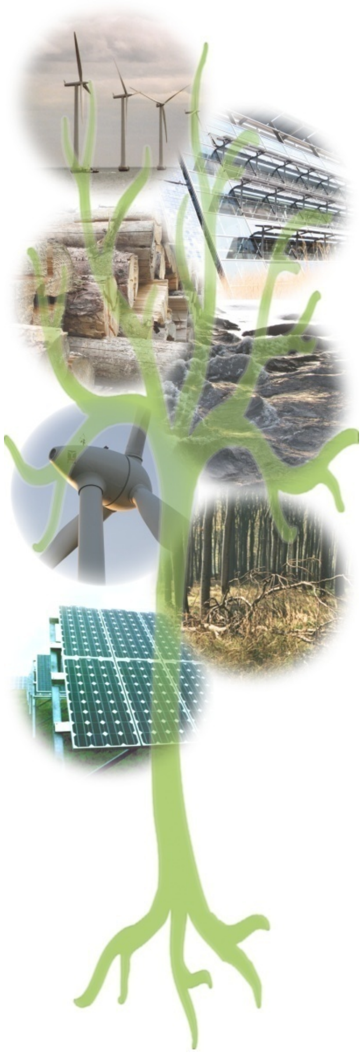
Design and impact of
a harmonised policy for
renewable electricity in Europe



Report D4.2

Cost-benefit analysis
of policy pathways for a harmonisation of RES(-E) support in Europe

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The beyond*2020* project *at a glance*

With Directive 2009/28/EC, the European Parliament and Council have laid the grounds for the policy framework for renewable energies until 2020. The **aim of this project** is to **look more closely *beyond 2020*** by designing and evaluating feasible pathways of a harmonised European policy framework for supporting an enhanced exploitation of renewable electricity in particular, and RES in general. Strategic objectives are to contribute to the forming of a European vision of a joint future RES policy framework in the mid- to long-term and to provide guidance on improving policy design.

The work comprises a detailed elaboration of feasible policy approaches for possible harmonisation of RES support in Europe, involving five different policy paths: i.e. uniform quota, quota with technology banding, fixed feed-in tariff, feed-in premium, or no further dedicated RES support besides the ETS. A thorough impact assessment is undertaken to assess and contrast different instruments as well as corresponding design elements. This involves: a quantitative model-based analysis of future RES deployment and corresponding cost and expenditures based on the Green-X model; and a detailed qualitative analysis, focussing on strategic impacts, as well as political practicability and guidelines for juridical implementation. Aspects of policy design are assessed in a broader context by deriving prerequisites for and trade-offs with the future European electricity market. The overall assessment focuses on the period beyond 2020; however a closer look is also taken at the transition phase before 2020.

The final outcome will be a finely-tailored policy package, offering a concise representation of key outcomes, a detailed comparison of the pros and cons of each policy pathway and roadmaps for practical implementation. The project is embedded in an intense and interactive dissemination framework consisting of regional and topical workshops, stakeholder consultation and a final conference.

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This report

presents the final outcomes of the cost- benefit assessment of RES(-E) policy pathways assessed throughout this project, documenting the approach and assumptions taken and illustrating the results and findings gained throughout the quantitative model-based analysis of future RES policy options beyond 2020

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Abbreviations

BAU	business as usual
EC	European Commission
ETS	emission trading system
EU-27	European Union comprising 27 Member States
FIP	feed-in premium
FIT	feed-in tariff
GC	generation costs
GDP	gross domestic product
GHG	greenhouse gas
MC	marginal cost
MS	Member State
NIMBY	not in my backyard
p_c	electricity price
PS	producer surplus
PV	photovoltaics
q_{el}	quantity of electricity generation
S	supply curve
p_F	feed-in tariff
p_I	investment subsidy
p_Q	penalty
PT	payback time
RES	renewable energy sources
RES-E	electricity generation from renewable energy sources
RES-H	heat generation from renewable energy sources
RES-T	renewable energy sources in the transport sector
SNP	strengthened national policies
TGC	tradable green certificate
TFEU	Treaty on the Functioning of the European Union
WACC	weighted average cost of capital

1 Introduction

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

The last decade was characterized by the successful deployment of RES across EU Member States – total RES deployment increased by more than 40%. In more detail:

- RES electricity generation grew by approximately 40%, RES heat supply by 30% and biofuels by a factor of 27 during the last decade,
- new renewables in the electricity sector (all technologies except hydropower) increased fivefold during the same period,
- total investments increased to about € 40 billion annually in 2009, and more than 80% of all RES investments in 2009 were in wind and PV.

This is 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 have increased even further over the last two years. The European Climate Package is one of the key factors that contributed to this development. The EU ETS Directive has introduced full auctioning post 2012, thus exposing fossil power generation to the full cost of carbon allowances. As a result, it has become less attractive for utilities to continue to pursue conventional power projects, and attention has shifted to renewable energy options. The renewable energy trajectory was set and accepted by all the European Council, the European Commission and the European Parliament in April 2009 (2009/28/EC). It involves binding RES targets for each Member State, based on an equal RES share increase modulated by Member State GDP. This provides a clear framework and vision for renewable technologies.

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 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 sectors (RES-E and RES-H), the growth rate of total generation has to continue in line with the trend observed during the last three years. Compared to the last decade, growth in RES-E needs to almost double from 3.4% per year to 6.7% per year by 2020. There also needs to be a substantial increase in growth in the RES-H sector from the 2.7% per year achieved over the last decade to 3.9% per year until 2020.

In order to create the investment climate for reaching the 2020 targets the longer term commitment for renewable energies 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.

Additionally we observe that national targets at Member State level have created strong commitment for renewable energies 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 an important element also for the post 2020 horizon.

1.2 Objective of this report

> *This report presents the final outcomes of the cost-benefit assessment of RES(-E) policy pathways assessed throughout this project, documenting the approach and assumptions taken and illustrating the results and findings gained throughout the quantitative model-based analysis of future RES policy options beyond 2020.*

To achieve the overall aim of providing guidance to policy makers and market actors, **a comprehensive quantitative analysis** has been carried out by application of a well known software tool with respect to assessing the effectiveness and economic efficiency of RES support instruments in a real-world energy policy context, namely the ***Green*-X** model. This software tool allows conducting in-depth analyses of future RES deployment and corresponding costs, expenditures and benefits arising from the preconditioned policy choices on country, sector and technology level.

This policy assessment complements and partly updates the previous related modelling activities – e.g. the quantitative assessment of RES policy options as conducted within the IEE projects futures-e (see e.g. Resch et al., 2009) and RE-Shaping (cf. Ragwitz et al., 2012) in the 2020 context, or the European Commission's "Energy Roadmap 2050" (European Commission, 2011) containing PRIMES modelling of feasible energy pathways for achieving long-term carbon commitments.

The finally compiled scenario work represents the outcome of an intensive feedback process established via lively debates at the national and the European level. A broad set of topical and regional workshops had been held all over Europe within the beyond2020 project throughout 2012 and 2013. Thereby, policy makers and key stakeholders provided essential inputs on draft outcomes and recommendations, facilitating to improve and reshape the work performed.

The results of the analysis are presented in a set of **transparent indicators**

- that provides insight in the possible future RES deployment up to 2030 under different boundary conditions – for the European Union as a whole as well as at country level.
- through which the impact in terms of costs and benefits in economic and partly environmental terms will be depicted in a clear and intelligible manner.

1.3 Organisation of this report

This report is organized as follows. Section 2 describes the applied method of approach for the model-based RES policy assessment and documents the key assumptions. Complementary to this, section 3 is dedicated to RES potentials and corresponding costs which both form the RES database of the Green-X model. Next to this section 4 introduces the RES(-E) policy pathways as defined during the inception phase of this project. A thorough policy assessment, evaluating the broad spectrum of RES(-E) policy pathways beyond 2020, complemented by a detailed sensitivity analysis on key parameter. Finally, conclusions and recommendations as represented in section 6 complete this analysis.

2 Method of approach & key assumptions

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

Constraints of the model-based policy analysis

- Time horizon: 2006 to 2030 – Results are derived on an annual base
- Geographical coverage: all Member States of the European Union as of 2012 (EU-27; without Croatia)
- Technology coverage: covering all RES technologies for power and heating and cooling generation as well biofuel production. The (conventional) reference energy system is based on EC modelling (PRIMES)
- Energy demand and prices: demand and price forecasts are taken form the EC Energy Roadmap 2050 (PRIMES high renewables, reference and energy efficiency case)
- Reference prices and market values: Sector- and country-specific reference prices are derived in accordance with the general energy scenarios used as overall demand and price reference, complemented by market values for variable RES-E technologies to incorporate their specifics in an adequate manner
- RES imports to the EU: generally limited to biofuels and forestry biomass meeting the sustainability criteria – moreover, physical imports of RES electricity are also considered as option for RES target fulfilment that mainly becomes viable in the period post 2020.

2.1 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- as well as technology level. The core strength of this tool lies on the detailed RES resource and technology representation accompanied by a thorough energy policy description, which allows assessing various policy options with respect to resulting costs and benefits. 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 focussed 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 for renewable electricity, biogas, biomass, bio-waste, 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, impact 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.

2.2 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 consumer (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 consumer / society.[1] 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)[2].

[1] 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 consider 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.

[2] 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.

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 1.

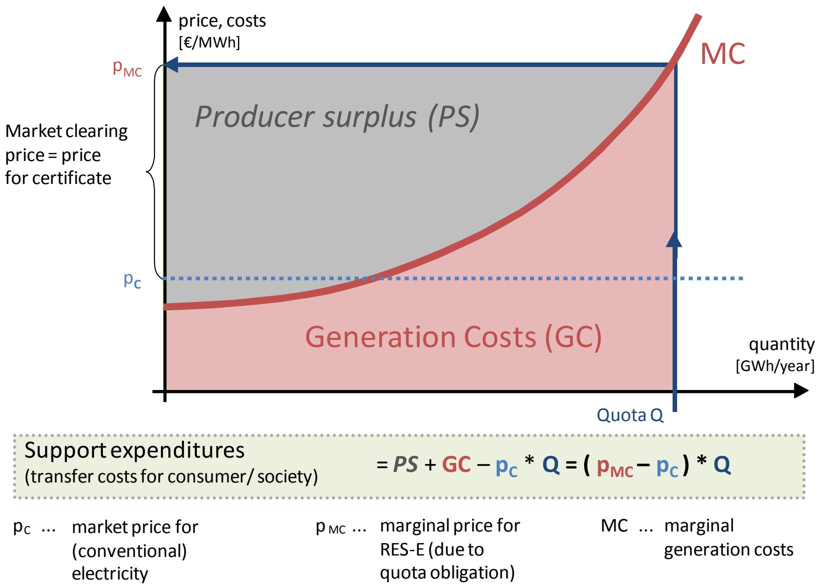


Figure 1 Basic definitions of the cost elements (illustrated for a RES trading system)

2.3 Overview on key parameters[3]

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 section 3). Table 1 shows which parameters are based on PRIMES and which have been defined for this study.

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

[3] Please note that assumed RES potentials and cost are thoroughly discussed in chapter 3 of this report and consequently left out in the subsequent depiction within this section.

More precisely, the PRIMES scenarios used are:

- The *high renewbales scenario* as of 2011 (EC, 2011)
- The *reference scenario* (with updated energy prices) as of 2011 (NTUA, 2011),
- The *energy efficiency scenario* as of 2011 (EC, 2011).

Note that the default reference for this prospective RES policy assessment represents the PRIMES high renewables case of the European Commission "Energy Roadmap 2050" (EC, 2011). Both other energy scenarios (i.e. PRIMES reference and PRIMES energy efficiency case) serve as alternative overall reference energy trends in the accompanying sensitivity analysis.

2.3.1 Energy demand

Figure 2 depicts the projected energy demand development at EU-27 level according to different PRIMES scenarios, all taken from the European Commission's Energy Roadmap 2050 (EC, 2011) – i.e. with regard to gross final energy demand (right) as well as concerning the gross electricity demand (left).

A comparison of the different PRIMES demand projections at EU-27 levels shows the following trends: The *PRIMES reference case* as of 2011 (NTUA, 2011) draws a modified picture of future demand patterns compared to previous baseline and reference cases. The impacts of the global financial crisis appear partly reflected, leading to a reduction of overall gross final energy demand in the short term, and a moderate growth in later years close to 2020. Beyond 2020 according to the *PRIMES reference case* (where the achievement of climate and RES targets for 2020 is conditioned) gross final energy demand is expected to decrease in the last decade until 2030. The decrease of gross final energy demand is even more pronounced in the *PRIMES high renewables case* (as of 2011) where in addition to short-term (2020) also long-term (2050) EU climate targets have to be met. The highest reduction can be observed in the *PRIMES energy efficiency case* (as of 2011) where in addition to above also proactive energy efficiency policies play a vital role.

For the electricity sector, demand growth is more pronounced in general. Differences between the distinct PRIMES cases follow a similar pattern: With an average annual growth of 0.8% over the whole period 2010 to 2030 the highest gross electricity demand by 2030 is expected under the *PRIMES reference case* where the average annual growth between 2010 and 2030 amounts to 0.8%. The *PRIMES high renewables case* indicates a similar demand growth than the previously discussed scenario up to 2015 but a stabilisation of electricity consumption for the period thereafter, leading to an average annual growth of 0.1% over the whole period 2010 to 2030. In contrast to above, a demand reduction is observable in the *PRIMES energy efficiency case*. Surprisingly, but of less importance for the prospective RES policy assessment, the *PRIMES reference case* assumes a 3% higher electricity consumption in 2010 than both other PRIMES cases.

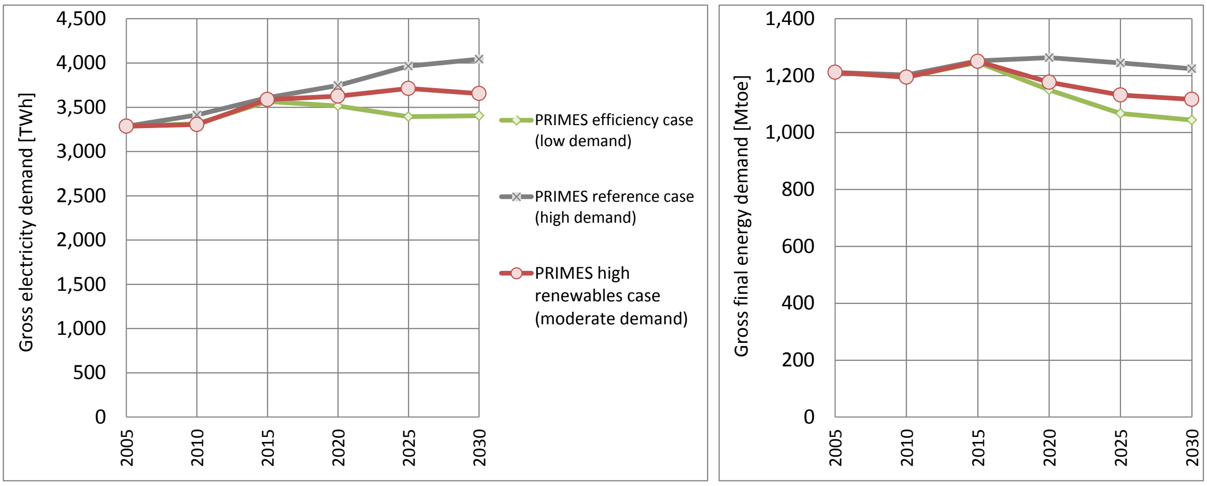


Figure 2 **Comparison of projected energy demand development at EU-27 level – gross electricity demand (left) and gross final energy demand (right). (Source: PRIMES scenarios)**

Subsequently within this report the following specification is used for indicating the assumptions used with respect to energy demand: As also illustrated in Figure 2 the high demand case refers to the *PRIMES reference case*, the low demand case is identical to the *PRIMES energy efficiency case* and a moderate energy demand corresponds to the *PRIMES high renewable case*.

2.3.2 Conventional supply portfolio

The conventional supply portfolio, i.e. the share of the different conventional conversion technologies in each sector, has been based on PRIMES forecasts on a country-specific basis. These projections on the portfolio of conventional technologies have an impact in particular on the calculations done within this study on the avoidance of fossil fuels and related CO_2 emissions. As it is at least out of the scope of this study to analyse in detail which conventional power plants would actually be replaced by for instance a wind farm installed in the year 2014 in a certain country (i.e. either a less efficient existing coal-fired plant or a possibly new high-efficient combined cycle gas turbine), the following assumptions are made:

- Keeping in mind that, besides renewable energy, fossil energy represents the marginal generation option that determines the prices on energy markets, it was decided to stick on country level to the sector-specific conventional supply portfolio projections as provided by PRIMES. Sector- as well as country-specific conversion efficiencies, as 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 stays unaffected, avoidance can be expressed in units of coal or gas replaced.
- A similar approach is chosen with regard to the avoidance of CO_2 emissions, where yearly changing average country- as well as sector-specific CO_2 intensities of the fossil-based conventional supply portfolio forms the basis.

Expected developments in the electricity sector

Next the detailed composition of the present (2010) and future (up to 2030) conventional supply portfolio is illustrated for the different PRIMES projections used. This is exemplarily done for the electricity where among all energy sectors the highest shares of RES (on total sectoral supply) are expected in forthcoming years. For this purpose the expected developments of fossil-based power generation and of nuclear energy are indicated in further detail.

Figure 3 illustrates the underlying aggregated EU-27 supply mix for the electricity sector in 2010 according to the *PRIMES High Renewables case (HighRES)*. This case serves as the reference case within the present study and therefore serves as a benchmark to contrast the timely variation of shares within the conventional supply portfolio. As can be seen from the figure, the fossil fuels constitute a major part of the supply mix in 2010 (i.e. 53% of total). They are composed of coal/lignite, natural gas and a small share of petroleum products and electricity generation from coke/blast-furnace gasses. The rest stems from nuclear (27%) and renewable energy (20%).

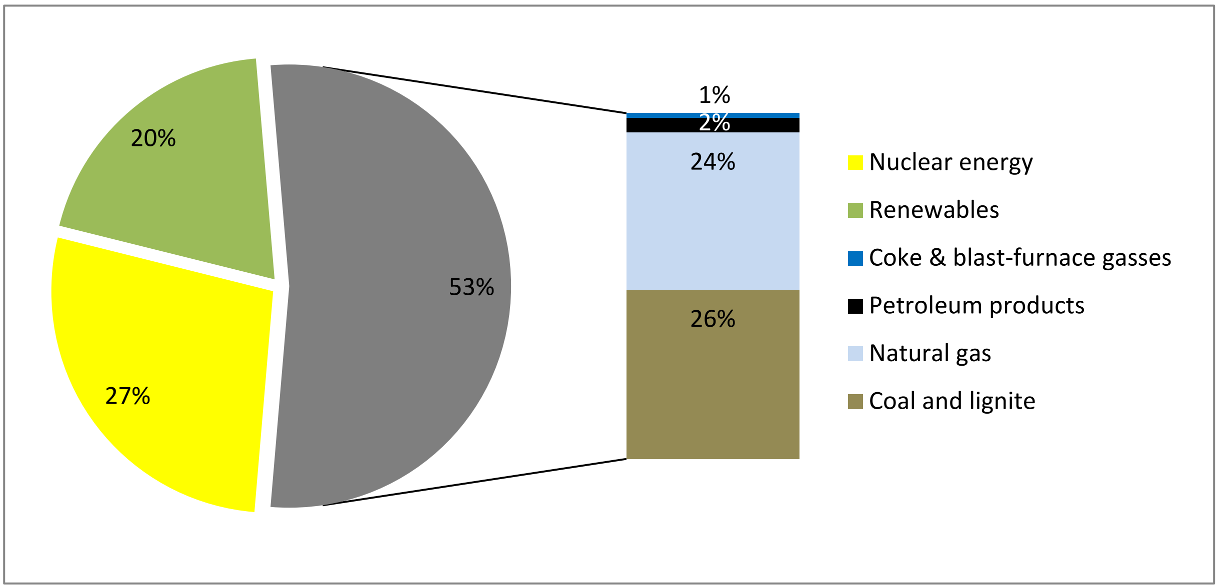


Figure 3 **PRIMES electricity generation mix 2010 according to the PRIMES high renewables scenario. (Source: EC (2011))**

In Figure 4 the relative composition[4] of the underlying EU-27 conventional supply mix (i.e. fossil fuels and nuclear energy) according the different PRIMES cases is illustrated for the years 2010, 2020 and 2030.

In particular the variation of the conventional supply mixes for the three *PRIMES scenarios (High Renewables, Reference, Efficiency)* is confronted with each other for each year. It can be seen that in the *PRIMES high renewables* scenario up to 2030 a considerable part of coal is being replaced by gas. In the reference case nuclear energy accounts the largest share and in the *PRIMES energy efficiency* scenario a situation in between the other scenarios can be observed.

In Figure 5 the 10-year-average yearly growth rates of generation by fuel type are illustrated for the three PRIMES scenarios. It can be seen that nearly all conventional generation decrease due to an increase in RE generation. Exemptions are the in the short run an increase in electricity generation from coke and blast-furnace gasses and in the long run an increase of petroleum products and nuclear energy in the *PRIMES reference case*. The most significant changes are apparent for the *PRIMES high renewables scenario* where a considerable amount of coal and petroleum electricity generation is being replaced by RE generation. A further observation is that up to 2020 mostly petroleum products are being replaced, whereas in the period from 2020 to 2030 primarily baseload technologies like coal and nuclear are replaced, which follows the logic that more expensive fuels are replaced first.

[4] Note that not only the relative composition but also the total amount of future conventional electricity generation differs significantly among the assessed PRIMES cases, in particular if expectations for 2030 are analysed. This is a consequence of differing expectations on overall electricity demand development and, more important, on the amount of electricity generation from RES.

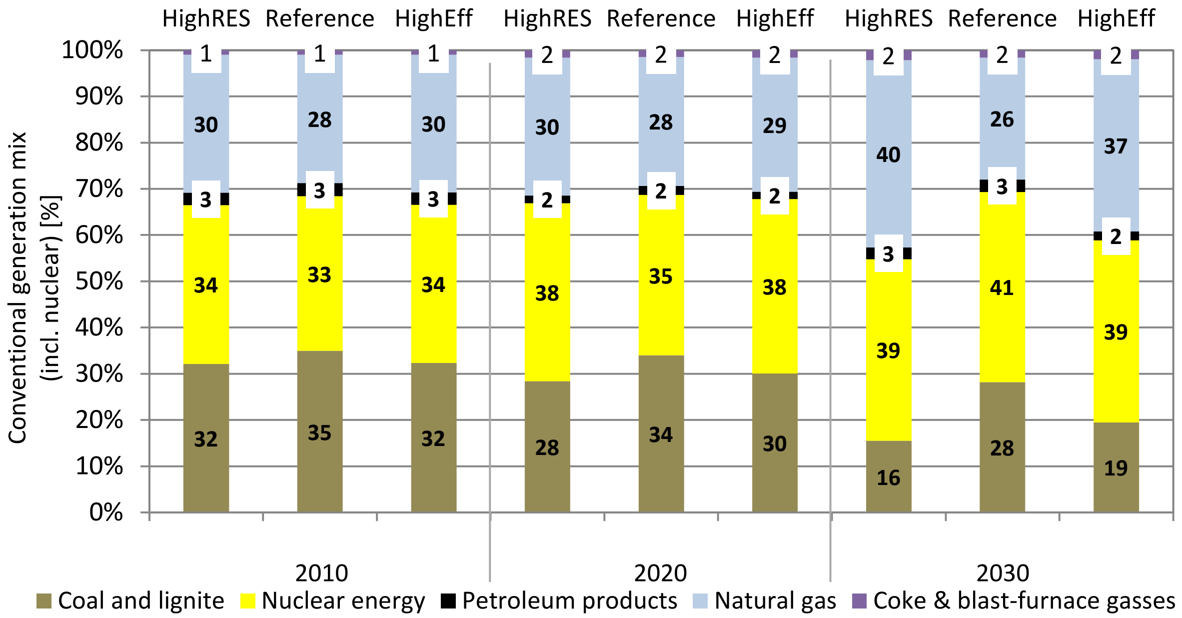


Figure 4 **Expected conventional generation mix up to 2030 according to PRIMES scenarios (reference, high renewables and high energy efficiency). (Source: EC (2011))**

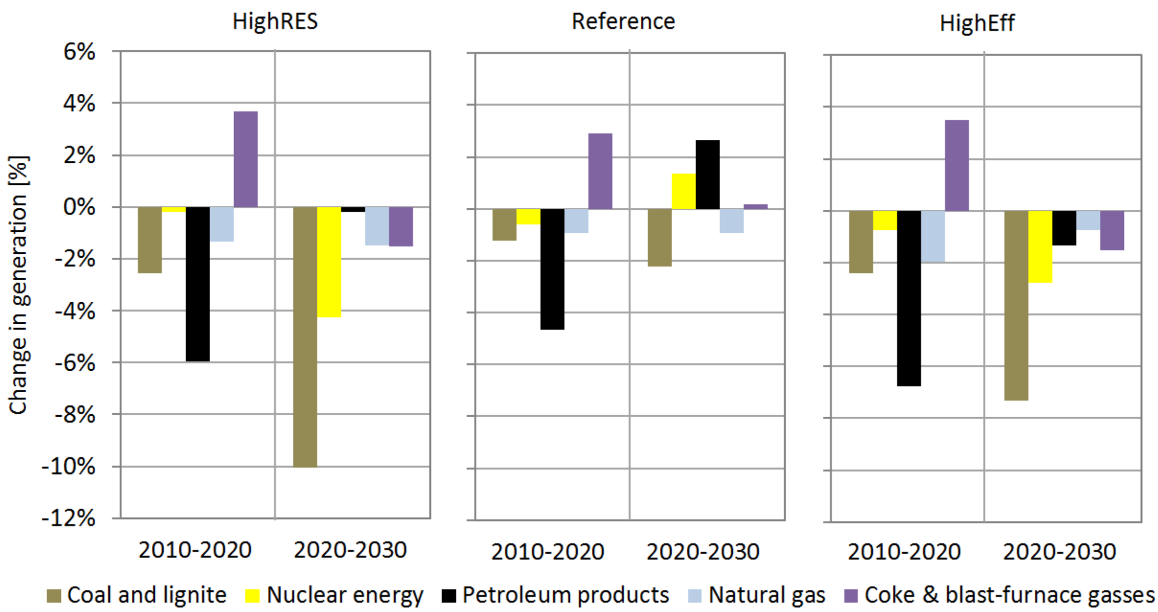


Figure 5 **Expected conventional generation mix up to 2030 according to PRIMES scenarios (reference, high renewables, energy efficiency). (Source: EC (2011))**

To sum up the scenarios assume partially different developments, especially in the later period up to 2030. A common assumption is the increase of the share of nuclear and similarly a decrease of coal and lignite on the overall conventional supply portfolio by 2030. However, the actual amount of the variation differs between the scenarios, e.g. the share of natural gas between 2010 and 2030 significantly varies among the scenarios and ranges from 26% (*PRIMES Reference scenario*) to 40% (*PRIMES High Renewables scenario*).

2.3.3 Fossil fuel and reference energy prices

Country- and sector-specific reference energy prices used in this analysis are based on the primary energy price assumptions applied in PRIMES scenarios as used for the European Commission's Energy Roadmap 2050 (EC, 2011). As shown in Figure 6 generally two different price trends are used – i.e. a default case of moderate energy prices that reflects the price trends of the *PRIMES reference case*, and a low price case referring to the *PRIMES energy efficiency* and *PRIMES high renewables case*. Compared to energy prices as observed in 2011 all price assumptions, even for the later years up to 2020, appear comparatively low.

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 since 2005 between 6 and 30 €/t but in the first quarter of 2012 prices remained on a low level with averages around 7 €/t. In the model, it is assumed that CO_2 prices are directly passed through to electricity prices as well as to prices for grid-connected heat supply.

Increased RES-deployment has a CO_2 price reducing effect since it reduces the demand for CO_2-reductions through alternative measures. This effect appears to be well anticipated in PRIMES scenarios, compare for example CO_2 prices of the baseline and the reference case shown in Figure 7.

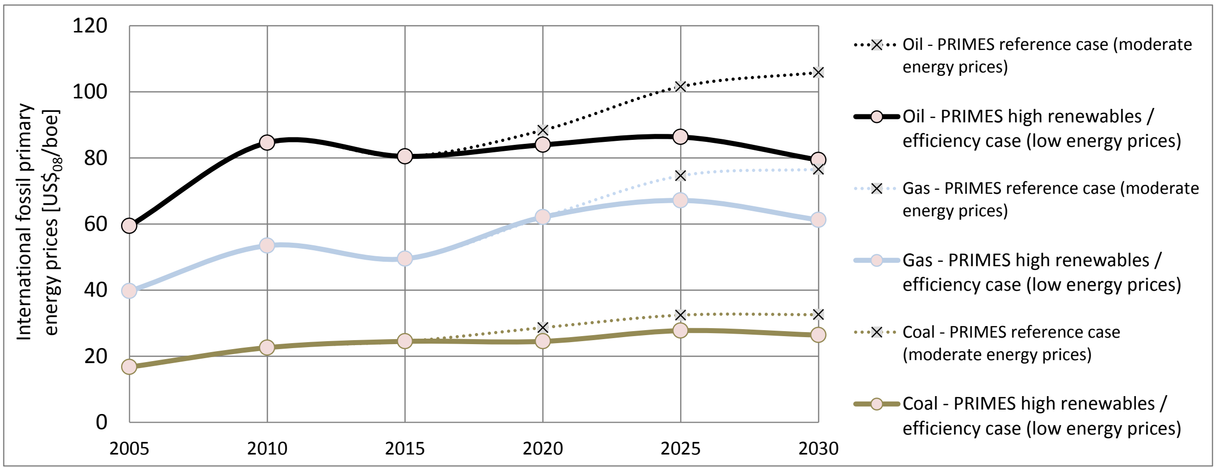


Figure 6 Primary energy price assumptions in US$$_{2008}$/boe (Source: PRIMES scenarios)

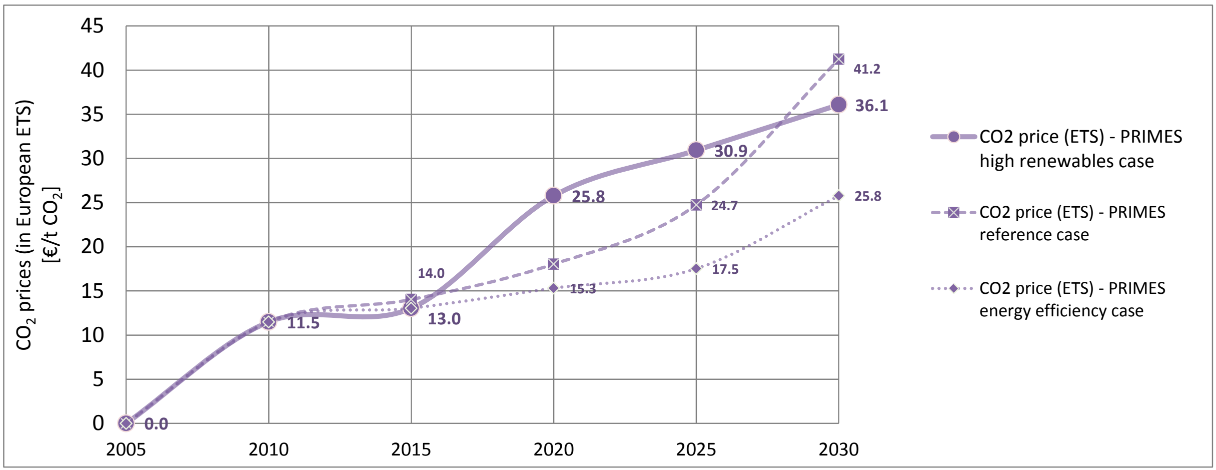


Figure 7 CO2 price assumptions in €$_{2010}$/ton (Source: PRIMES scenarios)

Reference prices for the electricity sector are taken from the *Green-X*+ model.[5] Based on the primary energy and CO_2 prices and a detailed representation of the power sector in EU Member States,

[5] The Green-X+ model builds on the initial version of the Green-X model where a detailed representation of Europe's electricity market was in focus. Offering a detailed representation of the conventional power sector as of today it is operated by AXPO GmbH in cooperation with TU Wien / EEG. The model offers in contrast to Green-X a detailed representation of power supply and demand on an hourly basis at country level. It serves as profound tool for analysing price-forward curves in Europe's regional electricity markets under different market conditions (i.e. power sector regulation, RES support and carbon pricing).

the *Green-X+* model determines country-specific average reference wholesale electricity prices for each year in the period 2006 to 2030. Please note that for variable RES expectations on technology-specific market values are used in modelling as reference for cost calculations as well for investment decisions. Reference prices for the heat and transport sector are based on primary energy and carbon prices as well as the typical country-specific conventional supply portfolio including demand specifics. Note that heat prices in case of grid-connected heat supply from district heating and CHP-plant do not include the cost of distribution – i.e. they represent the price directly at defined hand over point.

Default sectoral reference energy prices in the case of an ambitious RES deployment (i.e. based on strengthened national RES policies) are illustrated in Table 2. More precisely, these prices represent the weighted average at European level (EU-27) and refer to a moderate energy demand and a low price development according to the *PRIMES high renewables case* as of 2011. A graphical illustration of the EU average of all reference prices for electricity and grid-connected heat supply used in this analysis is given in Figure 8. Complementary to average prices at EU level, error bars indicate the range in country-specific average prices between EU Member States for the default case of moderate energy demand and price trends.

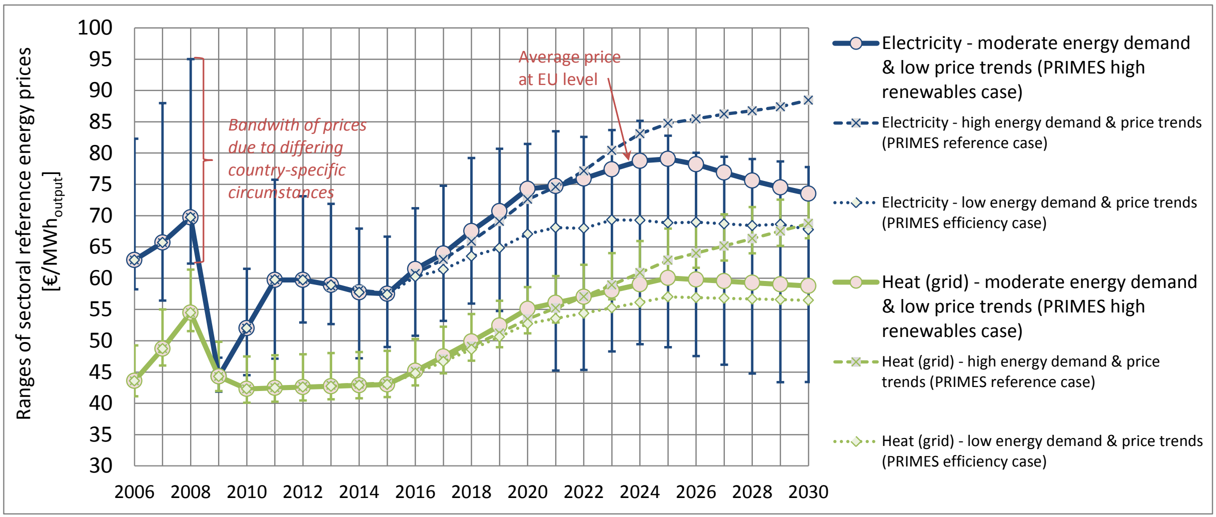


Figure 8 **Assumed development of wholesale electricity and grid-heat prices on average at EU-27 level according to different energy demand and price trends (Source: Own elaboration based on Green-X+ and PRIMES scenarios)**

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

Attention is dedicated in the model-based assessment to incorporate the impact of investor's risk on RES deployment and corresponding (capital / support) expenditures. In contrast to the complementing detailed bottom-up analysis of illustrative financing cases as conducted in RE-Shaping within an own dedicated work package (see Rathmann et al. (2011)), Green-X modelling aims to provide the aggregated view at the national and European level with less details on individual direct financing instruments. More precisely, debt and equity conditions as resulting from particular financing instruments are incorporated by applying different weighted average cost of capital (WACC) levels.[6]

[6] Note that the impact of a proactive risk mitigation on the required cost and expenditures for achieving the Member States 2020 RES targets has been illustrated in a recent study named "Financing Renewable Energy in the European Energy Market" (de Jager et al., 2011). This study was done on behalf of the European Commission, DG ENER, and conducted by a consortium led by Ecofys.

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%*	

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 the determination of the WACC exemplarily for two differing cases – a default and a high risk assessment. Within the model-based analysis, a range of settings is applied to reflect investor's risk appropriate. Thereby, risk refers to two different issues:

- A *'policy risk'* related to uncertainty on future earnings caused by the support scheme itself – e.g. referring 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, with respect to policy risk the range of settings used in the analysis 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 e.g. with RES trading (and related uncertainty on future earnings on the certificate market). An overview on the settings used by type of policy instrument or pathway, respectively, is given in Table 4 below.

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

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)	1.15
QUO (quota system with uniform TGC)	1.30
QUO banding (quota system with banded TGC)	1.30
ETS (no dedicated RES support)	1.30
TEN (tenders for selected RES-E technologies)	1.20

- A '*technology risk*' referring to uncertainty on future energy production due to unexpected production breaks, technical problems etc... Such deficits may cause (unexpected) additional operational and maintenance cost or require substantial reinvestments which (after a phase out of operational guarantees) typically have to be born by the investors themselves. In the case of biomass this also includes risk associated with the future development of feedstock prices. Table 4 (below) illustrates the default assumptions applied to consider investor's technology risk. The expressed technology-specific risk factors are used as multiplier of the default WACC figure. Ranges as indicated for several RES categories arise from the fact that risk profiles are expected to change over time as well as that a certain RES category includes a range of technologies (and for instance also a range of different feedstock in the case of biomass) and unit sizes. The lower boundary as applicable for PV or for several RES heat options indicates also a differing risk profiling of small-scale investors that partly tend to show a certain "willingness to invest", requiring a lower rate of return than commercial investors.

Please note that as default both policy and technology risk are considered in the assessment, leading to a different – typically a higher – WACC than the default level of 7.5%.

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)	0.90-0.95
Hydro small-scale	0.95	Solar thermal heat. & water	0.41-0.90
Photovoltaics	0.75-1.00	Heat pumps	0.68-0.90
Solar thermal electricity	1.1	*RES-transport / biofuels*	
Tide & wave	1.15	Traditional biofuels	1.05
Wind onshore	0.9	Advanced biofuels	1.05
Wind offshore	0.95	Biofuel imports	-

2.3.5 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.

General scenario conditions

Consumer expenditure 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 the 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;[8]
- The guaranteed duration of financial support is limited.[9]

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 several 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 BAU-settings (referring to a BAU scenario) compared to, e.g. the more optimistic view assumed for reaching an accelerated RES deployment as preconditioned in the policy assessment referring to the ambitious target of 20% RES by 2020. 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, as default moderate technological learning is preconditioned for all policy cases.

In the following, the model settings and assumptions are described for each type of support instrument separately. These assumptions refer to advanced support schemes as applied in the discussion of strengthened national and harmonized European wide policy instruments.

Feed-in tariffs / premiums

Premium and fixed feed-in tariffs are defined as technology-specific; settings are applied so as to achieve an overall low burden for consumers. Tariffs decrease over time reflecting the achieved cost reductions on a technology level, but this annual adjustment in the level of support applies only to new installations. More precisely, whenever a new plant is installed, the level of support is fixed for the guaranteed duration (of 15 years as commonly applied in the case of generation-based support). A low risk premium (leading to a WACC of 7.5 %) is applied for fixed feed-in tariffs to reflect the small degree of uncertainty associated with the well-defined design of this instrument. In contrast to that, for feed-in premium systems a moderate

[8] This means that only plants constructed in the period 2021 to 2030 are eligible to receive support from the new schemes. Existing plants (constructed before 2021) remain in their old scheme.

[9] 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.

risk premium serves to reflect uncertainty on earnings from selling electricity on the power market.

Quota obligations with tradable green certificates (TGC)

Two different trading schemes are investigated in this analysis:

- A common RES trading system (covering all RES(-E) options)[10] offering uniform support for all RES options; or;
- An advanced RES trading system where technology-specification of support is introduced via a banding approach.[11]

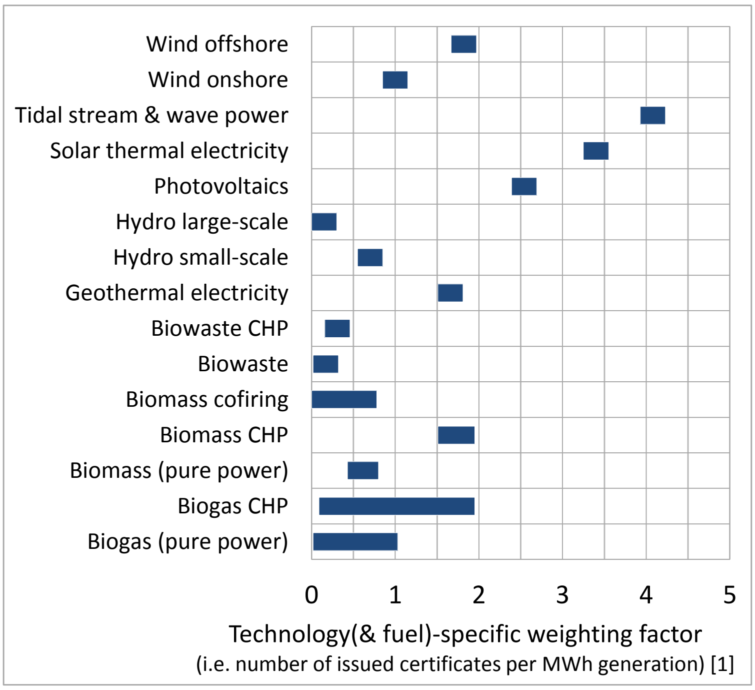


Figure 9 Technology-specific weighting factors (as assumed for the policy pathway of quotas with technology banding)

In the latter case different weighting is given to different RES technologies in terms of the number of green certificates per MWh generation, e.g. wind offshore obtains 1.8 times the weighting as wind onshore – aiming to reflect the differing cost level or stages of market maturity, respectively, among the involved RES technology options. This approach is in accordance with previous adaptations taken in TGC schemes within several European countries.

Advanced RES trading systems are used in the case of “strengthened national RES policies” in those countries which have already currently implemented a TGC system for supporting RES-E, namely Belgium, Poland, Romania and Sweden.[12] Moreover, they are used in one of the policy pathways assessed for the post-2020 period. The applied assumptions with respect to technology-specific weighting factors are illustrated in Figure 9. Thereby, ranges indicate in most cases a further graduation of weighting factors by fuel (biomass) or technology (biogas). In the case of PV, wind offshore and biowaste the indicated range reflect the anticipated decrease of support

[10] More precisely, it is assumed that this common TGC system includes neither technology-specific quotas nor any technology-specific weighting mechanisms etc. Accordingly, it represents a policy scheme suitable for supporting the most efficient RES(-E) options in a competitive environment.

[11] Note that in the case of strengthened national policies, the assumption is taken that a technology-specific weighting is introduced in order to achieve the required deployment of novel RES(-E) options without over-subsidizing mature low-cost RES(-E) technologies.

[12] Note that for Italy and the UK which both have also implemented a TGC scheme the anticipated switch to another (price-driven) support scheme is conditioned for the period beyond 2013.

over time – i.e. the upper boundary refers to 2021 (when the new scheme is assumed to start) and the lower range refers to 2030 (i.e. the end of our assessment period). Please note further that as default a penalty payment of 45 €/TGC is assumed for the advanced RES trading scheme while for the technology-neutral quota system a higher penalty (125 €/TGC) is used to allow incentivising the deployment of more costly RES-E technologies (if required for target fulfilment).

For both cases 'policy risk' is assumed to be at a higher level. Thereby, risk refers to the uncertainty about future earnings (on the power as well as on the TGC market).

Tenders for selected large-scale RES-E technologies

EU-wide tenders are assumed to be in place for new wind and centralised solar systems beyond 2020 under one of the assessed policy pathways (see section 4 for details), representing a variant of the reference case where a continuation of the current approach of having a variety of nationally defined support incentives implemented stands in focus. Specific design settings for the EU-wide tendering scheme can be summarised as follows:

- RES investors apply for a guaranteed remuneration (i.e. via a fixed power purchase agreement, similar to a fixed feed-in tariff system) to cover their expenses.
- Strategic behaviour is assumed to be partly in place, meaning that investors set their offer prices according to the marginal bid at technology and country level.
- Duration of support is limited to 15 years, i.e. a new installation can only receive financial support during the first 15 years of operation.

2.3.6 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 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.

Modelling the impact of non-economic barriers on the feasible technology diffusion

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

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

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

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

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

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

where:

- $\Delta P_{M\ n}$ .... realisable potential (year n, country level)
- $\Delta P_{M\ min}$ ...... lower boundary (minimum) for realisable potential (year n, country level)
- $\Delta P_{M\ ne}$ .... realisable potential econometric analysis (year n, country level)
- $P_{stat\ long\text{-}term}$ .. static long-term potential (country level)
- a .... econometric factor, technology specific
- b .... econometric factor, technology specific
- c............. econometric factor, technology specific
- A quadratic factor yield from the econometric analysis
- B linear factor yield from the econometric analysis
- C constant factor yield from the econometric analysis (as default 0, considering market saturation in the long-term)
- X_n .... calculated factor - expressing the dynamic achieved long-term potential as percentage figure: In more detail …

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

- $\chi_{M\ max}$ absolute amount of market restriction assuming very low barriers; $\chi_{M\ max}$ [0, 1]; to minimise parameter setting $\chi_{M\ max} = 1$
- $\chi_{M\ min}$ absolute amount of market restriction assuming very high barriers; $\chi_{M\ min}$ [0, $\chi_{M\ max}$]
- b_M barrier level market / administrative constraint assessment (level 0 - 5) [13]; 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.[14] [15]

[13] 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.

[14] 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.

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

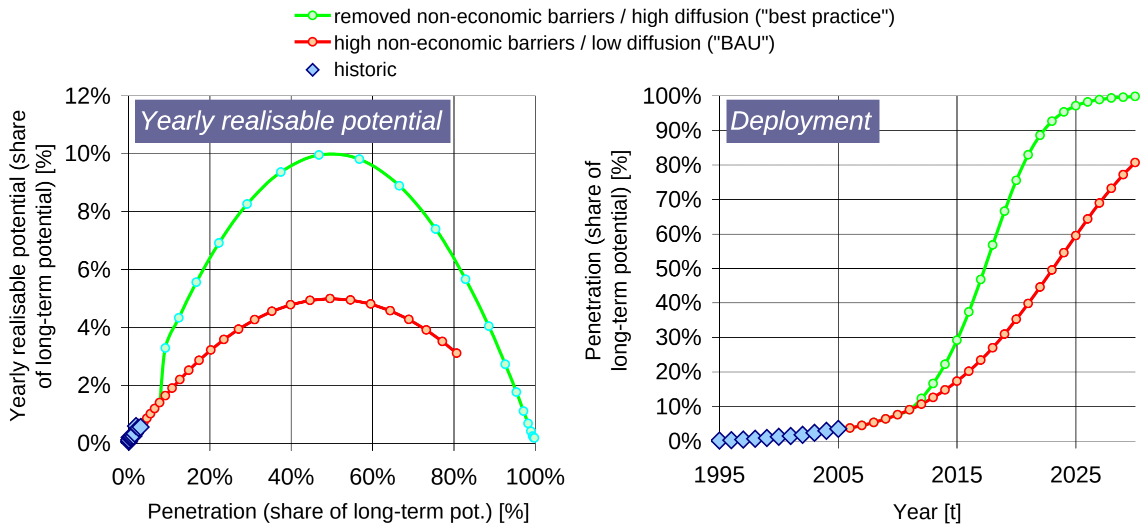
Within the scenario work two different variants of settings with respect to the non-economic barriers of individual RES technologies have been applied:

- *High non-economic barriers / low diffusion ("BAU settings")*

  This case aims to reflect the current situation (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")*

  This case represents the other extreme where the assumption is taken that non-economic barriers will be mitigated in time.[16] This more optimistic view is applied in the policy assessment referring to the ambitious target of 20% RES by 2020. 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 10 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

Figure 10 illustrates the applied approach: On the right-hand side the resulting yearly realisable potential in dependence of applied barrier level and on the left-hand side related deployment – in case that no other (financial) constraint would exist – are depicted, illustrating schematically applied variants with respect to non-economic barriers as used in the follow-up scenario assessment.

[16] 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 2010.

3 Potentials and cost for RES in Europe

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 Europe's RES potentials and accompanying costs of an intensive assessment process conducted within several studies in this topical area. The derived data on realisable short (2020) and mid-term (2030) potentials for RES fits to the requirements of the model ***Green-X*** and served as sound basis for the subsequently depicted policy assessment in the light of 20% RES by 2020.

Please note that within this illustration the future potential for considered biomass feedstock was 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 as outlined in section 3.4.

3.1 Realisable mid-term (2030) potentials for RES in Europe

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 of an intensive assessment process on Europe's RES potentials and accompanying costs that has been conducted within several studies in this topical area. This shall provide clarification on the pending question if sufficient RES are applicable to meet Europe's power demand in the absence of nuclear power. More precisely, a comparison will be provided that refers to 2030, indicating the demand for renewable sources according to the Advanced scenario of the energy [r]evolution study as well as the applicable potentials.

The derived data on realisable mid-term (2030) potentials for RES fits to the requirements of the ***Green-X*** model, a specialised energy system model developed by TU Wien / EEG that allows to perform a detailed quantitative assessment of the future deployment of renewable energy on country-, sector- as well as technology level within the EU and its neighbouring countries.[17] Within the course of this study Green-X will be used to complement the literature-based assessment of RES policy implications as well as of related costs / expenditures.

3.1.1 Classification of potential categories

We start with a discussion of the general background and subsequently present the status quo of consolidated data on potentials and cost for RES in Europe as applicable in the Green-X database. These figures indicate what appears to be realisable within the 2030 timeframe.

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

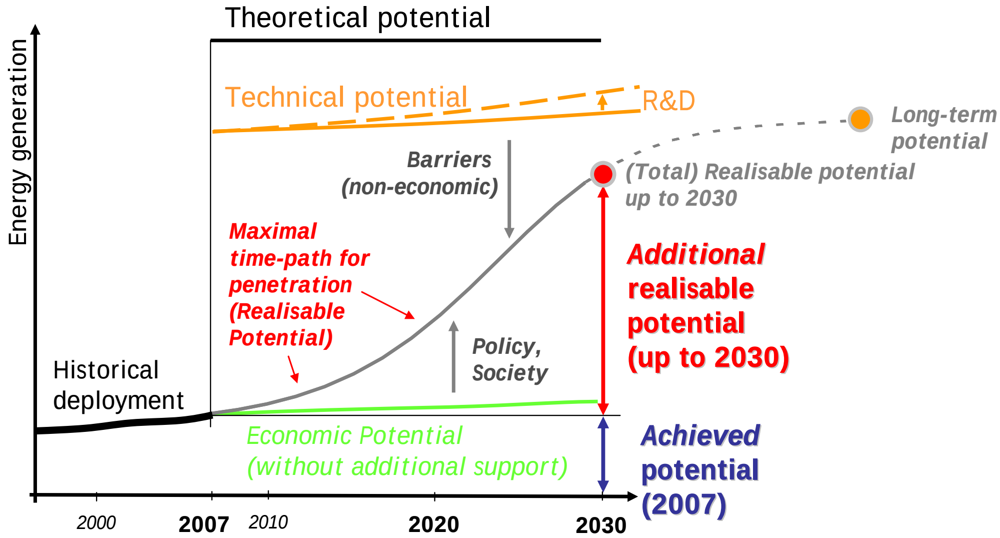


Figure 11 Definition of potential terms

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 2030: provides an illustration of the derived realisable potential for the year 2030.
- Long-term potential: in this report, long-term potentials refer to the 2050 timeframe and consequently what can be realised until then. Obviously, this is closely linked (among other constraining factors) to infrastructural prerequisites.

Figure 11 (above) shows the general concept of the realisable potential up to 2030 as well as in the long-term (2050), the technical and the theoretical potential in a graphical way.

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

The input database of the ***Green-X*** model offers a detailed depiction of the achieved and feasible future deployment of the individual RES technologies in Europe – in particular with regard to costs and penetration in terms of installed capacities or actual & potential generation. Realisable future potentials (up to 2030 / 2050) are included by technology and by country. In addition, data describing the technological progress such as learning rates are available. Both serve as crucial input for the model-based assessment of future RES deployment. Note that an overview on the method of approach used for the assessment of this comprehensive data set is given in Box 1 (below).

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

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

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

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

3.1.3 Mid-term (2030) realisable potentials for RES in the electricity sector - extract from the Green-X database

Next, we take a closer look on the mid-term prospects for RES in the electricity sector, illustrating the identified potentials that can be principally realised in the 2030 timeframe. In the power sector, RES-E options such as hydropower or wind energy represent energy sources characterised by a natural volatility. Therefore, in order to provide an accurate depiction of the future development of RES-E, historical data for RES-E is translated into electricity generation potentials[18] – the *achieved*

[18] 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

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 mid-term potentials* up to 2030 – were assessed[19] taking into account the country-specific situation as well as overall realisation constraints.

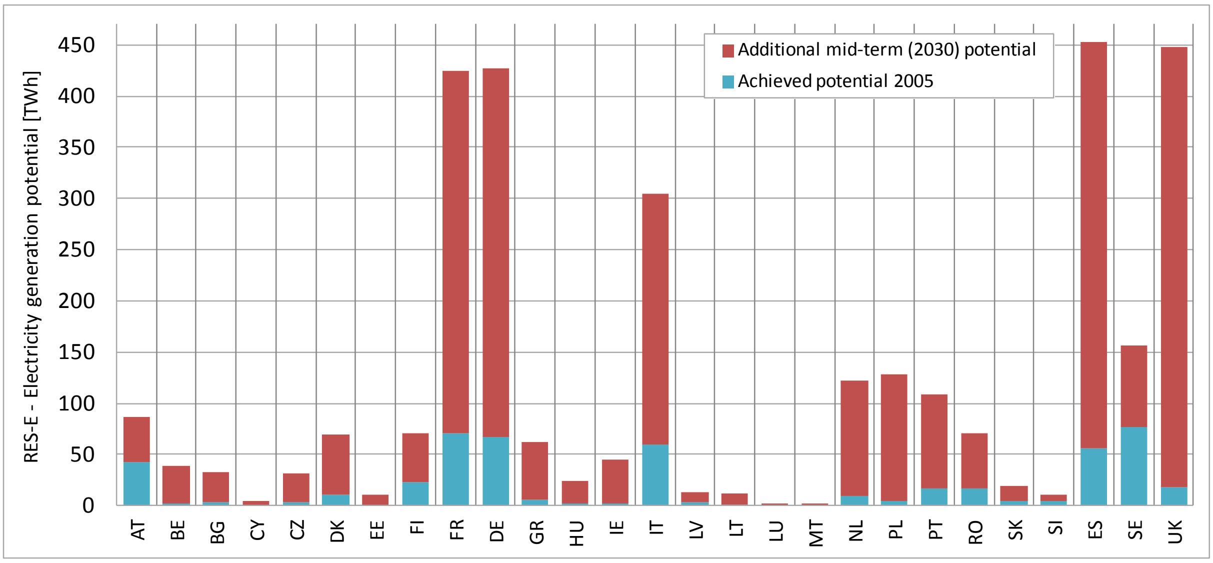


Figure 12 Achieved (2005) and additional mid-term potential 2030 for electricity from RES in the EU 27 on country level.

Figure 12 depicts the achieved and additional mid-term potential for RES-E in the EU 27 at country level. For EU 27 countries, the already achieved potential for RES-E equals 503 TWh, whereas the additional realisable potential up to 2030 amounts to 2676 TWh (about 81% 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 13 relates derived potentials to gross electricity demand. More precisely, it depicts the total realisable mid-term potentials (up to 2030), as well as the achieved potential (2005) for RES-E as share of gross electricity demand in 2005 for all Member States and the EU 27 in total. As applicable from this depiction, significant additional RES potentials are becoming apparent for several countries. In this context especially notable are Portugal, Denmark and Ireland, as well as most of the new Member States. If the indicated realisable mid-term potential for RES-E, covering all RES-E options, would be fully exploited up to 2030, almost all our electricity needs as of today (97% compared to 2005's gross electricity demand) could be *in principle*[20] covered. For comparison, by 2005 already installed RES-E plants possess the generation potential to meet about 15% of demand.

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.

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

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

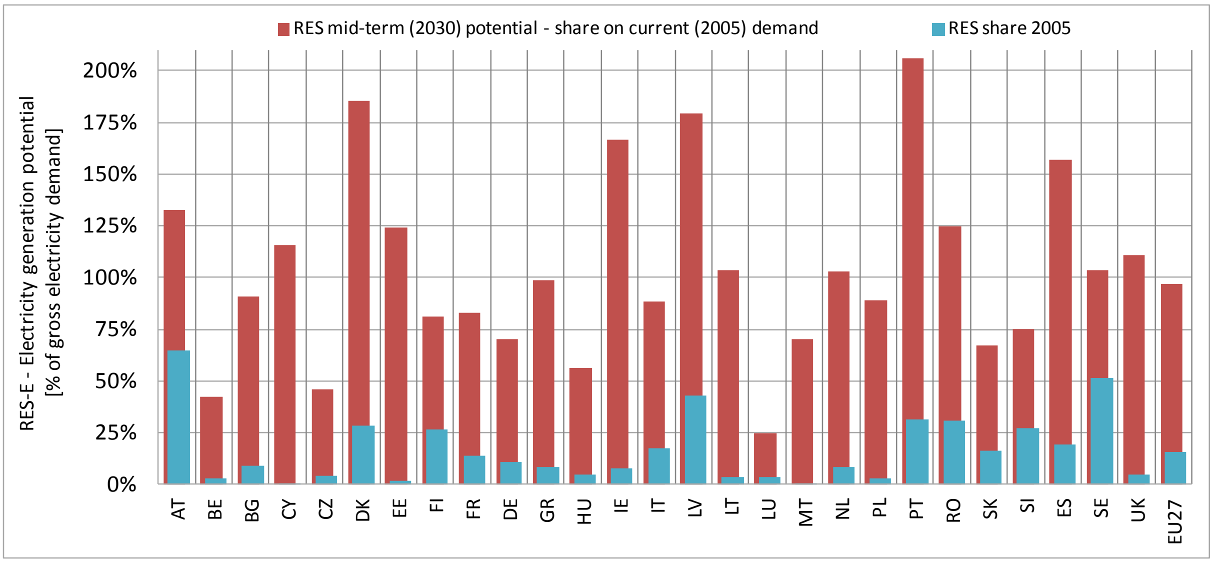


Figure 13 **Total realisable mid-term potentials (2030) and achieved potential for RES-E in EU 27 countries as share of gross electricity demand (2005).**

Additionally, the above-mentioned relations of the total realisable mid-term potential (2030) to the gross electricity demand are addressed in Figure 14 with respect to different scenarios on the future development of the electricity demand. A strong impact of the electricity demand development on the share of renewables is noticeable: In a reference demand scenario (according to PRIMES), a total achievable RES-E share of 79% in the year 2030 would appear feasible, whereas in an efficiency demand scenario, 93% of the expected future electricity demand by 2030 could be generated by renewables. As already discussed in the previous figure, if the total realisable mid-term potential for RES-E was fully exploited up to 2030, 97% of current (2005) gross consumption could be covered, meaning even the efficiency demand scenario takes an increasing electricity demand into account.

