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Monitoring and evaluation of policy instruments to support renewable electricity in EU Member States

Final Report

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P.O.Box 1406
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Fraunhofer Institute Systems and Innovation Research

Energy Economics Group

Final Report

Monitoring and evaluation of policy instruments to support renewable electricity in EU Member States

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Authors: Mario Ragwitz (Fraunhofer ISI)
Anne Held (Fraunhofer ISI)
Gustav Resch (EEG)
Thomas Faber (EEG)
Claus Huber (EEG)
Reinhard Haas (EEG)

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Contact details:

Dr. Mario Ragwitz

Fraunhofer Institute Systems and Innovation Research
Breslauer Str. 48
D-76139 Karlsruhe
Germany
Phone: +49(0)721/6809-157
Fax: +49(0)721/6809-272
Email: mario.ragwitz@isi.fhg.de

Dr. Gustav Resch

Vienna University of Technology
Energy Economics Group (EEG)
Gusshausstrasse 25 / 373-2
A-1040 Vienna
Austria
Phone: +43(0)1/58801-37354
Fax: +43(0)1/58801-37397
Email: resch@eeg.tuwien.ac.

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EXECUTIVE SUMMARY

Since the publication of the White Paper "Energy for the future" (EC, 1997) and the adoption of the Directive 2001/77/EC (EC, 2001) on renewable energies in the electricity sector (RES-E), the EU renewable energy sector has developed in a dynamic way. All 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. The main existing policies comprise feed-in tariffs, quota obligations based on tradable green certificates (TGCs), investment grants, tender procedures and tax measures. Due to the different nature of the various policy schemes, the effects of these instruments on technological development, RES-E market diffusion and evolution of generation costs as well as cost for society differ significantly. Until now RES-E support measures have been implemented exclusively on a national level, aiming to meet the national indicative targets as set in the RES-E directive. However, based on the presently implemented policies, most of these targets will most likely not be met as was indicated in the communication of the European Commission in 2004 COM (2004) 366 (only Denmark, Finland, Germany and Spain are on track to reach the national target). An important reason for this is that the support level offered to RES-E is still very heterogeneous among the EU countries and certainly too low in a number of Member States, i.e. sometimes below long-term marginal costs. Furthermore, the identified key barriers to the development of RES-E which are of an administrative, financial, and social nature as well as insufficient electricity grid capacity are not being appropriately addressed by national authorities. Additionally the risk level associated with RES-E investments is still evaluated as comparatively high by the relevant financial institutions in some markets. Altogether, the effectiveness of present RES-E support is still limited in a number of cases and shows a rather uneven distribution across the EU. Besides these facts, the economic efficiency of RES-E support is lower than would be possible in an advanced policy environment and shows a clear heterogeneity among member states.

In the **present 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.

As **general conclusions** from the present study 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,
- most of the **European success story** to promote RES-E during the past decades was driven by implemented **feed-in tariffs**, which have proven to be an effective as well as economically efficient policy instrument,
- in order to **minimise the costs for society**, **technology specific instruments** are preferable to non-technology specific support,

- **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:***

- ► The **best progress towards the targets set in the RES-E directive** was achieved in countries with **stable support systems** and **low overall barriers** for the development of RES-E, i.e. Denmark, Finland, Germany and Spain in the present analysis.
- ► The **effectiveness of the promotion of innovative technologies like wind energy, agricultural biogas and photovoltaics** has been the highest in countries having **feed-in tariffs** as their main support system, even though not all feed-in countries have been equally successful. These technologies offer most significant future potentials for the mid to long term.
- ► L**ow cost options in the overall RES-E technology portfolio like sewage gas and certain fractions of solid biomass have been supported effectively but not always efficiently in countries with non-technology specific RES-E promotion scheme**s like tax incentives and quota obligations based on TGCs, although significant progress can be seen under some of the implemented feed-in systems as well.
- ► Comparing the **current level of support offered under the different systems with the resulting effectiveness** of the promotion schemes for **the case of wind energy** it is striking that three countries - Italy, the UK and Belgium - 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 growth rates**.

  The high annuity results in particular from the extrapolation of the presently observed high certificate prices. Although the latter assumption might be questioned (empirical evidence supporting this assumption is given in the report), the results show that certificate systems can lead to high producer profits resulting from high investment risks.
- ► On the other hand, it seems typical for **countries supporting wind energy 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 wind energy.

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

- ► Results suggest that the **most significant efficiency gains can be achieved simply by strengthening and improving national RES-E support** schemes – more than two thirds of the overall cost reduction potential of policy harmonisation can be attributed to the optimisation of national support schemes.
- ► The **effectiveness of the various RES-E support schemes largely depends on the credibility of the system.** The **continuation** of a **policy – avoiding stop-and-go – is important to create a stable growth in renewable energy sources** and, in addition, also cause lower societal costs as a result of a lower risk premium (of investors).

► **Administrative barriers** can have a significant impact on the success of an instrument and **hamper the effectiveness of policy schemes which may be very powerful in principle**.

► **If technology-specific support instruments are applied coordination and harmonisation** of the support mechanisms between the Member States **might lead to lower transfer costs** for consumers**.** Otherwise gains may be marginal or there may even be losses incurred.

As model runs clearly indicate, a properly designed, harmonised, technology-specific promotion of RES-E at cluster or European level would cause lower transfer costs for consumers in total, accompanied by a better equalisation of consumer burden among the countries. Of course, the necessary pre-condition of reaching an international agreement is that a 'fair' burden sharing concept is developed, which considers both national and international benefits from RES-E generation.

► By **focusing on transfer costs for consumers**, the comparison of the individual promotion instruments leads to the following findings:

- A **quota obligation based on TGCs** is **less efficient from a societal point-of-view** compared to the other instruments analysed **such as feed-in tariffs** because a **higher risk must be borne** by the investor, and **efficiency gains are absorbed by** the producers (high producer surplus) and not by the consumers;
- **Feed-in tariffs** (and also tender schemes) are useful to promote a more homogeneous distribution among different technologies **by setting technology-specific guaranteed tariffs.** The implementation of such a policy can support **the long-term technology development of various RES-E options** which are currently not cost-efficient.

1 INTRODUCTION

It is the European Union's objective to increase the share of electricity produced from renewable energy sources to 21 % in the EU-25 (22% in the EU-15) by 2010. This is the core element of Directive 2001/77/EC, which requires the Member States of the EU to apply appropriate instruments in order to achieve the national targets for RES in the electricity sector. The choice of instrument is left largely up to the Member States themselves. However, Articles 3 and 4 of the Directive provide for a monitoring system which observes the development in the individual Member States. If it can be anticipated that national targets will not be reached, it is then possible for the Commissions to request a Community framework for regulations promoting electricity from renewable energy sources (see Article 4 § 2 2001/77/EC). As provided for in the Communication of the EU Commission COM(2004) 366 and asked for by the Council (Energy) in its conclusions of 29 November 2004, further targets are then to be set in 2007 for the year 2020.

This present report examines the development of renewable energy sources in the electricity sector (RES-E) in the individual Member States of the European Union. In particular, the support instruments being used in the Member States are documented and assessed with regard to their impacts on the share of renewable energies in electricity production in empirical investigations as well as model-based scenario calculations. The effectiveness and efficiency of current and future instruments promoting electricity production from renewable energy sources in Europe are analysed in detail. The most effective and efficient instruments are identified and the (future) costs of electricity production from renewable energy sources and the government support necessary to guarantee stable growth are estimated. The intention is to identify the essential elements for the further development of national and EU-wide measures.

The **core questions** analysed in this report can be summarized as follows:

- Which support instruments for renewable electricity are currently being implemented in the individual Member States of the EU? Which instrument changes have occurred in the past or are planned in the future?
- Which of the support instruments used (e.g. feed-in tariffs, investment grants, tender schemes, quotas based on tradable green certificates) are the most effective; which are the most efficient from a historical perspective and from a prospective analysis?
- What are the general minimum criteria able to be determined for effective and efficient support instruments?

1.1 Method of approach – evaluation criteria

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].

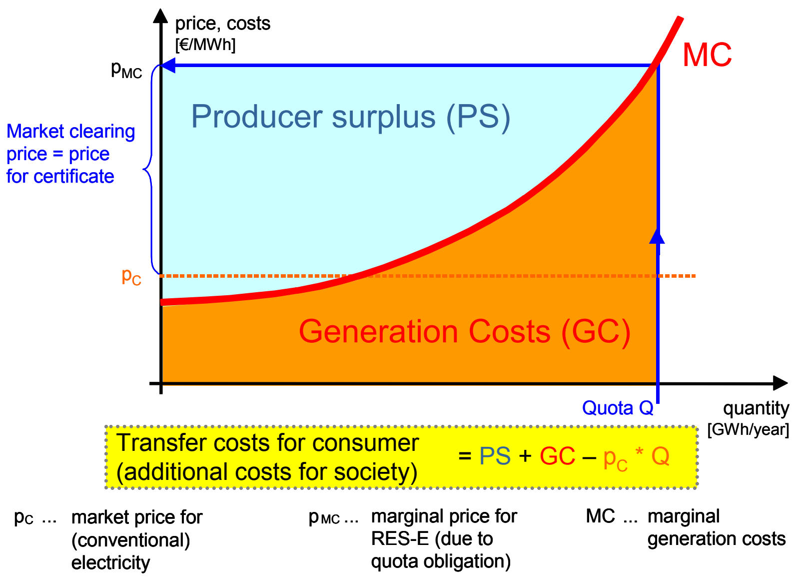

Figure 1. Basic definitions of the cost elements (illustrated for a TGC system)

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.

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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.

2 GENERAL CHARACTERISATION OF SUPPORT SCHEMES FOR RENEWABLE ENERGY SOURCES IN THE ELECTRICITY SECTOR (RES-E)

Promotion instruments can be classified according to different criteria (i.e. whether they affect demand for or supply of RES-E or whether they support capacity or generation). So that a common terminology can be applied at least within this thesis, Table 1 provides a classification of these instruments, covering all the currently applied strategies referring to the promotion of RES-E deployment. A brief explanation of the terminology is provided below for instruments of high relevance.

Table 1. Classification of promotion strategies

		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 (RPS) based on TGCs	
Voluntary	Investment focussed	• Shareholder programmes • Contribution programmes		• Voluntary agreements
	Generation based	• Green tariffs		

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

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 total price for RES-E production, or an additional premium on top of the electricity market price paid to RES-E producers. Apart from the level of the tariff, its guaranteed duration represents an important parameter for assessing the actual financial incentive. FITs allow technology-specific and band-specific promotion as well as an acknowledgement of future cost-reductions by implementing decreasing tariffs (see, e.g. the German Renewable Energy Act).

Quota obligations based on Tradable Green Certificates (TGCs) are generation-based quantity-driven instruments. The government defines targets for RES-E deployment and obliges any party of the electricity supply-chain (e.g. generator, wholesaler, or consumer) with their fulfilment. Once defined, a parallel market for renewable energy certificates is established and their price is set according to demand and supply conditions (forced by the obligation). Hence, for RES-E producers, financial support may arise from selling certificates in addition to the income from selling electricity on the power market.

Production tax incentives are generation-based price-driven mechanisms that work through payment exemptions from the electricity taxes applied to all producers. This type of instrument thus differs from premium feed-in tariffs solely in terms of the cash flow for RES-E producers: it represents an avoided cost rather than additional income.

Tendering systems are quantity-driven mechanisms. The financial support can either be investment-focused 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 subsidies 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 size of the 'bid price' per kWh for a guaranteed duration.

As well as the regulatory instruments described above, more and more voluntary approaches have appeared with on-going market liberalisation. They are mainly based on the willingness of consumers to pay premium rates for renewable energy. However, in terms of effectiveness so far – i.e. actual installations resulting from their appliance – their impact on total RES-E deployment is negligible.

Figure 2 provides an overview of the renewable electricity support systems used in the EU-25 and Bulgaria and Romania.

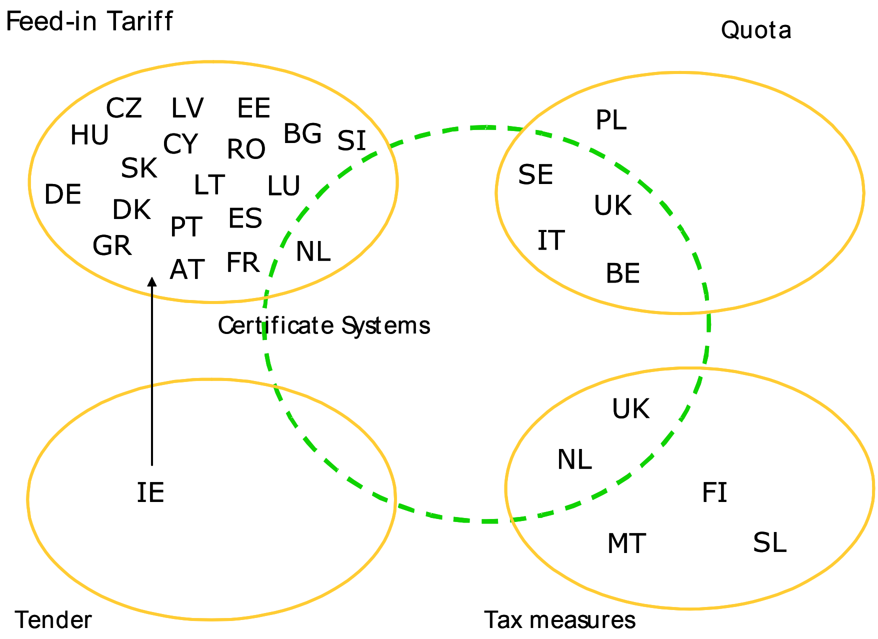

Figure 2. Overview of renewable electricity support systems in EU-25 & BU, RO

3 CURRENT STATUS OF RES-E MARKETS IN SELECTED EU MEMBER STATES

First we would like to present the status of the RES-E markets for selected EU Member States which are representative for specific RES support instruments. The following countries have been selected as characteristic candidates for each of the relevant policy schemes[3]:

Support scheme	EU Member State
Feed-in tariff	DE, ES, FR, AT
Quota	UK, BE, SWE, IT
Tender	IE
Tax measure	FI

In Figure 3, the RES-E generation in 2003 is shown for the selected countries. It is obvious that hydropower is still the dominating source in most of the ten countries concerned, but the 'new' RES-E have started to play a more prominent role. Particularly in Germany, Finland, Spain and the UK, non-hydro sources like wind, biogas and solid biomass provide a significant contribution.

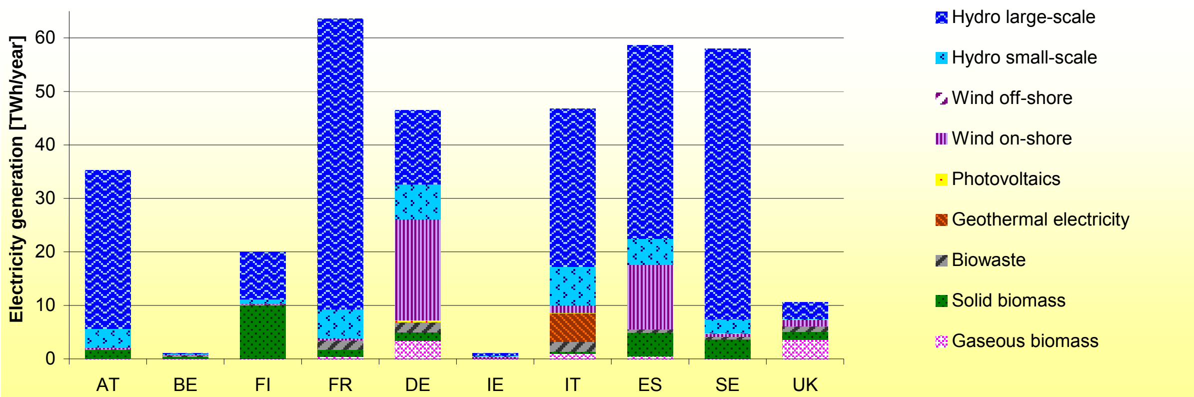

Figure 3. Total achieved RES-E generation potential in 2003[4]

In order to show the recent progress of the ten Member States in more detail, the additional RES-E generation potential[5] in the period 1997-2003 is presented in Figure 4. As

3 The past policy changes in these countries are shown in Figure 8. In the near future, only Ireland is considering a major policy shift towards a feed-in system.

4 Wind on-shore: - Wind turbines that are installed on land, instead of being installed off-shore (in the sea). The term on-shore is not limited to costal areas.

5 The electricity generation potential represents the output potential of all plants installed up to the end of each year. Of course, the figures for actual generation and generation potential differ in most cases – due to the fact that, in contrast to the actual data, the potential figures

can be seen, Germany and Spain have by far the largest achievements since 1997 in terms of additional generation capacity of new RES-E. By far the slowest progress was made in Belgium and Ireland. In terms of technology, wind energy dominates followed by solid biomass and biogas. Austria, France, Italy and Spain have added large-scale hydro-power generation capacity.

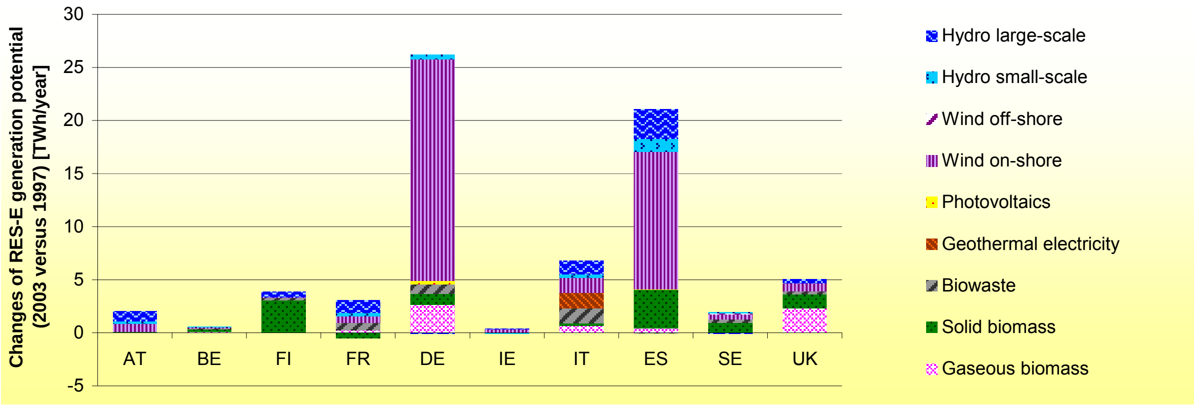

Figure 4. Total additional RES-E generation potential (2003 versus 1997)

In a next step we would like to show the progress made by these countries since the publication of the White Paper "Energy for the future" in 1997 in terms of the RES-E share in gross electricity consumption. In Figure 5, the RES-E share is shown based on the generation potential, which represents the actual generation corrected by the annual volatility of hydropower and wind energy. As can be observed, only a few countries have actually significantly increased their RES-E share within the considered period. Notably Finland, Germany and Spain have made reasonable progress towards reaching the 2010 targets.

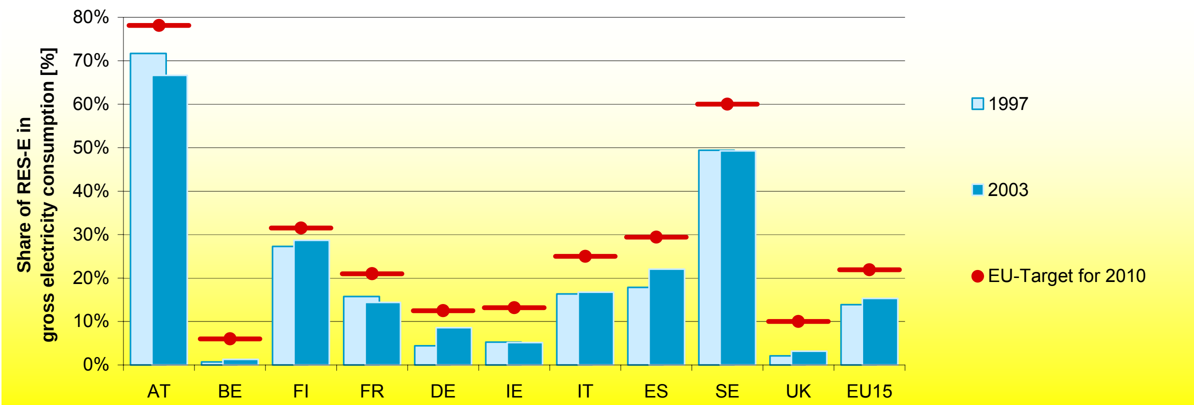

Figure 5. Share of renewable electricity generation potential in gross electricity consumption (2003 versus 1997) based on the generation potential

represent normal conditions, e.g. in case of hydropower, the normal hydrological conditions, and furthermore, not all plants are installed at the beginning of each year.

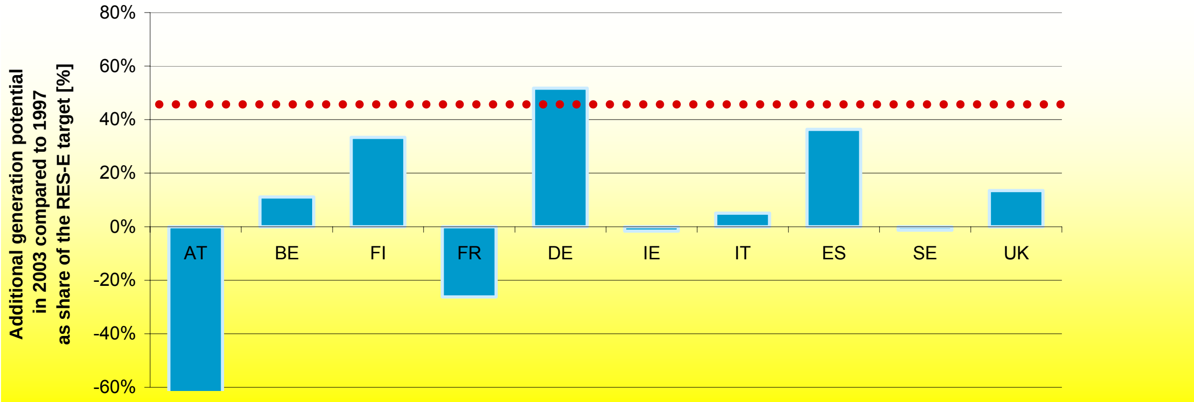

Figure 6. Additional generation potential in 2003 compared to 1997 as a share of the total additional generation potential needed by 2010 according to the RES-E directive

In Figure 6 we show the progress made in reaching the Member State targets for 2010 in more detail by depicting the fraction of the difference to target between 1997 and 2010 which was already achieved by 2003. If countries were on track in a linear annual break-down of the target, they should have fulfilled 46.2% of the difference to target by 2003. As can be seen, most countries, except Austria and France, have increased their RES-E share since 1997. However, only Finland, Germany and Spain show the growth needed to reach the target based on a linear extrapolation of the historical development.

Clearly, there are two different explanations for slow progress in reaching the RES-E target: too little progress concerning the development of renewable technologies or a high growth in gross electricity consumption.

Clearly a slow progress towards reaching the RES-E target might have two different reasons: too little progress concerning the development of renewable technologies or a high growth of gross electricity consumption. In order to separate the two effects Figure 7 shows the average annual growth rate of the renewable electricity generation potential and the average annual growth of the electricity consumption. As can be seen especially in countries like Ireland, Austria and Spain the progress made on the development of RES-E was diminished to a significant extent by the growing electricity consumption. In other countries like Sweden and France the slow progress on the promotion of renewables was the main reason for the limited success in approaching the targets. We would like to clearly state here that the average annual growth of the RES-E generation potential given in Figure 7 should not be primarily used to evaluate the progress with respect to RES-E in the different countries. The reason is that this quantity represents a biased indicator (if applied for measuring RES-E progress), which is naturally at a high level in countries with low RES-E share and visa versa. In order to judge the progress in terms of RES-E promotion the effectiveness indicator defined in section 4 represents the better suited indicator.

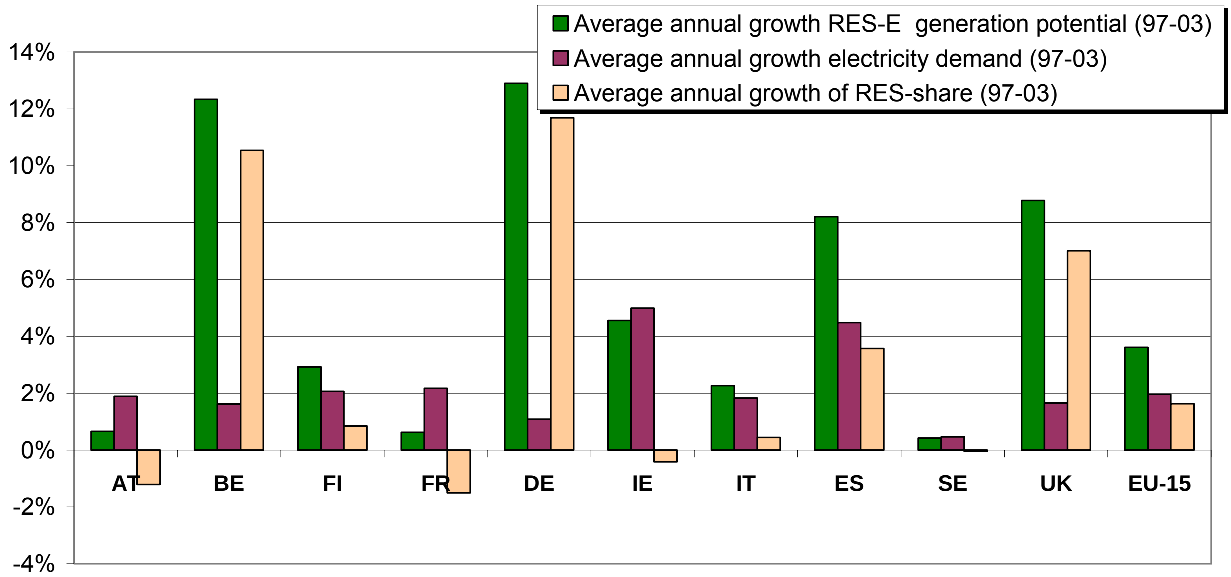

Figure 7. Comparison of average annual growth rates of renewable electricity generation potential and electricity demand in the period 1997-2003

In the following tables a detailed characterisation of the present status of the RES-E markets and the policy environment in the selected member states will be given. Besides stating the main policy instrument for the promotion of RES-E the crucial implementation details of this policy are given as well as additional support schemes, which supplement the main instrument. Furthermore we shortly review the status of the RES markets in those countries and give the critical barriers that hindered stronger progress during the recent past (This information builds on the results derived in the EU financed projects FORRES 2020 and OPTRES.).[6]

6 For further information please visit: www.isi.fhg.de/forres and www.optres.fhg.de

Austria

Main instrument	**Feed-in tariffs** (terminated by 31 December 2004)
Main implementation details	Renewable Energy Act 2003. (Ökostromgesetz). Technology-specific FITs guaranteed for 13 years for plants which get all permissions between 1 January 2003 and 31 December 2004 and, hence, start operation by the end of 2006. An amendment to the Renewable Energy Act, which was proposed in 2004, was rejected in December 2004. Since the active period of the former instrument has not been extended, there is currently a kind of "policy vacuum" in Austria. No new plants receive permissions. In August 2005 the time limit for implementing of already approved biogas, biomass and small hydro installations has been extended until December 2007. The level of tariffs implemented in 2003 can be summarised as follows: In general, this support is guaranteed for the first 13 years of operation. Small hydro: 31.5-62.5 €/MWh PV systems: (Only active in early 2003 as a limitation was included – i.e. until a national cumulative capacity of 15 MW was reached) 600 €/MWh for plants < 20 kW_{peak} ;470 €/MWh for plants > 20 kW_{peak} Wind systems: 78 €/MWh for new plants Geothermal energy: 70 €/MWh for electricity fed into the grid Solid biomass and waste with large biogenic fraction: 102-160 €/MWh, 65 €/MWh (hybrid plants) Biogas: 103 – 165 €/MWh Sewage and landfill gas: 30 - 60 €/MWh
Additional support	Investment incentives of up to 30% on federal and regional level.
Status of RES-E market	Stimulated by the feed in tariffs a steady growth especially in the sectors of wind energy and biomass electricity was observed. Currently there is a hold on further RES-E investments, because no support (other than moderate investment incentives) exists.
Main barriers	Continuity is the main problem due to short operational period (until end of 2004) of the feed in tariffs. In some areas grid shortages represent a barrier.

Belgium

Main instrument	**Quota / TGC and feed-in-tariffs (minimum tariffs)**
Main implementation details	In Belgium a combined support scheme is implemented by the regional authorities (except for wind offshore), FIT shall secure the price level of the TGCs. The main promotion scheme for RES in Belgium is a green certificate system with mandatory demand and guaranteed minimum prices ('fall-back prices') for green certificates at federal level. Minimum prices are: Wind offshore: 90 €/MWh Wind onshore: 50 €/MWh Solar: 150 €/MWh Biomass and other RE: 20 €/MWh Hydro: 50 €/MWh Companies which do not reach the target by the end of the certificate accounting period have to pay a penalty. The penalties are varying according to regions. The penalty prices per certificate (1 MWh) in 2005 are: Flanders: 125 €/missing certificate (1 MWh) until 2010 Walloon: 100 €/missing certificate (1 MWh) until 2007. New penalties will be introduced in 2005. Brussels: 75 €/missing certificate (1 MWh) until 2006. Penalty is 100 € between 2007-2010
Additional support	Investment support available
Status of RES-E market	Still an immature RES-E market due to policy change in 2002 and due to small size of the regional certificate markets.
Main barriers	Because of the possibility of banking of certificates and formerly increasing penalty rates and a shortage on certificates, not much trading has taken place, as it is more favourable of paying penalties the first year and use the certificates in later periods. Due to the division by regions the Belgium market is not fully transparent. Furthermore the markets are rather small, resulting in an illiquid market with little trade.

Finland

Main instrument	**Tax exemption**
Main implementation details	Exemption on energy tax for renewable electricity: Value of tax exemption: Wind: 7.3 €/MWh Biomass/Small hydro: 4.4 €/MWh Recycled fuels 2.5 €/MWh
Additional support	Investment incentives are available for new investments (up to 30%, in case of wind up to 40%)
Status of RES-E market	Renewables cover currently around 28% of the Finnish total electricity consumption supplied by two key sources: hydro power (70%) and biomass (30%). Over the past decade a significant increase has been realised in the deployment of biomass in particular in the form of CHP and large units for pure electricity generation.
Main barriers	The value of total available support does not completely cover the price gap with fossil or nuclear based competitors. This holds in particular for wind energy. Furthermore political instability and resulting uncertainty on future energy support programmes have sometimes resulted in withholding new renewable energy investments.

France

Main instrument	**Feed-in-tariffs**
Main implementation details	FITs for RES-E plant < 12 MW (this limit does not apply to wind on-shore) guaranteed for 15 years (20 years PV and Hydro): Support level of FITs: Wind: 30,5-83,8 €/MWh[7] Biomass 49-61 €/MWh Geothermal: 76-79 €/MWh PV: 152,5-305 €/MWh Landfill gas: 45-57,2 €/MW Hydro: 54,9-61 €/MWh[8] MSW: 25,8-47,2 €/MWh
Additional support	Investment subsidies for Photovoltaics, Biomass and Biogas Tender system for installations > 12 MW with guaranteed price contracts (except for wind on-shore, which is generally supported by FITs). Calls for projects have been published for biogas and wind technology.

7 Stepped FIT: 83,8 €/MWh for the first 5 years of operation and then between 30,5 and 83,8 €/MWh depending on the quality of site

8 Producers can choose between four different schemes. The table shows the flat rate option. Within other schemes tariffs vary over time (peak/base etc.)

Status of RES-E market	Renewables cover currently around 16% of the French total electricity consumption. This supply is covered mainly by hydro power. Despite significant resources wind, biomass and geothermal energy play currently an insignificant role in the electricity sector.
Main barriers	Concerning wind, resistance by local authorities regarding the regulative approval of new projects can be specified as a problem. Moreover grid integration and future acceptance by the grid operator represents a barrier to further RES-development.

Germany

Main instrument	**Feed-in tariffs**	
Main implementation details	German Renewable Energy Act: FITs guaranteed for in general 20 years In more detail, FITs for new installations (installed after August 8, 2004) are (digression):[9]	
	Hydro:	37-76.7 €/MWh (1%/a for large hydro)
	Wind[10]:	55-91 €/MWh (2%/a)
	Biomass & Biogas:	84-195 €/MWh (1,5 %/a)
	Landfill-, Sewage- & Mine Gas:	66.5-96.7 €/MWh (1,5 %/a, except of Mine Gas)
	PV & Solar thermal electricity:	457-624 €/MWh (5-6,5%/a)
	Geothermal:	71.6-150 €/MWh (1%/a, starting 2010)
Additional support	Soft loans and investment incentives by the market incentive programme for biomass CHP, small hydropower. Soft loans by a federal investment bank DtA (a relevant share of Germanys wind energy investments is financed by government loans)	
Status of RES-E market	The renewable energy market in Germany is mature showing large growth rates even at high penetration rates. Biomass and wind-offshore might be considered as the only source that is lacking behind the expectations (high growth of biomass can be observed since the revision of the Renewable Energy Act in 2004). The stable policy support has stimulated continuous and high growth especially in the case of wind energy, PV and biogas installations during the past decade.	

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9 The level of the tariff per kWh is constant for an installation after commissioning for in general 20 years, but depends on the date of commissioning. The later the initial operation is, the lower the tariff will be according the degression rates given in brackets.

