level with averages between 6 and 8 €/t in 2015. In the model, it is assumed that CO_2 prices are directly passed through to electricity prices as well as to prices for grid-connected heat supply.

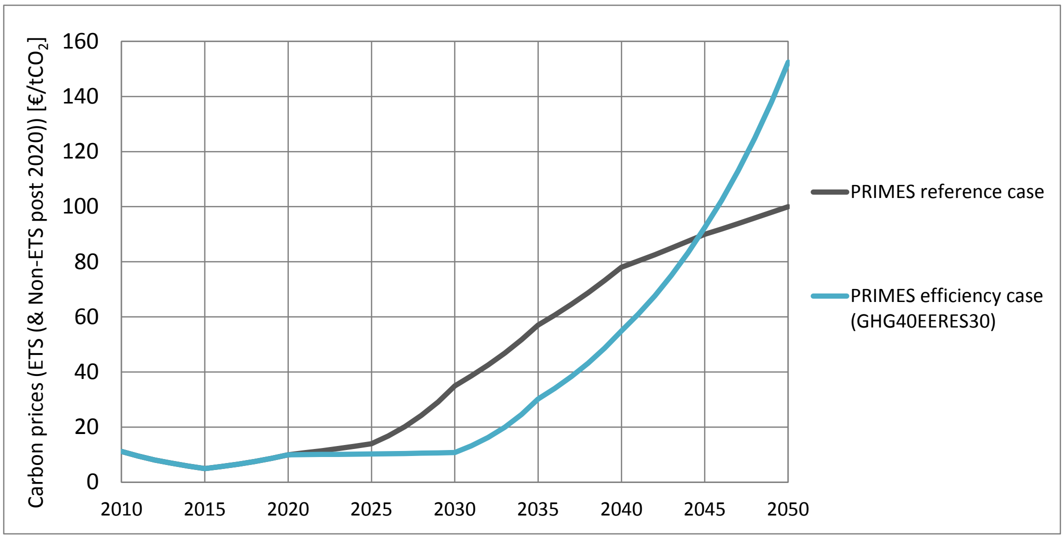

Figure 8 CO2 price assumptions in €2010/ton. Source: PRIMES scenarios (EC, 2013)

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

2.5.4 Assumptions for simulated support schemes

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

Consumer expenditure related to RES support schemes is heavily dependent on the design of policy instruments. In the policy variants investigated, it is obvious that the design options of the various instruments were chosen in such a way that expenditure is low. Accordingly, it is assumed that investigated schemes are characterized by:

- A stable planning horizon;
- A continuous RES-E policy / long-term RES-E targets and;
- A clear and well defined tariff structure / yearly targets for RES(-E) deployment.

In addition, for all investigated scenarios, the following design options are assumed:

- Financial support is restricted to new capacity only;[3]
- The guaranteed duration of financial support is limited.[4]

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

- *Removal of non-financial barriers and high public acceptance in the long term:* In all derived scenario runs it is assumed that the existing social, market and technical barriers (e.g. grid integration) can be overcome in time. More precisely, the assumption is taken that their impact is still relevant at least in the short-term as is reflected in the “business-as-usual” settings compared to, e.g. the more optimistic view assumed for reaching an accelerated RES deployment. Further details on the modelling approach to reflect the impact of non-economic barriers are provided in the subsequent section of this report;
- *A stimulation of ‘technological learning’ is considered – leading to reduced investment and O&M costs for RES over time:* Thereby, generally moderate technological learning is assumed for all assessed cases.

2.5.5 RES technology diffusion – the impact of non-economic RES barriers

In several countries financial support appears sufficiently high to stimulate deployment of a RES technology, in practice actual deployment lacks however far behind expectations. This is a consequence of several deficits not directly linked to the financial support

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[3] This means that only plants constructed in the period 2021 to 2040 are eligible to receive support from the new schemes. Existing plants (constructed before 2021) remain in their old scheme.

[4] 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 generation-based support.

offered which in literature are frequently named “non-economic /non-cost barriers”. These barriers refer to administrative deficiencies (e.g. a high level of bureaucracy), diminishing spatial planning, problems associated with grid access, possibly missing local acceptance, or even the non-existence of proper market structures.

In the Green-X model dynamic diffusion constraints are used to describe the impact of such non-economic barriers. Details on the applied modelling approach are explained subsequently.

Within Green-X dynamic diffusion constraints are used to describe the impact of such non-economic barriers. They represent the key element to derive the feasible dynamic potential for a certain year from the overall remaining additional realisable mid- / long-term potential for a specific RES technology at country level. The application of such a constraint in the model calculations results in a technology penetration following an “S-curve” pattern – obviously, only if financial incentives are set sufficiently high to allow a positive investment decision.

In accordance with general diffusion theory, penetration of a market by any new commodity typically follows an “S-curve” pattern. The evolution is characterised by a growth, which is nearly exponential at the start and linear at half penetration before it saturates at the maximum penetration level. With regards to the technical estimate of the logistic curve, a novel method has been employed by a simple transformation of the logistic curve from a temporal evolution of the market penetration of a technology to a linear relation between annual penetration and growth rates. This novel procedure for estimating the precise form of the logistic curve is more robust against uncertainties in the historic data. Furthermore, this method allows the determination of the independent parameters of the logistic function by means of simple linear regression instead of nonlinear fits involving the problem of local minima, etc.

Analytically the initial function, as resulting from an econometric assessment has a similar form to equation (1). However, for model implementation a polynomial function is used, see equation (2). This translation facilitates the derivation of the additional market potential for the year n if the market constraint is not binding, i.e. other applicable limitations provide stronger restrictions. As absolute growth rate is very low in the case of an immature market, a minimum level of the yearly realisable additional market potential has to be guaranteed – as indicated by equation (3).

$$X_n = \frac{a}{\left\{1 + b * e^{[-c*(\text{year}\,n - \text{start year} + 1)]}\right\}} \tag{1}$$

$$\Delta P_{Mne} = P_{stat\,long-term} * \left[A * X_n^2 + B * X_n + C\right] * \left[\chi_{Mmin} + \frac{\chi_{Mmax} - \chi_{Mmin}}{4} * b_M\right] \tag{2}$$

$$\Delta P_{Mn} = \text{Max}\ [\Delta P_{M\,min}; \Delta P_{M\,ne}] \tag{3}$$

where:

$\Delta P_{M\,n}$........ realisable potential (year n, country level)

$\Delta P_{M\,min}$...... lower boundary (minimum) for realisable potential (year n, country level)

$\Delta P_{M\,ne}$…….	realisable potential econometric analysis (year n, country level)
$P_{stat\ long\text{-}term}$ …..	static long-term potential (country level)
a…………	econometric factor, technology specific
b…………	econometric factor, technology specific
c…………	econometric factor, technology specific
A	quadratic factor yield from the econometric analysis
B	linear factor yield from the econometric analysis
C	constant factor yield from the econometric analysis (as default 0, considering market saturation in the long-term)
X_n ……….	calculated factor - expressing the dynamic achieved long-term potential as percentage figure: In more detail … $X_n = \frac{\text{dynamic achieved potential (year n, country level)}}{\text{total long - term potential (country level)}}$; X_n [0, 1]
$\chi_{M\,max}$	absolute amount of market restriction assuming very low barriers; $\chi_{M\,max}$ [0, 1]; to minimise parameter setting $\chi_{M\,max} = 1$
$\chi_{M\,min}$	absolute amount of market restriction assuming very high barriers; $\chi_{M\,min}$ [0, $\chi_{M\,max}$]
b_M	barrier level market / administrative constraint assessment (level 0 - 5) [5]; i.e. the country-specific parameter to describe the impact of non-economic barriers

For parameter setting, the econometric assessment of past deployment of the individual RES technologies at country level represents the starting point, whereby factors A, B and C refer to the "best practice" situation as identified via a cross-country comparison.[6] [7]

Generally two different variants of settings with respect to the non-economic barriers of individual RES technologies are used:

- High non-economic barriers / low diffusion ("business-as-usual settings")

  This case aims to reflect the current situation (business-as-usual (BAU) conditions) where non-economic barriers are of relevance for most RES technologies. The applied technology-specific parameters have been derived by an econometric assessment of past deployment of the individual RES technologies within the assessed country.

- Removed non-economic barriers / high diffusion ("Best practice")

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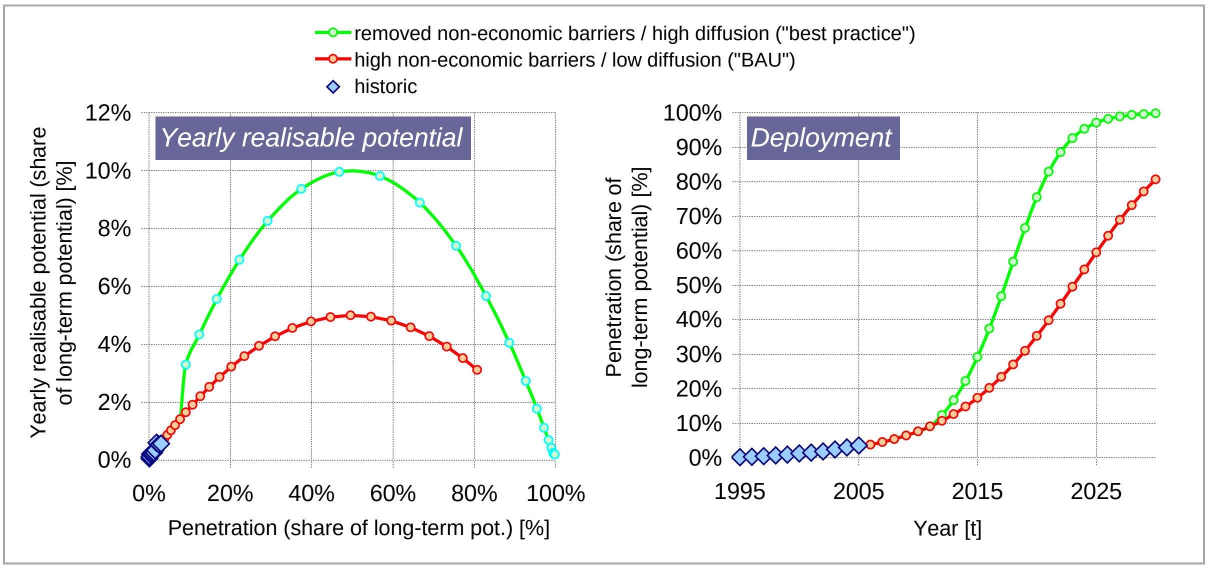
[5] A value of 0 would mean the strongest limitation (i.e. no diffusion, except minimum level), while 4 would mean the strongest feasible diffusion (according to "best practice" observations).

Note, if the level number '5' is chosen, the default approach would be replaced by a simplified mechanism: In this case the yearly realisable potential is defined as share of the dynamic additional realisable mid-term potential on band level. Hence, it can be chosen separately how much of the remaining potential can be exploited each year.

[6] For the "best practice" country the applied market barrier b_M equals 4 – see notes as given in the corresponding description. Consequently, the comparison to this "ideal" case delivers the barrier level b_M for other countries.

[7] For novel technologies being in an early stage of development and consequently not applicable in historic record similarities to comparable technologies are made.

This case represents the other extreme where the assumption is taken that non-economic barriers will be mitigated in time.[8] Applied technology-specific settings refer to the "best practice" situation as identified by a cross-country comparison. Accordingly, an enhanced RES deployment can be expected – if financial support is also provided in an adequate manner.



Note: Key parameter have been set in this schematic depiction as follows: A = (-B) = -0.4; b_M was varied from
2 (high barriers / low diffusion) to 4 (removed barriers / high diffusion)

Figure 9: Schematic depiction of the impact of non-economic barriers on the feasible diffusion at technology and country level: Yearly realisable potential (left) and corresponding resulting feasible deployment (right) in dependence of the barrier level

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

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

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[8] More precisely, a stepwise removal of non-economic barriers is preconditioned which allows an accelerated RES technology diffusion. Thereby, the assumption is taken that this process will be launched in 2016.

Determining the necessary rate of return is based on the weighted average cost of capital (WACC) methodology. WACC is often used as an estimate of the internal discount rate of a project or the overall rate of return desired by all investors (equity and debt providers). This means that the WACC formula[9] determines the required rate of return on a company's total asset base and is determined by the Capital Asset Pricing Model (CAPM) and the return on debt.

Formally, the pre-tax cost of capital is given by:

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

Table 2 explains how to determine the WACC for two example cases – a default and a high risk assessment. Within the model-based analysis, a range of settings is applied to accurately reflect the risks to investors. Risk refers to two different issues:

- A "policy risk" is related to the uncertainty about future earnings caused by the support scheme itself – e.g. refers to the uncertain development of certificate prices within a RES trading system and / or uncertainty related to earnings from selling electricity on the spot market. As shown in Table 2, the range of settings used in the analysis with respect to policy risks varies from 7.5% (default risk) up to 9.8% (high risk). The different values are based on a different risk assessment, a standard risk level and a set of risk levels characterised by a higher expected / required market rate of return. 7.5% is used as the default value for stable planning conditions as given, e.g. under advanced fixed feed-in tariffs. The higher value is applied in scenarios with less stable planning conditions, i.e. in the cases where support schemes cause a higher risk for investors as associated with e.g. RES trading (and related uncertainty about future earnings on the certificate market). An overview of the settings used by the type of policy instrument or pathway, respectively, is given in Table 3.
- A "technology risk" refers to uncertainty about future energy production due to unexpected production breaks, technical problems etc... Such problems may cause (unexpected) additional operational and maintenance costs or require substantial reinvestments which (after a phase-out of operational guarantees) typically have to be borne by the investors themselves. In the case of biomass, this also includes risks associated with the future development of feedstock prices. Table 4 (below) illustrates the default assumptions applied to consider investors' technology risks. The expressed technology-specific risk factors are used as a multiplier of the default WACC figure. The ranges indicated for several RES categories reflect the fact that risk profiles are expected to change over time and that specific RES categories cover a range of technologies (and for instance also a range of different feedstocks in the case of biomass) and unit sizes. The lower boundary for PV or for several RES heat options also indicates a different risk

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

profile of small-scale investors who may show a certain “willingness to invest”, requiring a lower rate of return than commercial investors.

Table 2: Example of value setting for WACC calculation

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

Table 3: Policy risk: Instrument-specific risk factor

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

Table 4: Technology-specific risk factor

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

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

2.6 Potentials and costs for RES in the European Union

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

This section illustrates the consolidated outcomes on RES potentials and accompanying costs of an intensive assessment process conducted within several studies in this topical area. The derived data on realisable long-term (2050) potentials for RES in the European Union and assessed neighbouring countries fits to the requirements of the model Green-X and serves as sound basis for the subsequently depicted policy assessment of RES cooperation between the EU and its neighbours.

Please note that within this illustration the future potential for considered biomass feedstock is pre-allocated to feasible technologies and sectors based on simple rules of thumb. In contrast to this, within the Green-X model no pre-allocation to the sectors of electricity, heat or transport is undertaken as technology competition within and across sectors (as well as between countries) is appropriately reflected in the applied modelling approach.

2.6.1 The Green-X database on potentials and cost for RES – background information

The input database of the Green-X model offers a detailed depiction of the achieved and feasible future deployment of the individual RES technologies, initially constraint to the European Union (EU28) but within the course of recent projects extended to neighbouring countries / regions (i.e. Western Balkans, North Africa and Turkey). This comprises in particular information on costs and penetration in terms of installed capacities or actual & potential generation. Realisable future potentials (up to 2050) are included by technology and by country. In addition, data describing the technological progress such as learning rates are available. Both serve as crucial input for the model-based assessment of future RES deployment.

Note that an overview on the method of approach used for the assessment of this comprehensive data set is given in Box 2 (below).

Box 2: About the Green-X potentials and cost for RES

The Green X database on potentials and cost for RES technologies provides detailed information on current cost (i.e. investment -, operation & maintenance -, fuel and generation cost) and potentials for all RES technologies at country level. Geographically the scope of the database has been extended within this project from the EU28 to the assessed neighbouring countries / regions (i.e. Western Balkans, Turkey and North Africa).

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

EU within 2008. The active involvement of key stakeholders and their direct feedback on data and scenario outcomes helped to reshape, validate and complement the previously assessed information.

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

Within this study and parallel activities the database has been extended geographically. The extended version comprises in addition to EU member states also all Contracting Parties of the Energy Community (i.e. Western Balkans), Turkey and selected North African countries. Within the case study work in the BETTER project a literature survey has been conducted, complemented by gathering of statistical information on land use, etc. Finally, a GIS-based assessment of wind and solar potentials was undertaken to derive an up-to-date data set following a harmonised approach for these important renewable energy technologies.

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

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

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

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

2.6.2 Classification of potential categories

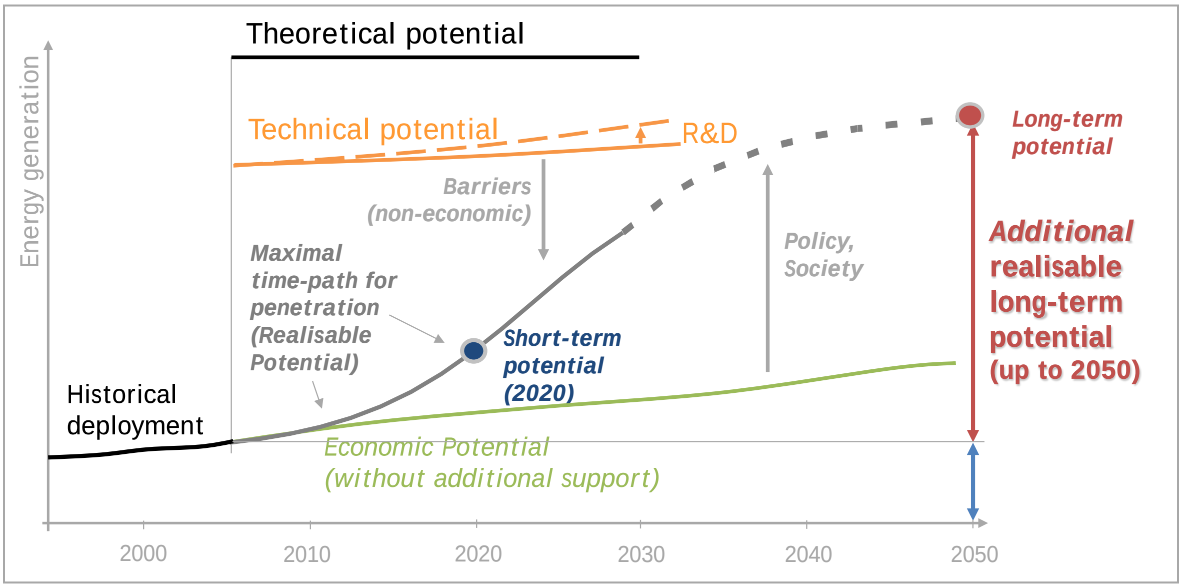

Figure 10: Definition of potential terms

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

- *Theoretical potential:* To derive the theoretical potential, general physical parameters have to be taken into account (e.g. based on the determination of the energy flow resulting from a certain energy resource within the investigated region). It represents the upper limit of what could be produced from a certain energy resource from a theoretical point-of-view, based on current scientific knowledge;
- *Technical potential:* If technical boundary conditions (i.e. efficiencies of conversion technologies, overall technical limitations as e.g. the available land area to install wind turbines as well as the availability of raw materials) are considered, the

technical potential can be derived. For most resources, the technical potential must be considered in a dynamic context. For example with increased R&D expenditures and learning-by-doing during deployment, conversion technologies might be improved and, hence, the technical potential would increase;

- *Realisable potential:* The realisable potential represents the maximal achievable potential assuming that all existing barriers can be overcome and all driving forces are active. Thereby, general parameters as e.g. market growth rates, planning constraints are taken into account. It is important to mention that this potential term must be seen in a dynamic context – i.e. the realisable potential has to refer to a certain year;
- *Realisable potential up to 2020:* provides an illustration of the previously assessed realisable (short-term) potential for the year 2020;
- *Realisable potential up to 2050:* provides an illustration of the derived realisable (long-term) potential for the year 2050.

Figure 10 (above) shows the general concept of the realisable potential up to 2020 as well as in the long-term (2050), the technical and the theoretical potential in a graphical way.

2.6.3 Realisable long-term (2050) potentials for RES – extract from the Green-X database

The subsequent graphs and tables aim to illustrate to what extent RES may contribute to meet the energy demand within the European Union (EU 28) up to the year 2050 by considering the specific resource conditions and current technical conversion possibilities[10] as well as realisation constraints in the investigated countries.

As explained before, *realisable long-term potentials* are derived, describing the feasible RES contribution up to 2050 from a domestic point of view. Thus, only the domestic resource base is taken into consideration, excluding for example feasible and also likely imports of solid biomass[11] or of biofuels to the European Union from abroad. Subsequently, an overview is given on the overall long-term potentials in terms of final energy by country, followed by a detailed depiction done for the electricity sector.

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

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

RES potentials in terms of (gross) final energy[12]

Summing up all RES options applicable at country level, Figure 11 depicts the achieved (as of 2005) and additional long-term (2050) potential for RES in all EU Member States. Note that potentials are expressed in absolute terms. Consequently, large countries (or more precisely those countries possessing large RES potentials) are getting apparent. For example, France, Germany, Italy, Poland, Spain, Sweden and the UK offer comparatively large potentials. To illustrate the situation in a suitable manner for small countries (or countries with a lack of RES options available), Figure 12 shows a similar depiction in relative terms, expressing the realisable long-term (2050) potential as share on current (2005) gross final energy demand.

