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Overview of RES Characteristics and Future Scenarios*

Introduction

In addition to its environmental benefits, the use of renewable energy sources (RES) may contribute to increasing energy security. Among others, this fact is attributed to the indigenous availability of RES. At the same time, however, an increased use of RES involves certain risks to energy security. To give an example, an increased use of wind energy and its fluctuating electricity output could pose problems for system management and the existing electricity grid. Due to the heterogeneity of RES, with regard to their availability, energy conversion costs or other techno-economic characteristics, a detailed knowledge about these facts and the existing framework conditions is required for the evaluation of the role of RES for energy security. This background paper first introduces a general overview of RES characteristics in the context of energy security. Specific characteristics of different existing RES and the corresponding conversion technologies are described with a focus on the technological and the economic dimensions. In addition, special attention is drawn to the dynamics of RES' economic characteristics. Based on this information, insights into the main opportunities and risks of RES for energy security are provided.

Taking into account the benefits of RES in terms of environmental factors and increase in security of supply, the EC pursues the objective to supply 20 percent of the gross final energy consumption in 2020 from RES (The European Parliament and the Council of the European Union 2009). Nevertheless, the use of RES usually involves higher generation costs compared to the use of most conventional energy conversion technologies. To compensate for the economic disadvantages of some RES technologies, national governments have implemented different policy schemes that provide financial support for such technologies in order to make projects economically feasible. The major policy schemes in the electricity sector represent feed-in tariffs and quota obligations with an integrated trade of green certificates. In the first case, a fixed tariff is paid for one unit of renewable electricity or a premium is paid for one unit of renewable electricity on top of the market price. The quantity of renewable electricity is then a result of the predetermined tariff level. In contrast, in the case of quota obligations, the government sets targets for renewable electricity generation; and the price of the green certificate is a consequence of the predetermined target. With respect to the heat sector, the most applied support schemes are investment and fuel incentives. Regarding the transport sector, the European Commission in a Directive in 2003 proposed a certain annual quota of biofuel use.

Against this background, this chapter estimates the potential quantitative contribution of RES to increase security of supply according to different scenarios. Based on the existing simulation model Green-X and its detailed RES database, three future scenarios are presented referring to the overall SECURE policy storylines. Subsequently, results of the scenario calculations are presented, involving the analysis of the costs arising from an increased use of RES, which is again caused by the application of renewables support schemes in the respective scenario. In addition, some policy options of how to promote renewable energy sources effectively and efficiently are evaluated.

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1. Characteristics of Renewable Energy Conversion Technologies

A broad set of different energy conversion technologies options using RES exist today. However, these technologies differ considerably with regard to the stage of technological and market development as some are at an advanced stage of development while others are still at the initial stage.

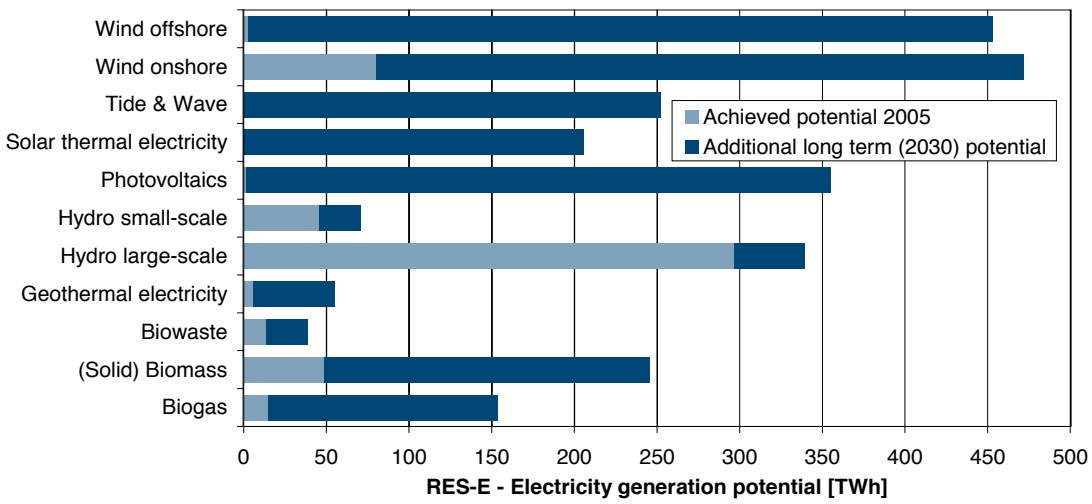
Additionally, the economic dimension of RES technologies influences their market development. The second section discusses the present range of energy conversion costs of RES technologies, consisting mainly in capital costs of RES within all three energy sectors, as well as possible future cost developments.

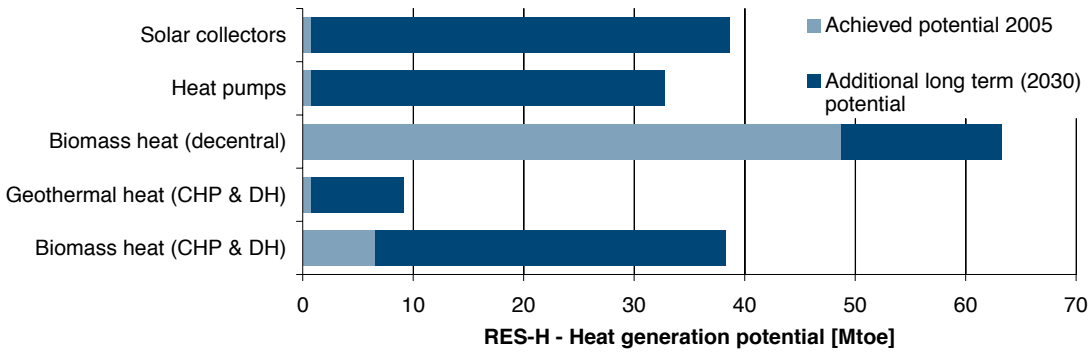
Due to the domestic nature of most RES conversion technologies, they contribute significantly to increasing Europe's import independence from fossil fuels. On the other hand, RES may involve higher risks due to the usage of novel technologies, output volatility and political circumstances.

1.1 The Technological Dimension of Renewable Energy Conversion Technologies

From a theoretical viewpoint, a broad range of RES is eligible for various conversion technologies. But due to existing constraints regarding the available resource potential, in the final count, the number of RES that are convertible is limited. The following part addresses the different RES potential categories. It also gives some figures of currently installed and identified RES potentials that are realizable up to the year 2030.

- 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 – it becomes substantially higher the further one looks into the future.

1.2 The Economic Dimension of Renewable Energy Technologies

The economic dimension is an important aspect that will determine the future growth rates of RES technologies. On the one hand, up-front investment costs are of relevance for potential investors, since these will determine the resulting generation costs and the achievable profit. On the other hand, future cost reductions will change the overall specific investment expenditures.

1.2.1 Current Economic Characteristics of Renewable Energy Conversion Technologies

The broad range of costs for several RES technology options is caused by site specific conditions, for example, Photovoltaics or wind energy locations. Then, costs strongly depend on the available technological options – compare, for example, co-firing and small-scale CHP plants for biomass. Demand-specific conditions leading to various degrees of utilization (e.g. full load hours in case of heating systems) also affect economics of RES technologies. All factors together lead to a broad range of conversion costs.

Nevertheless, in order to give a better illustration of the current economic conditions of the various RES options in the electricity sector some examples are pointed out here. According to the above mentioned impact parameters, wind onshore generation costs vary between 60 €2006/MWh and 105 €2006/MWh whereas offshore wind generation cost reach up to 150 €2006/MWh. The biggest range of generation costs is noted in the Biomass sector from 50 €2006/MWh to 210 €2006/MWh. At the end of the scale solar energy converters, especially Photovoltaics amount to 380 €2006/MWh up to 1200 €/MWh.

