# Action plan for deriving *dynamic* RES-E policies

Report of the project ***Green-X***
- a research project within
the fifth framework programme
of the European Commission,
supported by DG Research

Claus Huber, Thomas Faber, Reinhard Haas, Gustav Resch – EEG
John Green, Samanta Ölz, Sara White – IT Power
Hans Cleijne, Walter Ruijgrok   KEMA
Poul Erik Morthorst, Klaus Skytte – RISØ
Miguel Gual, Pablo del Rio, Félix Hernández, AndrésTacsir – CSIC
Mario Ragwitz, Joachim Schleich – FhG-ISI
Wolfgang Orasch – WIENSTROM
Marcus Bokemann – EGL
Christine Lins   EREC

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**Scientific Co-ordination:**

**Claus Huber**

**Energy Economics Group, Austria**

**E-mail: Huber@eeg.tuwien.ac.at**

**Telephone: +43 58 801-373 60**

**Facsimile: +43 58 801-373 97**

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Co-ordination: Reinhard Haas, Energy Economics Group (EEG), Institute of Power Systems and Energy Economics, Vienna University of Technology.

Project partners:
- EEG - Energy Economics Group, Institute of Power Systems and Energy Economics, Vienna University of Technology, Austria
- 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

Contact/Information: web-site: http://www.green-x.at
or directly by contacting one of the project partners

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Energy Economics Group (EEG), Institute of Power Systems and Energy Economics, Vienna University of Technology.

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# 1 Introduction

At the EU level, the 'Directive of the European Parliament and the Council on the promotion of electricity from renewable energy sources in the internal electricity market (RES-E Directive)' (European Parliament and Council, 2001 – Directive 2001/77/EC) sets a minimum framework for RES-E policy. However, in line with the Principle of Subsidiary, it allows each Member State to choose the support scheme, which "corresponds best to its particular situation".

Quite a number of different instruments are being used in the attempt by the individual countries and the EU to support the development of renewable energy technologies and at the same time to reduce greenhouse gas emissions. The most important ones are mentioned below:

- Feed-in tariffs
- Tradable green certificates
- Tendering systems
- Emissions trading schemes / tradable emission allowances

These policy instruments may be used individually or simultaneously either at the national level or at the EU level. Moreover, the Member States and the EU may want to achieve not only one but several targets in applying these instruments. For example, this is the case for the indicative targets for the use of renewable energy and the national GHG-reduction targets.

Analysing the interaction of these instruments with each other and with different targets is not trivial. Instead, such analyses turn out to be highly complex theoretically and methodologically. The many instruments that exist to support renewable energy technologies and they interact at multiple levels. The most important ones being:

- Prices at the power spot market
- Consumer prices for electricity
- The volume of implemented renewable power capacity
- The national and international GHG emission levels;

The core objective of this project is to facilitate a continuous and significant increase in the share of RES-E with minimal costs to European citizen. To identify the most important strategies (e.g. Tradable Green Certificates, Feed-In Tariffs, Investment Subsidies, Emissions Trading, $CO_2$-taxes) in a dynamic way the computer-based toolbox ***Green-X*** has been developed. Although within the scope of this project it has not been feasible to investigate all possible issues within this field, the cases analysed cover not only the needs and opportunities at the level of the national Member States, but also those at the level of the EU. However, the most important ones have been treated thoroughly.

This report, which is the final outcome from the Green-X project (Contract N$^{o}$: ENG2-CT-2002-00607), with funding from the European Commission, DG Research, provides recommendations on the way forward for the promotion of renewable energy for electricity generation in the EU. It is addressed primarily to energy policy maker, as well as to other people interested in renewable energy and energy policy.

## 1.1 Outline of this report

This report is divided into 8 chapters. After a short introduction, explaining the motivation and the objective of this project, chapter 2 summarised the current electricity generation from RES-E in the EU 15 as well as the future potential up to 2020. A survey on different types of promotion strategies and policy instruments historically and currently applied within EU member states is given in chapter 3. The method of approach is explained in chapter 4. Firstly, the criteria used to evaluate the different policy schemes are defined. Secondly, the core product of this project, the ***Green-X*** computer model is presented in brief. Its structure and the methodology are elaborated and illustrative Figures provide an impression of how the model looks. Chapter 5 evaluates the different policy schemes in a dynamic framework and describes the effects of the support mechanisms for RES-E. The main results from simulations with the ***Green-X*** computer programme are presented in chapter 6, using two different targets: business as usual (BAU) and an ambitious RES-E target for 2020. To analyse the effects of the different policy instruments, these targets would be reached by applying different support schemes. Finally, the main conclusions and recommendations resulting from this study are derived in chapter 7. It includes 'action plans' describing policy adjustments needed to implement the recommendations.

# 2 Electricity generation from RES in EU 15 Member States

Before an assessment and a discussion about efficient and effective RES-E policy should take place the historical development, the current situation and the future perspectives of RES-E in EU 15 Member States are described briefly.

## 2.1 Historical development of electricity generation from RES

The historical RES-E data are based on a comprehensive data-collection (Eurostat (2003), IEA (2002) and statistical information gained on national level). Regarding the years 2003 to 2005, as only few data are available on country and technology level 'forecast' is based on a ***Green-X*** model run.

The (projected) electricity generation by RES-E category for the year 2004 is shown in Figure 2.1 on country level. Figure 2.2 depicts the corresponding development of RES-E in total EU-15 over time (from 1990 to 2004) – with (left hand side) and without hydropower (right hand side).

Two countries, Austria and Sweden, generate more than a third of electricity from these sources; others a much lower proportion. The largest share of RES is still provided by 'large-scale' hydropower (i.e. with capacities larger than 10MW). Such plants have mostly been established before the post-1980's 'new' RES-E. Besides hydropower, biomass, biowaste and wind are currently the most important. There are a number of noteworthy observations including:

- the large proportions of operating wind power in Denmark, Spain, and Germany
- the significant contribution of geothermal power in Italy
- the relative high proportion of RES-E generated from biomass (incl. biowaste and biogas) in the UK, Finland, Sweden and Germany.

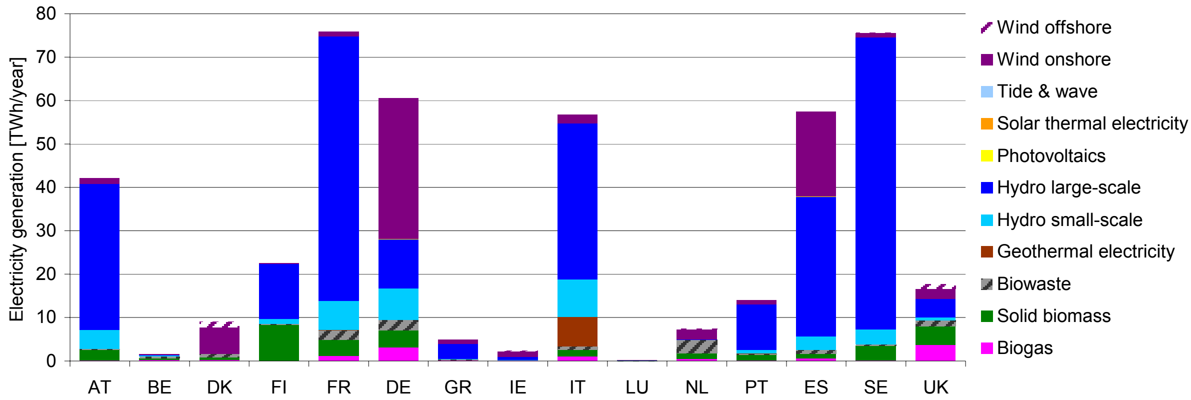
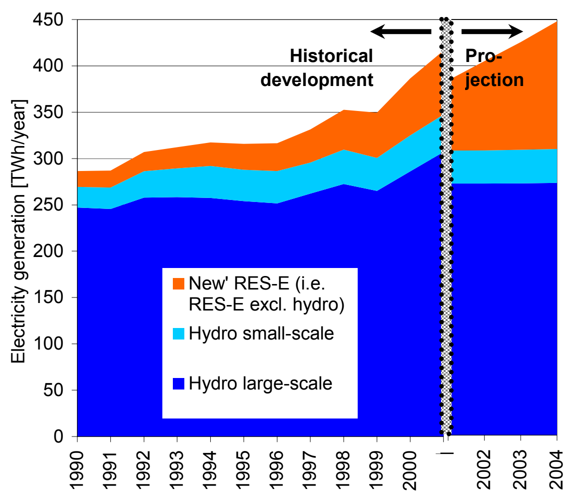



*Figure 2.1 Electricity generation (achieved potential) from various RES in EU countries in 2004.*
*Source: Own investigations; Eurostat, 2004, **Green-X** model run*



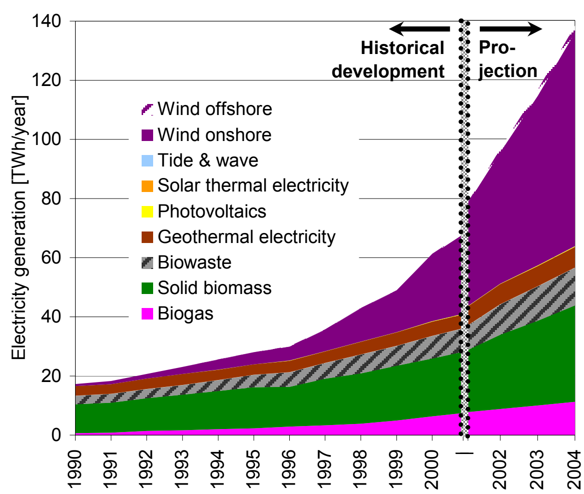




*Figure 2.2 Electricity generation from RES in EU-15 countries from 1990 to 2004 – including (left hand side) & excluding (right hand side) hydro. Source: Own investigations; Eurostat, 2004, **Green-X** model run.*

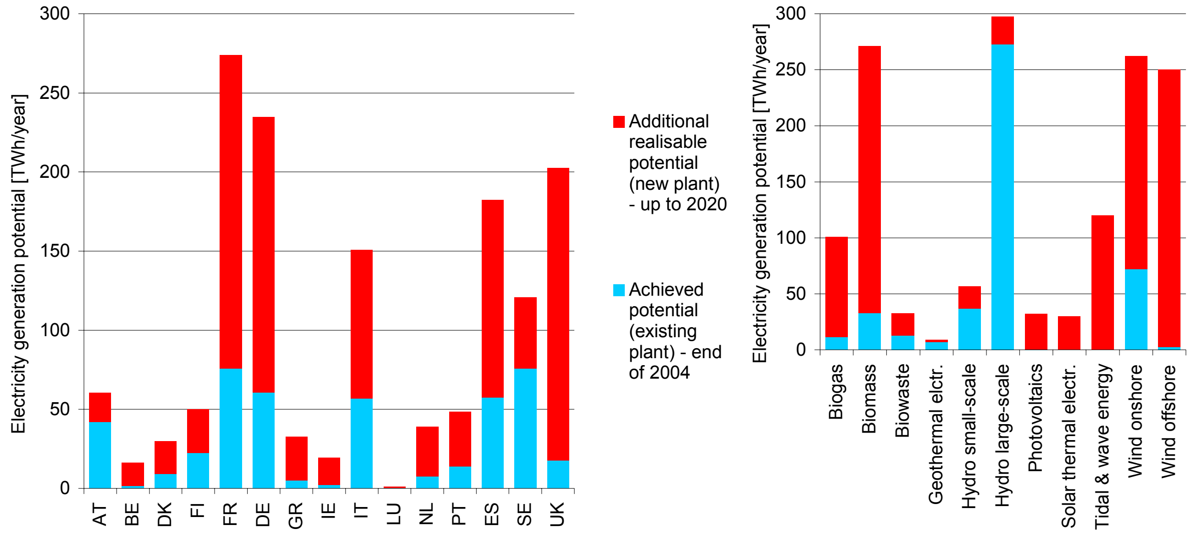



*Figure 2.3 Achieved (2004) & additional mid-term RES-E potential (up to 2020) in EU-15 countries – by country (left) and by RES-E category (right)*

## 2.2 Future potential of RES-E in EU 15 Member States

An overview on the different RES-E options available in total EU-15 up to 2020 is given in Figure 2.3. In the entire EU 15 the already achieved potential for RES-E equals 448 TWh[1], whereas the additional realisable potential up to 2020 amounts to 1078 TWh. Currently hydro power is the dominant technology but with limited future potential. The large (future) potential of wind energy (incl. on- and offshore), solid biomass and biogas may contribute to a large extent. In addition, new technologies like wave power and tidal stream or solar thermal electricity are yet to be developed in the EU.

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

# 3 Survey of RES-E promotion strategies

## 3.1 Background

It is well known that RES-E requires public support in order to penetrate the electricity market. This has been recognised at the EU level and by the individual EU 15 Member States, which have been promoting RES-E for many years.

At the EU level, a 'Directive of the European Parliament and the Council on the promotion of electricity from renewable energy sources in the internal electricity market (RES-E Directive)' (European Parliament and Council, 2001 – Directive 2001/77/EC) was approved in 2001, setting targets for the deployment of renewable electricity by 2010. In addition, the Directive states that, taking account of the wide diversity of promotion schemes between Member States, it is too early to set a Community-wide framework regarding support schemes. By 27th October 2005 the Commission should present a report on the experience gained with the application and coexistence of different support schemes in the Member States. The report may be accompanied by a proposal for a Community framework for RES support schemes (art.4.2).

Therefore, at least in the short to medium term, support policies in Member States will continue to be crucial for the penetration of RES in the electricity market[2].

## 3.2 Classification of promotion strategies

| | | Price-driven | Capacity-driven |
|---|---|---|---|
| Regulatory | Investment focussed | • Rebates<br>• Tax incentives | • Tender systems |
| | Generation based | • Feed-in tariffs<br>• Production tax incentives | • Quotas (RPS) based on TGC<br>• Tender systems |
| Voluntary | Investment focussed | • Shareholder Programs<br>• Contribution Programs | |
| | Generation based | • Green tariffs | |

*Table 3.1 Classification of promotion strategies for RES-E*

These policies can be classified according to different criteria (i.e., whether they affect demand or supply of RES-E or whether they support capacity or generation). Support schemes can be grouped in several categories – see also Table 3.1:

- Investment incentives establish an incentive for the development of renewable energy projects as a percentage over total costs, or as an amount of Euros per installed kW. The levels of these incentives are usually technology-specific and may vary significantly between regions.
- Feed-in Tariffs (FITs) are generation based fixed price incentives that usually take the form of either a total price for renewable production, or an additional premium on top of the electricity market price paid to RES-E producers. Besides the height of the tariff its guaranteed duration represents an important parameter for an appraisal of the actual financial incentive (compare for example the case of Spain and Germany). Furthermore, feed-in tariffs easily allow technology-specific promotion as well as an acknowledgement of future cost-reductions by implementing decreasing tariffs.
- Production tax incentives are generation-based price-driven mechanisms that work through payment exemptions of electricity taxes applied to all producers. This type of instrument differs from feed-in schemes in terms of the cash flow of RES-E producers, since it represents a minus cost instead of an additional income.
- Tendering systems can either be investment-focussed or generation-based, but in both cases they are capacity-driven mechanisms. 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 one-time investment incentive, they offer a 'bid price' per kWh given to winner projects that may receive it through out the duration of the contract.
- Quota obligations based on Tradable Green Certificates (TGCs) are generation-based capacity-driven instruments. These instrument are usually implemented through government defined targets and obligations on consumers or suppliers of electricity. Once defined, a parallel market for renewable energy certificates is established and their price is set following demand and supply conditions (forced by the obligation).

Besides these regulatory instruments voluntary approaches appear today which are mainly based on the willingness of consumers to pay premium rates for renewable energy. Nevertheless, so far in terms

[2] The 'RES-E Directive' also contains several prescriptions regarding mandatory guarantees of origin, ensuring grid access and reporting obligations.

of effectiveness – i.e. actual installations resulting from their appliance – their impact on total RES-E development is negligible.

In the following section a short overview is given on currently implemented promotion strategies for RES-E in the EU-15 countries. Table 3.2 provides a brief overview on this topic – listing countries, promotion strategies and the technologies addressed.

## 3.3 Currently implemented support schemes in EU 15 countries

Almost all countries have implemented some type of investment subsidy for technologies in their early phase of development, such as tidal stream and wave energy, photovoltaics, solar thermal electricity or offshore wind.

The most widespread mechanism promoting renewables production has traditionally been the so-called feed-in tariff systems. The countries that have been more successful in deploying RES-E are characterised by relatively high (feed-in) incentive-levels and long-term stable frameworks (Germany, Denmark & Spain are good examples in the development of wind energy).

Tax incentives are applied in Finland, Netherlands and the UK. In Finland the tax break works almost as a feed-in scheme reducing the real cost of renewables significantly. In the Netherlands and the UK, the tax break is a small part of a broader scheme. In the first case, the tax reduction provides a 'minus cost' of about 20 €/MWh to renewable producers, which in combination with the feed-in scheme represents the basic renewables incentive. In the case of the UK, the Climate Change Levy provides some 6.3 €/MWh exemption to renewable producers in addition to the revenues from the TGC system.

Tendering systems have been applied in France for onshore wind projects, and are currently applied in Ireland through the AER scheme. According to recent discussions in Denmark and France, it is planned to reapply this type of instrument for offshore wind projects.

Finally, quota systems based on Tradable Green Certificates (TGCs) schemes are applied in the UK (replacing the NFFO tendering system), Belgium, Italy and Sweden.