10 Stepped FIT: In case of onshore wind 87 €/MWh for the first 5 years of operation and then between 55 and 87 €/MWh depending on the quality of site.

Main barriers	Partially exploited potentials and limited grid capacity in the northern parts of Germany presently slow down growth of onshore wind energy on a high level of the market. Offshore wind energy develops slower than expected due to unexpected high costs and unsolved technical problems (high distance from land and large water depths). Biomass development was slower than expected (until 2005) due to fuel price uncertainty and high infrastructure costs. Most of the low-cost potentials (wood wastes) have already been exploited.

Ireland

Main instrument	**Tender (until end of 2005) / Feed-in Tariffs starting in 2006**
Main implementation details	Tender system: Alternative Energy Requirement (AER V, AER VI)[11]: Price caps of purchase contracts: Large scale wind (> 85MW): 52 €/MWh; Small scale wind (< 85MW): 57 €/MWh; Offshore Wind : 84 €/MWh; Biomass: 64 €/MWh; Biomass-CHP: 70 €/MWh; Biomass-anaerobic digestion: 70 €/MWh; Hydro (< 5 MW): 70 €/MWh Tariffs under the new feed-in tariff (draft figures January 2006): Large scale wind (>5MW) 57 €/MWh Small scale wind (<5MW) 59 €/MWh Biomass (including landfill gas) 70 €/MWh Hydro and other biomass 72 €/MWh The duration of the feed-in tariff is 15 years.
Additional support	Tax relief for investment in RES-E
Status of RES-E market	Traditionally hydropower is by far the most important renewable electricity source in Ireland, though in recent years production from other RES-E such as wind and biogas is increasing. However, compared to a high wind power potential in Ireland, until 2003 relatively moderate growth rates could be observed. As a result of the bidding round in 2004 the amount of additionally installed wind power capacity was considerably higher than in former years (153 MW).
Main barriers	The crucial barriers for further growth rates in Ireland are caused by the characteristics of the tender system. One constraint can be the fact, that bidding winners do not realize their projects due to non-economic contract conditions. The AER also tends to lead to relatively poor quality of equipment as the lower-price bids win the competition. Uncertainty about

11 Front weighting of the tariffs is allowed by offering the possibility to increase the price the first 7,5 years of the contract combined with a decrease of 35 % for the remaining contract duration.

	future target setting (both levels and technology preferences) seems to one constraint of the Irish tender system, since it is a stop-start programme. Moreover projects eligible may not exceed certain capacity levels which may lead to a certain inefficiency of the project design.

Italy

Main instrument	**Quota / TGC**
Main implementation details	Quota obligation (based on TGCs) on electricity suppliers: 2.35% target (2004), increasing yearly up to 2008; TGC issued for all (new) RES-E (incl. large Hydro and MSW) – with rolling redemption[12]; Relatively high certificate prices up to 117 €/MWh, certificates are issued only for plants with production of more than 50 MWh per year. Green certificates are only issued during the first 8 years of operation of a plant.
Additional support	Feed-in tariffs for PV, tariffs 445-490 €/MWh; total capacity limit 100 MW
Status of RES-E market	The quota system can be called still rather immature. The interim targets of the quota obligation set by the national government have not been reached. Among the new renewables in the electricity sector only wind energy and biowaste have shown relevant growth rates in the recent years.
Main barriers	The major problem of developing new production capacity seems to be problems in getting authorisation at the local level, high risk level for investors and high grid connection costs.

12 In general only plant put in operation after 1st of April 1999 are allowed to receive TGCs for their produced green electricity. Moreover, this allowance is limited to the first 8 years of operation (rolling redemption).

Spain

Main instrument	**Feed-in Tariff**
Main implementation details	FITs (Royal Decree 436/2004): RES-E producer have the right to opt for a fixed price or for a premium tariff[13]. Both are adjusted by the government according to the variation in the average electricity sale price. In more detail the level of the fixed tariff for 2004 amounted to: Wind: 64.9 €/MWh PV[14]: 216-414 €c/kWh Small Hydro: 57.7-64.9 €/MWh Biomass: 57.7-64.9 €/MWh Most operators have chosen the premium option in 2005 due to high electricity prices.
Additional support	ICO-IDAE funding line, which provides with special conditions to investments in RE and RUE investments. In general, investment incentives, soft loans and tax incentives were defined under the "*Plan de Fomento de las Energias Renovables*" (RES Promotion Plan), whose aim is to support RES investments with 13.1 % public financial sources
Status of RES-E market	Wind power has developed impressively. The biomass sector still needs an integral policy and probably higher tariffs in the feed-in system. Concentrating solar thermal power production shows impressive activities with regard to project development: about 200 MW of installed capacity are under construction.
Main barriers	Small hydro needs to overcome the administrative barriers.

Sweden

Main instrument	**Quota / TGC**
Main implementation details	Quota obligation (based on TGC) on consumers: Increasing from 7.4% in 2003 up to 16.9% in 2010. Non-compliance leads to a penalty, which is fixed at 150% of the average certificate price in a year (26 €/MWh in 2005). The certificate price is insufficient to initiate significant investments into new capacities.
Additional support	Investment incentives of 15% for wind power. During a transition period the certificate trading scheme will be complemented by targeted support for wind power production in the form of environmental bonus, (13-19

13 In case of a premium tariff, RES-E generators earn in addition to the (compared to fixed rate lower) premium tariff the revenues from the selling of their electricity on the power market.

14 Depending on the plant size: <5kW: 360 €/MWh or >5kW: 180 €/MWh

	€/MWh) for wind energy in 2004. This will be progressively be phased out by 2009. The environmental tax benefits can make some biomass CHP systems competitive.
Status of RES-E market	Renewables cover currently approximately 50% of the Swedish total electricity consumption. This supply is covered mainly by hydro power. The use of biomass has increased substantially over the past decade, but this growth is mainly based on biomass co-firing, which can be profitable in the present quota system. New investments in biomass generation capacity is limited. Wind capacity installed in Sweden is relatively low although the wind resource in the south of the country is comparable to Denmark.
Main barriers	Low penalty level set in the quota system leads to the strategy to fulfil the quota through buy-out. The Government has declared that in the (near) future the certificate system may be opened for import. This market opening may pose a threat for investments in renewables in Sweden if a level playing field with the relevant import country (Norway) is lacking.

United Kingdom

Main instrument	**Quota / TGC**
Main implementation details	Quota obligation (based on TGCs) for all RES-E: Increasing from 3% in 2003 up to 10.4% by 2010 and 15.4% in 2015. The non-compliance 'buy-out' price for 2003-2004 was set at £30.51/MWh (45 €/MWh), for 2004-2005 at £31.39/MWh (45 €/MWh), for 2005-2006 at £32.33/MWh (48 €/MWh). The actual certificate price is typically higher than the buy-out price due to the system of recycle payments.
Additional support	In addition to the TGC system, eligible RES-E are exempt from the Climate Change Levy certified by Levy Exemption Certificates (LEC's), which cannot be separately traded from physical electricity. The 2004 levy rate is 4.3 £/MWh (6.3 €/MWh). Investment grants in the frame of different programs (e.g. Clear Skies Scheme, DTI´s Offshore Wind Capital Grant Scheme, the Energy Crops Scheme, Major PV Demonstration Program and the Scottish Community Renewable Initiative).
Status of RES-E market	The UK RES market can probably be called the most mature market among the countries with quota obligations in Europe. The relative success of the systems is partially based on the fact that buy-out revenues for non-compliances are recycled to the suppliers in proportion to the certificates they have used for complying with the obligation. This mechanism increased the certificate price above the buy-out price because the market is short. High prices in the first year gave the Renew-

	able obligation certificate market a kick- start. Targets specified for 2010 and 2020 and duration specified until 2027. Compared to other quota systems the UK system provides a higher long-term security for achieving targets and for renewable energy investors.
Main barriers	Grid connection issues and grid capacities as well as severe competition on the electricity market disadvantage RES despite of the support programs.

4 EFFECTIVENESS OF THE IMPLEMENTED SUPPORT SCHEMES IN SELECTED EU MEMBER STATES

Under the effectiveness of a policy scheme for the promotion of renewable electricity we understand the increase of electricity generation potential[15] due to this policy as compared to a suitable reference quantity. Such a reference quantity could be the additional available renewable electricity generation potential[16] or the gross electricity consumption.

We define the effectiveness of a Member State policy in the following as the ratio of the change of the electricity generation potential during a given period of time and the additional realisable mid-term potential until 2020 for a specific technology, where the exact definition of the effectiveness reads as follows:

$$E_n^i = \frac{G_n^i - G_{n-1}^i}{ADD - POT_{n-1}^i}$$

E_n^i Effectiveness Indicator for RES technology i for the year n

G_n^i Electricity generation potential 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 the effectiveness has the advantage of giving an unbiased indicator with regard to the available potentials of a specific country for individual technologies. Member States, only need to develop specific RES-E sources proportionally to the given potential to show comparable effectiveness of their instruments. This appears to be the correct approach because the Member State targets determined in the RES-E directive are also derived based mainly on the realisable generation potential of each country.

In the following section we will show this effectiveness indicator for the sectors wind onshore and PV for the period 1997-2004 and for solid biomass and biogas for the period 1997-2003. As in most EU Member States, significant policy changes took effect during this period. The evolution of the main support instrument for each country is given in Figure 8. This figure shall serve as the relevant basis for the interpretation of the effectiveness indicator presented. As can be seen, only Austria, Finland, Germany, Ireland and Spain did not experi-

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

16 The additional potential up to 2020 used in this report is based on the figures derived in the EU projects Green-X and FORRES 2020, which have been officially used by the European Commission do analyse future targets for renewable energies up to 2020.

ence a major policy shift during the period 1997-2005. Belgium, Sweden and the UK changed their instruments into quota systems based on tradable green certificates during 2002 or later. Although the introduction of the new systems in these Member States took place during or after 2002, the policy changes caused investment instabilities even in the periods before this date. Therefore, for the period 1997-2003 (or 1997-2004) for which the effectiveness indicator is analysed in the subsequent section, a mixed policy is considered in Belgium, France, Italy, Sweden and the UK. In principle it would seem desirable to present temporal correlations between the implemented policies and the effectiveness indicator which are both known in the time domain. However, previous analyses have shown that only restricted information results from the temporal representation of the effectiveness indicator. Therefore we will show this quantity as an average value for the period 1997-2003 for case of biogas and solid biomass and 1997-2004 for the case of wind on-shore and PV.

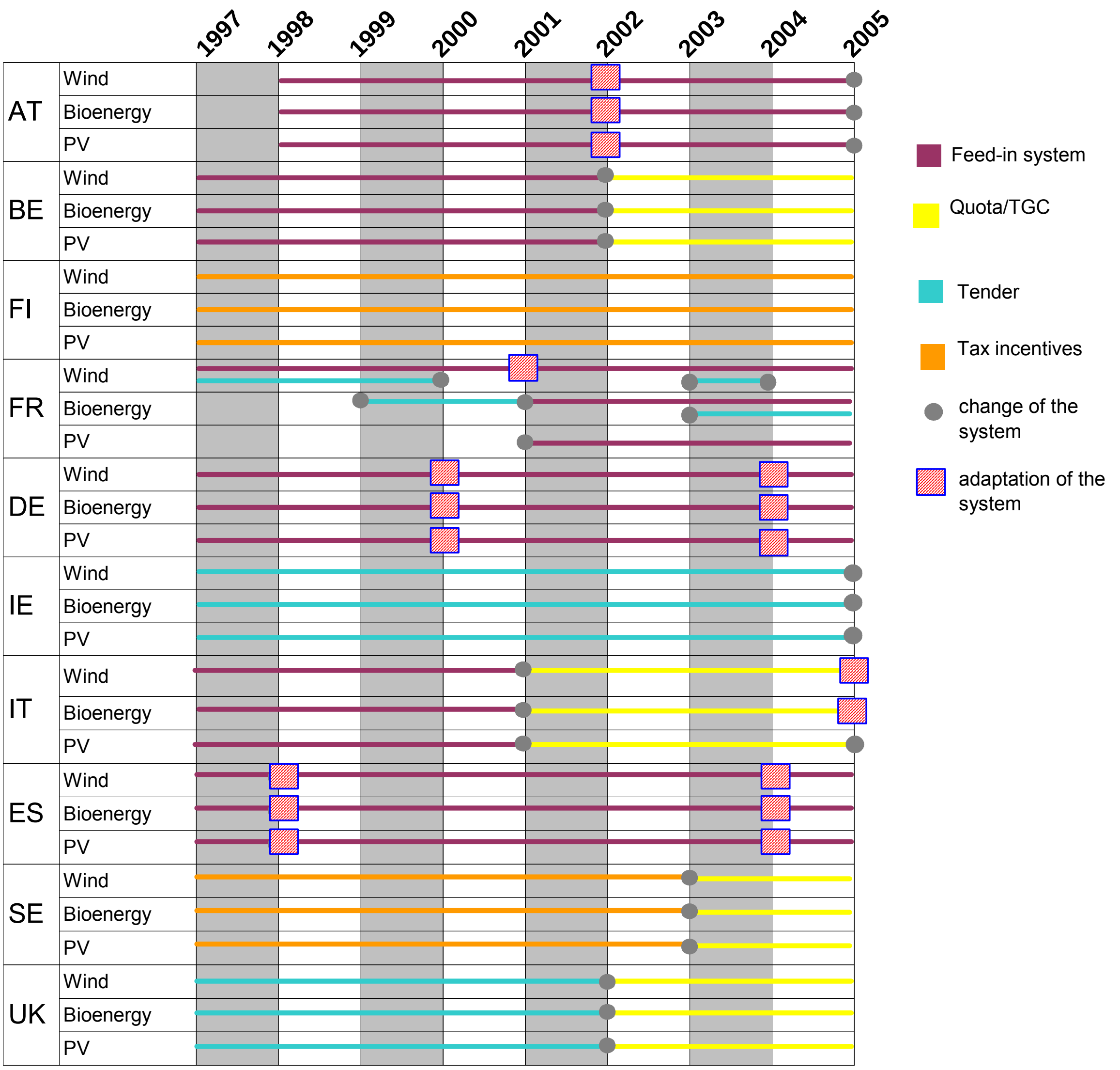

Figure 8. Evolution of the main policy support scheme in selected EU Member States

Figure 9 shows the average annual effectiveness indicator for **wind on-shore** electricity generation for the years 1997-2004 for all countries selected in the present analysis.

Several messages can be derived from this figure. Firstly, the three Member States Germany, Spain, and Ireland with the highest effectiveness during the considered period did not experience a major policy shift during the entire period 1997-2004. Even more striking is the fact that Germany and Spain - two countries with long term stability of RES-E support based on feed-in systems - show a significantly higher effectiveness than the rest of the countries considered here. The high investment security and low administrative and regulative barriers have stimulated a strong and continuous growth in wind energy during the last decade. It is commonly stated that the high level of the feed-in tariffs would be the main driver for investments in wind energy in these two countries. However, as will be shown at the end of this section in Figure 15 and Figure 18, the tariff level is not particularly high in the two countries when compared with the other countries analysed here. The conclusion can therefore be drawn that a long term and stable policy environment is a key criterion for success in developing RES markets. As can be observed in 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.

A detailed analysis of the main barriers and success factors in wind energy for each of the countries analysed is given in Table 2.

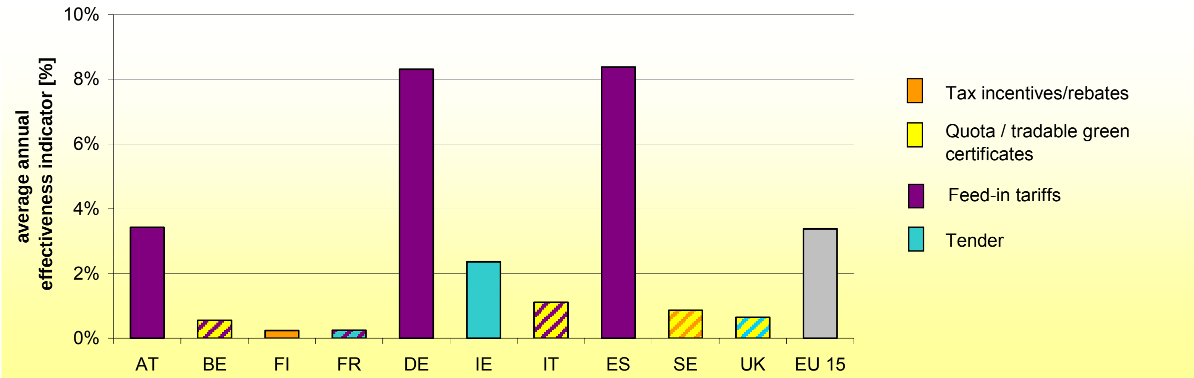

Figure 9. Effectiveness indicator for wind on-shore electricity in the period 1997-2004.

Note: The relevant policy schemes during this period are shown in different colours

Table 2. Summary of main barriers and success factors for wind energy (1997-2004)

Member State	Support level	Main barriers	Comments
AT	sufficient	grid capacity policy instability	The growth of wind energy has significantly accelerated since the new feed-in law was launched in 2003
BE	high	investment risk	Continuous growth at a low level, no acceleration of market growth observed since the introduction of the quota system in 2002
FI	low	level of support social acceptance	Finland is one of the few countries in the EU-15 where the level of support is clearly insufficient to promote wind on-shore
FR	sufficient - high	administrative / regulative grid connection rules	Significant administrative / regulative barriers exist at regional / department level. Large number of administrative procedures necessary to get a project approved
DE	sufficient	grid (some regions) regional planning	In Northern Germany, insufficient grid capacity hampers development of wind energy. New distance regulations for wind energy constitute a clear barrier regarding regional planning.
IE	sufficient	stop-and-go character of support system grid capacity	The nature of the tender system implies that very discontinuous growth takes place leading to market instabilities, many projects that have been awarded are not realised because offers are economically unfeasible
IT	high	investment risk grid capacity	Despite the high support level growth is only moderate due to the uncertainty of the certificate system, lack of private financial funds and experience among investors as well as limited grid capacity in some regions
ES	sufficient - high		The market grew continuously at high level high support and generally low barriers
SE	low	level of support investment risk	Support level is clearly insufficient to develop viable projects
UK	high	investment risk	The tender system (until 2002) showed very low effectiveness: many projects that have been awarded are not realised because offers were economically unfeasible or environmental and planning permissions were not granted. Since the introduction of the quota system, the high level of investment risk is the main barrier followed by insufficient grid capacities in the Western UK

Table 3. Summary of main barriers and success factors / solid biomass electricity (1997-2003)

Member State	Support level	Main barriers	Comments
AT	high	policy instability	The growth of biomass electricity has significantly accelerated since the new feed-in law was launched in 2003. Austria focused its policy on small plants which led to comparatively high promotion costs
BE	high	investment risk	Some growth in biomass since the introduction of the quota system in 2002 in particular because co-firing is permitted
FI	sufficient	level of support	Finland shows a continuous growth of biomass electricity due to strong tradition in the forestry industry and a well balanced mix of investment support and generation-based support
FR	low - sufficient	level of support administrative / regulative barriers	Significant administrative / regulative barriers exist at regional/department level, a large number of administrative procedures is necessary to get a project approved
DE	sufficient	level of support (until 2004) security of fuel supply	Limited security of the fuel (wood) supply (missing infrastructure and markets) led to some retention for banks and finance organisations and consequently to the cancellation of a number of projects
IE	low	stop-and-go character of support system technology selection of the tender system	Biomass was hardly targeted in the Irish tender rounds also based on the fact that the potential of cheap wood-based fuels is very limited
IT	high	investment risk	Despite the high support level the growth is only moderate due to the uncertainty of the certificate system, lack of private financial funds and experience among investors, the option of co-firing biomass offers large potentials at low costs
ES	low	level of support	The main barrier to a stronger growth in the biomass sector is the level of support
SE	low - sufficient	level of support investment risk	Sweden has shown growth since 2000 (the moderate effectiveness is based on capacity growth until 2000), neither the quota system nor the tax incentives have given sufficient support despite the fact that Sweden has a traditionally strong forestry sector
UK	high	investment risk	The tender system (until 2002) showed moderate effectiveness but with a clear stop and go nature (most projects were realised in one year - 2001). Since the introduction of the quota system, the high level of investment risk is the main barrier, the option of co-firing biomass offers significant potentials at low costs

In Figure 10 the effectiveness indicator for RES support for electricity from solid biomass is shown. It can be seen that, on the EU-15 level, a significantly smaller proportion of the available potential was able to be exploited on an annual basis during the period 1997-

2003. As is well known, the development of biomass electricity is lagging behind expectations on an EU level even though it is cost efficient in countries where sufficient exploitable wood waste potentials exist. The main barrier to the development of this RES-E source is often infrastructural rather than economic. Since solid biomass represents the cheapest RES-E source in some countries such as Finland and Sweden it attracts the largest share of RES-E investment under policy schemes which are not technology-specific. The tax measures in Finland and in Sweden (before 2002) as well as the present Swedish support scheme (quota obligation) result in concentration on the current least-cost technology. Very often additional RES-E generation under these support schemes is possible even without investments in additional generation capacity.

The static efficiency of these instruments is improved at the cost of ignoring promising future technology options with significant potential for technology learning. Certainly the long term traditions in the biomass sector and the importance of the forestry industry in countries like Finland and Sweden are strong success factors for the development of the biomass electricity sector. Thereby, the low generation costs of biomass plants in Finland are a result of the fact that most plants are large scale industrial units operating in CHP mode.[17] The demand for (industrial process) heat in the Scandinavian countries is a good basis for CHP-plants leading to reduced electricity generation costs. For this reason Finland has a good background for building of cost-efficient large-scale plants. Finland possesses for example of the worlds largest biofuel-fired CHP-plant, Alhomens Kraft with an electrical capacity of 240 MW. Moreover, the dominant solid biofuel source in Finland is black liquor[18]. All the described factors lead to favourable generation costs in Finland.

However, the nature of the RES support scheme which promotes only the cheapest technology options is a critical success factor as well, which can also be concluded from the UK case.

A detailed analysis of the main barriers and success factors in the field of biomass electricity for each of the countries analysed is given in Table 3

17 In 2000, the share of biomass CHP in electricity production from all RES was 34%.

18 In 2000, more than half of the biomass fuel used for primary energy supply was black liqour.

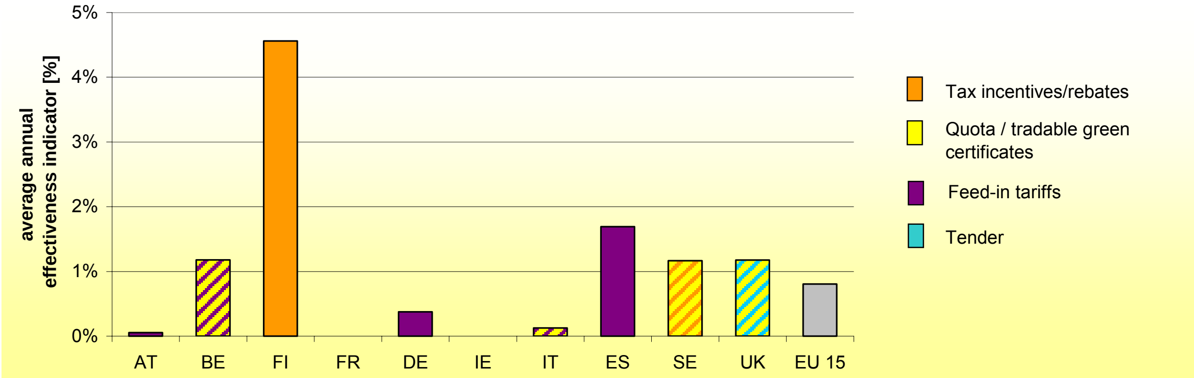

Figure 10. Effectiveness indicator for solid biomass electricity in the period 1997-2003.

Note: The relevant policy schemes during this period are shown in different colours

In Figure 11 the effectiveness indicator for RES support for biogas electricity is shown. Similar to the sector of solid biomass electricity, the overall progress on EU level was relatively low in the period 1997-2003. The highest growth is shown by Germany, which applies fixed feed-in tariffs and the UK, which used a tender system until 2002 and a quota system since 2003. Italy, Austria and Belgium also showed a comparatively high effectiveness. However, the biogas development in the UK, in Italy and in Belgium seems to be dominated by landfill gas, which represents the cheapest kind of biogas fuel. This conclusion results from observing the composition of gaseous biomass in the year 2001 illustrated in Figure 12. Thus, the policy effectiveness reached by the German and the Austrian systems seems to have a better performance than the UK, Italy and Belgium for the case of the more innovative option of agricultural biogas. The Swedish and the Finish tax rebates have been unable to trigger relevant investments in biogas plants. This demonstrates again that these systems are not suited to stimulate the market diffusion of new technologies. Similarly the Irish tender rounds seem to have ignored biogas as an option for increasing RES-E generation capacity.

A detailed analysis of the main barriers and success factors in biogas electricity is given in Table 4 for each of the countries analysed.

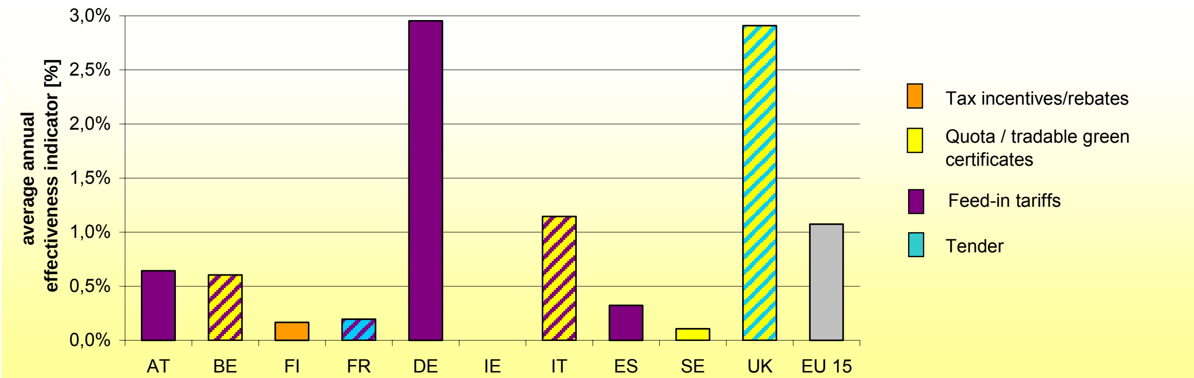

Figure 11. Effectiveness indicator for biogas electricity in the period 1997-2003.

Note: The relevant policy schemes during this period are shown in different colours

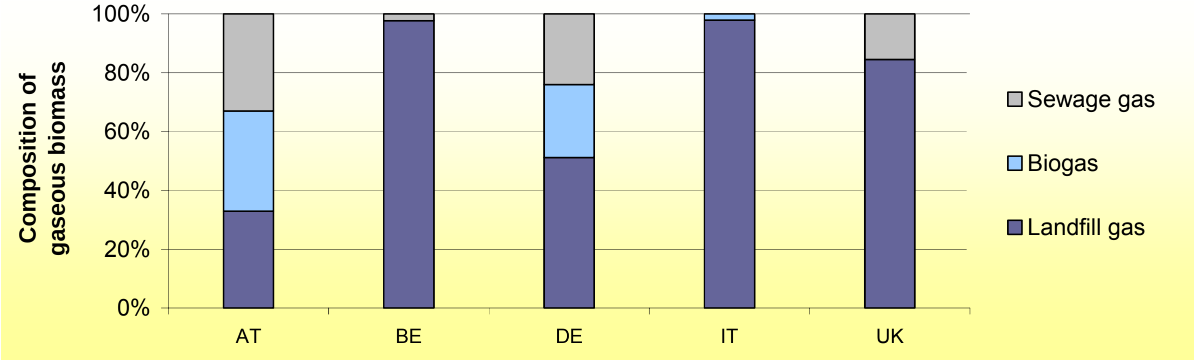

Figure 12. Share of different gaseous biomass types in selected countries for the year 2001.

Table 4. Summary of main barriers and success factors / biogas electricity (1997-2003)

Member state	Support level	Main barriers	Comments
AT	high	policy instability	The growth of biogas electricity has significantly accelerated since the new feed-in law was launched in 2003. Austria focused its policy on small plants which led to comparatively high promotion costs; in the sector of agricultural biogas in particular the Austrian policy was very successful Austria shows a balanced share between agricultural biogas and landfill gas
BE	high	investment risk	Biogas electricity production showed steady growth until 2002 The high level of investment risk led to low growth in recent years The biogas portfolio is largely dominated by landfill gas
FI	low	level of support	No targeted support given for biogas electricity
FR	low	level of support administrative / regulative barriers	The level of support is too low to generate sufficient interest among investors; significant administrative / regulative barriers exist at regional / department level. The biogas portfolio is largely dominated by landfill gas
DE	sufficient	administrative regulations regarding the approval / licensing of biogas plants	The steady market growth observed during the last decade has accelerated since the tariffs were increased in 2004. Almost equal share between agricultural biogas and landfill gas
IE	low	stop & go nature of support system technology selection of the tender system	Biogas was hardly targeted in the Irish tender rounds, existing biogas production is almost entirely based on landfill gas
IT	high	investment risk for the more expensive biogas fractions pure focus on landfill gas	Strong growth of biogas electricity especially since 2001 Almost the entire biogas generation is based on landfill gas Despite the high support level, the growth in agricultural biogas is very low due to the uncertainty of the certificate system, lack of private funds and experience among investors
ES	low - sufficient	level of support	The strongest growth was achieved in sewage gas
SE	low	level of support investment risk	Sweden shows hardly any growth in the biogas sector since both the former tax incentives as well as the present certificate system are not sufficiently attractive to justify investments
UK	high	pure focus on landfill gas investment risk for the more expensive biogas fractions	The tender system (until 2002) showed high effectiveness with a clear focus on expansion of landfill gas; hardly any development in agricultural biogas. The growth continues under the quota system

As presented in Figure 13, the sector of photovoltaic electricity generation has the strongest growth in Germany followed by Austria and Spain during the considered period (1997-2004). The support system in these three countries consisted of fixed feed-in tariffs supplemented by additional mechanisms like soft loans in Germany. As was expected, quota obligations and tax measures give only very little incentives for investments in PV technology, since these schemes generally promote only the cheapest available technology.

A detailed analysis of the main barriers and success factors in the filed of photovoltaics is given in Table 5 for each of the countries analysed.

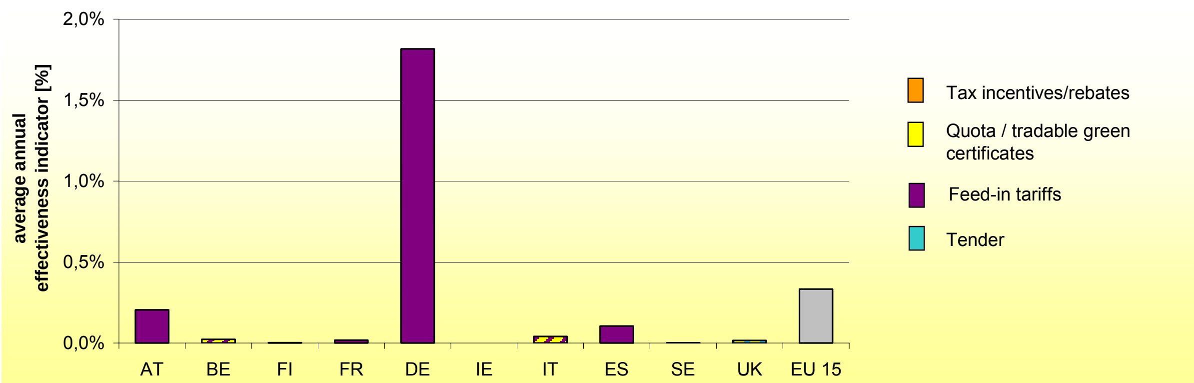

Figure 13. Effectiveness indicator for photovoltaic electricity in the period 1997-2004.

Note: The relevant policy schemes during this period are shown in different colours

Table 5. Summary of main barriers and success factors / PV (1997-2004)

Member state	Support level	Main barriers	Comments
AT	high	policy instability capacity cap	The level of support under the former feed-in act was reasonably high, however the overall capacity cap of 15 MW was the main barrier
BE	low	level of support	The level of support of 15 € cents / kWh is insufficient to stimulate investments.
FI	low	level of support	No targeted support for PV
FR	low	level of support	The level of support of 15 € cents / kWh is insufficient to stimulate investments.
DE	sufficient - high		Very strong growth of PV; since amendment of the renewable energy act in 1-2004 the growth has accelerated significantly leading to a slightly overheated market
IE	low	level of support	No targeted support for PV
IT	low	level of support	The level of support is insufficient to stimulate any investments
ES	sufficient		The increased capacity limit (to 100 kW) determining eligibility for the higher tariff level makes many medium-scale projects profitable and has significantly driven the market during the last year
SE	low	level of support	No targeted support for PV
UK	low	level of support	No targeted support for PV

Finally we would like to present the average effectiveness indicator for small hydropower in Figure 14. It can be seen that the effectiveness takes the highest level in Spain followed by Belgium and Germany. It should be considered here, however, that the remaining potential in Belgium is by far the smallest among the countries under consideration. The level of support is moderate to sufficient in all countries considered, except in Finland where the support level has to be considered insufficient. Administrative procedures within the EU are generally complex and lengthy, and present a significant barrier to small hydro deployment. In particular the licensing of water use, environmental and planning permission, construction authorisation and plant commissioning represent the main administrative barriers for the construction of small hydro plants.

