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Assessment and optimisation of renewable energy support schemes in the European electricity market

Recommendations for implementing effective & efficient renewable electricity policies

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Assessment and optimisation of renewable energy support schemes in the European electricity market

This project is supported by the European Commission within the framework of the Intelligent Energy for Europe programme. The consortium consisting of six European partners analysed the effectiveness as well as the economic efficiency of currently implemented sup-port schemes for renewable energies in the electricity sector in the enlarged European Union. The project gives recommendations for future improvements of the existing promotion measures for RES-E. Furthermore the consortium has carried out an extensive stakeholder consultation, which with focus on the identification of existing market barriers to the development of renewable electricity in the EU. Key stakeholders were invited to share their experiences via a web-based questionnaire.

The effectiveness and efficiency of current and future RES-E support schemes was analysed with particular focus on a single European market for renewable electricity products. Current best practices have been identified, and an assessment is made of the (future) costs of RES-E and the relevant support necessary to initiate stable growth. The main barriers to a higher RES-E deployment as perceived by market actors and stakeholders have been assessed. The **central project questions** that have been analysed during the OPTRES project are:

- What is the current level of support for RES-E in Europe compared to the corresponding costs of RES-E generation?
- Which funding mechanisms are being implemented today? Which funding schemes should be fostered for financially viable projects?
- Which of the currently implemented support schemes (investment incentives, feed-in law, obligation, portfolio standard, tender procedure) are the most effective and which are the most efficient?
- Are these support schemes compatible with the principles of the internal electricity market and what are the effects of different RES-E support mechanisms on the restriction of trade?
- Which interactions take place between the various RES-E support schemes in different countries?
- Which interactions of RES-E support schemes with other policies like CO_2 certificate trading occur?
- To what extent are avoided external costs internalized in RES-E support schemes and what are the real socio-economical costs due to RES-E support if external costs are internalised?
- What alternative innovative policies and regulatory frameworks are there to the currently existing ones?
- Is a harmonisation of RES-E support in Europe preferable with respect to effectiveness and efficiency in the future and which instruments are optimal in a harmonised scenario?

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Intelligent Energy Europe

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1 INTRODUCTION

Energy policy represents the main driver for the enhanced deployment of *electricity from renewable energy sources (RES-E)* as observed in several European countries. It is the core objective of this report to provide a concise summary on recommendations how to derive effective and efficient support schemes for RES-E as required for establishing the necessary correction of our energy system towards sustainability and supply security. Building on a brief analysis of the variety of support schemes as implemented in the past and at present, a prospective analysis of possible future support options will illustrate the way forward. Possible trade-offs between RES-E support and other policies and markets are discussed, in order to draw a concise set of conclusions and to derive recommendations for the way forward.

1.1 Key present trends

Renewable electricity has increased significantly in the last years at global scale and especially within Europe. A major reason for this development at European level are national promotion strategies triggered by the Directive 2001/77/EC on renewable energies in the electricity sector (European Parliament and Council, 2001). All EU member states have introduced policies to support the market introduction of RES-E and most of them have started to improve the corresponding administrative framework conditions (e.g. planning procedures grid connection). The market diffusion of new renewable energy sources has increased significantly over the last decade. The existing policies encompass feed-in tariffs, quota-based tradable green certificates (TGCs), investment grants, tender procedures and tax measures. Until now these policies are implemented exclusively on a national level, thus among others aiming at fulfilling the national targets as set in the RES-E directive. However, based on the presently implemented policies these targets will most likely not be met (European Commission 2004, European Commission 2006). An important reason is that the support systems for RES-E in most EU countries are still not designed in a suitable way. In some member states growth is only moderate since investments in renewables are accompanied by high risks due to uncertainties in the policy framework. Furthermore key barriers identified for an enhanced deployment of RES-E, which are of administrative, financial, and social nature as well as insufficient electricity grid capacity are not appropriately addressed by national authorities. Altogether the effectiveness of the present RES-E policy environment in most EU countries is still limited and shows a rather uneven distribution across the EU.

Besides this fact the economic efficiency of RES-E support is lower than possible under an advanced policy environment and shows a clear heterogeneity among member states. The reason for the latter fact is mainly based on structural design differences of the different implemented policy schemes. In particular instruments involving a high price uncertainty for RES-E producers lead to high risk premiums and therefore limited economic efficiency from the societal point of view. In future large efficiency gains can be reached by increasing the technology differentiation of implemented policy measures in order to reduce the windfall profits for low cost technologies and to allow for an early market introduction and corresponding technology learning of technologically less mature technologies.

Therefore, a significant optimisation potential for national policies exists and could be continuously exploited by fine-tuning the existing policy measures. Measures to improve the market compatibility of feed-in tariffs are being implemented as well as design options for quota systems that aim to reduce the risk for investors and to introduce a technology differentiation of the support scheme. Although the basic nature of the existing instruments is certainly different between some counties one can observe clear tendencies towards a convergence of important properties of the policy measures. Some quota systems get design features which mirror the advantages of feed-in systems and visa versa. For example quota systems are combined with minimum feed-in tariffs or differentiated with respect to different technologies. Premium feed-in tariffs aim at improving the market compatibility of RES-E generation. This leads to a mutual improvement of the existing measures and to a gradual increase of the effectiveness as well as of the efficiency of RES-E support.

1.2 Compatibility with other policies

The existence of support schemes promoting RES-E will by themselves not only have an impact on the price of CO_2-permits in the EU emission trading system, but also influence quantity and distribution of the reduction of CO_2-emissions. In a similar manner the co-existence of different support schemes in different regions of Europe will influence, not only the price of power in these regions, but also cross border trade of power between the regions.

In general, the development of RES-E will imply a lower price of CO_2-permits in the EU emission trading system, independent of support system. But how much will depend on design and implementation of the considered support scheme.

If no interconnectors to neighbouring countries exist and no participation in an international emission trading scheme is foreseen, the implementation of RES-E will directly lead to lower CO_2-emissions in a country. Participation in a competitive liberalised power market will imply that CO_2-reductions will be shared among all participating countries no matter where RES-E technologies are developed. If the country is part of an emission-trading scheme, the CO_2-quotas will act as “buffer” and no additional CO_2-reduction will be achieved by an increased deployment of RES-E. Therefore, in the long-term it is important that the allocation of CO_2-quotas is co-ordinated with the long-term targets of utilising RES-E resources.

1.3 Evaluation of support schemes in a dynamic framework – Method of approach

Support instruments have to be *effective* in order to increase the penetration of RES-E and *efficient* with respect to minimising the resulting public costs (transfer cost for society) over time. The criteria used for the evaluation of the various instruments are based on the following conditions:

► *Minimise generation costs*

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

- *Lower producer profits*

  If such cost-efficient systems are found various options should be evaluated with the aim of minimising the transfer costs for consumer / society.[1] This means that feed-in tariffs, subsidies or trading systems should be designed in such a way that public transfer payments are also minimised. This implies lowering generation costs as well as producer surplus (PS)[2].

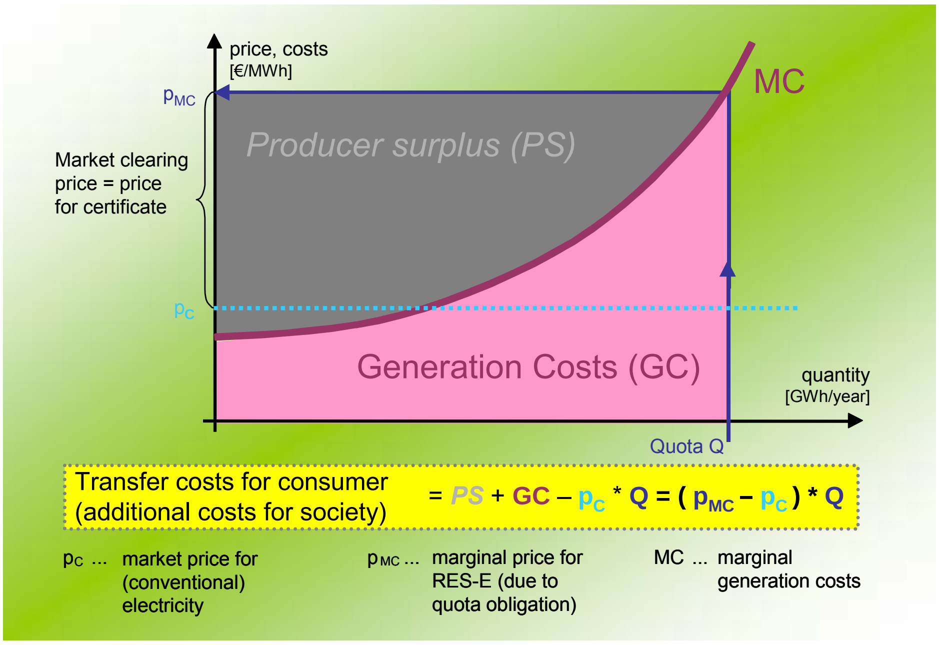

Figure 1. Basic definitions of the cost elements (illustrated for a TGC system)

In some cases both goals – minimise generation costs and producer surplus – may not be reached together so that compromises have to be found. For a better illustration of the cost definitions used, the various cost elements are shown in Figure 1.

1.4 Outline of this report

As a starting point for the more comprehensive discussion of the effectiveness and efficiency of RES-E support schemes an evaluation of policy instruments will be carried out from the historic perspective in the following chapter 2. Thereby, a concise picture will be given on the funding mechanisms implemented today. The level of support for RES-E will be compared to the corresponding costs of RES-E generation, and, finally, the effectiveness and efficiency of the implemented schemes will be analysed.

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[1] Transfer costs for consumers / society (sometimes also called additional / premium costs for society) are defined as the direct premium financial transfer costs resulting from the consumer to the producer due to the RES-E policy compared to the reference case of consumers purchasing conventional electricity from the power market. This means that these costs do not consider any indirect costs or externalities (environmental benefits, change of employment, etc.). The transfer costs for society are either expressed in M€/year or related to the total electricity consumption. In the latter case, the premium costs refer to each MWh of electricity consumed.

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

Next, chapter 3 will provide the complementary evaluation of the different support schemes for RES-E from the future perspective. Thereby, the question about the effectiveness and the efficiency of various support schemes will be discussed by analysing results gained from simulation runs with the help of the toolbox ***Green*-X**.

As a further step, in chapter 4 interactions of RES-E policies with other policies and markets will be illustrated. Theoretical examples aim at illustrating possible trade-offs at a regional level.

Finally, in chapter 5 the main conclusions and recommendations will be presented.

2 EVALUATION OF POLICY INSTRUMENTS FOR PROMOTING RENEWABLE ELECTRICITY FROM THE HISTORIC PERSPECTIVE

In this chapter the evaluation of policy instruments shall be carried out from the historic perspective. In this respect the instruments will be classified according to different general criteria in a first step. Then the effectiveness of the instruments for developing additional generation capacity will be analysed. In a next step the economic efficiency of the support measures will be investigated from the investors point of view. In a last step the lessons learned on a country level will be given.

2.1 Classification of policy instruments and evolution of RES-E policies in the EU

A fundamental distinction can be made between direct and indirect policy instruments. In this context, direct policy measures aim at the immediate stimulation of RES-E, whereas indirect instruments focus on improving long-term framework conditions (Harmelink et al. 2006). Besides regulatory instruments, there are also voluntary approaches to the promotion of RES-E, which are mainly based on consumers' willingness to pay premium rates for green electricity. Further important classification criteria are whether policy instruments address price or quantity, and whether they support investment or generation. Table 1 provides an outline of policy instruments used to promote RES-E.

Table 1. Classification of promotion strategies
Source: Haas et al., 2001

		Direct		**Indirect**
		Price-driven	**Quantity-driven**	
Regulatory	Investment focussed	• Investment incentives • Tax incentives	• Tendering system	• Environmental taxes
	Generation based	• Feed-in tariffs • Rate-based incentives	• Tendering system • Quota obligation based on TGCs	
Voluntary	Investment focussed	• Shareholder programmes • Contribution programmes		• Voluntary agreements
	Generation based	• Green tariffs		

Within this study the assessment of direct promotion strategies is carried out by focussing on the comparison between price-driven, (e.g. FITs) and quantity-driven (e.g. Tradable Green Certificate (TGC)-based quotas,) strategies, see Table 1. These instruments are explained in more detail below.

Feed-in tariffs (FITs) are generation-based, price-driven incentives. The price per unit of electricity that a utility or supplier or grid operator is legally obligated to pay for electricity from RES-E producers is determined by the system. Thus, a federal (or provincial) government regulates the tariff rate. It usually takes the form of either a fixed amount of money paid for RES-E production, or an additional premium on top of the electricity market price paid to RES-E producers. Besides the level of the tariff, its guaranteed duration represents an important parameter for an appraisal of the actual financial incentive. FITs allow technology-specific promotion as well as an acknowledgement of future cost-reductions by applying dynamic decreasing tariffs.

Quota obligations based on Tradable Green Certificates (TGCs) are generation-based, quantity-driven instruments. The government defines targets for RES-E deployment and obliges a particular party of the electricity supply-chain (e.g. generator, wholesaler, consumer) with their fulfilment. Once defined, a parallel market for renewable energy certificates is established and their price is set following demand and supply conditions (forced by the obligation). Hence, for RES-E producers, financial support may arise from selling certificates in addition to the revenues from selling electricity on the power market. With respect to technology-specific promotion in TGC systems this is also possible in principle. Yet it should be noted that a market separation for different technologies will lead to much smaller and less liquid markets.

Tendering systems are quantity-driven mechanisms. The financial support can either be investment-focussed or generation-based. In the first case, a fixed amount of capacity to be installed is announced and contracts are given following a predefined bidding process which offers winners a set of favourable investment conditions, including investment grants per installed kW. The generation-based tendering systems work in a similar way. However, instead of providing up-front support, they offer support in the form of a ‘bid price’ per kWh for a guaranteed duration.

Investment incentives establish an incentive for the development of RES-E projects as a percentage of total costs, or as a predefined amount of € per installed kW. The level of these incentives is usually technology-specific.

Production tax incentives are generation-based, price-driven mechanisms that work through payment exemptions from the electricity taxes applied to all producers. Hence, this type of instrument differs from premium feed-in tariffs solely in terms of the cash flow for RES-E producers: it represents a negative cost instead of additional revenue.

Figure 2 shows the evolution of the main support instrument for each country. Only 8 out of the 15 countries did not experience a major policy shift during the period 1997-2006. The current discussion within EU Member States focuses on the comparison of two opposed systems, the FIT system and the quota regulation in combination with a TGC-market. The latter replaced existing policy instruments in some European countries such as Belgium, Italy, Sweden, the UK and Poland. Although these new systems were not introduced until or even after 2002, the announced policy changes caused investment instabilities prior to this date. Other policy instruments such as tender schemes are not yet used in any European country as the dominating policy scheme. However, there are instruments as production tax incentives and investment incentives, which are frequently used as supplementary instruments. Only Finland and Malta apply them as their main support scheme.

