Contract N°: IEE/12/833/SI2.645735

Project Acronym: DIA-CORE

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

D2.5: Prospects for RES in Europe up to 2030

Project Coordinator: **Fraunhofer ISI**

Work Package **4** Leader Organization: **TU Wien / EEG**

Authors: **Gustav Resch, André Ortner, Marijke Welisch, Sebastian Busch, Lukas Liebmann, Gerhard Totschnig (TU Wien / EEG)**

June 2016

Co-funded by the Intelligent Energy Europe
Programme of the European Union

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
CB8	German Institute for Economic Research	DIW	DE
CB9	University of Utrecht	UU	NL
CB10	AXPO Austria	AXPO	AT

Table of Contents

Figures

Tables

Boxes

1 Introduction

1.1 Policy context

The first decade of the new millennium was characterized by the successful deployment of RES across EU Member States – total RES deployment increased by more than 40%. More precisely:

- RES electricity generation grew by approximately 40%, RES heating and cooling supply by 30% and biofuels by a factor of 27 during the period 2001 to 2010,
- New renewables in the electricity sector (all technologies except hydropower) increased fivefold during the same period,
- Total investments in RES technologies increased to about € 40 billion annually in 2009 and more than 80% of all RES investments in 2009 were in wind and PV.
- With respect to PV an ongoing trend of achieving impressive cost reductions from year to year has started in the final period close to 2010.

These 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).

Despite the challenges posed by the financial and economic crisis, RES investments were generally less affected than other energy technologies and partly increased even further over the last couple of years. The European Energy and Climate Package is one of the key factors that contributed to this development. The EU ETS (Emissions Trading System) Directive has introduced full auctioning post 2012, thus exposing fossil power generation to the full cost of carbon allowances, at least in theory. In practice, an oversupply of allowances has however led to a deterioration of prices on the carbon market.

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.

Implementing the 2020 RES Directive has taken another step forward with the formulation of the National Renewable Energy Action Plans (NREAPs), which outline the national strategies concerning support schemes, cooperation mechanisms and (non-cost) barrier mitigation, in particular with respect to grid-related and administrative issues. In addition, a detailed reporting framework for the European Commission and Member States has been drawn up to ensure that these strategies are well established and coordinated.

Despite the successful development of the RES sector over the last decade, substantial challenges still lie ahead. For the renewable energy electricity and heating & cooling sectors (RES-E and RES-H&C), the growth rate of total generation has to continue in line with the trend observed during the last five years. For meeting 2020 RES targets, compared to the period 2001 to 2010, yearly growth in RES-E needs to almost double from 3.4% (2001 to 2010) to 6.7% in the years up to 2020. There also needs to be a substantial increase in growth in the RES-H&C sector from the 2.7% per year achieved over the past decade to 3.9% per year until 2020. Therefore, the EU as a whole should continue to uphold the past level of achievement and the most successful countries could even over-achieve the 2020 targets by continuing to follow their present trend.

In order to create the investment climate for reaching the 2020 targets the longer term commitment for renewable energy in Europe is an important condition. The more confidence investors have in the market growth for RES technologies beyond 2020, the better they will develop the supply chain and align structures within utilities and other companies.

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. In a next step, Europe's way forward towards 2030 has been discussed intensively. Thus, at the Council meeting of this October (2014) the next step was taken: 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.

Additionally we observe that binding national RES targets at Member State level have created strong commitment to renewable energy throughout the EU and are the key driver for RES policies at the moment. They are a key element for setting up the administrative procedures, regulatory frameworks, regional planning and national infrastructure development. As these elements will also be crucial for the RES deployment after 2020 binding national targets appear as a crucial element also for the 2030 time horizon, in order to give confidence to the investors.

1.2 Objective and structure of this report

This report provides an **outlook on possible RES developments in the European Union up to 2030,** illustrating the outcomes of quantitative RES policy assessments undertaken within the DIA-CORE project by use of TU Wien's Green-X model.

The two focal points incorporated are:

- A closer look at RES developments until 2020, discussing **the need for and impact of RES cooperation** (for achieving binding national RES targets) **in the 2020 context**, and
- an **outlook to 2030, discussing possible RES developments and related impacts on costs and benefits** in the light of the Council agreement on (at least) 27% RES by 2030.

The report is structured as follows: Chapter 2 describes overall methodological approach and specifies the various RES policy cases that are assessed in this report.

Subsequently Chapter 3 analyses costs and benefits of RES in the 2020 context with a particular focus on the need for and impact of cooperation. Thereby Chapter 3 represents an update of prior work conducted within the European project “Cooperation between EU MS under the Renewable Energy Directive and interaction with support schemes”.

Chapter 4 focuses on the 2030 discussion, presenting scenarios of future RES developments up to 2030 in the EU and at country level. Results illustrate feasible deployment paths under distinct policy concepts and inform on consequences in terms of costs and benefits.

Chapter 5 complements the above with topical assessments on how costs of the RES policy interventions can be maintained at acceptable levels, shedding light on the impact of improving RES policy design, removing non-cost barriers and de-risking investments through improved financing conditions.

Finally, Chapter 6 draws conclusions related to both assessed focal topics.

2 Model-based assessment

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.

2.1 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.

2.2 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.

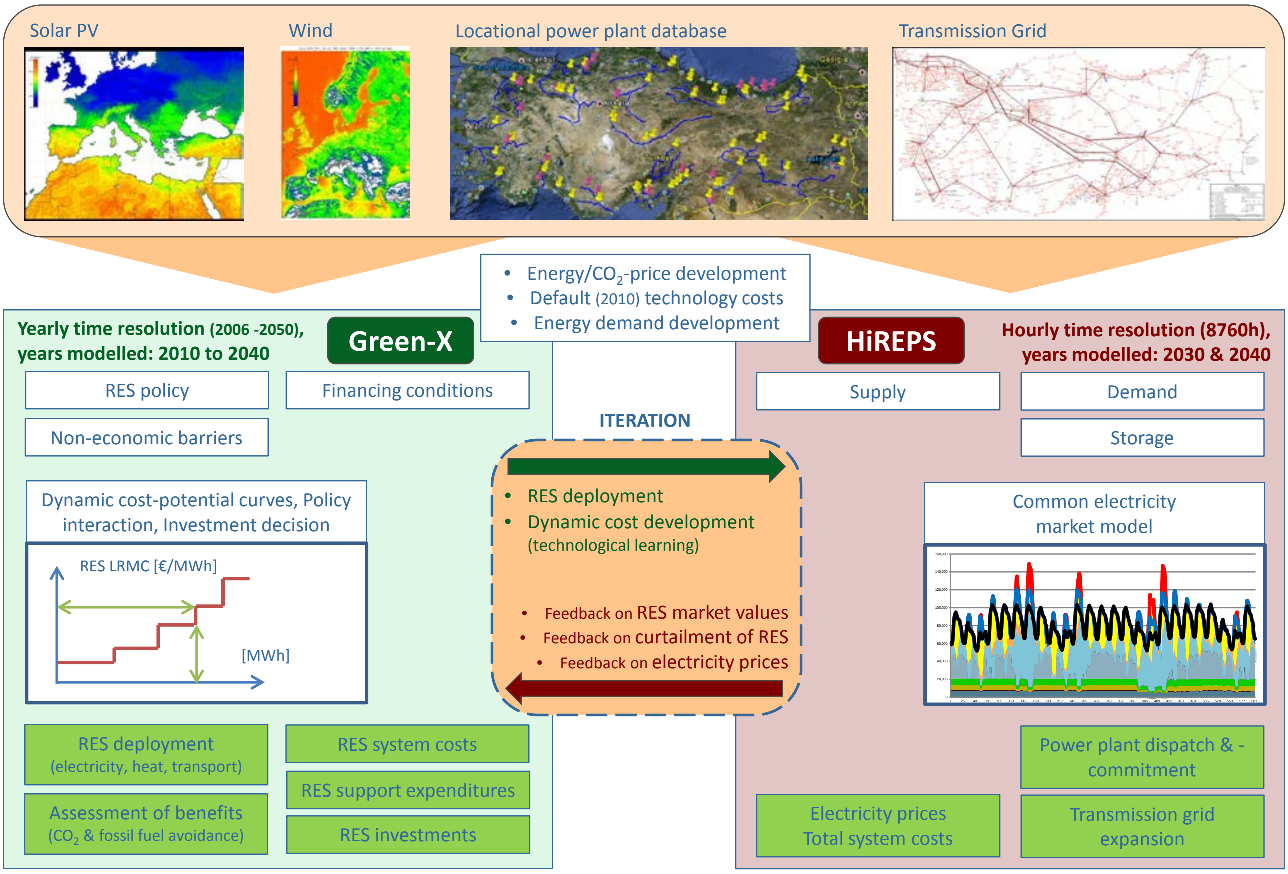


Figure 1: Model coupling between Green-X (left) and HiREPS (right) for a detailed assessment of RES developments in the electricity sector

Figure 1 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.

2.3 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	

2.3.1 Energy demand

Figure 2 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).

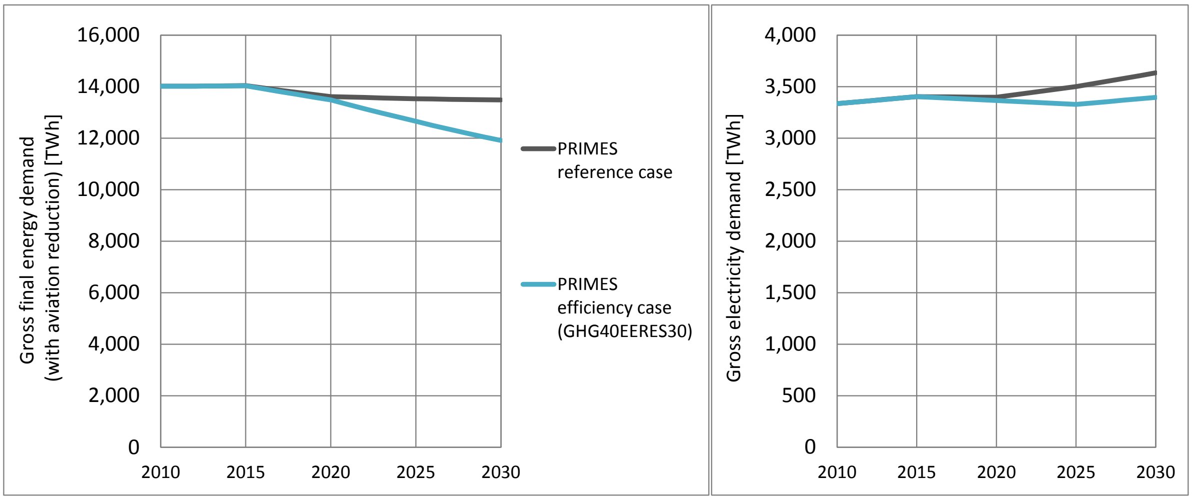


Figure 2: Comparison of projected energy demand development at European (EU-28) level – gross electricity demand (left) and gross final energy demand (right). Source: PRIMES scenarios (EC, 2013)

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 3 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.

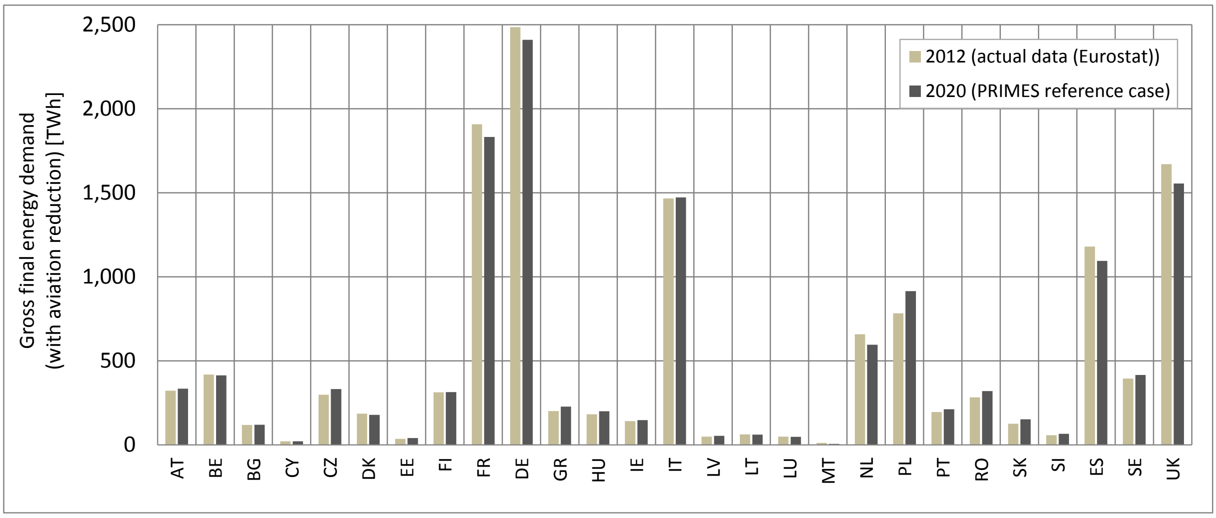


Figure 3: Comparison of actual 2012 and projected 2020 gross final energy demand by Member State. Source: PRIMES scenarios (EC, 2013)

2.3.2 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 4 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%.

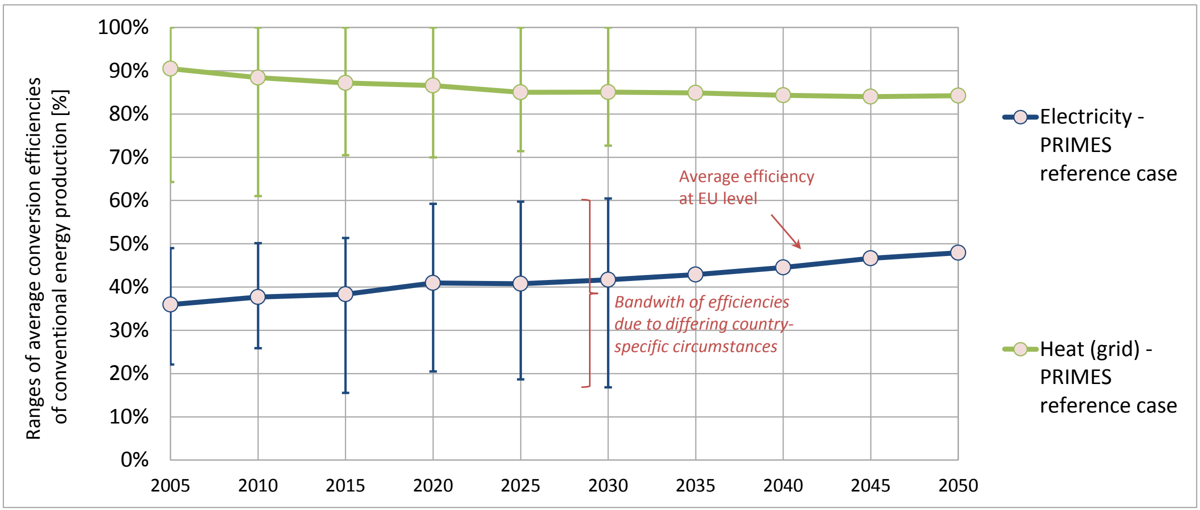


Figure 4: Country-specific average conversion efficiencies of conventional (fossil-based) electricity and grid-connected heat production in the EU28. Source: PRIMES scenarios (EC, 2013)

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 5. Error bars again illustrate the variation across countries.