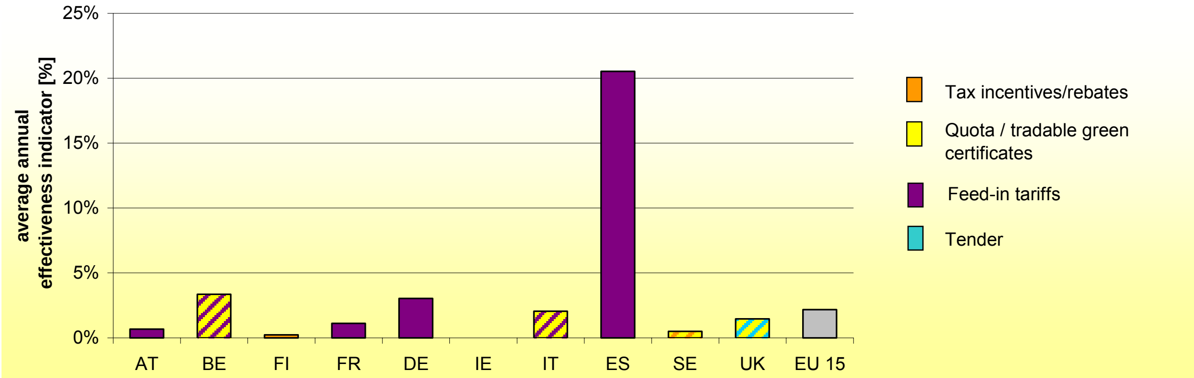

Figure 14. Effectiveness indicator for small hydro power in the period 1997-2003.

Note: The relevant policy schemes during this period are shown in different colours

4.1 Evaluation of the level of RES support in relation to the effectiveness

To complete this section, we would like to compare the observed effectiveness of the different support schemes with the level of financial support as seen from the perspective of an investor for the case of wind energy (we concentrate on the case of wind energy for the reason that costs as well as support levels can be analysed in a very transparent way). This analysis will be performed for the most recent year 2004. In a first step, the actual level of the payments per kWh of electricity generation in the year 2004 is shown for the policy systems considered. In a second step, we present the effectiveness indicator defined as above versus the expected annuity for an investment in wind energy for each country. In this way, one can correlate the effectiveness of a policy with the average annuity of expected profit. As a result it is possible to analyse whether the success of a specific policy is primarily based on the high financial incentives, or whether other aspects have a crucial impact on the market diffusion of wind power in the countries considered.

Figure 15 shows the actual average country-specific level of support and the range of tariffs for the year 2004. Belgium applies a mixture of quota obligations and a minimum tariff system to increase investment security, whereas the system can be generally classified as a quota system. The level of support for countries applying quota obligations turns out to be generally higher than in other countries if only the payments during one individual year are considered. One exception is the very low support level in Sweden. The Irish tender system is characterised by a relatively modest support level as well.

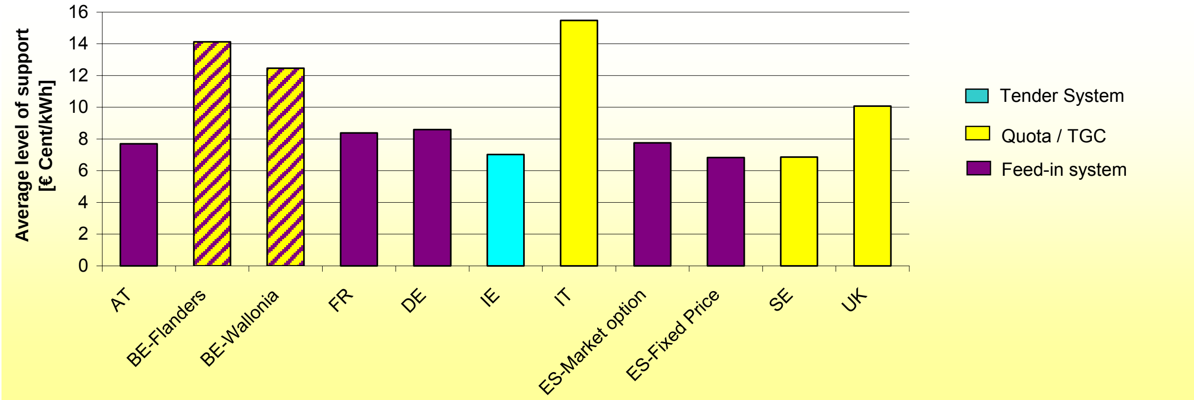

Figure 15. Comparison of actual support for wind power on-shore (2004)[19]

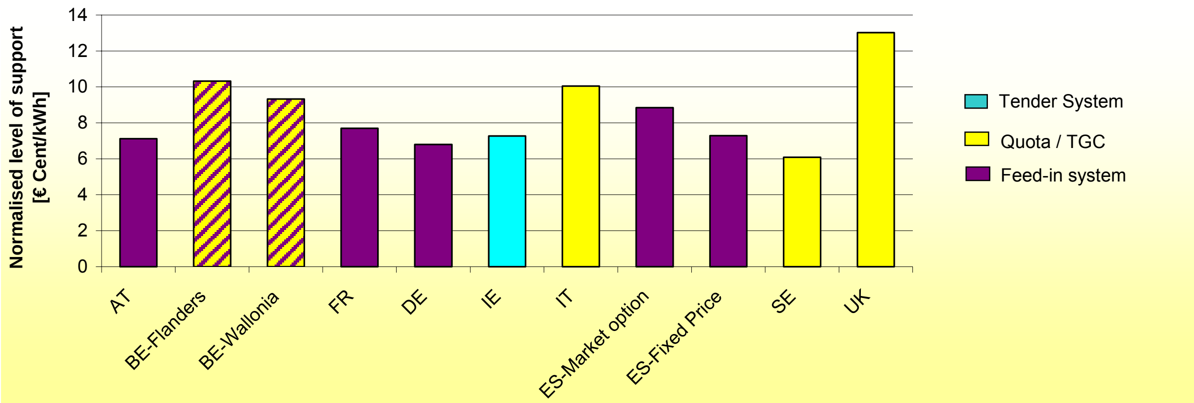

Figure 16. Normalised level of support for wind on-shore in selected EU Member States (2004)

Note: the data presented above is scaled for the country-specific duration of support, additional support measures are considered and the country-specific resource conditions are accounted for.

The annual payments presented in Figure 15 now have to be translated into a quantity that characterises the total expected profit of an investment. Therefore the duration of the payments has to be included.[20] Another aspect is that the support level presented

19 For the case of Germany the tarifs reflect the situation after the revision of the FIT in 2004.

20 An extreme example is the Italian certificate price which appears to be very high. However, considering the duration of the support, the high price partly is justified by the fact that Italian

contains only the most important instruments. Additional measures like soft loans or tax reductions are not shown. Furthermore it has to be taken into account that different wind conditions require different support levels. Thus country-specific wind yields are used to calculate the income generated during the lifetime of the plant.

In a first step we would like to show the normalised support level by considering the duration of support and by including relevant additional support measures like production and investment tax incentives as well as the country-specific resource availability. The duration of support is accounted for by calculating the annuity of the support level based on a uniform interest rate of 6.6% and a duration of support of 15 years.

The resource availability is accounted for by normalising the support level to a uniform number of 2000 full-load hours per year. Therefore the actual support level is rescaled linearly by the ratio of the country-specific full-load hours and the uniform value (in this way the support level for countries with very good resource conditions is increased while the support level for countries with poor resource conditions is decreased).

An alternative approach to calculating the actual support over the entire lifetime from an *investor's perspective* is to determine the average expected annuity of the renewable investment. The annuity calculates the specific discounted average return on every produced kWh by taking into account income and expenditure throughout the entire lifetime of a technology.

$$A = \frac{i}{(1-(1+i)^{-n})} * \sum_{t=1}^{n} \frac{Income_t - Expenditure_t}{(1+i)^t}$$

A= annuity; i=interest rate; t=year; n=technical lifetime

The average expected annuity of wind energy investments for Germany, Spain, France, Austria, Belgium, Italy, Sweden, the UK and Ireland was calculated based on the expected support level during the period the promotion is given. The level of support in the German system is annually adjusted according to the degression incorporated in the German EEG. For the four countries using quota obligation systems, the certificate prices of the year 2004 were extrapolated for the entire active period of the support.[21] Furthermore an interest rate of 6.6% was assumed[22] and country-specific prices of wind technology were used according to the average market prices of wind turbines in those countries in 2004. Therefore the annuity of expected profit considers country-specific wind resources, duration of support as well as additional promotion instruments like soft loans and investment incentives. An important limitation of this approach concerns the

renewable electricity producers are only allowed to deal with green certificates during the first 8 years of the plant's operation time.

21 This assumption is questionable because certificate prices might relax as the certificate markets in those countries mature. However, only very little knowledge exists about the temporal development of prices in these markets.

22 An interest rate of 4% was used for Germany based on the soft loans granted.

fact that an estimate is needed of the future evolution of certificate prices in quota systems. Such an estimate does not usually exist. We assumed therefore that TGC prices remain constant at 2004 levels. This assumption is justified by the development of green certificate prices observed during the last two years in the European market shown in Figure 17. Except for the development in the UK no clear trend towards declining certificate prices can be observed in the recent past. The decreasing TGC price in UK was accompanied by a sharply increasing electricity price in 2005, therefore the total level of support for RES-E did not decrease.

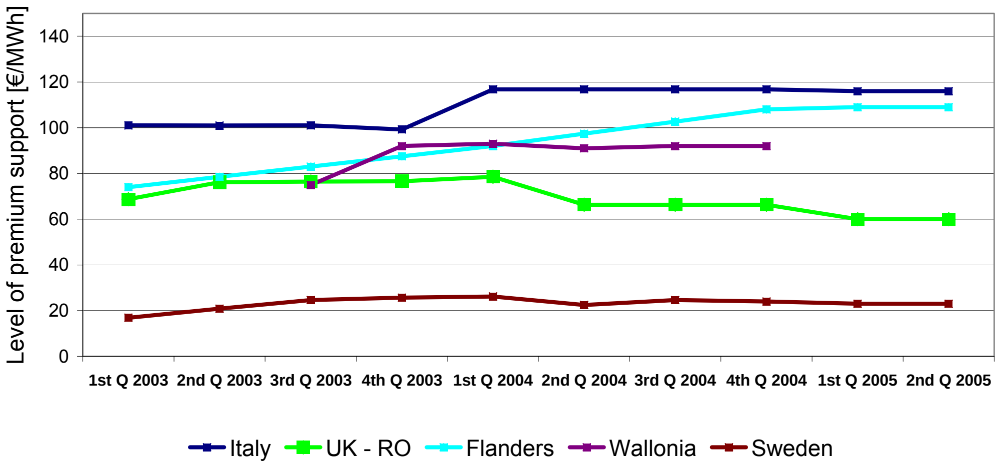

Figure 17. Development of Green-certificate prices in Belgium, Italy, Sweden and UK between 2003 and 2005.

In a second step, the correlation shall be analysed between the annuity for investments and the effectiveness of the support instrument as shown in Figure 9. This is done in a qualitative manner by plotting the effectiveness versus the annuity in Figure 18. It should be mentioned that Belgium has two different quota schemes, one in Wallonia and the other in Flanders. Based on the new Spanish feed-in law (RD 436/2004), three different tariff options exist in parallel, a fixed price option, a market-oriented option with a feed-in-premium and a transitional solution with a lower premium price.

In a similar way, the correlation between the effectiveness and the normalised level of support is shown in Figure 19.

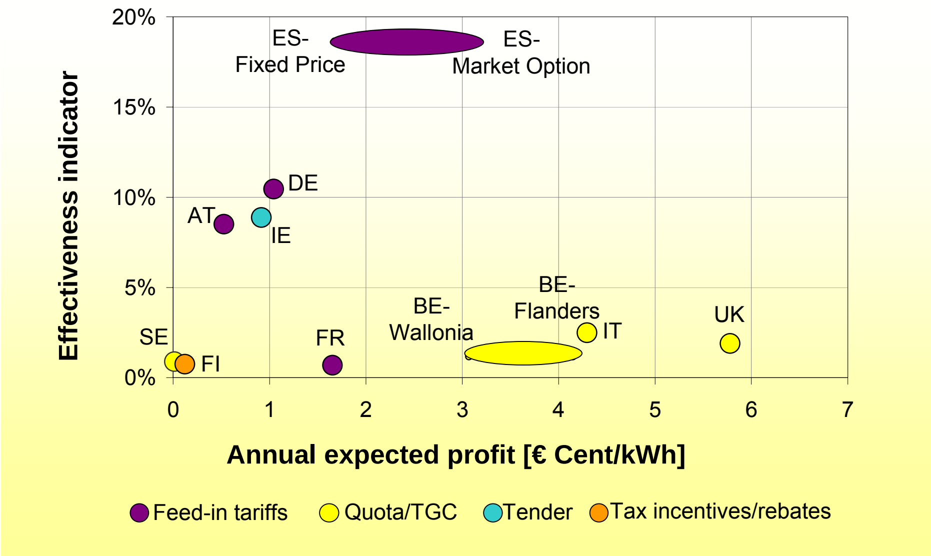

Figure 18. Effectiveness indicator in relation to the annuity of expected profit for wind on-shore (2004)

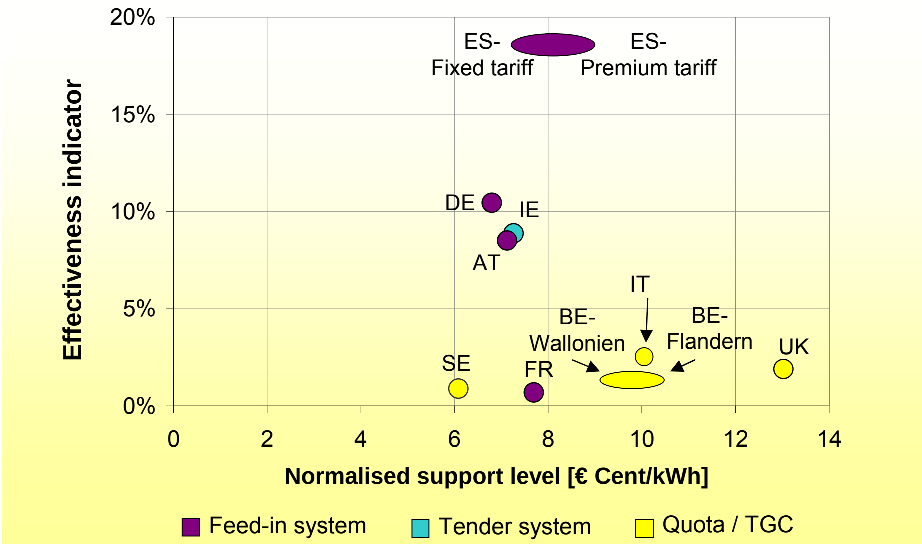

Figure 19. Effectiveness indicator in relation to the normalised level of support for wind on-shore (2004)

Results:

- Generally the expected annuity as well as the effectiveness shows a broad spectrum in quantitative terms for the countries under consideration. It has to be mentioned that the different instruments show a different level of experience and policy schemes in some countries - in particular quota obligation systems - are still in a transitional period.
- It is striking that three countries - Italy, the UK and Belgium - which have recently transformed their markets into quota systems as the main support instrument, have a

high expected annuity of support but low growth rates. The high annuity results in particular from the extrapolation of the presently observed certificate prices.

- Based on this assumption, which is mainly justified by empirical observations[23], the results show that certificate systems can lead to high producer profits resulting from high investment risks[24].
- On the other hand, it seems typical for countries with feed-in-tariffs to be more effective at generally moderate levels of support. An exception to this rule is France, where administrative barriers are preventing rapid development of wind energy.
- Spain had the highest growth rates in terms of the effectiveness indicator offering an adequate profit. The reason why the profits are expected to be higher in Spain than in the other feed-in countries is not a high support level, but rather relatively low electricity generation costs due to good resource conditions on the one hand and low investment costs on the other hand.
- Ireland reached a level of effectiveness in 2004 similar to countries with feed-in-tariffs like Germany and Austria despite a significantly lower absolute support level, but with similar expected profit. A lower support level is required in Ireland than in Germany because of the significantly better wind resources (2600 full load hours have been assumed for the typical Irish location, the corresponding figure in Germany amounts to 1800).[25]
- Since relatively favourable wind conditions were assumed for Austria, the support level does not seem to be able to stimulate further capacity growth for sites with unfavourable wind conditions. As a consequence it can be suspected that the effectiveness of the Austrian support system will drop in the future, since the quality of the remaining wind sites usually decreases in line with capacity growth.
- In Sweden, the small growth in wind power is the result of a very low expected profit.
- As a general conclusion it can be stated that the investigated feed-in systems are effective at relatively low producer profits. On the other hand, it can be observed that the present quota systems only achieve rather low effectiveness at comparably high profit margins. We would like to emphasise however, that these quota systems are

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23 Until now there is no clear trend of decreasing certificate prices under the different quota systems in the EU. Such decrease of certificate prices should be expected only if the risk level under existing certificate markets decreases significantly.

24 It should be stated here however, that in the case that long term contracts are negotiated between RES producer and the obliged party, e.g. a utility, only a certain fraction of the 'producer profit' will actually be earned by the RES producer.

25 The high Irish growth rate in 2004 has to be carefully considered since the comparatively high capacity development in 2004 is due to the impacts of the last Irish bidding round. In former years the growth rate was much smaller (a tender system seems to be an instrument which allows rapid growth in a short period of time).

relatively new instruments in the countries currently applying them. Therefore the behaviour observed might still be marked by significant transient effects.

5 THE IMPACT OF SUPPORT SCHEMES ON THE FUTURE DEPLOYMENT OF RES-E

- a model based analysis of markets, technology portfolios and costs under different policy assumptions

In this chapter, an evaluation of the different support schemes for RES-E is conducted from a future perspective. Based on calculations made with the help of the computer model ***Green-X***[26], the economic efficiency of policy instruments will be analysed in depth, in which the transfer costs for consumers / society (due to the promotion of RES-E) are the dominant indicator for the assessment.

5.1 Definition of investigated scenarios

As illustrated below, a broad set of scenarios is examined:

- The **reference scenario** indicates RES-E deployment if no further support would be given for new RES-E after 2006. This variant clearly indicates the transfer costs for consumers referring to existing plants (installed up to 2006) due to earlier support guarantees expiring in the following years.
- **No harmonisation:** national policies remain in place and determine the future development of RES-E. Two variants are investigated:
  - RES-E policies are applied as currently implemented (without any adaptation) – until 2020, i.e. a **business as usual (BAU) forecast**. Under this variant a moderate RES-E deployment is projected for the future up to 2020.
  - **Strengthened efforts** are made by the Member States to meet the overall RES-E directive target in 2010. As a result it is predicted that national RES-E policies will improve with respect to their efficiency and effectiveness. More precisely, it is assumed that these changes will become effective immediately (2006) and applied policy settings will stay in place also beyond 2010. Besides adapting financial support conditions, a removal of non-financial barriers (i.e. administrative deficiencies etc.) is also presumed for the future.

    In addition to this default case, resulting in an accelerated RES-E deployment and, consequently, an ambitious RES-E target for 2020, two further sub-variants of

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26 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.

"strengthened national policies" are analysed: First, a case of national policies causing a similar to above overall future RES-E deployment (ambitious target), but without enhanced promotion of novel, currently more expensive RES-E options such as photovoltaics. Secondly, a case of efficient & effective national policies for achieving only a moderate RES-E deployment by 2020 – similar to the BAU forecast (BAU-target).

- Starting in 2006, a **harmonisation of support schemes takes place at the EU-15 level**. To be able to analyse the effect of different (harmonised) policies compared to the above scenarios, it is assumed that the same RES-E targets as under BAU conditions on the one hand and as resulting under strengthened national efforts on the other should be reached by 2020.[27] The following currently most promising and favourable policies were investigated under harmonised conditions: feed-in tariffs, quota obligations based on tradable green certificates (TGCs), and tender and tax incentives.
- In addition, the impact of a **coordination of instruments** is investigated for the dominating schemes (i.e. feed-in tariffs and quota obligations based on tradable green certificates) **at "cluster" level**. Thereby, two clusters are defined: The Member States Austria, France, Germany and Spain (which currently stick to feed-in tariffs) comprise one cluster; and another cluster is made up of Belgium, Italy, Sweden and the United Kingdom (i.e. countries which currently apply quota obligations based on TGCs). For both cluster coordinated feed-in tariffs and quota obligations are compared to purely national as well as harmonised (at EU-15 level) support schemes. Again, it is assumed that similar RES-E targets as above (i.e. BAU and ambitious target) should be achieved by 2020 on cluster level. Accordingly, it is assumed that coordination activities will start in 2006.

The following figures aim to illustrate these cases. Thereby, Figure 20 depicts the different paths of the resulting RES-E deployment within the EU-15, whilst Figure 21 lists the set of investigated policy scenarios in a detailed manner.[28]

27 Note that the overall RES-E targets are similar but on technology and country level differences are obviously.

28 Please note that the depiction of investigated policy scenarios as done in Figure 21 excludes the reference case, where it is assumed that no support will be provided for new RES-E from 2006 on.

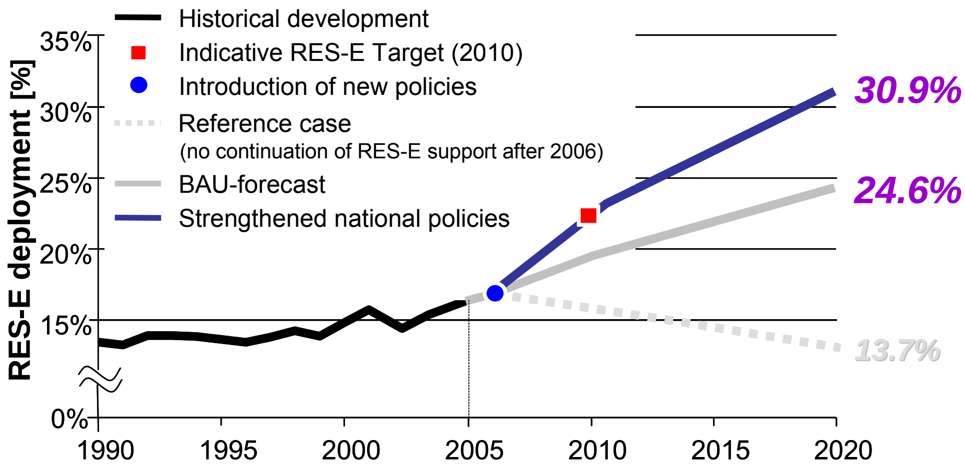

Figure 20. Investigated paths of future RES-E deployment in the EU-15

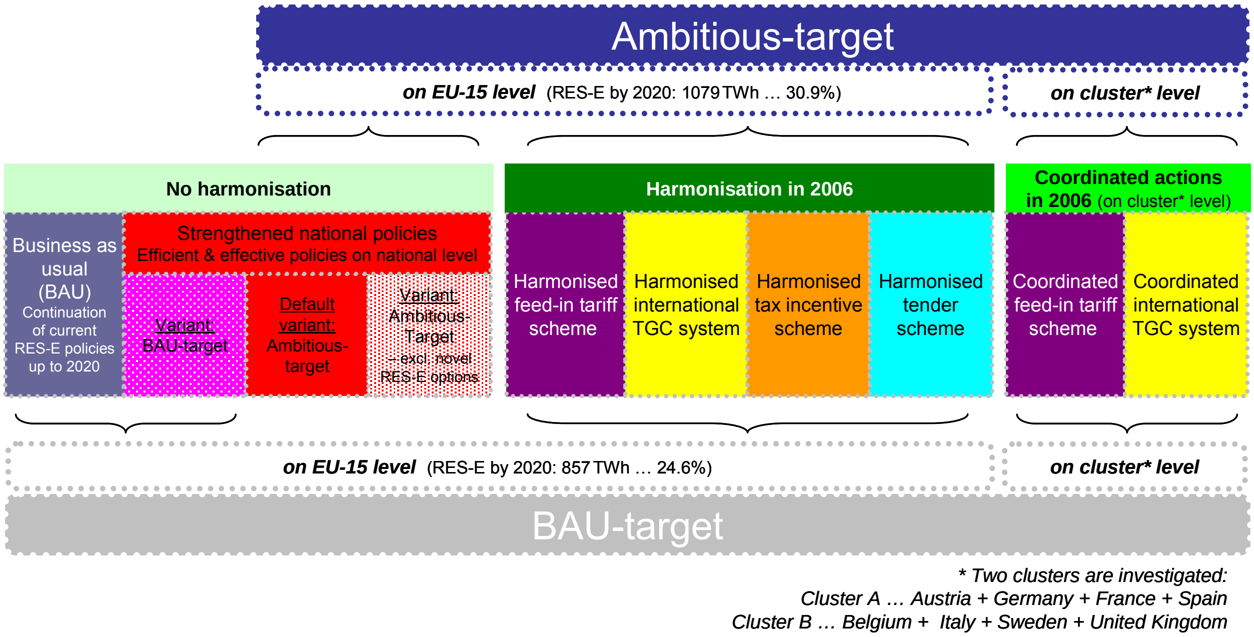

Figure 21. Detailed overview on investigated policy cases

5.2 Key assumptions

Besides the comprehensive 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. - which was derived in the project Green-X and continuously updated within follow-up activities, the assumptions made with respect to the applied policy instruments are discussed below.

5.2.1 General assumptions

► ***Gross electricity consumption***

Electricity demand was set according to the DG TREN Outlook 2030: European Energy and Transport Trends to 2030 Outlook (Mantzos et. al 2003) – Baseline forecast. This means that electricity demand is projected to rise – on average – by 1.8% p. a. up to 2010 and by 1.5 % p. a. thereafter. Of course, on country level different demand projections are used. For example while the demand forecast for France is 2.2% p.a. up to 2010, a projection of only 1.1% p.a. is assumed for Germany.

► ***Primary energy prices for biomass products***

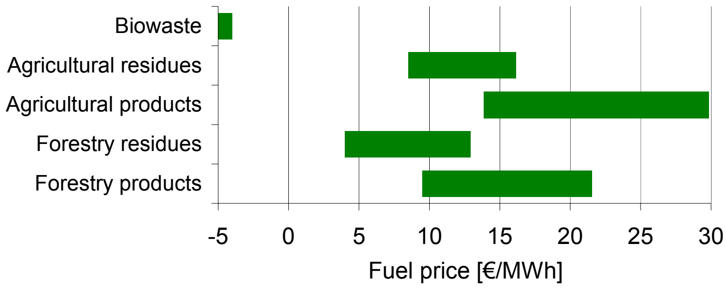

Figure 22. Variation of the prices for the different biomass products in EU 15

Figure 22 gives an overview about the variations of biomass prices in EU 15 countries. The price level differs among the countries and biomass fractions. Current prices are based on an assessment conducted within the Green-X project and are expressed in $€_{2005}$. Prices are lowest for biowaste, followed by forestry and agricultural residues, and they are high for both forestry and agricultural products. It is assumed that the costs for bioenergy products remain constant till 2010. In the period 2010-2015 a slight rise of 0.5% per annum and after 2015 a price increase of 1% is projected.

► ***Reference electricity prices***

For each EU 15 Member State the power price has been derived initially endogenously within the ***Green-X*** model considering interconnection constraint among the countries. These calculations are based on:

- Primary energy projections from DG Research's "World Energy, Technology and Climate Policy Outlook" (WETO, 2003).
- A moderate CO_2 constraint (assuming a tradable emission allowance price up to 10 €/t-CO_2)
- The impact of RES-E policies has been considered – reflecting the BAU-conditions (i.e. a continuation of current support for RES-E) as common for all simulation runs with respect to the analysis of support schemes.

Figure 23 provides an illustration of the dynamic development of the resulting reference electricity prices for each country as well as for the EU-15 on average.

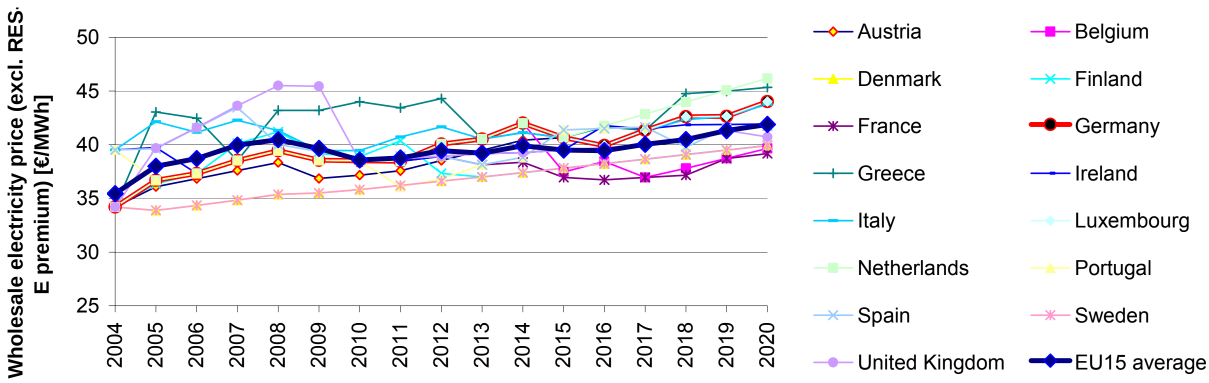

Figure 23. Development of applied reference electricity prices in EU-15 countries

► *<u>Interest rate / weighted average cost of capital</u>*

The determination of the necessary rate of return is based on the weighted average cost of capital (WACC) methodology. WACC is often used as an estimate of the internal discount rate of a project or the overall rate of return desired by all investors (equity and debt providers). This means, the WACC formula[29] determines the required rate of return on a company's total asset base and is determined by the Capital Asset Pricing Model (CAPM) and the return on debt. Formally, the pre-tax cost of capital is given by:

$$WACC = g_d \cdot r_d + g_e \cdot r_e = g_d \cdot [r_{fd} + r_{pd}] + g_e \cdot [r_{fe} + \quad \cdot r_{pe}] \cdot (1 + r_t)$$

Table 6. Example on value setting for WACC calculation

WACC methodology	Abbreviation / calculation	Default risk assessment		High risk assessment	
		Dept (d)	Equity (e)	Dept (d)	Equity (e)
Share equity / debt	g	75.0%	25.0%	75.0%	25.0%
Nominal risk free rate	r_n	4.1%	4.1%	4.1%	4.1%
Inflation rate	i	1.9%	1.9%	1.9%	1.9%
Real risk free rate	$r_f = r_n - i$	2.0%	2.0%	2.0%	2.0%
Expected market rate of return	r_m	4.3%	7.1%	4.3%	11.0%
Risk premium	$r_p = r_m - r_f$	2.3%	5.1%	2.3%	9.1%
Equity beta	b		1.6		1.6
Tax rate (corporation tax)	r_t		30.0%		30.0%
Post-tax cost	r_{pt}	4.3%	10.2%	4.3%	16.6%

29 The WACC represents the necessary rate a prospective investor will look for a prospective investing in a new plant.

Real cost	$r = r_{pt} * (1+r_t)$	4.3%	13.2%	4.3%	21.5%
Weighted average cost of capital	***WACC***	**6.5 %**		**8.6 %**	

Table 6 illustrates exemplarily the determination of the WACC. In total, a set of three options are considered in the analysis, varying from 6.5% up to 8.6%. The different values are based on different risk assessment, a standard risk level and a set of risk levels characterised by a higher expected market rate of return. The 6.5% value is used as default for stable planning conditions as given e.g. under advanced fixed feed-in tariffs; whilst the higher values are applied in scenarios with lower stable planning conditions, i.e. in the cases where support schemes cause a higher risk for the investors (e.g. a TGC system). For a detailed listing of the policy-specific settings see Table 7. To analyse the effects of different strategies, for the simulation no technology-specific risk premiums (different WACC according to their maturity and risk characteristics) are used.

Table 7. Policy-specific settings with respect to the WACC

Support scheme	*Interest rate / weighted average cost of capital*
(Fixed) Feed-in tariffs	6.5%
Premium feed-in tariffs	7.55%
Tender	7.55%
Quotas / tradable green certificates	8.6%
Tax incentives	8.6%

► Potentials and costs for RES-E

The general modelling approach within ***Green-X*** to describe both supply-side electricity generation technologies is to derive *dynamic cost-resource curves* for each generation option in the investigated region. Dynamic cost curves are characterised by the fact that the costs as well as the potential for electricity generation can change year by year. The magnitude of these changes is given endogenously in the model, i.e. the difference in the values compared to the previous year depends on the outcome of this year and the (policy) framework conditions set for the simulation year. The following overview aims to illustrate the background data of the Green-X model with respect to potentials and costs for RES-E from a static point-of-view. [30]

30 The data has been derived initially in 2001 based on a detailed literature survey and a development of an overall methodology with respect to the assessment of specific resource conditions of several RES-E options. In the following, especially within the projects Green-X and

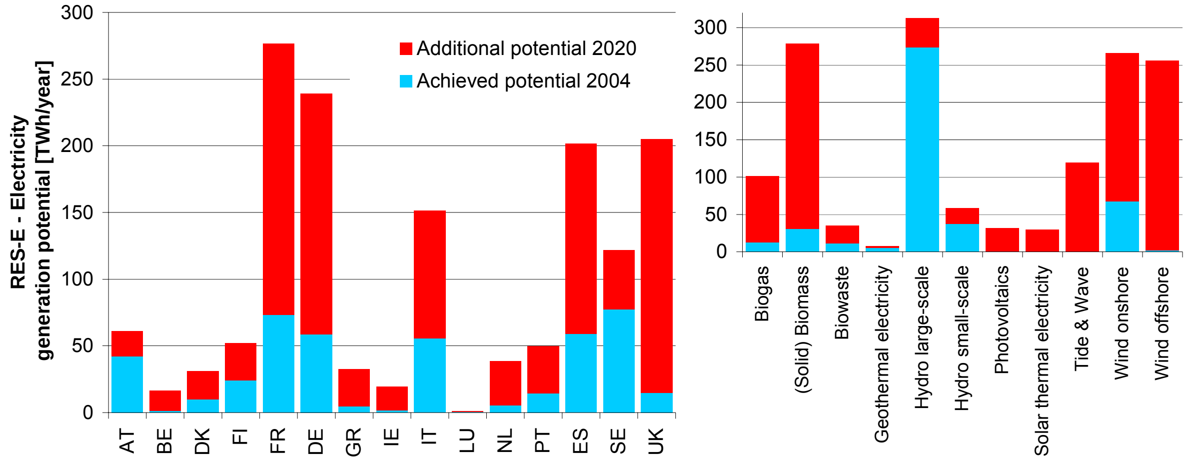

Figure 24. Achieved (2004) and additional mid-term potential 2020 for electricity from RES in the EU-15 – by country (left) and by RES-E category (right)

RES-E such as hydropower or wind energy represent energy sources characterised by a natural volatility. Therefore, in order to provide accurate forecasts of the future development of RES-E, historical data for RES-E had to be translated into electricity generation potentials – the achieved potential. More precisely, this potential data refers to the year 2004 – taking into account the recent development on country level of this rapidly growing market. Thereby, a forecast is undertaken to deliver missing data on country and technology level for the year 2004.[31] In addition, future potentials were assessed taking into account the country-specific situation as well as realisation constraints. Figure 24 depicts the achieved and additional mid-term potential for RES-E in the EU-15 by country (left-hand side) as well as by RES-E category (right-hand side). For EU-15 countries, the already achieved potential for RES-E equals 441 TWh[32], whereas the additional realisable potential up to 2020 amounts to 1056 TWh (about 38% of current gross electricity consumption).

