EUROPE TAKES THE CHALLENGE – THE WAY FORWARD IN PROMOTING RENEWABLE ELECTRICITY

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Abstract

Energy policy is the main driver for the enhanced deployment of electricity from renewable energy sources (RES-E) as observed in several countries worldwide. It is the core objective of this paper to provide a comprehensive summary of recommendations on how to derive effective and cost-efficient support schemes for RES-E which are necessary to steer our energy system in the direction of sustainability and supply security.

A prospective analysis of possible future RES support options – build on recently policy debates – at European level aims to signpost the way forward. Investigations on national support measures versus European-wide harmonized RES policies serve to identify recommendations of future RES policy designs. The issue of the effectiveness and efficiency of support schemes is discussed based on the results obtained from simulation runs using the Green-X model. As key criterion for achieving an enhanced future deployment of RES-E in an effective and efficient manner, besides the continuity and long-term stability of any implemented policy, the technology specification of the necessary support is identified.

Introduction

Energy policy is the main driver for the enhanced deployment of electricity from renewable energy sources (RES-E) as observed in several countries worldwide. Now, to the first time in Europe, binding targets for renewable energy sources (RES), regardless the energy sector, have been set – 20% RES up to 2020 indicates a huge future challenge for upcoming years. Despite, efforts have to be taken in all three energy sectors, the electricity sector will play a major role in achieving the overall target. In this context the target of 20% RES by 2020 includes all three energy sectors (electricity, heat and transport) whereas Member States are free to decide their sectoral contribution. Additionally, the national targets are allocated uneven, accordingly to their RES share in 2005 and a flat rate approach. Therefore the new RES Directive foresees different flexibility mechanisms which are considered in the following investigations as well. However, efficient and effective support measures have to be implemented in order to accompany a strong increase in the share of RES-E with low transfer costs for the society. Several policy options will be discussed with respect to their effectiveness – the development of RES-E – and their efficiency – the associated costs to the development of RES-E.

Besides the Feed-In Tariffs and the quota systems based on Tradable Green Certificates (TGC), some flexibility mechanism are needed in order to support Member States with moderate RES potentials achieving their RES targets up to 2020. Since all these promotion schemes show different reaction in terms of RES deployment as well as the associated costs, the core objective of this paper is to depict the pros and cons of these policy design options with respect to their impact on future growth of RES and the corresponding costs, and finally draw recommendations for policy makers.

*Methodology – the tool **Green-X***

The model ***Green-X*** has been developed by the Energy Economics Group (EEG) at Vienna University of Technology in the research project “***Green-X*** – Deriving optimal promotion strategies for increasing the share of RES-E in a dynamic European electricity market”, a joint European research project funded within the 5th framework program of the European Commission, DG Research (Contract No. ENG2-CT-2002-00607). Initially focused on the electricity sector, this tool and its database on RES potentials and costs have been extended within follow-up activities to incorporate renewable energy technologies within all energy sectors.

Green-X covers geographically the EU-27, and can easily be extended to other countries such as Turkey, Croatia or Norway. It allows to investigate the future deployment of RES as well as accompanying cost – comprising capital expenditures, additional generation cost (of RES compared to conventional options), consumer expenditures due to applied supporting policies, etc. – and benefits – i.e. contribution to supply security (avoidance of fossil fuels) and corresponding carbon emission avoidance. Thereby, results are derived at country- and technology-level on a yearly basis. The time-horizon allows for in-depth assessments up to 2020, accompanied by concise out-looks for the period beyond 2020 (up to 2030).

Within the model, the most important RES-Electricity (i.e. biogas, biomass, biowaste, wind on- & offshore, hydropower large- & small-scale, solar thermal electricity, photovoltaics, tidal stream & wave power, geothermal electricity), RES-Heat technologies (i.e. biomass – subdivided into log wood, wood chips, pellets, grid-connected heat -, geothermal (grid-connected) heat, heat pumps and solar thermal heat) and RES-Transport options (e.g. first generation biofuels (biodiesel and bioethanol), second generation biofuels (lignocellulotic bioethanol, BtL) as well as the impact of biofuel imports) are described for each investigated country by means of dynamic cost-resource curves. This allows besides the formal description of potentials and costs a detailed representation of dynamic aspects such as technological learning and technology diffusion.

Besides the detailed RES technology representation the core strength of the model is the in-depth energy policy representation. ***Green-X*** is fully suitable to investigate the impact of applying (combinations of) different energy policy instruments (e.g. 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 country- or at 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.

Additionally, the impact of market behaviors on the future RES development is implemented in the simulation tool. Hereby, non-economic barriers, as grid connection issues and planning bureaucracy will reduce the growth potential per technology and therefore hamper a possibly fast increasing RES share. A structural overview of the simulation tool ***Green-X*** provides Figure 1.

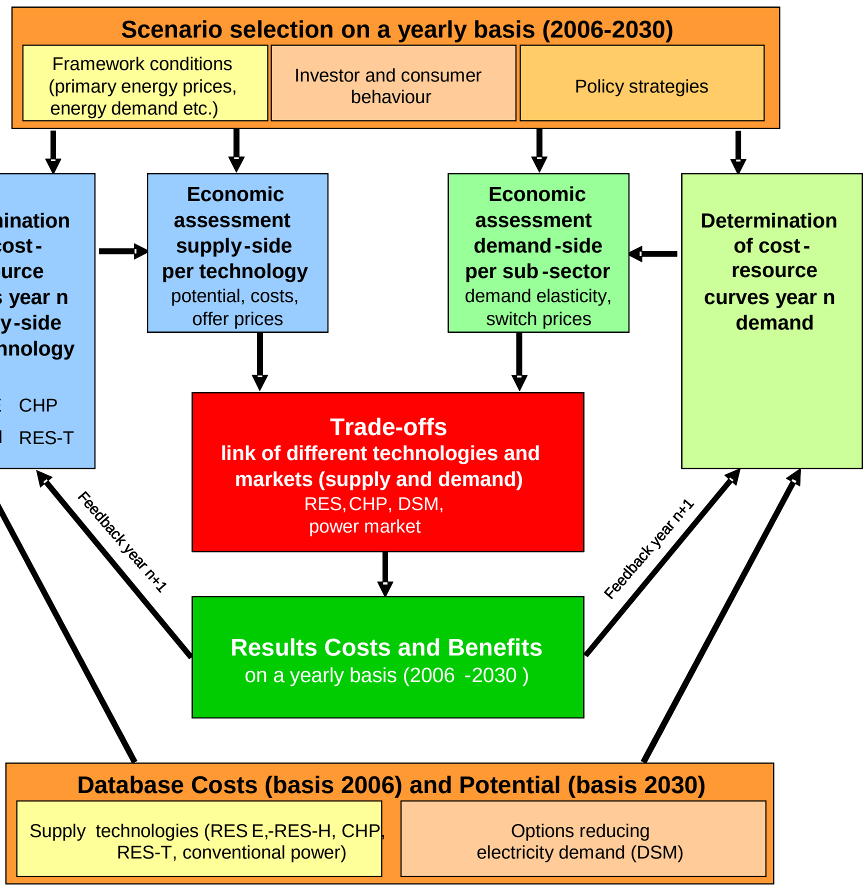

*Figure 1 Overview of the simulation tool **Green-X***

Some available results of the toolbox ***Green-X*** are listed below. Generally, the results are derived on a yearly basis by determining the equilibrium level of supply and demand within each considered market segment – e. g. tradable green certificate market (TGC, both national and international), electricity power market.

A broad set of results on RES installations can be obtained on a country- and technology-level:

- total energy output by sector, by country, by technology;
- total installed capacity of RES by sector, by country, by technology;
- share of gross final energy production or demand;
- average RES generation costs by sector, by country, by technology;
- impact of simulated energy policy instruments on supply portfolio, generation costs
- impact of selected energy policy instruments on total costs and benefits to society (consumer) – transfer costs due to RES policy options.