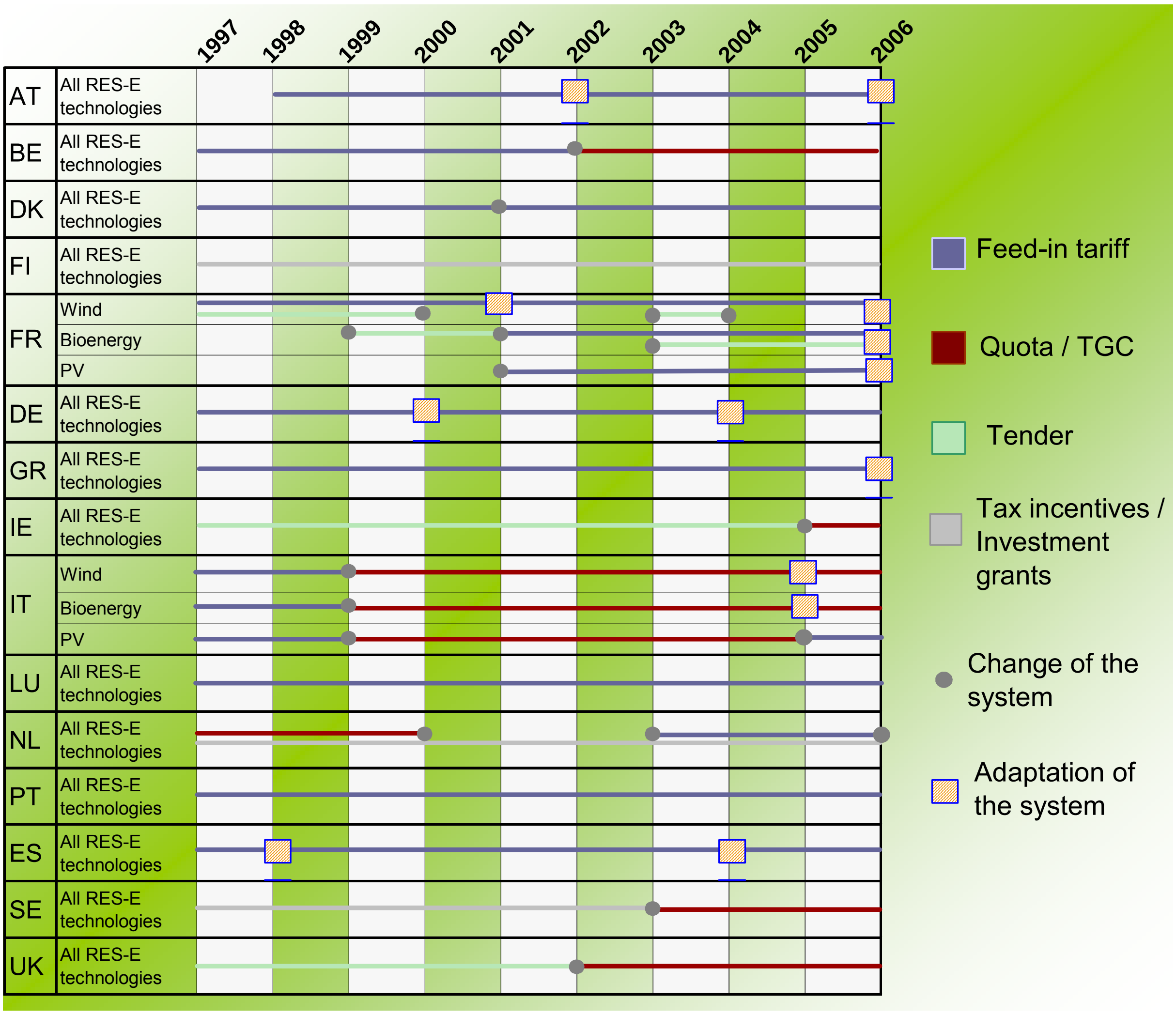

Figure 2. Evolution of the main policy support scheme in EU-15 Member States

2.2 Effectiveness of policy instruments

In this section the effectiveness of a policy to increase the generation from renewable electricity is presented where the definition of effectiveness used in this analysis is given in equation (1).

$$E_n^i = \frac{G_n^i - G_{n-1}^i}{ADD - POT_n^i} \quad (1)$$

E_n^i	Effectiveness indicator for RES technology i for the year n
G_n^i	Existing normalised electricity generation by RES technology i in year n
$ADD - POT_n^i$	Additional generation potential of RES technology i in year n until 2020

This definition of effectiveness has the advantage of being unbiased with regard to the available potential for individual technologies in a specific country. Member States need to deploy RES-E-capacities proportional to the given potential in order to demonstrate the comparable effectiveness of their instruments. This appears to be a meaningful approach since the Member State targets, as determined in the Directive 2001/77/EC, are also derived based mainly on the realisable generation potential of each country.

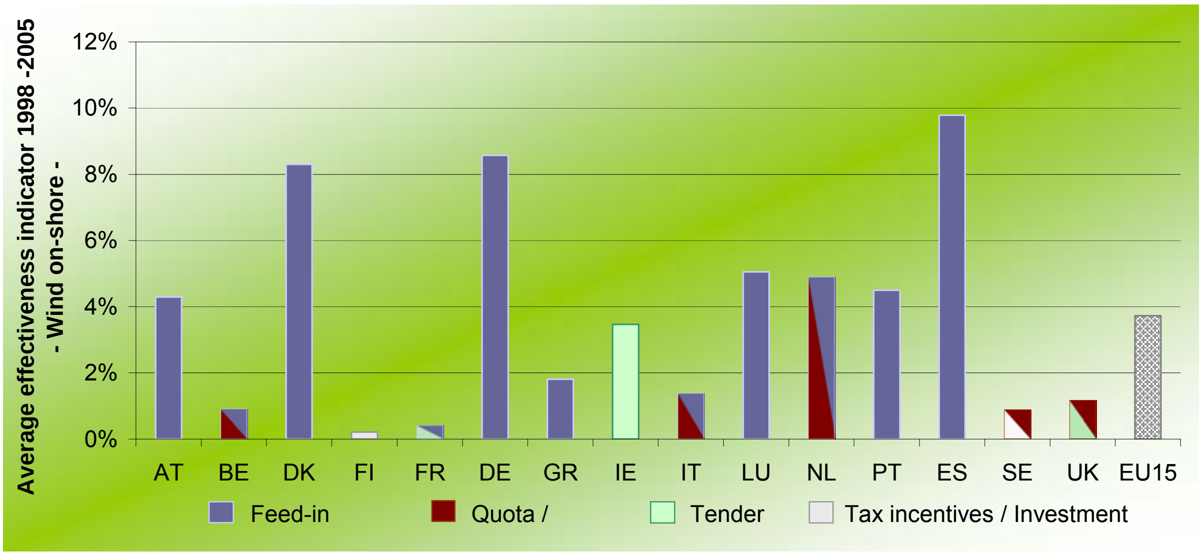

Figure 3. Effectiveness indicator for wind onshore electricity in the period 1998-2005 in the EU-15 showing the relevant policy schemes during this period

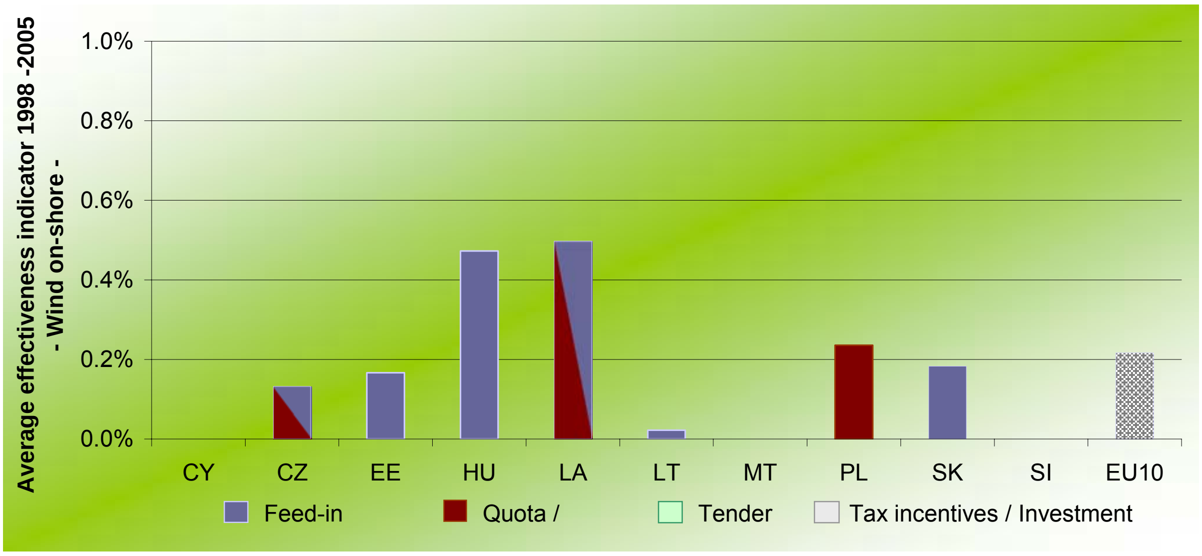

Figure 4. Effectiveness indicator for wind onshore electricity in the period 1998-2005 in the EU-10 showing the relevant policy schemes during this period

Figure 3 and Figure 4 show the average annual effectiveness indicator for wind onshore electricity generation for 1998-2005 for EU-25 countries. Several findings can be derived from these figures. Firstly, the three Member States showing the highest effectiveness during the considered period, Demark, Germany, and Spain, applied fixed feed-in tariffs during the entire period 1998-2005 (with a relevant system change in Denmark in 2001). The resulting high investment security as well as low administrative barriers stimulated a strong and continuous growth in wind energy during the last decade. It is often claimed that the high level of the feed-in tariffs is the main driver for investments in wind energy especially in Spain and Germany. However, as will be shown in Section 2.3, the tariff level is not particularly high in these two countries compared with other countries analysed here. This indicates that a long-term and stable policy environment is actually the key criterion for the success of developing RES-E markets. As can be observed from a country like France, high administrative barriers can significantly hamper the development of wind energy even under a stable policy environment combined with reasonably high feed-in tariffs. Progress was generally much slower in new Member States than in EU-15 countries. Of the former, Latvia showed the highest relative growth in the period considered.

2.3 Economic efficiency from society's point-of-view

In order to analyse the economic efficiency of support from the historic perspective we compare the level of support for the case of wind energy onshore and the corresponding costs of electricity generation. Based on this definition the analysis shows (see Figure 5) that, for many countries, the support level and the generation costs are very close. Countries with costly potentials frequently show a higher support level. A clear deviation from this rule can be found in the three quota systems in Belgium, Italy and the UK, for which the support is presently significantly higher than the generation costs. The reason for the higher support level expressed by the current green certificate prices is due to still immature TGC markets, the non-technology-specific application form of the currently applied TGC-systems as well as in a higher risk premium requested by investors. For Finland, the level of support for wind onshore is clearly too low to initiate any steady growth in capacity. In the case of Spain and Germany, the support level indicated in Figure 5 appears to be above the average level of generation costs. However, the low cost potentials have already been exploited in these countries due to the recent successful market growth. Therefore a level of support that is moderately higher than average costs seems to be reasonable. Of course, the potential technology learning effects also have to be taken into account.

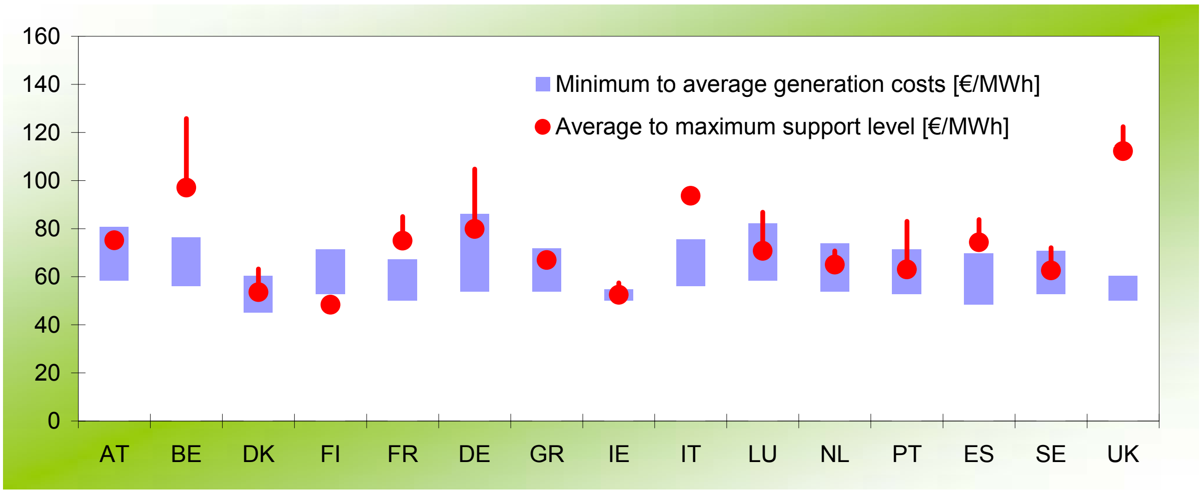

Figure 5. Support level ranges (average to maximum support) for direct support of wind onshore in EU-15 Member States (average tariffs are indicative) compared to the long-term marginal generation costs (minimum to average costs)

The comparison of costs and support level ranges for wind onshore in the EU-10 countries as shown in Figure 6 leads to the conclusion that the support level might be sufficient to stimulate investments in at least four countries: Cyprus, the Czech Republic, Hungary and

Lithuania. In most of the other countries, the level of support is below marginal generation costs.

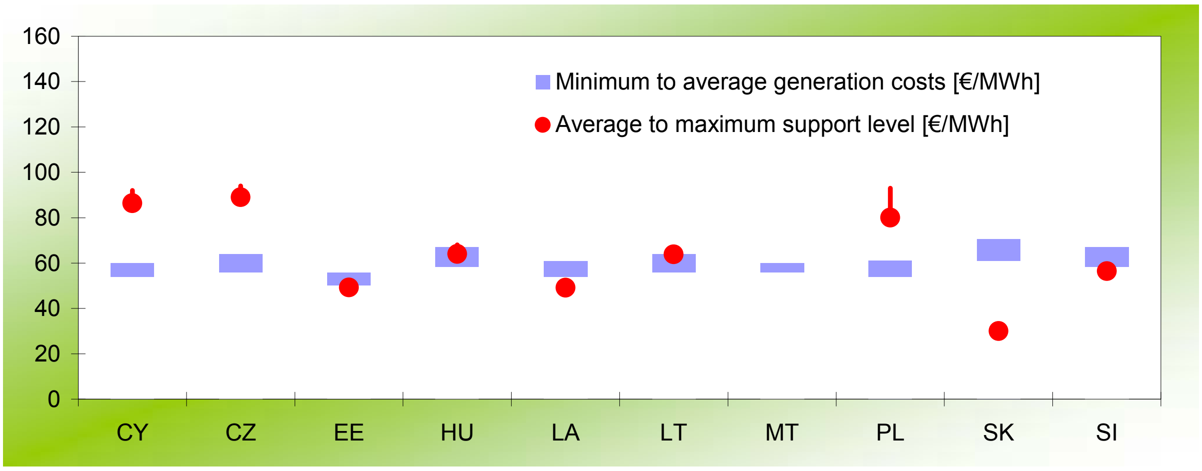

Figure 6. Support level ranges (average to maximum support) for direct support of wind onshore in EU-10 Member States (average tariffs are indicative) compared to the long-term marginal generation costs (minimum to average costs)

2.4 Expected revenues and profits for investors

In order to correlate the effectiveness of an instrument with the efficiency of support as defined in the previous section the levelised profit of potential wind energy investments was calculated for Austria, Belgium, the Czech Republic, France, Germany, Ireland, Italy, Lithuania, Spain, Sweden and the UK for the year 2004. Thus, calculations are based on the effective support conditions in each country during the year 2004.