The country-specific situation with respect to the achieved as well as the future potential shares of available RES-E options is depicted below in more detail. Figure 25 indicates the share of the various RES-E in the *achieved* potential for each EU-15 country. As already mentioned, (large-scale) hydropower dominates current RES-E generation in most EU-15 countries. However, for countries like Belgium, Denmark,

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FORRES 2020, comprehensive revisions and updates have been undertaken, taking into account reviews of national experts etc.

31 At technology-level, actual data for the year 2004 is only available for wind energy and photovoltaics for all investigated countries.

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

Germany, the Netherlands or the UK – most characterised by rather poor hydro resources – wind, biomass, biogas or biowaste are in a leading position.

Next, Figure 26 shows the share of different energy sources in the *additional* RES-E mid-term potential for the EU-15 for 2020. The largest potential is found in the sector of wind energy (43%) followed by solid biomass (23%), biogas (8%) as well as promising future options such as tidal & wave (11%) or solar thermal energy (3%).

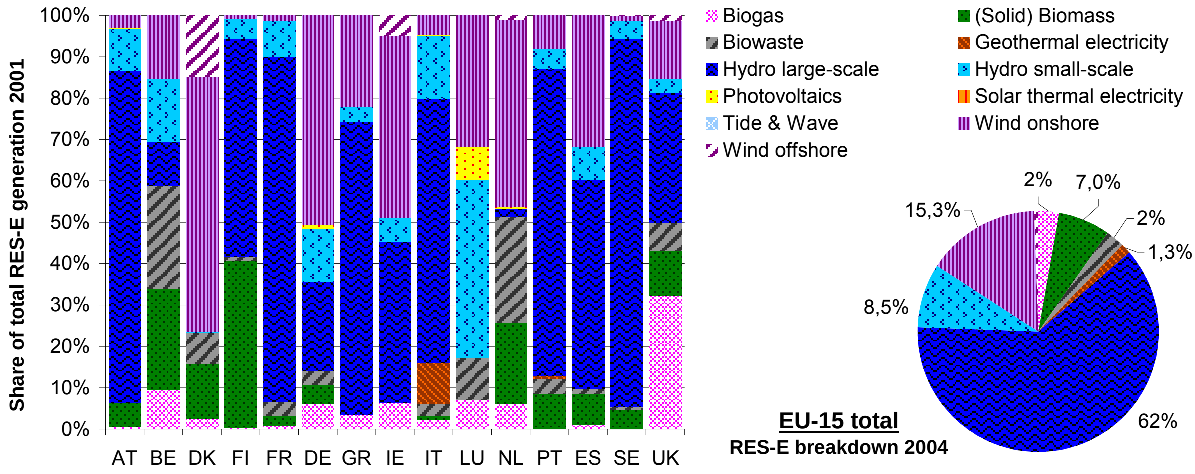

Figure 25. RES-E as a share of the total achieved potential in 2004 for the EU-15 – by country (left) as well as for total EU-15 (right)

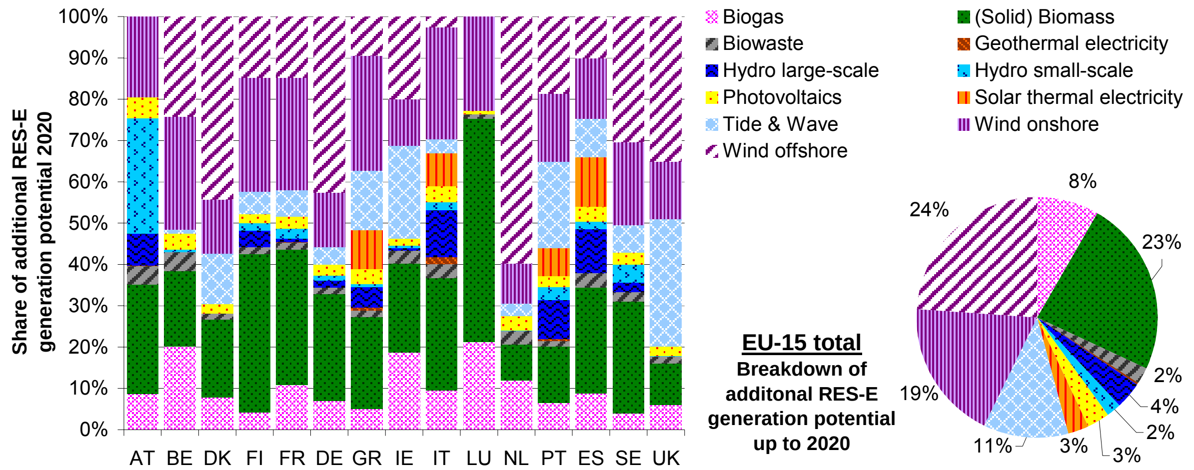

Figure 26. RES-E as a share of the total additional realisable potential in 2020 for the EU-15 – by country (left) as well as for total EU-15 (right)

In the model ***Green-X***, the electricity generation costs for the various generation options are calculated by a rather complex procedure – internalized within the overall set of modelling procedures. In this way, plant-specific data (e.g. investment costs, efficiencies, full load-hours, etc.) are linked to general model parameters such as interest rate and depreciation time. The latter parameters are dependent on a set of user input data as policy instrument settings, etc.. Nevertheless, in order to give a better illustration of the current[33] economic conditions of the various RES-E options, Figure 27 depicts *long-run marginal generation costs*[34] by RES-E category. Thereby, for the calculation of the capital recovery factor two different settings are applied with respect to the payback time:[35] On the one hand, a default setting, i.e. a payback time of 15 years, is used for all RES-E options – see Figure *27* (left), and on the other hand, the payback is set equal to the technology-specific life time – see Figure *27* (right).

The broad range of costs for several RES-E represents, on the one hand, resource-specific conditions as are relevant e.g. in the case of photovoltaics or wind energy, which appear between and also within countries. On the other hand, costs also depend on the technological options available – compare, e.g. co-firing and small-scale CHP plants for biomass.

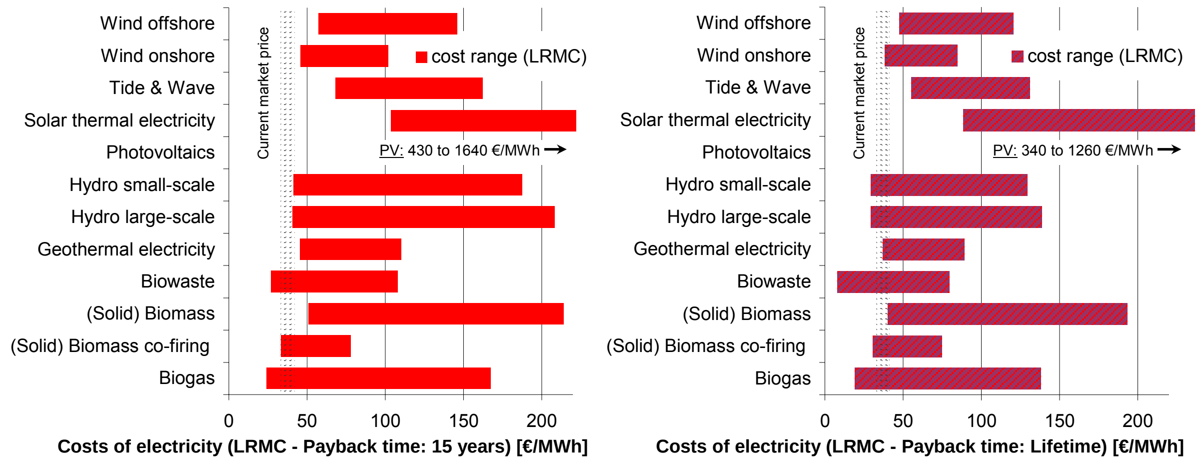

Figure 27. Long-term marginal generation costs (for the year 2005) of different RES-E technologies in EU-15 countries – based on a default payback time of 15 years (left) and by setting payback time equal to lifetime (right).

► *Future cost projection – technological learning*

Within the model **Green-X** the following dynamic developments of the electricity generation technologies are considered

– Investment costs (experience curves or expert forecast)

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33 Generation costs refer to the starting year for model simulations, i.e. 2005 and, hence, are expressed in $€_{2005}$.

34 Long-run marginal costs are relevant for the economic decision whether to build a new plant or not.

35 For both cases a default weighted average cost of capital (WACC) in size of 6.5% is used.

– Operation & Maintenance costs (expert forecast)
– Improvement of the energy efficiency (expert forecast)

For most technologies the investment cost forecast is based on technological learning, see Table 8 As learning is taking place on the international level the deployment of a technology on the global level must be considered. For the model runs global deployment consists of the following components:

– Deployment within the EU-15 Member States is endogenously determined, i.e. it is derived within the model.
– For the new EU Member States (EU-10+) forecasts of the future development by RES-E categories are taken from the project 'FORRES 2020'; for details see Ragwitz et al. (2004).
– Expected developments in the 'Rest of the world' are based on forecasts as presented in the IEA World Energy Outlook 2004 (IEA, 2004).

Default assumptions with respect to technological learning or the cost decrease, respectively, as depicted in Table 8 are based on a literature survey and discussions at expert level. Major references are discussed below:

Various studies have recently treated the aspects of technological learning with respect to energy technologies. In a general manner, covering a broad set of RES-E technologies, experience curves are discussed in Grübler et al. (1998), Wene C. O. (2000), McDonald, Schrattenholzer (2001) and BMU (2004). A focus on photovoltaics is given in Schäffer et al. (2004), whilst in case of wind energy Neij et al. (2003) provides the most comprehensive recent survey. With respect to the future cost development of emerging new technologies like tidal and wave energy a stick to expert forecasts given by OXERA Environmental (2001) seems preferable.[36]

Table 8. Dynamic assessment of investment costs for different RES-E technologies

RES-E category	***Applied approach***	*Assumptions*
Biogas	Experience curve (global)	LR (learning rate) = 12.5% up to 2010, 10% afterwards
Biomass	Experience curve (global)	LR = 12.5% up to 2010, 10% afterwards
Geothermal electricity	Experience curve (global)	LR = 8%
Hydropower	Expert forecast	Cost decrease 1.25%/yr
Photovoltaics	Experience curve (global)	LR = 20% up to 2010, 12% afterwards
Solar thermal elec-	Experience curve	LR = 20% up to 2010, 12% afterwards

36 The currently implemented modelling approach accounts solely learning on the commercial market place. Efforts with respect to R&D, which do not result in additional deployment measurable in terms of MW installed, would otherwise be neglected, but are of crucial relevance for technologies in the early phase of deployment – see (Grübler et al., 1998).

tricity	(global)	
Tidal & Wave	Expert forecast	Cost decrease 5%/yr up to 2010, 1%/yr after 2010
Wind on- & off-shore	Experience curve (global)	LR = 9.5%

Note: Learning rates refer to a cost development in terms of real and not nominal cost.

5.2.2 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 [37]
- limiting the time in which investors can receive (additional) financial support. [38]

With respect to model parameters reflecting *non-financial aspects of support*, the following settings are applied[39]:

- 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[40].

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37 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.

38 In the model runs, it is assumed that the time frame is restricted to 15 years for all instruments providing a generation-based support.

39 Note that equal settings for non-financial barriers are applied in all scenarios – in order to be able to clearly determine the aspects related to design.

40 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 re-

In the following, the model settings and assumptions are described for each type of support instrument separately.

► ***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 commonly applied in the case of generation-based support). A low risk premium (leading to a WACC of 6.5%) is applied to reflect the small degree of uncertainty associated with the well defined design of this instrument.

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

A common TGC system (covering all RES-E options)[41] is investigated to increase liquidity and competition on the TGC market. Compared to the other support schemes, risk is assumed to be on a 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).

► ***Tenders***

A common tendering system (covering all RES-E options) is applied. The winners of the yearly auctions receive support according to their bids guaranteed for a period of 15 years – i.e. a PPA guaranteeing support similar to a fixed feed-in tariff. A moderate risk premium (leading to a WACC of 7.55%) is assumed, which refers solely to the risk of making investments (i.e. required permissions, planning etc.) prior to an auction (not knowing if bids will be successful). In order to illustrate the impacts of investors' strategic behaviour,[42] two variants are calculated – which differ by neglecting or considering this impact.

► ***Tax incentives***

Tax incentives are technology-specific; premiums are defined for each RES-E option separately in order to achieve an overall low burden for consumers, incentives de-

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flected in the BAU-settings applied compared to, e.g. the more optimistic view assumed for reaching a more ambitious target in 2020.

41 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.

42 If an investor knows that the costs of his plant are (much) lower than the marginal bid that will still be accepted (win), he can increase his offer strategically, i.e. it is sufficient that the offer price is a bit lower than the expected marginal offer.

crease over time reflecting the achieved cost reductions on a technology level. A high risk premium (leading to a WACC of 8.6%) is applied referring to the uncertainty about future earnings from selling electricity on the power market and about future support.

5.3 Results of the model runs

5.3.1 National support schemes - Business as usual (BAU) vs. strengthened national policies

Before comparing the outcomes of the scenarios referring to the investigated support instruments in particular, the currently implemented broad variety of different national policies is analysed:

On the one hand, the BAU-scenario is depicted – representing the likely future under non-harmonised conditions among the EU-15 Member States. As mentioned before, within this variant a continuation of current RES-E policies is assumed up to 2020.

On the other hand, the "strengthened national policies" scenario illustrates the consequences of immediate actions set by Member States in order to meet the 2010 targets of the RES-E directive. Thereby, it is assumed that, besides strengthening the effectiveness, an improvement of the efficiency of the national support schemes is undertaken. This includes also a rigorous removing of non-economic deficits for the deployment of RES-E – as currently still appearing within several countries.

The total amount of RES-E generation within the EU-15 was around 449 TWh/a in 2004.[43] Without any changes in the support schemes in place on a country-level (i.e. BAU), electricity production would rise to about 584 TWh/a in 2010 (19.1% of gross electricity demand) and 857 TWh/a in 2020 (24.6%). The amount for 2010 is - following the BAU demand projection taken from Mantzos et al. (2003) – around 93 TWh/a or about 3 percentage points less than the indicative target described in the 'RES-E Directive' (2001/77/EC). In contrast, rigorously and immediately improving the support conditions (including a removal of non-financial deficiencies) in all countries would make it possible to meet the overall RES-E target on EU-15 level.[44] In this variant, a RES-E generation of 682 TWh (22.2%) will be achieved by 2010, rising to 1079 TWh (30.9%) by 2020.

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43 Note: RES-E generation in 2004 refers to the available potential of RES-E – i.e. installed capacity times normal (average) full load hours by technology. 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 built in 2004 is not fully available for the whole period 2004.

44 Note that it is utterly impossible for all countries to meet their target by 2010. Therefore, it is assumed that shortfalls in, e.g. Austria, are compensated by overfulfilment in countries such as Germany.

The dynamic development of RES-E generation is depicted in Figure 28 for both cases – illustrating the overall deployment (left) and the technology-specific development (right) on EU-15 level. Due to limited public support and acceptance, the amount of large-scale hydropower plants increases only marginally in absolute terms.[45] In relative terms, the share drops significantly from around 60% in 2004 to 35% (BAU) and 29% (strengthened national policies) in 2020. The 'winner' among the technologies considered is wind energy, both onshore and offshore.

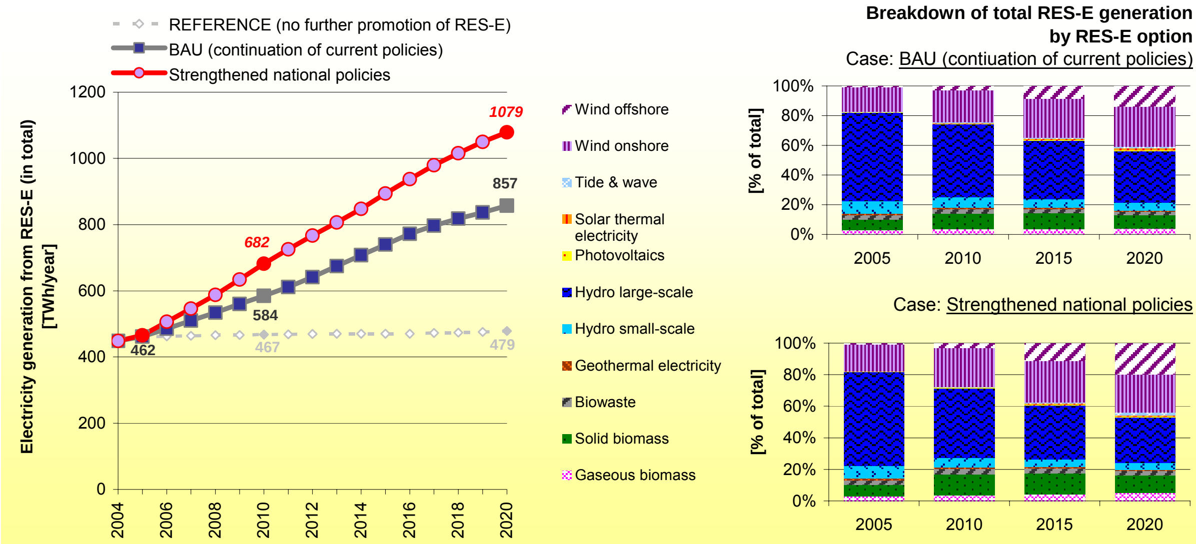


*Figure 28. Development of **total RES-E generation** in the period 2004 to 2020 on EU-15 level in the BAU case and with strengthened national policies*

Under BAU conditions it can be expected that by 2020 around 42% (25%) of total RES-E production from new plants (installed in the period 2005 to 2020) is coming from wind onshore, leading to a share of around 27% on total RES-E generation in 2020. Corresponding figures for wind offshore are 25% with regard to new installations and 14% as share of total RES-E generation by 2020, respectively. In the BAU case other RES-E options will achieve a much less significant increase.

For the variant on strengthened policies corresponding figures are e.g. for wind offshore 31% with regard to new installations, and 20% for total RES-E generation by 2020. It is notable that for achieving a higher RES-E deployment, almost all RES-E options have to substantially enter the market. In this context, besides wind energy, other relevant increases can be expected for solid biomass (e.g. +4% with regard to total RES-E generation or 15% in terms of RES-E generation dedicated to new installations) and biogas.

45 Considering the effects of the Water Framework directive (European Union and Parliament, 2000), total electricity generation from (large-scale) hydro may even be lower in 2020 compared to the current level.

A graphical illustration of the issues described above is given in *Figure 29*, indicating a technology-specific breakdown of electricity generation from new RES-E plant (installed in the period 2005 to 2020) at the EU-15 level for both policy variants. Please note, that within the BAU-case the overall generation potential of new plant is in size of 455 TWh, whilst under strengthened national policies 677 TWh refer to new installations by 2020.

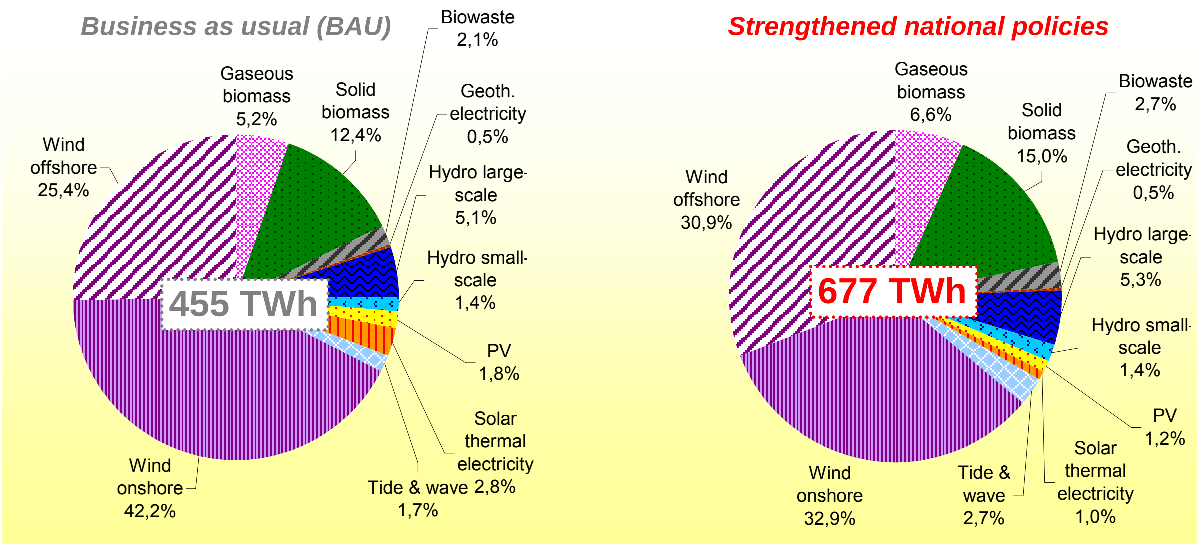


*Figure 29. Technology-specific **breakdown of electricity generation from new RES-E plant** (installed in the period 2005 to 2020) at EU-15 level for the BAU-case (left) and with strengthened national policies (right)*

High investments are necessary to be able to build up the new capacity. Figure 30 shows the total investment needs for RES-E over time up to 2020 for both cases. Thereby, on the right hand side of this figure a breakdown of the investment needs is given for each RES-E option for the BAU-case (upper part) as well as for the case of strengthened national policies (lower part). While necessary investments into wind onshore and biogas plants are relative stable over time – especially within the BAU variant, investments into solid biomass plants (including biowaste) mainly occur in the first years (2005-2015) and for wind offshore and solar thermal electricity mainly after 2010. The investments (within the EU and worldwide) stimulate technological learning, leading to lower generation costs in the future.

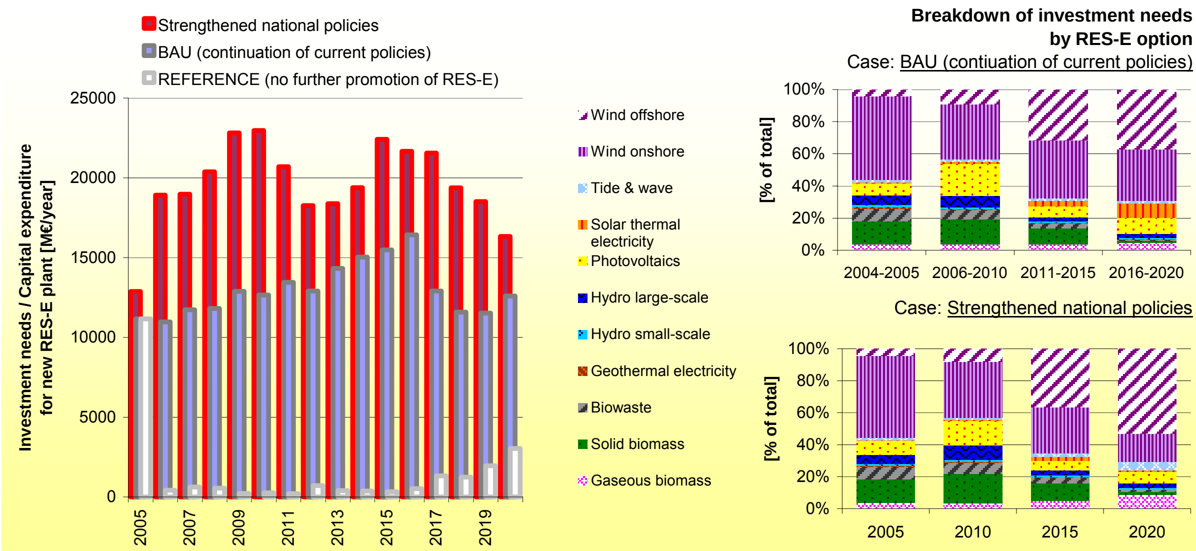


Figure 30. ***Total investment needs*** *in the period 2005-2020 within the EU-15 – in the* ***BAU case*** *and under* ***strengthened national policies***

Next, Figure 31 provides a comparison of the necessary specific financial support for new RES-E installations (on average) for both cases. 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 MWh_{RES-E} 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 less financial support per MWh_{RES-E} as can be seen by comparing the figures for the BAU-case and strengthened national policies variant.[46]

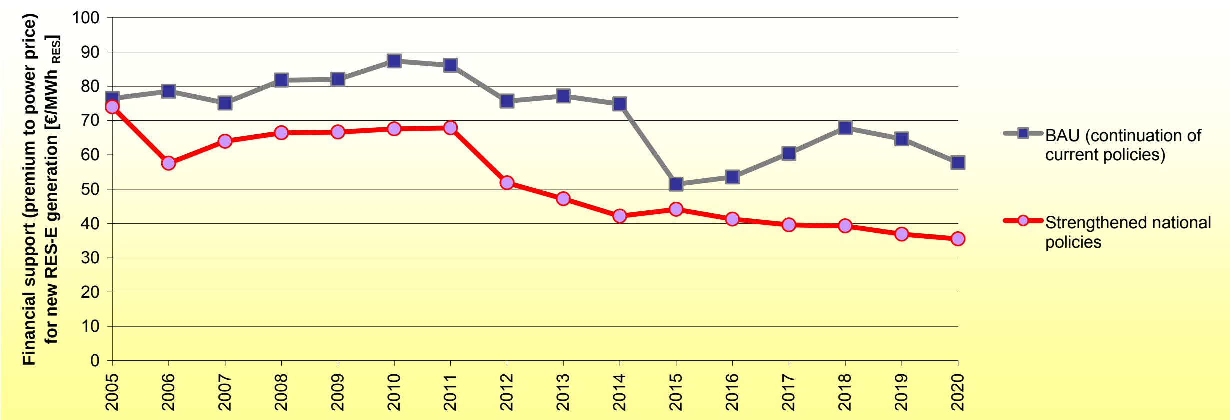
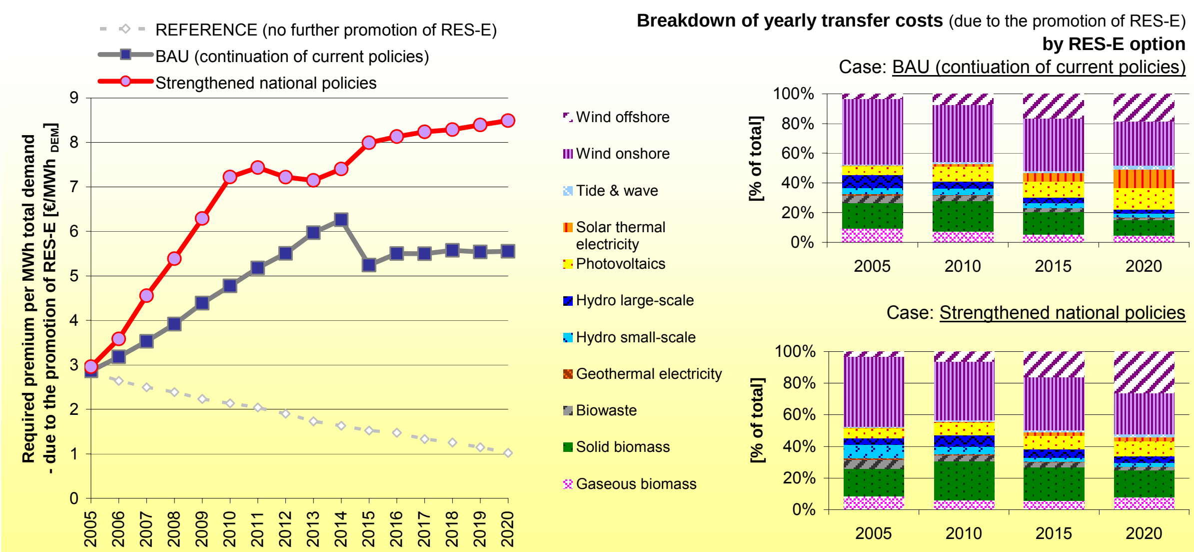


Figure 31. *Comparison of* ***financial support*** *(premium to power price on av-*

46 For a detailed discussion on how to strengthen (national) support policies we refer to the paragraph as stated at the end of this section and to chapter 6 of this report, respectively.

*erage at EU-15 level) for **yearly newly installed RES-E plant** in the period 2005-2020 for the <u>BAU case</u> and under <u>strengthened national policies</u>*

The overall yearly financial support required to achieve the RES-E deployment depicted above is discussed next. Figure 32 illustrates the necessary yearly consumer expenditure at the EU-15 level for both variants – expressed as an (average) premium per MWh total demand. In this context, the consumer expenditure due to the support for RES-E represents a net value referring to the direct costs of applying a certain support scheme.[47] As can be seen, a fairly steady rise in required spending occurs in the next ten years in the BAU-case, starting from a level of 2.9 €/MWh_{DEM} in 2005 up to about 6.3 €/MWh_{DEM} in 2014.[48] After 2015, the required expenditure remains nearly constant at a level of 5.5 €/MWh_{DEM} up to 2020.[49] Obviously, within the strengthened policy variant, which is characterized by a tremendously 51% higher RES-E deployment in the investigated period 2006 to 2020, greater financial support (+26%) is required to achieve the ambitious RES-E target set for 2010. Accordingly, a steeper rise in required expenses occurs in the period up to 2010, leading to a peak at 7.4 €/MWh_{DEM} by 2011. Later on, the necessary premium remains more or less constant, increasing slowly to about 8.5 €/MWh_{DEM} by 2020.



47 E.g. in 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.

48 Note: these figures represent the average on an EU-15 level. On a country-level, huge differences appear in case of non-harmonised support (BAU). For a detailed discussion of this topic, see Huber et al. (2004).

49 The decrease in the consumer expenditure on EU-15 level is caused by a significant reduction of the TGC price in the UK in the years after 2014. In the period 2005-2014, the required quota obligation cannot be reached, so high penalties have to be paid.

*Figure 32. Development of **necessary yearly transfer costs** for consumer due to the promotion of RES-E on EU-15 level in the period 2005-2020 for the BAU case and under strengthened national policies*

An overall comparison at EU-15 level of both RES-E generation and corresponding cumulative transfer costs for consumer is given in Figure 36 below. This depiction shows the most important indicators for the evaluation of support instruments: On the one hand, it depicts the resulting RES-E generation in 2020 – referring to new installations in the period 2006 to 2020 – and thereby indicating the effectiveness of a support scheme. On the other hand, with respect to the efficiency of financial support it shows the required cumulative transfer costs for consumer – again, referring to new RES-E installations in the period 2006 to 2020. Both indicators are expressed in relative terms, indicating the deviation of the "strengthened national policies"-scenario to the BAU-case.

As can be seen, the surplus of 51% in terms of additional RES-E deployment as under strengthened efforts compared to the BAU-case results in only 26% higher cumulative transfer cost.

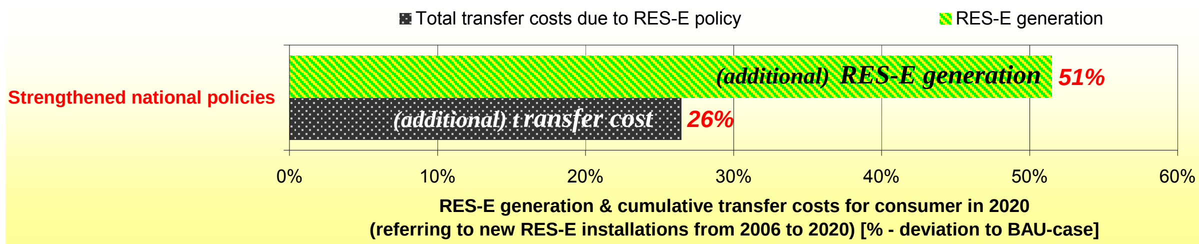


*Figure 33. Comparison of **RES-E generation from new plant** (installed 2006 to 2020) and **corresponding cumulative transfer costs** for consumer at EU-15 level 2020 for the BAU case and under strengthened national policies – expressing the deviation to the BAU case*

Note: In the case of a TGC scheme total transfer costs paid after 2020 are estimated assuming that the average TGC price of the last three years is constant up to the phase out of the support

► *Sub-variants with regard to "strengthened national policies"*

As mentioned in section 5.1, two further sub-variants of "strengthened national policies" are analysed:

On the one hand, a case of national policies resulting in – similar to the default variant - an accelerated RES-E deployment and, consequently, an ambitious RES-E target for 2020 is achieved. In contrast to the default case of strengthened national policies no enhanced promotion of novel, currently more expensive RES-E options such as photovoltaics is assumed.