The reasons behind this apparent variety have been explored to different degrees and include:

- Technology and country specificity – different stages of development and costs, differing local resource conditions.
- Political willingness and coherence – countries which have undergone past liberalisations and are embedded into market oriented policies (UK, Ireland) are prone to apply capacity-driven schemes as quotas based on TGCs; and,
- Unlevelled electricity markets – Important differences appear when analysing the individual EU15 electricity markets in terms of their work-arrangements, institutional set-ups and fiscal schemes (heterogeneous energy tax levels).

From a technological point-of-view, RES-E options that receive greater attention in the EU15 are: wind, photovoltaics, small hydro and biomass in its different forms.

*Table 3.2 Current promotion strategies for RES-E in the EU-15 countries*

| | Major strategy | RES-E TECHNOLOGIES CONSIDERED | | | |
|---|---|---|---|---|---|
| | | **Large Hydro** | **Small Hydro** | **'New' RES (Wind on- & offshore, PV, Solar thermal electricity, Biomass, Biogas, Landfill gas, Sewage gas, Geothermal)** | **Municipal Solid Waste** |
| **Austria** | **FITs** | No | 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. Investment subsidies mainly on regional level. | | FITs for waste with a high biodegradable fraction |
| **Belgium** | **Quota/TGC + guaranteed electricity purchase** | No | Federal: The Royal Decree of 10 July 2002 (operational from 1st of July 2003) sets minimum prices for RES-E. Except for offshore wind it will be implemented by the regional authorities: Wallonia: Quota obligation (based on TGCs) on electricity suppliers – increasing from 3% in 2003 up to 12% in 2010. Flanders: Quota obligation (based on TGCs) on electricity suppliers – increasing from 3% (no MSW) in 2004 up to 6% in 2010. Brussels region: No support scheme yet implemented. | | |
| **Denmark** | **FITs** | No | Act on Payment for Green Electricity (Act 478): Fix settlement prices instead of former high FITs. Valid for 10 years. Tendering plans for offshore wind. | | No |
| **Finland** | **Tax Exemption** | No | Tax refund: 4.2 € /MWh (plant <1MW) | Mix of tax refund and investment subsidies:Tax refund of 6.9 €/MWh for Wind and of 4.2 €/MWh for other RES-E. Investment subsidies up to 40% for Wind and up to 30 % for other RES-E. | Tax refund (2.5 €/MWh) |
| **France** | **FITs** | No | FITs for RES-E plant < 12 MW guaranteed for 15 years (20 years PV and Hydro). Tenders for plant >12 MW. FITs in more detail: Biomass: 49-61 €/MWh, Biogas: 46-58 €/MWh, Geothermal: 76-79 €/MWh, PV: 152.5-305 €/MWh; Landfill gas: 45-57.2 €/MWh; Wind[3]: 30.5-83.8 €/MWh; Hydro[4]: 54.9-61 €/MWh. Investment subsidies for PV, Biomass and Biogas (Biomass and Biogas PBEDL 2000-2006). | | FIT: 25.8-47.2 €/MWh |
| **Germany** | **FITs** | Only refurbishment | German Renewable Energy Act: FITs guaranteed for 20 years[5]. In more detail, FITs for new installations (2004) are: Hydro: 37-76.7 €/MWh; Wind[6]: 55-91 €/MWh; Biomass & Biogas: 84-195 €/MWh; Landfill-, Sewage- & Mine gas: 66.5-96.7 €/MWh; PV & Solar thermal electricity: 457-574 €/MWh; Geothermal: 71.6-150 €/MWh | | No |
| **Greece** | **FITs + investment subsidies** | No | FITs guaranteed for 10 years (at a level of 70-90% of the consumer electricity price)[7] and a mix of other instruments: a) Law 2601/98: Up to 40% investment subsidies combined with tax measures; b) CSF III: Up to 50% investment subsidies depending on RES type | | No |
| **Ireland** | **Tender** | No | Tendering scheme – currently AER VI with technology bands and price caps for small Wind (<3 MW), large Wind (>3 MW), small Hydro (<5 MWp), Biomass, Biomass CHP and Biogas. In addition, tax relief for investments in RES-E. | | No |
| **Italy** | **Quota/TGC** | 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[8]; penalty in size of 84.2 €/MWh (2004) but market distortions appear[9]. Investment subsidies for PV (Italian Roof Top program). | | | |
| **Luxembourg** | **FITs** | No | No | FITs[10] guaranteed for 10 years (PV: 20 years) and investment subsidies for Wind, PV, Biomass and small Hydro. FITs for Wind, Biomass and small Hydro: 25 €/MWh, for PV: 450 €/MWh. | No |
| **Netherlands** | **FITs + tax exemption** | | Mixed strategy: Green pricing, tax exemptions and FITs. The tax exemption for green electricity amounts 30 €/MWh and FITs guaranteed for 10 years range from 29 €/MWh (for mixed Biomass and waste streams) to 68 €/MWh for other RES-E (e.g. Wind offshore, PV, Small Hydro). | | No |
| **Portugal** | **FITs + investment subsidies** | No | FITs (Decree law 339-C/2001 and Decree law 168/99) and investment subsidies of roughly 40% (Measure 2.5 (MAPE) within program for Economic Activities (POE)) for Wind, PV, Biomass, Small Hydro and Wave. FITs in 2003: Wind[11]: 43-83 €/MWh; Wave: 225 €/MWh; PV[12]:224-410 €/MWh, Small Hydro: 72 €/MWh | | No |
| **Spain** | **FITs** | Depending on the plant size[13] | FITs (Royal Decree 2818/1998): RES-E producer have the right to opt for a fixed price or for a premium tariff[14]. Both are adjusted by the government according to the variation in the average electricity sale price. In more detail (only premium, valid for plant < 50 MW): Wind: 27 €/MWh; PV[15]: 180-360 €c/kWh, Small Hydro: 29 €/MWh, Biomass: 25-33 €/MWh. Moreover, soft loans and tax incentives (according to "Plan de Fomento de las Energías Renovables") and investment subsidies on a regional level | | Premium FIT: 17 €/MWh |
| **Sweden** | **Quota/TGC** | No | Quota obligation (based on TGC) on consumers: Increasing from 7.4% in 2003 up to 16.9% in 2010. For Wind Investment subsidies of 15% and additional small premium FITs ("Environmental Bonus"[16]) are available. | | No |
| **United Kingdom** | **Quota/TGC** | No | Quota obligation (based on TGCs) for all RES-E: Increasing from 3% in 2003 up to 10.4% by 2010 – penalty set at 30.5 £/MWh. 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 current levy rate is 4.3 £/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) | | No |

3 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.
4 Producers can choose between four different schemes. The figure shows the flat rate option. Within other schemes tariffs vary over time (peak/base etc.).
5 The law includes a dynamic reduction of the FITs (for some RES options): For biomass 1% per year, for PV 5% per year, for wind 2% per year.
6 Stepped FIT: In case of onshore wind 87 €/MWh for the first 5 years of operation and then 55 to 87 €/MWh depending on the quality of site.
7 Depending on location (islands or mainland) and type of producer (independent power producers or utilities)
8 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).
9 GRTN (Italian Transmission System Operator) influences strongly the certificates market selling its own certificates at a regulated price – namely at a price set by law as the average of the extra prices paid to acquire electricity from RES-E plant under the former FIT-programme (CIP6).
10 Only valid for plants up to 3 MW (except PV: limited to 50 kW).
11 Stepped FIT depending on the quality of the site.
12 Depending on the size: <5kW: 420 €/MWh or >5kW: 224 €/MWh.
13 Hydropower plant with a size between 10 and 50 MW receive a premium FIT of 6-29 €/MWh depending on the plant size.
14 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.
15 Depending on the plant size: <5kW: 360 €/MWh or >5kW: 180 €/MWh
16 Decreasing gradually down to zero in 2007

# 4 Method of approach

## 4.1 Evaluation criteria

Support instruments have to be effective for increasing 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 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 choose technologies, sizes and sites so that generation costs are minimised.

► ***Lower producer profits***

If such cost-efficient systems are found, – in a second step – various options should be evaluated with the aim to minimise transfer costs for consumer / society.[17] This means that feed-in tariffs, subsidies or trading systems should be designed in a way that public transfer payments are also minimised. This implies lowering producer surplus (PS)[18].

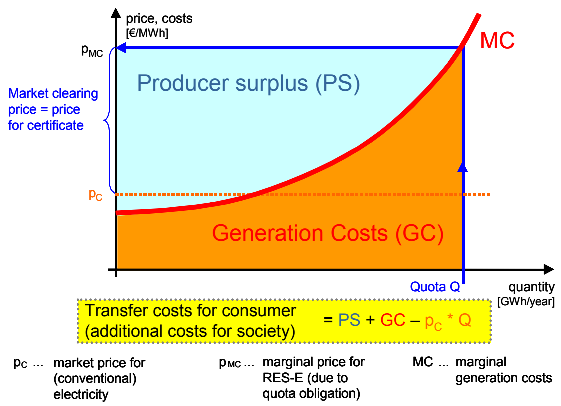



*Figure 4.1 Basic definitions of the cost elements (illustrated for a TGC system)*

In some cases both goals – minimise generation costs and producer surplus – may not be reached together so compromise solutions must be found. For a better illustration of the used cost definitions the various cost elements are expressed in Figure *4.1*.

## 4.2 The computer programme *Green*-X

The evaluation of the different promotion policy strategies and their trade-offs with other instruments and policies is based on both theoretical analysis carried out within the project Green-X and the calculations made with the help of the computer model ***Green-X***. Before these results are presented, the computer programme ***Green-X*** is briefly described.

The ***Green-X*** computer model is the core product developed within the project Green-X. It is an independent computer programme and allows to simulate different scenarios, which enable 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[19] over time. Figure 4.2 gives an overview of the core elements of the ***Green-X*** model.

The general modelling approach to describe both supply-side electricity generation technologies and electricity demand reduction options is to derive *dynamic cost-resource curves* for each generation and reduction option in the investigated region. Dynamic cost curves are characterised by the fact that the costs as well as the potential for electricity generation / demand reduction 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.

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

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

[18] The producer surplus is defined as the profit of the 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 defines the producer surplus.

[19] In the near future, it is planned to extend the geographical coverage of the model to the 10 new Member States, the candidate countries Bulgaria and Romania as well as Switzerland and Norway. A possible further extension to other neighbouring countries such as, e.g. the Balkan states and Turkey seems likely later-on.

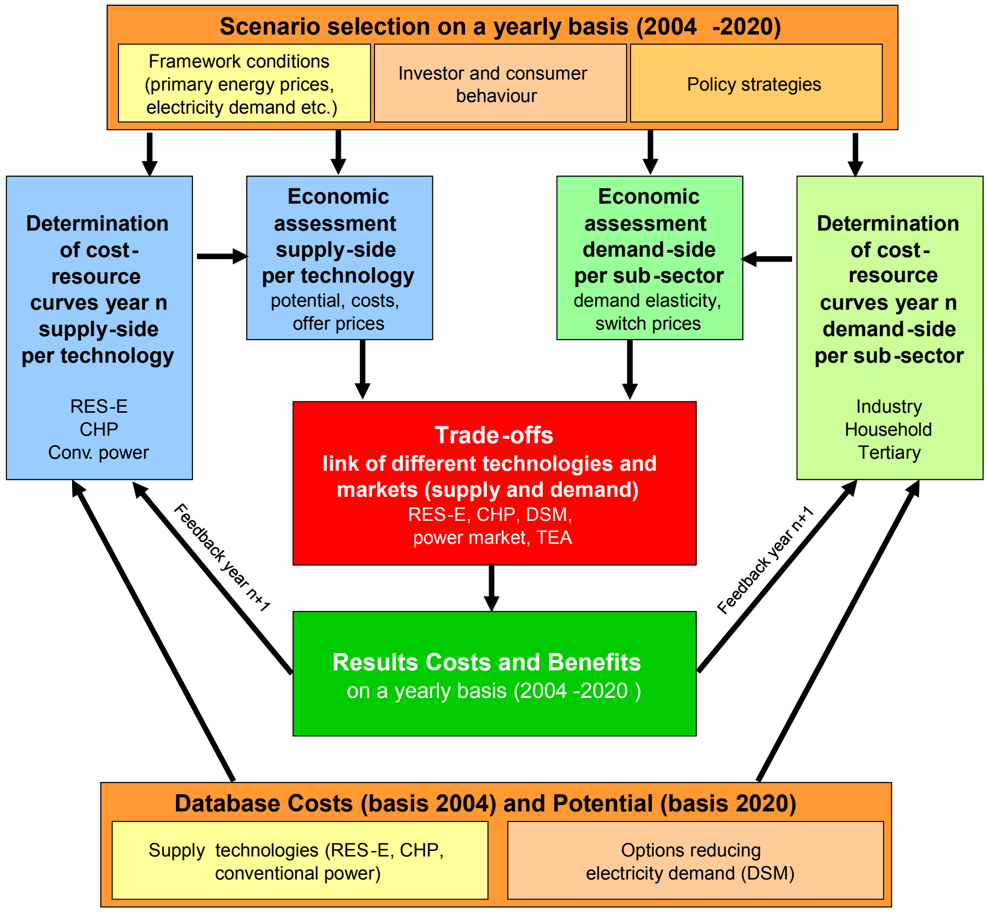



*Figure 4.2 Overview on the computer model* ***Green-X***

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 instruments can be applied to all RES and conventional options separately for both combined heat power and power production only. In addition, general taxes including 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) can be adjusted and the effects simulated.[20] As ***Green-X*** represents a dynamic simulation tool, the user has the possibility to change policy and parameter settings within a simulation run (i.e. by year). Furthermore, all instruments can be set for each country individually.

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

The results on a yearly basis are derived 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, tradable emissions permit market. This means that the different technologies are collected within each market and the point of equilibrium varies with the calculated demand.

In more detail, the ***Green-X*** model provides the following outputs for each Member State and for the European Union as a whole as well as for each technology on a yearly base up to 2020:

- General results, including:
  - Installed capacity [MW]
  - Total fuel input electricity generation [TJ, MW]
  - Total electricity generation [GWh]
  - National electricity consumption [GWh]
  - Import / export electricity balance [GWh, % of gen.]
  - Total $CO_2$-emissions from electricity generation compared to selected scenario baseline (BAU, Kyoto-target, etc.) [%]

[20] Thereby, various instrument-specific parameters can be defined, such as for example, in the case of a quota obligation the reference point of the quota (as share of total demand or generation), the imposed penalty in the case of non-compliance with the quota, etc.

– Market price electricity (yearly average price) [€/MWh]
– Market price Tradable Green Certificates [€/MWh]

- Impact on producer, including:
  – Total electricity generation costs [M€, €/MWh]
  – Total producer surplus for electricity generation [M€, €/MWh]
  – Marginal generation costs per technology for electricity generation [€/MWh]
- Impact on consumer, including:
  – Additional costs due to promotion of RES-E [M€, €/MWh]
  – Additional costs due to DSM strategy [M€, €/MWh]
  – Additional costs due to CO2-strategy [M€, €/MWh]
  – Total (transfer) costs due to the selected support schemes and policy options [M€]

For illustration of the computer model, some screen-shots are copied in Figure 4.3 to Figure 4.6.