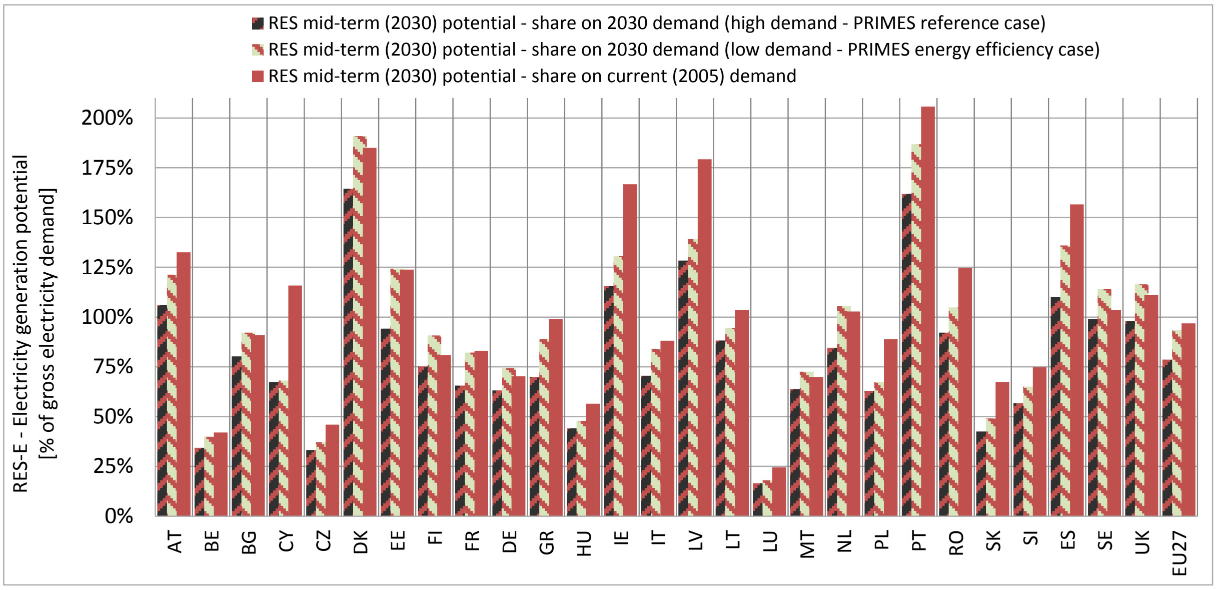


Figure 14 **Total realisable mid-term potentials (2030) and achieved potential for RES-E in EU 27 countries as share of gross electricity demand (2005 & 2030) in a reference and an efficiency demand scenario.**

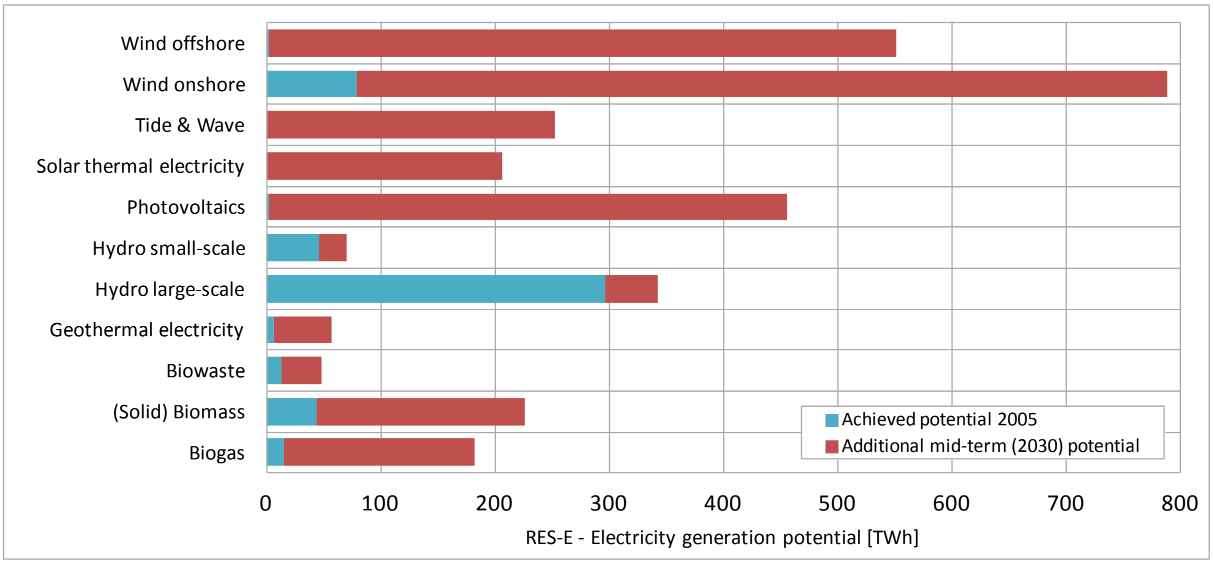


Figure 15 Total realisable mid-term potentials (2030) and achieved potential for RES-E in EU 27 countries on technology level.

Figure 15 demonstrates both the achieved and the additional realisable mid-term potential up to 2030 on a technology level for the whole EU 27. The figure depicts a high penetration and a small additional realisable potential for hydropower, both small- and large-scale. Wind onshore and solid biomass technologies are both already well developed, but still an enormous additional potential has to be realized to meet future RES-E targets. 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.

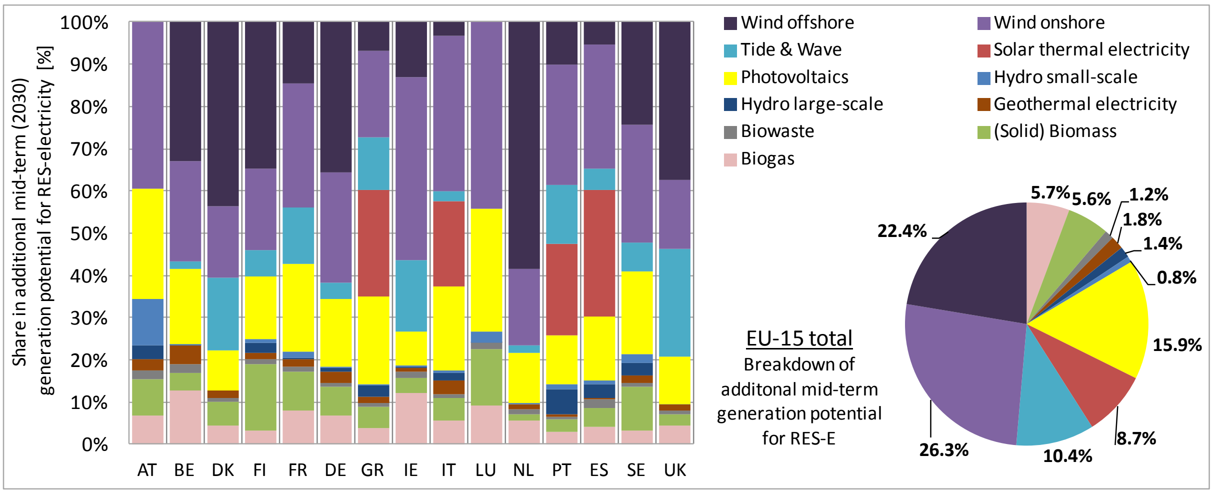


Figure 16 RES-E as a share of the additional realisable potential in 2030 for the EU-15 - by country (left) as well as for total EU-15 (right).

Next, future perspectives are indicated at the country level. As already mentioned, hydropower dominates current RES-E generation in most EU countries, followed by wind, biomass, biogas and biowaste. Figure 16 shows the share of different energy sources in the *additional* RES-E mid-term potential up to 2030 for the EU-15. The largest potential is found for wind energy (49%) followed by photovoltaics (16%) and biomass (13% - as aggregate of solid and gaseous biomass as well as biowaste), as well as promising future options such as tidal & wave (10%) or solar thermal energy (9%).

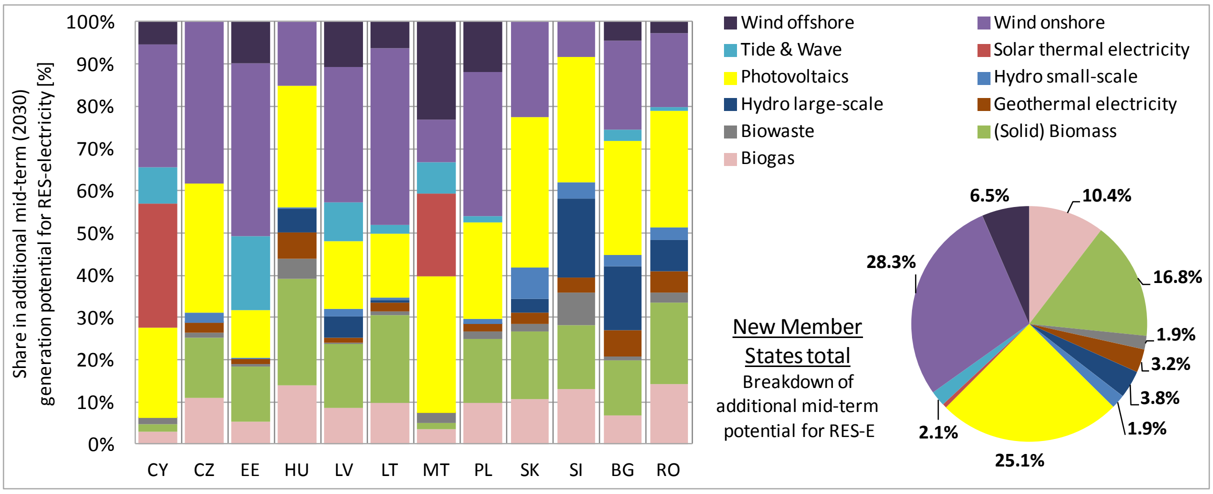


Figure 17 RES-E as a share of the additional realisable potential in 2030 for the New Member States – by country (left) as well as for total NMS (right).

In the New Member States, currently (2005), almost 88% of the renewable electricity is generated by hydro power plants and 10% by solid biomass, mainly co-fired in thermal fossil fuel-based power plants. Only a minor part is provided by more novel technologies such as wind energy and biogas. Figure 17 provides the 2030 depiction for New Member States (NMS), illustrating the share of different RES-E options in the additional mid-term potential up to 2030. In line with the EU-15, the largest potentials for these countries exist in the sectors of wind energy (35%) and photovoltaics (25%) followed by solid biomass (17%) and biogas (10%). Unlike the situation in the EU-15, the refurbishment and construction of large hydro plants holds significant potentials in some countries (4% of total NMS's future RES-E potential).

3.1.4 Mid-term (2030) realisable potentials for RES in the heating and cooling sector - extract from the Green-X database

Next, we take a closer look on the mid-term prospects for RES in the heating and cooling sector, illustrating the identified potentials that can be principally realised in the 2030 timeframe. Additionally, the historical record (by the end of 2005, as reference year of the Directive 2009/28/EC) 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 mid-term potentials up to 2030 – were assessed taking into account the country-specific situation as well as overall realisation constraints.

Figure 18 depicts the achieved and additional mid-term potential for RES-H&C in the EU 27 at country level. For EU 27 countries, the already achieved potential for RES-H&C equals 58.68 Mtoe, whereas the additional realisable potential up to 2030 amounts to 220.63 Mtoe (about 37% of 2005's gross heating and cooling demand). Obviously, large countries such as France, Germany, Italy or UK possess the largest RES-H&C 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-H&C potentials in absolute terms.

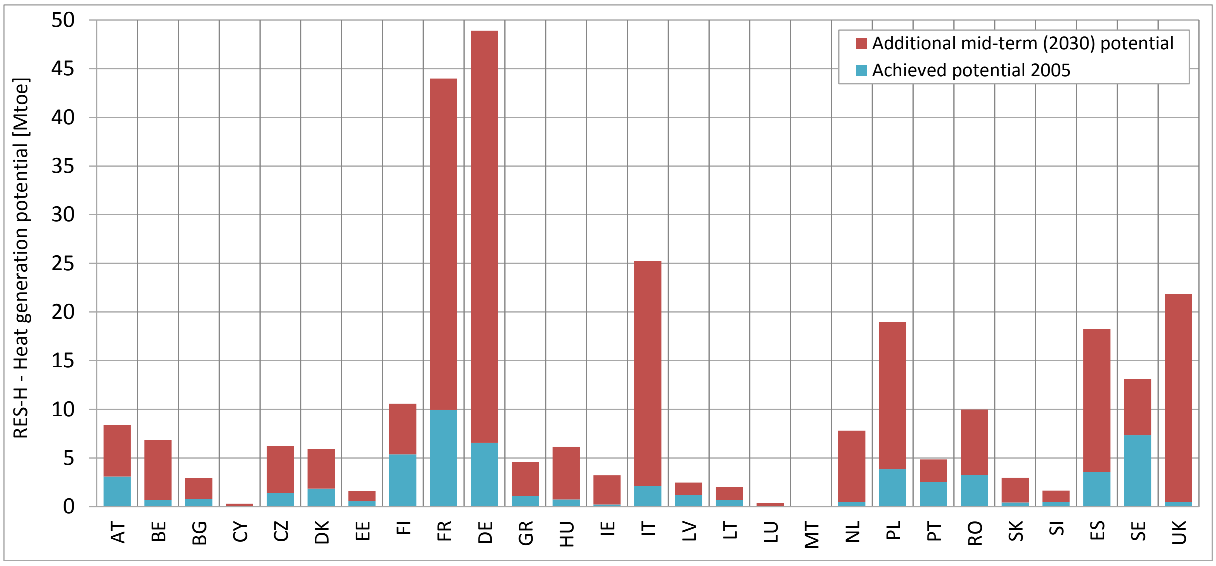


Figure 18 **Achieved (2005) and additional mid-term potential 2030 for heatling and cooling from RES in the EU 27 on country level.**

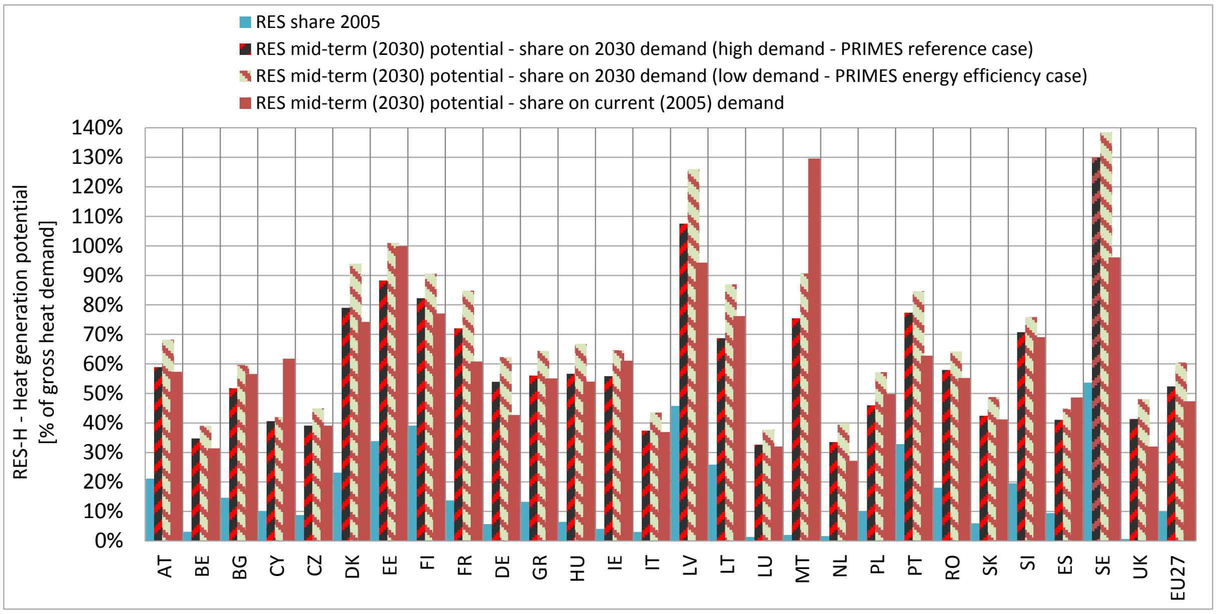


Figure 19 **Total realisable mid-term potentials (2030) and achieved potential for RES-H&C in EU 27 countries as share of gross heating and cooling demand (2005 & 2030) in a reference and an efficiency demand scenario.**

Consequently, Figure 19 relates derived potentials to gross heating and cooling demand. More precisely, it depicts the total realisable mid-term potentials (up to 2030), as well as the achieved potential (2005) for RES-H&C as share of gross heating and cooling demand in 2005, 2030 in a reference scenario and an efficiency scenario for all Member States and the EU 27 in total. As applicable from this depiction, significant additional RES potentials are becoming apparent for several countries. In this context especially notable are Sweden, Latvia and Estonia, as well as Malta. A strong impact of the heating and cooling demand development on the share of renewables is noticeable: In a reference demand scenario (according to PRIMES), a total achievable RES-H&C share of 52% in the year 2030 would appear feasible, whereas in an efficiency demand scenario, 60% of the expected future heating & cooling demand by 2030 could be generated by renewables.

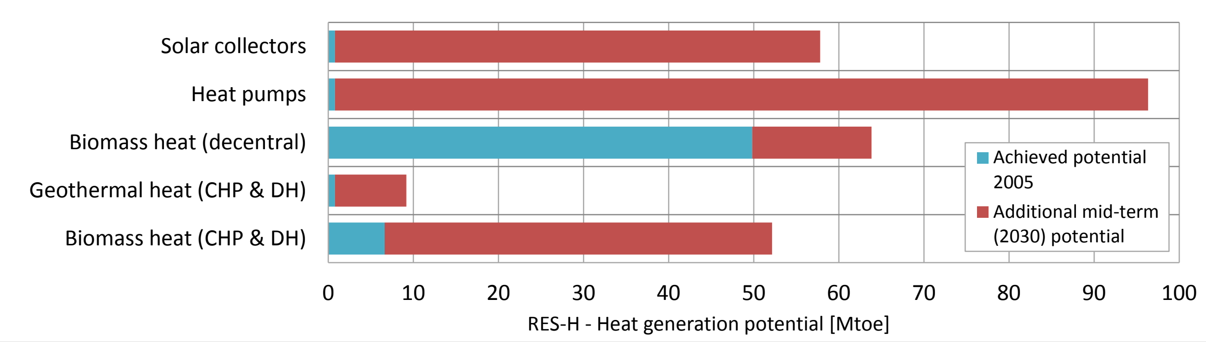


Figure 20 Total realisable mid-term potentials (2030) and achieved potential for RES-H&C in EU 27 countries on technology level.

Figure 20 demonstrates both the achieved and the additional realisable mid-term potential up to 2030 on a technology level for the whole EU 27. The figure depicts a high penetration and a small additional realisable potential for decentral biomass applications. Solar heat collectors and heat pumps are both only weak developed, but still an enormous additional potential has to be realized to meet future RES-H&C targets. Moreover, biomass CHP and DH technologies provide a large additional potential, waiting to be exploited in forthcoming years.

3.1.5 Mid-term (2030) realisable potentials for RES in the transport sector - extract from the Green-X database

Finally, we take a closer look on the mid-term prospects for RES in the transport sector, illustrating the identified potentials that can be principally realised in the 2030 timeframe. Additionally, the historical record (by the end of 2005, as reference year of the Directive 2009/28/EC) 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 mid-term potentials up to 2030 – were assessed taking into account the country-specific situation as well as overall realisation constraints.

Figure 21 depicts the achieved and additional mid-term potential for RES-T in the EU 27 at country level. For EU 27 countries, the already achieved potential for RES-T equals 3.48 Mtoe, whereas the additional realisable potential up to 2030, excluding imports, amounts to 46.12 Mtoe (about 13% of 2005's gross transport fuel demand). Obviously, large countries such as France, Germany, Spain or UK possess the largest RES-T 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-T potentials in absolute terms.

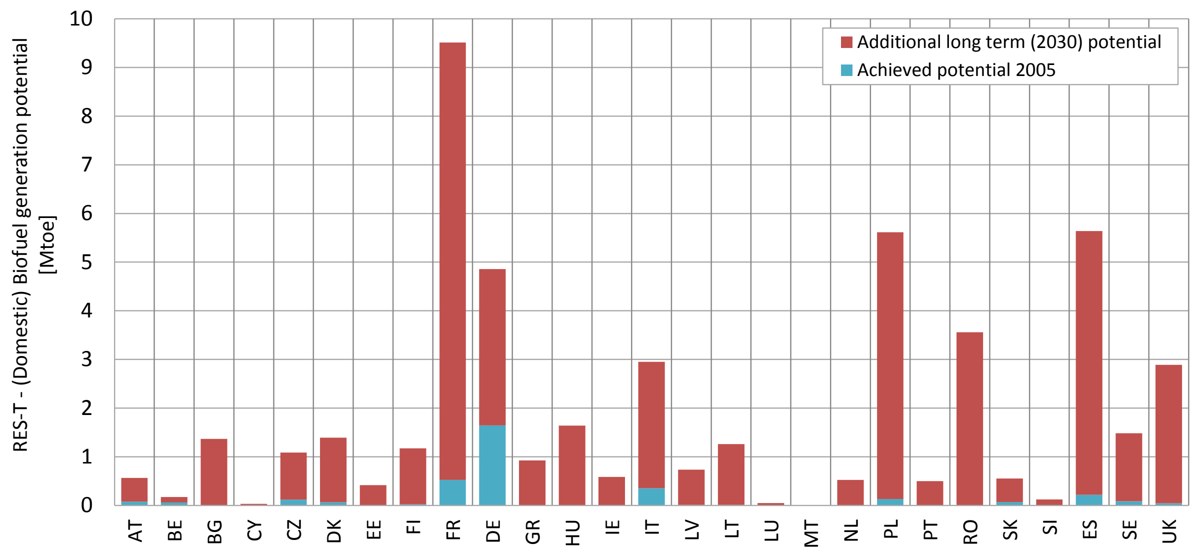


Figure 21 **Achieved (2005) and additional mid-term potential 2030 for transport from RES in the EU 27 on country level.**

Consequently, Figure 22 relates derived potentials to gross transport demand. More precisely, it depicts the total realisable mid-term potentials (up to 2030), as well as the achieved potential (2005) for RES-T as share of gross transport demand in 2005, 2030 in a baseline scenario and an efficiency scenario for all Member States and the EU 27 in total. As applicable from this depiction, significant additional RES potentials are becoming apparent for several countries. In this context especially notable are Lithuania, Latvia and Estonia, as well as Romania and Bulgaria. A strong impact of the transport fuel demand development on the share of renewables is noticeable: In a reference demand scenario (according to PRIMES), a total achievable RES-T share of 13% in the year 2030 would appear feasible, whereas in an efficiency demand scenario, 17% of the expected future transport demand by 2030 could be generated by renewables.

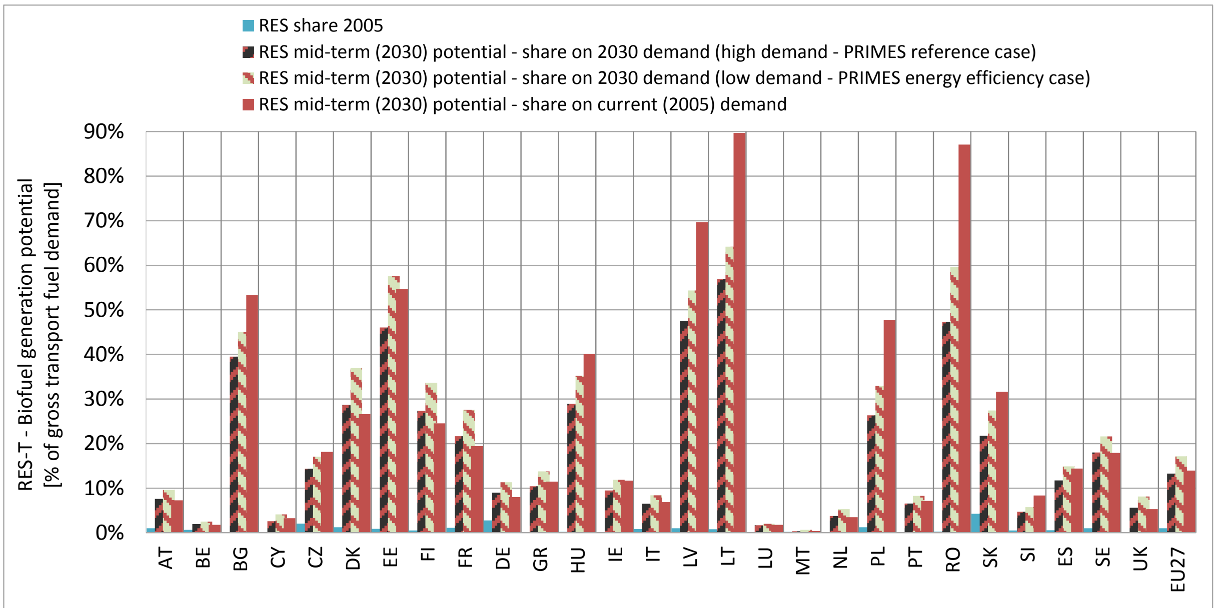


Figure 22 **Total realisable mid-term potentials (2030) and achieved potential for RES-T in EU 27 countries as share of gross transport fuel demand (2005 & 2030) in a reference and an efficiency demand scenario.**

3.2 RES cost

3.2.1 State-of-the-art - the current situation (as of 2010)

Economic conditions of the various RES technologies are based on both economic and technical specifications, varying across the EU countries.[21] In order to illustrate the economic figures for each technology Table 5 represents the economic parameters and accompanying technical specifications for RES technologies in the electricity sector, whilst Table 6 and Table 7 offer the corresponding depiction for RES technologies for heating and cooling and biofuel refineries as relevant for the transport sector. Note that all expressed data aim to reflect the current situation - more precisely, they refer to the year 2010 and are expressed in real terms (i.e. $€_{2010}$).

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

In the following the current investment cost for RES technologies are described alongside the data provided in Table 5, Table 6 and Table 7, whereby a focus may be put on the description of some key technology options. Since the original development of the ***Green-X*** database in the year 2004, several updates and adjustments have become necessary due to cost dynamics of RES technologies. In many cases, there was a trend for an increase of investment costs in the years up to 2008, followed by a stagnation or decrease in subsequent years.

Firstly, explanatory notes are provided on the technology-specific investment costs as depicted in Table 5:

- The current costs of biogas plants range from 1445 €/kW_{el} to 5085 €/kW_{el} with landfill gas plants offering the most cost efficient option (1445 €/kW_{el} – 2255 €/kW_{el}) and agricultural biogas plants (2890 €/kW_{el} – 5085 €/kW_{el}) being the highest cost option within this category;
- The costs of medium- to large-scale biomass plants only changed slightly and currently lie in the range of 2540 €/kW_{el} to 3550 €/kW_{el}. Biomass CHP plants typically show a broader range (2950 €/kW_{el} – 4885 €/kW_{el}) as plant sizes are typically lower compared to pure power generation. Among all bioelectricity options waste incineration plants have the highest investment costs ranging from 5150 €/kW_{el} to 7695 €/kW_{el} whereby CHP options show about 5% higher investment cost but offer additional revenues from selling (large amounts of) heat;
- The current investment costs of geothermal power plants are in the range of 2335 €/kW_{el} to 7350 €/kW_{el}., whereby the lower boundary refers to large-scale deep geothermal units as applicable e.g. in Italy, while the upper range comprises enhanced geothermal systems;
- Looking at the investment costs of hydropower as electricity generation option it has to be distinguished between large-scale and small-scale hydropower plants. Within these two categories, the costs depend besides the scale of the units also on site-specific conditions and additional requirements to meet e.g. national / local environmental standards etc. This leads to a comparatively broad cost range from 870 €/kW_{el} to 6265 €/kW_{el} for new large-scale hydropower plants. Corresponding figures for small-scale units vary from 980 €/kW_{el} to 6590 €/kW_{el};

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

- In 2010 typical PV system costs were in the range 2675 €/kW_{el} to 3480 €/kW_{el}. These cost levels were reached after strong cost declines in the years 2008 and 2009. This reduction in investment cost marks an important departure from the trend of the years 2005 to 2007, during which costs remained flat, as rapidly expanding global PV markets and a shortage of silicon feedstock put upward pressure on both module prices and non-module costs (see e.g. Wiser et al 2009). Before this period of stagnation PV systems had experienced a continuous decline in cost since the start of commercial manufacture in the mid 1970's following a typical learning curve. The new dynamic began to shift in 2008, as expansions on the supply-side coupled with the financial crisis led to a relaxation of the PV markets and the cost reductions achieved on the learning curve in the meantime factored in again. Furthermore, the cost decrease has been stimulated by the increasing globalization of the PV market, especially the stronger market appearance of Asian manufacturers.
- The investment costs of wind onshore power plants are currently (2010) in the range of 1350 €/kW_{el} and 1685 €/kW_{el} and thereby slightly lower than in the previous year. Two major trends have been characteristic for the wind turbine development for a long time: While the rated capacity of new machines has increased steadily, the corresponding investment costs per kW dropped. Increases of capacity were mainly achieved by up-scaling both tower height and rotor size. The largest wind turbines currently available have a capacity of 5 to 6 MW and come with a rotor diameter of up to 126 meters. The impact of economies of scale associated with the turbine up-scaling on turbine cost is evident: The power delivered is proportional to the diameter squared, but the costs of labour and material for building a turbine larger are constant or even fall with increasing turbine size, so that turbine capacity increases disproportionally faster than costs increase. From around 2005 on the investment costs have started to increase again. This increase of investment cost was largely driven by the tremendous rise of energy and raw material prices as observed in recent years, but also a move by manufacturers to improve their profitability, shortages in certain turbine components and improved sophistication of turbine design factored in.

Table 5 Overview on economic-& technical-specifications for new RES-E plant (for the year 2010)

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

Table 6 Overview on economic-& technical-specifications for new RES-H&C plant (grid & non-grid) (for the year 2010)

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

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

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

Table 7 Overview on economic-& technical-specifications for new biofuel refineries (for the year 2010)

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

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

For RES-H&C plants as displayed in Table 6 the distinction between grid-connected and non-grid heating systems is important. Among the first category are biomass and geothermal district heating systems and among the latter one biomass non-grid heating systems, solar thermal heating systems and heat pumps. Depending on the scale investment costs for biomass district heating systems currently range between 380 €/kW$_{heat}$ and 580 €/kW$_{heat}$, and for geothermal district heating systems between 820 €/kW$_{heat}$ and 2160 €/kW$_{heat}$. In case of non-grid biomass heating systems the investment costs differ depending on fuel type between 390 €/kW$_{heat}$ and 685 €/kW$_{heat}$. Heat pumps currently cost from 735 €/kW_{heat} up to 1195 €/kW_{heat} and for solar thermal heating systems depending on scale the specific investment costs reach from 660 €/kW_{heat} to 880 €/kW_{heat}.

Table 7 provides the current investment cost data for biofuel refineries. With regard to the fuel input / output different plant types are included in the database. Biodiesel plant (FAME) currently cost from 205 €/kW_{trans} to 835 €/kW_{trans}, bio ethanol plants from 605 €/kW_{trans} to 2150 €/kW_{trans} and BTL plant from 825 €/kW_{trans} to 6190 €/kW_{trans}. Please note that in the case of advanced bio ethanol and BtL the expressed cost and performance data represent expected values for the year 2015 - the year of possible market entrance with regard to both novel technology options.

While the investments costs of RES technologies as described above are suitable for an analysis at the technology level, for the comparison of technologies the generation costs are relevant. Consequently, the broad range of the resulting generation costs, due to several influences, for several RES technologies is addressed subsequently. Impacts as, variations in resource- (e.g. for photovoltaics or wind energy) or demand-specific conditions (e.g. full load hours in case of heating systems) within and between countries as well as variations in technological options such as plant sizes and/or conversion technologies are taken into account. In this context, for the calculation of the capital recovery factor a payback time of 15 years, which represents rather an investor's view than the full levelized costs over the lifetime of an installation, and weighted average cost of capital of 6.5% are used.

As can be observed from Figure 23, Figure 24 and Figure 25 the general cost level as well as the magnitude of the cost ranges vary strongly between the different technologies. It is thereby striking that RES-H&C options under favourable conditions are either competitive or close to competitiveness, while all RES-T options still are above the market price. Looking at RES-E options the situation is more diverse. The most conventional and cost efficient options like large hydropower and biogas can generate electricity below market prices. It is also noticeable that wind power (onshore) cannot deliver electricity at market prices even at the best sites. Of course, this proposition holds only for current market prices which have decreased substantially in the wholesale market in the near past. For most RES-E technologies the cost range at the EU level appears comparatively broad. In the case of PV or wind energy this can be to a lesser extent ascribed to (small) differences in investment costs between the Member States, but more crucial in this respect are the differences in resource conditions (i.e. the site-specific wind conditions in terms of wind speeds and roughness classes or solar irradiation and their formal interpretation as feasible full load hours) between the Member States. In the case of photovoltaics the broad cost range results also from differences in terms of application whereby the upper boundary refers to facade-integrated PV systems.

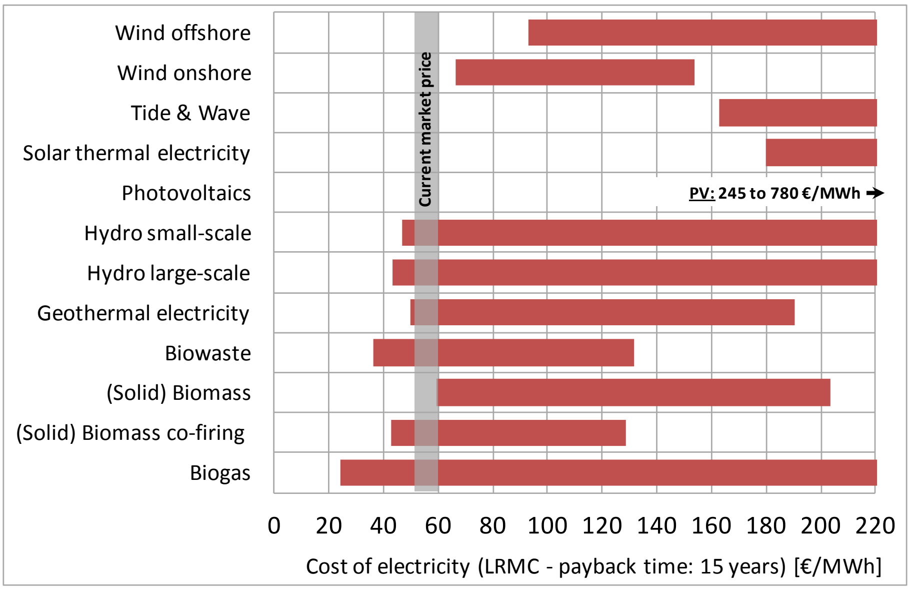


Figure 23 **Long-run marginal generation costs (for the year 2010) for various RES-E options in EU countries**

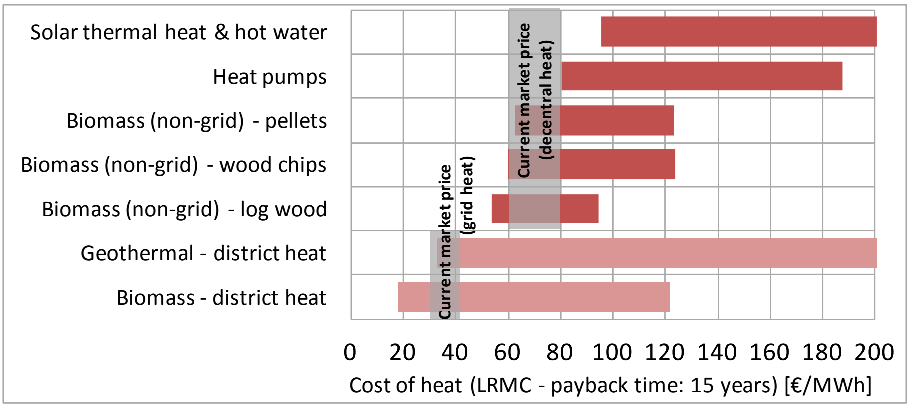


Figure 24 **Long-run marginal generation costs (for the year 2010) for various RES-H&C options in EU countries**

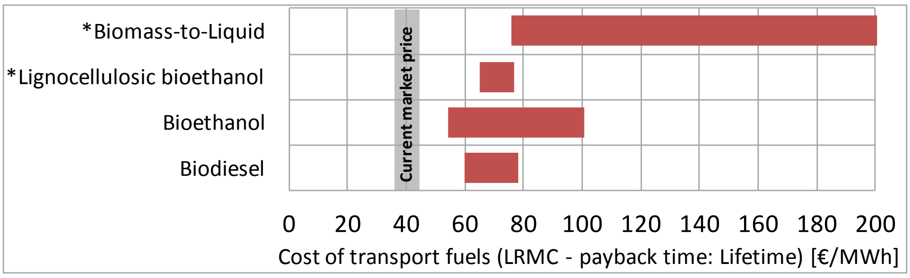


Figure 25 **Long-run marginal generation costs (for the year 2010[22]) for various RES-T options in EU countries**

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

3.2.2 Technological change - future cost and performance expectations

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

- Deployment within the EU 27 Member States is endogenously determined, i.e. is derived within the model.
- Expected developments in the "rest of the world" are based on forecasts as presented in the IEA World Energy Outlook 2011 (IEA, 2011).

Table 8 Assumed learning rates in case of moderate (default) learning expectations – exemplarily depicted for selected RES-E technologies

Assumed learning rates for selected RES-E technologies	*Geographical scope*	*Moderate learning*		
		2006 - 2010	*2011 - 2020*	*2021 - 2030*
Solid biomass - small-scale CHP	global learning system	cost increase*	10.0%	10.0%
Photovoltaics	global learning system	20.0%	20.0%	17.5%
Wind energy	global learning system	cost increase*	7.0%	7.0%

Note: *A cost increase (compared to 2006 levels) up to 2008 is assumed for solid biomass and wind energy (as well as for almost all other energy technologies) in line with historical observations. This increase is mainly caused by rising energy and raw material prices and in line with the assumptions on the development of energy prices (where high energy prices serve as default reference).

It is distinguished between a pessimistic scenario, with relatively low expectations on future cost reductions and a moderate scenario, assuming a more rapid RES deployment in Europe and at global scale. The identical assumed learning rates are depicted for both cases in Table 8. The consequences of the assumed RES technology diffusion and the underlying technology learning rates and efficiency improvements regarding the cost reduction of RES are depicted in Figure 26 (accelerated RES deployment) and Figure 27 (moderate RES deployment). Remarkable is the negative development in the period 2007 to 2009 for most energy technologies, but probably mostly affecting the cost of wind turbines. This increase of investment cost was largely driven by the tremendous rise of energy and raw material prices as observed in recent years and expected to prolong in the near to mid future – i.e. in line with the corresponding energy price assumptions where "high energy prices" serve as default case.[23] However, still substantial cost reductions are observable and expected for novel technology options such as photovoltaics, solar thermal electricity or ocean technologies.

[23] For wind energy also an overheating of the global market was observable throughout that period, where supply could not meet demand. This lead to a higher cost increase compared to other energy technologies.

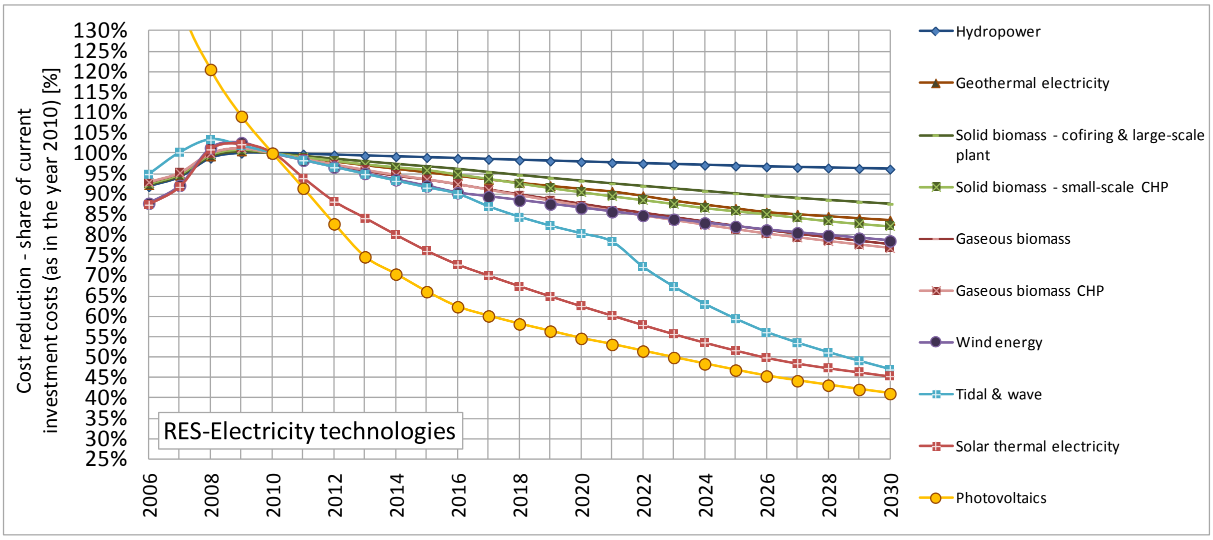


Figure 26 **Cost reduction of RES-E investments as share of current investment costs (2010) based on moderate technological learning expectations (default) in accordance with the Green-X Advanced scenario (where a strong take-up of RES-E is assumed)**[24]

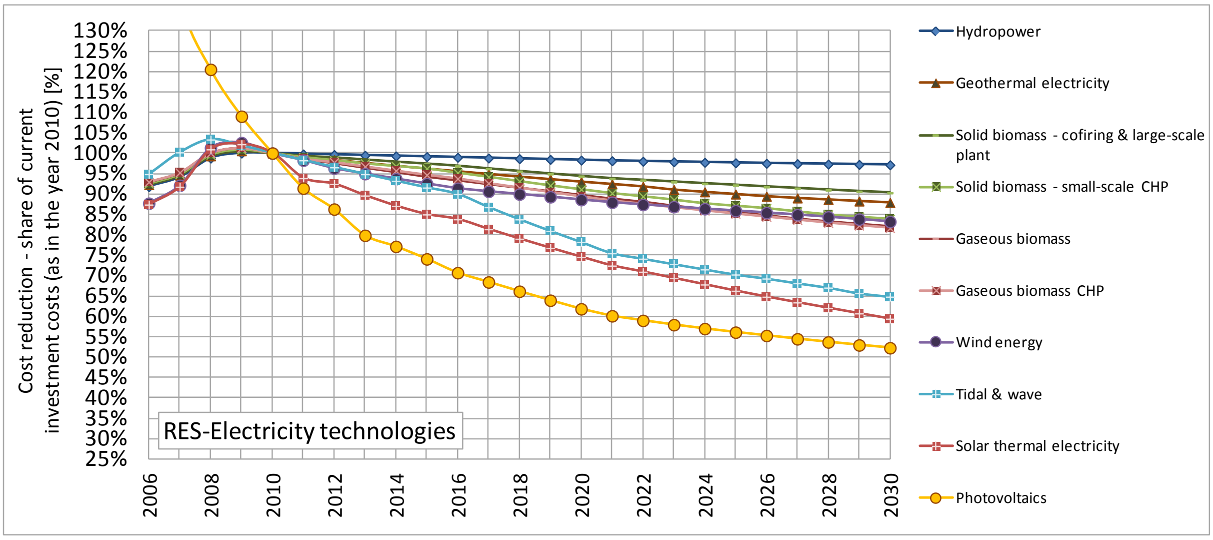


Figure 27 **Cost reduction of RES-E investments as share of current investment costs (2010) based on moderate technological learning expectations (default) according to the assessed "business-as-usual (BAU)" case(Source: Re-Shaping study, see Ragwitz et al., 2012)**

Complementary to above, an overview on the resulting cost ranges is given for selected key technologies in Figure 28 (for solar PV and CSP) and Figure 29 (for wind on- and offshore).

[24] Deployment of RES-E technologies within the EU 27 is taken from the Green-X Advanced scenario where a strong RES uptake is assumed, leading at EU level to a RES share in gross electricity demand of about 67% by 2030. For the rest of the world the IEA's WEO 2011 projection, more precisely the 450ppm scenario, is used.

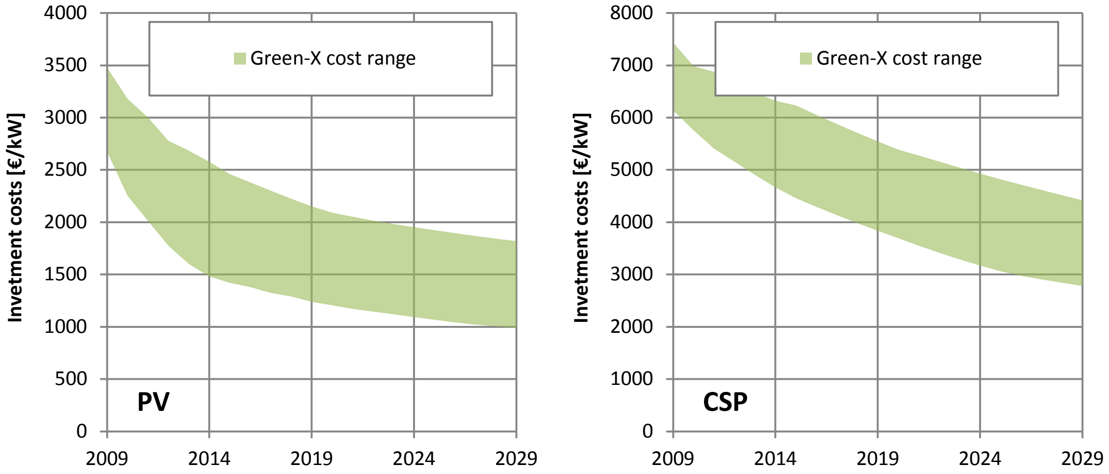


Figure 28 Comparison of resulting ranges (of investment costs) for solar technologies (PV, CSP)

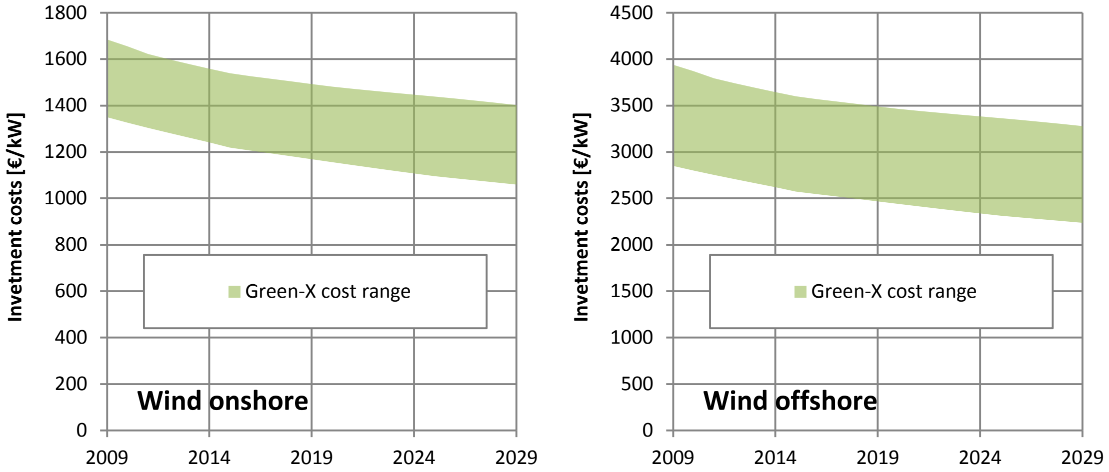


Figure 29 Comparison of resulting ranges (of investment costs) for wind technologies (onshore, off-shore)

4 Policy pathways for a harmonisation of RES(-E) support in Europe

This section summarises the outcomes of the detailed elaboration of feasible pathways for the harmonisation of RES(-E) support in Europe. In order to define the policy pathways, we conducted an extensive literature review, including work already performed by the members of the research team, as well as a stakeholder consultation and a consortium-internal cross-check.

Pathways are defined at two levels. A first level involves degrees of harmonisation: i.e. at which legislative/administrative level the decisions on instruments and design elements are taken, and whether there are national RES-E targets in addition to a European target. On a second level, there are some components of the pathways that need to be harmonised: instruments, design elements, framework conditions and other elements, including the use of cooperation mechanisms and cost-allocation alternatives. The combination of all these components under different degrees of harmonisation results in a broad set of different pathways for analysis and evaluation.

4.1 Classification of policy concepts

In the debate on the convergence of support schemes for RES, different concepts such as "convergence", "coordination", "cooperation", and "harmonisation" are used and sometimes conflated. As a result, we have aimed to provide further clarification on the terminology, in accordance with Gephart *et al* (2012), classifying and defining the meanings of the different concepts:

- *"Convergence"* simply means that policies (and possibly related regulations) are becoming similar in different Member States (MSs). Thus, the following concepts can be classified as means to achieve the overarching goal of convergence;
- *"Coordination"* might refer to knowledge exchange between governments and possible alignment of certain elements of a support scheme;
- *"Cooperation"* either refers to governments loosely working together or it might refer to the RES Directive (2009/28/EC) and its inherent possibilities to establish statistical transfers of renewable energy, joint renewable energy projects (among MSs or with third countries) or joint support schemes (that is, merged support schemes) as specified in Articles 6, 7, 9 and 11 of the Directive. All of these concepts have different implications: e.g. regarding who initiates the convergence (top-down or bottom-up), regarding different levels of the binding nature of a given instrument and different levels of detail;
- *"Harmonisation"* is generally regarded as a top-down implementation of common, binding provisions concerning the support of RES-E throughout the EU (Bergmann *et al* 2008). However, harmonisation admits many possibilities concerning what needs to be harmonised and how, along a continuum from "Full" to "Minimum" harmonisation, depending on the combination of "what" options (i.e., targets, support scheme, design elements, support level) and "how" options (i.e., whether decisions are taken at EU or MS level). Different levels of harmonisation can, in principle, be combined within the same instrument.

4.2 Degrees of harmonisation

In order to keep the discussion on the pathways manageable, we consider four alternatives here, as illustrated in Table 9. We focus on several critical aspects, which from our work in this project have been useful for the definition of pathways: i.e. whether there are MS targets in addition to the EU-wide target, and at what administrative level the decision on instruments and design elements (and, particularly, support levels) is taken (EU or MS). A brief description of the different alternatives follows.[25] We have considered four major degrees of harmonisation. Obviously, there might be other possibilities within the wide range of alternatives, but we believe that the ones selected cover the major aspects of harmonisation.[26]

Table 9 Degrees of harmonisation considered in this report.

Degree of harmonisation	MS targets	Support scheme	Decision on design elements	Decision on support level
Full	No	EU-wide	EU	EU
Medium	No	EU-wide	EU	EU (plus additional MS support)
Soft	Yes	Same instru-ment used in MS, not uniform	MS (some imposed by EU)	MS
Minimum	Yes	MS decision.	MS (some imposed by EU)	MS

- *Full harmonisation* involves the setting up of EU-wide targets (no MS targets), an EU-wide support scheme, harmonisation of framework conditions and harmonisation of the design elements of the support scheme selected. There is a very limited role to be played by the MSs. Full harmonisation involves harmonisation of: the *level* of support; support *schemes*; and the *legal framework* as a whole, including regulatory issues. An EU-wide socialisation of the costs of support takes place. The focus on Full harmonisation is justified because this seems to have been a long-term aspiration of the European Commission. As observed by Guillon (2010), the European Commission has repeatedly mentioned that harmonisation remains a long-term goal (European Parliament and Council, 2001 and/or European Commission 2005, 2008). Notwithstanding this, while Full harmonisation remains a long-term aspiration, lower degrees of harmonisation are also possible and it is very difficult at this stage to tell what will be the final degree of harmonisation. Thus, we also consider softer degrees of harmonisation.
- *Medium harmonisation* would be very close to Full harmonisation. There is also one EU-wide instrument and EU support level, but countries may provide additional (albeit limited) support for specific technologies, either within the EU-wide support scheme (i.e., additional remuneration based on local benefits under feed-in tariffs or premia) or as an additional instrument to the EU-wide support scheme (i.e., investment subsidies or soft loans). The latter option would be more feasible in the case of quotas with TGC or tendering schemes, since it would be very difficult or even impossible for MSs to provide additional support directly incorporated into an EU-wide TGC or tendering scheme. Countries may be willing to provide additional support depending upon the local benefits of RES-E. It should be taken into account that having additional support per country would mean that the EU target may be exceeded (since the EU-support level is set to reach those targets). Alternatively, the EU support level may be set taking into account the amount of RES-E that MSs are willing to have and may inform the Commission on the level of support and amount of RES-E that it would like to promote. The level of EU-wide support would thus be set interactively. Another option would be to have (indicative) national targets and use Art. 6 cooperation mechanisms (statistical transfers) to redistribute the additional RES-E capacity across countries.

[25] For a discussion on different degrees of harmonisation, see Bergmann *et al* (2008) and Guillon (2010).

[26] In particular, an alternative which has not been discussed is the possibility to combine an EU-wide support level (as in Full and Medium harmonisation) with MS targets (as in Soft and Minimum harmonisation).

But no MS targets have been assumed in this scenario because an EU-wide support scheme with a single support level would render MS targets meaningless.

- *Soft harmonisation*. This harmonisation alternative would be closer to Minimum harmonisation than to Full harmonisation. There is an EU-wide target, but also national targets consistent with the EU target. Countries have to implement domestically the support scheme that has been decided at EU level. However, countries may use whatever design element they deem best and support levels may differ across countries.[27] There might be some design elements imposed at the EU level.
- At the other end of the spectrum, under *Minimum harmonisation*, EU-wide targets as well as national targets are set by the EU. MSs decide on both the type of support scheme that they apply and its design elements. MSs may set whatever support level they deem most appropriate. There might be minimum design elements set by the EU (e.g. authorisation procedures and an obligation to support different technologies).

4.3 Policy instruments

RES-E promotion has traditionally been based on three main (primary) mechanisms: feed-in tariffs (FITs), quotas with tradable green certificates (TGCs) and tendering (see del Río and Gual 2004, Ragwitz *et al* 2007, Schaeffer *et al* 2000, and Huber *et al* 2004 for further details).

- *Feed-in tariffs* offer financial support per kWh generated, paid in the form of guaranteed (premium) prices and combined with a purchase obligation by the utilities. The costs are usually borne by consumers. The most relevant distinction is between fixed feed-in tariff (FITs) and fixed premium (FIP) systems. The former provides total payments per kWh of electricity of renewable origin while the latter provides a payment per kWh on top of the electricity wholesale-market price (Sijm 2002). Each has its pros and cons: in general, while FIPs are usually considered more market-compatible, FITs provide greater certainty for investors.
- *TGCs* are certificates that can be sold in the market, allowing RES-E generators to obtain revenue. This is additional to the revenue from their sales of electricity fed into the grid. Therefore, RES-E generators benefit from two streams of revenue from two different markets: the market price of electricity, plus the market price of TGCs multiplied by the number of kWh of renewable electricity fed into the grid (Schaefer *et al* 2000). The issuing (supply) of TGCs takes place for every MWh of RES-E, while demand generally originates from an obligation. Electricity distribution companies must surrender a number of TGCs as a share of their annual consumption. Otherwise, they will have to pay a penalty. The TGC price results from the interaction of supply and demand, and depends on the level of the quota (Q) and the marginal costs of RES-E generation (MC_{RE}). The expected TGC price (P_{TGG}) covers the gap between the marginal cost of renewable electricity generation at the quota level and the price of electricity (P_e). P_e and P_{TGG} move in opposite directions: an increase in P_e reduces the TGC price accordingly.
- *Tendering.* The government invites RES-E generators to compete for either a certain financial budget or a certain capacity of RES-E generation. Within each technology band the cheapest bids per kWh are awarded contracts and receive the guaranteed remuneration (Schaeffer *et al.*, 2000). The operator pays the bid price per kWh. A fund financed by a levy

[27] There is no possible combination of the key elements of the medium and soft alternatives, since having national targets is incompatible with support levels being decided at EU level. This is because there is no possibility for countries to do anything extra themselves to reach those targets: i.e., they cannot change the support level to reach those targets. National targets only make sense if countries have an instrument in their hands to reach them (i.e., support levels).

on electricity consumers or taxpayers covers the difference between this bid price and the market price of electricity.

4.4 Identified policy pathways

Combining the degrees of harmonisation with the instruments and relevant design elements leads to several policy paths for a harmonisation of RES(-E) support in Europe. Banded and unbanded TGCs, premium and fixed FITs are currently widely-used instruments in the EU MSs. Tendering schemes are not widespread, but there is a trend in some countries to use them for large-scale RES projects. Unbanded TGCs were initially adopted in the U.K. and Italy, but concerns about the lack of incentives for the deployment of less mature technologies led to a shift to banded TGCs. Unbanded TGCs are still present in Belgium, Poland, Romania and Sweden. A uniform quota is still proposed by those arguing in favour of inter-technology competition (i.e., competition between different renewable energy technologies to meet the target, even if this means technologies with different maturity levels). However, it is widely acknowledged that this technology neutrality would involve the dominance of mature technologies without allowing immature technologies to penetrate the market. The costs of immature technologies (partly) depend on their diffusion; this would mean that their costs would make them unattractive for adoption, since these technologies will be needed in the future for cost-effective compliance with RES-E (and CO_2) targets. Their advancement along their learning curves (through diffusion) is required, which calls for technological diversity and, thus, justifies a banded TGC.

Table 10 summarises the policy pathways considered that have been analysed in a detailed manner within the course of this project. The list of identified pathways has become significantly longer than initially proposed: taking into account the aforementioned policy paths and the design elements, their combination may lead to several alternatives for the design of the pathway. In this section, we consider the possible combinations in greater depth.

Accordingly, 16 policy pathways are defined, taking into account the main RES-E support instruments (TGCs, FITs and tendering), their main design elements and different degrees of harmonisation. Within those policy packages, further choices have to be made regarding some design elements and the role of MSs: see subsequent sections for our recommendations in this respect.

Table 10 Overview on RES(-E) policy pathways (beyond2020)

<table>
<tr><th colspan="3">Overview on RES(-E) policy pathways beyond2020

Degree of harmonisation / Characterisation / Instrument</th><th>FIT (feed-in tariff)</th><th>FIP (feed-in premium)</th><th>QUO (quota system with uniform TGC)</th><th>QUO banding (quota system with banded TGC)</th><th>ETS (no dedicated RES support)</th><th>TEN (Tendering for large scale RES)</th></tr>
<tr><td>Full</td><td colspan="2">• EU target
• One instrument</td><td>1a</td><td>2a</td><td>3a</td><td>4a</td><td rowspan="3">5</td><td rowspan="3">6
Sensitivity to 7 (national support, but harmonisation for selected technologies)</td></tr>
<tr><td>Medium</td><td colspan="2">• EU target
• One instrument
• Additional (limited) support allowed</td><td>1b</td><td>2b</td><td>3b</td><td>4b</td></tr>
<tr><td>Soft</td><td colspan="2">• EU & National targets
• One instrument
• MS can decide on various design elements incl. support levels</td><td>1c</td><td>2c</td><td>3c</td><td>4c</td></tr>
<tr><td>Minimum</td><td>• With minimum design standards for support instruments</td><td rowspan="2">• EU & National targets
• Cooperation mechanism (with or w/o increased cooperation)</td><td colspan="6">7d
Reference with minimum design criteria (national RES support with increased cooperation and with minimum design standards)</td></tr>
<tr><td>No</td><td>• No minimum design standards for support instruments</td><td colspan="6">7
Reference (national RES support w/o increased cooperation and w/o minimum design standards)</td></tr>
</table>

5 Results of the assessment of RES(-E) policy pathways

This chapter introduces and discusses the outcomes of the impact assessment of the RES (-E) policy pathways that have been described in the last chapter. The assessment comprises a thorough analysis of several key indicators. Most prominently, the resulting deployment and the corresponding support expenditures will be discussed for each pathway, but also results for further cost and benefit categories and cost allocations will be displayed. In the following at first hand section 5.1 will give a glance on key results and then subsequently section 5.2 will provide detailed outcomes of the impacts of all assessed pathways. Thereafter, a sensitivity analysis of key input parameter is conducted.