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

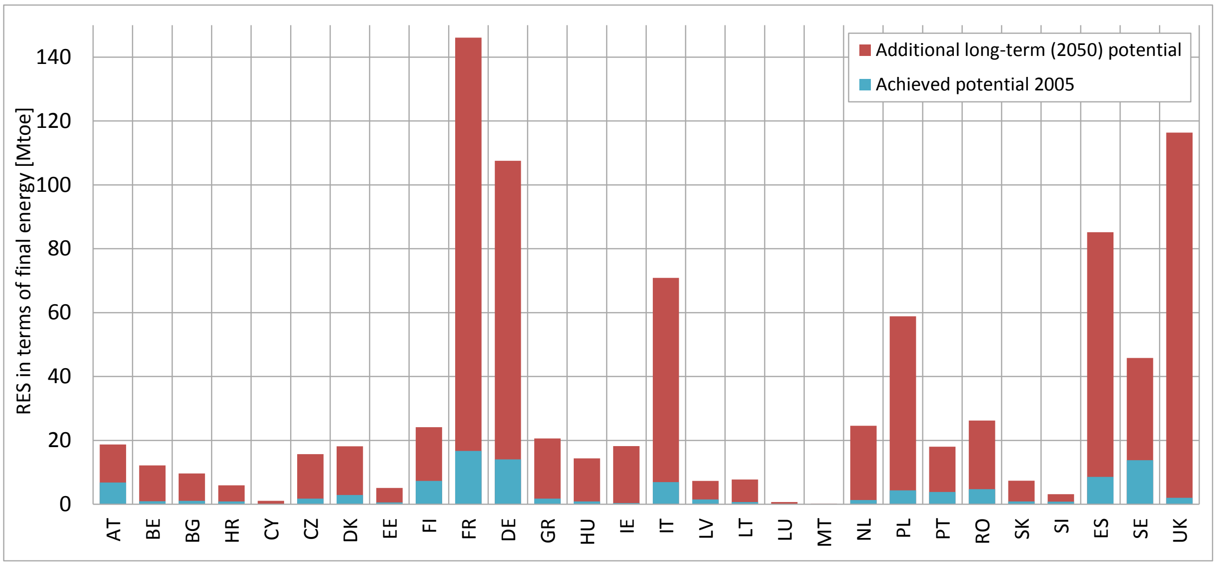

Figure 11: Achieved (2005) and additional long-term (2050) potential for RES in terms of final energy for all EU Member States (EU 28) – expressed in absolute terms

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

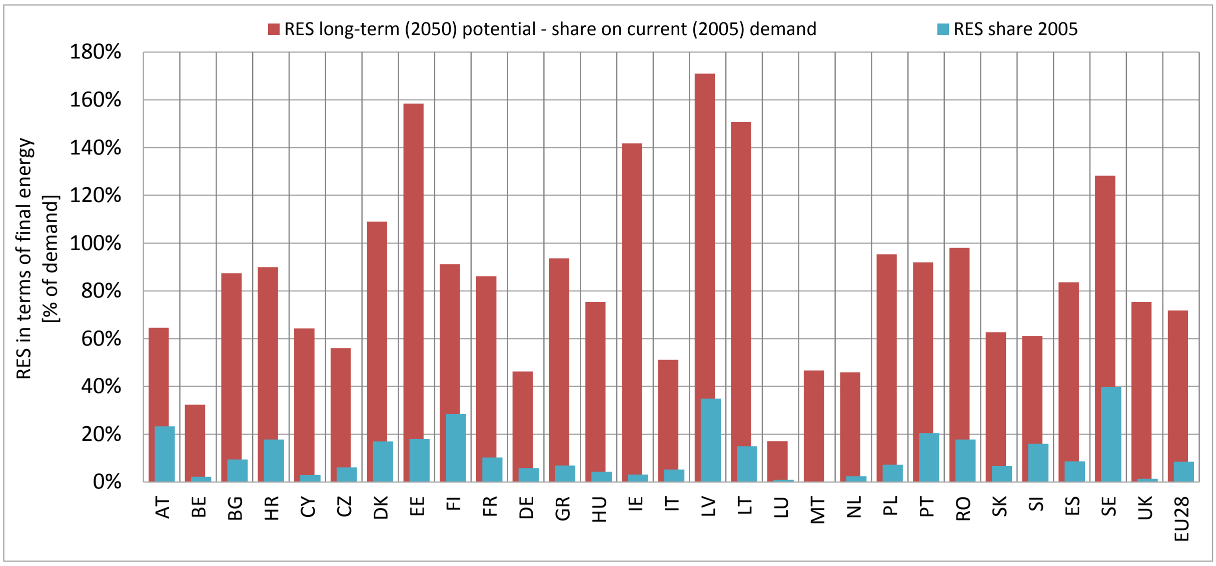

Figure 12: Achieved (2005) and total long-term (2050) potential for RES in terms of final energy for all EU Member States (EU 28) – expressed in relative terms, as share on (gross) final energy demand

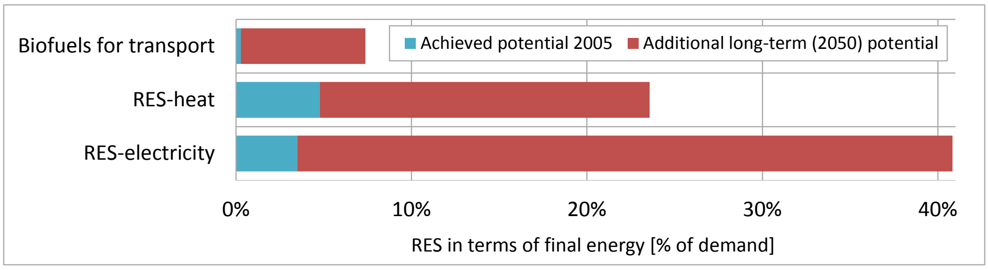

Figure 13: Sector-specific breakdown of the achieved (2005) and additional long-term (2050) potential for RES in terms of final energy at EU 28 level – expressed in relative terms, as share on current (2005) (gross) final energy demand

Finally, a sector-specific breakdown of the realisable RES potentials is given in Figure 13 for the EU28. The largest contributor to meet future RES targets represents the electricity sector among all analysed countries. The overall long-term potential for RES-electricity in comparison to overall current (2005) gross final energy demand lies at around 41% for the EU28. Next to renewable electricity follows RES in heating and cooling in all assessed regions. Renewables in heating & cooling may achieve (in case of a full exploitation) a share of 23.6% in total final energy demand at EU28 level. The smallest contribution can be expected from biofuels in the transport sector, which offer (considering solely domestic resources) potentials, again expressed as share in total gross final energy demand at around 7.4% for the EU28.

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

Next, we take a closer look on the long-term prospects for RES at sector level, illustrating identified RES potentials in the 2050 time frame in further detail for the electricity sector. In the power sector, RES-E options such as hydropower, solar 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 on electricity generation is translated into electricity generation potentials[13] – the *achieved potential* at the end of 2005 – taking into account the recent development of this rapidly growing market. The historical record was derived in a comprehensive data-collection – based on (Eurostat, 2007; IEA, 2007) and statistical information gained on national level. In addition, *future* potentials – i.e. the *additional realisable long-term potentials* up to 2050 – were assessed[14] taking into account the country-specific situation as well as overall realisation constraints.

Below we provide a cross-country and technology comparison at EU28 level, before discussing the potentials for renewable electricity in assessed neighbouring countries / regions (i.e. Turkey, Western Balkans, North Africa).

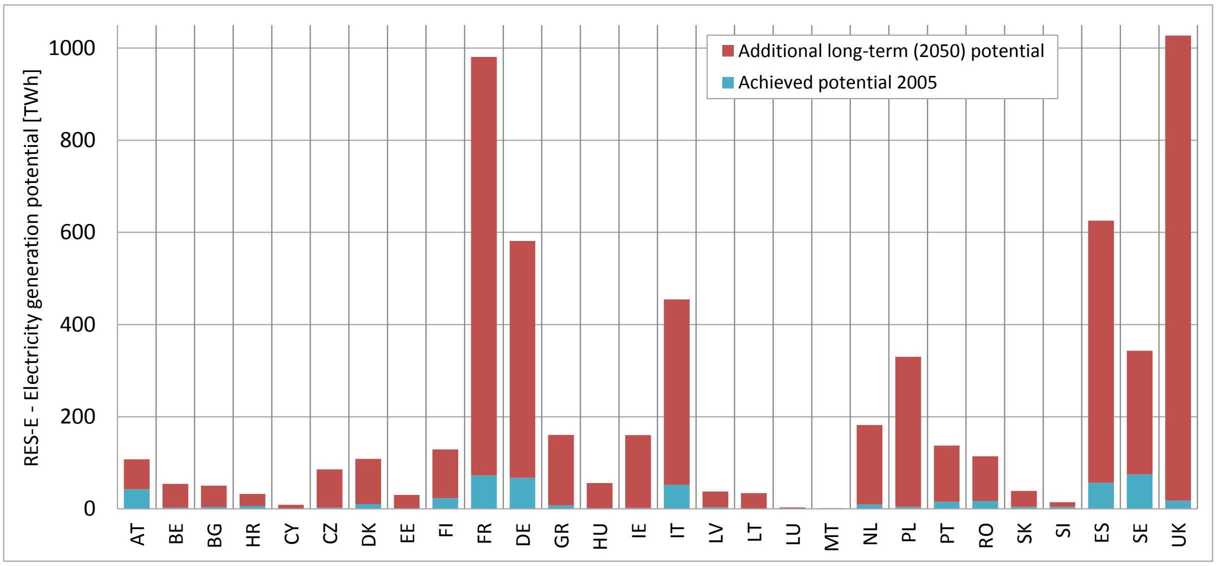

Figure 14: Achieved (2005) and additional long-term potential 2050 for electricity from RES in the EU 28 at country level.

Figure 14 depicts the achieved and additional mid-term potential for RES-E in the EU 28 at country level. For the 28 Member States, the already achieved potential for RES-E

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[13] 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.

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

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

Consequently, Figure 15 relates derived potentials to gross electricity demand. More precisely, it depicts the total realisable long-term potentials (up to 2050), as well as the achieved potential (2005) for RES-E as share of gross electricity demand in 2005 for all Member States and the EU 28 in total. As applicable from this depiction, significant additional RES potentials are becoming apparent for several countries. In this context especially notable are Portugal, Denmark and Ireland, as well as most of the new Member States. If the indicated realisable long-term potential for RES-E, covering all RES-E options, would be fully exploited up to 2050, almost twice of all our electricity needs as of today (178% compared to 2005's gross electricity demand) could be *in principle*[15] covered. For comparison, by 2005 already installed RES-E plants possess the generation potential to meet about 15% of demand.

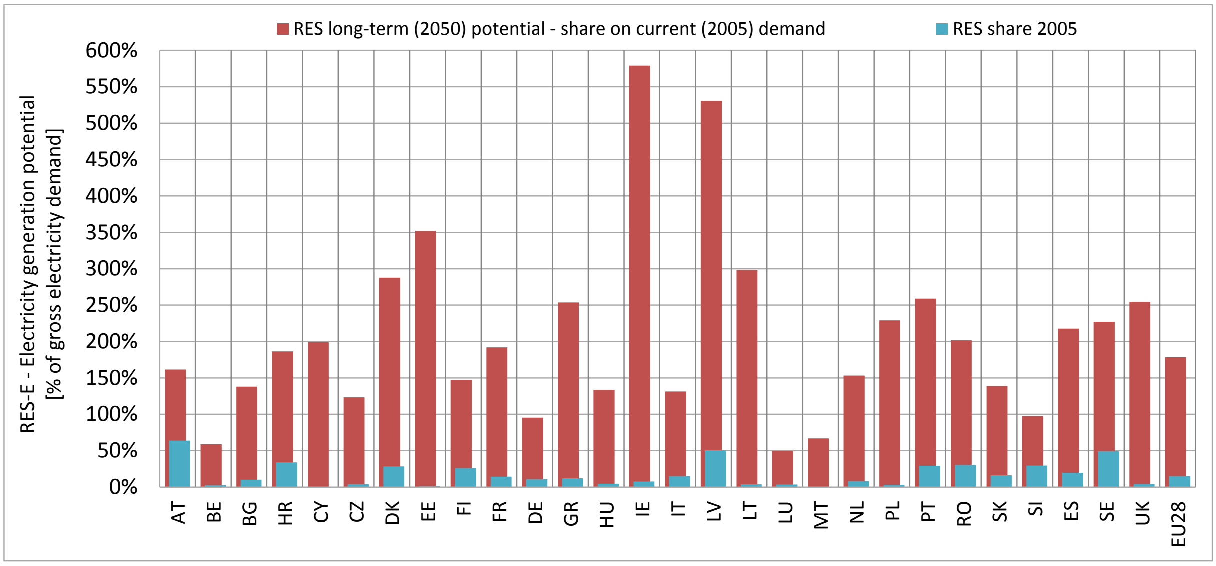

Figure 15: Achieved (2005) and total long-term (2050) potential for electricity from RES in the EU 28 at country level, expressed in relative terms as share of gross electricity demand (2005)

A closer look at the technology-level is provided by Figure 16. This graph offers a technology breakdown of the achieved (2005) and the additional realisable long-term

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

(2050) potential for the EU28 as an aggregate. The figure depicts a high penetration and a small additional realisable potential for hydropower, both small- and large-scale. In general terms, wind onshore and solid biomass technologies are both already well developed, but still an enormous additional potential is apparent. Moreover, technologies like wind offshore, tidal stream and wave power as well as photovoltaics provide a large additional potential, waiting to be exploited in forthcoming years. A comparison of the additional long-term potential across technologies in terms of size leads to the following ranking: Wind onshore with an additional realisable potential of 2,054 TWh ranks first, followed by offshore wind (1,284 TWh) and photovoltaics (976 TWh). All other RES-E options (e.g. solar thermal electricity, biomass or biogas) offer a valuable but in magnitude significantly lower additional potential at EU28 level.

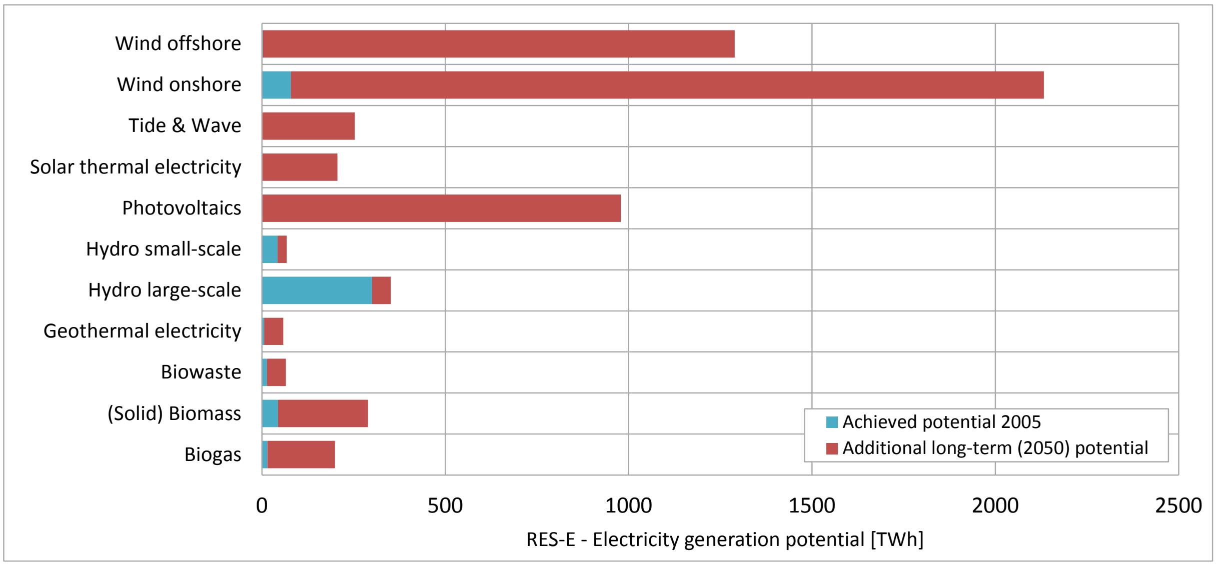


Figure 16: Achieved (2005) and additional long-term (2050) potential for electricity from RES in the EU28 at technology level

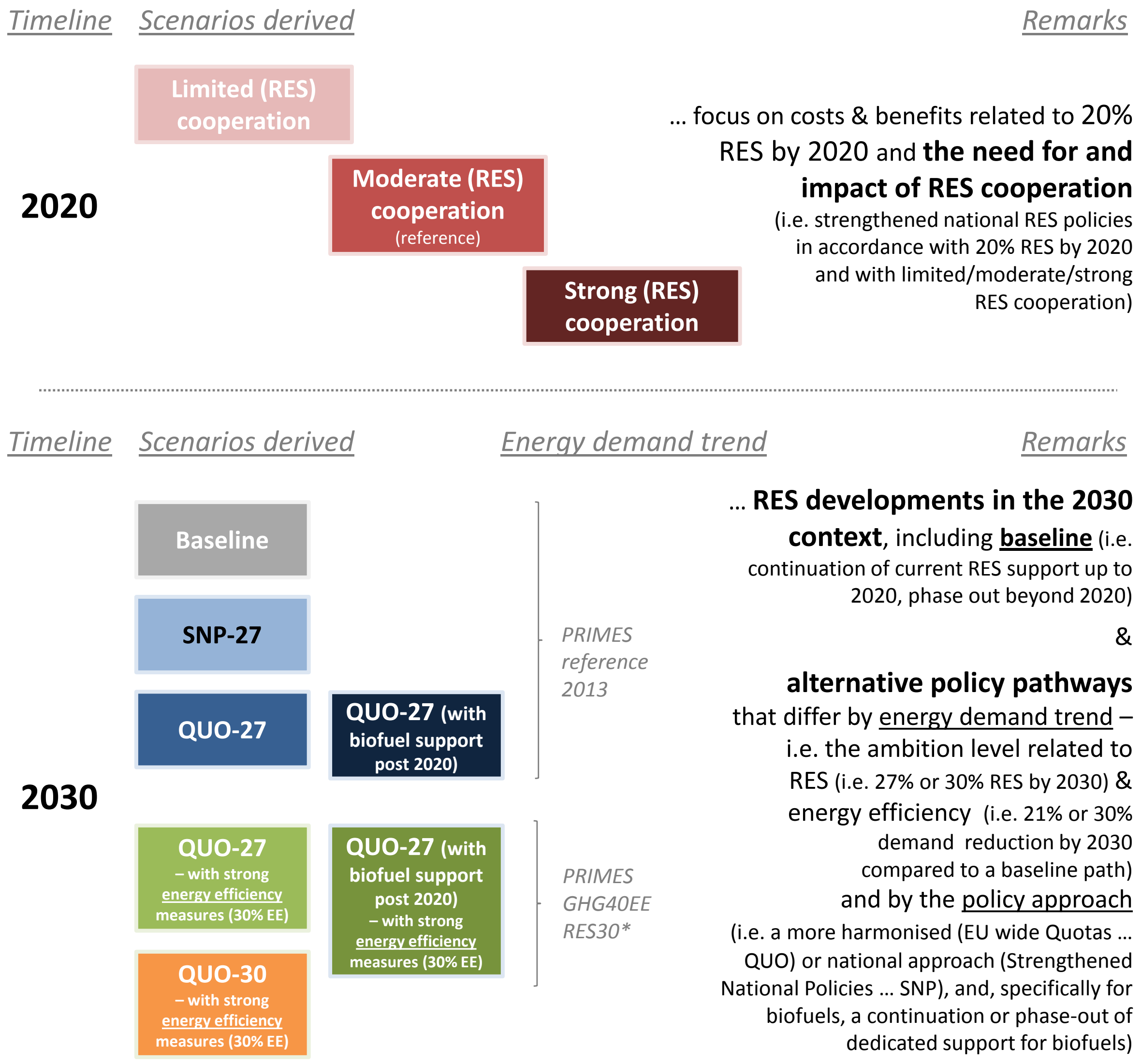
2.7 Assessed cases

The model-based assessment of future RES deployment within the EU has two focal points in time:

- In the 2020 context a focus is put on the discussion on the need for an impact of RES cooperation for achieving binding national 2020 RES targets.
- In the 2030 context, scenarios aim to provide a quantitative basis for discussing possible RES developments and related impacts on costs and benefits in the light of the new Council agreement on 27% RES by 2030.

While framework conditions are kept identical – i.e. scenarios build on the energy demand and price projections provided by the latest publicly available PRIMES scenario (i.e. reference and energy efficiency case) (EC, 2013) – the assessed cases are tailored to topical needs.

Thus, Figure 17 provides a brief overview on all assessed cases. Next to that the scenario definition is introduced in further detail by distinct focal point.



… focus on costs & benefits related to 20% RES by 2020 and **the need for and impact of RES cooperation** (i.e. strengthened national RES policies in accordance with 20% RES by 2020 and with limited/moderate/strong RES cooperation)

… **RES developments in the 2030 context**, including **baseline** (i.e. continuation of current RES support up to 2020, phase out beyond 2020)

&

alternative policy pathways that differ by energy demand trend – i.e. the ambition level related to RES (i.e. 27% or 30% RES by 2030) & energy efficiency (i.e. 21% or 30% demand reduction by 2030 compared to a baseline path) and by the policy approach (i.e. a more harmonised (EU wide Quotas … QUO) or national approach (Strengthened National Policies … SNP), and, specifically for biofuels, a continuation or phase-out of dedicated support for biofuels)

*Impact Assessment (SWD(2014) 15) accompanying the European Commission's communication "A policy framework for climate and energy in the period from 2020 to 2030" (January 2014)

Figure 17: Overview on assessed cases

2.7.1 Assessment of RES cooperation in the 2020 context

A set of three distinct scenarios has been derived to identify the need for and impacts of RES cooperation. Common to all cases is that a continuation of national RES policies until 2020 is assumed. More precisely, the assumption is made that these policies will be further optimised in the future with regard to their effectiveness and efficiency in order to meet 2020 RES targets (as set by the RE Directive 2009/28/EC) both at EU level and at national level. Thus, all cases can be classified as "strengthened national (RES) policies", considering improved financial support as well as the mitigation of non-economic barriers that hinder an enhanced RES deployment.[16]

To identify possible cost-saving potentials that come along with a stronger use of cooperation mechanisms, three different variants of national RES support and RES cooperation, respectively, have been assessed. These scenarios can be distinguished as follows:

- The reference case is defined by a scenario of "**moderate cooperation**". In this scenario Member States make effective use of cooperation, but still seek to achieve some domestic deployment that otherwise would have been realised more cheaply in a different Member State. The case of moderate cooperation is chosen as the reference case as this can be expected to become the default beyond 2020. This case will be compared to two sensitivity variants, "strong cooperation" and "limited cooperation".

  A "European perspective" is taken in the second variant that can be classified as "**strong cooperation**" where an efficient and effective RES target achievement is envisaged rather at EU level than fulfilling each national RES target purely domestically.[17]

- As third option a "national perspective" is researched where Member States primarily aim for a pure domestic RES target fulfilment and, consequently, only **"limited cooperation"**[18] is expected to arise from that.

2.7.2 Outlook to 2030: RES developments under baseline conditions and according to alternative policy pathways

Different scenarios have been defined for the deployment and support of RES technologies in the EU in the 2030 context. Obviously, the RES policy pathway for the years up to 2020 appears well defined given the EU RES directive 2009/28/EC and the

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[16] Note that all changes in RES policy support and non-economic barriers are assumed to become effective immediately (i.e. by 2015).

[17] In the "strong cooperation / European perspective" case we assume a full alignment of financial incentives across the EU. Next to that, under "moderate cooperation" economic restrictions are applied to limit differences in applied financial RES support among Member States to a still comparatively moderate level – i.e. differences in country-specific support per MWh RES are limited to a maximum of 10 €/MWh$_{RES}$, while in the "limited cooperation / National perspective" variant this feasible bandwidth is set to 20 €/MWh$_{RES}$. Consequently, if support in a country with low RES potentials and / or an ambitious RES target exceeds the upper boundary, the remaining gap to its RES target would be covered in line with the flexibility regime as defined in the RES Directive through (virtual) imports from other countries.

[18] Within the corresponding model-based assessment the assumption is taken that in the case of "limited cooperation / National perspective" the use of cooperation mechanisms as agreed in the RES Directive is reduced to the necessary minimum: For the exceptional case that a Member State would not possess sufficient RES potentials, cooperation mechanisms would serve as a complementary option. Additionally, if a Member State possesses barely sufficient RES potentials, but their exploitation would cause significantly higher support expenditures compared to the EU average, cooperation would serve as complementary tool to assure target achievement.

corresponding national 2020 RES targets and accompanying National Renewable Energy Action Plans for the period up to then. Exploring RES development beyond 2020, however, means entering terrain characterized by a higher level of uncertainty – both with respect to the policy pathway and with regard to the potentials and costs of applicable RES technology options. Thus, the scenarios defined for this assessment aim to provide a first reflection of the decision on the 2030 energy and climate framework taken at the recent Council meeting in October (2014) where Member States agreed on a binding EU target of at least 27% RES by 2030. Figure 17 summarises the general settings of all scenarios assessed, indicating the policy concept and the ambition level with respect to renewable energy for 2030, respectively.

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

- Within the Strengthened National Policies (SNP) scenario (that relates to a target of 27% RES by 2030), a continuation of the current policy framework with national RES targets (for 2030 and beyond) is assumed. Each country uses national (in most cases technology-specific) support schemes in the electricity sector to meet its own target, complemented by RES cooperation between Member States (and with the EU's neighbours) in the case of insufficient or comparatively expensive domestic renewable sources. In the SNP scenario support levels are generally based on technology specific generation costs per country.
- In the scenarios referring to the use of a quota system (i.e. QUO-27 and QUO-30), an EU-wide harmonised support scheme is assumed for the electricity sector that does not differentiate between different technologies. In this case the marginal technology to meet the EU RES-target sets the price for the overall portfolio of RES technologies in the electricity sector. The policy costs occurring in the quota system can be calculated as the certificate price multiplied by the RES generation under the quota system. These costs are then distributed in a harmonised way across the EU so that each type of consumer pays the same (virtual) surcharge per unit of electricity consumed. [19]
- As a further sensitivity variant for the 2030 RES target we assessed the impact of having dedicated support for biofuels also in the period post 2020 (whereas under default conditions no financial support for biofuels in transport is prescribed).
- Additionally, we also shed light on the impact of complementary energy efficiency measures: Although a target of 27% for energy efficiency has already been fixed for 2030, we show ranges with regard to the actual achievement of energy efficiency to cover both, a higher or substantially lower level of ambition in terms of energy efficiency policy: Under reference conditions an improvement in energy efficiency of 21% compared to the 2007 baseline of the PRIMES model is projected for 2030,

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

whereas in the "GHG40EERES30" case, assuming a medium ambition level for energy efficiency, an increase to 30% is assumed.

