2030 RES targets for Europe

- a brief pre-assessment of feasibility and impacts

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1 Executive Summary

This report provides an analysis of future renewable energy pathways towards 2030 within the framework of the Keep on Track! project, following a two-fold approach:

On the one hand, possible European and national 2030 RES targets are calculated whereby different levels of ambition on EU scale in terms of 2030 RES share are considered for the 27 EU Member States (as of 2012). In order to exemplify the transfer of a 30%, 35%, 40% or 45% RES target on EU scale to national targets the EC methodology is used as it was applied in the 2020 time frame. Following the 2020 RES directive the EU target is then allocated to differentiated national targets based on a flat rate approach (i.e. same additional share for each country) modulated by the Member State's GDP per capita.

On the other hand, by use of a specialised energy system model (Green-X) a quantitative assessment was conducted to show pathways for achieving calculated 2030 RES targets that can be expected under aligned framework conditions. Results show the expected 2030 RES deployment at EU and country level and provide detailed breakdowns at sector level. Moreover, the outcomes offer insights on a limited set of impacts on related cost and benefits. However, as such this analysis does neither aim for a comprehensive and complete impact assessment related to consequences of certain RES targets, nor does it aim for an assessment of policy options to achieve these targets.

The results on possible future RES deployments show that generally European RES-shares from 30% to 45% can be achieved with the exception that 45% can only be realized with additional energy efficiency measures to reduce future demand (growth) and the precondition that already in the period up to 2020 additional efforts are taken. When comparing the Member States' RES deployment resulting from the modelling exercise with the possible national RES targets resulting from applying the EC methodology, it can be seen that under aligned framework conditions some countries would over-fulfill their target and some would rely on cooperation mechanisms to meet their targets. This does not mean that those countries do not hold sufficient potentials, but the overall EU target is achieved in a more cost-efficient manner by using cooperation mechanisms.

When focusing on the contribution of the electricity, heating & cooling and transport sector in achieving the 2030 targets, the electricity sector with a current (2011) share of 22% experiences the strongest RES growth reaching shares from 52% to 89% in 2030. The heating & cooling sector where RES account for a share of 15% at present (2011), shows the second largest contributions translating into shares of 29% to 35% in 2030. With regard to national contribution the analysis points out that RES deployment in the electricity sector is well spread across the EU and no single region appears to dominate. Obviously, country-specific differences are applicable, mainly as a consequence of the uneven starting point but also reflecting differences in nationally or regionally available RES potentials. However, in the heating & cooling sector the major contribution is expected to come from the north-eastern part of Europe. In the transport sector significant differences occur with respect to biofuel production across Europe but physical trade together with an assumed blending obligation leads to equal RES shares in consumption in this assessment.

A quantitative cost-benefit analysis of the resource-based modelling of RES deployment for meeting the different RES targets in 2030 shows a diverging gap between costs and benefits ranging from € 13 billion additional annual savings in case of a 30% RES target to € 36 billion additional annual costs in case of a 45% RES target.[1] Comparing the low with the high energy demand scenarios highlights the importance of accompanying energy efficiency measures. A stable or even growing energy consumption significantly increases the efforts to be taken on the supply side for meeting assumed RES shares, leading in the cases of high RES shares to strong increases in related support expenditures whereas assessed benefits rise non-proportionally. Please note however that the results of this brief pre-assessment have to be interpreted considering that the cost-benefit analysis does not include certain costs, like infrastructure investments, and certain benefits as, for example, employment effects.

1 Note that both figures refer to the low energy demand case where the assumption is taken energy efficiency plays a vital role to limit future energy demand (growth).

2 Introduction

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

As outlined in detail in the Re-Shaping study (see Ragwitz et al., 2012), the first decade of the new millennium was characterized by the successful deployment of RES across EU Member States – total RES deployment increased by more than 40%. More precisely:

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

These impressive structural changes in Europe's energy supply are the result of a combination of strong national policies and the general focus on RES created by the EU Renewable Energy Directives in the electricity and transport sectors towards 2010 (2001/77/EC and 2003/30/EC).

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

The pathway for renewables towards 2020 was set and accepted by all the European Council, the European Commission and the European Parliament in April 2009. The related policy package, in particular the EU Directive on the support of energy from renewable sources (2009/28/EC), subsequently named as RES Directive, comprises the establishment of 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 in the short to mid-term.

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

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

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

The EU Energy Roadmap 2050 gave first signals of renewable energy development pathways beyond the year 2020 and identified renewables as a "no-regrets" option. In a first step, Europe's way forward towards 2030 is being discussed currently. Thus, the current debate focuses on the issue of defining and implementing targets for 2030 and if so what kind of targets will be needed.

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

2.2 Objective and structure of this report

This report aims to provide a summary of possible future renewable energy pathways towards 2030 within the framework of the Keep on Track! project. For doing so, as outlined in section 3 of this report (i.e. short description of methodology and key assumption), a two-fold approach is used:

On the one hand, European and national 2030 RES targets are calculated, see section 4. Different levels of ambition on EU scale in terms of 2030 RES share are considered for the 27 EU Member States (as of 2012). In order to exemplify the transfer of a 30%, 35%, 40% or 45% RES target on EU scale to national targets the EC methodology is used as it was applied in the 2020 time frame. Following the 2020 RES directive the EU target is then allocated to differentiated national targets based on a flat rate approach (i.e. same additional share for each country) modulated by the Member State's GDP per capita.

On the other hand, by use of a specialised energy system model (Green-X) a quantitative assessment was conducted to show pathways for achieving calculated 2030 RES targets that can be expected under aligned framework conditions. The outcomes of this model-based assessment are described in section 5, indicating results on RES deployment at EU and country level, and in section 6, analysing a limited set of impacts on related cost and benefits. Please note however that as such this analysis does neither aim for a comprehensive and complete impact assessment related to consequences of certain RES targets, nor does it aim for an assessment of policy options to achieve these targets.

This report concludes with a summary of key findings, see section 7. Note further that the Annex to this report provides a detailed description of the methodology and the assumptions taken for the model-based analysis of possible future RES deployment.

3 Short description of methodology and key assumptions

3.1 Calculation of possible 2030 RES targets

This report reflects the Keep on Track! project findings with respect to potential 2030 RES targets. Consequently, different levels of ambition on EU scale in terms of 2030 RES share are considered for the 27 EU Member States (as of 2012). In order to transfer of a 30%, 35%, 40% or 45% RES target on EU scale the EC methodology has been used as it was applied in the 2020 time frame.

The detailed approach used to calculate national RES targets for 2030 can be described as follows:

1. *Starting point (2020 RES deployment):* Binding 2020 RES targets are used as starting point for defining 2030 targets. More precisely, the assumption is taken that binding national 2020 RES targets are met in time – thus, as such these targets represent the starting point (i.e. the expected status of RES deployment by 2020) for all follow-up calculations. [2]
2. *European effort (for meeting assumed 2030 EU-RES targets):* Taking into account the specific European 2030 RES target within each scenario (i.e. 30%, 35%, 40% and 45%) the overall required RES deployment in energetic terms is calculated and the required additional effort depicted (see Table 4-1).
3. *Flat rate increase:* Half of this additional effort is then converted to relative terms on the expected overall gross final energy demand in 2030.
4. *Additional effort based on GDP per capita:* The second half is weighted by the expected national GDP per capita of 2020 and then converted to relative terms by the expected gross final energy demand of 2030.
5. Finally, both percentage-points are added to the target of 2020 and then rounded to full numbers.

Thus, as such this approach considers the Member State's economic strength in terms of GDP as well as efforts made in the past. On the other hand, the approach ignores other aspects such as the potential availability of renewable resources and related costs.

For illustrative purposes, Figure 5-1 provides a graphical depiction of how individual national 2020 RES targets have been calculated, indicating a breakdown of the overall targets into the individual components (i.e. starting point (RES share in 2005), flat rate increase, additional effort based on GDP per capita, etc.). As opposed to the 2020 targets setting, no first mover bonuses are considered. Since there is a legally binding support framework in place in the period prior 2020, first mover bonuses are deemed to be unfair. Neither are any caps on overall targets being considered herein.

2 The first column of Table 4-1 gives an overview of these national 2020 RES targets.

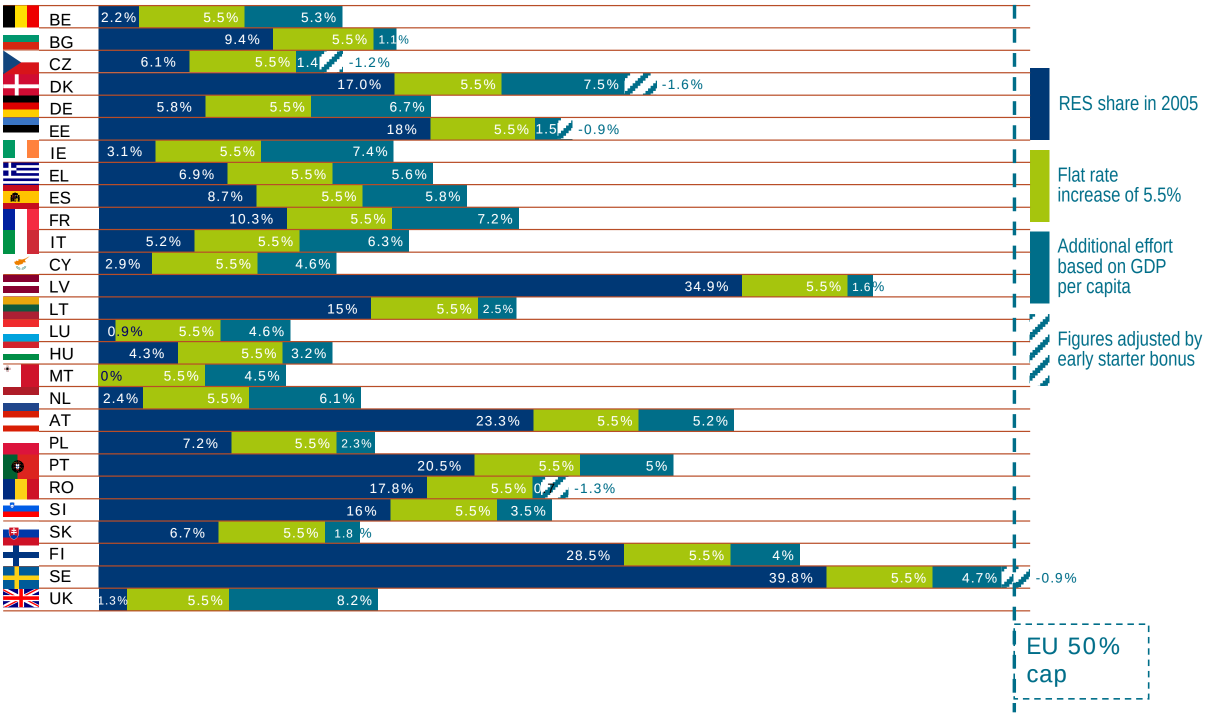

Figure 5-1 How 2020 RES targets are defined: Breakdown of national targets into individual components

3.2 Model-based assessment of possible RES developments for meeting potential 2030 RES targets

Complementary to above, by use of a specialised energy system model (Green-X) a quantitative assessment was conducted to show pathways for achieving calculated 2030 RES targets, indicating feasible RES deployment at country level that can be expected under aligned framework conditions as well as related impacts on costs and benefits in a brief manner. However, as such this analysis does neither aim for a comprehensive and complete impact assessment related to consequences of certain RES targets, nor does it aim for an assessment of policy options to achieve these targets.

Note that the Annex to this report provides a detailed description of the methodology and the assumptions taken for this analysis of possible RES deployment. In contrast to that, below only a brief summary of relevant background information is provided.

3.2.1 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 (EU27; 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: demand forecasts are taken form the EC Energy Roadmap 2050 (reference and high renewables case)

- 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 national RES target fulfilment (in particular under all cases of high 2030 RES targets).

3.2.2 The policy assessment tool: the Green-X model

The Green-X model was applied to perform a detailed quantitative assessment of the future deployment of renewable energy on country- and sector 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 in the Annex to this main report, whilst for a detailed description we refer to www.green-x.at.

3.2.3 Overview on assessed cases

The assessment illustrates the country-specific RES deployment that can be expected if a certain RES share (on gross final energy demand) shall be met by 2030 at EU level. More precisely, the assumption is taken that at EU level a RES share of 30%, 35%, 40% or 45% shall be achieved at EU level by 2030 (see Table 3-2). In order to indicate the country-specific efforts related to the required RES expansion in a fair and transparent manner the assumption is taken that all framework conditions (i.e. non-economic barriers and financial incentives for RES) would be further aligned across Member States beyond 2020. Green-X modelling incorporates RES policy interventions and as part of that support levels of individual RES technologies depend on the level of ambition of the pursued RES share in 2030. Since energy demand (growth) is a crucial parameter for the feasibility / impacts of RES targets (defined in relative terms, as shares of demand), two variants of future demand trends are assessed – i.e. a low and a high energy demand case based on PRIMES modelling (PRIMES energy efficiency and PRIMES reference case as of 2011, see below).

Table 3-1 Overview of assessed RES scenarios up to 2030

Scenario acronym:	30-eff	30-ref	35-eff	35-ref	40-eff	40-ref	45-eff	45-ref
RES target 2030	30	30	35	35	40	40	45	45
Demand trend:	Low Energy Demand (PRIMES efficiency case 2011)	High Energy Demand (PRIMES reference case 2011)	Low Energy Demand (PRIMES efficiency case 2011)	High Energy Demand (PRIMES reference case 2011)	Low Energy Demand (PRIMES efficiency case 2011)	High Energy Demand (PRIMES reference case 2011)	Low Energy Demand (PRIMES efficiency case 2011)	High Energy Demand (PRIMES reference case 2011)

3.2.4 Overview on key parameters

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. With respect to the potentials and cost of RES technologies we refer to the Annex to this report and/or the Green-X database, respectively. Table 3-1 shows which parameters are based on PRIMES and which have been defined for this study.

More precisely, the PRIMES scenarios used are:

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

Table 3-2: 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

4 Results on 2030 RES targets – European and national targets

The recent debate on targets for renewable energy sources focuses on the level of ambition on European level. For complementing this, European target are also transferred into national targets in the subsequent exercise. Several approaches exist in literature on how to share this effort. However, so far no detailed methodology has been presented for the post-2020 period, and therefore we assume the same approach as it was implemented in the RES Directive 2009/28/EC. Thus, as such this approach considers the Member State's economic strength in terms of GDP as well as efforts made in the past. On the other hand, the approach ignores other aspects such as the potential availability of renewable resources and related costs.

As outlined in the method of approach (see section 3.1), different levels of ambition on EU scale in terms of 2030 RES share are considered for the 27 EU Member States (as of 2012). In order to transfer of a 30%, 35%, 40% or 45% RES target on EU scale the EC methodology has been used as it was applied in the 2020 time frame.

In context of this methodology, Table 4-1 indicates the associated national RES targets by 2030. In case of a 30% EU RES target, Denmark and the UK face the most ambitious increase of RES compared to 2020 amounting to 12%. The other way round, due to their moderate GDP expectations in 2020 the Baltic and South-East European region experience only a 7% increase from 2020 level. In absolute numbers, Sweden possesses a target of 59% followed by Latvia (49%) and Finland (47%). On the lower end of the list, Czech Republic, Luxembourg and Malta hold a target of 20%. With respect to the 35% RES target by 2030, hardly any relative changes are observed in comparison to the 30% RES target.

If it comes to an even more ambitious target of 40% RES by 2020 the effort sharing shifts slightly from the new Member States towards the former EU15 countries. Nevertheless, Sweden as frontrunner would result in a 69% RES by 2030 whereas the Czech Republic on the lower end would need to meet 27% RES by 2030. Again, the most ambitious EU target of 45% RES by 2030 would not change the overall effort sharing approach compared to the 40% target. However, this would imply a national target of 75% overall RES in Sweden and only 31% in Czech Republic. Although there is only Sweden as frontrunner, countries like Austria, Denmark, Finland or Latvia follow with a target of 59% RES in 2030. In contrast, on the lower end besides Czech Republic there are Bulgaria and Hungary with a 32% target, Slovenia (33%) and many other at 34% RES.

Table 4-1 National 2030 RES targets in accordance with assumed 2030 EU RES targets, applying the EC methodology for effort sharing

		2020	2030	2030	2030	2030
EU target	**%**	20	**30**	**35**	**40**	**45**
Results on national RES targets						
			Flatrate + GDP adjusted			
Austria	AT	34	44	49	54	59
Belgium	BE	13	23	27	32	37
Bulgaria	BG	16	23	26	29	32
Cyprus	CY	13	22	26	30	35
Czech Republic	CZ	13	20	24	27	31
Denmark	DK	30	42	48	53	59
Estonia	EE	25	32	36	39	42
Finland	FI	38	47	51	55	59
France	FR	23	34	39	45	50
Germany	DE	18	29	34	40	45
Greece	GR	18	28	33	38	43
Hungary	HU	13	21	24	28	32
Ireland	IE	16	27	33	38	44
Italy	IT	17	27	32	37	42
Latvia	LA	42	49	52	55	59
Lithuania	LT	23	30	34	38	41
Luxembourg	LU	11	20	25	29	34
Malta	MT	10	20	24	29	34
Netherlands	NL	14	25	30	36	41
Poland	PL	15	23	26	30	34
Portugal	PT	31	40	45	49	54
Romania	RO	24	31	35	38	42
Slovakia	SK	14	22	25	29	33
Slovenia	SI	25	35	40	45	51
Spain	ES	20	30	34	39	44
Sweden	SE	49	59	64	69	75
United Kingdom	UK	15	27	33	39	46
Background for effort sharing calculation:						
Expected gross final energy consumption 2030 (according to PRIMES reference case (2011))	Mtoe		1,259	1,259	1,259	1,259
Required RES deployment 2030 (for target achievement)	Mtoe		378	441	504	567
Requiered effort (increase in RES deployment compared to 2020)	Mtoe		119	182	245	308
Half effort	Mtoe		59.7	91.2	122.7	154.2
Flat rate to share half of the required effort	%		5.4	7.9	10.4	12.9
Residual per capita	toe/capita		0.11	0.17	0.24	0.30

Note: The data expressed at the bottom of this table serves as background for the effort sharing calculations. For details on the applied approach used see section 3.1 of this report.

5 Results on possible RES developments for meeting 2030 RES targets

This section discusses the results on possible future RES developments in the time horizon towards 2030. Therefore, four different RES targets are pursued meeting a share of 30%, 35%, 40% and 45% RES of gross final energy demand by 2030. In order to depict the uncertainty of the related RES developments, two different trends of future gross final energy demand are taken into account.[3]

Starting at a RES share of 13% in gross final energy demand by end of 2011, the short term RES developments are built on the trajectories of the NREAP's towards 2020. Consequently, all scenarios meet the 2020 RES targets by achieving at least 20% RES by 2020 at European level. Figure 5-1 depicts the RES development at EU level between 2017 and 2030 on an annual level for all four scenarios plus the demand sensitivities.