5.1 Key results on RES-E deployment and related support expenditures for selected policy pathways

Next, only a brief overview of the results gained within the final assessment is given, indicating the key outcomes for RES policy assessment, using the example of the EU level for the electricity sector only: see Figure 30, Figure 32 and Figure 33.

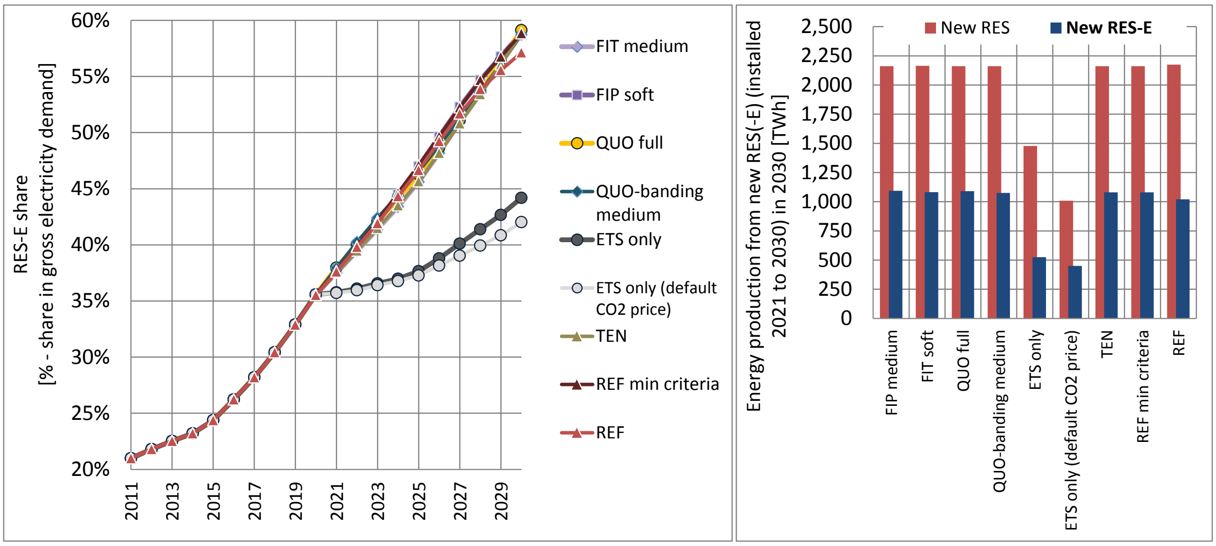


Figure 30 Comparison of the resulting RES-E deployment over time for all RES-E (left) as well as by 2030 for new RES-E and RES installations only (from 2021 to 2030) (right) in the EU-27 for selected cases.

More precisely, Figure 30 illustrates for a selection of policy pathways[28] the feasible RES-E deployment over time (left) as well as by 2030 (right), indicating the penetration of new RES-E installations within the observed time frame. It becomes evident that, without dedicated support, RES-E deployment would stagnate after 2020, reaching a share of RES-E of 42.0% by 2030.[29] This indicates that an ETS by itself does not provide sufficient stimulus for RES-E deployment. In contrast to the "no support" case, within all other policy variants the expected deployment of RES in the electricity sector by 2030 ranges from 57.1% to 59.2%. If total RES deployment is taken into consideration, "no

[28] In order to increase the readability for each type of assessed support instrument only one representative is chosen for these depictions – i.e. for a feed-in tariff system its performance in the case of a medium harmonisation is shown while for uniform quotas the variant referring to full harmonisation is illustrated.

[29] This figure refers to the variant of low carbon prices. If moderate-to-high carbon prices are assumed, a RES-E share of 44.2% can be reached.

(dedicated RES) support" would lead to a RES share in gross final energy demand of 21.2%[30] by 2030, while in all other policy paths it appears feasible to reach the targeted RES share of 31.2% by 2030.

Complementary to above, Figure 37 provides a technology-breakdown of RES-E deployment in 2030 at EU-27 level, indicating the amount of electricity generation by 2030 that stems from new installations of the assessed period 2021 to 2030 for the analysed policy pathways. Apparently, wind energy (on- & offshore) and biomass dominate the picture. Even in the "ETS only" cases significant amounts of new installations can be expected, in particular for onshore wind energy. Among all other cases at first glance only small differences are applicable as a moderate to ambitious RES target generally requires a larger contribution of the various available RES-E options. Technology-neutral incentives evaluated in the QUO full (3a) variant of harmonised uniform RES-E support fail however to offer the necessary guidance to more expensive novel RES-E options on a timely basis. Consequently, the deployment of CSP, tidal stream or wave power, but also to a negligible extent offshore wind may be delayed or even abandoned. The gap in deployment would be compensated by an increased penetration of cheap to moderate RES-E options, in particular onshore wind and biomass used for co-firing or in large-scale plants.

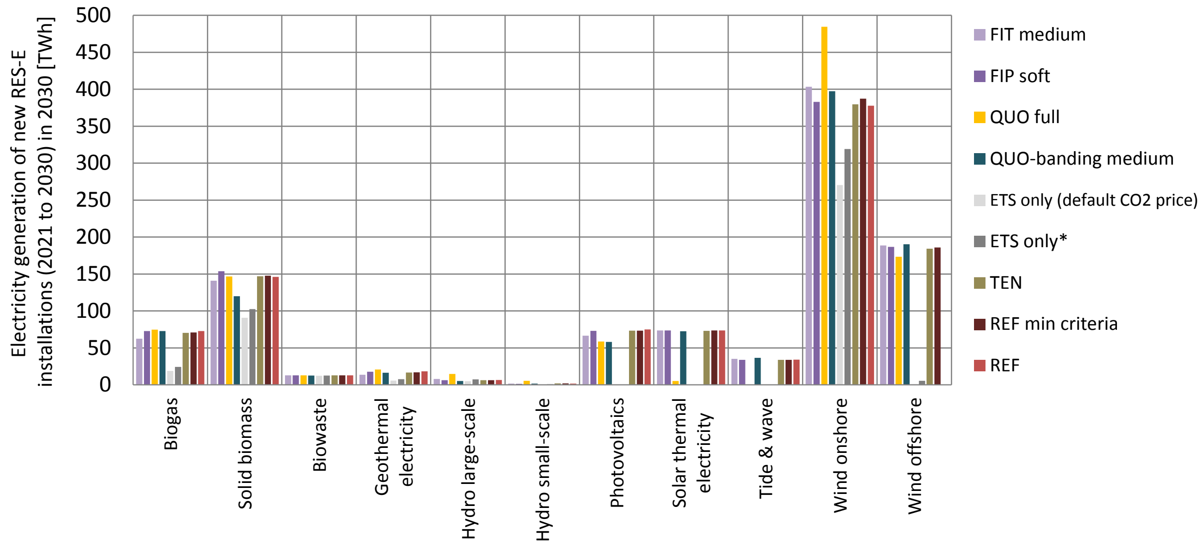


Figure 31 Technology-specific breakdown of RES-E generation from new installations (2021 to 2030) at EU-27 level in the year 2030 for selected cases

Figure 32 complements above depictions, indicating – in addition to RES-E deployment – the cost impact, in particular the resulting support expenditures for new RES-E installations. More precisely, Figure 32 offers a comparison of both overall deployment of new RES-E plants (installed between 2021 and 2030) by 2030 and the corresponding support expenditures (on average per year for the period 2021 to 2030) for the selected policy pathways. Apparently, soft harmonisation a via feed-in premium system, strengthened national RES policies complemented by strong cooperation and coordination (prescribing minimum design criteria) or medium harmonisation in the case of quotas with technology banding appear suitable to keep RES well on track to reach moderate-to-ambitious deployment targets for 2030. Related support expenditures can then be maintained on a comparatively low level (at € 22.9 to € 24.1 billion as a yearly average for new RES-E installations), while the uniform RES support involved in the case of a harmonised RES trading regime (without banding) may lead to a significant increase of the consumer burden (to € 28.5 billion). Best performers in terms of cost-effectiveness among the basket of selected policy pathways are the system of fixed feed-in tariffs under medium harmonisation and a variant of the reference case of strengthened national policies (with minimum design criteria) where EU-wide tenders are used for wind (on- and offshore)

[30] Again, this figure refers to the case of low carbon prices. Note that in the case of moderate / high carbon prices a RES share of 26.3% appears feasible.

and centralised solar systems (large-scale PV and CSP) – i.e. under these cases yearly average (2021-2030) support expenditures for new RES installations in the forthcoming decade reach the comparatively lowest levels (€ 18.5 to 19.0 billion €).

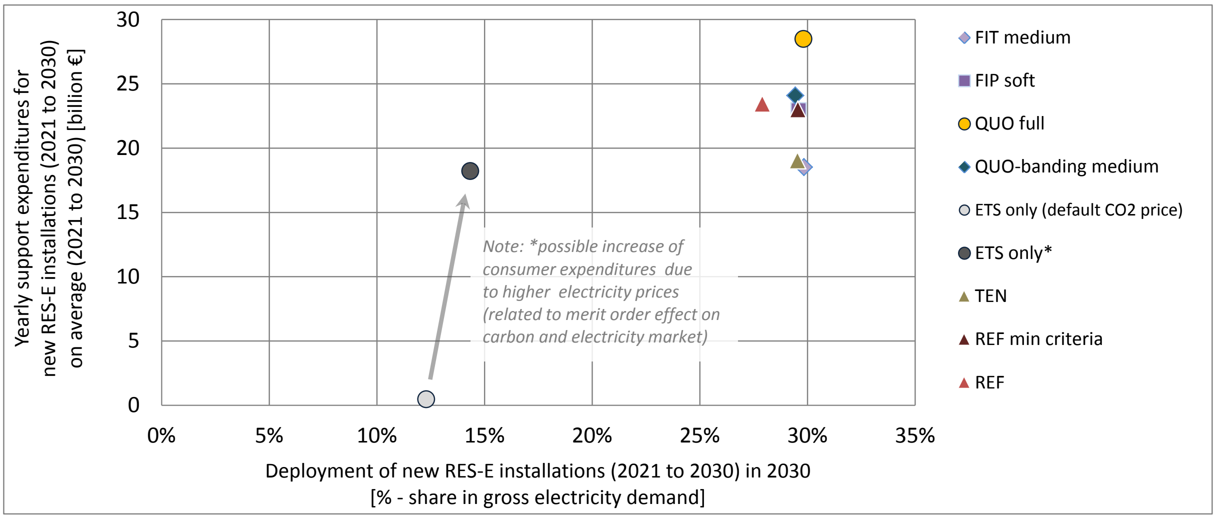


Figure 32 Comparison of the resulting 2030 deployment on new RES-E (installed 2021 to 2030) and the corresponding (yearly average) support expenditures in the EU-27 for selected cases.

In the case of "no (dedicated RES) support", obviously no support expenditures for RES are applicable. If long-term climate targets are taken seriously, meaning that Europe strives for the 80%-95% GHG reduction by 2050, no dedicated RES support may, however, possibly cause the following effects. A comparison of the two variants of "no support", characterised by either low (in the case of no strong carbon commitment) or moderate-to-high carbon prices (reflecting a strong long-term carbon commitment: i.e. an 80%-95% GHG emission reduction by 2050), indicates that, in the absence of a strong RES deployment, a rise in electricity prices may lead to an indirect consumer burden of almost similar magnitude to that involved in the case of perfectly-tailored RES policies. In the absence of continuous RES support and related expansion, this is caused, on the one hand, by a reduction of the so-called "merit order" effect that usually goes hand in hand with RES deployment. On the other hand, a lower RES-E penetration leads to higher carbon prices and, thus, also higher electricity prices, since more alternatives have to enter the (common) carbon market in order to comply with the carbon target.[31] [32]

How does the degree of harmonisation affect the economic performance of policy instruments? A first indication of the impact arising from that is provided next. Figure 33 compares yearly average (2021 to 2030) support expenditures for new RES-E (installed 2021 to 2030) for all assessed policy pathways. Remarkably, the type of instruments chosen plays a more prominent role than the degree of harmonisation. Only small differences are applicable among the variants by type of instruments. For example the cost-effectiveness of a feed-in premium system appears nearly unaffected by the degree of harmonisation: only a negligible difference between the resulting support expenditures under full, medium or soft harmonisation can be observed, i.e. expenditures range from € 22.6 to € 22.9 billion. Although almost negligible, uniform quotas show a better performance under soft harmonisation, where harmonised uniform support is complemented by (limited) national incen-

[31] Note however, that both the merit order effect on electricity and CO_2 price are distributional effects between consumers and producers. These effects cause consumer profits on the one hand and losses for (conventional) producers. Therefore the benefit discussed above only exists from the consumers' point of view.

[32] Complementary to RES several options exist to mitigate GHG emissions, including supply-side options such as nuclear power, carbon capture and sequestration of thermal (fossil and biomass) power plants and an increase in energy efficiency both at the supply (i.e. increased conversion efficiencies of thermal power generation units and/CHP) and at the demand side (i.e. a more efficient use of energy and/or a reduced demand for energy services). All these options may benefit due to an increase of their competitiveness in the case of high(er) energy and/or carbon prices.

tives, aiming to steer parts of the investments towards those regions where national 2030 RES target fulfilment appears more challenging than in others. In contrast to above, feed-in premiums and banded quotas show a better performance in the case of full harmonisation, and, finally, a fixed feed-in tariff system appears generally unaffected by the degree of harmonisation.

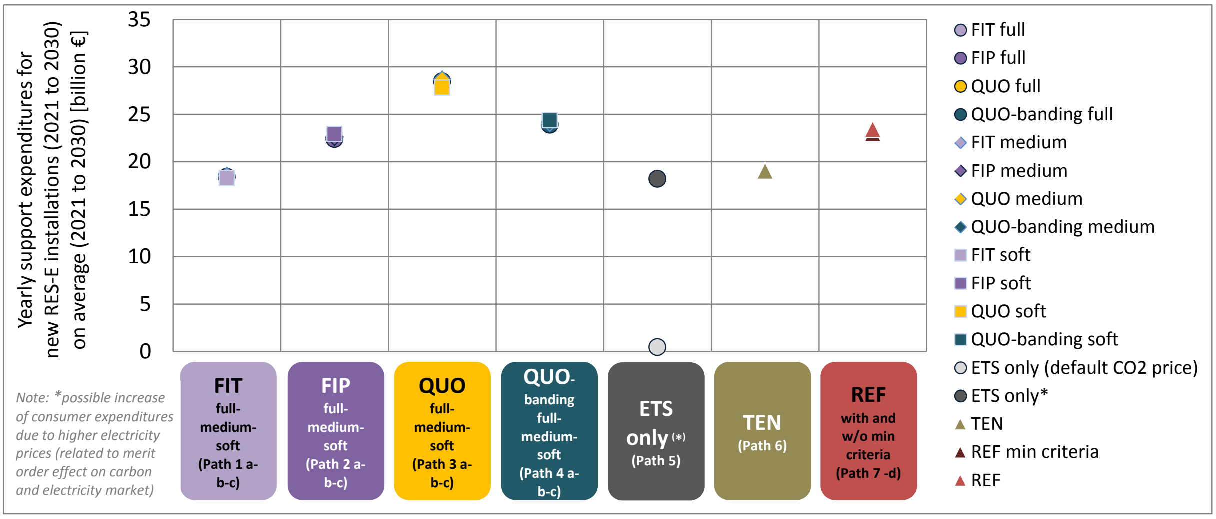


Figure 33 **Comparison of (yearly average) support expenditures for new RES-E (installed 2021 to 2030) in the EU-27 for all assessed cases.**

Indicators on costs and benefits of RES(-E)

Indictors on costs and benefits of an accelerated RES deployment in the European Union offer central information for decision makers. In this context, Figure 34 (RES-E) and Figure 35 (RES total) summarise the assessed costs and benefits arising from the future RES(-E) deployment in the focal period 2021 to 2030. More precisely, these graphs provide for the researched selected cases the on average per year throughout the period 2021 to 2030 arising investment needs and the resulting costs – i.e. additional generation cost, and support expenditures. Moreover, they offer an indication of 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 – monetary expressed as avoided expenses for emission allowances). Other benefits – even of possibly significant magnitude - such as job creation or industrial development were neglected in this assessment.

As applicable in Figure 34 (RES-E) and Figure 35 (RES total) benefits depend on the amount of new RES installations and are of similar magnitude among all assessed cases – an exception from this general observation are the "ETS only" scenarios where, as discussed above, RES deployment is significantly lower since, in contrast to other cases, in the absence of dedicated RES support assumed RES target for 2030 are not met. Remarkably, compared to the reference case of strengthened national support without minimum design criteria a slight decrease of benefits is however also applicable in the other cases where 2030 RES targets are presumably met. This is caused by an overfulfilment in that reference path where MSs primarily aim for a national target fulfilment and a resulting oversupply in very few of them (although support for RES was deteriorated). For investment needs and also for cost indicators (i.e. additional generation cost and support expenditures) a similar trend as discussed for benefits can be seen: Costs and expenditures are lowest for the "ETS only" cases although the consumer burden appears still considerably in the electricity sector if indirect impacts are taken into consideration – i.e. the increase of wholesale electricity prices that comes along with a decrease of RES-E deployment, see related discussion above. Among all other cases capital expenditures and additional generation cost are somewhat smaller in the case of a uniform quota scheme while, as also discussed above, support expenditures are significantly higher in magnitude. The comparison to reference indicates however even for this otherwise less preferred pathway a small saving potential compared to reference if RES in all three sectors (i.e. electricity, heat and transport) are taken into consideration, cf. Figure 35. This is mainly because of the assumed inhomogeneous incentives for RES in heating and cooling among MSs under the reference policy track (where several countries increase support considerably to achieve their given targets domestically).

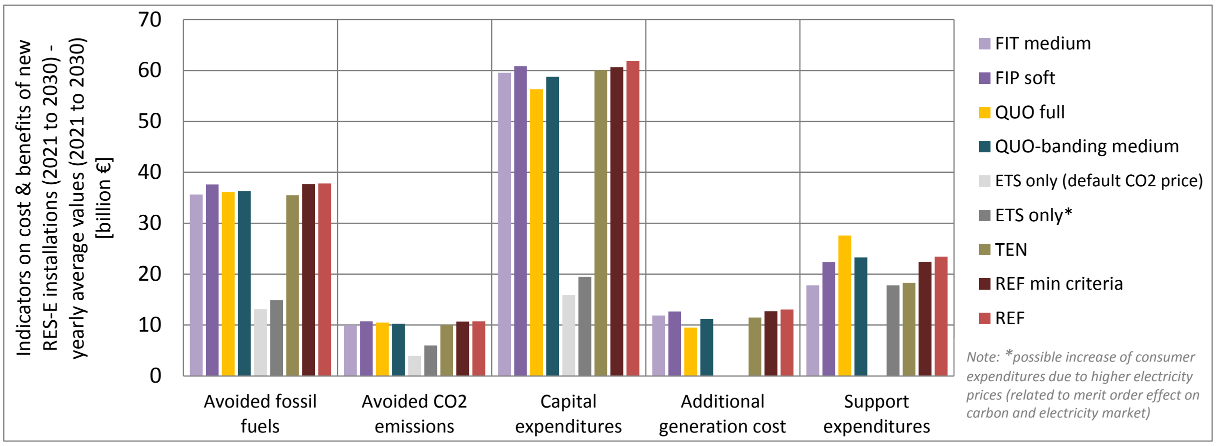


Figure 34 **Indicators on yearly average (2021 to 2030) cost and benefits of new RES-E installations (2021 to 2030) at EU-27 level for selected cases, monetary expressed in absolute terms (billion €)**

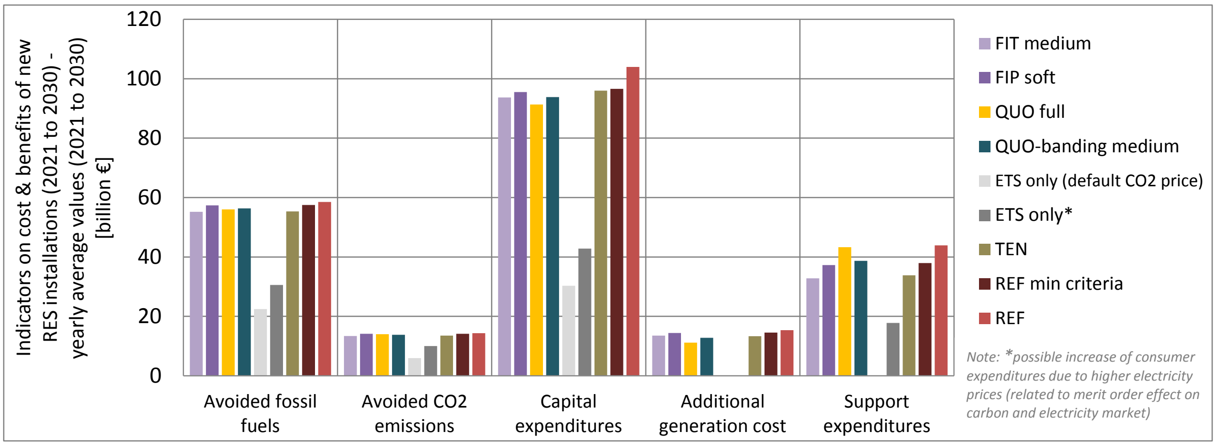


Figure 35 **Indicators on yearly average (2021 to 2030) cost and benefits of new RES installations (2021 to 2030) at EU-27 level for selected cases, monetary expressed in absolute terms (billion €)**

5.2 Comparison of RES(-E) policy pathways by degree of harmonisation

Next, we provide further insights on the outcomes of the model-based RES(-E) policy assessment, discussing results on RES(-E) deployment and economic as well as environmental impacts for all assessed RES(-E) policy pathways. Since the number of cases is large a clustering appears necessary whereby the degree of harmonisation is used to group pathways into different clusters. This helps identifying the particularities of certain instruments under different settings.

5.2.1 Full harmonisation

A closer look on results on RES deployment and related cost, expenditures and benefits is taken next for all cases of full harmonisation. This allows for a comparison of the specifics and impacts arising from the type of policy instrument chosen in its most pronounced form – i.e. when applied across the EU following a harmonised design as well as under harmonised framework conditions.

Results on RES(-E) deployment

As a starting point, Figure 36 shows for each type of key instrument (i.e. feed-in tariff, feed-in premium, uniform quota and quota with banding) the resulting RES-E deployment over time (left) as well as by 2030 (right), indicating the deployment of new RES-E installations within the observed time frame. Obviously, all four instruments show a similar performance in terms of effectiveness under the assessed framework conditions and assumptions. The targeted RES deployment of 31.2% (as share in gross final energy demand) is achieved by 2030, and new RES (installed in the period 2021 to 2030) contribute more than half of total RES volumes to that (i.e. 53% as share in RES energy production). In the electricity sector minor differences are applicable in the development of total RES-E generation over time, mainly because of design settings or specifics of certain instruments – by 2030 these differences diminish and a RES-E demand share of about 59% is reached (i.e. there is a narrow corridor for the resulting RES share by 2030, ranging from 58.7% to 59.1%).

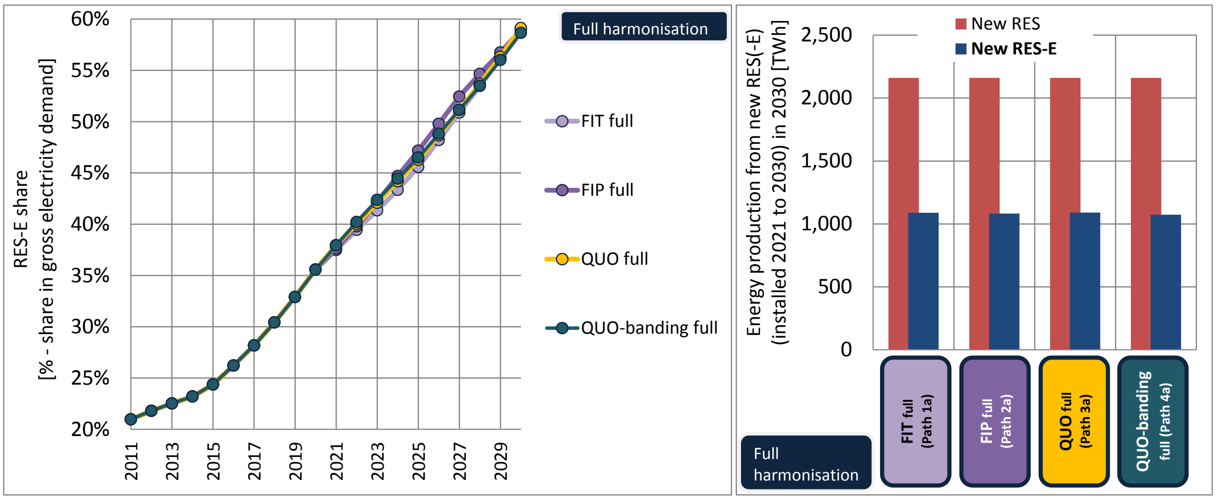


Figure 36 **Comparison of the resulting RES-E deployment over time for all RES-E (left) as well as by 2030 for new RES-E and RES installations only (from 2021 to 2030) (right) in the EU-27 for all cases of full harmonisation.**

Figure 37 shows which RES-E options contribute most at EU-27 level in the assessed period 2021 to 2030 depending on the applied policy pathway. Obviously, wind energy (on- & offshore) and biomass dominate the picture. At first glance, small differences among the reviewed cases are applicable as a moderate to ambitious RES target generally requires a larger contribution of all available RES-E options. Technology-neutral incentives evaluated in the QUO full (3a) variant of harmonised uniform RES-E support fail to offer the necessary incentives to more expensive novel RES-E options on a timely basis. Consequently, the deployment of CSP, tidal stream or wave power, but also to a negligible extent offshore wind may be delayed or even abandoned. The gap in deployment would be compensated by an increased penetration of cheap to moderate RES-E options, in particular onshore wind and biomass used for co-firing or in large-scale plants.

Complementary to the technology-breakdown shown in Figure 37 and discussed above Figure 38 provides a breakdown of the expected electricity generation in 2030 that results from the new RES-E capacity (installed 2021 to 2030) by country, expressing the share of domestic RES-E production in the respective gross electricity consumption for all assessed cases of full harmonisation. While at EU-27 level new RES-E account for about 27% of gross electricity demand, at MS level generally large differences are observable. More or less independent from the underlying type of policy instrument in countries like Spain, Portugal, Estonia, Ireland or UK a strong RES-E deployment can be expected in the forthcoming decade, and the demand share of new RES-E would be by far higher than at EU average. On the contrary, Luxembourg, Cyprus, Czech Republic, Slovakia, Slovenia and Belgium would face only lower volumes of RES-E deployment – i.e. new RES-E account for less than 15% of domestic gross electricity consumption. Allocation impacts of the type of policy instrument are however applicable. While a feed-in premium system and a quota with technology-banding provide comparatively similar allocation signals, a system of fully harmonised feed-in tariffs and an EU-wide harmonised uniform quota scheme lead to different deployment patterns. Thereby, different effects come into play:

- A uniform quota offering technology-neutral incentives for new RES-E installations shifts investments from more expensive novel RES-E technologies to low-hanging fruits. More precisely, the marginal impact arises however from moderate to expensive potentials of wind onshore and large-scale biomass that would not be tapped in the case of tailored technology-specific support. Since support is now, i.e. under a uniform trading regime, more generous for these technologies, these potentials are exploited. As scenarios point out this diverts investments for example from countries like Ireland, Spain, Greece or the UK towards Bulgaria, Portugal or Sweden.
- In contrast to all other cases, in the case of fixed feed-in tariffs the necessary premium, i.e. difference between RES-E costs and reference electricity prices, is not decisive for the investment decision, only the levelised costs of electricity generation come into play. Thus, countries with generally lower wholesale electricity prices than at EU average face higher volumes of RES-E deployment and vice versa. A system of fixed feed-in tariffs would for example lead to a significantly lower RES-E deployment in Austria, Germany, Italy, Greece, Cyprus, Malta and Slovenia compared to a feed-in premium system. In turn, RES-E deployment would increase in countries like Denmark, Finland, France, Sweden, Spain and the UK.

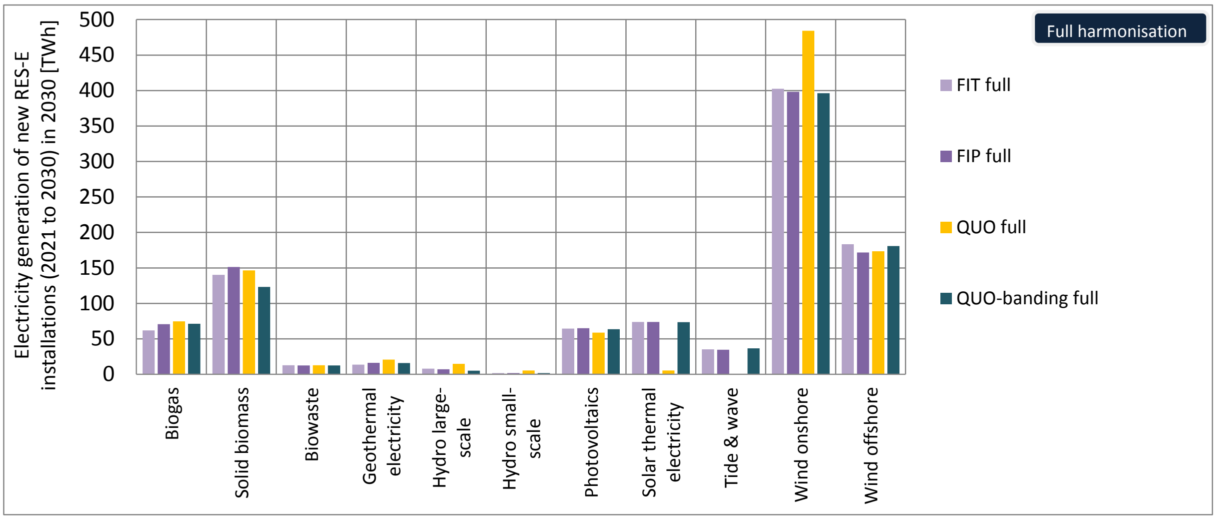


Figure 37 Technology-specific breakdown of RES-E generation from new installations (2021 to 2030) at EU-27 level in the year 2030 for all cases of full harmonisation

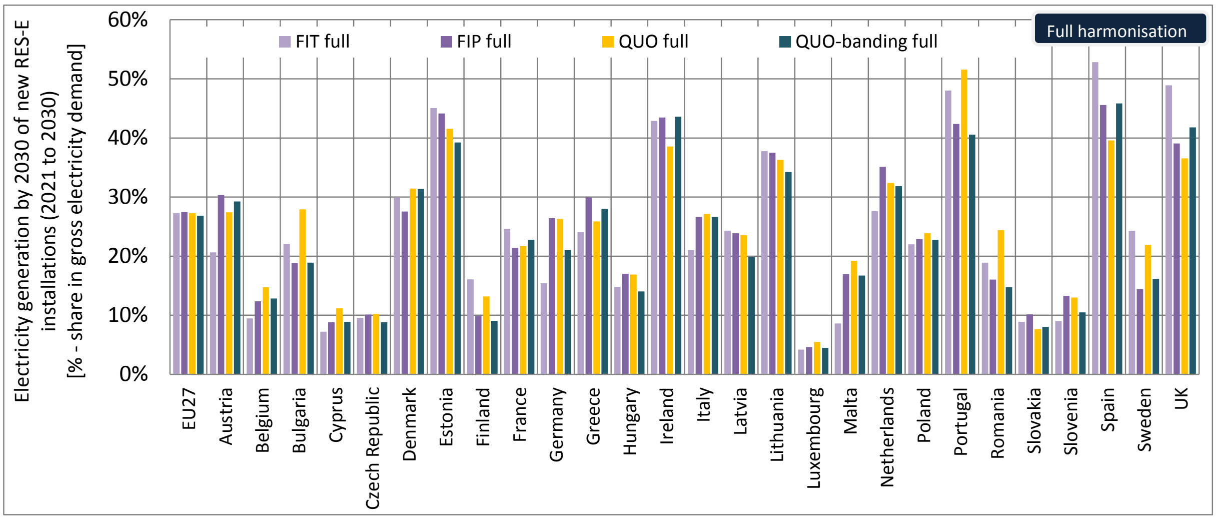


Figure 38 **Country-specific breakdown of RES-E generation from new installations (2021 to 2030) in the year 2030 for all cases of full harmonisation**

Results on support expenditures for RES(-E)

Looking at the financial side of RES(-E) support in the period studied, two different indicators are taken into account. A short description of each is given initially to assist in the interpretation.

(Average) financial support for a new RES-E plant

> *This indicator shows the dynamic development of the necessary financial support per MWh of RES-E generation for new installations (on average). Expressed values refer to the corresponding year. The amount represents the average additional premium on top of the power price guaranteed (for a period of 15 years) for a new RES-E installation in a given year from an investor's viewpoint; whilst from a consumer perspective, it indicates the additional expenditure per MWh_{RES-E} required for a new RES-E plant compared with a conventional option (characterised by the power price).*

Figure 39 compares the necessary financial support per MWh of RES-E generation for new installations at the EU-27 level for all cases of full harmonisation, indicating the technology-specific average figure for the period 2021 to 2030 (left) as well as the dynamic development on average for all RES-E options (right). The period 2021 to 2030 is chosen because the various policy options are only applied in this period.

The required average financial support per MWh_{RES-E} shows a different development over time for the assessed cases: In the case of feed-in premiums it remains rather constant in early years but decreases in the final period close to 2030. A fixed feed-in tariff system leads to a steep decline right after its introduction while later on a moderate but constant increase is apparent. In the analysed quota systems (with and without technology banding) in the first year a high financial incentives occurs, indicating a supply shortage while later on an ambiguous development can be observed – i.e. a decline in the period up to 2027 and later on a steady increase. Generally, average support is higher under a technology-neutral scheme than in quota with technology banding. A closer look on technology-specific average figures as well as on the yearly average support for RES-E in total (cf. Figure 39 (left)) provides further insights and indicates a clear ranking of the assessed cases: The least-cost option in terms of support expenditures is the system of fixed feed-in tariffs because of the secure and stable remuneration offered. A bit more risky from an investor viewpoint but with the system benefits to offer locational signals a harmonised feed-in premium system performs second best. Next to that ranks a quota with technology banding. The most costly option from a consumer perspective is the technology-neutral quota system. Accordingly, Figure 39 also points out that harmonising RES-E support in such a way that only one uniform support level is offered, i.e. a common RES trading system without technology banding, would lead to a significant increase of the average level of RES-specific financial support. In the years close to 2030 cheap RES potentials are no longer sufficiently applicable to meet the increasing demand for RES. Consequently, more costly RES options are required that then set the common price in the RES trading scheme, and, hence, an excessive support of less costly technologies occurs.

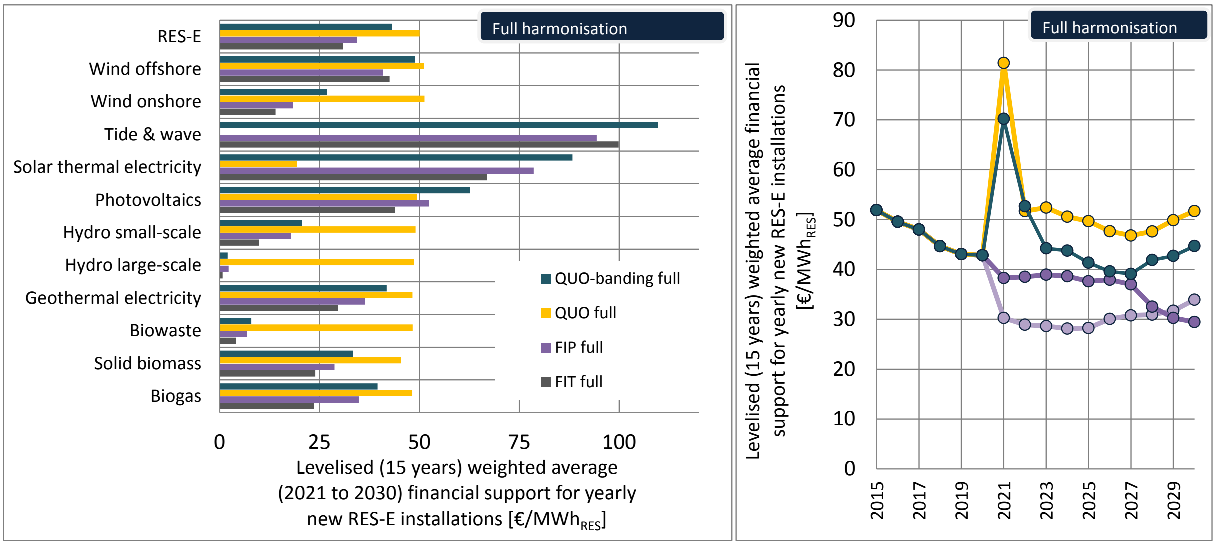


Figure 39 Comparison of financial support (premium to power price) for new RES-E installations at EU-27 level in the period 2021 to 2030 for cases of full harmonisation, depicted by technology on average (left) and over time (indicating also the development up to 2020) (right)

Yearly support expenditures for RES(-E)

Support expenditures (or transfer costs) for consumers/society are defined as the direct premium financial transfer costs from the consumer to the producer due to the RES-E policy compared to the case of consumers purchasing conventional energy (electricity). This means that these costs do not consider any indirect costs or externalities (environmental benefits, impacts on employment, etc.).

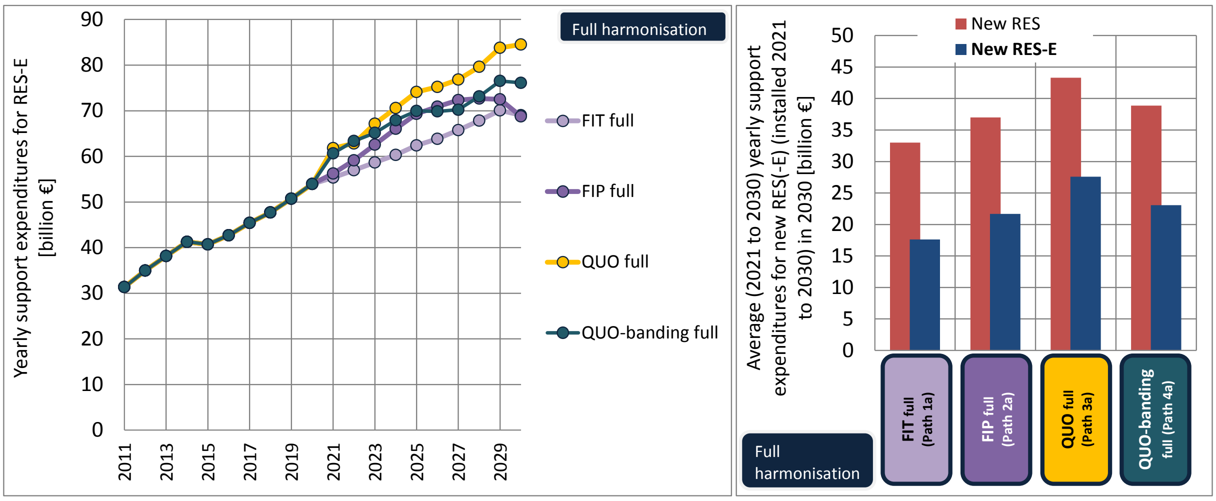


Figure 40 Comparison of the resulting support expenditures for all RES-E over time (left) as well as on average (2021 to 2030) for new RES-E and RES installations only (from 2021 to 2030) (right) in the EU-27 for all cases of full harmonisation.

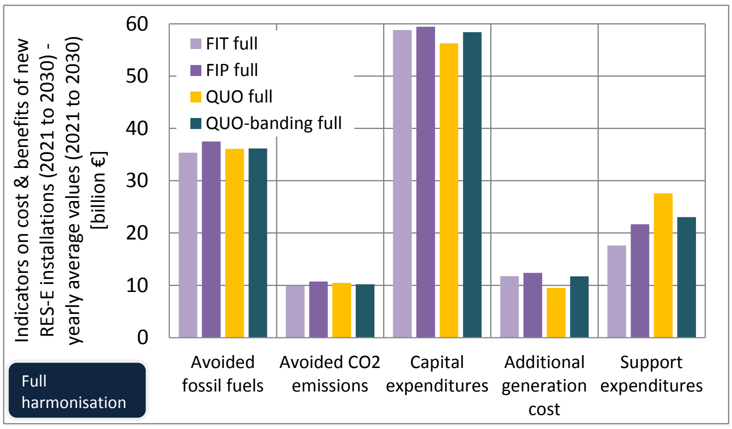
In this context, Figure 40 (left) provides a comparison of the dynamic evolution of the required support expenditures in the period 2011 to 2030 for all RES-E (i.e. existing and new installations in the focal period). Note that these figures represent an average premium at EU-27 level while at country-level significant differences occur, even in case of harmonised support settings. Complementary to that, Figure 40 (right) shows yearly average support expenditures for new RES and RES installations in the period 2021 to 2030.

The same conclusion is reached as for the previous indicator. Assuming a similar target has to be achieved, policy options providing technology-specific incentives offer the possibility of achieving lower consumer expenditures compared to the case where harmonised uniform RES support is conditioned.

Indicators on costs and benefits of RES(-E)

An accelerated RES deployment in the European Union does have a price, but this is also accompanied by increased benefits. Figure 41 (RES-E) and Figure 42 (RES total) provide a concise summary of the assessed costs and benefits arising from the future RES(-E) deployment in the focal period 2021 to 2030. More precisely, these graphs provide for all cases of full harmonisation the on average per year throughout the period 2021 to 2030 arising investment needs and the resulting costs – i.e. additional generation cost, and support expenditures. Additionally, they offer an indication of 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 – monetary expressed as avoided expenses for emission allowances). Other benefits – even of possibly significant magnitude - such as job creation or industrial development were neglected in this assessment.

A closer look on Figure 41 (RES-E) and Figure 42 (RES total) indicates benefits are of similar magnitude among all cases of full harmonisation. This is because of the assumed RES target for 2030 that has to be met within all cases. Remarkably, compared to the reference case of strengthened national support without minimum design criteria a slight decrease of benefits is applicable, caused by an over-fulfilment in that reference path where MSs primarily aim for a national target fulfilment and a resulting oversupply in very few of them (although support for RES was deteriorated). Capital expenditures and additional generation cost are somewhat smaller in the case of a uniform quota scheme compared to the other policy paths while, as discussed above, support expenditures are significantly higher in magnitude. The comparison to reference indicates however even for this otherwise less preferred pathway a small saving potential compared to reference, mainly caused by the assumed inhomogeneous incentives for RES in heating and cooling among MSs under this policy track.



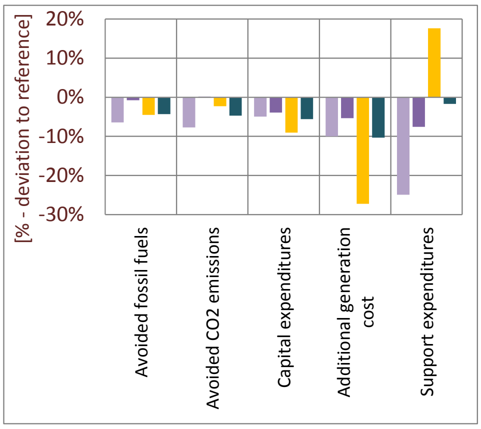


Figure 41 **Indicators on yearly average (2021 to 2030) cost and benefits of new RES-E installations (2021 to 2030) at EU-27 level for all cases of full harmonisation, expressed in absolute terms (left) and as deviation to the reference case (of strengthened national support without minimum design criteria) (right).**

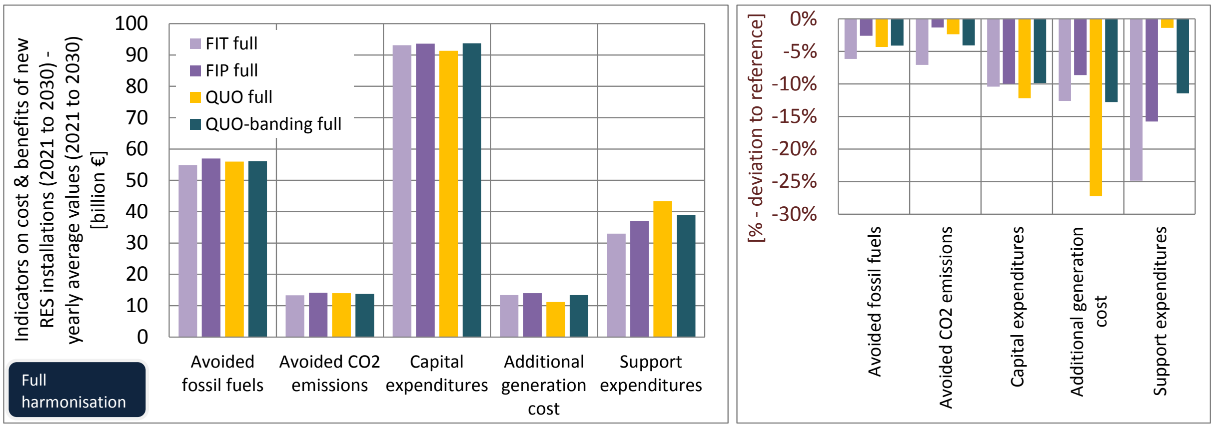


Figure 42 **Indicators on yearly average (2021 to 2030) cost and benefits of new RES installations (2021 to 2030) at EU-27 level for all cases of full harmonisation, expressed in absolute terms (left) and as deviation to the reference case (of strengthened national support without mini-mum design criteria) (right).**

Cost allocation across Member States

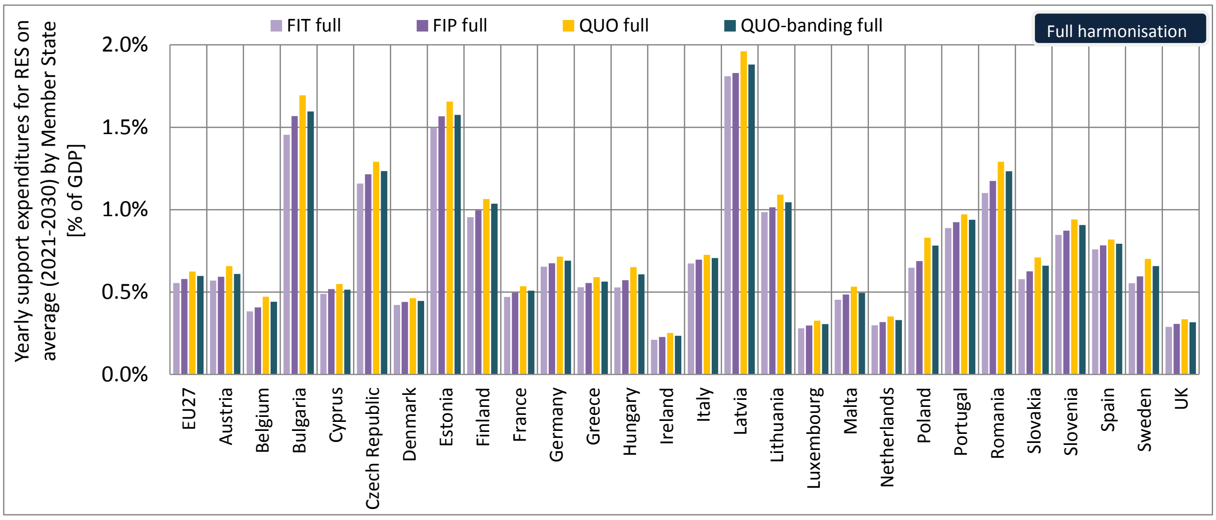


Figure 43 **Country-specific average (2021 to 2030) support expenditures for RES in total for all cases of full harmonisation**

Figure 43 illustrates subsequently the country-specific policy cost – i.e. the yearly average (2021 to 2030) support expenditures for RES in total by MS. Cost figures are in this context expressed in relative terms, i.e. as share of projected country-specific gross domestic product (GDP). The underlying country-specific allocation of support expenditures reflects already a burden-sharing that is either partly implied by the policy instrument itself or that has to be done ex-post. Default expenditures for RES installations within a country (in accordance with deployment) have to be retransferred across countries under a harmonised scheme. In the case of full harmonisation the assumption is taken that all electricity consumers across the EU have to share the expenses related to RES-E support also in a fully harmonised manner. Thus, in practical terms this means that all consumer pay the same premium on top of their electricity prices, dedicated to cover support expenditures for new RES-E installations in the years beyond 2020. In line with the general assumption that the harmonised scheme refers only to new installations after its introduction (i.e. post 2020), support for existing plants (installed before 2021) remains however purely at the national level – i.e. at the country of origin. This sort of cost allocation is for example automatically facilitated in the case of quota systems by the introduction of similar quota targets among all Member States (or among all obliged actors across the EU). As applicable in Figure 43, an inhomogeneous picture occurs: A few

Member States, namely Latvia, Bulgaria, Estonia, the Czech Republic, Romania and Finland carry significant cost in relation to their economic wealth (i.e. GDP). In turn, countries like Ireland, Luxembourg, the Netherlands and the UK are better off than the EU average. Remarkably, the choice of the policy instruments in the case of full harmonisation affects the country-specific distribution of monetary expenses generally only to a moderate extent, specifically the impact of any kind of harmonisation on the largest payers remains comparatively small.

Complementary to above, Figure 44 indicates the monetary transfer between Member States resulting from the underlying cost allocation of support expenditures for new RES-E installations under the harmonised schemes. This transfer represents the difference between actual support expenditures and the fictitious expenditures that would occur if support was completely national.

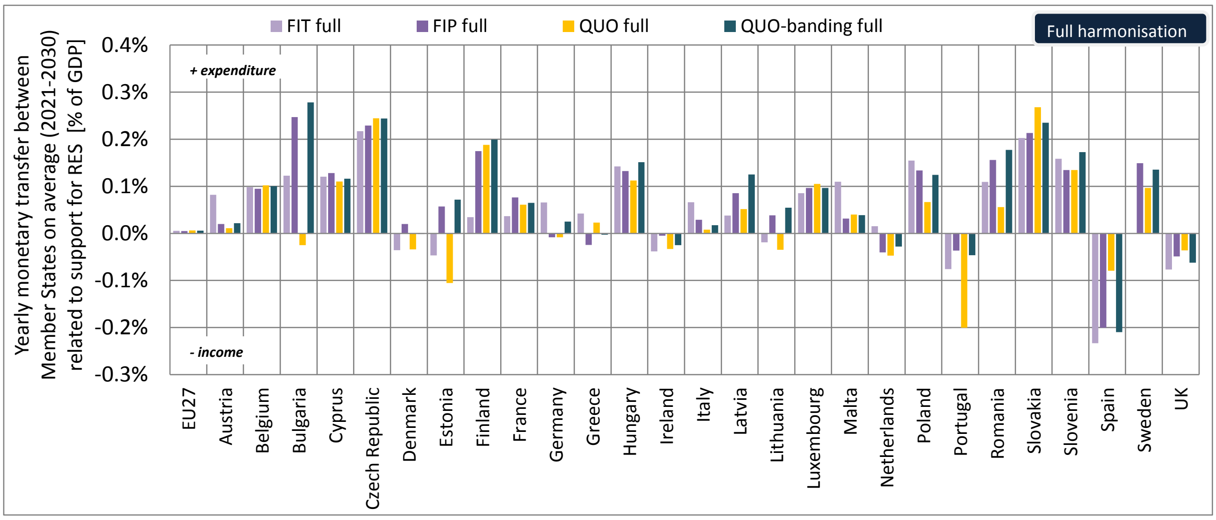


Figure 44 **Country-specific average (2021 to 2030) monetary transfer related to support expenditures for RES in total for all cases of full harmonisation**

5.2.2 Medium harmonisation

This section describes the specific impacts induced by the type of policy instrument chosen for a medium degree of harmonisation. As described in section 4.2 and Table 9 specifically, the main differences to the above described full harmonisation cases are possible secondary instruments that can be used complementary by MS. These instruments may be used by MSs to either: (a) provide additional financial incentives for specific technologies (additional to the EU or MS support); or (b) offer incentives to specific technologies which are not supported by the EU or MS scheme. Results on RES(-E) deployment.

Results on RES(-E) deployment

Figure 45 shows for each type of key instrument (i.e. feed-in tariff, feed-in premium, uniform quota and quota with banding) the resulting RES-E deployment over time (left) as well as by 2030 (right), indicating the deployment of new RES-E installations within the observed time frame. All four instruments show a similar performance in terms of effectiveness under the assessed framework conditions and assumptions. The targeted RES deployment of 31.2% (as share in gross final energy demand) is achieved by 2030, and new RES (installed in the period 2021 to 2030) contribute more than half of total RES volumes to that (i.e. 53% as share in RES energy production). In the electricity sector minor differences are applicable in the development of total RES-E generation over time, mainly because of design settings or specifics of certain instruments – by 2030 these differences diminish and a RES-E demand share of about 59% is reached (i.e. there is a narrow corridor for the resulting RES share by 2030, ranging from 58.7% to 59.2%).

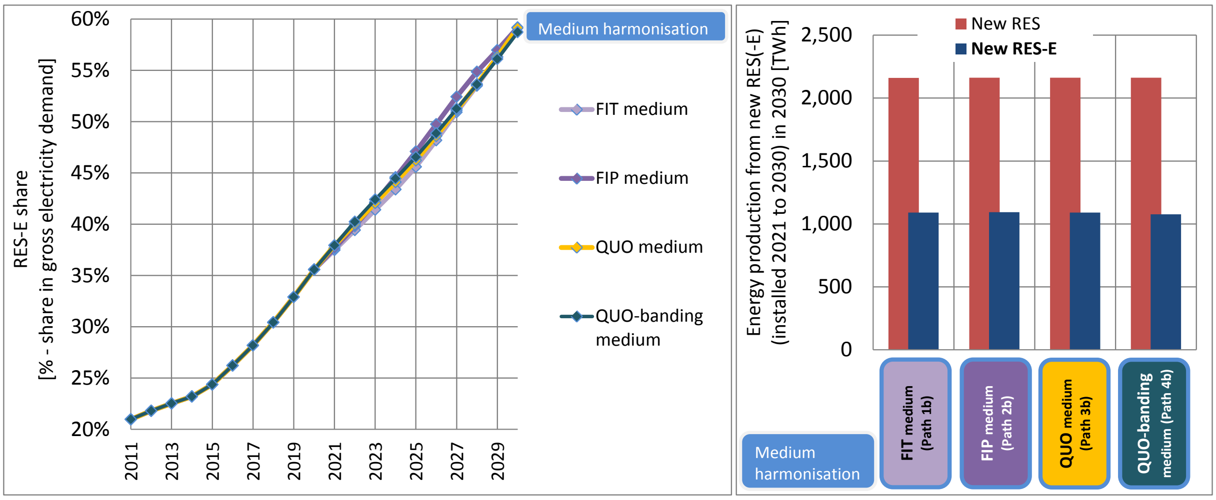


Figure 45 **Comparison of the resulting RES-E deployment over time for all RES-E (left) as well as by 2030 for new RES-E and RES installations only (from 2021 to 2030) (right) in the EU-27 for all cases of medium harmonisation.**

The electricity generated by newly installed RES-E technology options in the assessed period 2021 to 2030 are depicted in Figure 46 at EU-27 level depending on the applied policy pathway. As can be seen, wind energy (on- & offshore) and biomass dominate the picture. Small differences among the reviewed cases are applicable as a moderate to ambitious RES target generally requires a larger contribution of all available RES-E options. Technology-neutral incentives evaluated in the QUO full (3b) variant of harmonised RES-E support, with additional (limited) support allowed, fail to offer the necessary guidance to more expensive novel RES-E options on a timely basis. Consequently, the deployment of CSP and tidal stream or wave power may be delayed or even abandoned. The gap in deployment would be compensated by an increased penetration of cheap to moderate RES-E options, in particular onshore wind and biomass used for co-firing or in large-scale plants.

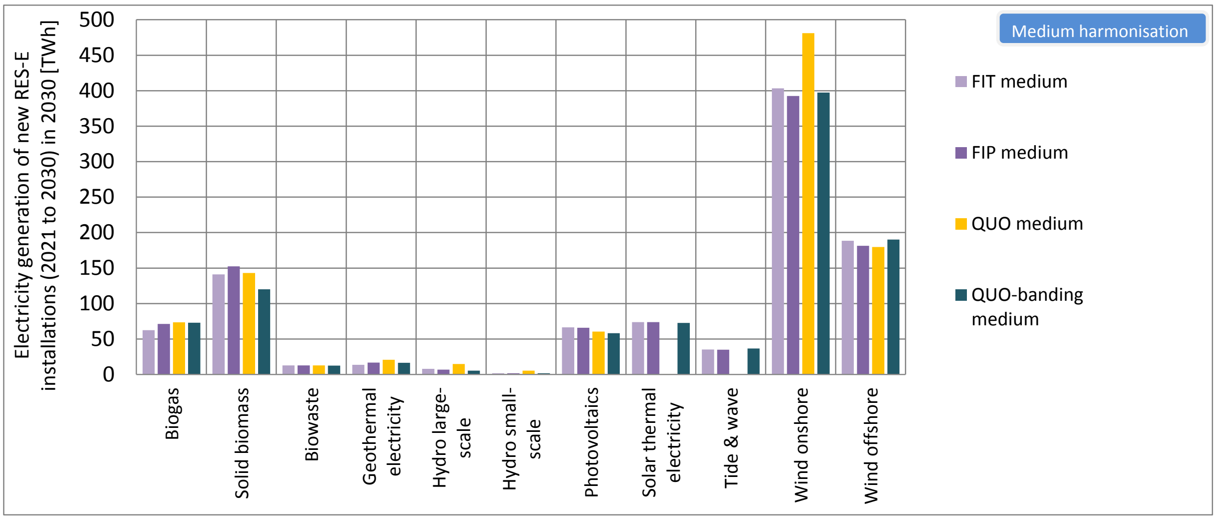


Figure 46 **Technology-specific breakdown of RES-E generation from new installations (2021 to 2030) at EU-27 level in the year 2030 for all cases of medium harmonisation**

Additionally to the technology-breakdown shown in Figure 46 and discussed above, Figure 47 provides a breakdown of the expected electricity generation in 2030 for new RES-E (installed 2021 to 2030) by country, expressing the share of domestic RES-E production in the respective gross electricity consumption for all assessed cases of medium harmonisation. While at EU-27 level new RES-E account for about 27% of gross electricity demand, between MS level generally large differences are observable. More or less independent from the underlying type of policy instrument in countries like Spain, Portugal, Estonia, Ireland or UK a strong RES-E deployment can be expected in the forthcoming decade, and the demand share of new RES-E would be by far higher than at EU average. On the contrary, Luxembourg, Cyprus, Czech Republic, Slovakia, Slovenia and Belgium would face only lower volumes of RES-E deployment – i.e. new RES-E account for less than 15% of domestic gross electricity consumption. Allocation impacts of the type of policy instrument are however applicable as it was the case under the full harmonized schemes described in 5.2.1. While a feed-in premium system and a quota with technology-banding provide comparatively similar deployment signals, a system of medium harmonised feed-in tariffs and an EU-wide harmonised uniform quota scheme (all four options allowing for additional country specific support) lead to different deployment patterns. Thereby, different effects come into play:

- A uniform quota offering technology-neutral incentives for new RES-E installations shifts investments from more expensive novel RES-E technologies to low-hanging fruits. More precisely, the marginal impact arises however from moderate to expensive potentials of wind onshore and large-scale biomass that would not be tapped in the case of tailored technology-specific support. Since support is now, i.e. under a uniform trading regime, more generous for these technologies, these potentials are exploited. As scenarios point out this diverts investments for example from countries like Ireland, Spain, Greece or the UK towards Bulgaria, Portugal or Sweden.
- In contrast to all other cases, in the case of fixed feed-in tariffs the necessary premium, i.e. difference between RES-E costs and reference electricity prices, is not decisive for the investment decision, only the levelized costs of electricity generation come into play. Thus, countries with generally lower wholesale electricity prices than at EU average face higher volumes of RES-E deployment and vice versa. A system of fixed feed-in tariffs would for example lead to a significantly lower RES-E deployment in Austria, Germany, Italy, Greece, Cyprus, Malta and Slovenia compared to a feed-in premium system. In turn, RES-E deployment would increase in countries like Denmark, Finland, France, Sweden, Spain and the UK.