Please note that all alternative RES policy pathways (SNP and all QUO cases) build on a strengthening of national policies already in the period before 2020, serving to meet the given 2020 RES targets and where a gradual mitigation of currently prevailing non-economic RES barriers is presumed.

As reference for all alternative policy scenarios, a baseline case is derived, assuming that RES policies are applied as currently implemented (without any adaptation) until 2020, while for the post-2020 timeframe a gradual phase-out of RES support is presumed. Moreover, in the baseline case the assumption is taken that non-economic barriers remain.

3 Results of the model-based assessment of costs and benefits of RES

This chapter presents system-wide results on costs and benefits of RES in the 2020 and 2030 perspective. Beginning with the EU-wide overview, this analysis provides a comprehensive overview of different scenario options for the whole of Europe. What this means specifically at the Member State level is also shown, by presenting four case studies on selected countries – namely Italy, France, Belgium and UK and their development possibilities under the different scenarios analysed.

3.1 RES developments in the European Union up to 2030

3.1.1 The aggregated picture: Total RES use up to 2030

We start with an analysis of RES deployment according to Green-X RES policy cases conducted on the basis of corresponding PRIMES scenarios that have been developed for and are discussed in the Impact Assessment accompanying the Communication from the European Commission “A policy framework for climate and energy in the period from 2020 to 2030” (COM(2014) 15 final). More precisely, Figure 18 below shows the development of the RES share in gross final energy demand throughout the period 2015 to 2030 in the EU 28 according to the assessed Green-X cases. As reference or 2030 also the shares in the PRIMES scenarios are indicated. Noticeably, an alignment to PRIMES results could be achieved at the aggregated level (total RES deployment, EU28) for the policy track aiming for a RES share of 30% (QUO-30) by 2030. This finding is also confirmed by a subsequent more detailed analysis that involves sector-specific results also indicates that comparatively similar trends are observable by 2030 for the EU 28 at sector level.

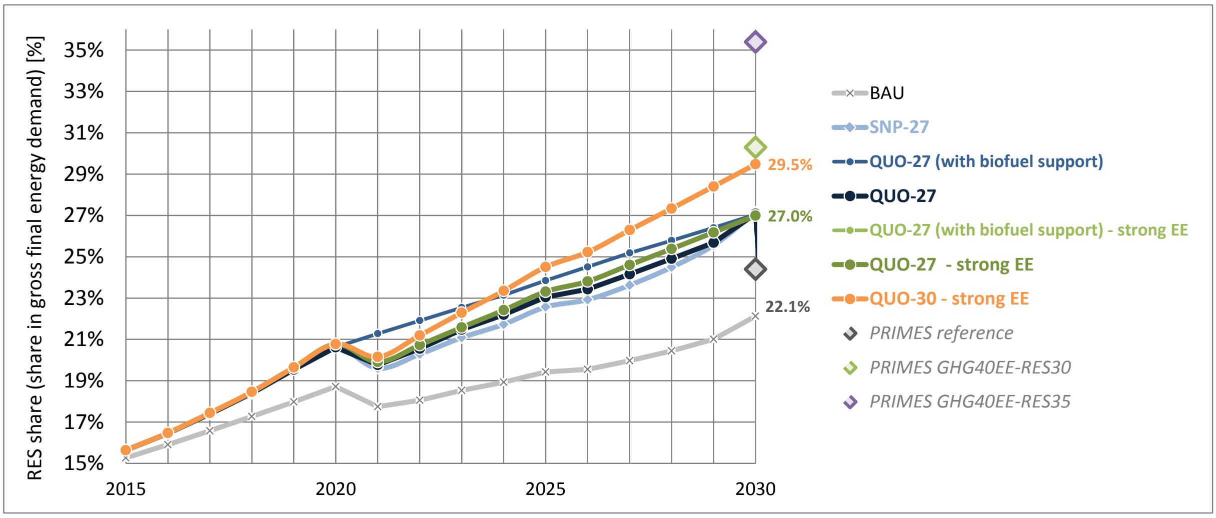

Figure 18: Comparison of the resulting RES deployment in relative terms (i.e. as share in gross final energy demand) over time in the EU 28 for all assessed cases (incl. PRIMES scenarios)

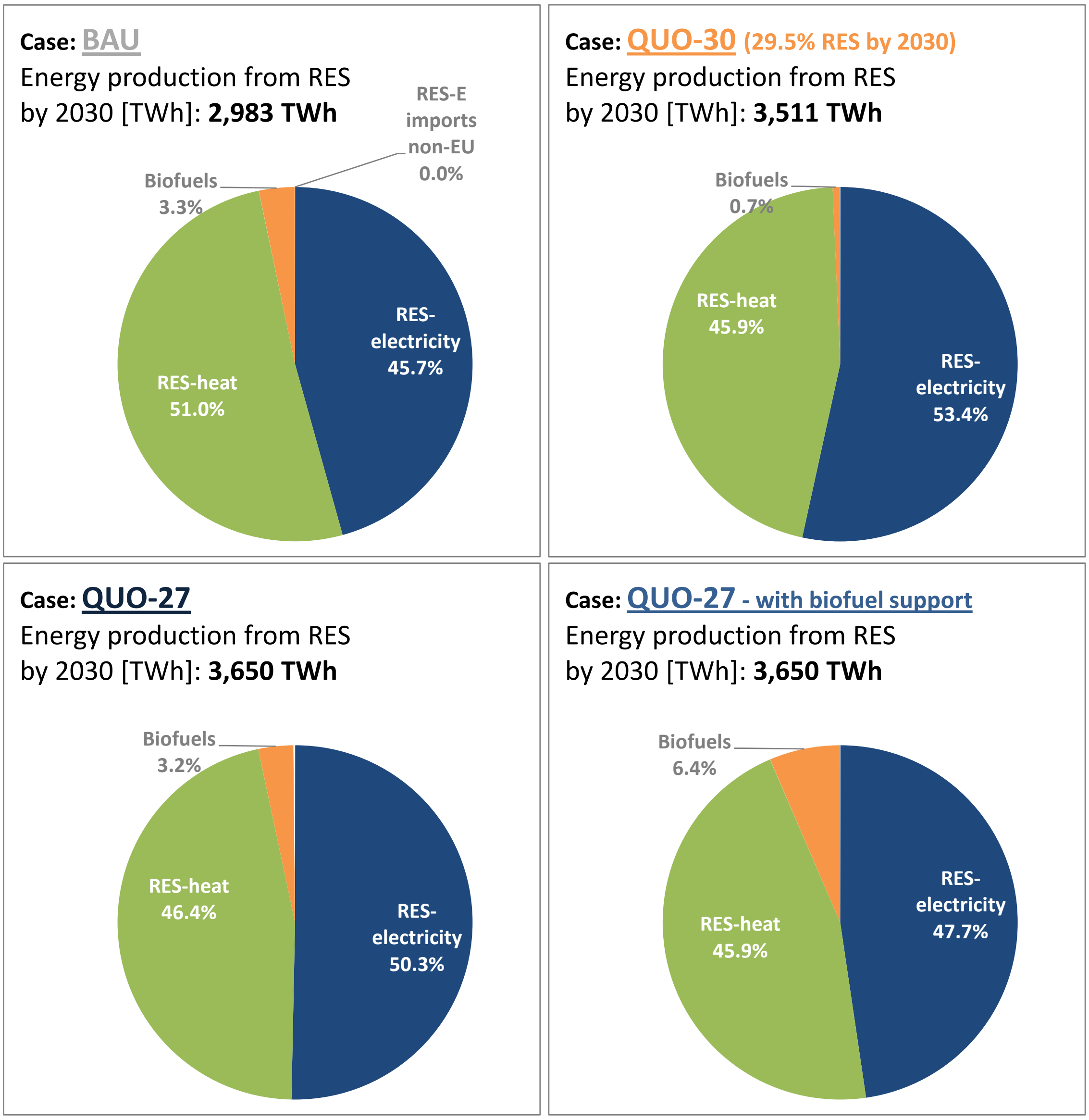

Figure 19: Sector-specific RES deployment at EU 28 level by 2030 for selected cases

Figure 19 takes a closer look at the sector-specific RES deployment at EU-28 level. While sector-specific RES shares differ only to a small extent among the assessed cases, (strong) differences are observable regarding the overall deployment of new RES installations: 27% RES by 2030 in comparison to the baseline (BAU scenario) means a 41% increase in the deployment of new RES installations post 2020 – if similar developments are prescribed concerning overall energy demand developments in forthcoming years. If proactive energy efficiency policies and measures are however taken as assumed in the PRIMES efficiency scenario, leading to demand decline by 30% instead of 21% as assumed in the reference case, a substantially higher RES share can be achieved by 2030 with less new RES installation: an increase by 37% in the deployment of new RES installations compared to BAU would then lead to a 2030 RES share of 29.5% (cf. QUO-30).

3.2 Costs and benefits of RES in the 2020 perspective

Background information

Macro-economic effects are measured at the macro- level and comprise gross and net effects in an economy. **Gross effects** refer to the RES sector, i.e. they show the effects in all industries that are directly related to RES. To get the real **net effects** (net employment, GDP) of RES deployment – net of all costs – for the overall economy (all sectors) all positive and negative effects of RES deployment should be included.

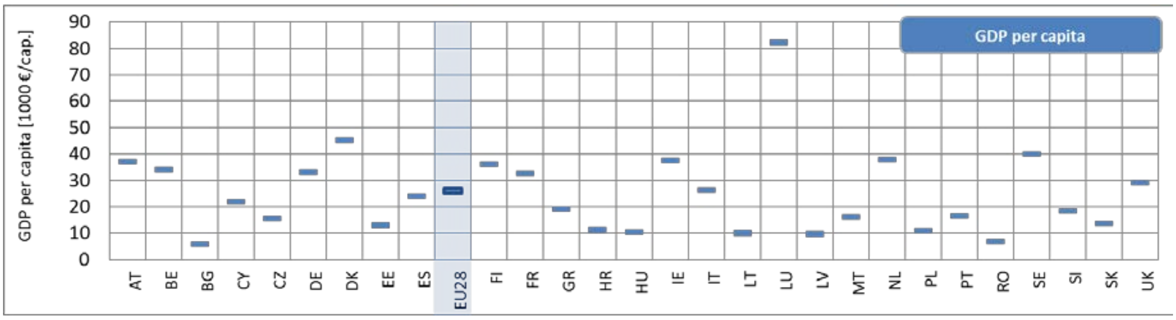

Figure 20: GDP per capita [1000 €/capita] (on average (2011-2020)) of the 28 EU Member States

To put the effects outlined in the following sections into perspective, Figure 20 depicts the respective Member States GDP per capita. This way, absolute effects as shown in Figure 25 for the EU28 level are made quantifiable in their relative values at country level as well (cf. Figure 25).

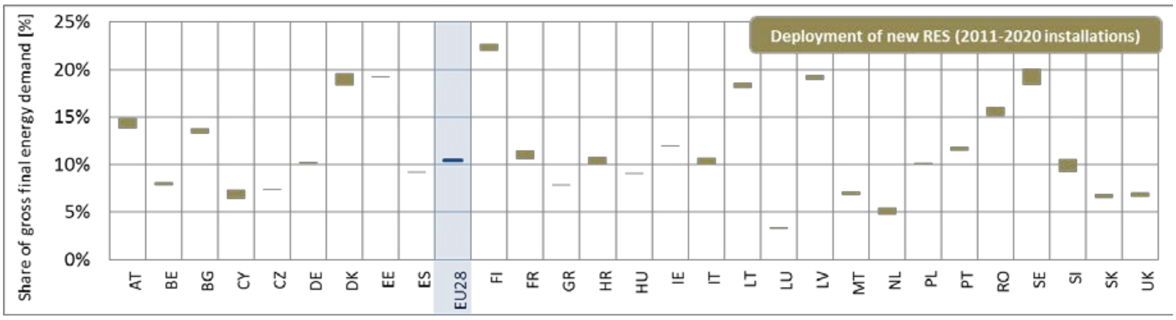

Figure 21: Deployment by 2020 of new RES (installed in the period of 2011 to 2020)

Figure 3, on the other hand, shows how the 2020 generation that stems from new RES installations of this decade (i.e. 2011 to 2020) is to be valued at Member State level, for comparative reasons expressed as (RES) share in the respective Member State's gross final energy demand.[20] Note that all subsequent indicators refer to this expansion.

Costs and benefits at EU level

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[20] The research interest lies in assessing costs and benefits for the period 2011 to 2020 and specifically of the new deployment of RES needed to achieve the 2020 targets. Therefore, the focus of the analysis takes these new installations as a reference in the following.

Focal points of the assessment were both the period up to 2020, which is shown in the following, and the upcoming decade up to 2030. For the period up to 2020 different intensities of cooperation between the Member States were analysed, all in accordance with EU target of 20% RES by 2020 and related Member State targets set out by the RES Directive (2009/28/EC).

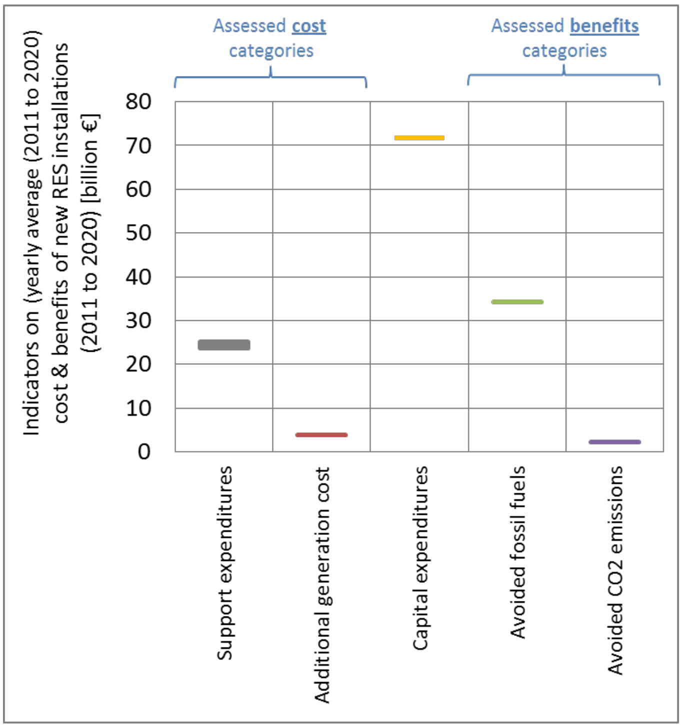

Figure 22: Indicators on yearly average expenditures or costs and benefits of new RES installations (2011 to 2020) at EU level for all assessed cases, expressed in absolute terms (billion €)

Overall it can be stated that not all Member States will reach their 2020 target via their own domestic RES deployment alone. This means that volumes of RES would have to be exchanged (virtually) to a certain extent between Member States. While Deliverable 2-5 of the DIA-CORE project shows the detailed flows, this discussion solely focuses on the resulting costs and benefits for Member States. Figure 22 shows indicators on yearly average costs and benefits of new RES installations for the years 2011 to 2020. Specifically, a range is displayed for support expenditures, additional generation costs, capital expenditures and benefits resulting from avoided expenses for CO_2 emission allowances. This range depicts values from different scenarios (a limited, medium and strong cooperation scenario among EU Member States) during the assessed period of time.

More parameters and assumptions underlying these scenarios can be found in the Annex to this Background Report. Concretely it can be seen that the largest bandwidth occurs with support expenditures. The maximum expenditures on average for this period are 25.2 billion € at EU level whereas in the case of stronger cooperation across the EU this value falls to 23.5 billion €. The other categories do not exhibit such substantial variance. Specifically, additional generation costs are roughly at 3.8 billion € per year, whereas capital expenditures are significantly higher at between 71 to 72 billion €.

Benefits in terms of avoided fossil fuels are in the area of annually 34 billion €. The monetary expression of CO_2 emission avoidance, or more precisely avoided expenses for CO_2 emission allowances, can be quantified to around 2.2 billion € per year.[21] In the

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[21] The CO_2 price in the scenarios presented in this report is also based on recent PRIMES modelling, see Figure 14. Actual market prices for EU Allowances have fluctuated between 6 and 30 €/t since 2005 but remained on a low level with averages around 7 €/t in the first quarter of 2012. For fossil

following subsection these cost-benefit categories are displayed at Member State level to give an overview of the distributional effects.

Insights into different cost benefit categories at Member State level

Figure 25 shows how costs, namely support expenditures and additional generation costs, as well benefits from avoided fossil fuels and CO_2 emissions are distributed over the different Member States. Furthermore, capital expenditures are shown. Capex are counted as a neutral category, being neither costs nor benefits, as they do imply expenditures but also induce macro-economic added value. To better visualise the importance of the amount for the respective Member State, the values are displayed as share of the states' GDP. Again a range is shown over the different cooperation scenarios analysed.

Looking into **support expenditures**, one can see that spreads as well as shares vary over the different Member States. The highest share and at the same time biggest variation can be seen in Latvia, where between roughly 0.6 to 0.8% of the GDP would be needed in terms of support expenditures to achieve the 2020 goals envisaged by the commission. As can be seen in Figure 20, this is largely due to the fact that the Latvian GDP per capita is comparatively low whereas the required deployment of new RES is comparatively large (cf. Figure 21). Thus, this shows that especially the lower income Member States partly face relatively high expenditures in direct comparison. Most of the other Member States range in the area of 0.1 to 0.2% of their GDP in this cost category. These values can be quite diverging when looking at the respective absolute values of GDP. While e.g. Cyprus and Sweden exhibit the same relative share in support costs, Sweden's GDP per capita is nearly double the Cyprian. This benchmark has to be kept in mind when interpreting all relative values depicted in the following. The EU average lies close to 0.2% of GDP.

Additional generation costs have a more diverse distribution in the share of GDP of the respective member states, whereas the share is comparatively small in all countries Czech Republic exhibits the highest share in the given range, with around 0.12%. It is followed by Slovakia, Finland and Denmark which all have shares of around 0.06% of their GDP in additional generation costs. Countries with very low shares are e.g. Cyprus, Greece or the Netherlands with below 0.02%. The EU average lies at 0.04%.

The next category, **capital expenditures** taken on by the respective member states shows even more variation over the different states and at a much higher level – up to almost 1.6 % of GDP for some states as Latvia and Bulgaria. Outliers with quite low shares of their GDP (around 0.2%) in terms of capex are the UK, the Netherlands and Luxembourg. An average value over all 28 EU Member States lies around 0.54% of GDP. Austria, Belgium, Cyprus and Germany, for example can also be located in this area with their range over the different scenarios.

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fuel prices, a default case of moderate energy prices that reflects the price trends of the *PRIMES reference case* has been assumed, i.e. reflecting relatively low prices for fossil fuels.

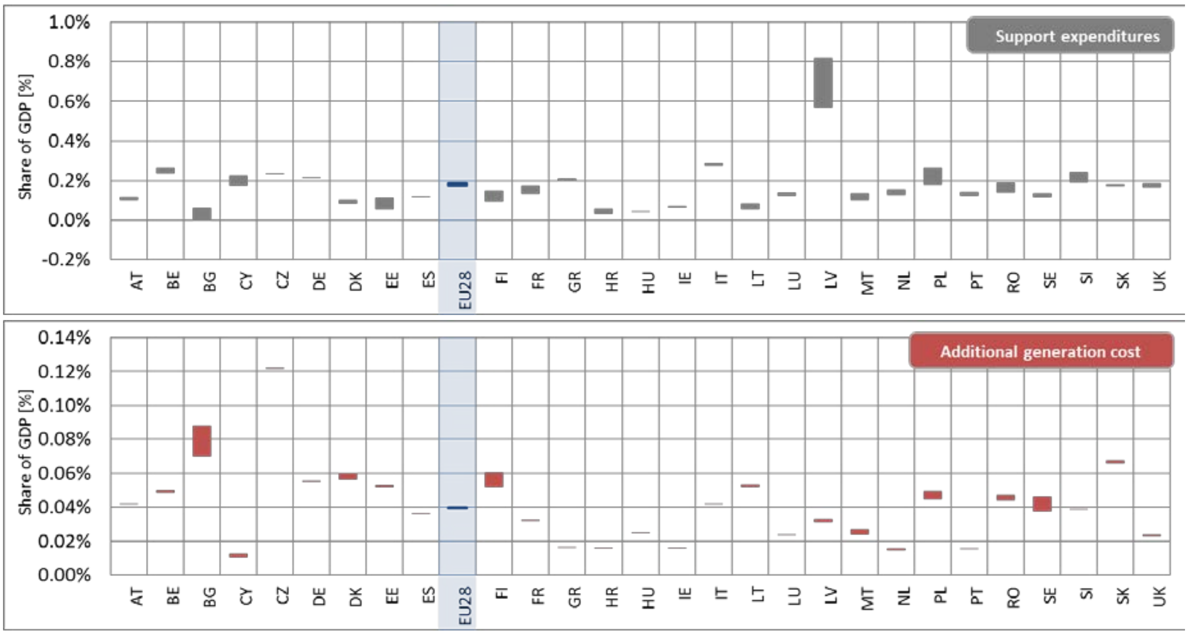

Figure 23: Range of average yearly values of costs for new RES installations (2011-2020)

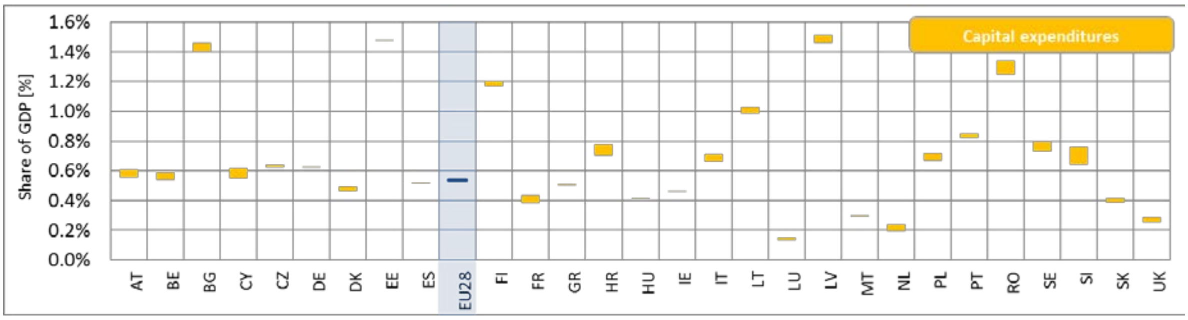

Figure 24: Range of average yearly values of capital expenditures for new RES installations (2011-2020)

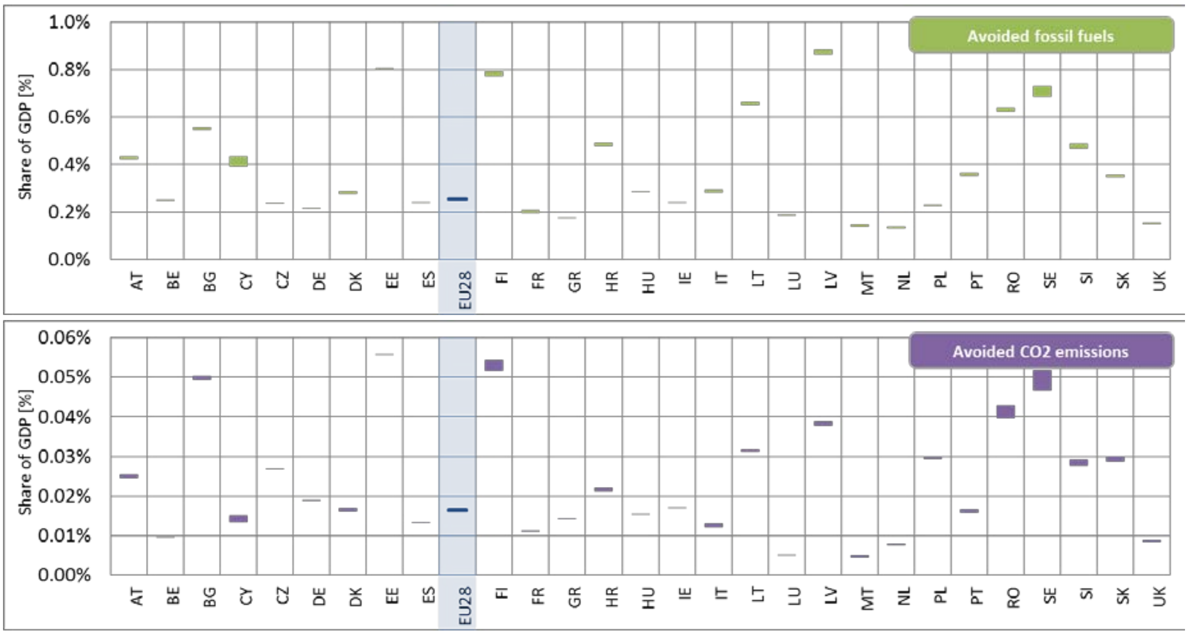

Figure 25: Range of average yearly values of benefits for new RES installations (2011-2020)

Looking into benefits from new RES installations, **avoided fossil fuels** is the first category that has been assessed. Member States that benefit the most in relative terms are Finland, Sweden and Latvia, saving around 0.8, 0.7 and 0.9% of their GDP. Countries that exhibit lower savings are the UK, the Netherlands and Malta – all three are below the threshold of 0.2% of GDP. The EU average lies at 0.26% of GDP.

