Green-X

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

Final report

of the project ***Green*-X**
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0 Executive Summary

0.1 Motivation

Currently, the renewable energy market in Europe is relatively protected and non-harmonised among the individual Member States. In the future, due to the evolution of important EU energy-related policies, such as the EU-Directive on renewables in the electricity sector or the fulfilment of the Kyoto target in combination with the liberalisation of the electricity market, the structure of the European electricity market, in general, and the conditions for RES-E, in particular, will be fundamentally reshaped. Hence, it is necessary to find optimal strategies in order to generate a continuous and significant increase in the development of RES-E.

The core objective of this project is to facilitate a significantly increased RES-E generation in a liberalised electricity market with minimal costs to European citizen. To identify most important strategies the dynamic toolbox ***Green-X*** has been developed. Related objectives are:

- to find a set of efficient and sustainable dynamic instruments integrating strategies for RES-E, CHP generation, DSM activities and GHG-reduction;
- to address / include major stakeholders and decision makers in the development process of the toolbox ***Green-X***;
- to disseminate the toolbox and the results to key stakeholders and policy makers.

By disseminating the toolbox and the results of this project to policy makers and various stakeholders, acceptance of an EU-wide effective promotion system will be improved.

0.2 Survey of RES-E policy strategies

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 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[1].

What are the currently implemented promotion schemes for RES-E within the EU 15 Member States?

Almost all Member States 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.

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

Table 0.1 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[2]: 30.5-83.8 €/MWh; Hydro[3]: 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[4]. In more detail, FITs for new installations (2004) are: Hydro: 37-76.7 €/MWh; Wind[5]: 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)[6] 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[7]; penalty in size of 84.2 €/MWh (2004) but market distortions appear[8]. Investment subsidies for PV (Italian Roof Top program).			
Luxembourg	**FITs**	No	No	FITs[9] 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[10]: 43-83 €/MWh; Wave: 225 €/MWh; PV[11]:224-410 €/MWh, Small Hydro: 72 €/MWh		No
Spain	**FITs**	Depending on the plant size[12]	FITs (Royal Decree 2818/1998): RES-E producer have the right to opt for a fixed price or for a premium tariff[13]. Both are adjusted by the government according to the variation in the average electricity sale price. In more detail (only premium, valid for plant < 50 MW): Wind: 27 €/MWh; PV[14]: 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"[15]) 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

2 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.
3 Producers can choose between four different schemes. The figure shows the flat rate option. Within other schemes tariffs vary over time (peak/base etc.).
4 The law includes a dynamic reduction of the FITs (for some RES-E options): For biomass 1% per year, for PV 5% per year, for wind 2% per year.
5 Stepped FIT: In case of onshore wind 87 €/MWh for the first 5 years of operation and then between 55 and 87 €/MWh depending on the quality of site.
6 Depending on location (islands or mainland) and type of producer (independent power producers or utilities)
7 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).
8 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).
9 Only valid for plants up to 3 MW (except PV: limited to 50 kW).
10 Stepped FIT depending on the quality of the site.
11 Depending on the size: <5kW: 420 €/MWh or >5kW: 224 €/MWh.
12 Hydropower plant with a size between 10 and 50 MW receive a premium FIT of 6-29 €/MWh depending on the plant size.
13 In case of a premium tariff, RES-E generators earn in addition to the (compared to fixed rate lower) premium tariff the revenues from the selling of their electricity on the power market.
14 Depending on the plant size: <5kW: 360 €/MWh or >5kW: 180 €/MWh
15 Decreasing gradually down to zero in 2007

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;
- 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 0.1 (see previous page) provides a summary of most important RES-E policies as currently implemented in EU 15 Member States.

0.3 Method of approach

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 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.[16] This means that feed-in tariffs,

[16] 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 €/yr or related to the total electricity consumption. In the later case the premium costs refer to each MWh of electricity consumed.

subsidies or trading systems should be designed in a way that public transfer payments are also minimised. This implies lowering producer surplus[17].

In some cases both goals – minimise generation costs and producer surplus – may not be reached together so compromise solutions must be found.

0.4 The toolbox ***Green-X***

As already mentioned, to be able to identify most important strategies the dynamic toolbox ***Green-X*** has been developed. It is an independent interactive *dynamic* simulation model on the basis of the existing *static* computer model ElGreen, developed for the previous EU project ElGreen, and the theoretical framework developed in this project.

Figure 0.1 gives an overview of the core elements of the ***Green-X*** model. [18] 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 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.

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.[19] 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.

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[17] 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.

[18] 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.

[19] 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.

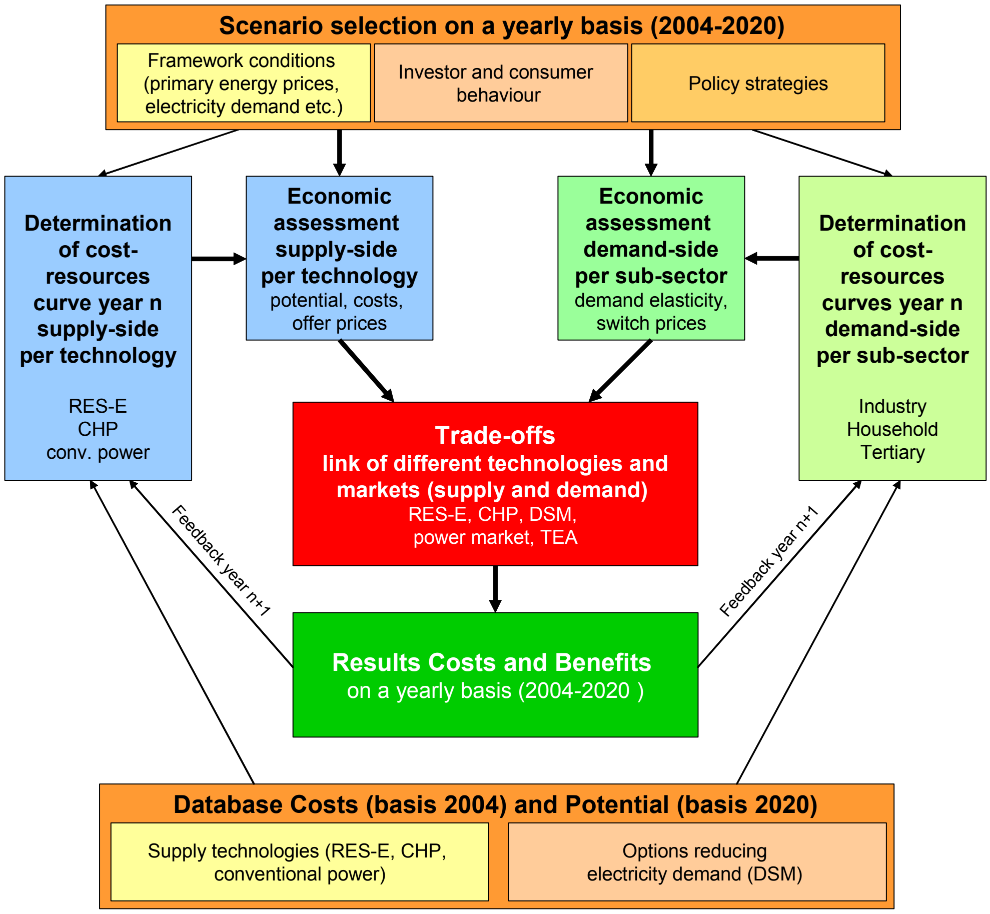

*Figure 0.1 Overview on the computer model **Green-X***

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.