Secondly, a case of efficient & effective national policies for achieving only a moderate RES-E deployment by 2020 – similar to the BAU forecast (BAU-target) – is assessed.

In the following, the outcomes will be discussed with a focus on consequences from a financial point-of-view. Below, Figure 34 compares the necessary financial support for new RES-E installations (on average at EU-15 level) for all variants on purely national RES-E policies. As can be seen by comparing the BAU-case (grey line) with the corresponding sub-variant of strengthened national policies for achieving a similar RES-E deployment by 2020 (pink line), a reduction of financial premiums per MWh_{RES-E} to less than half of current levels is feasible by improving support conditions and removal of non-financial barriers solely on national level. In contrast, an exclusion of novel RES-E options for achieving a more ambitious RES-E target does not affect financial support levels as much on European average – compare the default case of strengthened national policies (red line) with the variant where an exclusion of novel RES-E options is assumed (dotted red line).

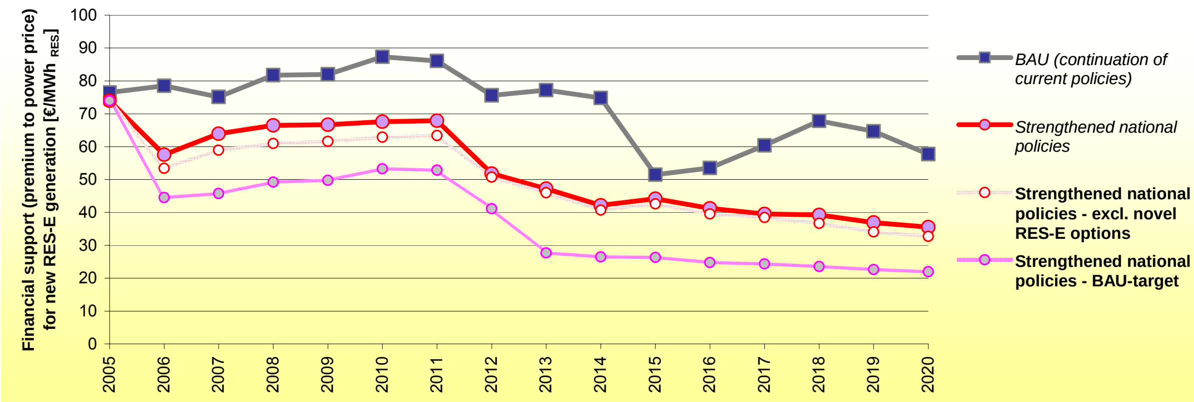


Figure 34. *Comparison of **financial support** (premium to power price on average at EU-15 level) for **yearly newly installed RES-E plant** in the period 2005-2020 for the <u>BAU-case</u> and all variants on <u>strengthened national policies</u>*

Finally, Figure 35 provides a comparison at EU-15 level of RES-E generation and corresponding cumulative transfer costs for consumer (due to the promotion of RES-E) – both referring to new RES-E installations in the period 2006 to 2020. Thereby, both indicators are expressed in relative terms, indicating the deviation of the "strengthened national policies"-variants to the BAU-case.

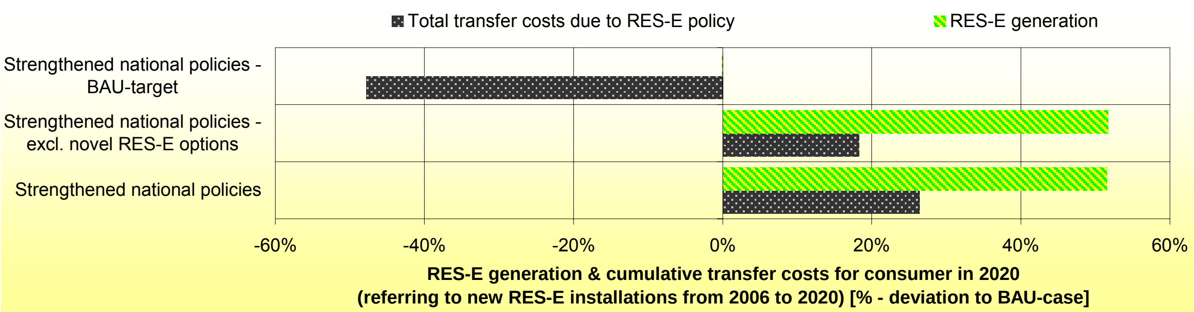


*Figure 35. Comparison of **RES-E generation from new plant** (installed 2006 to 2020) and **corresponding cumulative transfer costs** for consumer at EU-15 level 2020 for all variants on strengthened national policies – expressing the deviation to the BAU case*

Note: In the case of a TGC scheme total transfer costs paid after 2020 are estimated assuming that the average TGC price of the last three years is constant up to the phase out of the support

As illustrated, for achieving a significantly higher RES-E deployment by 2020 compared to the BAU-case, i.e. +51% in terms of new RES-E installations, 26% higher cumulative transfer cost for the default case on "strengthened national policy", where also novel RES-E options are promoted. Hence, if such more expensive RES-E options are excluded from the promotion policy, the necessary consumer expenditures can be slightly reduced, i.e. transfer costs increase by 18% (compared to BAU).

In contrast, for achieving a similar RES-E deployment by 2020 as under BAU conditions, adapted effective & efficient national policies (i.e. the variant "strengthened national policies – BAU-target") would reduce the overall consumer burden by -48%.

Remark: "How can (national) support policies for RES-E be strengthened / improved?"

- **Remove non-financial deficits**

  Non-economic deficits comprise administrative (planning, bureaucracy) as well as technical barriers (grid connection / extension). It is of great importance for achieving an effective policy and, consequently, an enhanced RES-E deployment to rigorously remove these barriers. In this context, the following measures are recommended:

  – Introduce transparent mechanisms and rules for grid access of new RES-E plant;
  – Start / continue information campaigns;
  – Integrate and coordinate RES-E support with other policies like climate change, agricultural policy or demand side management issues.

- **Target new support schemes solely to new RES-E installations** [50]

  Within any support mechanisms existing and new plants should not be mixed. This means that existing plant (constructed before a new support scheme is introduced) should remain in their old scheme, whilst the new scheme refers to new plant solely.

50 Assuming a fully competitive market with transparent framework conditions, there would be no need to provide any support for existing plants that are fully depreciated or that were financially supported in an adequate way in the past. However, in practice, as long as market transparency for instance with regard to the use of system charges is still lacking, there is a need to provide additional guidance also for them.

- **Guarantee, but strictly limit the duration of financial support**

  The support mechanism of any instrument should be guaranteed for a certain, but restricted time frame. As a rule of thumb a period of 15 to 20 years can be recommended as this often represents an acceptable depreciation time from an investor's point of view. In contrast, a lifetime guarantee of financial support results in unnecessarily high societal cost. It is obviously, that both guaranteed duration and the provided specific support, e.g. the height of a feed-in tariff, have to be set in a close context to each other. [51]

51 That means a long guaranteed duration would allow lower specific support, whilst a short support period would require high specific support to achieve a similar deployment.

Remark: "How can (national) support policies for RES-E be strengthened / improved?" (continued)

- **Include the full basket of available RES-E options**

  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 – especially 'inexpensive' options such as hydropower – increase both generation costs and transfer costs for consumer.

- **Set incentives to accelerate future cost reductions**

  Clear and transparent mechanism to reduce the specific financial support over time is highly recommended to avoid unnecessarily high societal cost. This can easily be implemented in case of feed-in tariffs by setting dynamically decreasing rates, which aim to reflect future experience gains (in line with the expected learning rate).

5.3.2 Comparison of the harmonised support schemes – reaching the BAU or the ambitious target in 2020 at the EU-15 level

In the following, a brief comparison is made of the support schemes at EU-15 level. Two different RES-E targets, i.e. the BAU target and an ambitious target (as under strengthened national policies), have to be met by 2020. For a comparison of the effectiveness and economic efficiency of the support schemes, three indicators as used above, but now briefly explained, are taken into consideration in the following.

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

Unit: €/MWh$_{RES}$

This indicator shows the dynamic development of the necessary financial support for new RES-E installations (on average). Expressed values refer to the corresponding year. From an investor's point-of-view, the amount represents the average additional premium on top of the power price provided (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$_{RES}$ for a new RES-E plant compared to a conventional option (characterised by the power price).

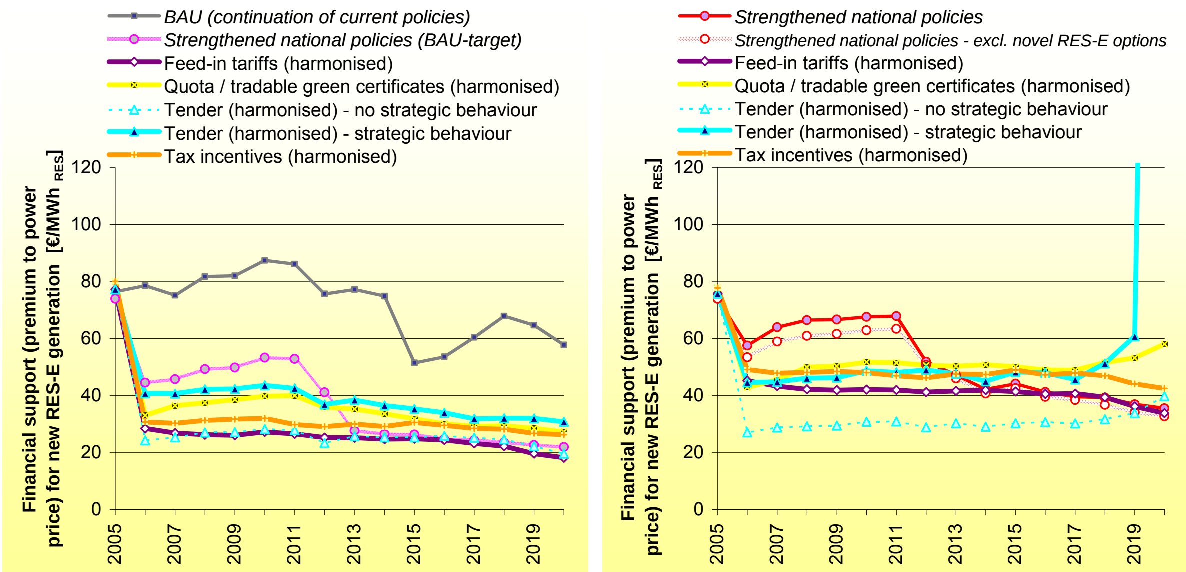


*Figure 36. Comparison of **financial support** (premium to power price on average at EU-15 level) for **yearly newly installed RES-E plant** for the investigated support schemes in case of the <u>BAU</u> (left) & the <u>ambitious target</u> (right)*

Figure 36 illustrates the average financial support at the EU-15 level for a new RES-E plant over time for all modelling variants referring to the BAU (left) as well as the ambitious target (right). As can be seen, the required financial support per MWh_{RES} decreases in every case referring to the BAU target over time. In order to achieve the ambitious RES-E target, the differences between the support instruments become more evident as discussed at the end of this section.

► *<u>(Yearly) transfer costs for consumers (due to the promotion of RES-E)</u>*

Unit: €/MWh_{DEMAND}

Transfer costs for consumers / society (sometimes also called additional / premium costs for consumers / society) are defined as the direct premium financial transfer costs borne by consumers due to the RES-E policy compared with consumers purchasing conventional electricity from the power market.

This means that these costs do not take any indirect costs or externalities (environmental benefits, change of employment, etc.) into account. The transfer costs for consumers are related to the total electricity consumption, i.e. they refer to each MWh of electricity consumed.

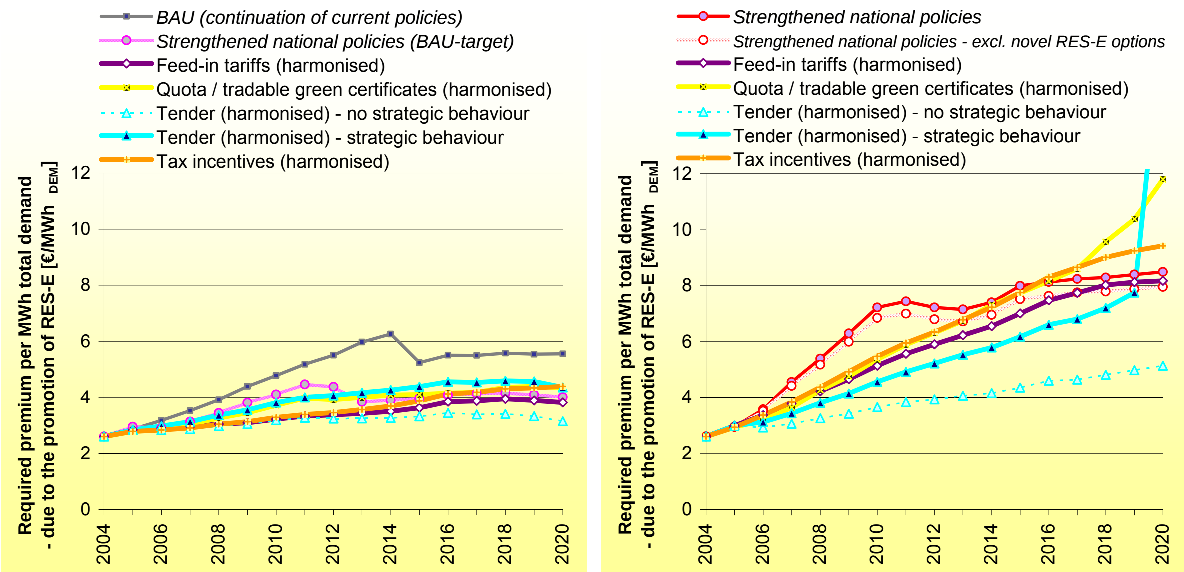


Figure 37. Comparison of the average ***required premium per MWh total demand*** *at EU-15 level (i.e. the yearly transfer costs for consumers) due to the promotion of RES-E for the support schemes investigated*
for the *__BAU__* *(left) & the* *__ambitious target__* *(right)*

Figure 37 provides a comparison of the required consumer expenditure, i.e. the yearly transfer costs due to the promotion of RES-E for all modelling variants referring to the BAU- (left) as well as the ambitious target (right). Note that these figures represent an average premium on EU-15 level – whilst the country-specific situation differs even in the case of harmonised promotion settings.

► *__Total transfer costs for consumers (due to the promotion of RES-E)__*

Units: % (in comparison to the BAU-case)

Total or cumulated transfer costs for consumers in 2020 summarise both the cumulated consumer burden within the investigated period 2005 (or 2006) 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 expenditure for the years after 2020 are translated into their present value in 2020.[52] *More precisely, the cumulated cost burden within the investigated period is calculated by summing up present values of the yearly transfer costs. Residual costs refer to RES-E plants installed up to 2020, and accordingly their guaranteed*

52 An interest rate of 2.5% is applied as default.

support.[53]

A comparison of the cumulated transfer costs for consumers due to the promotion of new RES-E installed in the period 2006 to 2020, i.e. the time in which the investigated support schemes are actually applied, is given in Figure 38 for all investigated cases.

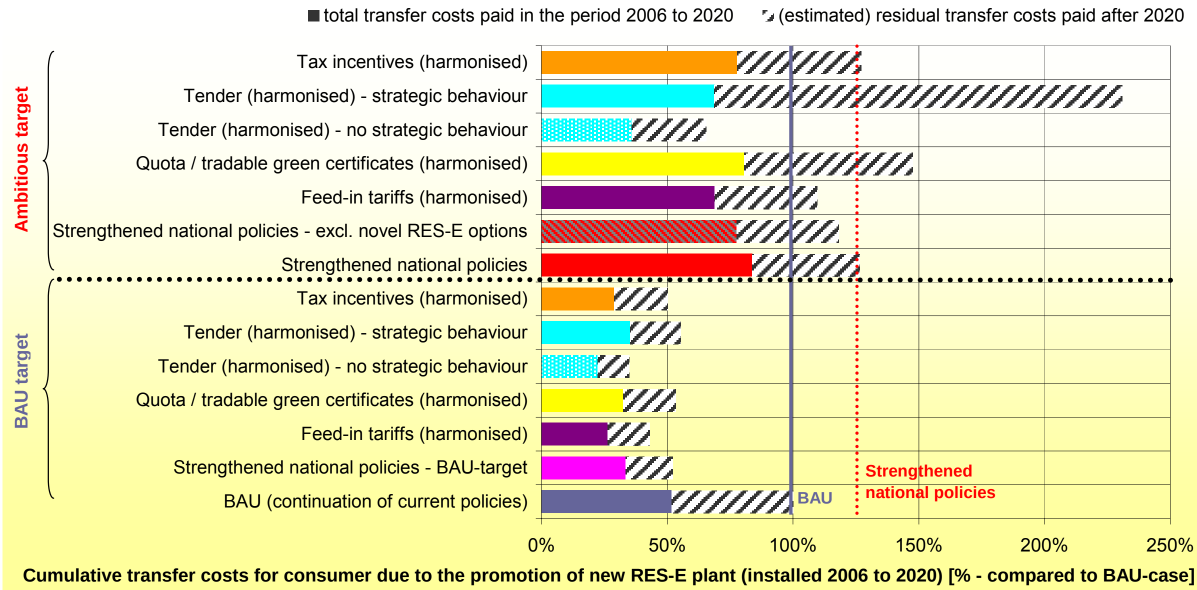


*Figure 38. Comparison of necessary **cumulated consumer expenditure** due to the promotion of new RES-E (installed 2006 to 2020) for the harmonised support schemes in case of the <u>BAU-target</u> (down) and the <u>ambitious target</u> (up)*

Note: In the case of a TGC scheme, the total transfer costs paid after 2020 are estimated assuming that the average TGC price of the last three years remains constant up to the phase-out of the support

<u>Results:</u>

Looking at the BAU target, if current policies are retained up to 2020 (BAU), then cumulative consumer expenditure is the highest. However, **national policies which are reinforced and improved represent a proper solution**. This is clearly visible when comparing both variants of strengthened national policies referring to the ambitious target with the corresponding harmonised policy schemes. For both purely national variants a lower consumer burden occurs compared to most harmonised policy options. This underpins the importance of improving the design of support instruments.

53 Assume, e.g. a wind power plant is installed in 2015 and 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.

The total transfer **costs for society are lowest when applying tendering schemes – if strategic investor behaviour is neglected, but a high burden occurs if such (probable) behaviour is taken into account.**

A **TGC system results in the highest support** (neglecting tendering systems with strategic behaviour in the case of the BAU-target). In the case referring to the BAU-target, financial support rises in the early years (up to 2011) of implementation, but falls later on. For the ambitious target, the financial support is quite steady, characterised by a slight growth in the last period.

Tax incentives also require **higher transfer costs** and/or **financial incentives** to achieve a RES-E penetration similar to that achieved under feed-in tariffs. This is a result of the higher risk from an investor's point-of-view – i.e. associated with uncertain earnings on the conventional power market as well as due to a possible phase-out of the support scheme.

Technology-specific feed-in tariffs represent the best option among all harmonised policy variants, setting a steadily decreasing financial incentive and **leading to a low societal burden**.

5.3.3 Comparison of setting coordinated activities on "cluster" level

In the following the impact of setting coordinated activities among groups of countries is investigated. Thereby, two "clusters" of countries are taken into consideration:

- Cluster A – compromising Austria, France, Germany and Spain – all countries which currently apply feed-in tariff schemes;
- Cluster B – consisting of Belgium, Italy, Sweden and the United Kingdom – countries which currently apply a TGC-system for the promotion of RES-E.

More precisely, it is investigated how harmonisation on cluster level may improve the situation with respect to transfer costs for consumer due to the promotion of RES-E. For both clusters two different support schemes, namely feed-in tariffs and quotas are applied in order to achieve a similar[54] RES-E deployment at the cluster level in 2020 as under BAU-conditions (i.e. continuation of current policies) as well as with regard to the ambitious target (i.e. by strengthening national policies). Furthermore, these scenarios are compared to the harmonised cases at EU-15 level (as discussed in the previous section) with respect to deployment and transfer costs for consumer.

► ***CLUSTER A (Austria, France, Germany, Spain)***

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54 More precisely, as the applied **Green-X** model represents a simulation tool where RES-E deployment results as a consequence of applied policy settings, a tolerance interval in size of +/- 1% in terms of total RES-E deployment was accepted.

The consequences of setting harmonised activities within this group of countries (which currently use Feed-in tariff schemes) are illustrated below. First, Figure 39 gives a comparison of the financial support (i.e. premium to power price on average) for yearly newly installed RES-E plant. Thereby, all variants referring to the BAU-target are shown on the left hand side, whilst the policy cases for the ambitious target are shown on the right. Next, in a similar manner the resulting yearly transfer cost for consumer are illustrated in Figure 40.

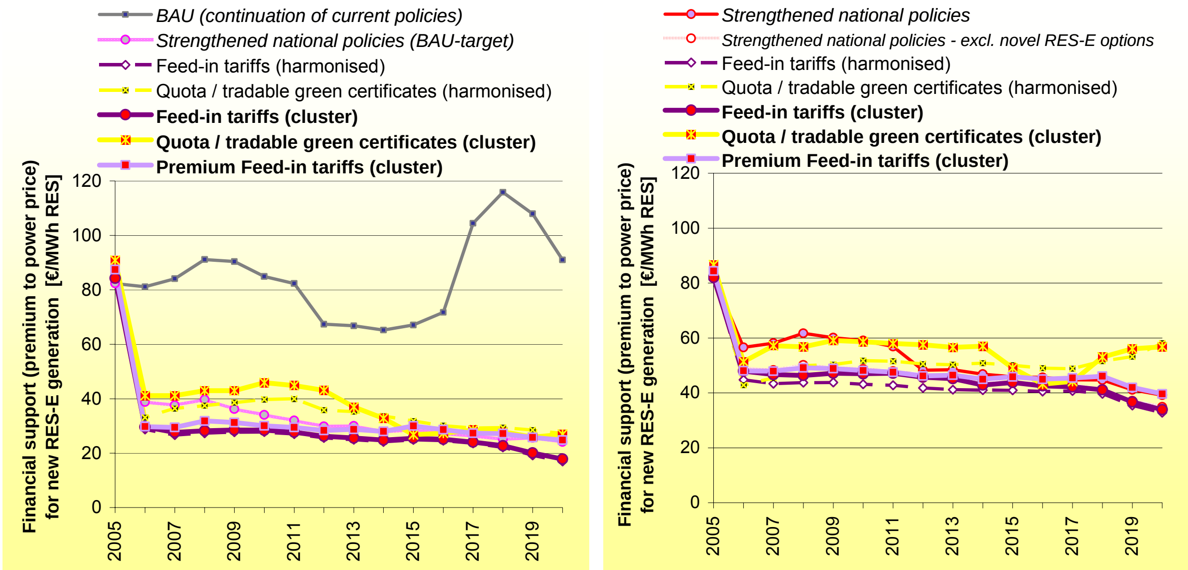

Figure 39. *Comparison of **financial support** (premium to power price on average)*
***for yearly newly installed RES-E plant** for the support schemes investigated at cluster level (CLUSTER A)*
for the <u>BAU</u> (left) & the <u>ambitious target</u> (right)

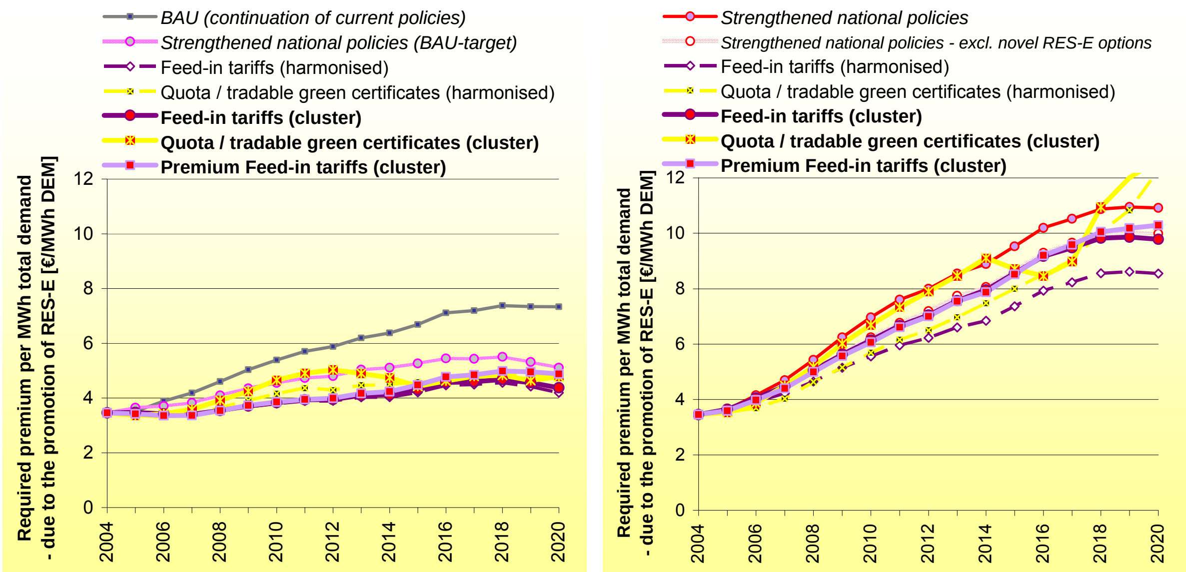

Figure 40. Comparison of the average **required premium per MWh total demand** (i.e. the yearly transfer costs for consumers) due to the promotion of RES-E for the support schemes investigated at cluster level (CLUSTER A) for the <u>BAU</u> (left) & the <u>ambitious target</u> (right)

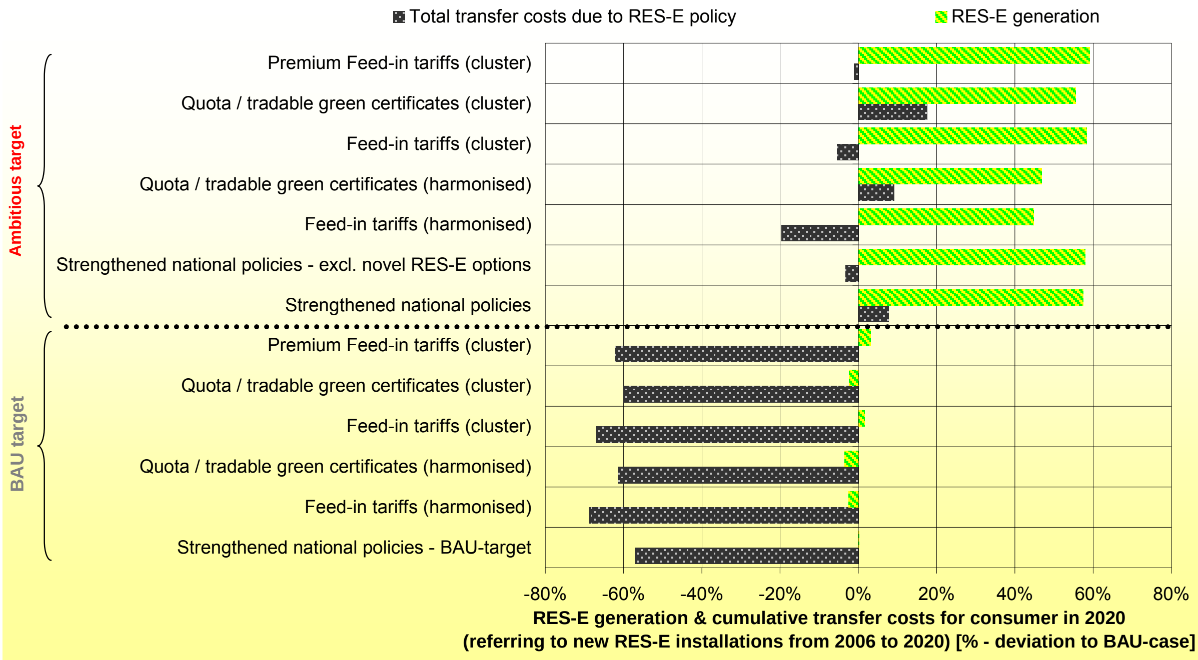

Figure 41. Comparison of **RES-E generation from new plant** (installed 2006 to 2020) and **corresponding cumulative transfer costs** for consumer at cluster level for <u>all investigated cases</u> – expressing the deviation to the BAU case (CLUSTER A)

Note: In the case of a TGC scheme total transfer costs paid after 2020 are estimated assuming that the average TGC price of the last three years is constant up to the phase out of the support

Finally, Figure 41 compares at cluster level both RES-E generation and corresponding cumulative transfer costs for consumer for all investigated cases. More precisely, this figure provides a comparison of the most important indicators for the evaluation of support instruments: On the one hand, indicating the effectiveness of a support scheme it depicts the resulting RES-E generation in 2020 – referring to new installations in the period 2006 to 2020. On the other hand, with respect to the efficiency of financial support it shows the required cumulative transfer costs for consumer – again, referring to new RES-E installations in the period 2006 to 2020. Thereby, for a better comparison both indicators are expressed in relative terms, indicating the deviation to the BAU-case.

Results:

Compared to the BAU-case, i.e. the continuation of current policies, the **transfer costs** (referring to new installations in the period 2006 to 2020) can be **reduced by more than 60 per cent** within all the coordinated support variants investigated (at cluster level).[55]

By setting coordinated activities within this group of countries (which currently stick to feed-in tariff schemes), the **transfer costs due to the promotion of RES-E can be significantly reduced**. Similar to the in-depth investigation on the EU-15 level, **feed-in tariffs are the preferable instrument to reduce the consumer burden**. Also the premium feed-in tariff variant, where a higher risk is taken into consideration, results in lower transfer costs compared to a TGC system. **In the case of an ambitious target, the TGC system is the worst option even when compared to non-harmonised national (but strengthened) policies**.

In contrast, **by improving support schemes with respect to their effectiveness and efficiency at the national level, i.e. as assumed within the “strengthened national policies” variants, differences to coordinated actions become smaller or even vanish**. Only the variants which refer to coordinated actions based on feed-in systems are preferable to solely national efforts. In a premium feed-in scheme, transfer costs can be reduced by 7% and by 12% within a fixed feed-in system compared to the default case of “strengthened national policies”. These improvements are mainly caused by setting differing technological preferences, i.e. by neglecting novel RES-E options as assumed for all coordinated activities, which result in a lower consumer burden according to the model-based analysis. By neglecting these currently more expensive RES-E options also for the purely national policy in-

55 Of course, such efficiency improvements are also achievable solely at a national level – as can be seen in the case of strengthened national policies which result in an uneven higher RES-E deployment.

vestigations as done in the case "strengthened national policies – excl. novel RES-E options", it can be seen that almost similar improvements of the economic efficiency can be achieved compared to the pure fixed feed-in tariff system. The only remaining differences appear due to the fact that in a common feed-in system, where all investigated countries stick to this policy scheme, the main preferences of it affect all countries. Namely these are the lower risk, which occurs from an investor's viewpoint, and the technology specific support, that reduces unnecessarily high producer margins. Accordingly, societal costs are still marginal lower in a coordinated fixed feed-in system compared to the case of strengthened national polices, where still some countries stick to non-technology specific support policies.

Note that **a harmonisation on EU-15 level would result in lower transfer costs but also a lower RES-E deployment** in this group of countries. This is caused by the fact that e.g. a high RES-E deployment is already currently achieved within three of the four cluster countries, consequently the cheap available additional realisable potential is smaller compared to the other European Member States.

► *CLUSTER B (Belgium, Italy, Sweden, United Kingdom)*

Similar to above, the following figures aim to illustrate the consequences of investigated policy variants referring to CLUSTER B. In this context, a comparison of the financial support (i.e. premium to power price on average) for yearly newly installed RES-E plant is depicted in Figure 42. Again, scenarios referring to the BAU-target are placed left and policy cases with regard to the ambitious target are shown on the right. Below, in a similar manner the resulting yearly transfer cost for consumer are illustrated in Figure 43. Finally, the overall comparison at cluster level of RES-E generation and cumulative transfer costs for consumer, both referring to new RES-E installations from 2006 to 2020, is shown in Figure 44.