Background information and assumptions of the study

This section highlights the cornerstones of the recently passed European Renewables Directive (European Commission 2008) and furthermore depicts the basic modeling assumptions, focusing in more detail on the realizable RES potentials up to 2020. Finally, the investigated cases, indicating the different scenario assumptions with respect to promotion schemes and target settings are presented in detail. These scenarios build the basis for a further policy debate with respect to effectiveness and efficiency of promotion schemes.

Background on the European Renewable Energy Directive (European Commission 2008)

With the European Commission proposal for a Directive on the promotion of the use of renewable energy sources (COM (2008) 19) the Renewable Energy Roadmap was translated in EU legislation by setting Member State (MS) targets for the year 2020. Following the Directive proposal, which was adopted by the European Parliament and the Council of the European Union in December 2008, the EU target is allocated to differentiated national targets. In order to achieve a cost-efficient exploitation of the European potentials, several flexibility measures have been intensively discussed. The main elements of the Directive are described below:

The overall target of achieving a share of 20% RES by 2020 refers to “final” energy consumption, which in contrast to the commonly applied statistical definition includes electricity and heat distribution and transmission losses as well as own consumption of the energy branch. Moreover, all three energy sectors are affected by RES: electricity, heating & cooling and transport. The decision on the mix of contributions from these sectors to reach their binding national targets is left to the Member States.

Following the Directive proposal the EU target is allocated to differentiated national targets based on a flat rate approach (same additional share for each country) modulated by the Member State’s GDP. Therefore, sufficient flexibility is intended to be ensured for Member States to implement the Directive in the way that suits their particular national circumstances best. Consequently, this comprises that Member States are free to decide on appropriate domestic RES support, choosing the means that best suits their national circumstances. Moreover, as national targets are defined in a way that does not explicitly reflect the national resource availability, the proposal aims to provide an option for Member States of achieving their targets by supporting the development of renewable energy in other Member States as well as third countries.

According to the Commission proposal, the minimum 10% share of biofuels or, more precisely, renewable energies in transport is applicable in all Member States. In order to tackle the oil dependence of the transport sector, which is one of the most serious issues affecting security of energy supply that the EU faces, an accelerated biofuel deployment is seen as appropriate tool. Hereby, the 10% target for renewable energies in transport has been set at the same level for each Member State in order to ensure consistency in transport fuel specifications and availability. It is expected that Member States which do not have the relevant resources to produce biofuels will be able to obtain renewable transport fuels from elsewhere. While it would technically be possible for the European Union to meet its biofuel needs solely from domestic production, it is both likely and desirable that these needs will in fact be met through a combination of domestic EU production and imports from third countries. In this context concerns have been raised about whether biofuel production is sustainable. The Directive therefore defines environmental sustainability criteria to ensure that biofuels that are to count towards the European targets are sustainable and that they are not in conflict with our overall environmental goals. This means that accounted biofuels must achieve at least a minimum level of GHG savings and respect a number of requirements related to biodiversity. This aims to prevent the use of land with high biodiversity value, such as natural forests and protected areas, being used for the production of raw materials for biofuels.

The RES Directive also aims to remove unnecessary barriers for an accelerated RES deployment – for example by simplifying administrative procedures, by improving grid access and by fostering the development of infrastructural prerequisites for new RES projects.

With respect to the flexibility mechanisms between Member States in order to achieve the overall 20% RES by 2020 target the three main options on which are agreed on are:

- Statistical transfers between Member States

  Under a flexibility regime that builds on statistical transfer between Member States, the Member State itself is in charge of trading. Any surplus of RES generation which is not needed for own target compliance could be qualified for such trade. The trading responsibility can be commissioned to accredited agents, e.g. the support scheme operator, the transmission system operator, or – for GO purchase within a quota system – the quota obliged parties. The RES producers do not directly sell their production to another country for target compliance (they will continue to do so for the voluntary market and disclosure purposes, as in the current situation). They are solely supported by the domestic support scheme.

- Project based mechanisms (Joint Projects)

  Under the project based investment mechanism, a Member State that is not able to fulfill its RES target solely on a domestic basis would be allowed to financially support RES plants in another Member State and receive Guarantees of Origin in exchange for target compliance (the same basic mechanism as recently discussed for Guarantees of Origin trade between private actors). Such project-based investments could offer the possibility to access additional RES potentials in countries not interested (and not obliged) to develop these potentials themselves, e.g. – as often argued – some New Member States. It would also allow for a more active involvement of private RES project developers.

- Joint target compliance

  On a voluntary basis, two or more Member States may decide to combine their RES targets and pursue their target fulfillment jointly through joint support schemes.

Model assumptions

First, the identified RES potentials up to 2020 are discussed in terms of overall RES potential on final energy demand on a national level. Additionally, the potentials within the electricity sector are illustrated in more detail on national level as well as on technology level. Since, in this study all RES potentials refer to the realizable mid-term potential, a brief description of potential categorization is given below:

- *Theoretical potential:* For deriving 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 can be produced from a certain energy resource from a theoretical point-of-view – of course, based on current scientific knowledge;
- *Technical potential:* If technical boundary conditions (i.e. efficiencies of conversion technologies, overall technical limitations as e.g. the available land area to install wind turbines as well as the availability of raw materials) are considered the technical potential can be derived. For most resources the technical potential must be considered in a dynamic context – e.g. with increased R&D conversion technologies might be improved and, hence, the technical potential would increase;
- *Realizable potential:* The realizable potential represents the achievable potential assuming that all existing barriers can be overcome and all driving forces are active. The realizable potential is limited by assumed maximum market growth rates and planning

constraints. Therefore, the realizable potential has to refer to a certain year[1] – it becomes substantially higher the further one looks into the future.

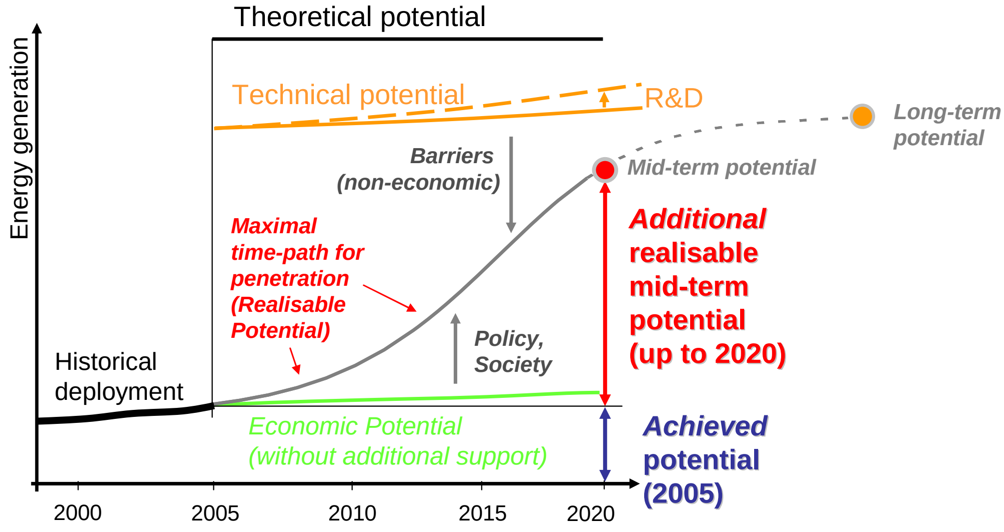

Figure 2 *Methodology for the definition of potentials*

Figure 2 shows the general concept of the realizable mid-term potential up to 2020, the technical and the theoretical potential in a graphical way.