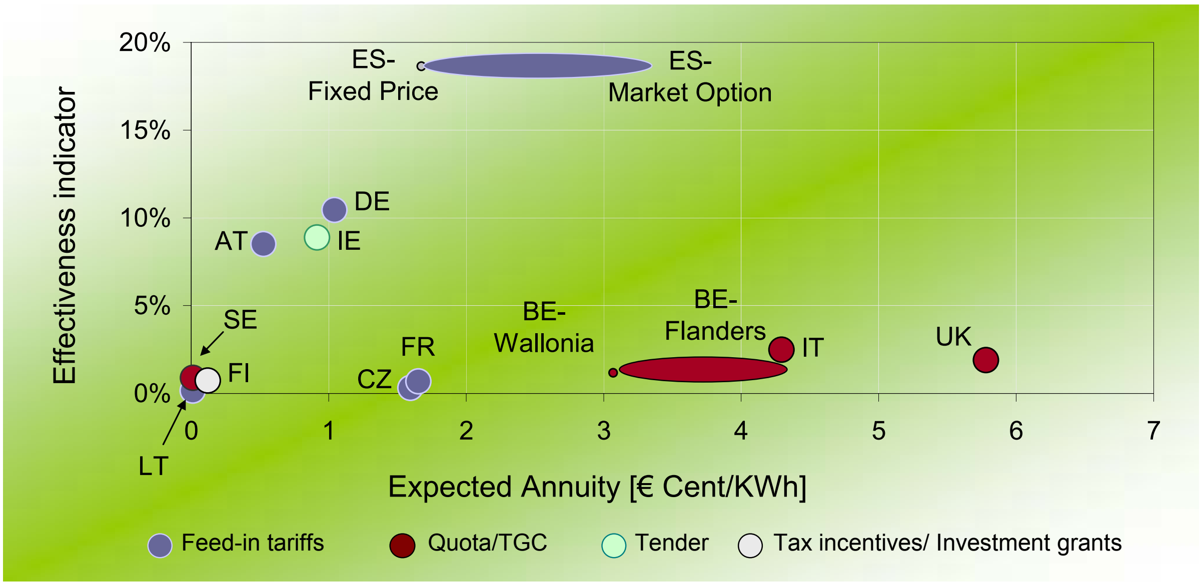

Figure 7. Effectiveness indicator versus levelised profit. The figure shows a possible levelised profit per unit of electricity generated of an investment in wind onshore in 2004

By plotting the effectiveness versus the levelised profit as shown in Figure 7 the correlation between the levelised profit for investments and the effectiveness reached by the support instrument in the respective year are analysed.

In Figure 7, the expected levelised profits as well as the effectiveness show a broad spectrum in quantitative terms for the countries under consideration. It should be pointed out that the different instruments have different levels of maturity and that policy schemes in some countries - in particular quota obligation systems - are still in a transitional phase. It is striking that Italy, the UK and Belgium, which have recently transformed their markets using quota systems as the main support instrument, are characterised by high expected levelised profits but low effectiveness. The high levelised profit results in particular from the extrapolation of the presently observed certificate prices. Although this assumption is questionable, the results show that certificate systems lead to higher producer revenues than FITs, which compensates for high investment risks. Furthermore, the recent development of certificate prices does not show a decreasing tendency. On the other hand, countries with FITs seem to be typically more effective at generally moderate levelised profits per unit of electricity generated. The fact that expected profitability is significantly lower for FITs is directly linked with a higher efficiency of this strategy because additional costs for consumers are lower. This issue is linked to economic efficiency from society’s point-of-view.

2.5 Country-specific results – lessons learned

This section presents some of the lessons learned from specific countries with respect to effectiveness and efficiency.

- **Spain** achieved the highest growth rates in terms of effectiveness over the last two years as well as in terms of the average value between 1998 and 2005 combined with an adequate profit for investors. However, the expected profit in Spain, which is higher than in the other feed-in countries, is not due to a high support level, but rather to relatively low onshore wind electricity generation costs as a result of good resource conditions on the one hand and low investment costs on the other. This ultimately results in the lowest costs for society per kWh of new electricity generated from RES.
- **Germany** shows high average policy effectiveness concerning the support of wind onshore despite an already mature market and partially exploited low-cost potentials in the northern parts of Germany. As a result, wind power plants have been erected at less favourable locations than in former years leading to a lower expected profit than in Spain at a significantly higher support level. The successful market development of wind onshore energy in Germany can be attributed to a favourable level of feed-in tariffs, but also to a stable and continuous policy framework providing investment security for potential investors.
- **Denmark**'s promotion system, which was mainly based on FITs, was quite successful. This system was abolished in 2000 and, since then, policy effectiveness in the area of wind onshore support has fallen significantly.
- In **Austria**, the former FIT system, offering attractive incentives, worked very well with respect to effectiveness. However, the success in terms of RES-E deployment was accompanied by discussions on the resulting required consumer expenditure. Criticism on the efficiency of the FIT system grew, partly due to the fact that no clear mechanism was implemented to reduce the FIT offered for new installations over time.

Finally, the discussions led to a drop in acceptance and to an abolishment of the old tariff.

- A recent example of a FIT success story, especially with respect to wind, is **Portugal.** Policy effectiveness for wind onshore support in Portugal has risen significantly over the last three years.
- Another specific case is the **Netherlands**. At the end of the 1990s, the Netherlands were among the first countries to consider a TGC system in addition to tax exemptions for RES-E. This system was based on open trade with other countries including certificates from existing plants. This led to huge imports of green electricity and high windfall profits for owners of depreciated plants (e.g. hydropower) in Austria, Switzerland and Norway. Windfall profits were also caused by the possibility to account for financial support in the country of origin as well as in the Netherlands. Hence, the Dutch support system only stimulated a moderate increase in national RES-E capacities. Finally, in 2003, the system was changed to a mixed system of TGC and FITs.
- **France** is one exception to this cluster of FIT success stories. High administrative barriers here – especially the long and complex processes of obtaining building permits – are preventing a rapid development of wind energy despite the existence of favourable feed-in tariffs.
- **Slovenia** represents another exception so far. Here it is likely that the initially chosen level of FIT was too low to stimulate investment.
- A tender system has only been practised in **Ireland** in recent years. In 2004, the Irish tender system achieved a high level of effectiveness similar to countries with feed-in-tariffs like Germany and Austria despite the significantly lower absolute support level. However, the high Irish growth rate in 2004 has to be considered carefully since the comparatively high capacity development in this year is due to the results of the last Irish bidding round. The growth rate was actually much lower in previous years. A tender system seems to be an instrument which can promote rapid growth in a short period of time if ambitious quota targets are set.

In the countries with quota-based TGC systems, the lessons learned are as follows:

- In the **UK**, the major problem – aside from high certificate prices[3] – is that so far the quota has never been almost fulfilled. In 2004, only 2.2 % of electricity was generated from “new” RES while the quota was 3.3 %. One main reason for this failure is the high risk associated with unsafe earnings within the trading scheme as seen by investors. So far no stimulation of the development of novel RES-E options took place as investing in low-cost RES-E options appeared to be much more attractive. Moreover, because banking is not allowed, RES-e generators fear that the certificate price will drop the closer they come to the quota.
- There is a similar situation in **Italy**. Certificate prices here are high (see Figure 5) and quota fulfilment is moderate (about 80 % of the quota of 2.2 % was fulfilled in 2005). One major reason for the high certificate price is the low validity of the certificates of eight years. Non-fulfilment of the quota can be explained by the uncertainty on the market with regard to future certificate price developments.

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[3] Current certificate prices are on a high level, caused by the fact that penalty payments are recycled to competitors fulfilling their obligation.

- In **Belgium** there are two parallel TGC systems in Flanders and Walloon. A comprehensive analysis is available for Flanders. The TGC prices in Flanders are among the highest in Europe. If the windfall profits due to the promotion of old existing capacity are taken into account, the additional costs for customers for generating new electricity from RES increase to about 18 cent/kWh.
- In **Sweden**, certificate prices are very low – see Figure 5 – but the quantities of new RES-E installed are also very low. One reason is that some old capacity is also allowed[4] in the Swedish quota system. This results in many more certificates being produced than redeemed. These certificates are banked. Yet due to these windfall profits and the high “free rider” rates, the specific costs per kWh of new RES-e generated are high. Even though TGC prices in Sweden are very low, the costs per kWh of actually induced new RES-E generation are by far the highest.

For all other EU countries, it has to be stated that the experiences so far do not yet allow any appraisal of the success of the implemented policies.

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[4] Recently, this system has been modified and currently mainly new capacities qualify for certificates traded.

3 PROSPECTIVE ANALYSIS BASED ON THE MODEL *Green-X*

An evaluation of the different support schemes for RES-E is conducted in this chapter from a future perspective. The question about the effectiveness and the efficiency of various support schemes is discussed in two different ways, namely by analysing theoretical aspects and based on results gained from simulation runs with the help of the toolbox ***Green-X***.[5]. Thereby, the transfer costs for consumers / society (due to the promotion of RES-E) are the dominant indicator for the assessment.

3.1 *Green-X* scenarios – Overview on investigated cases

First, an overview of the investigated scenario paths and cases is given. Please note that geographically all scenarios refer to the Europe Union as of 2006, comprising 25 Member States. Results on RES-E deployment and accompanying parameters such as transfer cost etc. are derived on a yearly basis covering the time horizon 2005 to 2020. Thus, the model runs try to consider the spread of possible RES-E policy options within the EU as follows:

- **No harmonisation**, where national policies remain in place and determine the future development of RES-E. Thereby, two variants are investigated:
  - RES-E policies are applied as currently implemented (without any adaptation) – business as usual (**BAU**) forecast
  - An improvement of national RES-E policies with respect to their efficiency and effectiveness is undertaken (**improved national policies**). These changes will become effective immediately (2006), in order to meet the overall RES-E directive target in 2010. Thereby, it is assumed that besides adapting financial support conditions also non-financial barriers (i.e. administrative deficits etc.) will be removed in the future.
- It is assumed that after a transition period a **harmonisation of support schemes** takes place at the European level, where new and improved harmonised policies offering equal financial incentives all over Europe are applied for new RES-E installations from 2015 on. To be able to analyse the effect of different (harmonised) policies compared to non-harmonised conditions (improved national policies) it is assumed that the same RES-E target as under non-harmonised conditions should be reached by 2020 – i.e. a RES-E generation of about 1156 TWh on EU25 level. The following currently most promising policies are investigated under harmonised conditions:
  - A Feed-in tariff scheme as the most prominent representative of **technology-**

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[5] The ***Green-X*** computer model is the core product developed in the project Green-X. It is an independent computer programme and allows different scenarios to be simulated enabling a comparative and quantitative analysis of the interactions between RES-E, CHP, DSM activities and GHG-reduction within the liberalised electricity sector both for the EU as a whole and individual EU 15 Member States over time.

Note: for details regarding the project or the model Green-X please visit www.green-x.at.

specific instruments.[6]

- A Quota obligation based on TGCs with international trade – applied as a generic scheme where **no technology-specific** support is set.

A graphical depiction of the investigated cases is given in Figure 8 below. Besides above listed scenarios on future RES-E policies also sensitivity investigations are conducted to determine the impact of other key parameter. More precisely, these cases build on the BAU scenario with regard to RES-E policies and illustrate the impact of conventional energy prices and additional demand side measures to reduce future electricity demand growth.

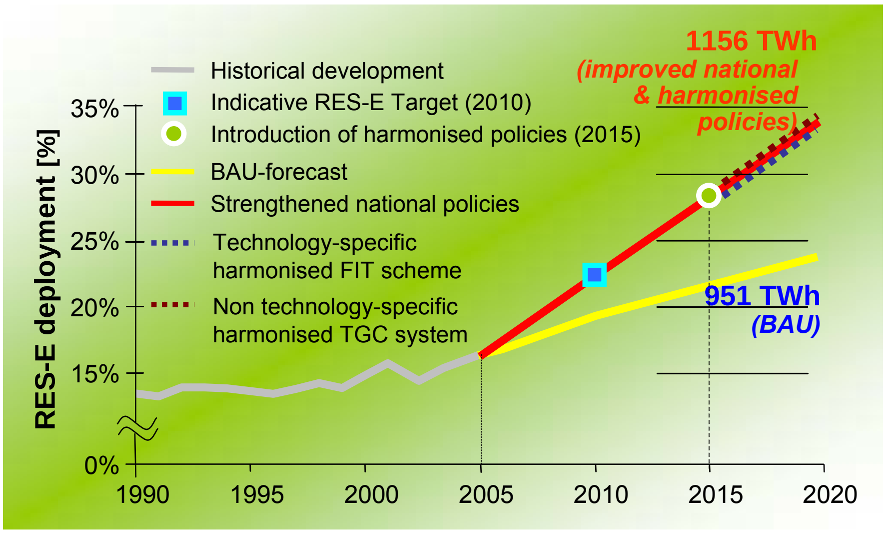

Figure 8. Overview on investigated cases

The availability of biomass and the allocation of biomass resources across sectors are crucial as this energy is faced with high expectations with regard to its future potentials. It is worth to mention that its allocation to the sectors of electricity, heat or transport is not explicitly predetermined in the applied modelling approach. Although the policy analysis undertaken in this study is done for the electricity sector solely, with regard to biomass all energy sectors have been considered. Consequently, the sectoral biomass allocation on country level depends on the resource availability and the assumed sectoral support conditions. More precisely, on the one hand, in case of BAU policies for RES-E also a continuation of support schemes as currently applied at the national level for biomass heat and biofuels is assumed. On the other hand, in case of improved national or harmonised RES-E policies also a higher level of ambition is assumed for the support of bioheat and biofuels.

3.2 Key assumptions

Besides the comprehensive ***Green-X*** database for RES-E – including potentials and costs for RES-E within Europe on a country and technology level, assumptions with respect to future technological change and technology diffusion, etc. – the assumptions made with

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[6] In the case of technology-specific support two variants are taken into consideration differing by the applied perception for novel RES-E technologies. In the default case also novel technologies are supported, whilst in the sensitivity variant support is limited to less novel RES-E options.

respect to the applied policy instruments are discussed below in a concise manner. For a detailed description of all input parameter we refer to the final report of the OPTRES-project (Ragwitz et al., 2007).

3.2.1 Overview on key parameters

In order to ensure maximum consistency with existing EU scenarios and projections the key input parameters of the scenarios are derived from PRIMES modelling and from the FORRES 2020 study[7]. Table 2 shows which parameters are based on PRIMES and which have been defined for this study. More precisely the PRIMES scenarios used are:

- The European Energy and Transport Trends by 2030 / 2005 / Baseline
- The European Energy and Transport Trends by 2030 / 2006 / Efficiency Case (13.5% demand reduction compared to baseline)

Table 2. Main input sources for scenario parameters

Based on PRIMES	Defined for this study
Energy demand	Reference electricity prices
Primary energy prices	RES cost (FORRES 2020, incl. biomass)
Conventional supply portfolio and conversion efficiencies	RES potential (FORRES 2020)
CO_2 intensities	Biomass import restrictions
	Technology diffusion
	Learning rates
	Weighted average cost of capital (WACC)

In general the hypothesise is taken that improved RES-E policies are accompanied by an active energy efficiency policy (i.e. building on the *PRIMES energy efficiency scenario*) whereas in case of a continuation of current RES-E support no proactive demand side measures (DSM) are presumed as default. To illustrate solely the impact of DSM a sensitivity case is conducted in addition to the default BAU scenario.

With respect to conventional reference energy prices it is assumed that energy prices remain on current levels for the near future. Accordingly, the *PRIMES high energy price case* represents the default setting for the overall RES-E policy discussion. In addition, a sensitivity case to the BAU scenario is derived to illustrate the impact of low energy prices on RES-E deployment and accompanying policy transfer cost.[8]

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[7] "FORRES 2020 - Analysis of the Renewable Energy Sources' evolution up to 2020", project conducted by Fraunhofer Isi, EEG, Ecofys, REC and KEMA, Tender No. TREN/D2/10-2002. For details see e.g. (Ragwitz et al., 2005)

[8] Energy price projections in case of low energy prices are taken from the *PRIMES baseline case* as of 2005.