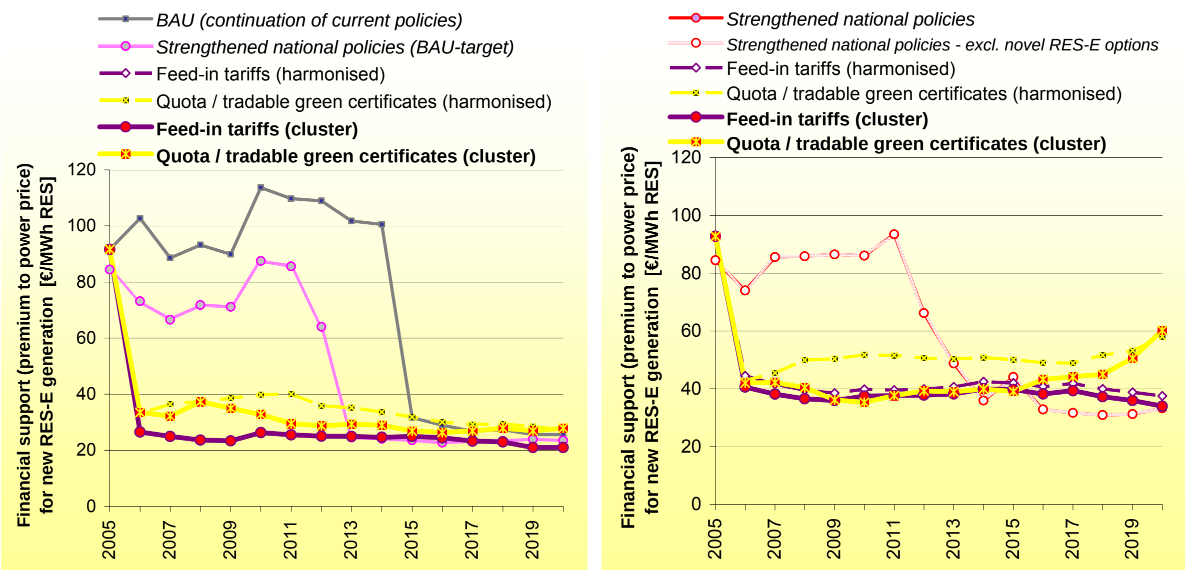

Figure 42. Comparison of **financial support** (premium to power price on average)
for yearly newly installed RES-E plant for the support schemes investigated at cluster level (CLUSTER B)
for the BAU (left) & the ambitious target (right)

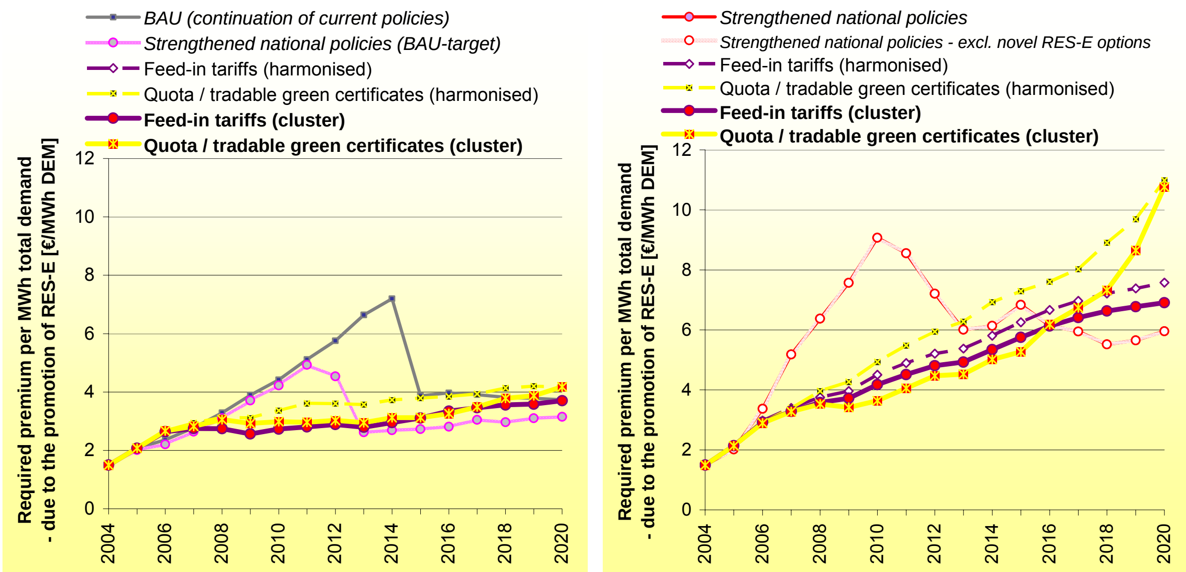

Figure 43. Comparison of the average **required premium per MWh total demand** (i.e. the yearly transfer costs for consumers) due to the promotion of RES-E for the support schemes investigated at cluster level (CLUSTER B)
for the BAU (left) & the ambitious target (right)

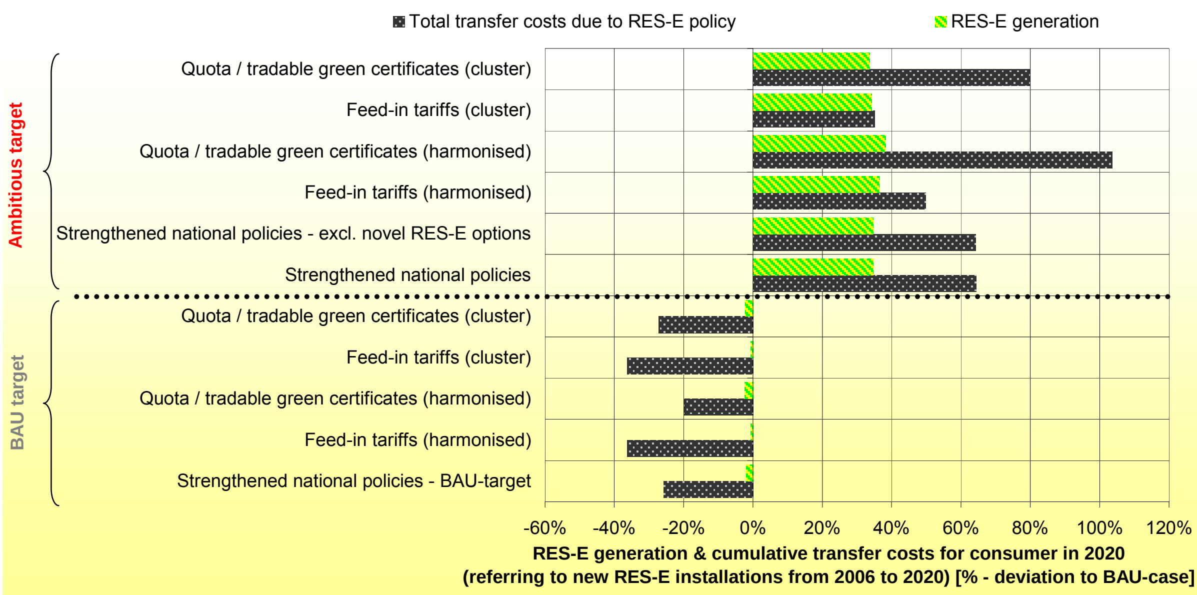

*Figure 44. Comparison of **RES-E generation from new plant** (installed 2006 to 2020) and **corresponding cumulative transfer costs for consumer** at cluster level for all investigated cases – expressing the deviation to the BAU case (CLUSTER B)*

Note: In the case of a TGC scheme total transfer costs paid after 2020 are estimated assuming that
the average TGC price of the last three years is constant up to the phase out of the support

Results:

Coordinated activities are preferable from a societal point-of-view **compared to the BAU-case** for the countries which currently have TGC-systems.

The **gains – i.e. reduced transfer costs – are not as high as for the "CLUSTER A".**[56]

Similar to the investigations done before, **feed-in tariffs, coordinated at cluster level, would be the preferable instrument to reduce the consumer burden** for these countries as well. However, with improved TGC systems, which allow trade at cluster level and include all available RES-E options, the consumer burden (referring to new installations in the period 2006 to 2020) can also be reduced compared to the BAU-case.

Improvements made at a national level as in the "strengthened national policies" case are preferable to a TGC system coordinated at cluster level. This is caused by the fact that setting additional support measures on a national level (as is done in the UK by applying investment subsidies and tax incentives) seems preferable to opting for a pure TGC system at cluster level.[57]

Note that in the case of **striving for an ambitious RES-E target, a harmonisation on EU-15 level would result** – compared to the case of "strengthened national policies" – **in a higher RES-E deployment, whilst the associated transfer costs can only be reduced in the case of harmonised feed-in systems**.

56 This indicates that current (BAU) promotion activities, especially for novel technologies such as photovoltaics, are weaker in this set of countries compared to the strong incentives set in countries like Germany and Spain. Accordingly, within the countries comprised within "CLUSTER B", which all currently stick to TGC-systems as dominant promotion instrument, no novel RES-E options contribute to the achievement of the BAU-target. Additionally, the BAU-target is also in total comparatively lower than in the countries of "CLUSTER A". Consequently, the cost burden can not be reduced as much with coordinated actions.

57 The additional support as done by applying investment subsidies and / or tax incentives represents a rather save income for investor's compared to the unsafe earnings as gained through the TGC-system. Accordingly, the level of investor risk and the corresponding risk premium is slightly reduced compared to a pure TGC-system.

5.3.4 Consequences from a national point-of-view: The case of Germany and the UK

In the following the impact of setting harmonised policies or coordinated actions is analysed from a national viewpoint. Such an assessment is undertaken exemplarily for Germany and the United Kingdom. Both countries are chosen due to their differing background regarding RES-E:

On the one hand, Germany is well known for its significant historical achievements in promoting RES-E by setting favourable incentives. Consequently, Germany is today – for several years – the leading country world wide with respect to wind power installations and, additionally, extensive promoter of novel RES-E options such as PV. However, domestic resource conditions are rather moderate for both technologies.

In contrary, the UK is characterised by favourable resource conditions, e.g. large future potentials in the area of wind or wave energy. The achieved progress in terms of MW installed is comparatively low. Besides, the UK is a representative for a country consequently sticking to a TGC-system with regard to the promotion of RES-E, whilst Germany strives for promotional activities based on Feed-in systems.

► ***Germany***

First, the two purely national policy variants are discussed – i.e. the BAU-case, representing a continuation of current RES-E policies and the case of a strengthened and improved national promotional policy. In both variants the indicative target as set by the 'RES-E directive' will be fulfilled in this country. Differences among the policy variants appear especially in the period after 2015, where within the BAU-case the continuous growth of RES-E will slow down suddenly – due to the rapidly decreasing financial support. Consequently, in the BAU-case total RES-E deployment in 2020 will contribute to meet 21% of the gross national electricity demand, whilst in case of a strengthened and improved national promotional policy 28.4% would be feasible. In this context, Figure 45 gives a brief illustration of the overall deployment (left) as well as the technology-specific development (right).

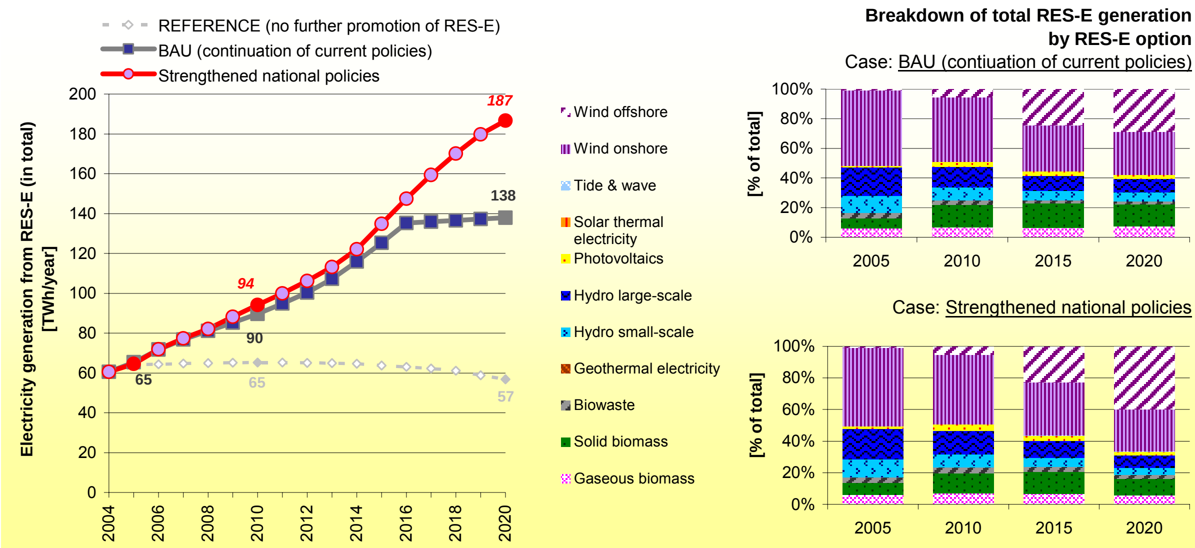

Figure 45. Development **of total RES-E generation** in the period 2004 to 2020 in Germany in the BAU case and with strengthened national policies

Due to less public support and acceptance as well as the diminishing future potential, the share of large scale hydro will decrease steadily in relative terms. The most promising future option for Germany is wind offshore, where a huge growth is expected especially under strengthened efforts.

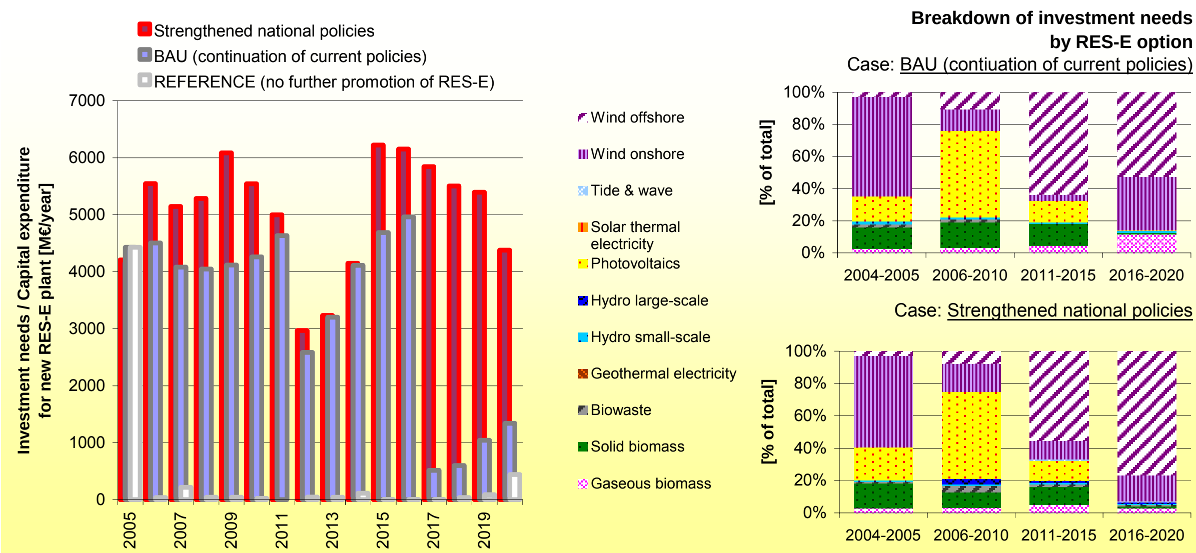

Figure 46. Total **investment needs** in the period 2005-2020 within Germany – in the BAU case and under strengthened national policies

The required investments in new RES-E plant are illustrated in Figure 46 for the period up to 2020. While necessary investments into wind onshore are decreasing steadily, although replacement of existing wind mills takes place, wind offshore and photovoltaics seems to attract the most with growing shares.

Figure 47 compares the necessary financial support for new RES-E installations (on average) for both cases. As mentioned previously, this indicator describes from an investors point-of-view the average additional premium on top of the power price guaranteed (normalised 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-E} for a new RES-E plant compared to a conventional option (characterised by the power price). We would like to emphasise here that these figures can not be compared directly to the average remuneration for German EEG-generation, because it only considers new generation installed after 2005. Within both cases it is noticeable that the expressed average financial support decreases rather fast in the period 2009 to 2012. This is mainly caused by the fact that a large reduction of yearly PV installations is projected for the same period - as feed-in rates decrease faster than projected progress in terms of cost reductions. Again, the importance of improving the design of policy instruments as well as of a rigorous removal of non-economic hindrances is getting apparent: A higher share of RES-E deployment is possible to achieve with less financial support per MWh_{RES-E} as can be seen by comparing the figures for the BAU-case and strengthened policies variant. Only in the final period up to 2020 financial support is on higher level under strengthened policies – due to the diminishing support and the consequently low further penetration within the BAU-case..

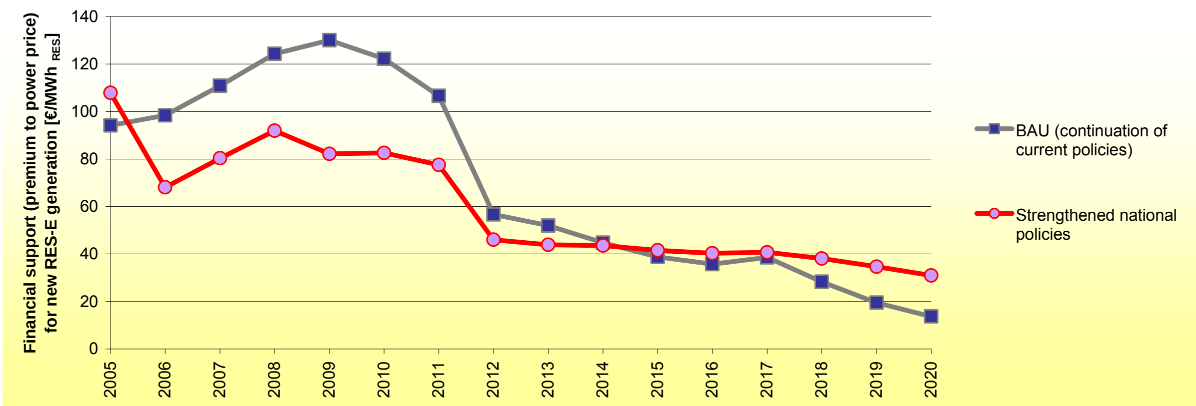

Figure 47. Comparison of ***financial support*** *(average premium to power price)* ***for new RES-E generation*** *in Germany in the period 2005-2020 for the BAU case and under strengthened national policies*

Next, Figure 48 illustrates the necessary yearly consumer expenditure for both variants – expressed as (average) premium per MWh total demand. Due to the diminishing additional deployment in the second decade, consumer burden is higher under strengthened efforts – but accompanying RES-E deployment is uneven higher.

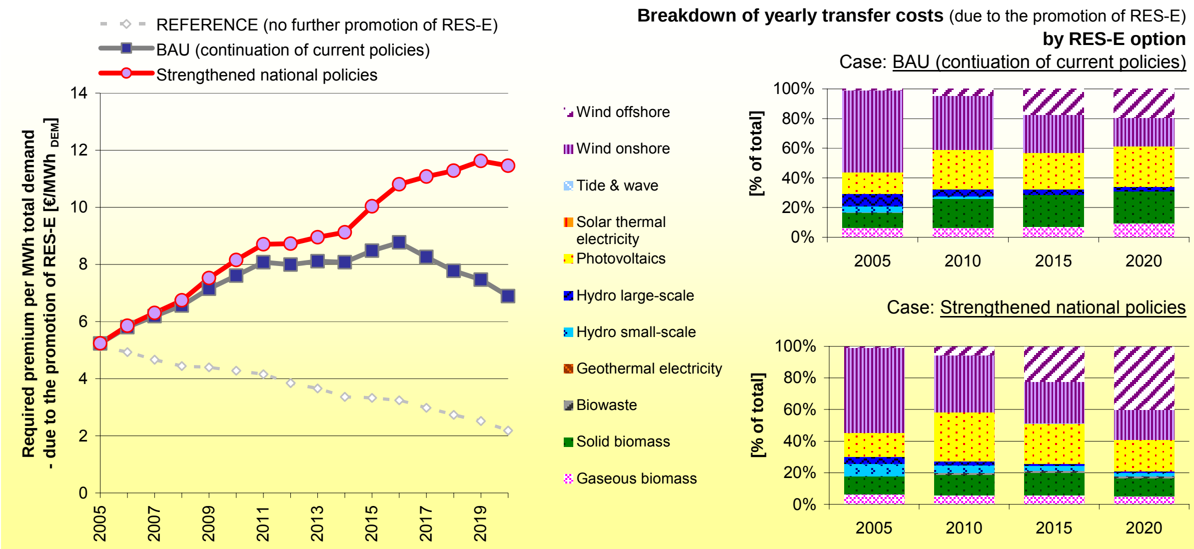

*Figure 48. Development of **necessary yearly transfer costs for consumer** due to the promotion of RES-E in Germany in the period 2005-2020 for the BAU case and under strengthened national policies*

Finally, a comparison of the impact of applied harmonised, respectively non-harmonised policy set-tings on resulting RES-E deployment and accompanying transfer costs for consumer is undertaken. Thereby, utmost all variants are taken into account.

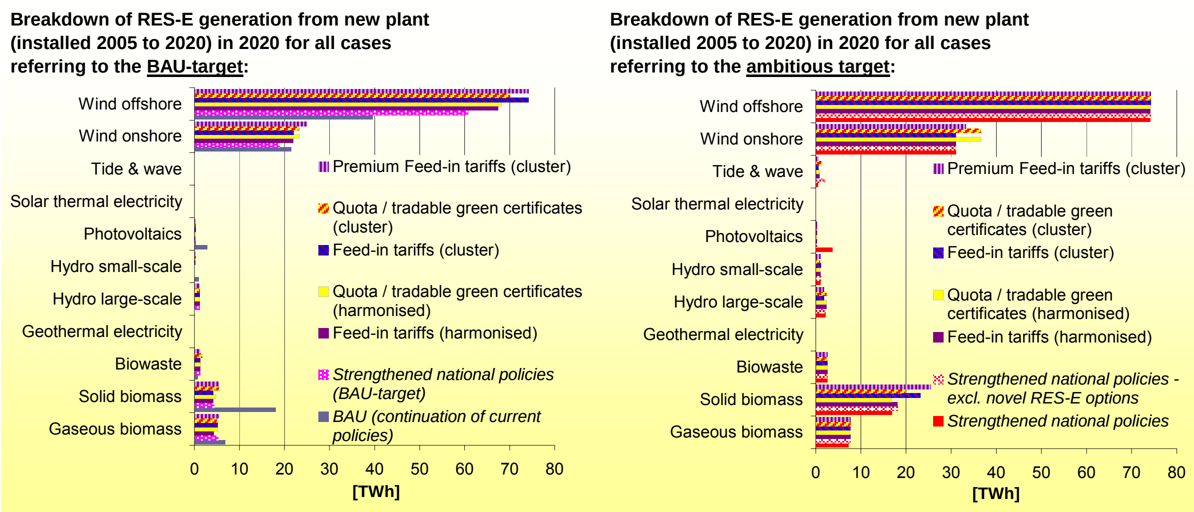

*Figure 49. Technology-specific **breakdown of electricity generation from new RES-E** plant (installed in the period 2005 to 2020) in Germany for 2020 for the investigated cases referring to the BAU- (left) and the ambitious target (right)*

Figure 49 (left) illustrates which RES-E options contribute most for the achievement of the BAU-target. As stated above, the highest penetration can be expected for wind offshore – but also wind onshore and – especially under BAU-conditions – solid and gaseous biomass are of relevance. This is also the case for the more ambitious target, where a slightly more homogenous contribution can be observed, see Figure 49 (right).

Below, Figure 50 compares for all investigated cases referring to the ambitious target from a national perspective exemplarily for Germany the resulting RES-E generation and the corresponding cumulative transfer costs for consumer, both referring to new RES-E installations in the period 2006 to 2020.

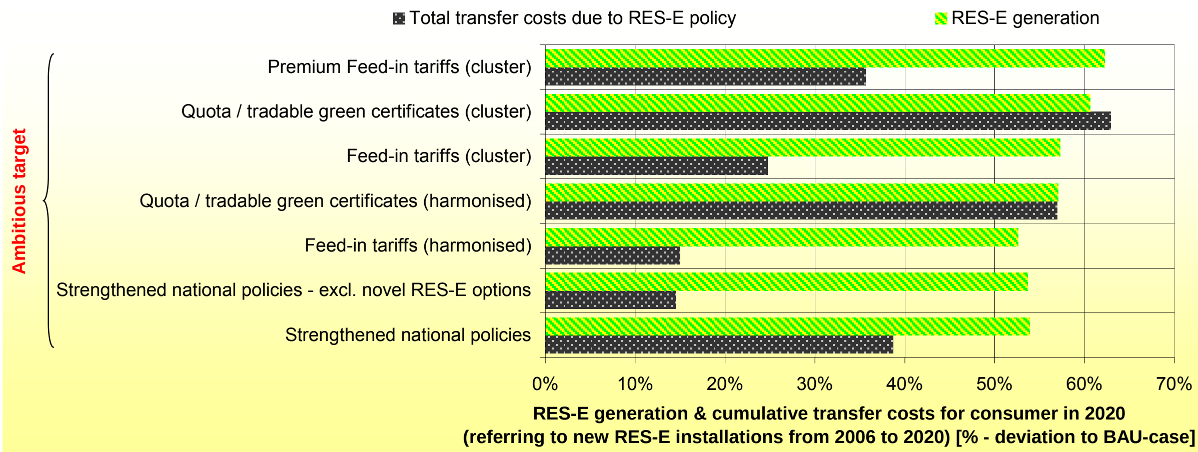

Figure 50. *Comparison of **RES-E generation from new plant** (installed 2006 to 2020) and **corresponding cumulative transfer costs for consumer** in Germany*
for all cases referring to the <u>ambitious target</u> – expressing the deviation to the BAU case

Note: In the case of a TGC scheme total transfer costs paid after 2020 are estimated assuming that the average TGC price of the last three years is constant up to the phase out of the support

<u>Results:</u>

As can be seen in the prior figures, **all policy variants result in a higher RES-E deployment in 2020 compared to the BAU-case**. This is **caused by the rapid decrease in financial support** (e.g. in wind offshore or PV) **under BAU-conditions** and the resulting stop in deployment in the later years. Consequently, even within an EU-wide TGC-system, a higher RES-E penetration can be expected for Germany in 2020.

Feed-in systems applied under harmonised conditions or coordinated at cluster level as well as strengthened national policies[58] **are the most promising policy option**

58 The consumer burden in case of strengthened national policies referring to the ambitious target can be kept on a similar level as within coordinated or harmonised feed-in tariffs – simply by reducing support of novel RES-E options. However, the consequences of such a strategy have to be analysed and discussed in a broader context.

for Germany – independent of the target to be achieved. Obviously, also by opting for a TGC-System a stronger application of RES-E could be achieved, but only with very high societal costs.

► United Kingdom

Again, as a starting point the two purely national policy variants are discussed – i.e. the BAU-case, where a continuation of current RES-E policies is assumed and the case of a strengthened and improved national support policy.

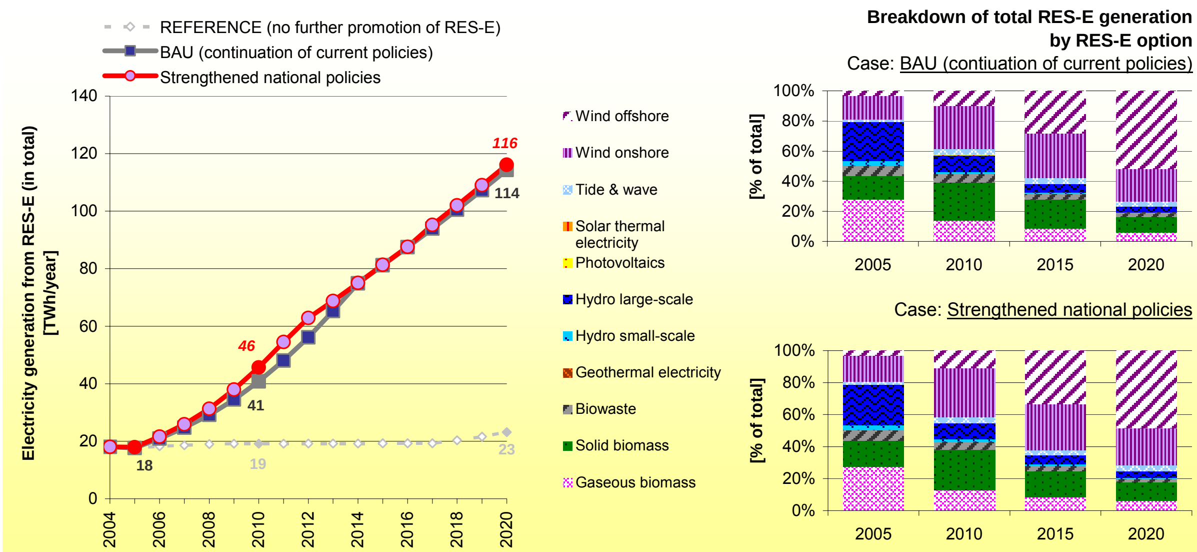

Figure 51. Development of **total RES-E generation** in the period 2004 to 2020
in the UK in the <u>BAU case</u> and under <u>strengthened national policies</u>

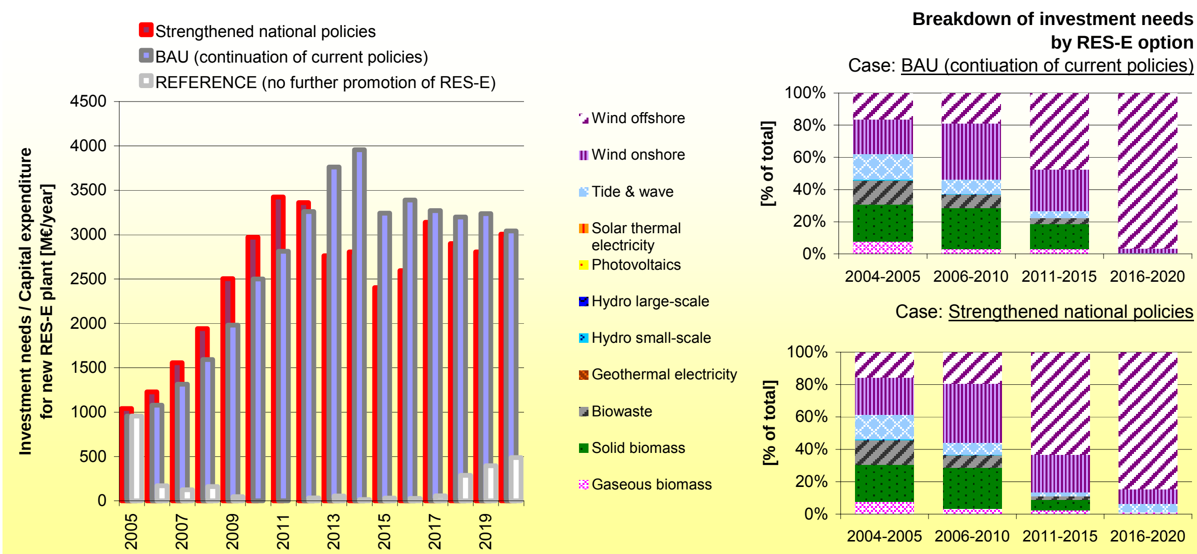

*Figure 52. Total **investment needs** in the period 2005-2020 within the UK – in the BAU case and under strengthened national policies*

In the BAU-case United Kingdom will fail to fulfil the indicative target as set by the 'RES-E directive' – a RES-E share of 9% can be expected, which is about 1% in terms of total demand below the goal. With slight adaptations of the current support scheme and especially by improving the situation with respect to non-economic hindrances, the goal can be met as indicated by the strengthened policy variant. Differences among the two policy variants appear in the first decade up to 2015, which illustrates the importance of immediate actions. In this context, Figure 51 provides a brief depiction of the overall deployment (left) and the technology-specific development (right). Similar to Germany, wind energy represents the most promising RES-E option – onshore in the near future and offshore in the mid-term. This is also illustrated in Figure *52*, which shows the necessary capital expenditures in new RES-E plant for the period up to 2020.

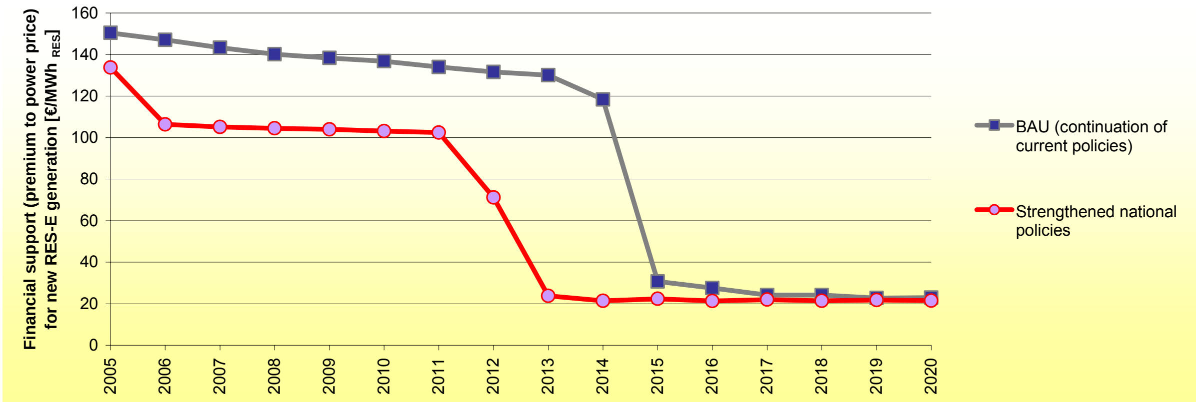

*Figure 53. Comparison of **financial support** (average premium to power price)*
***for new RES-E generation** in the UK in the period 2005-2020 for the BAU case and under strengthened national policies*

Figure 53 depicts the necessary financial support for new RES-E installations (on average) for both cases. The situation in the UK in the near future is characterised by a high demand for RES-E (due to the quota obligation), accompanied by a slightly decreasing lack of investors confidence and still valuable non-economic barriers such as less social acceptance for wind onshore. This market shortage results in high TGC prices as expressed in the figure above. However, even in the BAU-case it can be expected that improvements will take place, which cause the drop in required or respectively provided support premiums after 2014.