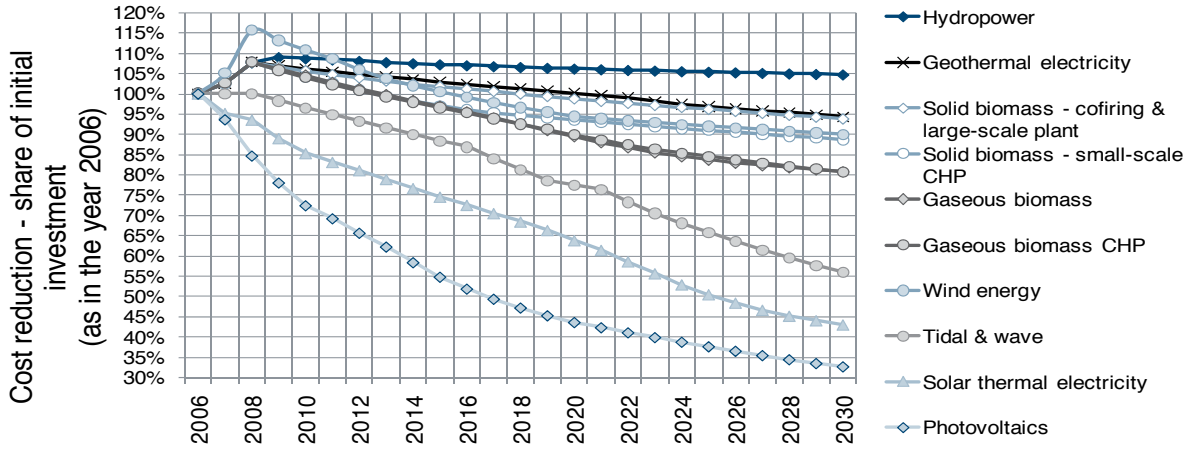
In contrast, the heat sector distinguishes between grid connected heat supply and non-grid connected heat supply, wherein the latter faces higher market prices. Among the RES-H technologies, solid biomass is in most cases within the non-grid connected sector, already competitive with conventional options (50 €2006/MWh to 75 €2006/MWh). Again solar thermal power generation is on the upper end at 75€ 2006/MWh up to 200 €2006/MWh. Grid connected heat supply systems vary between 30 €2006/MWh and 120 €2006/MWh.

Finally, in the transport sector the costs of all technologies are still above the current market price and therefore depend on financial support measures (bioethanol 60 €2006/MWh to 100 €2006/MWh and biodiesel 55 €2006/MWh to 65 €2006/MWh).

1.2.2 Future Development of Economics of Renewable Energy Conversion Technologies

With respect to the future cost development, technological learning is a crucial parameter, especially in the mid- to long term. Technological learning considers a certain cost reduction with each doubling of produced output. As learning takes place on the international level, the deployment of a technology on the global level must be considered. In order to illustrate the development of initial investment costs, influenced by learning effects but also by other parameters such as raw material prices and oil prices, Figure 1 depicts the cost development exemplarily for the electricity generation technologies up to the year 2030. Remarkable is the negative development in the period 2007 to 2009 for most energy

Figure 1 Cost Reduction of RES-E Investments as Share of Initial Investment Costs (2006) in a Pessimistic Scenario with regard to Technological Progress according to the "Policy Case"



Source: Green-X calculations

technologies, but obviously mostly affecting the cost of wind energy converters, is remarkable. This increase in investment cost is largely driven by the tremendous rise of energy and raw material prices as observed in recent years and was expected to prolong in the near to mid future. In this context, the impact of rising energy and raw material prices even compensates the cost reductions achieved due to technological learning. So, although technology learning is achieved, the overall investment costs are increasing in this period. However, still substantial cost reductions are expected for novel technology options such as photovoltaics, solar thermal electricity or tidal stream and wave power.

1.3 Opportunity of Renewable Energy Sources to Security of Supply

As stated by Ölz et al. 2007,[1] the use of RES may contribute to increasing energy security due to several characteristics.

First, since RES mainly represent indigenous resources, the replacement of imported fossil primary energy carriers, such as gas or coal, leads to a reduction of import dependency.

Second, the decentralized availability of RES and predominantly small plant sizes often leads to decentralized generation resulting in the following advantages: firstly, less infrastructural risks as the plants may be located closer to the demand involving a reduced risk for the grid infrastructure; secondly, the impacts of potential shutdowns or blackouts on the electricity system are reduced.

Third, RES technologies with the exception of biomass-based applications are not dependent on any fuel costs. Hence, in contrast to conventional energy conversion technologies based on the use of fossil fuels, there are neither fuel price fluctuations nor risks. Furthermore, the use of RES technologies in the electricity market under certain support conditions may have an impact on electricity prices. In this way, Sensfuß et al. 2008 calculate the impact of wind power feed-in on electricity prices using the example of Germany.[2] Following the basic mechanism of electricity markets, where the operation of electricity generation plants is selected according to the merit order of the marginal costs, wind electricity may replace generation options with high marginal costs, as for example, gas turbines, in periods of peak load. Thus, electricity prices are affected by the wind power feed-in.

Finally, a diversification of the existing power plant portfolio through an increased use of RES may lead to the portfolio effect and therewith reduce risks. Figure 2 summarizes the opportunities identified for RES to contribute to security of supply.

Figure 2: Overview of Opportunities for Security of Supply regarding RES

Decentralised character	Mainly indigenous resources	No fuel cost (except BM)	Portfolio effect
• Location closed to demand → Less infrastructure risk • Reduced impact on electricity system in case of shutdowns	• Reduction of import dependency	• Reduction of price risks induced by fossil fuel prices • Price effect of wind power feed-in	• Diversification of power plant portfolio

1.4 The Risk of Renewable Energy Conversion Technologies to Security of Supply in the Electricity Sector

Assessing the risk of RES technologies to security of supply implies investigation of many parameters on the technology level. Generally, a RES conversion plant shows different risk with respect to security of supply, depending on the plant size. If, for instance, a large-scale hydro power plant suddenly ceases to produce electricity, the impact on security of supply is much higher than if one wind turbine does not generate its forecast electricity amount.

Furthermore, the risk of volatile fuel costs does not affect every RES technology to the same extent. Thus, some technologies in the electricity sector show a very volatile energy output in the short-term and others more in the long-term, while some others do not show any volatile energy output at all. Generally, it should be mentioned that the volatile energy output represents one of the most relevant risks of RES, since they require a certain amount of back-up capacity in the energy system and therefore do not contribute largely to the overall security of energy supply.

Economic risk parameters are very sensitive to the overall risk assessment of a renewable technology. On the one hand, the current economic crunch will decrease the overall energy demand and, therefore, contribute positively to energy supply security, while on the other hand the financial crises could hamper a strong growth of RES. In this context, an adequate and long-term stable policy framework is required in order to attract potential investors.

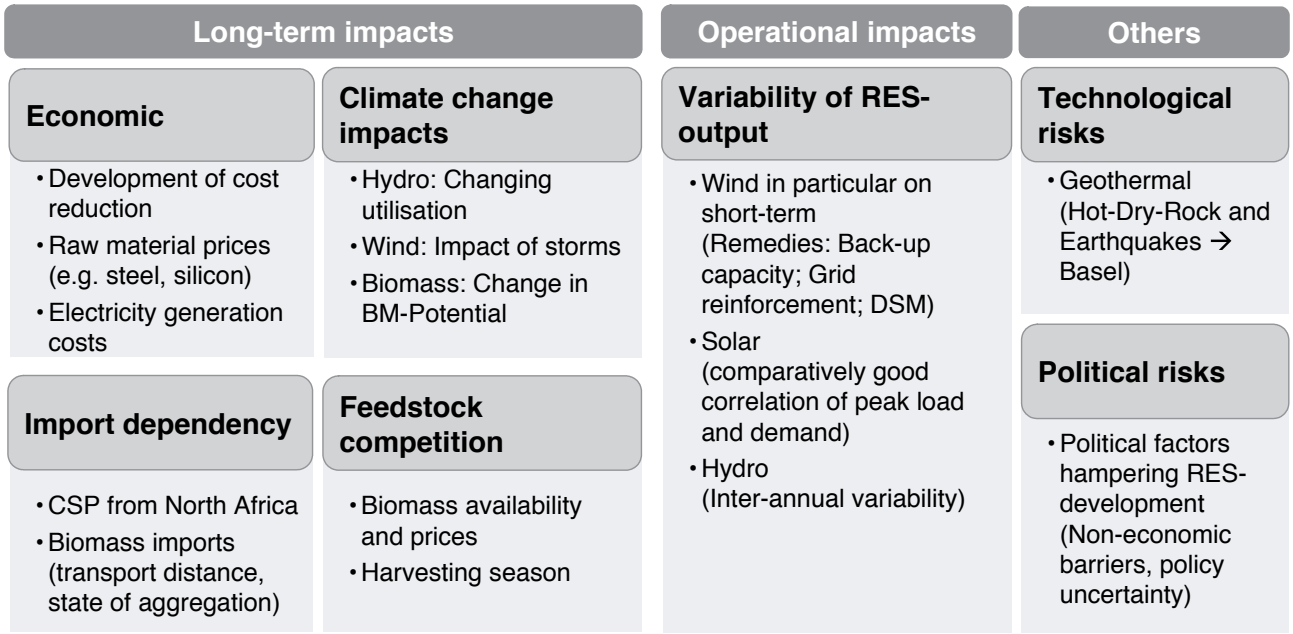
According to Figure 3 the assessment of risk can be made in terms of long-term impacts, operational impacts and others. Generally, the risk assessment depends on the type and penetration of RES and system characteristics:

- The higher the penetration of RES, the higher is the risk of volatile power outputs.
- The more diverse the portfolio of renewable technologies, the smaller is the impact of price volatilities.
- The more stable the political framework conditions, the lower is the risk for potential investors
- The higher the share of domestic energy production, the higher the security of supply – as a domestic energy resource, a large contribution of RES is required by exploiting all kinds of technologies in order to establish a reliable, constant renewable energy system.