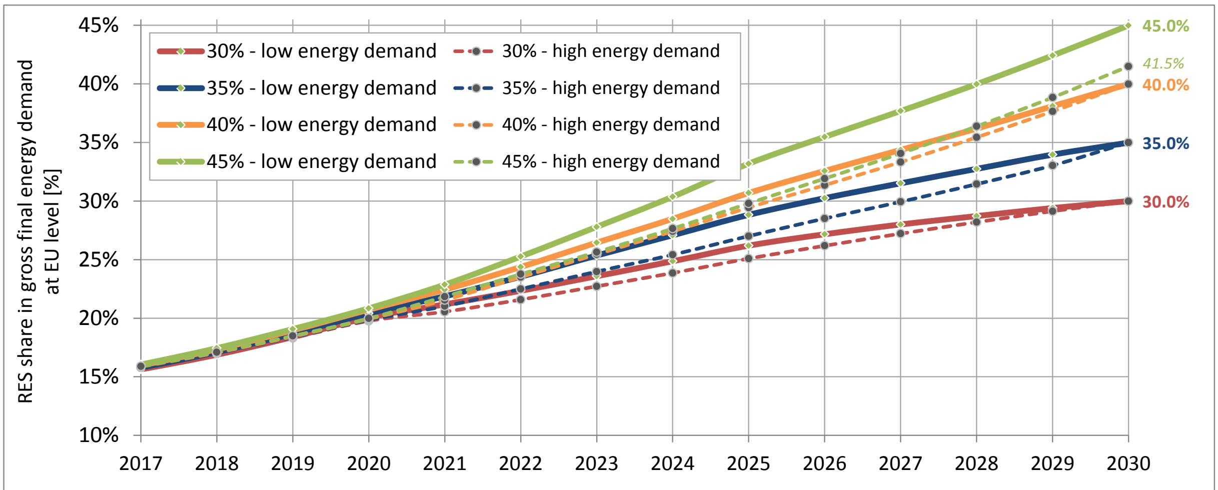

Figure 5-1 RES pathways up to 2030 at EU level according to different EU targets by 2030 depending on the future gross final energy demand.

Generally, the 2030 targets of achieving a RES share of 30%, 35%, 40% or 45% are met within the scenarios with one exception: the 45% RES share by 2030 is only achievable through accompanying strong energy efficiency measures as otherwise 41.5% appear as upper limit. Moreover, 45% RES by 2030 requires enhanced action already before and not only beyond 2020. Thus, within these scenarios the 2020 RES targets are slightly exceeded and beyond 2020 an even stronger level of ambition is necessary. In contrast the 35% and 40% RES scenario follow a continued level RES growth beyond 2020 in the first years, and the 40% picks up within the last years towards 2030. With respect to the

3 Please note that an overall discussion of the underlying energy demand pattern and the conventional energy supply portfolio in the reference system is given in section 9 of this report.

30% RES scenario, RES growth decreases in the period beyond 2020 – as such this represents a stagnation of successful past RES developments for several Member States. In general, the low energy demand scenarios allow meeting the targets at rather constant annual RES growth rates compared to high energy demand scenarios. In the later, a strong RES contribution is expected to be required in the period 2025 to 2030.

Table 5-1 RES share by 2030 according to four different scenarios (EU target by 2030: 30%, 35%, 40% and 45%) on national level depending on future gross final energy demand.

		2030	2030	2030	2030	2030	2030	2030	2030
		30	30	35	35	40	40	45	45
Results on (domestic) **RES deployment** by **2030 (Green-X scenarios)**		Low Energy Demand (PRIMES efficiency case 2011)	High Energy Demand (PRIMES reference case 2011)	Low Energy Demand (PRIMES efficiency case 2011)	High Energy Demand (PRIMES reference case 2011)	Low Energy Demand (PRIMES efficiency case 2011)	High Energy Demand (PRIMES reference case 2011)	Low Energy Demand (PRIMES efficiency case 2011)	High Energy Demand (PRIMES reference case 2011)
Austria	AT	54.0%	50.0%	55.8%	53.6%	60.4%	56.5%	63.5%	56.4%
Belgium	BE	15.3%	15.1%	17.0%	18.2%	20.8%	21.5%	24.5%	22.4%
Bulgaria	BG	26.5%	28.5%	30.2%	32.0%	35.1%	37.5%	38.9%	38.8%
Cyprus	CY	15.5%	16.9%	17.3%	18.8%	19.4%	20.1%	21.2%	20.1%
Czech Republic	CZ	17.5%	17.5%	19.8%	20.5%	22.3%	22.4%	24.5%	23.4%
Denmark	DK	38.6%	43.2%	44.8%	49.0%	52.0%	60.8%	60.0%	63.3%
Estonia	EE	49.9%	49.2%	56.6%	50.4%	59.6%	53.1%	62.8%	52.6%
Finland	FI	59.7%	55.4%	60.1%	56.7%	62.6%	61.8%	65.0%	61.8%
France	FR	35.2%	31.7%	37.3%	34.2%	41.4%	38.3%	46.0%	39.1%
Germany	DE	27.7%	29.2%	36.0%	36.5%	41.1%	40.7%	45.5%	42.3%
Greece	GR	28.6%	29.0%	32.2%	32.3%	36.6%	35.4%	40.7%	35.8%
Hungary	HU	19.2%	19.8%	21.8%	21.9%	23.5%	23.0%	25.4%	23.4%
Ireland	IE	26.2%	26.0%	28.6%	28.1%	30.7%	31.2%	35.1%	31.6%
Italy	IT	24.7%	24.3%	29.1%	28.5%	33.2%	31.4%	36.6%	31.6%
Latvia	LA	61.0%	55.8%	62.4%	57.4%	64.1%	58.1%	65.9%	58.1%
Lithuania	LT	43.1%	41.0%	45.0%	43.4%	47.6%	47.0%	51.2%	47.3%
Luxembourg	LU	11.0%	11.7%	13.4%	13.7%	15.7%	15.5%	18.2%	16.5%
Malta	MT	16.9%	16.9%	20.2%	19.0%	22.0%	20.1%	23.4%	20.3%
Netherlands	NL	17.3%	19.9%	25.0%	28.7%	33.9%	34.0%	39.4%	35.3%
Poland	PL	27.2%	24.0%	27.7%	25.8%	29.2%	27.9%	31.5%	27.9%
Portugal	PT	47.6%	50.1%	54.4%	55.9%	60.7%	61.5%	65.6%	62.1%
Romania	RO	37.7%	37.2%	40.5%	37.7%	41.9%	41.3%	44.3%	41.2%
Slovakia	SK	23.1%	22.1%	25.6%	25.3%	27.7%	27.5%	30.1%	27.8%
Slovenia	SI	33.2%	31.6%	34.6%	33.3%	37.7%	37.0%	40.9%	37.1%
Spain	ES	28.8%	30.7%	35.3%	37.3%	41.7%	42.5%	48.1%	42.6%
Sweden	SE	61.8%	61.3%	64.7%	63.9%	68.3%	67.1%	71.3%	67.6%
United Kingdom	UK	24.8%	26.2%	31.2%	31.5%	37.2%	37.6%	43.8%	39.0%
RES-electricity imports from Non-EU countries [TWh]:		10.9	34.1	57.3	104.8	116.0	233.4	196.5	341.2

Although the different scenarios are met on EU scale by 2030, different perspectives are given on Member State level. Hence, Table 5-1 provides an overview of the eight assessed cases on Member State level. Comparing these results to the associated national 2030 RES targets derived in section 4 indicates that under the assumed aligned framework conditions (related to RES support and barriers) some countries would be over-fulfilling their targets while others would not meet their national targets purely domestically and, consequently, rely on cooperation mechanisms. Austria, Bulgaria, Estonia, Portugal are those countries exceeding their national targets in all scenarios, but the over-supply decreases with the level of ambition of the EU RES target by 2030. Additionally, some Member States are stronger affected by the gross final energy demand forecasts than others. As a general tendency, Central and Eastern European countries appear more sensitive in this respect than the remainder.[4]

The following assessment focuses on the sectoral contribution to meet the different RES targets by 2030. First, the 30% RES by 2030 scenario is analysed and the development of the different sectors are depicted in Figure 5-2. Strongest growth rates are expected for RES in the electricity sector where renewable electricity (RES-E) is expected to cover more than half of Europe's electricity demand in 2030. Compared to the years before 2020 for RES-E this implies however a slight reduction of the speed of transition. More than a doubling of their contribution is also expected for RES in the heating and cooling sector (RES-H&C), reaching a share of 28 to 29% in 2030. Under a 30% RES target the development of biofuels in the transport target would rather stagnate at EU level but a shift from first to second generation biofuels is expected to take shape. The sensitivity case of high energy demand (growth) indicates that less success in implementing energy efficiency measures affects the heating and cooling sector most. Consequently, the resulting decrease of RES-H&C shares needs to be compensated by increased contributions that stem from RES-E and from biofuels in transport.

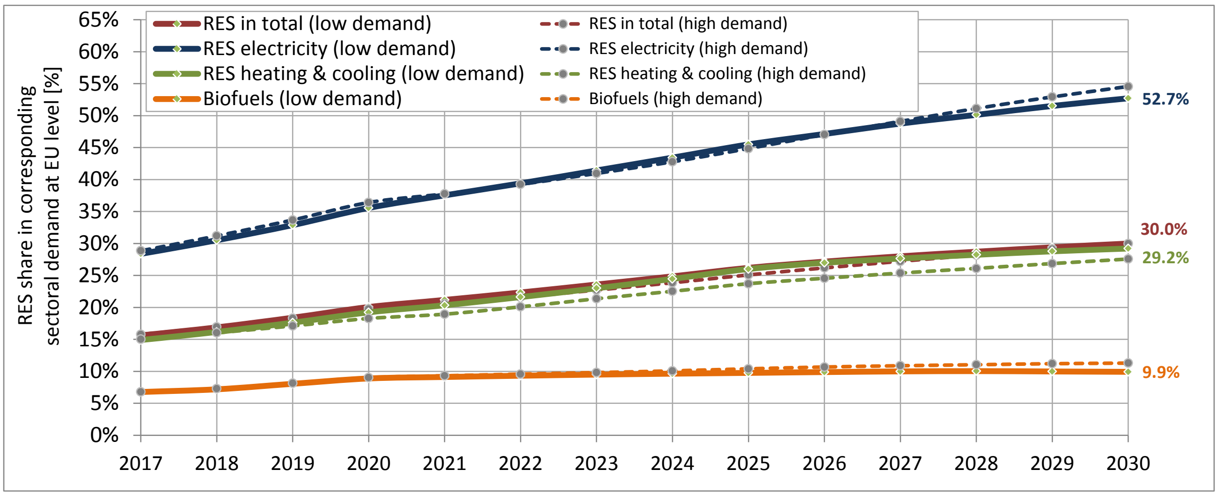

Figure 5-2 Future RES pathways up to 2030 at EU level, pursuing a 30% target, in total and per energy sector depending on the future gross final energy demand.

4 A closer look on the underlying demand trends indicates that in Central and Eastern Europe energy efficiency potentials appear larger in magnitude than for the rest of Europe. Thus, exploiting them to a significantly lower extent (as assumed in the high demand case) has a stronger impact on feasible RES shares under the underlying framework conditions.

Table 5-2 RES share in 2030 per energy sector on national level, pursuing a 30% RES target depending on the future gross final energy demand.

RES share in 2030 per energy sector on national level (in the case of a 30% RES target)		30 RES-E	30 RES-E	30 RES-H&C	30 RES-H&C	30 RES-T	30 RES-T
		Low Energy Demand (PRIMES efficiency case 2011)	High Energy Demand (PRIMES reference case 2011)	Low Energy Demand (PRIMES efficiency case 2011)	High Energy Demand (PRIMES reference case 2011)	Low Energy Demand (PRIMES efficiency case 2011)	High Energy Demand (PRIMES reference case 2011)
Austria	%	104.6%	100.9%	50.3%	45.2%	9.9%	11.3%
Belgium	%	21.8%	25.1%	15.4%	12.7%	9.9%	11.3%
Bulgaria	%	35.6%	42.3%	31.5%	31.9%	9.9%	11.3%
Cyprus	%	24.5%	29.6%	17.2%	17.2%	9.9%	11.3%
Czech Republic	%	22.8%	24.8%	18.4%	17.4%	9.9%	11.3%
Denmark	%	45.5%	68.9%	55.3%	53.1%	9.9%	11.3%
Estonia	%	35.9%	49.9%	75.8%	69.3%	9.9%	11.3%
Finland	%	40.4%	38.8%	87.0%	82.6%	9.9%	11.3%
France	%	48.8%	42.5%	41.5%	37.7%	9.9%	11.3%
Germany	%	46.0%	49.8%	26.8%	27.4%	9.9%	11.3%
Greece	%	51.8%	50.7%	28.9%	28.1%	9.9%	11.3%
Hungary	%	25.4%	25.8%	20.8%	21.9%	9.9%	11.3%
Ireland	%	77.8%	77.6%	14.6%	13.6%	9.9%	11.3%
Italy	%	62.7%	59.4%	14.3%	14.2%	9.9%	11.3%
Latvia	%	73.6%	73.0%	92.3%	81.6%	9.9%	11.3%
Lithuania	%	47.6%	54.6%	69.8%	61.5%	9.9%	11.3%
Luxembourg	%	10.8%	11.3%	14.7%	14.1%	9.9%	11.3%
Malta	%	26.6%	28.7%	26.4%	22.0%	9.9%	11.3%
Netherlands	%	41.1%	47.6%	10.3%	10.3%	9.9%	11.3%
Poland	%	36.5%	35.7%	31.3%	26.3%	9.9%	11.3%
Portugal	%	67.7%	82.5%	71.4%	68.0%	9.9%	11.3%
Romania	%	51.2%	49.0%	42.0%	42.6%	9.9%	11.3%
Slovakia	%	33.1%	30.5%	21.7%	21.3%	9.9%	11.3%
Slovenia	%	54.6%	53.3%	42.8%	40.3%	9.9%	11.3%
Spain	%	69.3%	73.3%	20.0%	19.3%	9.9%	11.3%
Sweden	%	73.0%	76.7%	88.3%	83.1%	9.9%	11.3%
United Kingdom	%	58.1%	63.5%	13.2%	12.3%	9.9%	11.3%
EU 27	%	52.4%	53.7%	29.2%	27.6%	9.9%	11.3%

Notes: Data on RES-E refer to domestic production, excluding imports from third countries. Data on RES-T comprise only biofuels and refer to biofuel consumption (and not domestic production)

Regardless the gross final electricity demand scenario considered, Austria would be self-sufficient in RES electricity by 2030 whereas all other countries would not.[5] In contrast, in countries like Belgium, Luxembourg or Czech Republic RES-E deployment would remain at a level below one quarter of their electricity consumption, indicating that a 30% RES targets implies for these countries rather

5 As a general remark please note that countries exceeding their domestic electricity demand are expected to export their surplus to abroad. As such this reflects the principles of a more integrated European electricity market that is expected to take shape until 2030, at least at the regional level.

a stagnation of past RES-E developments under the assumed aligned framework conditions.[6] Thus, these differences with respect to RES-E are mainly a consequence of the uneven starting point but also reflect differences in regional RES potentials. Nevertheless the level of ambition with respect to the RES policy intervention is similar for all Member States. When it comes to the heating and cooling sector, a high contribution of RES is expected in the northern and eastern part of Europe where country-specific RES shares above 90% are applicable by 2030 in a few exceptional cases. Countries as Luxembourg will achieve a higher RES contribution in the heating and cooling sector than in the electricity sector. As already discussed above, for biofuels in the transport sector the modelling indicates that a 30% RES target would lead to rather a stagnation of deployment in the period beyond 2020. As applicable from Table 5-2 biofuels achieve equal shares in domestic transport fuel demand across all Member States, reflecting harmonised patterns with respect to biofuel consumption but not for related production. Thus, it is a consequence of physical trade together with an assumed continuation (and alignment) of blending obligations and shall not be misunderstood with biofuel production where significant differences occur across Europe at present and it is expected that this will remain in future.

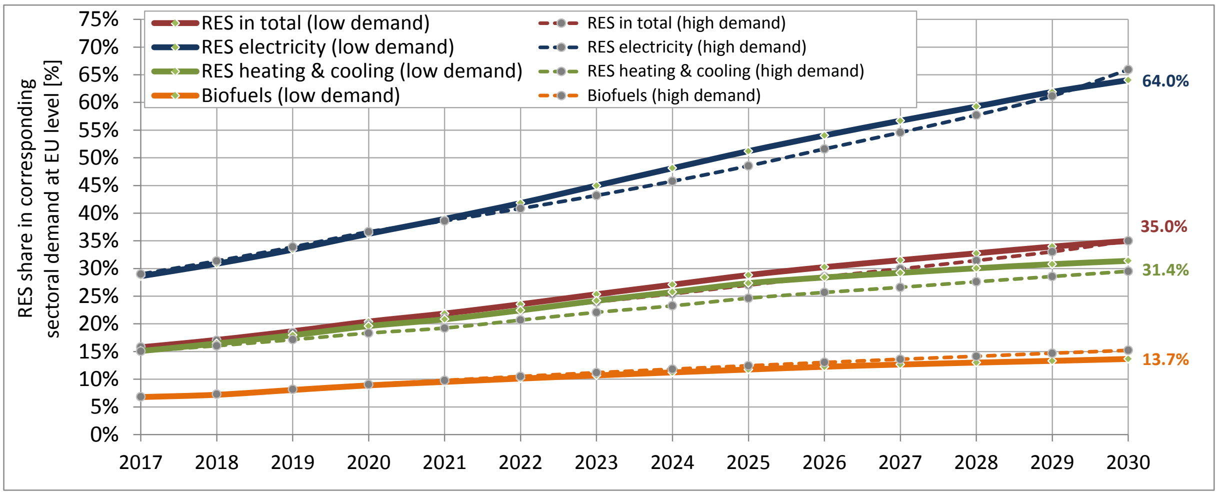

Figure 5-3 Future RES pathways up to 2030 at EU level, pursuing a 35% target, in total and per energy sector depending on the future gross final energy demand.