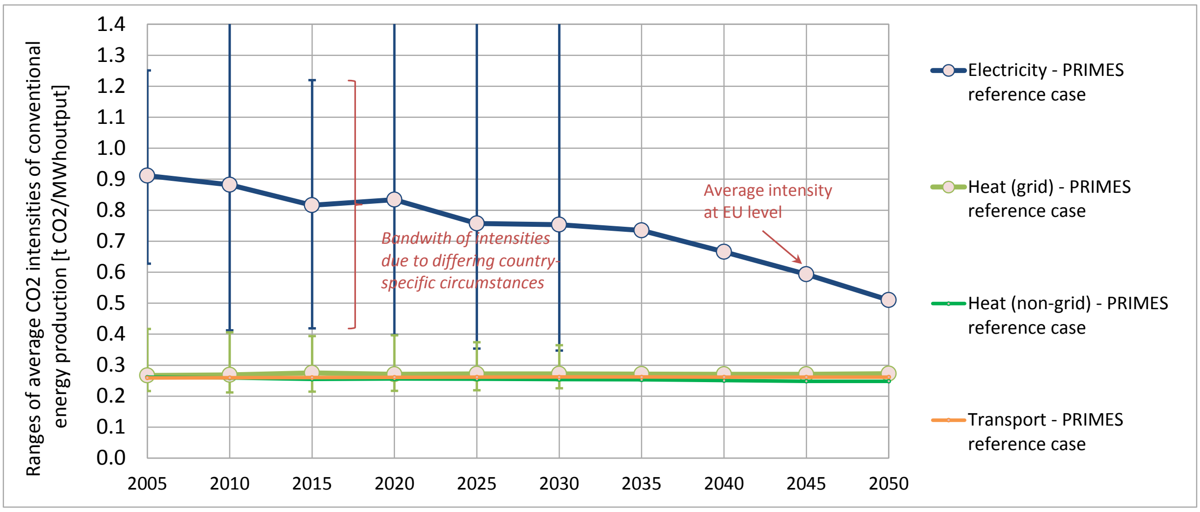


Figure 5: Country-specific average sectorial CO2 intensities of the conventional (fossil-based) energy system in the EU28. Source: PRIMES scenarios (EC, 2013)

2.3.3 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 6 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.

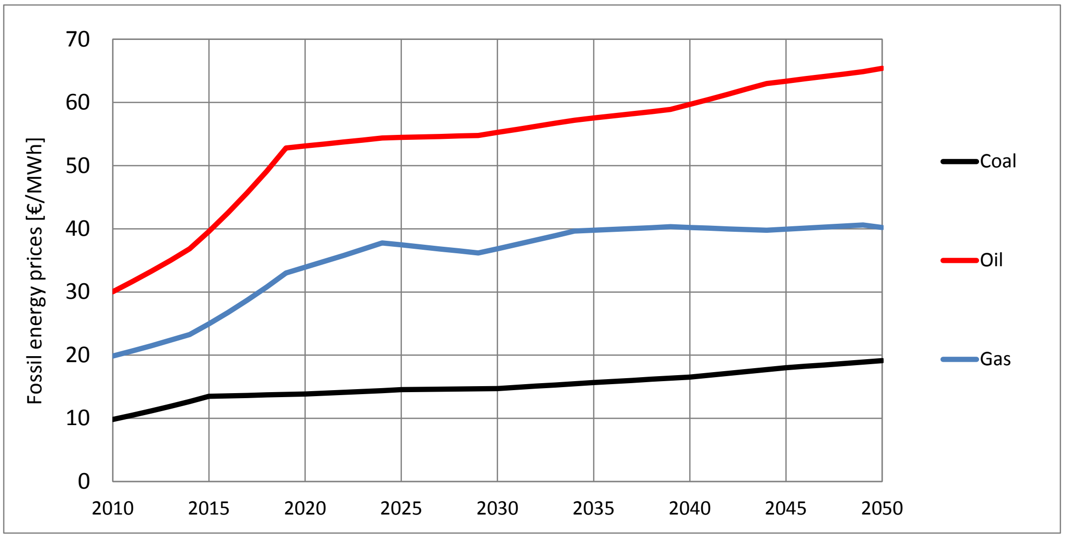


Figure 6: Primary energy price assumptions in € / MWh. Source: PRIMES scenarios (EC, 2013)

The CO_2 price in the scenarios presented in this report is also based on recent PRIMES modelling, see Figure 7. 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.

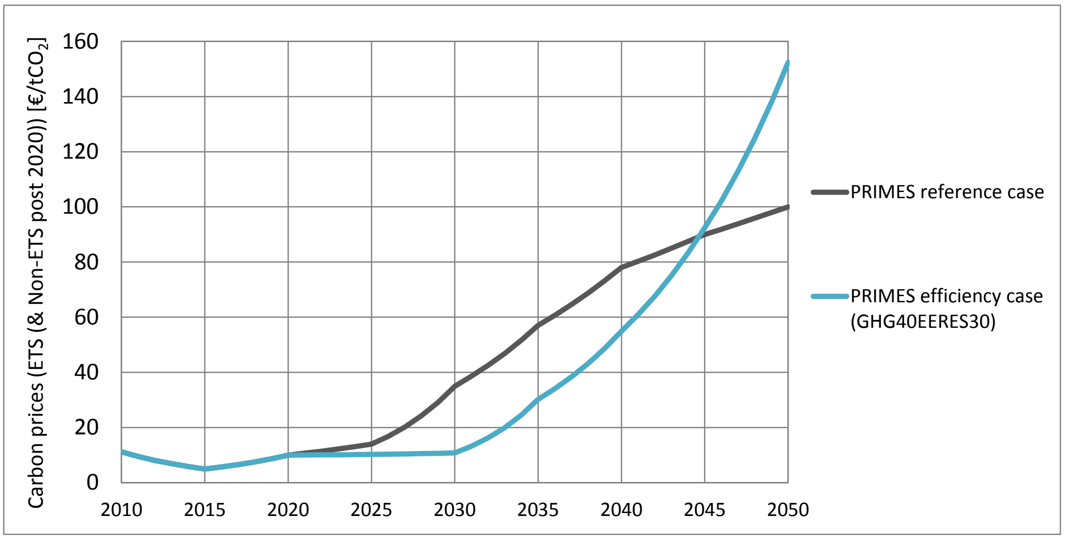


Figure 7 CO2 price assumptions in €2010 / ton. Source: PRIMES scenarios (EC, 2013)

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.

2.3.4 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;[1]
- The guaranteed duration of financial support is limited.[2]

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.

2.3.5 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

[1] 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.

[2] 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).

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

$$\Delta P_{Mne} = P_{stat\,long-term} * \left[A * X_n^{\,2} + B * X_n + C\right] * \left[\chi_{M\min} + \frac{\chi_{M\max} - \chi_{M\min}}{4} * b_M\right] \qquad (2)$$

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

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 ...

$$X_n = \frac{\text{dynamic achieved potential (year n, country level)}}{\text{total long - term potential (country level)}} \quad ; X_n\ [0,\ 1]$$

$\chi_{M\ max}$ 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) [3]; 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.[4] [5]

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")

---

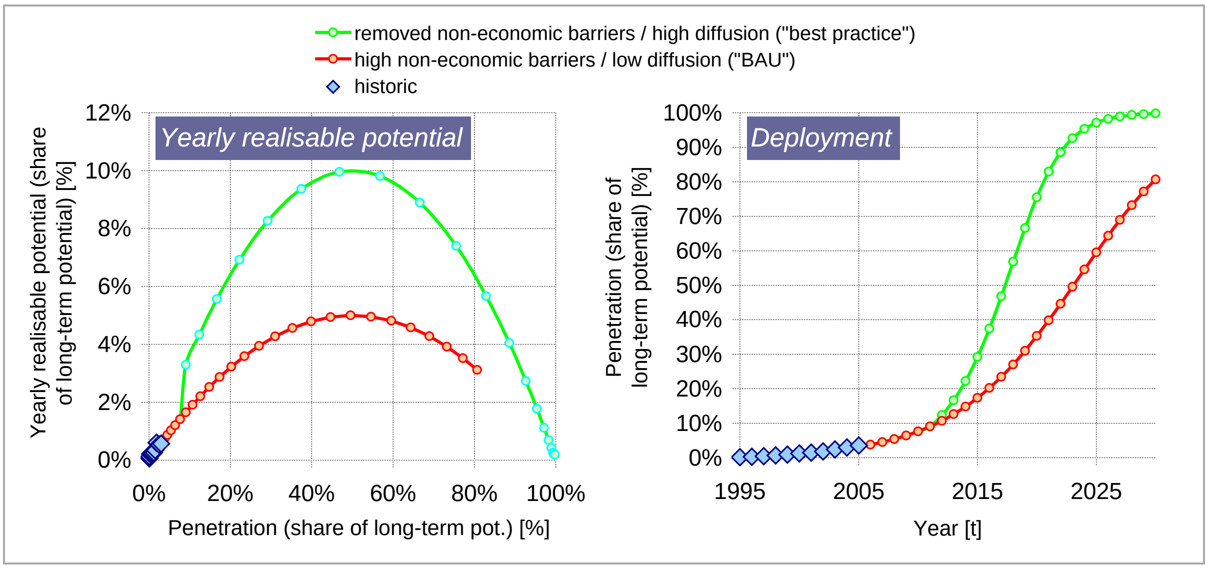
[3] A value of 0 would mean the strongest limitation (i.e. no diffusion, except minimum level), while 4 would mean the strongest feasible diffusion (according to "best practice" observations).

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.

[4] 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.

[5] 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.[6] 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 8: 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

2.3.6 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.

[6] 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[7] 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:

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

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

[7] 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.

2.4 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.

1.1.1 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

2.4.1 Classification of potential categories

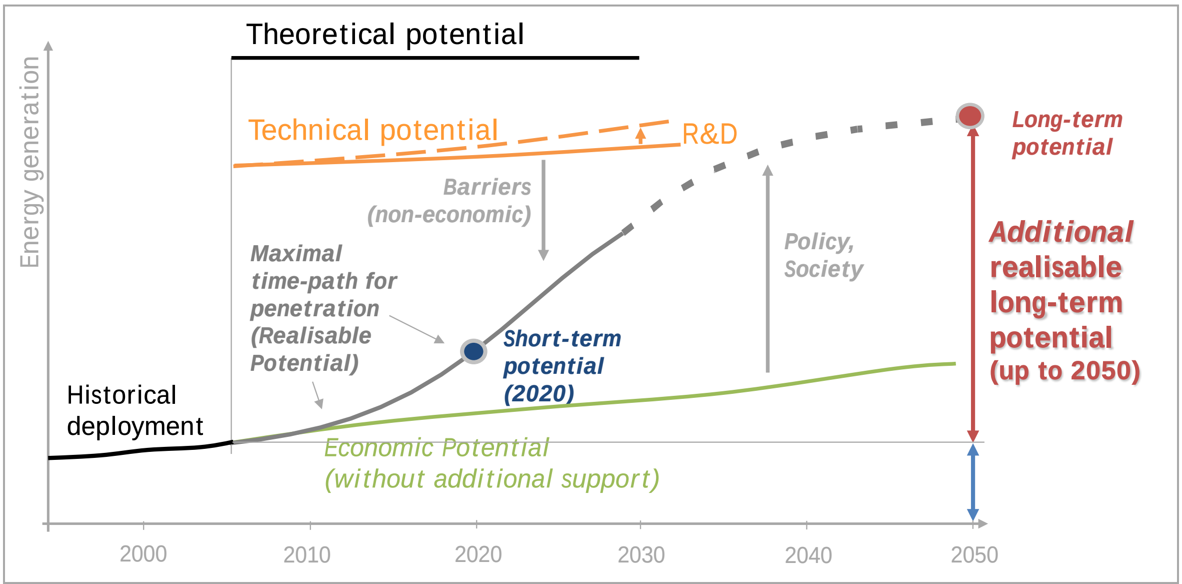


Figure 9: Definition of potential terms

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 9 (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.

2.4.2 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[8] 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[9] 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.

[8] 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.

[9] 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[10]

Summing up all RES options applicable at country level, Figure 10 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 11 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.

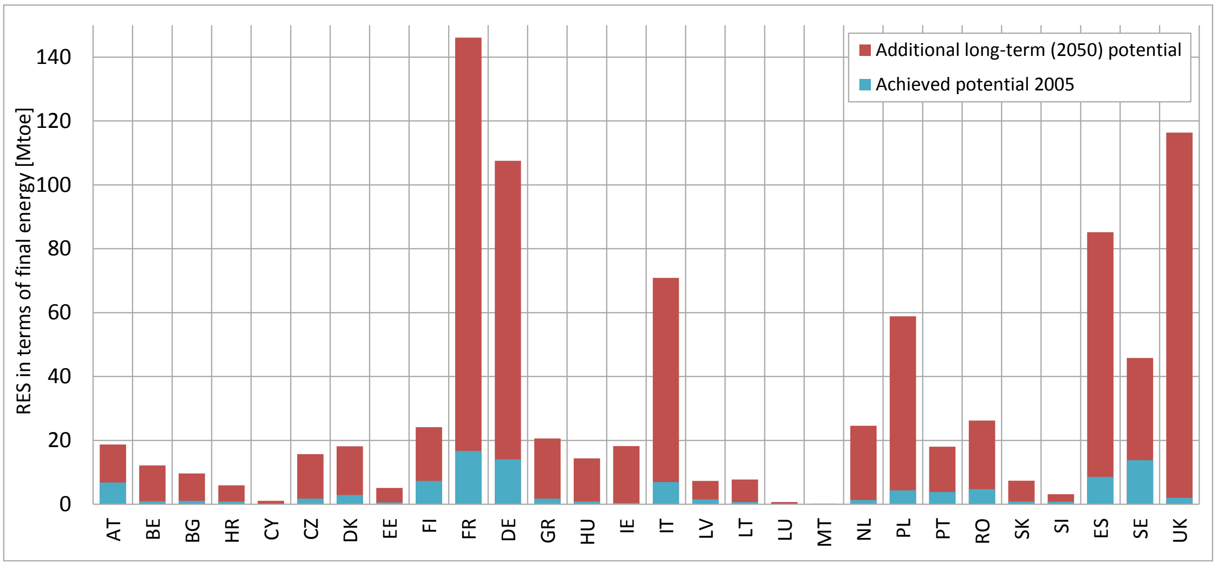


Figure 10: Achieved (2005) and additional long-term (2050) potential for RES in terms of final energy for all EU Member States (EU 28) – expressed in absolute terms

[10] (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.

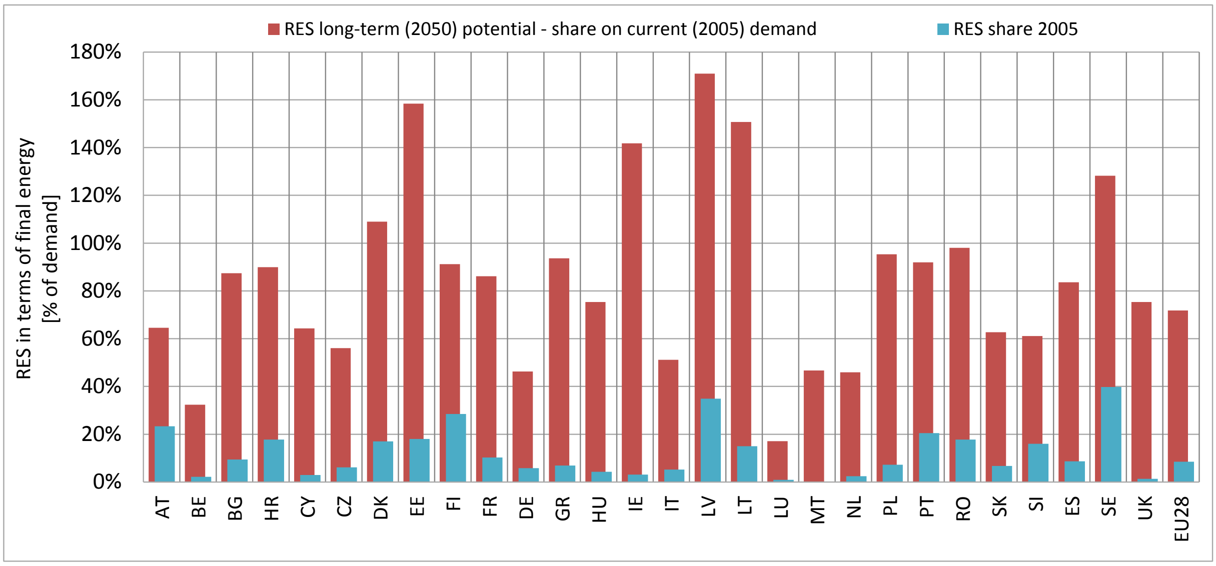


Figure 11: Achieved (2005) and total long-term (2050) potential for RES in terms of final energy for all EU Member States (EU 28) – expressed in relative terms, as share on (gross) final energy demand

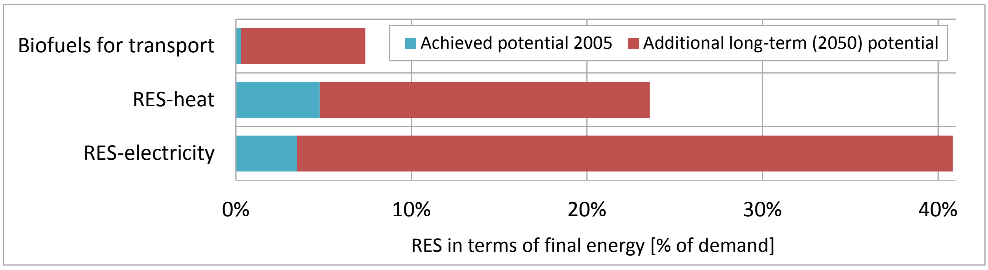


Figure 12: Sector-specific breakdown of the achieved (2005) and additional long-term (2050) potential for RES in terms of final energy at EU 28 level – expressed in relative terms, as share on current (2005) (gross) final energy demand

Finally, a sector-specific breakdown of the realisable RES potentials is given in Figure 12 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[11] – 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[12] 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).