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 [%]
  - 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 CO_2-strategy total [M€, €/MWh]
  – Total (transfer) costs due to the selected support schemes and policy options

0.5 Results from the simulation runs with the *Green-X* toolbox

0.5.1 Scenario definitions and assumptions

Various simulation runs have been carried out to analyse the effect of RES-E policy on RES-E deployment, portfolio and costs. Thereby, it has been tried to consider the spread of possible RES-E policy deployment within the EU. In more detail the following scenarios have been defined:

- No harmonisation, where currently implemented policies remains available (without any adaptation), i.e. **business as usual (BAU) forecast**
- After a transition period of 7 years (as indicated in the EU-Directive (EC/77/01), 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 have been investigated under harmonised conditions:
  – Feed-in tariff
  – International TGC system
  – National TGC system
- 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, a fictitious target for the year 2020 of **1000 TWh** was set for RES-E generation in EU15 countries – 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
    - International TGC system
  – 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.

0.5.2 General model assumptions are:

The model runs are based on the following general assumptions:

- Gross electricity consumption is based on the baseline forecasts published by DG TREN “European Energy and Transport Trends to 2030 Outlook”, Mantzos et. al 2003;
- Primary energy prices are based on WETO 2003 project “World Energy, Technology and Climate Policy Outlook” on behalf DG Research;
- Biomass prices and projections are based on an assessment conducted within the Green-X project and various among the Member States;

- The determination of the necessary rate of return is based on the weighted average cost of capital (WACC) methodology. Two options are considered in the analysis, namely 6.5% (default case) and 8.6% (higher risk case);
- For most technologies the future investment costs are based on endogenous technological learning. Learning rates are assumed at least for each decade separately referring to the global development of the considered technology. For the other (less mature) technologies standard cost forecasts are used (e.g. wave energy).

As the effectiveness and the efficiency of the support mechanisms hugely depend on the design, 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 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[20].

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; [21]
- Restriction of the duration in which investors can receive the (additional) financial support. [22]

For the policy instrument "quota obligation in combination with tradable green certificates" the following options are chosen:

- 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;[23]
- Additional support for less mature RES-E technologies does not exist;
- Constant yearly interim targets; [24]
- Penalties for not fulfilling the quota obligation are set to high amounts (up to 150 €/MWh).

For the policy instrument "feed-in tariff" the following design criteria have been used:

- 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. [25]

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[20] 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.

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

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

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

[24] 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).

0.5.3 Key results of the simulation runs

Total amount of RES-E generation within the EU 15 was around 449 TWh/a in 2004.[26] 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).[27] 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.

Figure 0.2 compares the dynamic development of RES-E generation for the BAU case (left-hand side) and the application of a harmonised feed-in tariff scheme starting already in 2005 for the 1000 TWh target (right-hand-side).

The highest electricity production from new RES-E plants will come from wind energy, both onshore and offshore up to 2020. Assuming that around 848 TWh/a will produced by RES-E technologies in 2020 (BAU target), it can be expected that approximately 45% (30%) of the new generation is coming from wind onshore (offshore), leading to a total share of around 30% wind onshore and 15% wind offshore. Other significant increases can be expected for solid biomass (plus 8%) and biogas (plus 6%). Due to less public support and acceptance, the amount of large scale hydro power will increase only marginally in absolute terms. In relative terms the share drops significantly from around 60% (2004) to 33% in 2020.

The portfolio reaching the 1000 TWh differs partly significantly compared to fulfilling the lower BAU target (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.

[25] 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

[26] 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.

[27] 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.

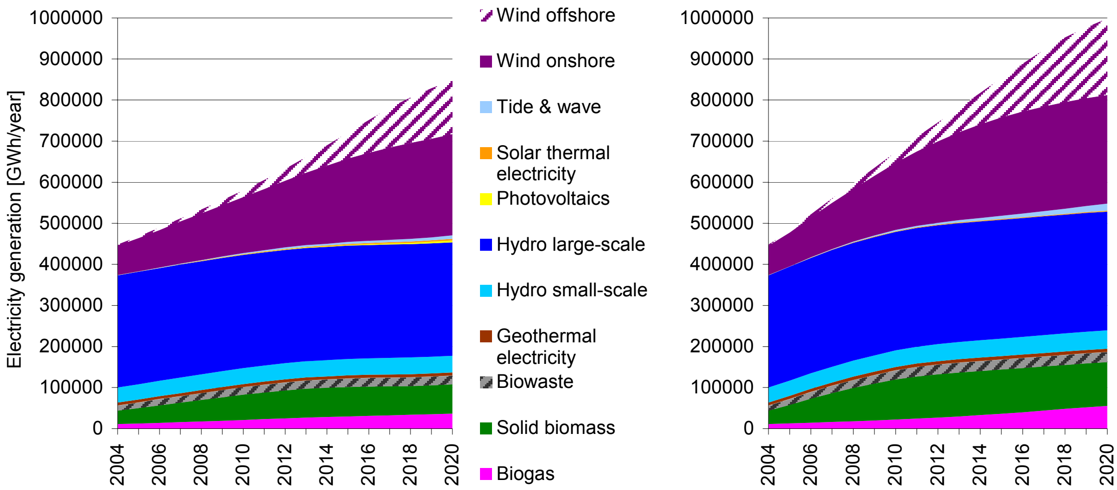

Figure 0.2 Development of RES-E generation 2004-2020 within EU 15 in the BAU scenario (left) and under a harmonised feed-in tariff scheme reaching a RES-E production of 1000 TWh in 2020 (right).

High investments are necessary to be able to build up the new capacity. Figure 0.3 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) stimulates technological learning, leading to lower generation costs in the future.

Assuming a RES-E target of 1000 TWh in 2020, 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.