Finally, savings can be quantified for the **avoided CO_2 emissions** in the different scenarios assessed. Again variation is quite large in the EU, whereas the share of GDP is significantly smaller than with avoided fossil fuels. Countries benefitting the most are Estonia, Sweden, Finland and Bulgaria – all smaller or equal 0.05% of their GDP. The EU average lies below 0.02% of the GDP in this case. An important point concerning savings in fossil fuels and avoided CO_2 emissions is that countries substituting more of their conventional power plants benefit relatively more in these categories.

A trend among Member States shows that overall, Eastern European and Baltic states face higher support expenditures but also benefit more in terms of avoided fossil fuels and CO_2 emissions. Countries that are already well on track with their target achievement do not observe substantial increases in neither category.

3.3 Costs and benefits of RES in the 2030 perspective

The outcomes of Green-X modelling related to capital, O&M, and fuel expenditures of RES as well as to additional generation costs, support expenditures and savings related to fossil fuel (imports) are presented in this section.

Thus, Figure 26 summarises the assessed costs, expenditures and benefits arising from future RES deployment in the focal period 2021 to 2030. More precisely, these graphs show the *additional*[22] investment needs, O&M and (biomass) fuel expenditures and the resulting costs – i.e. additional generation cost, and support expenditures for the selected cases (all on average per year throughout the assessed period). Moreover, they indicate the accompanying benefits in terms of supply security (avoided fossil fuels expressed in monetary terms – with impact on a country's trade balance) and climate protection (avoided CO_2 emissions –expressed in monetary terms as avoided expenses for emission allowances).

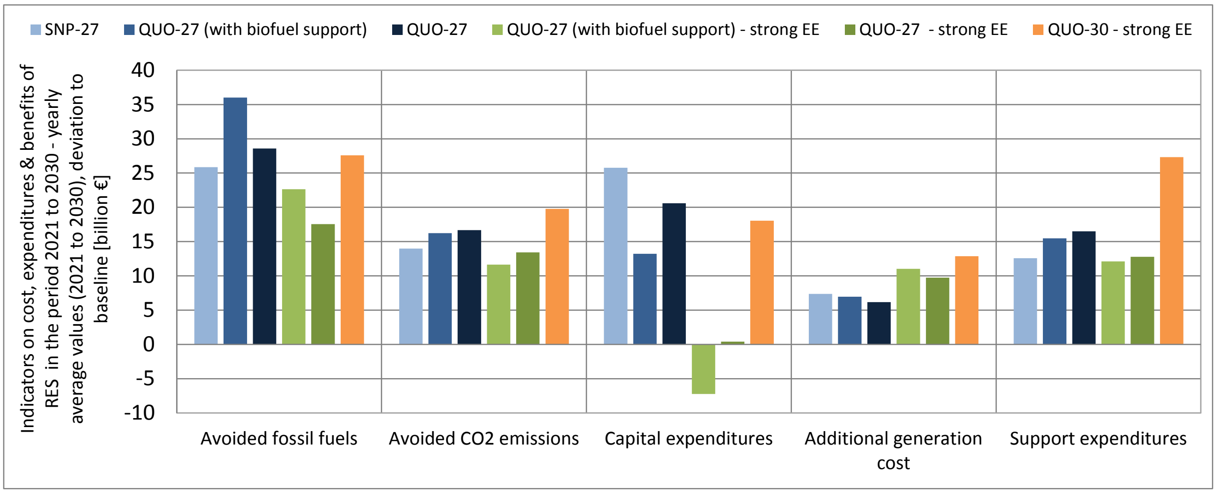

Figure 26: Indicators on yearly average cost, expenditures and benefits of RES at EU 28 level for all assessed cases, monetary expressed in absolute terms (billion €) per decade (2021 to 2030)

Some key observations can be made from Figure 26:

- Not so surprisingly scenarios that reach a 27% target lead to overall costs in a comparable order of magnitude. Also it can be observed that a 27% Quota generally leads to lower capital expenditures / additional generation costs compared to the case of national policies, however these savings hardly can be passed on to consumers due to the marginal technology determining the price for all technologies.

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

- Moving from a 27% to a 30% target comes at a cost, in this case average yearly support expenditures would almost double to a level of 27 billion Euros in order to “achieve” the last three percentage points of RES deployment.
- These extra costs however are also mirrored by increasing benefits. In all scenarios average yearly capital expenditures are surpassed by the monetary value of avoided fossil fuels. In other words: Fuels cost savings of conventional plants alone are sufficient to finance the capital costs of new RES installations.
- Furthermore when interpreting the numbers it has to be kept in mind that all scenarios assume a reference case with respect to energy demand development. Thus efficiency improvements could make a 30% target much more easily achievable.

3.4 Case studies: Insights at country level on costs and benefits

The following three case studies provide insights into how costs and benefits develop in the different scenarios at the country level. We zoom in on three different markets with a wide geographical spread. Specifically, Italy, Belgium and France are shown and their specific developments analyzed.

3.4.1 Italy

3.4.1.1 Country Profile Italy

By a referendum in 1987 Italy rejected the use of nuclear energy (wikipedia, 2016). Since Italy barely commands any own resources it is heavily dependent on imports from countries like France, Switzerland and Slovenia, whose energy mixes paradoxically include a significant share of nuclear power. General electricity prices for end consumers have been above the EU-average mainly because of the fact that new RES deployment has to be supported by grid cost and taxes (Deloitte, 2015).

The gross inland energy consumption decreased from 2012 to 2014 by approximately 15 Mtoe (9%) (Eurostat 1. , 2015). Looking at Eurostat data one can see that since 2000 there is a downward trend in energy consumption for all sectors (excluding the service sector) (Eurostat 2. , 2015) (Deloitte, 2015).

Table 5: Gross inland energy consumption by fuel type in Italy. Source: (Eurostat 1. , 2015)

Indicators (Mtoe)	**Year 2012**	**Year 2014**
Total	165,683	151,027
solid fuels	15,723	13,067
petroleum products	59,892	55,825
gas	61,356	50,706
nuclear	0	0
renewable	23,874	26,512
waste (non-renewable)	1,132	1,158

Italy's gross inland energy consumption in 2014 is mainly dominated by petroleum products (38%) and gas (34%), followed by renewables (16%) and solid fuels (9%). Nuclear power, as mentioned before, is not in use.

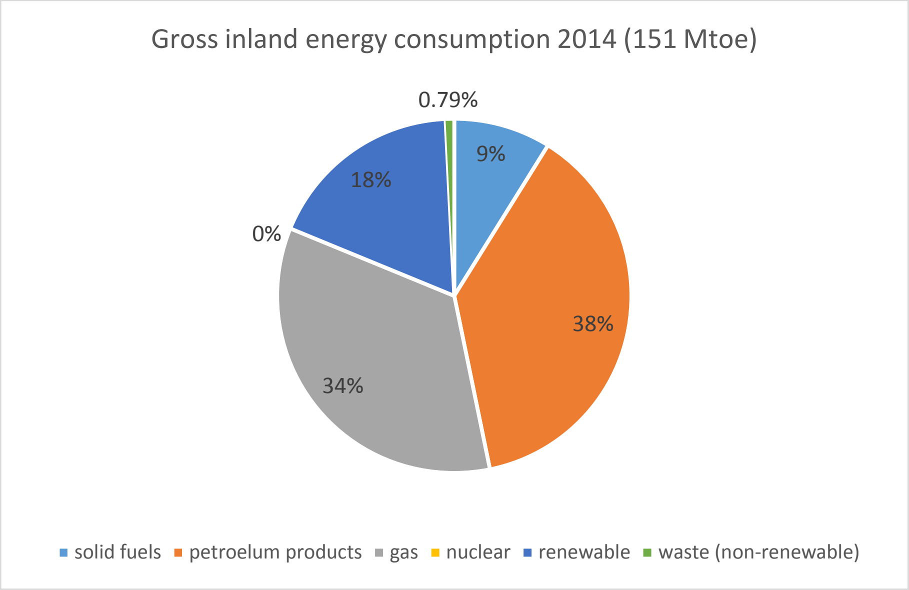

Figure 27: Italy's gross inland energy consumption in 2014. Source: based on (Eurostat 1. , 2015)

"In 2013, in terms of installed power, net efficient power generation reached 124,750 MW" (Terna, 2013). Italy's electricity net generation from 2013 is depicted in Figure 32. One can see that more than 66% of the net electricity generation is generated by thermal plants (gas turbine plants, combined cycle plants, coal fired thermal power plants etc.) and around 32% are generated by renewables (where hydro power plants make up around 60% of its total renewable production) (Terna, 2013).

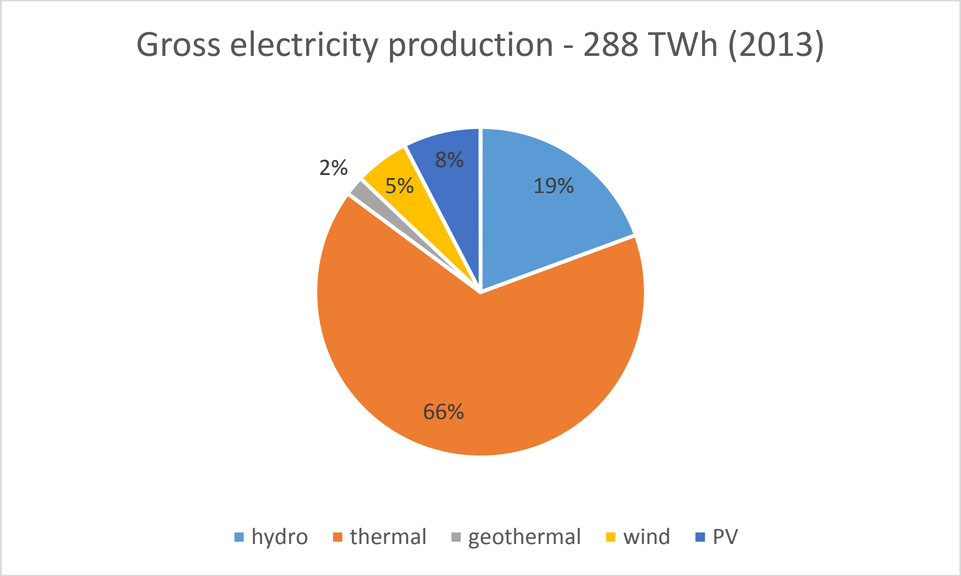

Figure 28: Electricity net generation in 2013 (288 TWh). Source: based on (Terna, 2013)

In 2013 the following objectives were set by the SEN (Senate of the Republic Italy) regarding the Italian energy sector by 2020:

- The reduction of energy costs by aligning prices to European average prices
- To meet and overachieve the EU's 2020 targets and Italy's National Action Plan of June 2010 (NAP).
- To improve supply security, by reducing foreign dependency from 84% to 67% of total energy needs.
- To boost growth and employment by investing 170-180 billion by 2020, either in conventional or renewable technologies

(Deloitte, 2015) (SEN, 2013).

Concerning the "20-20-20" targets by the European Commission, the following goals were set:

- A reduction of GHG emissions by 18% compared to 2005.
- Energy savings amounting to 15,5 Mtoe of annual final energy consumption between 2011 and 2020.
- A 17% share of renewable energy in final gross consumption.

(Deloitte, 2015) (European Parliament, 2009)

3.4.1.2 Cost and benefit analysis Italy

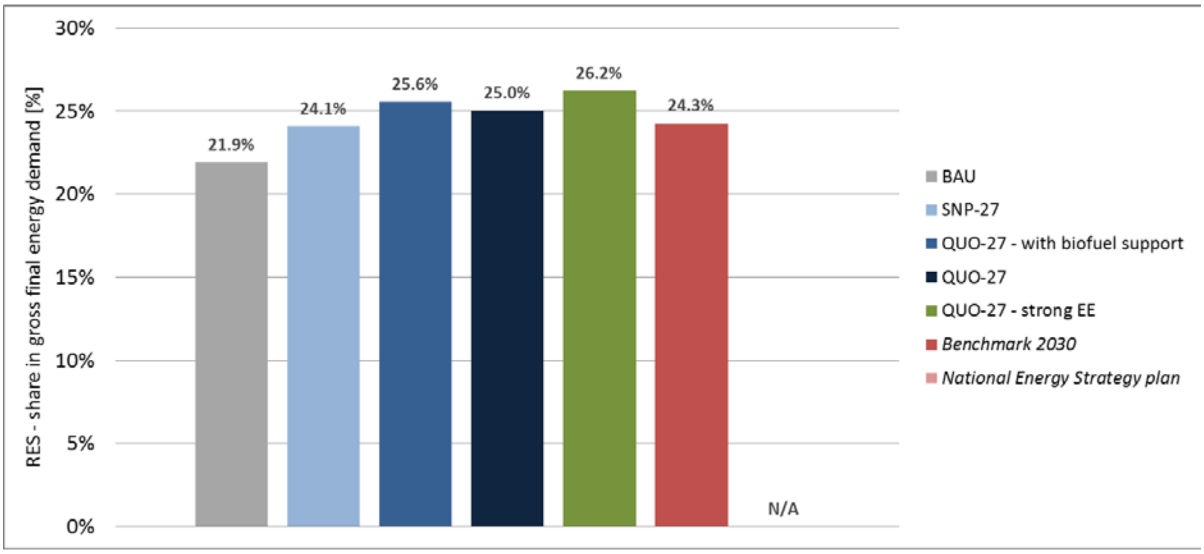

Figure 29: Comparison of the resulting RES deployment in relative terms (i.e. as share in gross final energy demand) for the year 2030 in Italy, for all assessed cases (incl. Benchmark 2030 and NESP.

Figure 33 clearly shows that, in the BAU scenario, additional efforts would be needed to reach the Benchmark 2030 RES share in gross final energy demand. The SNP scenario would have a slightly lower RES share than the benchmark 2030 scenario, whereas all QUO-27 scenarios would overachieve the target envisaged.

In the BAU scenario the total RES share in gross final energy demand would reach 21.9%, while the other scenarios show a range between 24.1% and 26.2% of the share of renewables in gross final energy demand. The highest share, amounting to 26.2%, could be reached in the QUO-27 energy efficiency scenario. The notably higher RES share in all QUO-27 cases, compared to the SNP scenario, indicates cheap potentials for deployment of renewables in Italy. Under a harmonized EU-wide quota system, more RES capacity would be installed in Italy, decreasing the share other Member states with lower potentials.

The Italian government has not published a strategy plan for 2030 thus far. Therefore, no specific RES share for the National energy strategy plan is depicted in Figure 33.

Figure 34 depicts the assessed cost, expenditures and benefits for Italy arising from future RES deployment in the focal period 2021 to 2030 according to the assessed scenarios. Precisely the additional (difference to BAU) investments are shown, costs and benefits arising in the respective scenario.

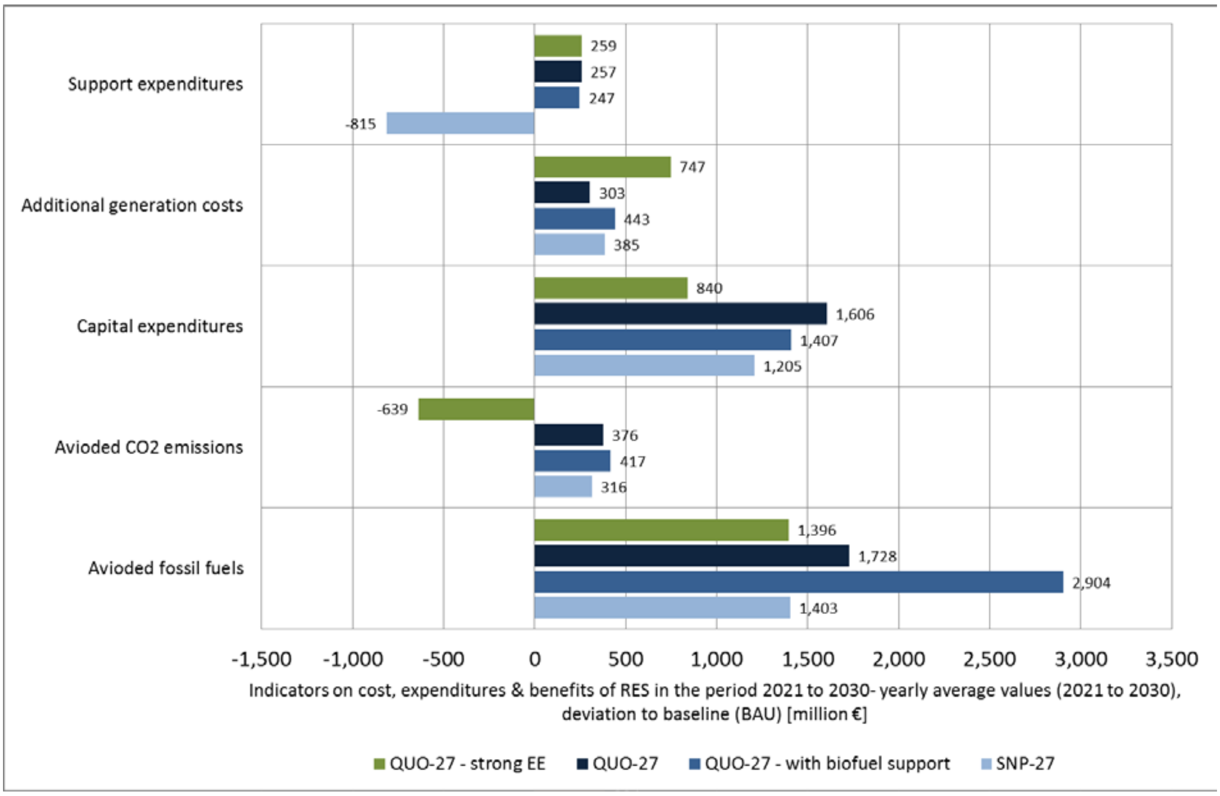

Figure 30: Indicators on yearly average cost, capital expenditures and benefits of RES in Italy for four assessed scenarios, monetary expression in absolute terms (million €) per decade (2021-2030)

- In the SNP scenario case, Italy would reach a relatively high RES share in gross final energy demand compared to the BAU scenario. It is also clearly visible that compared to all the other scenarios, the SNP scenario would be a "cheap" scenario regarding costs. First of all, support expenditures would be the lowest. Due to reduced non-economic barriers, the support expenditures would be 815Mio. € lower compared to the BAU scenario. Around 0.34% of Italy's GDP would be required to cover the yearly total support expenditures which amount to 6,221 Mio. €, whereas in the BAU scenario 0.38% of GDP would needed. Moreover the additional generation costs and capital expenditures are the second lowest in this scenario. They amount to 385 Mio. € and 1,205 Mio. € respectively in addition to the BAU scenario.

Yearly additional generation costs and capital expenditures would require 0.23% and respectively 0.29% of Italy's GDP (the EU average amounts to 0.16% and 0.46% of GDP). If Italy chooses to strengthen its national policy, it would produce more electricity with wind onshore and through the use of biomass. Regarding benefits, the amount of avoided CO_2 emissions and the avoided fossil fuels would be the lowest of all scenarios, due to the relatively small RES share in gross final energy demand, namely 24.1%. The savings would amount to 316Mio. € and 1,403Mio. € respectively (additionally to the BAU scenario).

- All QUO-27 scenarios show a higher RES share in gross final energy demand, compared to the SNP scenario. Therefore, higher costs, but also benefits can be expected. The support expenditures are 17% higher than in the SNP scenario. A relatively high percentage of GDP (0.40%) would be required to cover the yearly total support expenditures (the EU average in terms of the share of GDP amounts to 0.30%). The additional generation costs and the capital expenditures are 1% or 4% higher than in the SNP scenario. Regarding benefits, significant changes are visible. They are the highest among all assessed scenarios. Avoided CO_2 emissions and avoided fossil fuels lead to increases of 417Mio. € and 2,904Mio. € respectively compared to the BAU scenario, and of 5 and 10% compared to the SNP scenario. In general all QUO-27 scenarios exhibit higher costs, but also higher benefits compared to the SNP scenario.

- In the QUO-27 scenario, where biofuel is not supported, no notable change regarding support expenditures is visible. While the additional generation costs decrease by 3% (compared to QUO-27 scenario), we can observe the highest capital expenditures. “No biofuel support” implies an additional uptake of RES deployment in other sectors, which leads to higher costs (e.g. capital expenditures). The total capital expenditures amount to 5,725 Mio. € but would require only 0.3% of the Italian GDP which is lower than the EU average. Due to the lower RES share in gross final energy demand, the benefits are also lower. Avoided CO_2 emissions and avoided fossil fuels, decrease by 2 and 7% respectively (in comparison to the default QUO-27 scenario).

- In case of energy efficiency, in cases of overall lower energy demand, lower costs and benefits are clearly visible. The capital expenditures are the smallest, compared to all the other scenarios. The yearly total costs amount to 4,960 Mio. € and would require only 0.27% of the GDP, whereas the EU average amounts to 0.30%. The yearly total support expenditures are more or less the same as in the other scenarios and represent a GDP share of around 0.4% (the EU average amounts to 0.28%). The higher additional generation costs (in comparison to the other scenarios), are caused by the lower reference price). Benefits regarding avoided CO_2 emissions and avoided fossil fuels are among the lowest of all assessed scenarios. Compared to the BAU scenario, 630 Mio. € less can be saved in terms of avoided CO_2 emissions. In contrast to that, the avoided fossil fuels show a monetary value, which is close to the monetary value that would be reached in the SNP scenario.

3.4.2 France

3.4.2.1 Country profile France

Since the 1970ies, due to little coal and oil resources France's energy mix is mainly dominated by nuclear power (France has the largest share of nuclear energy in their energy mix worldwide). Following Germany, France has the second largest electricity generation capacity and acts as a net exporter of base-load electricity (e.g. to Italy, UK, Switzerland, Belgium, Spain) but still is short of peak capacity (World Nuclear Assosication, 2016). Nevertheless France has to start lowering its nuclear share and restructure its future energy mix, since a gradual phase out of nuclear energy is planned for the upcoming years (Deloitte, 2015).

Gross inland energy consumption decreased from 2012 to 2014 by approximately 9 Mtoe (3,6%) (Eurostat 1. , 2015). Looking at Eurostat data, one can see that the decrease can be mainly associated to the industrial and service sectors (Eurostat 2. , 2015).