3.2.2 Assumptions for simulated support schemes

A number of key input parameters as described below are defined for each of the model runs referring to the specific design of the support instruments.

► *General scenario conditions*

Consumer expenditure is heavily dependent on the design of policy instruments. In the policy variants investigated, it is obvious that the design options of the various instruments are chosen in a way that such expenditure is low. Accordingly, it is assumed that the investigated schemes are characterised by:

- stable planning horizon
- continuous RES-E policy / long term RES-E targets
- clear and well defined tariff structure / yearly targets for RES-E technologies.

In addition, for *all* investigated scenarios, with the exception of the BAU scenario (i.e. currently implemented policies remain available without adaptation up to 2020), the following design options are assumed:

- financial support is restricted to new capacity only [9]
- the guaranteed duration of financial support is limited. [10]

With respect to model parameters reflecting *dynamic aspects* such as technology diffusion and technological change, the following settings are applied:

- A stimulation of ‘technological learning’ is considered – leading to reduced investment and O&M costs for RES-E, increased energy efficiency over time.
- Removal of non-financial barriers and high public acceptance in the long term[11].

Next, the model settings and assumptions are described for each type of support instrument separately. These assumptions refer to advanced support schemes as applied in the discussion of improved national and harmonised international policy instruments.

► *Feed-in tariffs*

Feed-in tariffs are defined as technology-specific; settings are applied in order to achieve an overall low burden for consumers. In this way, tariffs decrease over time reflecting the achieved cost reductions on a technology level, but this annually adapted level of support refers only to new installations. More precisely, whenever a new plant is installed, the level of support is fixed for the guaranteed duration (of 15 years as assumed to be commonly applied in the case of generation-based support). A low risk premium (leading to a WACC of 6.5%) is foreseen to reflect the small degree of uncertainty associated with the well defined design of this instrument.

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[9] This means that only plants constructed in the period 2005 to 2020 are eligible to receive the support given under the new schemes. Existing plants (constructed before 2005) remain in their old scheme.

[10] In the model runs, it is assumed that the time frame in which investors can receive (additional) financial support is restricted to 15 years for all instruments providing a generation-based support.

[11] In the scenario runs, it is assumed that the existing social, market and technical barriers (e.g. grid integration) can be overcome in time. Nevertheless, their impact is still relevant as is reflected in the BAU-settings (referring to the BAU scenario) compared to, e.g. the more optimistic view assumed for reaching a more ambitious target in 2020.

► *Quota obligations based on tradable green certificates (TGCs)*[12]

A common TGC system (covering all RES-E options)[13] is investigated to increase liquidity and competition on the TGC market. Compared to the other support schemes, risk is assumed to be on a moderate to high level (leading to a WACC of 8.6%). Thereby, risk refers to the uncertainty about future earnings (on the power as well as on the TGC market).

3.3 Results of the simulation runs

This chapter is dedicated to provide a comprehensive discussion of all major outcomes of the conducted scenarios on the possible future RES-E deployment and the accompanying costs. First, results referring to the cases of non-harmonised conditions, where national policies remain as driver for the future RES-E deployment, are discussed. In this context, the two variants – i.e. the BAU and the "improved national policies"-case – are compared and the sensitivity of the outcomes with regard to demand and energy price assumptions are illustrated for the BAU scenario. In these cases it is assumed that at least the type of support instrument as currently implemented in each of the different Member States remains in place up to 2020. Later on, section 3.3.2 outlines the results of the scenarios referring from a topical viewpoint to a harmonisation of support policies at the European level.

3.3.1 Results with regard to non-harmonised conditions – BAU & improved national policies-scenario

► *Renewable electricity deployment*

Total amount of RES-E generation within the EU 25 was around 460 TWh/a in 2004, corresponding to a share of about 15% of gross electricity demand.[14] Without any changes in the support schemes in place in the different member states, RES-E will achieve a demand share of 18.2% in 2010 within the European Union. In this context, Figure 9 provides the corresponding illustration, depicting the total RES-E deployment in the period 2005 to 2020 in relative terms – i.e. as share of gross electricity demand – at EU 25 level for all investigated cases based on purely national RES-E support schemes. It is notable that RES-E deployment stays more or less unaffected in the short term (up to 2010) of low[15] energy prices as observable for the sensitivity case

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[12] Note that in the case of improved national policies currently implemented quota systems are accompanied by other support schemes such as investment subsidies or tax incentives in order to achieve the required deployment of novel RES-E options without over-subsidizing mature low-cost RES-E technologies.

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

[14] Note: RES-E generation in 2004 refers to available potential of RES-E times normal (average) full load hours of the technologies. This means actual generation can differ from this value due to (i) variation of generation from average conditions (e.g. for hydropower or wind) and (ii) new capacity build in 2004 is not fully available for the whole period 2004.

[15] Low energy prices shall mean especially decreasing oil and gas prices compared to current levels. We refer to the final report of the OPTRES-project (Ragwitz et al., 2007) for details on assumed price developments of conventional energies and corresponding reference wholesale electricity prices.

"BAU with low energy prices".[16] If RES-E support is accompanied by energy efficiency measures as assumed for the variant "BAU with accompanying DSM", a higher demand share in size of 18.8% is feasible in 2010. By 2020 the differences between the BAU case and its sensitivity variants are getting more apparent: A share of 23.6% is projected for the default BAU case, whilst in case of accompanying DSM activities the deployment in relative terms would achieve a level of 27%.[17] Again, the impact of the underlying energy price development is comparatively low – in the case of low prices RES-E deployment would be reduced by 3% at EU 25 level, corresponding to a share of 22.9%.

In contrast, improving the support conditions for RES-E, including a removal of non-financial deficits and the implementation of energy efficiency measures, rigorously and immediately within all countries will allow meeting the European target as set by the RES-E directive. In the "improved national policies"-case a RES-E share of 20.9% occurs for 2010, rising to a level of 34.1% in 2020.

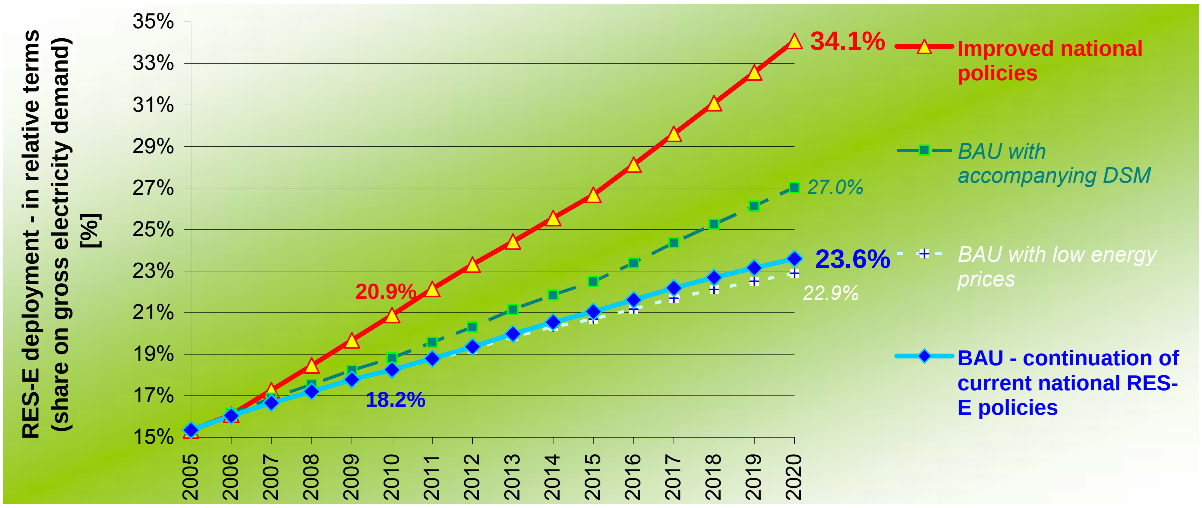

Figure 9. Total RES-E deployment in the period 2005 to 2020 expressed as share of gross electricity demand at EU 25 level in the BAU case (incl. sensitivities on demand and energy prices) & the "improved national policies" variant

The dynamic development of RES-E generation for the both cases – i.e. the default BAU case and "improved national policies" variant – is depicted in absolute terms at EU 25 level in Figure 10. More precisely, this figure provides an illustration of the technology-specific development for new RES-E plant, whilst the RES-E stock, comprising all plants installed up to the end of 2004, is indicated by one grey and black patterned area. If currently implemented RES-E policies are kept in place as assumed in the BAU-case, total amount of RES-E generation will increase from

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[16] The low impact of energy prices on total RES-E deployment has two main reasons: On the one hand, mainly possible new RES-E installations are affected and, on the other hand, most countries apply feed-in systems based on fixed tariffs and, consequently, provide a financial incentive to install a new RES-E plant that is independent of market prices. Obviously, resulting transfer cost (due to RES-E support) as discussed later in this section would be on a higher level if deployment stays unaffected of comparatively low conventional reference prices. In contrast, only in countries sticking to TGC systems or premium tariffs a notable impact on RES-E penetration can be observed.

[17] A slow down of the electricity demand growth in the near future and even a demand reduction in the period thereafter as assumed in the underlying demand projection of the *PRIMES energy efficiency case* would affect the contribution of the stock of already existing RES-E plants, i.e. installed before 2005, largely. In this case, the RES-E stock accounts to a demand share of 12.7% instead of 10.7% by 2020.

460 TWh in 2004 up to about 951 TWh in 2020. This figure for 2020 comprises almost equal contributions of new RES-E installations (from 2005 to 2020) in size of 520 TWh (55% of total RES-E), and of the stock of existing RES-E plants installed prior 2005, accounting for 431 TWh equal to a share of 45% on total RES-E generation by 2020 in the BAU-case. "Improved national policies" induce a tremendously higher deployment of new RES-E in the investigated period: By 2020 an amount of 725 TWh refers to new RES-E plant installed 2005 to 2020, corresponding to 63% of the total RES-E generation in size of 1156 TWh.

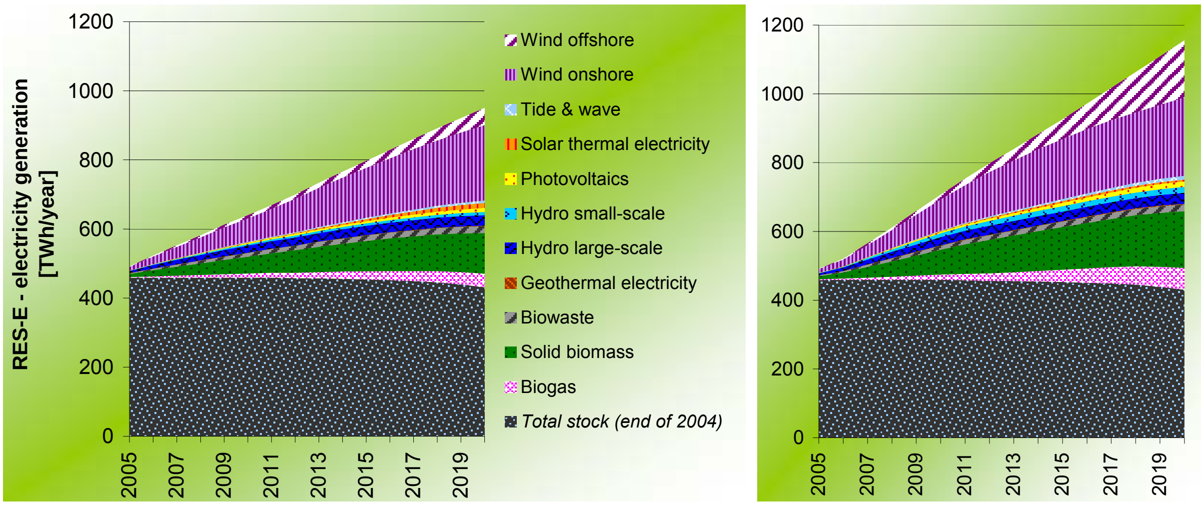

Figure 10. Development of total RES-E generation in the period 2005 to 2020 at EU 25 level in the BAU case (left) & the "improved national policies" variant (right)

Some technology-specific notes are listed below:

- Due to less public support and acceptance, the amount of large scale **hydro power** plants will increase only marginally in absolute terms.[18] In relative terms the share on total RES-E generation drops significantly from around 62% in 2004 to 34% (BAU-case), respectively 28% ("improved national policies"-case) in 2020.
- In both policy cases **wind onshore** and **biomass** belong to the dominant RES-E options, both together accounting to more than half of additional deployment. It can be expected that in 2020 about 42% (BAU) or 31.5% (improved national policies)[19], respectively, of total production of new RES-E plants installed in the period 2005 to 2020 is coming from wind onshore, increasing the share of wind onshore in total RES-E generation in 2020 to a level of 23% (improved national policies) to 27% (BAU). Corresponding figures for solid biomass are 23% (BAU and "improved national policies") with regard to new installations, and 16% (BAU) to 17% (improved national policies) for total RES-E generation by 2020.
- In the case of "improved national policies" **wind offshore** achieves a significant

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[18] Considering the effects of the Water Framework directive (European Parliament and Council, 2000) the total electricity generation from (large scale) hydro can even be lower in 2020 compared to the current level.

[19] In absolute terms wind onshore achieves a higher level in the case of "improved national policies" compared to the BAU development – i.e. new installations of the period 2005 to 2020 have a generation potential of 228 TWh in the "improved national policies"-case, whilst the corresponding figure for the BAU-case is 218 TWh.

deployment at a similar level as solid biomass, accounting for 23% with regard to new installations or 14% in total. In the BAU case wind offshore development is lacking far behind, achieving a share on new RES-E in size of only 10%, corresponding to 51 TWh in absolute terms – compared to 166 TWh in case of "improved national policies".

- Other significant increases can be expected for **biogas**, achieving a share in size of 8% (BAU) to 9% (improved national policies) on the total production from new RES-E installations in 2020.). The remaining part in size of 94 (BAU) to 103 TWh (improved national policies), corresponding to about 1/6 of total new RES-E generation by 2020, comprises **large- and small-scale hydropower, biowaste, photovoltaics, geothermal electricity** as well as novel RES-E options such as **tidal stream, wave power and solar thermal electricity**.