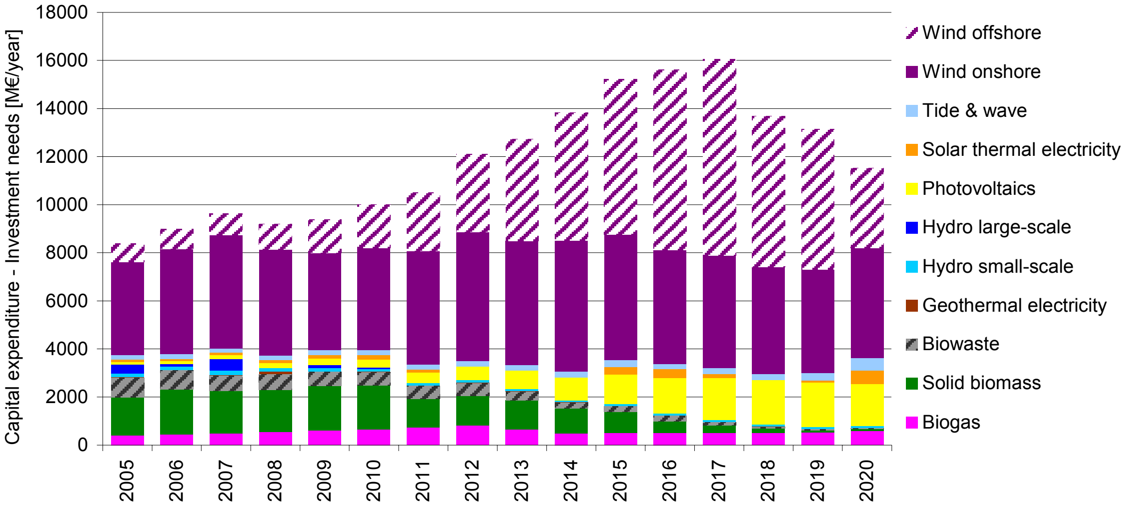

Figure 0.3 Total investment needs in the period 2005-2020 within the EU-15 in the BAU scenario (B1)

Most interesting for the evaluation of the efficiency of the different support mechanism is to compare the necessary financial public support. 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 0.4. 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.

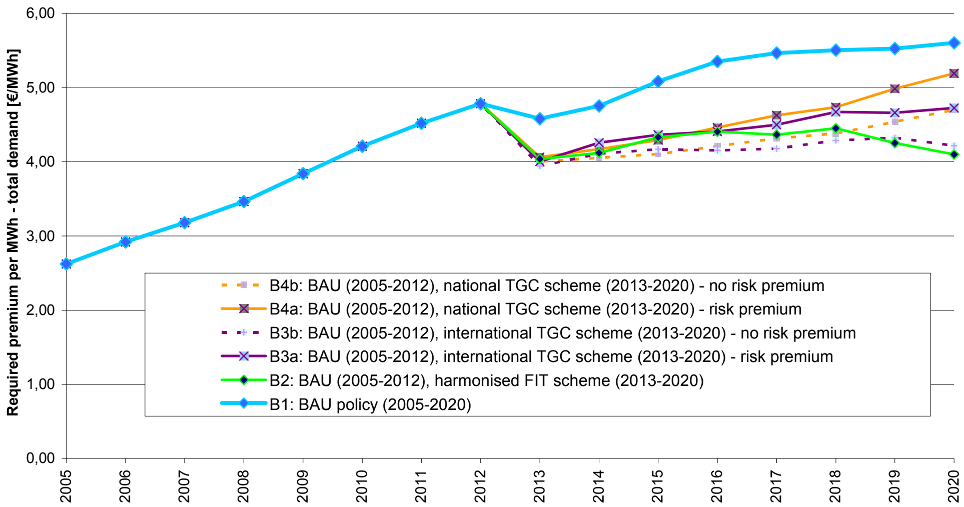

Figure 0.4 Comparison of necessary transfer costs for consumer reaching the BAU target 2020 (848 TWh in 2020)

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.

- 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.[28] 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 if it is assumed that existing capacity remains in their old promotion scheme, i.e. the new schemes are applied to new capacity only.

[28] 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).

The yearly transfer costs for society for all investigated 1000 TWh cases are depicted in Figure 0.5. 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 already 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 onwards.[29]

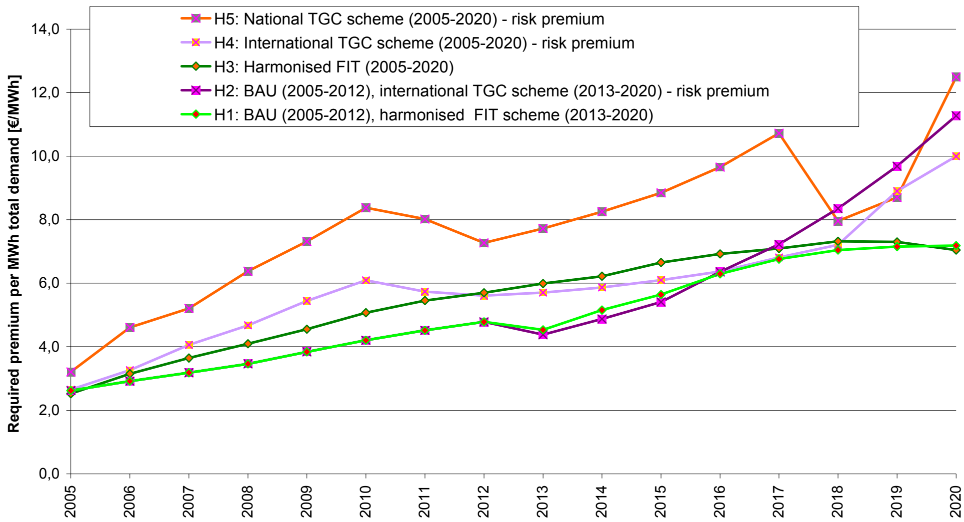

Figure 0.5 Comparison of necessary transfer costs for consumer reaching the 1000 TWh target in 2020 starting 2005 and 2013 with a harmonised approach (H1 – H6)

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[30]. 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 Figure 0.4 and Figure 0.5 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 is already paid up to 2020.[31]

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.

[29] 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.

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

[31] 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 0.4 and Figure 0.5, 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.

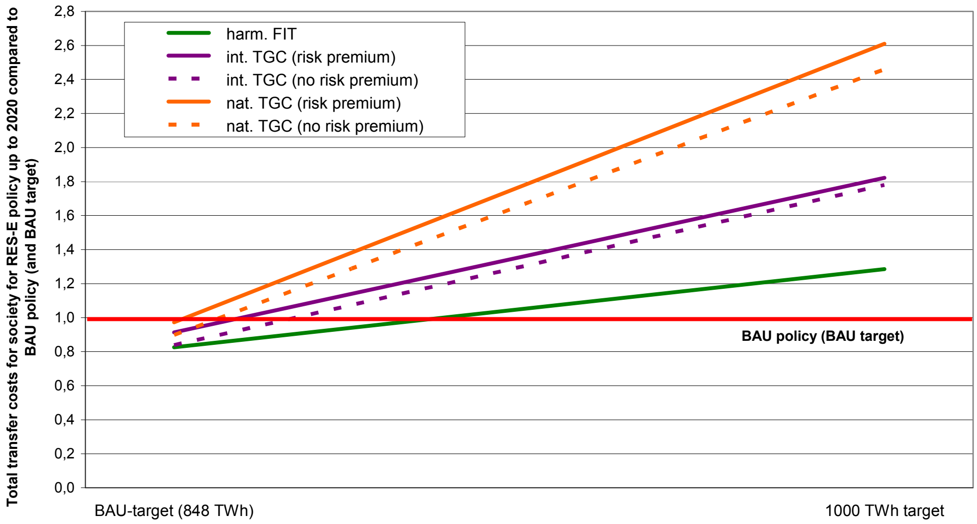

Figure 0.6 Comparison of total transfer costs for the consumer reaching a moderate target (BAU – left) and an ambitious target (1000 TWh – right).