2. Future Pathways of RES and Associated Policy Costs

Taking into account technical and economic constraints of RES technologies, discussed above, this section provides quantitative analysis of potential future RES pathways up to 2030, according to the three main policy lines within the SECURE project. Three different demand projections accompanied by the associated energy prices form the basis of the policy themes on the one hand; on the other hand, the differently implemented RES support measures are of high relevance for the results. Moreover, all scenarios refer to realizable RES potentials of renewable energies (see Panzer

Figure 3: Overview of Threat Identification for Security of Supply regarding RES



et al, 2009) determined for this chapter, taking into account dynamic aspects. The assessment of future renewable energy pathways in terms of development is based on scenario calculations seeking to meet the overall 20 percent RES by 2020 target in the EU.

The first sub-section focuses on the possible future development of renewable energies in all three energy sectors in terms of quantitative capacity installations as well as generation in the European Union. Additionally, potential surpluses and shortfalls with respect to the 20 percent RES by 2020 target are discussed here. These analyses depict the impact of national policy schemes on future development in all three policy themes. Consequently, the second sub-section provides a comparison of additional generation costs due to enhanced RES development and highlights the difference in society costs.

2.1 Pathways of RES Deployment

2.1.1 Muddling Through – Business as Usual:

This scenario is characterized by high gross final energy demand growth rates in all sectors on global scale accompanied by relatively low raw energy prices. However, the projected sectoral contribution can be analyzed best by depicting deployment on sectoral level in relative terms – i.e. by indicating the deployment of RES-E, RES-H and RES-T as shares of corresponding gross demands. In this context, Table 1 gives an overview on results for 2006 – forming the starting year of the simulation – 2010, 2020 and 2030. Although a constant increase of the share of renewables can be observed in all sectors, the overall development of renewables fails to meet the 20 percent RES by 2020 target by far. In this respect, renewables only contribute to 13 percent to the overall gross final energy demand in 2020. Nevertheless, the strongest increase is seen in the electricity sector where almost a quarter of the electricity demand is met by renewables. The share of biofuels in transport fuel demand remains comparatively low throughout the decades up to 2030. Generally, the relatively slow increase of renewables even slows down beyond 2020 and results at 15 percent RES on gross final energy demand in 2030.

Next, the RES development is discussed on technology level for each energy sector. The bulk of RES-E in 2030, illustrated in Figure 4, will be mostly produced by technologies that are already at present well established or close to the market. Hence, wind

onshore (378 TWh/yr), large-scale hydro (320 TWh/yr), solid biomass (128 TWh/yr), biogas (78 TWh/yr), small hydro (55 TWh/yr) will contribute about 83.7 percent to RES-E production. In contrast, novel RES-E options with huge future potentials such as PV (60 TWh/yr), solar thermal electricity (113 TWh/yr) or tidal & wave energy (35 TWh/yr) and wind offshore (33 TWh/yr) enter the market and achieve a steadily growing share. However, remarkable contributions can, under a Business as Usual scenario, only be expected in the period beyond 2020. Generally, current support measures lead to an increased share of RES-E generation, but mainly driven by already experienced technologies, whereas the development of novel technologies is strongly limited, also caused by existing non-economic barriers.

In contrast to the electricity sector, the renewable heat sector is under Business as Usual circumstances also strongly dominated by already well established energy technologies, where, as already mentioned, the biggest RES share is achieved in the individual, non-grid heat sector. Here solid biomass generated about 50 Mtoe in 2006 but only grows to 54 Mtoe in 2030, whereas novel technologies like heat pumps (2.3 Mtoe) and solar thermal heat and water (3.4 Mtoe) show bigger growth rates. Nevertheless, biomass plays a crucial role in the heat sector and, besides in the individual heating plants, is also often used in co-firing plants. With respect to the overall target achievement of 20 percent RES by 2020, which has failed under Business as Usual, it must be concluded that strong efforts have to be made in the heat sector to achieve a much higher growth rate than the 8.5 percent increase seen in Figure 5.

Finally, the development of the renewable transport sector according to the Business as Usual scenario is given in Figure 6. Traditional biofuel generation triples beyond 2010 from 3 Mtoe as of 2006 to 9 Mtoe by 2030. Additional contribution is expected from advanced biofuel generation (second

Table 1: Share of Renewable Energies in Electricity, Heat and Transport Fuel Demand

% deployment				**European Union 27**	
	2006	2010	2020	2030	
Share of RES-E on electricity demand	16%	20%	35%	50%	
Share of RES-H on heat demand	10%	12%	20%	31%	
Share of RES-T on transport fuel demand	1%	2%	8%	10%	
Share of RES on final demand	**9%**	**11%**	**20%**	**30%**	
Share of RES on primary demand	7%	9%	18%	26%	*(Eurostat convention)*
	10%	13%	23%	35%	*(Substitution principle)*

Figure 4: Future Renewable Energy Generation within the Electricity Sector in the European Union up to 2030 on Technology Level according to the Muddling Through Scenario

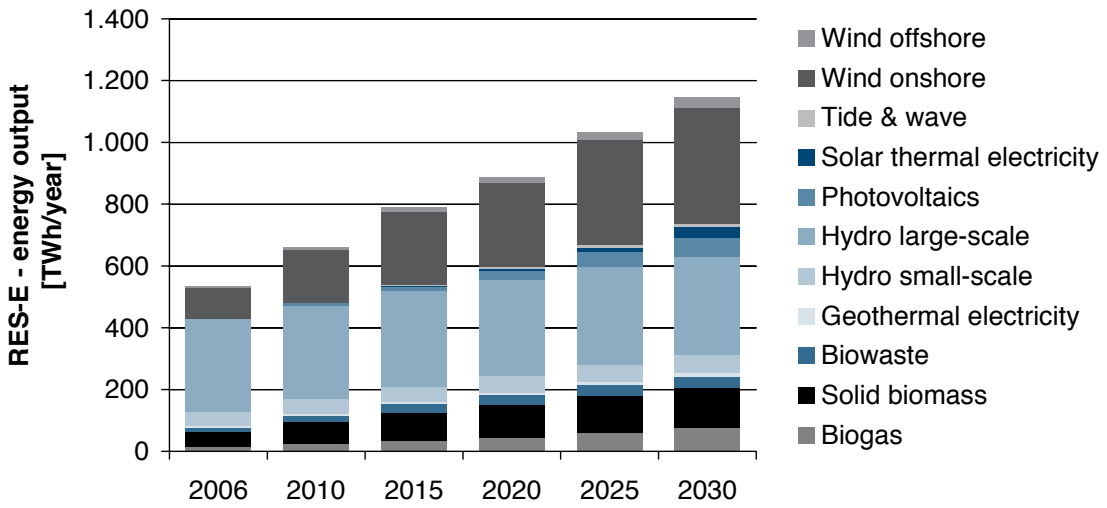
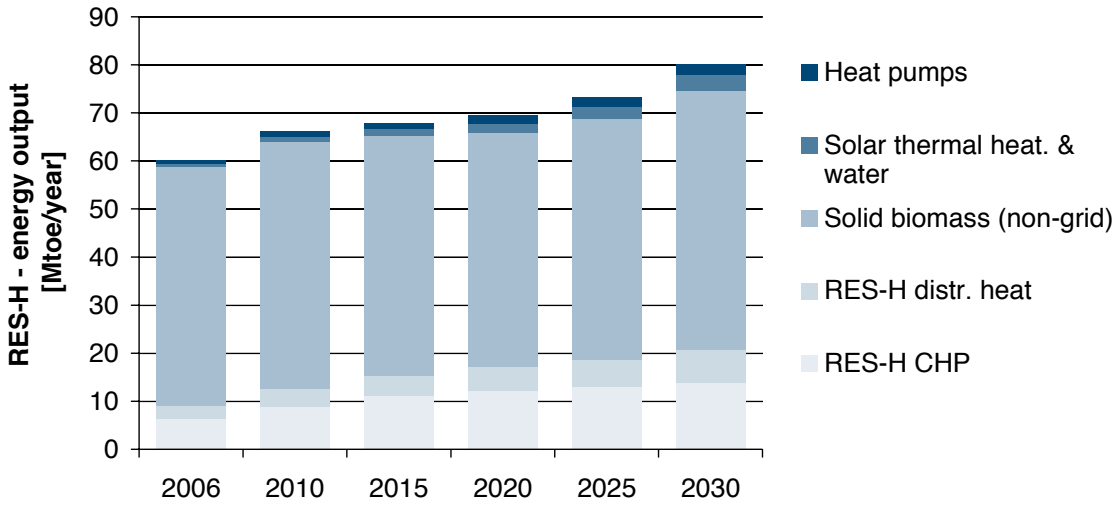