The overall mid-term potential for RES in the European Union amounts to 349 Mtoe, equaling a share of 28.5% on the overall current gross final energy demand. This indicates the high level of ambition of the recently agreed target of meeting 20% RES by 20202. In general, large differences between the individual countries with regard to the achieved and the feasible future potentials for RES are observable. For example, Sweden, Latvia, Finland and Austria represent countries with a high RES share already at present (2005), whilst Bulgaria and Lithuania offer the highest additional potential compared to their current energy demand. However, in absolute terms both are rather small compared to other countries large in size or, more precisely, with large realizable future potentials.

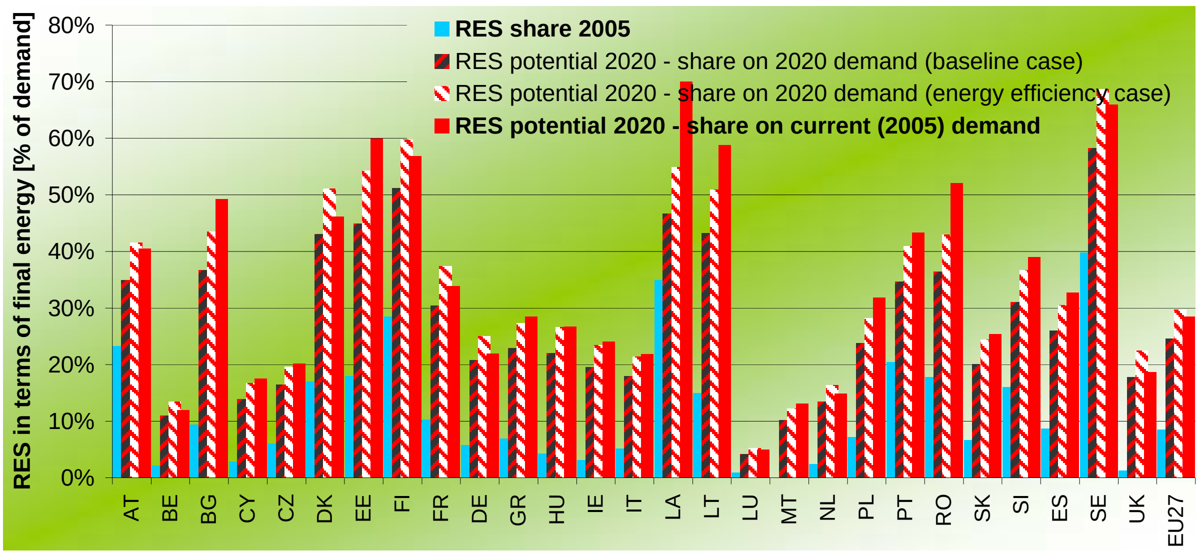

Figure 3 *The impact of demand growth - Mid-term (2020) potential for RES as share on current (2005) and expected future (2020) gross final energy demand.*

[1] In this study the realizable potential always refers to the year 2020 – the so called realizable mid-term potential.

[2] It is worth to mention that biofuel imports from abroad are not considered in this depiction. Adding such in size of 5% of the current demand for diesel and gasoline (i.e. half of the minimum target of 10% biofuels by 2020) would increase the overall RES potential by 1.2%.

Figure 3, above, depicts derived potentials to the expected future energy demand at country level. The total realizable mid-term potentials[3] (up to 2020) for RES as share on final energy demand in 2005 and in 2020, considering two different demand projections – a baseline and an energy efficiency scenario[4] is compared. The impact of setting accompanying demand side measure to reduce demand growth is getting apparent – especially in New Member States: If the demand increases as expected under 'baseline' conditions only 25% of EU's overall final energy consumption could be covered by RES, even if the indicated realizable mid-term potential would be fully exploited up to 2020. In contrast, RES may contribute to meet about 30% of total final energy demand, if demand stabilizes as preconditioned in the 'energy efficiency' case.

Additionally, above mentioned relations of the total realizable mid-term potential (2020) to the gross electricity demand are addressed in Figure 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 baseline demand scenario an in total achievable RES-E share in the year 2020 of 39% would appear feasible, whereas in an efficiency demand scenario 45% of the electricity demand could be generated by renewables. If the total realizable mid-term potential for RES-E was fully exploited up to 2020, 48% of current gross consumption could be covered, meaning even more than in the efficiency demand scenario. Consequently, even the 'energy efficiency case' takes an increasing electricity demand into account. However, in some Member States, especially Denmark and Sweden, the 'energy efficiency case' expects a demand decrease in comparison to the gross final electricity demand of 2005 or at least an demand stabilization, as in Malta.

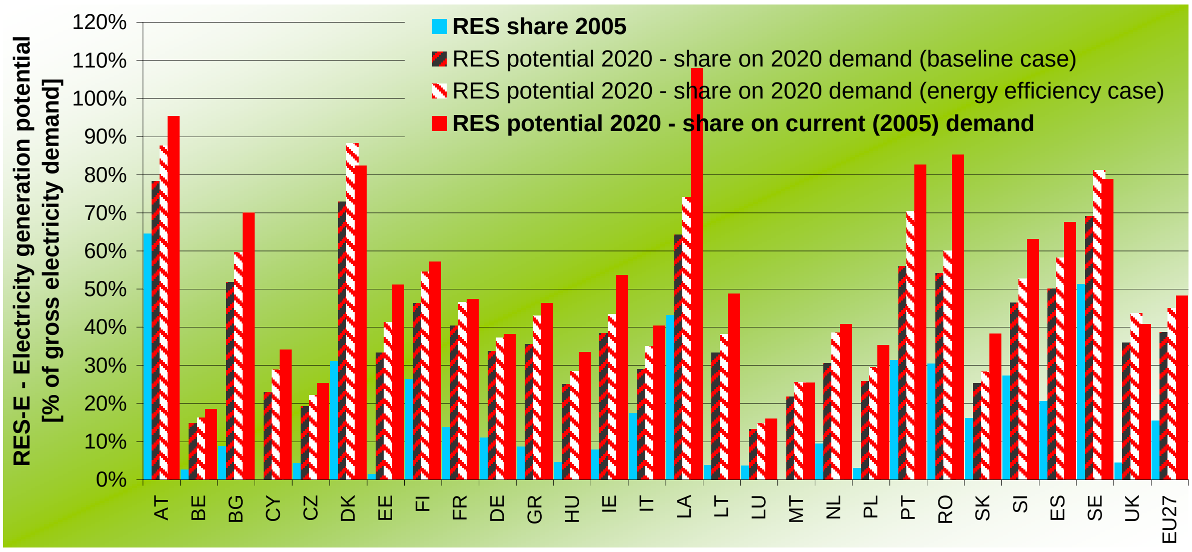

Figure 4 *Total realizable mid-term potentials (2020) and achieved potential for RES-E in EU-27 countries as share of gross electricity demand (2005 & 2020) in a baseline and an efficiency demand scenario.*

Figure 5, below, demonstrates the achieved as well as the additional realizable mid-term potential up to 2020 on a technology level for the whole EU-27. Observable is a high penetration accompanied by a relatively small additional realizable potential for hydropower, both small- and large-scale. In contrast, wind onshore as well as solid biomass energy are already well developed but still provide an enormous additional potential in order to meet future RES-E targets. Moreover, technologies like wind offshore, tide and wave power as well as solar thermal electricity and photovoltaics provide a large additional potential to be exploited up to 2020 whereas hardly any exploitation is already observed. However, these potentials are distributed unevenly among all European Member States, so that the

[3] The total realisable mid-term potential comprises the already achieved (as of 2005) as well as the additional realisable potential up to 2020.