Note: All transfer costs refer total costs for society retaining the BAU policy

A comparison of the full transfer costs for the consumer is given in Figure 0.6. In all investigated cases the application of a technology specific support scheme (in this case design as a technology specific feed-in tariff with a dynamically decreasing guaranteed amount according to the technological progress) leads to the lowest financial transfer costs for society. In the case of a moderate RES-target (BAU), differences are relative low. 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.

In the case of an ambitious RES-E deployment it can be clearly conclude that technology specific support mechanisms are preferable from the consumers point-of-view compared to schemes, which do not consider a technology specific support to fulfil the 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.

0.6 Conclusions and recommended actions

The following conclusions can be drawn from the project ***Green-X***.

- 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. inclusive 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).
- 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 Table 0.2.

Table 0.2 Optimal RES-E policy in dependency of the core issue[32]

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

- 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, etc. 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. [33]
  - 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;

[32] Note: 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).

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

- 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;
- The effects of different RES-E instruments on RES-E deployment, conventional power generation and its emission and prices, mainly depend on the design of the instruments, too. This means, if they are set in a similar way, the effects are similar too;
- 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 TEA 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.

Summing up, a coordination and harmonisation of the support between the Member States can be recommended. Figure 0.1 provides a suggested design of efficient instruments so as to minimise costs for consumers.

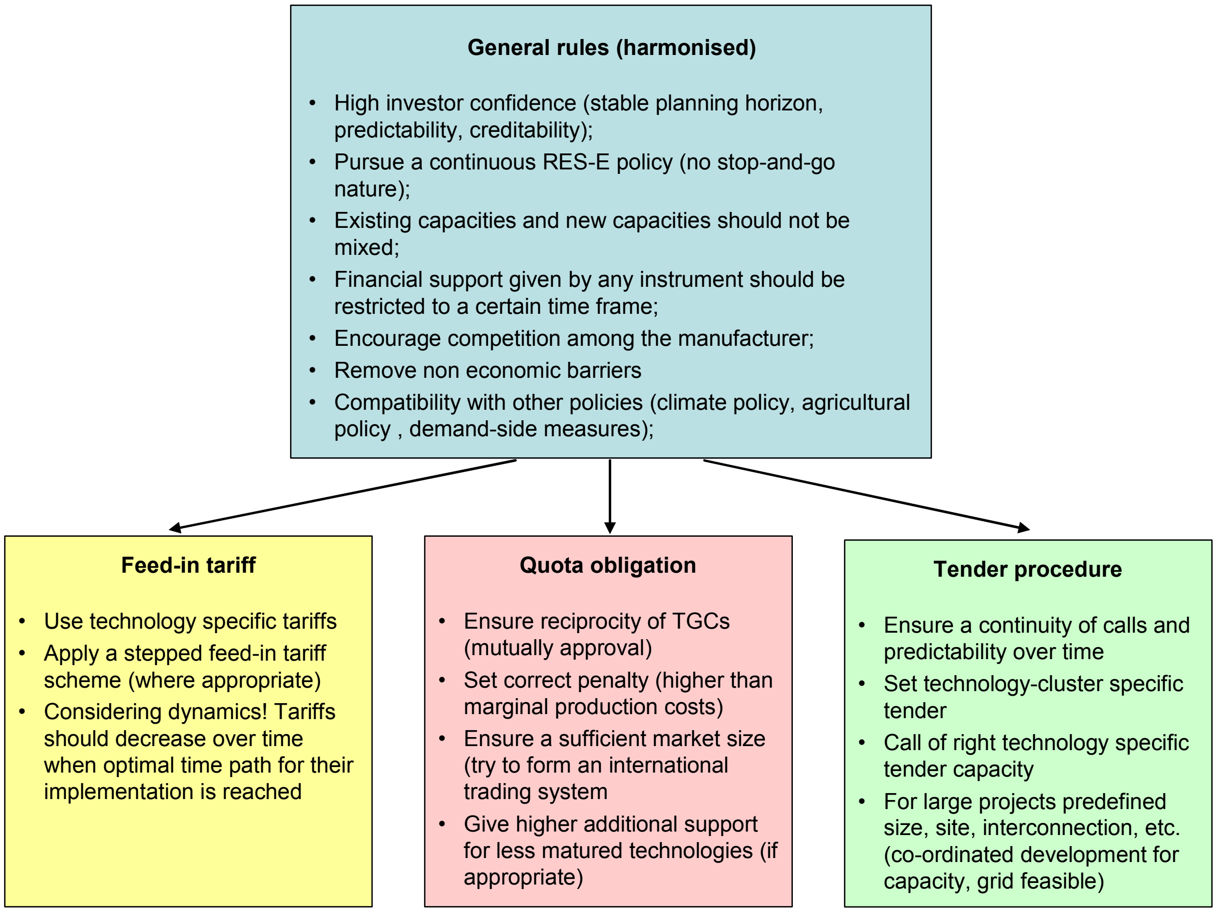

Figure 0.7 Efficient design options for RES-E support instruments from the consumer's perspective

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Figures

Tables

Boxes (i.e. illustrative example mainly based on simulation results)

1 Introduction

1.1 Motivation

Even though there is a common agreement within the EU to increase the share of electricity from renewable energy sources (RES-E), each country has decided to take a different approach to its implementation. Different support mechanisms have been and still are used in different Member States. In addition, new instruments such as tradable green certificates and emission allowance systems are being designed in order to work within the liberalised market.

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 (FIT)
- Tradable green certificates (TGC)
- Tendering systems
- Emissions trading schemes / tradable emission allowances (TEA)
- Demand side measures (DSM)
- Distributed combined heat and power (CHP) obligation
- Clean development mechanism (CDM) and joint implementation (JI)

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 different instruments might influence a number of issues, 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 many instruments that exist to support renewable energy technologies and they interact at multiple levels. 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.

1.2 Objective of this project

The overall objective of the Green-X project is to analyse the possibility for a continuous and significant increase in the development of RES-E with minimal costs to European citizens. In order to make these analyses, it is important to understand the different policy instruments available for supporting renewable sources, how these instruments interact, and what this implies for EU and national policies for implementing renewable energy technologies and for achieving GHG-reductions. The project has determined a cost efficient dynamic time-path for the deployment of renewables across the EU. To identify the most important strategies a dynamic computer model has been developed.

The general interactions of the different work-packages within the ***Green-X*** project are depicted in *Figure 1.1* and are described briefly below.

