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Background report on

Costs and Benefits of RES in Europe up to 2030

Project Coordinator: **Fraunhofer ISI**

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1 Introduction

The policy context
- past progress and future perspectives for RES in the EU

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

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

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

The aim of this Background Report is to present costs and benefits resulting from increased RES deployment in the 2020 and 2030 frameworks. After briefly outlining the methodology, findings are presented and subsequently policy recommendations will be derived.

Methodological Aspects

To properly assess impacts of RES deployment the **system boundaries** must be clearly defined as should **research question** and **time horizon**. One further question is the dimension of the effect, i.e. whether we focus on economic effects only or whether environmental, technological and social effects should be included.

Allocating costs either to a RES-based technology system or to a fossil fuel based system as well as allocating costs to heat and power is not always clear-cut. Therefore, the analysed **technologies and systems** (heat, electricity) should be (clearly) specified. Furthermore, the **geographic area** that is covered by the analysis is crucial as well as whether **sectoral or overall economic effects** are considered. When looking at the impacts of RES deployment or RES policies, three main types of effects can be identified (see Figure 1) that occur at three different levels:

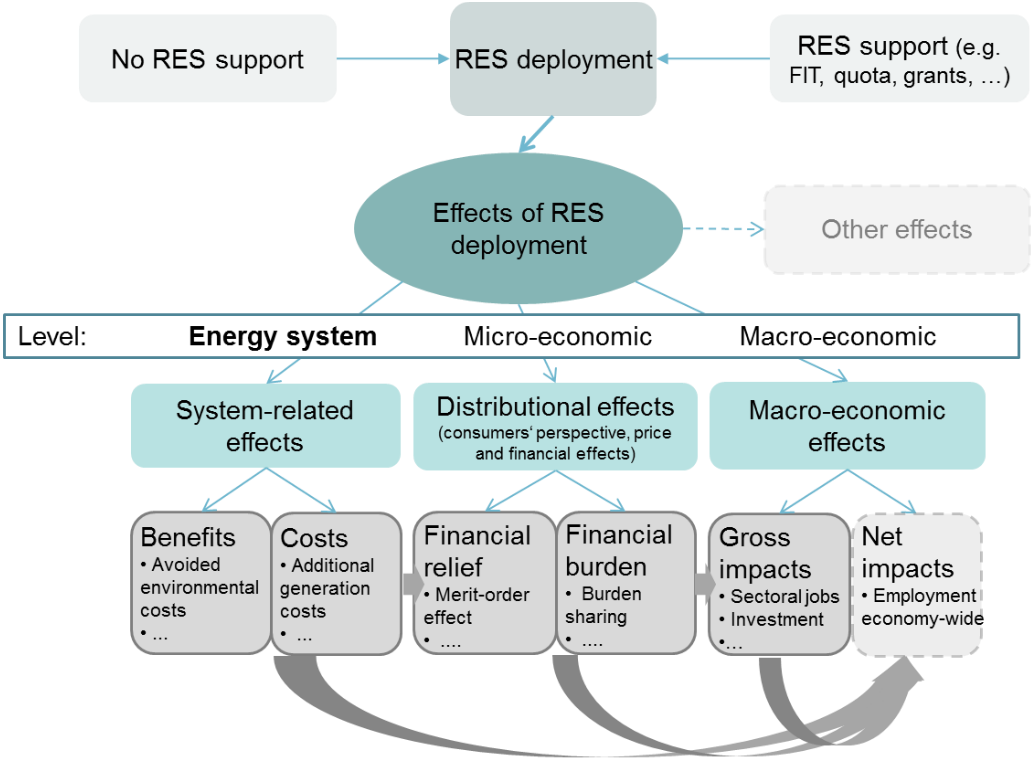

Figure 1: Categories of main effects related to RES deployment

Source: Breitschopf and Diekmann, 2011, adapted

System-related effects encompass all benefits and direct and indirect costs of RES deployment. While direct costs are directly related to electricity or heat generation, indirect costs are caused by integrating RE into the existing generation system. Benefits from RES-use arise e.g. as a result of avoided GHG emissions and air pollutants. The main characteristics of system-related costs and benefits are that they represent **additional costs or benefits of a RES-based generation system compared to a reference system based on nuclear and fossil fuels.** Furthermore, system-related effects reflect the **costs** of **input factors** based on market prices (labour, capital, natural resources).

Distributional effects focus on costs that accrue for selected economic agents or groups from a micro-economic perspective. They show to what extent the different economic agents have to bear the additional costs or benefit from the additional positive effects – **who pays for RES deployment and who receives the resulting revenues from this deployment**.

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

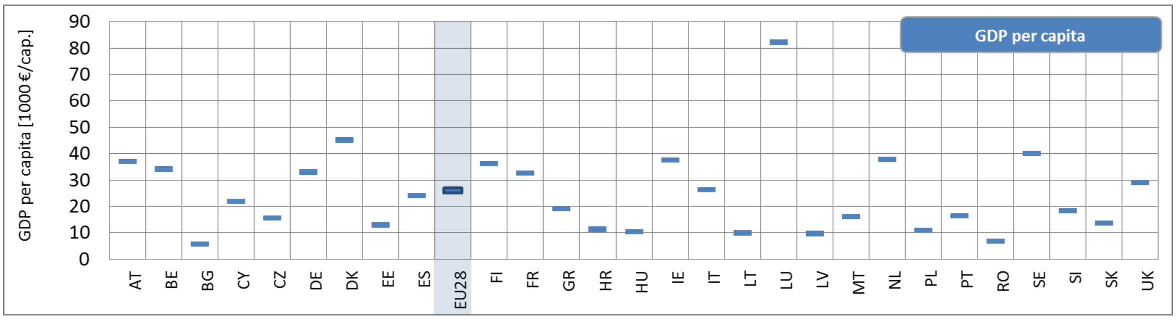

Figure 2: GDP per capita [1000 €/capita] (on average (2011-2020)) of the 28 EU Member States

To put the effects outlined in the following sections into perspective, Figure 2 depicts the respective Member States GDP per capita. This way, absolute effects as shown in Figure 7 for the EU28 level are made quantifiable in their relative values at country level as well (cf. Figure 7).