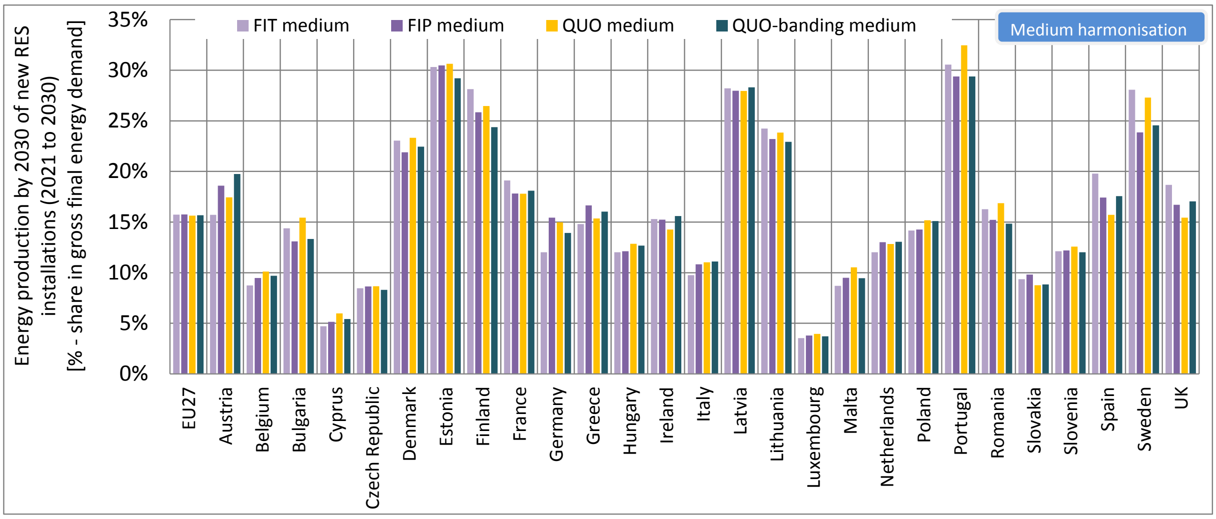


Figure 47 Country-specific breakdown of RES-E generation from new installations (2021 to 2030) in the year 2030 for all cases of medium harmonisation

Results on support expenditures for RES(-E)

Figure 48 (left) provides a comparison of the dynamic evolution of the required support expenditures in the period 2011 to 2030 for all RES-E (i.e. existing and new installations in the focal period). Note that these figures represent an average premium at EU-27 level while at country-level significant differences occur, even in case of harmonised support settings. Complementary to that, Figure 48 (right) shows yearly average support expenditures for new RES and RES installations in the period 2021 to 2030.

Assuming an equal target has to be achieved, policy options providing technology-specific incentives offer the possibility of lowering consumer expenditures compared to the case where harmonised RES support with additional (limited) national support is conditioned.

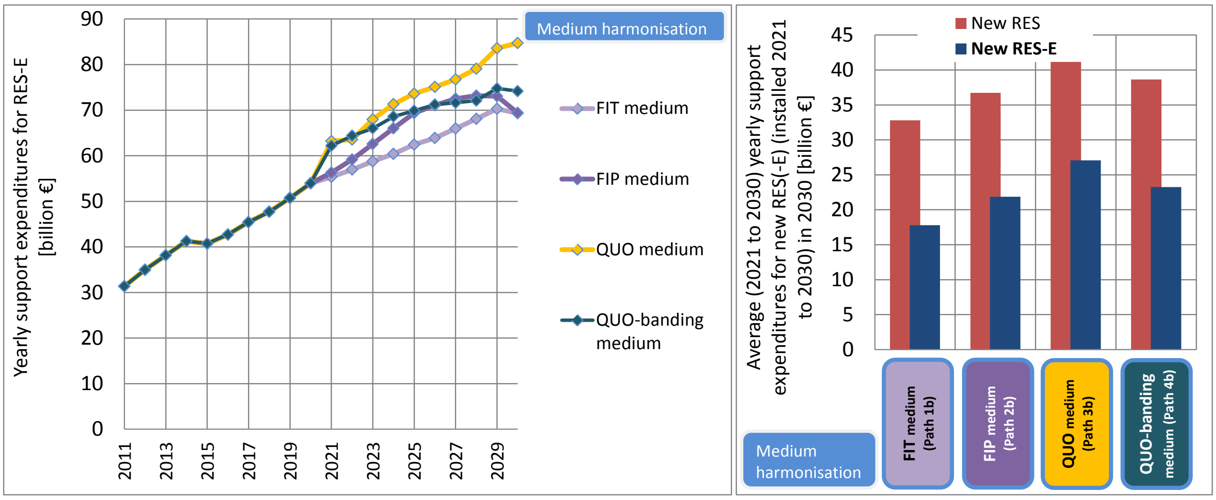


Figure 48 Comparison of the resulting support expenditures for all RES-E over time (left) as well as on average (2021 to 2030) for new RES-E and RES installations only (from 2021 to 2030) (right) in the EU-27 for all cases of medium harmonisation.

Furthermore it can be observed that towards the end of the period under consideration the "peak" in support expenditures seems to be reached at a level of about € 70 billion (this does not apply for the technology-neutral quota scheme).

Indicators on costs and benefits of RES(-E)

Cost and benefit indicators of an accelerated RES deployment in the European Union are depicted in Figure 49 (RES-E) and Figure 50 (RES total). They summarize the assessed costs and benefits resulting from the future RES(-E) deployment in the period from 2021 to 2030. More precisely, these graphs provide for all cases of medium harmonisation the on average per year value of capital expenditures and the corresponding additional generation costs and support expenditures. Additionally, they offer an indication of 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 – monetary expressed as avoided expenses for emission allowances). Other benefits – even though of possibly significant magnitude - such as job creation or industrial development were neglected in this assessment.

Figure 49 (RES-E) and Figure 50 (RES total) indicate that benefits are of comparable magnitude among all cases of full harmonisation. Remarkably, compared to the reference case of strengthened national support without minimum design criteria a slight decrease of benefits can be observed, caused by an over-fulfilment in the reference case. Capital expenditures and additional generation cost are somewhat smaller in the case of a uniform quota scheme compared to the other policy paths while, as discussed above, support expenditures on the other hand are higher in magnitude. The comparison to the reference case indicates however even for this otherwise less preferred pathway small savings, mainly caused by the assumed inhomogeneous incentives for RES in heating and cooling among MSs under this policy track.

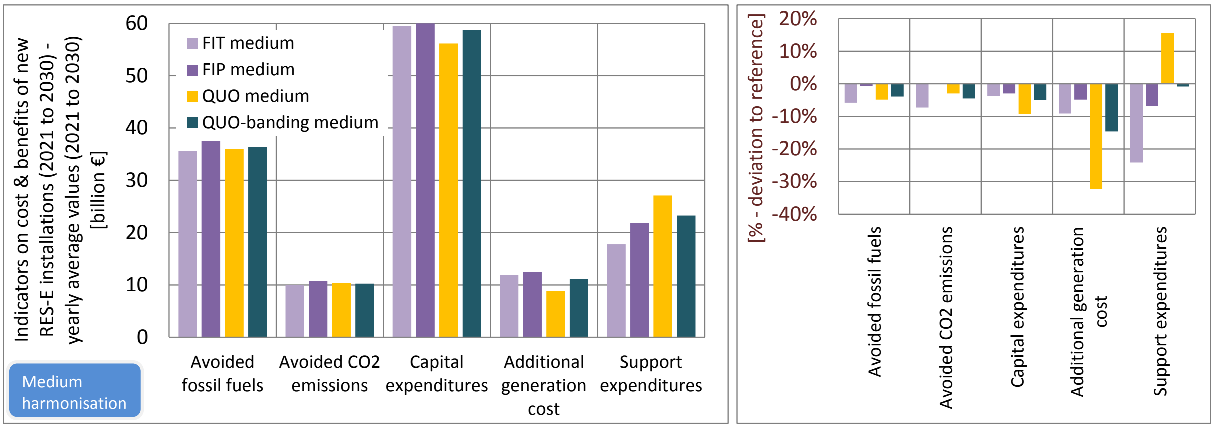


Figure 49 **Indicators on yearly average (2021 to 2030) cost and benefits of new RES-E installations (2021 to 2030) at EU-27 level for all cases of medium harmonisation, expressed in absolute terms (left) and as deviation to the reference case (of strengthened national support without minimum design criteria) (right).**

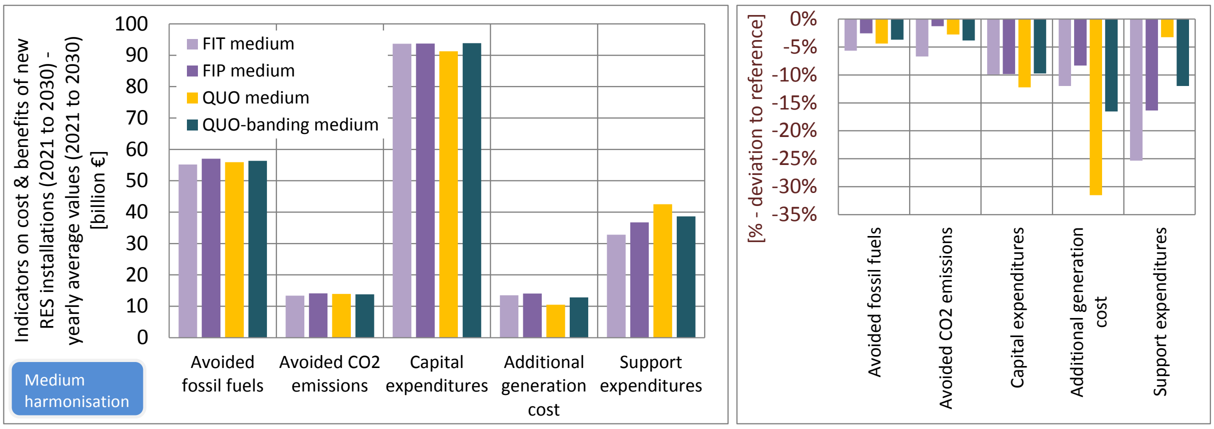


Figure 50 **Indicators on yearly average (2021 to 2030) cost and benefits of new RES installations (2021 to 2030) at EU-27 level for all cases of medium harmonisation, expressed in absolute terms (left) and as deviation to the reference case (of strengthened national support without minimum design criteria) (right).**

Cost allocation across Member States

The country-specific policy costs – i.e. the yearly average (2021 to 2030) support expenditures for RES in total by MS – are depicted in Figure 51. Cost figures are in this context expressed in relative terms, i.e. as share of projected country-specific gross domestic product (GDP). The underlying country-specific allocation of support expenditures reflects already a burden-sharing that is either partly implicitly done by the policy instrument itself or that has to be done ex-post. Default expenditures for RES installations within a country (in accordance with deployment) have to be retransferred across countries under a harmonised scheme. In the case of medium harmonisation the assumption is taken that all electricity consumers across the EU have to share the expenses related to RES-E support as well in a harmonised manner. This results in the same premium on top of electricity prices, dedicated to cover support expenditures for new RES-E installations in the years beyond 2020. The only country-specific in a medium harmonised policy scheme are additional support expenditures in form of upwards deviation of feed in tariffs or premiums and specific investment grants in both types quota systems respectively. In line with the general assumption that the harmonised scheme refers only to new installations after its introduction (i.e. post 2020), support for existing plants (installed before 2021) remains however purely at the national level – i.e. at the country of origin. This sort of cost allocation is for example automatically facilitated in the case of quota systems by the introduction of similar quota targets among all Member States (or among all obliged actors across the EU). As applicable in Figure 51, an inhomogeneous picture occurs: A few

Member States, namely Latvia, Bulgaria, Estonia, the Czech Republic, Romania and Finland carry significant cost in relation to their economic wealth (i.e. GDP). In turn, countries like Ireland, Luxembourg, the Netherlands and the UK are better off than the EU average. Remarkably, the choice of the policy instruments in the case of medium harmonisation affects the country-specific distribution of monetary expenses generally only to a moderate extent. Specifically the impact of any kind of harmonisation on the largest payers remains comparatively small.

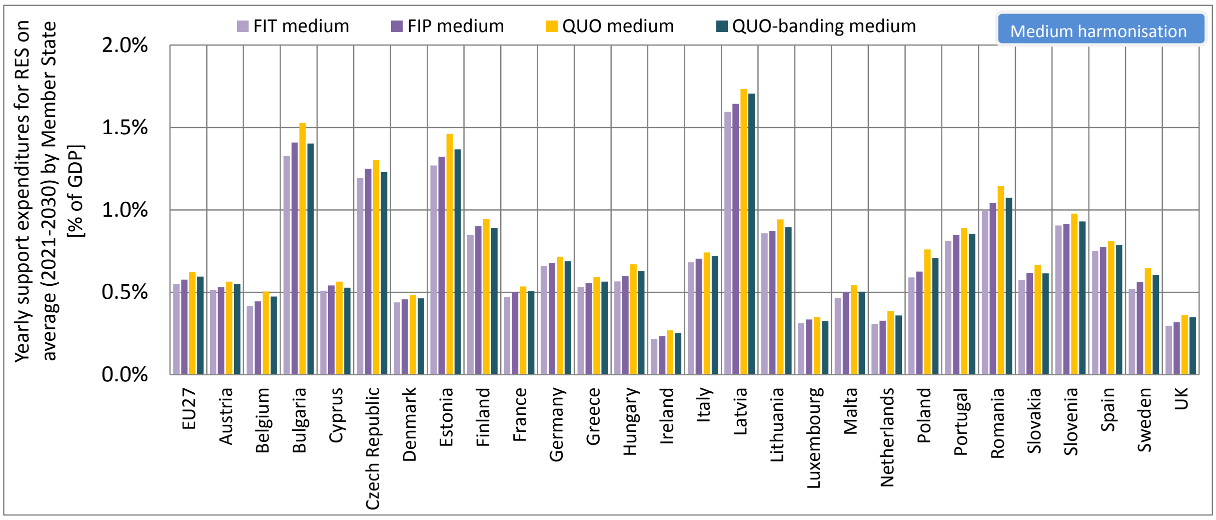


Figure 51 Country-specific average (2021 to 2030) support expenditures for RES in total for all cases of medium harmonisation

Corresponding to above, Figure 52 indicates the monetary transfer between Member States resulting from the underlying cost allocation of support expenditures for new RES-E installations under the harmonised schemes. This transfer represents the difference between actual support expenditures and the fictitious expenditures that would occur if support was completely national.

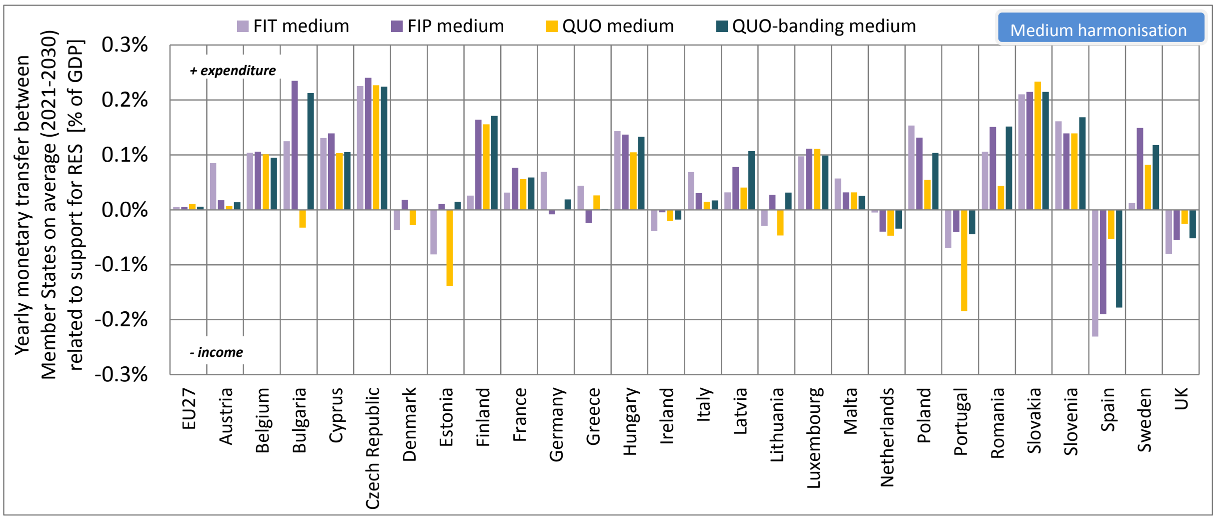


Figure 52 Country-specific average (2021 to 2030) monetary transfer related to support expenditures for RES in total for all cases of medium harmonisation

5.2.3 Soft harmonisation

As described in section 4.2 and Table 9 specifically, one important difference to the full- and medium harmonisation cases are specific RES targets for Member States. Under Soft harmonisation, the EU-wide target coexists with national targets.

Results on RES(-E) deployment

Figure 53 shows for each type of key instrument (i.e. feed-in tariff, feed-in premium, uniform quota and quota with banding) the resulting RES-E deployment over time (left) as well as by 2030 (right), indicating the deployment of new RES-E installations within the observed time frame. As with both levels of harmonization described before, all four instruments show a similar performance in terms of effectiveness under the assessed framework conditions and assumptions. The targeted RES deployment of 31.2% (as share of gross final energy demand) is achieved by 2030, and new RES-E (installed in the period 2021 to 2030) contribute about half of total RES volumes (i.e. 53% as share in RES energy production). In the electricity sector minor differences can be observed in the development of total RES-E generation over time, mainly because of design settings or specifics of certain instruments – by 2030 these differences diminish and a RES-E demand share of about 59% is reached (i.e. there is a narrow corridor for the resulting RES share by 2030, ranging from 58.5% to 59.0%).

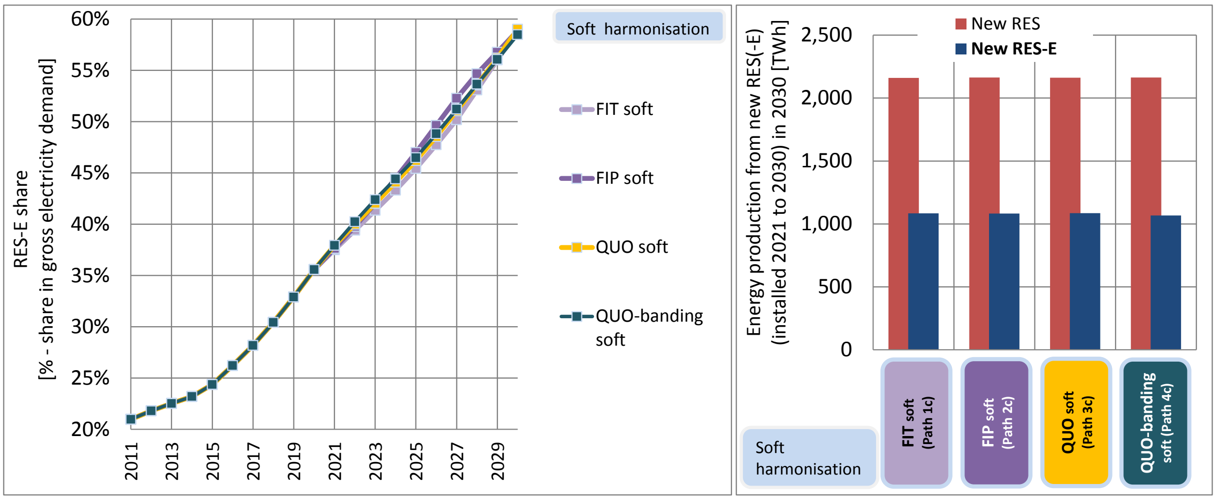


Figure 53 Comparison of the resulting RES-E deployment over time for all RES-E (left) as well as by 2030 for new RES-E and RES installations only (from 2021 to 2030) (right) in the EU-27 for all cases of soft harmonisation.

Figure 54 shows, which RES-E options contribute most at EU-27 level in the assessed period 2021 to 2030 depending on the applied policy pathway. Apparently, wind energy (on- & offshore) and biomass dominate the picture. At first glance, small differences among the reviewed cases are applicable as a moderate to ambitious RES target generally requires a larger contribution of all available RES-E options. Technology-neutral incentives evaluated in the QUO soft (3c) variant of uniform RES-E support fail to offer the necessary guidance to more expensive novel RES-E options in the discussed timeframe. Therefore, the deployment of CSP and tidal stream or wave power may be delayed or even abandoned. The gap in deployment would be compensated by an increased penetration of cheap to moderate RES-E options, in particular onshore wind and biomass used for co-firing or in large-scale plants if compared to the QHO-banding (4c) support scheme.

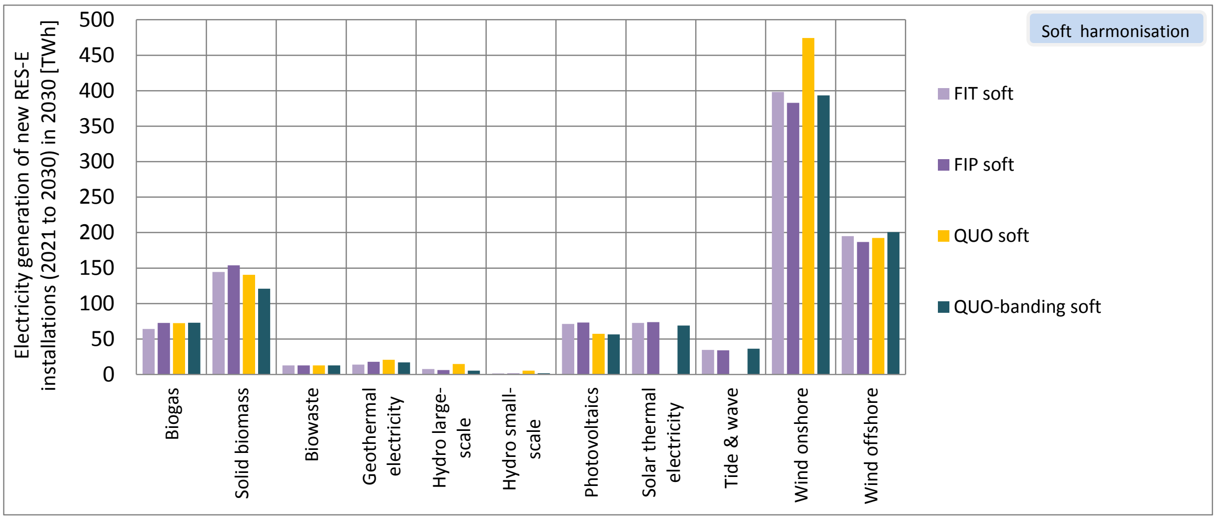


Figure 54 **Technology-specific breakdown of RES-E generation from new installations (2021 to 2030) at EU-27 level in the year 2030 for all cases of soft harmonisation**

Complementary to the technology-breakdown shown in Figure 54 and discussed above, Figure 55 provides a breakdown of the expected electricity generation in 2030 that results from new RES-E capacity (installed 2021 to 2030) by country, expressing the share of domestic RES-E production in the respective gross electricity consumption for all assessed cases of soft harmonisation. While at EU-27 level new RES-E account for about 27% of gross electricity demand, at Member State level generally large differences are observable. More or less independent from the underlying type of policy instrument in countries like Spain, Portugal, Estonia, Ireland or UK a strong RES-E deployment would arise forthcoming decade, and the demand share of new RES-E would be by far higher than at EU average. On the contrary, Luxembourg, Cyprus, Czech Republic, Slovakia, Slovenia and Belgium would face only lower volumes of RES-E deployment – i.e. new RES-E account for less than 15% of domestic gross electricity consumption. Allocation impacts of the type of policy instrument can however be found. While a feed-in premium system and a quota with technology-banding provide comparatively similar allocation signals, a system of soft harmonised feed-in tariffs and an EU-wide harmonised uniform quota scheme lead to different deployment patterns. Thereby, different effects come into play:

- A uniform quota offering technology-neutral incentives for new RES-E installations shifts investments from more expensive novel RES-E technologies to low-hanging fruits. More precisely, the marginal impact leads to a switch from moderate to expensive potentials of wind onshore and large-scale biomass that would not be tapped in the case of tailored technology-specific support. Since support is now, i.e. under a uniform trading regime, more generous for these technologies, these potentials are exploited. As scenarios point out this diverts investments for example from countries like Ireland, Spain, Greece or the UK towards Bulgaria, Portugal or Sweden.
- In contrast to all other cases, in the case of fixed feed-in tariffs the necessary premium, i.e. the difference between RES-E total support costs and reference electricity prices, is not decisive for the investment decision, only the levelized costs of electricity generation come into play. Thus, countries with generally lower wholesale electricity prices than at EU average face higher volumes of RES-E deployment and vice versa. A system of fixed feed-in tariffs would for example lead to a significantly lower RES-E deployment in Austria, Germany, Italy, Greece, Cyprus, Malta and Slovenia compared to a feed-in premium system. In turn, RES-E deployment would increase in countries like Denmark, Finland, France, Sweden, Spain and the UK.

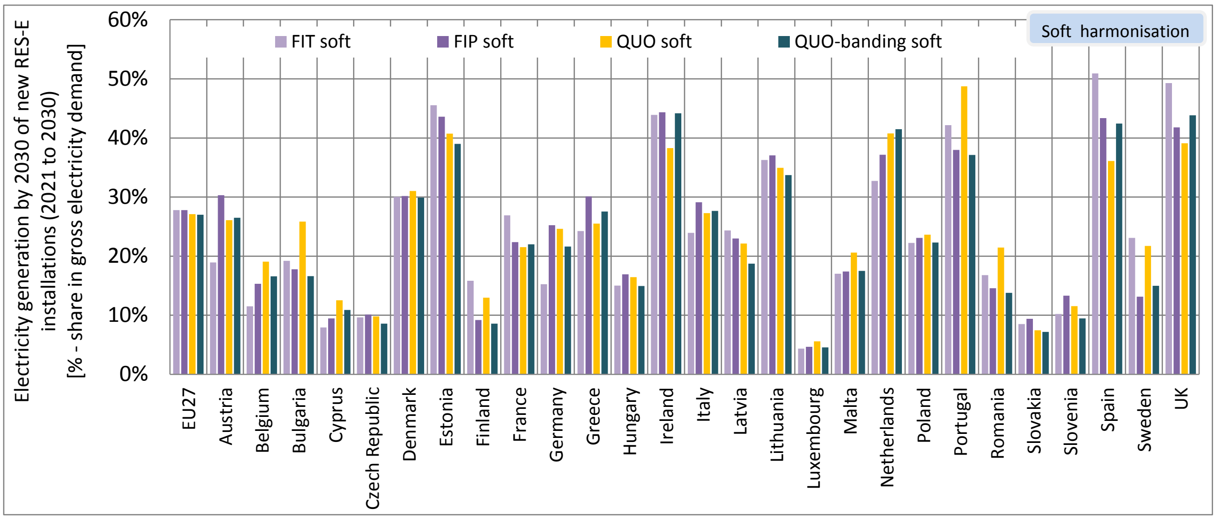


Figure 55 Country-specific breakdown of RES-E generation from new installations (2021 to 2030) in the year 2030 for all cases of soft harmonisation

Results on support expenditures for RES(-E)

Yearly support expenditures for RES(-E)

> *Support expenditures (or transfer costs) for consumers/society are defined as the direct premium financial transfer costs from the consumer to the producer due to the RES-E policy compared to the case of consumers purchasing conventional energy (electricity). This means that these costs do not consider any indirect costs or externalities (environmental benefits, impacts on employment, etc.).*

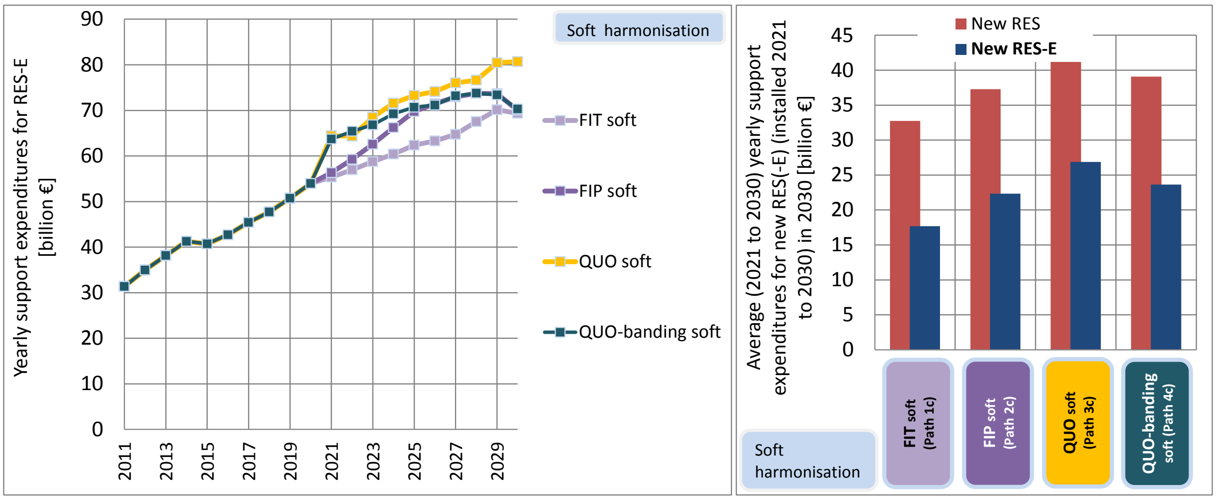


Figure 56 Comparison of the resulting support expenditures for all RES-E over time (left) as well as on average (2021 to 2030) for new RES-E and RES installations only (from 2021 to 2030) (right) in the EU-27 for all cases of soft harmonisation.

In this context, Figure 56 (left) provides a comparison of the dynamic evolution of the required support expenditures in the period 2011 to 2030 for all RES-E (i.e. existing and new installations in the focal period). Note that these figures represent an average premium at EU-27 level, while at country-level significant differences occur, even in case of harmonised support settings. Complementary to that, Figure 56 (right) shows yearly average support expenditures for new RES and RES installations in the period 2021 to 2030.

Assuming a similar target has to be achieved, policy options providing technology-specific incentives offer the possibility of achieving lower consumer expenditures compared to the case where uniform RES support is conditioned.

Indicators on costs and benefits of RES(-E)

Indictors on costs and benefits of an accelerated RES deployment in the European Union offer central information for decision makers. Figure 57 (RES-E) and Figure 58 (RES total) provide a concise summary of the assessed costs and benefits arising from the future RES(-E) deployment in the period from 2021 to 2030. The graphs provide for all cases of soft harmonisation the yearly average values for the period 2021 to 2030 of capital expenditures and corresponding costs – i.e. additional generation cost, and support expenditures. Moreover, they offer an indication of 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 – monetary expressed as avoided expenses for emission allowances). Other benefits – even of possibly significant magnitude - such as job creation or industrial development were neglected in this assessment.

As can be seen in Figure 57 (RES-E) and Figure 58 (RES total) benefits are of similar magnitude among all cases of soft harmonisation. This is because of the assumed RES target for 2030 is met by all cases. Remarkably, compared to the reference case of strengthened national support without minimum design criteria a slight decrease of benefits is applicable, caused by an over-fulfilment in the reference Case. Capital expenditures and additional generation cost are somewhat smaller in the case of a uniform quota scheme compared to the other policy paths while, as discussed above, support expenditures are on the other hand of higher magnitude. The comparison to the reference case indicates however even for this otherwise less preferred pathway a small savings potential.

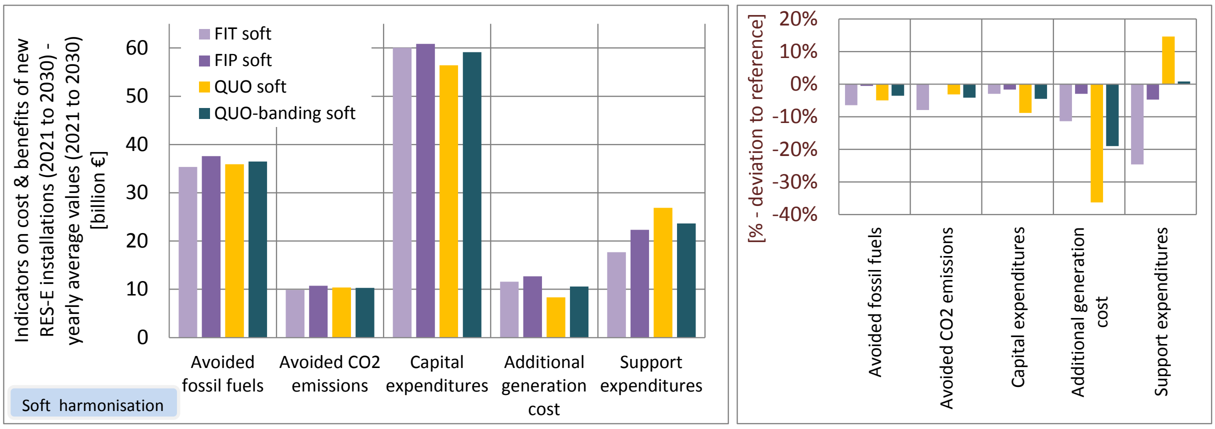


Figure 57 Indicators on yearly average (2021 to 2030) cost and benefits of new RES-E installations (2021 to 2030) at EU-27 level for all cases of soft harmonisation, expressed in absolute terms (left) and as deviation to the reference case (of strengthened national support without minimum design criteria) (right).

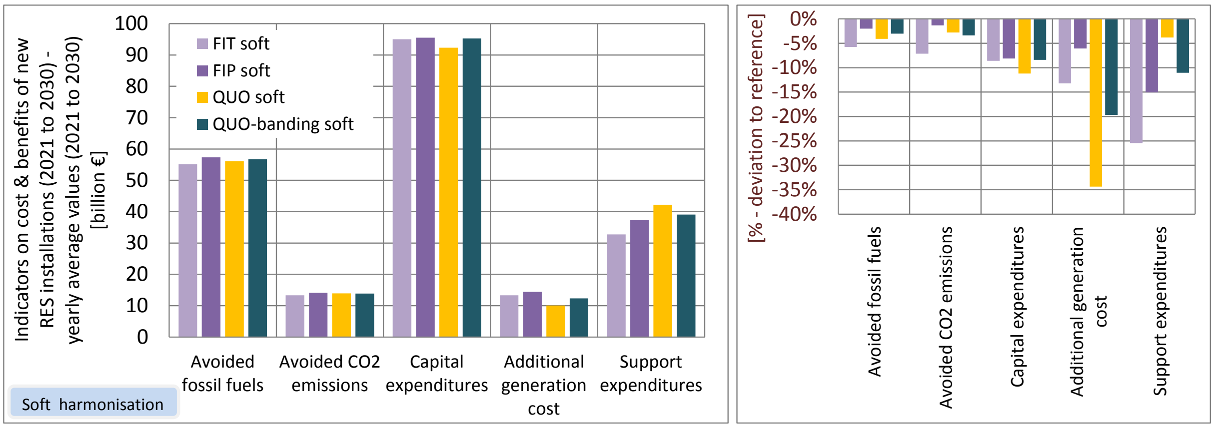


Figure 58 **Indicators on yearly average (2021 to 2030) cost and benefits of new RES installations (2021 to 2030) at EU-27 level for all cases of soft harmonisation, expressed in absolute terms (left) and as deviation to the reference case (of strengthened national support without mini-mum design criteria) (right).**

Cost allocation across Member States

The provided picture on cost allocations across MSs in this section differs noticeably to latter cases of harmonisation, because of the deviant assumption of MS specific RES targets. Figure 59 illustrates subsequently the country-specific policy cost – i.e. the yearly average (2021 to 2030) support expenditures for RES in total by MS. Cost figures are in this context expressed in relative terms, i.e. as share of projected country-specific gross domestic product (GDP). The underlying country-specific allocation of support expenditures reflects already a burden-sharing that is either partly implicitly done by the policy instrument itself or that has to be done ex-post. As applicable in Figure 59, an inhomogeneous picture occurs: A few Member States, namely the Czech Republic, Latvia, Slovenia, and Bulgaria carry significant cost in relation to their economic wealth (i.e. GDP). In turn, countries like Ireland, Austria, Sweden, Luxembourg, and the UK are better off than the EU average. Remarkably, the choice of the policy instruments in the case of soft harmonisation affects the country-specific distribution of monetary expenses generally only to a moderate extent; specifically the impact of any kind of harmonisation on the largest payers remains comparatively small.

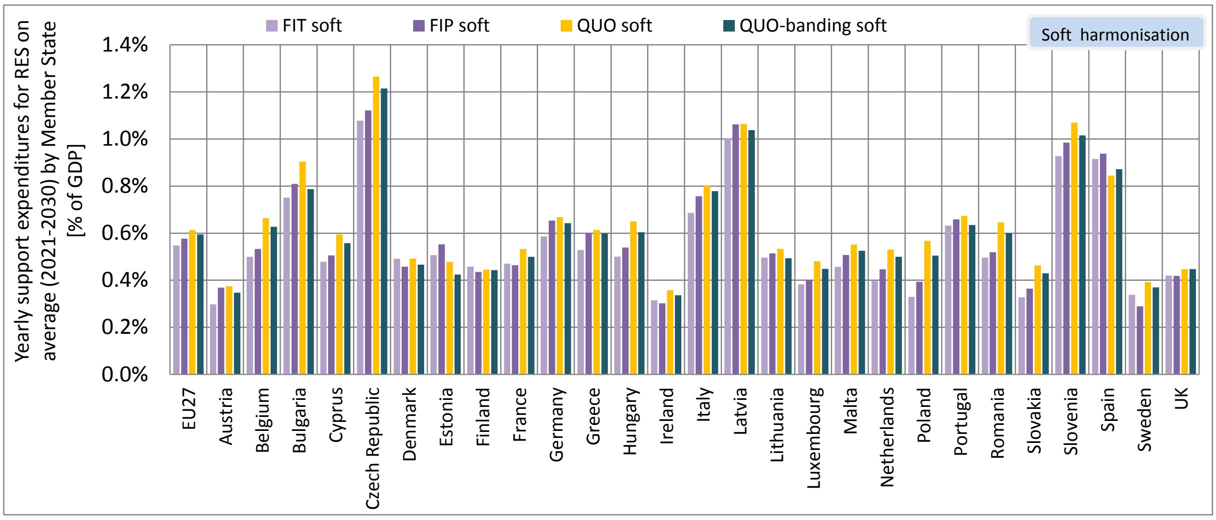


Figure 59 **Country-specific average (2021 to 2030) support expenditures for RES in total for all cases of soft harmonisation**

Complementary to above, Figure 60 indicates the monetary transfer between Member States resulting from the underlying cost allocation of support expenditures for new RES-E installations under the (softly) harmonised schemes. This transfer represents the difference between actual support expenditures and the fictitious expenditures that would occur if support was completely national.

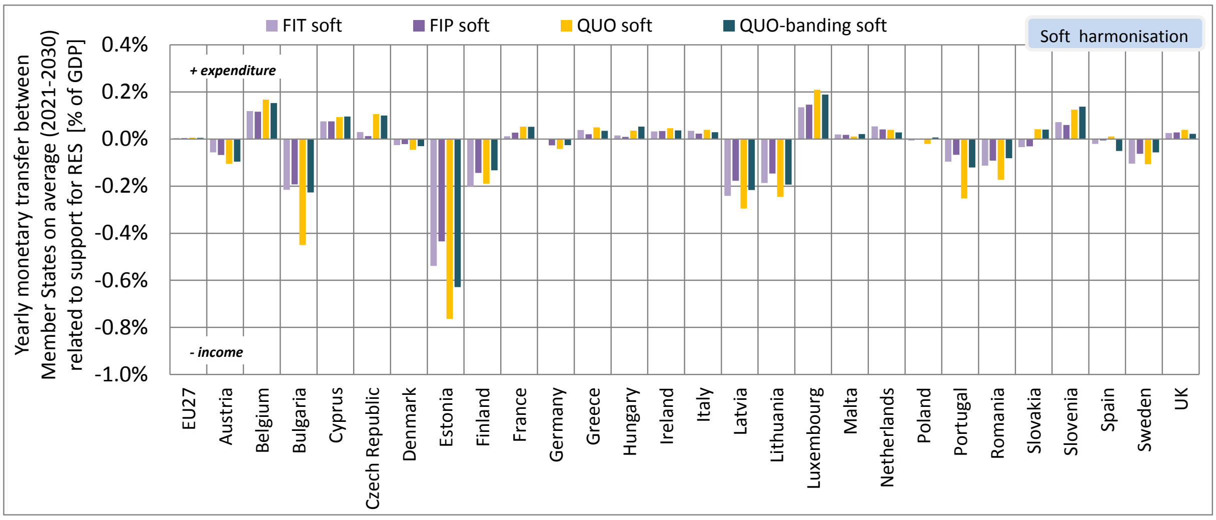


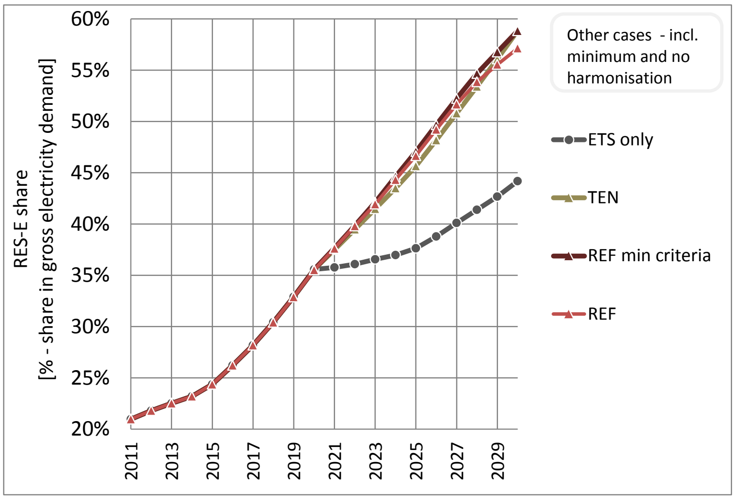
Figure 60 Country-specific average (2021 to 2030) monetary transfer related to support expenditures for RES in total for all cases of soft harmonisation

5.2.4 Other cases, including minimum and no harmonisation

This section discusses the impacts of the "special cases" of the policy pathways. These include the two variants of the reference cases, the ETS only pathway and a pathway that combines harmonised tenders for selected technologies with national support schemes.

Results on RES(-E) deployment

Figure 61shows on the left hand side the development of the RES-E share over time for the regarded policy pathways, whereas on the right hand side the energy production from RES-E in 2030 is displayed. Again all pathways with dedicated RES-E support reach approximately a share in gross electricity demand of slightly below 60% in 2030. Only the ETS only pathway fails to reach such ambitious levels and leads to a RES-E share of slightly below 45% in 2030.



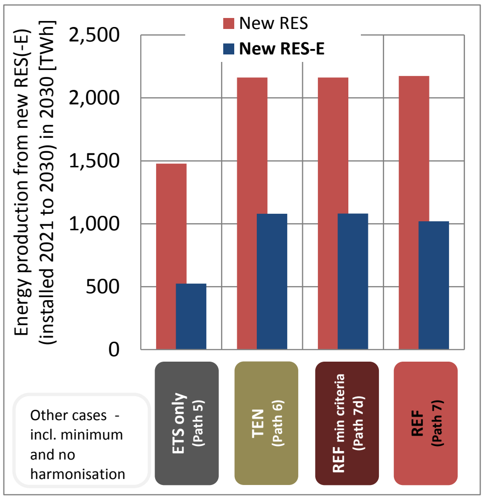


Figure 61 Comparison of the resulting RES-E deployment over time for all RES-E (left) as well as by 2030 for new RES-E and RES installations only (from 2021 to 2030) (right) in the EU-27 for all other cases, including minimum and no harmonisation.

As can be observed from Figure 62 the generation of newly installed RES-E capacities is distributed rather similarly across technology options between the regarded pathways. In particular electricity generated by wind and biomass dominates the picture. Moreover it is striking that in the case of the

ETS only pathway higher cost options such as those powered by solar irrigation or tidal and wave energy do not see any additional deployment.

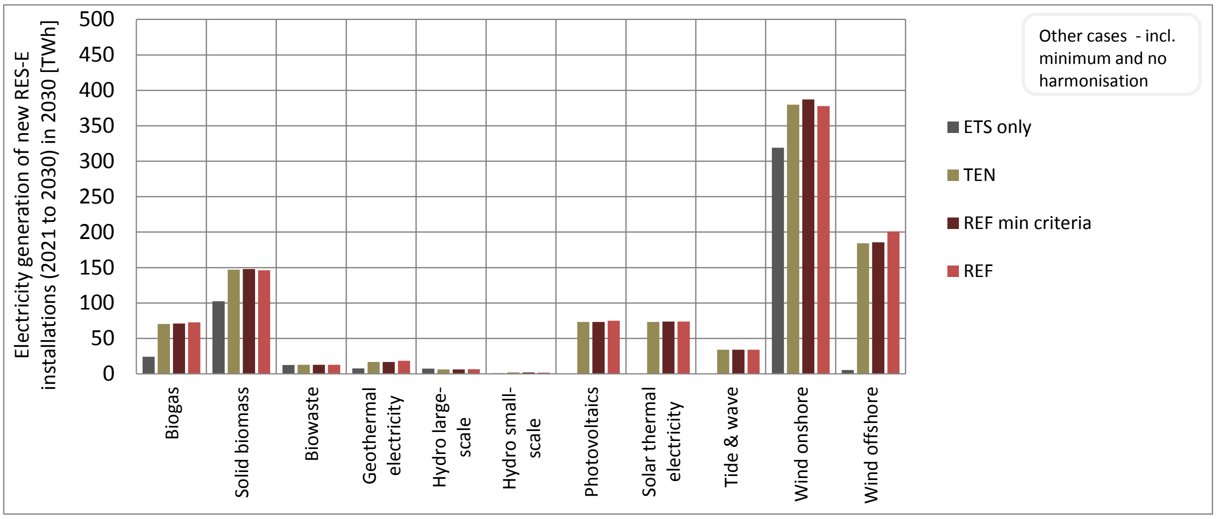


Figure 62 **Technology-specific breakdown of RES-E generation from new installations (2021 to 2030) at EU-27 level in the year 2030 for all other cases, including minimum and no harmonisation**

Figure 63 shows the disaggregation of RES-E generation in 2030 by Member State as share of gross electricity demand. Obviously the ETS only pathway leads to a lower RES-E share in all Member States. While both reference pathways lead to very similar results, choosing the Tender pathway leads to some redistribution of RES-E generation across Member States. It can be observed that comparatively higher shares of RES-E generation are reached in Member States that for instance offer high potential for deployment of large scale PV (e.g. Portugal, Spain), or already have a mature market for RES-E (e.g. Germany).

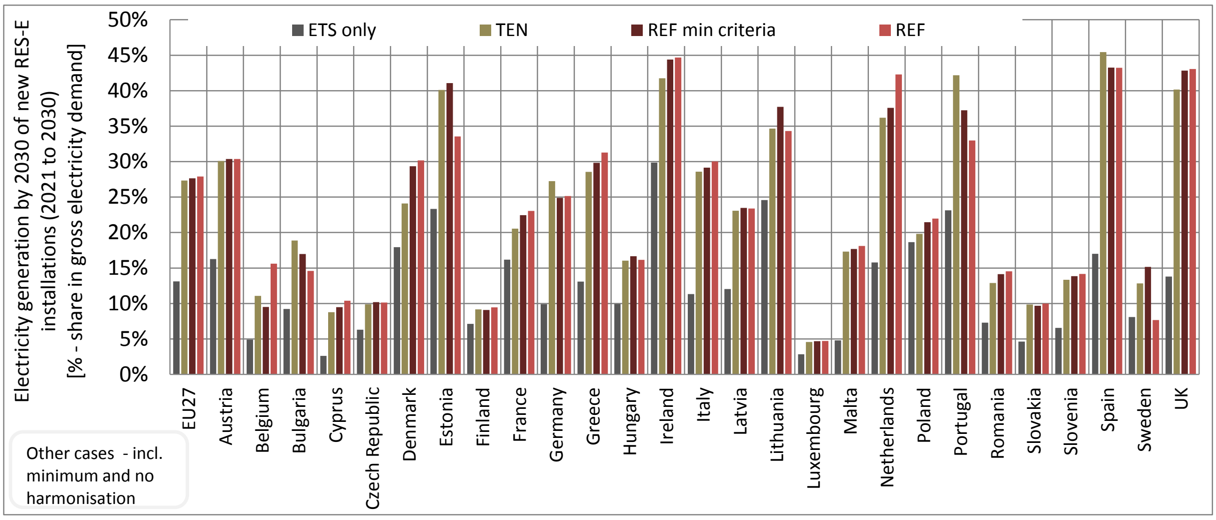


Figure 63 **Country-specific breakdown of RES-E generation from new installations (2021 to 2030) in the year 2030 for all other cases, including minimum and no harmonisation**

Results on support expenditures for RES(-E)

Yearly support expenditures for RES(-E)

Support expenditures (or transfer costs) for consumers/society are defined as the direct premium financial transfer costs from the consumer to the producer due to the RES-E policy compared to the case of consumers purchasing conventional energy (electricity). This means that these costs do not consider any indirect costs or externalities (environmental benefits, impacts on employment, etc.).

Figure 64 displays on the left hand side the evolution yearly support expenditures for RES-E and on the right hand side the average yearly support expenditures for both new installations of RES in total and RES-E. With respect to yearly support expenditures a "peak" seems to be reached by 2027 with aggregated expenditures amounting to roughly € 75 billion and declining towards € 70 billion afterwards. The tendering pathway never exceeds the € 70 billion mark. An exception is the ETS only pathway. In the case of "no (dedicated RES) support", obviously no support expenditures for RES arise. If long-term climate targets are taken seriously, meaning that Europe strives for the 80%-95% GHG reduction by 2050, no dedicated RES support may, however, possibly have the following effects. A comparison of the two variants of "no support", characterised by either low (in the case of no strong carbon commitment) or moderate-to-high carbon prices (reflecting a strong long-term carbon commitment: i.e. an 80%-95% GHG emission reduction by 2050), indicates that, in the absence of a strong RES deployment, a rise in electricity prices may lead to an indirect consumer burden of almost similar magnitude to that involved in the case of perfectly-tailored RES policies. In the absence of continuous RES support and related expansion, this is caused, on the one hand, by a reduction of the so-called "merit order" effect that correlates with high levels of RES-E deployment. On the other hand, a lower RES-E penetration leads to higher carbon prices and, thus, also higher electricity prices, since more alternatives have to enter the (common) carbon market in order to comply with the carbon cap. On the right hand side it be observed that installing a EU wide tendering scheme for large scale options could lead to quite substantial cost savings of roughly up to 20% for newly installed RES capacities in all sectors. For the ETS pathway the average yearly expenditures are equal for both cases as the carbon price would only trigger RES generation in the electricity sector.

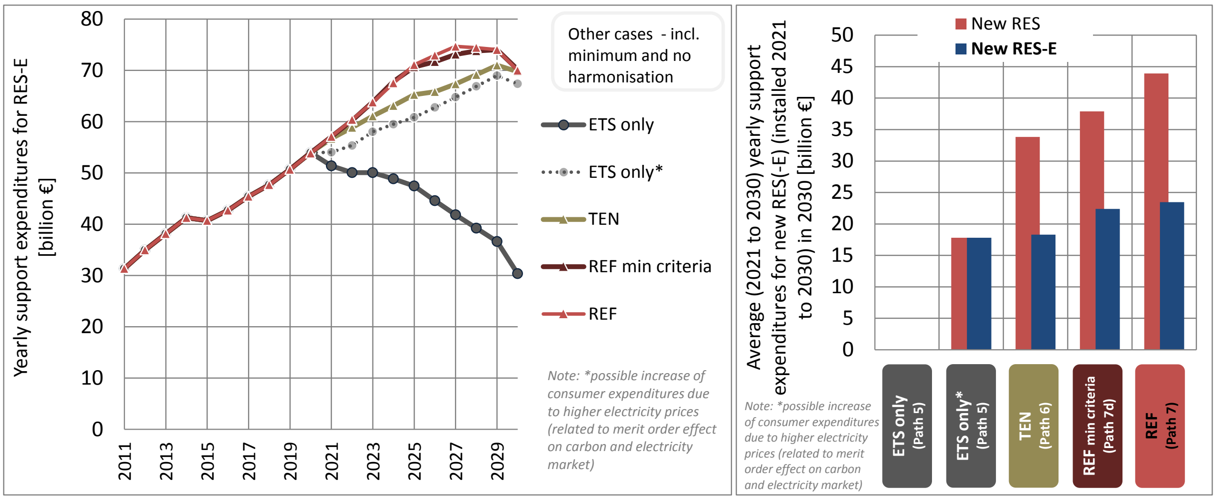


Figure 64 Comparison of the resulting support expenditures for all RES-E over time (left) as well as on average (2021 to 2030) for new RES-E and RES installations only (from 2021 to 2030) (right) in the EU-27 for all other cases, including minimum and no harmonisation.

Indicators on costs and benefits of RES(-E)

Figure 65and Figure 66provide a broader picture with respect to the costs and benefits of newly constructed RES-E and RES installations respectively for the timeframe 2021 to 2030. In each figure the costs and benefits are expressed as yearly average values on the left hand side and on the right hand side they are shown in relative terms compared to the reference pathway. It can be observed for the case of RES-E that most of the pathways perform relatively similar for most of the indicators. As could already be seen above the Tender pathway again performs a bit better with respect to support expenditures. Additionally it can be seen that the sum of benefits (avoided fossil fuels and CO2 emissions) almost adds up to the value of the resources that are extracted from society for electricity generation (capital expenditures).

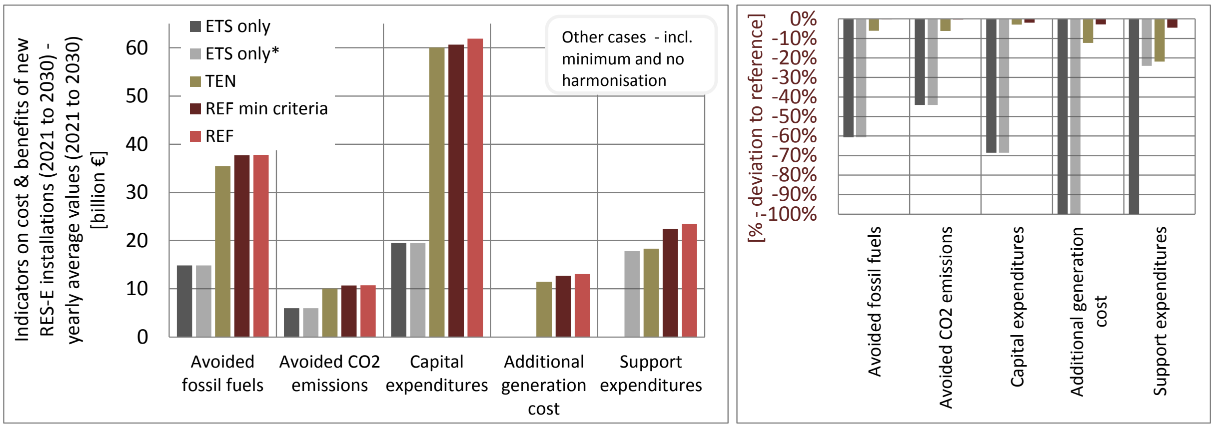


Figure 65 **Indicators on yearly average (2021 to 2030) cost and benefits of new RES-E installations (2021 to 2030) at EU-27 level for all other cases, including minimum and no harmonisation, expressed in absolute terms (left) and as deviation to the reference case (of strengthened national support without minimum design criteria) (right).**

Obviously the ETS only pathway again is a special case in that it does not (directly) cause additional generation costs and all other effects are less pronounced due to the lower volume of RES-E generation. For the case of RES in all sectors, essentially the same conclusions can be drawn from a qualitative point of view, albeit the effects differ in their overall magnitude.

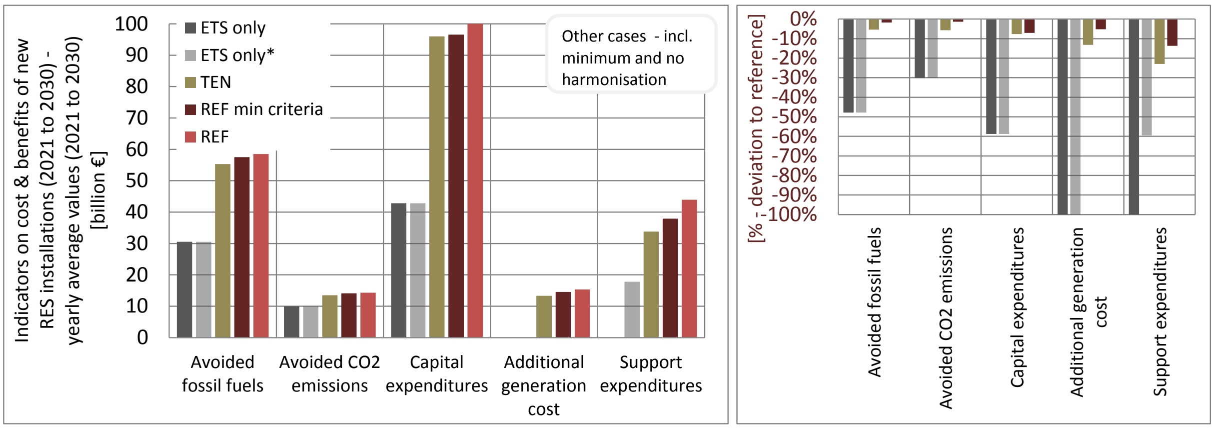


Figure 66 **Indicators on yearly average (2021 to 2030) cost and benefits of new RES installations (2021 to 2030) at EU-27 level for all other cases, including minimum and no harmonisation, expressed in absolute terms (left) and as deviation to the reference case (of strengthened national support without mini-mum design criteria) (right).**

Cost allocation across Member States

Figure 67 illustrates subsequently the country-specific policy cost – i.e. the yearly average (2021 to 2030) support expenditures for RES in total by MS. Cost figures are in this context expressed in relative terms, i.e. as share of projected country-specific gross domestic product (GDP). The underlying country-specific allocation of support expenditures reflects already a burden-sharing that is either partly implicitly implied by the policy instrument itself or that has to be done ex-post. It can be observed again that the burden is not distributed equally across Member States. However, the distribution is much more balanced compared to the case of for instance full harmonisation. The reason therefore is that in the case of national support instruments the support expenditures are allocated according to the national targets that include a GDP weighting, whereas in the case of full harmonisation the assumption is taken that all consumer in the EU pay the same premium on top of their electricity prices, dedicated to cover support expenditures for new RES-E installations in the years beyond 2020.