Next, the necessary financial incentive for the promotion of RES-E is presented. Figure 54 illustrates the accompanying yearly transfer costs for consumer for both variants – expressed as (average) premium per MWh total demand. In this context, the consumer expenditure due to the support for RES-E represents a net value referring to the direct costs of applying a certain support scheme. As there can be seen a rather steep rise in required expenditures occurs in the next ten year in the BAU-case, starting from a level of 2.9 €/MWh$_{DEM}$ in 2005 up to about 13 €/MWh$_{DEM}$ in 2014. After 2015 required expenditures drop significantly to a steady level of about 5.5 €/MWh$_{DEM}$. Within the strengthened policy variant, characterised by a possible faster deployment of RES-E in the short term, the gap between demand and supply can sooner be closed. Consequently, transfer costs do not reach such a high peak as under BAU-conditions.

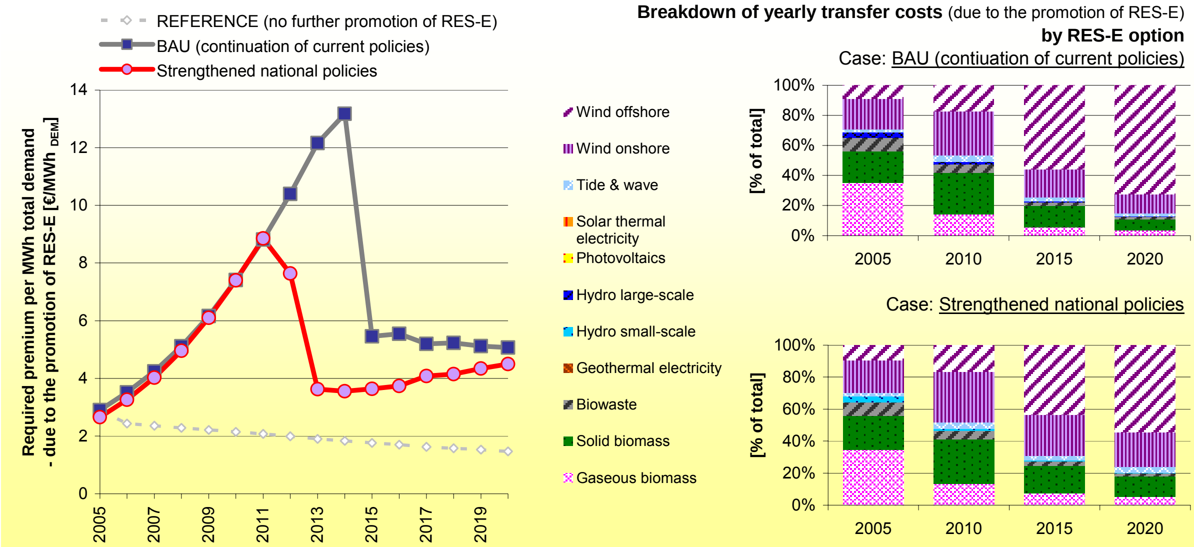

*Figure 54. Development of necessary **yearly transfer costs for consumer** due to the promotion of RES-E in the UK in the period 2005-2020 for the <u>BAU case</u> and under <u>strengthened national policies</u>*

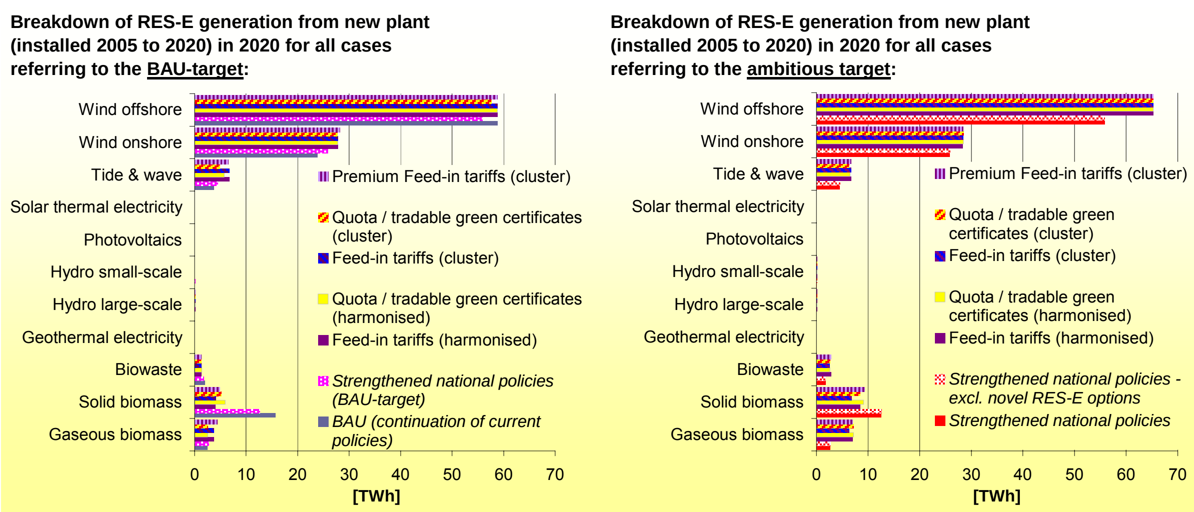

*Figure 55. Technology-specific **breakdown of electricity generation from new RES-E** plant (installed in the period 2005 to 2020) in the UK for 2020 for the investigated cases referring to the BAU- (left) and the ambitious target (right)*

Figure 55 (left) depicts the RES-E options contributing most to the achievement of the BAU-target within various of the investigates policy variants. Again, the highest penetration can be expected for wind offshore – but also wind onshore and – especially under BAU-conditions – solid and gaseous biomass are of relevance. This is also the case for the more ambitious target, where a slightly more homogenous contribution can be observed, see Figure 55 (right).

An overall comparison with respect to United Kingdom is given in Figure 56, depicting the resulting RES-E generation and the associated cumulative transfer costs for consumer, both referring to new RES-E installations in the period 2006 to 2020, for all investigated cases.

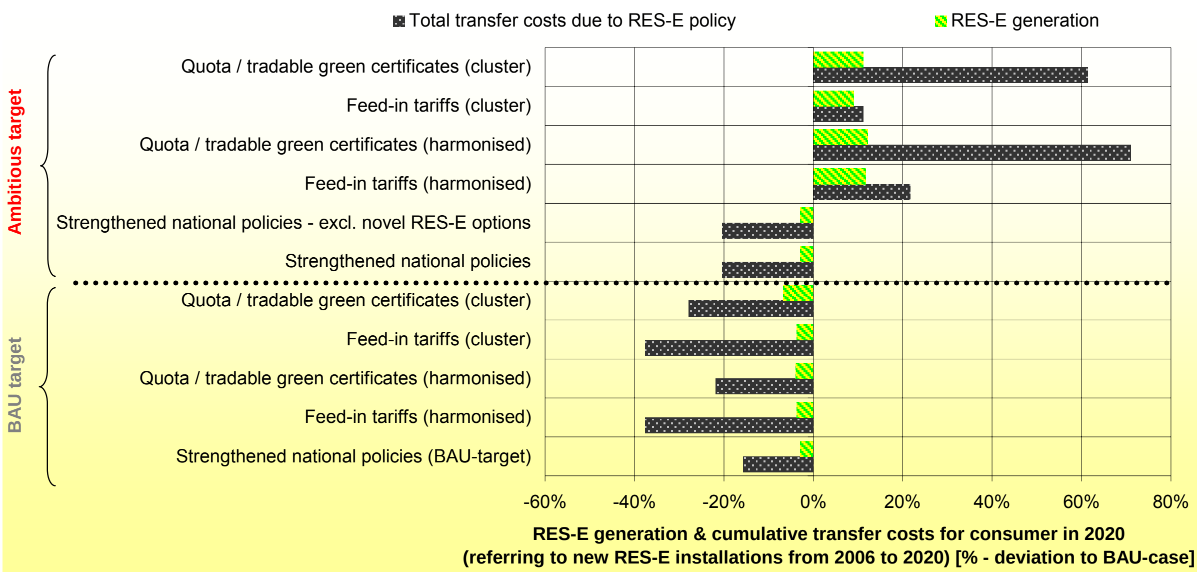

*Figure 56. Comparison of **RES-E generation from new plant** (installed 2006 to 2020) and **corresponding cumulative transfer costs for consumer** in the United Kingdom for all investigated cases – expressing the deviation to the BAU case*

Note: In the case of a TGC scheme total transfer costs paid after 2020 are estimated assuming that the average TGC price of the last three years is constant up to the phase out of the support

Results:

The **policy variants** referring to the **ambitious target** result in a higher RES-E deployment in 2020 – **due to** the assumed **rigorous removal of non-economic deficits**, which play a crucial role in the UK.

For achieving an ambitious mid-term RES-E goal, **feed-in tariffs occur as the preferable option** – due to the **technology specification of support conditions**. Especially coordinated actions on the basis of feed-in tariffs – i.e. applied on cluster level – seem to be favourable for the UK.

Comparing the variants referring to the moderate BAU-target, a similar conclusion can be drawn. Thereby, **all policy variants seem to be preferable compared to the status quo**.

5.4 Sensitivity analysis

In the following, sensitivity cases will be outlined, accompanying the set of scenarios as described in the previous sections. In more detail, resulting electricity generation from RES-E and accompanying transfer costs for consumer will be compared to the default development of the BAU-scenario as well as the case of strengthened national policies for a variation of:

- The reference price for (conventional) electricity (i.e. by imposing differing CO_2-constraints);
- Assumptions referring to technological learning (i.e. by varying learning rates as assumed on technology level).

► *Impact of the reference price for (conventional) electricity*
(due to differing CO_2-constraints)

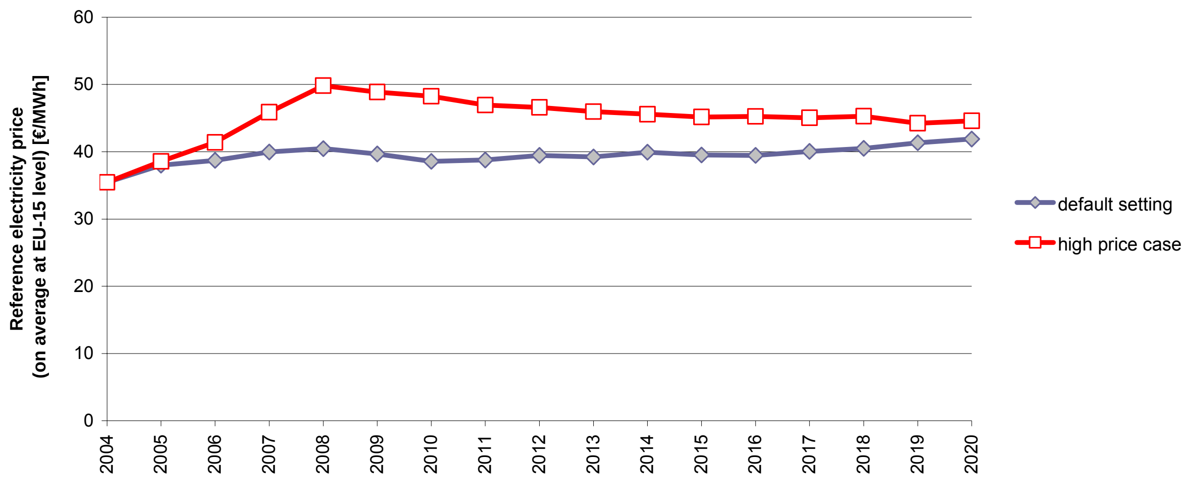

Figure 57 Development of the applied reference electricity price (on the wholesale market) up to 2020 for the sensitivity investigations

The first sensitivity case describes the impact of the reference price for (conventional) electricity on the outcomes of the analysis. Figure 57 depicts the development of this parameter for the investigated cases. Note that these scenarios are calculated by modelling also the conventional power market in the EU15. Hence, differing reference prices are a result of applied CO_2 constraints, i.e. represented by the impact of Tradable Emission Allowances (TEA). More precisely, the following variants are investigated:

- A 'moderate price case' – i.e. where a **moderate impact of TEA** can be observed (assuming an increasing tradable emission allowance price up to 10 €/t-CO_2). This variant represents the ***default case*** with respect to the conventional power market – as used for all scenarios illustrated in the previous sections.
- A 'high price case' – i.e. characterised by high reference prices as a result of a **strong impact of TEA** (assuming an increasing tradable emission allowance price up to 20 €/t-CO_2).[59]

As can be seen in Figure 57, in case of a high CO_2 constraint the power market requires a few years to match with the changing framework conditions. However, differences in prices will obviously remain also in the mid to long term, but they are rather small between a high and a medium CO_2 constraint (in contrast to a case where no CO_2 constraint is applied).

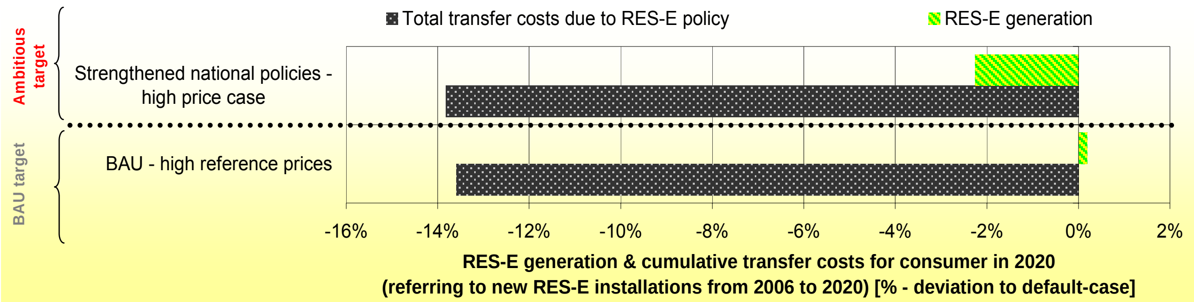

Figure 58 *Comparison of **RES-E generation from new plant** (installed 2006 to 2020) and **corresponding cumulative transfer costs for consumer** at the EU-15 level for all sensitivity cases (variation of reference price) – expressing the deviation to the default cases (BAU (lower part) & strengthened national policies (upper part))*

The **impact on RES-E deployment** retaining current RES-E policies (BAU-policies) as well as in case of strengthened national policies is depicted in Figure 58, illustrating the deviation to the default cases at EU-15 level with regard to new RES-E installations in the investigated period 2006 to 2020.

On the face of it, one might argue that RES-E generation would not be influenced tremendously by a moderate variation of the reference price for (conventional) electricity on EU-15 level, as only a few countries are currently applying a promotional scheme where the financial incentive is defined as fixed premium on top of the elec-

59 Considering recent developments market for tradable emission allowances, one might conclude that the presumed 'high price case' can be seen as a rather moderate projection of future conventional power prices.

tricity market price.[60] Hence, the results of the sensitivity cases do indeed show only small differences in terms of RES-E deployment:

- In the BAU-case a rather small positive correlation can be observed (+0,2%).
- Surprisingly, a negative correlation can be observed in case of an ambitious target – i.e. a higher reference price results in a slightly lower RES-E deployment (-2%). The reason for this must be seen in the dynamic deployment in the early years where it can be argued that more cheaper technologies penetrate the market.

Considering the **resulting transfer costs** for consumer due to the promotion of RES-E, a higher sensitivity can be expected and also observed in Figure 58. The sensitivity investigation clearly indicates:

- Transfer costs and electricity prices are negatively correlated. Consequently, the consumer burden due to higher electricity prices would be – of course only partly – compensated by lower promotional costs and vice versa.
- The impact on transfer costs is comparatively much higher than on RES-E deployment[61] (i.e. in size of -14% compared to +/-0% for RES-E deployment).

► *Impact of technological learning*

Next, the impact of technological learning is investigated. Two variants are compared with the default assumptions with respect to technological learning as applied in all previous investigations. Again, policy settings are similar in all cases, i.e. assuming a retaining of current RES-E policies on country-level (BAU-case) and an improvement of national promotion strategies (strengthened national policies). Based on these assumptions the impact of technological learning on both RES deployment and corresponding transfer costs can be observed. In contrast to these assumptions, for achieving a similar RES deployment the impact of technological learning on societal transfer cost is obvious: Reduced technological progress, i.e. 'lower learning', would cause a higher cost burden, whilst increased progress, i.e. 'higher learning', would result in lower cost.

In more detail, the following variants are analysed:

- A '**low learning case**' – i.e. characterized by low learning rates for all RES-E – (LR = 85% of default);
- A '**high learning case**' – i.e. characterized, in contrast to above, by high learning rates – (LR = 115% of default).

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60 Compare e.g. the Spanish RES-E policy which contains as major instrument technology specific premium feed-in tariffs. Under such a scheme the financial incentive for new RES-E is positive correlated to the electricity market price.

61 A further aspect – neglected in these model runs – is the impact of electricity prices on the overall demand for electricity, characterised by its price elasticity. A reduced demand in case of a higher reference price would cause a higher RES-E premium per MWh of demand for consumer.

Varied settings with respect to technological learning refer to the future development of investment-, O&M-costs as well as improvements of the conversion efficiency and related performance parameter. For those RES-E options, where it was decided to stick to expert forecasts (e.g. tidal and wave energy – see section 5.1), similar adaptations are undertaken.

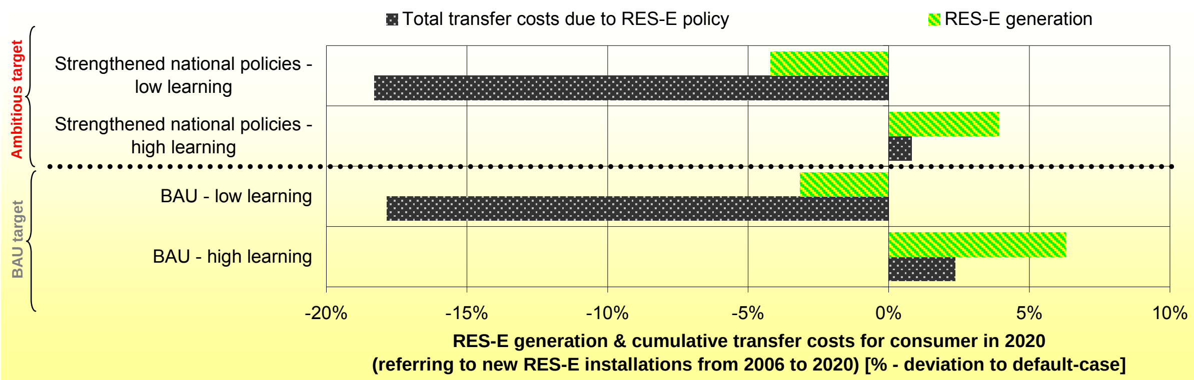

Figure 59 *Comparison of **RES-E generation from new plant** (installed 2006 to 2020) and **corresponding cumulative transfer costs for consumer** at the EU-15 level for all sensitivity cases (<u>variation of technological learning</u>) – expressing the deviation to the default cases (BAU (lower part) & strengthened national policies (upper part))*

Similar to the previous sensitivity case, the impact of the variation of settings with respect to technological learning on **the deployment of new RES-E plant** up to 2020 at EU-15 level is illustrated in Figure 59, indicating the deviation to the default cases. The following can be observed:

- In the 'high learning case' for both targets (i.e. the moderate BAU- and the ambitious target) a higher RES-E deployment occurs.
- Of no surprise, in the 'low learning case' a lower RES-E deployment takes place.
- Summing up, variations of technological learning as investigated in size of $^{+}/_{-}$15% to default effect RES-E deployment in size of -4.5% to + 6%.

With respect to the **resulting transfer costs for consumer** due to the promotion of new RES-E the following observations are of relevance:

- The higher RES-E deployment in case of higher learning leads to no significant cost increase, as lower financial incentives are required due to the accelerated decrease of RES-E generation costs.
- The lower RES-E deployment in case of lower learning has a high impact on resulting transfer cost – i.e. where -4% RES-E deployment cause about -18% less consumer burden.

In general, a stronger impact of technological progress on RES-E deployment can be observed for novel, currently more expensive RES-E options. Accordingly, their lower or higher penetration has also a stronger impact on the resulting transfer costs than in case of 'inexpensive' RES-E technologies.

6 DESIGN CRITERIA FOR RES-E SUPPORT INSTRUMENTS

A number of design criteria for RES-E policy instruments are generic, i.e. they should be implemented regardless of the specific support scheme under consideration. Therefore we would like to list these design criteria first before moving on to the design criteria for the different instruments: feed-in tariffs, quota systems based on TGCs and tender systems. This chapter builds on the conclusions derived from the empirical as well as the model based investigations performed in this study.

6.1 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 are:

- The full basket of technologies given in the RES-E directive which can be reasonably utilised in a given country should be included in a support scheme. This requirement encompasses the inclusion of the least cost generation options, e.g. refurbishment of large hydropower, as well as of less mature and more expensive technologies, e.g. concentrating solar power in southern European countries. Least cost generation options contribute to a high static efficiency of the support scheme, whereas the early promotion of less mature technologies increases the dynamic efficiency.
- Long-term and sufficiently ambitious targets are essential in order to ensure a sufficient level of investor security. Also the applied policy instrument should remain active long enough to provide stable planning horizons. It follows that stop-and-go policies are not suitable and that for a given project the support scheme should not change during its lifetime.
- A transparent and fair access to the electricity grid should be provided.
- Generally the financial incentive level should be higher than the marginal costs of generation (in the case of a quota system the level of penalty is relevant).
- The support offered by any promotion instrument 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; it is important to consider the compatibility with the conventional power market and other policies.

Besides these generic design criteria, instrument-specific design criteria have been identified and are discussed in the following section.

6.2 Design criteria – instrument-specific

Quota System

The following criteria should be implemented for a quota system:

- Guarantee a sufficient market liquidity and competition within TGC markets in order to secure market functionality. In a quota system one should aim for an international market in the medium term. Small technology-specific markets should be avoided, e.g. one negative example is the former TGC system for small hydropower in Austria. Even in larger markets, the concentration of market power may occur (e.g. currently observed in UK) and violate the market functionality. Therefore a minimum number of independent players should be required in TGC markets.
- The penalty needs to be set correctly, i.e. it should be significantly higher than marginal production costs at quota level. The violation of this requirement led to the limited effectiveness of the Swedish and the Polish quota systems.
- Additional support has to supplement the quota system in order to support less mature technologies unless the system is designed to support different types of technologies, e. g. by using technology-specific certification periods.
- A guaranteed minimum tariff should be implemented in immature markets in order to ensure investment security.
- Set long term quota in order to ensure investor confidence.

Feed-in System

The following criteria should be implemented for a feed-in system:

- The level of tariffs needs to be guaranteed for a sufficiently long duration in order to reduce investment risks.
- Technology-specific tariffs should be used and the level of tariffs should be sufficiently high (higher than marginal generation cost in order to ensure a sufficient return on investments).
- In order to enforce technological learning, the tariff offered for new contracts should decrease in a foreseeable manner over time.
- If reasonable, a graduated tariff design should be implemented to reduce windfall profits and therefore reduce costs for consumers.[62]

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62 Graduated feed-in tariffs have to be based on a well defined efficiency criteria. Such a criteria is given in the case of wind energy by the actual achieved capacity factor – as currently implemented for the support of wind onshore in countries like France, Germany, and Portugal. In case of biomass or hydropower the plant size or the fuel input may serve as a differentiator for support heights.

Tender system

The following criteria should be implemented for a tender system:

- Ensure continuity of calls and predictability over time.
- Tenders should be technology-specific and a reasonable capacity (not too high and not too low) should be included in the tenders. If capacity is too low, administration and transaction costs increase, if the capacity is too high, the options for strategic bidding increase.
- The interaction with other policy objectives has to be considered beforehand, e.g. environmental planning rules have to be coordinated at an early stage in order not to violate the projects (successful bids) in the realisation phase.
- A penalty for non-compliance should be implemented in order to avoid unreasonably low bids.

7 MAIN FINDINGS ON THE PROPERTIES OF FEED-IN SYSTEMS AND QUOTA SYSTEMS

The main properties of the two most important instruments used in Europe, of feed-in systems and quota systems are listed in the following. The different key properties given in the following are either derived in the scope of the present analysis or based on previous work mainly on EU level. For each statement given in the following the key references will be given.

I. Analysis of the main properties of feed-in systems

1. Proven to be successful and effective

Feed-in tariffs (FITs) have been successful in triggering a considerable increase of RES-E technologies in almost all the countries in which they have been introduced and where their effectiveness was not significantly hampered by major barriers (administrative barriers, grid access, etc.). (see section 4 of this report and Green-X (2004), OPTRES (2005), Uyterlinde (2003), Huber (2001)).

2. The risk premium required by investors can be minimised by the high level of price security in the system

The capital costs for RES investments observed in countries with established feed-in systems have proven to be significantly lower than in countries with other instruments which involve higher risks of future return on investments. (see section 4 of this report and Green-X (2004), Huber (2001), Cleijne (2004)).

3. Low costs for society

Feed-in tariffs can lower costs for society primarily in two ways. The application of stepped tariffs reduces producer profits in comparison to support schemes with uniform market clearing, thus reducing the cost for society. A tariff which is reduced over time in line with technology learning can also reduce the cost for society. (see section 5 of this report and Green-X (2004), OPTRES (2005), Huber (2001)).

4. Helps to promote a specific portfolio among different RES-E technologies

The technological differentiation of feed-in tariffs helps to promote a specific portfolio of technologies. In this way, learning can be stimulated across the portfolio which helps to reduce future costs. Another way to express this fact is that feed-in tariffs typically have a very high dynamic efficiency. Due to an early market diffusion of technologies that are important for stable RES growth in the long term, the future costs for society can be significantly reduced. The latter advantage might, however cause higher RES-E generation costs in the short term (see next item). (see section 5 of this report and Green-X (2004), OPTRES (2005), Huber (2001)).

5. Leads to a minimisation of costs for society but not necessarily to minimisation of generation costs (depending on the technology portfolio supported under the feed-in system)[63]

A feed-in tariff does not necessarily lead to the minimisation of generation costs, especially if technology-specific tariffs and stepped tariffs are applied. Nevertheless, a feed-in tariff can lead to cost minimisation for society if the tariffs are selected appropriately (see section 5 of this report and Green-X (2004), OPTRES (2005), Huber (2001)). Important aspects of so doing are:

1. The risk reduction for investors due to guaranteed tariffs leads to lower generation costs since capital can be acquired at lower interest rates.
2. Stepped tariffs can help to reduce producer surplus.
3. Decreasing tariffs over time help to reduce costs for society and encourages cost reductions.
4. Since market liquidity problems cannot occur, the abuse of market power can be excluded.

6. Helps to reach an area or plant-size specific distribution of a RES-E technology

As the tariffs can be stepped according to plant size or location, a more homogenous distribution with regard to plant size and location can be achieved. In this way, the acceptance of renewable technologies can be enhanced as more people have contact with the technology and their density in hot-spot areas is lower at the beginning. (see Green-X (2004), Huber (2001)).

7. Relatively homogenous premium costs for society over time

The combination of technology-specific tariffs and stepped tariffs can lead to more homogeneous costs for society over time. This is because technologies with higher costs can be integrated into the support from the beginning thus inducing technology learning at an early stage, which helps to overcome price hikes later on when the growth of cheaper technologies reaches its limits. (see Green-X (2004), OPTRES (2005)).

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63 Costs for society are the sum of the generation costs and the producer profit. Although generation costs might not be minimal for certain support systems the total costs for society might be minimised. The most prominent example of reducing the costs for society (based on the same generation costs) is the application of stepped feed-in tariffs, in order to reduce the producer profit.

8. Encourages competition among manufacturers but not among investors in the early phase of deployment

A tariff system does not encourage the same degree of competition among investors for the cheapest generation costs in the early phase of development which might occur under the conditions of a perfect market. Therefore it is not guaranteed that the entire potential for the reduction of specific generation costs is being exploited. However, competition among manufacturers is encouraged to a full degree, since perfect market conditions exist for RES plants and components. This results in the realisation of cost-efficient RES installations under feed-in systems.

Furthermore even if generation costs are slightly above the theoretical minimum due to the absence of competition among investors, the costs for society are not necessarily higher, depending on the analysed time frame, RES-E target and the setting of the feed-in tariffs (see item "Does not necessarily lead to minimisation of generation costs (if RES-E specific tariffs are applied) but to minimisation of costs for society"). (see Green-X (2004), OPTRES (2005)).

9. RES-E targets will be met by adjusting tariff level over time

A tariff system creates a protected market, which is not linked to the development of electricity demand. Therefore it is not possible to exactly meet a specific target for RES-E. But as tariffs for new contracts can be adjusted, there is flexibility for the modification of the system in line with set targets. In contrast to other systems, overachievement of the set targets is also possible. (see Green-X (2004), OPTRES (2005)).

II. Analysis of the main properties of the quota system in combination with tradable green certificates

1. Must be proven to be successful and effective – this mainly depends on the applied design criteria

The quota systems based on TGCs implemented in five EU member states have so far shown only limited growth, in all cases the interim targets set by the national governments have not been fulfilled. So far these markets are rather young and it has to be seen, whether these systems become more effective as markets mature. High investment risk is currently the main barrier in countries with quota systems.

Up to now, there is no rigorous and comprehensive publication, which assesses the performance of TGC schemes. Perhaps it is too early to determine (except in those cases where it has become manifestly clear that a TGC system has not worked like for small scale hydro power in Austria). In most cases narrow markets emerge as the real problem. The success of a TGC system depends on the right design, including admitted technologies, validity of the certificates, penalty level, market volume, stability of the conditions, etc. (see section 4 of this report and Green-X (2004), OPTRES (2005), Huber (2001)).

2. Investors are confronted with a higher risk

Due to the uncertainty on the TGC market a higher risk for investors occurs, leading to higher weighted average cost of capital and therefore higher generation costs and higher costs for the consumer. (see Green-X (2004), OPTRES (2005), Huber (2001), Cleijne (2004)).

3. Leads to higher costs for society if targets are set ambitious (but not RES-E specific)

Despite the fact that tradable green certificates may lead to minimal total RES-E system costs, it is likely / possible that costs for society are not minimal. The reason is that the producer can absorb most of the efficiency gains.[64] The premium costs for society mainly depend on the RES-E target, the market conditions as well as the additional support schemes.

The direct premium costs for the consumer can be diminished if (i) TGC system is standardised, (ii) an international TGC system is applied, and (iii) an additional support scheme or different technology specific targets in the case of an ambitious RES-E target is given. (see section 5 of this report and Green-X (2004), OPTRES (2005), Huber (2001)).

4. Helps to promote currently most cost efficient RES-E technologies

Within a single TGC system all RES-E technologies compete on the same TGC market. Hence, only the currently most efficient RES-E options will be chosen to generate electricity, i.e. currently more expensive technologies will not be promoted. The consequences are that the efficiency of already relative mature technologies increases, however currently less efficient – but for the future promising and necessary – technologies are less promoted. (see section 5 of this report and Green-X (2004), OPTRES (2005), Huber (2001)).

5. Leads in theory to minimisation of generation costs (if just one RES-E target)

A quota obligation system based on tradable green certificates leads in theory to minimal total RES-E system costs in the short term due to the concentration on the lowest cost technologies (whether this is actually the case depends on the balance between cost savings due to the application of low cost technologies and the level of cost increase due to higher costs of capital). In the medium to long term, however, inefficiencies may occur due to the lack of incentives to invest in currently less mature technologies. (see section 5 of this report and Green-X (2004), OPTRES (2005), Huber (2001)).

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64 In this context, the terminology 'producer' shall represent the whole chain of actors involved in the supply side of a RES-E technology – i.e. from the technology manufacturer up to the investor. Thinking in a broader sense, as recent developments in the UK have shown, it might also happen that other actors, that are involved in the trading scheme – especially those with strong market power like conventional energy supplier, gain high revenues from the unnecessarily high subsidisation.

6. Leads to a concentration effect of RES-E technologies with respect to area and plant type distribution

Due to the focus on the most competitive technologies and locations for RES-E technologies a concentration effect is caused by quota systems.

7. Costs for society increase over time as more expensive generation options need to be exploied

The additional costs for the consumer are relatively low at the beginning of the TGC system (if one abstracts from high risk premium for an immature quota system). The reasons are, firstly, a low TGC volume in the initial stage, and secondly, a low TGC price as most cost efficient generation options will be exploited first. But these costs increase by the end of the period (depending on how ambitious the target is). (see section 5 of this report and Green-X (2004), OPTRES (2005), Huber (2001)).

8. Competition among investors

Due to the establishment of a market structure competition among investors occurs. The level of competition depends on the market structure. Preconditions are completely fully liquid and transparent market for TGCs characterised by many sellers and buyers and, usually, the absence of market power. In countries with a high market volume or if the market is based at the international level these conditions are fulfilled. However, implementing a TGC system in a small size should be pursued with caution. (see Green-X (2004), Huber (2001), Cleijne (2004)).

9. RES-E target can be reached exactly (in theory)

One conceptual advantage of a quota obligation is that the target will be reached exactly under the assumption that a sufficiently high incentive is set. This means that the penalty for not purchasing a certificate is higher than the investment needed to meet the quota. It has to be noted, however, that the presently applied quota systems are not on track with the targets set in the RES-E directive and that in some examples, e.g. in the UK, the interim targets set by the national governments are not reached, despite the fact that the penalty is set at a reasonable level.

Applying an international trading scheme it is important that the penalty is set correct in all participating countries (that means above the marginal generation cost). If in at least one country the penalty is set incorrectly, i.e. it is lower than the marginal generation costs (minus the power price), the common target will not be reached. (see section 5 of this report and Green-X (2004), OPTRES (2005), Huber (2001)).

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9 GLOSSARY[65]

Biofuel – fuel derived from organic sources, e.g biogas, biomass and the biodegradable fraction of waste. Use of biofuel is neutral in terms of carbon dioxide emissions.

Biogas – the combustible mix of methane (50-75%), carbon dioxide (25-50%), as well as oxygen and nitrogen derived from the anaerobic digestion of organic material, especially wastes. Agricultural, sewage, landfill and organic wastes, produce biogas by anaerobic digestion that can be collected and combusted for electricity generation. Note that several EU countries exclude landfill gas and sewage gas from their renewable energy support programmes because of the link with established processes.