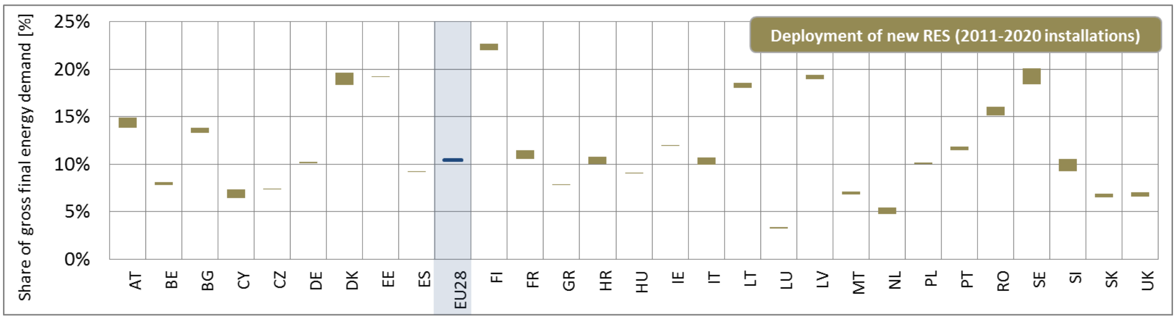

Figure 3: Deployment by 2020 of new RES (installed in the period of 2011 to 2020)

Figure 3, on the other hand, shows how the 2020 generation that stems from new RES installations of this decade (i.e. 2011 to 2020) is to be valued at Member State level, for comparative reasons expressed as (RES) share in the respective Member State's gross final energy demand.[1] Note that all subsequent indicators refer to this expansion.

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

The policy assessment tool: the Green-X model

By use of a specialised energy system model (Green-X) a quantitative assessment was conducted 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.

As in previous European 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 energies on country-, sector- as well as 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 characterisation of the model is given in the Annex to this Background Report, whilst for a detailed description we refer to www.green-x.at.

2 Costs and Benefits of RES up to 2020

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

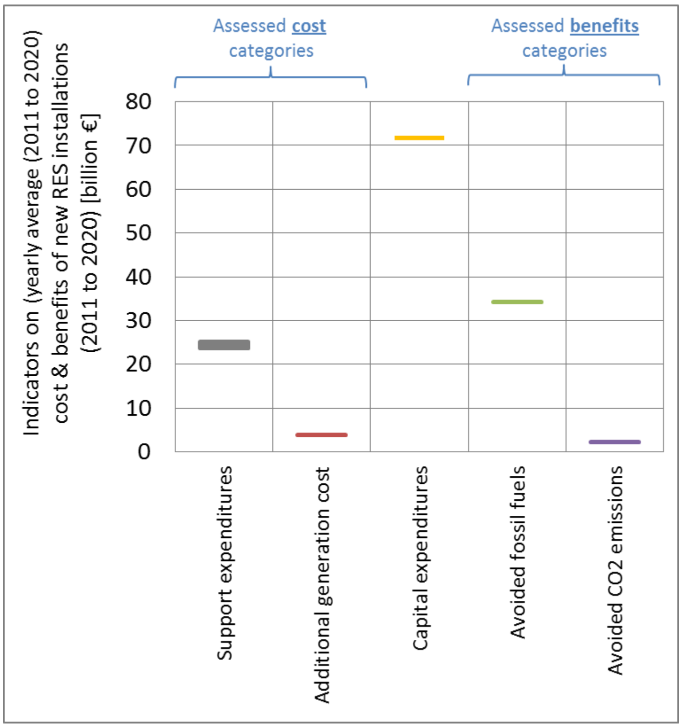

Figure 4: Indicators on yearly average expenditures or costs and benefits of new RES installations (2011 to 2020) at EU level for all assessed cases, expressed in absolute terms (billion €)

Overall it can be stated that not all Member States will reach their 2020 target via their own domestic RES deployment alone. This means that volumes of RES would have to be exchanged (virtually) to a certain extent between Member States. While Deliverable 2-4 of the DiaCore project shows the detailed flows, this Background Report solely focuses on the resulting costs and benefits for Member States. Figure 4 shows indicators on yearly average costs and benefits of new RES installations for the years 2011 to 2020. Specifically, a range is displayed for support expenditures, additional generation costs, capital expenditures and benefits resulting from avoided expenses for CO_2 emission allowances. This range depicts values from different scenarios (a limited, medium and strong cooperation scenario among EU Member States) during the assessed period of time.

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

Benefits in terms of avoided fossil fuels are in the area of annually 34 billion €. The monetary expression of CO_2 emission avoidance, or more precisely avoided expenses for

CO_2 emission allowances, can be quantified to around 2.2 billion € per year.[2] In the following subsection these cost-benefit categories are displayed at Member State level to give an overview of the distributional effects.

Insights into different cost benefit categories at Member State level

Figure 7 shows how costs, namely support expenditures and additional generation costs, as well benefits from avoided fossil fuels and CO_2 emissions are distributed over the different Member States. Furthermore, capital expenditures are shown. Capex are counted as a neutral category, being neither costs nor benefits, as they do imply expenditures but also induce macro-economic added value. To better visualise the importance of the amount for the respective Member State, the values are displayed as share of the states' GDP. Again a range is shown over the different cooperation scenarios analysed.