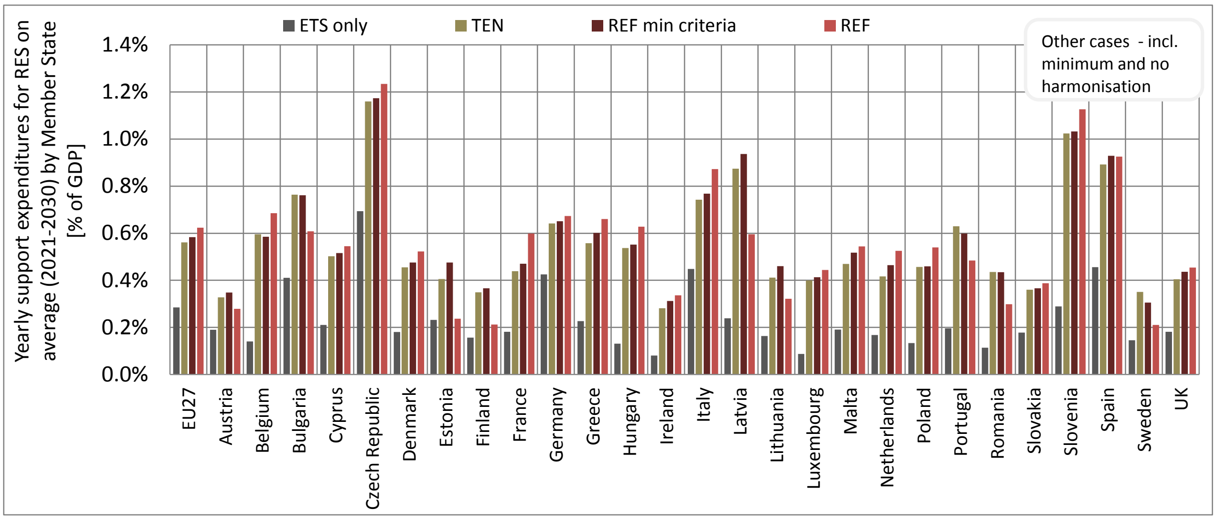


Figure 67 **Country-specific average (2021 to 2030) support expenditures for RES in total for all other cases, including minimum and no harmonisation**

Complementary to above, Figure 68 indicates the monetary transfer between Member States resulting from the underlying cost allocation of support expenditures for new RES-E. This transfer represents the difference between actual support expenditures and the fictitious expenditures that would occur if support was completely national.

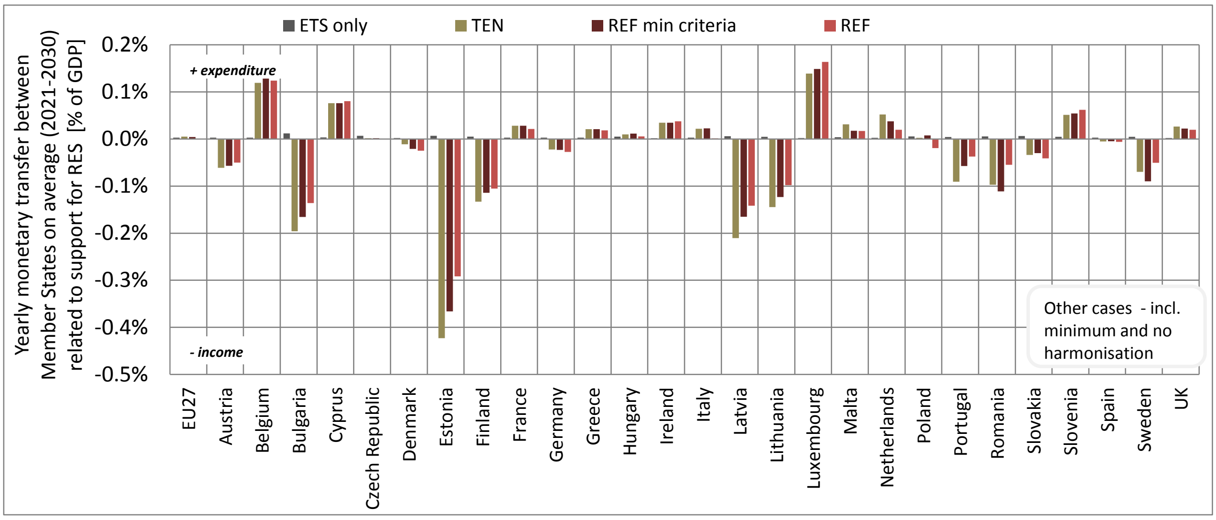


Figure 68 **Country-specific average (2021 to 2030) monetary transfer related to support expenditures for RES in total for all other cases, including minimum and no harmonisation**

5.3 Comparison of RES(-E) policy pathways by type of instrument – with a focus on effort sharing across Member States

Impacts at the aggregated level (EU-27)

The performance of two policy instruments, namely of an EU-wide harmonised feed-in premium system and of a harmonised uniform quota scheme accompanied by a certificate trading regime, is assessed next. These prominently discussed instruments are chosen to increase understanding on how the degree of harmonisation may affect outcomes. In contrast to section 5.1 where light was shed only on the overall cost impact for RES-E at the aggregated (EU-27) level the assessment undertaken below is broader in scope. To start with, Table 11 allows for a comprehensive comparison of key results at EU-27 level, indicating the impact on technology-specific RES deployment (top) as well as on costs and benefits that come along with the deployment of new RES-E (middle) and of new RES installations (bottom).

Table 11 Selected key results at EU-27 level for policy paths of feed-in premium and uniform quota systems under different degrees of harmonisation: Technology-breakdown of energy production from new RES (installed 2021 to 2030) (top) and yearly average (2021 to 2030) cost and benefits of new RES-E (middle) and of new RES installations (2021 to 2030) (bottom)

Type of instrument		Feed-in premium			Uniform quota		
Degree of harmonisation		full	medium	soft	full	medium	soft
Pathway no.		2a	2b	2c	4a	4b	4c
Item	Unit						
Energy production from new RES (installed 2021 to 2030) in 2030 by technology							
Biogas	TWh	70.7	71.1	72.8	71.4	72.9	72.9
Solid biomass	TWh	151.4	152.5	153.8	123.3	120.0	120.8
Biowaste	TWh	12.6	12.8	12.9	12.5	12.6	12.8
Geothermal electricity	TWh	16.3	16.9	17.9	15.8	16.4	17.2
Hydro large-scale	TWh	7.1	6.7	6.3	5.1	5.3	5.3
Hydro small-scale	TWh	1.6	1.6	1.5	1.8	1.7	1.7
Photovoltaics	TWh	65.1	66.0	73.2	63.7	58.2	56.6
Solar thermal electricity	TWh	73.7	73.7	73.8	73.4	72.6	69.1
Tide & wave	TWh	34.7	34.8	34.0	36.7	36.7	36.4
Wind onshore	TWh	398.4	392.6	382.9	396.3	397.4	393.3
Wind offshore	TWh	171.8	181.4	186.7	180.9	190.3	200.8
RES-E imports from non-EU	TWh	80.5	83.7	68.5	93.5	92.8	81.5
RES-E total	TWh	1083.9	1094.0	1084.1	1074.4	1076.8	1068.4
RES-H total	TWh	952.0	942.4	954.3	961.2	959.1	969.2
Biofuels totoal	TWh	125.3	125.6	125.6	125.6	125.9	125.6
RES total	TWh	2161.2	2162.1	2164.0	2161.1	2161.8	2163.1
Yearly average (2021-2030) costs and benefits of new RES-E (installed 2021 to 2030)							
Avoided fossil fuels	billion €	37.5	37.6	37.6	36.2	36.3	36.5
Avoided CO_2 emissions	billion €	10.7	10.7	10.7	10.2	10.2	10.3
Capital expenditures	billion €	59.5	60.1	60.8	58.4	58.8	59.1
Additional generation cost	billion €	12.4	12.4	12.7	11.7	11.2	10.6
Support expenditures	billion €	21.7	21.9	22.3	23.1	23.3	23.6
Yearly average (2021-2030) costs and benefits of new RES (installed 2021 to 2030)							
Avoided fossil fuels	billion €	57.0	57.0	57.3	56.1	56.4	56.7
Avoided CO_2 emissions	billion €	14.1	14.1	14.1	13.7	13.8	13.8
Capital expenditures	billion €	93.6	93.8	95.5	93.7	93.8	95.3
Additional generation cost	billion €	14.0	14.1	14.4	13.4	12.8	12.3
Support expenditures	billion €	37.0	36.7	37.3	38.9	38.7	39.1

Some key findings gained from Table 11 are as follows:

- Differences between the assessed instruments (feed-in premium and uniform quota) are applicable, for example the increase of support expenditures (+6% for RES-E, +5% for RES) that makes a technology-neutral quota scheme more costly from a consumer perspective. Since the instruments among each other are sufficiently compared above we ignore them subsequently and in turn focus on the impact arising from the degree of harmonisation.

- A soft instead of a full harmonisation affects technology preferences only to a modest extent: In the case of feed-in premium systems an increase of the deployment of PV (+12%, comparing soft with full) and of wind offshore (+9%) is apparent which in turn leads to a decrease of wind onshore (-4%) and of RES-E imports from abroad (non-EU, -15%). In the case of uniform quotas the need for RES-E imports also decreases when moving from full to soft harmonisation (-13%), and a drop in deployment is applicable for PV (-11%). On the contrary, a rise in penetration can be expected for wind offshore (+11%) and for geothermal electricity (+9%), indicating that complementary country-specific support as assumed for soft harmonisation may be beneficial for selected more costly RES-E technologies (but not for all, since the underlying overall RES target is not assumed to increase). Notably, in the case of medium harmonisation differences to full are smaller in magnitude. With respect to RES in heating and cooling and biofuels in transport differences between full, medium and soft harmonisation are generally of negligible magnitude.
- A closer look on the indicators for costs and benefits indicates that benefits are not affected, at least at the aggregated level. Under both types of instruments an increase of support expenditures (+3% for RES-E but less than 1% for RES total, soft compared to full) and of capital expenditures (about +2% on average) can be seen while for additional generation cost no common trend can be identified.

Impacts on country-specific RES deployment

Next, a closer look is taken on country-specific outcomes, starting with impacts of the degree of harmonisation on RES development by MS. Zooming in from the European perspective, Figure 69 (RES-E) and Figure 70 (RES) give a more detailed comparison of renewables deployment across MSs for the researched policy paths. More precisely, Figure 69 shows a breakdown of the expected electricity generation in 2030 stemming from new RES-E (installed 2021 to 2030) by country, expressing the share of domestic RES-E production in the respective gross electricity consumption for the assessed variants of feed-in premium and of uniform quota systems. The corresponding depiction for RES total is provided by Figure 70, expressing the share of domestic RES production in 2030 on country-specific gross final energy demand.

While at EU-27 level new RES-E account for about 27% to 28% of gross electricity demand, between MS level generally large differences are observable. A similar observation can be made for RES in total, i.e. when adding RES in heating and cooling and biofuels in transport to RES-E deployment, and comparing that with gross final consumption. Thereby, at EU-27 level new RES (installed 2021 to 2030) account for about half of the required effort to meet the 2030 RES target. A closer look on the electricity sector indicates that independent from the underlying type of policy instrument and from the degree of harmonisation in countries like Estonia, Ireland, Lithuania, Netherlands, Portugal, Spain and the UK RES-E achieves a strong development in the forthcoming decade, and the demand share of new RES-E would be by far higher than EU average. In contrast to above, countries like Cyprus, Czech Republic, Finland, Luxembourg, Slovakia, and Slovenia RES-E development would be modest – i.e. new RES-E account for less than 15% of domestic gross electricity consumption upon all assessed paths. Allocation impacts of the type of policy instrument and, more important here, of the degree of harmonisation can be identified:

- Compared to a feed-in premium system offering distinct incentives by technology under technology-neutral support (uniform quota) RES-E would deploy significantly stronger in Bulgaria, Denmark, Finland, Portugal, Romania and Sweden. In turn, since aggregated deployment is hardly changed, RES-E deployment is reduced remarkably in Greece, Slovakia, Spain and the UK.
- The degree of harmonisation has a strong impact on RES-E deployment in countries like Belgium, Cyprus, Denmark, Germany, Netherlands, Portugal, Romania, Spain and the UK. Whether the move from full to soft harmonisation causes an upwards or a downwards trend depends on how far default deployment under full harmonisation would be from assumed

national 2030 RES targets.[33] In Belgium, Netherlands and the UK this would imply an increase of RES-E deployment under both types of instruments. Contrarily, in Austria, Bulgaria, Latvia, Lithuania, Portugal and Spain soft harmonisation leads to a decrease of RES-E development compared to a fully harmonised scheme.

- Similar trends as discussed above with respect to the impact of the degree of harmonisation on country-specific RES-E deployment are also applicable for total RES. Generally, differences between soft and full harmonisation are even more pronounced since under soft harmonisation the assumption is taken that countries tailor their support incentives for RES-H to their national needs, i.e. the national RES targets. This has a strong effect on overall RES deployment in particular in countries like Austria, Estonia, Latvia and Lithuania. They represent countries where biomass contributes already today significantly to heat supply. Moreover, for them underlying 2030 RES targets are comparatively easy to achieve considering their domestic resources and related cost.

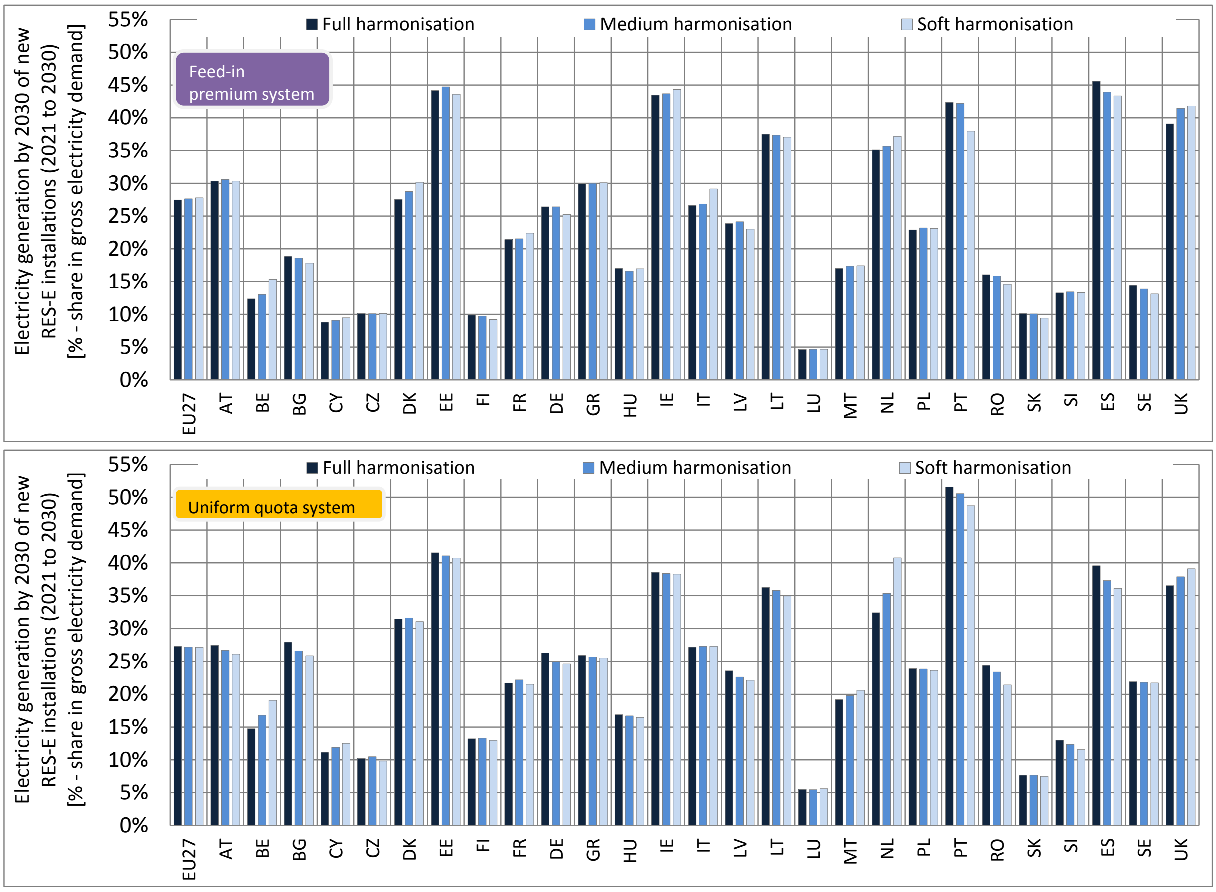


Figure 69 **Country-specific breakdown of RES-E generation from new installations (2021 to 2030) in the year 2030 for policy paths based on a feed-in premium system (top) and on a uniform quota scheme (bottom) under different degrees of harmonisation (full, medium and soft)**

[33] Following the "2020 logic" introduced by the 2020 RES directive (2009/28/EC) these presumed national targets distribute the required EU effort across MSs in the case of soft (or minimum or no) harmonisation. Consequently, those countries being more far off from their national target trajectory under a harmonised scheme would implement in the case of soft harmonisation complementary incentives (in addition to the default EU-wide harmonised scheme) to achieve a better match between domestic demand, i.e. the given targets, and supply of RES. In turn, this reduces the efforts necessary at EU level, leading to a decrease of deployment in other MSs.

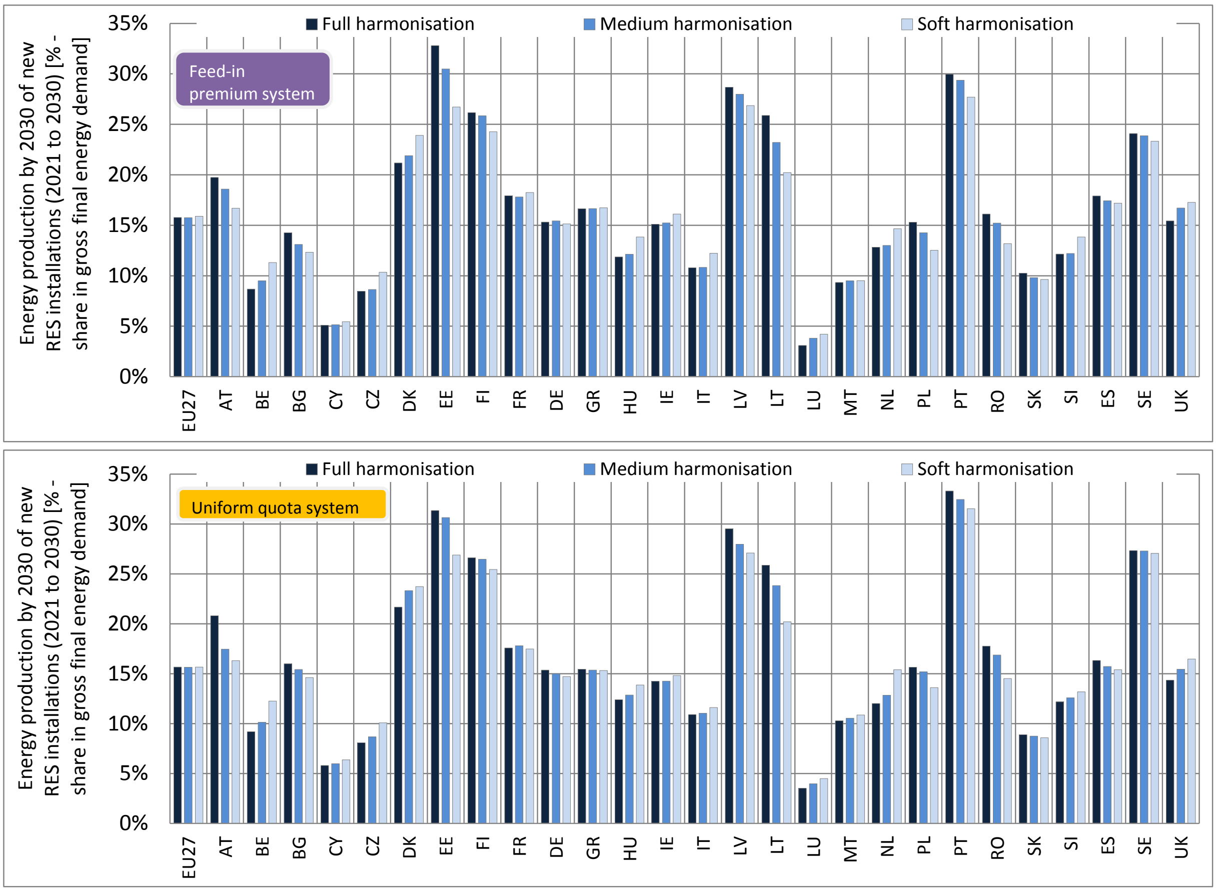


Figure 70 **Country-specific breakdown of RES production from new installations (2021 to 2030) in the year 2030 for policy paths based on a feed-in premium system (top) and on a uniform quota scheme (bottom) under different degrees of harmonisation (full, medium and soft)**

Cost allocation – effort sharing across Member States

Differences in country-specific RES deployment have been assessed previously. Consequently, this subsection is dedicated to shed light on who pays for that and how that is affected by the degree of harmonisation.

The country-specific policy costs – i.e. the yearly average (2021 to 2030) support expenditures for RES in total by MS – are shown in Figure 71. Note that cost figures are therein expressed in relative terms, i.e. as share of projected country-specific gross domestic product (GDP). The underlying country-specific allocation of support expenditures reflects already an effort-sharing that is either partly implicitly done by the policy instrument itself or that has to be done ex-post. Default expenditures for RES installations within a country (in accordance with deployment) have to be retransferred across countries under a harmonised scheme. In accordance with the general assumption that the harmonised scheme refers only to new installations after its introduction (i.e. post 2020), support for existing plants (installed before 2021) remains however purely at the national level – i.e. at the country of origin. The detailed approach for the sharing of expenses for new RES installations differs by degree of harmonisation:

- In the case of full harmonisation the assumption is taken that all electricity consumers across the EU have to share the expenses related to RES-E support also in a fully harmonised manner. Thus, in practical terms this means that all consumer pay the same premium on top of their electricity prices, dedicated to cover support expenditures for new RES-E installations in the years beyond 2020. This sort of cost allocation is for example automatically facilitated in the case of quota systems by the introduction of similar quota targets among all Member States (or among all obliged actors across the EU).

- Under medium similar to full harmonisation we assume that the costs related to the EU-wide RES-E policy scheme have to be shared across MSs in a fully harmonised manner. Since in the case of medium harmonisation MSs have the freedom to provide limited complementary support, the cross-country effort sharing is however limited to the EU-wide harmonised part, and not to the complementary national incentives. Thus, expenditures related to the latter have to be covered by the countries themselves.
- In the case of soft harmonisation a different approach for effort sharing comes into play: As starting point, an effort sharing across MSs of support expenditures related to the EU-wide harmonised part of the RES-E policy scheme takes place.[34] The ultimate effort sharing is later on done via RES cooperation. Thus, since national RES target are now in place, RES cooperation serves to distribute support expenditures in accordance with MSs' needs for meeting their own targets. As such this redistribution is in that case not limited to expenditures for RES in the electricity sector. In contrast to full or medium harmonisation, where support expenditures for the domestic development of RES in heating and cooling are solely kept by the MSs themselves, under soft harmonisation an effort sharing may also involve expenses for RES-H, at least in principle.

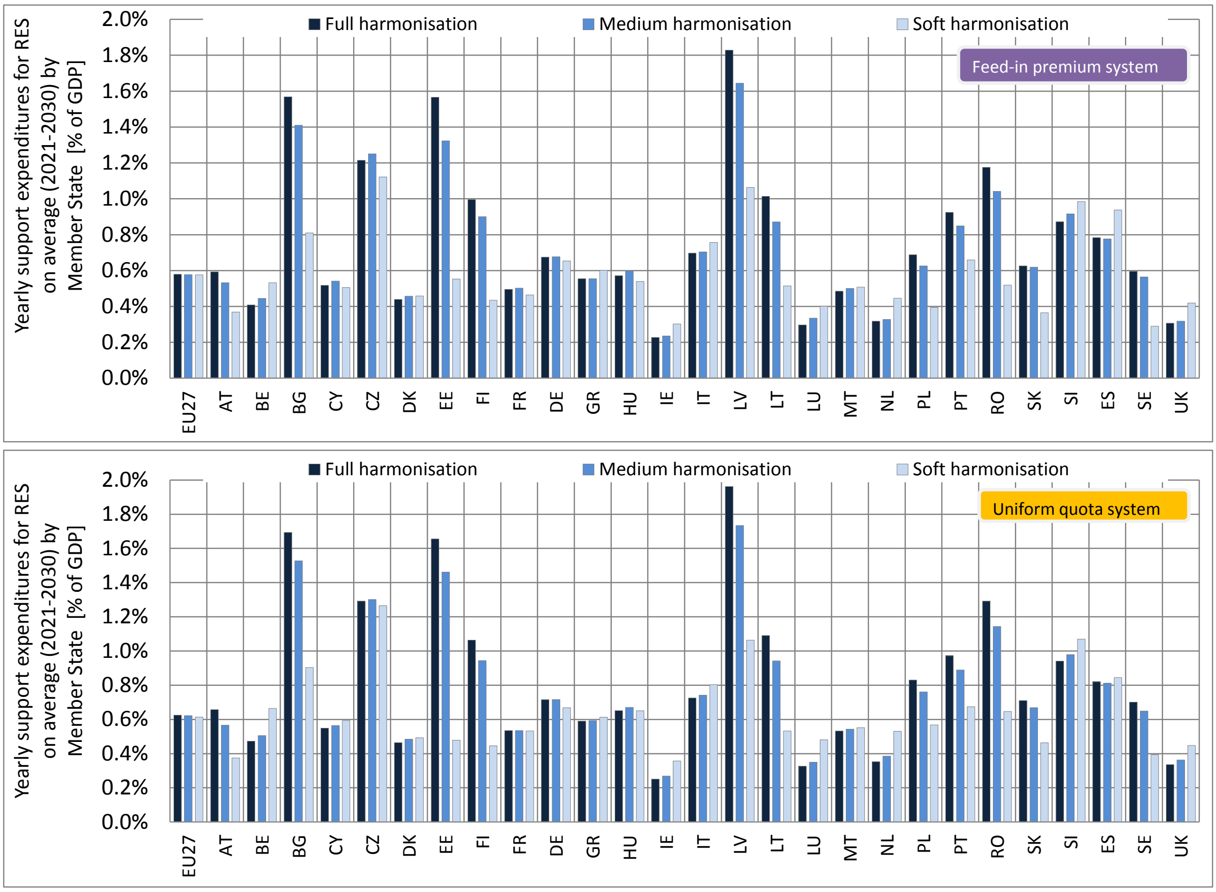


Figure 71 Country-specific average (2021 to 2030) support expenditures for RES in total for policy paths based on a feed-in premium system (top) and on a uniform quota scheme (bottom) under different degrees of harmonisation (full, medium and soft)

Some key findings derived from Figure 71 are:

- The efforts a country has to take differ significantly across the European Union in the case of full harmonisation. Expressing yearly average (2021 to 2030) support expenditures in rela-

[34] This comprises the costs related to the common base premium under a feed-in premium system or the whole expenditures for a quota scheme which can then however be complemented by additional incentives (e.g. investment incentives) at MS level.

tion to a country's economic wealth shows that significantly higher costs are applicable for selected MSs, namely Bulgaria, Czech Republic Estonia, Finland, Latvia, Lithuania, Portugal, Romania and Slovenia. In turn, countries like Belgium, Denmark, Ireland, Luxembourg, Netherlands and the UK are better off than the EU average. As analysed in section 5.2.1 these trends are generally rather independent from the type of policy instruments applied under full harmonisation.

- Medium harmonisation, i.e. where MSs have the opportunity to provide limited additional incentives complementary to the EU-wide harmonised base support, may help to increase equity in effort sharing across Europe. However, only a slightly more balanced distribution can be identified in comparison to full harmonisation.
- Soft harmonisation comes along with a comparatively well-balanced distribution of support expenditures for RES across MSs. Since presumed national 2030 RES targets are defined in accordance with the "2020 logic" differences in economic wealth between countries appear well reflected. The majority of the MSs that would face a high burden under full harmonisation have in the case of soft harmonisation significantly reduced expenditures to cover. For Bulgaria, Estonia, Finland, Lithuania and Romania this implies a cut to (more than) the half compared to full harmonisation – but also Austria, Latvia, Poland, Portugal and Sweden would significantly better turn off. For two countries, namely Slovenia and Spain, a move from full to soft harmonisation would lead to a slight increase in expenditures and, consequently, increase their gap to the EU-average.

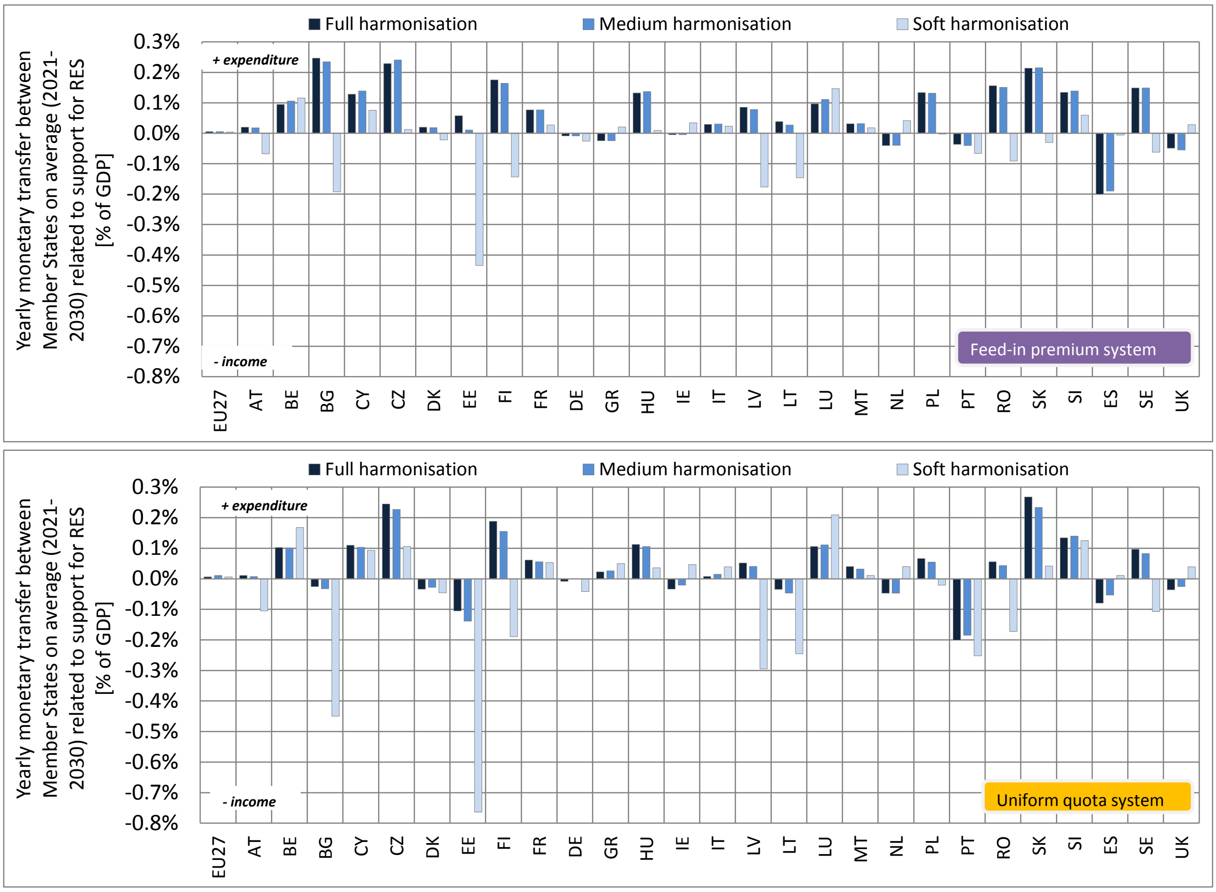


Figure 72 **Country-specific average (2021 to 2030) monetary transfer related to support expenditures for RES in total for policy paths based on a feed-in premium system (top) and on a uniform quota scheme (bottom) under different degrees of harmonisation (full, medium and soft)**

Complementary to above, Figure 72 shows the monetary transfer between Member States resulting from the underlying cost allocation of support expenditures for new RES-E installations under the harmonised schemes. Thus, under soft harmonisation also the impact of RES cooperation comes into play. The indicated transfer represents the difference between actual support expenditures and the fictitious expenditures that would occur if support was completely national. Additionally, support expenditures related to RES-E imports from non-EU countries are taken into consideration, leading to expenditures of less than 0.01% of GDP at EU-27 level on average throughout 2021 to 2030.

The monetary transfer appears comparatively small in magnitude under full or medium harmonisation. In contrast to that, under soft harmonisation a significant amount of reallocation of monetary expenses takes place that generates a remarkably high income for Bulgaria, Estonia, Finland, Latvia and Lithuania. In the case of a uniform quota schemes also Portugal has to be added to that list.

5.4 Sensitivity analysis: Assessing the impact of changing key parameter on the performance of policy pathways

A closer look on the impact of changing key parameters and framework conditions on the resulting indicators of cost and benefits for all representative policy pathways of a full harmonised RES support and selected other cases is given in this section. We start with analysing the effects of imperfect framework conditions, and conclude shortly by a spotlight on possible impacts of grid constraints.

5.4.1 Impact of non-economic barriers: How do policies perform under imperfect framework conditions?

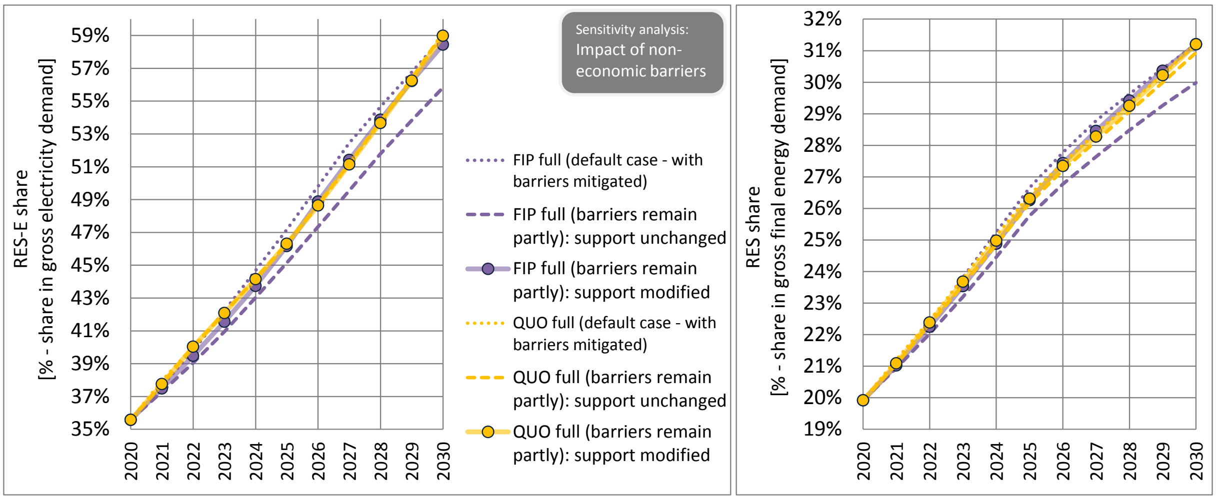


Figure 73 Comparison of the resulting RES-E deployment (left) and RES deployment (right) over time (from 2021 to 2030) in the EU-27, including policy pathways for full harmonisation with "perfect" and "imperfect" framework conditions including an adapted financial support for the latter variant to meet the specified RES target.

As beforehand described, the policy options discussed, related to a possible harmonisation of RES support, are applied assuming "perfect" framework conditions. This comprises the assumption that currently existing non-economic barriers are fully mitigated by 2020. To ease profounder understanding on how support instruments perform under imperfect conditions, a sensitivity assessment was conducted on the performance of harmonised feed-in premiums and uniform quotas under "imperfect" conditions in which non-economic barriers persist partially in place. The direct impact was studied, assuming no change of the initially defined policy design of full harmonisation, as well as a variant where the design of support instruments was modified in order to achieve given RES targets. While the first variant generally indicates the decrease in RES deployment due to imperfect framework conditions, the latter variant shows the necessary adaptation of financial support in order to "bring RES back on track" to meet the specified RES target (under the new "imperfect" framework conditions). Figure 73 depicts the resulting RES-E deployment (left) and RES deployment (right) over time (from 2021 to 2030) in the EU-27 for the chosen policy pathways and sensitivity analysis. Figure 74 offers a summary of key outcomes of this assessment, illustrating the change of primary indicators on cost and benefits for the assessment variants compared to their corresponding default case (of full harmonised feed-in premiums or of uniform quotas with mitigated barriers).

The direct impact of "imperfect" framework conditions (i.e. less "perfect" than the ones initially anticipated by the policy maker) for the instruments assessed can be summarised as follows:

- In the case of feed-in premiums a decrease of RES(-E) deployment (-1.3% RES and -3.2% RES-E compared to default) is apparent (Figure 73). These deployment reductions translate to a change of RES-E generation from new installations in 2030 by -10.4% and a reduced RES-E share by minus 5.2 percentage points (Figure 74). Consequently, it follows a reduction of related costs and benefits by 12 to 17 percent (Figure 74).
- In the case of uniform quotas the RES(-E) deployment and resulting benefits are only slightly affected. In opposition, costs and expenditures increase substantially. Support expenditures and additional generation cost are expected to increase by 19.1% and 25.2% respectively, compared to the default position.

The necessary adaptation in policy design is mainly an increase of financial incentives to facilitate a stronger expansion of alternative, generally more expensive, RES technologies. It results in a similar RES deployment to that of the default case but has a strong impact on costs and expenditures:

- In the case of feed-in premiums, additional generation cost are about as high (-0.8%) and support expenditures increase by about 3.9% compared to the default case of a full harmonised FIP support scheme (Figure 74).
- The increase of additional generation cost (+25.8%), support expenditures (+19.8%), and capital expenditure (+5.3%) for fully harmonised uniform quotas are strongly affected to mitigate "imperfect" framework conditions.

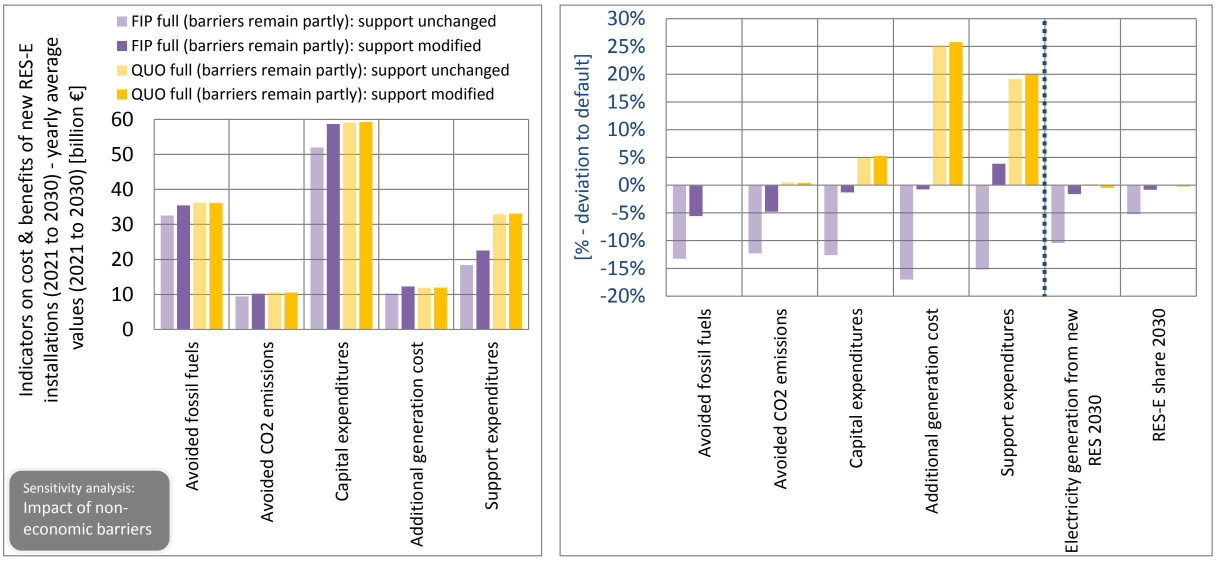


Figure 74 **Indicators on yearly average (2021 to 2030) cost and benefits of new RES-E installations (2021 to 2030) at EU-27 level for all other cases, including minimum and no harmonisation, expressed in absolute terms (left) and as deviation to the default case (right).**

Summing up, it can be concluded that for RES deployment, feed-in tariffs appear more sensitive to changing framework conditions than quotas. In contrast, costs display a strong sensitivity in the case of quotas. In particular, additional generation cost and support expenditures increase significantly if framework conditions are less perfect than anticipated by the policy maker.

5.4.2 Impact of grid constraints

The impacts of grid constraints on the performance of policy pathways as a sensitivity analysis is discussed in this subchapter. Figure 75 provides the central assessment results for the cost and benefit indicators on yearly average (2021 to 2030) (left) and as deviation to the reference case (of strengthened national support without minimum design criteria) (right). It is apparent that the "ETS only" case is most affected by grid constraints due to the non-existence of compensational dedicated RES policies. All other pathways are affected only to a negligible extent.

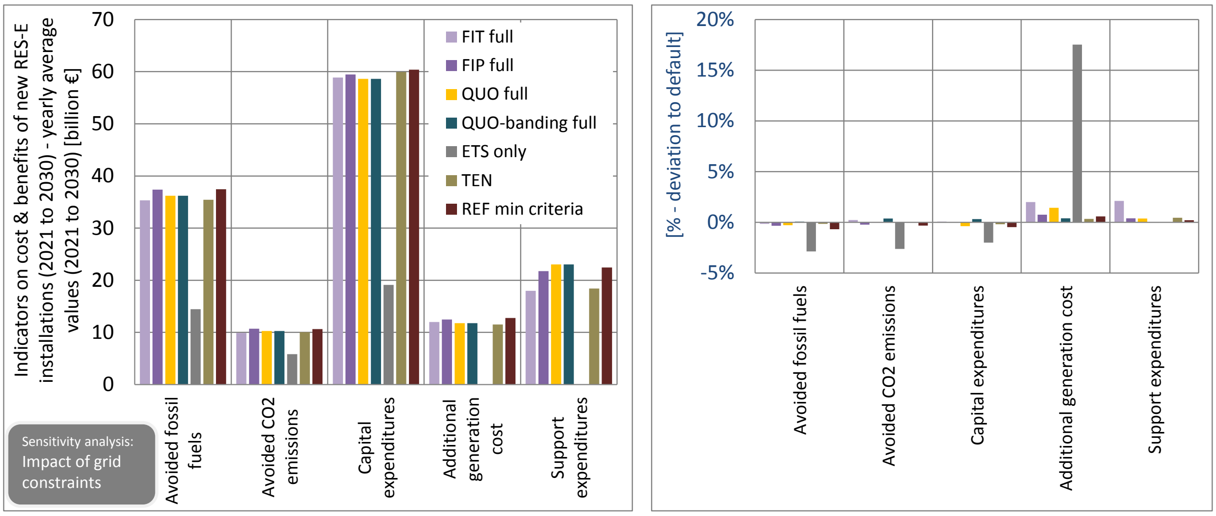


Figure 75 **Indicators on yearly average (2021 to 2030) cost and benefits of new RES-E installations (2021 to 2030) at EU-27 level for all other cases, including minimum and no harmonisation, expressed in absolute terms (left) and as deviation to the reference case (of strengthened national support without minimum design criteria) (right).**

6 Conclusions

The current RES Directive (Directive 2009/28/EC) lays the basis for the EU's RES policy framework until 2020, but a strategy and clear commitment to RES beyond 2020 is needed (if RES is to deliver what is expected by 2050). The results of this assessment support the need for dedicated 2030 RES targets and for accompanying policy action rather than simply offering a criticism of harmonisation (as long as adequate instruments that offer some sort of technology-specification are used). Such targets and policy action are essential if renewables are to play the key role as outlined in the Commission's *Energy Roadmap 2050*[35].

The results of the model-based policy assessment also indicate that cooperation and coordination among Member States (e.g. through a prescription of minimum design criteria) appear beneficial and, indeed, are required to tackle current problems in RES markets. Thus, such an approach would also appear to be fruitful for the period beyond 2020. It also appears promising to complement national support activities by an EU-wide harmonised scheme offering support for selected key technologies like wind and centralised solar.

In terms of cost-effectiveness best performer is a harmonised fixed feed-in tariff system, offering safe and secure revenue streams for investors. Other candidates for a soft, medium or full harmonisation are feed-in premiums and quotas with technology banding. By contrast, "simplistic approaches" to RES policy harmonization (e.g. via a uniform RES certificate trading) cannot be recommended – neither in the short nor in the long term (compare also Resch *et al* (2010)).

Moreover, the model-based assessment clearly points out that the degree of harmonisation has only a small impact upon the performance of an instrument at the aggregated level – i.e. differences between a soft, medium or full harmonisation in terms of costs and benefits appear generally negligible as long as the European level is concerned. Important differences become however apparent at the national level concerning the distribution of efforts. The detailed assessment of impacts on cost allocation, i.e. the sharing of support expenditures for RES across MSs, points out:

- Independent from the type of policy instruments applied the efforts a country has to take differ significantly across the European Union in the case of full harmonisation;
- Medium harmonisation, i.e. where MSs have the opportunity to provide limited additional incentives complementary to the EU-wide harmonised base support, may help to increase equity in effort sharing across Europe. However, only a slightly more balanced distribution can be identified in comparison to full harmonisation;
- Soft harmonisation comes along with a comparatively well-balanced distribution of support expenditures for RES across MSs. The assumed adoption of national 2030 RES targets is here the decisive element: Following the "2020 logic" introduced by the 2020 RES directive (2009/28/EC) national 2030 RES targets are defined for all cases of soft (or minimum or no) harmonisation. Since the target setting procedure takes that explicitly into account, differences in economic wealth between countries appear well reflected.

[35] European Commission, 2011. Energy Roadmap 2050, COM(2011) 885/2.

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Annex A: Detailed results by policy pathway

This Annex offers an overview on results by policy pathway, illustrating details on RES deployment and related costs, expenditures and benefits, partly at EU and partly at Member State level. Thus, key outcomes are provided by policy pathway subsequently.

Remarks:

Note that, generally, a suitable mixture of support instruments is also envisaged for RES in heating & cooling. Thereby, a similar conceptual approach is taken to that discussed for RES electricity, where support instruments are either harmonised or tailored to the country-specific needs. However, in contrast to the electricity sector no socialisation of related cost and expenditures is assumed. In contrast to that for biofuels in transport physical trade across the EU is assumed, meaning that support follows current practices.

Feed-in Tariff system in the case of *full harmonisation*

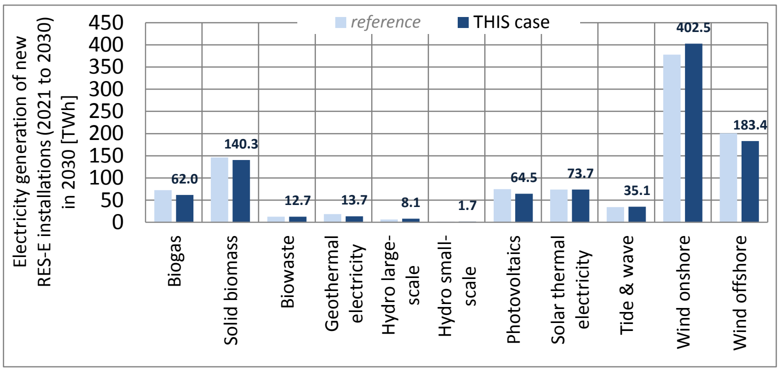
FIT
full
(Path 1a)

Brief characterisation: This policy pathway prescribes the EU-wide adoption of a system of fixed feed-in tariffs to support RES-E. Since full harmonisation is chosen, only an EU-wide target for RES deployment by 2030 is set and an EU-wide harmonised support scheme (i.e. the fixed feed-in tariff scheme) aims to provide the necessary financial support to stimulate investments in new RES installations in the electricity sector beyond 2020.

Thus, there is a very limited role to be played by the MSs since full harmonisation involves harmonisation of: the detailed design of the support scheme selected, including the level of support by technology, and the legal framework as a whole, including regulatory issues. An EU-wide socialisation of the costs of support for RES-E takes place whereby the assumption is taken that consumer pay an EU-wide equalised fee per MWh electricity consumed, independent from the actual location of a RES-E plant.

General notes on the design of the feed-in tariff system:

- A system of fixed feed-in tariffs is implemented. A new installation consequently receives the guaranteed remuneration for its electricity feed-in during the whole duration of support whereby also an inflation adaptation is assumed.
- Support levels (i.e. tariffs) differ by technology. Moreover, for wind onshore and PV a “stepped design” is implemented, meaning that within an efficiency corridor support levels reflect site specifics and a higher remuneration is offered to plants at less suitable sites (i.e. lower full load hours) than for plants at best sites whereby care is taken to assure that revenues remain higher to let investor’s strive for best sites.
- Duration of support is limited to 15 years, i.e. a new installation can only receive financial support during the first 15 years of operation.
- An automatic digression of support levels is foreseen, meaning that in accordance with learning expectations a lower support is guaranteed for a new installation in a certain year than in one year before.



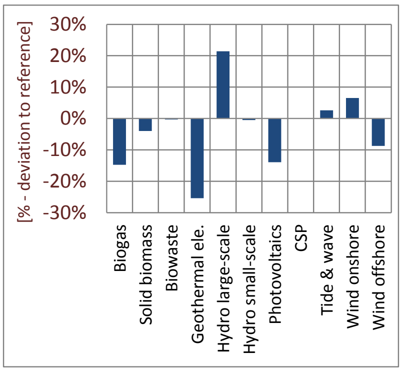


Figure A - 1. Technology-specific breakdown of RES-E generation from new installations (2021 to 2030) at EU-27 level in the year 2030, indicating deployment in absolute terms (left) and the change compared to reference (right) (for the assessed policy pathway 1a (FIT full))

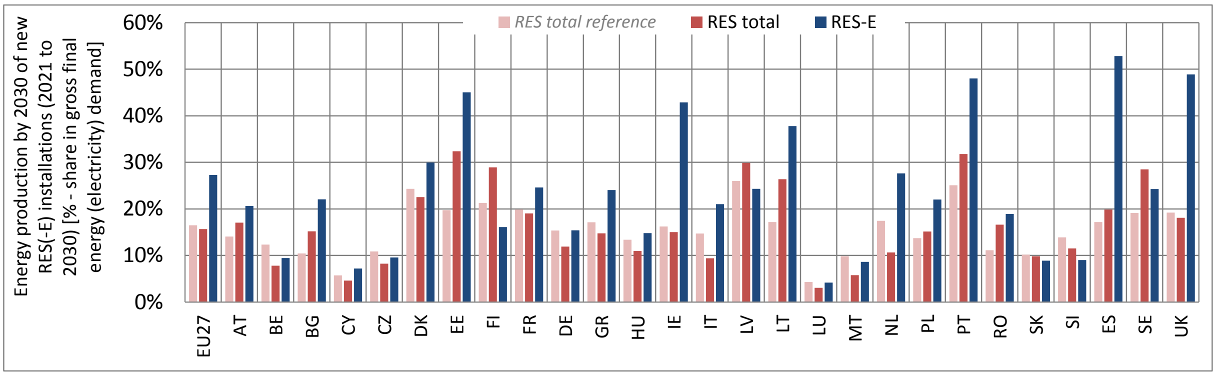


Figure A - 2. Country-specific breakdown of RES and RES-E generation from new installations (2021 to 2030) in the year 2030, indicating RES(-E) deployment as share in corresponding demand (i.e. gross final energy demand for RES total, and gross electricity demand for RES-E) (for the assessed policy pathway 1a (FIT full))

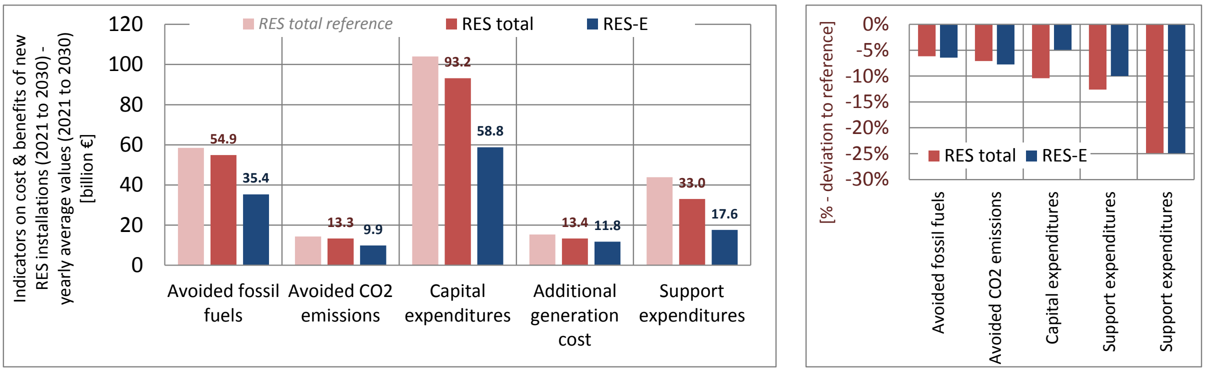


Figure A - 3. Indicators on cost/expenditures and benefits of new RES(-E) installations (2021 to 2030), expressing yearly average (2021 to 2030) monetary values at EU-27 level in absolute terms (left) and the change compared to reference (for the assessed policy pathway 1a (FIT full))

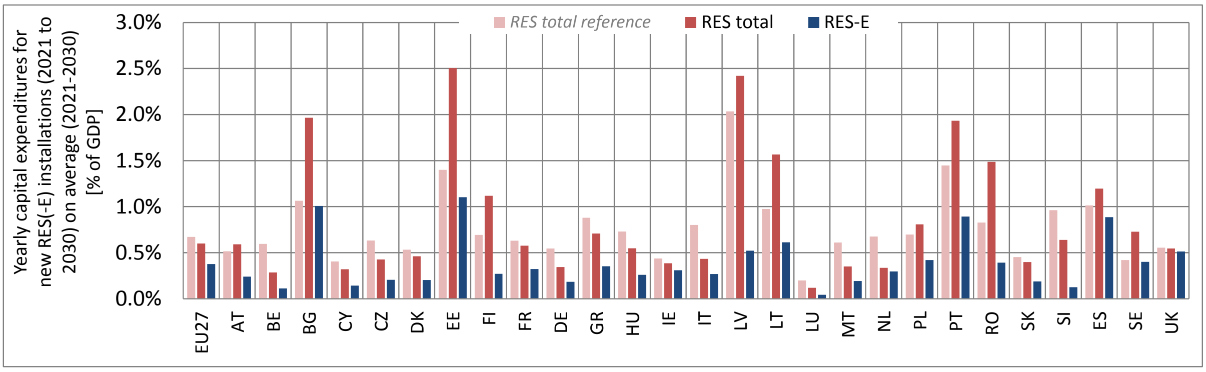


Figure A - 4. Country-specific breakdown of yearly average (2021 to 2030) capital expenditures in new RES and RES-E installations (2021 to 2030), expressing investments as share of (country-specific) GDP (for the assessed policy pathway 1a (FIT full))

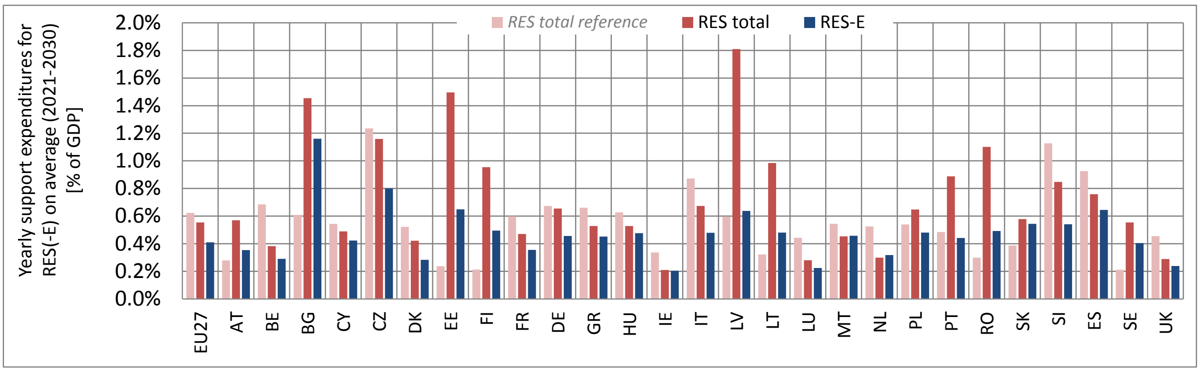


Figure A - 5. Country-specific breakdown of yearly average (2021 to 2030) support expenditures for RES total and RES-E, expressing expenditures as share of (country-specific) GDP (for the assessed policy pathway 1a (FIT full))

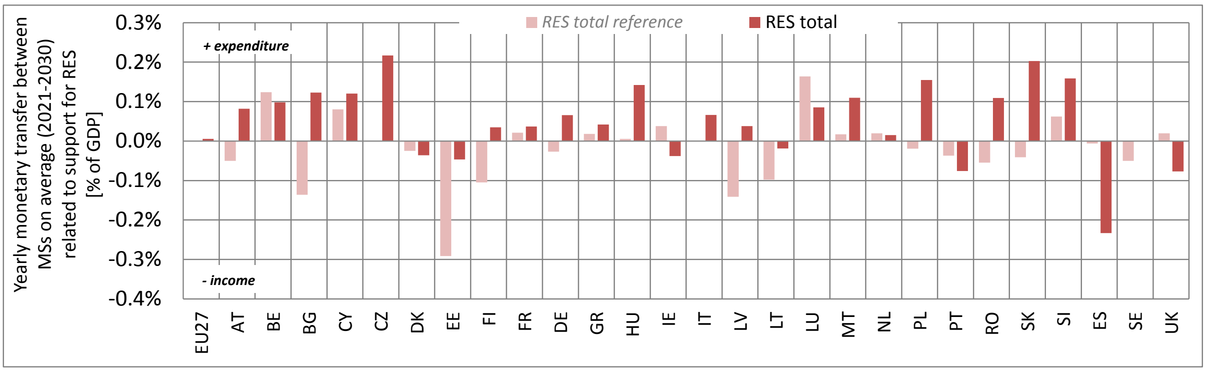


Figure A - 6. Yearly average (2021 to 2030) monetary transfers between Member States related to the support for RES, expressing additional expenditures (+) or income (-) as share of (country-specific) GDP (for the assessed policy pathway 1a (FIT full))

Note: Additional expenditure or income stems from the underlying cost allocation under a full or medium harmonisation of RES support, or they refer to RES cooperation in the case of soft, minimum or no harmonisation, respectively.

Feed-in Premium system in the case of *full harmonisation*

FIP
full
(Path 2a)

Brief characterisation: This policy pathway prescribes the EU-wide adoption of a system of feed-in premiums to support RES-E. Since full harmonisation is chosen, only an EU-wide target for RES deployment by 2030 is set and an EU-wide harmonised support scheme (i.e. the feed-in premium scheme) aims to provide the necessary financial support to stimulate investments in new RES installations in the electricity sector beyond 2020.

Thus, there is a very limited role to be played by the MSs since full harmonisation involves harmonisation of: the detailed design of the support scheme selected, including the level of support by technology, and the legal framework as a whole, including regulatory issues. An EU-wide socialisation of the costs of support for RES-E takes place whereby the assumption is taken that consumer pay an EU-wide equalised fee per MWh electricity consumed, independent from the actual location of a RES-E plant.

General notes on the design of the feed-in premium system:

- A system of fixed feed-in premiums is implemented in order to allow for locational signals across the EU.
- A new installation consequently receives the guaranteed premium for its electricity feed-in during the whole duration of support whereby also an inflation adaptation is assumed.
- Support levels (i.e. premiums) differ by technology. Moreover, for wind onshore and PV a "stepped design" is implemented, meaning that within an efficiency corridor support levels reflect site specifics and a higher remuneration is offered to plants at less suitable sites (i.e. lower full load hours) than for plants at best sites whereby care is taken to assure that revenues remain higher to let investor's strive for best sites.
- Duration of support is limited to 15 years, i.e. a new installation can only receive financial support during the first 15 years of operation.
- An automatic digression of support levels is foreseen, meaning that in accordance with learning expectations a lower support is guaranteed for a new installation in a certain year than in one year before.