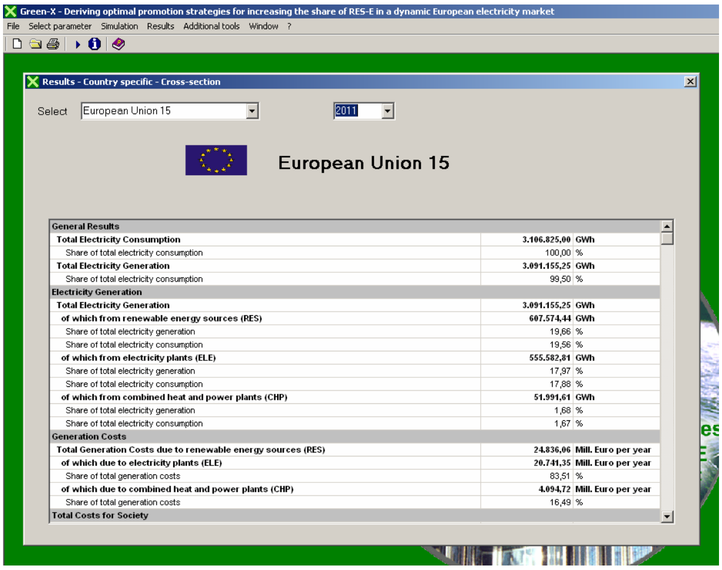



*Figure 4.4 Result table - country specific results*

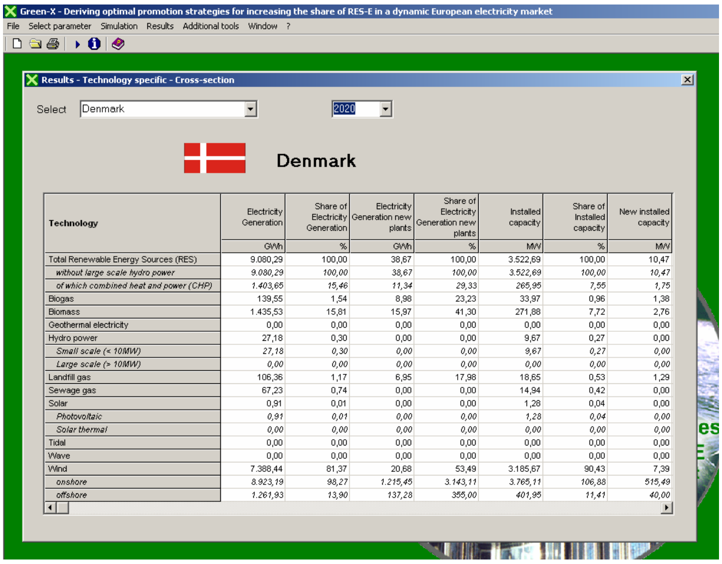



*Figure 4.5 Result table - technology specific results on country level*

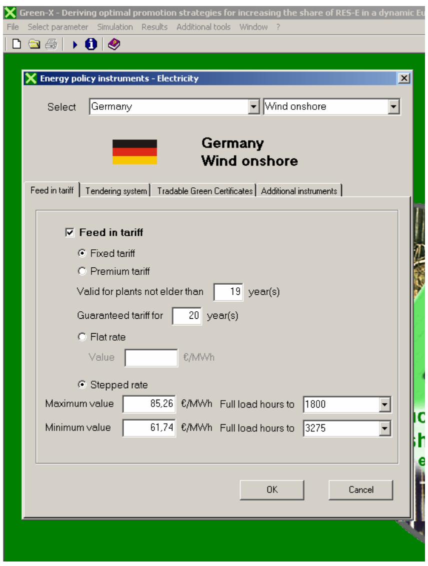



*Figure 4.3 Design options in the case of a feed-in tariff*

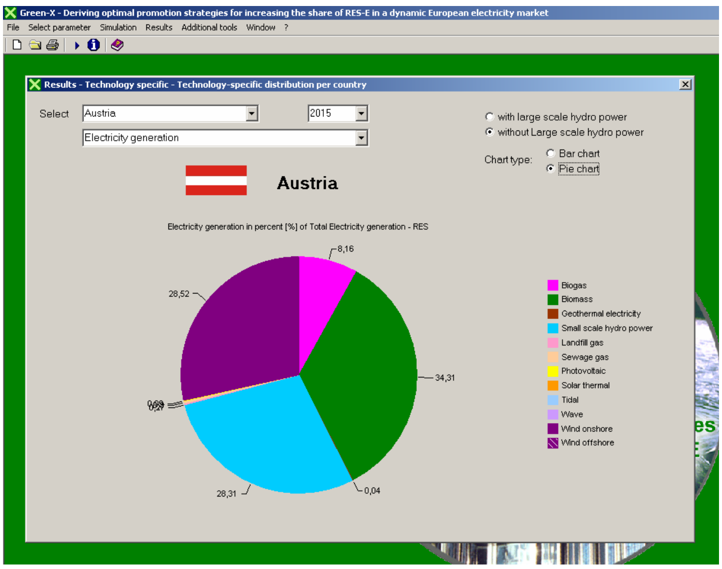



*Figure 4.6 Result figure – technology specific distribution per country*

# 5 Evaluation of different policies schemes in a dynamic framework


*Figure 5.1 Beneficial conditions for a successful RES-E deployment.*

## 5.1 Beneficial conditions for a successful RES-E deployment

In the long-term a substantial penetration of RES-E technologies can only take place if framework conditions are set such that various barriers in the different areas will be removed. This 'institutional context' issue is of high relevance. Beneficial conditions and criteria for a successful RES-E deployment are depicted in Figure 5.1 and summarised in Table 5.1 and Table 5.2.

## 5.2 Comparison of support schemes

There is no clear favourite support scheme; each instrument has its pro and cons. Most important differences among the analysed support schemes are:

- In contrast to a feed-in tariff scheme or a tender procedure, no adjustment is necessary to fulfil targets under a quota obligation if the penalty (penalties) is set right;
- From society's perspective, the cost effectiveness of the support scheme depends on the target that should be met. The RES-E target greatly influences the cost effectiveness of the applied instrument.[21]
- A tender scheme (based on price bids) represents a mix between a feed-in tariff (the price is guaranteed by a contract, hence, the risk and uncertainty about the economic conditions are low) and a TGC system (competition among the investors exist). A tender scheme (based on price bids) is similar to a stepped feed-in tariff, but with the difference that the granted price for RES-E will be determined by the market itself and not by a regulatory authority.[22]
- Generation costs can be minimised in the early phase of RES-E deployment by avoiding a differentiation among the promotion of the different RES-E options. In practise, a TGC system fits best due to the competitive character. In the long term higher generation costs may occur as alternative RES-E potentials can not be used at time.
- Feed-in tariffs and tender schemes are useful in promoting a more homogeneous distribution among different technologies by setting technology-specific guaranteed tariffs. The long-term technology development of various RES, which are currently not cost-efficient, can be stimulated by implementing such a policy. This can be essential to decrease future generation costs for these technologies and to increase the available future potential. This means, there will be a higher potential available at lower costs in the future. Of course, this positive effect is compensated by economic distortions among the RES.
- Governmental planning and control effort increase with the complexity of the feed-in tariff scheme or the diversification of the tender procedure. The gain for society occurring from a more specific approach must be compared with these premium costs. In addition, the rent seeking and lobbying activities increase under such conditions compared to a simpler implementation or a TGC system.

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[21] In the case of 'low' targets similar costs for society occur, irrespective of the chosen strategy. In the case of 'high' targets costs depend (significantly) on the chosen instrument and its design

[22] Under the assumption of a 'perfect' market, the feed-in tariffs set by the public body are higher and thus inefficient from the society's point-of-view compared with a tender scheme. However, a feed-in tariff can be the more efficient solution when considering strategic bidding, the problems of an oligopoly structure and higher administration and transaction costs of the tender scheme.

*Table 5.1 Evaluation of support schemes fulfilling beneficial conditions for RES-E deployment*

| Area | Important issues | General issues independent from the chosen instrument (partly design options) | Policy specific issues | | | | |
|---|---|---|---|---|---|---|---|
| | | | **Feed-in tariffs** | **Premium feed-in tariffs** | **Quota with TGCs** | **Quota with TGCs & additional support or technology specific quotas** | **Tender scheme** |
| **Society / Policy** | Low premium prices for power consumer | Within any support scheme existing and new capacity should not be mixed | New tariffs should be offered to new capacity only | | Quota obligation should refer to new capacity, which are built after a certain starting year | | Automatically fulfilled by offering tender for new capacity |
| | | Time frame for a particular financial support mechanism should be restricted | Guaranteed contract time should be limited | | TGCs should be issued over a pre-defined period of time | | Guaranteed contract time should be limited |
| | | Premium costs can be reduced by providing technology specific support and encourage competition | Applying technology specific tariffs and stepped FIT design if appropriate;(lower producer surplus) | Higher or lower costs depending on the actual power price development compared to fixed FIT | TGC system must not be least costs options from the consumers point-of-view (higher producer surplus) | Additional support for more expensive technologies (may) help to reduce costs for consumer | Low costs for consumer by applying technology-cluster specific calls |
| | | Stable planning horizon reduce necessary risk premium and, hence, public support | Low risk premium due to guaranteed contract | Medium risk premium due to uncertainty on power market | High risk premium due to uncertainty on TGC and power market | | Low risk premium due to guaranteed contract |
| | | Admitting least cost technologies (e.g. include biomass co-firing or retrofit of large hydro power) | Offer specific tariffs for co-firing or retrofit activities | | Include least cost options into quota system if new capacity is used | | Offer specific tariffs for co-firing or retrofit activities |
| | Increasing public acceptance | Low additional costs for consumer | See above | | See above | | See above |
| | | Investment structure (involvement of local and regional investors) | Attractive also for regional and local investors due to low risk premium | Less attractive for regional and local investors as power market activities are necessary (remedy: long-term contracts) | Mainly for national and international investors (medium to big size) due to higher risk and trading system attractive | | Depends on tender structure; mainly big investors participate (exemption: tender for small capacities) |
| | | Portfolio of RES-E technologies | Depending on the technology specific tariffs | | Reduced portfolio due to least cost approach | More homogenous mix than under pure quota system | Depending on portfolio of technology specific tenders |
| | | Regional distribution of RES-E technologies | Can be "adjusted" by tariff design (stepped tariff and technology specific support) | | Hot spots due to least cost approach | Diminishing of hot spots due to additional subsidies | Depending on tender structure |
| | | Regional side-effects | Effects on employment, local benefits, local emission reduction, etc. depend on technology portfolio and regional distribution and continuity of RES-E policy | | | | |
| | | Creation of public awareness of energy and sustainable issues | Issues like $CO_2$ reduction, security of supply depends on transparency, stability and credibility of energy policy and investment structure | | | | |
| | High effectiveness in deploying of RES-E | A particular scheme should be fast and effective in increasing the capacity of RES-E technologies | Proven to allow a high deployment rate in the past | | Effectiveness depends significantly on the design of the obligation scheme (preconditions: reciprocity of TGCs, full competition, long-term targets, stable investment conditions, appropriate level of penalty in the case of non-compliance) | | Effectiveness depends significantly on the design (continuity of policy, technology-cluster setting) |

*Table 5.2 Evaluation of support schemes fulfilling beneficial conditions for RES-E deployment*

| Area | Important issues | General issues independent from the chosen instrument (partly design options) | Policy specific issues | | | | |
|---|---|---|---|---|---|---|---|
| | | | Feed-in tariffs | Premium feed-in tariffs | Quota with TGCs | Quota with TGCs & additional support or technology specific quotas | Tender scheme |
| Investor / stake-holder | Appropriate financial support | Minimum rate-of return necessary | Minimum level of guaranteed tariff | | Preconditions are: (i) appropriate quota (extension of RES-E capacity), (ii) function of the TGC market and, (iii) high penalty for non-compliance | | Competition among investors drops revenues |
| | High investor confidence / low policy risk | Credibility of the system | Guaranteed by contract | | Clear rules for participation to TGC scheme, confidence in retaining policy | | Guaranteed by contract |
| | | Stable planning horizon | Minimum contract time | | Clear published mid to long-term targets | | Minimum contract time |
| | Simple and transparent | Low transaction costs | Low transaction costs if design is simple; in this case, however, higher costs for consumer | | Transaction costs depends on market structure like maturity and size | | Higher costs due to tender procedure |
| | | No entrance barriers for competitive fringes | In general less distortions (depending on design) | | Problems with oligopoly structure in small countries – formation of international TGC scheme | | Problems with oligopoly structure in small countries |
| | Continue RES-E policy | Attract interest of potential investors Increase confidence of banks, depending mainly on maturity of technology | Low risk for investors and banks due to long term contract (FIT) | Higher risk than standard FIT; but still low | Higher risk but also higher rates-of-return feasible; attractive for medium to large investors | | Low rates-of-return but low risk after win of the tender |
| Market | High conformity with the power market | No discrimination (free entrance to grid, power market, administrative processes, etc); market separation leads to lower turnover within the power market, but also to lower power market prices | No competition for RES-E; full market separation between RES-E and power market | Competition in power market for RES-E; no market separation RES-E and power market; | Competition in TGC and power market; but both markets are (fully) separated markets | | Competition for RES-E in tender; full market separation between RES and power market; |
| | High conformity with other policy instruments | Support scheme should not cause counterproductive effects on other policy schemes and vice versa | No direct interaction of electricity demand (policy – DSM) and FIT, due to lower demand share of RES-E increases | Higher power price reduce necessary premium; a constant premium leads to higher RES-E deployment | Interaction of electricity demand (policy – DSM) and quota obligation; reducing the electricity demand helps to fulfil the quota target | | No interaction of electricity demand (policy – DSM) and tender; see FIT |
| | Effective in the transition period | Clear separation of old and new system (existence of two systems within the transition period) | Easy and fast to abandon (for old plants contracts exists guaranteeing the support) | | Phase out of old TGC scheme problematically (unexpected price fluctuations). Two separated markets necessary in transition from old to new TGC system | | Easy and fast to abandon (contracts for exists plants remains available) |
| Long-term strategy / technology | Broad technology portfolio | In the case of an ambitious RES-E policy a broad RES-E portfolio is necessary | Depending on tariff setting; high if technology specific tariffs | | Low as quota system prefers least cost technologies | More well-balanced RES-E portfolio than under pure quota system | Depending on tender setting; high if many technology specific tenders |
| | Encouraging lower manufacturing costs | In the long term RES-E technologies must be fully competitive with conventional power | Due to the technology specific support high decrease of less mature technologies may be reached | | Due to the support of currently most cost-efficient technologies no additional support for these technologies may be necessary in the future | | Cost reduction in the different technologies depends on mix of offered technology-cluster calls |
| | Integration with other policies | Climate policy and RES-E policy are closely linked | RES-E policy has a positive impact on GHG emissions (substitution of conventional power); ambitious GHG policy leads to a reduction of additional support for RES-E policy as premium costs compared to power price drops | | | | |
| | | Agricultural policy | Integration of agricultural and energy policy may assist a more rapid deployment of affordable RES | | | | |
| | | Lower energy consumption | No impact | No direct impact; indirect via power price | Positive impact as quota is linked to energy demand | | No impact |

## 5.3 Interactions of RES-E support, GHG policy, DSM activities and promotion of CHP

On the one hand, the support of RES-E has an impact on the (conventional) power market,) and their greenhouse gas abatement and electricity demand (policy). Most relevant effects are independent from the support mechanism and can be concluded as depicted in Table 5.3.

On the other hand, the other energy policies have an effect on RES-E deployment too, which are summarised in Table 5.4.

*Table 5.3 Impact of RES-E deployment on other conventional power, GHG policy and electricity demand and CHP*

| Impact on / of | Policy | | | |
|---|---|---|---|---|
| | **conventional power** | **TEA** | **DSM** | **CHP** |
| **RES-E** | Electricity generation drops; Power price drops; $CO_2$-emissions drops | lower TEA price; $CO_2$-target are easier to reach | lower demand reduce costs for DSM | generation ambiguous depending on RES-E policy |

*Table 5.4 Impact of GHG policy, DSM activities and promotion of CHP on RES-E support schemes*

| Impact on / of | Issue | RES-E instrument | | |
|---|---|---|---|---|
| | | **TGC** | **FIT / tender** | **premium FIT, investment incentives, tax relief** |
| **TEA** | RES-E deployment | slightly decrease | no impact | increase |
| | transfer costs for consumer due to RES-E | decrease | no impact | ambiguous |
| | total transfer costs for consumer (TEA plus RES-E) | ambiguous | increase | increase |
| | RES-E target | easier to reach | easier to reach | (much) easier to reach |
| **DSM** | RES-E deployment | slightly decrease | no impact | decrease |
| | transfer costs for consumer due to RES-E | ambiguous | no impact | decrease |
| | total transfer costs for consumer (DSM plus RES-E) | ambiguous | increase | ambiguous |
| | RES-E target | easier to reach | easier to reach | harder to reach |
| **CHP** | RES-E deployment | ambiguous | no impact / increase | decrease for pure el. plants / ambiguous for CHP plants |
| | transfer costs for consumer due to RES-E | ambiguous | decrease / no impact | decrease for pure el. plants / ambiguous for CHP plants |
| | total transfer costs for consumer (CHP plus RES-E) | ambiguous | ambiguous | ambiguous |
| | RES-E target | ambiguous | ambiguous | ambiguous |

# 6 Results from simulations with the *Green-X* toolbox on EU level

## 6.1 Definition of scenarios

The aim of the scenario runs is to analyse the effects of different support schemes – both harmonised and non-harmonised policies among the EU 15 Member States – with respect to RES-E deployment, investment needs, generation costs and transfer costs for consumers.

The RES-E Directive (EC/77/01) sets a minimum framework for RES-E policy. However, in line with the Principle of Subsidiary, it allows each MS to choose the support scheme, which "corresponds best to its particular situation". Taking account of the wide diversity of promotion schemes between Member States, the Directive states that it is too early to set a Community-wide framework regarding support schemes. By 10/27/2005, the Commission should present a report on the experience gained with the application and coexistence of different support schemes in the Member States. The report may be accompanied by a proposal for a Community framework for RES support schemes (art.4.2). However, it does not prejudge what the RES-E policy scheme should be used for in the future. Not even if a common RES-E promotion scheme should be implemented. The directive also stipulates that such a proposal for a harmonised support framework should allow a transition period of at least 7 years (thereafter) in order to maintain investors' confidence and avoid stranded costs. Therefore, at least in the short/medium-term, national support schemes will continue to be used by MS to promote RES-E. In the future – at least - some sort of combination of a community framework (harmonisation) and continuation of MS policies for new and existing capacity is possible.

The model runs try to consider the spread of possible RES-E policy deployment within the EU in the following way:

- No harmonisation, where currently implemented policies remains available (without any adaptation), i.e. **business as usual** (BAU) **forecast** (scenario B1)
- **After a transition period of 7 years**, a **harmonisation** of the support schemes takes places. To be able to analyse the effect of different (harmonised) policies compared to the status quo (BAU) it is assumed that the same RES-E target as under BAU conditions should be reached by 2020. The following currently must promising and favourable policies should be investigated under harmonised conditions:
  - – Feed-in tariff (B2)
  - – International TGC system (B3)
  - – National TGC system (B4)
- To investigate how the RES-E target influences the efficiency of different support schemes, a second more **ambitious RES-E target** should be reached in 2020. More precisely, it is assumed that **1000 TWh** should come from RES-E technologies **in 2020** assuming:
  - – Current policy (BAU) up to 2012 - 7 year transition period - and a harmonised system thereafter. Again the goal should be reached by applying the following support mechanisms:
    - Feed-in tariff (H1)
    - International TGC system (H2)
  - – Harmonisation should already take place in 2005 and the indicative RES-E target in 2010 should be reached. Therefore, the effects of "early actions" and a high interim target (2010 goal) can be shown (scenario H3 to H5).

Figure 6.1 gives an overview of the investigated scenario paths.