Looking into **support expenditures**, one can see that spreads as well as shares vary over the different Member States. The highest share and at the same time biggest variation can be seen in Latvia, where between roughly 0.6 to 0.8% of the GDP would be needed in terms of support expenditures to achieve the 2020 goals envisaged by the commission. As can be seen in Figure 2, this is largely due to the fact that the Latvian GDP per capita is comparatively low whereas the required deployment of new RES is comparatively large (cf. Figure 3). Thus, this shows that especially the lower income Member States partly face relatively high expenditures in direct comparison. Most of the other Member States range in the area of 0.1 to 0.2% of their GDP in this cost category. These values can be quite diverging when looking at the respective absolute values of GDP. While e.g. Cyprus and Sweden exhibit the same relative share in support costs, Sweden's GDP per capita is nearly double the Cyprian. This benchmark has to be kept in mind when interpreting all relative values depicted in the following. The EU average lies close to 0.2% of GDP.

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

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

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[2] Please refer to the Annex for details on the underlying CO_2 and fossil fuel prices.

Austria, Belgium, Cyprus and Germany, for example can also be located in this area with their range over the different scenarios.

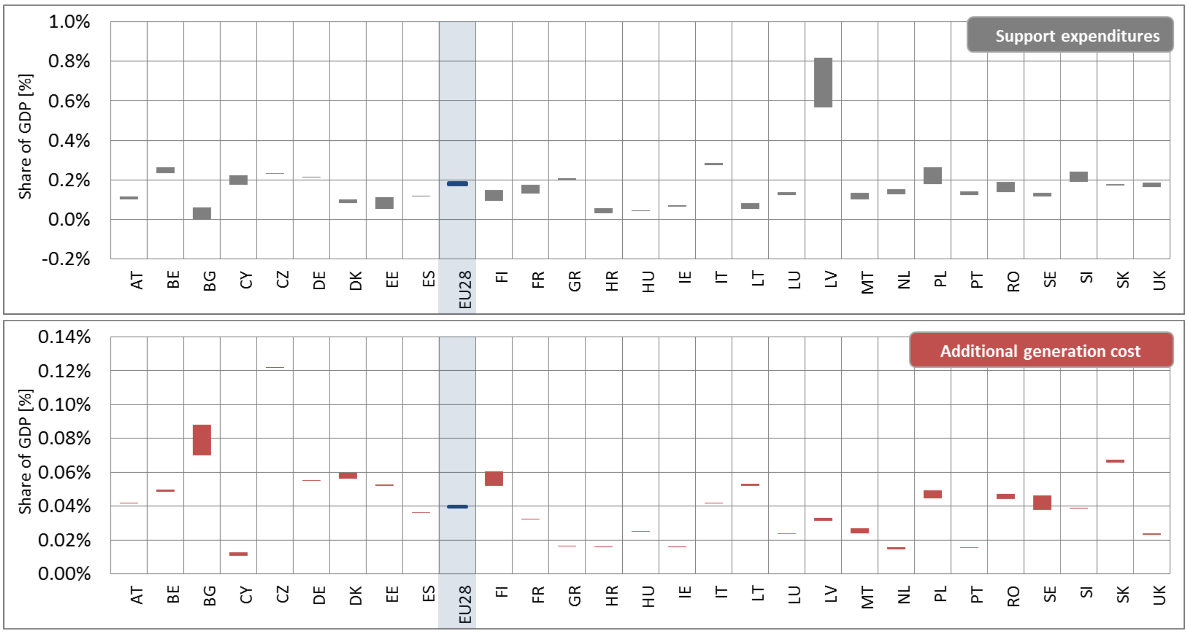

Figure 5: Range of average yearly values of costs for new RES installations (2011-2020)

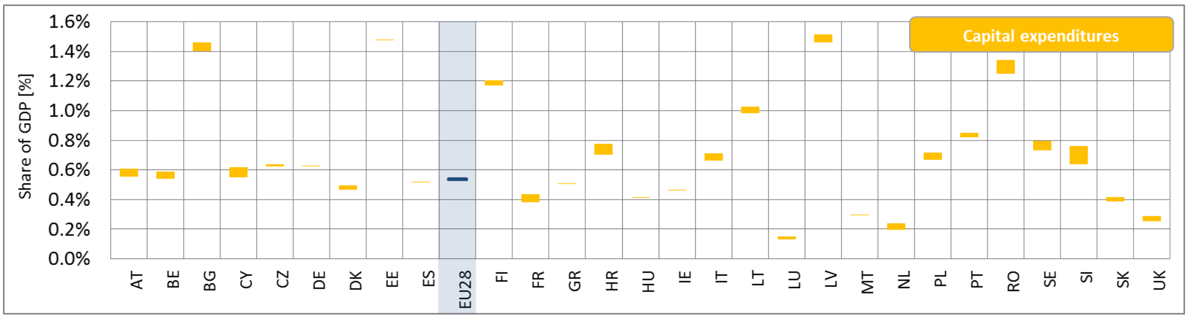

Figure 6: Range of average yearly values of capital expenditures for new RES installations (2011-2020)

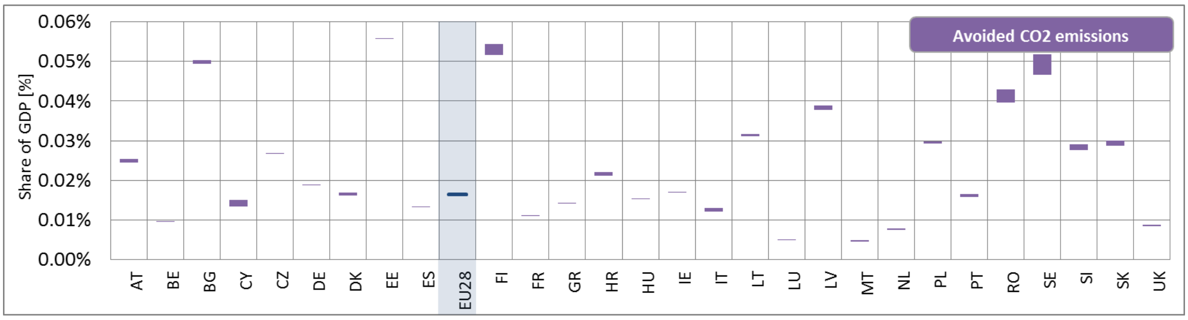

Figure 7: Range of average yearly values of benefits for new RES installations (2011-2020)

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

Finally, savings can be quantified for the **avoided CO_2 emissions** in the different scenarios assessed. Again variation is quite large in the EU, whereas the share of GDP is significantly smaller than with avoided fossil fuels. Countries benefitting the most are Estonia, Sweden, Finland and Bulgaria – all smaller or equal 0.05% of their GDP. The EU average lies below 0.02% of the GDP in this case.