► *Capital expenditure and induced technological progress*

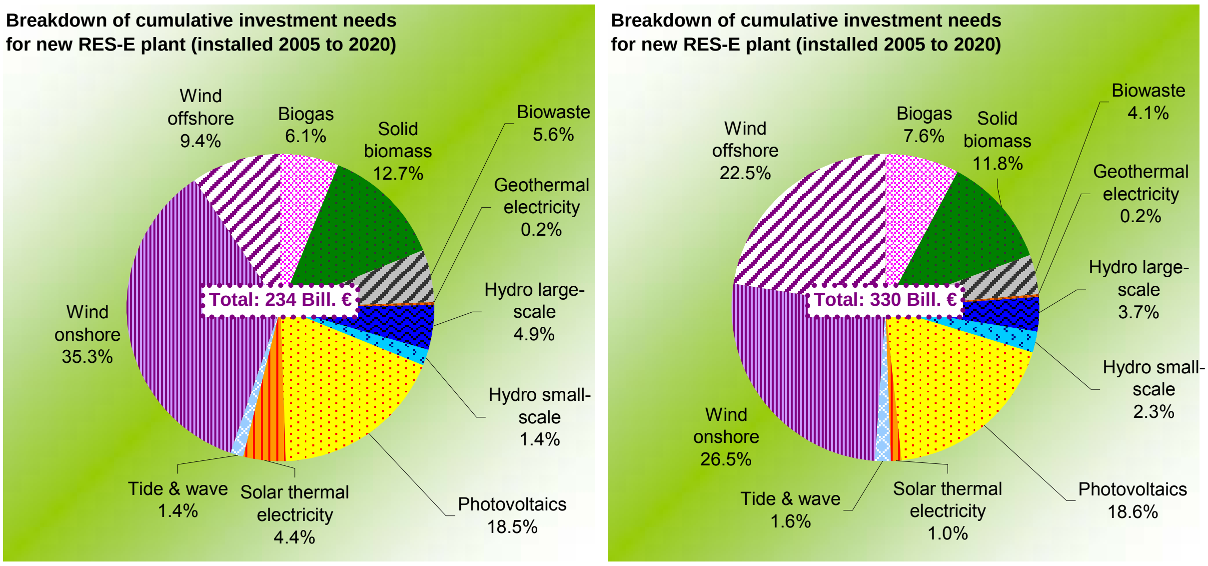

Figure 11. Breakdown of cumulative investment needs in the period 2005-2020 within the EU 25 in the BAU case (left) & the "improved national policies"-variant (right)

Significant investments are necessary to be able to build up the new capacity. Figure 11 shows a technology-specific breakdown of the cumulative investment needs for RES-E plants installed in the investigated period 2005 to 2020 assuming BAU (left) as well as improved national policies (right). The cumulative capital expenditure for the BAU-case is in size of 234 billion €, whilst in the case of improved national policies an amount of 330 billion € occurs – which is in line with the about 40% higher RES-E deployment. It is notable that photovoltaics accounts to an about nine times higher share on investments compared to generation, which underpins the high capital cost of this novel RES-E option. Besides biowaste, also characterised by high upfront investment needs, all other RES-E options hold a similar or lower share due to comparatively lower specific investment cost.

It is obvious that these investments (within the EU and worldwide) stimulate technological learning, leading to lower generation costs in the future. The highest decrease is projected for photovoltaics – it can be expected that specific cost of PV systems are in 2020 -43% lower compared to the present situation (as of 2005). Other significant reductions are projected for solar thermal electricity (-35%), tidal &

wave (-30%) and wind energy (-19%).

► *Benefits of an increased RES-E deployment*

The increased RES-E deployment reduces demand for fossil fuels. As briefly explained in the final report of the OPTRES-project (Ragwitz et al., 2007) sector- and country-specific conversion efficiencies as projected by PRIMES for the future evolution of the conventional supply portfolio are used to get a sound proxy to calculate from derived renewable generation figures back to the amount of avoided primary energy.

It is getting apparent that renewable energy is an important element in improving the security of energy supply in Europe. Even the figures for the moderate BAU-case seem impressive: The total amount of avoided fossil fuels due to new RES-E capacities (installed in the period 2005 to 2020) is in size of 97 Mtoe in 2020. Assuming an unaffected conventional fuel mix, almost half of the reduction would refer to natural gas, followed by hard coal (35%), lignite (9%) and oil (6%). In the case of gas, it equals to 8% of the *default* total EU gas consumption in 2020 or 10% of *default* gas import needs, respectively.[20] In monetary terms these figures correspond to 23 billion € reduced yearly expenses for fossil fuels from 2020 on.[21]

Obviously, due to the higher RES-E deployment in the case of “improved national policies”, savings also increase: In terms of energy yearly savings by 2020 rise from 97 Mtoe to 142 Mtoe (+46%), and in monetary terms from 23 to 34 billion € (+47%).

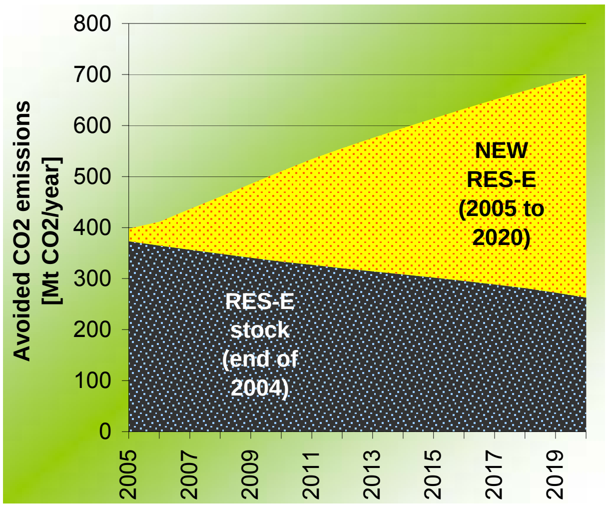

Figure 12. Avoided CO_2 emissions due to the (additional) RES deployment in the case of “improved national policies”

Apparently, if fossil fuels are avoided, the correlated GHG emissions are avoided as well. Figure 12 illustrates the avoidance of CO_2 emissions due to the additional RES-E deployment (referring to new installations in the period 2005 to 2020) exemplarily for the case of “improved national policies”. Thereby, it also depicts the corresponding emission avoidance of the existing stock of RES-E plant installed up to the end of 2004. As indicated therein, the additional RES-E deployment reduces CO_2 emissions by 438 Mt/yr[22] in 2020 which corresponds to 8% of total EU 25 GHG emissions in 1990[23], whereas CO_2 emission reductions due to total RES-E deployment (incl. the existing stock) in 2020 is 701 Mt, or 13% of 1990’s total EU 25 GHG emissions.

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[20] Default figures refer to the adapted PRIMES projections – i.e. without additional RES deployment in the observed period 2005 to 2020.

[21] This represents a possible saving with regard to a countries trade balance as most fossil fuels are imported from abroad.

[22] In the BAU-case the CO_2 avoidance is somewhat smaller, i.e. 294 Mt is the corresponding figure with regard to the additional RES-E deployment.

[23] GHG emissions in 1990, the base year of the Kyoto Protocol, were 5231 Mt CO_2 equivalents according to (EEA, 2006).

► *Financial support for RES-E*

Next, the necessary financial support for the above discussed future RES-E deployment is presented. Figure 13 depicts for both investigated cases – i.e. the BAU-case as well as the case of "improved national policies" – the necessary consumer expenditure for society at the EU25 level due to the underlying national RES-E policies and the corresponding induced RES-E deployment. In this context, the consumer / societal expenditure due to the support for RES-E represents a net value referring to the direct costs of applying a certain support scheme.[24] This depiction illustrates also the technology-specific shares for new RES-E plant, whilst the expenditures associated with the RES-E stock, comprising all plants installed up to the end of 2004, is indicated by one grey and black patterned area.[25]

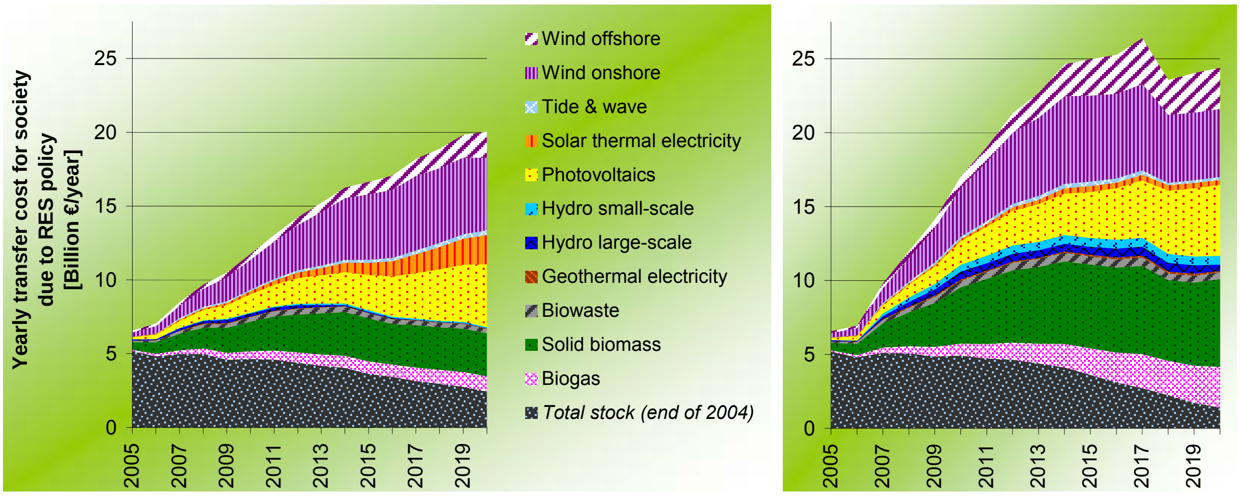

Figure 13. Development of necessary consumer expenditure on EU 25 level in absolute terms for the BAU case (left) & the "improved national policies"-variant (right)

A rather steady rise in required consumer expenditures occurs in the next ten year in the BAU-case. In relative terms, expressing the expenditures as premium per MWh total demand, a rise from a level of 2.1 €/MWh$_{DEM}$ in 2005 up to about 5.0 €/MWh$_{DEM}$ in the final years 2019 and 2020 is projected.[26] Obviously, within the "improved national policies"-variant, characterised by a 40% higher RES-E deployment in the investigated period 2005 to 2020, in total a higher financial support is required to achieve the ambitious RES-E target as set for 2010. Accordingly, a steeper rise of required expenditures occurs in the period up to 2017, leading to a peak in size of 7.7 €/MWh$_{DEM}$ by 2017. Later on the necessary premium decreases[27] and remains rather constant at a level of 7.1 €/MWh$_{DEM}$ in the final years up to 2020.

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[24] E.g. in the case of a fixed feed-in tariff its marginal value per MWh$_{RES-E}$ is calculated by subtracting the reference wholesale electricity price from the guaranteed promotional tariff.

[25] A comparison of the technology-specific figures on transfer cost (Figure 13) with the corresponding RES-E generation as illustrated in Figure 10 might be of interest. It is notable that for some novel technologies such as PV or solar thermal electricity large differences occur.

[26] These figures represent the average at the EU 25 level. At country-level huge differences appear in case of non-harmonised support (BAU- as well as "improved national policies"-case). For a detailed discussion of this topic see Huber et al. (2004).

[27] The decrease in the consumer expenditures at EU 25 level is caused by a significant reduction of the TGC price in the UK in years after 2017. In the period 2005-2014 the required quota obligation can not

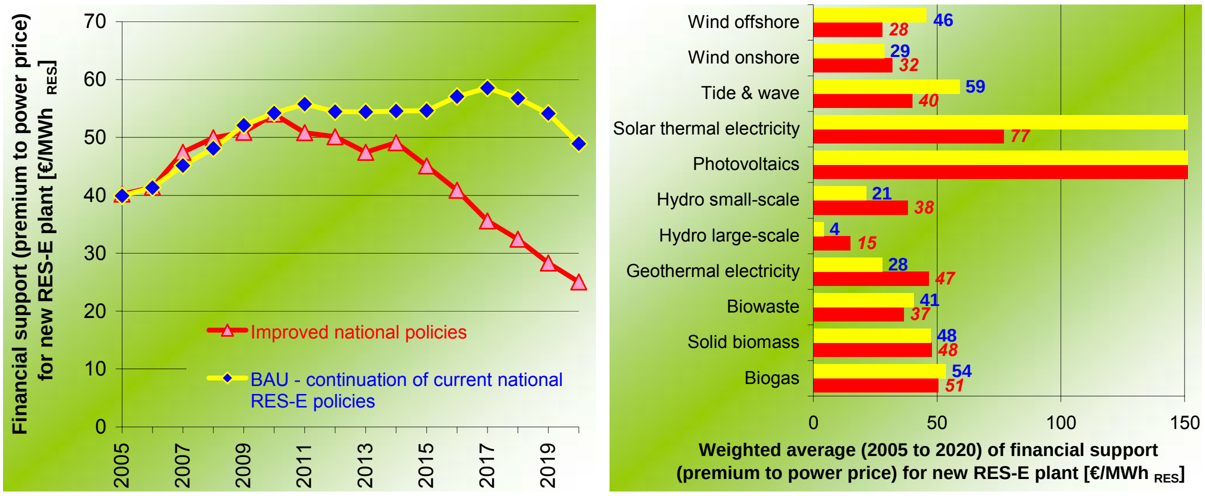

Figure 14. Comparison of financial support (premium to power price) for new RES-E generation on EU 25 level in the period 2005-2020 for the BAU case & the "improved national policies" variant, indicated over time (left) or by technology on average (right)

Finally, Figure 14 provides a comparison of the necessary financial support per MWh of RES-E generation for new installations for both cases at the EU25 level, indicating the dynamic development on average for all RES-E options (left) as well as the technology-specific average figure for the whole period 2005 to 2020 (right). This indicator describes from an investors point-of-view the average additional premium on top of the power price guaranteed (for a period of 15 years) for a new RES-E installation in a certain year, whilst from a consumer perspective it indicates the required additional expenditure per $\mathrm{MWh}_{\mathrm{RES}}$ for a new RES-E plant compared to a conventional option (characterised by the power price).The importance of improving the design of policy instruments is getting apparent: A higher share of RES-E deployment is possible to achieve with significantly less financial support per $\mathrm{MWh}_{\mathrm{RES\text{-}E}}$. The cost differences among the different RES-E technologies are also getting apparent as observable in Figure 14 (right), which underpins the necessity to set appropriate incentives at technology-level for achieving an effective & economically efficient RES-E support and corresponding deployment.

3.3.2 Harmonisation: Comparison of two harmonised support strategies with the case of improved national policies

In the following three different classes of support schemes are investigated with respect to the resulting costs. Therefore the efficiency of the support is analysed for each policy option. The three classes of policy options comprise:

- **National support** based on the scenario "**Improved national policies**" as illustrated in the previous section.
- **Harmonisation of support** after a transition period in 2015 based on a **non-technology specific support scheme**, e.g. quota obligation based on TGCs

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be reached in the UK, so comparatively high penalty payments occur. Later on TGC prices decrease, first slowly, but in 2018 a significant drop to a level of 10 €/MWh is projected. Accordingly, the corresponding consumer expenditure in the UK is also reduced dramatically, which, of course, also influences the average consumer expenditures on EU 25 level.

- **Harmonisation of support** after a transition period in 2015 based on a **technology specific support scheme**, e.g. a feed-in tariff

In addition, a further variant of a **harmonised RES support** based on a **technology specific support scheme** is also taken into consideration, where support is limited to less novel RES-E technologies.

In all cases a similar target of future RES-E deployment in 2020 is taken into account in order to conduct a proper investigation of the economic efficiency of the different policy options – i.e. it is assumed that similar to the “improved national policies”-case about 1156 TWh have to be generated by RES-E at the EU25 level by 2020, equal to a RES-E penetration in size of 34.1%[28] on total demand. The dynamic path to achieve this overall target is almost equal among all four cases, determined by the applied design criteria in combination with market diffusion or resource exploitation on country level.

Next, only differences among the investigated cases with regard to the resulting required financial support are discussed. For a detailed depiction of the corresponding renewable electricity deployment[29] we refer to the final report of the OPTRES-project (Ragwitz et al., 2007).

Looking at the financial aspects related to the support of RES-E in the observed period, three different indicators are taken into account. To assist the interpretation of the applied indicators with respect to the assessment of energy policy strategies, for each of them a short explanation is given initially.