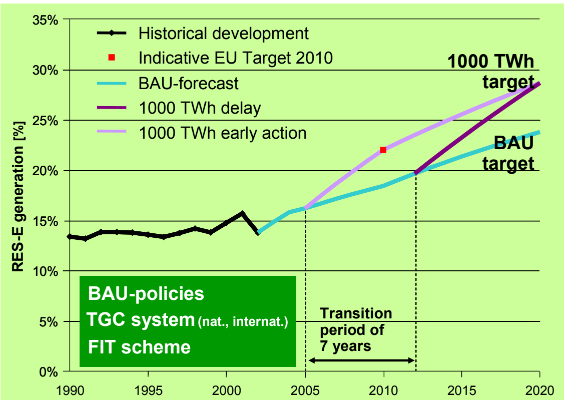


*Figure 6.1 Investigated cases*

## 6.2 General scenario assumptions

► ***Gross electricity consumption***

Electricity demand according to DG TREN Outlook 2030: European Energy and Transport Trends to 2030 Outlook (Mantzos et. al 2003) – Baseline forecast. This means that electricity demand 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 6.2 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 €2002. 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.

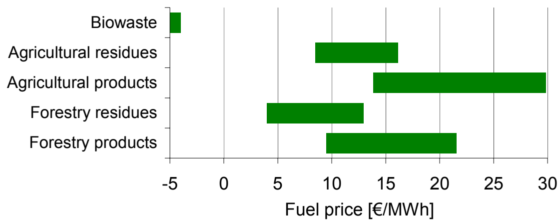


*Figure 6.2 Variation of the prices for the different biomass products in EU 15*

### ► *Electricity prices*

For each EU 15 Member State the power price is derived endogenously within the Green-X model considering interconnection constraint among the countries. The calculations are based on

- Primary energy projections from the WETO project.
- Different $CO_2$-policy assumptions[23], namely no-$CO_2$ constraint, medium $CO_2$ constraint (assuming a tradable emission allowance price up to 10 €/t-$CO_2$) and high $CO_2$ constraint (assuming a tradable emission allowance price up to 20 €/t-$CO_2$)
- RES-E policies are as described in chapter 5.1. Note, RES-E policy significantly influences the power market price.

### ► *Interest rate / weighted average cost of capital*

The determination of the necessary rate of return is based on the weighted average cost of capital (WACC) methodology.[24] Two options are considered in the analysis, namely 6.5% and 8.6%. The different values are based on different risk assessment, one standard risk level and a higher risk level characterised by a higher expected market rate of return. The 6.5% value is used as the default value; the 8.6% is used for the sensitivity analysis and is applied in scenarios with lower stable planning conditions and support schemes cause a higher risk for the investors (TGC system). 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.[25]

### ► *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)
- 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 6.1. 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. 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).

[23] In a sensitivity analysis different $CO_2$-contraints are assumed. The default assumption refers to a medium $CO_2$-constraint of up to 10 €/t-$CO_2$.

[24] 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).

[25] For determining the exact setting of the support level such a technology specific WACC approach is useful. Such a procedure is - in a more detailed (country specific) analysis – feasible by applying the model ***Green-X***.

*Table 6.1 Dynamic assessment of investment costs for different RES-E technologies*

| RES-E category | Applied approach | Assumptions |
|---|---|---|
| Biogas | Experience curve (global) | LR (learning rate) = 5% |
| Biomass | Experience curve (global) | LR = 5% |
| Geothermal electricity | Experience curve (global) | LR = 5% |
| Hydropower | Expert forecast | No cost decrease in considered period |
| Photovoltaics | Experience curve (global) | LR = 15% up to 2010, 10% after 2010 |
| Solar thermal electricity | Experience curve (global) | LR = 15% up to 2010, 10% after 2010 |
| Tidal & Wave | Expert forecast | Cost decrease 5%/year up to 2010, 1%/year after 2010 |
| Wind on- & offshore | Experience curve (global) | LR = 9% |

## 6.3 Assumptions for simulated support schemes

Within this project the two most important support schemes within the EU are analysed, namely (i) a quota obligation in combination with tradable green certificates and (ii) a feed-in tariff system. A number of key input parameters are defined for each of the model runs and they are described below.

### ► *General scenario conditions*

Transfer costs for society hugely depend on the design of policy instruments. The design options of the instruments are chosen in a way such that transfer costs for society are low. In the model run, it is assumed that all investigated strategies – BAU as well as for reaching the 1000 TWh target by 2020 - are characterised by:

- Stable planning horizon
- Continuous RES-E policy / long term RES-E targets
- Clear and well defined tariff structure / yearly quota for RES-E technologies
- Reduced investment and O&M costs, increased energy efficiency over time.
- Reduction in barriers and high public acceptance in the long term[26].

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

- Financial support is restricted to new capacity only [27]
- Restriction of the duration in which investors can receive (additional) financial support. [28]

[26] In the scenario runs it is assumed that the existing social, market and technical barriers (.e.g. grid integration) can be overcome in time. The reduction depends on the assumed target, i.e. a more optimistic view is assumed for reaching the 1000 TWh target in 2020 compare to the BAU target

[27] This means that only plants constructed after the start year of the different scenarios (2004 and 2013 respectively) are allowed to receive the support.

### ► *Scenario conditions assuming a quota obligation[29]*

- Tradable green certificates are standardised
- Full competition, i.e. (i) a high level of market transparency exist, (ii) an appropriate level of trading volume is available, (iii) investors are seeking the most efficient RES-E resources, leading to an idealised, fully competitive TGC market;[30]
- Additional support for less mature RES-E technologies does not exist
- Constant yearly interim targets[31]
- Penalty for not fulfilling the quota obligation are set high amounts up to 150 €/MWh.

### ► *Scenario conditions assuming a feed-in tariff scheme[32]*

- Guaranteed tariffs are technology specific,
- Tariffs are set as low as is reasonable without causing a lower deployment rate over the RES-E portfolio.
- Guaranteed tariffs decrease over time or at least remain constant for certain RES-E technologies
- Tariffs for wind energy are designed as a stepped feed-in tariff [33]

[28] In the model runs it is assumed that the time frame is restricted to 15 years

[29] With the exception of the quota obligation given in the current RES-E policies (BAU scenario)

[30] Otherwise costs rise due to strategic price setting.

[31] Interim targets are set in a way that the percentage increase between the single years is constant in the period 2013-2020 (for the case of a harmonised strategy beyond 2012) and in the period 2006-2010 and 2011-2020 (for the case that the indicative target in 2010 should be reached)

[32] With the exception of the feed-in tariffs schemes given in the current RES-E policies (BAU scenario)

[33] This means that the feed-in tariff will be reduced if actual generation is high. To set an incentive for investors to implement the most efficient technologies and locations, the reduction in the guaranteed price must be less than the total revenue that can be gained if an efficient plant and location are chosen. Profits will thus be higher at more cost effective sites. A stepped tariff e.g. is implemented in Germany

## 6.4 Results - BAU target in 2020

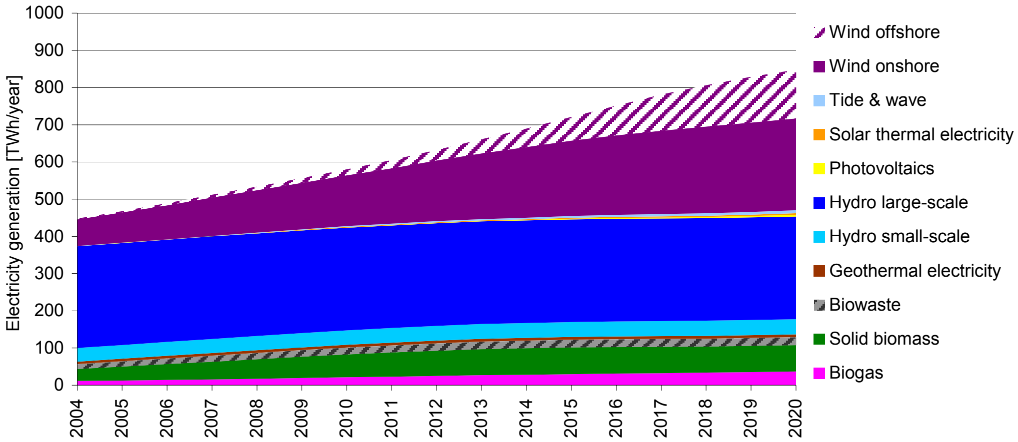


*Figure 6.3 Development of RES-E generation 2004-2020 within EU 15 in the BAU scenario (B1)*

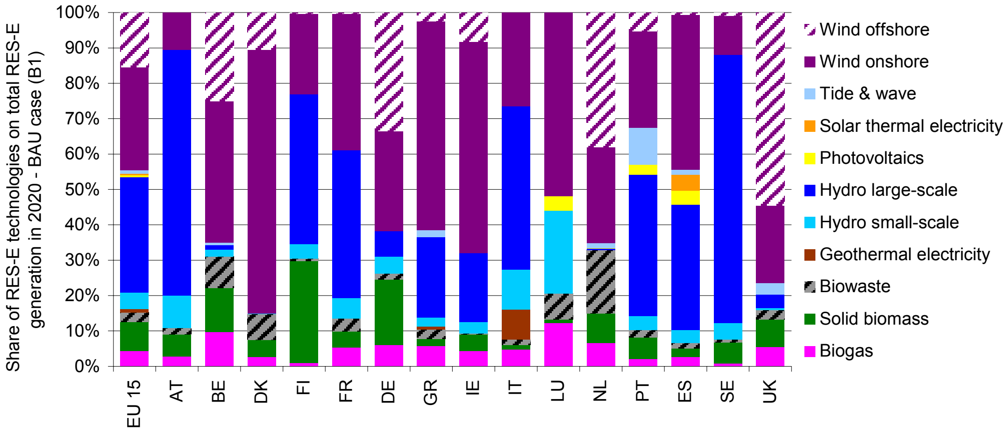


*Figure 6.4 Portfolio of RES-E technology on RES-E generation in 2020 among the Member States under BAU conditions (B1)*

Total amount of RES-E generation within the EU 15 was around 449 TWh/a in 2004.[34] Without any changes in the support scheme the electricity production will rise to about 581 TWh/a in 2010 (19,0%) and 848 TWh/a in 2020 (24,3%). This amount is - following the BAU demand projection from Mantzos et. al. (2003a) – around 93 TWh/a or 2% less than the EU target as described in the 'RES-E Directive' (01/77/EC).[35] Remaining the current policy schemes, the EU target 2010 can be reached with a delay of around 3 years (efficiency demand according to Mantzos et. al (2003)) and 5 years (BAU demand according to Mantzos et. al (2003)), respectively.

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

[35] Assuming an electricity demand projected according to the efficiency scenario (Mantzos et. al., 2003b), the share of RES-E amounts 20% in 2010 and 26,9% in 2020.

The dynamic development of RES-E generation for the BAU case is depicted in Figure 6.3. On country level large differences in the future RES-E deployment exists. Three countries would reach the indicative RES-E targets without any adaptation of their current strategy in 2010; namely Germany, the Netherlands and UK (assuming a binding penalty). Substantial additional RES-E development can be expected in most countries after 2010.

Due to less public support and acceptance, the amount of large scale hydro power plants will increase only marginally in absolute terms.[36] In relative terms the share drops significantly from around 60% in 2004 to 33% in 2020. The 'winner' among the considered technologies is wind energy, both onshore and offshore. It can be expected that around 45% (30%) of the RES-E production of plants installed after 2004 in 2020 is coming from wind onshore (offshore), leading to a share of

[36] Considering the effects of the Water Framework directive (EC, 2000b) the total electricity generation from (large scale) hydro can even be lower in 2020 compared to the current level.

around 30% wind onshore and 15% wind offshore on total RES-E generation in 2020, respectively. Other significant increases can be expected for solid biomass (+ 8%) and biogas (+ 6%). The portfolio of RES-E technologies significantly differs among the Member States as can be seen from Figure 6.4.

It can be expected that the highest amount of 'new' RES-E will be produced in the UK and Germany following by France, Spain and Italy. In general, actual generation depends on the applied policy and partly varies significantly.

High investments are necessary to be able to build up the new capacity. Figure 6.5 shows the total investment needs for RES-E over time assuming BAU policy up to 2020. While necessary investments into wind onshore and biogas plants are relative stable over time, investments into solid biomass plants (including biowaste) mainly occur in the first years (2005-2015) and for wind offshore and photovoltaic mainly after 2010. The investments (within the EU and worldwide) stimulate technological learning, leading to lower generation costs in the future.

Next, the necessary financial incentive for the promotion of RES-E is discussed. Figure 6.6 compares the average financial support for new RES-E capacity for the four investigated cases B1 to B4. The amount represents the additional premium costs for society compared to the power market price.[37] With respect to the BAU policy (B1) it can be conclude that the average premium costs remains constant up to 2012 and decreases thereafter. The reduction, however, is lower than introducing a harmonised well designed technology specific feed-in tariff scheme (B2). Again, the necessary support nearly drops continuously over time.[38] In contrast to this scheme the entity of both a national and international TGC system is to promote currently least cost generation options (only).[39] Hence, in the first year(s) premium costs are low but increase over time as cheap production options are already used.[40]

It can be observed that premium costs for society are higher applying a national TGC scheme compared to an international one. In addition, considering the higher risk associated with a TGC scheme for the investors the necessary support is higher than applying a technology specific well designed feed-in system.[41]

The application of current policies leads to a high spread of the granted financial premium costs among the countries as depicted in Figure 6.7a.

The necessary premium support per MWh new RES-E generation can be mainly harmonised between the countries by applying harmonised feed-in tariff schemes, see Figure 6.7b, or fully by applying an international TGC scheme, see Figure 6.7c.[42] In contrast to this two schemes national TGC systems do not (automatically) lead to similar or the same financial incentives for new RES-E production in all countries as illustrated in Figure 6.7d.[43] The premium depends on the national RES-E target setting. Assuming that the same national RES-E deployment as under the BAU policy should be reached, high distortions between the countries occur.[44]

Summing up, it can be concluded that the application of a harmonised approach leads to a uniform support per MWh of RES-E technologies in the countries. This means that distortions of the technological development of each RES-E technology among the Member States can be avoided.

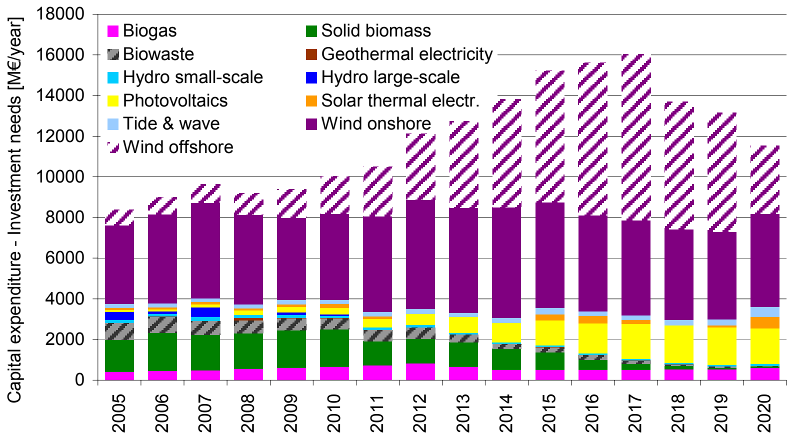


*Figure 6.5 Total investment needs in the period 2005-2020 within the EU-15 in the BAU scenario (B1)*

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[37] Note: At this stage a power price reduction due to the promotion of RES-E is neglected. Hence, premium costs are (slightly) overestimated.

[38] Note: The incentive compatible feed-in tariff is designed that the necessary amount dynamically drops. The slight increase in 2014 results as a higher share of more expensive technologies is exploited.

[39] By using technology-cluster specific quotas or granting additional support for less mature technologies a different dynamic support development can be reached

[40] The development of the premium costs depends on the mid term target, the available potential and the cost reduction due to technological learning. This means the necessary support can increase or decrease over time.

[41] For comparison purpose, the 'necessary' premium for the case of no risk premium is depicted in Figure 6.6 too (dotted lines).

[42] The remaining differences occur due to the different technology mix. In the case that for each technology the same tariff level – which of course is inefficient with respect to the costs for society – is grated the premium support would be equal in each countries too.

[43] Note: Harmonisation in the case of a feed-in scheme means that the same tariffs for the different technologies are granted. As the RES-E portfolio, however, differs within the countries (slightly) variations in the average support occur.

[44] This fact confirms the existence of large variations in the current RES-E support.