3 Outlook to 2030

This section illustrates the outcomes of the model-based assessment of future RES deployment up to 2030 within the European Union and regarding the Member States according to different RES policy pathways. These pathways are described in detail in the Annex of this Background Report.

Direct impacts of future RES deployment: Costs, expenditures and benefits related to (at least) 27% RES by 2030

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 short qualitative discussion based on key indicators.

The different scenarios assessed can be found in detail in the Annex to this Background Report. In short, they can be summarised as follows: 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.

- 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 support schemes in the electricity sector to meet its own target, complemented by RES cooperation if necessary. 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**), which are described in more detail in the Annex, an EU-wide harmonised support scheme is assumed for the electricity sector, such that 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. Each type of consumer across the EU then pays the same (virtual) surcharge per unit of electricity consumed.[3]

As a further sensitivity variant for the 27% RES by 2030 target we assessed the impact of having **no dedicated support for biofuels** post 2020.

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[3] 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.

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 it is assumed that non-economic barriers remain.

Indicators of costs, expenditures and benefits of RES

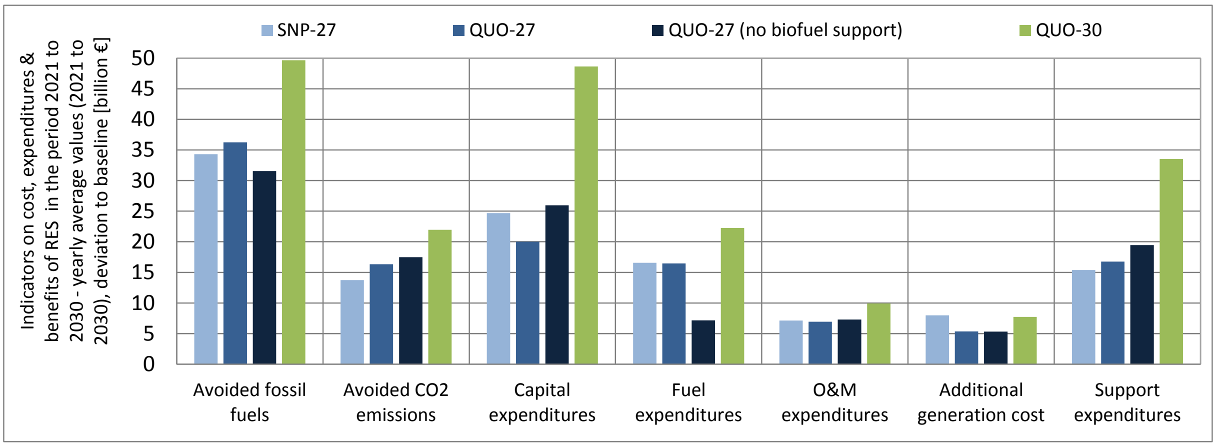

Figure 8: **Indicators on yearly average cost, expenditures and benefits of RES at EU 28 level for all assessed cases, monetary expressed in absolute terms (billion €) per decade (2021 to 2030)**

Figure 8 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*[4] 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). So to say, all values are deviations from the baseline scenario, i.e. discontinuing support policies for RES after 2020 (i.e. a gradual phase-out in accordance with PRIMES reference scenario is presumed) which would lead the EU to a RES share of 21.1% in 2030 according to Green-X modelling results. 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).

Some key observations can be made from Figure 8:

- 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 as well as lower additional

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[4] *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.

generation costs compared to the case of national policies. However these savings hardly can be passed on to consumers due to the "one size fits" all approach inherent to all technology neutral policy instruments.[5]

- Moving from a 27% to a 30% target comes at a cost, in this case average additional generation costs increase by about 50% to about 7.5 billion € per year 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: Fuel cost savings of conventional plants alone are sufficient to finance the support expenditures necessary for new RES installations.
- System-related benefits in terms of avoided fossil fuels and avoided CO_2 emissions have a larger effect for those states that substitute more of their fossil generation, so depending on where new RES installations are deployed, CO_2 emission avoidance will develop differently.
- 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.

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[5] The rationale behind this is that technology neutral instruments enable windfall profits for producers of cheaper technologies. The result is that the main share of the profits remains on the producer side. Nevertheless, the differences are negligible in this respect.

4 Concluding remarks

As shown in the introductory section of this Background Report, it is a challenging task to appropriately assess costs and benefits resulting from an increased use of renewables. The analysis performed with the Green-X model served to better understand especially the system related dimension and produces the following results:

Costs and benefits of RES deployment in the 2020 context

The European Commission guidance for the design of renewables support schemes highlights maximising 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 that costs and benefits of RES targets are rather unevenly distributed among EU Member States. Therefore stronger cooperation between countries will be of mutual benefit.

Quite some variation among Member States can be observed in the different cost and benefit categories. Concretely, **system-related benefits** in terms of avoided fossil fuels and avoided CO_2 emissions are visible in all Member States, but have a larger effect for those states who substitute more of their fossil generation, not least for exporting RES under a increased RES cooperation scenario. Support costs, which fall under the term of **distributional effects** are quite stable above the different members and amount to a share of 0.2% of GDP in an EU average. At the same time, capital expenditures are quite high overall and make up a substantial share of GDP for some Member States, whereas the rise in **generation costs** is relatively small at an average of 0.04% of EU-wide GDP.

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 an agreement on the effort sharing across Member States have to follow.