[4] In order to ensure maximum consistency with existing EU scenarios and projections, data on current (2005) and expected future energy demand was taken from PRIMES. The used PRIMES scenarios are:

The European Energy and Transport Trends by 2030 / 2007 / Baseline

The European Energy and Transport Trends by 2030 / 2007 / Efficiency Case (17% demand reduction compared to baseline)

Please note that this data (and also the depiction of corresponding RES shares in demand) may deviate from actual statistics.

highest hydro and biomass potentials are seen in the Central East European (CEE) countries whereas the northern part of Europe is dominated by wind potentials and the south of Europe the most solar potentials are identified.

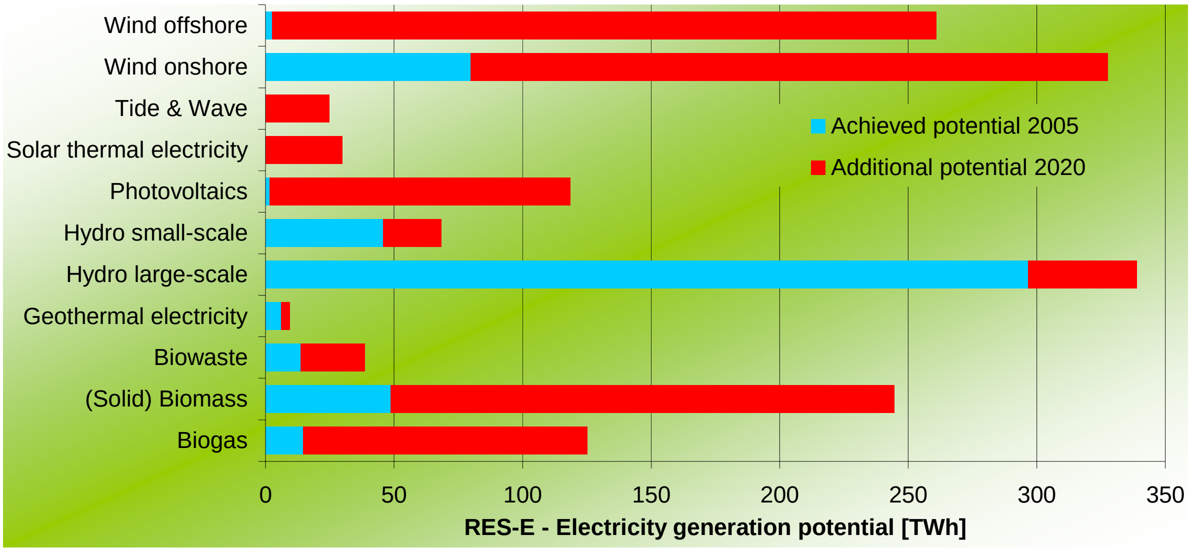

Figure 5 *Total realizable mid-term potentials (2020) and achieved potential for RES-E in EU-27 countries on technology level.*

Scenario assumptions

The core objective of this paper is to investigate on the impact of different RES-E policy measures on the future RES-E development at European as well as at Member State level. In this respect, the issue of the effectiveness and efficiency of support schemes is discussed mainly based on the results obtained from simulation runs using the Green-X model (www.green-x.at). In the following, an overview is given on the basic assumption of investigated scenario:

Principally two different pathways were assessed within this paper, assuming that either national or EU-wide harmonized RES policies determine the future RES deployment according to the policy debate of 2007 on European level. Additionally, it is again distinguished in both cases among two different policy design options.

In case that national policy schemes remain in place, the following two variants are investigated:

- RES policies are applied as currently implemented (without any adaptation) – until 2020, i.e. a **business as usual (BAU)** forecast. Meaning, some countries apply (premium) feed-in tariffs, other quota systems based on tradable green certificates (TGC) and others investment incentives, respectively tax deduction opportunities. In order to keep consistency the *BAU* case builds on the 'baseline" demand scenario up to 2020. Under this variant a moderate RES deployment is projected for the future up to 2020.
- **Strengthened national support**: National RES policies are implemented until 2020, but will be further optimized in the future with regard to their effectiveness and efficiency. More precisely the fine-tuning of national support schemes involves both (premium) feed-in tariff and quota systems with a technology-specification of RES support. Additionally, it is expected that non-economic barriers as grid connection issues or administrative bureaucracy will be overcome faster in future and therefore allow for higher RES-(E) growth rates. The strengthened national support case is in line with a more moderate demand projection than in the 'business as usual case'. Principally, the strengthening of policies is expected to be in force by the end of 2010.

In contrast to above, the impact of a harmonization of RES support is investigated. Hereby it is assumed that an early harmonization would take place, becoming effective already by 2011. Although this unlikely in the context to the recent policy debate, this assumption allows a better assessment of consequences arising from the applied support instruments. With respect to harmonized policy options, again it is differentiated between:

- **Harmonized uniform RES support** ('least cost'): Hereby it is assumed that a harmonized uniform RES trading scheme would be applied which comprises besides electricity also grid-connected heat supply. Consequently, it is expected that this would give a strong incentive for the full exploitation of the least cost technology options and less emphasis on novel innovative technologies in the short term. The fulfillment of the 20% RES target for 2020 at EU is envisaged in the applied quota obligation accompanied by an EU-wide trading scheme. However, this scenario assumes a fast overcoming of non-economic barriers as well and is based on a moderate demand projection up to 2020.
- **Harmonized technology-specific RES support** is based on a quota system with technology-specific TGC market: More precisely, a trading scheme based on a banding approach is applied, which gives a different weighting to different technologies in terms of the number of tradable green certificates (TGC) / guarantees of origin (GO) granted per MWh generation. Hereby, technology-specific incentives are used to bridge the "valley of death" for novel RES technologies such as PV, wave and tide and solar thermal electricity. The technology banding factors are set according to the generation cost of different RES technologies. This scenario pursues as well the 20% RES by 2020 target and builds on the moderate energy demand projection too.

Generally it is preconditioned in all scenarios (except BAU) to fulfill the target of 20% RES by 2020 at EU level. In the case that a Member State does not possess sufficient potentials[5] – from an economic viewpoint – statistical transfer between MS (i.e. where MS posses the possibility to transfer (i.e. trade) their surplus to other MS) would serve as complementary option.

In addition to the four investigated cases, sensitivity runs are carried out in order to illustrate the impact of the most crucial parameters. Hereby, especially the future energy demand development and the energy price development plays an important role in achieving the targets as well as the overcoming of non-economic barriers. Finally the impact of technology learning effects on the future RES development is shown as well.

[5] In the case of "strengthened national support" economic restrictions are applied to limit differences in applied financial RES support among countries to a feasible level. Consequently, if support in a country with low RES potentials and / or an ambitious RES target exceeds the upper boundary, the remaining gap to its RES target would be covered in line with the flexibility regime as defined in the RES directive via (virtual) imports from other countries.

Future RES-E development and corresponding costs at national policy options

Consequences of national RES policy options

Firstly the development of RES-E is analyzed if all European MS are implementing national promotion schemes. In this context, Figure 6 illustrates the future RES-E deployment in the EU-27 up to 2020 by depicting the RES-E share in gross electricity demand for both investigated cases – Business as Usual (BAU) and strengthened national policies, including several sensitivity variants i.e. as energy demand or energy prices.