► *(Average) financial support for new RES-E plant*

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

Figure 15 compares the necessary financial support per MWh of RES-E generation for new installations for the investigated cases at the EU25 level, indicating the dynamic development on average for all RES-E options (left) as well as the technology-specific average figure for the period[30] 2015 to 2020 (right). The period 2015 to 2020 is chosen, as only in this period different policy options are applied. The required financial support per $MWh_{RES\text{-}E}$ decreases in almost all cases over time. Comparing the instruments – i.e. the harmonised schemes based on either technology-specific support given by feed-in tariffs or non-technology specific support as assumed under a common quota obligation based on TGCs as well as the purely national case of

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[28] The RES-E share in size of 34.1% refers to the underlying demand projection with strong energy efficiency measures. In the case of a baseline demand development the projected RES-E deployment in size of 1156 TWh corresponds to demand share of 28.7%

[29] It is notable that only small differences occur among the investigated cases, as generally spoken, a more ambitious target requires a higher contribution of also currently more expensive RES-E options. Nevertheless, under the objective to keep transfer costs for consumer as low as possible only a small contribution can be expected from novel but comparatively high-cost RES-E options such as PV. This can be observed for the cases of harmonised support, where either non technology-specific incentives are applied or technology-specific instruments are limited to less novel RES-E options.

[30] 2015 to 2020 is chosen as in this period the different policy options are assumed to be active – i.e. assuming that a harmonisation of RES-E support takes place in 2015.

"improved national policies" – large differences can be observed. It can be seen that by applying technology-specific support[31] a tremendously lower financial support is required. As evident from this illustration, for reaching the similar target only harmonised schemes providing technology-specific support will lead to lower financial support levels compared to the default case of "improved national policies". In contrast, as clearly depicted in Figure 15, a harmonisation of RES-E support based on policy instruments that offers only one common support level, i.e. a common TGC system without technology banding, would lead to a tremendous increase of financial support as observable for the investigated case of an ambitious RES-E target.

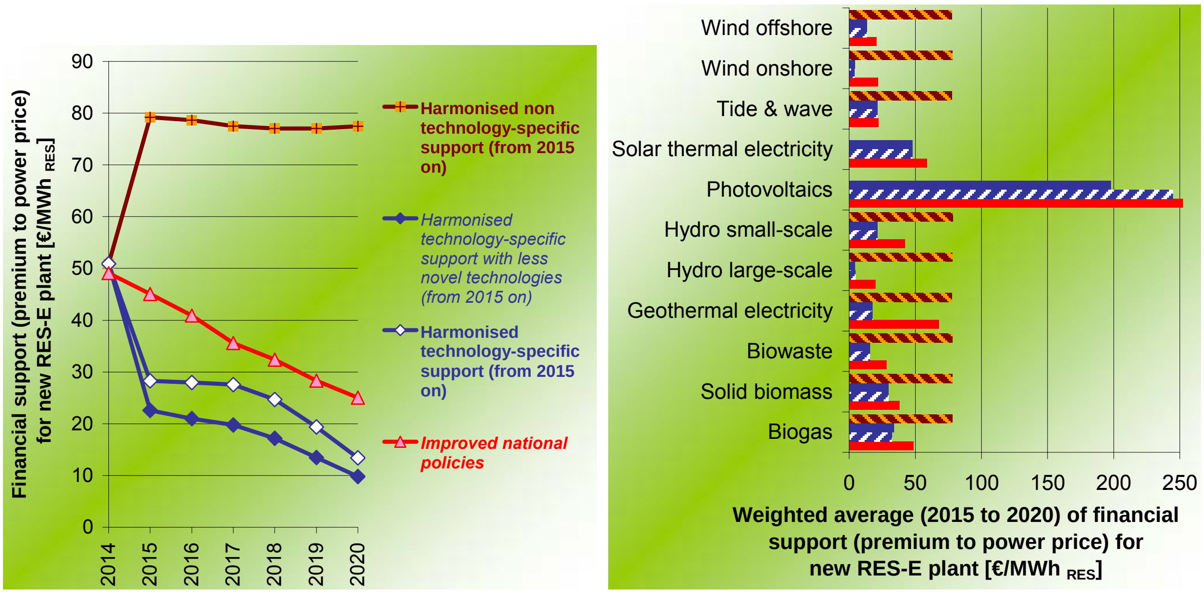

Figure 15. Comparison of financial support (premium to power price) for new RES-E generation on EU 25 level in the period 2015-2020 for the investigated cases, depicted over time (left) or by technology on average (right)

► Yearly transfer costs for consumer (due to the promotion of RES-E)

Transfer costs for consumer / society (sometimes also called consumer expenditure or additional / premium costs for consumer / society) are defined as direct premium financial transfer costs from the consumer to the producer due to the RES-E policy compared to the case that consumers would purchase conventional electricity from the power market. This means that these costs do not consider any indirect costs or externalities (environmental benefits, impact on employment, etc.). The transfer costs for consumers are either expressed in €/year or related to the total electricity consumption. In the later case the premium costs refer to each MWh of electricity consumed.

In this context, Figure 16 provides a comparison of the required dynamic development (left) as well as of the average (right) of the resulting consumer expenditure due to the promotion of RES-E in the period 2015 to 2020. Note that these figures represent an average premium at EU-25 level – whilst the country-specific situation differs even in case of harmonised promotional settings.

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[31] Technology-specific support is applied in all countries in case of harmonised support based on feed-in systems and in most countries in the scenario assuming "improved national policies".

Similar to the conclusion for the previous indicator one finds that for reaching the similar target only technology-specific harmonised schemes will lead to lower consumer expenditures compared to the default "improved national policies"-case. A clear ranking occurs: Lowest consumer expenditures in the investigated period 2015 to 2020 occur for harmonised technology-specific support. The resulting average premium can be expected in a range of 6.4 to 6.7 € per MWh gross demand, depending if novel RES-E options are neglected or not. Improved national policies represent the second best options with only a slightly higher cost burden in size of 7.4 €/MWh$_{DEM}$. As worst option harmonised non-technology RES-E support occurs, resulting in average cost of 9.3 €/MWh$_{DEM}$.

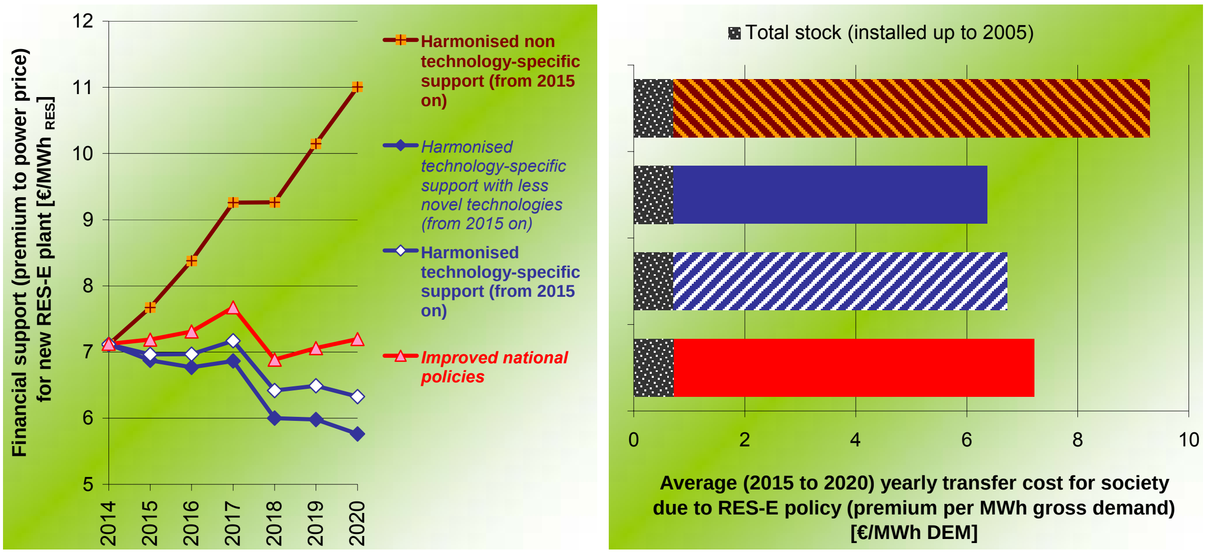

Figure 16. Comparison of the required consumer expenditure (premium per MWh gross demand) due to promotion of RES-E in the period 2015 to 2020 at EU-25 level for the investigated cases, depicted over time (left) or on average (right)

► Cumulated transfer costs for consumer (due to the promotion of RES-E)

Total or cumulated transfer costs for consumer in 2020 summarise both the cumulated consumer burden within the investigated period 2005 to 2020 as well as the residual costs for the years after 2020. Its calculation is done as follows: The required yearly consumer expenditure in the period 2005 to 2020 as well as the estimated residual expenditures for the following years after 2020 are translated into their present value in 2020.[32] *More precisely, cumulated cost burden within the investigated period is calculated by summing up present values of above explained yearly transfer costs. Residual costs refer to RES-E plant installed up to 2020, and accordingly their guaranteed support.*[33]

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 period 2005 to 2020 as well as the residual costs after 2020 – is given in Figure 17 for the

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[32] Thereby, as default an interest rate of 2.5% is applied.

[33] Assume e.g. a wind power plant is installed in 2015 and a support is guaranteed by a feed-in tariff scheme for 10 years. Accordingly, residual costs describe the required net transfer costs for the years 2021 to 2024.

investigated cases. More precisely, this depiction provides a sound illustration of 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.

The following conclusions are drawn from this depiction:

- Cumulated transfer costs for society are lowest by applying **technology-specific support harmonised** all over Europe as done by applying feed-in tariffs. Differences are marginal comparing the two variants, i.e. by considering or neglecting novel RES-E options.[34] The specific cumulated consumer expenditure appear to be in a range from 20.4 to 21.8 € per MWh induced RES-E generation.
- **"Improved national policies"** with a similar deployment of new RES-E lead to slightly higher specific cost in size of 25.8 €/MWh$_{RES-E}$ which corresponds to an increase in size of +18% compared to the technology-specific support provided within a harmonised scheme (incl. novel RES-E options).
- Higher specific cost can be expected in case of a continuation of current RES-E support. In the **BAU-case** the specific cost are in size of 33 €/ MWh$_{RES-E}$ (+49% compared to the harmonised technology-specific support). It is worth to mention that in the BAU-case the overall deployment of new RES-E is 29% lower compared to all other policy options.
- The most cost-inefficient policy option represents a **harmonised, but non technology-specific support**, leading to tremendously higher consumer expenditure in size of 36.6 €/MWh$_{RES-E}$ (+68% compared to the technology specific counterpart incl. novel RES-E options).

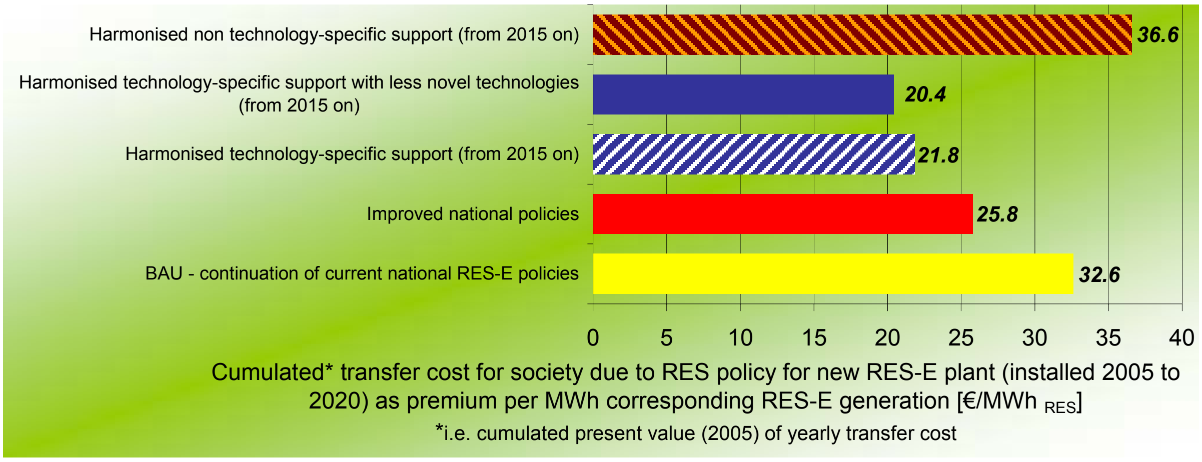

Figure 17. Necessary cumulated consumer expenditure (in 2020) due to the support of new RES-E (installed 2005 to 2020), expressed per MWh induced RES-E generation for the investigated cases

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

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[34] A neglect of novel RES-E options would reduce the cumulated expenditures by -6%.

4 MARKET INTERACTIONS - THEORETICAL CONSIDERATIONS

Economic efficiency in markets is an important criterion for the design of the power systems. Co-existence of different support schemes along with divergence in level of harmonisation (some systems are regional and some national) could generate as well positive as negative effects on the effectiveness in power systems including both thermal and renewable power production. In the traditional textbook harmonisation is efficient even if only small differences in the systems exist. Though significant transaction costs often exist in power markets, and therefore the gain also has to exceed the level of these costs. In general, the ultimate goal is to have common harmonised markets in order to gain from the existing synergies, i.e., aim at a common power market and common support scheme.

The focus in this section is how we can regionalise our RES-E support systems in the most efficient way. This in turn shows up to depend heavily on the starting point for the power system, where we are considering two cases:

1) *A common liberalised power market* comprising more member states, that are fairly strongly interconnected and where power prices in general are determined in common for the region.
2) *A system of separate national power markets* that are interconnected only to a moderate extent and where power prices are determined in the individual countries.

Using these two power system cases as starting point we analyse the effects of introducing a regional RES-E support system, exemplified by the instruments feed-in tariffs and tradable green certificates, as these presently are the most dominating support schemes used in the EU. Regionalising RES-E support schemes in this section means that support conditions for establishing renewable technologies are identical in the considered countries. In the case of a common feed-in scheme this implies identical tariffs for RES-E in the mentioned countries, while in the case of a green certificate scheme each country will determine its own certificate quota[35] and cross-border trade will equalise the certificate price for the chosen region. Of course, the natural given conditions for renewable technologies will differ between countries (wind regime or growth of biomass) as might the conditions at the power market. The deployment of RES-E in all cases will take place according to the profitability of the plants. The importance of the interactive effects are illustrated on, e.g., the deployment of RES-E, the price of power, conditions for conventional and RES-E power producers, regulation costs, and the price of CO_2-allowances. Additionally, the interactions with other support schemes such as an international emission allowance scheme are addressed.

In the two cases we consider two different countries with different energy systems and conditions for renewable technologies. Conditions are chosen to be differing because this is a prerequisite for achieving efficiency gains in co-ordination or harmonisation. For simplicity only wind power is considered of renewable technologies. The two countries are characterised in the following ways:

- *Country A*: Good conditions for wind power. Also the conventional power production is efficient, with high energy-efficiency, low production costs and low CO_2-emissions.

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[35] Expectedly in a close dialog between the participating countries.

- *Country B*: Medium conditions for wind power. The conventional power production is less efficient, characterised by older power plants with low energy-efficiency, high production costs and high CO_2-emissions

The analysis of coordination shows both advantages, as well as, disadvantages. To know whether a common support scheme is an advantage for the renewable energy producers, compared to national systems, this will depend on the situation in the participating countries, especially at the power market. And the analyses show that the choice in design of support scheme can help to diminish the problem of inefficient power production, following an introduction of renewable energy support schemes.

4.1 Regional Support Scheme and Regional Power Market

The first case to be considered is when countries participating in a regional power market change the support schemes from national ones to a common regional one. Thus, the starting point is two countries with already interacting power systems and a common power price determined by the liberalised market.