Table 6: Gross inland energy consumption by fuel type in France. Source: (Eurostat 1. , 2015)

Indicators (Mtoe)	Year 2012	Year 2014
Total	257,793	248,498
solid fuels	11,472	9,290
petroleum products	80,323	77,240
gas	38,220	32,597
nuclear	109,735	112,590
renewable	20,617	21,317
waste (non-renewable)	1,253	1,241

In Figure 18 France's gross inland energy consumption and its mix in 2014 is depicted. One can see that nuclear energy (44%) dominates, followed by petroleum products (30%), gas (13%), renewables (8%) and solid fuels (4%).

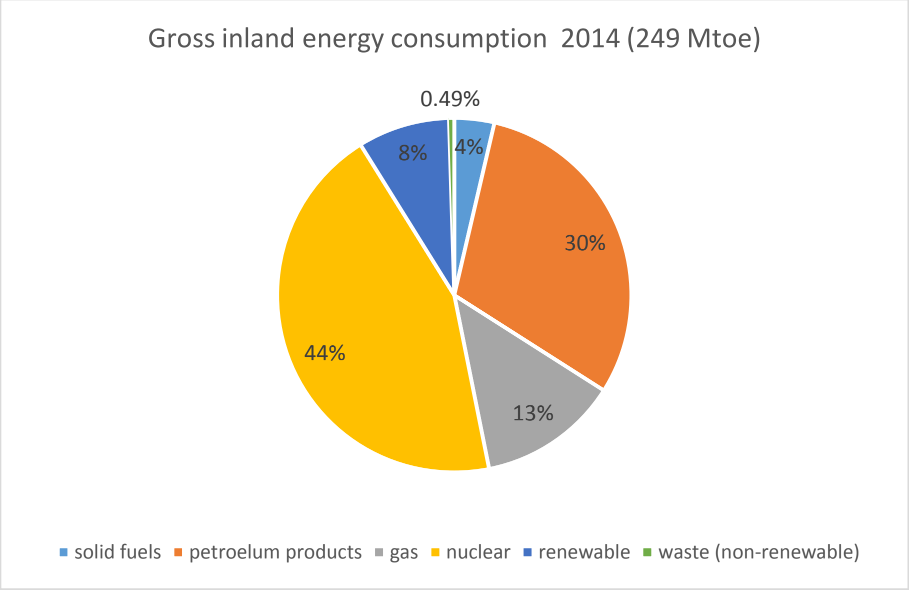

Figure 31: France's gross inland energy consumption in 2014. Source: based on (Eurostat 1. , 2015)

A study by Deloitte has assessed France's electricity system in terms of both electricity capacity and net generation in 2013. 49% (in total 63 GW) of capacity consisted of nuclear energy but delivered 73% (in total amount 404 TWh) of the power 76 TWh of the total 103 TWh, which are generated by renewables, come from hydro power. Solar and wind make only a small contribution to the electricity generation (3% and 1% of total generation) (Deloitte, 2015) (RTE, Réseau de transport d'électricité, 2013).

In July of 2015 the national assembly passed the law on energy transition for green growth in the law gazette 'Journal officiel' which was validated in the following month. The law specifies a binding roadmap for the future energy policy of France:

- A 40% reduction of greenhouse gas emissions until 2030 and 75% reduction until 2050 (both in comparison with 1990 levels).
- A 23% share of renewables in the final energy consumption until 2020 and 32% until 2030.
- A 50% reduction in the share of nuclear energy in electricity generation until 2025.
- A reduction of primary energy consumption from fossil fuels by 30% (between 2012 until 2030).
- A reduction of final energy consumption by 50% (2012 until 2050).

(Deloitte, 2015) (legifrance, 2015) (Frankreich in Deutschland - Französische Botschaft, 2015).

3.4.2.2 Cost and benefit analysis France

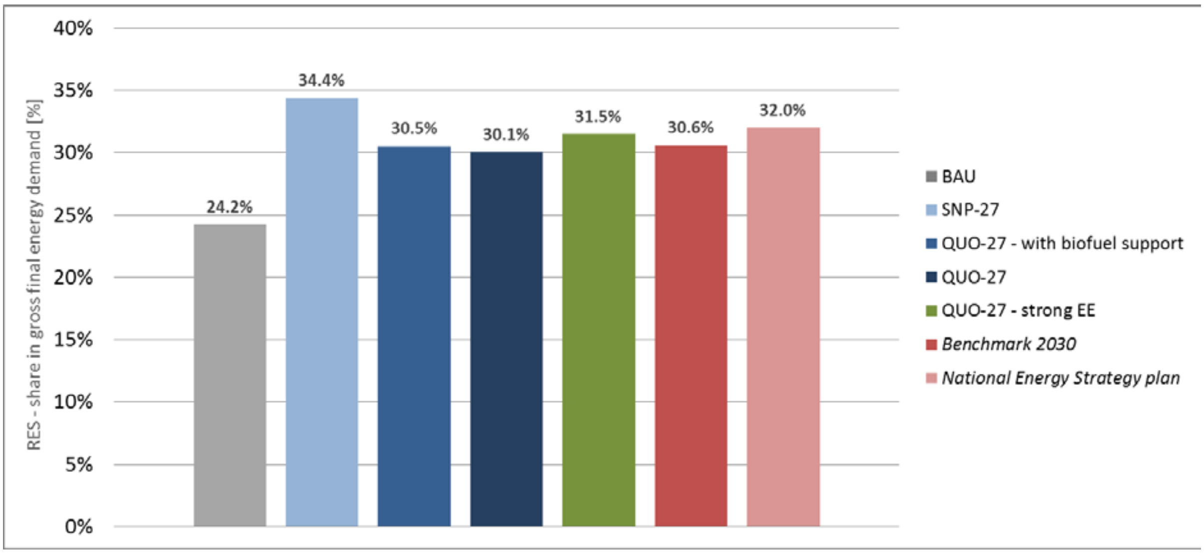

Figure 32: Comparison of the resulting RES deployment in relative terms (i.e. as share in gross final energy demand) for the year 2030 in France, for all assessed cases (incl. Benchmark 2030 and NESP)

In the BAU scenario, which assumes the phase out of the currently implemented support instruments after 2020, a RES share of 24.2% is expected for the year 2030. Additional efforts will be needed to reach the goals outlined in France's National energy strategy plan (NESP) which aims for a 32% RES share in gross final energy demand by 2030.

Evidently, France has ambitious plans for the future. The NESP, which amounts to 32.0% RES share in gross final energy demand, is higher than the calculated benchmark for 2030, which amounts to 30.6%. Additionally all the QUO-27 scenarios, which show a RES share in the range of 30.1% to 31.5%, will be more or less in line with the benchmark for 2030. Only the SNP scenario, with a share of 34.4% in gross final energy demand, will be higher than France's ambitious NESP. It can be seen that the higher RES share in the SNP case, compared to the QUO-27 scenarios, indicates comparably expensive potentials of RES in France. Under the harmonized European quota scheme, RES deployment would be reduced in France, but therefore increased in other European Member States, where the deployment of RES is comparatively cheaper.

Figure 21 depicts assessed costs, expenditures and benefits for France arising from future RES deployment in the focal period 2021 to 2030 according to the assessed scenarios. More accurately it shows the additional (the difference to the BAU scenario) investments, costs and benefits arising in the respective scenario.

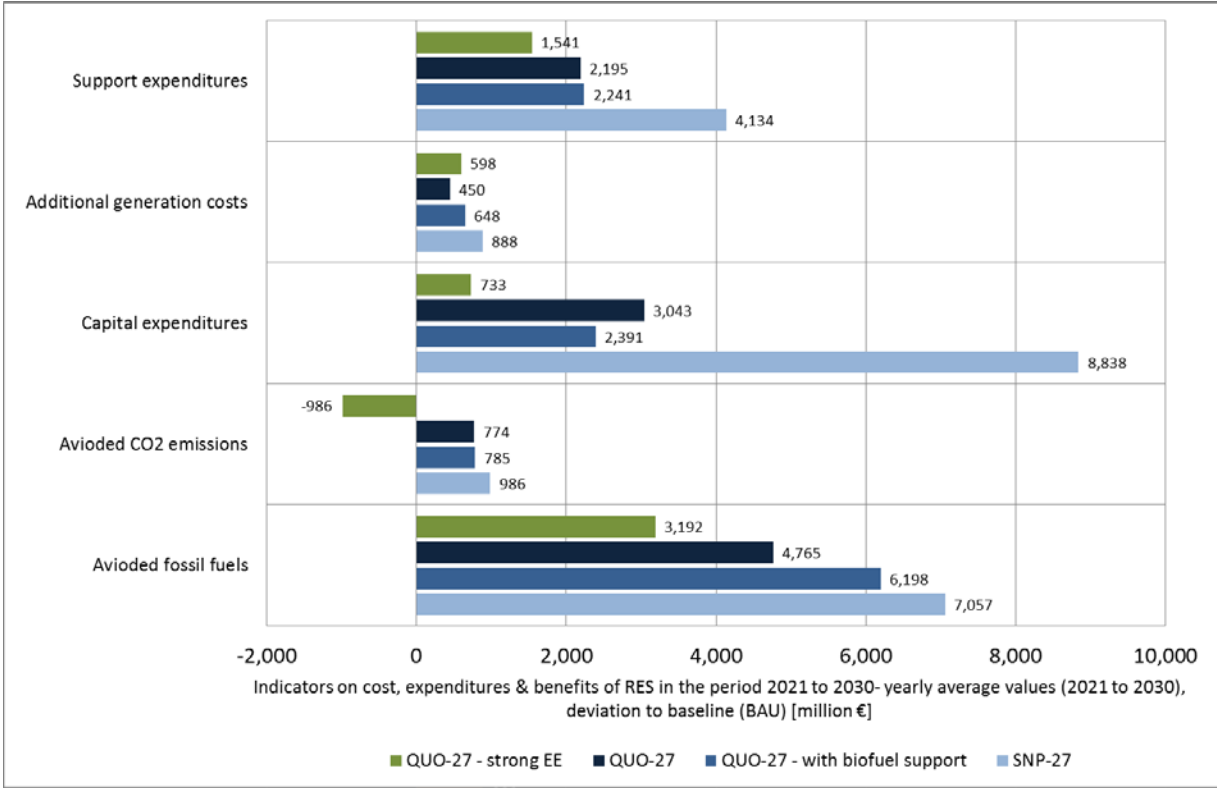

Figure 33: Indicators on yearly average cost, capital expenditures and benefits of RES in France for four assessed scenarios, monetary expression in absolute terms (million €) per decade (2021-2030)

Some key observations can be made from Figure 21:

- The SNP scenario clearly sticks out as the most expensive scenario, regarding cost, but also the benefits are the highest, compared to all the other assessed scenarios. Due to the significant higher RES share in gross final energy demand, it has the highest capital expenditures, support expenditures and additional generation costs, which amount to an additional 8,838 Mio. €, 4,134 Mio. € and 888 Mio. € per year respectively, compared to the BAU scenario. Regarding the total yearly capital expenditures of 15,061 Mio. €, 0.6% of the GDP is required to cover these costs, where the EU average amounts to only 0.46%. In this scenario more photovoltaic plants and heat pumps would be deployed in the electricity sector compared to the other scenarios.

  In the SNP scenario which has the highest RES share in gross final energy demand (even higher than the NESP), 130 TWh (from new installations[23]) RES-E would be generated by the year 2030, while in the BAU scenario, only 62 TWh would be generated (this means an increase by 109%). The key technologies which would increase the electricity production are photovoltaic power plants and offshore wind. The total installed hydropower capacity will only have a marginal

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[23] New installations after 2020

change in future deployment, and hydro power production will stay relatively stable in all scenarios. If France were to replace some of its nuclear power plants (which will reach their end of useful live between 2020 and 2035) with RES technologies, the additional generation from RES could help France, to keep its status as a net electricity exporter in the future while keeping their GHG emissions low.

- In the QUO 27 scenario costs as well as benefits are lower than in the SNP scenario. Support expenditures, additional generation costs and capital expenditures decrease by 28%, 14% and 43% respectively, compared to the SNP scenario, whereas benefits regarding avoided fossil fuels and CO_2 emissions only fall by 3% and 5%. Compared to the BAU scenario, an additional 2,391 Mio. € would be spent regarding capital expenditures. In total, the capital expenditures would amount to 8,615 Mio. € and represent 0.34% of France's GDP, which is slightly below the EU average (0.38% share of GDP). Under this harmonized EU-wide quota system, RES power plants would be built in the countries with the cheapest potentials across all of Europe, and therefore only 116 TWh (11% less than in the SNP scenario) would be produced from new RES-installations[24] in France by 2030 (less photovoltaic power plants and wind offshore would be deployed compared to the SNP scenario). Under a QUO-27 scenario, the neighboring country Spain would instead generate more electricity from renewables.. Quota scenarios in combination with a future phase out of nuclear power would change France's electricity system to have less generation surplus in the electricity sector compared to the SNP scenario.

- In the scenario QUO-27 without biofuel support, support expenditures do not change in a noteworthy manner, compared to the scenario where biofuel is supported. Due to a slight increase of the RES share in gross final energy demand, capital expenditures increase by 8%, whereas additional generation decreases by 13%. The total capital expenditures, which amount to an annual 9,267 Mio. €, represent 0.37% of the country's GDP, which is less than the EU average (approximately 0.43%). While no further benefits can be stated regarding avoided CO_2 emissions, the avoided fossil fuels would decrease by 5%, compared to the QUO scenario where biofuel is supported.

- Energy efficiency would lead to a lower energy demand than in all other assessed cases. Obviously the capital expenditures and support expenditures are the smallest, compared to the other scenarios and make up respectively 733 Mio. € and 1,541 Mio. € (in addition to the BAU scenario). Concerning avoided expenses for CO_2 emission allowances, 986 Mio. € can be saved annually, compared to the BAU scenario due to a relatively high RES share in gross final energy demand. The additional generation costs are higher than in the scenario without complementary energy efficiency measures to reduce overall energy demand (growth). When

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[24] New installations after 2020

assessing costs and benefits, policy makers should compare the reduced support costs of the energy efficiency scenario with potential costs to reach these energy savings.

3.4.3 Belgium

3.4.3.1 Country profile Belgium

After the last coal mine has been closed in Belgium in 1992, Belgium became heavily dependent on fossil fuel imports. This dependency includes the electricity sector (Belgium is a net importer of electricity mainly from France and the Netherlands). The future phase out of nuclear power (which is planned between 2015 and 2025) in combination with dependency on gas consumption will create new challenges Belgium has to deal with regarding security of supply (Deloitte, 2015).

Belgium's gross inland energy consumption decreased from 2012 to 2014 by approximately by 1,2 Mtoe (2,3%) (Eurostat 1. , 2015). Looking at the gross inland energy consumption by sector, one can identify slight decreases in the transport and residential area. (Eurostat 2. , 2015)

Table 7: Gross inland energy consumption by fuel type in Belgium. Source: (Eurostat 1. , 2015)

Indicators (Mtoe)	Year 2012	Year 2014
Total	54,646	53,367
solid fuels	3,260	3,290
petroleum products	21,707	23,249
gas	14,366	12,599
nuclear	10,394	8,694
renewable	3,352	3,357
waste (non-renewable)	712	664

Figure 22 shows the total gross inland energy consumption of Belgium, which amounted to 54 Mtoe in 2014. Around three quarters came from fossil fuels. To be more precise, 45% were covered by petroleum products, 24 % by gas and 6% by solid fuels. Nuclear power plants made up 17% of the mix. Only 6% of Belgium's gross inland energy consumption stems from renewable sources.

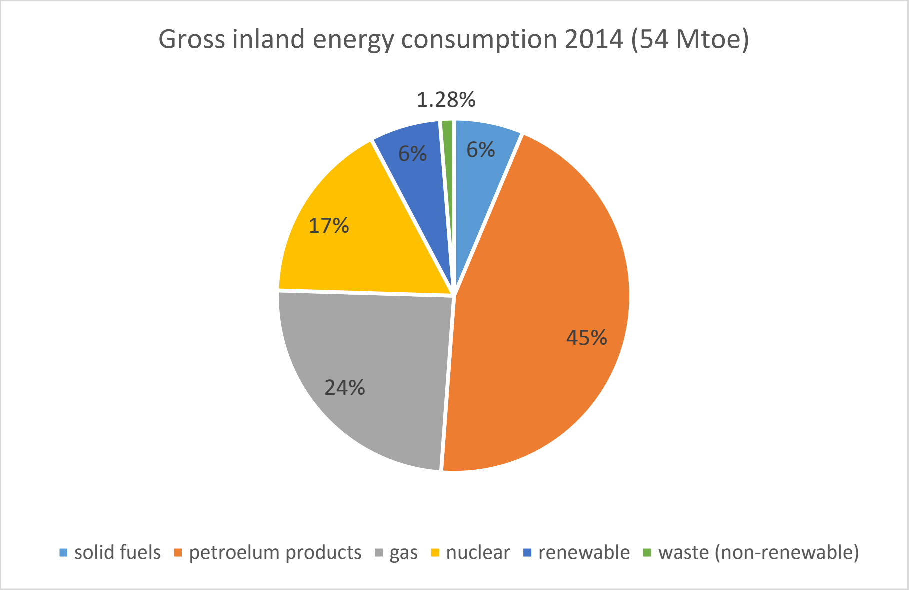

Figure 34: Belgium's gross inland energy consumption in 2014. Source: based on (Eurostat 1. , 2015)

Belgium's electricity system in 2013 depended on nuclear and gas as the main sources. 6 GW (or 29% of the total electrical installed capacity) are nuclear power and delivered 42.6 TWh or 57% of total electricity in 2013. With 4.3 GW (or 21% of the total installed capacity), gas delivered around 23TWh or 29% of the total electricity in 2013. While renewables represent 34% of installed capacity, they only deliver 7% to the total electricity (12.9 TWh). Photovoltaics make up 13% of the total renewable capacity but only contribute with less than 1% to electricity generation (Deloitte, 2015).

In 2009, targets regarding energy and climate in Belgium were set by the National Climate Plan. These targets were verified and updated in the 2014 National Reform Plan and include:

- Reducing primary energy consumption by 18% by 2020 (compared to a BAU projected scenario for 2020 calculated by the European energy model PRIMES 2007).
- A 13% RES share of gross final energy consumption by 2020.
- A 21% reduction of GHG emissions by 2020 compared to 2005 (in the ETS sector).
- A 15% reduction of GHG emissions by 2020 compared to 2005 (in the non ETS-sector).

(Deloitte, 2015).

3.4.3.2 Cost and benefit analysis Belgium

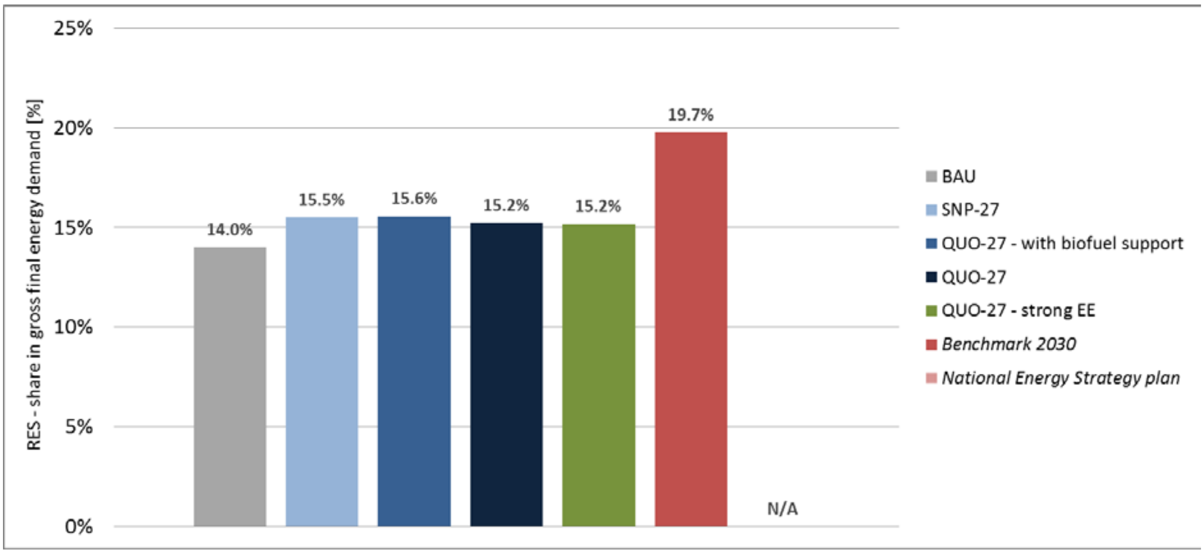

Figure 35: Comparison of the resulting RES deployment in relative terms (i.e. as share in gross final energy demand) for the year 2030 in Belgium, for all assessed cases (incl. Benchmark 2030 and NESP)

Figure 24 depicts that the RES share in gross final energy demand in all scenarios will be far under the calculated benchmark for 2030. While the BAU scenario will reach 14% (only one percentage point higher than the national 2020 target) of renewables in gross final energy demand by the year 2030, the other scenarios will be slightly higher, but still significantly below the benchmark 2030.

The highest share, namely 15.6%, can be reached in the QUO-27 scenario, followed by the SNP scenario, with a share of 15.5% in gross final energy demand. The quota scenarios, where biofuel will not be supported, as well as the energy efficiency scenario reach a share of 15.2%. Even though different support policies and framework conditions are assessed these scenarios, their RES share in gross final energy demand is subject to only minimal variations +/- 0.3%. For Belgium it does not matter much regarding their future RES share in gross final energy demand, whether the support system has a more national or European policy orientation. Belgium’s government still did not publish a strategy plan for 2030, and therefore no specific RES share for the National energy strategy plan is presented in Figure 24.

Figure 25 depicts the assessed costs, expenditures and benefits for Belgium arising from future RES deployment in the focal period 2021 to 2030 according to the assessed scenarios. More accurately it shows the additional (difference to BAU) investments, costs and benefits arising in the respective scenarios.