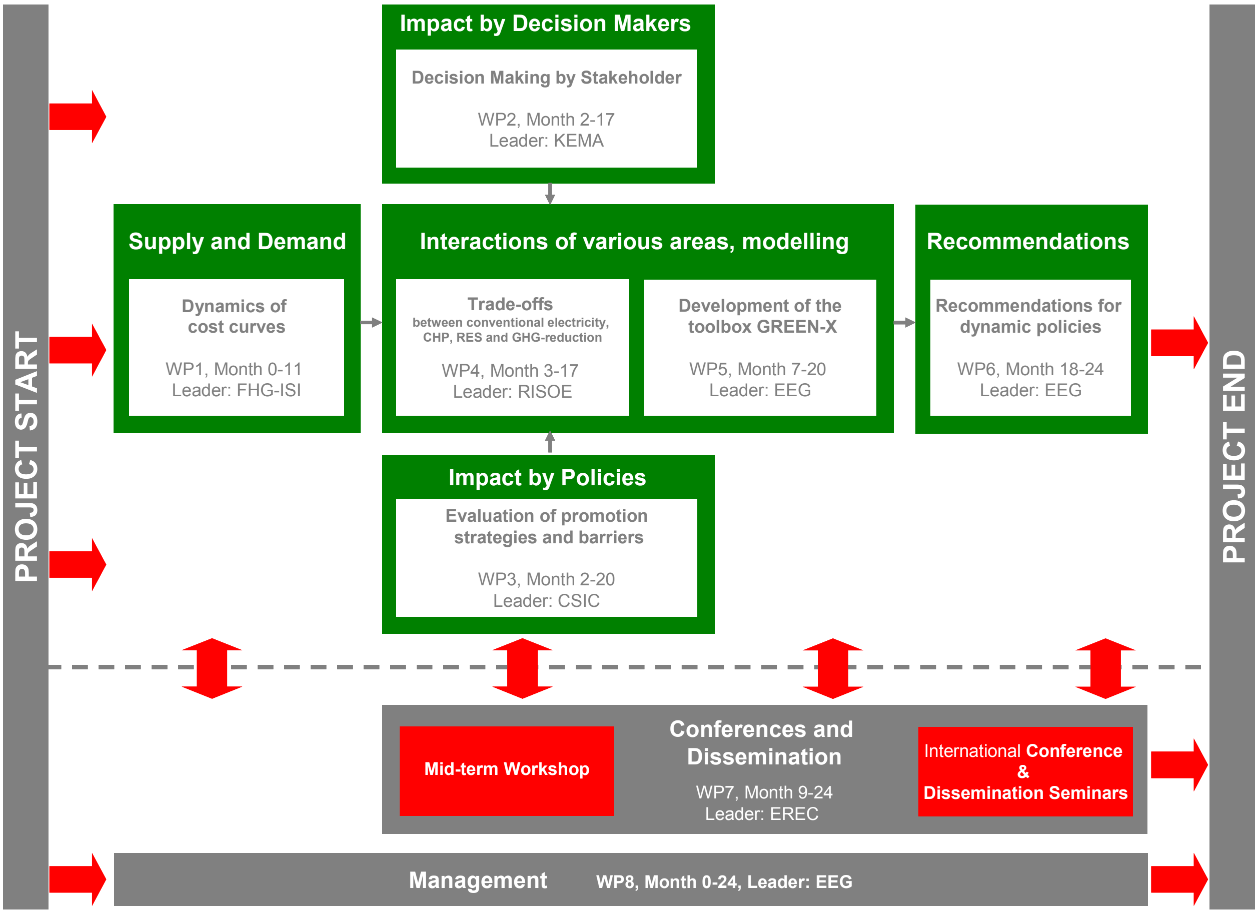

Figure 1.1 Work-packages and their Interactions within the project Green-X

WP 1 – Dynamics of cost curves: The aim of this package has been to analysis the dynamics of cost curves (= potential and costs) for the different RES-E technologies, for conventional electricity and CHP generation, and the most important demand-side activities for electricity applications in various EU countries. In addition, potential and costs for GHG reduction has been investigated for the electricity sector.

WP 2 - Impact of decision makers (Decision making by stakeholders): The major objective has been to understand the relationship between risks, required profits and project feasibility as seen and judged from the perspective of different stakeholders involved in the decision making process for new investments. These insights has been translated for the dynamic market model into rules and approaches which (i) promote the growth of renewable energy, (ii) provide stable market conditions and (ii) take into account the position of various stakeholders.

WP 3 - Impact of Policies (Evaluation of promotion strategies and barriers): The objective of this work package has been to identify and evaluate the appropriate policy instruments in place in EU Member States. These seek to (i) promote RES-E, (ii) support a more rational use of electricity (industry, household and tertiary sectors), (iii) regulate conventional electricity production, and (d) control GHG emissions (taxes, emissions trading).

WP 4 - Trade-offs: The objectives of this work package have been to analyse the various interactions of different types of policy instruments and market conditions, society restrictions, stakeholder behaviour in a dynamic way, as well as the linkages between RES-E, CHP, conventional electricity generation and GHG-reduction, and to evaluate how new environmental markets, such as CO_2 emission permits/credits, may affect or overlap with the promotion of CHP and/or RES-E. In addition, a theoretical framework for the ***Green*-X** toolbox has been derived.

WP 5 – Development of the *Green*-X toolbox: The toolbox has been developed, based on a formal framework, on the dynamic cost curves and on the determination of various promotion schemes gained in previous packages. The core element of this tool is the computer model aiming to maximise societal benefit for the EU. This allows a comparative, quantitative analysis of interactions between RES-E, conventional electricity and CHP generation, demand-side activities and GHG-reduction in the electricity sector, both within the EU as a whole and its Member States. The interactive *dynamic* simulation model has been created on the basis of the existing *static* computer model ElGreen, developed for a previous EU project. In addition, a comprehensive database for various cost curves and CO_2 reduction costs in the electricity sector (initiated in WP1) have been created and integrated within the new model.

WP 6 – Recommendations for dynamic policies: Results and recommendations have been derived based on various simulations using the ***Green*-X** computer model and insights gained from the formal assessment model and the evaluation of current promotion schemes. The objective of this phase has been to integrate and update the results from the previous work packages and to extract dynamic policy recommendations for a European-wide enhanced introduction of RES for electricity generation, more efficient use of electricity including linkage to conventional electricity and GHG reduction measures. The Action Plan aims to help policy makers find a set of efficient and sustainable policies to integrate RES-E with other EU related objectives, such as energy efficiency and climate change abatement over time, and to help various stakeholders derive an economically efficient portfolio strategy in a liberalised electricity market under the constraints of RES-E development and GHG reduction.

WP 7 – Conferences and Dissemination: The dissemination of the products, results and recommendations is of high importance to reach the core objective of this project, i.e. the achievement of a significant increase in the share of RES-E and a more rational generation and use of electricity.

WP 8 – Management: The objective of the management work package has been to organise the whole project to ensure timely inputs and to disseminate information widely, including via the project web-site.

1.3 Outline of this report

This report is divided into 7 chapters. After a short introduction, explaining the motivation, the objective and the work programme of this project, chapter 2 gives a survey on different types of promotion strategies and policy instruments historically and currently applied within EU member states.