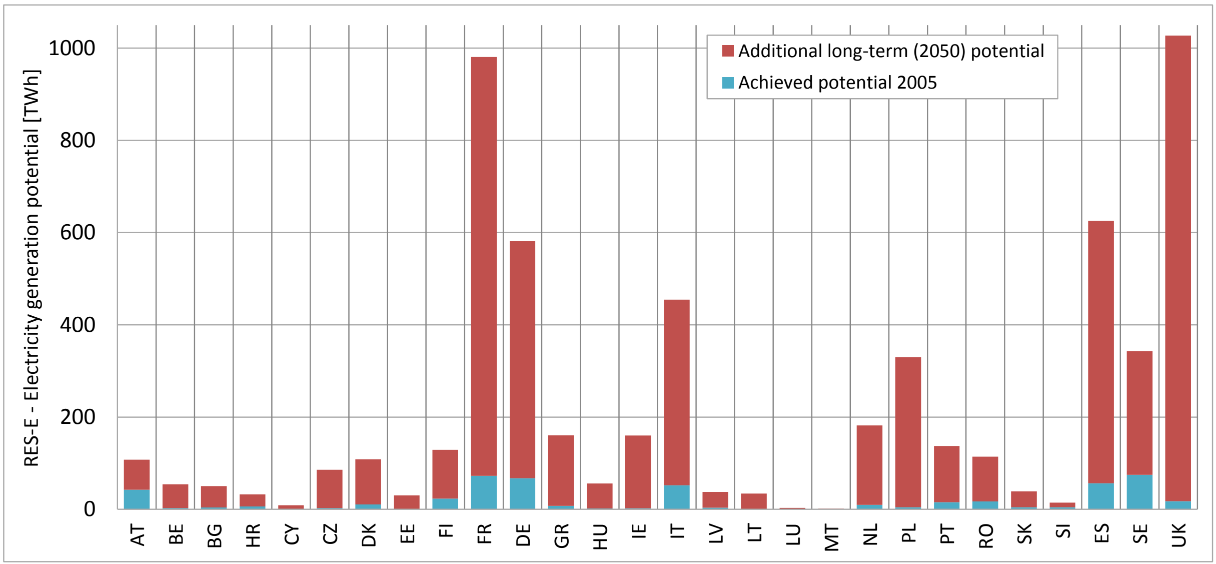


Figure 13: Achieved (2005) and additional long-term potential 2050 for electricity from RES in the EU 28 at country level.

Figure 13 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

[11] 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.

[12] 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 14 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*[13] covered. For comparison, by 2005 already installed RES-E plants possess the generation potential to meet about 15% of demand.

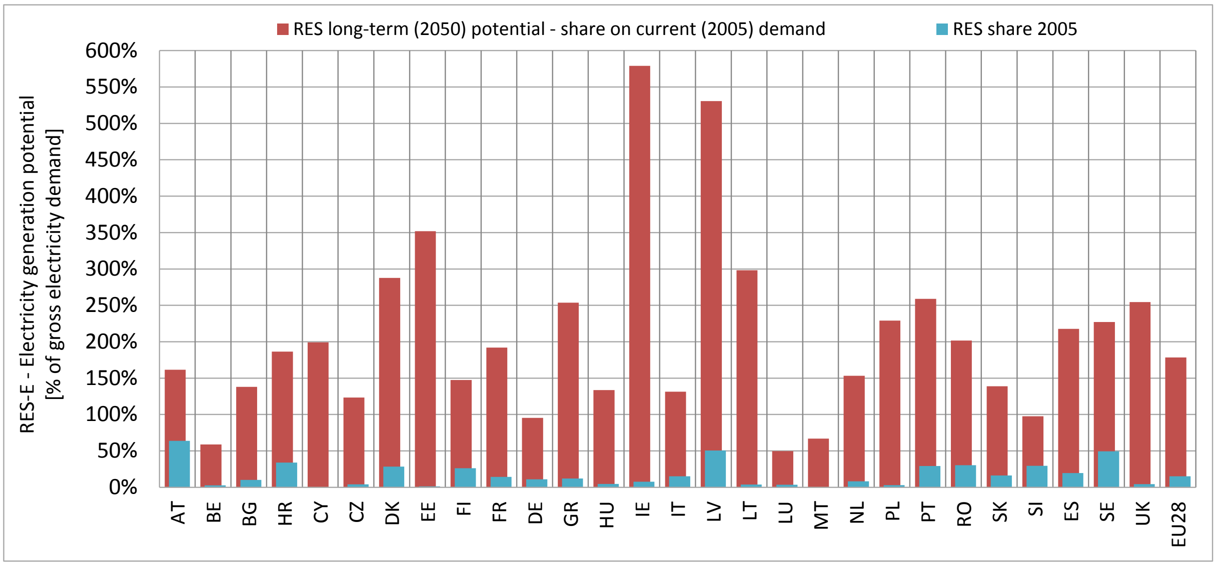


Figure 14: Achieved (2005) and total long-term (2050) potential for electricity from RES in the EU 28 at country level, expressed in relative terms as share of gross electricity demand (2005)

A closer look at the technology-level is provided by Figure 15. This graph offers a technology breakdown of the achieved (2005) and the additional realisable long-term

13 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.

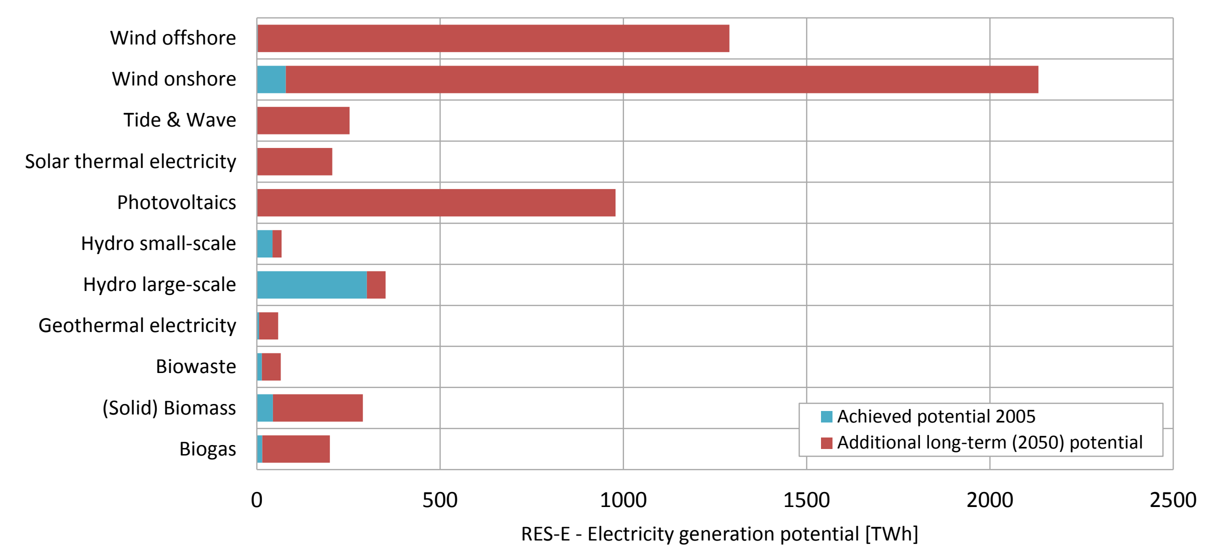


Figure 15: Achieved (2005) and additional long-term (2050) potential for electricity from RES in the EU28 at technology level

2.5 Assessed cases

The model-based assessment of future RES deployment 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 16 provides a brief overview on all assessed cases. Next to that the scenario definition is introduced in further detail by distinct focal point.

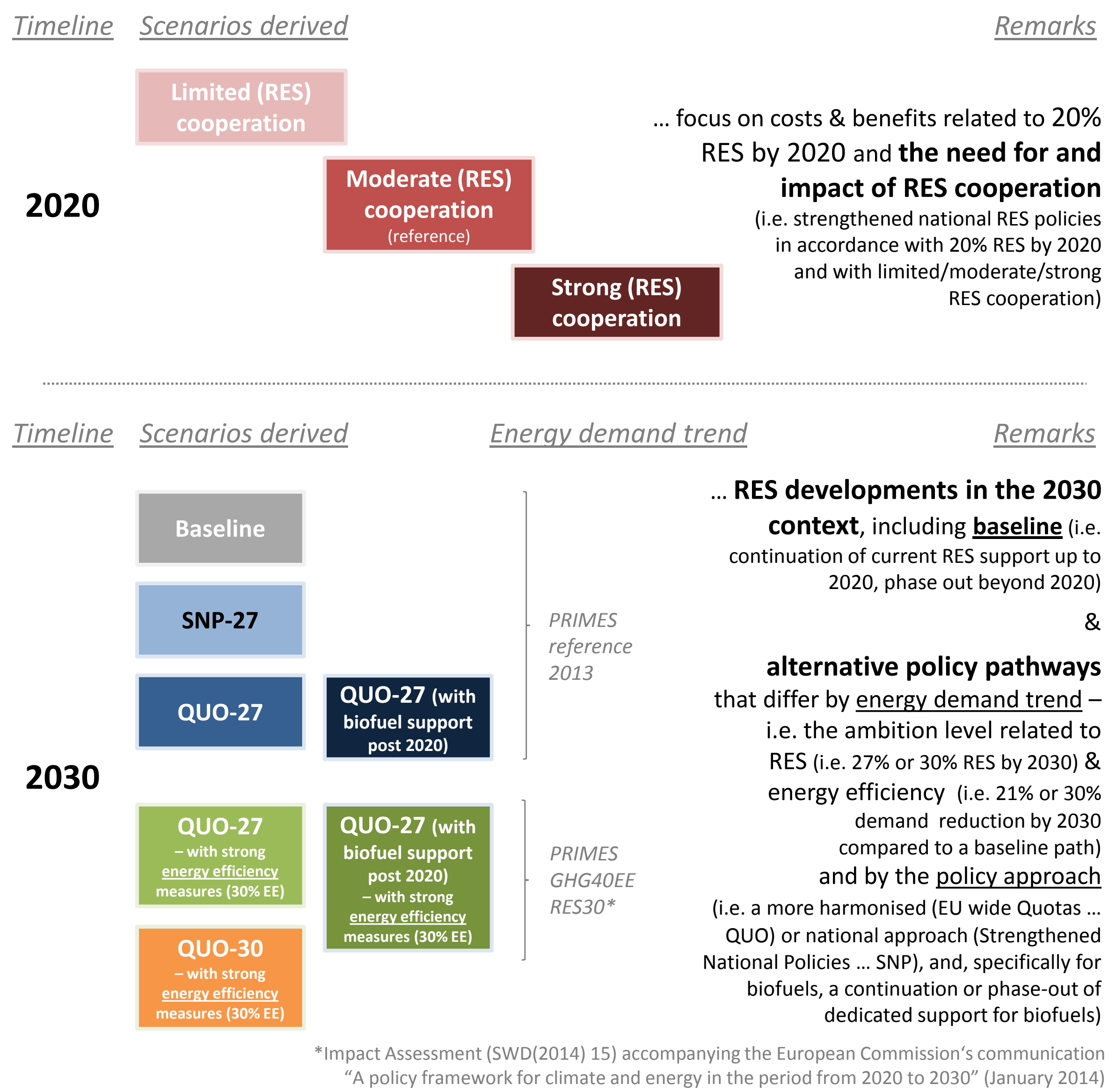


Figure 16: Overview on assessed cases

2.5.1 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.[14]

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.[15]

- 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"**[16] is expected to arise from that.

2.5.2 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

---

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

[15] 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.

[16] 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 16 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. [17]
- 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,

[17] 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 The need for and impact of RES cooperation for achieving 2020 RES targets

This section aims to shed light on the need for and impact of RES cooperation between Member States from a quantitative perspective, highlighting outcomes of a model-based prospective RES policy assessment dedicated to identify the cost-saving potential arising from a strong use of cooperation mechanisms at European as well as at country level. The work builds on previous related modelling activities and in particular provides an update of the work conducted in Klessmann et al. (2014).

3.1 RES deployment and (virtual) RES exchange by 2020

As a starting point, Figure 17 (below) compares the 2020 RES targets as set by the RES directive (2009/28/EC) with the resulting RES deployment according to distinct scenarios on the extent of use of RES cooperation (i.e. from limited to strong). More precisely, the graph shows both at EU and at national level the expected RES shares in gross final energy demand by 2020. While at EU level in all cases an equal level of RES deployment is achieved,[18] the country-specific deployment differs from case to case. Thereby "limited cooperation" shows generally less deviation between target and resulting national RES deployment while in the case of "strong cooperation" the differences are larger in magnitude.

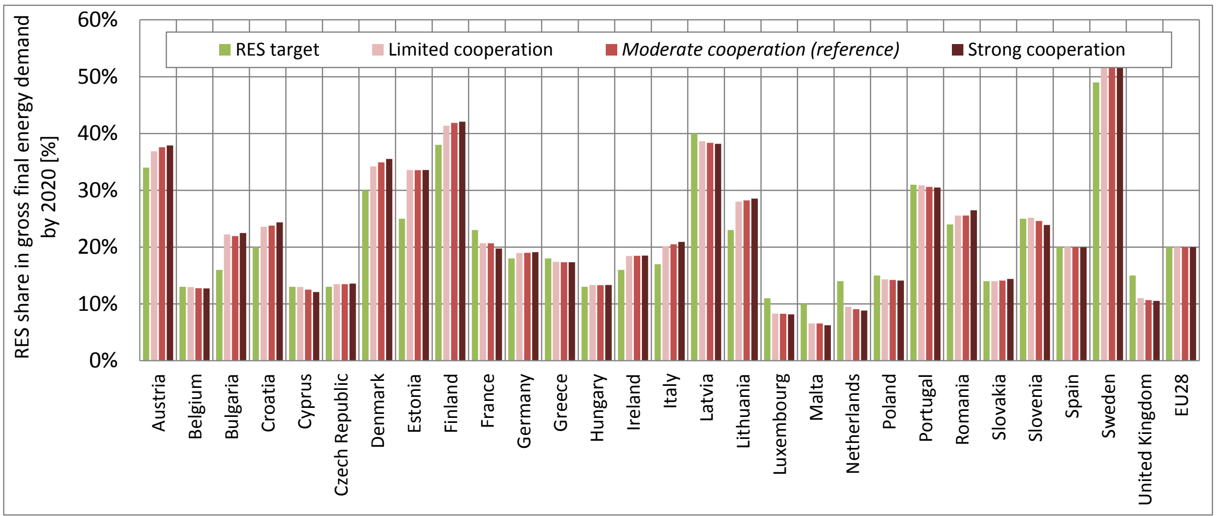


Figure 17: 2020 RES targets vs resulting RES deployment according to assessed scenarios of limited to strong RES cooperation

[18] In accordance with the National Renewable Energy Action Plans as submitted by the Member States throughout 2011 as well as with the PRIMES reference case a slight overfulfilment of national 2020 RES targets is assumed, leading to a RES share of 20.7% in gross final energy demand at EU level.