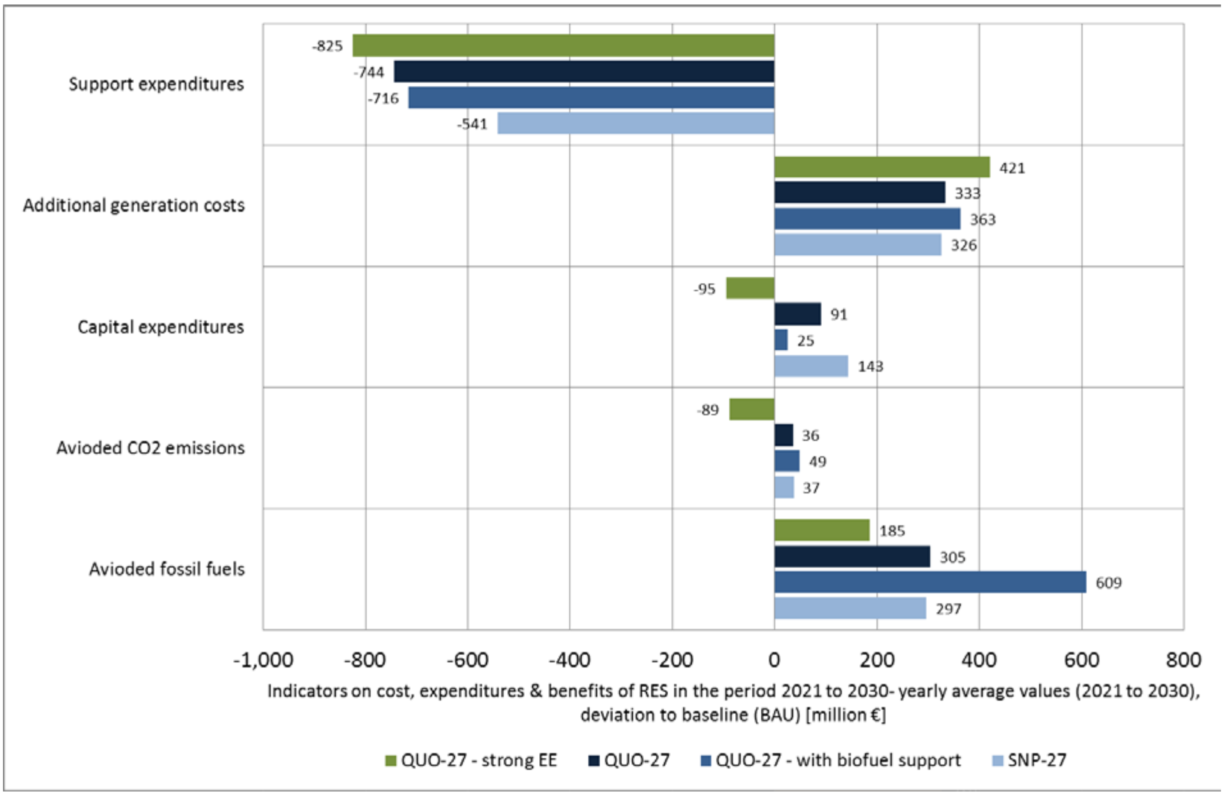

Figure 36: Indicators on yearly average cost, capital expenditures and benefits of RES in France for four assessed scenarios, monetary expression in absolute terms (million €) per decade (2021-2030)

Some key observations can be made from Figure 25:

- In the SNP scenario the highest capital expenditures can be seen, compared to all assessed scenarios. Each year in total 14,187 Mio. € expenditures would be needed. However, this amount makes up only 0.19% of the country's GDP, whereas the EU average amounts to 0.46%. Due to Belgium's high population density, the potential of wind onshore is limited and offshore wind offers the highest potentials among the different RES technologies. However, the key technology which would show the biggest impact when changing from BAU to the SNP scenario is heat pumps. The newly installed average capacity would change from 0.24 GW to 1.1 GW. The other technologies would be more or less in the same range in all assessed scenarios. Savings regarding support expenditures can be stated and they amount to 541 Mio. € less compared to the BAU scenario. Unlike the BAU scenario, all the other assessed scenarios imply a single energy market in Belgium, which implies lower support expenditures. In addition, these cost reductions stem from reduced non-economic barriers, which lower deployment costs of new RES installations (both in the SNP scenario and all QUO-27 scenarios). The additional generation costs would be 326 Mio. € higher compared to the BAU scenario. The total additional generation costs, which amount to 619 Mio. € each year, would represent a share of GDP which is in line with the EU average value. Due to a relatively low increase of RES deployment, compared to BAU, the avoided CO_2 emissions only increase by 15% and the avoided fossil fuels by 13%.

- The QUO-27 scenario shows lower capital expenditures than the SNP scenario, because expensive offshore wind capacity would be reduced by 10% while “cheaper” wind onshore would be increased by 6%. In this scenario, the capital expenditures would be even cheaper than the QUO-27 scenario, where biofuel is not supported. 716 Mio. € can be saved regarding support expenditures while 363 Mio. € additional generation costs incur, both in comparison to the costs of the BAU scenario. In the OUO-27 scenario the highest benefits would be reached, i.e.49 Mio. € - for avoided CO_2 emissions - and 609 Mio. € - for avoided fossil fuels – higher than in the BAU scenario. These slightly higher benefits are correlated with the slightly higher RES share in gross final energy demand. In comparison with all assessed QUO-27 scenarios, it can be stated that dedicated biofuel support - e.g. using biofuel in transport – generally leads to lower costs and higher benefits.

- Comparing the results of QUO 27 (without biofuel support), with the SNP scenario, it is clearly visible, that the same benefits can be reached, with different investment efforts. Significant savings are possible when moving from the SNP scenario, to the QUO 27 (no biofuel support) scenario. The capital expenditures, and support expenditures decrease by 6% and 19% respectively while the additional generation costs increase by only 1%. These savings come at a comparatively low cost. Only 0.18% and 0.20% of Belgium’s GDP is needed to cover the yearly total capital and support expenditures, while the EU average amounts to 0.43% and 0.31% respectively. Even though less investments would be needed, the benefits will remain the same as in the SNP scenario and amount to 36 Mio. € and 305 Mio. € (additional to the BAU scenario) regarding avoided CO_2 emissions and fossil fuels.

- Evidently the cheapest scenario regarding costs would be the QUO-27 scenario with increased energy efficiency, but also the benefits are relatively small. The lower demand in the energy efficiency scenario leads to less absolute RES generation to reach the same share in gross final energy consumption. It has the smallest support expenditures and capital expenditures. Compared to the BAU scenario, 82.5 Mio. € and 95 Mio. €, respectively could be saved per year. In comparison to the BAU scenario, benefits regarding CO_2 emissions become smaller, whereas more fossil fuels can be saved. Monetary savings decrease by 36% and increase by 8% respectively, compared to the BAU scenario. Since Belgium is a net importer of electricity, a higher share of RES deployment in combination with reduced energy consumption (i.e. higher energy efficiency) would induce fewer fossil fuel imports and positively impact the trade balance.

3.4.4 UK

3.4.4.1 Country profile UK

Large oil and gas resources in the North Sea, changed UK's import dependency from being an importer to a net exporter of energy from 1980 onward. In the late 90ies the production in the North Sea peaked, and afterwards UK resumed to being a net importer of energy again (for all main fuel types), but remains an exporter for petrol and fuel oil. After Estonia, Denmark, Romania, Poland, the Netherlands, Czech Republic, Sweden and Bulgaria, the UK had the ninth lowest import dependency in the EU in 2013. Driven by the European Renewables Directive in 2009, UK increased deployment of renewable energy sources in all three sectors. (Department of Energy & Climate Change, 2015)

As depicted in Table 3, the total gross inland energy consumption decreased from 2012 to 2014 by approximately 15 Mtoe (7%), which was mainly due a falling trend in the industrial sector (Eurostat 2. , 2015).

Table 8: Gross inland energy consumption by fuel type in UK. Source: (Eurostat 1. , 2015)

Indicators (Mtoe)	Year 2012	Year 2014
Total	203,984	189,340
solid fuels	38,808	29,939
petroleum products	69,905	68,628
gas	66,523	59,784
nuclear	18,161	16,444
renewable	8,816	12,108
waste (non-renewable)	750	673

Looking at UK's gross inland energy consumption and its mix in 2014, Figure 14 reveals that petroleum products (37%) are dominating, followed by natural gas (32%), solid fuels (16%), nuclear (9%) and renewables (6%).

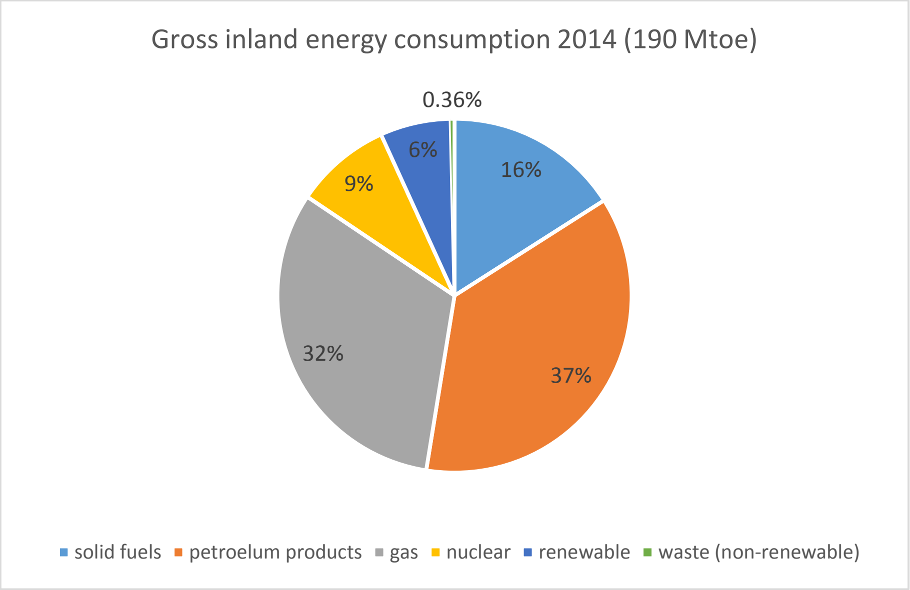

Figure 37: UK's gross inland energy consumption by fuel type in 2014. Source: based on (Eurostat 1. , 2015)

Taking a look at UK's electricity system one can observe that only a small percentage (17% or in total 16GW) of UK's electricity capacity consists of renewables. The biggest shares in UK electricity capacity are gas-fired generation (39% or in total 35GW) and coal (30% or in total 27 GW). Overall, around 73% of UK electricity capacity consist of fossil fuels and generate around 68% of the net electricity. Nuclear power plants contribute with around 19% to the net electricity generation. Additionally on the right hand side one can see that 12% of UK's net electricity generation stems from renewables (mainly from wind and solar), followed by fossil fuels (68%) and nuclear (19%) (Deloitte, 2015).

Regarding the 2020 goals, UK committed to the following binding targets:

- To save 18% of energy in reference to a 2007 business as usual scenario.
- To generate 15% of gross final energy consumption from renewable energy sources by 2020.
- A 21% reduction of GHG emissions by 2020 compared to 2005 (ETS sector).
- And a 16% reduction of GHG emissions by 2020 compared to 2005 (non ETS-sector).

(Deloitte, 2015).

For the year 2030 UK has not committed to any binding goals.

3.4.4.2 Cost and benefit analysis UK

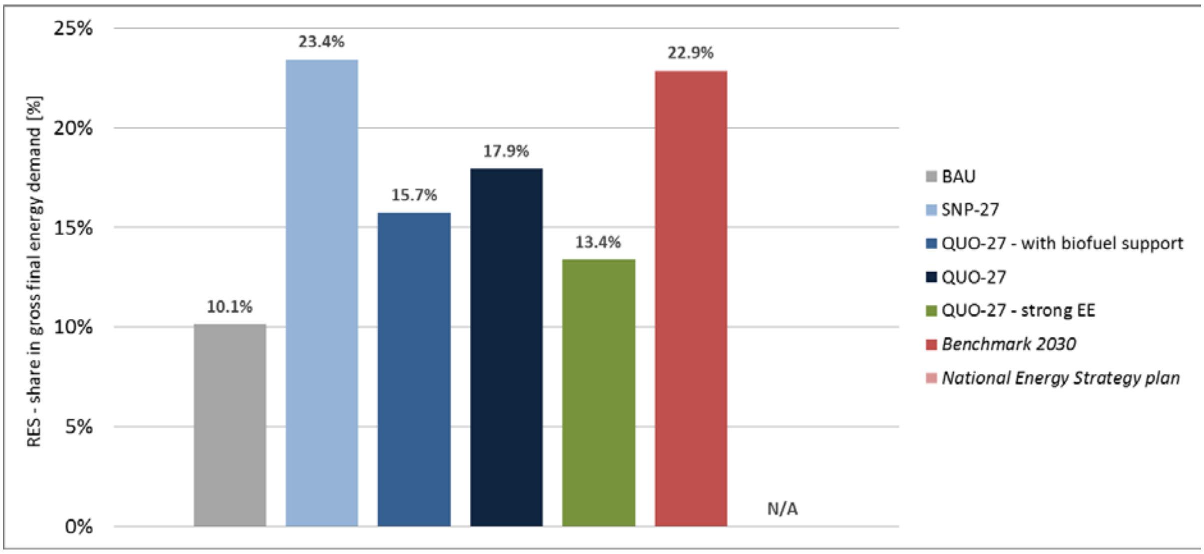

Figure 38: Comparison of the resulting RES deployment in relative terms (i.e. share in gross final energy demand) for the year 2030 in UK, for all assessed cases (incl. Benchmark 2030 and NESP)

Figure 16 clearly depicts that, in the BAU scenario, which assumes the gradual phase-out of the currently implemented support instruments after 2020, additional efforts would be needed in order to reach the envisaged Benchmark 2030 RES share in gross final energy demand. Only the SNP scenario shows a higher RES share than the calculated Benchmark 2030.

Comparing the results of all the assessed scenarios it shows that all alternative scenarios have a higher RES share in the year 2030 than the BAU scenario. While in the BAU scenario the total RES share in gross final energy demand is 10.1%, the other scenarios show a range between 13.4% and 23.4% of the RES share in gross final energy demand. The highest share, with 23.4%, can be reached in the SNP scenario. This notably high value, compared to the alternative QUO-27 scenarios, indicates that RES potentials in the UK are more expensive and less cost efficient than in the rest of the EU. The UK government has thus far not published any strategy plan for 2030, and therefore no specific RES share for the National energy strategy plan is presented in Figure 16.

Figure 17 depicts the assessed costs, expenditures and benefits for UK arising from future RES deployment in the focal period 2021 to 2030 according to the assessed scenarios. Precisely, it shows the additional investments, costs and benefits arising in the respective scenario (as a deviation from the BAU scenario).

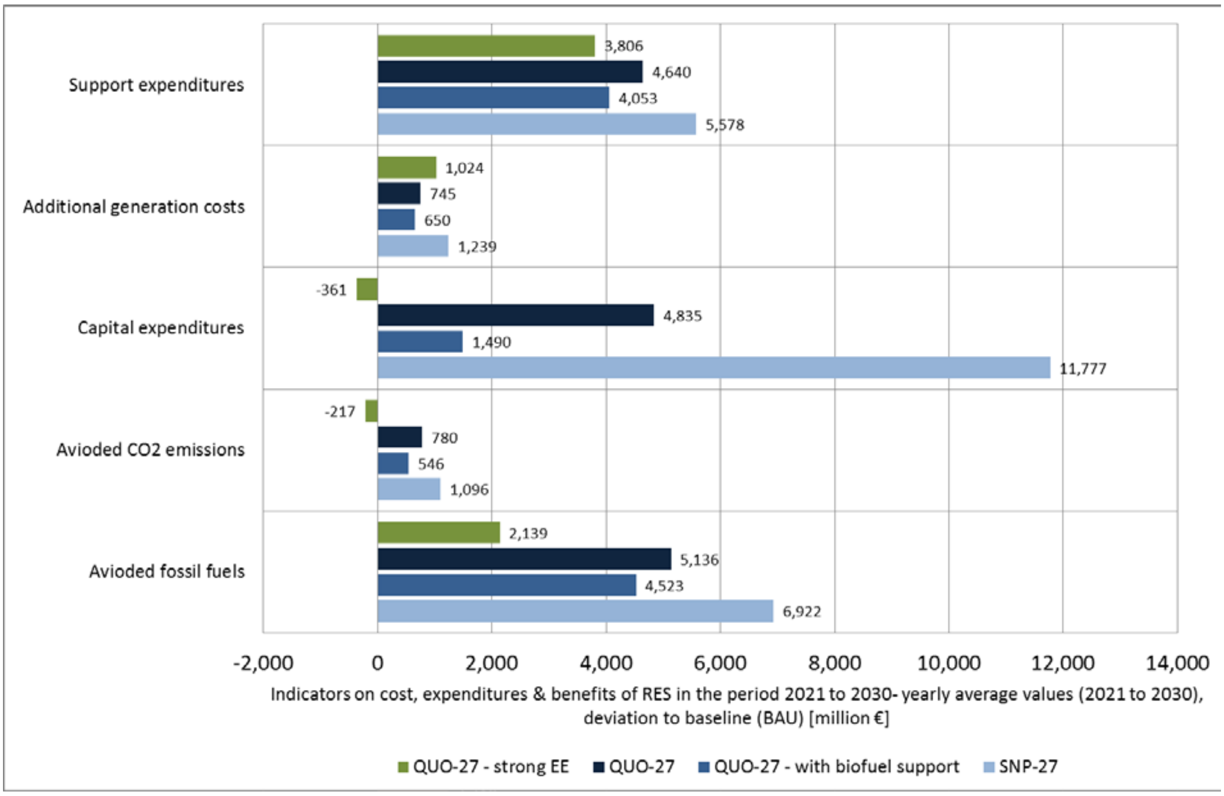

Figure 39: Indicators on yearly average cost, capital expenditures and benefits of RES in UK for four assessed scenarios, monetary expression in absolute terms (million €) per decade (2021-2030)

Some key observations can be made from Figure 17:

- In the SNP scenario, UK would reach the highest RES share in gross final energy demand. It is clearly visible that the SNP scenario is the most expensive scenario, regarding costs, but also the highest benefits are visible. Being a country with low and expensive potentials for RES deployment (e.g. little global radiation; landscape is densely populated for large deployment of wind onshore) a national policy scheme would lead to the highest costs. The SNP scenario has the highest support expenditures as well as additional generation costs and capital expenditures with 5,578 Mio. €, 1,239 Mio. €, 11,777 Mio. € respectively, in addition to the BAU scenario. The total capital expenditures amount to an annual 14,187 Mio. € and would represent 0.63% of the GDP of the UK, while the EU average is around 0.43% in this scenario. It also would have the highest benefits regarding to avoided CO_2 emissions and avoided fossil fuels, with 1,096 Mio. € and 6,922 Mio. € respectively (additional to the BAU scenario). In the SNP scenario, in which each country uses national support schemes in the electricity sector to meet its own targets, UK would deploy more (expensive) wind-offshore than in the other scenarios.

Furthermore it can be stated that only in the SNP scenario (relatively expensive) tidal power stations would be constructed. By the year 2030, 36 TWh of electricity (from new installations[25]) would be generated by tidal power stations. This translates into an annual average of 14 TWh between 2021 and 2030. While in the BAU scenario, offshore wind would be responsible for an average yearly 34% of the RES-total capital expenditures in the electricity sector, it would make up around 60% of the costs in the SNP scenario. In this scenario, electricity generated from tidal power stations would make up on average 22% of the annual capital expenditures (whereas in the BAU case and the other QUO-27 scenarios, tidal power stations would not be deployed).

- In the QUO-27 case in UK, the capital expenditures and the support expenditures, compared to the BAU scenario are the second lowest. Dedicated biofuel support - e.g. using biofuel in transport – induces lower support costs in general. On the one hand the capital expenditures and the additional generation costs decrease significantly by 72% and 32% compared to the SNP scenario case. On the other hand the benefits would decrease as well (17% less avoided fossil fuels and 27% less avoided CO_2 emissions compared to the SNP-scenario). All QUO-27 scenarios, which follow the "least cost" approach, would induce only small investments in expensive technologies in UK (e.g. offshore wind).

- In the scenario QUO-27 without biofuel support we see that the costs are higher compared to the other QUO-27 scenarios. Again the fact that a phase-out of biofuel support implies an uptake of RES deployment in other sectors, would lead to higher costs. Furthermore, the comparable higher RES share in final energy demand leads to higher support expenditures and capital expenditures. The yearly capital expenditures would be increase by 4,835 Mio. € compared to the BAU scenario, and the yearly total capital expenditure value of 7,245 Mio. € would require 0.32% of UK's GDP (EU average lies around 0.43%). While in the BAU scenario, offshore wind would be responsible for an average yearly 34% of the RES-total capital expenditures in the electricity sector, it would make up around 67% of the costs the QUO-27 scenario, in which biofuel is not supported. Moreover, the benefits are among the highest compared to all other scenarios. Each year, 780 Mio. € in avoided CO_2 emissions and 5,136 Mio. € in avoided fossil fuels could be saved, compared to the BAU scenario. These benefits are respectively 16% and 5% higher compared to the default QUO-27 scenario.

- Finally, an increase of energy efficiency would lead to the lower energy demand than in all the other assessed cases. Consequently, capital expenditures and support expenditures are the smallest, compared to the other scenarios. Compared to the BAU scenario, 361 Mio. € of capital expenditures would be saved annually. Nevertheless higher support expenditure costs can be observed. These amount to 3,806 Mio. € per year (in addition to the BAU scenario). Concerning the

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[25] New installation after 2020

avoided expenses for the CO_2 emission allowances, 217 Mio. € less have to be spent compared to BAU scenario. Although RES deployment has the lowest value compared to the other QUO scenarios, the additional generation costs are the highest (an annual increase by 1,024 Mio. € compared to the BAU scenario).

4 Complementary analyses of distinct aspects

4.1 Significance and impact at the macro-economic level – an assessment from a historic perspective

Within this section we shed light on macro-economic impacts related to RES deployment. Since the applied modelling system does not allow for a complete analysis of macro-economic impacts related to future RES deployment we focus on the historic perspective and the status quo, respectively. As a complement, we summarise however also key outcomes of a recent comprehensive forward-looking analysis of employment and growth impacts of renewable energy use within the European Union (cf. Duscha et al., 2014)

The cumulated installed power generation capacities based on hydro, geothermal, solar, wind, biomass, tide and wave power are depicted in Figure 40 and heat generation from biomass, biofuels, biogas, solar, heat pumps and geothermal sources in Figure 41 in 2011 and the most recently available year. Both figures reveal huge differences between the EU member states. However as the size of the countries, and hence the energy consumption differs significantly between the EU member states, one cannot draw a conclusion on the significance of RES in these countries.

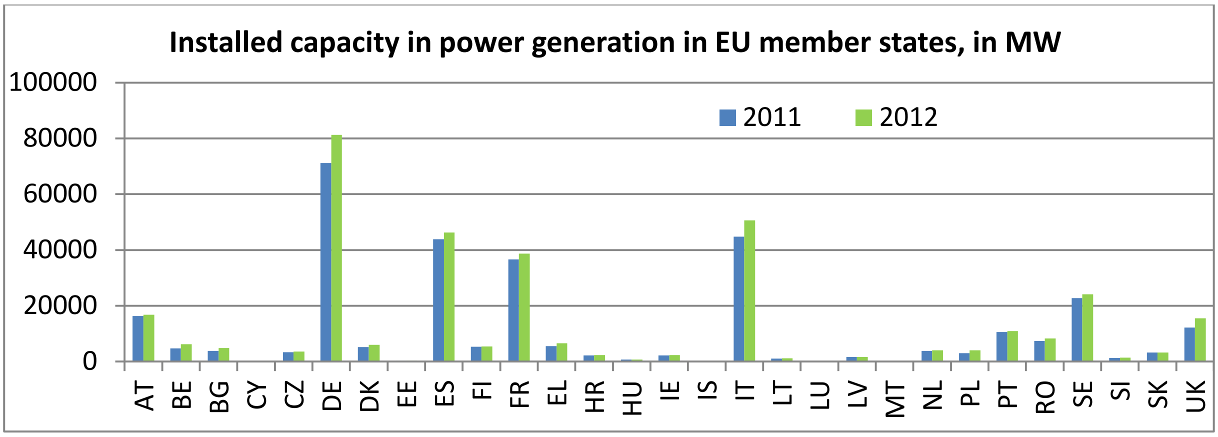

Figure 40: Installed power generation capacities by EU member states

Source: Fh-ISI, based on diverse data sources

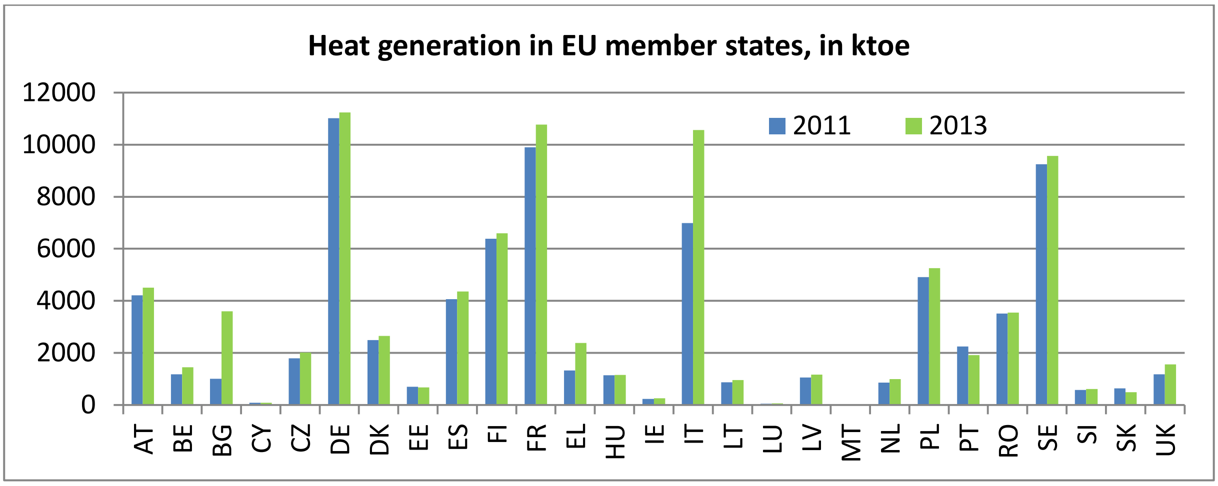

Figure 41: Heat generation by EU member states

Source: Fh-ISI, based on diverse data sources. Note: capacity data for heat generation are not available.