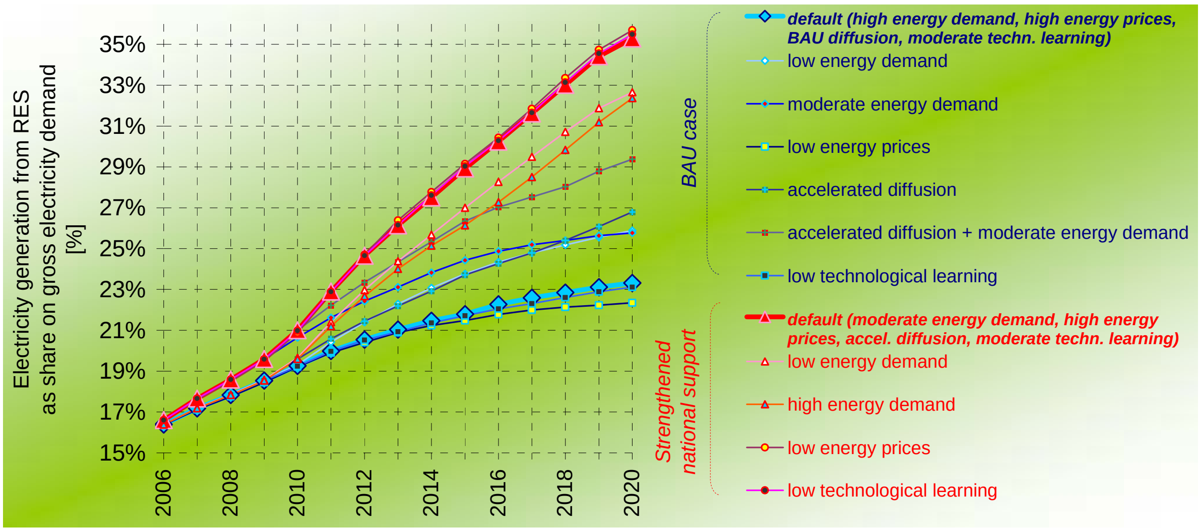

Figure 6 RES-E deployment (expressed as share in gross electricity demand) in the period 2006 to 2020 in the EU-27 according to the BAU and the "strengthened national support" case (incl. sensitivity variants)

A rather constant RES-E expansion, with a boost in the period when strengthening policies enter into force, can be expected with effective and efficient RES support in place while under BAU conditions a slow down of deployment is projected for the later years close to 2020. The generation potential of existing RES-E plants (installed up to the end of 2005) is in size of 70.4 TWh, corresponding to a RES-E demand share of 13.8%. RES-E deployment will rise up to 2020 under current support conditions (BAU) by about 140 TWh, contributing to meet 23.4% of gross electricity demand by 2020. The corresponding 2020 figures assuming a strengthened RES support are 510 TWh or 35.5% (as RES-E share in demand). Analyzing the sensitivity investigations indicates the huge impact of non-economic barriers on the future RES-E deployment: Retaining current financial support but with removal of such deficits would allow for a 2020 RES-E share of 26.8%, supplemented by energy efficiency measures to reduce demand growth this could be further increased to 29.4%. For other key parameters such as energy prices or technological learning a comparatively smaller impact can be observed[6]. Considering the 'baseline demand case' in combination with the strengthened national policies would not allow meeting the target by 2020, hence an even more ambitious development of RES-E would be required.

Table 1 below lists the capacity expansion in the period 2006 to 2020 at technology level for both main scenarios. Wind onshore represents the key technology option for power generation in France, achieving a comparatively similar and stable deployment within both policy cases, ranging from about 106 to 118 GW in total. Other stable technologies are small- (4.7 (BAU) to 4.9 GW (strengthened policies)) and large-scale hydropower (11.3 (BAU) versus 10.8 GW (strengthened policies)), biowaste (3.65 (BAU) vs. 3.67 GW (strengthened policies)) and geothermal electricity (0.33 (BAU) vs. 0,37 GW (strengthened policies)), but deployment is expected to stay well below wind onshore. In contrast to above, a significant contribution is projected for wind offshore (52.8 GW) – but only with improved support and framework conditions. A difference between strengthened national policies and BAU is also observable for photovoltaics, where 6.5 GW can be expected under BAU conditions whilst a more than four times higher deployment (28.7 GW) is achieved with strengthened support. Besides, biogas

6 For instance both cases are with respect to the resulting RES-E deployment less sensitive to changing energy prices as under BAU conditions a fixed financial incentive is applied (i.e. fixed feed-in tariffs) whilst under strengthened national policies the achievement of a similar overall 2020 RES target is preconditioned (at least at the European level).

(12.5 GW), solar thermal electricity (4.85 GW) and tidal stream & wave power (1.8 GW) achieve also comparatively high contributions under strengthened RES support. This tremendous stronger contribution of novel technologies as Photovoltaic, in the ‘strengthened national policy scenario’ is especially crucial if a same ambitious RES-(E) development is pursued beyond 2020. Due to the higher development of these new technologies in an already early stage, important technological learning effects might be achieved in order to bring these technologies closer to the competitiveness level on the energy market.

Table 1 Technology-breakdown of new RES installations in the period 2006 to 2020 in the EU-27 according to the BAU (left) and the “strengthened national support” case (right)

Breakdown by RES-electricity category			New RES-E installations							
			BAU (Business as usual)				Strengthened national policies			
		[Unit]	2006-2010	2011-2015	2016-2020	2006-2020	2006-2010	2011-2015	2016-2020	2006-2020
Biogas	BG	MW	1,588	1,700	2,341	5,629	1,803	3,364	7,330	12,498
(Solid) Biomass	BM	MW	7,612	7,013	6,054	20,679	8,498	11,577	8,803	28,878
Biowaste	BW	MW	1,479	1,158	1,011	3,648	1,661	1,222	790	3,674
Geothermal electricity	GE	MW	147	118	60	325	148	128	90	365
Hydro large-scale	HY-LS	MW	6,876	3,064	1,391	11,331	6,991	2,432	1,378	10,802
Hydro small-scale	HY-SS	MW	1,424	2,389	958	4,771	1,631	2,745	552	4,928
Photovoltaics	SO-PV	MW	2,834	1,096	2,580	6,510	2,963	8,366	17,372	28,700
Solar thermal electricity	SO-ST	MW	367	560	1,348	2,274	390	963	3,498	4,850
Tide & Wave	TW	MW	404	517	285	1,206	416	564	775	1,755
Wind onshore	WI-ON	MW	33,951	33,038	39,334	106,324	34,717	56,436	27,000	118,152
Wind offshore	WI-OFF	MW	1,727	1,735	942	4,404	2,149	12,817	37,851	52,817
RES-E TOTAL	RES-E	MW	58,409	52,389	56,304	167,101	61,365	100,614	105,440	267,419

On the one hand, strengthening national policy option does lead to a significant contribution of renewable energy source in the European Union, but on the other hand it does have a price. Comparing these two scenarios with respect to the required investments or capital expenditures (30 (BAU) versus 54 billion € (strengthened policies)) significant differences can be observed – see Figure 7. Moreover, the associated consumer expenditures due to RES support in total terms (15 (BAU) vs. 24 billion € (strengthened policies)) are considerable higher. Figure 7 shows, the huge impact of the exploitation of potentials of novel technologies like Photovoltaics and wind offshore but however this impact is mostly dominant in the later stage beyond 2015. Significant differences in capital expenditures are also recognized in wind onshore plants up to the year 2015.

With regard to the benefits of RES-E generation, the avoidance of fossil fuels in monetary terms (29 (BAU) vs. 42 billion € (strengthened policies)) are much higher as well. Other costs (i.e. additional generation costs) or benefits (i.e. avoided CO2 emissions) show less deviation or are of lower magnitude.