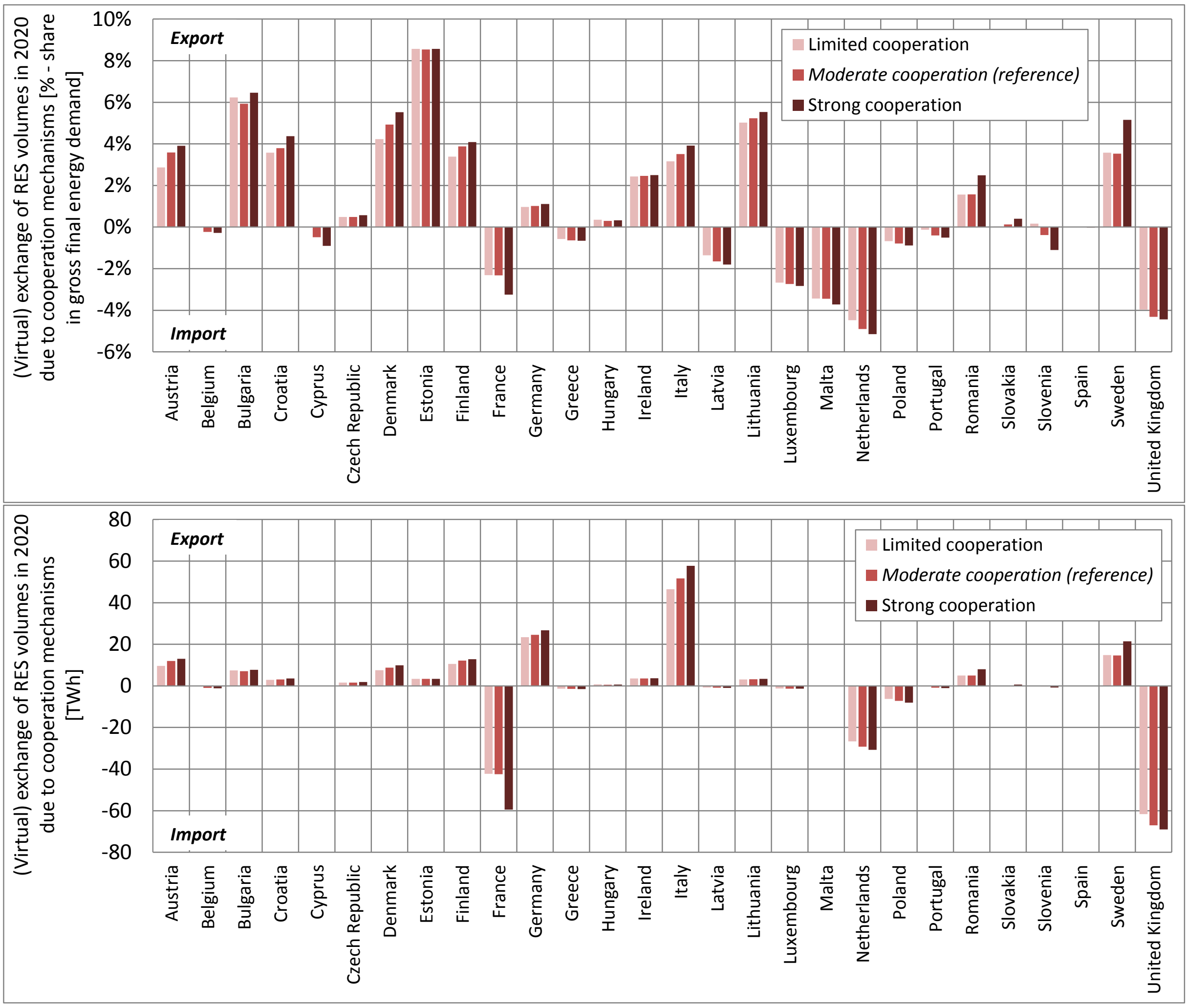


Figure 18: (Virtual) exchange of RES volumes between Member States in 2020 according to selected variants of "strengthened national RES policies", assuming limited, moderate (reference) or strong cooperation between Member States, expressed in relative terms (i.e. share in gross final energy demand) (top) and absolute terms (TWh) (bottom)

Next, Figure 18 provides a graphical illustration of (virtual) exchange of RES volumes needed in 2020 for RES target fulfilment according to assessed scenarios, showing the remaining resulting import and export volumes in relative terms (i.e. as share of gross final energy demand (top)) and in absolute terms (i.e. TWh (bottom)). Notably, also with tailored national support schemes in place, not all countries have sufficient realisable[19] potentials to fulfil their 2020 RES obligation purely with domestic action. As shown in the graph, Belgium, France, Greece, Latvia, Luxembourg, Malta, the Netherlands, Poland, Portugal and the United Kingdom have to rely, in all cases, on RES imports by 2020, albeit to a very different extent. Summing up the required imports of all related

[19] In the case of "limited cooperation", weak economic restrictions are specified for the exploitation of RES potentials, meaning that support levels for certain RES technologies may differ significantly between Member States (i.e. by up to 20 € per MWh RES).

countries, a gap ranging from 140 TWh (in case of limited cooperation) ranging to well above 170 TWh (in case of strong cooperation) occurs which needs to be covered via imports from other Member States which exceed their national obligations. This accounts for roughly 5.5% of the total of required RES deployment by 2020. Thus, this emphasises the need for intensifying cooperation between Member States, even if "national thinking" (of using domestic resources to gain related benefits etc.) maintains its dominance.

3.2 Costs and benefits of intensifying RES cooperation

Figure 19 shows the costs and benefits corresponding to the different policy cases in absolute terms (left hand side) and as relative change compared to the reference case of moderate cooperation. The left hand side reveals that increasing cooperation – at EU level – generally is beneficial as average yearly support expenditures can be lowered from 25.2 billion Euros to 23.5 billion Euros by moving from limited to strong cooperation. The right hand side reveals that a large fraction of the benefits is already achieved by moving from limited to moderate cooperation. This is further visible in the left-hand side of the graphic: the reference case compared to the the limited cooperation scenario exhibits substantially stronger relative changes as the reference case compared to the strong cooperation policy case.

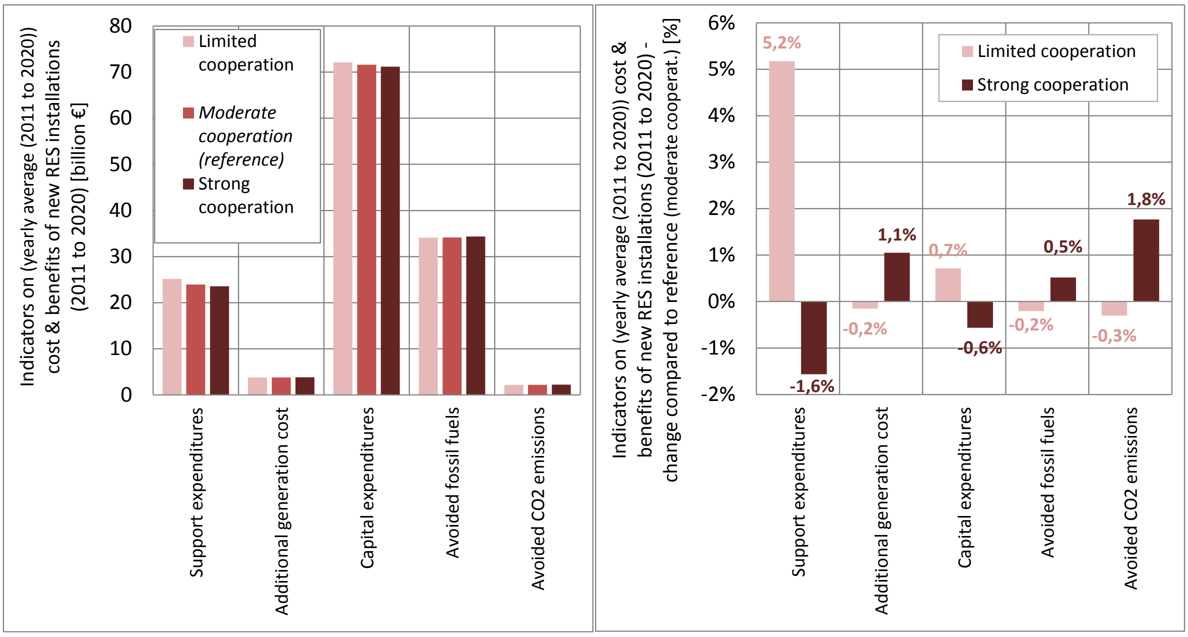


Figure 19: Indicators on yearly average (2011 to 2020) cost and benefits of new RES installations (2011 to 2020) at EU level for all assessed cases, expressed in absolute terms (billion €) (left) and assuming limited or strong cooperation between Member States, expressed as deviation from the (reference) case of moderate RES cooperation (right)

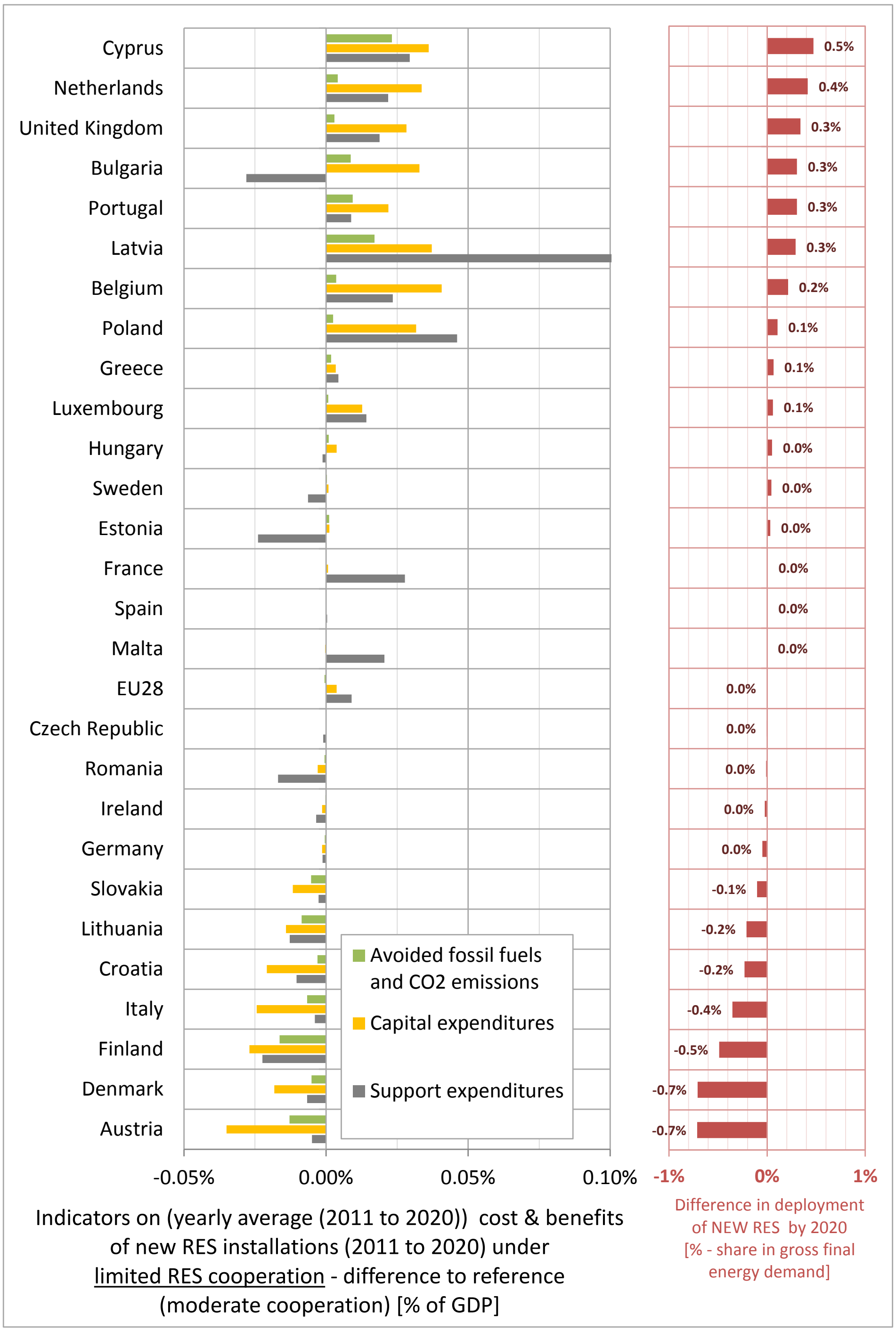


Figure 20: Indicators on (yearly average (2011 to 2020)) cost & benefits of new RES installations (2011 to 2020) under limited RES cooperation - difference to reference (moderate cooperation) [% of GDP]

At country level, a more heterogeneous picture with respect to costs and benefits that come along with intensified RES cooperation occurs. Figure 20 shows the sensitivity of limited cooperation against the reference case as share of the GDP. Moreover on a second scale the difference in deployment of new RES by 2020 as share of gross final energy demand is shown. It has to be kept in mind that the sensitivity against the reference case is depicted here and that countries where the difference is negative would generally act as “host” country for additional RES production in the moderate cooperation case; on the other hand the effect is strongest for countries that would already act as importers in the case of limited cooperation, such as e.g. UK, France or Latvia. A decrease in deployment generally goes hand in hand with a decline of investments (that may have macroeconomic consequences) as well as fossil and CO_2 avoidance.[20] Remarkably, importing countries may gain strongly from cost savings if strong RES cooperation is pursued, since support expenditures could be reduced significantly.

Figure 21 shows the sensitivity of limited cooperation against the reference case as share of the GDP. Moreover on a second scale the difference in deployment of new RES by 2020 as share of gross final energy demand is shown.

In contrast to the above, exporting countries show the opposite trend with respect to impacts on costs and benefits. In general, an increase in RES deployment comes along with benefits like carbon and fossil fuel avoidance. Often more important is a possible positive impact of domestic investments on the labour market. Mobilising more investments in RES however requires financial incentives, leading to an increase in support expenditures. According to Figure 21 this effect appears to be significant in magnitude for some countries like Sweden, Croatia, Bulgaria or Romania. There are however important caveats to consider for avoiding misinterpretations:

- The price that the importer has to pay for the exchanged RES volumes, and that the exporter can book as revenue is the key factor that impacts support expenditures at country level. In our modelling the simplistic proxy is made that the price for traded RES volumes equals the average EU-level support for a new RES-E installation in a given year. In practice, prices for RES exchange may differ from that and for example rise with increasing demand.
- Figure 21 shows the change compared to the reference case of moderate RES cooperation. Since increased cooperation is an attempt towards a more efficient resource exploitation, support levels are generally lower under these circumstances, and consequently also prices for RES exchange decline in our underlying modelling due to the simplification made.
- Thus, for a possible exporting country like Austria or Slovakia this does not mean that RES cooperation is not beneficial at all. It simply means that the assessment and the simplifications made indicate that revenues from selling their surplus in RES volumes may become smaller if a strong cooperation is pursued across the EU due to efficiency gains at the aggregate level.

[20] The indication of impacts on fossil fuel and carbon avoidance at the national level shall be seen as a rough estimate since for RES in the electricity sector it remains hard to predict under which geographical borders actual replacement takes place (due to the interconnected market, at least in parts of Europe).