The method of approach is explained in chapter 3. 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 4 evaluates the different policy schemes in a dynamic framework and describes the effects of the policies – promotion of renewable energy sources for electricity generation (RES-E), climate change (emissions trading), demand side activities (DSM) and support of combined heat and power production (CHP) – with respect to RES and conventional electricity deployment, greenhouse-gas-emissions (GHG), electricity demand, market prices, generation costs and the transfer costs imposed on society.

The trade offs of using RES-E policy instruments with the other policy schemes (climate change, DSM, CHP) are described in the chapter 5.

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 Survey of promotion strategies

The environment and energy contexts have traditionally been a major focus of attention of EU and Member State (MS) policy. This attention has intensified in recent years, as a response to both internal and external events and strategies (e.g. the Kyoto Protocol).

In this context, the EU and its MS have set ambitious goals in the environmental and energy policy realms. Although there might be conflicts between both policies, there are also interesting synergistic and reinforcing effects, which have significant policy implications. Actually, as stated in the Amsterdam Treaty, environmental protection is one of the major goals of energy policy (together with “security of supply” and “competitive energy systems”). The energy sector is instrumental in determining the success or failure of environmental policy.

The EU and its MS have a wide array of instruments at their disposal to achieve these goals. Particularly, Demand Side Management (DSM) activities, promotion of electricity from renewable energy sources (RES-E) and measures aimed at the mitigation of Greenhouse Gas (GHG) emissions are arguably three of the main instruments which have the potential to contribute to energy and environmental goals.

A brief overview of promotion strategies in these areas follows. Obviously, those instruments having the most direct influence on RES-E deployment are RES-E support schemes, and the use of these measures at both the EU and Member State levels is the main focus of the section below.

2.1 RES-E Policy

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 MS, 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[34]. 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 2.1:

- 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 mar-

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

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

Table 2.1 Classification of promotion strategies for RES-E

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

In the following section a short overview is given on currently implemented promotion strategies for RES-E in the EU-15 countries. Table 2.2 provides a brief overview on this topic – listing countries, promotion strategies and the technologies addressed.

Table 2.2 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 biodegrad-able 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[35]: 30.5-83.8 €/MWh; Hydro[36]: 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[37]. In more detail, FITs for new installations (2004) are: Hydro: 37-76.7 €/MWh; Wind[38]: 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)[39] 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[40]; penalty in size of 84.2 €/MWh (2004) but market distortions appear[41]. Investment subsidies for PV (Italian Roof Top program).			
Luxembourg	**FITs**	No	No	FITs[42] 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[43]: 43-83 €/MWh; Wave: 225 €/MWh; PV[44]:224-410 €/MWh, Small Hydro: 72 €/MWh		No
Spain	**FITs**	Depending on the plant size[45]	FITs (Royal Decree 2818/1998): RES-E producer have the right to opt for a fixed price or for a premium tariff[46]. 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[47]: 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"[48]) 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

35 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.
36 Producers can choose between four different schemes. The figure shows the flat rate option. Within other schemes tariffs vary over time (peak/base etc.).
37 The law includes a dynamic reduction of the FITs (for some RES-E options): For biomass 1% per year, for PV 5% per year, for wind 2% per year.
38 Stepped FIT: In case of onshore wind 87 €/MWh for the first 5 years of operation and then between 55 and 87 €/MWh depending on the quality of site.
39 Depending on location (islands or mainland) and type of producer (independent power producers or utilities)
40 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).
41 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).
42 Only valid for plants up to 3 MW (except PV: limited to 50 kW).
43 Stepped FIT depending on the quality of the site.
44 Depending on the size: <5kW: 420 €/MWh or >5kW: 224 €/MWh.
45 Hydropower plant with a size between 10 and 50 MW receive a premium FIT of 6-29 €/MWh depending on the plant size.
46 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.
47 Depending on the plant size: <5kW: 360 €/MWh or >5kW: 180 €/MWh
48 Decreasing gradually down to zero in 2007

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.

2.2 GHG policy

The EU has committed itself to reducing its GHG emissions by 8% from the 1990 base year level in the first commitment period 2008–2012 of the Kyoto Protocol, with differentiated commitments per Member State. The Kyoto Protocol (KP) was ratified by the EU and its Member States on 31 May 2002. Thereby, according to its Article 4, a single 'bubble' was formed for the EU in total – i.e. it allows EU countries to share their joint commitments differently from the common target. Accordingly, under the Burden Sharing Agreement (BSA), which became legally binding for the Member States with EU's ratification of the Kyoto Protocol, the 8% target was shared between the 15 Member States, allowing some countries to increase their emissions and obliging others to reduce.

Although the entering into force of the Kyoto Protocol is pending on Russian ratification, the EU has continued to take the lead in GHG mitigation and has approved a Directive establishing a European Emission Trading Scheme (EU ETS) (European Parliament and Council, 2003 – Directive 2003/87/EC). The EU ETS covers carbon dioxide emissions from large stationary sources including power and heat generators, oil refineries, ferrous metals, cement, lime, glass and ceramic materials, and pulp and paper. It is estimated that these sources will emit 46% of the Community's carbon dioxide emissions in 2010. A linking Directive approved in April 2004 allows the use of CDM credits (CERs) to be used to comply with the targets established for the EU ETS in the first commitment period (2005-2007). However, the long lead times of CDM projects and the risks and transaction costs which discourage their realisation makes it unlikely that they will make a large contribution to compliance with the Directive's targets. The relatively generous allowance allocations of National Allocation Plans also support to this conclusion.

The EU ETS will coexist with measures taken by MS to mitigate GHG in sectors included and not included in the Directive with the aim to comply with the BSA commitments. In general, these measures can be grouped in two categories: cross-cutting and sectoral measures. The latter applies only to one sector (e.g. energy transformation, manufacturing and construction, transport, residential and service, industrial processes, agriculture and waste). The former applies to more than one sector[49].

Although different emphasis may be given to certain policies in different MS, there seems to be a common pattern in the sectoral measures applied. In general, MS policies to tackle climate change rely mostly on measures for the mitigation of emissions in the energy sector. Some measures referring to the energy sector can be regarded also as cross-cutting measures, since they may have an impact on the emissions of more than one sector (e.g. industry and residential sectors).

Widely used planned or implemented measures include[50]:

- Energy. Promotion of renewable energy, investment support (tax reductions, subsidies, R&D support) for energy efficiency, information and awareness measures aimed at reduction of energy demand and energy efficiency (demonstration projects) and voluntary agreements with energy-intensive industries in order to optimise energy efficiency (or cost-efficient GHG reductions) in several sectors.
- Industry. Measures aimed at energy savings and efficiency (investment support, voluntary agreements, etc.), actions to reduce nitrous oxide and to limit fluoride gas emissions, measures aimed at reduction of non-energy related emissions and implementation of BATs in the context of the IPPC Directive.
- Building, commercial and residential sectors: energy savings and energy conservation, increased energy efficiency for public buildings, insulation standards for buildings (ordinances...), increased energy efficiency of household appliances and labelling schemes.
- Transport: promotion and improvement of public transport (multimodal systems), fiscal incentives for low fuel consumption vehicles, promotion of biofuels, increased fiscal pressure on private transport aimed at internalisation of external costs of road transport / private traffic, promotion of economic driving, public awareness raising measures aimed at reduction of individual private traffic, speed limits and spatial / physical transport planning to reduce traffic. These measures should be effective in order to mitigate the emissions from this sector, which are forecast to show the highest growth rate in the following decade.
- Agriculture and forestry. Measures to reduce methane and NO_X emissions, actions to reduce the factors of production and to improve farming practices, production of biofuels, promotion of refor-

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[49] The report "Integrated policy analysis of demand side energy efficiency & CHP, GHG and RES-E schemes in EU 15 countries" (Del Rio et.al., 2004) as composed within work package 3 of the project Green-X provides a detailed description of these policies per MS and sector. Of course, it has to be taken into account that no review of national policies and measures to mitigate climate change can ever be complete due to the ever evolving nature of policy development and that some measures specifically aim at GHG mitigation, whilst many others reduce GHG emissions only as a secondary effect.