Second, the 35% RES by 2030 scenario is addressed and the development of the different sectors are depicted in Figure 5-3. A comparison of RES deployment before and after 2020 indicates that a RES target of 35% implies across the EU a continuation of efforts necessary for meeting binding 2020 targets. Similar to a 30% RES target, strongest growth rates are expected for RES in the electricity sector in order to achieve a RES share in gross electricity consumption of 64% by 2030 at EU level. Compared to the development of RES heating & cooling (RES-H&C) under a 30% RES target, only limited additional efforts are expected to happen in the heating and cooling sector in the case of a 35% RES target. Thus, according to the model-based assessment RES-H&C accounts for a share in

6 For example the level of ambition with respect to the RES policy intervention is assumed to be similar for all Member States.

corresponding demand of 30% to 31% by 2030. For biofuels in the transport sector similar growth patterns are applicable for the period beyond 2020 than in the years before. Thus, under these assumptions biofuels achieve a share in transport fuel demand of 14% to 15% in 2030. Similar to the previous case, the demand sensitivity indicates that a higher energy demand (growth) affects the heating and cooling sector most. Thus, the resulting decrease of RES-H&C shares needs to be compensated by increased contributions of RES-E and of biofuels in transport. In this respect, RES-E imports from third countries start to play a decisive role.

Table 5-3 RES share in 2030 per energy sector on national level, pursuing a 35% RES target depending on the future gross final energy demand.

RES share in 2030 per energy sector on national level (in the case of a 35% RES target)		**35 RES-E** Low Energy Demand (PRIMES efficiency case 2011)	**35 RES-E** High Energy Demand (PRIMES reference case 2011)	**35 RES-H&C** Low Energy Demand (PRIMES efficiency case 2011)	**35 RES-H&C** High Energy Demand (PRIMES reference case 2011)	**35 RES-T** Low Energy Demand (PRIMES efficiency case 2011)	**35 RES-T** High Energy Demand (PRIMES reference case 2011)
Austria	%	112.6%	103.8%	48.2%	49.1%	13.7%	15.2%
Belgium	%	27.6%	31.2%	14.5%	14.2%	13.7%	15.2%
Bulgaria	%	46.8%	51.7%	31.6%	31.4%	13.7%	15.2%
Cyprus	%	27.4%	31.6%	17.3%	17.2%	13.7%	15.2%
Czech Republic	%	24.0%	28.3%	21.2%	19.6%	13.7%	15.2%
Denmark	%	67.1%	92.8%	56.9%	53.3%	13.7%	15.2%
Estonia	%	64.7%	51.1%	74.4%	68.8%	13.7%	15.2%
Finland	%	40.8%	42.3%	87.1%	82.4%	13.7%	15.2%
France	%	52.0%	45.3%	42.4%	39.1%	13.7%	15.2%
Germany	%	60.7%	66.7%	33.9%	30.8%	13.7%	15.2%
Greece	%	59.4%	57.7%	29.1%	27.8%	13.7%	15.2%
Hungary	%	27.0%	26.0%	23.6%	23.5%	13.7%	15.2%
Ireland	%	80.6%	79.9%	15.8%	14.3%	13.7%	15.2%
Italy	%	69.5%	66.4%	17.8%	17.3%	13.7%	15.2%
Latvia	%	75.2%	73.9%	93.0%	81.4%	13.7%	15.2%
Lithuania	%	56.4%	58.8%	68.4%	61.1%	13.7%	15.2%
Luxembourg	%	11.2%	12.8%	15.5%	12.8%	13.7%	15.2%
Malta	%	32.7%	30.6%	26.4%	22.0%	13.7%	15.2%
Netherlands	%	63.8%	74.0%	12.3%	12.4%	13.7%	15.2%
Poland	%	37.2%	35.9%	30.6%	27.7%	13.7%	15.2%
Portugal	%	87.5%	99.0%	71.0%	67.1%	13.7%	15.2%
Romania	%	56.4%	54.8%	43.8%	39.3%	13.7%	15.2%
Slovakia	%	35.3%	33.1%	24.2%	24.5%	13.7%	15.2%
Slovenia	%	59.0%	55.1%	40.5%	39.4%	13.7%	15.2%
Spain	%	88.8%	93.0%	20.1%	19.3%	13.7%	15.2%
Sweden	%	78.7%	81.7%	87.8%	83.1%	13.7%	15.2%
United Kingdom	%	73.9%	72.9%	15.5%	16.5%	13.7%	15.2%
EU 27	%	62.3%	63.3%	31.4%	29.5%	13.7%	15.2%

Notes: Data on RES-E refer to domestic production, excluding imports from third countries. Data on RES-T comprise only biofuels and refer to biofuel consumption (and not domestic production)

As shown in Table 5-3, indicating the country- and sector-specific RES contributions for the scenarios assuming a 35% EU-RES target, at national level a very inhomogeneous distribution of RES contribution is assessed. As already applicable under a 30% RES target, Austria would achieve self-sufficiency in meeting its electricity demand through domestic RES before 2030. In contrast to above, with still increasing RES-E deployment in Austria partly significant electricity exports start to take shape in the period close to 2030. In general, several other countries increase their RES-E share significantly under a 35% RES target. On the one hand, Denmark, Portugal and Spain would be able to supply more than 90% of their electricity demand through domestic RES in 2030. On the other hand, in countries like Luxembourg, Hungary or Czech Republic RES-E deployment is expected to remain at a comparatively low level, accounting for a quarter of their electricity needs, or even less, at the same point of time. Compared to the 30% RES scenario, Member States like Denmark or Germany show a significantly stronger RES contribution in the electricity sector. When it comes to the heating and cooling sector, similar than under a 30% target, the strongest deployment of RES-H&C is expected to take place in the northern and eastern part of Europe. For example, all Scandinavian and Baltic countries achieve a RES-H&C share of well above 50% by 2030. A Southern European country with an exceptionally high RES-H&C share is Portugal where biomass for heating purposes achieves high contributions in addition to default options like solarthermal collectors and heat pumps under these climate conditions. Similar to a 30% RES target, Luxembourg shows a higher RES contribution in heating and cooling than in the electricity sector but differences between both are getting smaller. The level of ambition has increased compared to the less ambitious 30% RES target, leading to higher shares in biofuel consumption across all Member States, see Table 5-3. As stated above, these equal shares are a consequence of physical trade together with an assumed continuation (and alignment) of blending obligations.

Third, the <u>40% RES by 2030</u> scenario is assessed and the RES developments by sector up to 2030 at EU level are shown in Figure 5-4. Comparing RES deployment before and after 2020 at EU level indicates that a RES target of 40% implies a strengthening of efforts necessary for meeting binding 2020 targets. Moreover, meeting 40% RES by 2030 requires action already before 2020 in order to be on track by 2030. Similar to the less ambitious targets discussed above, across all sectors RES-E are expected to achieve the strongest growth, leading to a RES share in gross electricity consumption of 73% to 76% by 2030 at EU level. A strong uptake is also applicable for RES in the heating and cooling sector where RES-H&C account for a share of 32% to 33% by 2030 but in contrast to the electricity sector the potential for further increases (and related structural changes) appears more limited under the given timeframe. Finally, strong growth is required also for biofuels in the transport sector, resulting in shares in related consumption of 16% to 17% by 2030.

A closer look at the implications of achieving less energy efficiency for reducing demand (growth) points out that RES in the electricity sector have to compensate the reduction of relative contributions of RES in heating and cooling and in transport. Thereby, RES-E imports from third countries are an important element – their contribution is expected to double in a high demand case compared to the low demand projection (i.e. accounting for a share in gross electricity demand at EU level of 6% instead of 3% by 2030).

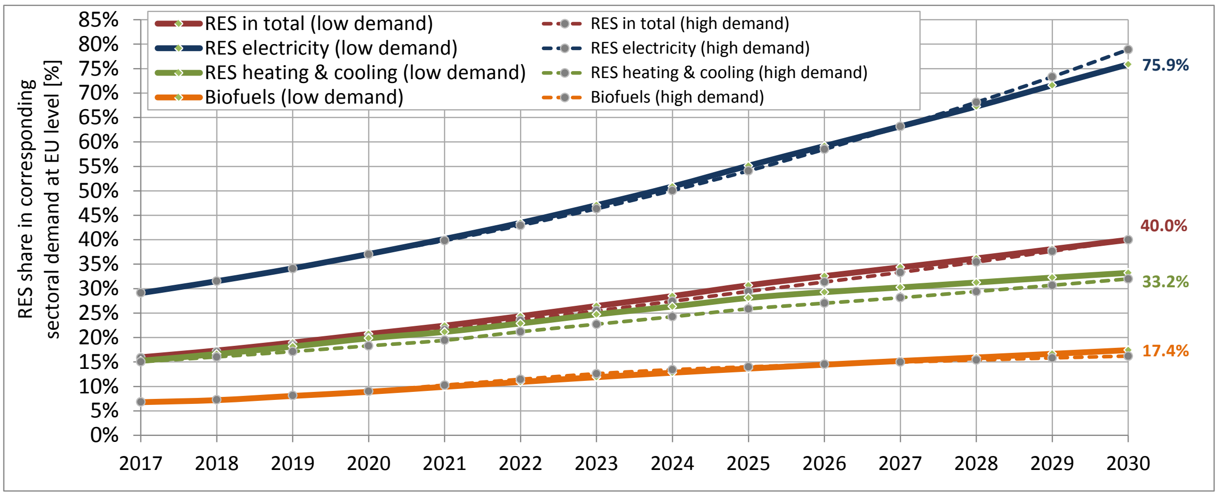

Figure 5-4 Future RES pathways up to 2030 at EU level, pursuing a 40% target, in total and per energy sector depending on the future gross final energy demand.

At national level, similar to the previous 35% RES target case and as a consequence of the uneven starting point together with differences in locally available RES options, a very inhomogeneous distribution of the resulting RES deployment by 2030 is apparent. Regardless the underlying gross final electricity demand trend besides Austria also Denmark, Portugal and Spain would be self-sufficient via RES electricity by 2030, meaning that national RES-E generation exceeds overall domestic electricity consumption. These surpluses will then be exported to their neighbours implying a functioning of electricity market integration at country and at a regional level. Especially, Denmark and Portugal show significant growth rates of RES-E in the period beyond 2020, implying a further strengthening of efforts compared to the 35% RES case. In contrast to above, Luxembourg, Hungary or Czech Republic still generate less than a third of their electricity consumption by renewables. The oversupply of RES on the Iberian peninsula requires strong investments in the infrastructure system in order to fulfil physical requirements. No surprise, for RES in heating and cooling the highest shares in corresponding demand by 2030 are applicable in Northern and Eastern Europe. On the upper limit Sweden stands in focus, achieving high RES contributions (i.e. 85% to 88% as share in corresponding demand) both in the electricity sector and in heating and cooling. As a generally trend, compared to the previously discussed case of 35% RES by 2030 a moderate increase in RES-H&C deployment is apparent across all over Europe – on average an increase in 2030 RES-H&C shares by 2 to 3 percentage points occurs. In comparison with the 35% RES target for biofuels in the transport sector higher shares in related consumption are applicable in all Member States. As stated previously, these equal shares are a consequence of physical trade together with an assumed continuation (and alignment) of blending obligations. Similar to previous cases Table 5-4 depicts all results on 2030 RES deployment by sector and by Member State.

Table 5-4 RES share in 2030 per energy sector on national level, pursuing a 40% RES target depending on the future gross final energy demand.

RES share in 2030 per energy sector on national level (in the case of a 40% RES target)		**40 RES-E** Low Energy Demand (PRIMES efficiency case 2011)	**40 RES-E** High Energy Demand (PRIMES reference case 2011)	**40 RES-H&C** Low Energy Demand (PRIMES efficiency case 2011)	**40 RES-H&C** High Energy Demand (PRIMES reference case 2011)	**40 RES-T** Low Energy Demand (PRIMES efficiency case 2011)	**40 RES-T** High Energy Demand (PRIMES reference case 2011)
Austria	%	116.1%	115.3%	54.1%	48.6%	17.4%	16.2%
Belgium	%	34.4%	37.7%	16.9%	16.9%	17.4%	16.2%
Bulgaria	%	56.0%	65.0%	35.1%	34.5%	17.4%	16.2%
Cyprus	%	30.9%	35.0%	17.2%	17.4%	17.4%	16.2%
Czech Republic	%	27.4%	33.7%	22.9%	20.1%	17.4%	16.2%
Denmark	%	83.9%	130.9%	62.6%	58.4%	17.4%	16.2%
Estonia	%	66.5%	59.5%	77.7%	69.4%	17.4%	16.2%
Finland	%	45.5%	52.4%	88.7%	85.8%	17.4%	16.2%
France	%	58.4%	55.1%	45.0%	40.4%	17.4%	16.2%
Germany	%	76.2%	71.8%	33.7%	36.2%	17.4%	16.2%
Greece	%	69.3%	65.4%	29.5%	29.2%	17.4%	16.2%
Hungary	%	27.9%	28.9%	24.5%	23.7%	17.4%	16.2%
Ireland	%	83.4%	90.1%	15.9%	15.5%	17.4%	16.2%
Italy	%	76.5%	73.3%	20.6%	19.4%	17.4%	16.2%
Latvia	%	77.3%	78.2%	93.3%	80.1%	17.4%	16.2%
Lithuania	%	60.4%	67.2%	69.7%	64.2%	17.4%	16.2%
Luxembourg	%	11.9%	18.0%	17.0%	14.4%	17.4%	16.2%
Malta	%	34.7%	33.0%	26.5%	22.3%	17.4%	16.2%
Netherlands	%	90.1%	87.0%	15.2%	15.9%	17.4%	16.2%
Poland	%	37.7%	40.1%	31.8%	29.4%	17.4%	16.2%
Portugal	%	104.5%	117.0%	71.2%	67.0%	17.4%	16.2%
Romania	%	63.4%	63.5%	42.4%	42.0%	17.4%	16.2%
Slovakia	%	37.1%	36.8%	25.9%	26.2%	17.4%	16.2%
Slovenia	%	61.0%	60.6%	44.0%	45.2%	17.4%	16.2%
Spain	%	108.1%	109.2%	20.4%	20.3%	17.4%	16.2%
Sweden	%	85.9%	87.3%	87.9%	84.8%	17.4%	16.2%
United Kingdom	%	84.5%	89.2%	20.6%	19.3%	17.4%	16.2%
EU 27	%	72.5%	73.1%	33.2%	32.0%	17.4%	16.2%

Notes: Data on RES-E refer to domestic production, excluding imports from third countries. Data on RES-T comprise only biofuels and refer to biofuel consumption (and not domestic production)

Finally, the 45% RES by 2030 scenario is addressed and RES developments in the different energy sectors up to 2030 at EU level are depicted in Figure 5-5. A comparison of RES deployment before and after 2020 at EU level indicates that a RES target of 45% requires a strengthening of efforts already before 2020 – thus, an overachievement of the target of 20% RES by 2020 appears indispensable for meeting a 45% RES target in 2030. Another precondition is the uptake of energy efficiency measures: a 45% RES share in 2030 can only be realized with additional energy efficiency measures to reduce future demand (growth). Similar to all less ambitious targets discussed above, across all sectors renewable electricity is expected to achieve the strongest growth, achieving a RES share in gross electricity consumption of 83% to 89% by 2030 at EU level. Noticeably, such a strong uptake in

RES-E deployment requires not only a strong exploitation of wind, solar, biomass and hydro potentials within Europe but also high RES-E imports from neighbouring countries (i.e. North Africa, Balkan) come into play – i.e. 6% of all electricity consumed within the EU by 2030 will stem from non-EU countries in the default (low) demand case. Similar to a 40% RES target, a strong deployment is also necessary for RES in heating and cooling where RES-H&C achieve a share of 35% by 2030. As stated previously, in contrast to the electricity sector the potential for further increases (and related structural changes) appears however more limited under the given timeframe. Biofuels in transport are expected to pick up beyond 2020 by more ambitious growth rates as in the years before 2020, resulting in 20.3% RES, or more precisely biofuels, in the transport sector by 2030.

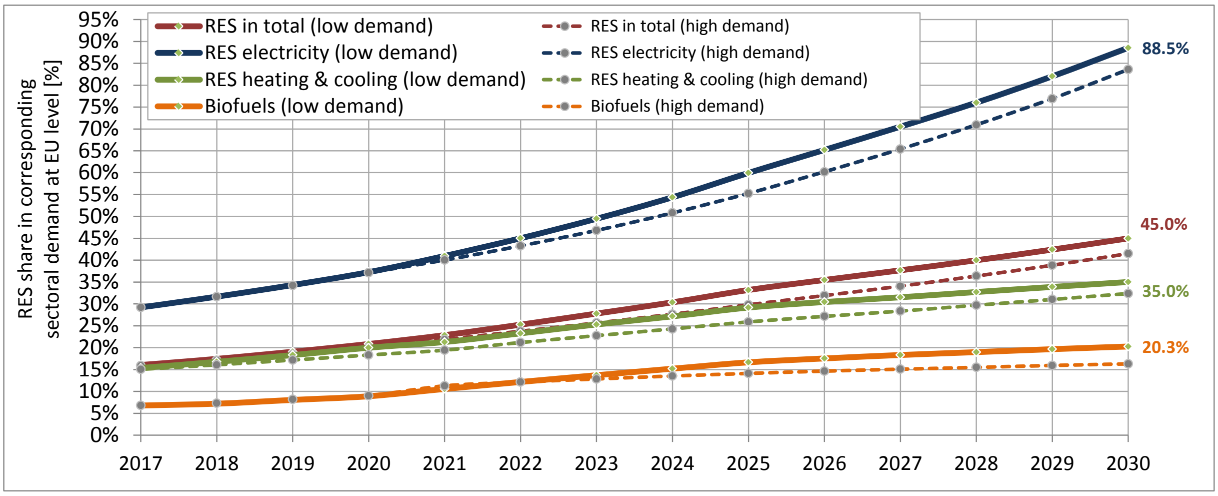

Figure 5-5 Future RES pathways up to 2030 at EU level, pursuing a 45% target, in total and per energy sector depending on the future gross final energy demand.