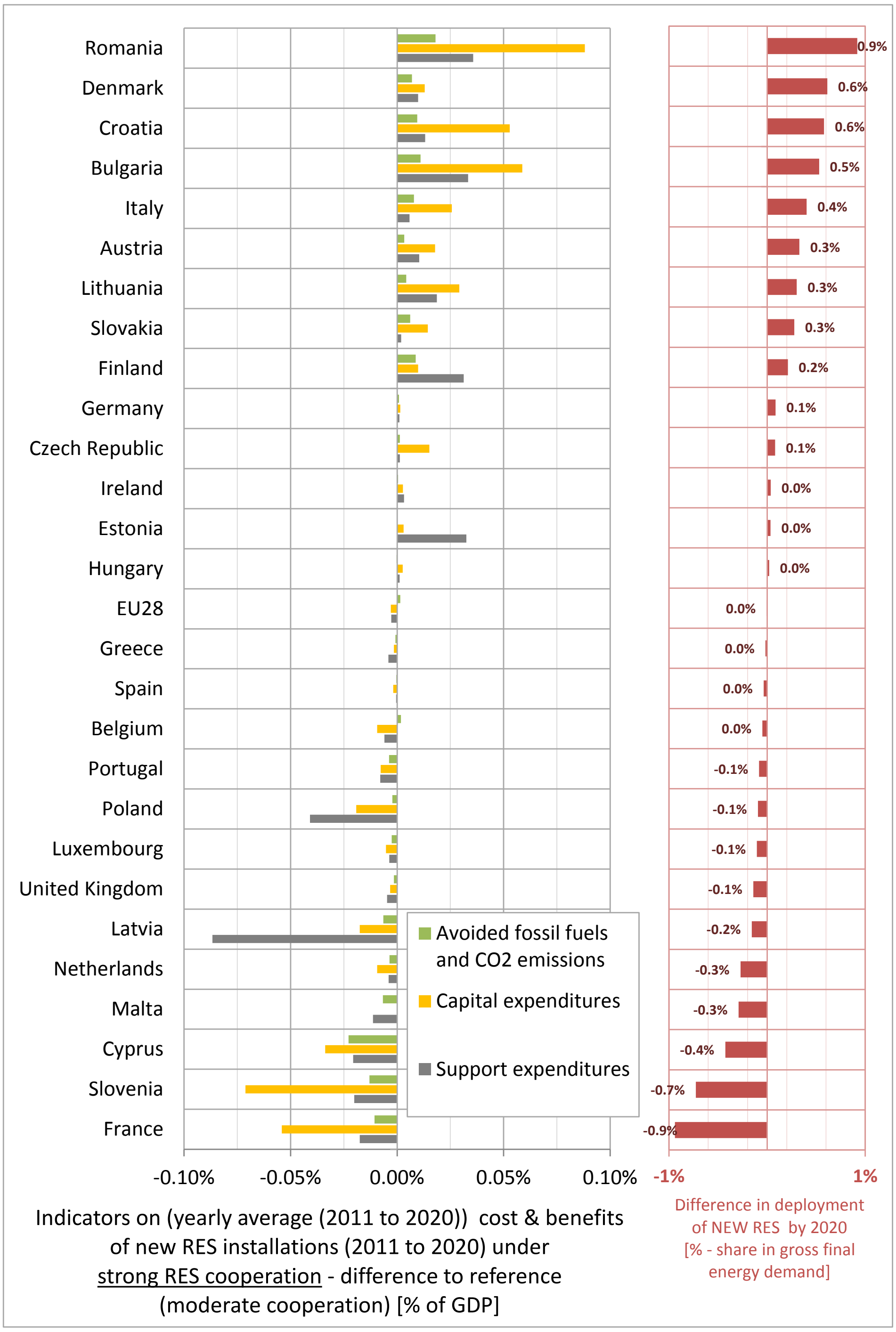


Figure 21: Indicators on (yearly average (2011 to 2020)) cost & benefits of new RES installations (2011 to 2020) under strong RES cooperation - difference to reference (moderate cooperation) [% of GDP]

4 Outlook to 2030: Scenarios on meeting (at least) 27% RES by 2030

This chapter illustrates the outcomes of the **model-based assessment of future RES policy developments up to 2030** within the European Union and its Member States. Compared to the previous chapters where a focus is laid on national policy approaches the scenario and policy scope is broadened, including approaches that aim for forming a level playing field across the EU through further alignment and harmonisation.

Overview on RES policy scenarios used in this exercise:

BAU	Business-as-usual scenario of RES policy schemes, non-economic RES barriers prevail	SNP-27	Strengthened national (RES) policies (in accordance with 2020 and 2030 RES targets)
QUO-27 (with biofuel support)	Harmonised (RES) support post 2020 (EU-wide quotas with certificate trading for RES-E), in accordance with 2030 RES target, with dedicated support for biofuels post 2020	QUO-27	Harmonised (RES) support post 2020 (EU-wide quotas with certificate trading for RES-E), in accordance with 2030 RES target
QUO-27 (with biofuel support) – strong EE	Harmonised (RES) support post 2020 (EU-wide quotas with certificate trading for RES-E), in accordance with 2030 RES target, with dedicated support for biofuels post 2020, with strong energy efficiency measures	QUO-27 – strong EE	Harmonised (RES) support post 2020 (EU-wide quotas with certificate trading for RES-E), in accordance with 2030 RES target, with strong energy efficiency measures
QUO-30 – strong EE	Harmonised (RES) support post 2020 (EU-wide quotas with certificate trading for RES-E), aiming for a higher RES share than prescribed by the 2030 RES target, with strong energy efficiency measures		

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:

- As described for one of the previous exercises, in 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.
- 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, 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.

We start with a discussion of RES deployment whereas results concerning the capital, O&M, and fuel expenditures of RES, additional generation costs and support expenditures as well as savings related to fossil fuel (imports) are discussed subsequently.

4.1 Results on RES deployment

4.1.1 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 22 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.

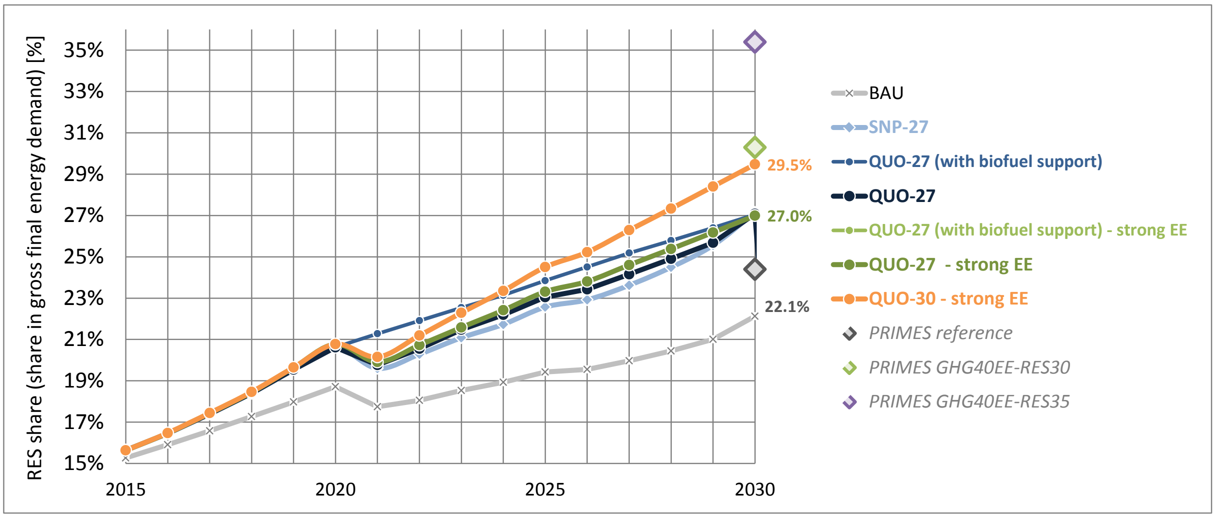


Figure 22: Comparison of the resulting RES deployment in relative terms (i.e. as share in gross final energy demand) over time in the EU 28 for all assessed cases (incl. PRIMES scenarios)

Figure 23 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).

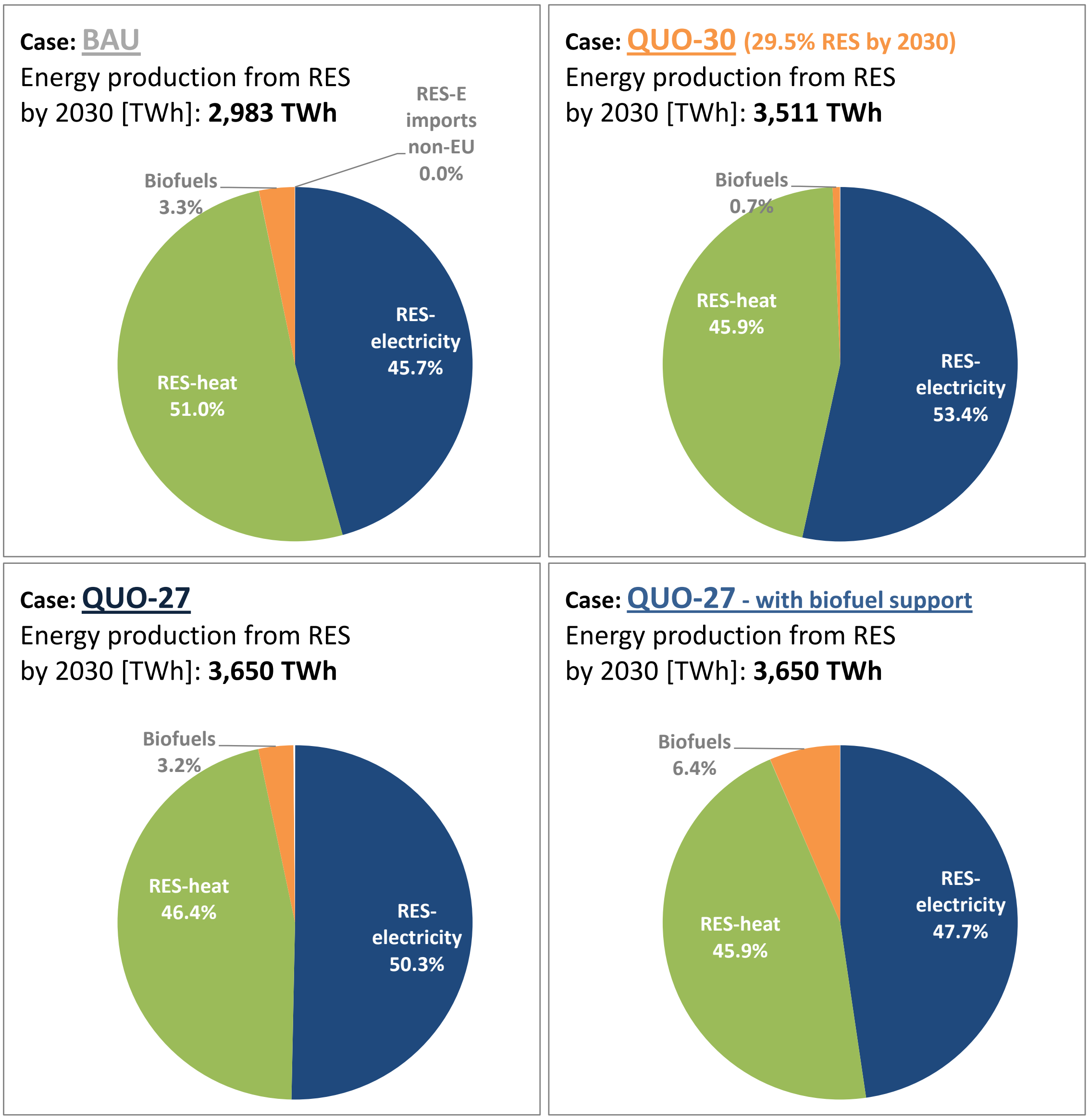


Figure 23: Sector-specific RES deployment at EU 28 level by 2030 for selected cases

4.1.2 Details on RES in the electricity sector

Next, a brief overview of the results gained for RES in the electricity sector is given, showing key indicators on RES deployment over time and at technology level (see Figure 24 and Figure 25).

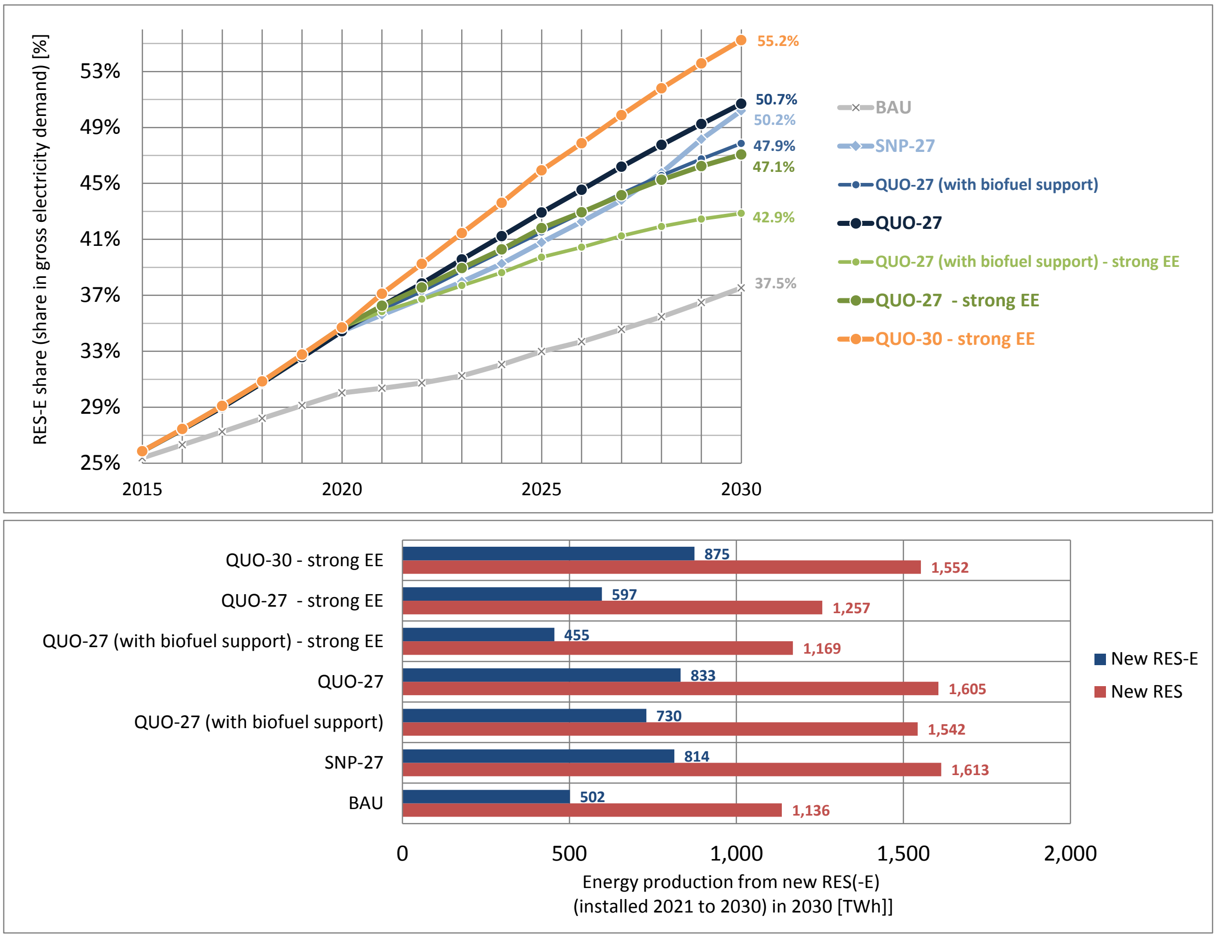


Figure 24: Comparison of the resulting deployment over time (top) and by 2030 for new RES-E and RES installations only (from 2021 to 2030) (bottom) in the EU 28 for all assessed cases.

More precisely, Figure 24 illustrates the feasible RES-E deployment for all assessed policy cases over time (top) as well as by 2030 (bottom), indicating the penetration of new RES-E installations within the observed time frame. It becomes evident that, without or with low dedicated support, RES-E deployment would increase modestly after 2020, reaching for example a share of 37.5% RES-E by 2030 in the baseline case. This indicates that the ETS alone complemented by only moderate dedicated RES incentives do not provide sufficient stimuli for RES-E deployment to maintain a level of ambition consistent with the development until 2020. In contrast to the baseline case, the expected RES deployment in the electricity sector increases more substantially in all other policy variants by 2030, ranging from 42.9% (QUO-27 with biofuels) to around

52.6% (QUO-30).

If total RES deployment is considered, a 21% RES share in gross final energy demand would be achieved under baseline conditions by 2030, while the targeted RES deployment volumes are reached in all other policy paths (i.e. 27% under SNP-27 and QUO-27 (with and without biofuel support), and 30% in the QUO-30, respectively).