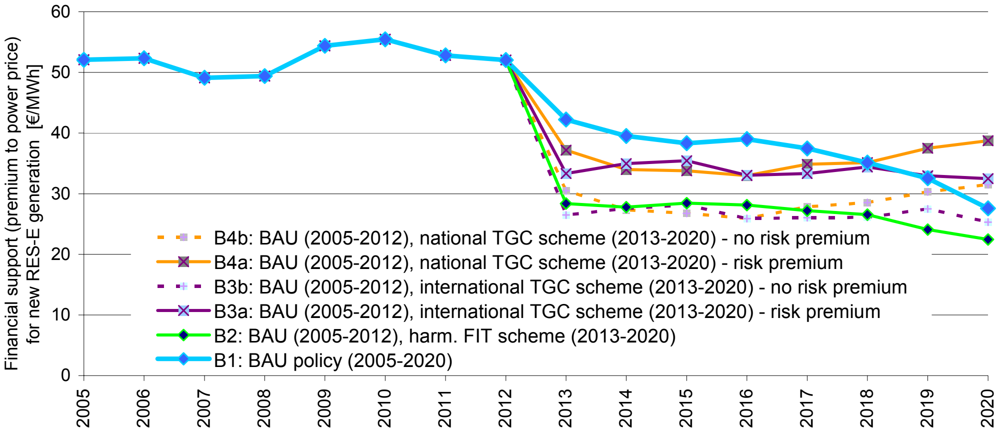
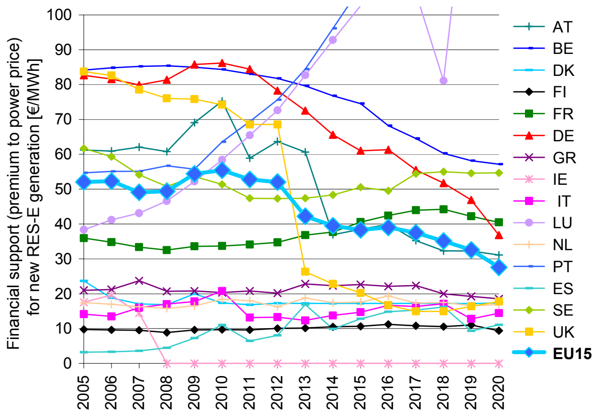
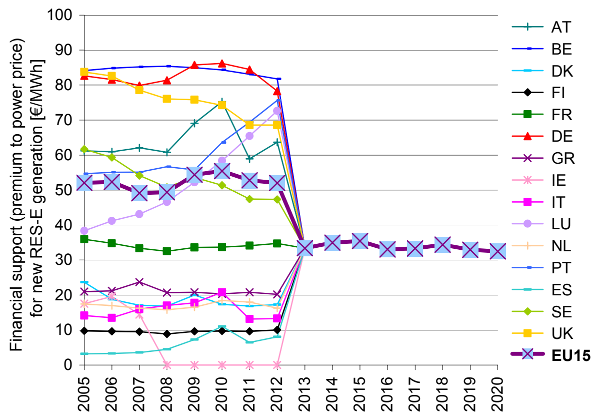


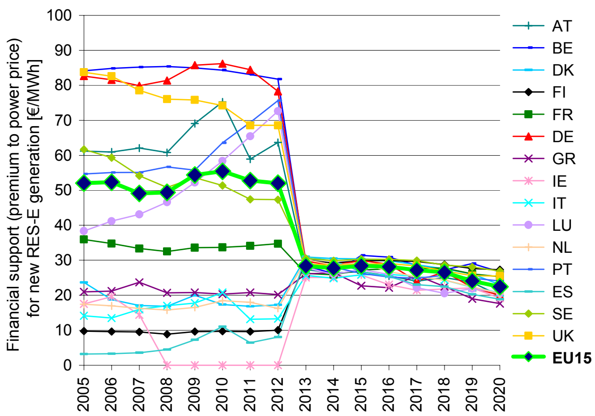

*Figure 6.6 Comparison of financial support (average premium to power price) for new RES-E generation on EU 15 level in the period 2005-2020 for the cases (B1-B4)*



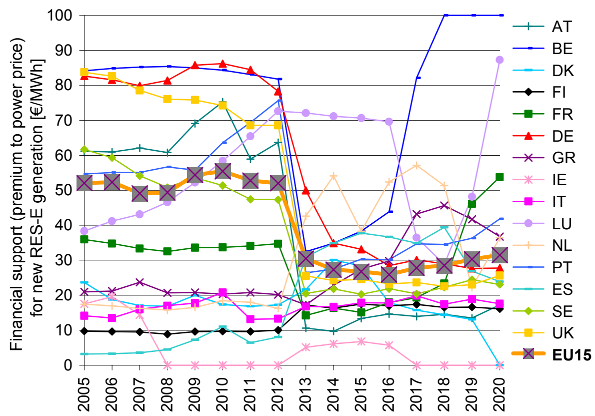

(a) **current RES-E policy schemes** (case B1)




(c) **international TGC scheme** after 2012 (case B3)




(b) internationally harmonised **feed-in tariff scheme** after 2012 (case B2)




(d) **national TGC schemes** after 2012 (case B4)

*Figure 6.7 Country specific financial support (average premium to power price) for new RES-E generation in the period 2005-2020 for the cases (B1-B4):*
*(a) applying **current RES-E policy schemes** (B1) … (top-left)*
*(b) applying an internationally harmonised **feed-in tariff scheme** after 2012 (B2) … (bottom-left)*
*(c) applying an **international TGC scheme** after 2012 (B3) … (top-right)*
*(d) applying **national TGC schemes** after 2012 (B4) … (bottom-right)*

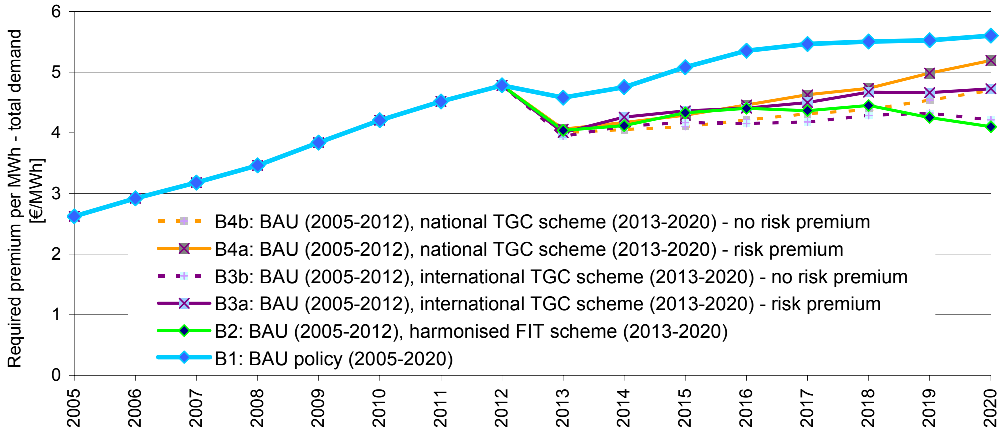



*Figure 6.8 Comparison of necessary transfer costs for consumer reaching the BAU target 2020 for the cases (B1–B4)*

The yearly necessary transfer costs for consumer on EU level reaching the BAU target over time are depicted for the four investigated cases in Figure 6.8. The yearly burden is highest remaining the current policy schemes. In this case transfer costs for society rise continuously over time. Costs are relative stable applying a technology specific feed-in tariff from 2013 on. In the case of a TGC scheme burden in the first years drop compared to the 2012 level, but increases over time

Harmonisation reduces the distortion with respect to the required transfer costs for the societies in the countries. The same promotion of one unit of new RES-E for each technology in the different Member States (harmonisation of the schemes), however, does not automatically results in a uniform burden for the consumer per MWh electricity consumption.[45]

In the case of a feed-in tariff or tender scheme the transfer costs (premium costs) for society depends on the actual national RES-E deployment. This means that the burden for the consumer is high in countries with a relative high potential as a high total electricity generation from RES-E occur. In addition, the costs rise if the share of relative ‘expensive’ RES-E technologies is high too. In the case of an international TGC scheme the burden depends on the agreed national RES-E target, i.e. the costs are independent from the actual national RES-E production; the different to the quota level can be sold at or must be purchased from the international TGC market.[46] Applying a national TGC scheme the transfer costs for consumer depends on the agreed TGC target too, however, without the opportunity to use all efficient RES-E generation options if the target setting among the countries is inappropriate.

In addition, the yearly transfer costs for consumer depend on the historical promotion of RES-E. These costs are independent from the actual RES-E policy as it is assumed that existing capacity remains in their old promotion scheme – the new schemes are applied to new capacity only.

Note that the *yearly* transfer costs represent the actually yearly imposed costs for society and are not fully comparable among each other with respect to the *total* burden for the consumer[47]. For example in the case of the BAU scenario some countries are granting investment incentives, leading to a high yearly costs for the new RES-E capacity but lower costs in the years thereafter. As the time horizon ends by 2020 in the Figure 6.8 the *total burden* for the consumer seams to be ‘too high’ in the BAU scenario compared to the other cases as a higher share of the costs are already paid up to 2020.[48] The yearly burden can be influenced by changing the guaranteed duration of the support. For example the yearly amount increases by guaranteeing a tariff for 10 years instead of 15 years. In this case, however, premium costs must be paid only 10 years so total burden remains approximately constant.

A comparison of the full transfer costs for the consumer is given in Figure 6.9. Total transfer costs for society after 2020 (dotted area) are higher under a TGC scheme than under a feed-in system as the TGC price is high in 2020. Total transfer costs for society are lowest applying technology specific support, followed by an international and a national TGC scheme and are highest retaining the current policy up to 2020.

[45] One approach how to harmonise the burden for the consumer among the countries is discussed in chapter 7.2.6.

[46] In this investigation it is assumed that each country is imposed by the same RES-E target for new plants. This means that the burden for RES-E policy after 2012 is equal among the consumer in the Member States (uniform quota for new RES-E generation).

[47] However, they are fully comparable regarding the *yearly burden* for the consumer.

[48] For the harmonised cases a guaranteed duration of 15 years is assumed. This means that a capacity, which is built in 2019 will receive a public support up to 2034. In Figure 6.8, however, only the costs for the years 2019 and 2020 are depicted, neglecting the full ‘sunk costs’ up to 2034 in the period after 2020.

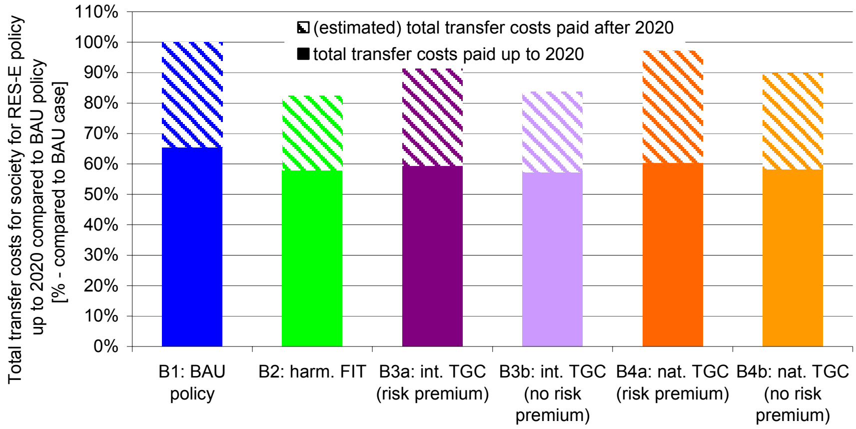



*Figure 6.9 Comparison of necessary cumulated total transfer costs for consumer due to RES-E policy up to 2020 reaching the BAU target 2020 (B1 – B4).*

*Note: In the case of a TGC scheme total transfer costs paid after 2020 are estimated assuming that the TGC price in the year 2020 is constant up to the phase out of the support*

## 6.5 Results - 1.000 TWh target in 2020

To analyse how the RES-E target influences the RES-E portfolio and the efficiency of different support schemes, model runs are carried out fulfilling a more ambitious RES-E target. Figure 6.10 depicts the deployment of RES-E generation reaching 1000 TWh in 2020 over time.

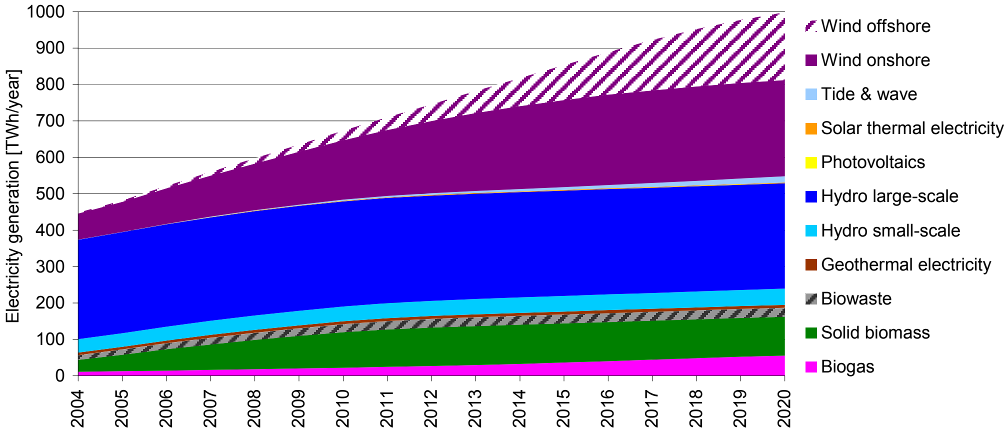



*Figure 6.10 Development of RES-E generation 2004-2020 within EU-15 in the 1000 TWh scenario (case H3)*

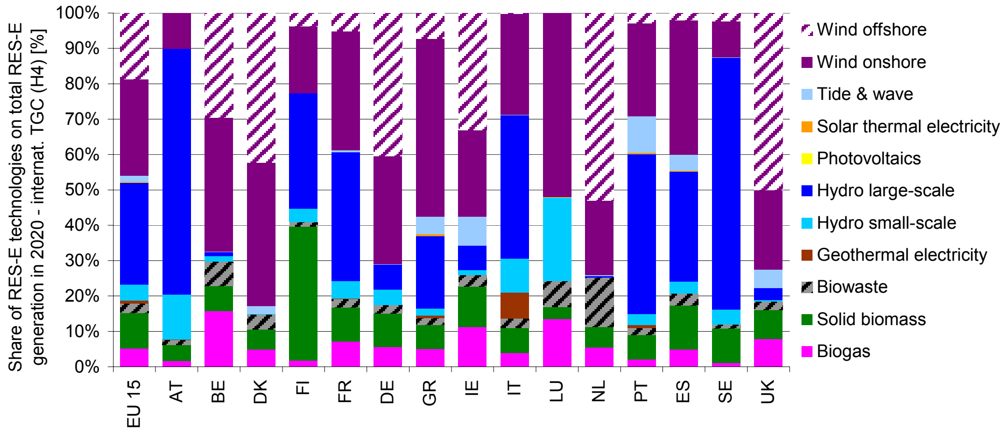



*Figure 6.11 Portfolio of RES-E technology on RES-E generation in 2020 among the Member States in the 1000 TWh scenario (variant H3)*

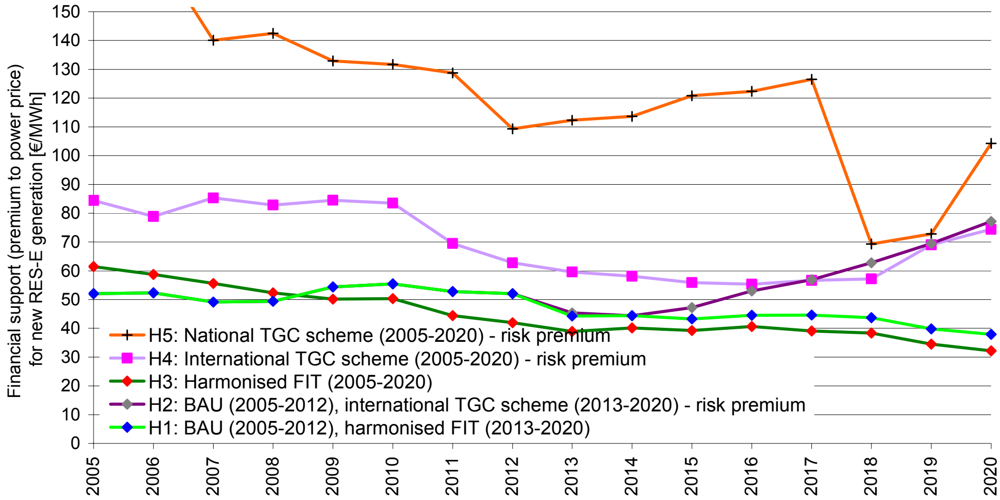



*Figure 6.12* *Comparison of financial support (average premium to power price) for new RES-E generation on EU 15 level in the period 2005-2020 for the cases (H1-H5)*

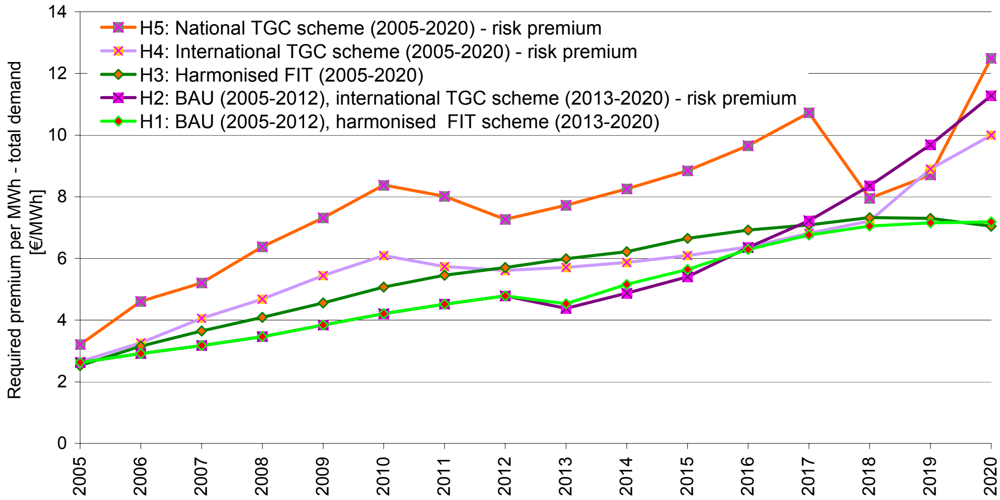



*Figure 6.13* *Comparison of necessary transfer costs for consumer reaching the 1000 TWh target in 2020 starting 2005 and 2013 with a harmonised approach (H1–H5)*

The portfolio reaching the 1000 TWh differs partly significantly compared to fulfilling the lower BAU target, i.e. 848 TWh by 2020. For example the share of wind onshore on the new RES-E generation 2005-2020 drops from around 45% to 36% as less additional potential is available contributing to a higher RES-E target. The share of wind offshore decreases too; but to a much lower extent. In contrast, electricity generation from (solid) biomass increases dramatically, from around 9% to 17%. With respect to the total RES-E production the portfolio is more homogenously distributed among the RES-E technologies, i.e. a higher spread of RES-E technologies is necessary fulfilling the ambitious target. The country specific portfolio (for the case of international trade) is depicted in Figure 6.11. The highest additional RES-E generation compared to reaching the BAU target is coming from in Germany, France, Spain, Italy, Sweden, Finland, Denmark und Ireland.