At national level, again a very inhomogeneous distribution of the resulting RES deployment by 2030 is apparent. The list of countries achieving self-sufficiency in electricity supply with domestic RES is getting longer: In addition to Austria, Denmark, Portugal and Spain thanks to a strong uptake of offshore wind also the Netherlands and the UK would become self-sufficient via RES electricity by 2030, meaning that national RES-E generation exceeds overall domestic electricity consumption and surpluses will then be exported to their neighbours. This implies a well-functioning of electricity market integration at country and at a regional level. In contrast to above, Luxembourg, Hungary or Czech Republic still show a moderate RES-E exploitation at the national level, i.e. domestic RES-E production is less than a third compared to domestic electricity consumption. As stated already with respect to a 40% RES target, the oversupply of RES-E on the Iberian peninsula requires strong investments in the infrastructure system and a massive extension of the power linkage to France. When it comes to the heating and cooling sector, the highest contributions of RES are applicable in in the northern and eastern part of Europe but compared to the 40% RES target no further uptake appears feasible in these countries under the given timeframe. On the upper limit stands Sweden, achieving high RES contributions (i.e. 90% to 91% as share in corresponding demand) both in the electricity sector and in heating and cooling. Compared to the previously discussed case (40% RES by 2030) on average at European level a moderate increase (i.e. by about 2 percentage points in RES-H&C deployment) is apparent. Thus, since northern countries face boundaries for a further uptake this is expected to take shape in the rest of Europe. For biofuels in the transport sector in comparison with the previous case higher shares in related consumption are applicable in all Member States. As discussed above, the equal shares at country level are a consequence of physical trade together with an assumed continuation (and alignment) of blending obligations. Similar to previous cases Table 5-5 expresses all outcomes on 2030 RES deployment by sector and by Member State. Note that in the high demand scenario the EU ends up with a RES share in gross final energy consumption of only 41.5%, meaning that the assumed RES target is then not met.

Table 5-5 RES share in 2030 per energy sector on national level, pursuing a 45% RES target depending on the future gross final energy demand.

RES share in 2030 per energy sector on national level (in the case of a 45% RES target)		**45 RES-E** Low Energy Demand (PRIMES efficiency case 2011)	**45 RES-E** High Energy Demand (PRIMES reference case 2011)	**45 RES-H&C** Low Energy Demand (PRIMES efficiency case 2011)	**45 RES-H&C** High Energy Demand (PRIMES reference case 2011)	**45 RES-T** Low Energy Demand (PRIMES efficiency case 2011)	**45 RES-T** High Energy Demand (PRIMES reference case 2011)
Austria	%	127.1%	116.5%	53.3%	47.7%	20.3%	16.3%
Belgium	%	41.1%	40.5%	19.5%	17.3%	20.3%	16.3%
Bulgaria	%	67.0%	68.9%	35.1%	34.8%	20.3%	16.3%
Cyprus	%	34.2%	35.1%	17.4%	17.3%	20.3%	16.3%
Czech Republic	%	32.7%	37.0%	23.1%	20.4%	20.3%	16.3%
Denmark	%	122.7%	136.6%	58.5%	60.8%	20.3%	16.3%
Estonia	%	76.4%	59.5%	78.1%	68.2%	20.3%	16.3%
Finland	%	48.6%	55.1%	90.8%	84.0%	20.3%	16.3%
France	%	67.4%	58.0%	47.4%	39.8%	20.3%	16.3%
Germany	%	82.3%	73.9%	37.9%	38.4%	20.3%	16.3%
Greece	%	78.6%	66.5%	31.2%	29.5%	20.3%	16.3%
Hungary	%	30.6%	30.6%	25.5%	23.7%	20.3%	16.3%
Ireland	%	96.3%	91.7%	17.5%	15.6%	20.3%	16.3%
Italy	%	84.1%	74.3%	22.4%	19.3%	20.3%	16.3%
Latvia	%	82.6%	80.4%	92.1%	78.9%	20.3%	16.3%
Lithuania	%	68.9%	69.0%	70.3%	63.4%	20.3%	16.3%
Luxembourg	%	15.7%	21.7%	18.4%	15.5%	20.3%	16.3%
Malta	%	36.4%	33.4%	26.8%	22.3%	20.3%	16.3%
Netherlands	%	105.1%	90.3%	17.7%	16.8%	20.3%	16.3%
Poland	%	42.5%	41.3%	32.5%	28.7%	20.3%	16.3%
Portugal	%	118.7%	119.2%	71.2%	66.9%	20.3%	16.3%
Romania	%	71.5%	64.0%	42.3%	41.4%	20.3%	16.3%
Slovakia	%	40.6%	38.9%	27.5%	25.5%	20.3%	16.3%
Slovenia	%	66.3%	61.2%	46.4%	45.0%	20.3%	16.3%
Spain	%	128.0%	110.0%	21.3%	20.0%	20.3%	16.3%
Sweden	%	90.5%	88.5%	89.7%	85.0%	20.3%	16.3%
United Kingdom	%	103.2%	92.0%	21.9%	20.9%	20.3%	16.3%
EU 27	%	82.8%	75.2%	35.0%	32.4%	20.3%	16.3%

Notes: Data on RES-E refer to domestic production, excluding imports from third countries. Data on RES-T comprise only biofuels and refer to biofuel consumption (and not domestic production)

This section closes with a comparison of RES deployment pathways derived within this model-based assessment of different 2030 RES targets with selected decarbonisation pathways derived for and described in the European Commission's Energy Roadmap 2050 (EC, 2011), see Box 1.

Box 1. Comparison of assessed 2030 RES target scenarios with the Energy Roadmap 2050 (EC, 2011)

Europe's road to 2050 – how to 2030 RES targets match with long-term decarbonisation pathways of the Energy Roadmap 2050?

The European Commission's Energy 2050 Roadmap (European Commission, 2011b) as published in December 2011 aimed to provide a first outlook on feasible decarbonisation pathways for Europe's energy system. The energy pathways presented therein aim for a cut in GHG emissions within the EU by 80-95% in 2050. Below a closer look is taken on how RES deployment matches between the 2030 RES target scenarios discussed above with decarbonisation pathways of the Energy Roadmap. In this context Figure 5-6 shows a comparison of RES deployment at EU level, expressed as share in gross final energy demand.

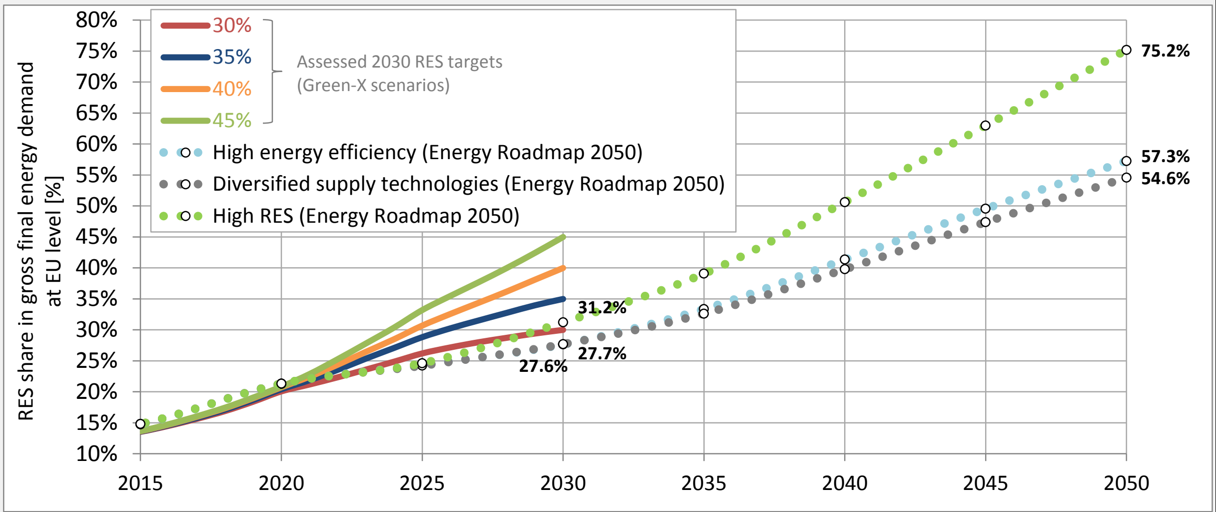

Figure 5-6 Comparison of 2030 RES target scenarios up to 2030 with selected decarbonisation pathways of the Energy Roadmap 2050 (Source: Own elaboration based on PRIMES scenarios)

If 2030 RES deployment is in focus a proper match can be seen between a 30% RES target and decarbonisation pathways – i.e. a 30% RES target lies in between the PRIMES diversified supply technologies case (27.7% RES by 2030) and the PRIMES high renewables case (31.2% RES by 2030). If long-term RES deployment is in focus the graphical illustration shows that, following a linear trend, a 35% and 40% RES target by 2030 appears to match best with the required RES contribution by 2050. Remarkably, all RES developments according to the Roadmap's decarbonisation pathways follow a surprising trend in the period 2020 to 2030 – i.e. after the strong RES growth in the years before 2020 follows a decade of stagnation where only a moderate growth is anticipated while in later years (after 2030) a linear upward trend can be observed.

6 Analysis of results

Following the results of chapter 5, this section discusses the implications of 30%, 35%, 40% and 45% RES targets on EU scale broken down on national level in more detail. Consequently, the possible national 2030 RES targets (see Table 4-1) derived by applying the EC methodology used for 2020 target setting are compared with national RES deployment resulting from the related modelling exercise on meeting 2030 RES targets in a cost-effective manner.[7] This helps to identify the room for RES cooperation among Member States beyond 2020. Finally, associated costs and benefits of meeting the discussed 2030 RES targets are compared later on.

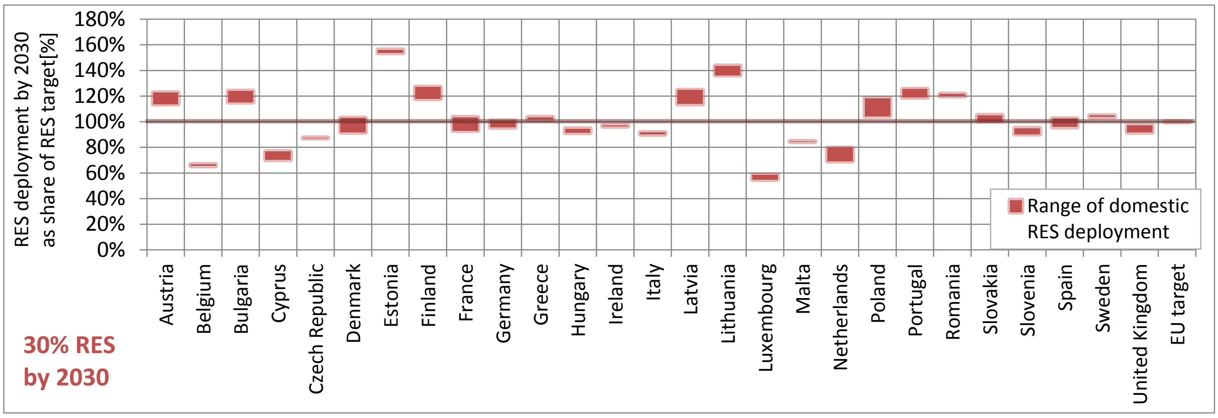

Figure 6-1 National RES contribution by 2030 compared to national RES target in a 30% EU target by 2030 – 100% represents an exact national target achievment by 2030, otherwise a lack or excess of national RES is forecasted.

First, Figure 6-1 depicts the national RES contribution compared to the national targets implying a 30% RES target on EU level. The ranges indicated in the figure highlight the difference between high and low energy demand sensitivities. Thus, 100% means an exact fulfilment of national RES targets whereas figures above indicated an overachievement and vice versa. Moreover, an underachievement does not mean that these Member States do not have to potential to meet their national targets, but rather that the overall EU target is achieved more cost-efficient if these countries take advantage of cooperation mechanisms. In the case of 30% RES on EU level, on the one hand, 11 countries would overachieve their targets whereas some of them, like Estonia or Lithuania even by more than 40%. On the other hand, according to the model-based assessment it can be expected that some countries would not aim for meeting their target purely domestically under the assumed

7 The comparison of possible targets and cost-effective deployment helps to identify the room for RES co-operation among Member States in the period beyond 2020.

framework conditions. Thus, Belgium, Cyprus, Luxembourg or the Netherlands would probably aim for RES cooperation at comparatively large volumes (compared to their assumed domestic RES target), acting as off-taker of surpluses in RES generation of other Member States.

Increasing the level of ambition on EU level towards a 35% RES target by 2030 has only moderate implications on the national RES contribution. Figure 6-2 shows a reduction in overachievment in the majority of countries compared to a less ambitious 30% target – i.e. Austria, Latvia or Poland are examples where surpluses in RES generation are getting smaller. In contrast to that, an increase in RES deployment is apparent in Spain and Germany. Among the list of countries having a deficit in required RES volumes by 2030, Cyprus, Czech Republic, Luxembourg, Malta and Slovenia would rely even stronger on cooperation mechanisms while countries like the Netherlands or United Kingdom would achieve higher domestic RES contributions thanks to offshore wind potentials that would be stronger exploited under a 35% RES target. In absolute terms the overall balance between excess and deficit of national target compliance is reduced compared to the 30% RES target.

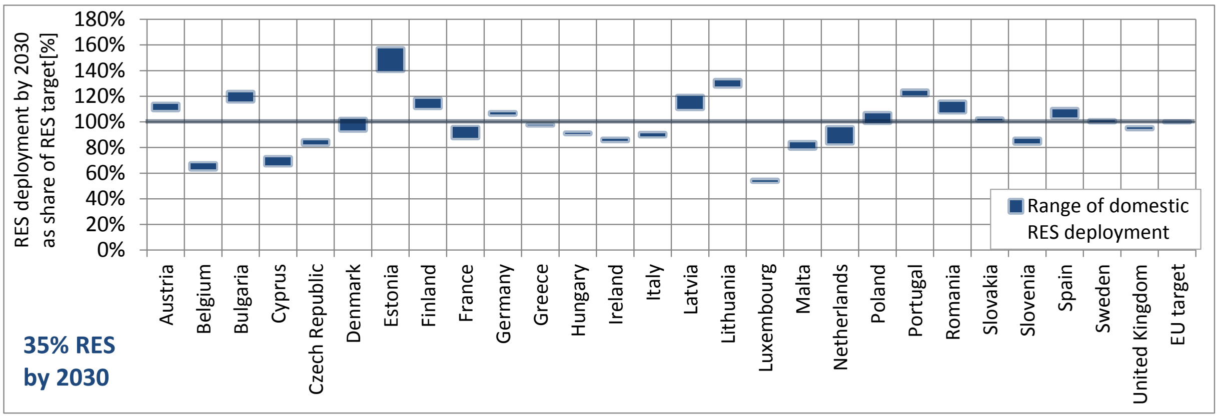

Figure 6-2 National RES contribution by 2030 compared to national RES target in a 35% EU target by 2030 – 100% represents an exact national target achievment by 2030, otherwise a lack or excess of national RES is forecasted.

Continuing the level of ambition on EU level towards a 40% RES target by 2030 turns the picture on the national RES contribution to a larger extent compared to the previous increase from 30% to 35% RES by 2030. Figure 6-3 shows a further reduction in overachievments in Austria, Latvia while a strong increase of RES deployment and consequently also in relative overachievemnt is observable in Bulgaria and Portugal. Poland even turns form an over- to an underachiement of its RES target whereas in Denmark the opposite trend is applicable, achieving significant surpluses in RES deployment. In contrast, countries as Hungary, Ireland, Italy and Malta are even stronger relying on cooperation mechanisms. Remarkably, Denmark, Spain and Portugal show a significantly higher RES contribution than in a 30% RES target scenario. For these countries the sensitivity in energy demand even decreases as they need to contribute significant shares of RES anyhow in order to comply with the 40% RES EU target.

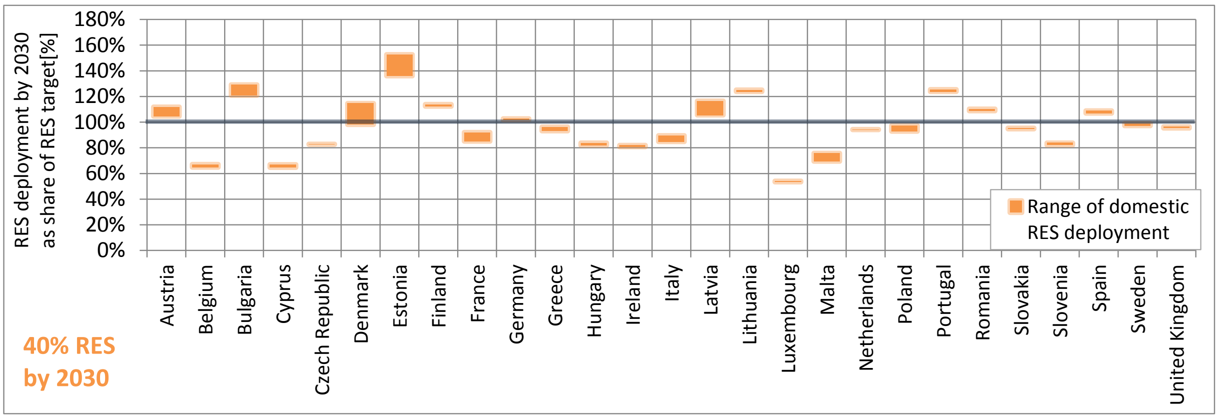

Figure 6-3 National RES contribution by 2030 compared to national RES target in a 40% EU target by 2030 - 100% represents an exact national target achievment by 2030, otherwise a lack or excess of national RES is forecasted.

Finally, increasing the level of ambition on EU level towards a 45% RES target by 2030 turns the picture on the national RES contribution more significantly than in previous cases. Figure 6-4 shows that countries as Austria and Latvia, which have generated RES excess energy in all scenarios even touch the limit of meeting their national targets. As a general trend, all Member States have to aim for an almost full exploitation of their domestic RES potentials that can be utilised within the considered up to 2030 time frame to meet a 45% RES target at EU level. Thereby, as discussed in section 5, also RES-E imports from non-EU countries have to play a vital role, contributing to meet about 6% of EU's gross electricity demand by 2030. For several countries the gap between domestic RES deployment and assumed national 2030 RES targets is increasing, meaning that countries as Cyprus, Czech Republic, Greece, Hungary, Ireland, Italy, Poland and the UK would have to rely even stronger on cooperation mechanisms. Thus, the EU target can only be met in case of strong energy efficiency measures, reducing the overall gross final energy demand.

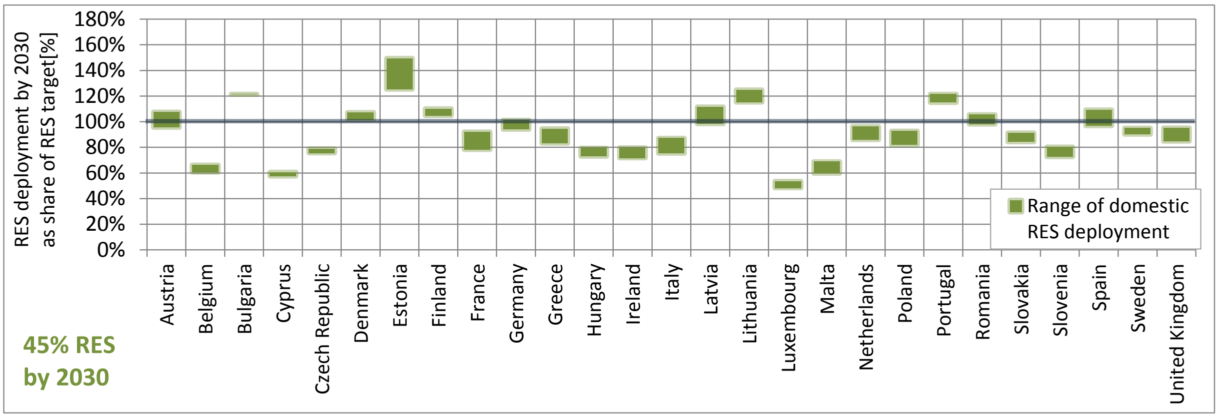

Figure 6-4 National RES contribution by 2030 compared to national RES target in a 45% EU target by 2030 - 100% represents an exact national target achievment by 2030, otherwise a lack or excess of national RES is forecasted.