To show the penetration of RES for each member state, the generation based on renewable sources is depicted as share to total primary energy consumption in Figure 42. Although the total RES capacity or RES based energy generation is small in Latvia, Austria, Finland, Portugal or Denmark compared to Germany, Italy, Spain, France and Sweden, the penetration or diffusion of RES in primary energy consumption is quite significant. In contrast, large countries with large absolute RES capacities and generation show an average significance of RES with respect to energy consumption.

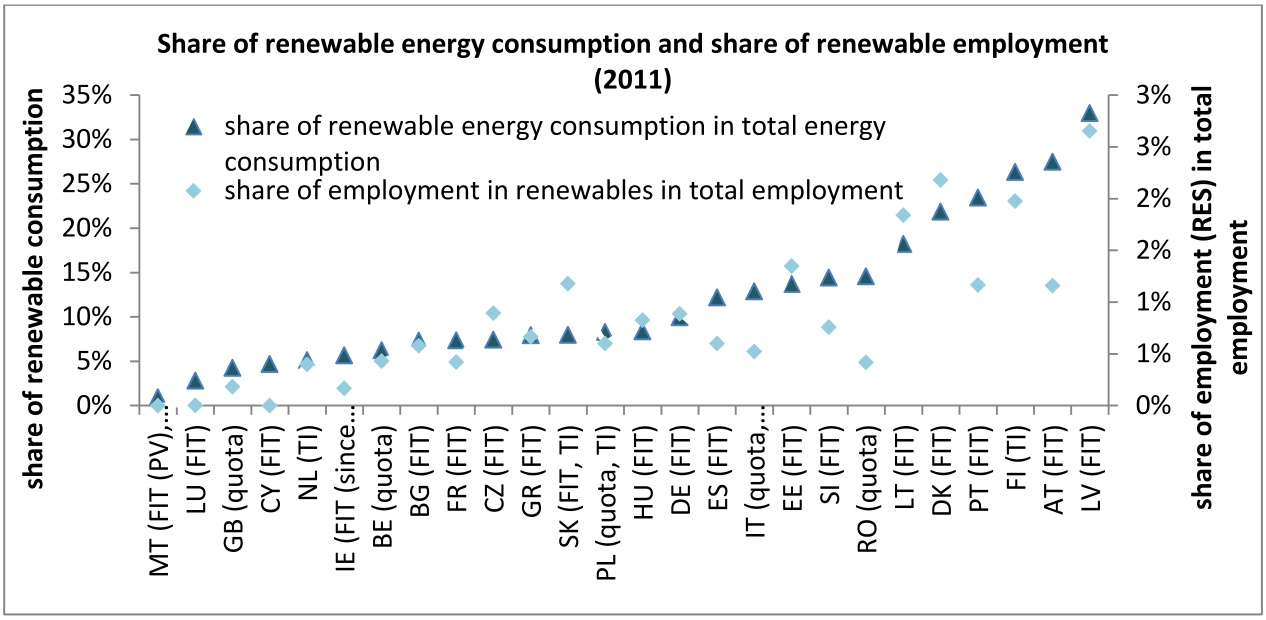

Figure 42: Share of RES consumption and share of RES employment by EU member states

Source: Fh-ISI, based on diverse data sources

To learn more on the economic impact of RES deployment, employment and value added are assessed. These numbers are depicted for all EU member states for 2011 and 2005, the years, in which these effects have been estimated for all EU countries. The assessment is based on annual investments of RES, which has a one-time impact on employment and value added, as well as on expenditures for operation, maintenance and fuels, which exert a permanent impact on the economy over the lifetime of the generation plant.

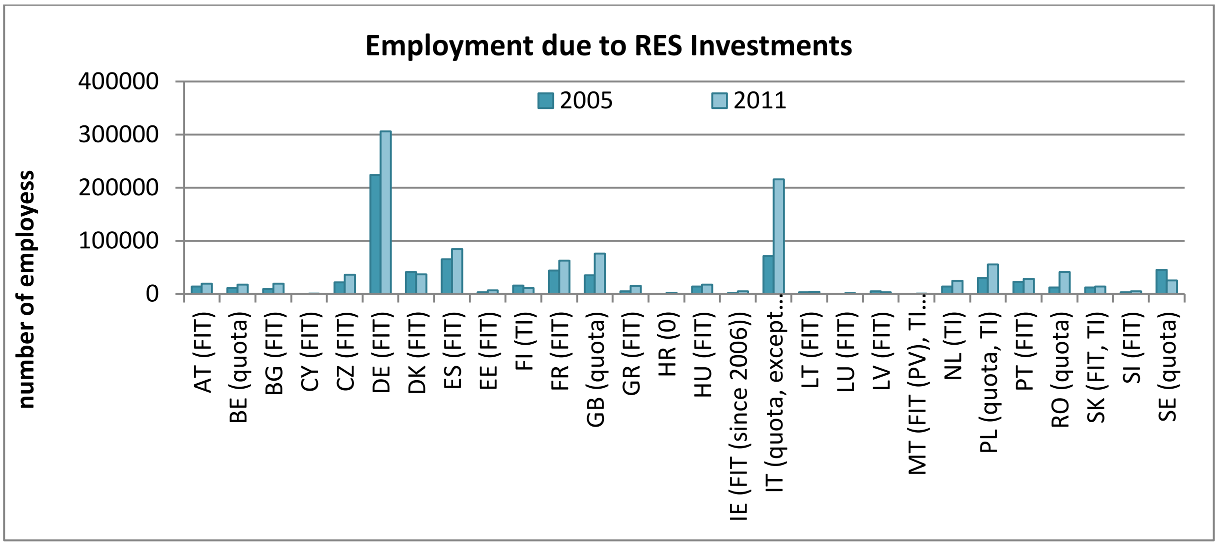

Figure 43: Goss employment through investments by EU member states

Source: Fh-ISI based on EmployRESI 2009, EmployRESII 2015, Rütter and Partner

Figure 43 depicts employment induced by investments, thus, one-time direct and indirect effects. Direct effects refer to employment in the RES related sectors, while indirect effects also account for employment impacts on upstream industries of RES sectors. The number of jobs induced by operation, maintenance and fuels are depicted in the Annex. They show a similar pattern per country but stretch over the lifetime of the generation plant. However, the absolute number of jobs in the country tells nothing on the economic significance of RES deployment. Therefore, the share of RES related employment to total employment is depicted in Figure 42 (light dots). Again countries with absolute high numbers of RES employment such as Germany and Italy display a less economic significance of RES deployment. In contrast, in Latvia, Denmark, Finland and Lithuania RES deployment seems to be more significant for employment than in Germany or Italy.

Besides jobs, the contribution of RES deployment to economic growth is assessed as value added per country and depicted per employee. In addition, Figure 44 depicts also value added per employees of the manufacturing sector, which includes investments and services of RES technologies, value added in the energy sector and the average value added per country. While the values added per employee in “RES- sector”, manufacturing and total economy do not differ largely, the value added in the energy sector outranges in each country. This sector includes generation, transformation, distribution, trade of all type of energy. Thus, it includes also generation, distribution of RES based electricity. It cannot be compared to the value added per RE, because the latter comprises only manufacturing and services (operation and maintenance) of the generation technology and, hence, covers industries across sectors such as manufacturing, services and trade (without renewable fuels). It can be considered as a kind of upstream sector for the energy sector. Overall, in some countries the output per employee in "RES-sector" is slightly higher than in the manufacturing sector, while the opposite applies in other countries. But given the assessment for the RES sector, and the small differences between manufacturing and "RES-sector", the output per employee, and, thus, productivity is rather similar for most countries.

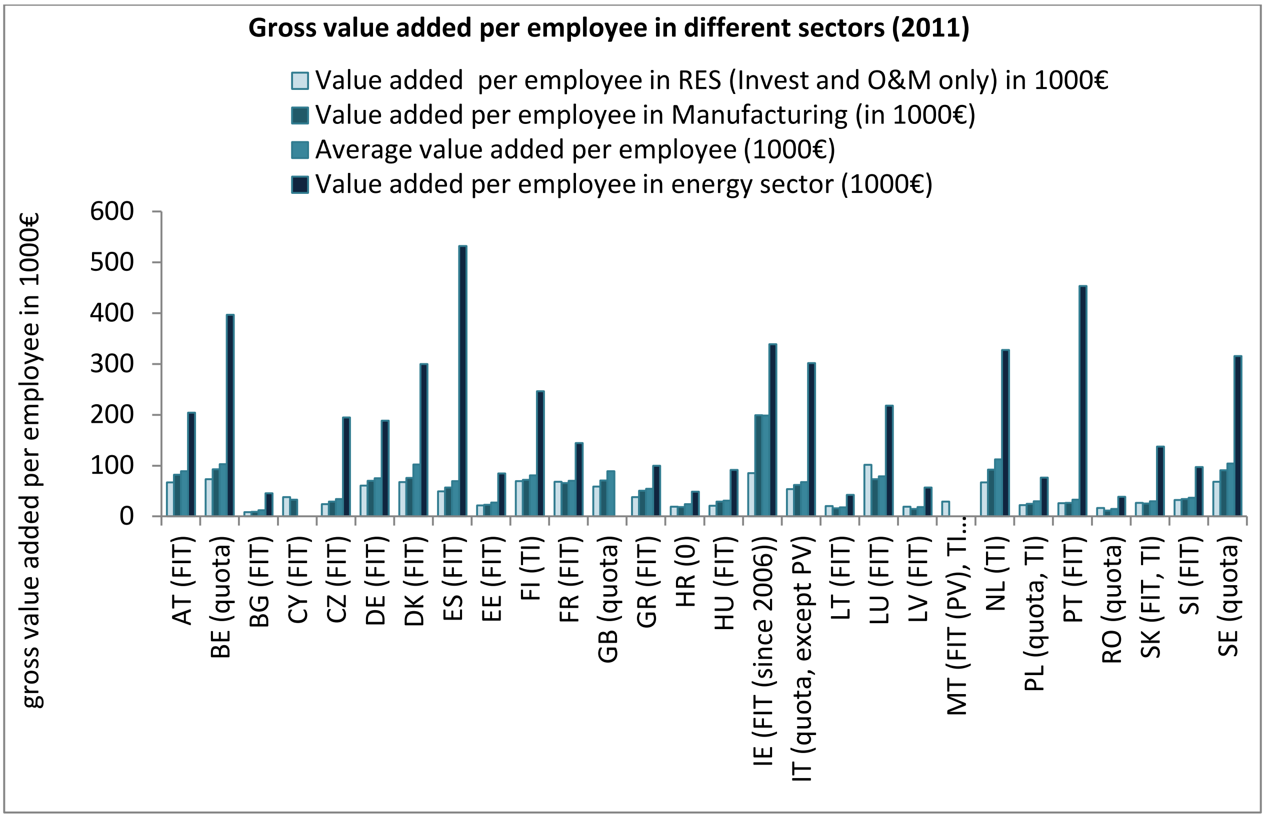

Figure 44: Value added per employee in different sectors, by EU member states

Source: calculation and depiction by Fh-ISI, data based on Eurostat, EmployRES I+II, Rütter and Partner. Note: energy sector includes generation, transformation, transport, distribution of energy, which includes the "RES fuels, heat or power". The energy sector is the downstream sector of RES- manufacturing, O&M sector. Thje RES manufacturing and O&M sector is part of the total manufacturing sector.

To see whether this gross employment is driven by the type of RES policy, e.g. feed-in scheme or a quota with tradable green certificate policy, the policies are indicated in Figure 45 above the share of RES employee for 2011. Most countries have established a feed-in scheme, some still applied a quota system in 2011 and only a few had additional instruments in force such as tax or investment incentives. Overall, there is no clear pattern between policy type and employment share. Sweden, which has a quota scheme, and Finland, which applies a tax and investment incentive scheme displayed a higher significance of RES for its economy in 2005 than in 2011. But this might depend on the investment impulse, which has been larger in 2005 (see Figure 43). Similarly, Denmark and Latvia, both with a feed-in scheme had a stronger investment impact in 2005 than 2011. Even so policies have certainly been an important driver for RES deployment, and hence for RES-related employment, it is probably the specific design of policies as well as their pull-effect, reliability and credibility that has driven RES investments and hence RES employment. Moreover, natural resources in RES certainly had an influence on RES deployment as well, such as the deployment level of PV in Italy and Spain and of hydro in Sweden, Finland and Austria suggests.

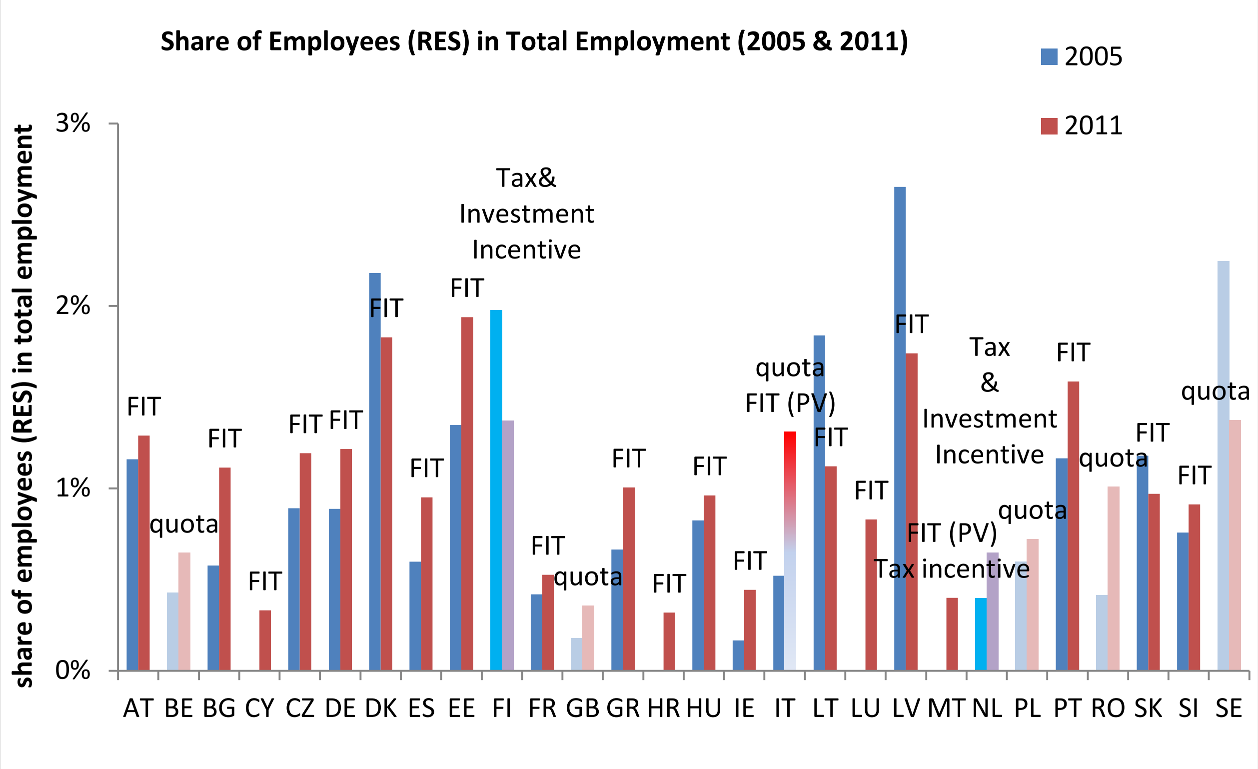

Figure 45: RES-E policy an share of RES gross employment to total employment by EU member states

Source: Fh-ISI based on EmployRESI 2009, EmployRESII 2015, Rütter and Partner

Subsequently we present key outcomes of a recent complementary prospective analysis of RES-related impacts on employment and growth.

Box 3: A prospective analysis of RES use in the EU: the EMPLOYRES-II study

A forward looking analysis of macroeconomic impacts, such as GDP or job creation, of RES policies has been carried out in the EmployRES-II study, cf. Duscha et al. (2014). To complement the findings from the Diacore study, the main findings from the EmployRES-II study are summarised in the following. In EmployRES-II, in a similar fashion as in Diacore the Green-X model has been applied to develop different RES expansion scenarios for the EU. Then the resulting capacities have been passed on to two macroeconomic models, NEMESIS and ASTRA, which used the capacities as impulses for economic feedback loops. In comparison to Dia-Core, the Green-X scenarios in EmployRES-II however were of a higher ambition level (30% and 35% respectively), thus it can be expected that the impacts discussed in the following, would be less pronounced in the Diacore scenarios.

Effects on on GDP

Figure 46 shows the impact of RES-policies on *net* GDP obtained with the NEMESIS model. The results show that RES policies will lead to moderate but positive GDP effects. On average, GDP will increase between 0.37% and 0.76% compared to BAU.

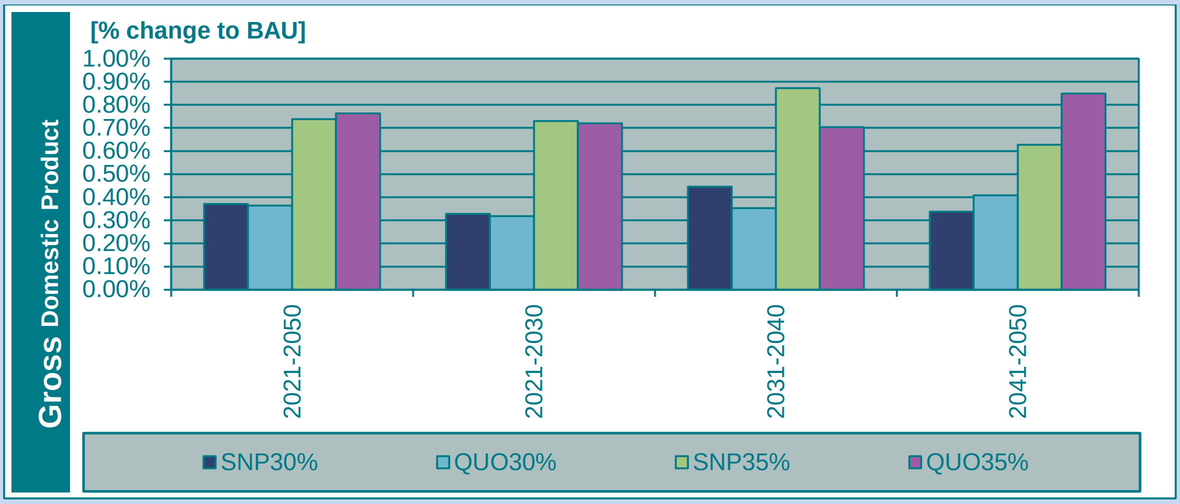

Figure 46: European GDP, % deviation, 10 years average on EU28 level based on NEMESIS

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

In the ASTRA model the overall impacts of RES deployment show a comparable pattern to the NEMESIS results. The impact on GDP is positive for all 4 scenarios. Furthermore, the overall impact of the more ambitious 35%-target scenarios tends to be stronger than for the 30% target scenarios. Similar to the NEMESIS results, the SNP 35 scenario is showing stronger GDP increase as the QUO 35 scenario between 2031 and 2041, and lower GDP increase between 2041 and 2050. However, there are some differences which can be attributed to the different model philosophy. ASTRA tends to attach higher weight to the supply side. Thus, the positive impulses from the investments tend to be more strongly counterbalanced by the higher generation costs the economy has to cope with.

Net effects on employment

Figure 47 shows the impact of RES policies on *net* employment obtained with the NEMESIS model. The results show that RES policies will lead to moderate but positive employment effects. On average, employment will increase between 0.28% and 0.64% compared to BAU. This is equivalent with an average increase of jobs in the EU between 600.000 and 1.400.000.

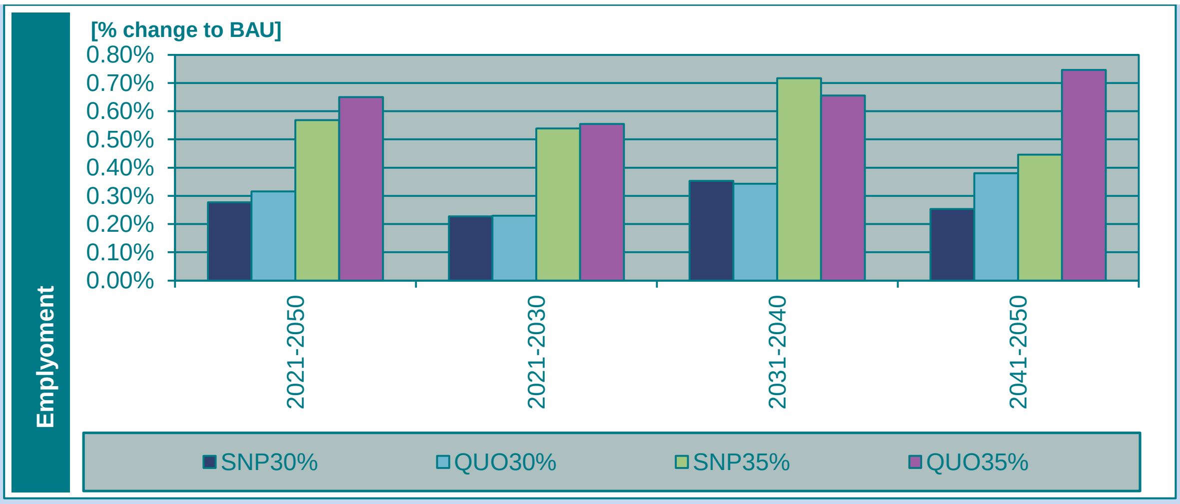

Figure 47: European Employment, % deviation, 10 years average on EU28 level based on NEMESIS

The positive development can be explained with the impacts of RES deployment on GDP. The main difference is that the average positive effects are slightly smaller than for GDP. This can be explained by two factors: First, the accelerator effects increase investments in all sectors. These investments contribute to an increase in labour productivity. Thus, the same amount of GDP can be produced with lower labour input. Secondly, the sectoral changes induced by RES deployment work towards benefiting sectors which are less labour intensive.

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

4.2 The merit-order effect: key findings of the analyses performed

One task of WP4 was to perform an **empirical analysis** for all major European’s electricity markets quantifying the **historic merit-order effect** induced by RES-E. This assessment has been complemented with the calculation of historic (wholesale) market values of wind onshore, wind offshore and large-scale solar PV in these markets. The results of this analysis have been related to corresponding findings in the relevant literature. Figure 48 and Figure 49 illustrate the results of our econometric approach for selected European countries that already reached considerable RES-E shares. In these figures, price effects are related to the size of the respective country’s electricity market: An increase in variable RES generation in the dimension of a one percent share of the average load of that country was used as a unit of reference for the price change. This approach is the most suitable for an overall comparison between Member States as they do differ in size (RES targets are also set in relative terms for this reason).