Investment needs can be estimated with around 14.000 to 16.000 M€/a. Similar to the BAU cases, investments for biomass mainly take place in the first decade. In the later phase investments needs increase for wind offshore, tide & wave as well as biogas.

Figure 6.12 shows the necessary financial support for all investigated 1000 TWh scenarios. Assuming a harmonised approach after 2012 (H1 and H2) a similar picture as for the BAU cases can be observed: namely that the necessary support in the case of a feed-in tariff scheme decreases and for a TGC scheme increases over time.[49] The effects of a harmonised strategy starting already in 2005 (H3 to H5) can be summarised as follows. Under this assumption different grant level are needed. In all cases – feed-in tariff, international and national TGC scheme – the support (slightly) drops over time. The amount, however, differs significantly. Costs in the case of a

[49] Despite using efficient mechanism, costs are higher for the 1000 TWh target in 2020 compared remaining the current strategies in place and reaching 848 TWh by 2020.

national TGC scheme are extreme high. The reason is that some countries are unable to reach their indicative RES-E in 2010. Hence, the national TGC price corresponds with their penalty price, which is assumed to be high (200 €/MWh).[50,51]

The yearly transfer costs for society for all investigated 1000 TWh cases are depicted in Figure 6.13. The effects with respect to the yearly transfer payments for the consumer / society correspond well with the development of the financial support curves per MWh of new RES-E generation. For the case that harmonisation should be taken place after a transition period of 7 years the following main effects can be observed: Yearly transfer costs are higher in the early phase applying a feed-in tariff scheme compared to an international TGC scheme as, firstly, the tariff is designed in a way that it drops over time and, secondly, a higher deployment occur in this (early) period.

Assuming a full harmonisation in 2005 the following conclusion can be drawn: Transfer costs within a TGC scheme are (much) higher if the target (quota) is very ambitious (high interim target 2010 target) and with advanced RES-E deployment, i.e. from 2018 onward.[52]

With respect to the total costs for society – see Figure 6.14 - it can be clearly conclude that technology specific support mechanisms are preferable compared to schemes, which do not consider a technology specific support to fulfil an ambitious RES-E target in the future. In all investigated cases the necessary average financial support is lower applying a well designed technology specific feed-in tariff system compared to a non technology specific TGC scheme or TGC scheme which allows an additional promotion of less mature technologies.

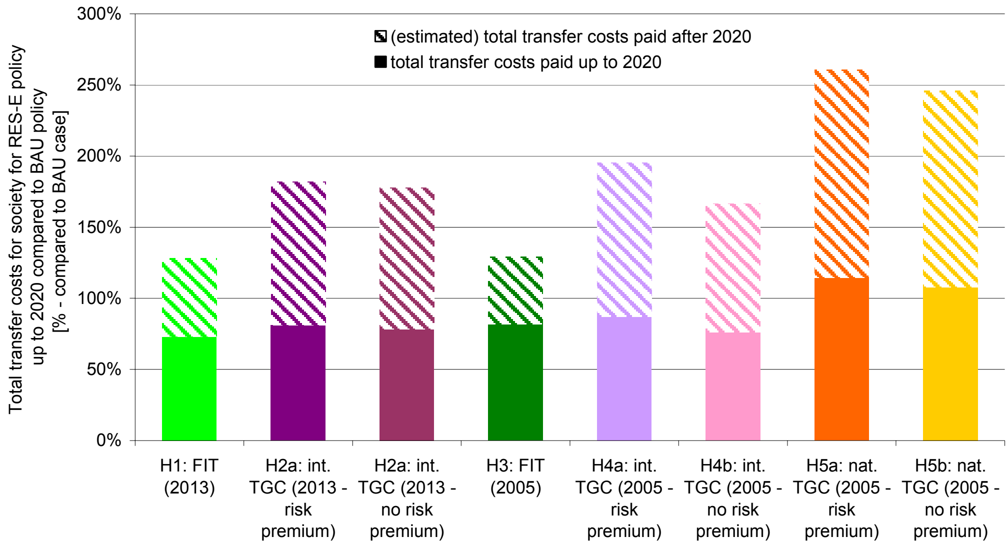



*Figure 6.14 Comparison of total transfer costs for consumer due to RES-E policy up to 2020 reaching the 1000 TWh target in 2020 (H1–H5).*

*Note: In the case of a TGC scheme total transfer costs paid after 2020 are estimated assuming that the TGC price in the year 2020 is constant up to the phase out of the support*

[50] Assuming a low penalty the incentive to fulfil the RES-E quota is low. Under this assumption investments will be postponed, i.e. higher costs occur later.

[51] To investigate the effect of reaching a high interim target (RES-E target 2010), model runs has been carried out assuming that this target must not be reached. It can be observed that in both cases – feed-in tariff and international TGC scheme - the necessary support is lower in the first years, however with a more moderate reduction over time.

[52] Note: Due to the high support level also less mature technologies will be stimulated. Therefore, in the later phase (after 2020) TGC price may be drop again.

## 6.6 Effects of RES-E deployment on conventional power price and $CO_2$ emissions

Finally, the effects of RES-E deployment should be analysed in brief. Figure 6.15 gives an impression of the impact of RES-E deployment on the wholesale electricity price. A price reduction of 5% (BAU target) to 10% (1000 TWh target) can be observed compared to the case of no additional promotion of RES-E in the future.[53]

This means that – neglecting possible back-up costs for RES-E – deployment of RES-E leads to a price reduction on the power market of 5% to 10%. [54] Total additional costs (burden) due to the promotion of RES-E by considering the additional transfer costs for consumer are in the magnitude of 3% (5%) for a feed-in tariff schemes and reaching the BAU target (1000 TWh target) up to 15% in 2020 in case of a TGC scheme for the 1000 TWh target.

Due to an additional price of 3% - 15%, however, $CO_2$-emissions from thermal power plants can be reduced by 20% to 25% - see Figure 6.16.

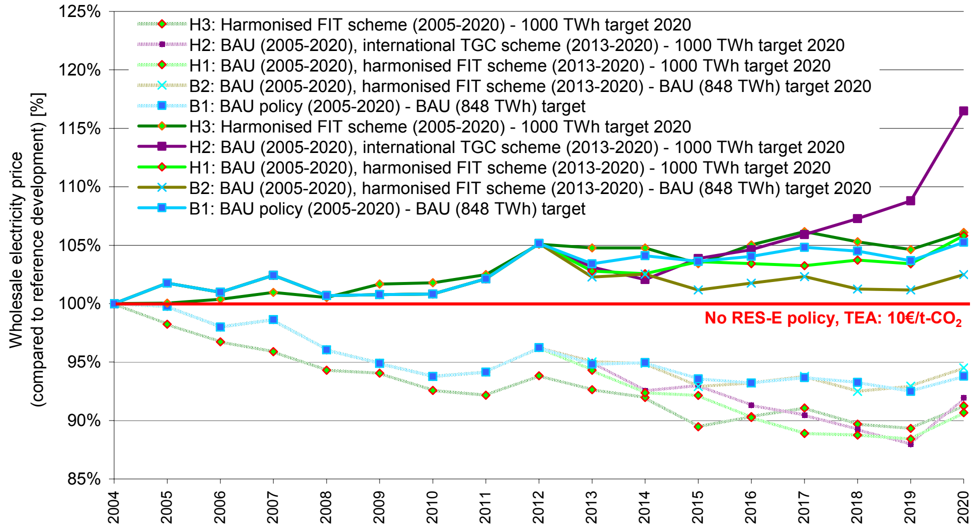



*Figure 6.15 Comparison of wholesale electricity price including RES-E premium compared to reference development (no RES-E policy and TEA price of 10€/t-$CO_2$)*

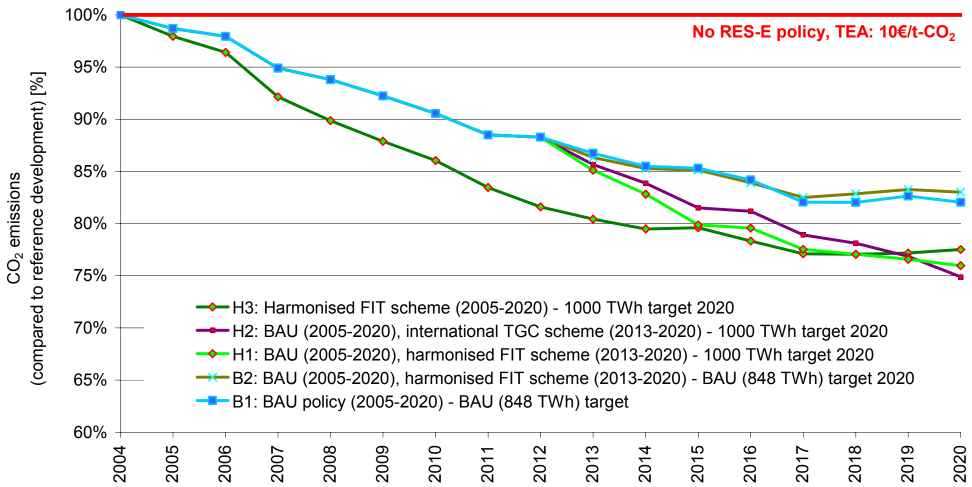



*Figure 6.16 Comparison of $CO_2$-emissions compared to reference development (no RES-E policy and TEA price of 10€/t-$CO_2$)*

[53] More precisely, it is assumption that (i) no RES-E policy exist in the future, and (iii), a market price for tradable emissions allowances of 10 €/t-$CO_2$,

[54] Or expressed the other way round: The backup costs for RES-E by implementing the same conventional power structure as without RES-E development would result in additional costs of 5% to 10% (2-4 €/MWh).

# 7 Recommended actions and final conclusions

## 7.1 Overcoming existing barriers

The future penetration of a RES-E technology depends on how it prevails over two categories of existing obstacles:

- Economic barriers – they are reflected by the net generation costs, i.e. inclusion of policy strategies.
- Non-economic barriers (mostly social, administrative, market and technical obstacles), – they restrict the available potential of electricity generation for the current year(s).

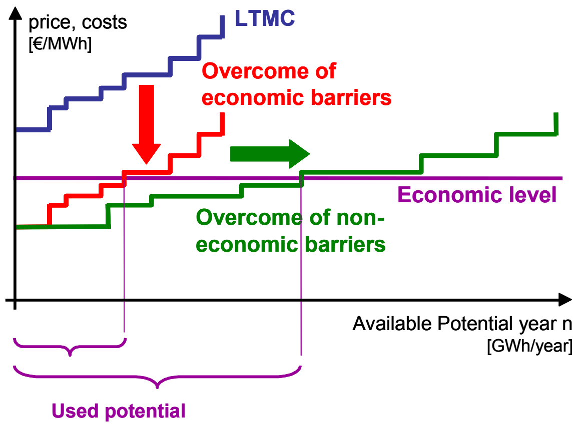



*Figure 7.1 Necessary conditions reaching a RES-E deployment*

Penetration of a technology will only take place if both categories of barriers can be overcome. So, on the one hand, it does not help to support a certain technology via a quota obligation, a guaranteed feed-in tariff or a tender scheme without preparing the framework conditions to overcome the other existing barriers, e.g. increasing the social acceptance using information campaigns, or decreasing administrative burdens for commissioning new plants, etc. In other words, low (net) generation costs but a low existing potential still results in less additional penetration.

On the other hand, providing a good environment at administrative, social, industrial and technical levels (i.e. admitting a huge potential) without economic incentives does not increase the future penetration rate of a certain technology. A high potential for electricity generation but high generation costs also results in a low market share.

### 7.1.1 Overcoming of economic barriers

- Independent of the type of instrument applied to support renewables, the careful design of the strategy is as important as the question which policy tool to implement, e.g.
  - Within any support mechanisms existing capacities and new capacities should be distinguished. Support should no longer be provided to plants that are fully depreciated or that were financially supported in the past;
  - The support mechanism of any instrument should be restricted to a certain time frame. The duration should depend on the policy scheme (e.g. development of the TGC price) and on the maximum annual additional costs that can be imposed on society. In addition, the support time should also depend on the evolution of the costs of the RES-E technology (i.e., progress along the learning curve).
- The RES-E support structure should also be directed towards supporting small-scale projects, as these small-scale projects - with a relatively short lead-time - could be an important part of the solution to the capacity shortage in electricity supply.
- The effectiveness of various RES-E support schemes largely depends on the credibility of the system. A stable planning with long term targets and guaranteed support is important to create a sound investment climate and to lower social costs as a result of a lower risk premium.
- Change of subsidy policy. The social and environmental costs of pollution are not internalised in current electricity prices of conventional power (within the TEA system $CO_2$ costs are partly internalised). If this kind of policy is changed, RES-E will be even more competitive

### 7.1.2 Overcoming non-economic barriers

Existing barriers for new RES-E generators should be removed rigorously and outstanding incentives should be provided:

► ***Policy / Social barriers:***

- Start / continue information campaigns
- Distortions resulting from unequal tax burdens and existing subsidies, and the failure to internalise all costs and benefits of conventional energy production and use, create high barriers to renewable energy.
- Integration and coordination of other policies like climate change, agricultural policy or DSM issues helps to reduce administration barriers
- Increasing the use of renewable energies should obviously be accompanied by end-use energy efficiency and demand side manage-

ment measures. Renewable energy development and increase of energy efficiency are strongly interdependent.[55]

► ***Technical barriers:***

- Reduce system operation costs: Some RES-E sources like wind energy or photovoltaics are often penalised due to the intermittency of their electricity generation. This means that additional costs are a direct burden on electricity generation in the form of additional system operation costs comprising system capacity and balancing costs.[56] Remedies to significantly mitigate system operation costs are: [57]
  - to improve forecast tools for wind energy
  - to re-design the market focusing on flexible loads on the demand side
- Correctly allocate grid extension costs: An upgrade or extension of the grid will be necessary in the future due to both new generation capacity and increasing demand, leading to additional costs for the system:
  - Full unbundling: Within a liberalised market full unbundling between generation, transmission / distribution and customer supply should take place. This means that grid upgrade / extension requirements, measures and corresponding costs have to be allocated to the regulated 'natural monopoly', the grid operator[58];
  - Imposing the true costs for transmission and distribution from generation to consumption (zonal price): The correct price signal, reflecting actual transmission and distribution costs will lead to an increase or decrease of the total generation costs. Transmission costs are lower for generators who are located closer to large consumers or who feed their electricity into the grid at a lower power level. Therefore, some RES-E technologies (e.g. photovoltaics) would profit from a zonal pricing approach. Other technologies like e.g. wind, however, would be suffered from such a price model. [59]

► ***Administration barriers:***

Due to long and complex permission procedures a long lead time in RES-E generation occurs, increasing the pressure and the costs to achieve agreed RES-E targets and / or may reduce the ambitiousness of RES-E targets in the future.

► ***Market barriers:***

In many countries a lot of market barriers exist, which have to be overcome:

- Electricity utilities maintain monopoly rights to produce, transmit and distribute electricity. High costs or the absence of standards for connection and transmission discourage renewable energy projects;
- Lack of information about available RES-E generation and about the current state of RE technologies, or negative past experiences with old technologies, and a lack of understanding about the benefits associated with renewable energy all act as barriers to their use;
- To a certain extent manufacturing structures are insufficiently developed, unable to use economies of scale in production. Due to the formation of technology clusters efficiency improvements can be excepted;
- Lack of access to affordable credit exists due firstly to the information asymmetry of financial institutions with respect to RES-E technologies and, secondly, higher risk due to the uncertainty of promotion schemes in many countries;

► ***Research and development:***

Research, technological development and innovation will remain major drivers for RES-E deployment in the coming decades. Even technologies close to maturity like wind energy will see further improvements and completely new concepts enter the markets. Aspects related to the systems technology for RES-E integration into existing energy infrastructures will receive more emphasis. Clear and comprehensive R&D activities help to reach this goal. The generation of new skills in new potential RE industries is necessary.

[55] The European Union has always stressed the pressing need to renew commitment both at Community and Member State level to promote energy efficiency more actively. In the light of the Kyoto agreement to reduce $CO_2$ emissions, improved energy efficiency together with increased use of renewables will play a key role in meeting the EU Kyoto target economically. In addition to a significant positive environmental impact, improved energy efficiency will lead to a more sustainable development and enhanced security of supply, as well as to many other benefits.

[56] According to Auer (2004) additional system operation costs are composed of 1/3 additional balancing costs and 2/3 additional capacity costs. For a wind penetration (share of installed wind capacity to peak load) of less than 10% system operation costs are estimated at 2-4 €/MWh and for a share greater than 10% at 5-6 €/MWh.

[57] Note that in general fluctuations and forecast errors of both supply and demand exist, i.e. supply and demand do not correlate

[58] In the case of centralised conventional power, the grid extension costs have, in the past, not been directly imposed on generation costs.