Next, a closer look is taken on investments in new RES capacities that need to be taken for achieving assessed 2030 RES targets and related RES deployment, respectively. Firstly, it should be noted that an indication of the required investments does not provide insights on the resulting costs – it simply depicts the need for adequate financing, but per se it is impossible to prejudge if such impulses in the economic system lead to positive or negative overall impacts. Figure 6-5 provides a comparison of average yearly investments in new RES in the period 2021 to 2030 at EU level according to the assessed RES target scenarios, including demand sensitivities. No surprise, capital expenditures increase with the height of the assumed 2030 RES target whereby a nearly linear trend is observable. Moreover, a strong impact is apparent from the underlying energy demand trend, i.e. in the case of a low energy demand (growth) RES volumes for meeting a given RES target (defined as share in demand) are lower than under a high demand case, and the same trend is applicable for corresponding investment needs. As expressed in Figure 6-5, at the lower end a 30% RES target requires annual investments at EU level in range of € 73 billion (low demand) to 99 billion (high demand) while at the upper end a 45% RES target corresponds to annual investments in new RES at EU level ranging from € 180 billion (low demand) to € 206 billion. Hence, mobilising these impressive capital volumes requires stable and reliable framework conditions of which binding RES targets are key element.

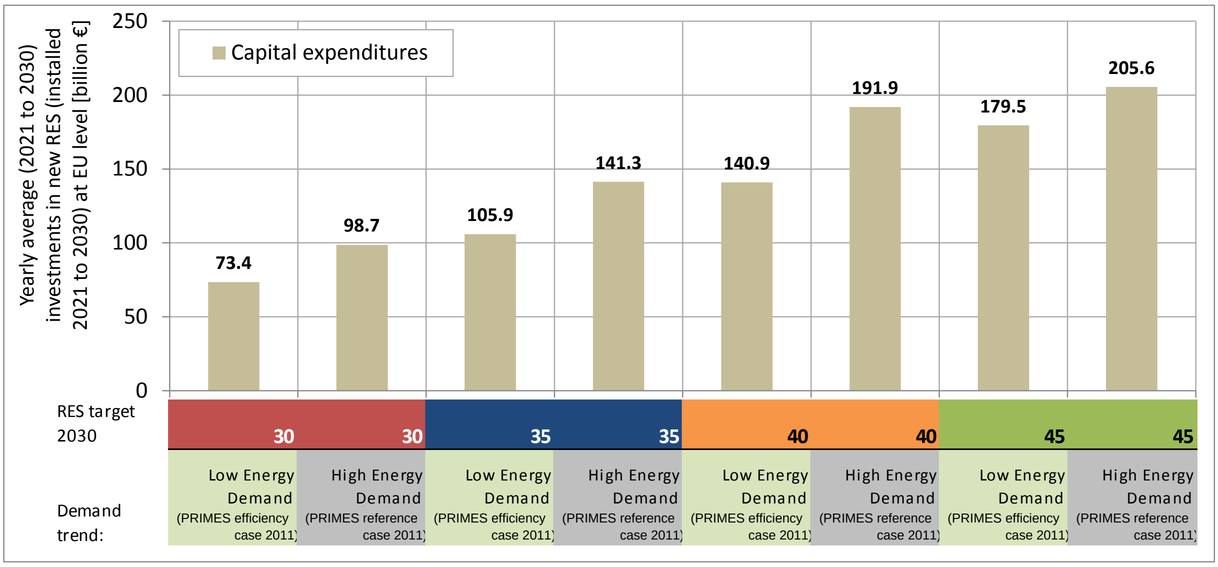

Figure 6-5 Comparison of investment needs (capital expenditures) according to the different RES targets by 2030.

Taking into account the costs and benefits of the enhanced RES generation when meeting the 30%, 35%, 40% and 45% RES target underpins the appropriate setting of binding future RES targets. On the one hand, the associated costs related to RES support mechanisms (i.e. the financial support on top of energy market revenues) are depicted for assessed scenarios of meeting assumed future RES targets. On the other hand, the benefits due to avoided fossil fuel imports and CO_2 emissions[8] are expressed in monetary terms. Figure 6-6 highlights the annual average costs and benefits between 2021 and 2030. Note that the overall brief assessment of costs and benefits does not consider additional benefits as employment effects nor does it consider additional costs as infrastructure investments. Moreover, the monetary expression of costs and benefits depends strongly on the development of international energy prices, impacting the reference system significantly.

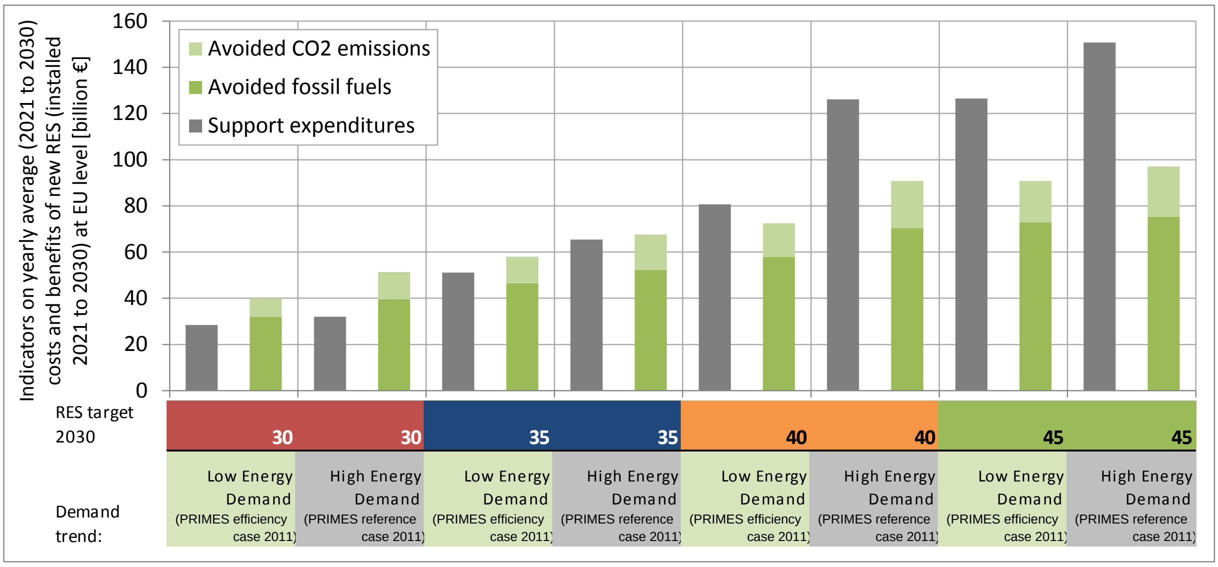

Figure 6-6 Comparison of costs (support costs for RES development) and benefits (monetary savings due to avoided fossil fuel and CO2 emissions) according to the different RES targets by 2030.

In case of a 30% RES by 2030 target the support costs will be significantly lower than the benefits. Thus, support costs of about € 27 billion could trigger about € 40 billion of benefits due to constant RES development and support. In case of high energy demand, both figures would be higher, but the difference of triggering positive benefits would even increase. A similar picture shows the 35% RES target by 2030. Although costs would increase over-proportionally there would still be a direct positive effect of an enhanced RES development. Taking into account a high energy demand scenario reduces the difference between savings and costs, resulting in only a small direct positive benefit. In contrast if it comes to 40% RES by 2030, support costs would be higher than the benefits of an ambitious RES development. Nevertheless, it has to be mentioned that other benefits as employment effects and domestic value-chain effects are neglected herein. Comparing the 40% RES scenario in the case of low energy demand to high energy demand highlights the importance of energy efficiency measures. In fact, high energy demand projections increase the required annual support

8 Avoided fossil fuels and CO_2 emissions are transferred to monetary terms by using the conventional supply portfolio of the reference energy system. More precisely, the assumption is taken that RES substitute the use of fossil fuels (being the marginal option on conventional market) and, consequently, contribute to avoid carbon emissions. Country and sector-specific information on average conversion efficiencies and CO_2 intensities are used as proxy to express the resulting avoidance, and, consequently, expected future fuel prices and CO_2 intensities are used to estimate the monetary expression.

costs significantly (about 35%) whereas the benefits increase only by about 20%. Finally, a closer look at the 45% RES target shows a stronger increase in annual support costs than in assessed direct benefits. Again, energy efficiency measures are of crucial importance at high ambitious RES targets since 45% RES accompanied by energy efficiency measures can be achieved at similar costs than 40% RES without energy efficiency measures. Thus 45% RES by 2030 are only possible in combination with strong energy efficiency measures but direct support costs exceed direct benefits still by about 35%.

7 Conclusions

First, this report has shown the distribution of a 30%, 35%, 40% and 45% RES target by 2030 for all EU Member States. The EC methodology, considering a flat rate approach and GDP weighting was applied in order to discuss the effort sharing. This shows that, under a 45% RES EU target, Sweden would have to meet a target of 75% RES on gross final energy demand by 2030 whereas the associated targets for Czech Republic would be 31%. In contrast, following 30% RES on EU level would imply 59% for Sweden and only one third of it for Czech Republic.

Second, a set of scenarios has been conducted by the Green-X model addressing potential future pathways of RES development on EU, national and sectoral level towards 2030. Following the overall EU targets of 30%, 35%, 40% and 45% RES by 2030 the general modelling approach was to derive the most cost-efficient pathways by enabling cooperation mechanisms in achieving national targets. Thus, not complying with its national target does not necessarily mean too little domestic potentials, but simply the overall EU target is achieved more cost-efficiently with transfers between Member States making use of cooperation mechanisms.

Generally, all different RES targets could be achieved by 2030. However, a target of 45% RES requires an accompanying strong energy efficiency package. Nevertheless, energy efficiency measures are of core importance in all scenarios as the different RES targets will be achieved in a more cost-efficient manner. Comparing the four scenarios shows an increasing contribution of the electricity sector with a rising height of the overall RES EU target. Consequently, RES in the electricity sector amount to almost 90% in 2030 if 45% RES need to be achieved in 2030. Moreover, only a moderate increase in the heating and cooling sector is observed whereas the contribution of the transport sector increases by three quarters in case of a 45% RES target compared to a 30% RES target. Thus, the national RES generation also shifts from countries with high heating and cooling potentials, like the north-eastern Europe, towards more electricity based Member States like Denmark and the Iberian peninsula.

Finally, a cost benefit analysis has been derived, comparing the support costs of the associated RES development to their benefits. In particular, the support costs are derived as the difference between support levels and energy market prices whereas the benefits refer to the monetary expression of avoided fossil fuels and avoided CO_2 emissions due to RES generation. The analysis has shown that with a 30% RES as well as with a 35% RES target support expenditures are significantly lower than the assessed direct benefits of additional RES generation. More ambitious targets in size of 40% and 45% RES are expected to trigger less direct benefits compared to the required support costs. Comparing the low with the high energy demand scenarios highlights the importance of accompanying energy efficiency measures – i.e. a stable or even growing energy consumption significantly increases the efforts to be taken on the supply side for meeting assumed RES shares, leading in the cases of high RES shares to strong increases in related support expenditures whereas assessed benefits rise non-proportionally. Please note however that the results of this brief pre-assessment have to be interpreted considering that the cost-benefit analysis does not include certain costs, like infrastructure investments, and certain benefits as, for example, employment effects.

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9 Annex 1 – Method of approach / Key assumptions

The method of approach and related key assumptions for the modelling work undertaken within this study will be discussed in detail subsequently. Note that an overview of the approach taken within the complementary 2030 RES target calculation is given in section 3 of this report.

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: demand forecasts are taken form the EC Energy Roadmap 2050 (reference and energy efficiency case)
- RES imports to the EU: generally limited to biofuels and forestry biomass meeting the sustainability criteria – moreover, under certain boundary conditions physical imports of RES electricity are also considered as option for national RES target fulfilment.

9.1 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.

9.2 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.[9] 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)[10].

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 9-1.

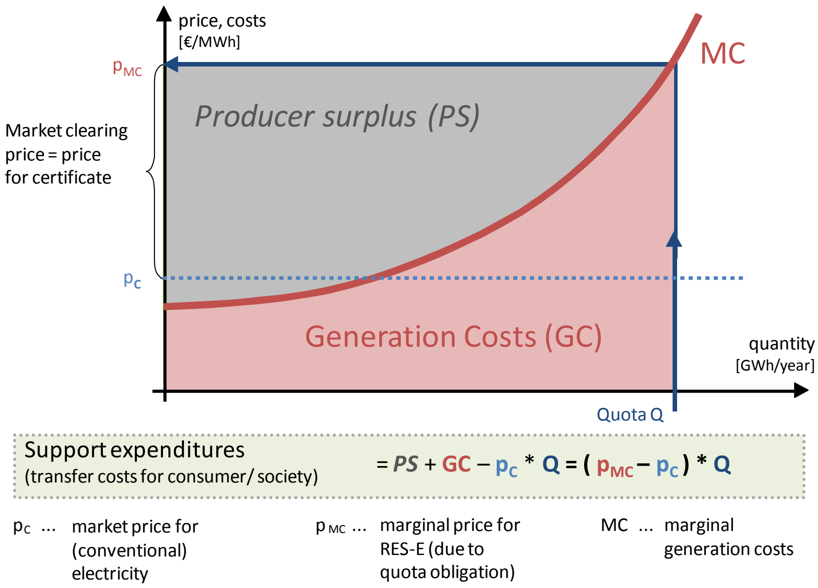


Figure 9-1: Basic definitions of the cost elements (illustrated for a RES trading system)

9.3 Overview on key parameters[11]

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 10).

9 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.

10 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.

11 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.

Table 9-1 shows which parameters are based on PRIMES and which have been defined for this study. More precisely, the PRIMES scenarios used are:

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

Table 9-1: 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

9.3.1 Energy demand

Figure 9-2 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.

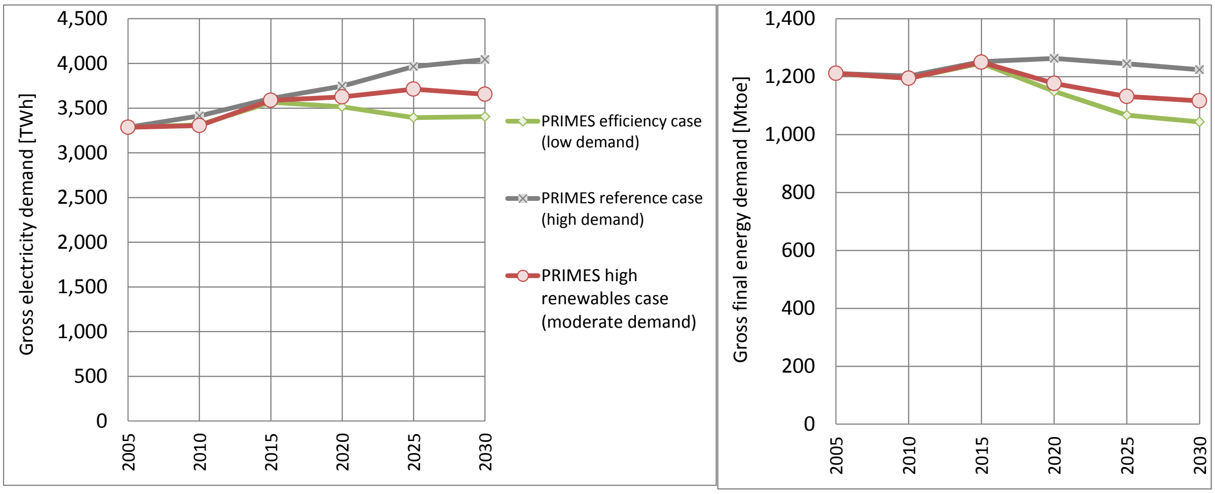


Figure 9-2: Comparison of projected energy demand development at EU-27 level - gross electricity demand (left) and gross final energy demand (right). (Source: PRIMES scenarios)

Subsequently within this report the following specification is used for indicating the assumptions used with respect to energy demand: As also illustrated in Figure 9-2 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*.

9.3.2 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 9-3 illustrates the underlying aggregated EU-27 supply mix for the electricity sector in 2010 according to the *PRIMES reference case*. This mix is the starting point of all scenarios 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. 54% of total). They are composed of coal/lignite, natural gas and a small share of petroleum products. The rest stems from nuclear (27%) and renewable energy (19%).

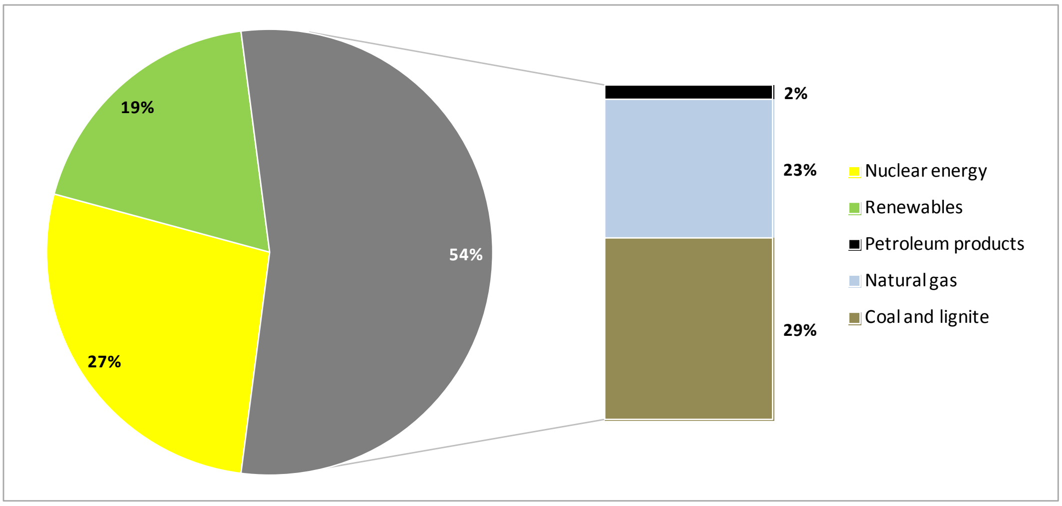


Figure 9-3: PRIMES electricity generation mix 2010. (Source: PRIMES reference case)

In the subsequent figures the relative composition[12] 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. Additionally the percentage changes against 2010 are depicted in more detail on the right hand side.