Figure 5: Future Renewable Energy Generation within the Heat Sector in the European Union up to 2030 on Technology Level according to the Muddling Through Scenario



generation – Fischer Tropsch, etc.) beyond 2015 up to 3 Mtoe in 2030. However, substantial increases are still considered in the biofuel import from abroad which amounts to 14 Mtoe in 2030. Generally, as shown in Table 1 the Business as Usual scenario does not meet either the 20 percent RES by 2020 target or the 10 percent biofuel by 2020 target.

In conclusion of this scenario, under Business as Usual conditions the largest renewable energy contribution is achieved in the electricity sector throughout Europe whereas the heat sector almost levels off up to 2030 due to missing support incentives.

2.1.2 Europe Alone – Strengthened National Policy:

In contrast to the scenario above, the Europe Alone scenario is characterized by strong emphasis on climate change issues at the European level implying low energy demand forecasts for the EU accompanied by relatively high raw energy and CO_2 prices but hardly any restrictions for the rest of the

Figure 6: Future Renewable Energy Generation within the Transport Sector in the European Union up to 2030 on Technology Level according to the Muddling Through Scenario

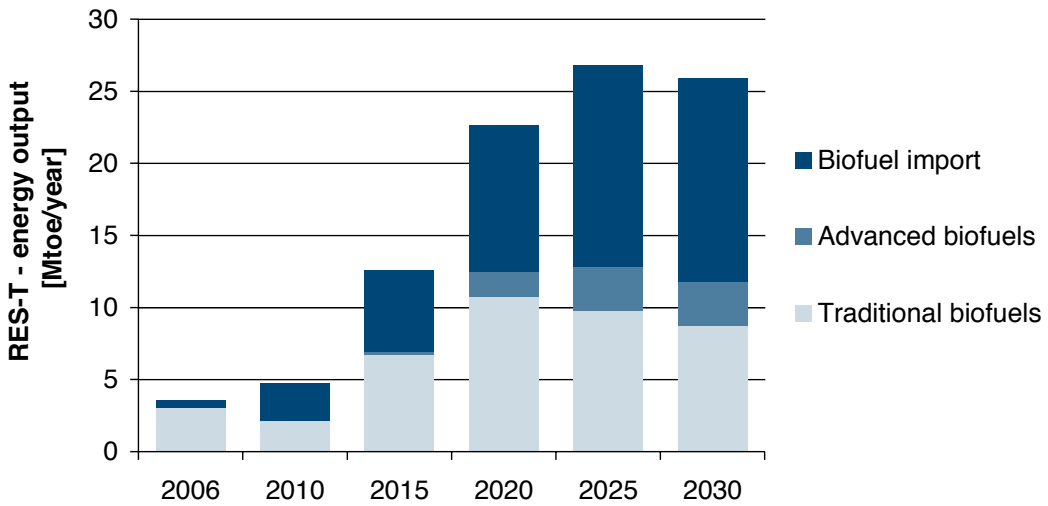


Table 2: Share of Renewable Energies in Electricity, Heat and Transport Fuel Demand

% deployment	2006	2010	2020	2030	European Union 27
Share of RES-E on electricity demand	16%	20%	35%	50%	
Share of RES-H on heat demand	10%	12%	20%	31%	
Share of RES-T on transport fuel demand	1%	2%	8%	10%	
Share of RES on final demand	**9%**	**11%**	**20%**	**30%**	
Share of RES on primary demand	7%	9%	18%	26%	*(Eurostat convention)*
	10%	13%	23%	35%	*(Substitution principle)*

world. Hence, renewable energy support measures are strengthened with respect to effectiveness and efficiency. The projected sectoral contribution in relative terms – i.e. by indicating the deployment of RES-E, RES-H and RES-T as shares of corresponding gross demands is depicted in Table 2. A strong increase of the share of renewables can be observed throughout all sectors, where the electricity sector even takes off stronger beyond 2020. In total, the overall development of renewables meets the 20 percent RES by 2020 target exactly; additionally, the biofuel target of 10 percent RES on diesel and gasoline in 2020 will be met. The biggest share of RES is still projected for the electricity sector where about half of the electricity demand is met by renewables in 2030. Generally, the strong increase of about one percent each year of renewables between 2010 and 2020 even continues beyond 2020 and results at 30 percent RES on gross final energy demand in 2030.

The RES development is separately discussed on the technology level for each energy sector. Caused by the high renewable energy share of about 50 percent in the electricity sector, the total amount of RES-E in 2030, illustrated in Figure 7, cannot solely be produced by technologies that are already well established or close to the market. However, wind onshore (477 TWh/yr), large-scale hydro (325 TWh/yr), solid biomass (228 TWh/yr), biogas (134 TWh/yr), small hydro (65 TWh/yr) will still contribute about 61.3 percent to RES-E production. Wind onshore already holds a higher share of RES-E than the currently dominant large-scale hydro power. In contrast, other RES-E options with huge future potentials such as PV (173 TWh/yr), solar thermal electricity (125 TWh/yr) or tidal & wave energy (72 TWh/yr), and especially wind offshore (360 TWh/yr), enter the market and achieve a strong and steadily growing share. Generally, improved support measures lead to a strong increase of the RES-E share with a broad portfolio of different technologies which is also a result of the overcoming of existing non-economic barriers.

Figure 7: Future Renewable Energy Generation within the Electricity Sector in the European Union up to 2030 on Technology Level according to the Europe Alone Scenario