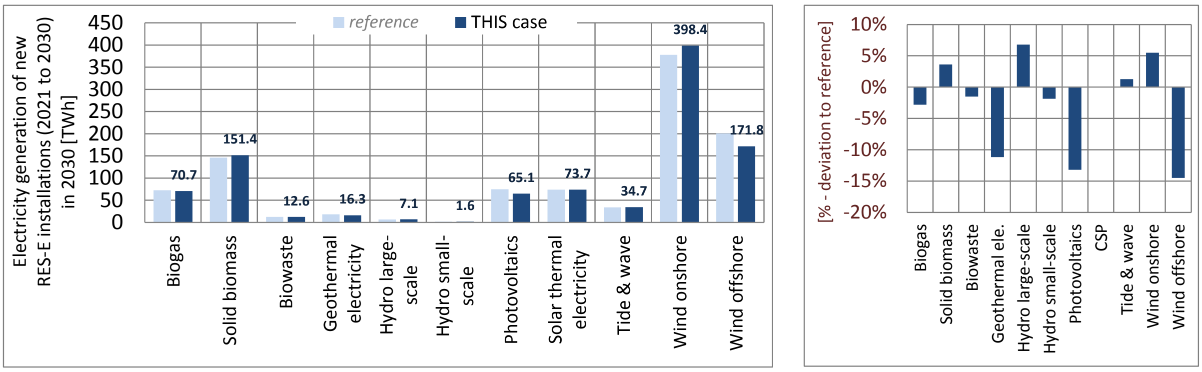


Figure A - 7. Technology-specific breakdown of RES-E generation from new installations (2021 to 2030) at EU-27 level in the year 2030, indicating deployment in absolute terms (left) and the change compared to reference (right) (for the assessed policy pathway 2a (FIP full))

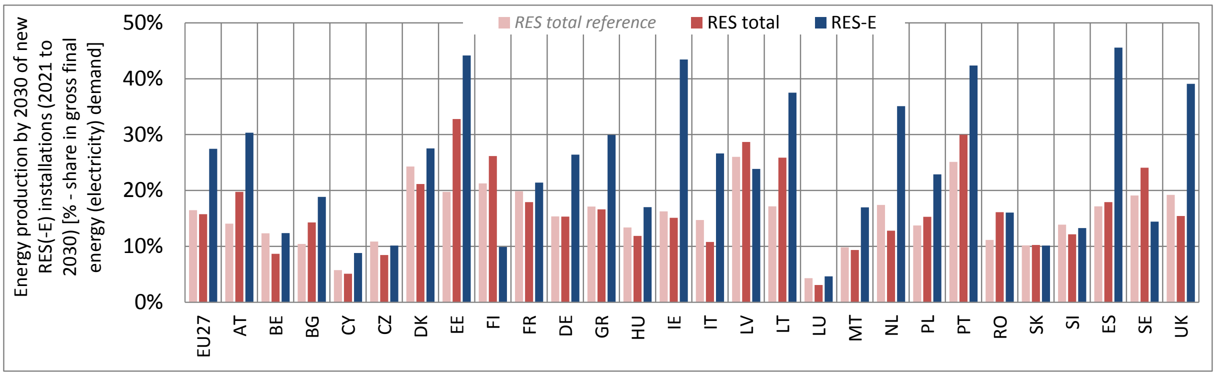


Figure A - 8. Country-specific breakdown of RES and RES-E generation from new installations (2021 to 2030) in the year 2030, indicating RES(-E) deployment as share in corresponding demand (i.e. gross final energy demand for RES total, and gross electricity demand for RES-E) (for the assessed policy pathway <u>2a (FIP full)</u>)

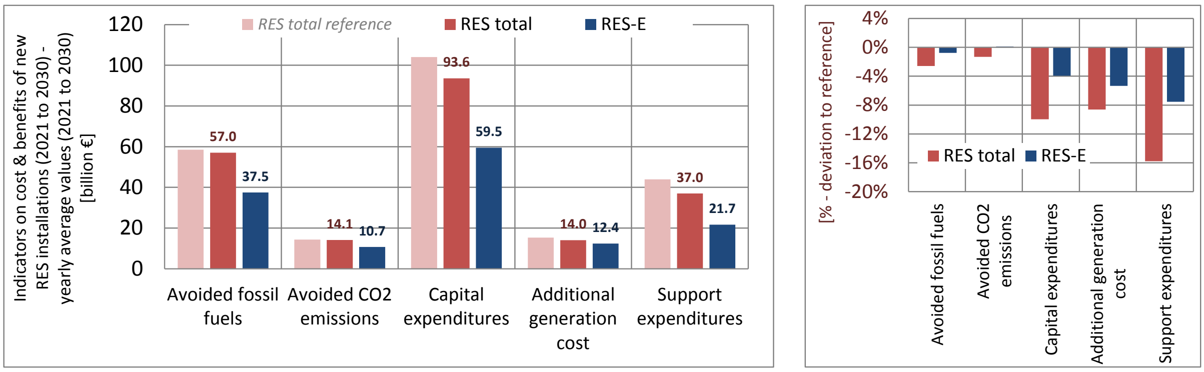


Figure A - 9. Indicators on cost/expenditures and benefits of new RES(-E) installations (2021 to 2030), expressing yearly average (2021 to 2030) monetary values at EU-27 level in absolute terms (left) and the change compared to reference (for the assessed policy pathway <u>2a (FIP full)</u>)

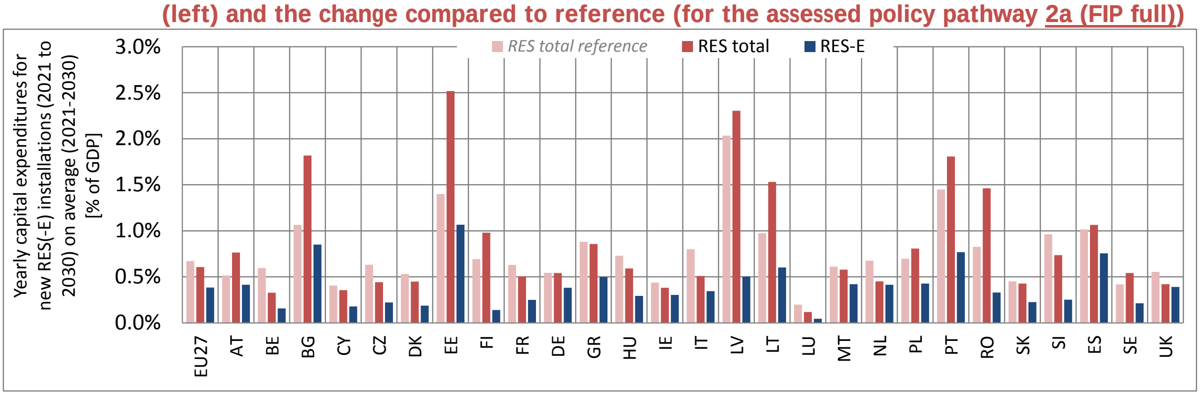


Figure A - 10. Country-specific breakdown of yearly average (2021 to 2030) capital expenditures in new RES and RES-E installations (2021 to 2030), expressing investments as share of (country-specific) GDP (for the assessed policy pathway <u>2a (FIP full)</u>)

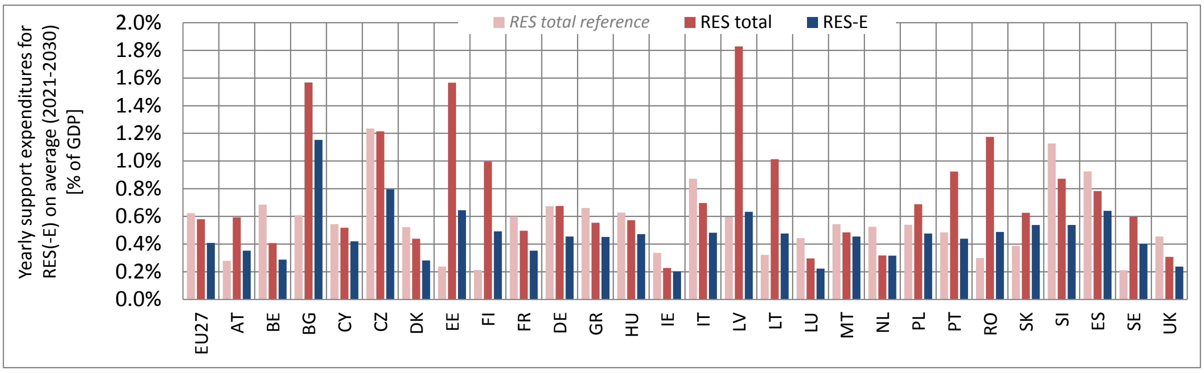


Figure A - 11. Country-specific breakdown of yearly average (2021 to 2030) support expenditures for RES total and RES-E, expressing expenditures as share of (country-specific) GDP (for the assessed policy pathway 2a (FIP full))

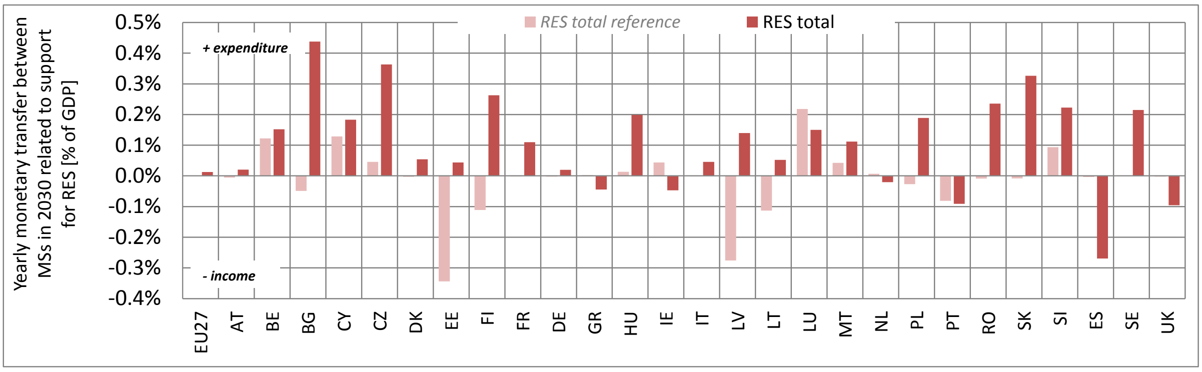


Figure A - 12. Yearly average (2021 to 2030) monetary transfers between Member States related to the support for RES, expressing additional expenditures (+) or income (-) as share of (country-specific) GDP (for the assessed policy pathway 2a (FIP full))

Note: Additional expenditure or income stems from the underlying cost allocation under a full or medium harmonisation of RES support, or they refer to RES cooperation in the case of soft, minimum or no harmonisation, respectively.

Quota system in the case of *full harmonisation*

QUO
full
(Path 3a)

Brief characterisation: This policy pathway prescribes the EU-wide adoption of a uniform quota system with tradable green certificates to support RES-E. Since full harmonisation is chosen, only an EU-wide target for RES deployment by 2030 is set and an EU-wide harmonised support scheme (i.e. the quota scheme) aims to provide the necessary financial support to stimulate investments in new RES installations in the electricity sector.

Thus, there is a very limited role to be played by the MSs since full harmonisation involves harmonisation of: the detailed design of the support scheme selected, in particular (yearly) quota targets for obliged actors, the height of penalties in the case of non-fulfilment and the legal framework as a whole, including regulatory issues. An EU-wide socialisation of the costs of support for RES-E takes place. Within a quota system this is determined by the height of RES-E targets – i.e. these are in the case of full harmonisation equally set across the EU, and consequently, consumer pay an EU-wide equalised fee per MWh electricity consumed, independent from the actual location of a RES-E plant.

General notes on the design of the uniform quota system:

- A uniform quota system is implemented, meaning that no differentiation of support takes place by technology.
- Quota targets, i.e. the shares of consumed/sold electricity that need to stem from RES-E plants, are defined on a yearly basis for obliged actors.
- Penalties for the case of non-fulfilment of quota obligations are defined.
- Duration of support is limited to 15 years, i.e. a new installation can only receive financial support through certificates during the first 15 years of operation.

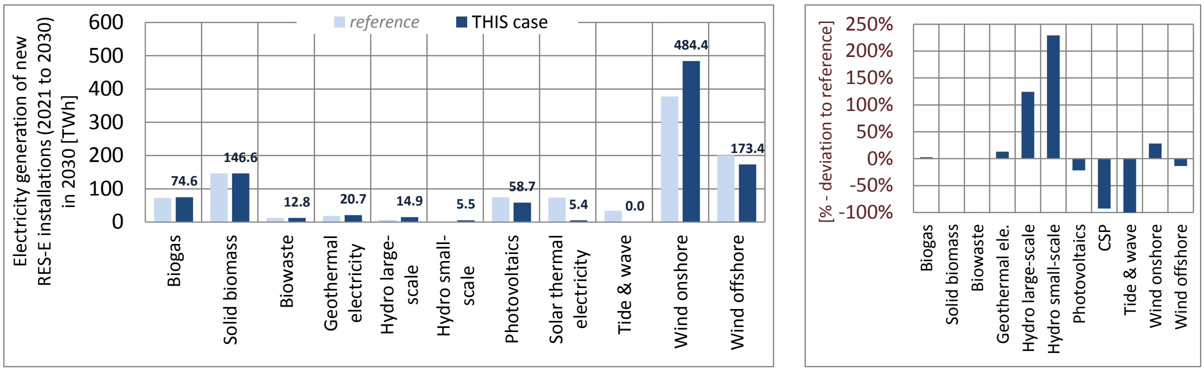


Figure A - 13. Technology-specific breakdown of RES-E generation from new installations (2021 to 2030) at EU-27 level in the year 2030, indicating deployment in absolute terms (left) and the change compared to reference (right) (for the assessed policy pathway 3a (QUO full))

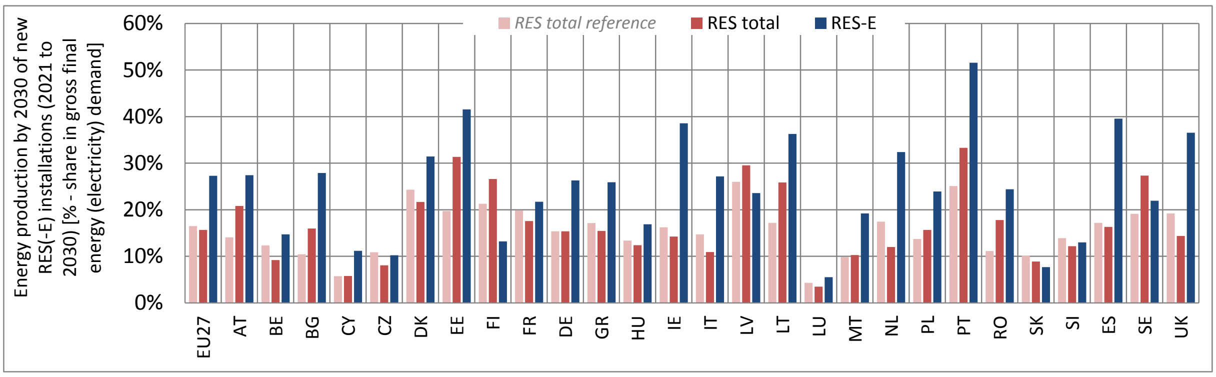


Figure A - 14. Country-specific breakdown of RES and RES-E generation from new installations (2021 to 2030) in the year 2030, indicating RES(-E) deployment as share in corresponding demand (i.e. gross final energy demand for RES total, and gross electricity demand for RES-E) (for the assessed policy pathway 3a (QUO full))

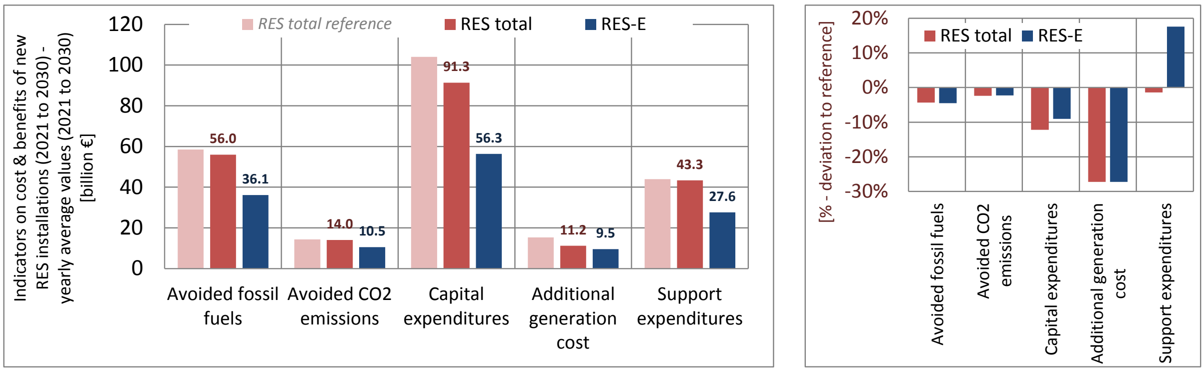


Figure A - 15. Indicators on cost/expenditures and benefits of new RES(-E) installations (2021 to 2030), expressing yearly average (2021 to 2030) monetary values at EU-27 level in absolute terms (left) and the change compared to reference (for the assessed policy pathway 3a (QUO full))

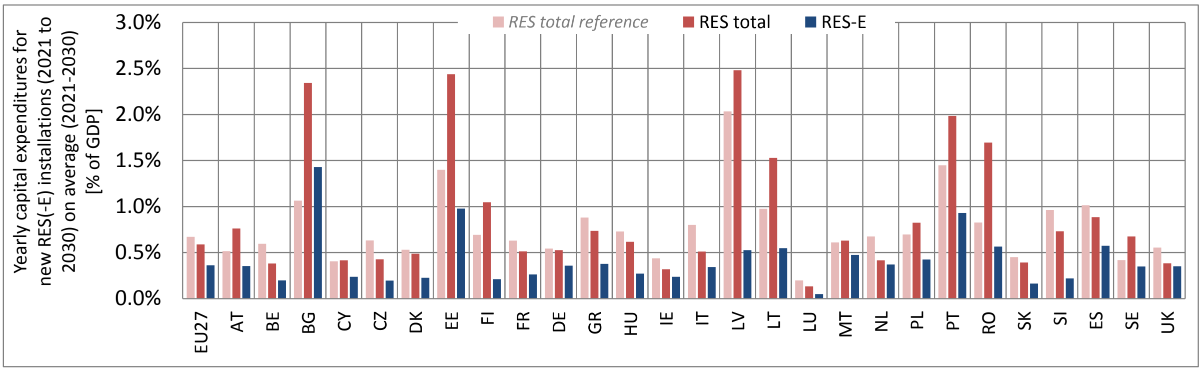


Figure A - 16. Country-specific breakdown of yearly average (2021 to 2030) capital expenditures in new RES and RES-E installations (2021 to 2030), expressing investments as share of (country-specific) GDP (for the assessed policy pathway 3a (QUO full))

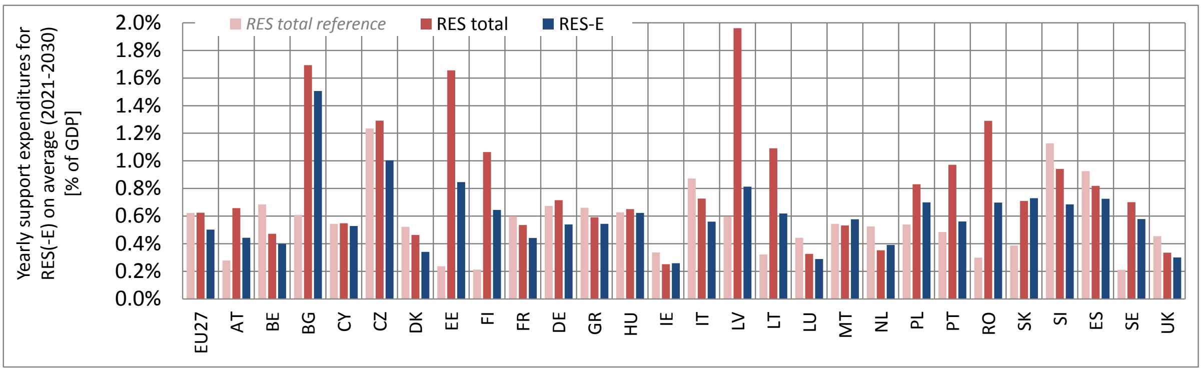


Figure A - 17. Country-specific breakdown of yearly average (2021 to 2030) support expenditures for RES total and RES-E, expressing expenditures as share of (country-specific) GDP (for the assessed policy pathway 3a (QUO full))

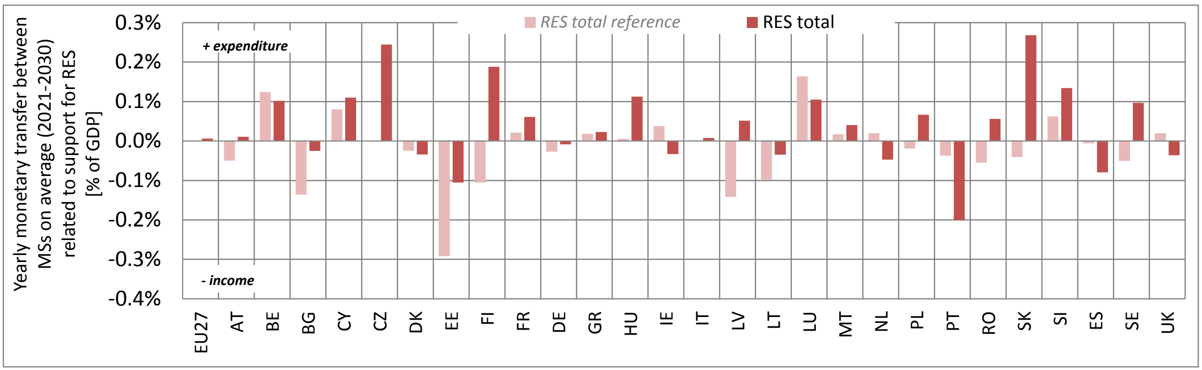


Figure A - 18. Yearly average (2021 to 2030) monetary transfers between Member States related to the support for RES, expressing additional expenditures (+) or income (-) as share of (country-specific) GDP (for the assessed policy pathway 3a (QUO full))

Note: Additional expenditure or income stems from the underlying cost allocation under a full or medium harmonisation of RES support, or they refer to RES cooperation in the case of soft, minimum or no harmonisation, respectively.

Quota system with banded TGC in the case of *full harmonisation*

QUO-banding full (Path 4a)

Brief characterisation: This policy pathway prescribes the EU-wide adoption of a quota system with banded TGCs to support RES-E. Since full harmonisation is chosen, only an EU-wide target for RES deployment by 2030 is set and an EU-wide harmonised support scheme (i.e. the quota system with banded TGCs) aims to provide the necessary financial support to stimulate investments in new RES installations in the electricity sector beyond 2020.

Thus, there is a very limited role to be played by the MSs since full harmonisation involves harmonisation of: the detailed design of the support scheme selected, in particular (yearly) quota targets for obliged actors, the height of penalties in the case of non-fulfilment, the technology-specific weighting factors determining the ratio between electricity generated and certificates issued, and the legal framework as a whole, including regulatory issues. An EU-wide socialisation of the costs of support for RES-E takes place. Within a quota system this is determined by the height of RES-E targets – i.e. these are in the case of full harmonisation equally set across the EU.

General notes on the design of the quota system with technology banding:

- A quota system with technology banding is applied, providing a different weighting to different technologies in terms of the number of green certificates (GC) granted per MWh generation, e.g. wind offshore obtains twice the weighting as wind on-shore. More precisely, these banding factors are adapted over time, i.e. from year to year, in order to reflect technological progress in terms of future cost reductions.
- Quota targets, i.e. the shares of consumed/sold electricity that need to stem from RES-E plants, are defined on a yearly basis for obliged actors.
- Penalties for the case of non-fulfilment of quota obligations are defined.
- Duration of support is limited to 15 years, i.e. a new installation can only receive financial support through certificates during the first 15 years of operation.

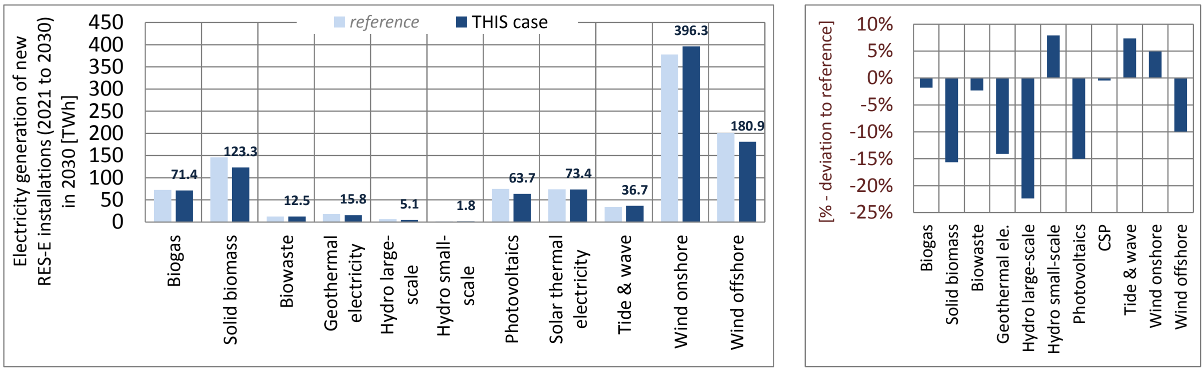


Figure A - 19. Technology-specific breakdown of RES-E generation from new installations (2021 to 2030) at EU-27 level in the year 2030, indicating deployment in absolute terms (left) and the change compared to reference (right) (for the assessed policy pathway 4a (QUO banding full))

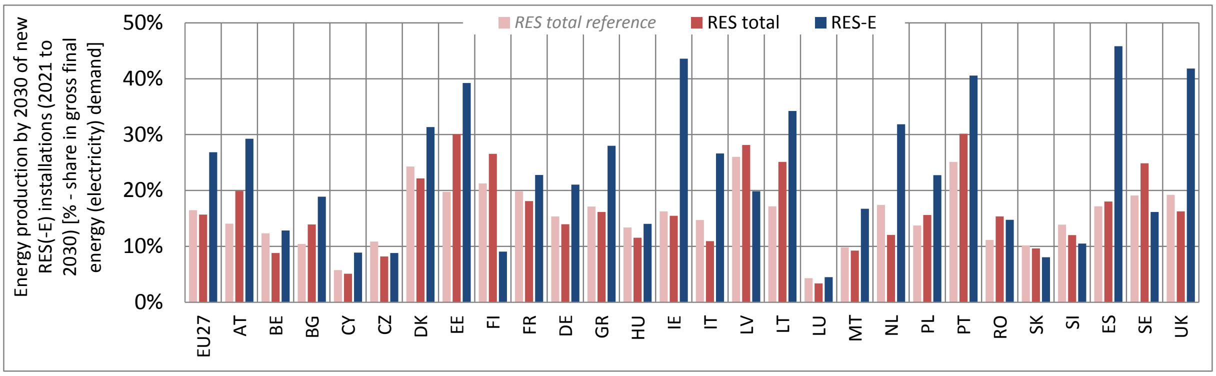


Figure A - 20. Country-specific breakdown of RES and RES-E generation from new installations (2021 to 2030) in the year 2030, indicating RES(-E) deployment as share in corresponding demand (i.e. gross final energy demand for RES total, and gross electricity demand for RES-E) (for the assessed policy pathway 4a (QUO banding full))

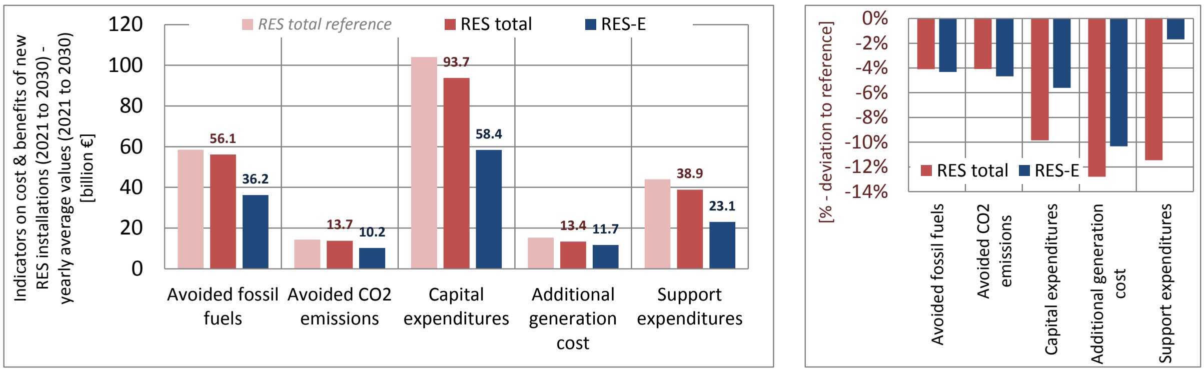


Figure A - 21. Indicators on cost/expenditures and benefits of new RES(-E) installations (2021 to 2030), expressing yearly average (2021 to 2030) monetary values at EU-27 level in absolute terms (left) and the change compared to reference (for the assessed policy pathway 4a (QUO banding full))

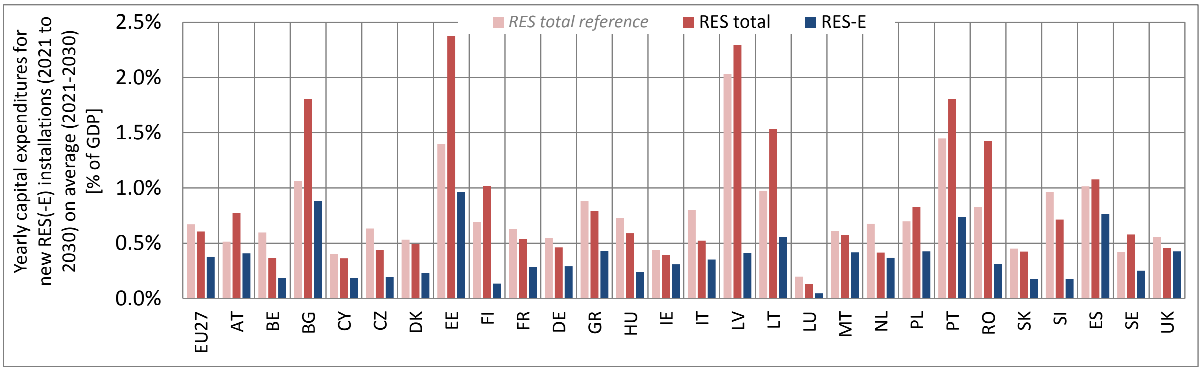


Figure A - 22. Country-specific breakdown of yearly average (2021 to 2030) capital expenditures in new RES and RES-E installations (2021 to 2030), expressing investments as share of (country-specific) GDP (for the assessed policy pathway 4a (QUO banding full))

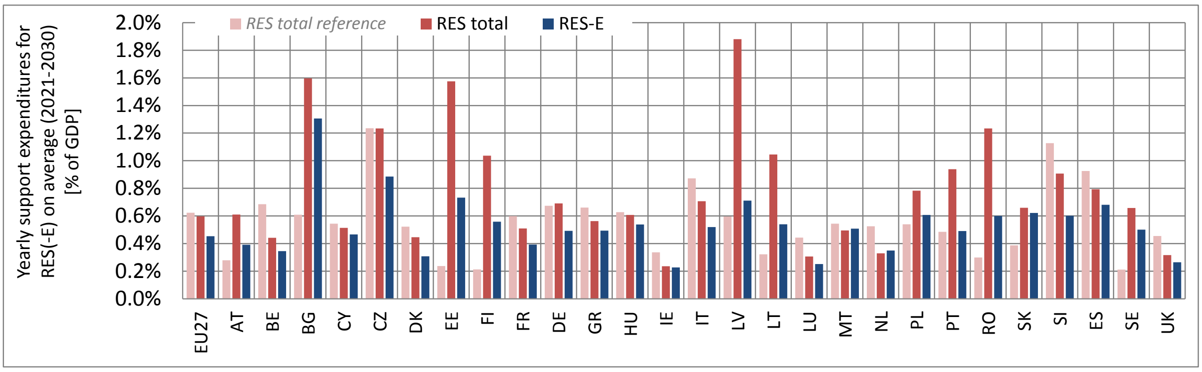


Figure A - 23. Country-specific breakdown of yearly average (2021 to 2030) support expenditures for RES total and RES-E, expressing expenditures as share of (country-specific) GDP (for the assessed policy pathway 4a (QUO banding full))

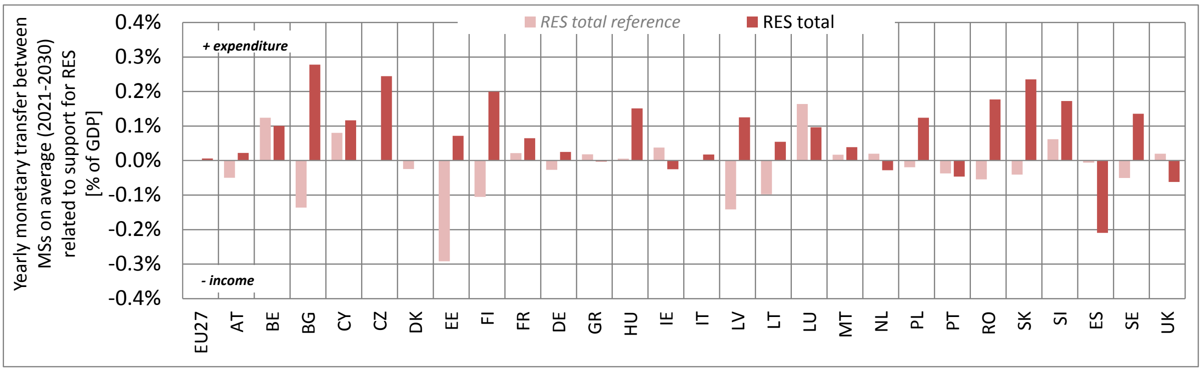


Figure A - 24. Yearly average (2021 to 2030) monetary transfers between Member States related to the support for RES, expressing additional expenditures (+) or income (-) as share of (country-specific) GDP (for the assessed policy pathway 4a (QUO banding full))

Note: Additional expenditure or income stems from the underlying cost allocation under a full or medium harmonisation of RES support, or they refer to RES cooperation in the case of soft, minimum or no harmonisation, respectively.

Feed-in Tariff system in the case of *medium harmonisation*

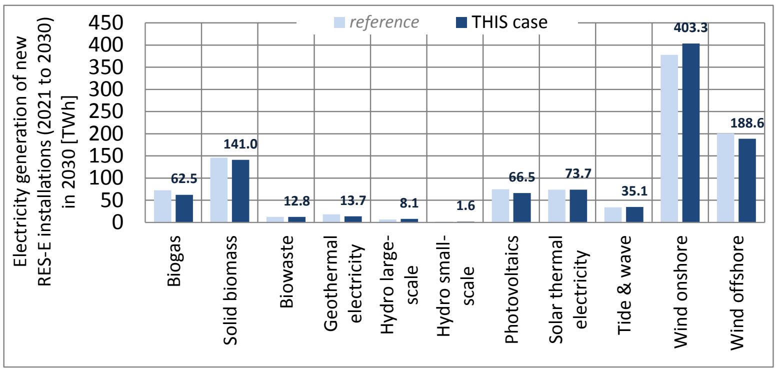
FIT
medium
(Path 1b)

Brief characterisation: This policy pathway prescribes the EU-wide adoption of a system of fixed feed-in tariffs to support RES-E. Since medium harmonisation is chosen, only an EU-wide target for RES deployment by 2030 is set and an EU-wide harmonised support scheme (i.e. the fixed feed-in tariff scheme) aims to provide the necessary basic funding which MSs may complement via additional limited incentives to stimulate investments in new RES-E installations.

Thus, there is a very limited role to be played by the MSs since medium harmonisation involves harmonisation of: the detailed design of the support scheme selected, including the level of basic support by technology, and the legal framework as a whole, including regulatory issues. Medium harmonisation gives MSs however the freedom to apply limited additional support on top of EU-wide harmonised incentives. An EU-wide socialisation of the costs related to the EU-wide harmonised basic support for RES-E takes place whereby the assumption is taken that consumer pay an EU-wide equalised fee per MWh electricity consumed, independent from the actual location of a RES-E plant.

General notes on the design of the feed-in tariff system:

- A system of fixed feed-in tariffs is implemented. A new installation consequently receives the guaranteed remuneration for its electricity feed-in during the whole duration of support whereby also an inflation adaptation is assumed.
- Support levels (i.e. tariffs) differ by technology. Moreover, for wind onshore and PV a "stepped design" is implemented, meaning that within an efficiency corridor support levels reflect site specifics and a higher remuneration is offered to plants at less suitable sites (i.e. lower full load hours) than for plants at best sites whereby care is taken to assure that revenues remain higher to let investor's strive for best sites.
- Duration of support is limited to 15 years, i.e. a new installation can only receive financial support during the first 15 years of operation.
- An automatic digression of support levels is foreseen, meaning that in accordance with learning expectations a lower support is guaranteed for a new installation in a certain year than in one year before.



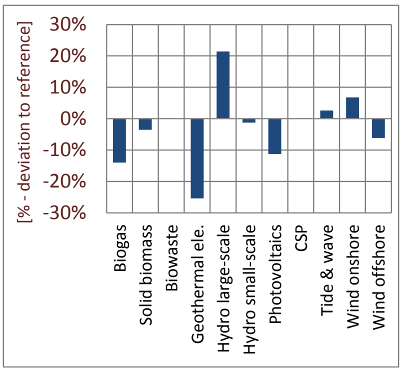


Figure A - 25. Technology-specific breakdown of RES-E generation from new installations (2021 to 2030) at EU-27 level in the year 2030, indicating deployment in absolute terms (left) and the change compared to reference (right) (for the assessed policy pathway 1b (FIT medium))

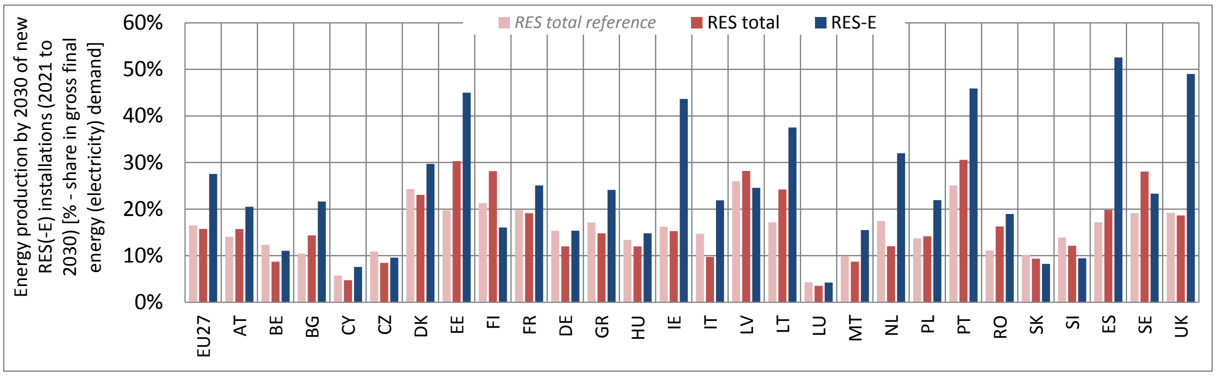


Figure A - 26. Country-specific breakdown of RES and RES-E generation from new installations (2021 to 2030) in the year 2030, indicating RES(-E) deployment as share in corresponding demand (i.e. gross final energy demand for RES total, and gross electricity demand for RES-E) (for the assessed policy pathway 1b (FIT medium))

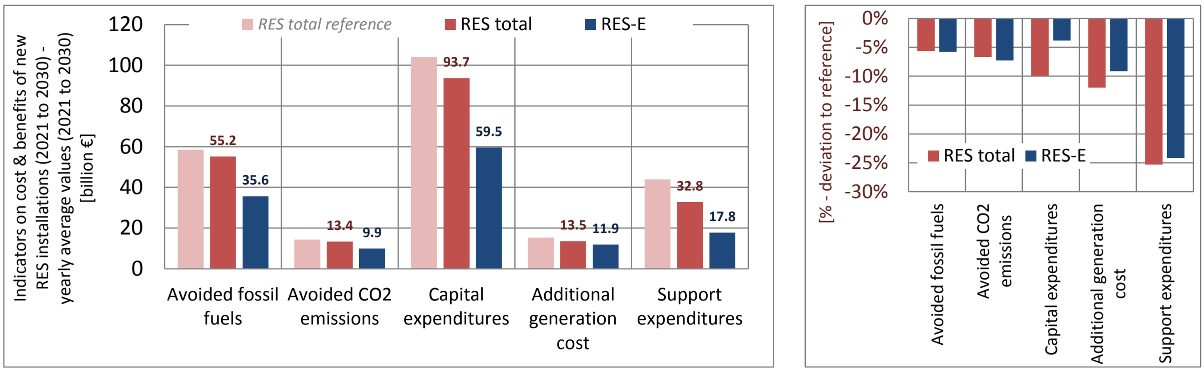


Figure A - 27. Indicators on cost/expenditures and benefits of new RES(-E) installations (2021 to 2030), expressing yearly average (2021 to 2030) monetary values at EU-27 level in absolute terms (left) and the change compared to reference (for the assessed policy pathway 1b (FIT medium))

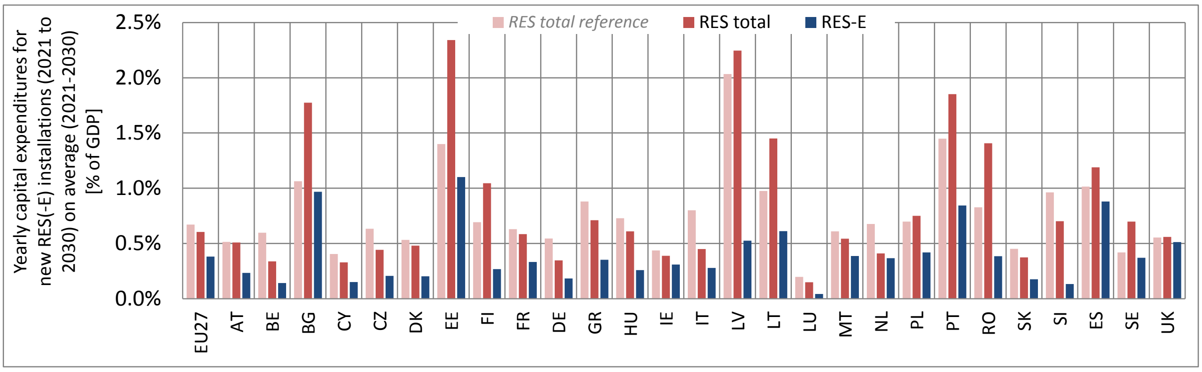


Figure A - 28. Country-specific breakdown of yearly average (2021 to 2030) capital expenditures in new RES and RES-E installations (2021 to 2030), expressing investments as share of (country-specific) GDP (for the assessed policy pathway 1b (FIT medium))

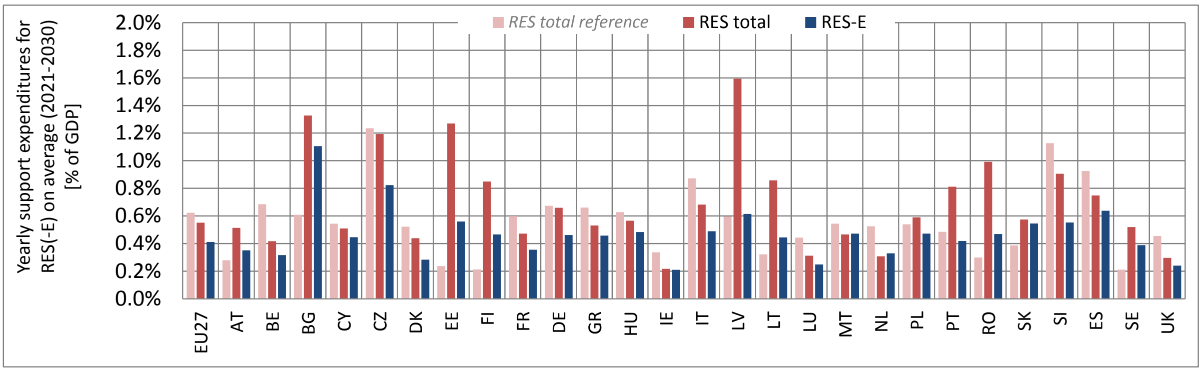


Figure A - 29. Country-specific breakdown of yearly average (2021 to 2030) support expenditures for RES total and RES-E, expressing expenditures as share of (country-specific) GDP (for the assessed policy pathway 1b (FIT medium))

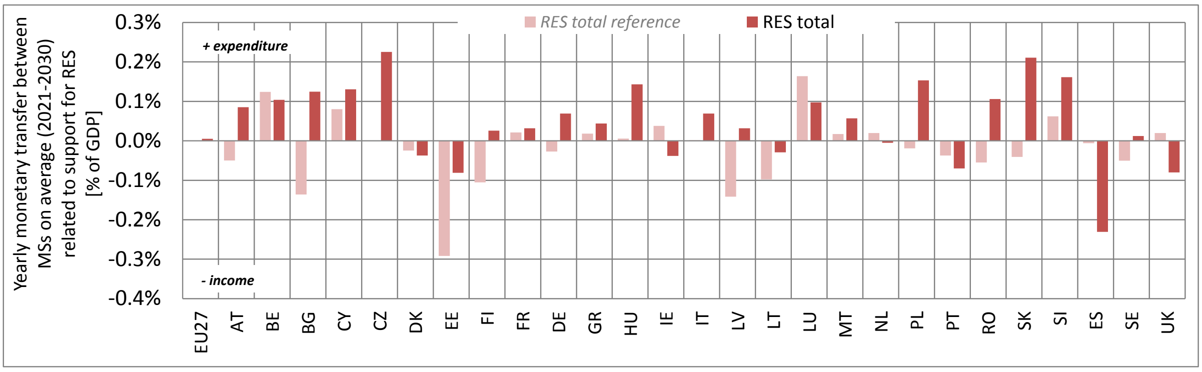


Figure A - 30. Yearly average (2021 to 2030) monetary transfers between Member States related to the support for RES, expressing additional expenditures (+) or income (-) as share of (country-specific) GDP (for the assessed policy pathway 1b (FIT medium))

Note: Additional expenditure or income stems from the underlying cost allocation under a full or medium harmonisation of RES support, or they refer to RES cooperation in the case of soft, minimum or no harmonisation, respectively.

Feed-in Premium system in the case of *medium harmonisation*

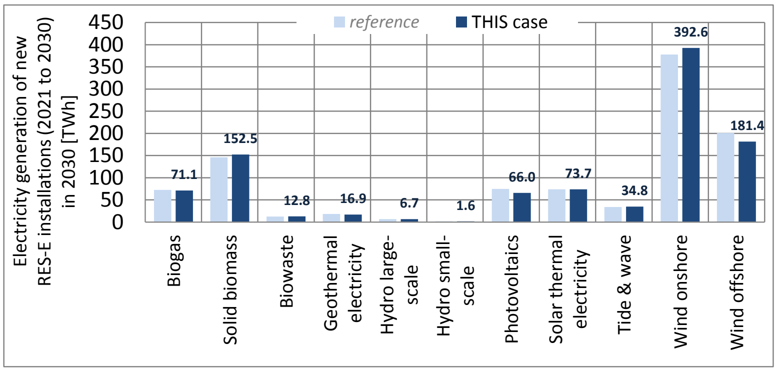
FIP
medium
(Path 2b)

Brief characterisation: This policy pathway prescribes the EU-wide adoption of a system of feed-in premiums to support RES-E. Since medium harmonisation is chosen, only an EU-wide target for RES deployment by 2030 is set and an EU-wide harmonised support scheme (i.e. the feed-in premium scheme) aims to provide the necessary basic funding which MSs may complement via additional limited incentives to stimulate investments in new RES-E installations.

Thus, there is a very limited role to be played by the MSs since medium harmonisation involves harmonisation of: the detailed design of the support scheme selected, level of basic support by technology, and the legal framework as a whole, including regulatory issues. Medium harmonisation gives MSs however the freedom to apply limited additional support on top of EU-wide harmonised incentives. An EU-wide socialisation of the costs related to the EU-wide harmonised basic support for RES-E takes place whereby the assumption is taken that consumer pay an EU-wide equalised fee per MWh electricity consumed, independent from the actual location of a RES-E plant.

General notes on the design of the feed-in premium system:

- A system of fixed feed-in premiums is implemented in order to allow for locational signals across the EU.
- A new installation consequently receives the guaranteed premium for its electricity feed-in during the whole duration of support whereby also an inflation adaptation is assumed.
- Support levels (i.e. premiums) differ by technology. Moreover, for wind onshore and PV a "stepped design" is implemented, meaning that within an efficiency corridor support levels reflect site specifics and a higher remuneration is offered to plants at less suitable sites (i.e. lower full load hours) than for plants at best sites whereby care is taken to assure that revenues remain higher to let investor's strive for best sites.
- Duration of support is limited to 15 years, i.e. a new installation can only receive financial support during the first 15 years of operation.
- An automatic digression of support levels is foreseen, meaning that in accordance with learning expectations a lower support is guaranteed for a new installation in a certain year than in one year before.



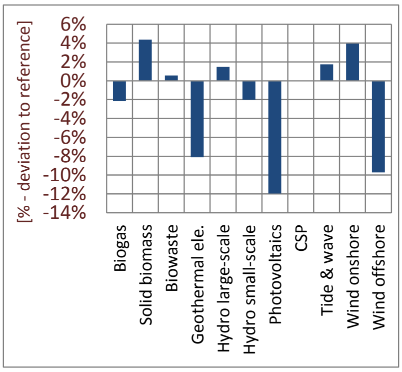


Figure A - 31. Technology-specific breakdown of RES-E generation from new installations (2021 to 2030) at EU-27 level in the year 2030, indicating deployment in absolute terms (left) and the change compared to reference (right) (for the assessed policy pathway 2b (FIP medium))

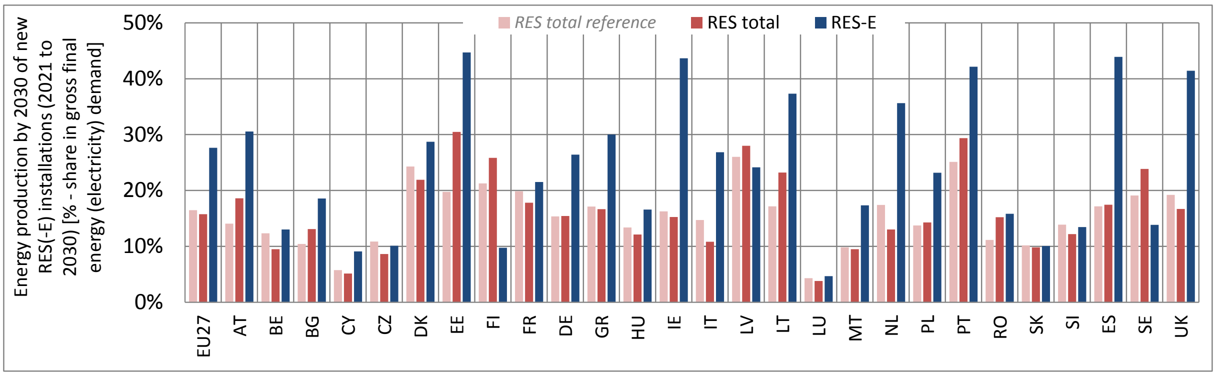


Figure A - 32. Country-specific breakdown of RES and RES-E generation from new installations (2021 to 2030) in the year 2030, indicating RES(-E) deployment as share in corresponding demand (i.e. gross final energy demand for RES total, and gross electricity demand for RES-E) (for the assessed policy pathway 2b (FIP medium))

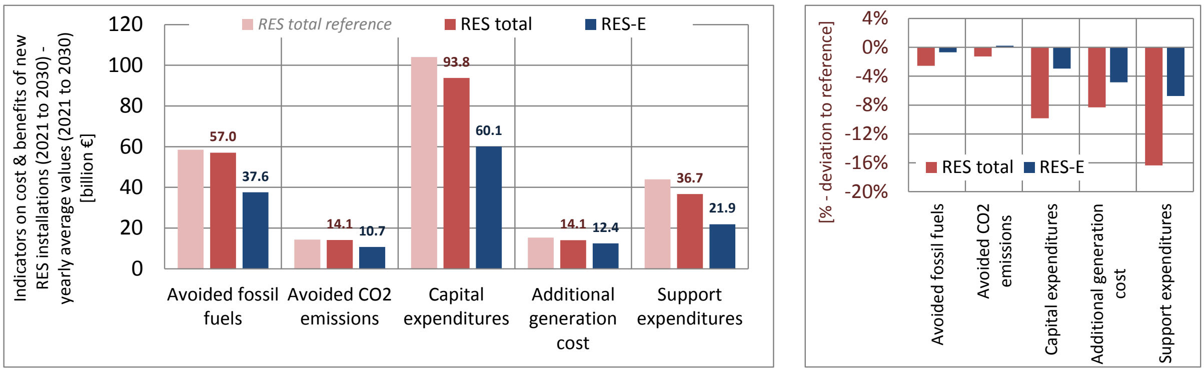


Figure A - 33. Indicators on cost/expenditures and benefits of new RES(-E) installations (2021 to 2030), expressing yearly average (2021 to 2030) monetary values at EU-27 level in absolute terms (left) and the change compared to reference (for the assessed policy pathway 2b (FIP medium))

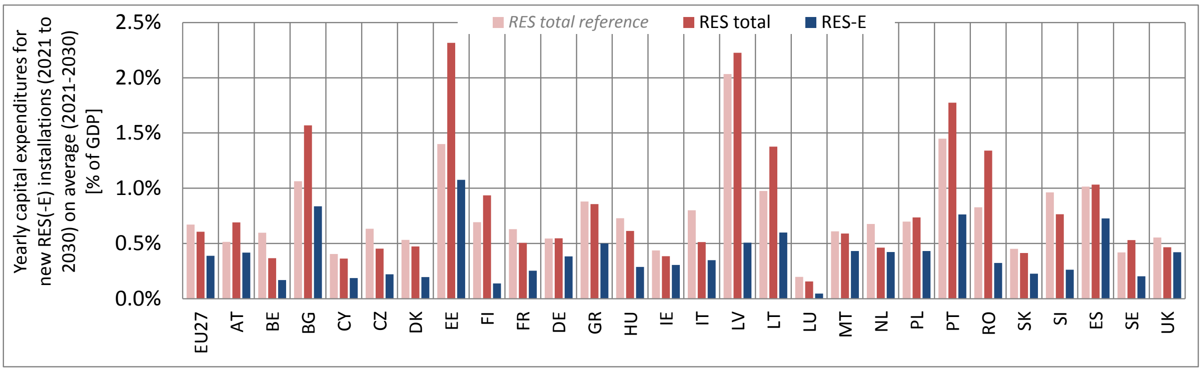


Figure A - 34. Country-specific breakdown of yearly average (2021 to 2030) capital expenditures in new RES and RES-E installations (2021 to 2030), expressing investments as share of (country-specific) GDP (for the assessed policy pathway 2b (FIP medium))

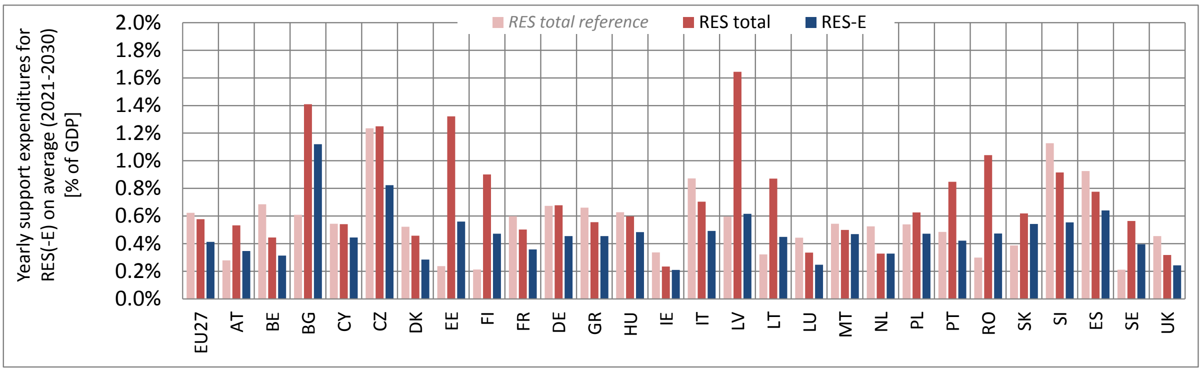


Figure A - 35. Country-specific breakdown of yearly average (2021 to 2030) support expenditures for RES total and RES-E, expressing expenditures as share of (country-specific) GDP (for the assessed policy pathway 2b (FIP medium))

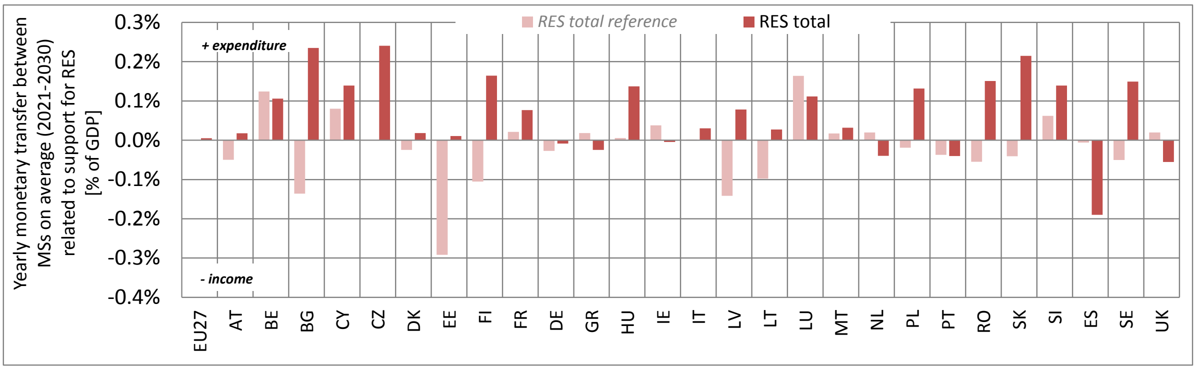


Figure A - 36. Yearly average (2021 to 2030) monetary transfers between Member States related to the support for RES, expressing additional expenditures (+) or income (-) as share of (country-specific) GDP (for the assessed policy pathway 2b (FIP medium))

Note: Additional expenditure or income stems from the underlying cost allocation under a full or medium harmonisation of RES support, or they refer to RES cooperation in the case of soft, minimum or no harmonisation, respectively.

Quota system in the case of *medium harmonisation*

QUO
medium
(Path 3b)

Brief characterisation: This policy pathway prescribes the EU-wide adoption of a quota system to support RES-E. Since medium harmonisation is chosen, only an EU-wide target for RES deployment by 2030 is set and an EU-wide harmonised support scheme (i.e. the quota system scheme) aims to provide the necessary basic support which MSs may complement via additional limited incentives to stimulate investments in new RES-E installations.

Thus, there is a very limited role to be played by the MSs since medium harmonisation involves harmonisation of: the detailed design of the support scheme selected, including the level of basic support by technology, and the legal framework as a whole, including regulatory issues. Medium harmonisation gives MSs however the freedom to apply limited additional support (i.e. via investment incentives) to complement the revenues gained through the EU-wide harmonised trading regime. An EU-wide socialisation of the costs related to the EU-wide trading regime takes place whereby the assumption is taken that consumer pay an EU-wide equalised fee per MWh electricity consumed.