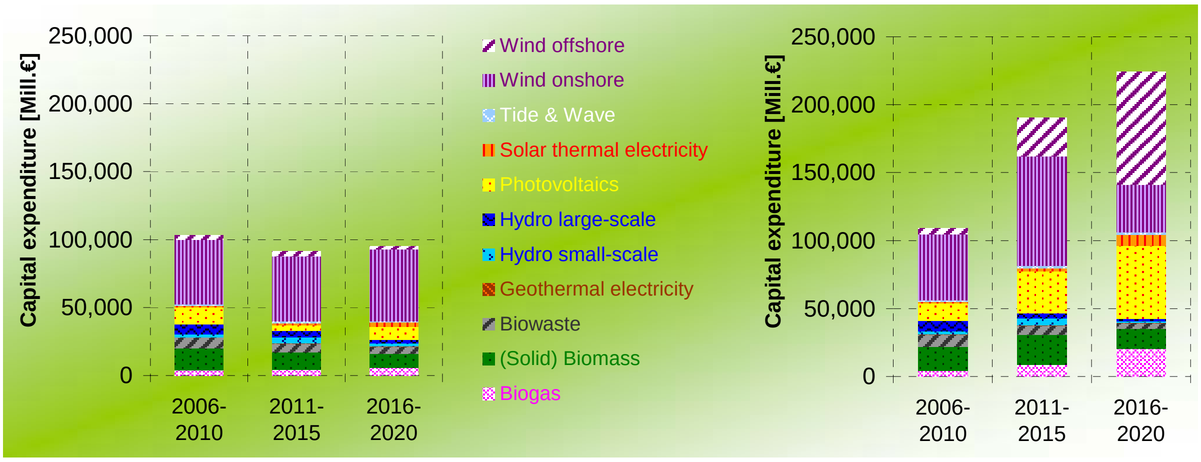

Figure 7 Capital expenditures due to new RES-E installations up to the year 2020 on technology level. On the right hand side the BAU case is illustrated whereas the left hand side depicts the ‘strengthened national policy’ case

A closer look on the impact of changing key parameter and framework conditions on the resulting deployment and costs is given below. Figure 8 offers a comparison of both RES deployment by 2020 as well as the corresponding consumer expenditures (on average per year for the period 2006 to 2020)) for new RES-E (installed 2006 to 2020).

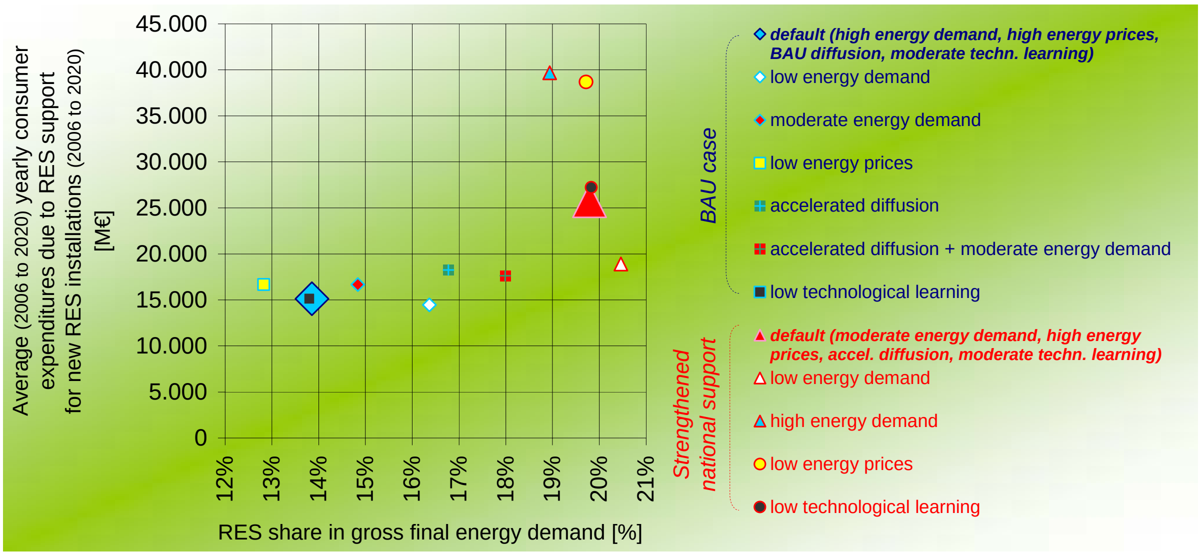

Figure 8 *Comparison of the resulting RES deployment by 2020 and the corresponding (yearly average) consumer expenditures due to RES support for new RES (installed 2006 to 2020) in the EU-27 for all investigated cases (BAU and the "strengthened national support" case (incl. sensitivity variants))*

In conclusion of national support measures and summarizing the results of Figure 8 it has to be mentioned that the EU possess the possibility to achieve its 2020 RES target, besides biofuel and biomass feedstock imports from abroad, with domestic action even only due to strengthening current RES support measures. In Figure 8 the red triangle represents the 'strengthened policy case' which achieves the 20% RES on final energy demand in 2020, whereas the blue square fails to meet the target by far – BAU case. However, due to strengthening the RES-(E) policies with respect to effectiveness and efficiency, the increase in terms of produced RES is much higher than the associated costs of the stronger RES-(E) deployment.

With respect to the sensitivity analyzes in above illustrated figure, a strong impact is noticed of energy demand on the RES development and the corresponding costs regardless the implemented support measure. Therefore, besides proactive RES support complementary demand side measures to lower or even inverse energy demand growth are of high importance for both target achievement and the resulting cost (see sensitivity variants on high / low energy demand). Likewise similar sensitivity impacts on RES deployment and especially on consumer expenditures are observed at the variation of energy prices. This significant impact on the resulting costs is especially noticeable in case of an ambitious RES deployment (see sensitivity variants on low energy prices for the impact on costs). However, from the current perspective the applied "high" energy prices (a crude oil price of about 100 US$ in 2020 seems appropriate) may serve as sound proxy for the overall cost assessment, whilst low energy prices as preconditioned in the sensitivity variants possibly overestimate the cost burden tremendously. In contrast, technological progress has less impact on RES deployment and costs in the short to mid-term (see sensitivity variants on low technological learning).

Finally, the topic of how to appropriate strengthening national policies is stressed, in order to pave the way towards more effective and efficient RES policy systems. As illustrated above in Figure 8, a removal of non-economic deployment barriers is of crucial relevance for all EU countries to assure a successful RES deployment in the mid- to long-run. An indication on what is meant by strengthening financial RES support concludes this assessment by aiming to provide assistance on the way forward and listing general remarks accompanied by illustrations based on the country-specific circumstances.

Besides continuity and long-term stability of any implemented policy, the key criterion for achieving an accelerated future RES deployment in an effective & efficient manner is the technology specification of the necessary support. This is reflected in current support for renewable electricity within several EU Member States. A fine tuning of several technology-specific incentives is however recommended. In general, an increase of incentives appears adequate, especially for biomass and biogas. For onshore wind energy a slight decrease is adequate, but only if other non-economic deficits are removed. For offshore wind specific incentives may be reduced, but a goal-directed policy framework that assures the availability of infrastructural prerequisites is required. Additionally, in order to allow RES heat playing its central role for RES target achievement the corresponding policy framework deserves similar attention as RES electricity.

Future RES-E development and corresponding costs at EU-wide harmonized policy options

Figure 9 (below) illustrates the contribution of several investigated RES-E options to the overall renewable generation in the assessed period 2006 to 2020 depending on the applied policy pathway. In addition to the harmonized policy options, the above mentioned national policy designs are indicated as well. Once again, as was seen in the case of "strengthened national policies", wind energy (on- & offshore) and biomass dominate the picture. At first glance, small differences among the investigated cases are applicable as a more ambitious target generally requires a larger contribution of all available RES-E options. Technology-neutral incentives as assessed in the "harmonized uniform" variant of least cost RES support fails to offer the necessary guidance to more expensive novel RES-E options in time. Hence, the renewable electricity sector is dominated by solid biomass, wind onshore, biogas and hydro power if a 'harmonized uniform' support scheme would be applied. Consequently, the deployment of PV, solar thermal electricity or wave power, but most important also wind offshore (see Figure 8) is delayed or even not taking place. Hence, the bridge of the "valley of death" for novel RES technologies will not be build, leading to missing future cost reduction potentials of novel technologies. In consequence, overall RES(-E) deployment stays well below all other ambitious policy pathways by 2020, therefore, Europe would fail to deliver the required RES volumes as needed for target fulfillment.