[50] Of course, not all these measures are specifically aimed at GHG mitigation but they certainly affect GHG emissions.

estation and forest conservation (grants), maintenance and enhancement of diversity, productivity, regeneration capacity and vitality of forests.

- Waste Management. Reduction of disposal of waste on landfills, promotion of waste recycling and waste recovery.

In contrast to sectoral measures, the implementation of cross-cutting measures differs by country. Austria, Denmark, Finland, France, Germany, Italy, the Netherlands, Sweden and UK have relied on the implementation of some form of energy/carbon tax (although the link with the carbon content of energy is sometimes weak). Voluntary agreements now exist in most countries (Netherlands, Germany, Spain, Finland, France, Belgium, Ireland and Italy) while only Denmark and UK have implemented a domestic emission trading scheme.

Apart from the EU ETS, some of these policies (i.e. environmental taxes) may significantly affect RES-E deployment in the EU.

2.3 Demand Side Energy Efficiency Policy & CHP

In a context of growing global energy demand, energy efficiency plays a crucial role in the transition towards sustainable development. Efficiency does not only depend on the quantity of energy being supplied by the product but, also, on the effectiveness of the service which is being demanded (through a process which transforms the fuel into heat or electricity). Therefore, fuel demand depends on the final use of energy, which determines the degree of substitution between factors of production. Thereby, the concept of energy service allows us to link energy demand and supply. This link is essential to reach a sustainable consumption. Therefore, it is necessary to improve the energy efficiency not only within the chain of energy supply but, also, according to the energy being demanded.

Table 2.3 shows the most relevant measures and standards applied to improve the energy efficiency at EU level.

Table 2.3 Major energy efficiency measures at the EU level

Climate Change • **Directive 3/76** • **Decision April 25th 2002** • **Directive 2003/87/EC**
2.3.1.1.1.1.1 Energy efficiency • COM 1998 • Decision 647/2000 (further at the back in the text) • COM 2000 (247) • Directive 2000/55/CE • Decision 2001/469
2.3.1.1.1.1.2 Energy performance • Directive 92/42 • Directive 96/57 • Directive 2003/66
2.3.1.1.1.1.3 CHP • CHP Directive (COM 2002 (415))

A wide range of initiatives have been taken at the Member State level to improve energy efficiency and introduce CHP over the last decades (especially during the 1990s). These measures have been taken in the industrial, household and tertiary sectors. An analysis of the policies included in the MURE II Data Base reveals that more than 1100 measures have been adopted by the MS aiming at energy efficiency improvement in the period 1970 to 2004.

Policy instruments can be classified into four main categories:

- education / information / training;
- financial / fiscal;
- legislation;
- others.

Strategies adopted by policy makers seem to have been mostly concentrated in the household sector. While in both the household and tertiary sector the predominant policies were those related to legislation, it can be observed that financial / fiscal measures were merely the predominant strategy among the industrial sector. For more details, see Del Rio et. al. (2004).

Regarding the technology / uses affected by the policy, the measures in the MURE II Database can be classified in several categories: specific sector appliances (in the case of households these include measures concerning appliances, in industry and the tertiary sectors other sector-specific issues such as motors and drivers, compressed air and process integration were also included), spatial temperature (including measures that were classified as heating, space heating, ventilation and conditioning, high and low temperature and refrigeration), hot water (including sanitary hot water), lighting and CHP.

3 Method of approach

3.1 Evaluation criteria

The evaluation of the various promotion instruments for RES-E will be based on the selection criteria described below. It must be kept in mind that such 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.[51] 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)[52].

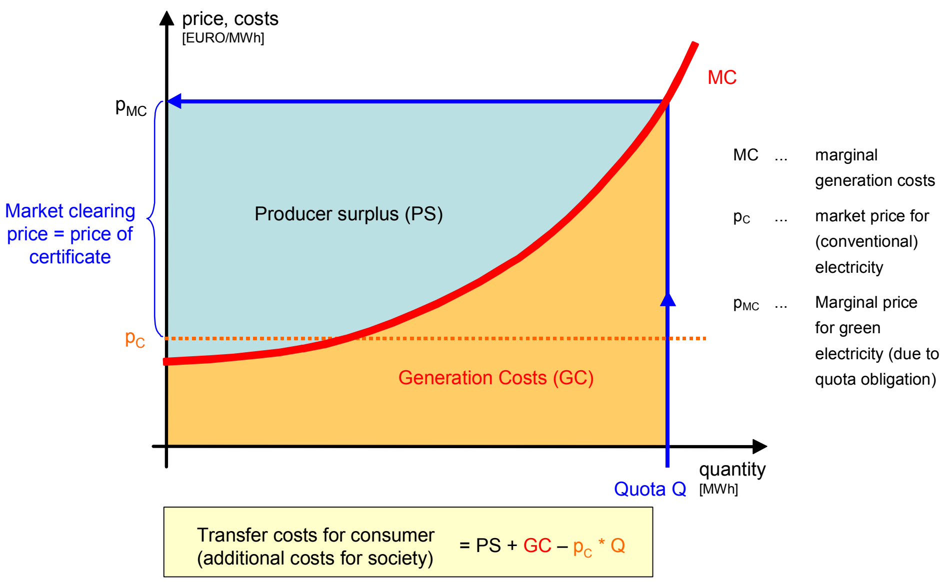

Figure 3.1 Basic definitions of the cost elements (illustrated for a TGC system)

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[51] 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 €/yr or related to the total electricity consumption. In the later case the premium costs refer to each MWh of electricity consumed.

[52] 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.

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 3.1*.

3.2 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.[53]

3.2.1 Overview of the computer model *Green*-X

The ***Green*-X** computer model is the core product of the project Green-X. It is an independent computer programme and has been developed with Microsoft Visual Basic as the programming tool and Microsoft Access as the database. Necessary requirements to run the computer programme ***Green*-X** are Microsoft Windows, Microsoft Office XP (and later).

The ***Green*-X** computer model 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[54] over time.

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. The equilibrium level of the dynamic cost-resource curves for both supply and demand in each market segment on an annual basis provides the model outputs.