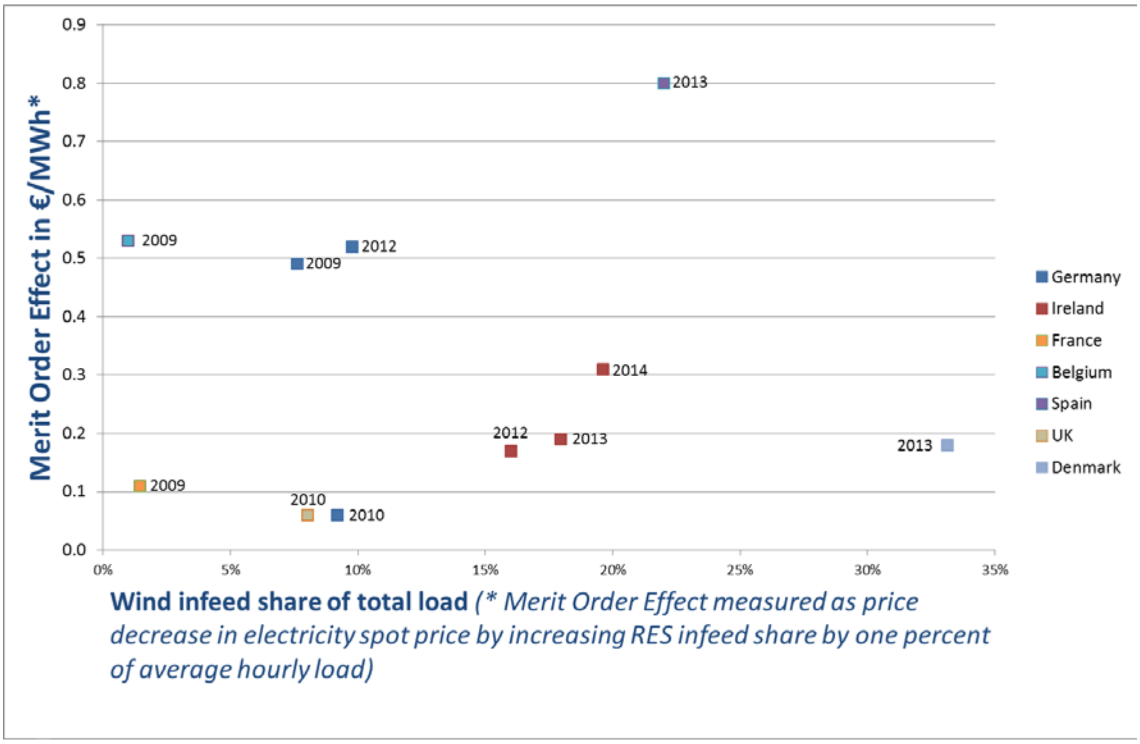

Figure 48: Historic merit-order effect induced by wind power - Comparison of price changes induced by feed -in of variable RES (2008-2013)

Apart from a few outliers, there is a clear trend that a higher load share of variable RES leads to lower electricity prices, and can thus induce a merit-order effect, cf. Figure 48 and Figure 49, respectively. This trend is even more apparent in more recent years, whereas earlier years show more dispersion, possibly due to other unobserved effects that also influence electricity spot prices. The results show that feed-in of electricity from variable renewables (wind power and photovoltaics) has a negative impact on (day-ahead) electricity prices. The intensity of the drop however varies between member states. One additional percent of wind infeed leads to a drop of 0.53 €/MWh for e.g. Germany and 0.8 €/MWh for Spain. Scaling this up to a yearly measure would have meant 180.7 Million € or 197.7 Million € of additional costs of consumption without additional RES generation in the years 2012 and 2013. These findings are similar to those found in the literature.

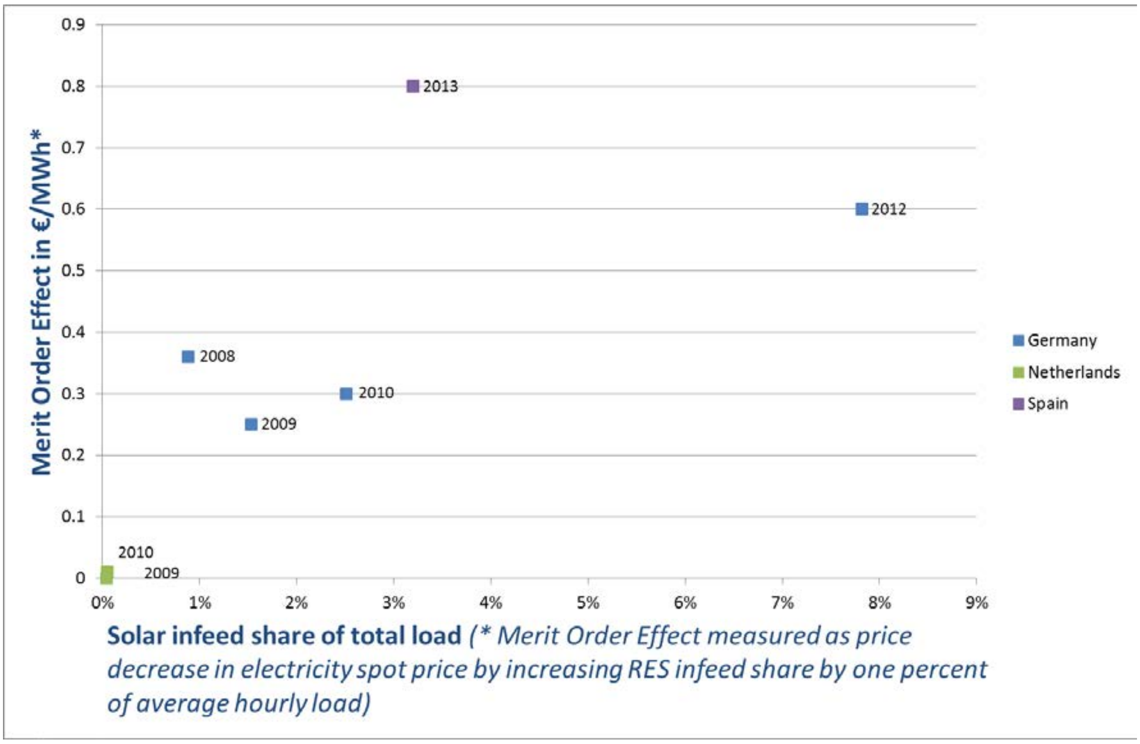

Figure 49: Historic merit-order effect induced by solar photovoltaics - Comparison of price changes induced by feed -in of variable RES (2008-2013)

The transition of Europe’s power systems towards more sustainability leads to trends in all important figures, therefore a **forward-looking perspective** have been taken as well. Based on a combination of three European-scale market- and investment models the expected future merit-order effect and market values of RES have been assessed under the assumption of different RES policy pathways and framework conditions. A description of important assumptions like fuel prices and demand forecasts are given in report D4.2.

In order to filter the impact of additional RES-E generation on electricity prices two model runs, which only differ in their RES-E share, are contrasted with each other. The first of these scenarios are called the *P-NoPolicy scenario*, which assumes that the EU ETS is the only source of support in place and no dedicated RES target will be achieved in 2030. In contrast to that the *P-Reference scenario* represents a world in which the RES target of 27% is reached by 2030 through the implementation of a dedicated RES support scheme.

Figure 50 shows the resulting day-ahead electricity price of both scenarios as an EU average. It can be seen that in each period of time the prices of the P-Reference scenario are below the ones in the P-NoPolicy scenario. We have found that an additional amount of RES-E, ceteris paribus, decreases average electricity prices by 2 to 5 percent depending on the actual amount and type of additional RES-E and the corresponding in- and divestments in the conventional generation park. To put this into perspective, this translates into around 0.04% of Europe´s GDP in terms of cheaper electricity consumption evaluated in wholesale prices. It has been assumed in the modelling that all conventional generators fully recover their total costs based on market revenues. However, it should be stressed that this analysis has been performed under the ceteris paribus condition. In reality, electricity markets are almost never in equilibrium and prices vary according to a large number of independent influences. This analysis has thus shown that given everything else remains constant, additional RES-E lowers average electricity prices. However, the resulting prices do not equally drop within the EU. Price drops are more significant in Member States where relatively expensive generation technologies can be substituted and those adjacent states, whose markets are comparably well coupled to it.

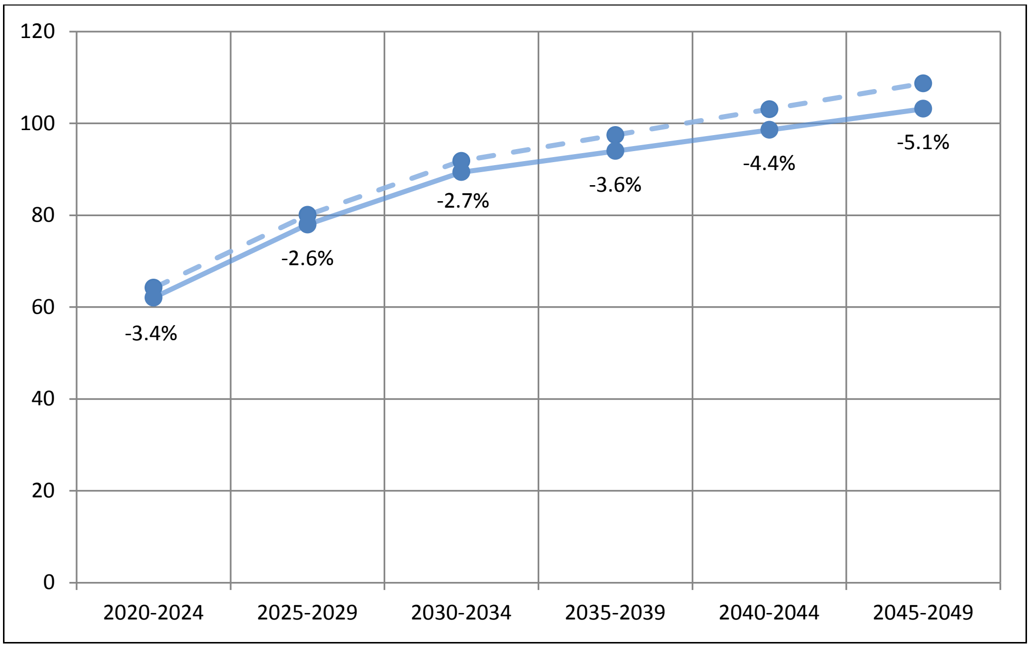

Figure 50: Average day-ahead electricity prices in EUR/MWh in the EU for the P-NoPolicy scenario (dashed line) and the P-Reference scenario (solid line).

The ratio between potential market revenues of RE generators and baseload generators considerably drops with increasing penetration, especially for variable RES (vRES). This peculiarity can partly be explained through a special characteristic of variable RE generation, which is marketed (and thus valued) in energy-only electricity markets. The marginal value of its generated electricity decrease with increasing market penetration, because less high priced generation is substituted at higher infeed levels. Therefore, market prices are low when (nearly zero priced) renewable electricity infeed is high and vice versa. This is a competitive disadvantage of variable (or non-dispatchable) electricity generation compared to dispatchable generation, which materialises in the form of relatively lower **market values** (or market revenues) as compared to revenues of the same amount of constant electricity generation. In order to compare relative market revenue changes of certain technologies between different countries / price zones the yearly market revenues are divided by the corresponding yearly average (day-ahead) price level in their price zone. The resulting figure is called the **market value factor**.

The historic market value factors of wind onshore and solar PV in European countries are presented in Figure 51 based on actual hourly day-ahead prices and corresponding RES generation. The figure shows that in the past, the market value of PV was higher than that of wind. This is due to the effect that the sun usually shines at peak demand times, where in the past high demand used to trigger higher electricity prices and thus lead to a higher value for electricity generated by photovoltaic power plants. Furthermore, as the subset of analysed years presented is quite early with a comparably low installed capacity, a merit-order effect induced through photovoltaics is also not very likely due to its substantially small share. As will be seen in the model-based analysis, larger capacities and thus higher infeed can lead to a substantial drop in the market value of PV.

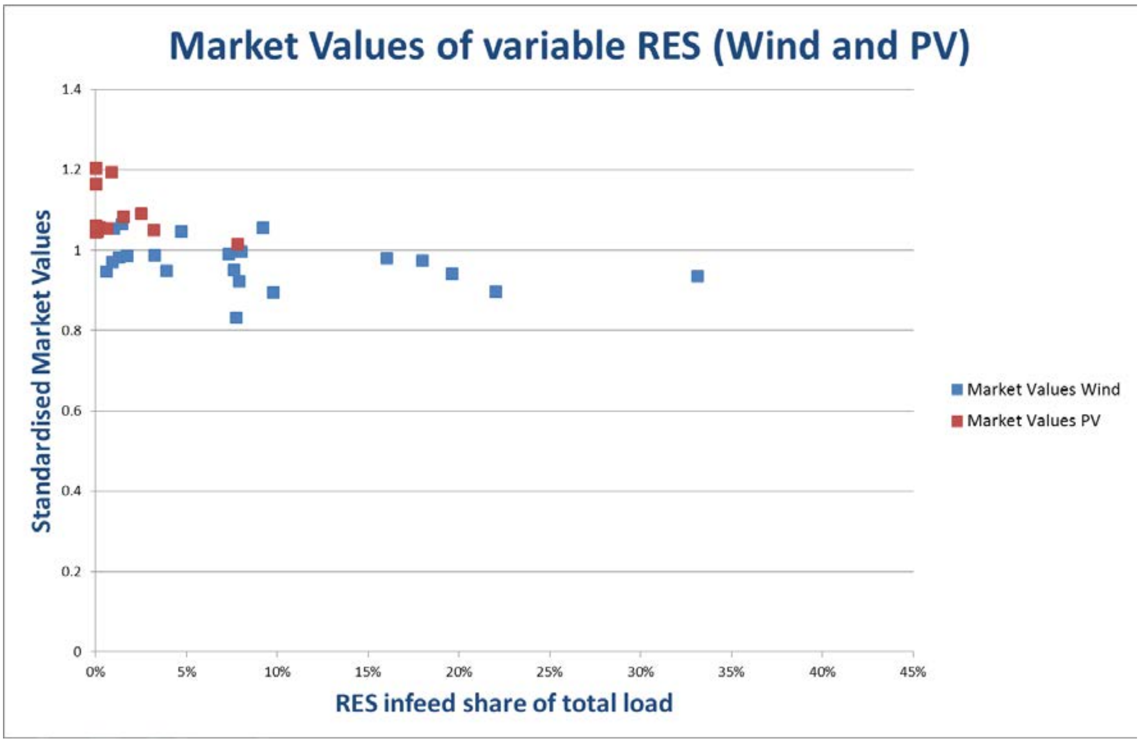

Figure 51: Historic market value factors of wind onshore and photovoltaics

To study the size of this effect in a forward-looking perspective a number of scenarios have been contrasted with each other (cf. Figure 52). A more detailed explanation of the modelled scenarios including an extensive set of sensitivity analyses can be found in deliverable D4.2 (Ortner et al., 2016). It can be seen that for both wind onshore and solar PV market value factor can drop down to 60% of average market revenues of a baseload generator in 2050. The range of variations differs between member states.

The key outcomes of the forward looking analysis are that market value factors considerably drop with increasing penetration, especially for variable RES (vRES). In the period until 2030 and 2050 the decreasing effect of market value factors becomes apparent. The average of market value factors over all EU countries drops for wind onshore, wind offshore and solar PV with increasing RES penetration by as much as 4 to 12 percentage points as compared to a baseline pathway. In particular, in certain countries drops can reach a dimension of 15 to 30 percentage points. These market value factor drops translate into a 1 to 2 €/MWh higher support costs for total renewable generation per year. In the modelled scenarios they are offset by a decline in average wholesale electricity prices in the range of around 3 €/MWh. However, these figures can considerably change over time, depending on the assumptions being taken and thus should be interpreted with appropriate care.

When it comes to the sensitivity of market revenues of variable renewables to framework conditions in electricity markets the results have shown that additional energy efficiency measures in combination with a more ambitious carbon pricing considerable impacts specific market revenues of RES. The impact depends on the technology in question but can reach up to 15 €/MWh. Further influencing factors are the future development of the high voltage transmission grid, whether additional demand side flexibility can be utilized and which market design will be chosen. Also market revenues are expected to change in between years due to intra-yearly differences in resource availability. These impacts are attributable to variations in meteorological conditions and can cause up to 10 €/MWh variations in specific market revenues of variable renewable generation.

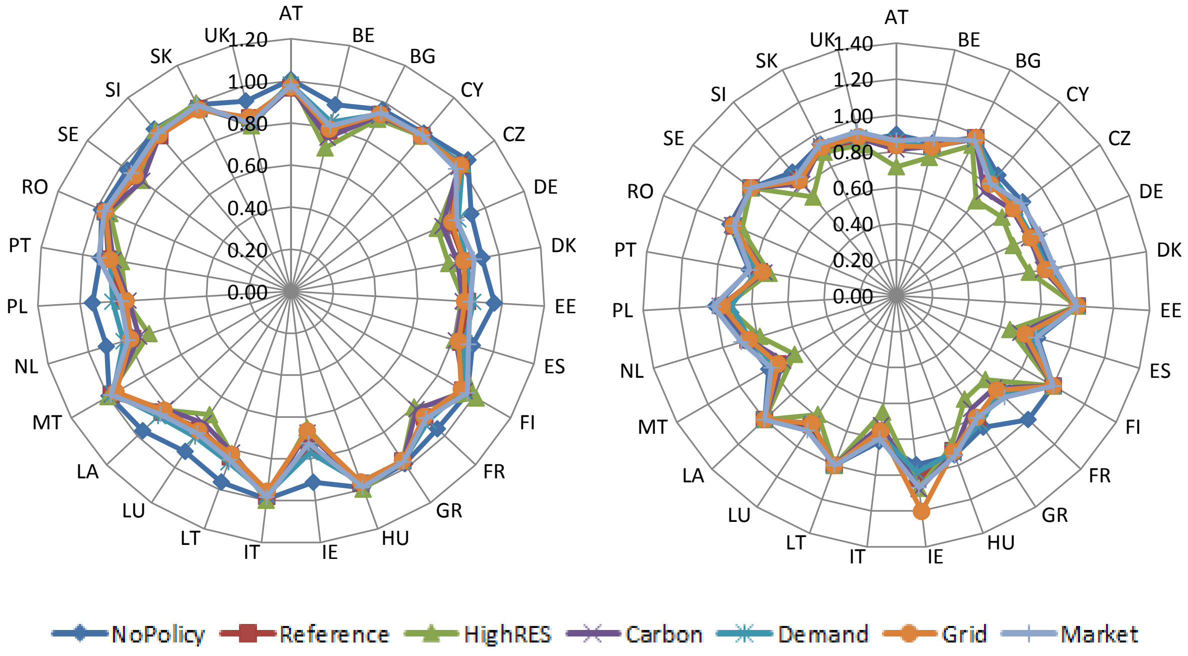

Figure 52: Modelled market value factor for different scenarios in 2050. Left graph: Wind onshore. Right graph: Solar photovoltaics (PV)

5 Conclusions

Key Messages and Recommendations

- System-related benefits in terms of avoided fossil fuels and CO_2 emissions vary considerably across Member States. Similarly, system-related costs, and in particular those related to capital expenditures, also vary across Member States and represent a substantial share of GDP for some of them.The financial burden of the binding EU-wide RES target of at least 27% of the EU's energy consumption by 2030 seems to be bearable. However, a clear concept and an agreement on the effort sharing across Member States has to follow.
- Alternative scenarios show that despite increased costs, a higher target set at EU level would increase system related benefits significantly. In addition, it would benefit the EU trade balance due to a (significantly) decreased demand for fossil fuels and related imports from abroad.
- If prevailing non-economic barriers were removed and energy efficiency measures implemented, a higher RES share for 2030 of 30% or more would be much more easily achievable..
- A trend among Member States shows that overall, Eastern European and Baltic states face higher support expenditures but also benefit more in terms of avoided fossil fuels and CO_2 emissions.

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7 Annex

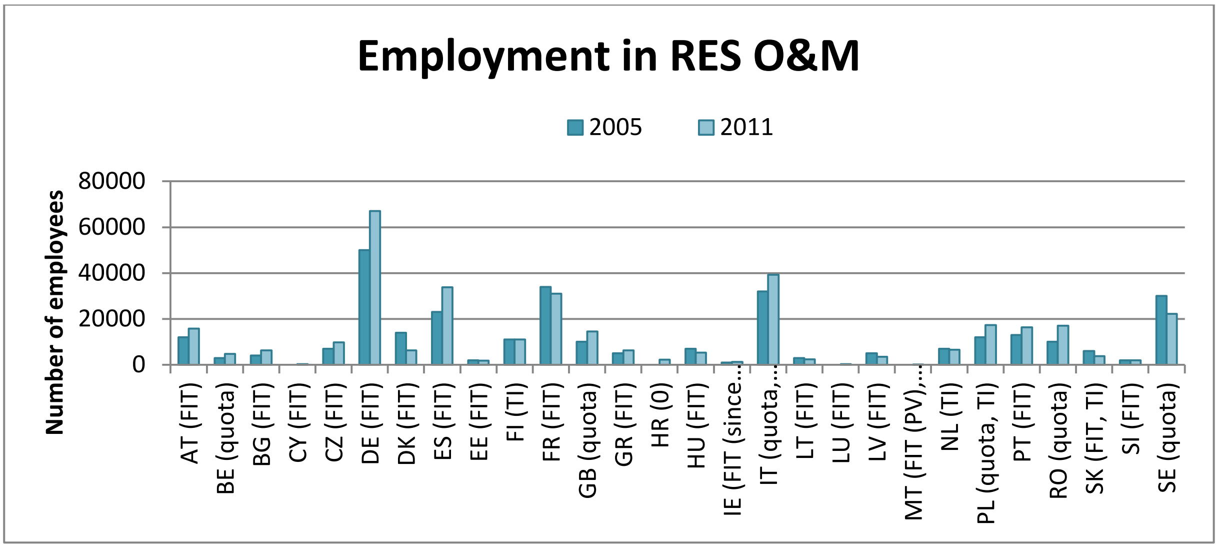

Figure 53: Goss employment through operation and maintenance by EU member states

Source: Fh-ISI based on EmployRESI 2009, EmployRESII 2015, Rütter and Partner

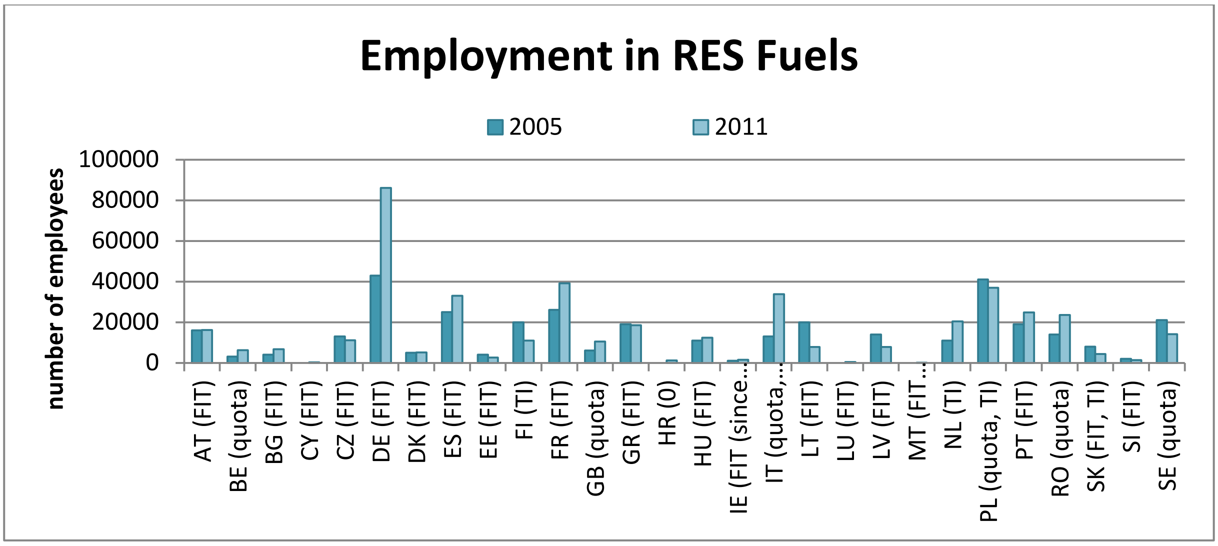

Figure 54: Goss employment through RE fuels by EU member states

Source: Fh-ISI based on EmployRESI 2009, EmployRESII 2015, Rütter and Partner