[59] Everywhere in EU, wind is suffering from weak grid connections. The government can enhance the use of offshore wind significantly if grid connections are provided in time (e.g. for UK, Netherlands)

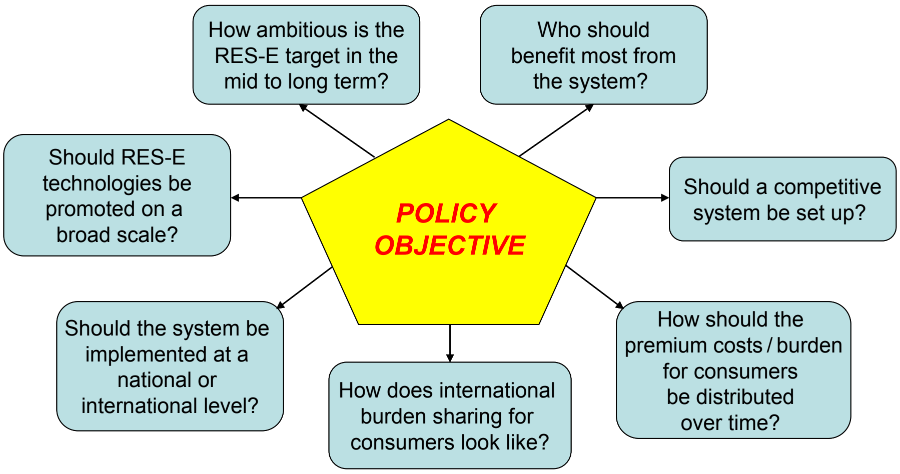



*Figure 7.2 Possible policy objectives in choosing the appropriate support scheme*

## 7.2 Which instrument fits best?

To answer the question which instrument fits best, it is necessary to identify the core policy objective behind the support of RES-E technologies. At a minimum, the following aspects should be considered in selecting the appropriate support mechanism, see Figure 7.2.

### 7.2.1 Should only some RES-E technologies be promoted or is it important to give all technologies a chance for development?

A technology specific support scheme has advantages and disadvantages. On the one hand, it may lead to a higher deployment rate as currently less mature technologies get a stimulus now and are available to a larger extent in the future. In addition, a diversification may reduce the costs for consumer compared with uniform non technology specific support, especially if the RES-E deployment is supposed to be ambitious. On the other hand, higher administration costs may occur. Furthermore, total system generation costs are higher - at least in the early phase.[60]

To optimise the level of technology diversification, it is necessary to counteract all negative effects (higher administration costs, reduced competition) with occurring benefits (lower costs for consumers, higher possible RES-E targets).

The ability to split the support depends on the policy instrument, i.e. the ability to provide technology specific support depends on the kind of RES-E instrument:

- ***Feed-in tariff scheme***

  A differentiation can be implemented most easily within a feed-in tariff scheme. Fewer problems occur applying such a scheme;

- ***Tender procedure***

  A technology split within tender scheme is feasible. Of course it is important to bear in mind that, on the one hand, too little diversification facilitates strategic bidding, and, on the other hand, too large split jeopardises competition due to the development of an oligopoly structure;

- ***Quota obligation***

  Implementing technology specific quotas is more critical, as too much diversification (significantly) reduces the advantage of a trading scheme. The setting of technology specific (linear) interim targets is difficult, especially if market size is low. The reason is that the available potential depends on technological diffusion in the past and varies dynamically over time. On international level (big markets) a certain technology is available on different degrees of maturity in the single countries. Hence, the yearly available potential is more stable than in a small market over time; while the potential drops in countries where most of the available potential is already used, a higher share is available in countries with a lower exploited potential.

  One alternative to creating different markets (sub-targets), at least at the national level, is to combine a quota obligation with investment subsidies, tax relief or tender scheme based on investment subsidies. These options avoid the issue that the available potential for each sub-quota (target) must be known and that large number of sub-markets jeopardises the liquidity and the transparency of the market. However, problems with respect to such an alternative approach occur when implementing the TGC system at the international level. As the TGC price is set at the international level, but the additional

[60] The generation costs in the later phase can be both, lower or higher, depending on the technological diffusion and available potential of the currently less mature but supported RES-E technologies.

support at the national level, strategic policy reactions are feasible: Countries providing less additional support gain from the (cheap) international TGC price without contributing to it to an adequate extent, i.e. without financing the system via national support.

On the one hand, if costs for currently most cost efficient technologies should be brought down (to competitive market prices) a TGC system is optimal. Of course, such a strategy can be problematic for RES-E development in the future as there is insufficient stimulus for the development of currently less mature technologies. On the other hand, if it is an objective to reduce generation costs of currently less mature technologies – in general, the cost reduction potential is huge due to high progress in technological learning – a technology specific support scheme fits well. Such a scheme can be easily implemented by a feed-in tariff or (to a certain extent) a tender scheme, leading to a more harmonised RES-E deployment in the mid- to long-term.

### 7.2.2 How ambitious is the RES-E target in the mid-to long-term? How fast should the growth of RES-E deployment be?

An ambitious RES-E deployment can only be reached by a simultaneous promotion of different RES-E technologies. This proposition is explained in Figure 7.3. It is assumed that two technologies A and B exist and that the marginal generation costs for technology A are lower than for technology B. Further assume – as can be observed in reality and implemented in the model ***Green-X*** – that the development of a technology follows a typical S-curve.

In the case that both technologies are simultaneously promoted, the diffusion process starts at the same time. The total RES-E deployment from technologies A+B increases as technology A and technology B are developed, i.e. a simultaneous support leads to high deployment, see the upper graph in Figure 7.3.

Under the assumption that the promotion of RES-E technologies takes place according to their respective economic generation costs a quite different situation occurs. In the illustrative example technology A is promoted first, i.e. a deployment of technology A but no development of technology B takes place in the early phase. Over time, if most of the (cheap) potential for technology A is used technology B is applied too. Hence, the total deployment of technology A+B requires a longer time period than under a simultaneous stimulus, see lower graph in Figure 7.3.

As long as the required RES-E target is less ambitious – more precisely, lower than the blue sum curve of technology A+B on the lower graph in Figure 7.3 – the sequence of the RES-E promotion does not influence RES-E deployment. In the case of a more ambitious RES-E target, a simultaneous stimulus is necessary.

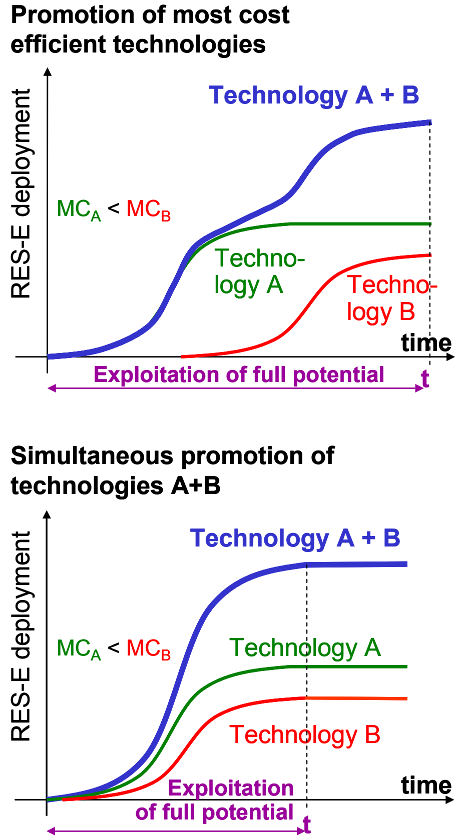



*Figure 7.3 Effect of a simultaneous promotion of RES-E technologies versus a serial promotion (according to the cost efficiency) with respect to total RES-E deployment*

### 7.2.3 Who should benefit from the system – RES-E industry, consumer, producer, etc?

One of the highest barriers in finding a joint agreement is that the benefit for different (interest) groups depends on the support mechanism as well as on its design.

- For RES-E manufacturers the continuity of the RES-E policy is most important. This means, the design of the instrument – guaranteeing a continuous demand for RES-E technologies – is more important than the kind of policy instrument. Of course, manufacturers of less mature RES-E options gain from the promotion of less cost efficient technologies which can be implemented most efficiently via a technology specific feed-in tariff (FIT) scheme or a tender system;[61]

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[61] This does not necessarily lead to the conclusion that manufacturers of currently cost efficient technologies prefer strategies that

- Investors in cheap RES-E generation options prefer a TGC system as windfall profits are higher under a scheme of uniform incentives for all technologies;
- The benefits for investors in more costly generation options (but still low enough to participate in the system) depend on investor preferences. If they are more risk-loving they prefer a TGC system and under the assumption that they are risk averse they prefer a FIT scheme (provided that the tariff is guaranteed for a longer period) guaranteeing a minimum rent;
- Consumers benefit most if their transfer costs for the promotion of RES-E are low[62]. In most cases and considered over a certain time frame, a feed-in tariff scheme[63] or tender procedure fulfils these requirements better than a uniform TGC system without any additional support. Of course, if additional support mechanisms like investment subsidies - both via fixed prices or tender procedures – or tax relief assist a TGC scheme transfer costs for consumer can also be reduced;
- Where the core objective is to minimise generation costs, a TGC system implemented at an international level is most appropriate, at least in the early phase of RES-E deployment. Note, in contrast to general economic theory, in the long term higher generation costs can occur if only the most cost efficient technologies are promoted. The reason is that the potential of less mature technologies, which must be used in the future if the long-term target is to be reached, is not available in the necessary magnitude. Hence, also (more) expensive technology options must be used simultaneously[64].

### 7.2.4 Should a competitive system be set up?

It must initially be clarified *where* competition should take place

► ***Should competition be fostered among manufacturers?***

Competition among manufacturers is mainly independent of the support mechanism. A competitive market can be achieved by overcoming existing market barriers, improving transparency and, most importantly, offering long-term development perspectives for the RES-E technology. The quality of the RES-E technology is influenced by the support scheme. When applying a TGC system or a tender scheme, manufacturers are encouraged to produce most cost efficient components. In contrast, a feed-in tariff scheme - under the assumption that the tariff is guaranteed long enough - facilitates the implementation of high quality components, as the objective of the investor is not only the minimisation of generation costs, but, rather, the maximisation of revenues gained from the tariff over the entire period.

► ***Should competition be enforced between generators?***

Competition depends on market volume, the number of competitors (national / international), transparency, etc. In general, a TGC system, a tender scheme or a combination of both are adequate instruments to achieve competition among investors.

### 7.2.5 How should the premium costs (burden) for consumers be distributed over time?

In general, at least as long as RES-E technologies are not competitive to conventional power and the amount of RES-E increases, the transfer costs for consumers rise over time for almost all RES-E support mechanisms[65], maybe not per MWh, but in total as RES-E capacity increase.[66]

If a simultaneous support scheme for different technologies is applied, e.g. via a feed-in tariff, costs are (relatively) higher in the early phase of the system compared to strategies that only support the currently most cost efficient technologies, e.g. a TGC scheme. The reason is that higher costs for promoting more expensive generation options already occur in the initial phase.

promote only cost efficient technologies. The reason is that under such conditions the danger of overheated markets exists.

[62] Note that consumers (voters) are the driving force behind politics and, hence, low public acceptance can overturn long-term RES-E policies.

[63] A necessary precondition for an efficient feed-in scheme is that the tariffs are technology specific. In addition, costs for consumers can be reduced further if (i) tariffs decreases over time and (ii) a stepped design is applied.

[64] The difference with other markets is that the demand is exogenously (artificially) given by policy and not by the market itself.

[65] The only exception is the '*investment incentive'* instrument. Costs related to this mechanism are already high in the first years and can - but may not - decrease over time.

[66] Note: total costs for the consumer may not increase, since the RES-E displaces conventional electricity, which may leads to a reduction in power price.

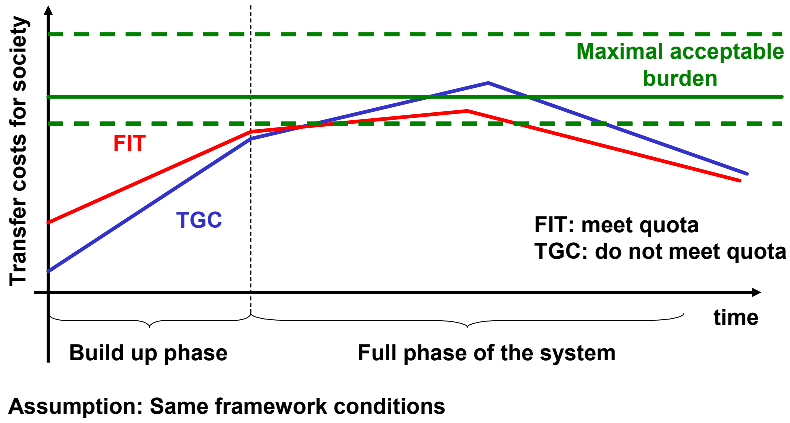


*Figure 7.4 Transfer costs for society applying an instrument with simultaneous support (feed-in tariff / FIT) and a mechanism promoting only the currently most cost efficient technologies (TGC scheme)*

In the mature phase costs can either (slightly) increase, be stable or (slightly) decrease. The net effect depends on the duration of the financial support, the RES-E target and technological learning rate. However, the cost increase is lower[67] if (i) a higher potential for the most cost efficient technologies is still available, (ii) the yearly available potential of medium cost efficient technologies is available in a higher magnitude[68] and (iii) generation costs of these technologies are lower due to technological learning.

If the burden increases significantly over time, there is the threat that the public acceptance decreases significantly. Consequently, the political pressure rise to change the instrument, leading to all negative consequences of a low long-term instability, not fulfilment of the initial targets etc.

The context is schematically illustrated in Figure 7.4 and Figure 6.13.

### 7.2.6 How does international burden sharing look like?

An accepted international burden sharing as well as a breakdown of this target an the Member State level are one of the crucial issues in finding a joint EU wide long-term (e.g. 2020) RES-E target.

A fair burden sharing among (the electricity consumers within) the different countries means that the additional costs due to RES-E generation is equal in terms of additional costs per total electricity consumed.[69]

In this respect it is also crucial how to assess the (distribution of the) additional benefits due to RES-E generation among the countries. Figure 7.5 illustrates the possible allocation in a fictive two country (country A and B) example. In the upper part it is assumed that all countries benefits from the RES-E production in the same way, i.e. as benefits are distributed equally, the costs should be borne equally too. The middle part of Figure 7.5 shows the situation assuming that all benefits of national RES-E generation remains in their own country, i.e. country B do not benefit from RES-E production in country A and vice versa. Under this assumption no compensation payments between country A and B are necessary. In reality the distribution between national and international benefits from RES-E deployment is between the two extreme cases – all countries benefit from RES-E generation in one country to the same extent and no benefits in another country occur. This situation is illustrated in the lower part of Figure 7.5. Considering national and international benefits, a trade-off between the countries should refer to the international relevant part only. Of course, to be able to assess national and international benefits a more detailed analysis including a macro-economic investigation is necessary. [70, 71]

[67] The cost reduction is higher if costs increase over time.

[68] In addition, due to the higher availability of the annual potential, it is not necessary to apply the most expensive generation options.

[69] This does not mean that all costs should be imposed directly and equally on the power price.

[70] National relevant benefits include e.g. rural and regional development, employment, local pollution, etc.

[71] International benefits refer to reduction of $CO_2$ emissions due to international trade (high if power market is liberalised and interconnected), effects on power price, industrial development, etc.

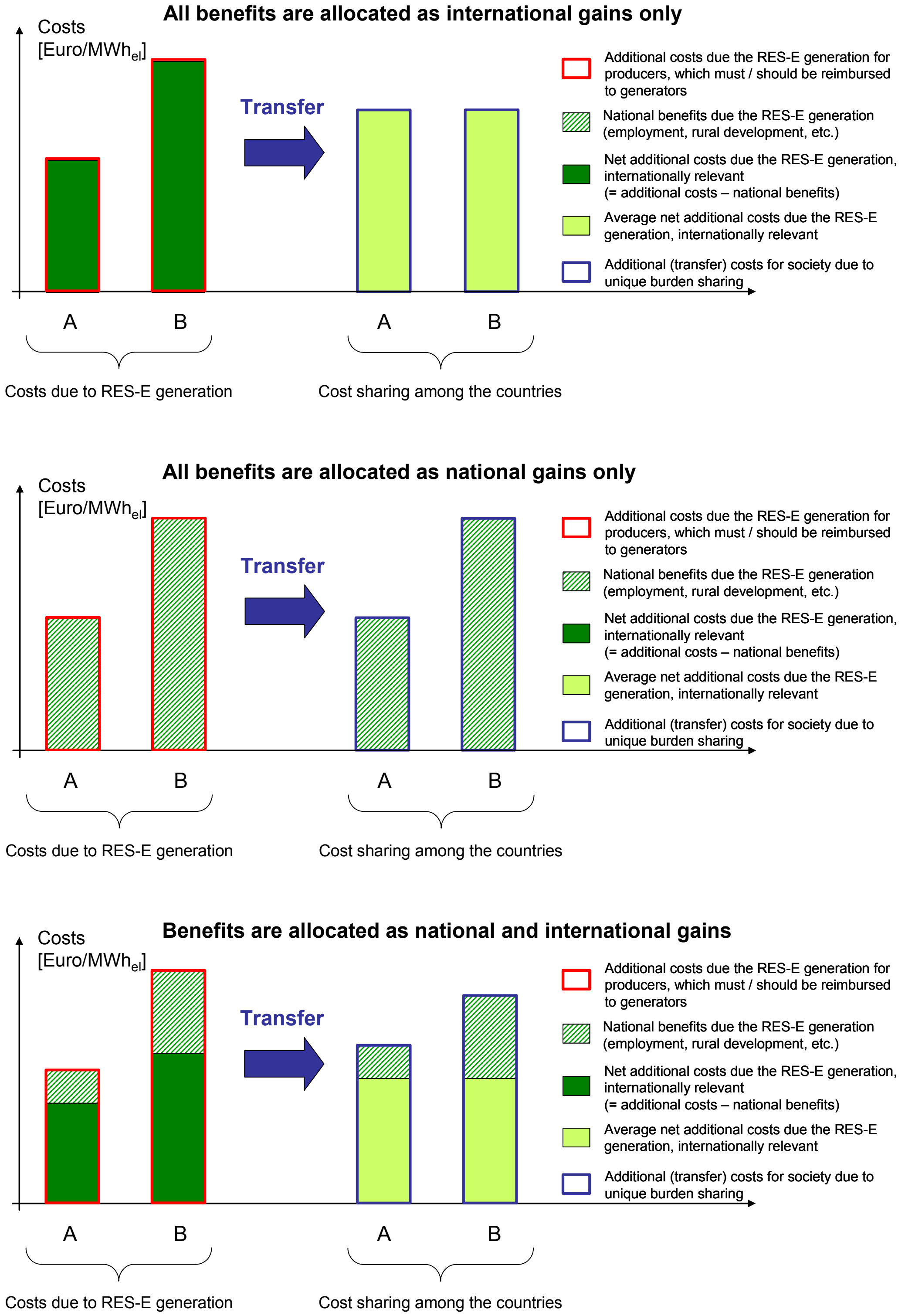


*Figure 7.5 Possible allocations of RES-E costs among the countries A and B*

How can such a burden sharing look like applying different support schemes? Generally, an international TGC system differs from the other support mechanisms with respect to burden sharing.