The agreed target of 27% RES appears feasible to achieve but not without a financial burden for the EU and at country level. 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). At the same time **generation costs** do not increase substantially with a high ambition target for RES deployment.

With a higher ambition for the target set at EU level, **system related benefits** would in turn increase, i.e. significantly more fossil fuels and CO_2 emissions would be avoided. Regardless, the increase in renewables would 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.

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 costs nicely with accompanying benefits. More than 27% RES by 2030 appears feasible but requires additional efforts to be taken.

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6 Annex I: Method of approach / Key assumptions

The method of approach and related key assumptions for the modelling work undertaken within this study will be discussed in detail subsequently.

Constraints of the model-based policy analysis

- Time horizon: 2010 to 2030 – Results are derived on an annual base
- Geographical coverage: all Member States of the European Union as of 2013 (EU 28)
- Technology coverage: covering all RES technologies for power, heating and cooling generation as well biofuel production. The (conventional) reference energy system is based on EC modelling (PRIMES)
- Energy demand: demand forecasts are taken from "EU energy, transport and GHG emissions trends to 2050: Reference Scenario 2013" (EC, 2013)
- RES imports to the EU: generally limited to biofuels and forestry biomass

The policy assessment tool: the Green-X model

As in previous 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.

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-28 and several other European countries (e.g. Western Balkan region, Turkey, etc.). 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.

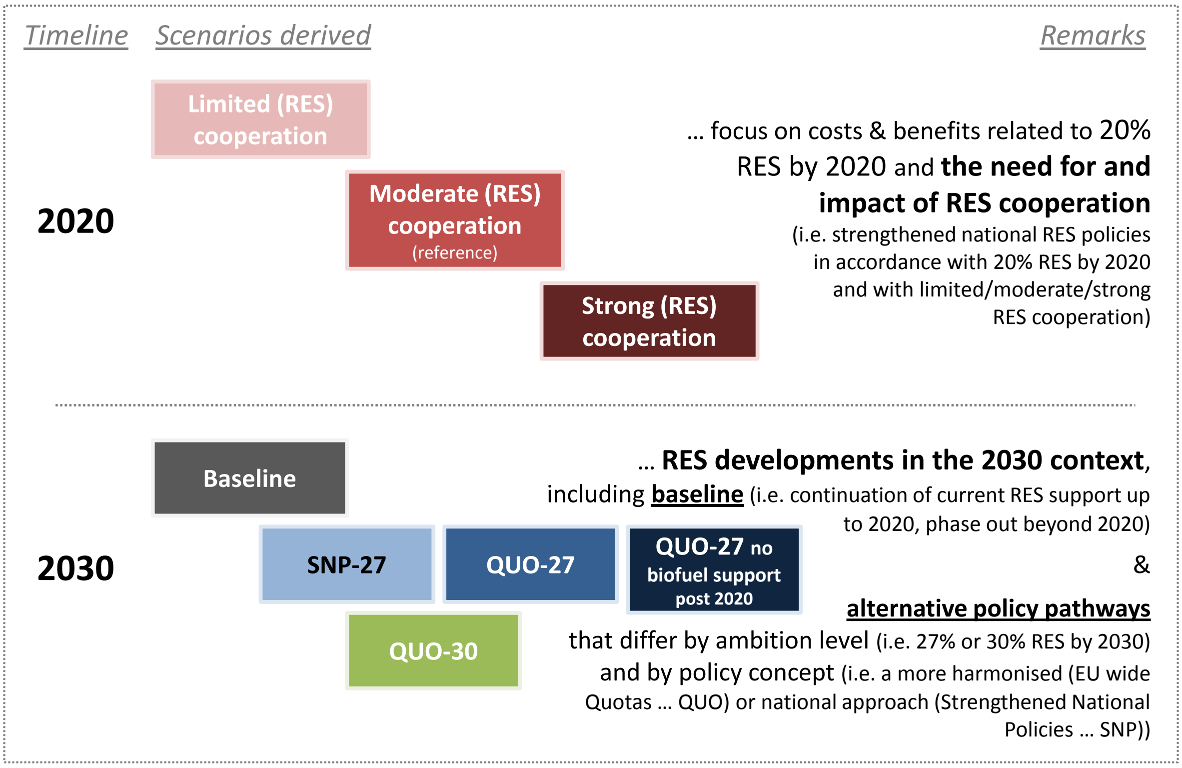
Assessed cases

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 PRIMES reference case (EC, 2013) – the cases assessed are tailored to topical needs.

Thus, Figure 9 provides a brief overview on all assessed cases and next to that the scenario definition is introduced in further detail by distinct focal point.



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

… **RES developments in the 2030 context**, including **baseline** (i.e. continuation of current RES support up to 2020, phase out beyond 2020) & **alternative policy pathways** that differ by ambition level (i.e. 27% or 30% RES by 2030) and by policy concept (i.e. a more harmonised (EU wide Quotas … QUO) or national approach (Strengthened National Policies … SNP))

Figure 9: Overview on assessed cases

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 the 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.[6]

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

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.[7]
- 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"**[8] is expected to arise from that.

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 corresponding national 2020 RES targets and accompanying National Renewable Energy Action Plans for the period up to then. Exploring RES development beyond 2020,

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[7] 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.

[8] 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.

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 9 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:

- 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 harmonized support scheme is assumed for the electricity sector that does not differentiate between different technologies. In this case the marginal technology to meet the EU RES-target sets the price for the overall portfolio of RES technologies in the electricity sector. The policy costs occurring in the quota system can be calculated as the certificate price multiplied by the RES generation under the quota system. These costs are then distributed in a harmonized way across the EU so that each type of consumer pays the same (virtual) surcharge per unit of electricity consumed.[9]

As a further sensitivity variant for the 27% RES by 2030 target we assessed the impact of having no dedicated support for biofuels post 2020. Moreover, please note that all alternative pathways build on the scenario of moderate RES cooperation as assessed and discussed in the 2020 context – i.e. where strengthened national policies serve to meet the given 2020 RES targets and where a gradual mitigation of currently prevailing non-economic RES barriers is presumed.