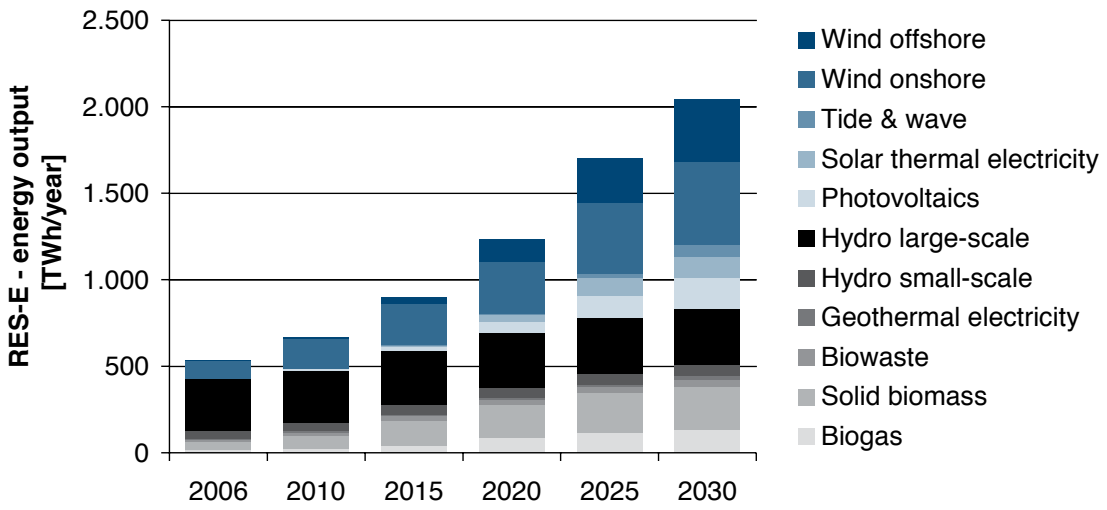
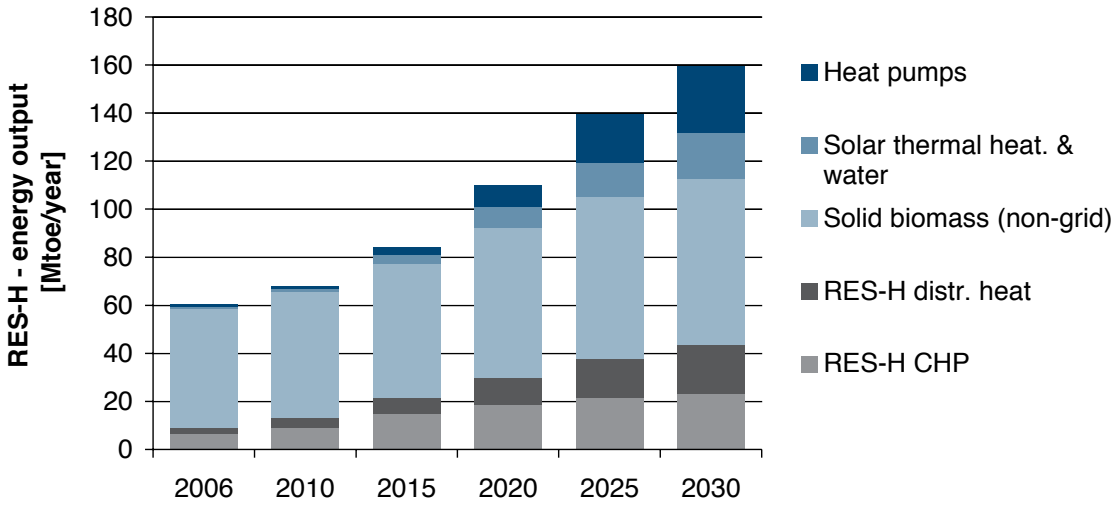
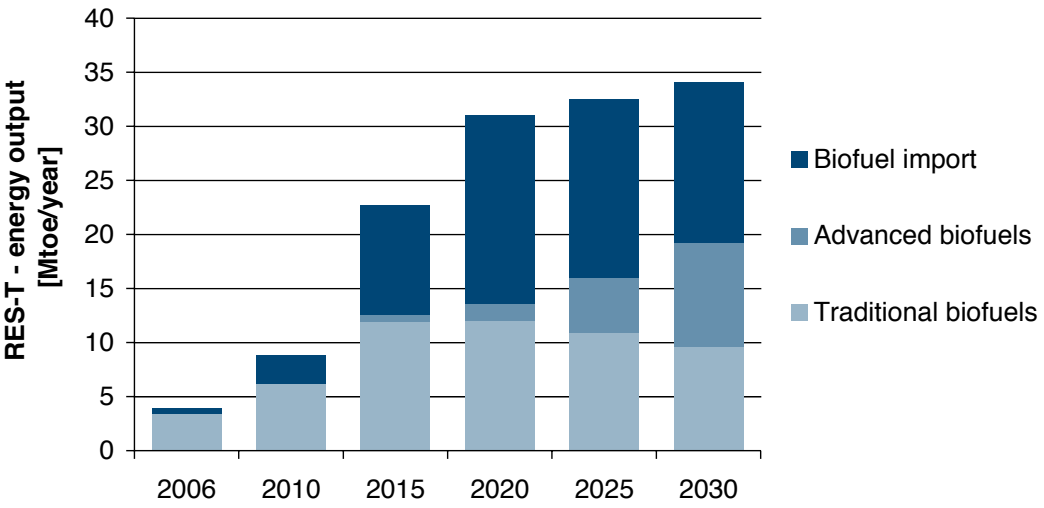


Figure 8: Future Renewable Energy Generation within the Heat Sector in the European Union up to 2030 on Technology Level according to the Europe Alone Scenario



Like the electricity sector, the renewable heat sector provides a big portfolio of different technologies in case of strengthened national policy measures. However, the biggest share is still achieved in the individual, non-grid heat sector which is supplied by solid biomass, solar thermal heat and water as well as heat pumps. Nevertheless, as already mentioned, about 27 percent is supplied by more efficient Combined Heat and Power plants. Solid biomass generated about 50 Mtoe in 2006 and grows to 69 Mtoe in 2030, whereas novel technologies, holding hardly any share in 2006, like heat pumps (28 Mtoe) and solar thermal heat & water (19 Mtoe) show much bigger growth rates. Nevertheless, biomass plays a crucial role in the heat sector and besides in the individual heating plants also often used in cofiring plants. With respect to the overall target achievement of 20 percent RES by 2020, which is met under strengthened national policies, it must be concluded that strong efforts have to be put on the heat sector in order to achieve a much this doubling of renewables in the heat sector compared to the Business as Usual

Figure 9: Future Renewable Energy Generation within the Transport Sector in the European Union up to 2030 on Technology Level according to the Europe Alone Scenario



case. Figure 8 shows the development of RES-H on technology level.

Figure 9, shows the development of the renewable transport sector according to the strengthened national policy scenario. Traditional biofuel generation triples beyond 2010 from 3 Mtoe as of 2006 to 9 Mtoe by 2030. Additional contribution is expected from advanced biofuel generation (second generation – Fischer Tropsch, etc.) beyond 2015 going up to 10 Mtoe in 2030. Generally, traditional biofuel generation equals the amount under the Business as Usual scenario whereas still high exploitable potentials are considered in the advanced biofuel technologies. However, substantial increases are still considered in the biofuel import from abroad which amounts to 15 Mtoe in 2030. Consequently, as shown in Table 2, the strengthened national policy scenario does meet both the 20 percent RES by 2020 target and the 10 percent biofuel by 2020 target; the latter refers to 10 percent biofuel on solely diesel and gasoline demand.

Given the uneven distribution of RES potentials within the European Union, member states are entitled to install flexibility mechanisms in order to exploit their RES potentials in a least-cost approach. Generally, also in this scenario, the electricity sector is still the strongest contributor of renewable energy, but the heat sector takes up strongly.

2.1.3 Global Regime (Full Trade) – Strengthened National Policy:

Principally, the Global Regime (Full Trade) scenario implies a strong emphasis on climate change issues on not only the European level but on global scale. Hence, energy demand growth forecasts are relatively low, but for Europe higher than the Europe Alone scenario, since it is not expected that the industry will strongly shift abroad. Caused by the low energy demand on global scale, raw energy prices are low and CO_2 prices are not as high as in the Europe Alone scenario, due to the global trade opportunity. However, renewable energy support measures are strengthened with respect to effectiveness and efficiency in order to pursue the 20 percent RES by 2020 target. The projected sectoral contribution in relative terms – i.e. by indicating the deployment of RES-E, RES-H and RES-T as shares of corresponding gross demands is depicted in Table 3. Generally, a strong increase of the share of renewables can be observed throughout all sectors, although the electricity sector slightly slows down close to 2030 and more development is then projected in the heat sector driven by a stronger demand increase in the electricity sector beyond 2020. In total, the overall development of renewables meets the 20 percent RES by 2020 target exactly; additionally the biofuel target of 10 percent RES on diesel and gasoline in 2020 will be met. The biggest share of RES is still projected for the electricity sector where slightly less than half of the electricity demand is met by renewables in 2030. Generally, the strong increase of about one percent each year of renewables between 2010 and 2020 even continues beyond 2020 and results at 29 percent RES on gross final energy demand in 2030.

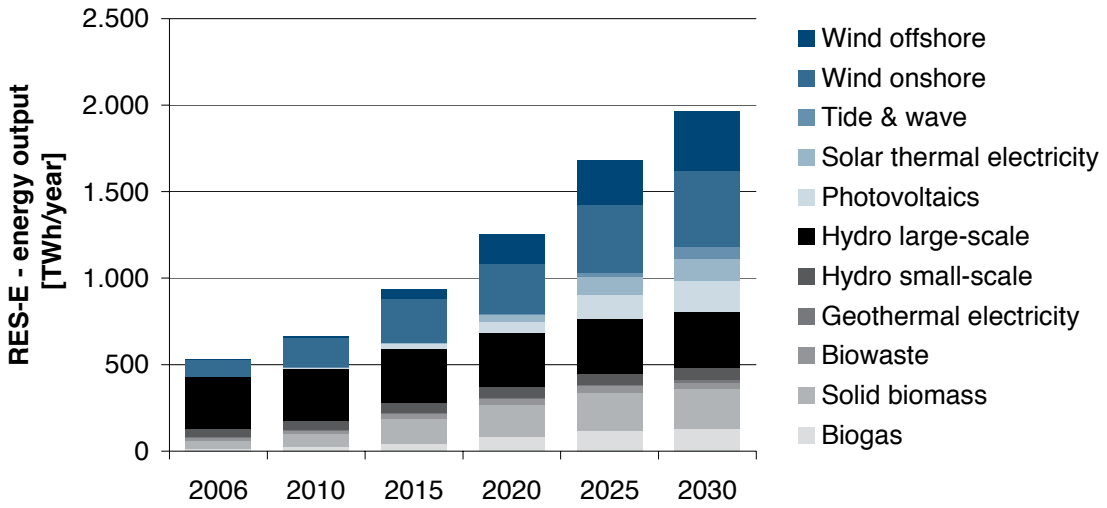
In the following, RES development is discussed in depth on technology level for each energy sector. In order to achieve the high renewables share of about 48 percent in the electricity sector, the total amount of RES-E in 2030, illustrated in Figure 10, a broad portfolio of different energy conversion technologies is required. However, wind onshore (442 TWh/yr), large-scale hydro (323 TWh/yr), solid biomass (233 TWh/yr), biogas (129 TWh/yr), small hydro (65 TWh/yr) will still contribute to about 60.6 percent to RES-E production. Wind onshore already