Figure 9-4 shows the variation of the conventional supply mix in the *PRIMES baseline scenario*. Whereas in the period up to 2020 the share of coal/lignite and natural gas slightly increases, the situation changed in the long run up to 2030 to the opposite. In the case of nuclear energy we can observe a reversed trend up to 2030 which results in an increase of the share of nuclear generation at the expense of fossil fuels, especially of natural gas.

12 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.

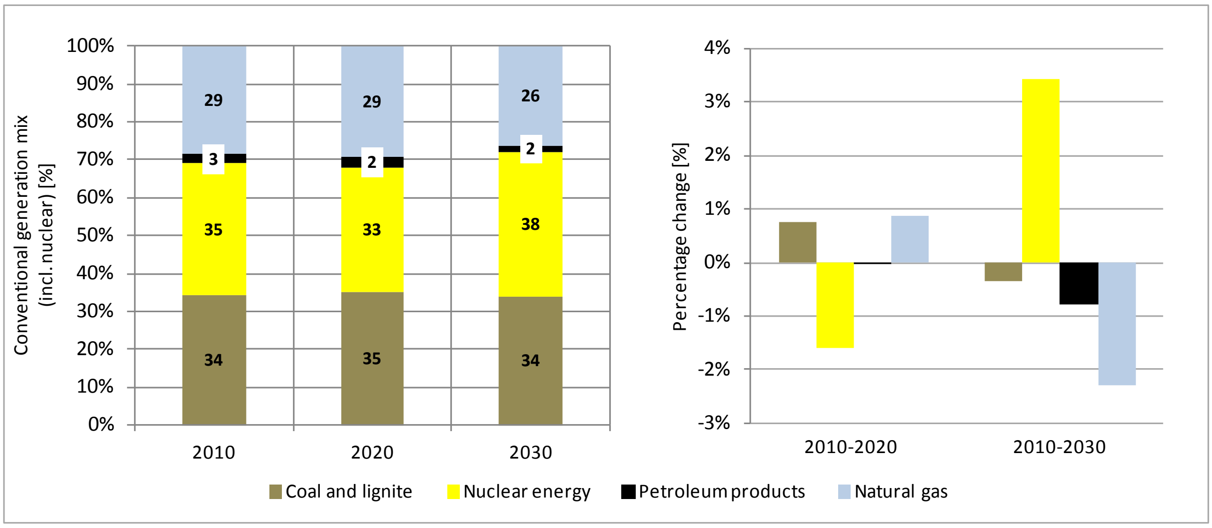


Figure 9-4 **Expected conventional generation mix up to 2030 according to the PRIMES baseline case. (Source: Based on PRIMES baseline case)**

As shown in Figure 9-5 an even stronger increase in percentage changes can be observed in the *PRIMES reference scenario*. By 2030 the scenario shows a considerable increase of the nuclear share which is balanced mostly by a reduction of the share of coal and lignite. The projected share of natural gas is supposed to decline as well, although the reduction is less pronounced than in the *baseline scenario*.

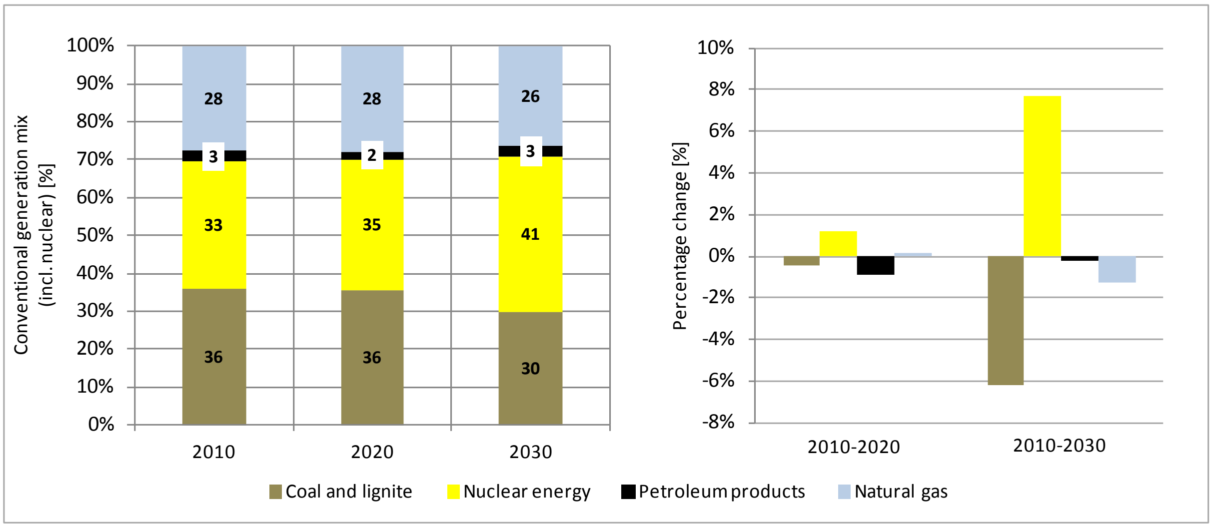


Figure 9-5 **Expected conventional generation mix up to 2030 according to the PRIMES reference case. (Source: Based on PRIMES reference case)**

The most significant changes in relative shares are apparent for the *PRIMES high renewables scenario*. As illustrated on the right hand side of Figure 9-6, the shares of natural gas and nucle-ar generation increase significantly on the expense of coal and lignite, whereas the share of pe-troleum products remains constant until 2030.

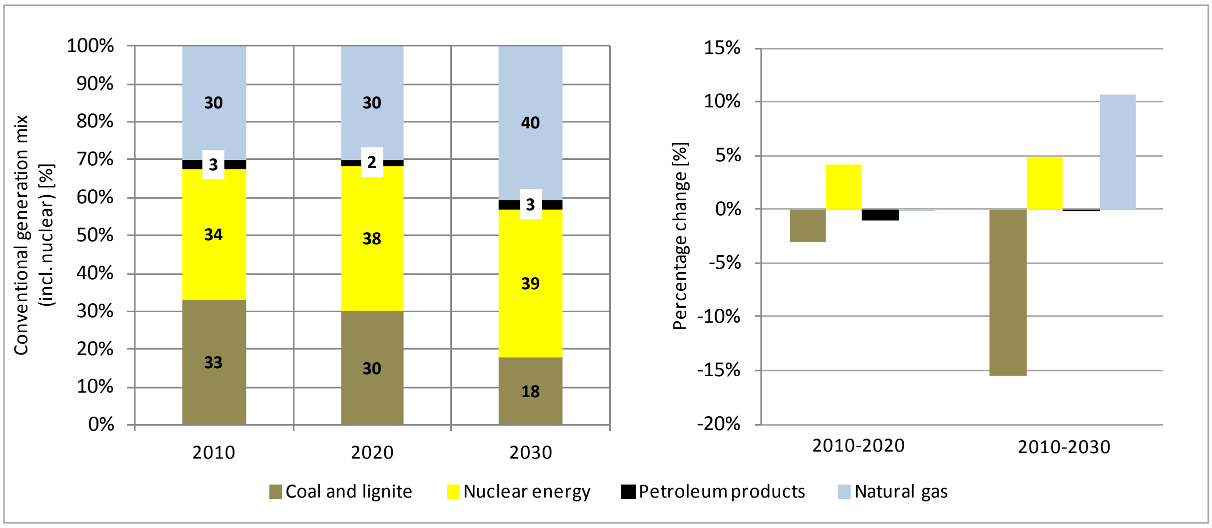


Figure 9-6 **Expected conventional generation mix up to 2030 according to the PRIMES high renewables case. (Source: Based on PRIMES high renewables case)**

To sum up the scenarios assume partially different developments, especially up to the period 2020. 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. The actual amount of the variation differs between the scenarios. Additionally, the expected change of the share of natural gas between 2010 and 2030 significantly varies among the scenarios and ranges from -2.3% (*PRIMES baseline scenario*) to 10.8% (*PRIMES high renewables scenario*).

9.3.3 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 9-7 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 9-8. 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 9-8.

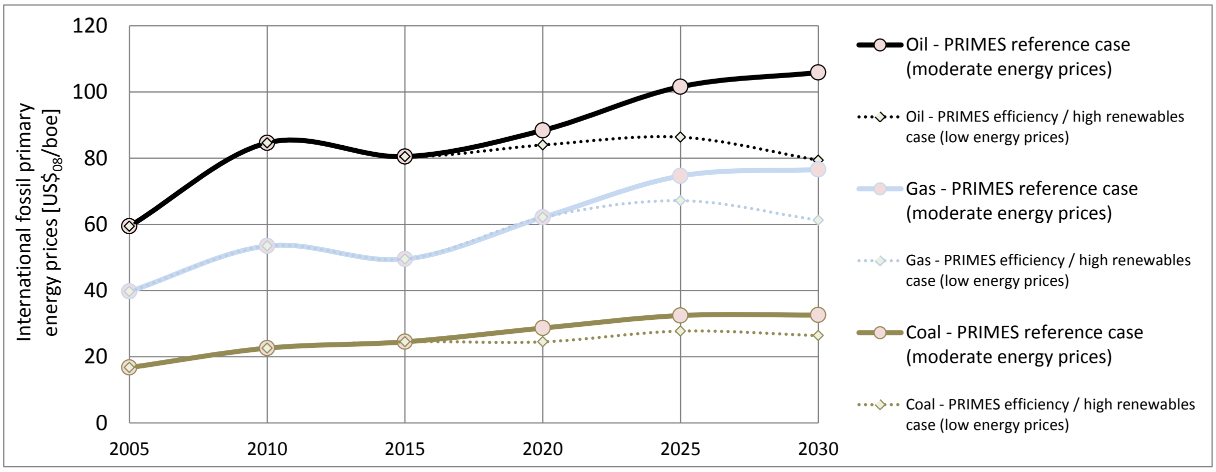


Figure 9-7: Primary energy price assumptions in US$$_{2008}$/boe (Source: PRIMES scenarios)

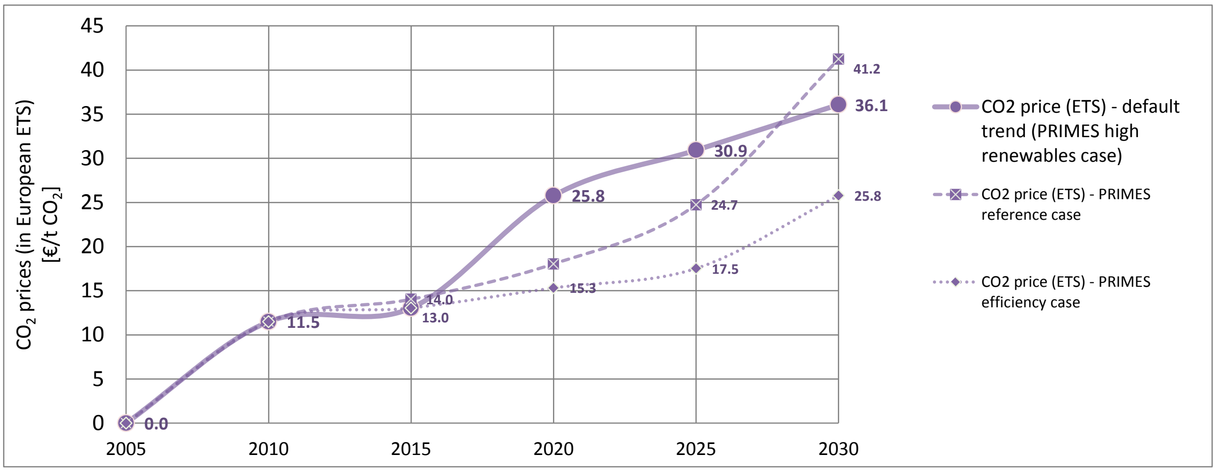


Figure 9-8: CO2 price assumptions in €$_{2010}$/ton (Source: PRIMES scenarios)

Reference prices for the electricity sector are taken from the *Green-X+* model.[13] Based on the primary energy and CO_2 prices and a detailed representation of the power sector in EU Member States, 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-

13 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 EGL Austria. 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).

plant do not include the cost of distribution – i.e. they represent the price directly at defined hand over point.

Table 9-2: Reference prices for electricity, heat and transport fuels (referring to the default case of moderate energy demand and price projections as well as an ambitious RES deployment)(Source: Own elaboration based on Green-X+ and PRIMES scenarios)

Sector reference energy prices at EU level											
Note: Weighted average at EU level, expressed per MWh output		Low demand case (PRIMES efficiency case)					High demand case (PRIMES reference case)				
		2010	2015	2020	2025	2030	2010	2015	2020	2025	2030
Electricity (wholesale)	€/MWh$_{output}$	52.0	57.4	67.1	68.8	67.8	52.0	57.6	72.6	84.7	88.5
Heat (grid)	€/MWh$_{output}$	42.3	43.0	52.7	57.0	56.5	42.3	43.2	53.5	62.9	68.8
Heat (non-grid)	€/MWh$_{output}$	75.0	74.6	84.9	88.2	83.5	75.0	74.6	86.1	96.3	98.9
Transport	€/MWh$_{output}$	50.0	51.3	58.3	60.7	56.6	50.0	51.3	61.3	71.4	75.5

10 Annex 2 – Potentials and costs of 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 feedstocks 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.

10.1 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.[14] 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.

10.1.1 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.

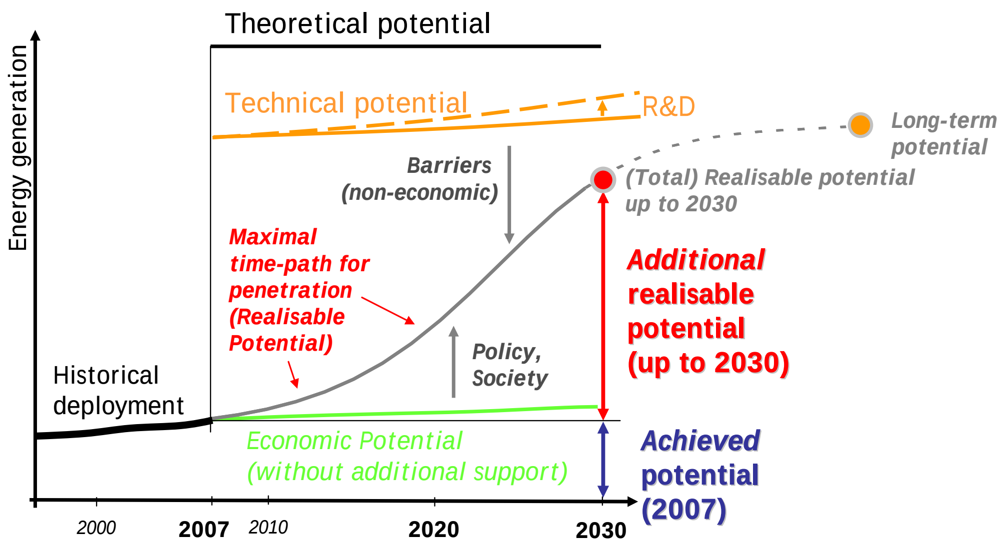


Figure 10-1. Definition of potential terms

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

14 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.

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 10-1 (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.

10.1.2 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 2 (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.

10.1.3 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[15] – the *achieved potential* at the end of 2005 – taking into account the recent development of this rapidly growing market. The historical record was derived in a comprehensive data-collection – based on (Eurostat, 2007; IEA, 2007) and statistical information gained on national level. In addition, *future* potentials – i.e. the *additional realisable mid-term potentials* up to 2030 – were assessed[16] taking into account the country-specific situation as well as overall realisation constraints.

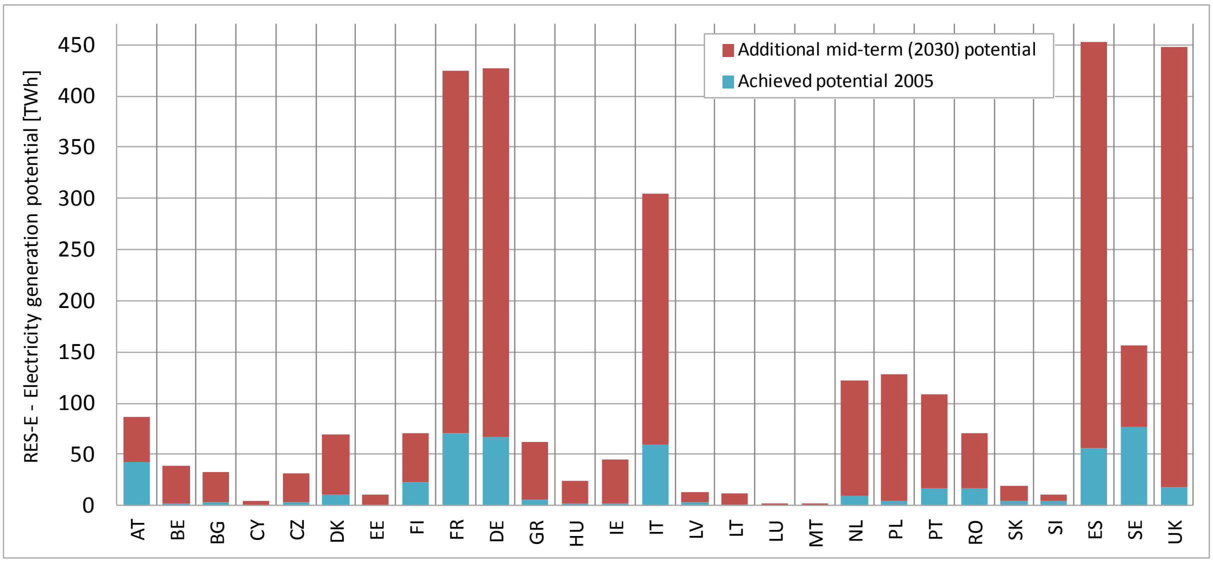


Figure 10-2. Achieved (2005) and additional mid-term potential 2030 for electricity from RES in the EU 27 on country level.

Figure 10-2 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 10-3 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

15 The electricity generation potential with respect to existing plant represents the output potential of all plants installed up to the end of 2005. Of course, figures for actual generation and generation potentials differ in most cases – due to the fact that in contrast to the actual data, potential figures represent, e.g. in case of hydropower, the normal hydrological conditions, and furthermore, not all plants are installed at the beginning of each year.