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

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 it is assumed that non-economic barriers remain.[10]

Criteria for the assessment of RES support schemes

Support instruments have to be *effective* in order to increase the penetration of RES and *efficient* with respect to minimising the resulting public costs – i.e. the transfer cost for consumers (society), subsequently named **support expenditures** – over time. The criteria used for evaluating the various policy instruments are based on two conditions:

- *Minimise generation costs*

  This objective is fulfilled if total RES-E generation costs (GC) are minimised. In other words, the system should provide incentives for investors to select technologies, scales and sites such that generation costs are minimised.

- *Reduce producer profits to an adequate level*

  Once such cost-efficient systems have been identified, the next step is to evaluate various implementation options with the aim of minimising the transfer costs for consumers / society.[11] This means that feed-in tariffs, investment incentives or RES trading systems should be designed in such a way that public transfer payments are also minimised. This implies lowering generation costs as well as producer surplus (PS)[12].

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[10] 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.

[11] Support expenditures - i.e. the transfer costs for consumers (society) – due to RES support are defined as the financial transfer payments from the consumer to the RES producer compared to the reference case of consumers purchasing conventional electricity on the power market. This means that these costs do not include any indirect costs or externalities (environmental benefits, change of employment, etc.). Within this report support expenditures (due to RES support) are either expressed in absolute terms (e.g. billion €), related to the stimulated RES generation, or put in relation to the total electricity / energy consumption. In the latter case, the premium costs refer to each MWh of electricity / energy consumed.

[12] The producer surplus is defined as the profit of green electricity generators. If, for example, a green producer receives a feed-in tariff of 60 € for each MWh of electricity sold and generation costs are 40 €/MWh, the resulting profit would be 20 € for each MWh. The sum of the profits of all green generators equals the producer surplus.

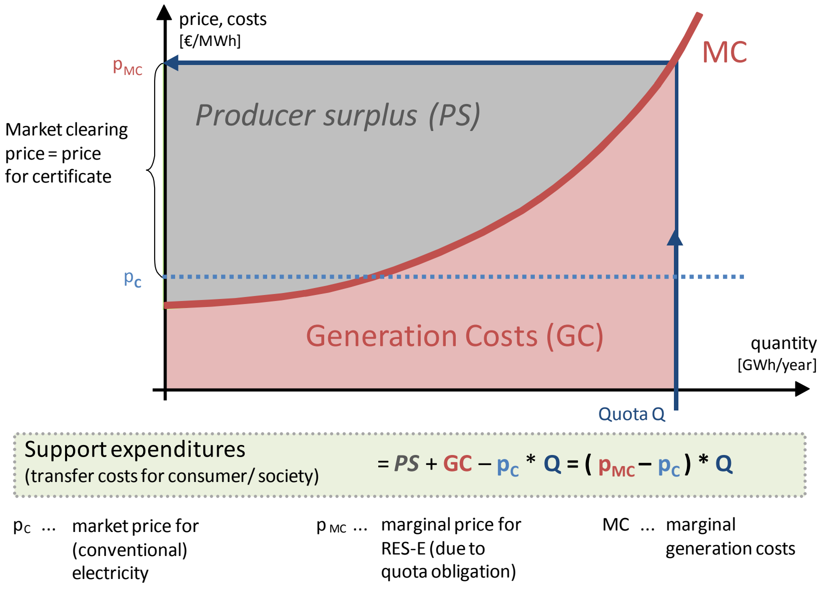

Figure 10: Basic definitions of the cost elements (illustrated for a RES trading system)

In some cases it may not be possible to reach both objectives simultaneously – minimise generation costs and producer surplus – so that compromises have to be made. For a better illustration of the cost definitions used, the various cost elements are illustrated in Figure 10.

Overview on key parameters

Table 1: Main input sources for scenario parameters

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

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 (see Resch et al. (2014)). Table 1 shows which parameters are based on

PRIMES and which have been defined for this study. More precisely, the PRIMES scenario used is the *reference scenario* as of 2013 (EC, 2013).

Energy demand

Figure 11 depicts the projected energy demand development at EU 28 level according to the PRIMES reference scenario with regard to gross final energy demand (right) as well as gross electricity demand (left).

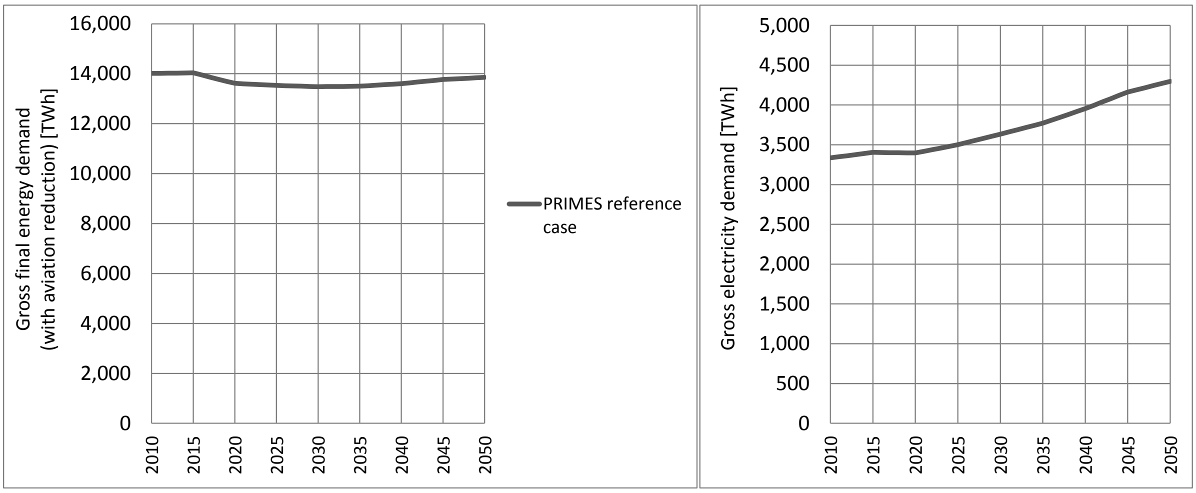

Figure 11: Comparison of projected energy demand development at European (EU-28) level – gross electricity demand (left) and gross final energy demand (right).