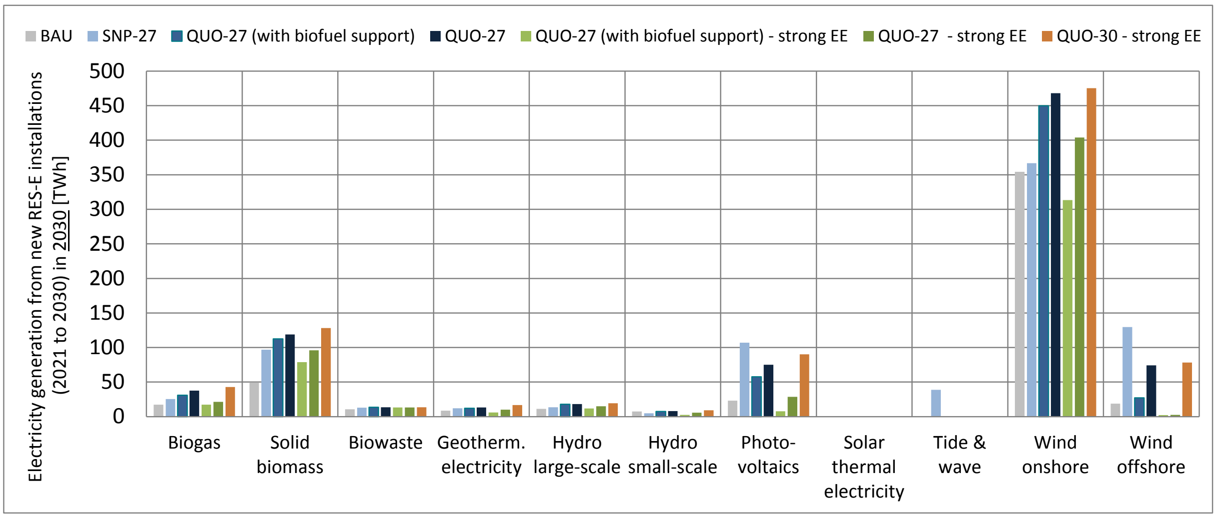


Figure 25: Technology-specific breakdown of RES-E generation from new installations by 2030 (incl. new installations from 2021 to 2030) at EU 28 level for all assessed cases.

Complementary to the above, Figure 25 provides a technology breakdown of RES-E deployment at EU 28 level by 2030. The figure shows the amount of electricity generation by 2030 that stems from new installations inthe assessed period 2021 to 2030, for each of the analysed policy pathways.. It is apparent that onhore wind energy, followed by biomass and in certain scenarios also photovoltaics and offshore wind energy dominate the picture. Even in the baseline case, significant numbers of new installations can be expected, in particular for onshore wind energy. Differences are observable between all the other cases and are a consequence of the targeted RES volumes (27% or 30% RES by 2030) or of the policy approach assumed to reach that target. An ambitious RES target (30% RES by 2030) generally requires a larger contribution of the various available RES-E options. Technology-neutral incentives as assumed under the policy variant with harmonised uniform RES-E support (QUO-27 and QUO-30) however fail to provide the necessary incentive to encourage more expensive and less mature RES-E options on a timely basis, what is particularly true for the QUO-27 case. Consequently, the deployment of CSP, tidal stream or wave power, but also to a certain extent offshore wind, may be delayed or even abandoned. The gap in deployment would be compensated by an increased penetration of low to moderate cost RES-E options, in particular onshore wind and biomass used for co-firing or in large-scale plants.

4.1.3 RES deployment by 2030 at country level

Figure 26 offers a comparison of the resulting country-specific RES deployment by 2030 according to selected scenarios: a baseline (BAU) case and two alternative policy pathways that refer to an EU-wide target of 27% RES by 2030 (i.e. QUO-27 and SNP-27) are included in the illustration.

Moreover, the graph also indicates possible country-specific (voluntary) 2030 RES targets, prescribed as 2030 RES benchmarks, following the approach used in Directive 2009/28/EC for defining 2020 RES targets. Thus, as such this approach considers the Member State's economic strength in terms of GDP as well as efforts made in the past. On the other hand, the approach ignores other aspects such as the potential availability of renewable resources and related costs.

It can be seen that under baseline conditions an EU target of 27% RES by 2030 appears out of reach for the majority of Member States. A comparison of the results related to alternative policy cases indicates partly significant differences in country-specific RES deployment; compare e.g. RES deployment in the UK or in Portugal according to the distinct case of having a more national or European policy orientation. In the case of the UK this nicely illustrates the low level of ambition of a 27% RES target: for doing so, offshore wind as largely available in northern parts of Europe is hardly required and would consequently deploy only to a limited extent if a “least cost” approach defines the way forward at EU level.

When looking at the baseline scenario, i.e. where countries follow a pathway with their current policy settings, the majority of the member states will not be able to reach a EU 27% or a more ambitioned national goal for RES deployment. As can be seen in Figure 26, this concerns countries such as the Netherlands or the UK whereas countries as Sweden or Austria already have policies in place that would lead them to (over-)fulfil the targets given that the policies are kept unchanged.

Looking into the countries where the indicative national 27% RES goal would be reached, different cases can be identified: For some countries, it does not matter much for their actual achievement whether they adapt a national goal or an overall 27% EU RES goal. This is the case for e.g. the Czech Republic or Belgium.

Comparing the RES deployment in other countries gives very different results when assuming potential own national goals for 2030 and when assuming no national policy strategy but only an overall EU 27% goal. These differences are especially evident in the UK, Portugal or Croatia. In concrete terms, a 27% EU goal would induce only limited investment in costlier technologies as e.g. offshore wind in the UK. In Portugal on the other hand, an overall 27% RES EU goal would induce a substantial expansion in relatively cheap onshore wind parks, whereas a national goal would come along with lower investments. The same can be seen for Croatia, which would also deploy more onshore wind under a harmonized 27 % RES goal.

This highlights the compared to 2020 low level of ambition that a 27% RES target represents: countries would focus on the “least cost” approach; further development of costlier technologies would not be needed since these would be deployed only to a very limited extent.

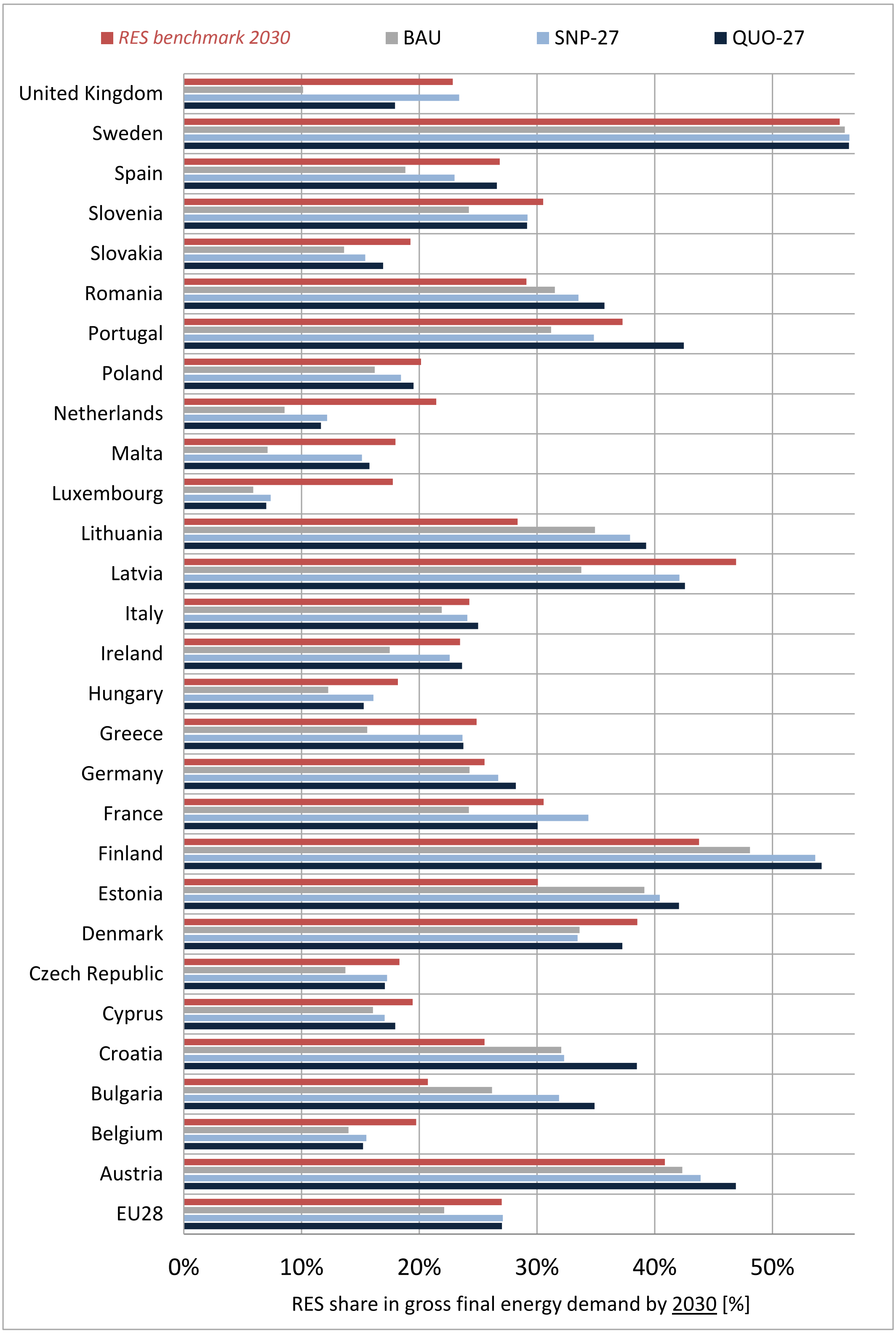


Figure 26: Comparison of the resulting country-specific RES deployment by 2030 according to selected scenarios (baseline and alternative policy pathways related to 27% RES by 2030)

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

The outcomes of Green-X modelling related to capital, O&M, and fuel expenditures of RES as well as to additional generation costs, support expenditures and savings related to fossil fuel (imports) are presented in this section. The results are complemented by a qualitative discussion based on key indicators.

4.2.1 Indicators of costs, expenditures and benefits of RES

Figure 27 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*[21] 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).

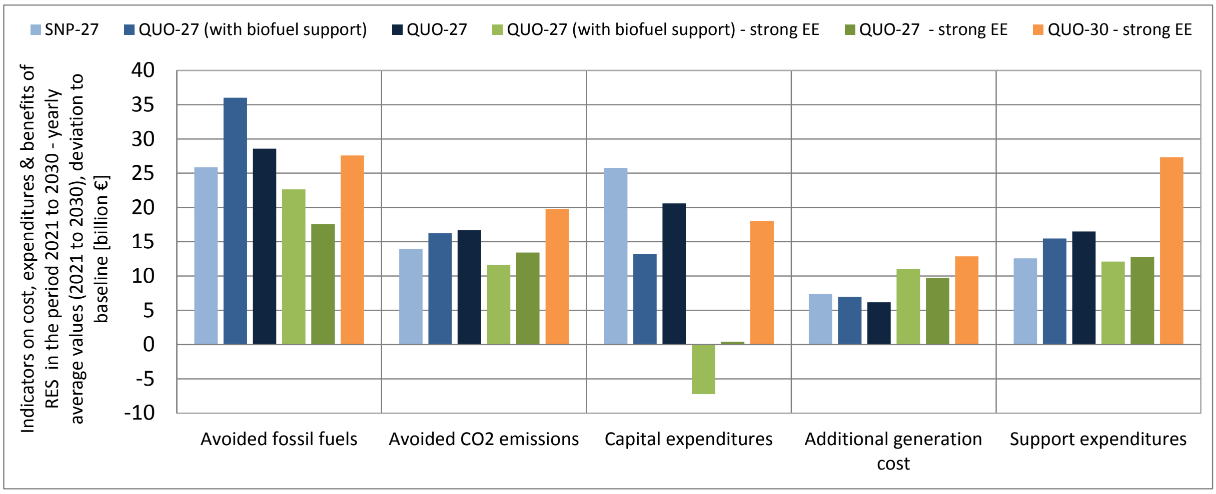


Figure 27: Indicators on yearly average cost, expenditures and benefits of RES at EU 28 level for all assessed cases, monetary expressed in absolute terms (billion €) per decade (2021 to 2030)

Some key observations can be made from Figure 27:

[21] *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.

- 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.
- 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.

4.2.2 Indicators of support expenditures for RES installations

Figure 28 complements the above depictions of RES deployment and overall economic impacts, indicating the resulting support expenditures for RES in relation to the RES deployment in more detail. More precisely, Figure 28 compares overall RES deployment by 2030 with the corresponding support expenditures (on average per year for the period 2021 to 2030) for the selected policy pathways by depicting the RES share in gross final energy demand. We can identify an almost linear relationship between an increase in RES-related support expenditures and an increase in RES deployment. Moreover Figure 28 reveals that a continuation of Business-as-Usual policies would lead to a share of about 22% in 2030.

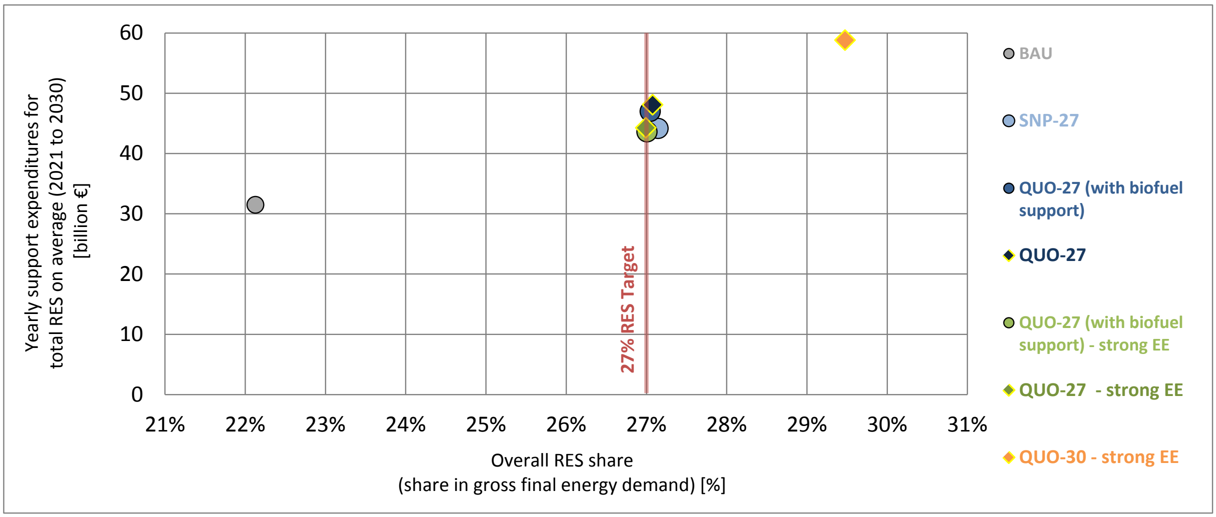
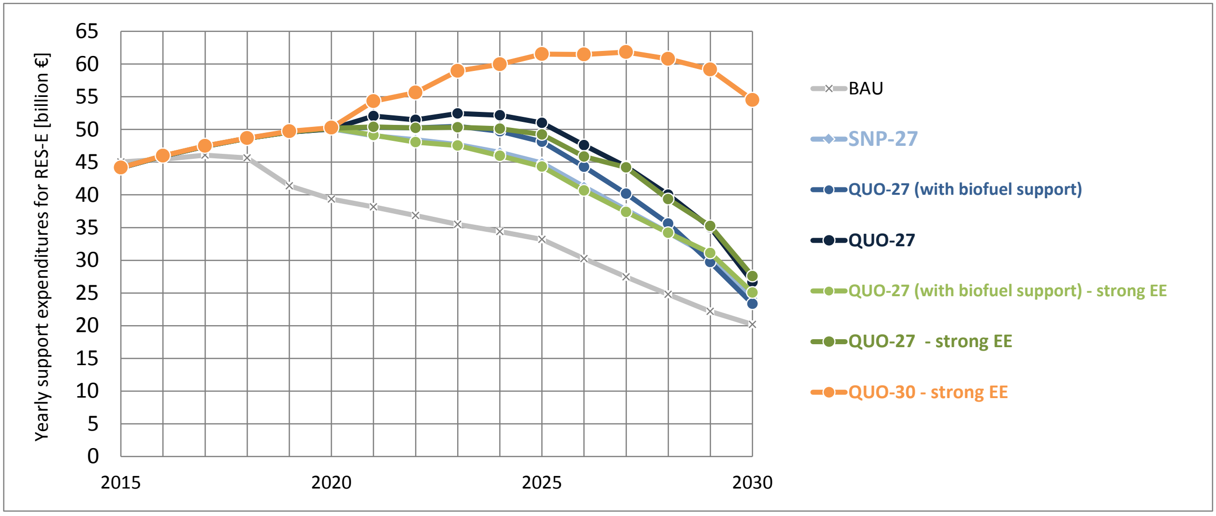


Figure 28: Comparison of the resulting 2030 RES deployment and the corresponding (yearly average) support expenditures for new RES (installed 2021 to 2030) in the EU 28 for all assessed cases.