Biomass - forestry and agricultural crops and residues used as fuel. Energy crops are grown specifically as a biomass fuel. All EU countries classify biomass as a renewable energy source, although several impose conditions before granting support.

Fixed Feed-In Tariffs - 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.

Premium Feed-In Tariffs - rather than fixing the total price per kWh paid to the renewable electricity producers, government fixes a premium to be added to the electricity price. Thus, the total payment per kWh produced fluctuates with the level of the power price.

Geothermal electricity – the geothermal heat derived from the ground is used to generate electricity and/or to supply heat for hot water and for heating buildings. Geothermal heat extracted from hot underground environment is accepted as being renewable in all EU countries.

Green Tariffs - electricity tariffs that either guarantee to provide a certain percentage of electricity from renewable energy sources, or guarantee that a certain percentage of the money paid for the tariff will be invested in new renewable energy capacity.

Hydro power - for electricity can either use a dam or use the natural flow of water in a 'run of the river' system. Large hydro power (larger than 10 MW) and small hydro power (smaller than 10 MW) are differentiated. Electricity from established large hydro plant are often excluded from renewable energy support programmes, since most large hydro schemes have been in operation for many years, are fully depreciated and do not need additional support for financial viability.

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

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65 This glossary contains individual definitions used in the EU project REXPANSION "A Review of Promotion Strategies for RES-E in EU15 countries".

Municipal Waste – municipal waste can be used as a fuel to produce electricity and heat. The biological content of municipal waste is considered as renewable energy source, and so in some countries the biomass portion of the waste is eligible for support.

Quota Obligation – the government defines targets for RES-E deployment and obliges any party of the electricity supply-chain (e.g. generator, wholesaler, or consumer) with their fulfilment.

Renewable Electricity (RES-E) - electricity generated from renewable non-fossil energy sources, i.e. wind, solar, geothermal, wave, tidal, hydropower, biomass, landfill gas, sewage treatment plant gas and biogas (this corresponds to the definition in Directive 2001/77/EC on renewables, article 2).

Renewable Energy Sources (RES) – in general, it comprises all energy sources 'obtained from persistent and continuing flows of energy occurring in the environment'. EU countries have historically taken differing approaches to defining which technologies are classified as being renewable. This particularly applies to sources linked to wastes and to large hydro plant. Likewise categorisation of the many forms of agricultural 'biomass' and 'biofuels' may vary between countries. These decisions have partly been dependent on government policy objectives and public perceptions in each given country. Directive 2001/77/EC on renewables, article 2, defines *renewable energy sources* as *"non-fossil energy sources (wind, solar, geothermal, wave, tidal, hydropower, biomass, landfill gas, sewage treatment plant gas and biogas."*

Solar energy – energy initially absorbed from sunshine. If the *solar radiation* is absorbed in a device providing a controlled energy supply, e.g. hot water or electricity, this is an *active solar* system. A *solar thermal* device uses heat, e.g. a solar water heater or a heat engine for electricity generation. Alternatively, the solar radiation may be absorbed as light in a *solar photovoltaic* (PV) device for immediate electricity generation based on the photoelectric effect. All EU countries consider PV to be a renewable energy technology.

Tendering systems / Auction - developers of renewable electricity projects are invited to bid for a limited capacity or electricity production in a given period. The companies that bid to supply electricity at the lowest costs win the contracts to do so. In a tendering system strategic behaviour may occur due to the fact that bidders have expectations of marginal bids for a certain action.

Tidal Energy - there are two different technologies, tidal barriers and tidal currents. Several EU countries have small support programmes to encourage the development of tidal power systems

Tidal barriers utilise the rise and fall of the tide (the tidal range) to trap sea-water at high tide in a reservoir behind a barrage. As the water leaves and/or enters the reservoir in a constrained duct, submerged hydro turbines generate electricity, as in conventional hydropower. There is only one significant tidal barrier power plant, which is at La Rance, Brittany, in France.

Tidal-current (or stream) power is derived from water turbines submerged in the wide expanse of a tidal flow or current; there is no constructed barrier. Such a turbine is therefore the water-equivalent of a wind turbine. As yet, there are no commercial tidal-current power plants.

Tradable Green Certificate Systems (TGC) – based on a target defined in a quota obligation system, a parallel market for renewable energy certificates is established and their price is set according to demand and supply conditions (forced by the obligation). Hence, for RES-E producers, financial support may arise from selling certificates in addition to the income from selling electricity on the power market.

Wave power – the energy in waves can be captured in a number of ways. One method is to funnel the waves into a partially filled vertical tube, to form an oscillating water column. The motion of the water forces air back and forth through an air turbine to produce electricity. Power from such devices is already sold commercially to the grid in Scotland. Several other types of wave energy device are under development. Several European countries with Atlantic coastlines support the development of wave power.

Wind energy – wind turbines, which capture the energy from the wind to produce electricity. They have been developed for various purposes, from large groups of grid-connected wind turbines, wind farms, both on-shore and off-shore, to very small autonomous turbines used for battery charging or in combined wind-diesel projects for off-grid application. Currently all EU countries accept wind power as being a renewable energy source.

Wind on-shore - wind turbines that are installed on land, instead of being installed off-shore (in the sea). The term on-shore is not limited to costal areas.

Wind off-shore - wind turbines that are installed in the sea.

ANNEX A – DETAILED RESULTS WITH RESPECT TO CHAPTER 5 (FUTURE RES-E DEPLOYMENT)

Technology specific breakdown of new RES-E generation (installed 2005 to 2020) for various investigated cases at EU-15 level

		BAU-target							Ambitious-target						
Breakdown of new RES-E generation (installed 2005 to 2020) [TWh]	REFERENCE (no further promotion of RES-E)	BAU (continuation of current policies)	Strengthened national policies - BAU-target	Feed-in tariffs (harmonised)	Quota / tradable green certificates (harmonised)	Tender (harmonised) - no strategic behaviour	Tender (harmonised) - strategic behaviour	Tax incentives (harmonised)	Strengthened national policies	Strengthened national policies - excl. novel RES-E options	Feed-in tariffs (harmonised)	Quota / tradable green certificates (harmonised)	Tender (harmonised) - no strategic behaviour	Tender (harmonised) - strategic behaviour	
Gaseous biomass	6,09	22,52	29,19	23,15	22,02	23,29	23,29	22,10	43,15	43,58	48,81	48,92	51,40	51,40	4
Solid biomass	4,85	53,42	35,61	20,01	26,90	25,22	25,22	20,05	97,51	100,56	70,24	72,42	64,60	64,60	7
Biowaste	1,76	9,11	10,99	7,66	8,92	10,12	10,12	6,51	17,65	18,87	20,48	19,83	17,64	17,64	1
Geothermal electricity	0,21	1,15	0,99	0,96	0,96	0,96	0,96	0,96	1,81	1,81	1,82	1,82	1,93	1,93	
Hydro large-scale	6,40	21,88	26,70	27,06	27,17	27,02	27,02	27,14	34,28	34,28	33,68	34,34	34,20	34,20	3
Hydro small-scale	1,55	6,01	6,43	6,51	6,44	6,56	6,56	6,42	9,32	9,32	9,44	9,32	9,23	9,23	
Photovoltaics	0,15	6,12	0,30	0,23	0,23	0,00	0,00	0,23	7,66	0,31	0,31	0,31	0,46	0,46	
Solar thermal electricity	0,11	12,08	4,37	0,16	0,16	0,00	0,00	0,16	6,75	7,64	0,17	1,16	0,53	0,53	
Tide & wave	0,22	7,19	11,23	11,23	8,55	7,97	7,97	10,00	17,67	20,25	21,76	18,17	14,30	14,30	2
Wind onshore	21,78	181,46	166,15	186,49	186,55	191,81	191,81	184,35	214,49	214,50	214,13	225,75	224,97	224,97	22
Wind offshore	1,13	109,30	137,74	149,00	136,16	144,21	144,21	146,21	201,50	201,51	220,12	214,61	213,24	213,24	22
RES-E TOTAL	44,26	430,24	429,70	432,48	424,05	437,18	437,18	424,14	651,77	652,62	640,94	646,65	632,49	632,49	64

Technology specific breakdown of new RES-E generation (installed 2005 to 2020) for various investigated cases in Germany

		BAU-target							Ambitious-target						
Breakdown of new RES-E generation (installed 2005 to 2020) [TWh]	REFERENCE (no further promotion of RES-E)	BAU (continuation of current policies)	Strengthened national policies (BAU-target)	Feed-in tariffs (harmonised)	Quota / tradable green certificates (harmonised)	Feed-in tariffs (cluster)	Quota / tradable green certificates (cluster)	Premium Feed-in tariffs (cluster)	Strengthened national policies	Strengthened national policies - excl. novel RES-E options	Feed-in tariffs (harmonised)	Quota / tradable green certificates (harmonised)	Feed-in tariffs (cluster)	Quota / tradable green certificates (cluster)	Premium Feed-in tariffs (cluster)
Gaseous biomass	2,07	6,82	5,21	4,31	5,19	5,11	4,92	5,44	7,25	7,66	7,66	7,45	7,70	7,59	7,73
Solid biomass	1,90	18,06	4,34	4,14	4,79	4,14	5,35	5,33	16,87	18,16	18,16	16,78	23,18	19,74	25,54
Biowaste	0,48	0,70	1,29	1,29	1,37	1,29	1,63	1,29	2,58	2,58	2,58	2,58	2,58	2,58	2,58
Geothermal electricity	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Hydro large-scale	0,00	0,00	1,16	1,16	1,16	1,16	1,16	1,16	2,13	2,13	2,40	2,38	1,79	2,40	1,79
Hydro small-scale	0,00	0,98	0,00	0,00	0,00	0,09	0,18	0,18	1,06	1,06	1,06	0,92	1,06	0,86	1,04
Photovoltaics	0,22	2,88	0,28	0,22	0,22	0,22	0,22	0,22	3,68	0,28	0,28	0,28	0,28	0,28	0,28
Solar thermal electricity	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Tide & wave	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,50	1,99	0,79	0,99	0,58	1,22	0,50
Wind onshore	4,23	21,46	18,94	21,93	23,31	21,93	23,19	24,99	31,02	31,02	31,02	36,59	31,02	36,52	33,18
Wind offshore	0,47	39,58	60,68	67,41	68,17	74,14	70,07	74,14	74,14	74,14	74,14	74,14	74,14	74,14	74,14
RES-E TOTAL	9,37	90,48	91,88	100,44	104,20	108,07	106,71	112,74	139,20	139,00	138,07	142,09	142,31	145,31	146,77

ANNEX B – SHORT CHARACTERISATION OF THE *GREEN-X* MODEL

Year of implementation:	2002-2004
Client:	European Commission, DG Research; FP5 Programme (ENG2-CT-2002-00607)
Consortium:	Project co-ordinator: EEG - Energy Economics Group at Vienna University of Technology, Institute of Power Systems and Energy Economics Project partners: IT Power, United Kingdom KEMA - KEMA Nederland B.V., The Netherlands RISOE - Risoe National Laboratory, Denmark CSIC - The Spanish Council for Scientific Research (Institute of Economy and Geography), Spain FhG-ISI - Fraunhofer Institute for Systems and Innovation Research, Germany WIENSTROM GmbH, Austria EGL - Elektrizitäts-Gesellschaft Laufenburg AG, Switzerland EREC - European Renewable Energy Council, Belgium
Publications / Web:	Huber et al. (2004): *Action plan for deriving dynamic RES-E policies* and *Green-X deriving optimal promotion strategies for increasing the share of RES-E in a dynamic European electricity market* Huber et al. (2004): *Final report of the project Green-X*, Web page: www.green-x.at.

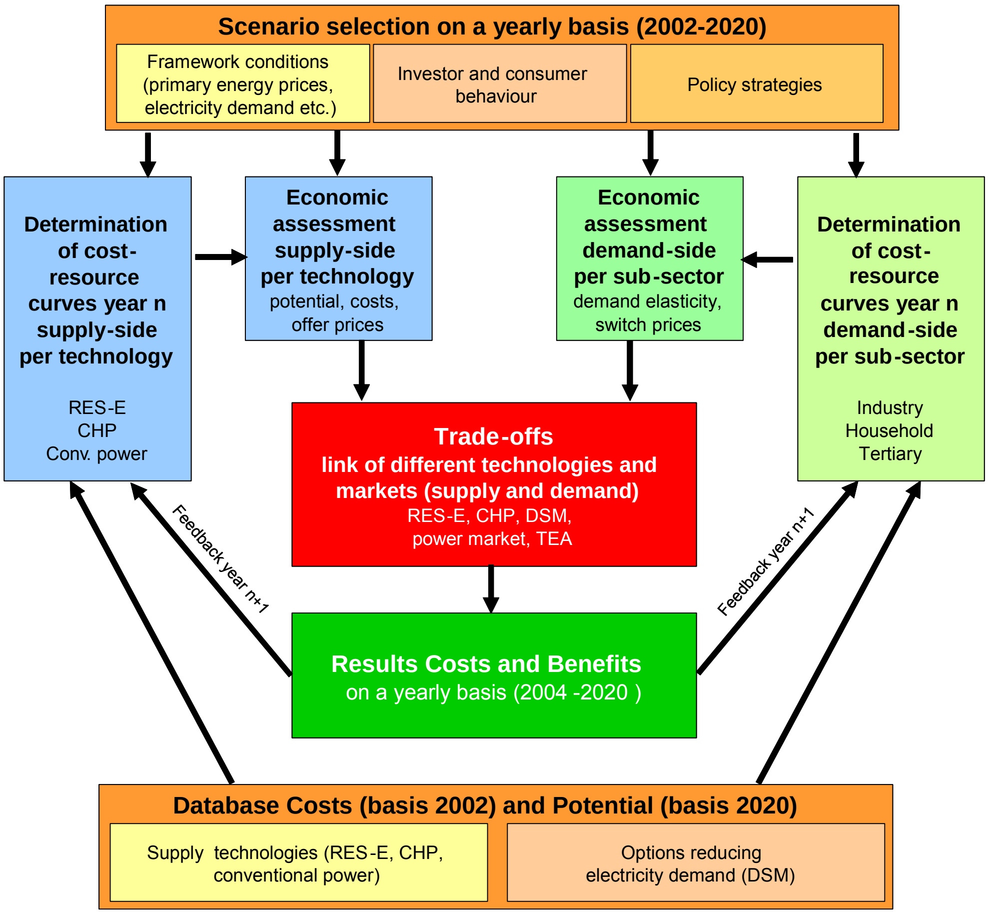

*Figure 60 Overview on the computer model **Green-X** (electricity sector)*

The computer model **Green-X** is an independent software tool developed under Microsoft Windows by EEG in the EC-funded project Green-X (5th FWP – DG Research, Contract N°: ENG2-CT-2002-00607).[66]

Two major variants of the **Green-X** model are currently available67:

► An extended variant with respect to the **intra-sectoral** coverage was developed, which **includes** besides RES-E **endogenous modelling of all conventional power generation options of the electricity sector** (incl. interconnections and according restrictions). Geographically this variant covers solely **the EU-15**. It allows a comparative, quantitative analysis of interactions between RES-E, conventional electricity and CHP generation, demand-side activities and GHG-reduction in the electricity sector, both within the EU-15 as a whole, as well as for individual member states.

66 For more details see: http://www.green-x.at

67 A further extension of the geographical coverage to Croatia as well as the sectoral coverage with respect to the inclusion of missing energy sectors (RES-transport and RES non-grid connected heat) is currently undertaken within follow-up activities of Green-X. This adaptation process will be completed at the end of 2005.

► An extended variant with regard to the **geographical coverage for RES**. It **covers** besides the EU-15 **all new member states (EU-10) as well as Bulgaria and Romania**. It enables a comparative and quantitative analysis of the future deployment of RES (in the electricity sector as well as the grid-connected heat sector – incl. CHP) based on applied energy policy strategies in a dynamic context. In this context, the impact of conventional generation within each sector is described by exogenous forecasts of reference energy prices on country level.

Within the model ***Green-X***, the most important RES-E (e.g. biogas, biomass, biowaste, wind on- & offshore, hydropower large- & small-scale, solar thermal electricity, photovoltaics, tidal & wave energy, geothermal electricity) and RES-H technologies (e.g. biomass, geothermal energy) are described for each investigated country by means of *dynamic cost-resource curves*. Dynamic cost curves are characterised by the fact that the costs as well as the potential for electricity generation / demand reduction can change each year. The magnitude of these changes is given endogenously in the model, i.e. the difference in the values compared to the previous year depends on the outcome of this year and the (policy) framework conditions set for the simulation year.

Based on the derivation of the dynamic cost curve, an economic assessment takes place considering scenario-specific conditions like selected policy strategies, investor and consumer behaviour as well as primary energy and demand forecasts.

Policies that can be selected are the most important price-driven strategies (feed-in tariffs, tax incentives, investment subsidies, subsidies on fuel input) and demand-driven strategies (quota obligations based on tradable green certificates (including international trade), tendering schemes). All the instruments can be applied to all RES technologies (and conventional options within the EU-15) separately for both combined heat and power and power production only. In addition, general taxes can be adjusted and the effects simulated. These include energy taxes (to be applied to all primary energy carriers as well as to electricity and heat) and environmental taxes on CO_2-emissions, policies supporting demand-side measures and climate policy options (trading of emission allowances on both the national and international level). As ***Green-X*** is a dynamic simulation tool, the user has the possibility to change policy and parameter settings within a simulation run (i.e. by year). Furthermore, each instrument can be set for each country individually.

Within this step, a transition takes place from generation and saving *costs* to bids, offers and switch *prices*. It is worth mentioning that the policy setting influences the effective support, e.g. the guaranteed duration and the stability of the planning horizon or the kind of policy instrument to be applied.

The results are derived on a yearly basis by determining the equilibrium level of supply and demand within each considered market segment – e.g. tradable green certificate market (TGC, both national and international), electricity power market and tradable emissions allowance market. This means that the supply for the different technologies is summed up within each market and the point of equilibrium varies with the demand calculated.

A broad set of results with respect to RES can be gained on country and technology-level:

- total electricity generation of RES-E within the country,
- total grid-connected heat generation from RES-H (CHP and heat plants),
- share of RES-E / grid-connected RES-H generation in total electricity / grid-connected heat production,
- average generation costs of RES-E / RES-H per kWh,
- electricity generation for each RES-E technology,
- grid-connected heat generation (CHP and heat plants) from each RES-H technology,
- average generation cost of each RES-E / grid-connected RES-H technology per kWh,
- import / export balance of RES-E,
- impact of simulated strategies on generation costs,
- impact of selected strategies on total costs and benefits to the society (consumer) – premium price due to RES-E / RES-H strategy.

<u>Modelling details:</u> From 'static' to 'dynamic' – the concept of dynamic cost resource curves for RES-E

The developed methodology of dynamic cost-resource curves with respect to electricity generation from renewable energy sources will be explained in the following. This concept refers to three basic principles, which are subject of explanation below.

Basic principles

► <u>Static cost-resource curves</u>

In general, renewable energy sources are characterised by a limited resource, and – if no cost dynamics are considered – costs rise with increased utilization, as e.g. in case of wind power sites with the best wind conditions will be exploited first, and as a consequence if best sites are gone, rising generation costs appear. On proper tool to describe both costs and potentials represents the *(static) cost-resource curve*[68].

In principle, a *static cost-resource curve* describes the relationship between (categories of) technical available potentials (of e.g. wind energy, hydropower, biogas) and

68 For 'static cost-resource curves' as explained above in literature no common terminology is applied. Other names commonly applied to this term are 'supply curves' or 'cost curves'. Nevertheless, with respect to (renewable) energy sources the term 'static cost-resource curves' gives – at least in the opinion of the author - a clear and unambiguous wording.

the corresponding (full) costs of utilisation of this potential at this point-of-time (Note, no learning effects are included in static cost-resource curves!).

On the left-hand side of Figure 61 a theoretically ideal continuous static cost-resource curve is depicted, taking into account that every location is slightly different from each other and, hence, looking at all locations e.g. for wind energy in a certain geographic area a continuous curve emerges after these potentials have been classified and sorted in a least cost way. The stepped function as shown on the right-hand side of Figure 61 represents a more practical approach as in real life the accuracy as needed for a continuous design is impossible. Thereby, sites with similar economic characteristics (e.g. in case of wind, sites with same range of full-load hours) are described by one band and, hence, a stepped curve emerges.

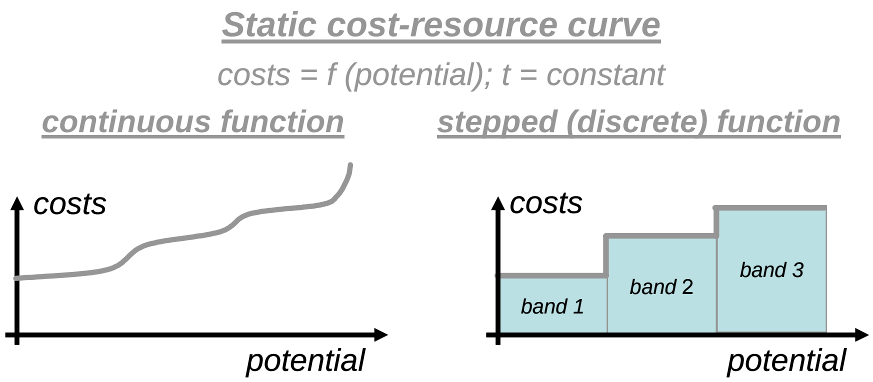

Figure 61 Characteristic run of a static cost-resource curve: Continuous (left) and stepped function (right)

► <u>Experience curves</u>

Forecasting technological development is a crucial activity, especially for a long time horizon. Considerable efforts have been made recently to improve the modelling of technology development in energy models. A rather 'conventional' approach relies exclusively on exogenous forecasts based on expert judgements of technology development (e.g. efficiency improvements) and economic performance (e.g. described by investment and O&M-costs). Recently, within the scientific community, this has often been replaced by a description of technology-based cost dynamics which allow endogenous forecasts, at least to some extent, of technological change in energy models: This approach of so-called technological learning or experience / learning curves takes into account that a decline of costs depends on accumulation of actual experience and not simply on the passage of time.

In general, *experience curves* describe how costs decline with cumulative production. In this context, the later is used as an indication for the accumulated experience gained in producing and applying a certain technology. In many cases empirical analysis have proven that costs decline by a constant percentage with each doubling of the units produced or installed, respectively. In general, an experience curve is expressed as follows:

$$C_{CUM} = C_0 * CUM^b$$

where:

C_{CUM}	Costs per unit as a function of output
C_0	Costs of the first unit produced or installed
CUM	Cumulative production over time
b	Experience index

Thereby, the *experience index (b)* is used to describe the relative cost reduction – i.e. *($1-2^b$)* – for each doubling of the cumulative production. The value *(2^b)* is called the *progress ratio (PR)* of cost reduction. Progress ratios or their pendant, the *learning rates (LR)* – i.e. *LR=1-PR* – are used to express the progress of cost reduction for different technologies. Hence, a progress ratio of 85% means that costs per unit are reduced by 15% for each time cumulative production is doubled.

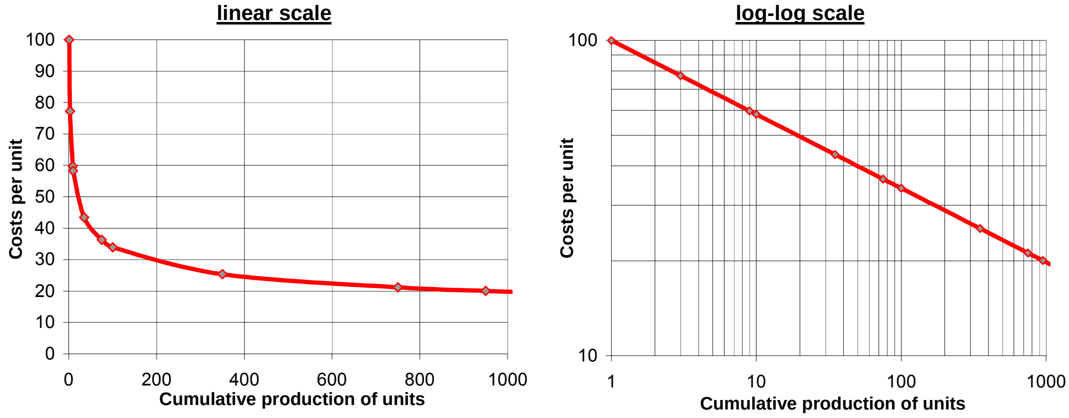

Figure 62 Characteristic run of an experience curve: On a linear (left) and on a
log-log scale (right). *Note: Parameter settings: LR=15%, C_0=100.*

In Figure 62 the characteristic run of an experience curve is illustrated: As indicated, by plotting such a curve on a log-log scale, a straight line occurs. Thereby, the gradient of the line reflects the according learning rate.

As described in (Grübler et al., 1998): *"… such straight-line plots should not be misunderstood to imply that 'linear' progress can be maintained indefinitely. The potential for cost reduction becomes increasingly exhausted as the technology matures."*

Mechanisms for the often called 'learning by doing' are manifold, including experience gained at different levels (i.e., of individuals in performing routine tasks, of organisations with respect to logistics, plant management) as well as economics of scale. For a brief discussion of this topic with respect to energy technologies in a general manner see (Grübler et al., 1998)69 or (Wene C.O., 2000) and in particular focussing on wind energy (Neij et al., 2003).

► Technology diffusion

Additionally to experience curves, another approach is of importance in the discussion of technology dynamics, aiming to identify general patterns by which technologies diffuse through competitive markets:70 In accordance with general diffusion theory, penetration of a market by any new commodity typically follows an 'S-curve' pattern, see Figure 63. It points to relatively modest growth in the early stage of deployment71, whilst the costs of technologies are gradually reduced to an economically competitive level. As this is achieved for more competitive technological concepts, there will be accelerating growth72 in deployment over the medium term. This will finally be followed by a slowing down in deployment73, corresponding to nearly full penetration of the market.

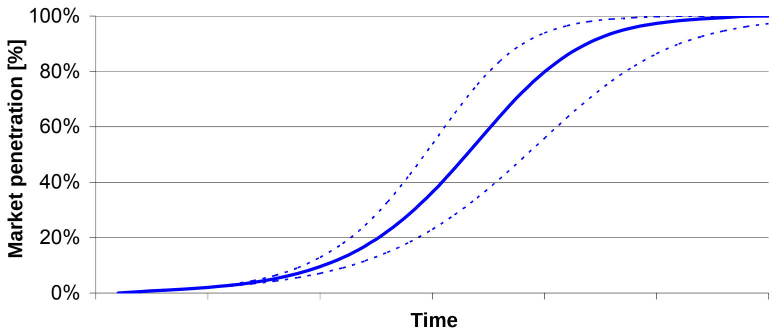

Figure 63 'S-curve' pattern: Market penetration of a new commodity

69 Thereby, the authors state that a learning curve (as discussed above) related to cumulative production or installation refer solely to the commercial marketplace. Consequently, learning due to RD&D expenditures are neglected, which is of crucial importance in case of emerging new technologies in their early phase of market penetration. Hence, they suggest a different approach by referring to cumulative investments – for further details see (Grübler et al., 1998).

70 For a brief discussion of this topic see (Grübler et al., 1998).

71 As long as the market is immature, high relative growth rates but low growth in absolute terms (i.e. capacity increase) can be observed.

72 Hence, also for successful technologies relative growth rates usually decrease constantly. In contrary, with increasing market maturity yearly installations measured in absolute terms still increase as long as approximately half of the overall long-term potential is exploited.

73 I.e. growth measured in both relative and absolute terms decreases.

9.1.1 The concept of dynamic cost resource curves for RES-E

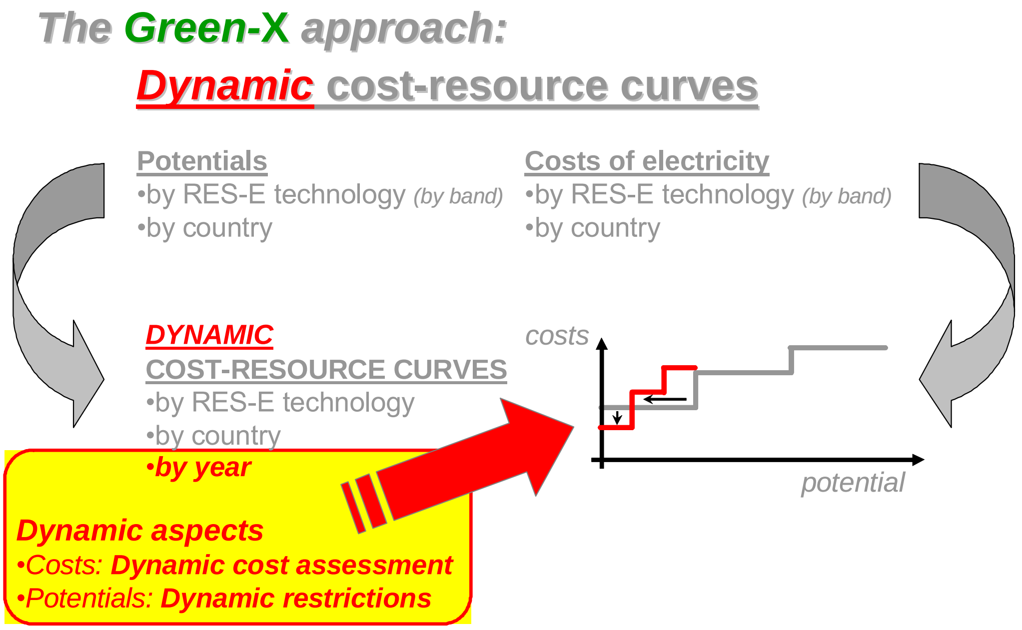

Figure 64 Method of approach regarding dynamic cost-resource curves for RES-E (for the model **Green-*X***)

A *dynamic cost-resource curve* represents a tool to provide the linkage between all three approaches described in the previous section, i.e., the formal description of costs and potentials by means of *static cost-resource curves*, the dynamic cost assessment as e.g. done by application of *experience curves*, and the implication of dynamic restrictions in accordance with *technology diffusion*.

In the following, the method of approach regarding dynamic cost-resource curves as developed for the model **Green-X** will be described. Thereby, Figure 64 gives an overall illustration. As mentioned above, the approach comprises the following parts:

► <u>The development of static cost-resource curves for each RES-E category in each investigated country.</u>

As mentioned before, static cost-resource curves describe available potentials and the according costs. Accordingly, an assessment of potentials and costs has to be undertaken according to model specific requirements – i.e. for **Green-X** a clear distinction between already existing plant, i.e. the achieved potential, and new generation options, i.e. the additional mid-term potential, is undertaken.

In case of new plants the economic conditions are described by long-term *marginal costs*, whilst for existing plants short-term marginal costs, including solely fuel and O&M costs, are of determinant.

With respect to the potentials, for new options the *additional realisable mid-term potentials* were assessed for each RES-E category on country-level, representing the maximal additional achievable potential up to the year 2020 under the assumption, that all existing barriers can be overcome and all driving forces are active. In addition, existing plants are described by their generation potentials, referring to normal climatic conditions in case of RES-E with natural volatility (e.g. hydropower, wind energy).

► <u>The dynamic assessment, including a dynamic assessment of costs as well as of deployment restrictions</u>

Dynamics have to be reflected in a suitable periodic manner – e.g. within the model ***Green-X*** this is done on a yearly basis. Hence, in order to derive dynamic cost-resource curves for each year, a dynamic assessment of the previous described static cost-resource curves is undertaken. It consists of two parts: The dynamic cost assessment and the application of dynamic restrictions.

Within ***Green-X*** costs[74] – in particular investment costs and operation- & maintenance costs – are adapted dynamically on technology level. Thereby, two different approaches can be applied: Standard cost forecasts or endogenous technological learning. Default settings are applied as follows:

- For conventional power generation technologies – as well as some RES-E technologies –well-accepted expert judgements are adopted.
- For most of RES-E technologies, e.g. wind power or PV, the approach of technological learning is applied. In this context, technology-specific learning rates are assumed at least for each decade separately[75], as default referring to the global development[76].

Next, to derive realisable potentials for each single year of the simulation, dynamic restrictions have to be applied to the predefined overall mid-term potentials. Generally spoken, this can be done by applying a restriction in accordance with the technology diffusion theory, following an 'S-curve' pattern. Within ***Green-X*** such an approach is chosen to describe the impact of market and administrative restrictions, representing the maturity of the market. Thereby, it represents the most important in the set of dynamic parameter describing the impact of non-economic barriers on the deployment of a certain RES-E. Note, besides market and administrative barriers also other restrictions can be included. In the model ***Green-X*** for instance industrial, social and

74 Note, besides the above mentioned cost parameters, dynamics are also considered with respect to other performance issues – i.e. efficiency improvements and in case of wind turbines an up-scaling of potentials (and achievable full load hours, respectively) in accordance with increasing hub-heights (due to rising turbine sizes).

75 In many cases experience has shown that the rate of technological learning is often closely linked to the development stage of a certain technology – i.e. at an early stage of development, if a technology is 'brand new', high learning rates can be expected and later, as the technology matures, a slowdown occurs – compare e.g. (Grübler et al., 1998) or (Wene, 2000).

76 As learning is usually taking place on the international level, the deployment of a technology on the global level must be considered.

technical restrictions are considered additionally. Important in this respect is to apply them on the ‘correct’ level: E.g. technical restrictions refer to characteristics within a certain region, whilst industrial barriers, indicating the production capacity of an industry (e.g. the manufacturing of wind turbines), refer to the international level.