Source: PRIMES scenarios (EC, 2013)

A comparison to alternative PRIMES demand projections at EU 28 levels shows the following trends: The *PRIMES reference case* as of 2013 (EC, 2013) draws a modified picture of future demand patterns compared to previous baseline and reference cases. The impacts of the global financial crisis are reflected, leading to a reduction of overall gross final energy demand in the short term, and moderate growth in later years towards 2020. Beyond 2020, according to the *PRIMES reference case* (where the achievement of climate and RES targets for 2020 is assumed) gross final energy demand is expected to stagnate and then moderately decrease.

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 12 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.

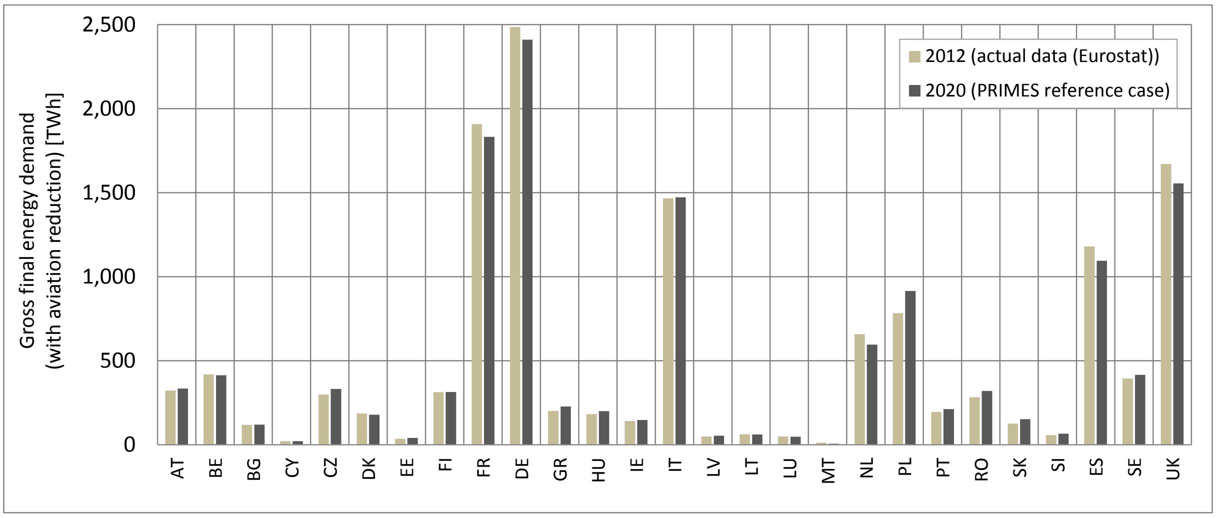

Figure 12: **Comparison of actual 2012 and projected 2020 gross final energy demand by Member State.**

Source: PRIMES scenarios (EC, 2013)

Conventional supply portfolio

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

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

- A similar approach is chosen with regard to the avoidance of CO_2 emissions, where the basis is the fossil-based conventional supply portfolio and its average country- and sector-specific CO_2 intensities that may change over time.

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

Figure 13 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%.

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 14. Error bars again illustrate the variation across countries.

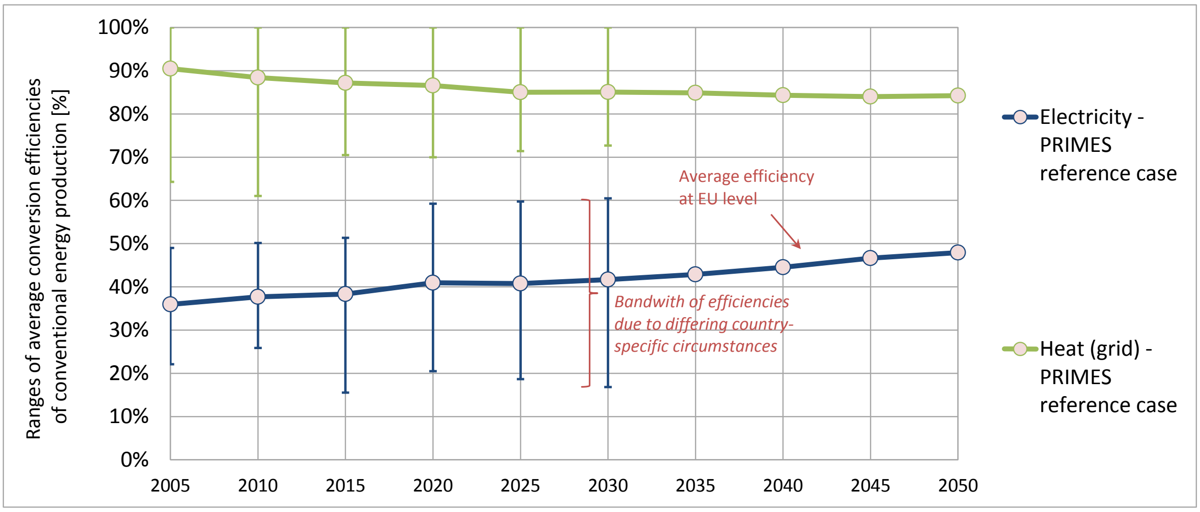

Figure 13: Country-specific average conversion efficiencies of conventional (fossil-based) electricity and grid-connected heat production in the EU28

Source: PRIMES scenarios (EC, 2013)