On the other hand, a harmonized but technology specific support scheme of RES-(E) would actively promote novel technologies as well. A special remark is put on wind offshore energy, since here are the largest deviations between technology specific and uniform RES-(E) policies. Having in mind the overall contribution of wind offshore energy in a technology specific support scheme – see Figure 9 – and considering the missing renewable electricity in order to fulfill the overall 20%RES target – shown in Figure 10, yellow dot – it is exactly the amount of RES-E missing in the 'uniform harmonized' policy option. Moreover, only minor differences are notable between a quota system based on technology specific weighted TGC's and a harmonized premium feed-in tariff, whereas the latter even stronger promotes important future technologies, like Photovoltaic or tide & wave energy, at currently highest generation costs.

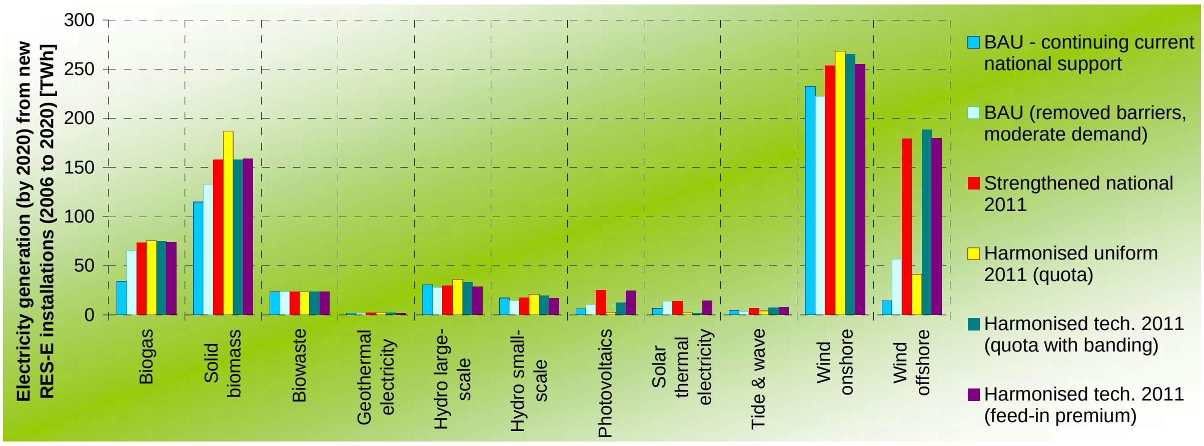

Figure 9 Technology-specific breakdown of RES-E generation from new installations (2006 to 2020) in the year 2020 for all key cases (national and (by 2011) harmonized RES support)

Looking in more detail on the arising consequences of harmonized policy choices, thorough investigations have been carried out in comparison with national policy designs. In this context, a closer look on the electricity sector is given in Figure 10 comparing the results of electricity generation (by 2020) from new RES-E installations and the present value (2006) of corresponding cumulated consumer expenditures due to their support (incl. residual cost after 2020) at EU-27 level for all key cases (national and (by 2011) harmonized RES support). This figure also takes into account the residual policy costs of RES-E plants installed in the period 2006 to 2020. Additionally, it has to be mentioned that the electricity generation from about 780 TWh is in line with the 20%RES by 2020 target of the EU.

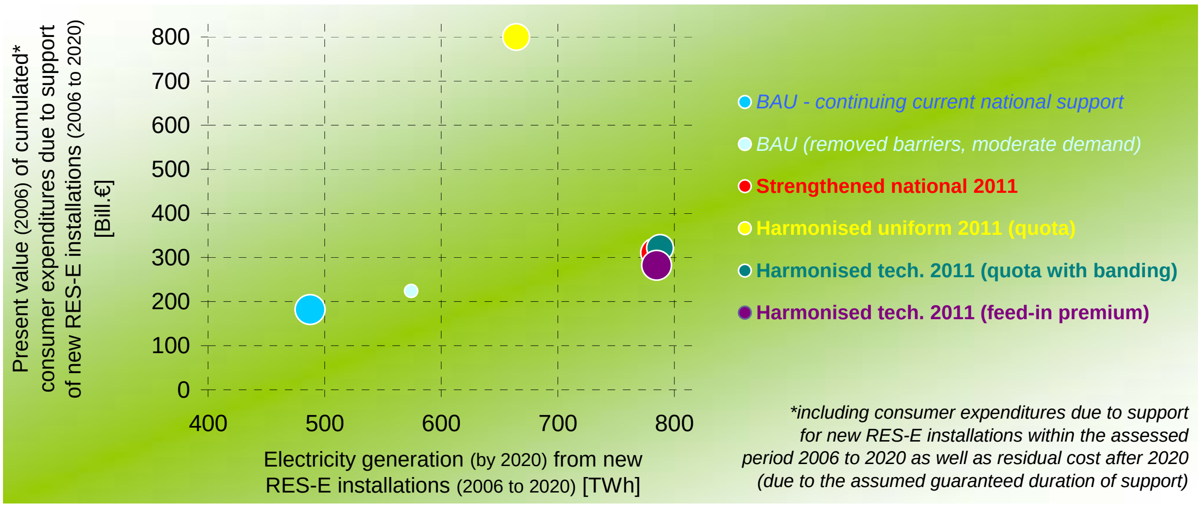

Figure 10 *Comparison of the resulting electricity generation (by 2020) from new RES-E installations and the present value (2006) of corresponding cumulated consumer expenditures due to their support (incl. residual cost after 2020) at EU-27 level for all key cases (national and (by 2011) harmonized RES support)*

As shown in Figure 10, minor differences are observable when comparing the policy cases for an accelerated RES deployment that offer either *national or harmonized technology-specific* RES support. Within all these case the EU's RES commitment of 20% RES by 2020 could be met, assuming that (moderate) energy efficiency measures complement RES support (as preconditioned in all key cases with the exception of BAU). Only very little improvements with respect to consumer expenditures due to RES-E support could be achieved by introducing a harmonized premium feed-in Tariff compared to strengthened national policies. Contrarily, it is also getting apparent that pursuing an ambitious RES target, a *uniform support* as preconditioned in the "least cost" variant of harmonized uniform RES-E support causes *tremendously higher consumer expenditures* compared to all other variants – i.e. about 800 ("least cost") compared to about 315 billion € (harmonized technology-specific support based on premium feed-in tariffs) occur for the period 2006 to 2020 at EU level. Therefore, a uniform support would result in lower additional generation costs, since only the most cost-efficient technologies would be exploited, but due to the uniform support level the overall consumer expenditures would be significantly increased, caused by high producer surpluses (Ragwitz 2007).

Besides, this more than doubling of consumer expenditures, the RES-E generation would be far below technology-specific support case and consequently the EU would fail to meet its RES goal by 2020. Therefore the uniform harmonized support scheme does not only avoid to set incentives for novel and therefore more expensive technologies – leading to a future problem – it especially causes high consumer expenditures in the mid-term by accompanied less renewable electricity generation. Although the consequences of a technology-neutral support scheme appear even larger in terms of cost and resulting RES deployment in the electricity sector, it has a big influence on the overall achievement of the 20%RES by 2020 target.

A comparison of the cumulated consumer expenditure for new RES-E installations – i.e. the total transfer costs due to the promotion of new installations in the observed period 2005 to 2020 as well as the residual costs after 2020 – is given in Figure 11. This diagram illustrates both the cost-efficiency and the effectiveness of RES-E support options – i.e. expressing the cumulated consumer expenditure per MWh induced RES-E generation.

Some key findings derived from these depictions are:

- The cumulated transfer costs for society are lowest when applying technology-specific support harmonized throughout Europe achieved by applying premium feed-in tariffs. In this case the specific cumulated consumer expenditures amount to 22.1 € per MWh induced RES-E generation.
- Strengthened national support with a similar deployment of new RES(-E) result in slightly higher specific costs of 23.6 €/MWh$_{RES\text{-}E}$ which corresponds to an increase of 7 % compared

to the technology-specific support provided within a harmonized premium feed-in tariff scheme.