Table 3: Share of Renewable Energies in Electricity, Heat and Transport Fuel Demand

% deployment				**European Union 27**	
	2006	2010	2020	2030	
Share of RES-E on electricity demand	16%	20%	36%	48%	
Share of RES-H on heat demand	10%	12%	19%	30%	
Share of RES-T on transport fuel demand	1%	2%	8%	10%	
Share of RES on final demand	**9%**	**11%**	**20%**	**29%**	
Share of RES on primary demand	7%	9%	18%	25%	*(Eurostat convention)*
	10%	13%	23%	33%	*(Substitution principle)*

holds a higher share of RES-E than the currently dominant large-scale hydro power. Additionally, wind offshore shows the strongest overall increase and amounts to 343 TWh/yr in 2030 so that wind energy in total already provides 40 percent of the overall RES-E generation. In contrast, novel RES-E options with huge future potentials such as PV (180 TWh/yr), solar thermal electricity (126 TWh/yr) or tidal and wave energy (71 TWh/yr) enter the market and achieve a strong and steadily growing share. It is necessary to emphasize that this broad portfolio of different technologies, required in order to meet the 20 percent target in 2020, is only achieved when the existing non-economic barriers are overcome.

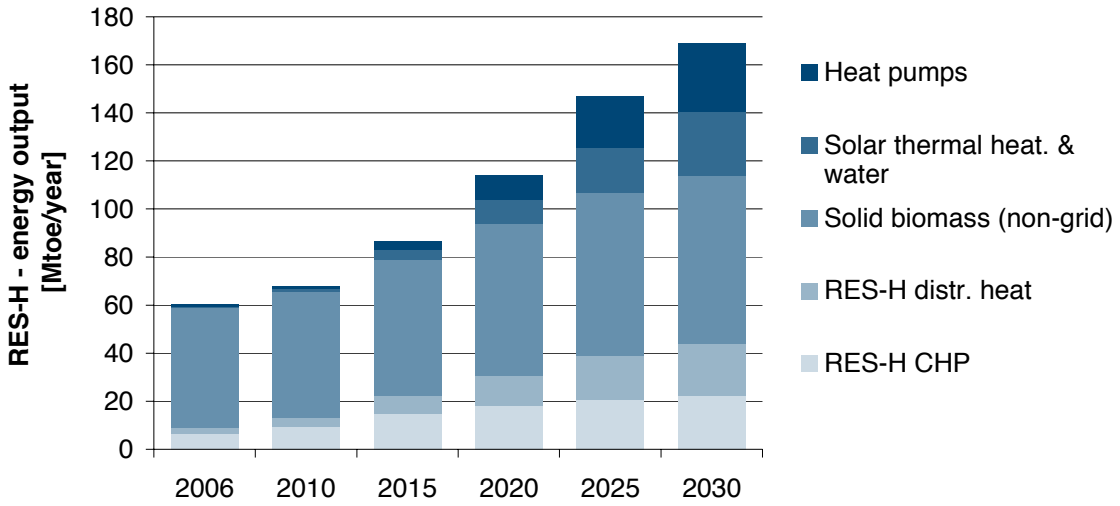
Figure 10: Future Renewable Energy Generation within the Electricity Sector in the European Union up to 2030 on Technology Level according to the Global Regime Scenario



As discussed in the electricity sector, the renewable heat sector also holds a big portfolio of different technologies in case of strengthened national policy measures. Although the biggest share of RES-H is still achieved in the individual, non-grid sector which is supplied by solid biomass, solar thermal heat and water as well as heat pumps about one quarter of the overall renewable heat is generated centrally and connected to distribution networks. In contrast, within the non-grid connected heat supply solid biomass generated about 50 Mtoe in 2006 and grows to 70 Mtoe in 2030, whereas novel technologies, holding hardly any share in 2006, like heat pumps (29 Mtoe) and solar thermal heat and water (26 Mtoe) show much bigger growth rates. Hence, the scenario predicts a decrease of the share of solid biomass within the non-grid heat sector from almost 100 percent now to below 45 percent up to 2030. Nevertheless, biomass plays a crucial role in the heat sector and, besides the individual heating plants, is also often used in co-firing plants. With respect to the overall target achievement of 20 percent RES by 2020, which is met under strengthened national policies, it must be concluded that strong efforts have to be put on the heat sector in order to achieve a doubling of renewables in the heat sector compared to the Business as Usual case. Figure 11 shows the development of RES-H on technology level.

Figure 12 illustrates, according to the strengthened national policy scenario, the development of the renewables in the transport sector. Generally, the global CO_2 constraints scenario results in a slightly higher transport fuel demand. Hence, the overall RES-T generation contributes to 37.4 Mtoe, but the allocation of the three major contributors equals the Europe Alone scenario. Traditional biofuel generation triples beyond 2010 from 3.4 Mtoe as of 2006 to 11.2 Mtoe by 2030. Additional contribution is expected from advanced biofuel generation (second generation – Fischer Tropsch, etc.) beyond 2020 up to 10 Mtoe in 2030. Generally, traditional biofuel

Figure 11: Future RES Generation within the Heat Sector in the EU on Technology Level according to the Global Regime Scenario



generation equals the amount under the Business as Usual scenario whereas still high exploitable potentials are considered in the advanced biofuel technologies. However, substantial increases are still considered in the biofuel import from abroad which amounts to 17 Mtoe in 2030. Consequently, as shown in Table 3, the strengthened national policy scenario does meet both, the 20 percent RES by 2020 target and the 10 percent biofuel by 2020 target whereas the latter refers to 10 percent biofuel on solely diesel and gasoline demand.

2.2 Costs of Enhanced Renewable Energy Generation

Based on the future projections of renewable energies presented above, this section discusses the associated costs of the development in detail. The assessment of future renewable energy pathways and corresponding costs is based on the same scenario calculations seeking to meet the overall 20 percent RES by 2020 target in the EU. Consumer expenditures caused by the different policy

Figure 12: Future Renewable Energy Generation within the Transport Sector in the European Union up to 2030 on Technology Level

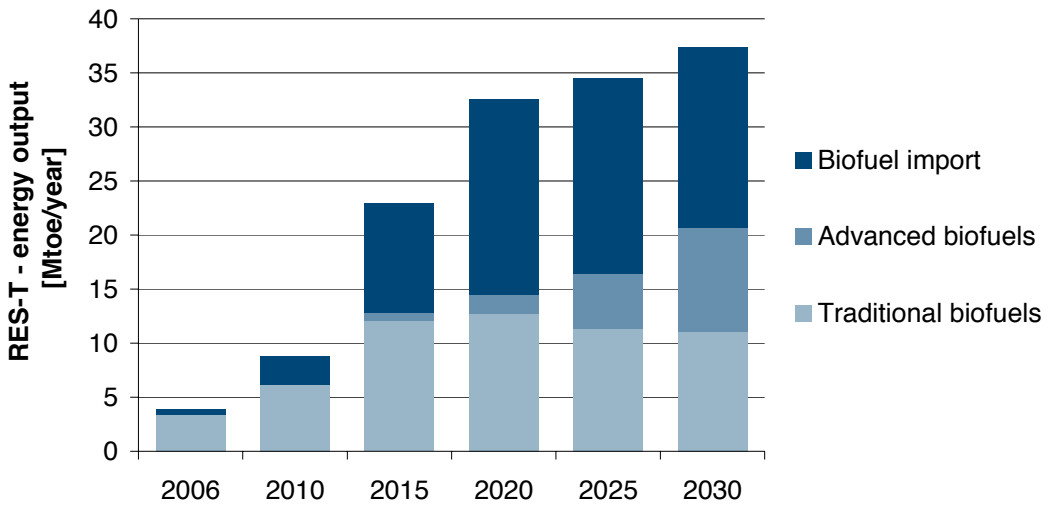
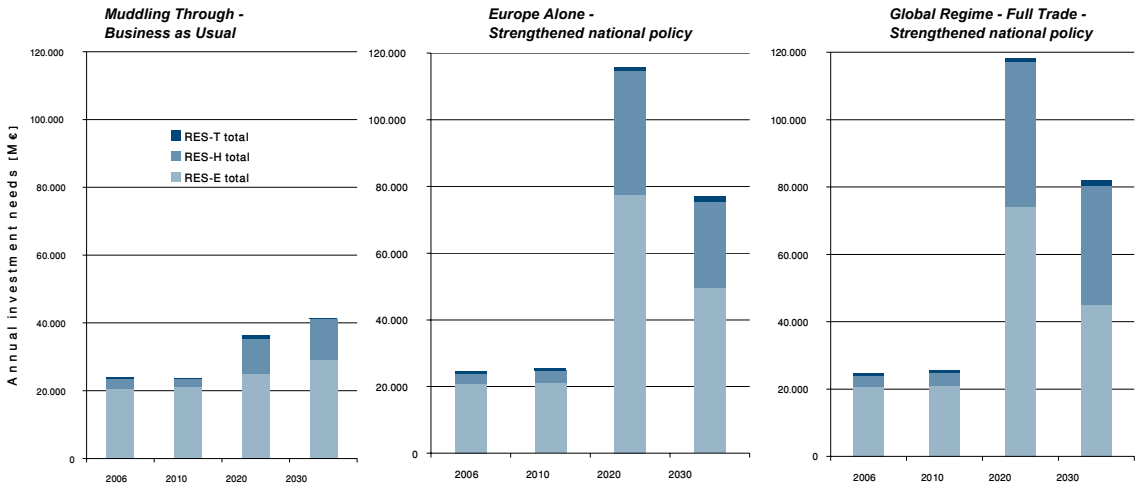