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

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

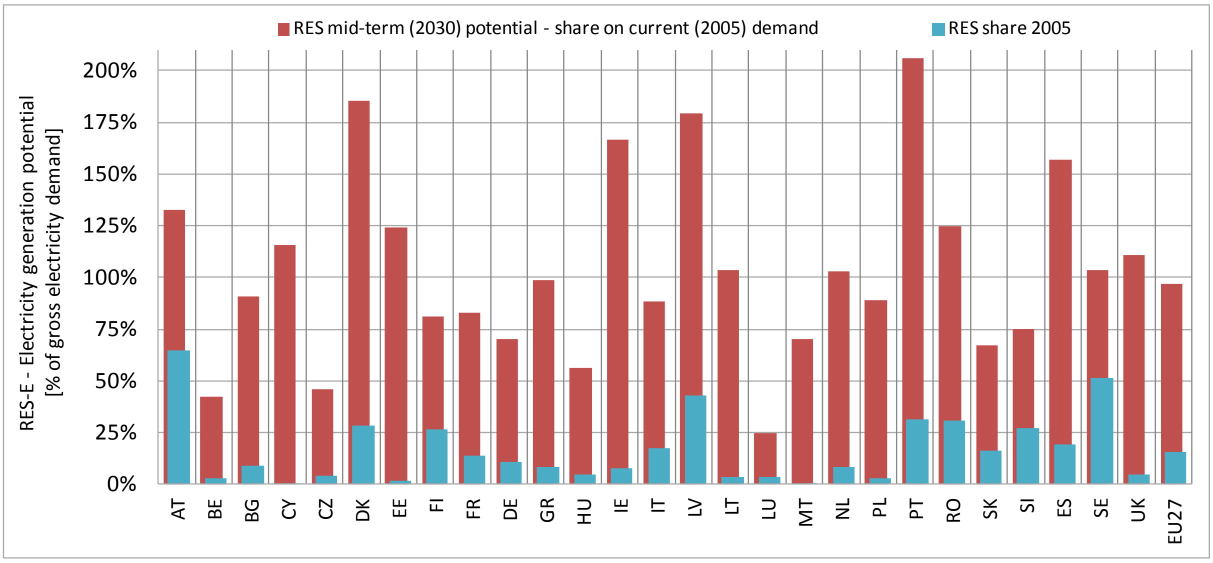


Figure 10-3. Total realisable mid-term potentials (2030) and achieved potential for RES-E in EU 27 countries as share of gross electricity demand (2005).

Additionally, the above-mentioned relations of the total realisable mid-term potential (2030) to the gross electricity demand are addressed in Figure 10-4 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.

17 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.

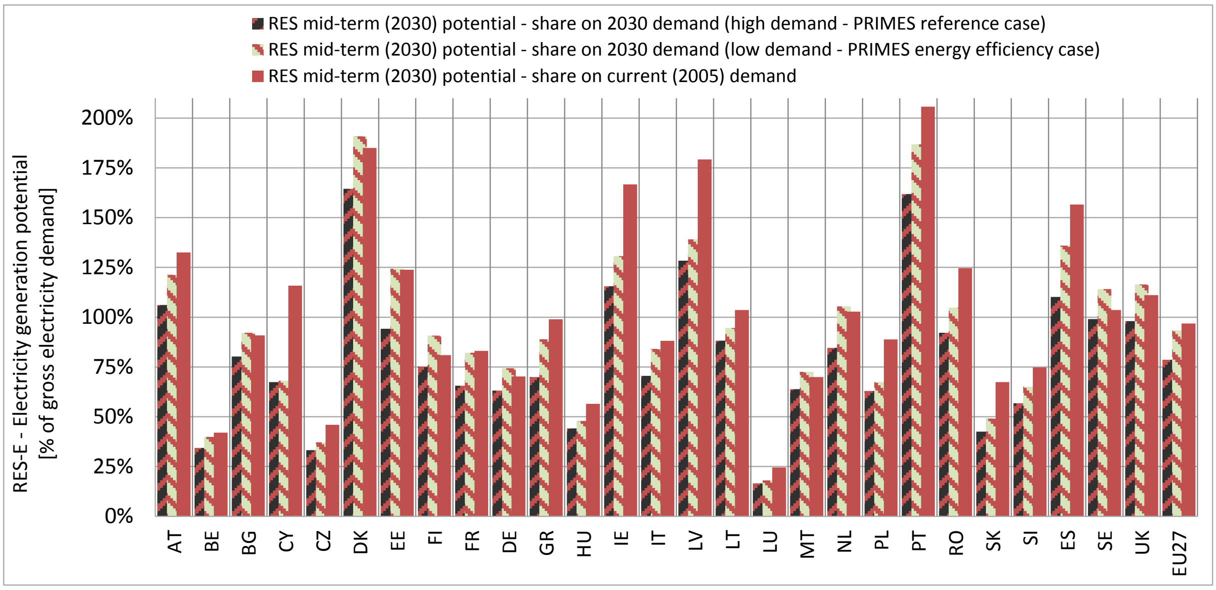


Figure 10-4. Total realisable mid-term potentials (2030) and achieved potential for RES-E in EU 27 countries as share of gross electricity demand (2005 & 2030) in a reference and an efficiency demand scenario.

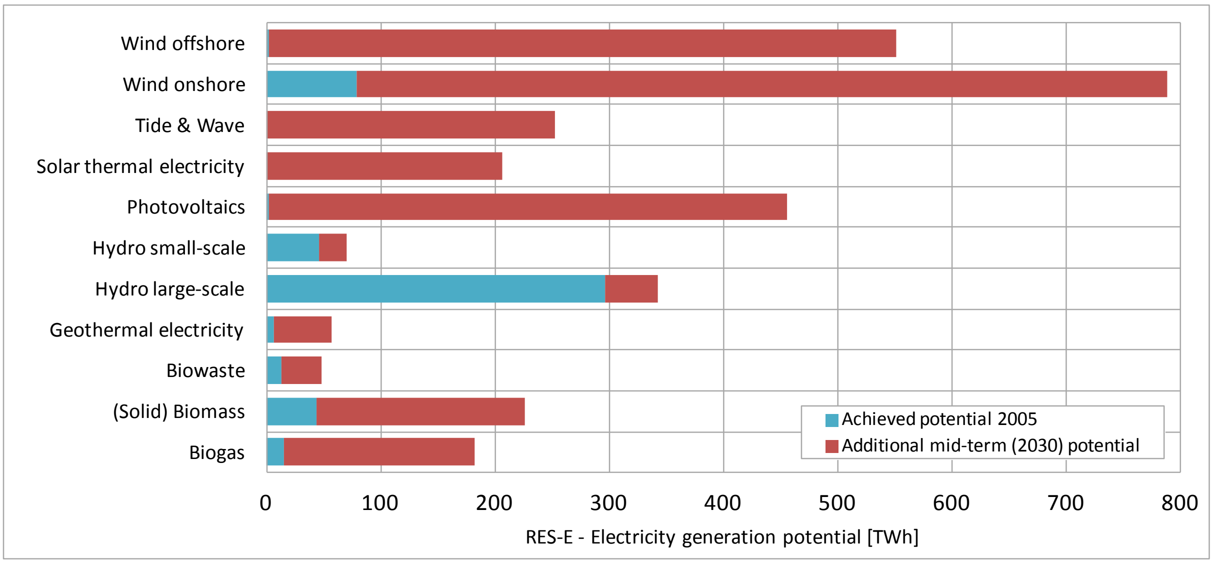


Figure 10-5. Total realisable mid-term potentials (2030) and achieved potential for RES-E in EU 27 countries on technology level.

Figure 10-5 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.

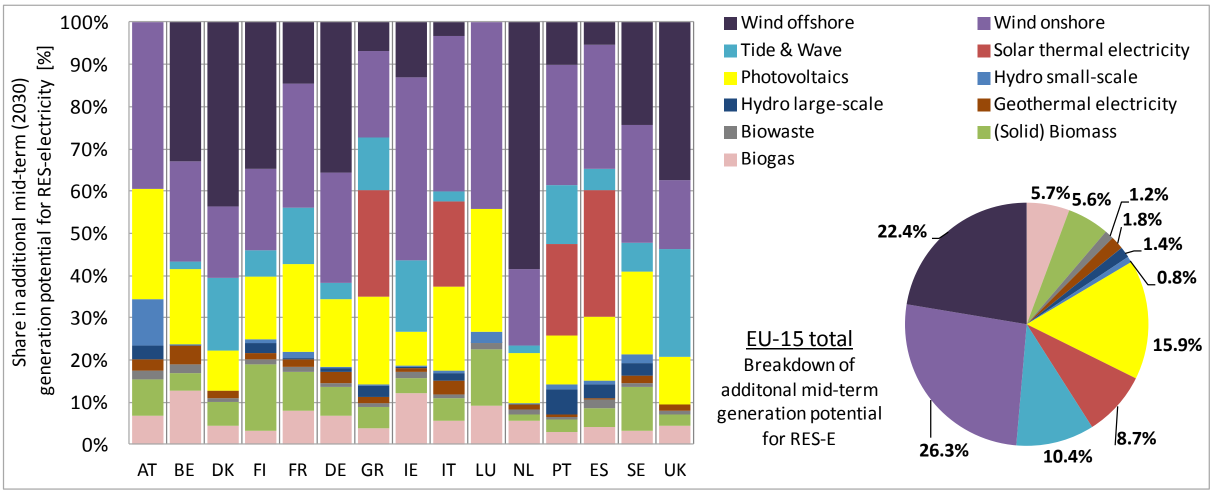


Figure 10-6. **RES-E as a share of the additional realisable potential in 2030 for the EU-15 - by country (left) as well as for total EU-15 (right).**

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 10-6 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%).

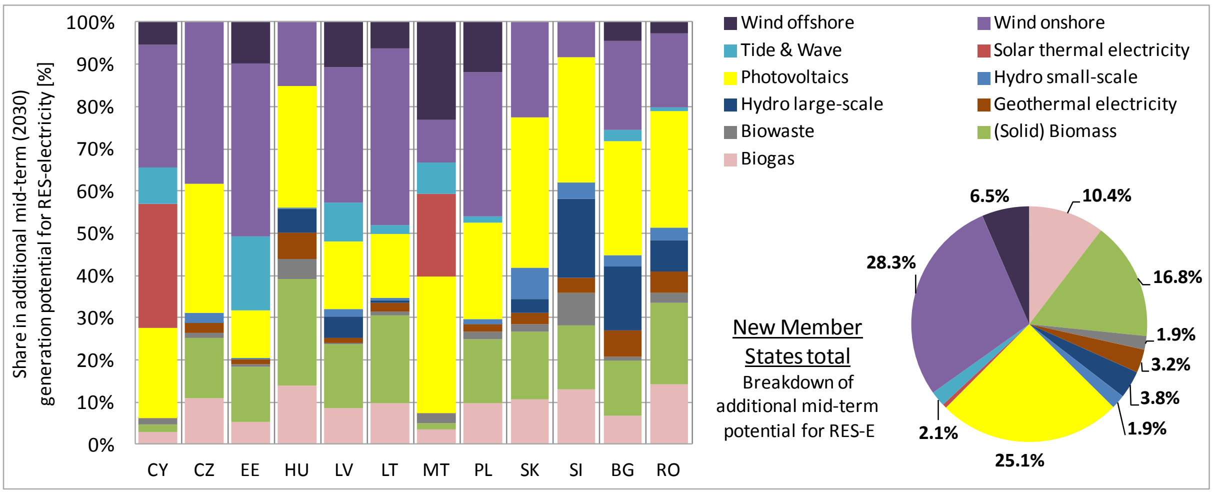


Figure 10-7. **RES-E as a share of the additional realisable potential in 2030 for the New Member States - by country (left) as well as for total NMS (right).**

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 10-7 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).

10.1.4 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.

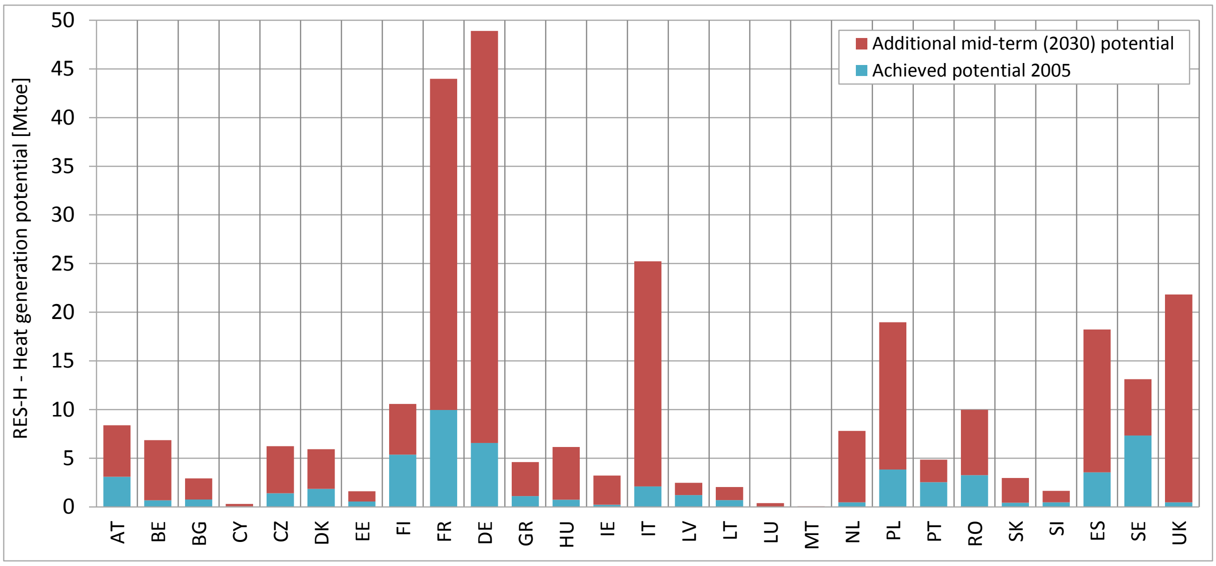


Figure 10-8 Achieved (2005) and additional mid-term potential 2030 for heatling and cooling from RES in the EU 27 on country level.

Figure 10-8 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.

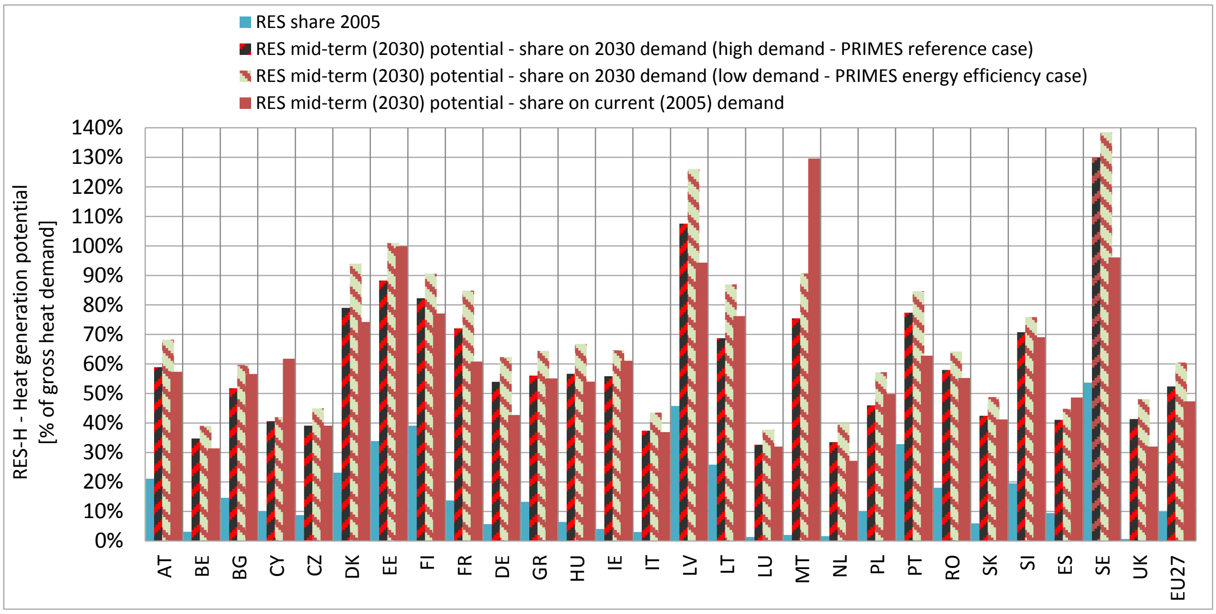


Figure 10-9 **Total realisable mid-term potentials (2030) and achieved potential for RES-H&C in EU 27 countries as share of gross heating and cooling demand (2005 & 2030) in a reference and an efficiency demand scenario.**

Consequently, Figure 10-9 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.

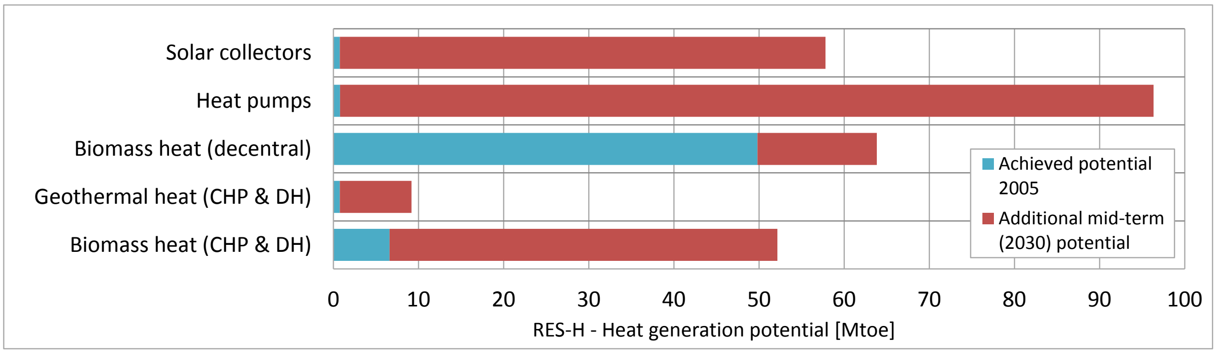


Figure 10-10 **Total realisable mid-term potentials (2030) and achieved potential for RES-H&C in EU 27 countries on technology level.**

Figure 10-10 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.

10.1.5 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 10-11 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.