► *A regional Feed-in Tariff*

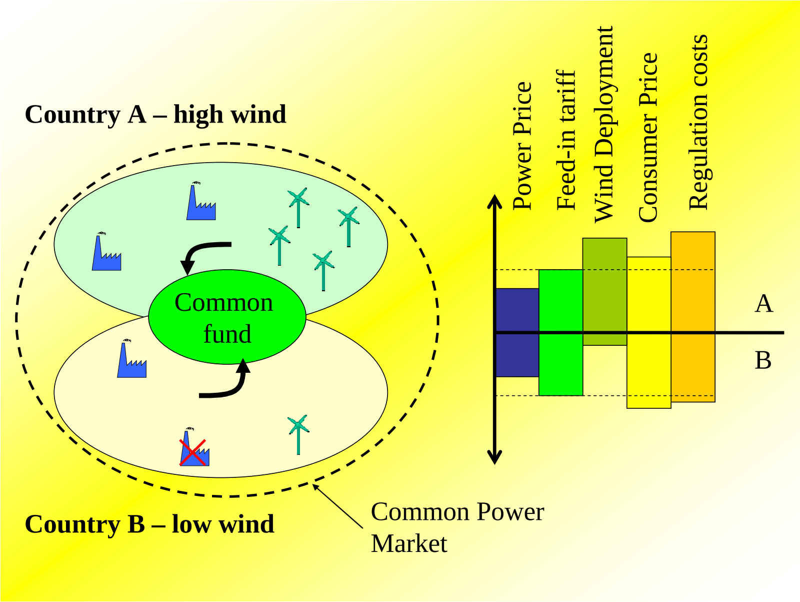

Figure 18. Illustrative example of the consequences of introducing a common feed-in tariff in two countries with a common regional power market. Assumptions: see text.[36]

The consequences of introducing a common feed-in tariff in two countries sharing a common regional power market are on an overall level illustrated in Figure 18, where the bars to the right illustrate the impact in each country (country B is shown pointing downwards) compared to a reference-line (dashed line). In the following the interactive effects will be commented on separately.

A common feed-in tariff gives a deployment of RES-E corresponding to the level of the feed-in tariff, where the distribution between countries will depend on available resources/efficiency in the individual countries. That is, deployment will happen in the

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[36] Observe that the sizes of the bars are not estimated using real data, but merely are shown for illustrative purposes.

most resource efficient countries and not in accordance with, e.g., a given distribution percentage. In the situation with Country A and B the case would be a significant increase of renewable power production units in Country A and lesser in Country B, cf. Figure 18. The RES-E production will capture a certain share of the power market and less will be available for conventional producers. Assuming that the RES-E is prioritised in production, then, in a common power market, RES-E production will always replace the most inefficient conventional power plants in the region, no matter where the RES-E is produced. Thus in general, we will see that the RES-E plants are located in the most resource efficient areas, while those thermal plants with the highest costs are pushed out of the market.

The impact of a common feed-in tariff on the spot price of power would be similar to a national development of RES-E that is, a decrease in the power price, if there is a net increase in the amount of renewable energy, and vice versa for a decrease. This effect is caused by the decrease in production from thermal power plants, the most inefficient power plants are replaced at the power market, and hence, the power price must be assumed to decrease with increasing supply curves. Since, the power price is common for Country A and B we can observe the same decrease in the power price in both countries. Most often, the price of power for consumers are to increase, as a result of an increase in renewable energy production, owing to consumers having to pay the feed-in tariff. But in this case, it is important to discuss the burden sharing of the costs between countries, as costs could be distributed very uneven if consumers are only to pay for national RES-E deployment. This problem could be solved having, e.g., a common pool to pay the feed-in tariff to the RES-E owners, which is funded accordingly to, e.g., the total power consumption or RES-E targets in the individual countries.

How the common feed-in system will influence the trade of power between the participating countries will totally depend on the location of the RES-E plants and the marginal conditions for the conventional power plants at the power market. Thus, no general conclusions can be drawn on the issue of trade between the participating countries. For intermitting renewable resources, e.g., wind power and photovoltaic, the common feed-in scheme might require a further development of transmission-capacity between countries and more resources used for regulation, as the renewable power from wind and solar is fluctuating and not necessarily produced in the most demanding areas. Furthermore, it is important to recognise the costs owing to increased regulation needs. That is, in general the country with the highest share of renewable energy also will bear a higher regulation cost. However this problem could be solved by including the regulation cost in the discussion of burden sharing between the participating countries.

At a common liberalised power market the CO_2-reductions induced by increased RES-E will be shared among all those countries participating in the power market, the distribution solely depending on the marginal conditions for conventional power at the power market. This means, that one country can be the host of implementing RES-E, while the replaced conventional power plant can be located in another country, having the benefit of the lower CO_2 emission. In a regional power market and regional support scheme, the CO_2 emission allowance price will decrease, as the most inefficient thermal power plants are pushed out of the power market.

> *The consequences of introducing a common feed-in tariff in two countries sharing a common regional power market almost adds up to an ideal case. New renewable plants are located in the most efficient way, while the most inefficient*

power plants are replaced. The more different the participating countries are, the more beneficial a common support scheme will be. The burden sharing of introducing a common feed-in tariff could be handled by introducing a common fund, financed by the participating countries e.g. according to their total power consumption (the same power price in all countries). Though more problematic, regulation costs could be handled in the same way. A final barrier is the distribution of the reduced CO_2*-emission that will only take place in those countries where power plants are replaced, but this is a general problem of all common power markets.*

► A regional Green Certificate market

If we still have a common power market for the participating countries, but a common Tradable Certificate Scheme (TGC) is introduced instead of a common feed-in tariff, almost the same consequences will be seen, the major difference being that no common fund is needed, because the burden sharing is part of a certificate scheme.

In a TGC-scheme the deployment of renewable energy depends on the total TGC-quota set for the region as a whole, while the individual TGC-quotas set in each of the participating countries determine the burden sharing of the consumers in each country. The RES-E plants will be located according to resources/efficiency and the long-term marginal costs of new renewable capacity will equal the TGC-price plus the power spot price. The TGC-quotas determine the development of the quantity of RES-E, costs given by market conditions, while the feed-in system determines the costs (level of feed-in), market conditions giving the quantity of RES-E developed.

Also in the TGC-case the most inefficient thermal power plants will be pushed out of the market and the impact on the spot power price will be identical to the feed-in case. The main difference to a feed-in system is that the quota obligation scheme is designed as an international scheme with trade across the borders. Following, there is no need to introduce common funding pools, as the national obligations are directly given by the national TGC-quotas. Thus, the costs of supporting renewable technologies are transferred directly to the power consumers according to the set TGC-quotas, those countries with the highest quota also putting the highest burden sharing on the power consumers.

RES-E production in a quota obligation scheme will normally not be prioritised, as is the case for the Feed-in system. This means that owners of RES-E plants will have to handle the balancing of production themselves or buy the service from somebody else (e.g., the TSO). This will imply that RES-E producers will react on the spot price to a further degree than in the case of the feed-in tariff, where RES-E producers are totally independent of the spot price. But only if the certificate price gets very low this will have a major influence. Also in this quota obligation system the CO_2-reductions induced by increased RES-E will be shared among all those countries participating in the power market, the distribution solely depending on the marginal conditions for conventional power at the power market. Hence, the price on emission allowances corresponds to the one for the feed-in tariff, with a decrease in the emission allowance price.

In general some of the same pros et cons are found by the introduction of a green certificate scheme as for the feed-in tariff, the main difference being no need for a common financial fund, the burden sharing being an integral part of TGC-systems.

4.2 Regional Support Scheme and National Power Market

In this case we will look at the consequences when a common regional support scheme is introduced into a power system consisting of national entities without strong interconnectors. Thus focus is on how a common regional support scheme for RES-E interacts with separated national power systems.

► *A regional Feed-In Tariff*

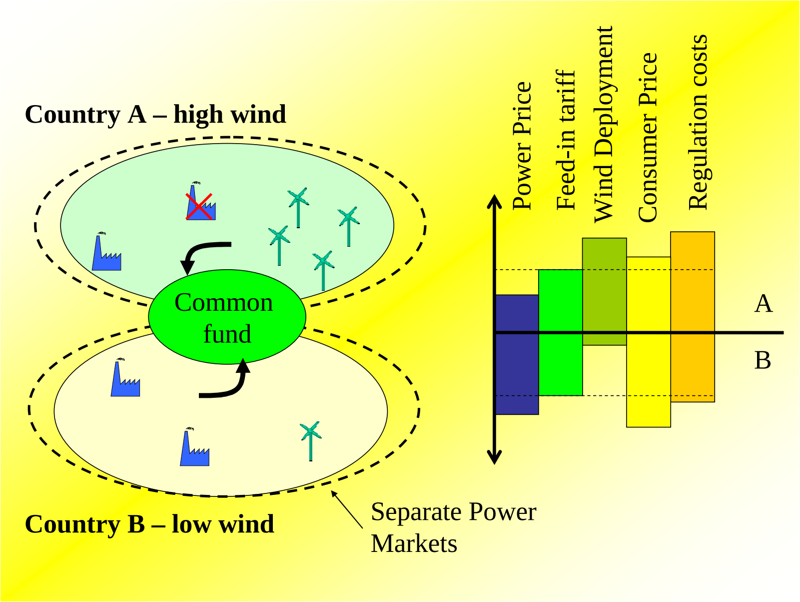

Figure 19. Illustrative example of the consequences of introducing a common feed-in tariff in two countries with separate national power markets. Assumptions: see text.

The consequences of introducing a common feed-in tariff in two countries having separate national power market are on an overall level illustrated in Figure 19. and commented on in the following.

A common feed-in tariff between countries gives an amount of RES-E corresponding to the level of the feed-in tariff, where the distribution between countries will depend on available resources or efficiency in the individual countries. Thus wind turbines will be sited in areas with the best resources irrespective of the conventional power production and power markets. But when we have to do with separate power markets the RES-E plants cannot replace inefficient power plants in other countries and therefore this scheme could potentially create problems for the country that has the best RES-E potential. Thus, a large part of the power could be delivered from the RES-E sources in this country, leaving a significantly smaller part to conventional power production, in extreme cases pushing well functioning production capacity out of the market. At the same time, the large deployment of RES-E would in general decrease the spot power price in this country and therefore moderate the incentives for investing in new conventional power, although there might be a need for capacity with high regulatory capabilities to handle intermittent RES-E production. Thus, a common regional feed-in tariff could bias the functioning and the development of the conventional parts of the power systems in the participating countries.

The more RES-E, the more the power price will go down in the considered country. That is, in countries with high RES-E deployment the decrease in the power price will be relatively higher, compared to countries with low RES-E deployment (cf. Figure 19.), and might leave power consumers in this country better off. But the final price to consumers will depend on the burden sharing of costs for paying the feed-in tariff and if a common fund is introduced between the participating countries. In addition, a high share of intermittent RES-E technologies set high demands for system functionality in order for the national power market to function. Therefore, discussion of burden sharing between countries regarding regulation cost also has to be included.

The interaction with the emission allowance scheme will also be dependent on the above-described inefficiency in this system, as the inefficient production from conventional power plant also affects the emission levels. The country with low deployment of renewable energy can end up using inefficient and highly emitting production plants, and hence drive up emission prices. Higher emission prices also affect the country with a large RES-E deployment, driving internal power prices up, again affecting consumer prices. In this case, the increased RES-E will only lead to CO_2 reductions in those countries where the RES-E is implemented. Thus, the participating countries cannot on beforehand know how much the RES-E development will help them in achieving their national CO_2 reduction targets.

> *Introducing a common feed-in tariff in two countries having separate national power markets will not by itself lead to an optimal solution. New renewable plants will be located in the most efficient places but the most inefficient power plants will not be replaced. Thus the situation at the renewable market will be optimal, but that will not be the case at the conventional part of the power market, where a biased development of the power system will take place, implying an inefficient reduction of CO_2-emissions. Also in this case a common financial fund could handle burden sharing and, perhaps, also regulation costs. Finally, a general barrier is the distribution of the reduced CO_2-emission that will only take place in those countries where power plants are replaced.*

► *A regional Green Certificate Market*

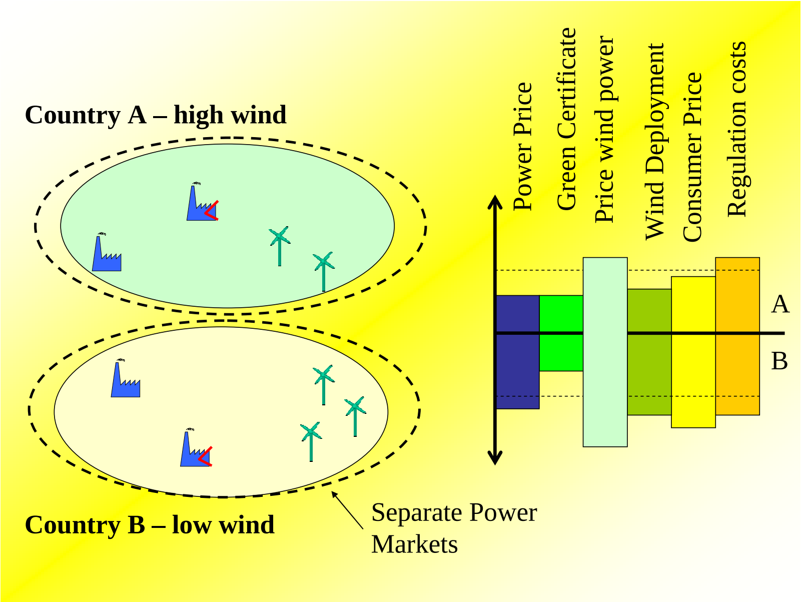

Figure 20. Illustrative example of the consequences of introducing a common TGC- scheme in two countries with separate national power markets. Assumptions:see text.

The consequences of introducing a common green certificate scheme in two countries having separate national power market are on an overall level illustrated in Figure 20. and commented on in the following.

In the case of a TGC-market the deployment of renewable energy will only depend on the level of the common quota for the region. Production of renewable energy will equal the quota, and price of certificates will through trade be equalised for the region (cf. Figure 20.). Deployment of RES-E will take place at the most *economic* efficient places, thus, e.g., the wind turbines will not necessarily be put up in the windiest sites, but where the *total income* is highest for the wind turbine owners. Therefore a combination of price and wind resources will determine where turbines are located. Only if power prices are the same in all the participating countries, the RES-E plants will be established where it is most efficient. But if efficiency of renewables is the same RES-E plants will be established where power prices are highest. This implies that countries with a fairly low efficiency for renewables might be chosen for development because of an inefficient conventional system with high power prices. This might lead to a non-optimal allocation of renewable resources, biased because of deficiencies in the existing conventional power system.

The deployment of RES-E will decrease power prices and this will have two effects: First, in a country with large RES-E deployment the decrease in power prices will also decrease the income for the renewable producer and hence lower incentives to establish new RES-E plants. This effect will decrease the problem of concentrating the RES-E production in specific countries. Second, if a country has a very inefficient thermal power production and thus has high power prices, this will be an incentive to develop RES-E which in the longer term will decrease power prices.

Regarding conventional power production the most inefficient conventional plants will be replaced within each of the countries, but it does not ensure that the most inefficient power plants *within the region* are replaced. Thus well functioning production capacity could be pushed out of the market, with a total social loss for the region. This implies that reduction of CO_2 will be less than optimal and, therefore, a higher price of CO_2 allowances will prevail. As for the feed-in system the increased RES-E will in this case only lead to CO_2 reductions in those countries where the RES-E is implemented. And because of the two above-mentioned price-effects it is even more difficult in this system to know how much the RES-E development will help them in achieving their national CO_2 reduction targets.