Figure 13: Annual Required Capital Expenditures in order to Achieve the Corresponding RES Generation for the Year 2006, 2010, 2020 and 2030 in Million Euro



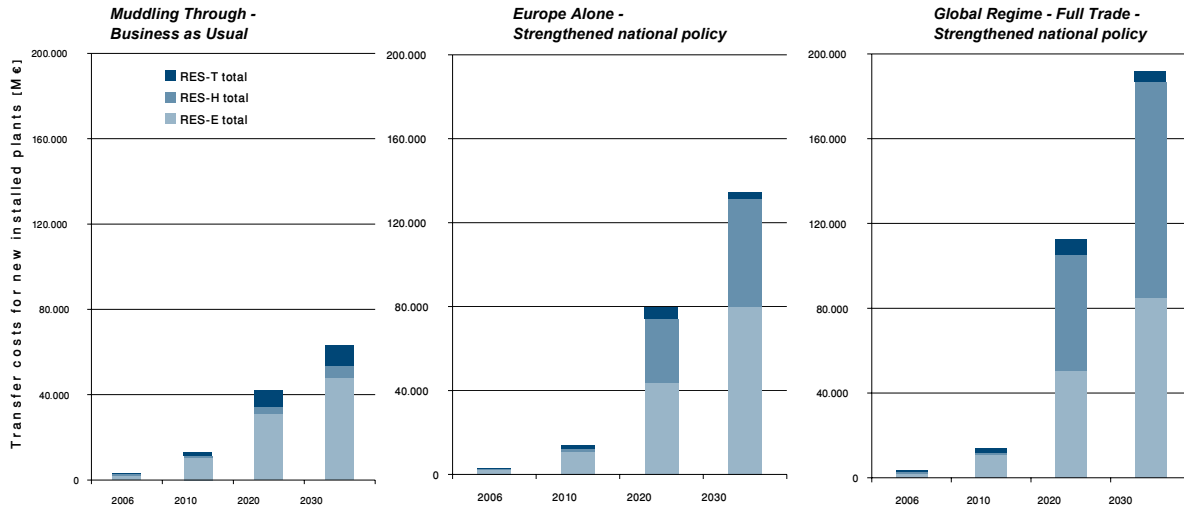
themes on future energy pathways are depicted In more detail and discussed along with additional generation costs of the corresponding RES development.

This paper focuses on the costs of the future development of renewable energies in all three energy sectors in line with the scenarios presented in the section above. Additionally, comparison of the deployment of renewable energies with the corresponding costs for the society will highlight the need for necessary design criteria for policy options.

2.2.1 Pathways of RES Deployment with Respect to its Costs

First, the capital expenditures needed in all three sectors are analyzed with respect to the three different policy themes, the Mudding Through, the Europe Alone and the Global Regime presented above. In order to achieve an ambitious share of renewables by 2020, huge investments have to be undertaken. Thus, it is necessary to implement efficient and effective policy measures in order to

Figure 14: Cumulated Transfer Costs to the Society due to RES Policy Measures according to Three Policy Themes in Million Euro on Sectoral Level



keep the RES surcharges for the energy consumers at a low level. Consequently, this section discusses the resulting costs for the society caused by the support of RES for all three policy themes.

Figure 13 demonstrates the annual needed capital expenditures within the Muddling Through - Business as Usual, Europe Alone - Strengthened National Policy and Global Regime (Full Trade) - Strengthened National Policy. Meeting the 20 percent RES by 2020, which only the two strengthened national policy schemes do, requires investments of about three times the investment needed in 2020 under current support options. Furthermore, comparing the three scenarios, it appears necessary that strong efforts have to be taken in the heat sector, where under BAU conditions only minor action is expected; meeting the 2020 target requires much higher contribution from the heat sector as well. Again, the capital expenditures reflect the higher energy demand in the Global Regime (Full Trade) scenario, resulting in more needed capital expenditures. When it comes to the period 2020 to 2030, partly due to the huge cost reductions of certain technologies less investment is needed in order to achieve approximately the same growth rate of 1 percent RES annually. These costs reductions are mainly driven by the assumed technological learning effects as well as efficiency improvements especially of novel technologies such as wind offshore, photovoltaic or solar thermal energy.

Transfer costs paid by the society are discussed in the following part. Depending on the support mechanism of RES plants, the investors receive a fixed or varying extra charge per energy unit generated on top of the energy market prices. Thus, transfer costs are determined by the difference of the cumulated costs of guaranteed support of RES plants to the energy wholesale market prices. These costs are then usually shared among all energy consumers. Thus, the design of financial support measures is very important to find the most efficient balance between the higher cost to the consumer and contribution from RES.

With respect to the Muddling Through – Business as Usual case, the annual transfer costs paid by the society are shown in Figure 14 (left figure) on sectoral level. In the Business as Usual case, although the stimulation of the RES markets is almost equal among the electricity and heat sector, the transfer costs are mainly relevant in the electricity sector. Since most of the realized renewable heat installations are within the individual sector they are already market competitive without additional support. However, keeping in mind that this scenario fails to meet the target in 2020 by far, strong emphasis has to be put in the renewable heat sector in this respect. In contrast, the transport sector lags behind in terms of RES generation but, nevertheless, is strongly dependent on financial support. In total, the policy costs amount to 42 billion Euro in 2020 and 63 billion Euro in 2030. With respect to the decrease of transfer costs in the year 2026 , it has to be taken into account that most RES technologies under Business as Usual conditions are eligible for financial support for 15 to 20 years, hence new installations from 2006 to 2010 are then on the market and, therefore, the overall policy costs are reduced.