General notes on the design of the uniform quota system:

- A uniform quota system is implemented, meaning that no differentiation of support takes place by technology.
- Quota targets, i.e. the shares of consumed/sold electricity that need to stem from RES-E plants, are defined on a yearly basis for obliged actors.
- Penalties for the case of non-fulfilment of quota obligations are defined.
- Duration of support is limited to 15 years, i.e. a new installation can only receive financial support through certificates during the first 15 years of operation.

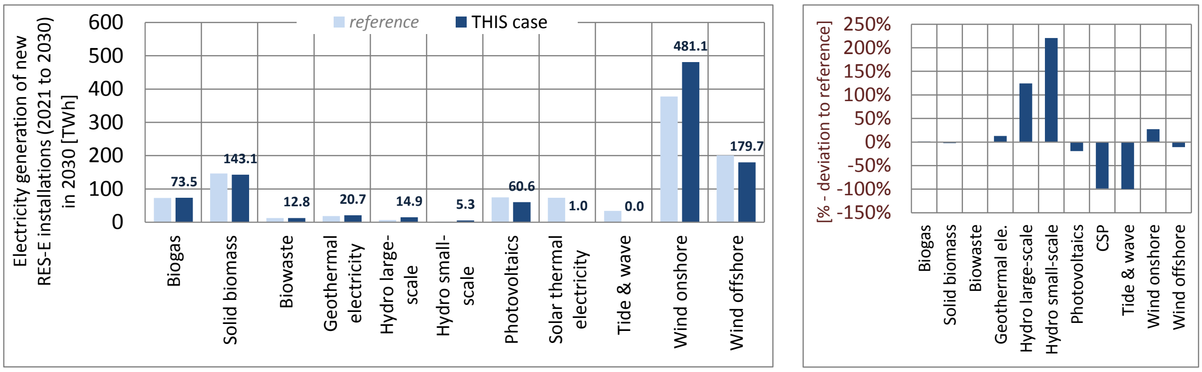


Figure A - 37. Technology-specific breakdown of RES-E generation from new installations (2021 to 2030) at EU-27 level in the year 2030, indicating deployment in absolute terms (left) and the change compared to reference (right) (for the assessed policy pathway 3b (QUO medium))

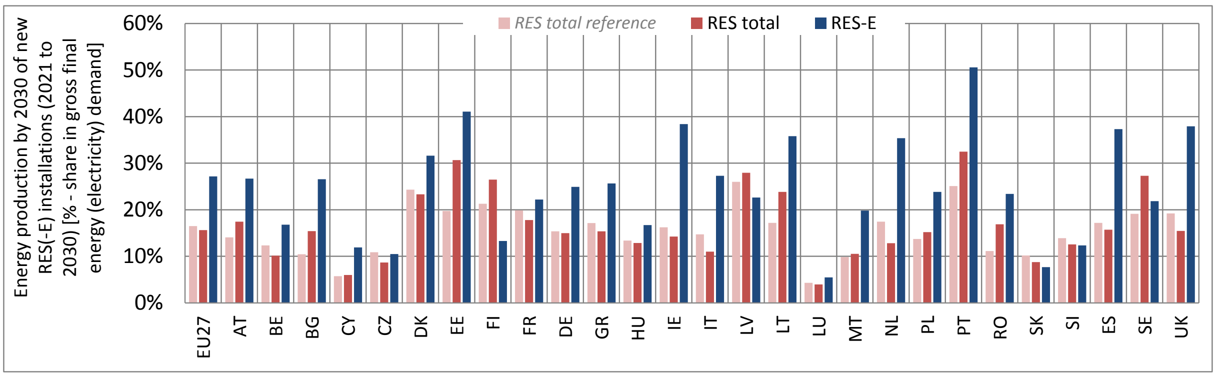


Figure A - 38. Country-specific breakdown of RES and RES-E generation from new installations (2021 to 2030) in the year 2030, indicating RES(-E) deployment as share in corresponding demand (i.e. gross final energy demand for RES total, and gross electricity demand for RES-E) (for the assessed policy pathway 3b (QUO medium))

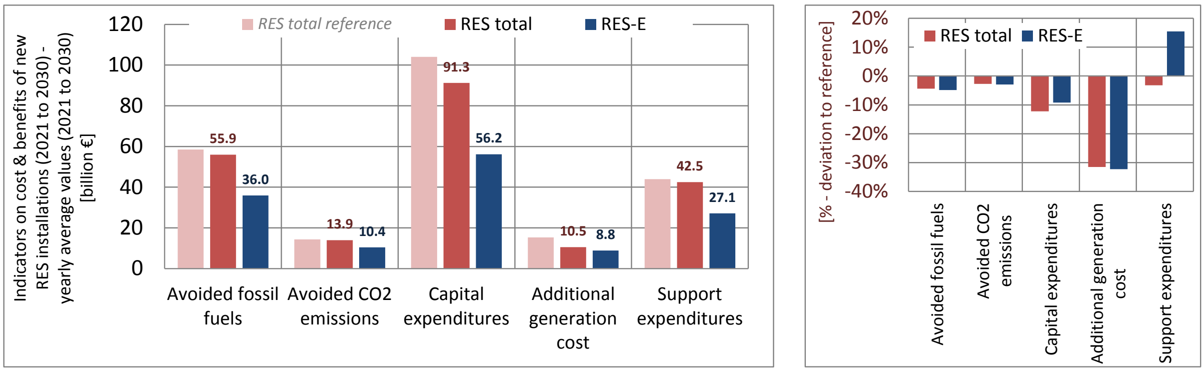


Figure A - 39. Indicators on cost/expenditures and benefits of new RES(-E) installations (2021 to 2030), expressing yearly average (2021 to 2030) monetary values at EU-27 level in absolute terms (left) and the change compared to reference (for the assessed policy pathway 3b (QUO medium))

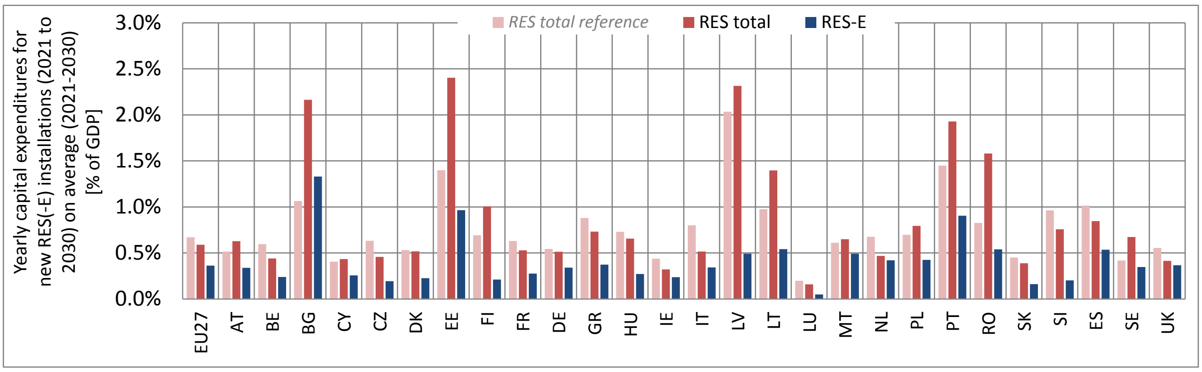


Figure A - 40. Country-specific breakdown of yearly average (2021 to 2030) capital expenditures in new RES and RES-E installations (2021 to 2030), expressing investments as share of (country-specific) GDP (for the assessed policy pathway 3b (QUO medium))

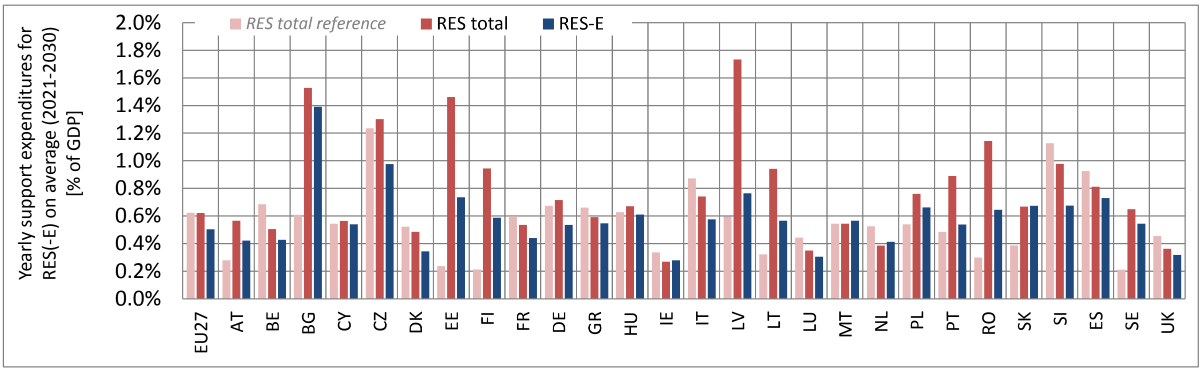


Figure A - 41. Country-specific breakdown of yearly average (2021 to 2030) support expenditures for RES total and RES-E, expressing expenditures as share of (country-specific) GDP (for the assessed policy pathway 3b (QUO medium))

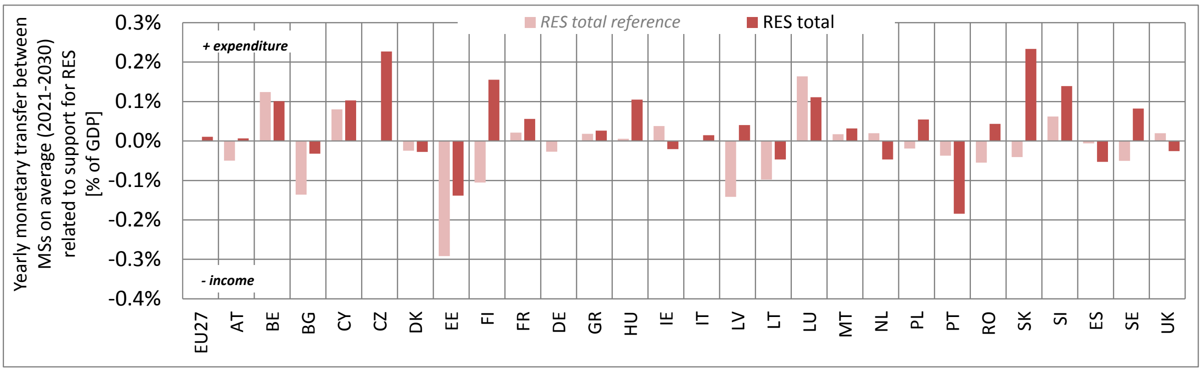


Figure A - 42. Yearly average (2021 to 2030) monetary transfers between Member States related to the support for RES, expressing additional expenditures (+) or income (-) as share of (country-specific) GDP (for the assessed policy pathway 3b (QUO medium))

Note: Additional expenditure or income stems from the underlying cost allocation under a full or medium harmonisation of RES support, or they refer to RES cooperation in the case of soft, minimum or no harmonisation, respectively.

Quota system with banded TGC in the case of *medium harmonisation*

QUO-banding medium (Path 4b)

Brief characterisation: This policy pathway prescribes the EU-wide adoption of a quota system with banded TGCs to support RES-E. Since medium harmonisation is chosen, only an EU-wide target for RES deployment by 2030 is set and an EU-wide harmonised support scheme (i.e. the quota system with banded TGC scheme) aims to provide the necessary basic support which MSs may complement via additional limited incentives to stimulate investments in new RES-E installations.

Thus, there is a very limited role to be played by the MSs since medium harmonisation involves harmonisation of: the detailed design of the support scheme selected, including the level of basic support by technology, and the legal framework as a whole, including regulatory issues. Medium harmonisation gives MSs however the freedom to apply limited additional support (i.e. via investment incentives) to complement the revenues gained through the EU-wide harmonised trading regime. An EU-wide socialisation of the costs related to the EU-wide trading regime takes place whereby the assumption is taken that consumer pay an EU-wide equalised fee per MWh electricity consumed.

General notes on the design of the quota system with technology banding:

- A quota system with technology banding is applied, providing a different weighting to different technologies in terms of the number of green certificates (GC) granted per MWh generation, e.g. wind offshore obtains twice the weighting as wind on-shore. More precisely, these banding factors are adapted over time, i.e. from year to year, in order to reflect technological progress in terms of future cost reductions.
- Quota targets, i.e. the shares of consumed/sold electricity that need to stem from RES-E plants, are defined on a yearly basis for obliged actors.
- Penalties for the case of non-fulfilment of quota obligations are defined.
- Duration of support is limited to 15 years, i.e. a new installation can only receive financial support through certificates during the first 15 years of operation.

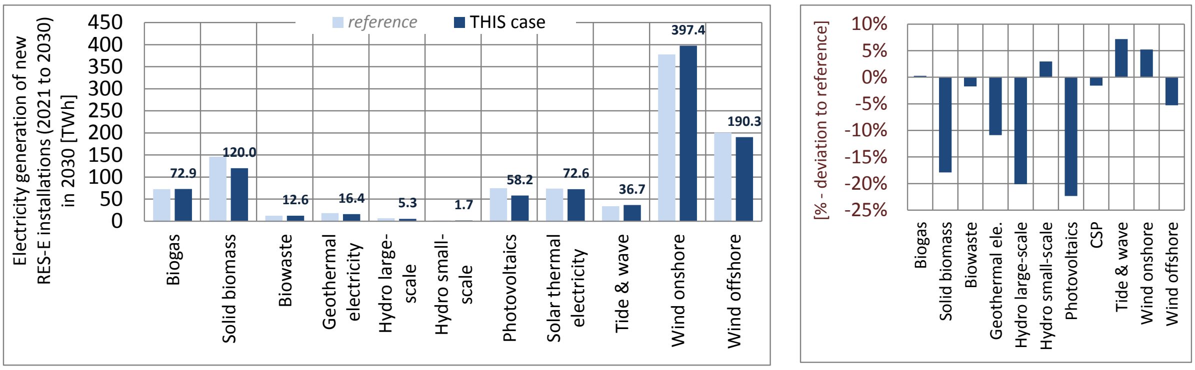


Figure A - 43. Technology-specific breakdown of RES-E generation from new installations (2021 to 2030) at EU-27 level in the year 2030, indicating deployment in absolute terms (left) and the change compared to reference (right) (for the assessed policy pathway 4b (QUO banding medium))

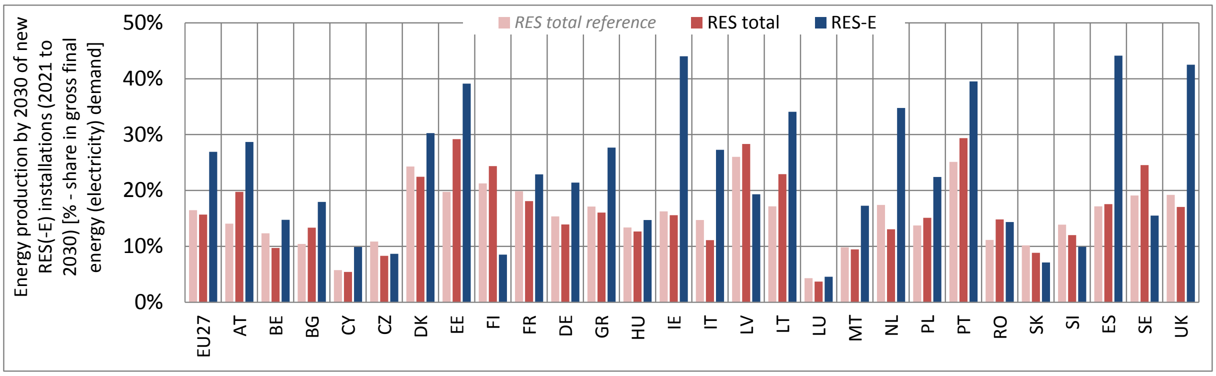


Figure A - 44. Country-specific breakdown of RES and RES-E generation from new installations (2021 to 2030) in the year 2030, indicating RES(-E) deployment as share in corresponding demand (i.e. gross final energy demand for RES total, and gross electricity demand for RES-E) (for the assessed policy pathway 4b (QUO banding medium))

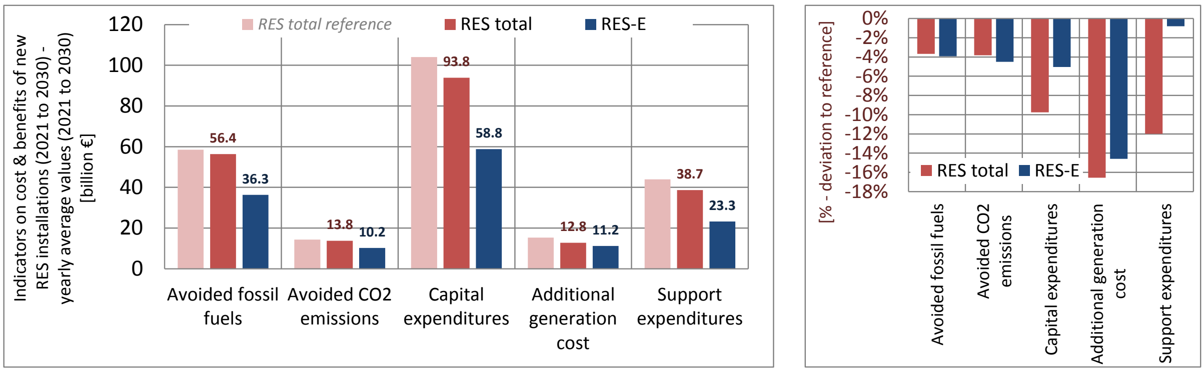


Figure A - 45. Indicators on cost/expenditures and benefits of new RES(-E) installations (2021 to 2030), expressing yearly average (2021 to 2030) monetary values at EU-27 level in absolute terms (left) and the change compared to reference (for the assessed policy pathway 4b (QUO banding medium))

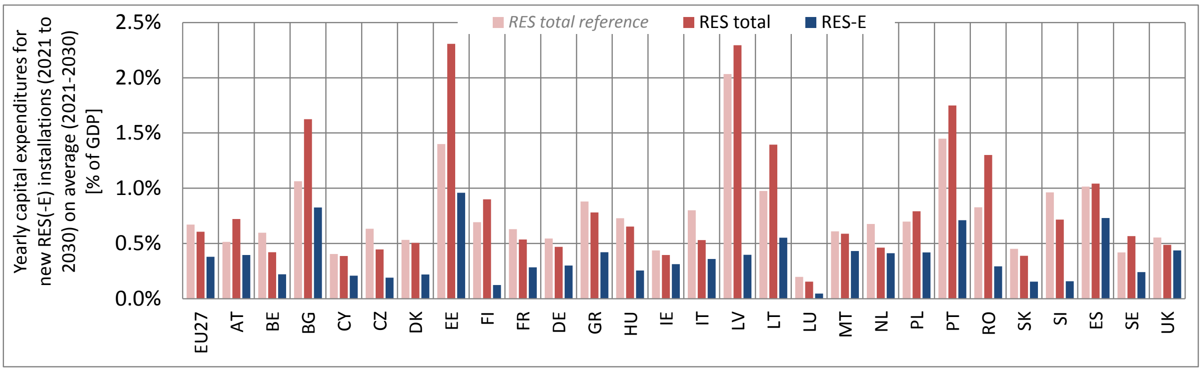


Figure A - 46. Country-specific breakdown of yearly average (2021 to 2030) capital expenditures in new RES and RES-E installations (2021 to 2030), expressing investments as share of (country-specific) GDP (for the assessed policy pathway 4b (QUO banding medium))

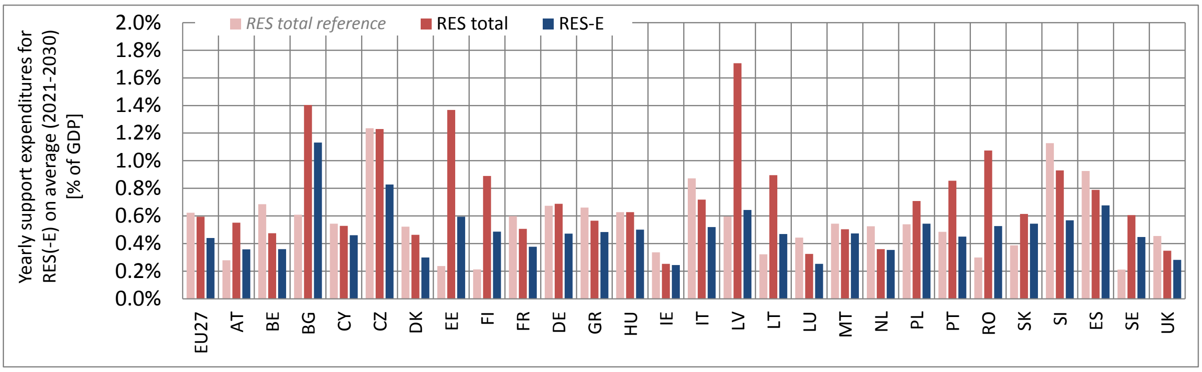


Figure A - 47. Country-specific breakdown of yearly average (2021 to 2030) support expenditures for RES total and RES-E, expressing expenditures as share of (country-specific) GDP (for the assessed policy pathway <u>4b (QUO banding medium)</u>)

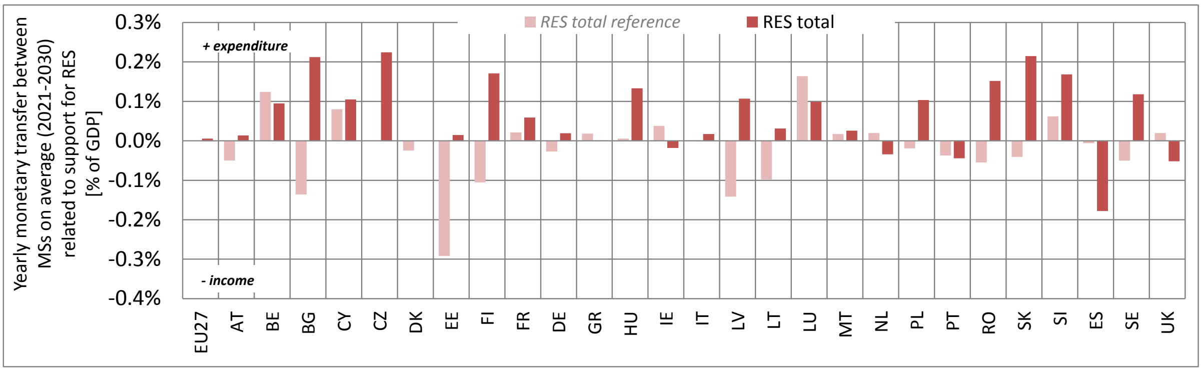


Figure A - 48. Yearly average (2021 to 2030) monetary transfers between Member States related to the support for RES, expressing additional expenditures (+) or income (-) as share of (country-specific) GDP (for the assessed policy pathway <u>4b (QUO banding medium)</u>)

Note: Additional expenditure or income stems from the underlying cost allocation under a full or medium harmonisation of RES support, or they refer to RES cooperation in the case of soft, minimum or no harmonisation, respectively.

Feed-in Tariff system in the case of *soft harmonisation*

FIT
soft
(Path 1c)

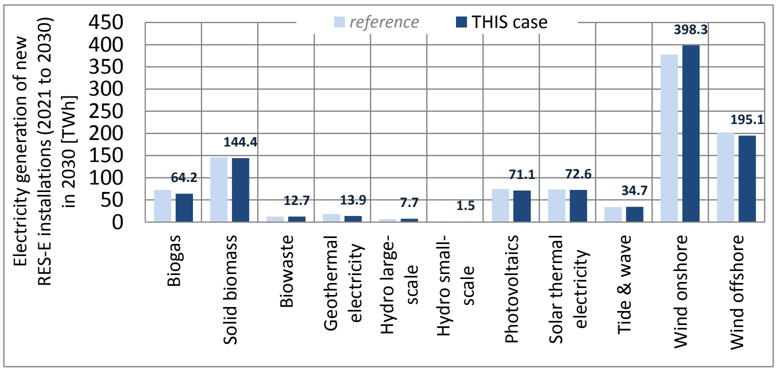
Brief characterisation: This policy pathway prescribes the EU-wide adoption of a system of fixed feed-in tariffs to support RES-E. Since soft harmonisation is chosen, an EU-wide and national targets for RES deployment by 2030 are set and an EU-wide harmonised support scheme (i.e. the fixed feed-in tariff scheme) aims to provide the necessary basic funding which MSs may complement via additional incentives to stimulate and steer investments in new RES-E installations.

Under soft harmonisation MSs have to implement domestically the support scheme that has been decided at EU level. However, countries may in principle use whatever design element they deem best and support levels may differ across countries. For the modelling exercise the assumption is taken that MSs do only partly make us of their freedom, i.e. support levels are now tailored to their country-specific needs to contribute best to domestic target fulfilment (i.e. higher incentives in countries where target fulfilment appears more challenging).

Since national targets for RES by 2030 are in place under this pathway, RES cooperation comes into play that finally affects the overall cost allocation across MSs – i.e. the ultimate height of support expenditures for RES at country level is defined by national RES deployment and the support expenditures related to that, and, on top of that, the additional revenues (for exporting countries) or additional expenditures (for importing countries) related to RES cooperation.

General notes on the design of the feed-in tariff system:

- A system of fixed feed-in tariffs is implemented. A new installation consequently receives the guaranteed remuneration for its electricity feed-in during the whole duration of support whereby also an inflation adaptation is assumed.
- Support levels (i.e. tariffs) differ by technology. Moreover, for wind onshore and PV a “stepped design” is implemented, meaning that within an efficiency corridor support levels reflect site specifics and a higher remuneration is offered to plants at less suitable sites (i.e. lower full load hours) than for plants at best sites whereby care is taken to assure that revenues remain higher to let investor’s strive for best sites.
- Duration of support is limited to 15 years, i.e. a new installation can only receive financial support during the first 15 years of operation.
- An automatic digression of support levels is foreseen, meaning that in accordance with learning expectations a lower support is guaranteed for a new installation in a certain year than in one year before.



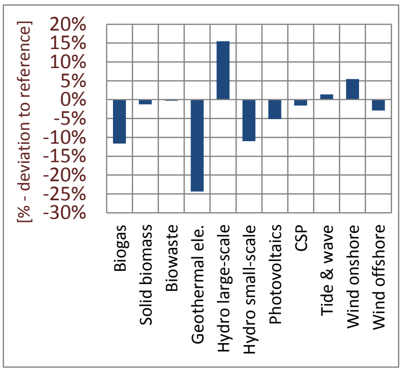


Figure A - 49. Technology-specific breakdown of RES-E generation from new installations (2021 to 2030) at EU-27 level in the year 2030, indicating deployment in absolute terms (left) and the change compared to reference (right) (for the assessed policy pathway 1c (FIT soft))

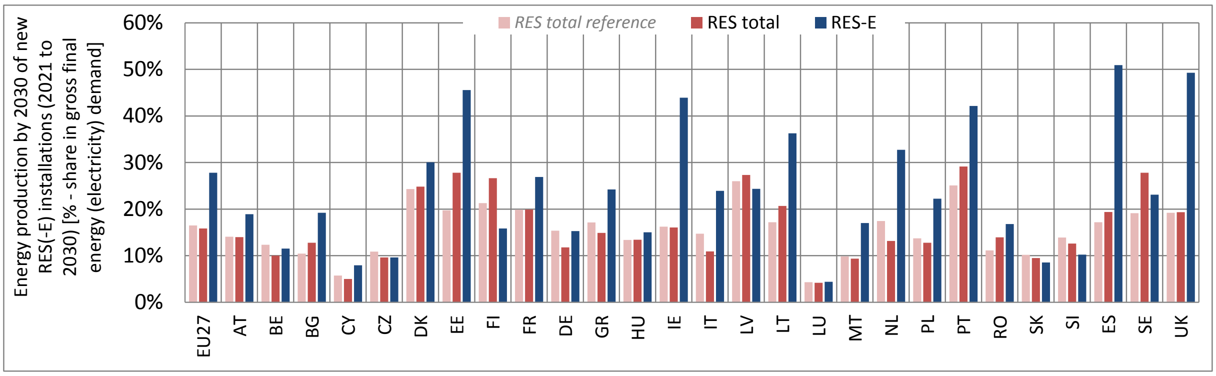


Figure A - 50. Country-specific breakdown of RES and RES-E generation from new installations (2021 to 2030) in the year 2030, indicating RES(-E) deployment as share in corresponding demand (i.e. gross final energy demand for RES total, and gross electricity demand for RES-E) (for the assessed policy pathway 1c (FIT soft))

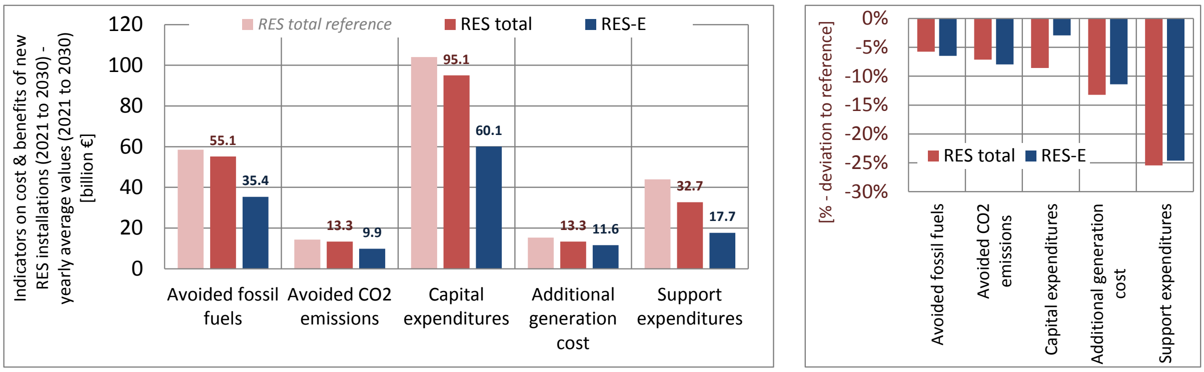


Figure A - 51. Indicators on cost/expenditures and benefits of new RES(-E) installations (2021 to 2030), expressing yearly average (2021 to 2030) monetary values at EU-27 level in absolute terms (left) and the change compared to reference (for the assessed policy pathway 1c (FIT soft))

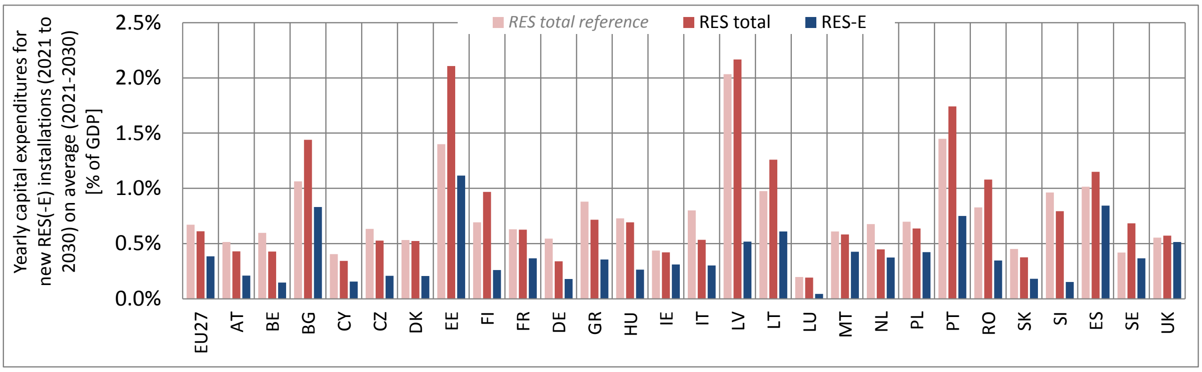


Figure A - 52. Country-specific breakdown of yearly average (2021 to 2030) capital expenditures in new RES and RES-E installations (2021 to 2030), expressing investments as share of (country-specific) GDP (for the assessed policy pathway 1c (FIT soft))

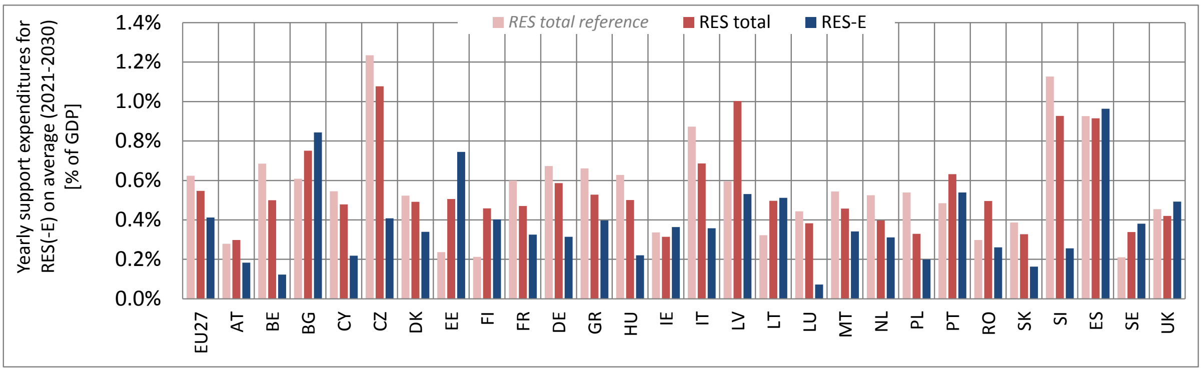


Figure A - 53. Country-specific breakdown of yearly average (2021 to 2030) support expenditures for RES total and RES-E, expressing expenditures as share of (country-specific) GDP (for the assessed policy pathway 1c (FIT soft))

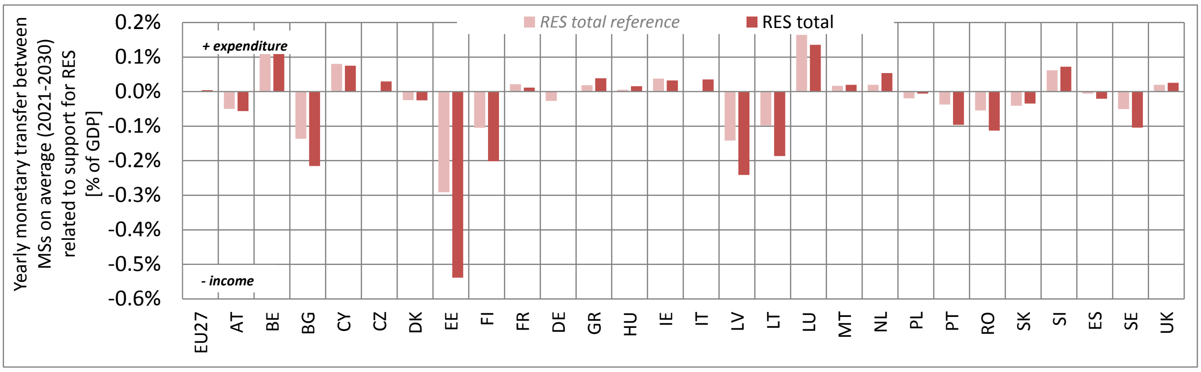


Figure A - 54. Yearly average (2021 to 2030) monetary transfers between Member States related to the support for RES, expressing additional expenditures (+) or income (-) as share of (country-specific) GDP (for the assessed policy pathway 1c (FIT soft))

Note: Additional expenditure or income stems from the underlying cost allocation under a full or medium harmonisation of RES support, or they refer to RES cooperation in the case of soft, minimum or no harmonisation, respectively.

Feed-in Premium system in the case of *soft harmonisation*

FIP
soft
(Path 2c)

Brief characterisation: This policy pathway prescribes the EU-wide adoption of a system of feed-in premiums to support RES-E. Since soft harmonisation is chosen, an EU-wide target and national targets for RES deployment by 2030 are set and an EU-wide harmonised support scheme (i.e. the fixed feed-in premium scheme) aims to provide the necessary basic funding which MSs may complement via additional incentives to stimulate and steer investments in new RES-E installations.

Under soft harmonisation MSs have to implement domestically the support scheme that has been decided at EU level. However, countries may in principle use whatever design element they deem best and support levels may differ across countries. For the modelling exercise the assumption is taken that MSs do only partly make us of their freedom, i.e. support levels (i.e. the premiums) are now tailored to their needs to contribute best to domestic target fulfilment (i.e. higher incentives in countries where target fulfilment appears more challenging).

Since national targets for RES by 2030 are in place under this pathway, RES cooperation comes into play that finally affects the overall cost allocation across MSs – i.e. the ultimate height of support expenditures for RES at country level is defined by national RES deployment and the support expenditures related to that, and, on top of that, the additional revenues (for exporting countries) or additional expenditures (for importing countries) related to RES cooperation.

General notes on the design of the feed-in premium system:

- A system of fixed feed-in premiums is implemented in order to allow for locational signals across the EU.
- A new installation consequently receives the guaranteed premium for its electricity feed-in during the whole duration of support whereby also an inflation adaptation is assumed.
- Support levels (i.e. premiums) differ by technology. Moreover, for wind onshore and PV a “stepped design” is implemented, meaning that within an efficiency corridor support levels reflect site specifics and a higher remuneration is offered to plants at less suitable sites (i.e. lower full load hours) than for plants at best sites whereby care is taken to assure that revenues remain higher to let investor’s strive for best sites.
- Duration of support is limited to 15 years, i.e. a new installation can only receive financial support during the first 15 years of operation.
- An automatic digression of support levels is foreseen, meaning that in accordance with learning expectations a lower support is guaranteed for a new installation in a certain year than in one year before.

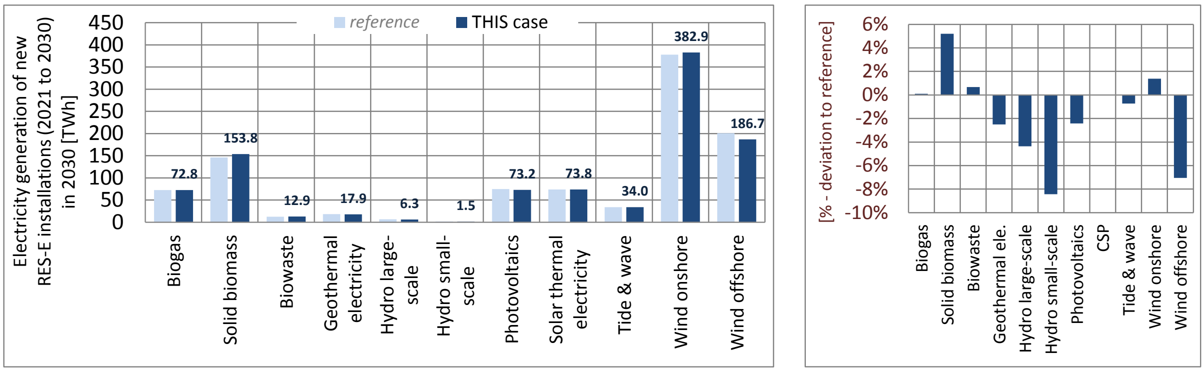


Figure A - 55. Technology-specific breakdown of RES-E generation from new installations (2021 to 2030) at EU-27 level in the year 2030, indicating deployment in absolute terms (left) and the change compared to reference (right) (for the assessed policy pathway 2c (FIP soft))

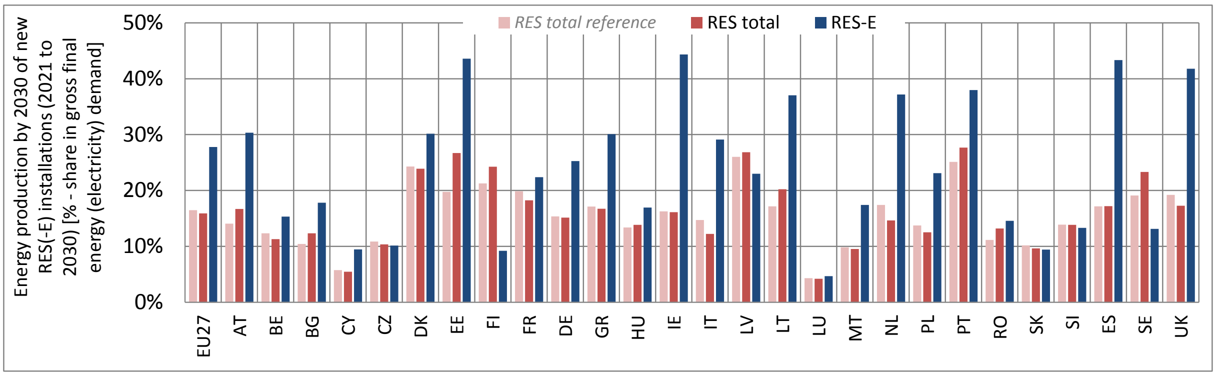


Figure A - 56. Country-specific breakdown of RES and RES-E generation from new installations (2021 to 2030) in the year 2030, indicating RES(-E) deployment as share in corresponding demand (i.e. gross final energy demand for RES total, and gross electricity demand for RES-E) (for the assessed policy pathway 2c (FIP soft))

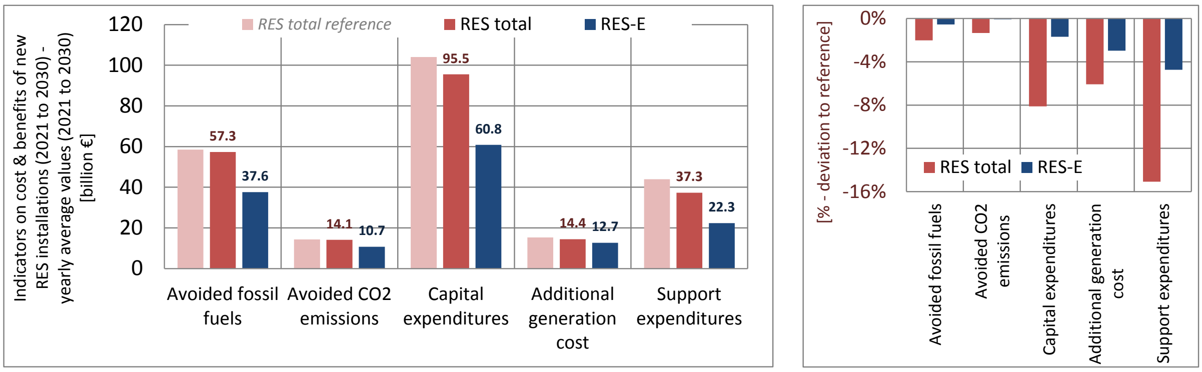


Figure A - 57. Indicators on cost/expenditures and benefits of new RES(-E) installations (2021 to 2030), expressing yearly average (2021 to 2030) monetary values at EU-27 level in absolute terms (left) and the change compared to reference (for the assessed policy pathway 2c (FIP soft))

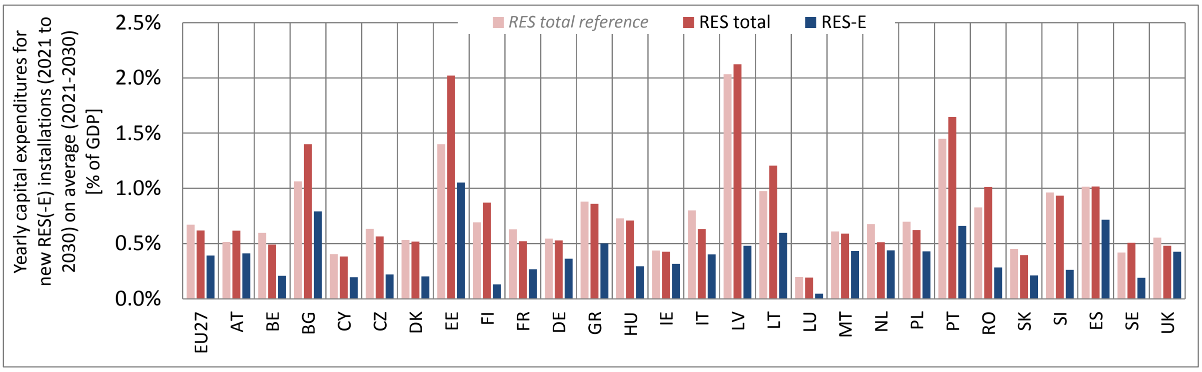


Figure A - 58. Country-specific breakdown of yearly average (2021 to 2030) capital expenditures in new RES and RES-E installations (2021 to 2030), expressing investments as share of (country-specific) GDP (for the assessed policy pathway 2c (FIP soft))

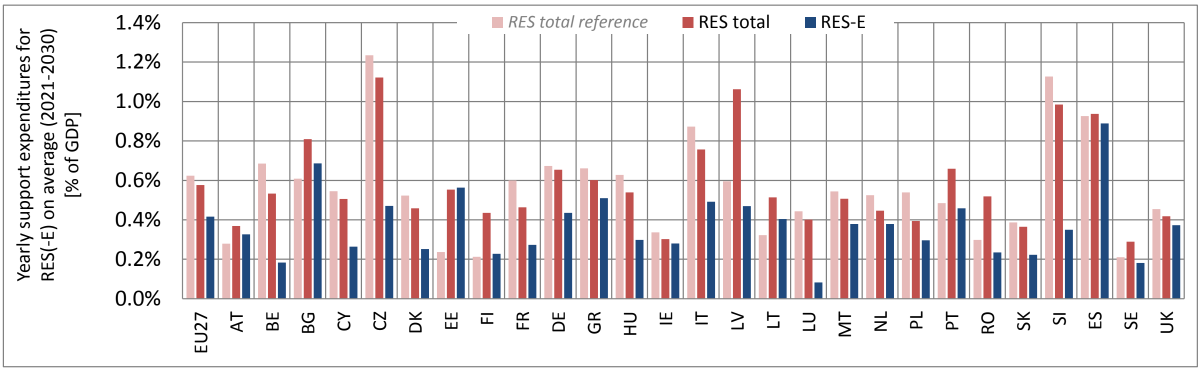


Figure A - 59. Country-specific breakdown of yearly average (2021 to 2030) support expenditures for RES total and RES-E, expressing expenditures as share of (country-specific) GDP (for the assessed policy pathway 2c (FIP soft))

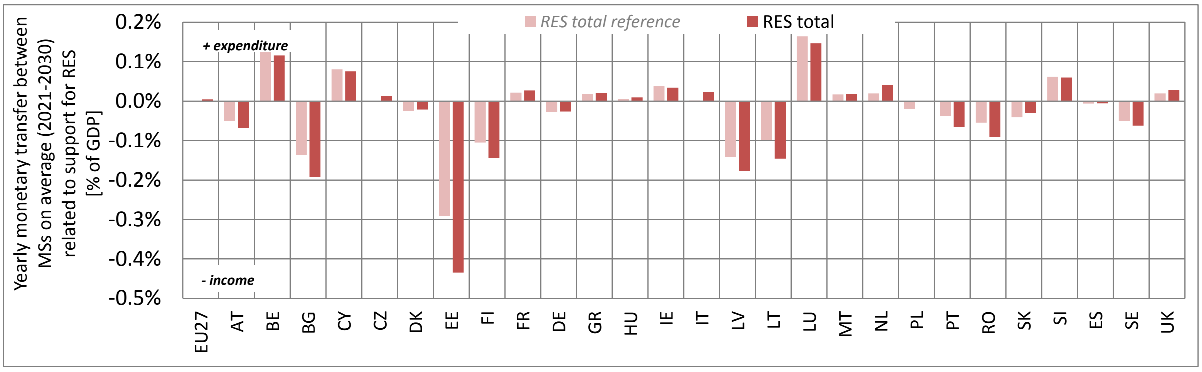


Figure A - 60. Yearly average (2021 to 2030) monetary transfers between Member States related to the support for RES, expressing additional expenditures (+) or income (-) as share of (country-specific) GDP (for the assessed policy pathway 2c (FIP soft))

Note: Additional expenditure or income stems from the underlying cost allocation under a full or medium harmonisation of RES support, or they refer to RES cooperation in the case of soft, minimum or no harmonisation, respectively.

Quota system in the case of *soft harmonisation*

QUO
soft
(Path 3c)

Brief characterisation: This policy pathway prescribes the EU-wide adoption of a quota system to support RES-E. Since soft harmonisation is chosen, an EU-wide target and national targets for RES deployment by 2030 are set and an EU-wide harmonised support scheme (i.e. the uniform quota scheme) aims to provide the necessary basic funding which MSs may complement via additional incentives to stimulate and steer investments in new RES-E installations.

Under soft harmonisation MSs have to implement domestically the support scheme that has been decided at EU level. However, countries may in principle use complementary incentives or select upon design elements in their main scheme (i.e. the quotas system). For the modelling exercise the assumption is taken that MSs do only partly make us of their freedom, i.e. they define complementary support (i.e. via investment incentives) according to their needs to contribute best to domestic target fulfilment. An EU-wide socialisation of support expenditures is only necessary for the part referring to the EU-wide harmonised basic support (i.e. the trading regime).

Since national targets for RES by 2030 are in place under this pathway, RES cooperation comes into play that finally affects the overall cost allocation across MSs – i.e. the ultimate height of support expenditures for RES at country level is defined by national RES deployment and the support expenditures related to that, the cross-country exchange of expenditures related to the trading regime for RES-E, and, on top of that, the additional revenues (for exporting countries) or additional expenditures (for importing countries) related to RES cooperation.

General notes on the design of the uniform quota system:

- A uniform quota system is implemented, meaning that no differentiation of support takes place by technology.
- Quota targets, i.e. the shares of consumed/sold electricity that need to stem from RES-E plants, are defined on a yearly basis for obliged actors.
- Penalties for the case of non-fulfilment of quota obligations are defined.
- Duration of support is limited to 15 years, i.e. a new installation can only receive financial support through certificates during the first 15 years of operation.

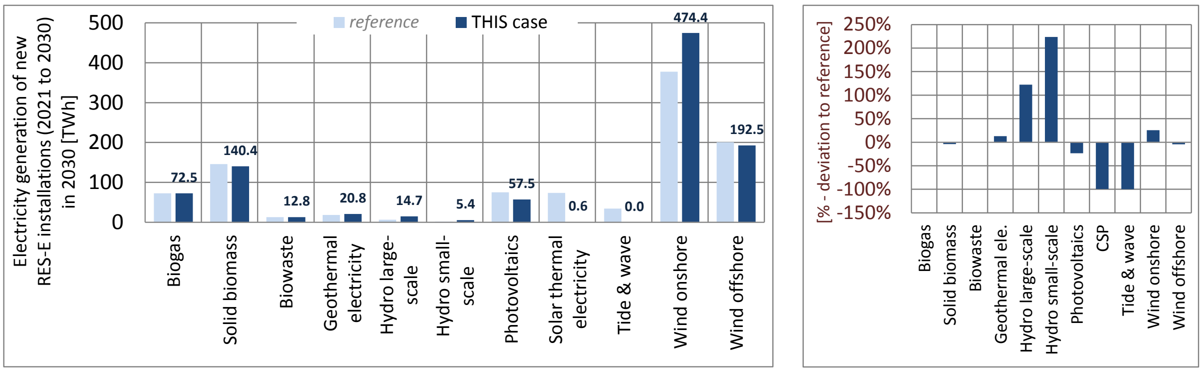


Figure A - 61. Technology-specific breakdown of RES-E generation from new installations (2021 to 2030) at EU-27 level in the year 2030, indicating deployment in absolute terms (left) and the change compared to reference (right) (for the assessed policy pathway 3c (QUO soft))

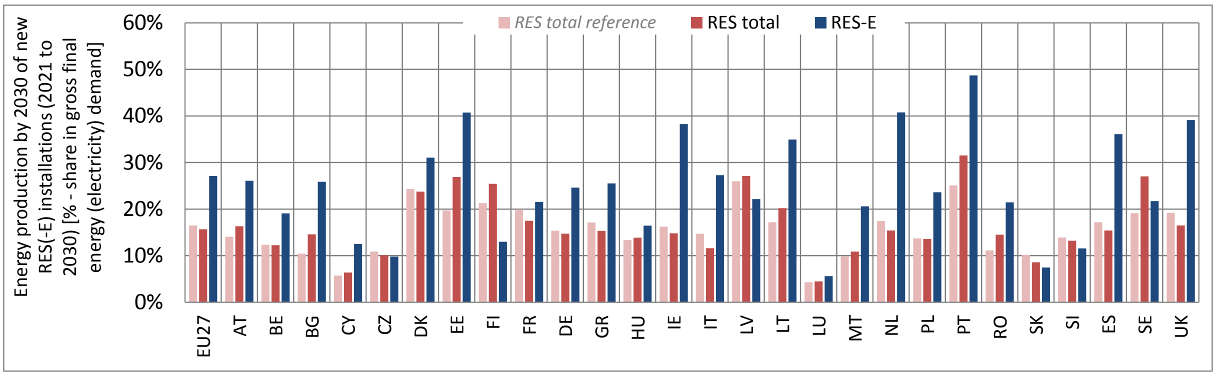


Figure A - 62. Country-specific breakdown of RES and RES-E generation from new installations (2021 to 2030) in the year 2030, indicating RES(-E) deployment as share in corresponding demand (i.e. gross final energy demand for RES total, and gross electricity demand for RES-E) (for the assessed policy pathway 3c (QUO soft))

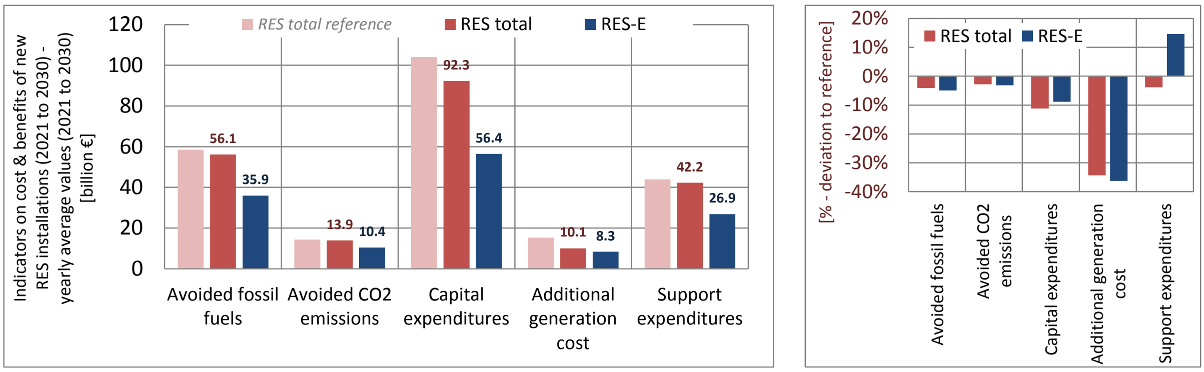


Figure A - 63. Indicators on cost/expenditures and benefits of new RES(-E) installations (2021 to 2030), expressing yearly average (2021 to 2030) monetary values at EU-27 level in absolute terms (left) and the change compared to reference (for the assessed policy pathway 3c (QUO soft))

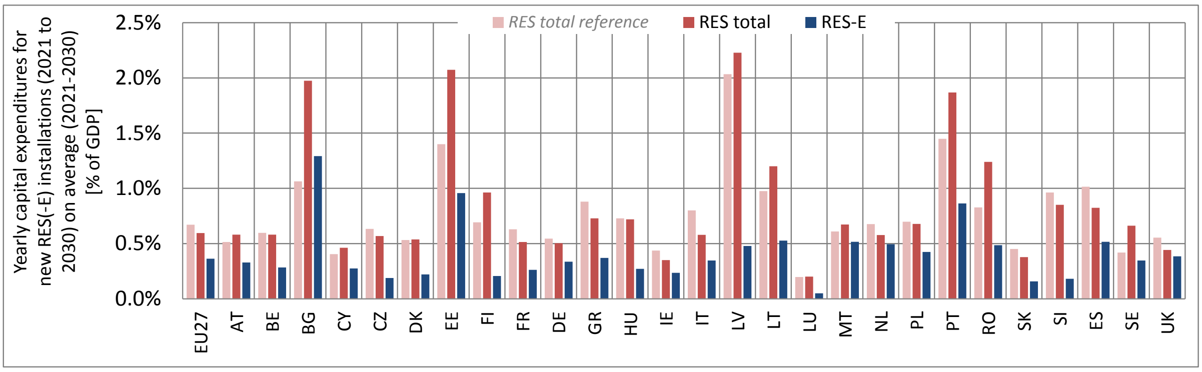


Figure A - 64. Country-specific breakdown of yearly average (2021 to 2030) capital expenditures in new RES and RES-E installations (2021 to 2030), expressing investments as share of (country-specific) GDP (for the assessed policy pathway 3c (QUO soft))

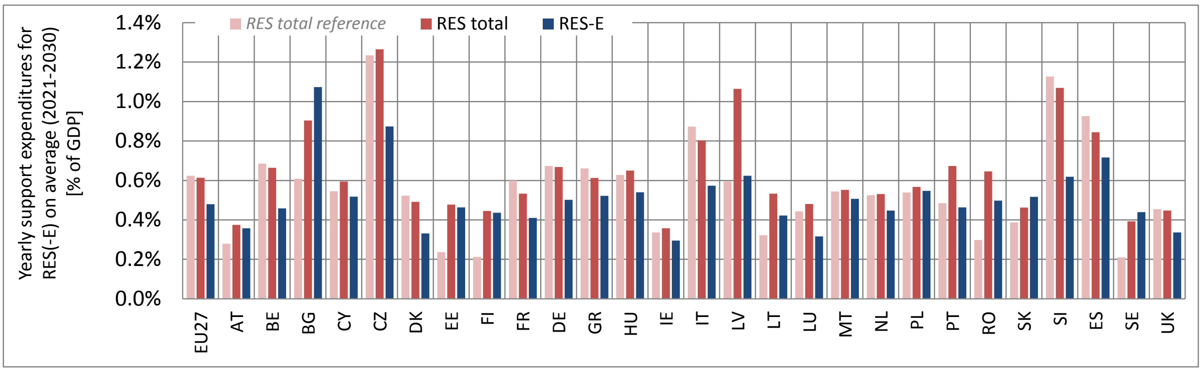


Figure A - 65. Country-specific breakdown of yearly average (2021 to 2030) support expenditures for RES total and RES-E, expressing expenditures as share of (country-specific) GDP (for the assessed policy pathway 3c (QUO soft))

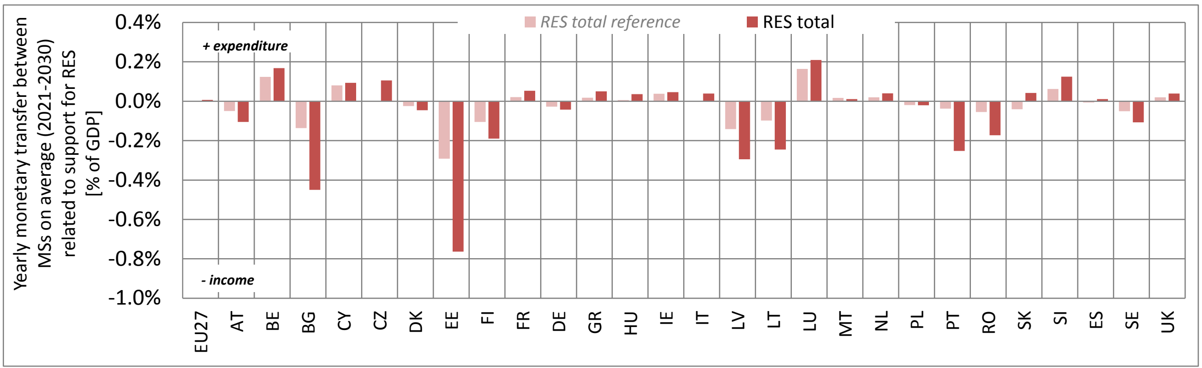


Figure A - 66. Yearly average (2021 to 2030) monetary transfers between Member States related to the support for RES, expressing additional expenditures (+) or income (-) as share of (country-specific) GDP (for the assessed policy pathway 3c (QUO soft))

Note: Additional expenditure or income stems from the underlying cost allocation under a full or medium harmonisation of RES support, or they refer to RES cooperation in the case of soft, minimum or no harmonisation, respectively.