> *Compared to an introduction of a feed-in tariff in a system with separate national power markets, the green certificate system aims at achieving an optimal economic solution at the given conditions, while an optimal resource allocation is not the goal. Thus neither are the RES-E technologies located in the most resource efficient areas, nor are the most inefficient power plants in the region being replaced, but given the separate markets the income of RES-E owners and conventional power producers are optimised. At the given conditions the green certificate market ensures an optimal distribution of plants. Compared to a feed-in tariff there is no need of a financial fund, but distribution of regulation costs might be a problem. Finally, also in this case a general barrier is the distribution of the reduced* CO_2*-emission that will only take place in those countries where power plants are replaced.*

5 CONCLUSIONS & RECOMMENDATIONS

In the OPTRES project the main national support instruments for RES-E implemented in EU Member States have been analysed based on a historical assessment of past achievements as well as on a prospective model based analysis. Furthermore the main barriers for the development of RES-E as well as key market interactions with conventional power markets have been analysed. In the following we aim to depict the *lessons learned* from this brief analysis in a concise manner. First, *conclusions* are drawn and, finally, a set of concrete *recommendations* are listed to illustrate the possible way forward towards implementing an effective & efficient support for renewable electricity in Europe.

5.1 Conclusions

As **general conclusions** from this project it can be stated that

- ► The **continuity and long term investment stability** of any implemented policy is a key criterion for the stable growth of RES-E markets as well as for reaching RES-E targets at low costs.
- ► To guarantee long term continuous deployment of renewable electricity **technology specific support** is the key element as a pure concentration on currently most cost-competitive technologies will tend to exclude more advanced technologies which are needed in the long run. In other words technology neutrality may be cost efficient in the short term, but will be more expensive in the long term.
- ► due to the producer profits involved with the promotion of RES-E **technology specific instruments** are preferable to non-technology specific support in order to **minimise the costs for society even in the short term**.
- ► Most of the **European success story** to promote RES-E during the past decades in an **effective and economically efficiency way** was driven by implemented **feed-in tariffs**, which are in practice implemented in a technology specific manner.
- ► **Non-economic barriers** (e.g. grid and administrative barriers) need to be diminished in order to increase the growth of many renewable energy markets in Europe.

More detailed conclusions from the analysis of historic trends and the model-based prospective analysis read as follows:

► *Based on the* ***analysis of historic trends:***

- Countries with **stable support systems** and **low overall barriers** for the development of RES-E, i.e. Denmark, Finland, Germany and Spain, have achieved the highest **progress towards the targets set in the RES-E directive.**
- In countries having **feed-in tariffs** as their main support system, the **effectiveness of the promotion of innovative and in the mid to long term most important technologies like wind energy, agricultural biogas and photovoltaics** has been the highest, even though not all feed-in countries have been equally successful.
- **In countries with non-technology specific RES-E promotion scheme**s like tax incentives and quota obligations based on TGCs **RES-E technologies like sewage gas and certain fractions of solid biomass have been supported effectively** due to their low cost characteristic in the overall technology portfolio
- Comparing the **current level of support offered under the different systems with the resulting effectiveness** of the promotion schemes it is shown that countries which have recently transformed their markets into **quota systems as the main support instrument**, show a **high expected annuity of support (and therefore high costs for consumers) but low effectiveness**.
- The results show that certificate systems can lead to high producer profits resulting from high investment risks and - more importantly - the non-technology specific support regime.On the other hand, it seems typical **for countries supporting RES-E based on feed-in-tariffs to be more effective at generally moderate levels of support. An exception to this rule can be observed in countries, where administrative barriers are preventing rapid development of RES-E.**

► *Referring to the* ***model-based prospective analysis****:*

- The **key criterion** besides continuity and long-term stability of any implemented policy **for achieving an enhanced future deployment of RES-E in an effective & efficient manner is the technology specification of the necessary support.** A pure concentration on currently most cost-competitive technologies would lead to initially exclude more novel technologies as needed in the long run. In contrast, any moderate to ambitious RES-E target would be failed without consideration of these moderate to novel RES-E options. In other words technology neutrality may be cost efficient in the short term, but will be more expensive in the long term. Even in the short term, the observable cost differences among cheap to moderate RES-E options recommend a support diversification.
- The results of the modelling exam clearly indicate that through an optimisation of RES-E support measures at the national level already the major part of possible efficiency gains[37] will be exploited – **about two thirds of the overall cost reduction potential can be attributed to the optimisation of national support schemes**. **Further efficiency improvements** at a considerably lower level (at about one third of the overall cost reduction potential) **are possible by an**

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[37] Please note that efficiency gains are measured in terms of premiums or consumer expenditures necessary to support renewables.

EU wide harmonisation of support schemes provided that a technology specification of the support is implemented and, furthermore, that a common European power market exists. In contrast, if harmonisation would mean to put all RES-E options in a common basket, where specific support is provided equally to all considered RES-E technologies, the accompanying consumer expenditures will achieve tremendous high levels for achieving an ambitious RES-E deployment. Consequently, a harmonised non-technology specific support would cause an increase of the inefficiency.

- On the way to an EU wide harmonisation the regional coordination may represent an essential step forward, where promotional systems can mutually learn from each other. Possibly **half of the additional cost benefits of an EU-wide harmonisation as compared to the nationally optimised schemes can be tapped through a regional coordination already**. Generally one should also consider that **a premature EU-wide harmonisation can hamper the national optimisation process as well as the overcoming of non-economic barriers at Member State level and can lead to significant market distortions if power markets are not fully liberalised**.

► *Conclusions based on* ***theoretical considerations on market interactions*** *read as follows:*

Concerning the introduction of common regional RES-E support schemes two conclusions are drawn from the present analyses:

- The almost ideal situation exists if the **region prior to regionalising RES-E support schemes** already has a **common liberalised power market**. In this case the introduction of a common support scheme for renewable technologies will lead to more efficient sitings of renewable plants, improving economic and environmental performance of the total power system.
- If no such common power market exits **regionalising RES-E support** schemes might due to interactions introduce **distortions in the conventional power system**. Thus in contrary to the intentions we might in this case end up in a system that is far from optimal with regard to efficiency and emissions. Thus the analysis clearly points out that efficiently liberalised power markets ensuring competition on the conventional market are a crucial precondition for effectively functioning RES-E markets. Furthermore, if one wants to create co-ordinated or common RES-E markets between member states **sufficient transmission capacities** including the existence of necessary economic incentives to utilise the interconnections are a prerequisite.

► *Finally, the following* ***recommendations of a more general nature*** *shall be kept in mind:*

- A **continuous long-term policy – avoiding a stop and go nature – is important to create a sound investment climate and to lower the societal transfer cost due to the support of RES-E** as a result of lower risk premium. The inherent characteristics of the different RES-E technologies should be taken into account, as well as national/regional peculiarities.
- The achievement of most policy targets for RES-E as well as the accompanying societal costs is closely linked to the future development of the electricity demand. Therefore, besides setting incentives on the supply-side for RES-E, accompanying

demand side measure to increase the energy efficiency help to minimise the overall societal burden.

- From a societal point-of-view **the use of the full basket of available RES-E technologies is highly recommended**. The effects of neglecting some technologies – i.e. either cheap options such as hydropower or novel technologies such as PV or tidal and wave energy – increase both generation costs and transfer costs for consumer / society in the long run.
- The **careful design of a support instrument is important to achieve an effective & efficient supporting policy**. The effects of different policy options on RES-E deployment, investor confidence, conventional power generation and its emission and prices are comparatively similar, if the design of the instruments is similar, too. Of course, as the instruments differ, the effort, the efficiency and complexity of reaching a similar impact varies among the support schemes.
- Within any support mechanisms **existing and new plants should not be mixed**. Support should no longer be provided to plants that are fully depreciated or that were financially supported in an adequate way in the past.
- **Financial support should be guaranteed, but strictly limited to a certain timeframe**. As a rule of thumb ten to twenty years seem adequate to set a proper operational incentive without over-subsidisation.
- The **consideration of the dynamics is essential in building up the design and choosing the most efficient and effective instrument**, as the impact of the instruments significantly differs if analysed from a static viewpoint. Of special importance is:
  - Technological diffusion due to changes of existing non-economic barriers over time;
  - Decreasing generation costs and hence lower necessary financial incentives;
  - Non-linear dynamic target /quota setting
- **Existing non-economic barriers for new RES-E generators should be rigorously removed** and outstanding incentives should be provided:
  - Start / continue information campaigns;
  - Integration and coordination of other policies like climate change, agricultural policy or DSM issues helps to reduce administration barriers;
  - Due to long and complex permission procedures in many countries a long lead time for RES-E projects occurs, increasing the pressure and the costs to achieve agreed RES-E targets.

5.2 What is the way forward?

In order to further improve the current policy setting on RES-E in Europe a number of necessary interim developments can be identified based on the OPTRES project. Most of the suggested measures can be initiated on an EU level and should be implemented in each member state individually based on the prevailing conditions:

- ***Diminish the key barriers for RES-E development***

  With regard to *administrative barriers* the lead times to obtain necessary permits have to be reduced in many countries, whereas especially clear guidelines and obligatory response periods for authorities are needed. Furthermore RES-E is still insufficiently taken into account in spatial planning. Concerning *grid barriers* one should tackle the problems of insufficient grid capacities in some areas, set clear rules on the transparency of grid access and guarantee the corresponding objectiveness of prices and decisions and limit the lead time for grid connection. *Unbundling* the power systems in EU should be continued, creating more transparency in transmission and distribution and, therefore, facilitating the development of RES-E sources. Finally, the *design of the liberalised power exchanges* should be reconsidered, the existing long bidding times hindering an efficient integration of intermittent sources as wind power and photovoltaic.

- ***Set long term targets on EU and Member State level***

  In order to trigger stable policy environments on member state level a clear long term and sufficiently ambitious target setting beyond 2010 is needed. On the EU level ambitious targets have been formulated in the recently publishes roadmap on renewable energies (COM (2006) 848), by setting a 20% target for renewable energies in terms of primary energy consumption. Such an EU wide target has now to been implemented on a member state level by also suggesting national sectoral targets for electricity, heat and transport. This will increase the investor confidence and therefore reduce the risk premium for RES-E investments. Furthermore many infrastructure developments are characterised by long planning horizons and a strong path dependence, e.g. grid extensions for offshore wind energy. Finally we would like to stress that any RES policy should have long term goals as key motivation. Evaluating a mid term RES policy (e.g. on a time frame until 2020) should always consider long term effects (e.g. on a time frame until 2050) in order to assess the potential of this strategy for long term CO_2 reduction and contribution to security of supply.

- ***Strive for competitive framework conditions in the conventional power market***

  As can be seen from the present analysis efficiently liberalised power markets ensuring competition on the conventional market are a crucial precondition for effectively functioning RES-E markets. In particular it will be very difficult to reach an EU wide harmonised support system for renewable energies before a functioning and truly European power market is established. Furthermore if one wants to create co-ordinated or joint RES markets between member states sufficient transmission capacities including the existence of necessary economic conditions to utilise the interconnections are a prerequisite.

- ### *Set minimum design criteria for support schemes – generic*

Minimum design criteria, which are independent of the policy instrument chosen in a particular country, should be respected. These include the support of the full basket of technologies given in the RES-E directive, which can be reasonably utilised in a given country. Generally the financial support level should be higher than the marginal costs of generation (in the case of a quota system the level of penalty is relevant) and should be restricted to a certain time frame. Only new capacities should be considered by any adaptation or change of the instrument. The abuse of market power in the different markets should be avoided, wherefore, compatibility with the conventional power market and other policies are important to consider. Another aspect is to secure stability for investors in RES-E technologies, hence the policy instrument should remain active for a sufficient period to provide stable planning horizons. Following, stop-and-go policies are not suitable, and an implemented project should not be faced with a change of support scheme during lifetime.

- ### *Minimum design criteria – instrument specific*

Furthermore instrument specific criteria should be respected.

Quota System:
In a quota system one should strive for a sufficiently liquid and competitive TGC markets in order to secure market functionality. Furthermore, the penalty needs to be set correctly, i.e., significantly higher than marginal production costs at quota level. Finally, additional support has to follow the quota system in order to support less mature technologies, unless the system is designed to support different types of technologies by using, e.g., band designs.

Feed-in System:
In a feed-in system technology specific tariffs should be used and the level of the tariffs should be set at the correct level (sufficiently high but not too high). In order to enforce technological learning, a decrease of the offered tariff for new contracts over time should be implemented and clearly communicated. Furthermore on should implement the system in a stepped (band specific) way, in order to reduce the costs for consumers.

- ### *Regionalisation / Co-ordination*

Based on the traditions of different Member States it is likely that they will not find one joint agreement with respect to support schemes. If this is the case, it is important that a co-ordination of the general framework conditions takes place. This means that the Member States establish clear rules of the framework conditions for the different promotion schemes. In a following step, systems with a sufficient degree of similarity which are applied in countries with a common power market can then be sub-harmonised or co-ordinated. Intensified co-ordination between countries should be the first step towards a harmonisation in the long term. Only if the preconditions of converged RES-E support in different countries and of sufficiently connected conventional power markets are provided one should start with multi-lateral agreements on merged RES-E markets. With regard to the occurring costs for society clear benefits of a multi-national promotion can be seen. An example for possible convergence criteria of support instruments could be a harmonisation of the different time frames of support, e.g. duration of support in feed-in systems and validity of certificates in TGC systems and / or the level of support. However, in such international system the definition of the burden is highly nontrivial and needs detailed analysis.

General design criteria for effective and efficient systems

Consider a dynamic portfolio of support schemes

Regardless whether a national or an international support system is concerned it should be emphasised that typically only one instrument is insufficient to stimulate a long-term growth of RES-E. Since generally a broad portfolio of RES technologies should be supported the mix of instruments selected should be adjusted to this portfolio. Whereas investment grants are normally a very suitable instrument for supporting immature technologies, feed-in tariffs fit well for the interim stage of market introduction of a technology. Once the markets and technologies are sufficiently mature and market size is large enough to guarantee competition among the market actors and competition on the conventional power market is guaranteed, a premium feed-in tariff or a quota obligation based on TGC can be the proper instrument. Such a mix of instruments can then be supplemented by tender procedures, which can be very efficient for example in the case of large scale projects such as wind offshore.

Optimise each instrument with regard to effectiveness and efficiency

Most instruments still possess significant optimisation potentials, even after the minimum design criteria described above have been met .A few examples of such optimisation options are:

In a *feed in system* a stepped design can clearly increase the efficiency of the instruments especially in countries where the productivity of a technology differs a lot between different technology bands.

In *quota systems based on TGCs* the technology or band specification, which is currently tested in Italy (based on technology specific certification periods) and in Belgium (based on technology specific certificate values) can be an important option to increase both the instruments effectiveness and efficiency. It is however important to emphasise that such technology specification should not be performed by setting technology specific quota and separating the TGC market as this would negatively influence the liquidity of the TGC markets. Furthermore the risk premium might be reduced by an introduction of minimum tariffs in a quota system.

Strive for an optimal design of an instrument

The gradual optimisation of each instrument will decrease the presently existing differences between the schemes. In this sense a continuous harmonisation of RES-E across Europe support can be reached without transforming all support instruments at once.

In the long term the difference in external costs should justify the magnitude of support for renewables (tax on conventional energy or technology-specific support for RES)

In the long term technological learning of RES-E on the one hand and the price increase of conventional electricity on the other hand should provide stable market conditions for renewables under the condition that the external costs of conventional electricity generation will be internalised appropriately.

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