- Marginally higher specific costs can be expected from continuing current RES-E support. In the BAU case, the specific costs are in the order of 24.9 €/MWh_{RES-E}. However, it is worth mentioning that the overall deployment of new RES-E is significantly lower in the BAU case (also with removed barriers) than to all other policy options – about 26% less RES-E generation in the BAU case.
- Compared to above, again slightly higher cost arise for the case of applying technology-specific support harmonized throughout Europe with application of a RES trading system with technology-banding. In this case the specific cumulated consumer expenditures amount to 27.2 € per MWh induced RES-E generation.
- The most inefficient policy option in terms of costs is harmonized, but non technology-specific support, which results in the much higher consumer expenditures in a range from 80.3 €/MWh_{RES-E}.

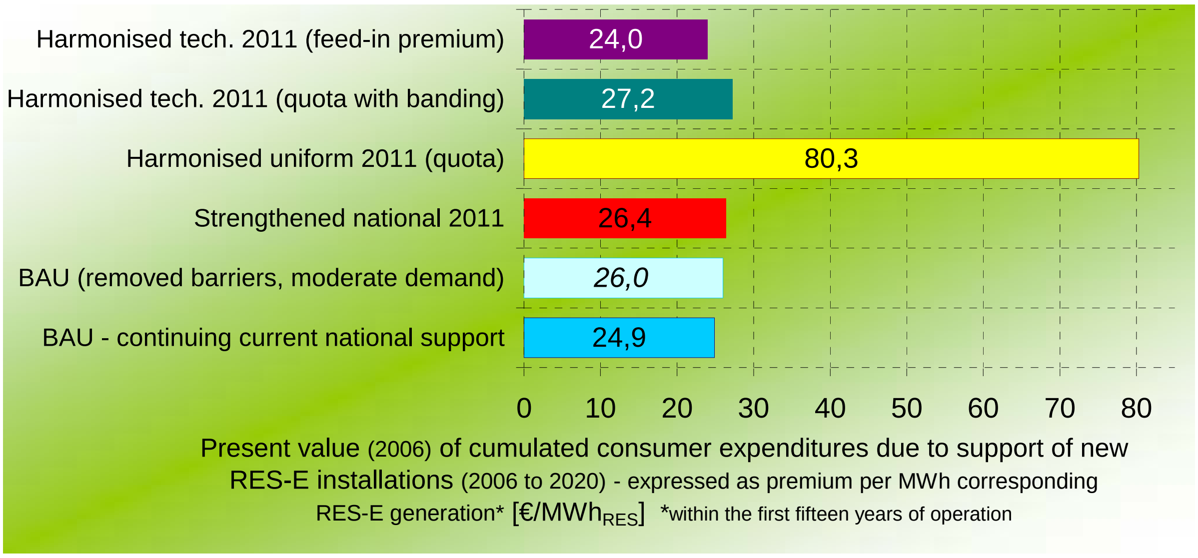

Figure 11 *Necessary cumulated consumer expenditure (in 2020) due to the support of new RES-E (installed 2005 to 2020), expressed per MWh induced RES-E generation for the investigated cases. Note: In the case of a TGC scheme, total transfer costs paid after 2020 are estimated assuming that the average TGC price in the years 2018 to 2020 is constant up to the phase-out of the support*

Conclusions and recommendations for policy makers

Investigations on different renewable energy policy designs have shown that neither from an economic point of view, nor an effective point of view, is a need for an early harmonization. It is rather more important to rapidly design RES support measures effective and efficient than to rush a harmonization across Europe.

Generally, an increased RES deployment brings large benefits to EU's supply security. The increased RES-deployment due to new RES installations in the case of optimized national RES support leads to a reduction in fossil fuel demand of yearly 264 Mtoe by 2020. Oil imports can be reduced by 9%, gas imports by 30% and coal imports even by 42%. This will significantly increase the EU's security of supply. In 2020 105 billion € can be saved on fossil fuels, which corresponds to 0.7% of GDP. This monetary expression is based on PRIMES high energy prices as used for this modelling exam. The results show that the 20% RES could be achieved at moderate cost, which illustrates the ability of RES to protect the EU economy against volatile fossil fuel prices. The financial support provided to increase the support of RES in the coming years should reflect these benefits to EU's supply security.

As indicated in several figures, technology-specification of RES support schemes is a precondition for effectiveness and efficiency. Therefore, a key criterion for achieving an accelerated future RES deployment in an effective and efficient manner with respect to consumer expenditures – besides the removal of non-economic deficiencies and the continuity and long-term stability of an implemented policy – is the technology specification of the necessary support. Concentrating only on the currently most cost-competitive technologies would exclude the novel RES technologies needed in the long run. The analysis clearly depicted that it will not be possible to meet Europe's RES commitment without considering moderate to novel RES options. Besides, even in the short term, the observable cost differences among cheap to moderate RES-E options recommend a diversification of support in order to reduce windfall profits.

Additionally to strong and effective RES policies (strong) energy efficiency policy should be considered in order to meet the overall RES target. In the absence of strong energy efficiency policies energy demand is higher and more RES is required in order to achieve the targeted share of 20% by 2020. Consequently, in that case more expensive RES technologies have to be utilized and the average yearly additional generation costs are expected to increase largely. Besides, taking realistic diffusion constraints for RES technologies into account it appears likely that Europe would fail to meet its 2020 RES obligation in case of continuing present demand growth patterns (PRIMES baseline). This underpins the importance of energy efficiency policy and RES policy to work as complementary tools for creating a more sustainable energy system in an economically efficient way.

Analyzes have shown that there is a need to support a wide range of RES technologies in order to bridge the "valley of death" for novel RES technologies such as PV, wave and tide and solar thermal electricity and provoke strong future cost reductions of these technologies. Even a policy approach based on pure cost minimization would still need to support a wide range of technologies: large-scale hydropower, solid biomass (for generation of both heat and power) and onshore wind power will be complemented by large amounts of offshore wind power, biogas and small hydropower. Associated costs vary largely between technologies and over time. Consequently, any future policy framework has to address this sufficiently by providing technology-specific support to the various RES options.

Generally, it needs to be mentioned that efforts are needed in all Member States. The model results show that in order to reach a RES share of 20% by 2020 within the EU strong efforts are needed in each Member State. As potentials and costs for additional RES deployment differ across Member States, the contribution of individual Member States to an overall share of 20% RES would be influenced by the applied policy selection. The resulting country-specific RES shares for 2020 in case of a "least cost" or any other harmonized RES policy differ to a certain extend for most countries from the recently agreed national 2020 RES targets, with which the European Commission aimed to allocate the resulting burden in a fair manner across Member States. Hence, this emphasizes the need for strengthened cooperation between Member States, where suitable accompanying flexibility mechanisms assist the achievement of national RES targets in an efficient and effective manner.

Generally, cooperation on regional level, of course offers some advantages as i.e. more mutual policy learning could considerably speed up the evolution of successful regulatory frameworks for RE, increasing the chances for achieving the 2020 targets while reducing cost. Furthermore, coordination or information exchange regarding national biomass strategies may be a precondition for the market to allocate feedstock resources efficiently to countries and sectors and to enhance feasibility of national biomass strategies. As well as an increased regional coordination on elements such as caps for wind power integration would allow to integrate a high penetration of wind power at lower overall consumer expenditures. In contrast, poorly designed harmonized RES policies will lead to very high consumer expenditures due to RES support measures, as it has been showed in this paper. Therefore, there is no recommendation to go for harmonized RES support schemes, since harmonization is a tool and not an aim in itself, but rather strengthen national policies with respect to their effectiveness and efficiency.

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