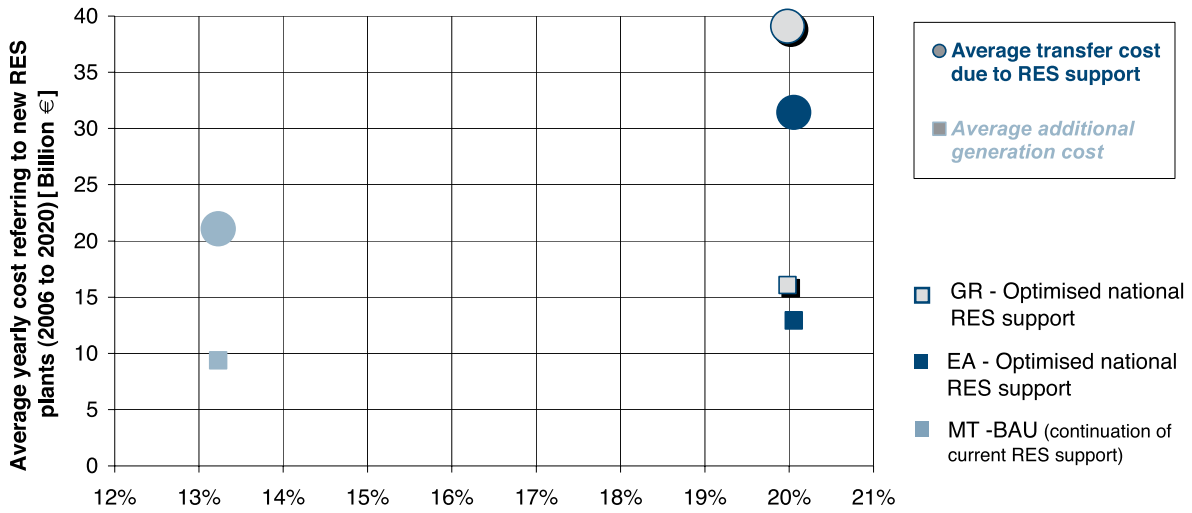
In contrast, in the Europe Alone – strengthened national policy case it is remarkable that on the one hand, obviously strong efforts are taken in the electricity sector, but on the other hand, transfer costs in the heat sector are expected to grow in the same magnitude. An ambitious RES deployment consequently asks for a strong contribution of all sectors. It is noticed that the transfer costs on sectoral as well as in total are increasing even more strongly beyond 2020. This fact is caused on the one hand by residual transfer costs from installations before 2020 as well as by the entry into the market of novel technologies, like solar and wind offshore energy. In total, the policy costs amount to 79.5 billion Euro in 2020 and 134 billion Euro in 2030. Special focus has to be put on the 2020 time horizon, when only less then a doubling of the overall transfer costs is sufficient to comply with the target but, as indicated above, covering three times more of the investment costs than in the Muddling Through case.

Finally, expected transfer costs within the Global Regime (Full Trade) based on strengthened national RES policies are depicted in Figure 14. As in the Europe Alone scenario, the Global Regime case also seeks to meet the 20 percent RES target.

Hence, obviously strong efforts are taken in the electricity sector and the heat sector. With respect to total RES development, the Global Regime (Full Trade) only results in slightly higher numbers than the Europe Alone case due to the higher gross final energy demand in the Global Regime (Full Trade). However, the resulting transfer costs are about 40 percent more in the Global Regime (Full Trade), since the preconditioned global CO_2 constraints lead to overall lower raw energy prices, which consequently increase the need for policy support for RES. Again, notable is that the transfer costs, both sectoral as well as overall, will increase more strongly beyond 2020 due to residual transfer costs from installations before 2020 as well as when novel technologies, like solar and wind offshore energy, are entering into the market. In total, the policy costs amount to 112.5 billion Euro in 2020 and 191.7 billion Euro in 2030.

An in-depth analysis with respect to the achieved RES deployment and the corresponding costs according to the three policy themes is provided in Figure 15 on the 2020 time horizon. The Muddling Through scenario, representing a continuation of the currently implemented policy options, would lead to only 13.3 percent RES in 2020 at high transfer costs, covered by the energy consumer. Non-economic barriers hamper a stronger development of renewables in general; additionally hardly any support is available for the important sector of renewable heat. Furthermore, implemented policy options need to be strengthened with respect to their effectiveness, resulting in more RES installation due to improved usage of the transfer costs, and their efficiency, meaning the difference of real RES generation costs and their (guaranteed) support level, in order to comply with the target. These improvements are necessary for the Europe Alone and Global Regime scenarios. Both scenarios meet the target but at different costs, due to the different demand and energy price assumptions. Demand projections influence the average generation costs while the energy price influences the transfer costs.

Figure 15: Comparing Average Additional Generation Costs (Square) as well as Transfer Costs (Circle) for Consumer due to RES Support to the Achieved RES Share in 2020 for Different Demand Projections



Conclusion

The use of renewable energy sources (RES) for electricity, heat or transport fuel production involves positive implications for the mitigation of climate change and for security of energy supply. In particular the domestic character of most RES facilitates the reduction of import dependency on fossil fuels. As most technology options using RES are not yet competitive with established technology options, the European Union encourages member states to promote the use of RES economically. As a consequence of political support measures, the strongest dynamic development could be observed

in the electricity sector, particularly with regard to the 'new' RES-technologies in Western European countries. A broad portfolio of technologies is being developed, though technologies such as hydropower, wind energy and solid biomass energy still dominate the overall composition.

Though there are positive impacts, an increased use of RES may constitute some risks for security of energy supply. In general, most RES-conversion technologies depend on the use of natural energy flows, resulting in a volatile character of the final energy output. These fluctuations may occur on varying time scales. Wind energy technologies or solar energy technologies show fluctuations on a short- to medium-term horizon, whereas hydro power output fluctuates rather on a seasonal level or even annually. The volatile character of some RES poses important challenges for the management of the electricity system and represents a risk for energy security. In addition, in both cases output volatilities are very sensitive to the electricity generation costs and may therefore have negative impacts on the economics of these plants.

In terms of the potential of RES in the time horizon of 2030, about 35 percent of the total gross final energy demand could be met by RES if all driving forces were active and all non-economic barriers were overcome. In a sectoral breakdown, this 35 percent is divided into 64 percent renewable electricity on gross final electricity demand, 30 percent renewable heat on gross final heat demand and about 11 percent of renewables in the transport sector. On the technology level, hydropower has historically dominated in the electricity sector and solid biomass in the heat sector, but in the long term several options such as wind, solar and geothermal energy will play an important role. Of course, these potentials are distributed very differently among the 27 EU member states necessitating a flexible exploitation of these RES potentials in order to meet the agreed EU targets.

Concerning the demand projections as well as raw energy prices, huge deviations appear regarding the three different, investigated policy themes (Muddling Through, Europe Alone and Global Regime [Full Trade]). Since 'Muddling Through' implies a continuation of currently set legislation with respect to energy demand development as well as CO_2 constraints it reflects a Business as Usual case. In contrast, two themes are developed within the SECURE project, which consider stronger CO_2 constraints policies. The Europe Alone scenario expects that only Europe will care about CO_2 constraints, and hence shows less energy demand in the EU member states accompanied by high CO_2 costs, resulting in high wholesale energy prices. On the other hand, the Global Regime (Full Trade) considers similar CO_2 constraints on a global scale, leading to a little higher energy demand in Europe than in the Europe Alone scenario and shows lower raw energy prices.

Principally, renewable energy sources offer a big potential to improve the security of supply due to domestic energy production on the one hand and their decentralized character on the other. The increased RES deployment due to new installations in the case of strengthened RES support could lead to a reduction in fossil fuel demand of yearly 539 Mtoe by 2030. Oil imports can be reduced by 18 percent, gas imports by 51 percent and coal imports by 68 percent. This will significantly increase the EU's security of supply. In 2030, 150 billion Euro of fossil fuels can be saved, which corresponds to 0.88 percent of GDP. This quantitative assessment is based on the Global Regime (Full Trade) scenario conducted by POLES energy modelling and the monetary figures refer to POLES energy prices. Given the energy prices as recently observed in all markets, saved expenses would still increase compared to the applied price developments. The results show that the 20 percent RES could be achieved at moderate cost, which illustrates the ability of RES to protect the EU economy against rising 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.

The Muddling Through scenario only avoids about 267 Mtoe fossil fuels consumption which corresponds to about 78 billion Euro, equalling 0.46 percent of the GDP in 2030. In contrast, the Europe Alone scenario based on strengthened national RES policies, implying improvements of currently implemented

policies with respect to efficiency and effectiveness, expects to meet the 20 percent RES target in 2020 and shows the same level of ambition beyond 2020. The Europe Alone scenario only avoids about 540 Mtoe fossil fuels consumption which corresponds to about 146 billion Euro, equalling 0.88 percent of the GDP in 2030. Finally, the Global Regime scenario based on strengthened national policy options foresees to meet the 20 percent RES target by 2020 as well, wherein a continuation of the strong RES deployment is expected to grow until 2030.

Taking into account the lessons learned from the assessment of future renewable energy pathways and the corresponding cost developments, some general conclusions can be drawn here:

Strong growth is needed in all three sectors

A high share of renewable energies in the mid- to long term cannot be reached without strong increases in all three sectors: renewable electricity, heat and biofuels. The future policy framework should address this need for growth in all sectors.

A wide range of technologies has to be supported

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.

RES policies should be supported by a strong energy efficiency policy

As also indicated in the comparison of the Europe Alone and the Global Regime (Full Trade) scenario to the Muddling Through scenario, it can be concluded that 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 percent by 2020. In that case, more expensive RES technologies have to be utilized and the average yearly transfer costs are expected to largely increase. This underpins the importance of energy efficiency policy and RES policy being used as complementary tools for creating a more sustainable energy system in an economically efficient way.

Endnotes

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