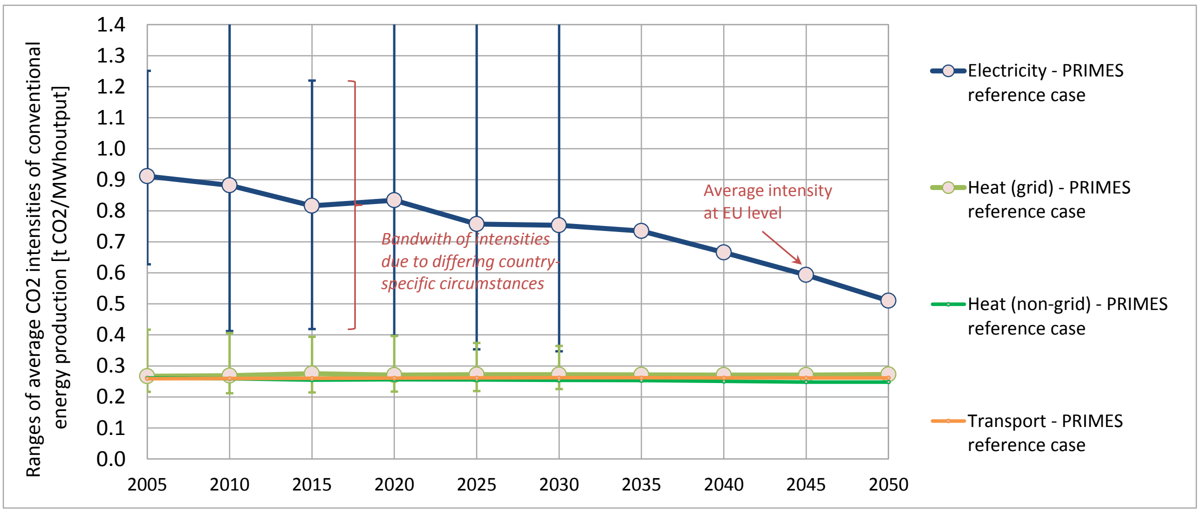

Figure 14: Country-specific average sectorial CO_2 intensities of the conventional (fossil-based) energy system in the EU28.

Source: PRIMES scenarios (EC, 2013)

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 15 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.

The CO_2 price in the scenarios presented in this report is also based on recent PRIMES modelling, see Figure 16. Actual market prices for EU Allowances have fluctuated between 6 and 30 €/t since 2005 but remained on a low level with averages around 7 €/t in the first quarter of 2012. In the model, it is assumed that CO_2 prices are directly passed through to electricity prices as well as to prices for grid-connected heat supply.

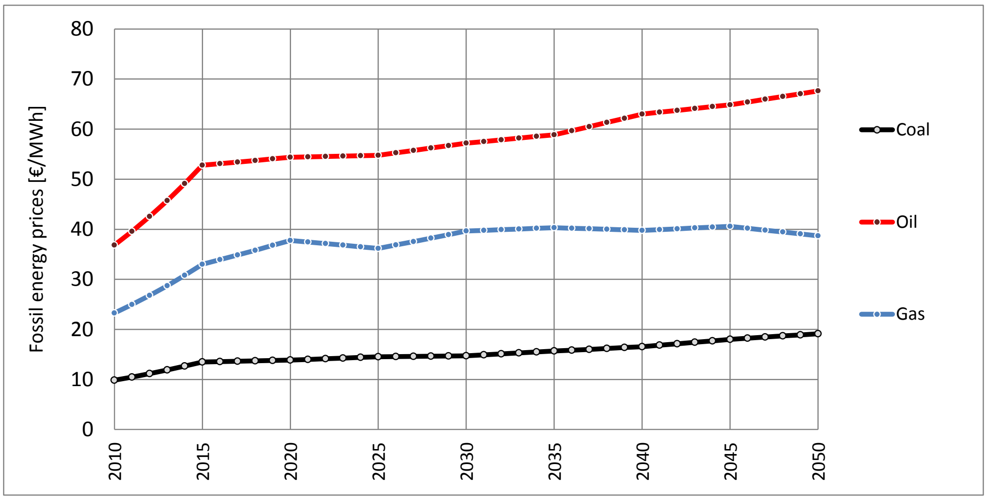

Figure 15: Primary energy price assumptions in €/MWh

Source: PRIMES scenarios (EC, 2013)

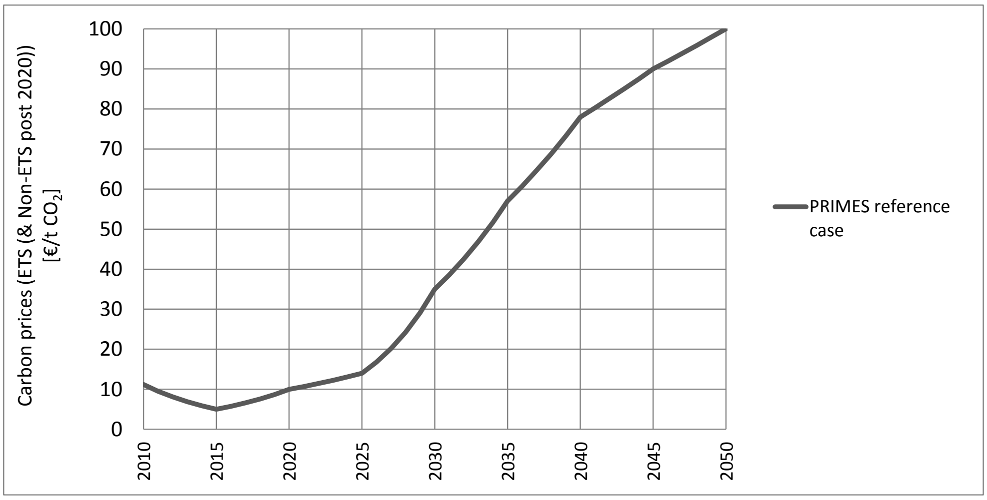

Figure 16: CO_2 price assumptions in $€_{2010}$/ton

Source: PRIMES scenarios (EC, 2013)