► ***International TGC system:***

The transfer costs for consumers depend on the agreed (national) RES-E target and not on the actual national RES-E production. While a high target leads to a high burden, a low target results in low additional costs for consumers.

A homogenous and 'fair' distribution of the RES-E costs among the (society within the) countries is possible if the targets are set in a way that the internationally relevant costs are set uniformly among the (consumers) in the countries. Differences in the share among the countries appears only due to the variation of the national benefits from RES-E production. The advantage of an international trading scheme is that no additional compensation payments among the countries are necessary, *if the allocation of the national target following such a procedure*. All distortions in the RES-E costs will be 'fully' compensated by trans-border trading of TGCs. In the case that all costs should be compensated internationally the national RES-E targets should be set uniform among the Member States, leading to the same direct transfer costs for consumers among the countries.

► ***All other support schemes***

In the case of a feed-in tariff scheme, a tender procedure or other price-driven support schemes like an investment incentive or tax relief the transfer costs for society depends on the actual RES-E generation within the country and the installed capacity respectively.

This means, higher transfer costs are imposed on consumers in countries with a (relatively) high RES-E potential compared with consumers in countries with a low (and cheap) RES-E potential. Hence, it is more difficult to reach harmonisation of the burden among the Member States. One remedy is to install a central (international) cost balance or fund system, collecting the internationally relevant costs / benefits and distributing them appropriately among the (generators) in the countries, see Figure 7.7. Hence, in contrast to an international TGC scheme additional administration effort is necessary reaching a 'fair' distribution of the costs for RES-E deployment. Transfer payments into the international fund decreases if the national benefits from RES-E rise. No compensation payments are necessary assuming that all benefits due to the promotion of RES-E remain within the country. Note, also within an international TGC scheme a comprehensive negotiation process is necessary reaching a 'fair' burden sharing agreement between the Member States.

Considering the different entity of an international TGC scheme and the other mechanisms a combination of international TGC scheme with other policies must be implemented carefully, otherwise distortions occur among the countries and the technologies, respectively. If investment incentives for less mature technologies were granted to increase their share and to reduce windfall profits for the most cost efficient technologies, transfer costs for consumers in those countries actually installing the capacity rise.

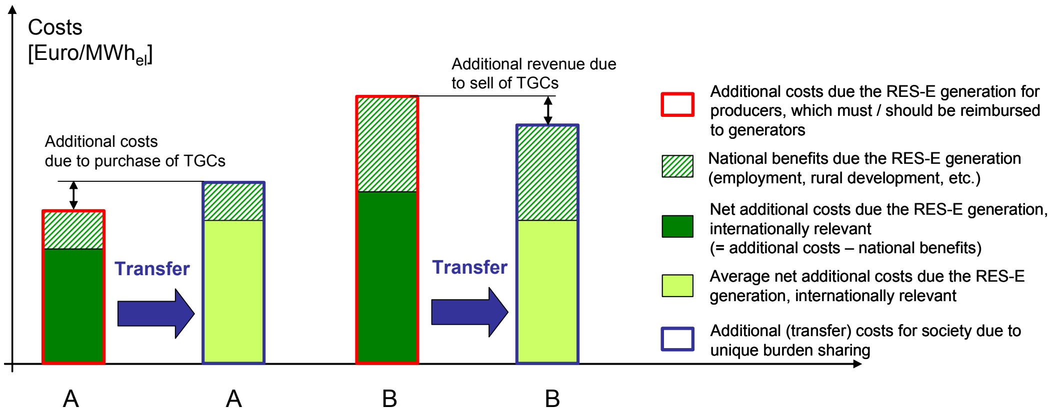


*Figure 7.6 Trade-off within an international trading scheme*

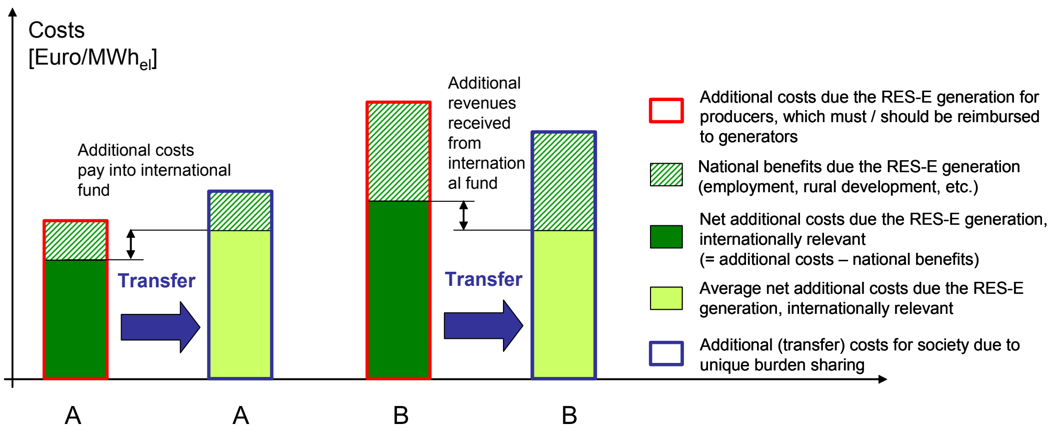


*Figure 7.7 Trade-off within a feed-in tariff scheme, a tender procedure, national TGC or other price driven schemes*

### 7.2.7 Should the system be implemented at the national or international level

In this context it is most important whether the power market is open or closed.

Assuming an international power market, no distortions occur when implementing either a national or an international scheme. In the case of a not fully open international power market, i.e. with restricted electricity exchange due to limited interconnections distortions occur in an international TGC scheme. RES-E deployment in countries with high respective power prices is favoured. The reason is that the total revenue from the purchase of the electricity from RES plants consists of the revenue from the (higher) power market price and the internationally (constant) TGC price, increasing the total price signal for investments (marginal generation costs).

In addition, the question depends on the national (indicative) RES-E target. On (a weighted) average, countries gain from the introduction of an international TGC system. However, some countries are worse off in an international compared to a national system. This fact should be considered in the negotiation process for implementing an international TGC system.

### 7.2.8 Summary

Table 7.1 summarises which instrument is most appropriate for reaching the corresponding political objective. Note the discussed effects refer to the most common design option of the instrument, i.e. by changing the design most effects can be changed too. It is assumed in more detail that:

- *Feed-in tariffs* are technology specific and decrease with technological progress
- *Quota obligations based on TGCs* are uniform, i.e. there are neither technology specific quotas nor additional support for less cost efficient RES-E options (e.g. tax relief or investment subsidies).
- *Tender schemes* are technology specific, but to maintain competition less specific than under a feed-in tariff system

It is worth mentioning that quite different effects occur applying different design options (e.g. implementing technology specific quotas within a TGC scheme or using no technology specific feed-in tariffs).

Also, the inherent characteristics of the different RES-E technologies should be taken into account, as well as national/regional peculiarities. In this context is worth mentioning that the different support mechanisms are highly influenced by the political stability of the schemes.

*Table 7.1 Optimal RES-E policy in dependency of the core issue*

| Policy issue | Feed-in tariff [A] | National TGC system [B] | International TGC system [B] | Tender procedure [C] |
|---|---|---|---|---|
| Ensure a broad RES-E technology portfolio | + + | - | - - | + + |
| Allow an ambitious RES-E target for a short period | + + | - - | - / + | + |
| Minimise generation system costs | - /+ | + / - | + / - | + |
| Minimise transfer costs for consumers | + + | - | - / + | + |
| Encourage competition among generators | - - | + | + + | + + |
| Leads to a homogeneous burden among consumers over time | + + | - - | + | + |
| Can contribute to a fair international burden sharing for consumers | - | - | + | - |

Note: The discussed effects refer to the most common design option of the instrument, i.e. by changing the design most effects can be changed too.

[A] Feed-in tariffs are technology specific and decreases with technological progress

[B] Quota obligations are uniform, i.e. there are neither technology specific quotas nor additional support for less cost efficient instruments (e.g. tax relief or investment subsidies)

[C] Tender schemes are technology specific, but to maintain competition less specific than under a feed-in tariff system

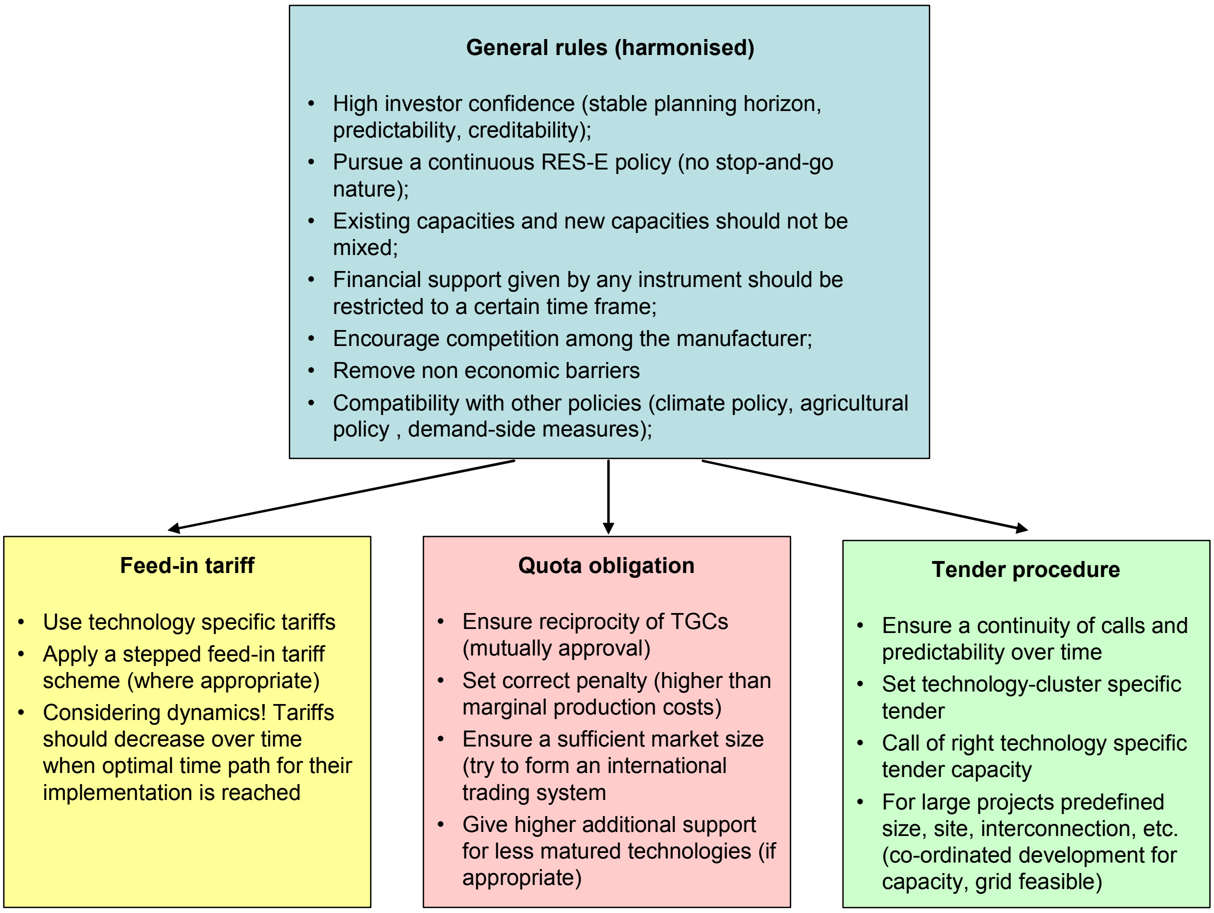


*Figure 7.8 Efficient design options for RES-E support instruments from the consumer's perspective*

For example, in the case of a feed-in tariff scheme problems may occur if the guaranteed tariffs are set inappropriate. This means if the amount of the tariff is more a result of bargaining process with interest groups than of an assessment of the necessary support to become economic for a certain technology. Also decisions which are based on short term gains instead of a stable long term strategy are critical. Similar to a feed in tariff, the allocation of the technology portfolio within a tender scheme or a national TGC system can be influenced significantly by various stakeholders and lobby groups negatively, leading to distortions and inefficient allocations among the different RES-E technologies.

Shifting the promotion of RES-E at the EU level means that the European Commission is responsible for the stability of the scheme and not 15 or 25 national governments. Hence, it is more difficult to change the framework conditions driven by policy pressure from different interest groups on national level. A good example in this context is the European emissions allowance trading scheme. Despite extensive discussions and disapproval from national interest groups the system is being implemented. However, it is necessary to design such a concept carefully.

## 7.3 What can a harmonised approach look like?

Based on both theoretical analysis and the results of the simulation results, it is useful to harmonise policy goals for new RES-E technologies at the EU level.

Agreeing on the same ambitious of RES-policy among the countries – this does not mean that each country must reach the same RES-E target, but rather applies the same effort to promote RES-E - significantly reduces the threat that single countries postpone their RES-E deployment for strategic reasons. This means that countries wait until generation costs decline due to technological learning, caused by the RES-E development in the other countries[72].

In principle, two options exist for reaching harmonisation:

► ***Full harmonisation***

If joint agreement is reached on which policy objectives (as discussed above) are most important and, hence, should be consequently realised, a full harmonised approach is preferable.

[72] Under this condition, the main costs are borne by the society in those countries investing in this technology first. Of course, this country has the first-mover advantage of developing its own RES-E industry.

► ***Sub-harmonisation***

Based on the traditions of different Member States it is likely that they will not find a joint agreement, which support scheme may be applied in the future exclusively to promote RES-E. If this is the case it is important that a harmonisation of the general framework conditions takes place. This means that the Member States establish clear rules of the framework conditions for the different promotion schemes if applied at the national level[73]. Common general rules can reduce distortions among the producer and consumer.

Figure 7.8 provides a suggested design of efficient instruments so as to minimise costs for consumers. For more details with respect to the design, we refer to chapter 5.

## 7.4 Summary and final remarks

The knowledge gained from carrying out the ***Green*-X** project can be summarised as follows:

- There is no clear favoured support mechanism, as each instrument has its pro and cons. Which instrument is to be preferable depends on the specific policy objective, see e.g. Table 7.1
- Considering dynamics is essential, as the impact of the instruments significantly varies from a static viewpoint. Of special importance is:
  - Technological diffusion due to changes of existing barriers over time
  - Decreasing generation costs and hence lower necessary financial incentives
  - Non-linear dynamic target /quota setting
- The design of an effective strategy is by far the most important success criteria. The effects on RES-E deployment, investor stability, conventional power generation and its emission and prices are similar if the design of the instrument is similar too. Of course, as the instrument differs, the effort, the efficiency and complexity of reaching a similar impact varies among the support schemes too;
- To ensure a significant RES-E deployment in the long-term, it is essential to build up a broad portfolio of different RES-E technologies.
  - To increase experience and confidence in new technologies. This issue is important to prepare the market for the case that these technologies can be used in the future.[74]
  - Demonstrating the viability of new technologies is important for achieving market maturity, as the overcoming of barriers depends on the confidence and experience gained from real projects. For example, banking institutions must be familiar and must trust in new technologies, and the risk assessment for new technologies will be reduced as the learning effect in the construction and administration occurs;
- The maximum RES-E deployment rate depends on the technological differentiation of the single RES-E technologies. Applying technology specific support schemes, the dynamics with respect to the total RES-E deployment can be significantly increased;
- Coordination and harmonisation of the support mechanism between the Member States leads to lower transfer costs for consumer;
- The development of a national RES-E industry requires a continuous RES-E policy;
- Implementing national policies in a different ambitious way among the countries is problematic within a liberalised power market. The benefits of ambitious policies only partly remain within the respective countries. Harmonisation of framework conditions and the associated burdens for consumer should be pursued;
- The future development of societal costs due to the promotion of RES-E is crucially influenced by the development of electricity prices on the conventional market. Thereby, a higher societal burden due to higher electricity prices will be compensated by lower societal costs related to the promotion of RES-E;
- The achievement of most policy targets for RES-E at acceptable societal costs is closely linked to the development of the electricity demand, too. Therefore, besides setting incentives on the supply-side for RES-E, accompanying demand-side measures would help to minimise the overall societal burden;
- Accompanying strategies to promote RES-E, such as a tradable emissions allowances system or an active DSM policy, are less efficient if they are introduced in an uncoordinated manner (on a national level) within an international power market, as the power price only reacts marginally on such policies compared to both an isolated electricity market and an internationally coordinated policy.

[73] Of course, interaction exists between different schemes: For example, a TGC system gains from the existence of a feed-in tariff scheme, as the costs of less efficient technologies decline due to technological learning, which in turn leads to lower transfer costs for consumers.

[74] Especially if the RES-E target increases significantly in the future.

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Green-X
Deriving optimal promotion strategies
for increasing the share of RES-E
in a dynamic European electricity market