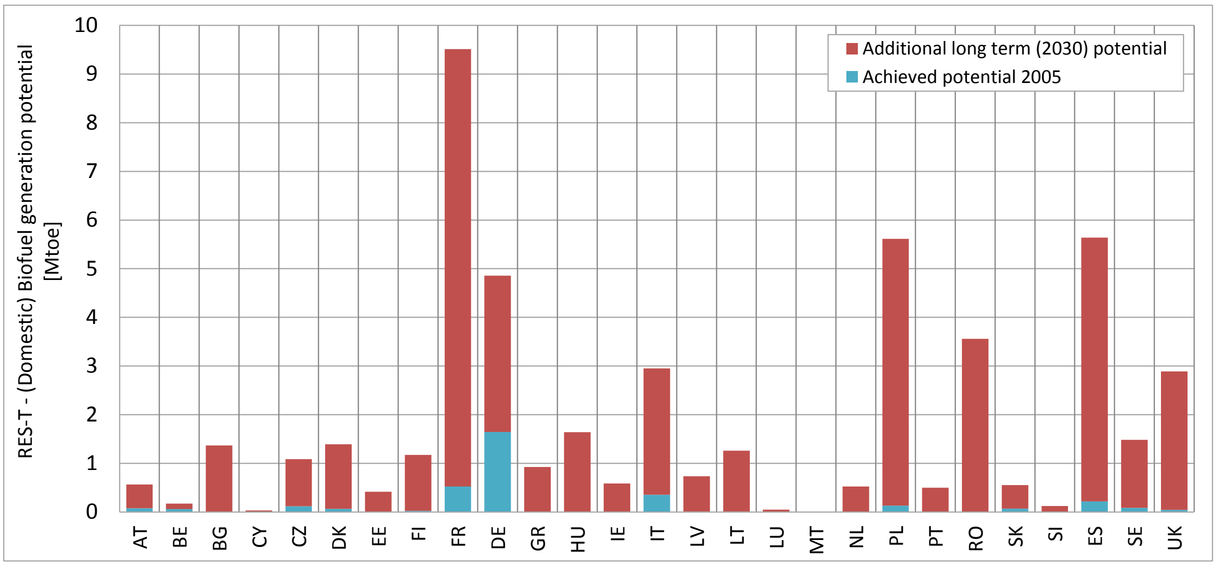


Figure 10-11 Achieved (2005) and additional mid-term potential 2030 for transport from RES in the EU 27 on country level.

Consequently, Figure 10-11 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.

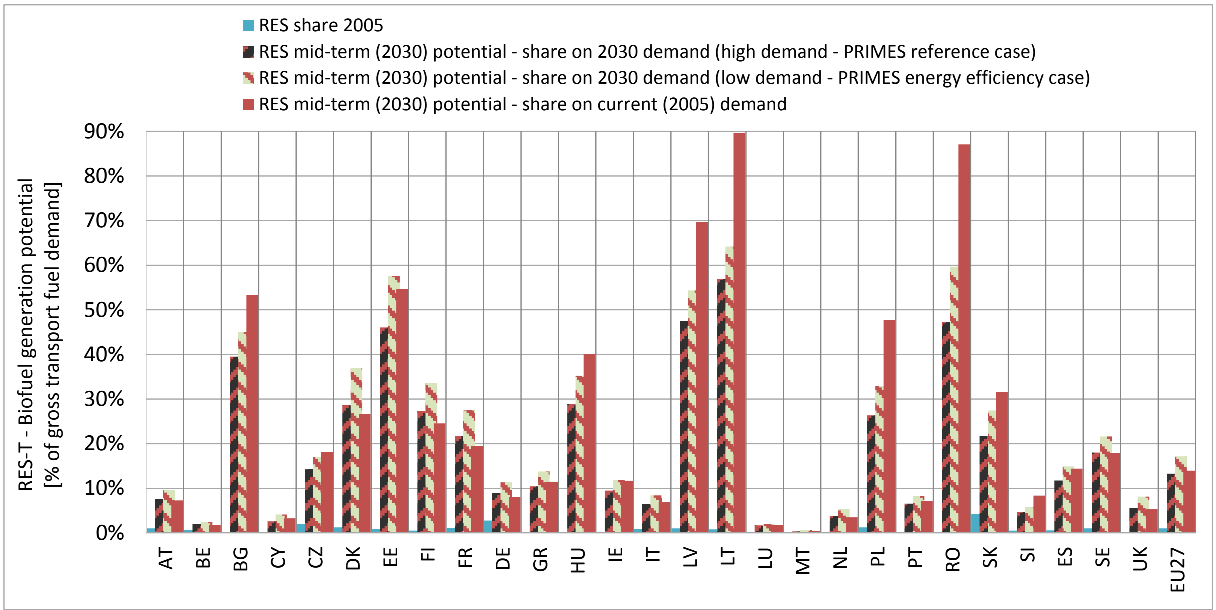


Figure 10-12 **Total realisable mid-term potentials (2030) and achieved potential for RES-T in EU 27 countries as share of gross transport fuel demand (2005 & 2030) in a reference and an efficiency demand scenario.**

10.2 RES cost

10.2.1 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.[18] In order to illustrate the economic figures for each technology Table 10-1 represents the economic parameters and accompanying technical specifications for RES technologies in the electricity sector, whilst Table 10-2 and Table 10-3 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

18 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.

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 10-1, Table 10-2 and Table 10-3, 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 10-1:

- 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};
- 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 10-1: Overview on economic-& technical-specifications for new RES-E plant (for the year 2010)

RES-E sub-category	*Plant specification*	*Investment costs [€/kW$_{el}$]*	*O&M costs [€/(kW$_{el}$* year)]*	*Efficiency (electricity) [1]*	*Efficiency (heat) [1]*	*Lifetime (average) [years]*	*Typical plant size [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 10-2: 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* *[€/kW_{heat}][2]*	*O&M costs* *[€/(kW_{heat}*yr)][2]*	*Efficiency (heat)[1]* *[1]*	*Lifetime (average)* *[years]*	*Typical plant size* *[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 10-3: Overview on economic-& technical-specifications for new biofuel refineries (for the year 2010)

RES-T sub-category	*Fuel input*	*Investment costs* *[€/kW_{trans}]*	*O&M costs* *[€/(kW_{trans}* year)]*	*Efficiency (transport)* *[1]*	*Efficiency (electricity)* *[1]*	*Lifetime (average)* *[years]*	*Typical plant size* *[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 10-2 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 10-3 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 10-13, Figure 10-14 and Figure 10-15 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.

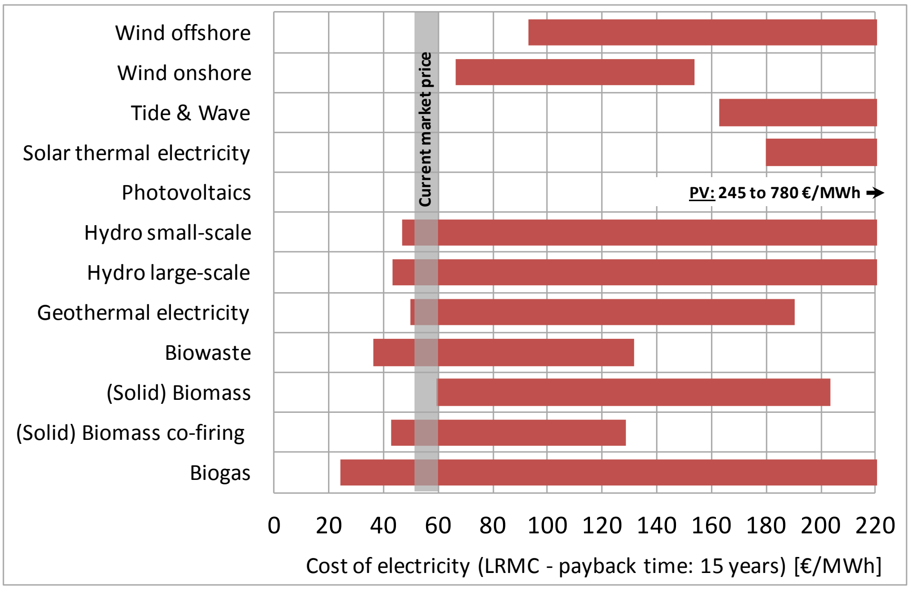


Figure 10-13: Long-run marginal generation costs (for the year 2010) for various RES-E options in EU countries

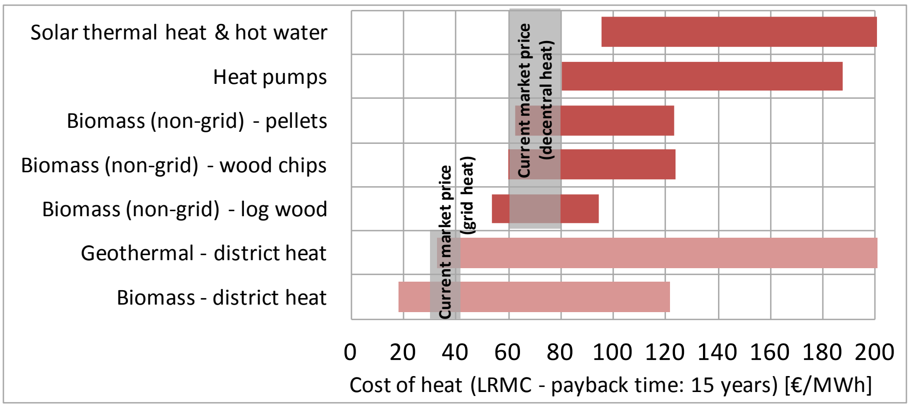


Figure 10-14: Long-run marginal generation costs (for the year 2010) for various RES-H&C options in EU countries

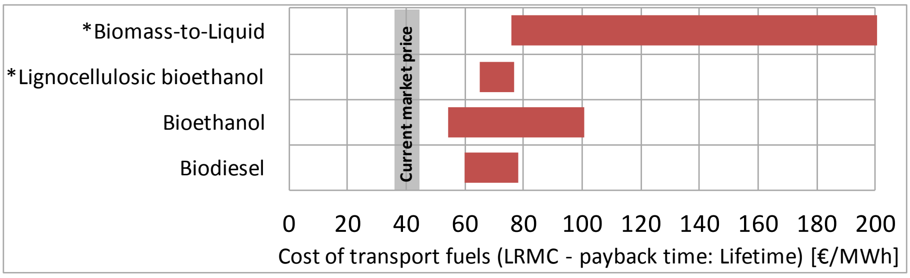


Figure 10-15: Long-run marginal generation costs (for the year 2010[19]) for various RES-T options in

19 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.

EU countries

10.2.2 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 10-4. 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 10-4. 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 10-16 (accelerated RES deployment) and Figure 10-17 (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.[20] However, still substantial cost reductions are observable and expected for novel technology options such as photovoltaics, solar thermal electricity or ocean technologies.

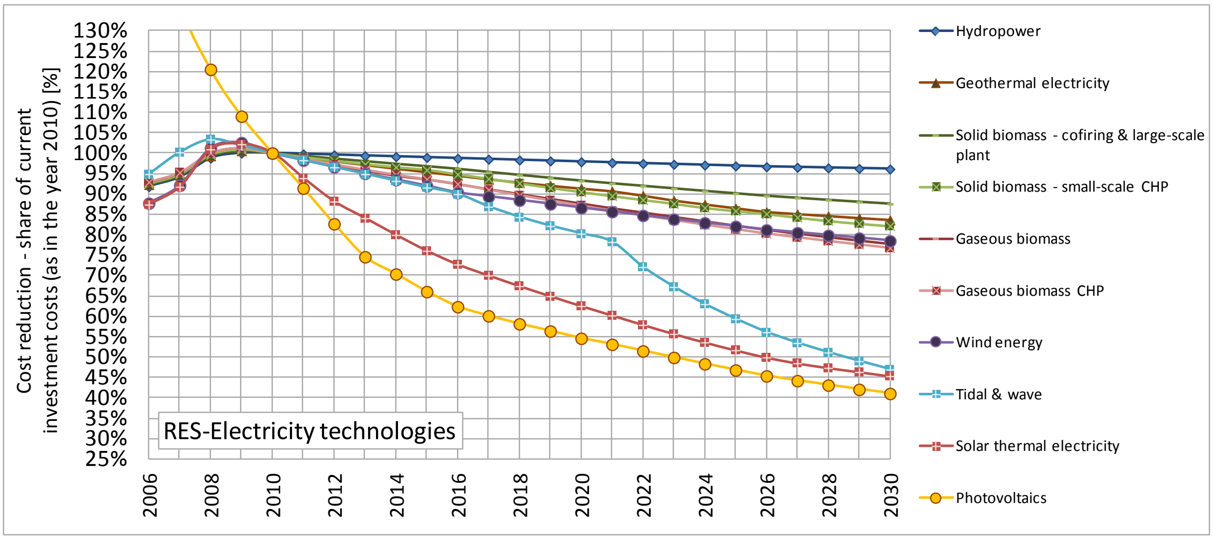
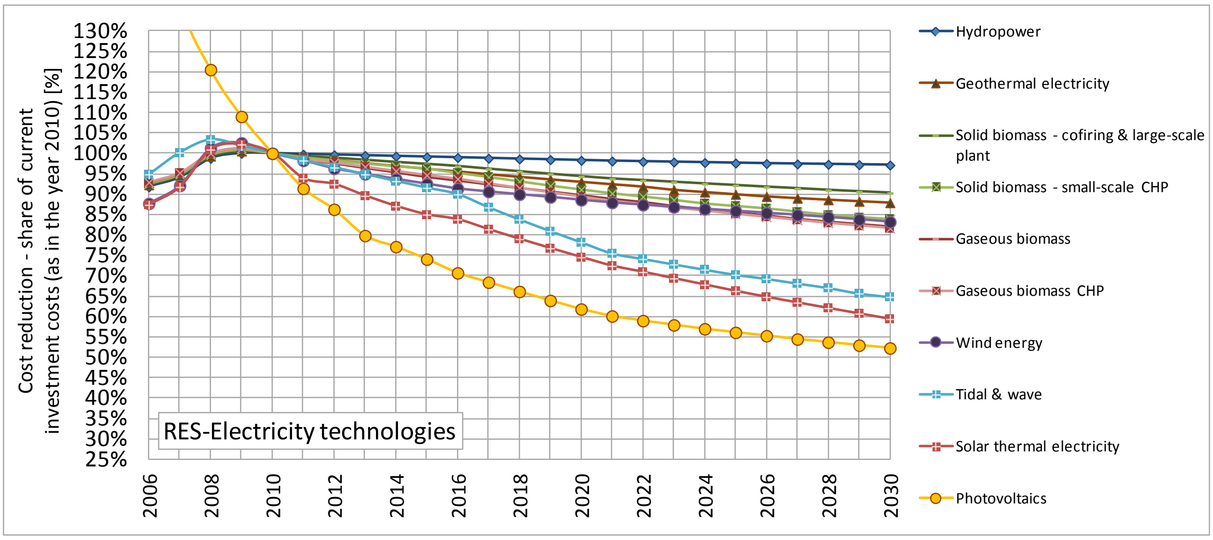


Figure 10-16. Cost reduction of RES-E investments as share of current investment costs (2010) based on moderate technological learning expectations (default) in accordance with the Green-X Advanced scenario (where a strong take-up of RES-E is assumed)[21]



20 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.

21 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 10-17. 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 10-18 (for solar PV and CSP) and Figure 10-19 (for wind on- and offshore).

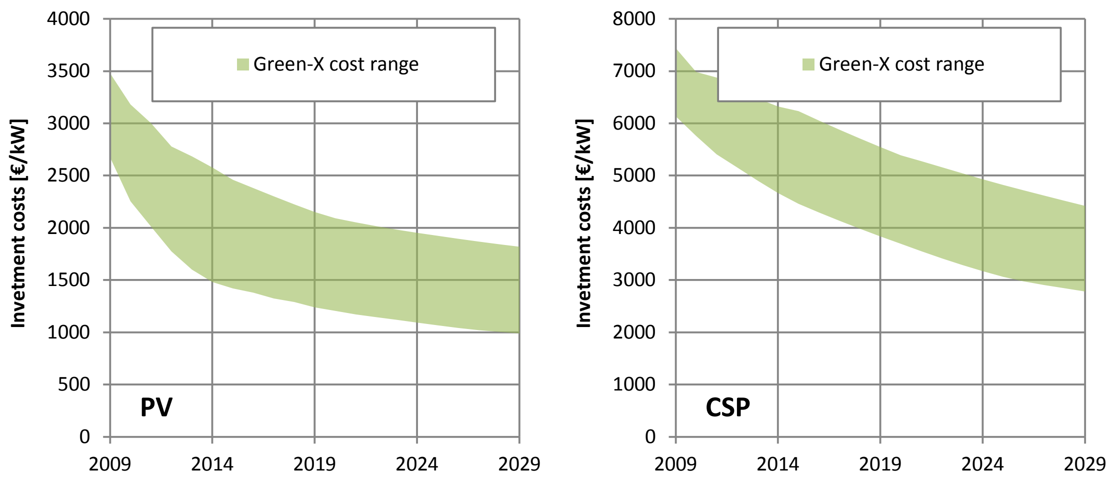


Figure 10-18. Comparison of resulting ranges (of investment costs) for solar technologies (PV, CSP)

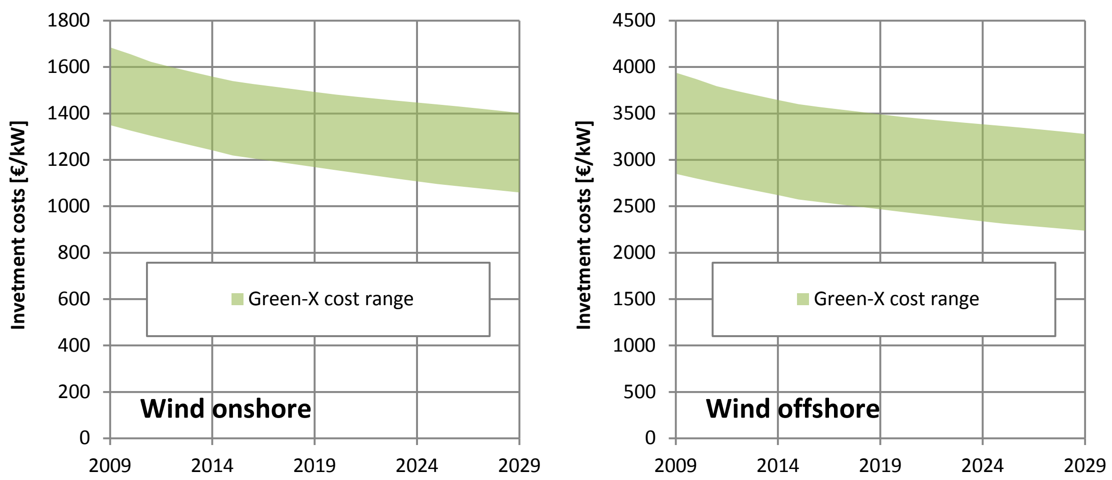


Figure 10-19. Comparison of resulting ranges (of investment costs) for wind technologies (onshore, offshore)