Quota system with banded TGC in the case of *soft harmonisation*

QUO-banding soft (Path 4c)

Brief characterisation: This policy pathway prescribes the EU-wide adoption of a quota system with banded TGCs feed-in tariffs to support RES-E. Since soft harmonisation is chosen, an EU-wide target and national targets for RES by 2030 are set and an EU-wide harmonised support scheme (i.e. the quota scheme with banding) aims to provide the necessary basic funding which MSs may complement via additional incentives to stimulate and steer investments in new RES-E.

Under soft harmonisation MSs have to implement domestically the support scheme that has been decided at EU level. However, countries may in principle use complementary incentives or select upon design elements in their main scheme (i.e. the quotas system). For the modelling exercise the assumption is taken that MSs do only partly make us of their freedom, i.e. they define complementary support (i.e. via investment incentives) according to their needs to contribute best to domestic target fulfilment. An EU-wide socialisation of support expenditures is only necessary for the part referring to the EU-wide harmonised basic support (i.e. the trading regime).

Since national targets for RES by 2030 are in place under this pathway, RES cooperation comes into play that finally affects the overall cost allocation across MSs – i.e. the ultimate height of support expenditures for RES at country level is defined by national RES deployment and the support expenditures related to that, the cross-country exchange of expenditures related to the trading regime for RES-E, and, on top of that, the additional revenues (for exporting countries) or additional expenditures (for importing countries) related to RES cooperation.

General notes on the design of the quota system with technology banding:

- A quota system with technology banding is applied, providing a different weighting to different technologies in terms of the number of green certificates (GC) granted per MWh generation, e.g. wind offshore obtains twice the weighting as wind on-shore. More precisely, these banding factors are adapted over time, i.e. from year to year, in order to reflect technological progress in terms of future cost reductions.
- Quota targets, i.e. the shares of consumed/sold electricity that need to stem from RES-E plants, are defined on a yearly basis for obliged actors.
- Penalties for the case of non-fulfilment of quota obligations are defined.
- Duration of support is limited to 15 years, i.e. a new installation can only receive financial support through certificates during the first 15 years of operation.

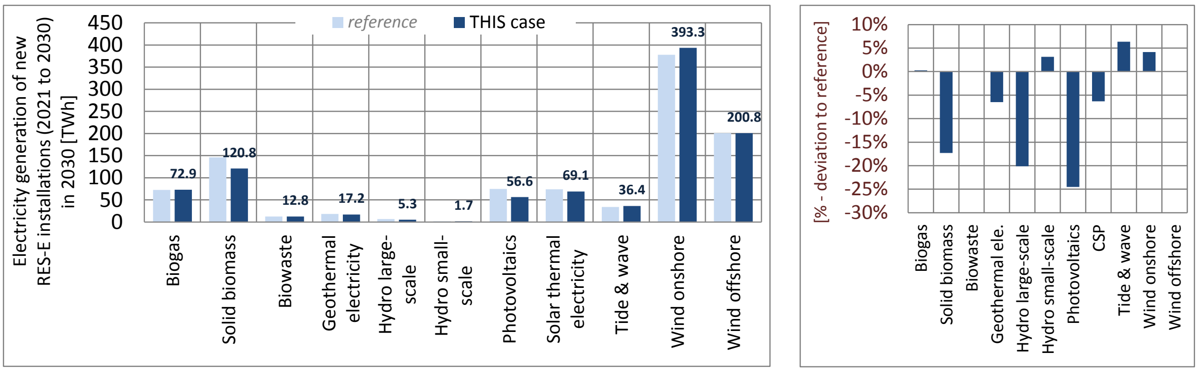


Figure A - 67. Technology-specific breakdown of RES-E generation from new installations (2021 to 2030) at EU-27 level in the year 2030, indicating deployment in absolute terms (left) and the change compared to reference (right) (for the assessed policy pathway 4c (QUO banding soft))

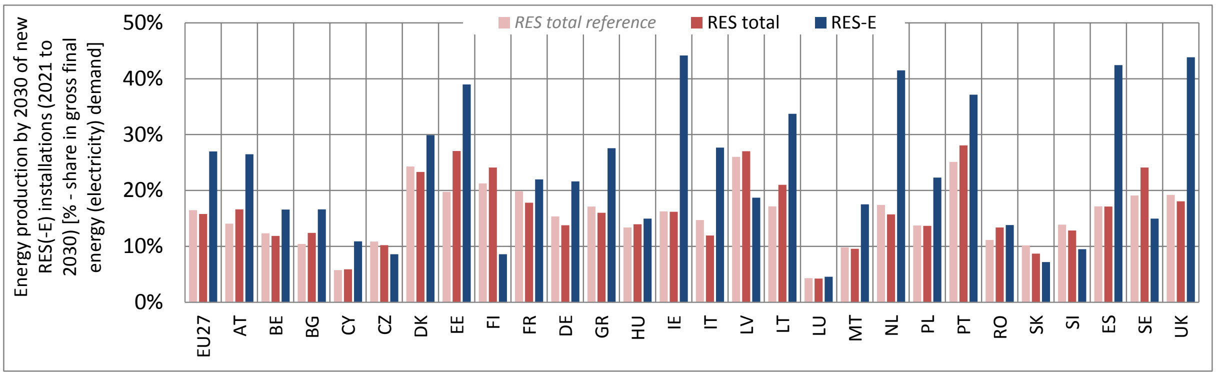
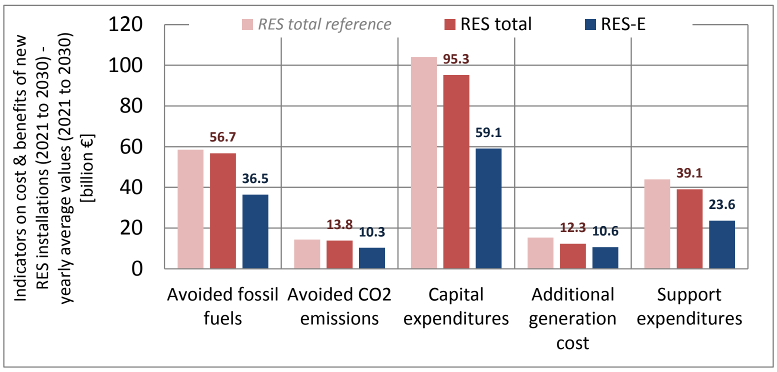


Figure A - 68. Country-specific breakdown of RES and RES-E generation from new installations (2021 to 2030) in the year 2030, indicating RES(-E) deployment as share in corresponding demand (i.e. gross final energy demand for RES total, and gross electricity demand for RES-E) (for the assessed policy pathway 4c (QUO banding soft))



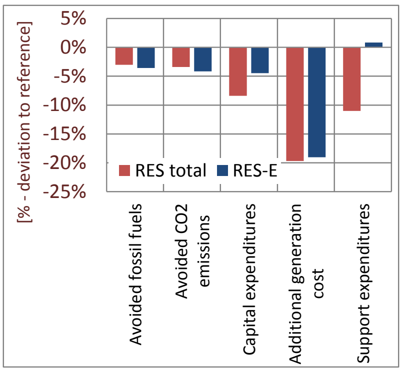


Figure A - 69. Indicators on cost/expenditures and benefits of new RES(-E) installations (2021 to 2030), expressing yearly average (2021 to 2030) monetary values at EU-27 level in absolute terms (left) and the change compared to reference (for the assessed policy pathway 4c (QUO banding soft))

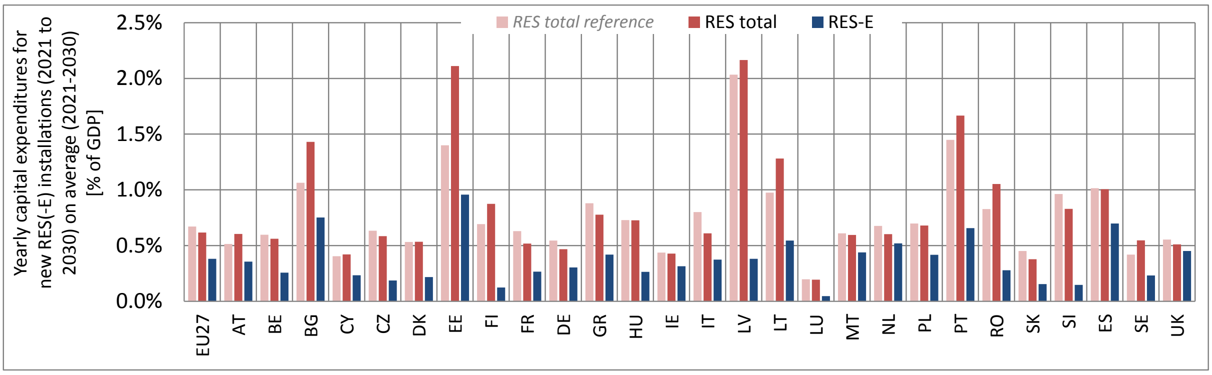


Figure A - 70. Country-specific breakdown of yearly average (2021 to 2030) capital expenditures in new RES and RES-E installations (2021 to 2030), expressing investments as share of (country-specific) GDP (for the assessed policy pathway 4c (QUO banding soft))

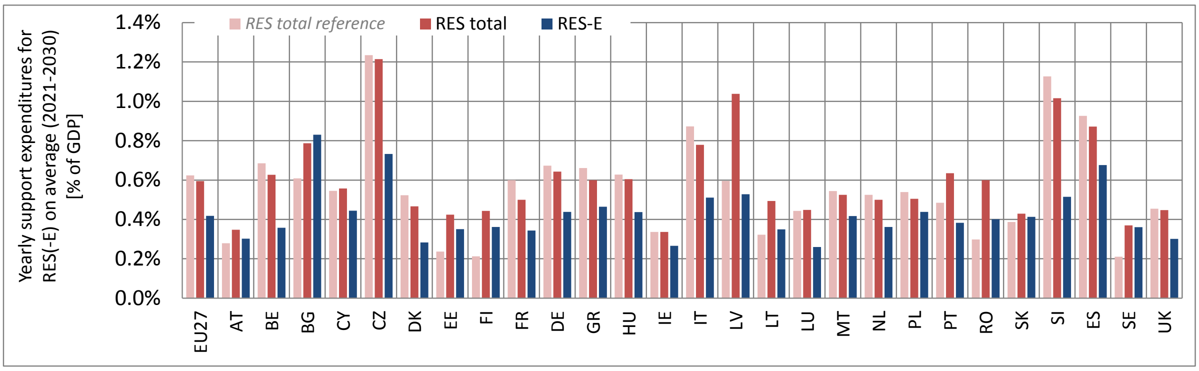


Figure A - 71. Country-specific breakdown of yearly average (2021 to 2030) support expenditures for RES total and RES-E, expressing expenditures as share of (country-specific) GDP (for the assessed policy pathway 4c (QUO banding soft))

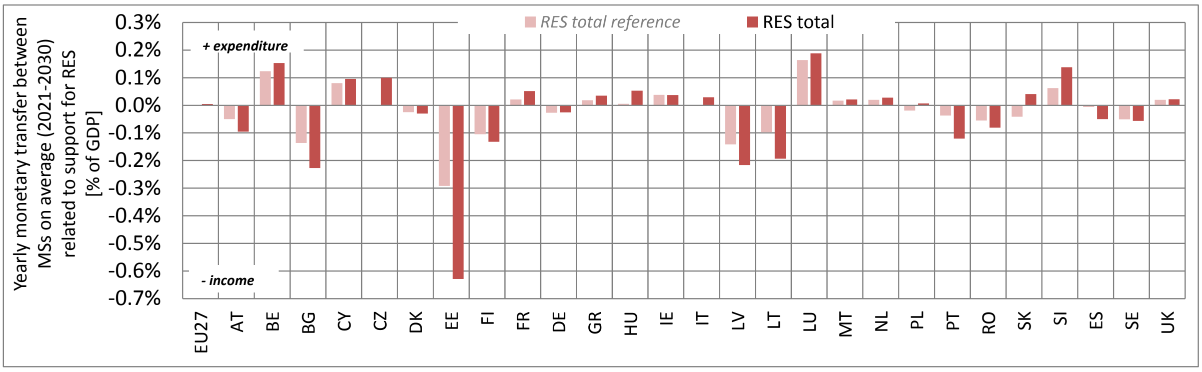


Figure A - 72. Yearly average (2021 to 2030) monetary transfers between Member States related to the support for RES, expressing additional expenditures (+) or income (-) as share of (country-specific) GDP (for the assessed policy pathway 4c (QUO banding soft))

Note: Additional expenditure or income stems from the underlying cost allocation under a full or medium harmonisation of RES support, or they refer to RES cooperation in the case of soft, minimum or no harmonisation, respectively.

ETS only

ETS
only
(Path 5)

Brief characterisation: Under this pathway, no binding RES targets would exist for 2030. Instead, the European Emission Trading Scheme (ETS) represents the key driver at EU level for the deployment of low carbon technologies in the period beyond 2020, under which two variants are considered: a scenario of "low carbon prices" corresponding to the Commission's policy option of a "business as usual" development; and a case of "moderate to high carbon prices", reflecting a decarbonisation without dedicated RES targets post-2020.

Subsequently, results for the latter variant are presented. Thus, since no dedicated incentives for RES are assumed to be in place no related (direct) support expenditures for new RES installed in the period 2021 to 2030 occur and, consequently, can be indicated.

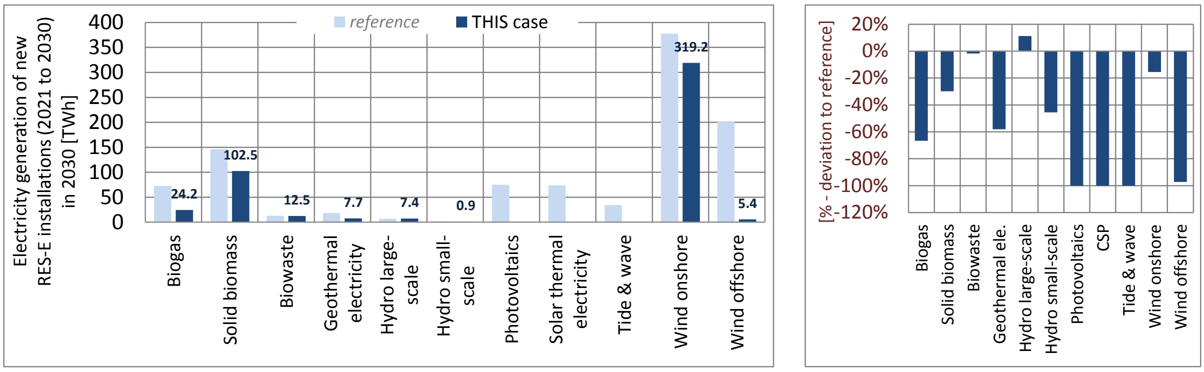


Figure A - 73. Technology-specific breakdown of RES-E generation from new installations (2021 to 2030) at EU-27 level in the year 2030, indicating deployment in absolute terms (left) and the change compared to reference (right) (for the assessed policy pathway 5 (ETS only))

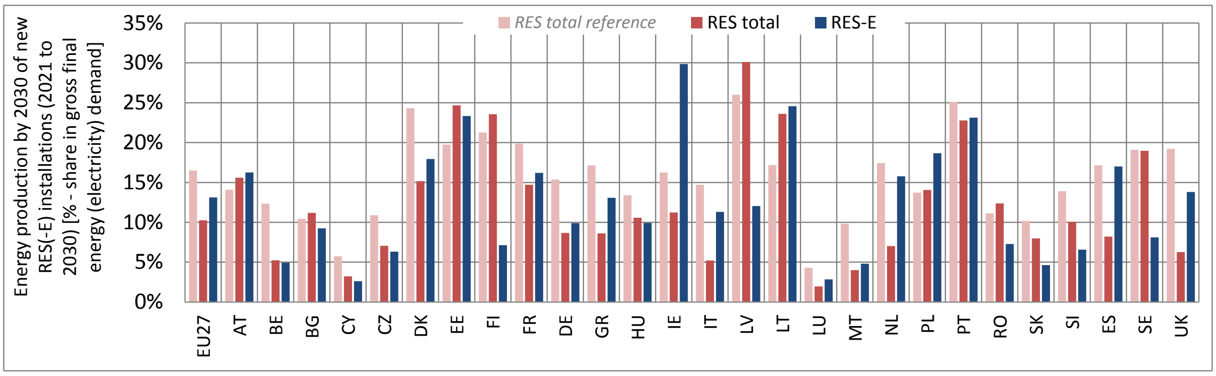


Figure A - 74. Country-specific breakdown of RES and RES-E generation from new installations (2021 to 2030) in the year 2030, indicating RES(-E) deployment as share in corresponding demand (i.e. gross final energy demand for RES total, and gross electricity demand for RES-E) (for the assessed policy pathway 5 (ETS only))

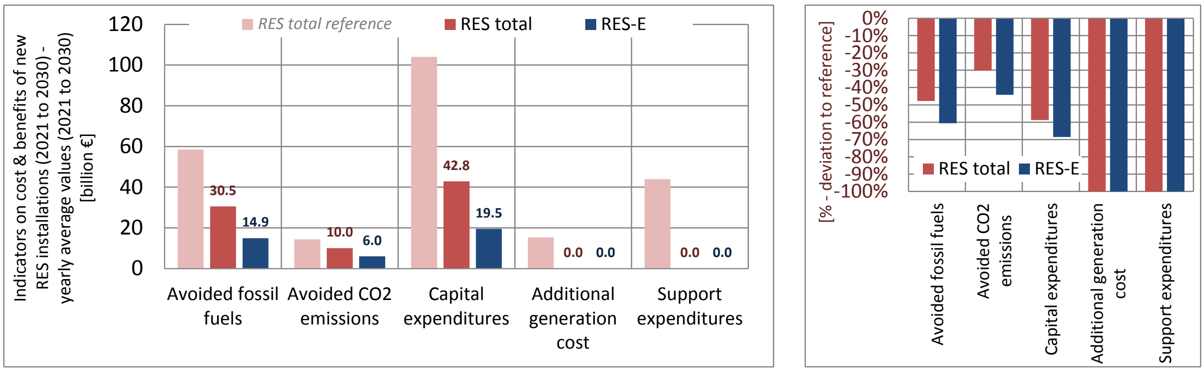


Figure A - 75. Indicators on cost/expenditures and benefits of new RES(-E) installations (2021 to 2030), expressing yearly average (2021 to 2030) monetary values at EU-27 level in absolute terms (left) and the change compared to reference (for the assessed policy pathway 5 (ETS only))

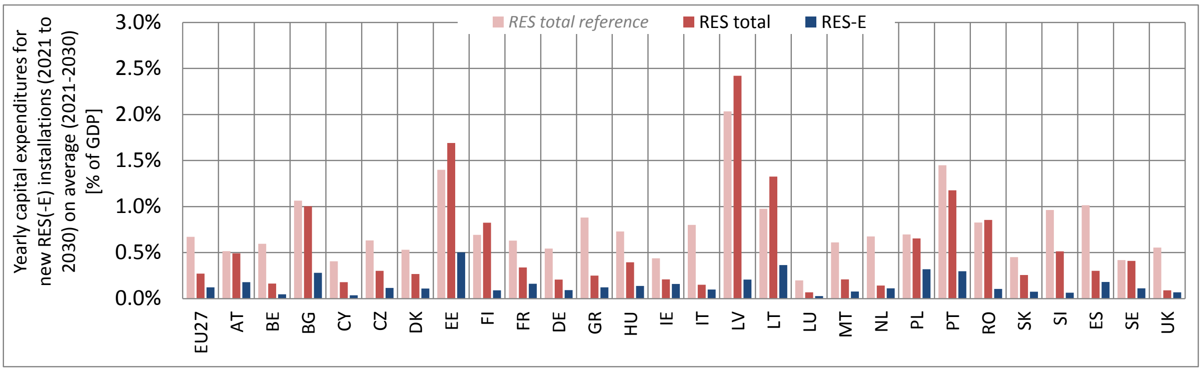


Figure A - 76. Country-specific breakdown of yearly average (2021 to 2030) capital expenditures in new RES and RES-E installations (2021 to 2030), expressing investments as share of (country-specific) GDP (for the assessed policy pathway 5 (ETS only))

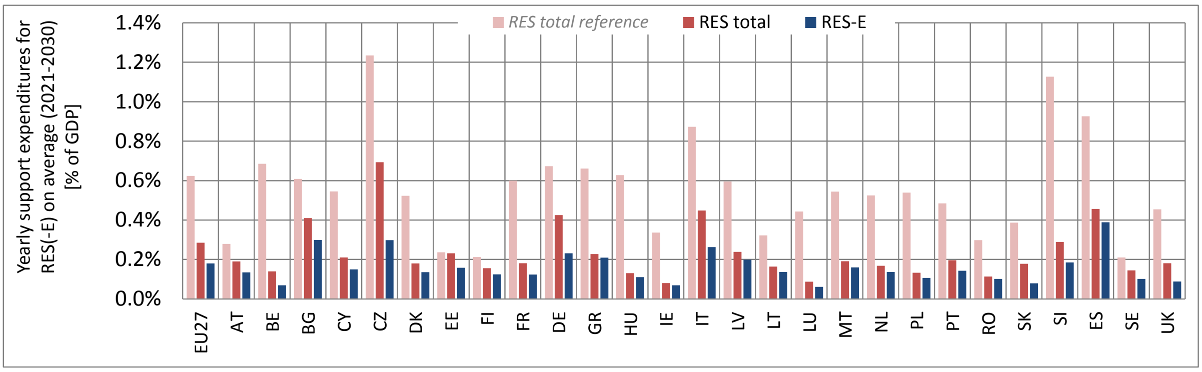


Figure A - 77. Country-specific breakdown of yearly average (2021 to 2030) support expenditures for RES total and RES-E, expressing expenditures as share of (country-specific) GDP (for the assessed policy pathway 5 (ETS only))

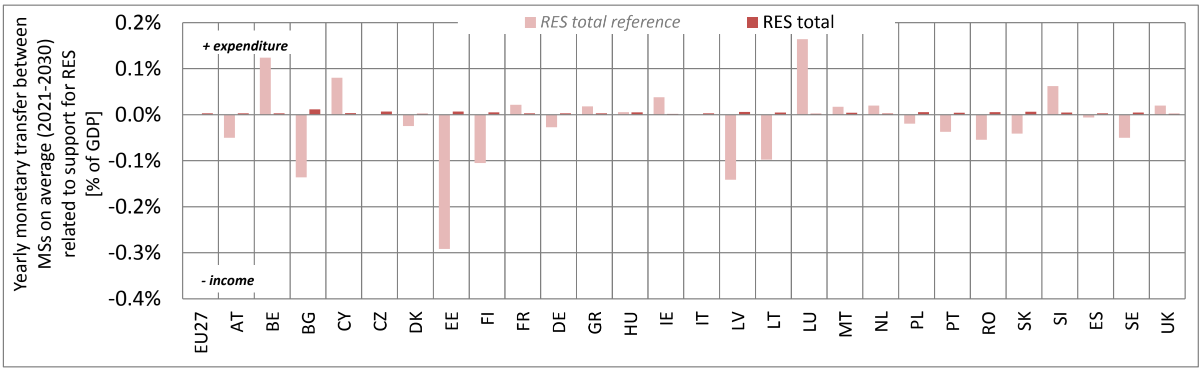


Figure A - 78. Yearly average (2021 to 2030) monetary transfers between Member States related to the support for RES, expressing additional expenditures (+) or income (-) as share of (country-specific) GDP (for the assessed policy pathway 5 (ETS only))

Note: Additional expenditure or income stems from the underlying cost allocation under a full or medium harmonisation of RES support, or they refer to RES cooperation in the case of soft, minimum or no harmonisation, respectively.

Tendering system – EU-wide tenders for selected RES-E technologies

TEN
(Path 6)

Brief characterisation: This policy pathway represents a variant of the reference case of strengthened national support under minimum harmonisation (i.e. with minimum design criteria). EU-wide tenders are used to support investments in new wind (on- and offshore) and centralised solar (large-scale centralised PV systems and CSP) installations. Note that no complementary support is foreseen for these technologies – i.e. the tendering system has to provide a sufficiently high remuneration.

Since national targets for RES by 2030 are in place under this pathway, RES cooperation comes into play that finally affects the overall cost allocation across MSs – i.e. the ultimate height of support expenditures for RES at country level is defined by national RES deployment and the support expenditures related to that, and, on top of that, the additional revenues (for exporting countries) or additional expenditures (for importing countries) related to RES cooperation.

General notes on the design of the EU-wide tendering system for wind and solar:

- EU-wide tenders are assumed to be in place for new wind and centralised solar systems beyond 2020.
- RES investors apply for a guaranteed remuneration (i.e. via a fixed purchase agreement, similar to a fixed feed-in tariff system) to cover their expenses.
- Strategic behaviour is assumed to be partly in place, meaning that investors set their offer prices according to the marginal bid at technology and country level.
- Duration of support is limited to 15 years, i.e. a new installation can only receive financial support during the first 15 years of operation.

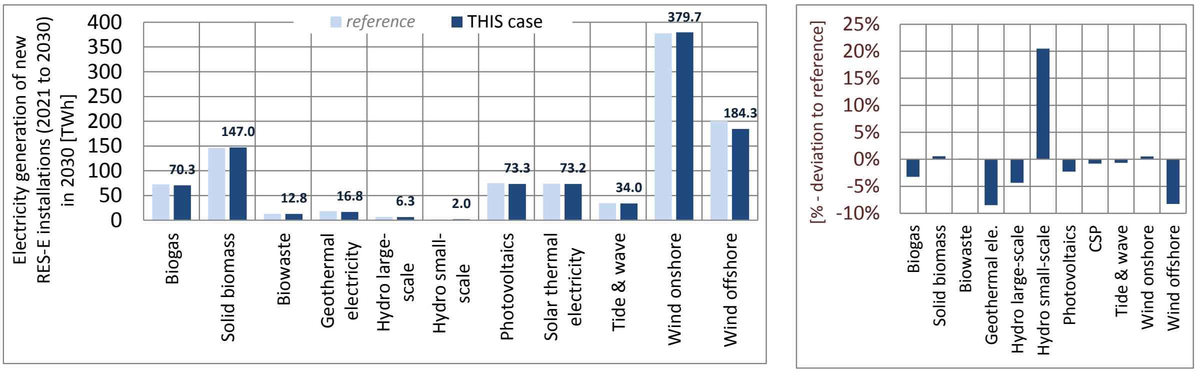


Figure A - 79. Technology-specific breakdown of RES-E generation from new installations (2021 to 2030) at EU-27 level in the year 2030, indicating deployment in absolute terms (left) and the change compared to reference (right) (for the assessed policy pathway 6 (TEN))

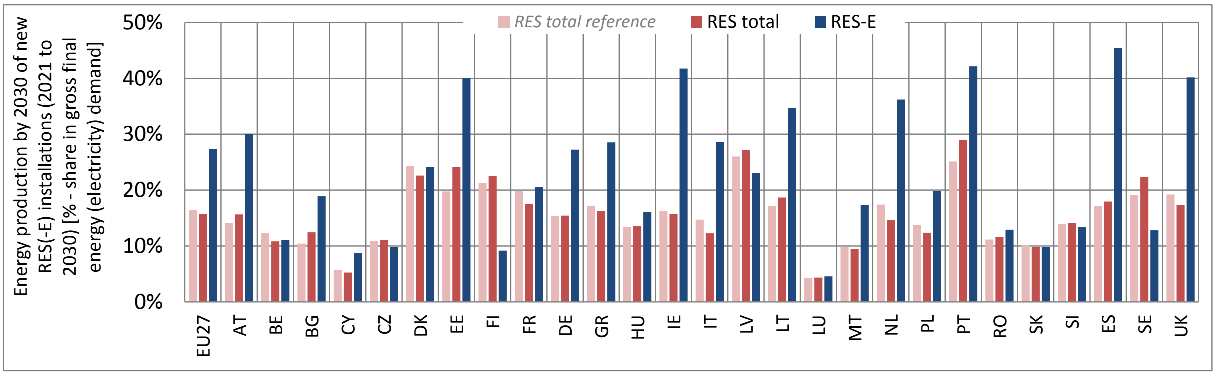


Figure A - 80. Country-specific breakdown of RES and RES-E generation from new installations (2021 to 2030) in the year 2030, indicating RES(-E) deployment as share in corresponding demand (i.e. gross final energy demand for RES total, and gross electricity demand for RES-E) (for the assessed policy pathway 6 (TEN))

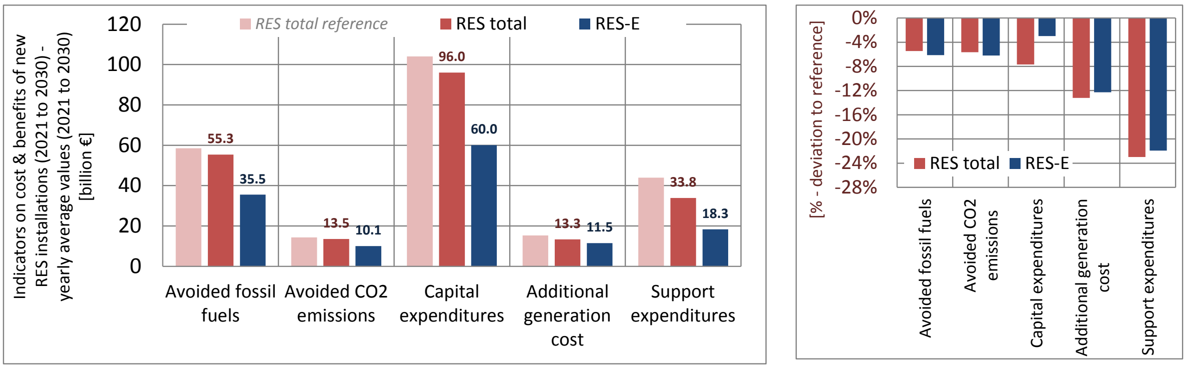


Figure A - 81. Indicators on cost/expenditures and benefits of new RES(-E) installations (2021 to 2030), expressing yearly average (2021 to 2030) monetary values at EU-27 level in absolute terms (left) and the change compared to reference (for the assessed policy pathway 6 (TEN))

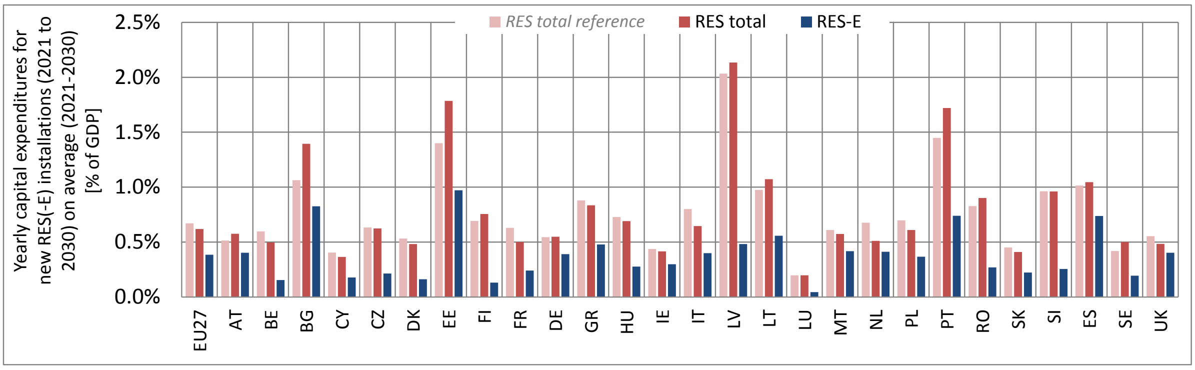


Figure A - 82. Country-specific breakdown of yearly average (2021 to 2030) capital expenditures in new RES and RES-E installations (2021 to 2030), expressing investments as share of (country-specific) GDP (for the assessed policy pathway 6 (TEN))

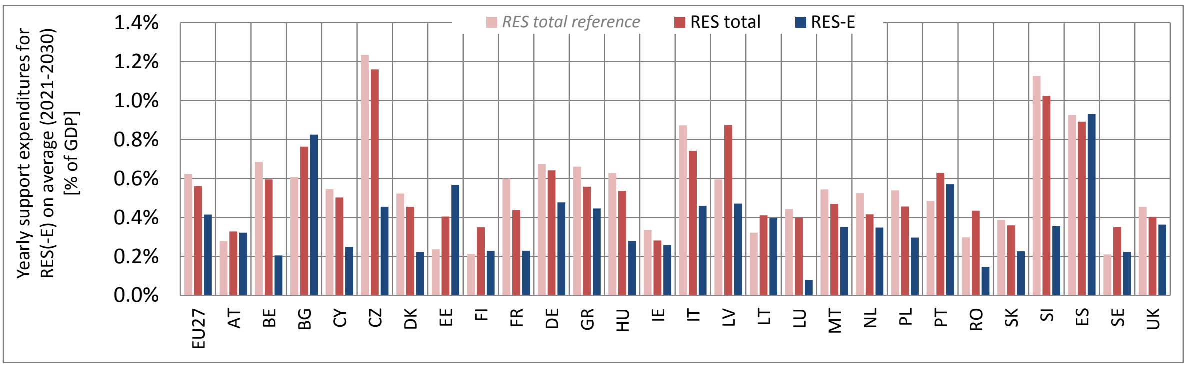


Figure A - 83. Country-specific breakdown of yearly average (2021 to 2030) support expenditures for RES total and RES-E, expressing expenditures as share of (country-specific) GDP (for the assessed policy pathway 6 (TEN))

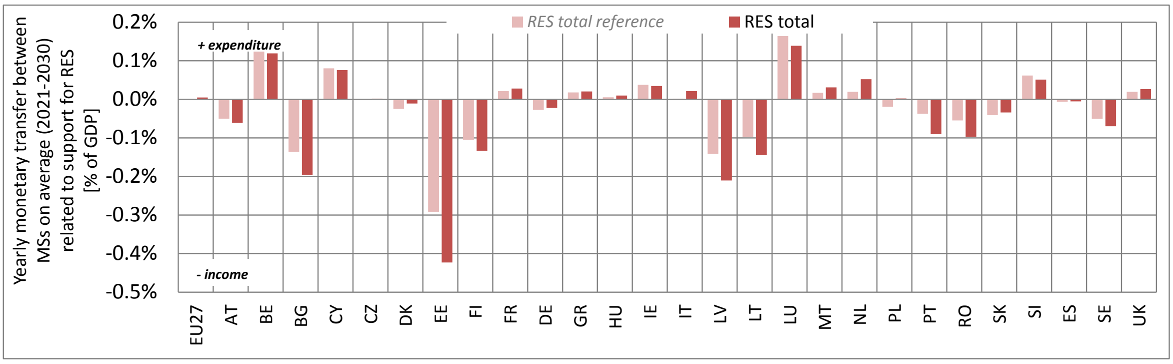


Figure A - 84. Yearly average (2021 to 2030) monetary transfers between Member States related to the support for RES, expressing additional expenditures (+) or income (-) as share of (country-specific) GDP (for the assessed policy pathway 6 (TEN))

Note: Additional expenditure or income stems from the underlying cost allocation under a full or medium harmonisation of RES support, or they refer to RES cooperation in the case of soft, minimum or no harmonisation, respectively.

Reference case with *minimum design standards*

REF min criteria (Path 7d)

Brief characterisation: This pathway builds on the assumption that the current policy framework as given by the RES Directive (2009/28/EC) will be prolonged for the period up to 2030, meaning (inter alia) that national RES targets for 2030 will be established. Similar assumptions are consequently made for RES support – i.e. a continuation of strengthened national RES policies until 2030 which will be further optimised in the future with regard to their effectiveness and efficiency. In particular the further fine-tuning of national support schemes will require in case of both (premium) feed-in tariff and quota systems a technology-specification of RES support.

Minimum harmonisation is assumed to be in place under this reference variant, implying that MSs decide on both the type of support scheme that they apply as well as its design elements. However, minimum design criteria need to be considered for certain design elements. Consequently, in this modelling exercise the assumption is taken that technology-specific support levels may differ only to a limited extent across the EU.[36] This brings up the need for intensified RES cooperation between MSs, where efficient and effective RES target achievement is envisaged at EU level, rather than simply the fulfilment of each national RES target using domestic resources. RES cooperation finally also affects the overall cost allocation across the EU – i.e. the ultimate height of support expenditures for RES at country level is defined by national RES deployment and the support expenditures related to that, and, on top of that, the additional revenues (for exporting countries) or additional expenditures (for importing countries) related to RES cooperation.

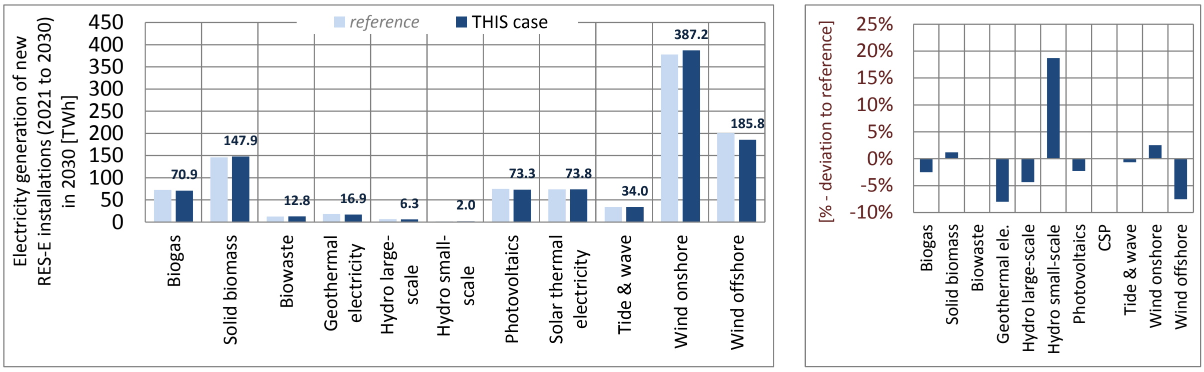


Figure A - 85. Technology-specific breakdown of RES-E generation from new installations (2021 to 2030) at EU-27 level in the year 2030, indicating deployment in absolute terms (left) and the change compared to reference (right) (for the assessed policy pathway 7d (REF min criteria))

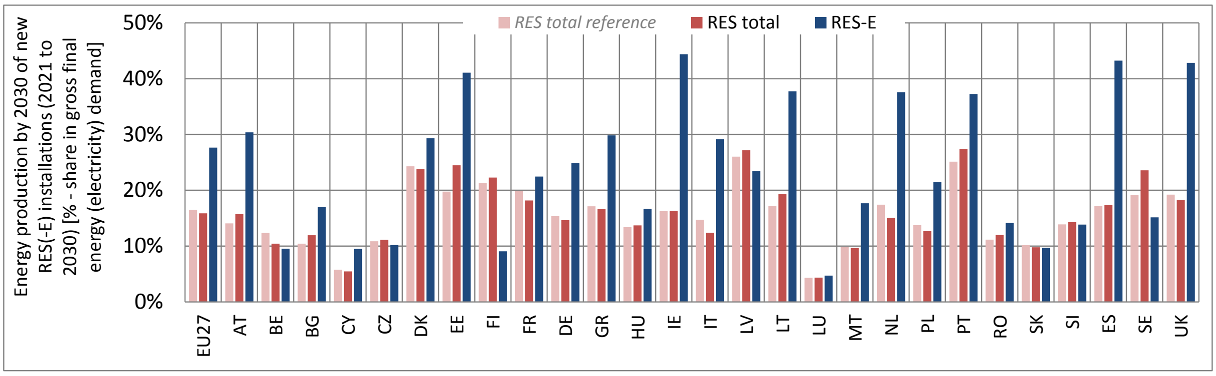


Figure A - 86. Country-specific breakdown of RES and RES-E generation from new installations (2021 to 2030) in the year 2030, indicating RES(-E) deployment as share in corresponding demand (i.e. gross final energy demand for RES total, and gross electricity demand for RES-E) (for the assessed policy pathway 7d (REF min criteria))

[36] More precisely, economic restrictions are applied to limit differences in applied financial support for certain RES technology among MSs to an adequately low level – i.e. differences in country-specific support per MWh RES are limited to a maximum of 10 €/MWh_{RES}.

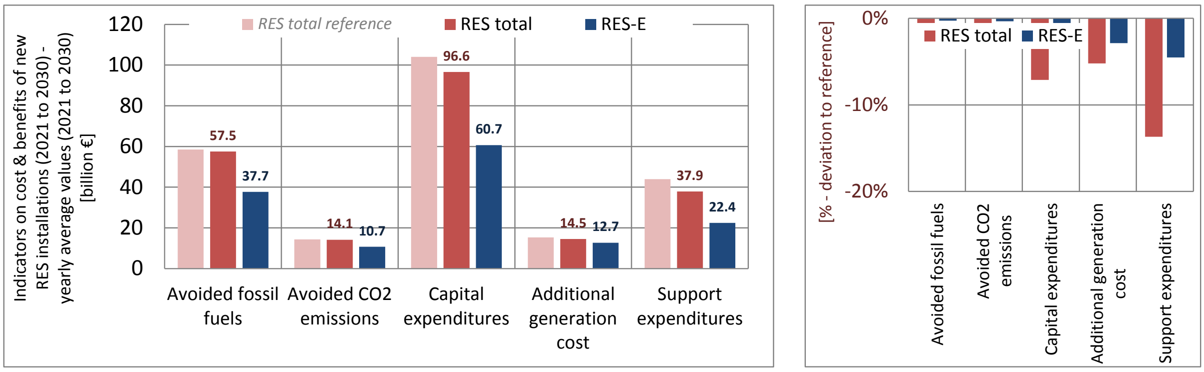


Figure A - 87. Indicators on cost/expenditures and benefits of new RES(-E) installations (2021 to 2030), expressing yearly average (2021 to 2030) monetary values at EU-27 level in absolute terms (left) and the change compared to reference (for the assessed policy pathway 7d (REF min criteria))

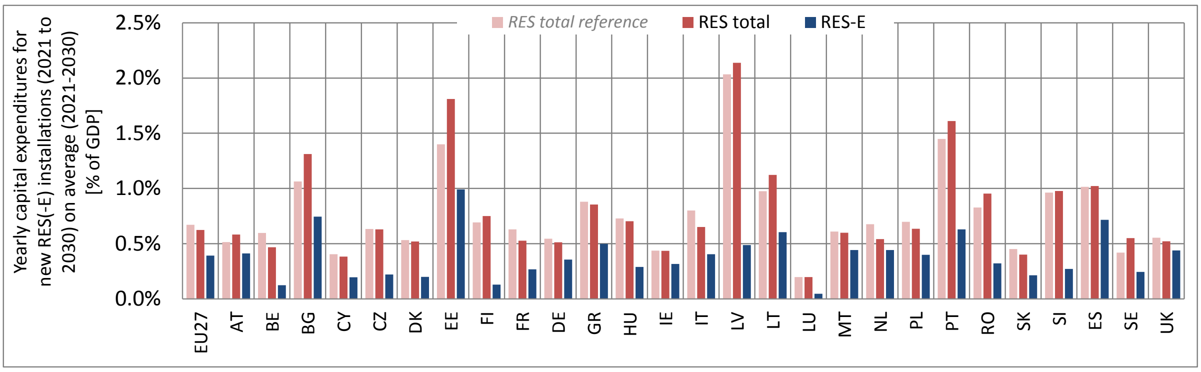


Figure A - 88. Country-specific breakdown of yearly average (2021 to 2030) capital expenditures in new RES and RES-E installations (2021 to 2030), expressing investments as share of (country-specific) GDP (for the assessed policy pathway 7d (REF min criteria))

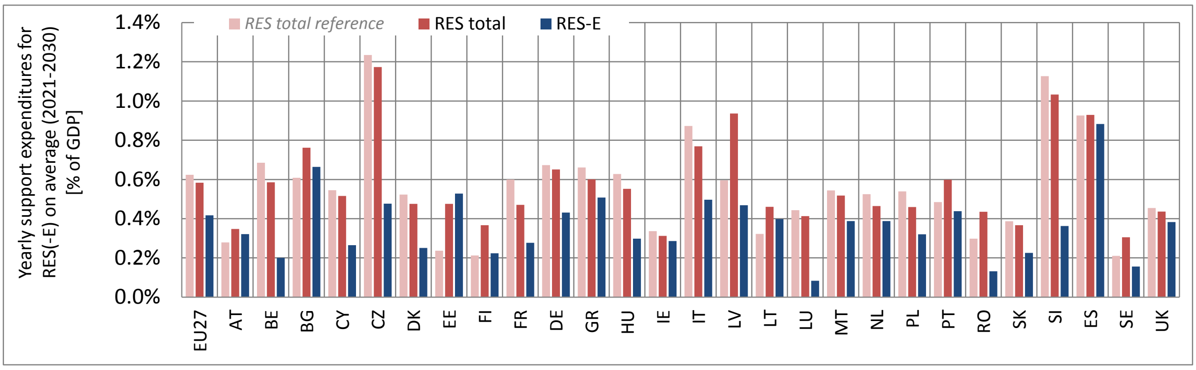


Figure A - 89. Country-specific breakdown of yearly average (2021 to 2030) support expenditures for RES total and RES-E, expressing expenditures as share of (country-specific) GDP (for the assessed policy pathway 7d (REF min criteria))

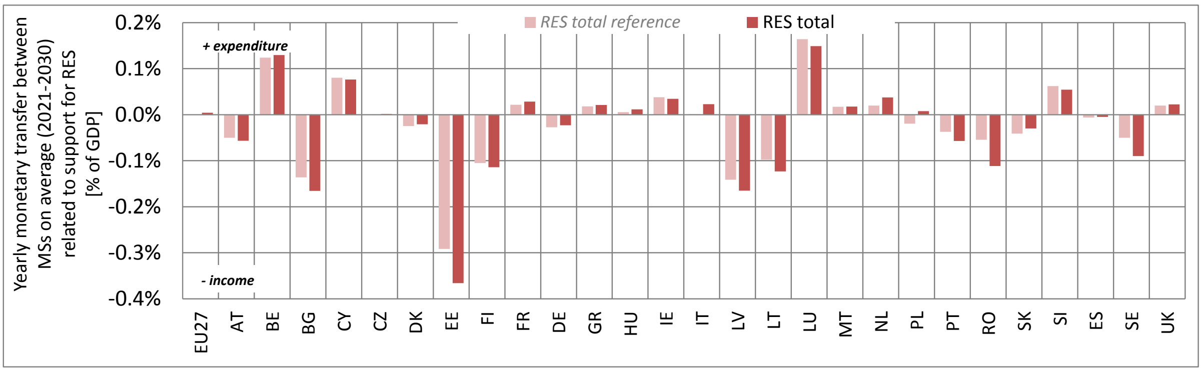


Figure A - 90. Yearly average (2021 to 2030) monetary transfers between Member States related to the support for RES, expressing additional expenditures (+) or income (-) as share of (country-specific) GDP (for the assessed policy pathway 7d (REF min criteria))

Note: Additional expenditure or income stems from the underlying cost allocation under a full or medium harmonisation of RES support, or they refer to RES cooperation in the case of soft, minimum or no harmonisation, respectively.

Reference case *without minimum design standards*

REF
(Path 7)

Brief characterisation: This pathway builds on the assumption that the current policy framework as given by the RES Directive (2009/28/EC) will be prolonged for the period up to 2030, meaning (inter alia) that national RES targets for 2030 will be established. Similar assumptions are consequently made for RES support – i.e. a continuation of strengthened national RES policies until 2030 which will be further optimised in the future with regard to their effectiveness and efficiency. In particular the further fine-tuning of national support schemes will require in case of both (premium) feed-in tariff and quota systems a technology-specification of RES support.

Since no sort of harmonisation is assumed to be in place under this reference variant, MSs have the freedom to decide on both the type of support scheme that they apply as well as its design elements. Within the modelling exercise, in order to provide a contrast to the other reference case of minimum harmonisation (path 7d) a "national perspective" is researched here where MSs primarily aim for a pure domestic RES target fulfilment and, consequently, only "limited cooperation"[37] is expected to arise from that. RES cooperation finally affects however the overall cost allocation across the EU – i.e. the ultimate height of support expenditures for RES at country level is defined by national RES deployment and the support expenditures related to that, and, on top of that, the additional revenues (for exporting countries) or additional expenditures (for importing countries) related to RES cooperation.

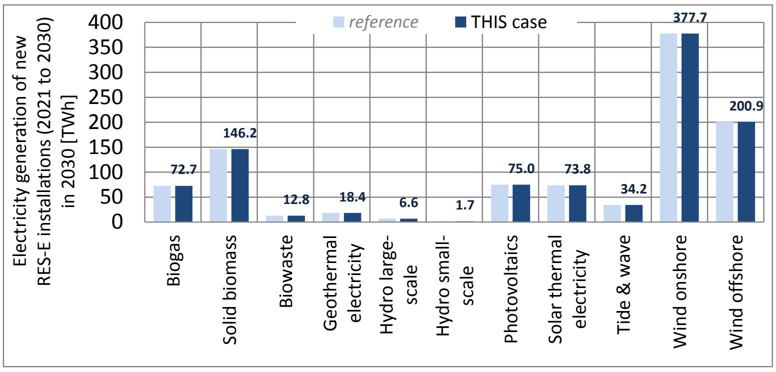


Figure A - 91. Technology-specific breakdown of RES-E generation from new installations (2021 to 2030) at EU-27 level in the year 2030, indicating deployment in absolute terms (for the assessed policy pathway 7 (REF))

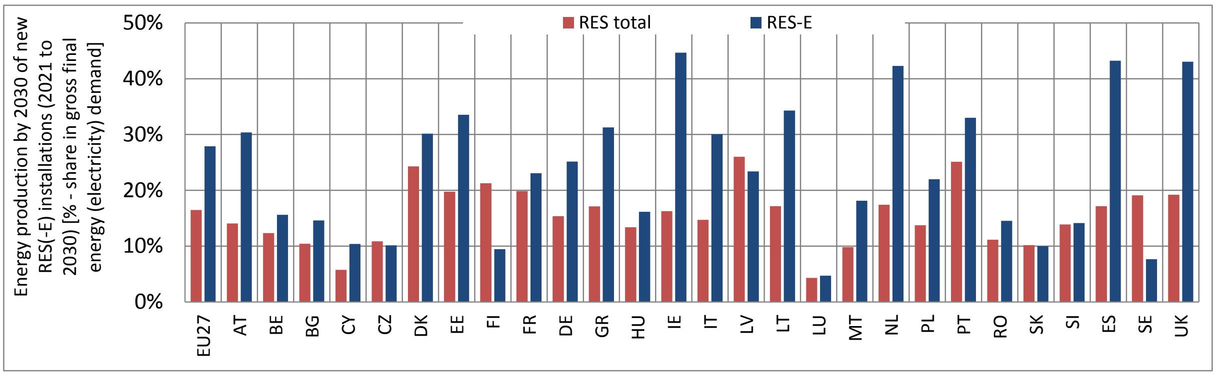


Figure A - 92. Country-specific breakdown of RES and RES-E generation from new installations (2021 to 2030) in the year 2030, indicating RES(-E) deployment as share in corresponding demand (i.e. gross final energy demand for RES total, and gross electricity demand for RES-E) (for the assessed policy pathway 7 (REF))

[37] 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 necessary minimum: For the exceptional case that a MS would not possess sufficient RES potentials, cooperation mechanisms would serve as a complementary option. Additionally, if a MS 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.

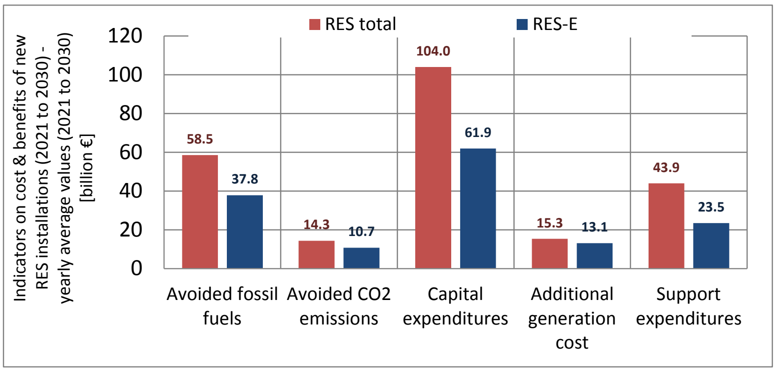


Figure A - 93. Indicators on cost/expenditures and benefits of new RES(-E) installations (2021 to 2030), expressing yearly average (2021 to 2030) monetary values at EU-27 level in absolute terms (for the assessed policy pathway 7 (REF))

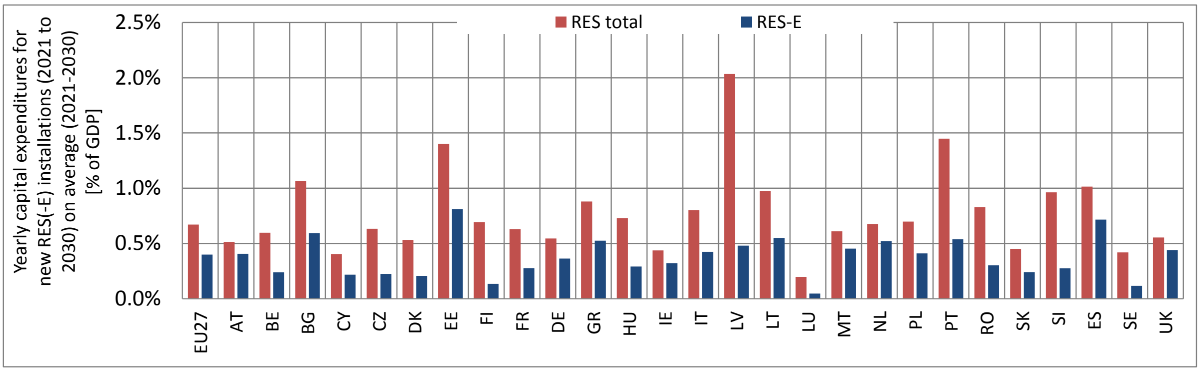


Figure A - 94. Country-specific breakdown of yearly average (2021 to 2030) capital expenditures in new RES and RES-E installations (2021 to 2030), expressing investments as share of (country-specific) GDP (for the assessed policy pathway 7 (REF))

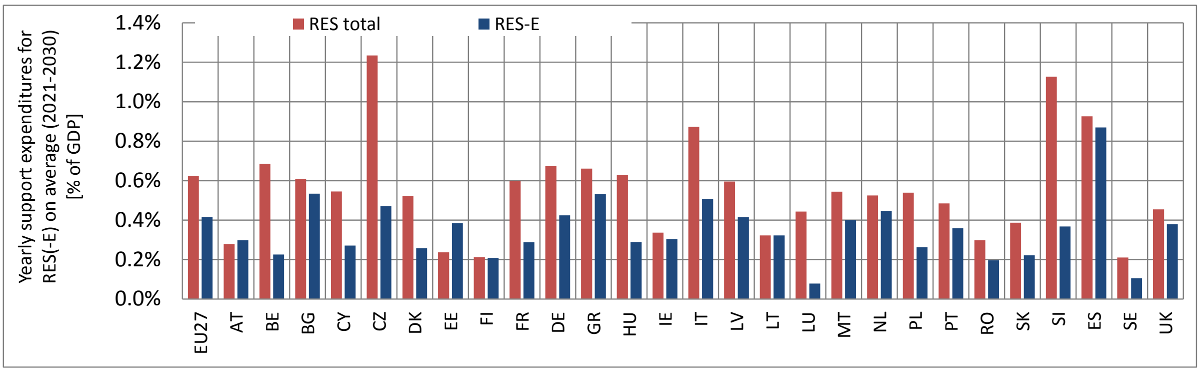


Figure A - 95. Country-specific breakdown of yearly average (2021 to 2030) support expenditures for RES total and RES-E, expressing expenditures as share of (country-specific) GDP (for the assessed policy pathway 7 (REF))

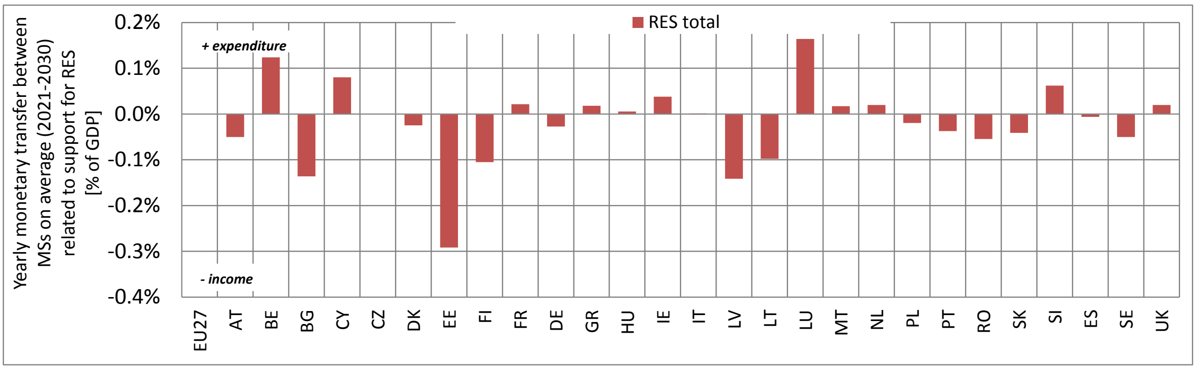


Figure A - 96. Yearly average (2021 to 2030) monetary transfers between Member States related to the support for RES, expressing additional expenditures (+) or income (-) as share of (country-specific) GDP (for the assessed policy pathway 7 (REF))

Note: Additional expenditure or income stems from the underlying cost allocation under a full or medium harmonisation of RES support, or they refer to RES cooperation in the case of soft, minimum or no harmonisation, respectively.

Project web: www.res-policy-beyond2020.eu

For further information on the topics addressed briefly within this report we refer to the following beyond2020 *publications:*

Addressed Topic	*Corresponding* beyond*2020 publication*
RES policy pathways beyond 2020: elaboration of feasible pathways for a possible harmonisation of RES(-E) support in Europe beyond 2020	del Rio *et al* (2012a): "Key policy approaches for a harmonisation of RES(-E) support in Europe - Main options and design elements"
Policy evaluation criteria: identification and definition of evaluation criteria for the subsequent impact assessment of feasible policy approaches for a harmonisation of RES(-E) support in Europe from a theoretical viewpoint, discussing and contrasting economic theory and practical applicability.	del Rio *et al* (2012b): "Assessment criteria for identifying the main alternatives - Advantages and drawbacks, synergies and conflicts"
Legal aspects: a general overview of all the Articles and provision in EU primary and secondary law which may have an impact on the EU's legislative competence in the field of RES support.	Fouquet *et al* (2012): "Potential areas of conflict of a harmonised RES support scheme with European Union Law"
Cost- benefit assessment: initial results of a quantitative model-based analysis of future RES policies beyond 2020	Resch *et al* (2012): "Cost-benefit analysis – initial results of the quantitative assessment of RES policy pathways beyond 2020"
Trade-offs with electricity markets: a literature review about the interactions between RES-E support instruments and electricity markets	Batlle *et al* (2012): "Review report on interactions between RES-E support instruments and electricity markets"
Strategic aspects of RES policy support: a brief pre-assessment of potential harmonisation pathways for RES-E support schemes by contextualising this debate in the wider EU integration process and the political and academic debate on harmonisation.	Gephart *et al* (2012): "Contextualising the debate on harmonising RES-E support in Europe - A brief pre-assessment of potential harmonisation pathways"

This report

presents the final outcomes of the cost- benefit assessment of RES(-E) policy pathways assessed throughout the beyond*2020* *project, documenting the approach and assumptions tak-en and illustrating the results and findings gained throughout the quantitative model-based analysis of future RES policy options beyond 2020*