Next a closer look is taken at the **financial impact of RES support in the electricity sector**. The support expenditures for RES-E or policy costs from a consumer perspective are analysed in more detail. In this context, (top) provides a comparison of the dynamic evolution of the required support expenditures in the period 2011 to 2030 for all RES-E (i.e. existing and new installations in the focal period). Note that these figures represent an average premium at EU 28 level, while significant differences may occur at the country-level, even in the case of harmonised support settings. Complementary to that, Figure 29 (bottom) shows yearly average support expenditures for new RES and RES-E installations in the period of 2021 to 2030.

When inspecting Figure 29 the yearly support expenditures it has to be kept in mind that absolute cost values are displayed in contrast to Figure 27 where differential costs (compared to the baseline) are displayed. From the lower part of Figure 29 it can be seen that new RES-E installations are responsible for the bulk of newly arising support expenditures.



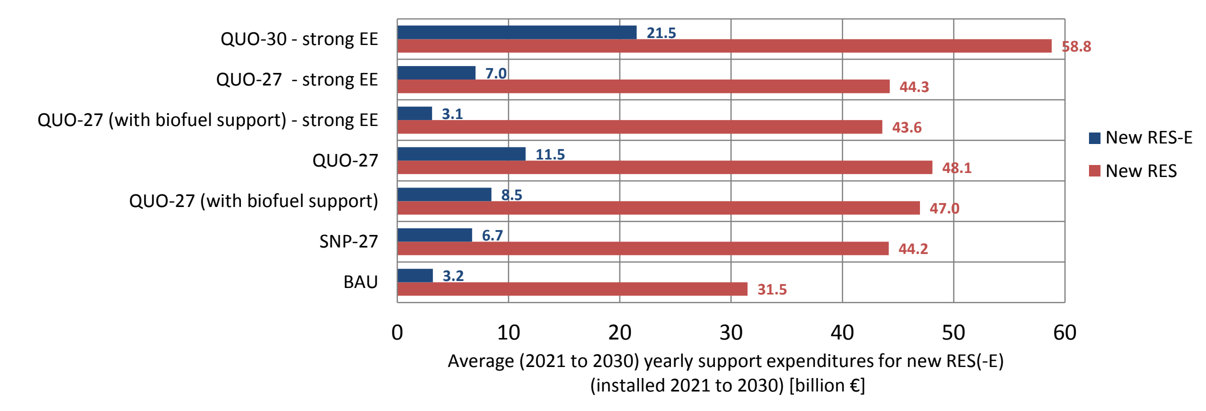


Figure 29: Comparison of the resulting yearly support expenditures over time (top) and on average (2021 to 2030) (bottom) for new RES-E and RES installations only (from 2021 to 2030) in the EU 28 for all assessed cases.

Figure 30 (left) shows the dynamic development of the necessary financial support per MWh of RES-E generation for new installations (on average) up to 2030 and, complementary to that, Figure 30 (right) expresses average values (for the forthcoming decade 2021 to 2030) per technology. The amount represents the average additional premium on top of the power price (normalised to a period of 15 years) for a new RES-E installation in a given year from an investor's viewpoint; whilst, from a consumer perspective, it indicates the additional expenditure per $MWh_{RES\text{-}E}$ required for a new RES-E plant compared with a conventional option (characterised by the power price).

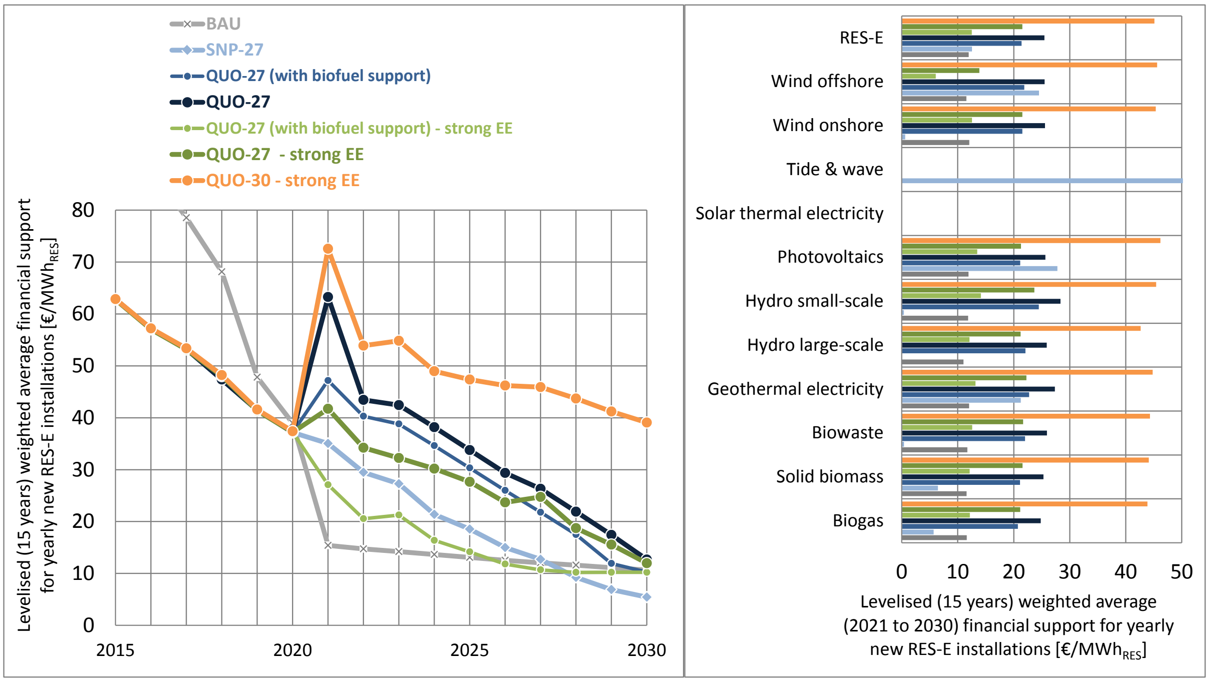


Figure 30: Comparison of financial support (premium to power price) for new RES-E installations at EU 28 level over time (2015 to 2030) (left) and on average (2021 to 2030) by technology (right)

In general, a decline of the required financial support per MWh_{RES-E} is apparent, but differences between the policy variants can be observed. Generally, the average support is higher under a technology-neutral scheme compared to policy approaches that offer incentives tailored to the specific needs. The decrease of financial support appears most pronounced under baseline conditions: Under this scenario a phase-out of currently strong deployment incentives for RES-E is assumed in the period post 2020. This causes a sharp decline of the financial support for *yearly new* constructed RES-E installations while cumulative support expenditures decline moderately.

4.3 Summary: the efforts required to meet (at least) 27% RES by 2030

4.3.1 Gross and net increases in RES deployment

For evaluating the ambition level of the 27% target, it is necessary to assess the required increase of renewable energy, both in terms of net and gross figures, which also consider replacements.[22] Assuming a share of 27% renewables in 2030, between 500 and 910 TWh of *additional* renewable energy will have to be deployed in the decade from 2020 and 2030, depending on the level of final energy demand (see left-hand side of Figure 31).[23] These are the net figures, which do not consider potentially needed replacements of older renewable energy installations. Compared to the decade from 2010 to 2020, in which about 1000 TWh of additional renewable energy is required to achieve a 20% share of renewables by 2020, the 2030 target does not appear to be ambitious in terms of net increase.

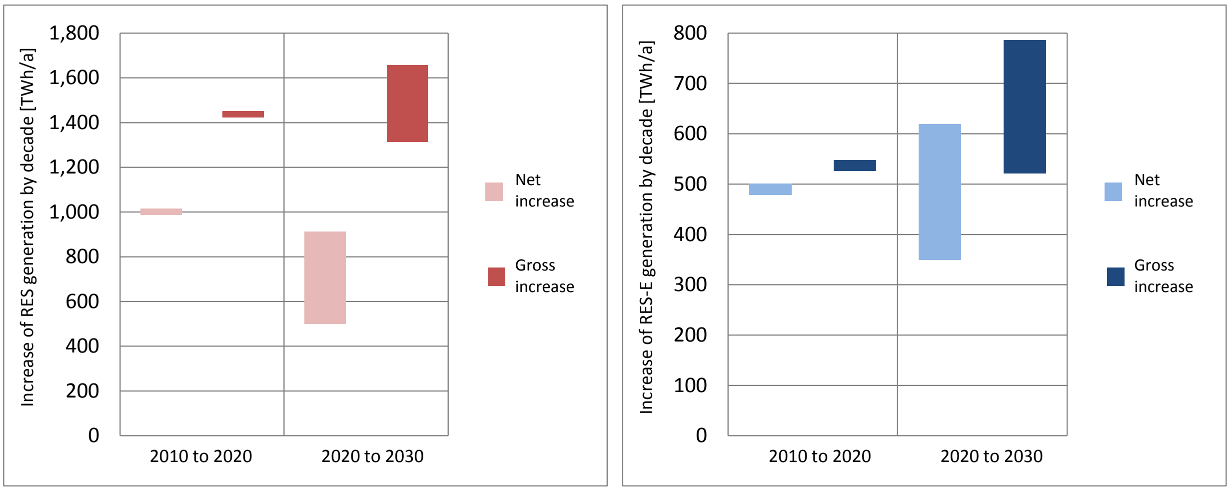


Figure 31 Net and gross increase of renewable generation at EU level by decade (2010-2020 vs. 2020-2030) across all energy sectors (left) and in the electricity sector (right) in accordance with a 27% renewables target for 2030 (Source: own assessment (Green-X) based on PRIMES scenarios)

[22] Figures on the gross increase in renewables stem from a detailed model-based assessment where scenarios of future renewables deployment are calculated with the Green-X model in accordance with a 27% renewables target for 2030 and with the distinct future energy demand projections (reference and projections). A brief recap of the approach taken and assumptions made is given in Annex I to this paper.

[23] The lower value refers to an improvement in energy efficiency of 30%, whereas the upper value refers to a 21% improvement compared to the 2007 baseline of the PRIMES model. 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. The 21% case represents the reference scenario 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) as of January 2014. The 30% case represents the energy efficiency scenario of medium ambition disclosed therein.

The required gross increase is, however, 82 to 163% higher, because gross figures include replacements for plants that will be decommissioned after 2020. The additionally required renewable energy ranges from 1,314 to 1,656 TWh for the above-mentioned projections for the future energy demand. Therefore, significant investments in renewables will be needed in all three sectors: electricity, heating/cooling and transport.

A closer look at the power sector (see right-hand side of Figure 31) indicates an ambiguous development for the necessary net increase in renewable electricity: compared to the time horizon between 2010 and 2020, the required volumes may decline by 29% or increase by 26%. This depends on the level of final energy demand as well as on the role of bio-fuels in the transport sector after 2020. A stronger decline of energy demand corresponding to a 30% energy efficiency target would lead to the lower boundary, while moderate energy efficiency measures (leading to energy demand savings of 21% compared to baseline) combined with no dedicated support for biofuels beyond 2020 may lead to an increase of additional net deployment of renewables in the electricity sector when compared to the decade from 2010 to 2020. When considering gross instead of net figures, the difference between this and the upcoming decade is even more striking: the additional amount of renewable electricity between 2020 and 2030 would have to remain *at least* on the same level as in this decade but might also have to increase by up to 46%. The strong increase is expected, if bio-fuels play a minor role in decarbonising the transport sector and if only moderate energy efficiency results are achieved.

4.3.2 The need for dedicated financial support for RES

To which extent dedicated support for renewables can be phased out in the upcoming decade will mainly depend on (i) the costs of renewable energy technologies and on (ii) future power and carbon prices. Further cost reductions for renewable energy technologies can be expected in the upcoming decade, also due to the increasingly global deployment of renewables. This will lower the costs of supporting the deployment of renewables. Future power and carbon prices are, however, subject to higher uncertainty. The EU carbon market is currently confronted with an oversupply of CO_2 emission allowances, while many EU power markets are struggling with overcapacity. Resolving these issues is also a matter of political intervention and therefore subject to high uncertainty. In the event that these markets regain their equilibrium, support costs for renewables can further decrease.

However, moderate support for renewable electricity generation will still be needed even beyond 2020, for two reasons:[24]

- Some less mature technologies (e.g. offshore wind, wave and tidal stream or concentrated solar power) will experience significant cost reductions thanks to technological learning also after 2020. Support for these technologies is motivated

[24] Further explanations on the impact of both opposing trends on the need for support are provided in Annex II.

by the fact that they will most likely be needed for the long-term decarbonisation objectives of the EU by 2050.

- Due to the price-reducing effect of renewables with variable generation costs close to zero, the market value[25] for variable renewables like solar and wind power is lower than the reference electricity price (see for example Sensfuß et al. 2008).

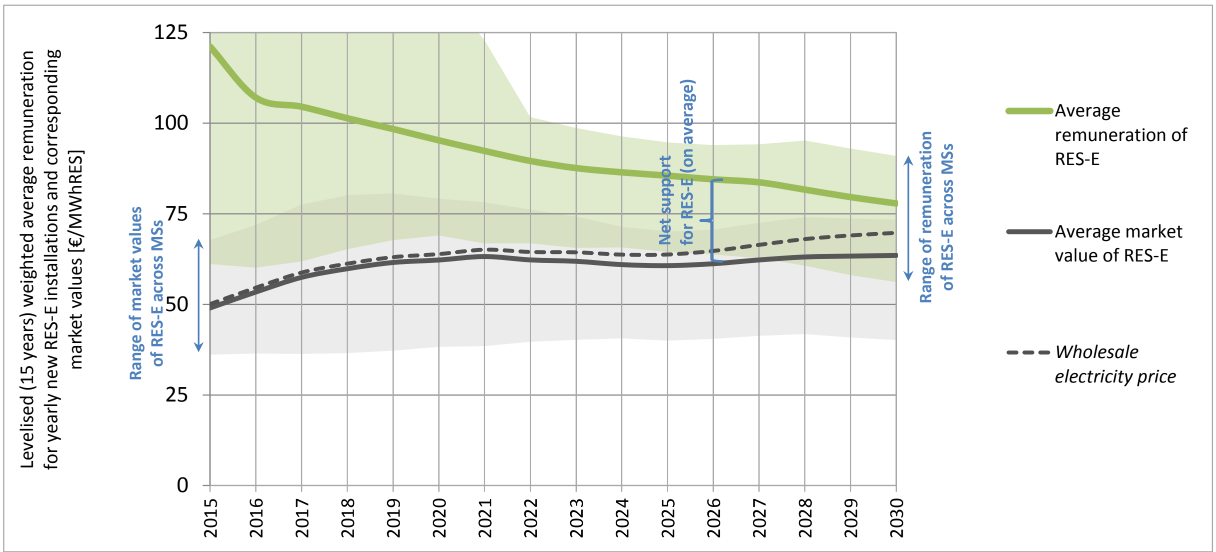


Figure 32: Future development of remuneration levels and corresponding market values of renewable energy technologies (on average) at EU-28 level according to a Green-X scenario of meeting 27% renewables by 2030 (Source: Own assessment (Green-X) based on PRIMES scenarios)

Our model-based assessment of future renewables deployment at national and EU level assuming achievement of the 27% target by 2030 confirms that the necessary remuneration for renewables is expected to decline over time, cf. Figure 32. On the one hand, the analysis indicates a strong decline in remuneration levels for renewables over the whole assessment period as a result of expected technological progress across all key renewable technologies. This positive trend is driven by cost reductions for onshore and offshore wind as well as solar photovoltaics, which are expected to be the dominant renewable energy technologies in the power sector beyond 2020. On the other hand, the decrease in market values of variable renewables partly diminishes these gains in later years. Market values for variable renewables are expected to more strongly decouple from average wholesale electricity prices. Overall, the need for net support, i.e. the difference between necessary remuneration and market value, is shrinking for renewable

[25] The market value of renewable electricity is defined as the potential income from selling the generated electricity at power exchanges. Therefore, it depends on electricity market prices weighted according to the actual feed-in of renewables into the grid. It typically deviates from average market price, as the output of variable renewables like wind and solar is not constant but weather-dependent.

electricity through to 2030: compared to the current situation (2015) a decline by more than 70% can be observed by 2030.

5 Keeping policy costs for renewables at an acceptable level: results of the prospective RES policy assessment

Below we aim for indicating the impact of suggested measures as derived in various fields within the DIA-CORE project. This comprises improvements in RES policy design and in corresponding framework conditions affecting renewables, the forming of a level playing field in energy supply as well as financing conditions.

5.1 Improving support scheme design and removing non-economic barriers

Overview on RES policy scenarios used in this exercise:

BAU	Business-as-usual scenario of RES policy schemes, non-economic RES barriers prevail	SNP-27 – barriers mitigated	Strengthened national (RES) policies (in accordance with 2020 and 2030 RES targets), non-economic RES barriers mitigated
SNP-27 – barriers prevail	Strengthened national (RES) policies (in accordance with 2020 and 2030 RES targets), non-economic RES barriers prevail		

In this subsection the quantitative impact of **various changes in RES policy design and in related framework conditions, specifically concerning non-economic barriers** that hinder the uptake of RES, will be shown and described. Those changes are indicated by two scenarios (see Figure 33 and Figure 34) that will be compared to a business-as-usual (BAU) scenario[26].

- Strengthened national policies – barriers remain: In this 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 support schemes in the electricity sector to meet its own target, but contrary to the BAU scenario it is complemented by RES cooperation if necessary. Support levels are generally based on technology specific generation costs per country.
- Strengthened national policies – barriers mitigated: In this scenario it is assumed that, additionally to the strengthened national policies, non-economic barriers are mitigated, which will facilitate the RES deployment.

[26] The business-as-usual (BAU) scenario reflects the currently implemented RES policy framework in the period up to 2020, and a gradual (or immediate in the case of biofuels) phase-out of RES support post 2020. Moreover, in that scenario non-economic barriers that limit the uptake of RES technologies in various countries are assumed to prevail.

Common to all assessed cases is the assumption that dedicated support for biofuels in transport will be phased-out post 2020, including for example a removal of blending obligations. This has a strong negative impact on biofuel deployment in the years after 2020 in particular, and also overall RES deployment is affected significantly (cf. Figure 33 (right)).[27]

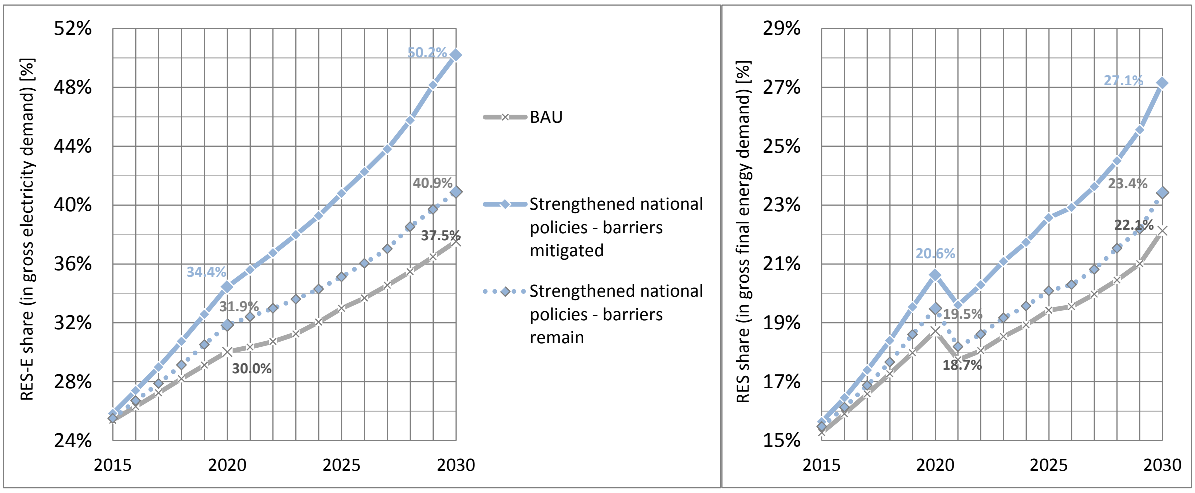


Figure 33: RES-E (left) and RES (right) deployment (expressed as share in gross electricity demand (left) / gross final energy demand (right)) in the period 2011 to 2020 in the EU-27 according to the BAU case and the case of "strengthened national policies" (incl. a sensitivity variant of prevailing barriers)

Looking at Figure 33 it is apparent that the "strengthened national policy-barriers remain" case, where the same framework conditions concerning non-economic RES barriers as in the BAU scenario are implemented, leads to a significant increase of the RES-share in the electricity sector (from 37.5% to 40.9% in 2030), as well as in the overall energy sector (from 22.1% to 23.4% in 2030) when compared to the BAU scenario. Retaining the same policy design, supplemented by a mitigation of non-economic deficits, would lead to an even more pronounced increase in the 2030 RES-E share to over 50% of gross electricity demand (compared to 37.5% in the BAU scenario). The corresponding figure for RES in total is 27.1% of gross final energy demand (instead of 22.1% in the baseline scenario).

The changes in the policy design and framework conditions (with impact on non-economic RES barriers) have a severe effect on the corresponding policy costs as well. Looking at the right side of Figure 34 it can be seen that the yearly support expenditures for RES until 2020 are up to 30% below the baseline scenario, even though the achieved RES share is higher. This indicates the cost reductions that can be achieved by an optimised policy design and improved framework conditions. After 2020 the yearly

[27] A steep decline in the overall RES share by about 1 percentage point is applicable in Figure 7 (right) from 2020 to 2021 in all assessed scenarios.

support costs of the assessed scenarios are generally higher than in the BAU scenario which is caused, on the one hand, by the strongly increased RES deployment compared to BAU, and, on the other hand, by the assumed (gradual) phase-out of RES support post 2020 under BAU conditions. Compared to BAU this leads to an increase of support expenditures in absolute terms, whereas specific support costs (measured in € per MWh RES generation) are expected to decline.

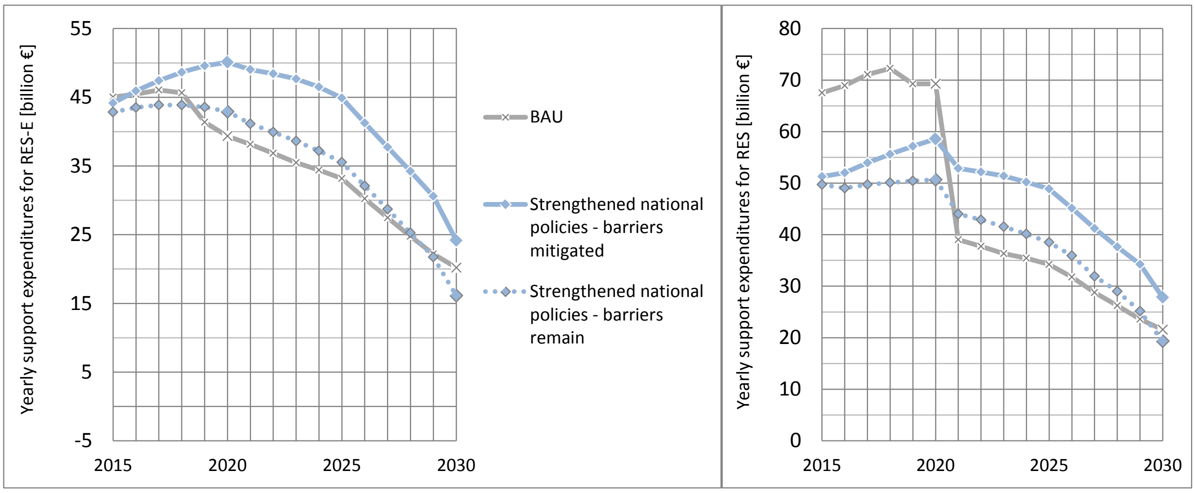


Figure 34: Yearly support expenditures for RES-E (left) and for RES (right) in the period 2011 to 2020 in the EU-27 according to the BAU case and the case of "strengthened national policies" (incl. a sensitivity variant of prevailing barriers)

5.2 Improving financing conditions through optimised RES policy design

This subsection aims to provide the quantitative underpinning of previously discussed findings and recommendations on improving financing conditions across the EU as analysed within WP 3 of the DIA-CORE project (cf. Noothout et al., 2016). The assessment of the impact of improving financing conditions builds on four different scenarios that are defined as follows:

- Two distinct renewables policy pathways are used, i.e. a **BAU scenario** that reflects the currently implemented renewables policy framework and where non-economic barriers that limit the uptake of renewables technologies in various countries are assumed to prevail, and, alternatively, an ideal policy world of **strengthened national renewables policies (SNP)**, assuming a strengthening of policy instruments in accordance with binding 2020 and 2030 renewables targets, together with a rapid mitigation of non-economic barriers.
- Both overall RES policy pathways are combined with the two WACC scenarios – i.e. **real** and **ideal WACC** conditions are thoroughly assessed and discussed in the remainder of this report. In the case of ideal WACC it was assumed that all member states have the same, best-in-class cost of equity (i.e. Germany). The cost of debt was kept at the country-specific level. This approach leads to a significant reduction of the WACC from 8.3% to 5.9% on the EU28 average.

Concerning the transition period, in the ideal WACC case the assumption is made that gradual improvements in financing conditions materialise in the years up to 2020, forming a level playing field for wind onshore investments across the EU in the period after 2020.

Key results of the model-based assessment of the impacts of improving financing conditions are summarised in Table 5. More precisely, this table provides an overview of results concerning deployment and policy costs – i.e. RES-related support expenditures – in the period up to 2020 and beyond (up to 2030). Impacts are shown for wind onshore, being in the spotlight for the risk evaluation performed.

Table 5: Key results on the impacts of improving financing conditions for wind onshore across the EU

Impacts of improvements in risk performance (WACC) at EU level (EU28)	Scenario:	Business-As-Usual (BAU)				Strengthened National Policies (SNP)			
		WACC real	WACC ideal			WACC real	WACC ideal		
	EU28 (average)	8.3%	5.9%			8.3%	5.9%		
				Change to WACC real				Change to WACC real	
	[Unit]				%*				%*
Impact on wind onshore									
Electricity generation from wind onshore									
2020	TWh	319.0	324.9	5.9	1.9%	353.7	362.6	8.9	2.5%
2030	TWh	560.1	576.6	16.5	2.9%	674.5	680.7	6.2	0.9%
Support expenditures for wind onshore, yearly average									
2016 to 2020	billion €	8.8	8.6	-0.2	-2.1%	8.7	8.4	-0.4	-4.2%
2016 to 2030	billion €	7.8	7.5	-0.2	-3.1%	8.4	7.1	-1.3	-15.6%

Note: * ... deviation to default (WACC real), expressed in percentage terms (compared to default)

Under BAU conditions the switch from a real to an ideal WACC case shows strong impact on wind onshore deployment: the amount of electricity generated from wind onshore increases by slightly less than 2% until 2020, and by about 3% until 2030 while the corresponding support costs decrease by up to 3.1%.

The scenarios of strengthened national policies (SNP) show a different picture. The reduction of yearly support expenditures would be around 4.2% for the period until 2020, and 15.6% for the forthcoming decade.

Summing up, calculations based on the Green X model show that if all countries had the same renewable energy policy risk profile as the best in class, the EU Member States could reduce the policy costs for wind onshore by more than 15%.

6 Conclusions

RES cooperation in the 2020 context

The European Commission guidance for the design of renewables support schemes highlights maximizing the benefits from intra-European trade in renewable energy through cooperation mechanisms as a key measure to ensure that Europe's energy market can function efficiently. The quantitative results above show the efficiency gains of cooperation mechanisms through reducing required remuneration costs, additional generation costs and capital expenditures.

Intensified use of cooperation mechanisms facilitates a more cost-efficient RES target fulfilment at EU level. This is confirmed by the model-based quantitative assessment conducted within this study.

Different degrees of cooperation between Member States – from pure domestic RES target fulfilment to efficient and effective target fulfilment at EU level – provide different magnitudes of efficiency gains. “Strong cooperation” compared to “limited cooperation” significantly decreases support expenditures by about € 17 billion over the whole period.

Prospects for RES beyond 2020

The binding EU-wide RES target of achieving at least 27% as RES share in gross final energy demand as adopted recently by the Council 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.

The agreed target of 27% RES appears feasible to achieve without strong efforts to be taken at EU and at country level. Even in the absence of additional energy efficiency measures alternative policy scenarios related to 27% RES by 2030 lead to moderate increases in system costs and support expenditures at EU-28 level compared to baseline conditions (where a phase-out of RES support beyond 2020 is presumed). A clear and guiding framework and a removal of currently prevailing non-economic barriers is however a key necessity to keep the cost burden low and to balance cost nicely with accompanying benefits.

More than 27% RES by 2030 appears feasible but requires additional efforts to be taken. The increase in renewables would regardless come along with increased benefits related to Europe’s trade balance due to a (significantly) decreased demand for fossil fuels and related imports from abroad.

The impact of suggested measures

Improvements in RES policy design, complemented by a removal of non-economic barriers that hinder the uptake of RES can bring down policy costs significantly. This has been demonstrated by our related assessment of impressively.

A further key element for keeping RES-related policy costs at acceptable levels is financing. Our calculations based on the Green X model have shown that if all countries had the same renewable energy policy risk profile as the best in class, the EU Member States could reduce the policy costs for wind onshore by more than 15%.

7 References

COM(2014) 15 final. COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS, A policy framework for climate and energy in the period from 2020 to 2030, Brussels, 22.1.2014.

COM(2014) 520 final. COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS, Energy Efficiency and its contribution to energy security and the 2030 Framework for climate and energy policy, Brussels, 23.7.2014.

De Jong, J. and C. Egenhofer, 2014. Exploring a Regional Approach to EU Energy Policies. CEPS Special Report No. 84 / April 2014. Brussels, Belgium, 2014. Accessible at www.ceps.eu.

DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

DIRECTIVE 2012/27/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.

European Commission, 2013b. EU energy, transport and GHG emissions trends to 2050: Reference Scenario 2013. Based on PRIMES modelling done by NTUA on behalf of the European Commission. DG Energy, DG Climate Action and DG Mobility and Transport. December 2013.

Held, A.; Ragwitz, M.; Eichhammer, W.; Sensfuss, F.; Pudlik, M.; Pfluger, B.; Resch, G.; Olmos, L.; Ramos, A.: Rivier, M.; Kost, C.; Senkpiel, C.; Peter, F.; Veum, K.; Slobbe, J.; de Joode, J. (2014): Estimating energy system costs of sectoral RES and EE targets in the context of energy and climate targets for 2030. Available at: http://www.isi.fraunhofer.de/isi-wAssets/docs/x/en/projects/REScost2030-Background-Report-10-2014_clean.pdf.

Held A., Ragwitz M., Resch G., Liebmann L., Genoese F., Pato Z., Szabo L., 2015. Implementing the EU 2030 Climate and Energy Framework – a closer look at renewables and opportunities for an Energy Union. Towards2030-dialogue project, Issue Paper No. 2. A report compiled within the project towards2030-dialogue, supported by the EASME of the European Commission within the “Intelligent Energy Europe” programme. Fraunhofer ISI, Karlsruhe (Germany), March 2015. Accessible at www.towards2030.eu.

SEC(2008) 85. COMMISSION STAFF WORKING DOCUMENT, IMPACT ASSESSMENT, Document accompanying the Package of Implementation measures for the EU's objectives on climate change and renewable energy for 2020, Brussels, 23.1.2008.

Sensfuß F., M. Ragwitz and M. Genoese, 2008. The Merit-order effect: A detailed analysis of the price effect of renewable electricity generation on spot market prices in Germany. Energy Policy, 36, 8, 3076-3084, (2008).

SWD(2014) 15. COMMISSION STAFF WORKING DOCUMENT, IMPACT ASSESSMENT, Document accompanying COM(2014) 15 final on “A policy framework for climate and energy in the period from 2020 to 2030”, Brussels, 22.1.2014.

SWD(2014) 255 final. COMMISSION STAFF WORKING DOCUMENT, IMPACT ASSESSMENT, Document accompanying COM(2014) 520 final on “Energy Efficiency and its contribution to energy security and the 2030 Framework for climate and energy policy”, Brussels, 23.7.2014.