Figure 3.2 gives an overview of the core elements of the ***Green*-X** model. In the following section the individual components will be described in brief.

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[53] Please note, the following characterisation of the ***Green*-X** toolbox refers to the extended version as developed within the project Green-X for in-depth analysis as described in the following chapters.

For the interested user, a public version is available at the end of the research project in October 2004. This version – in contrary to the extended version – is characterised by its clear focus on renewable energy sources. This includes a tool to calculate the impact of various promotion strategies on the development rates of RES-E, and a cost assessment (generation costs, costs for customers) of various strategies is available in its full function. Other uses of the extended ***Green*-X** version, such as for analysing interactions of RES-E with the conventional power market, demand-side measures, CHP strategies, complex climate change strategies, and electricity flows (import / export balances) within a liberalised power market considering grid restrictions are not applicable in all details as they require in-depth knowledge on the modelling behind to undertake the necessary settings. Instead the user can select between various default cases (regarding conventional power market, impact of GHG-emission trading, etc.).

[54] 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.

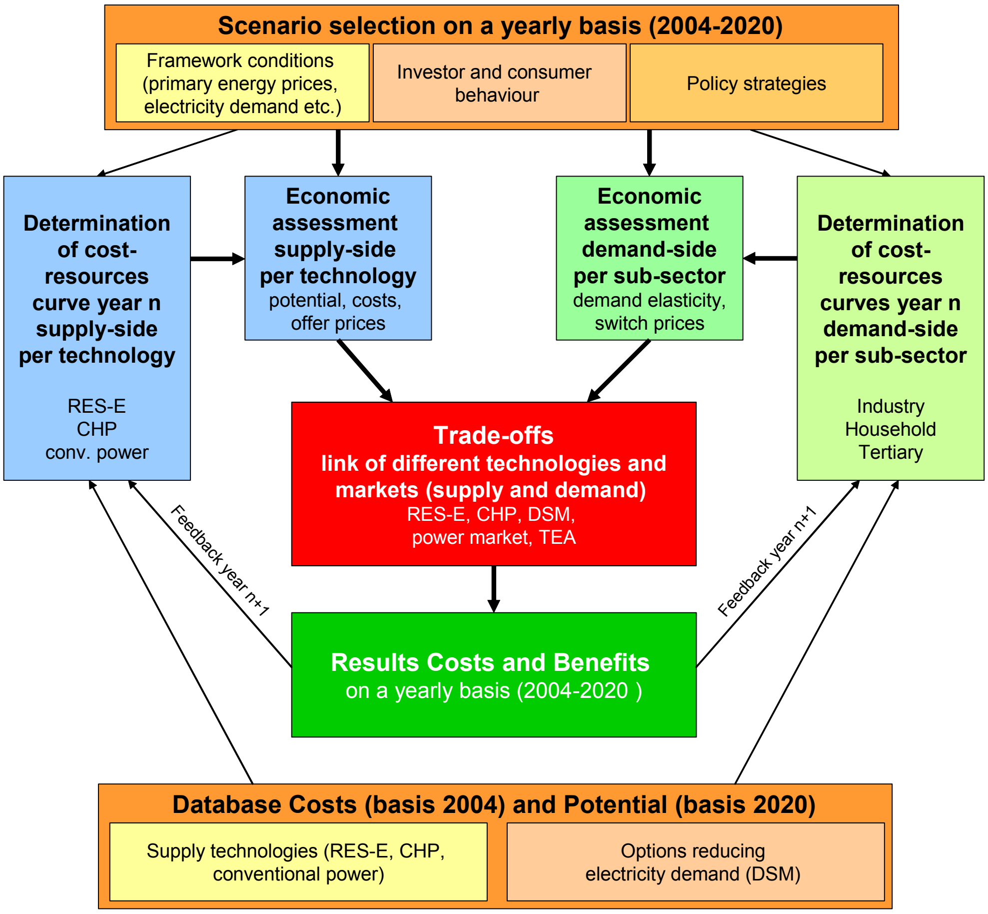


Figure 3.2 Overview on the computer model ***Green-X***

3.2.2 General database

A comprehensive database is required to carry out a detailed country- and technology-specific impact analysis of different policies. The database covers potentials and costs most important electricity generation technologies, both from renewable energy sources for electricity generation (RES-E) and conventional plants within each EU 15 Member State as well as sector-specific options to reduce electricity demand.

In the ***Green-X*** toolbox it is assumed that most of the parameters (data) are not constant within one country and one technology respectively. Therefore, technologies are split into “bands”, which are characterised by similar economic characteristics, such as

- the same fuel input, e.g. solid biomass: forestry products (wood), forestry residues (bark, sawmill by-products), agricultural products (energy crops), agricultural residues (straw etc.), biogenic fraction of waste (MSW+ISW),
- the same sub-technology and energy efficiency categories, e.g. photovoltaics systems: facade integrated systems, roof system,
- the same range of full-load hours, e.g. wind energy onshore: 2600 h/a, 2500 h/a, 2400 h/a, 2100 h/a, …. , 1500 h/a.
- the same range of plant-sizes, e.g. biomass: small-, medium- and large-scale plant.

Supply-technology database

To meet all necessary requirements, as background data a comprehensive supply-technology database covers the most important parameters for both existing plants and possible new options. The database contains data to determine electricity generation costs and the potential for this generation at band (plant) level for pure electricity and combined heat and power plants for each of the EU 15 Member States. In order to obtain results which are consistent with the classification according to the RES-E Directive, similar technology groups and sub-groups are used. This means that renewable energy sources for electricity generation (RES-E) are divided into 10 RE technologies split into 17 sub-technologies in the database.

The database for conventional power plants is split according to the primary energy carriers (hard coal and lignite, oil, gas and nuclear). To derive a precise cost-resource curve, an additional distinction is made for each fuel input category according to the conversion technology applicable to the corresponding primary energy carrier. Generally speaking, these are combined cycle gas turbine, gas engine, gas turbine (open- and closed cycle), steam turbine (split into sub-critical and over-critical), fluidised bed combustion, internal gasification combined cycle and internal combustion engine. *Table 3.1* summarises the available technologies on the supply side.

The following key information is available in the supply technology database.

- construction year of existing plants
- electricity / heat generation of existing plants
- long-term potential (year 2020) of electricity / heat generation from new plants
- full-load hours electricity / heat generation
- efficiency electricity / heat generation
- current investment costs
- current operation and maintenance costs
- specific CO_2 emissions

Table 3.1 Considered technologies for pure electricity as well as and combined heat and power generation (if technically feasible)

RES-E technologies	**Conventional electricity technologies**
Biogas	Coal and coal products
Biomass	*Hard coal*
Forestry products (wood),	*Lignite / brown / peat coal*
Forestry residues (bark, sawmill by-products etc.),	Liquid fuel and refinery gas
Agricultural products (energy crops),	Natural gas and gas work gas
Agricultural residues (straw etc.),	Nuclear power plants
Biogenic fraction of waste (MSW+ISW)	
Geothermal electricity	
Hydro power	
Small scale hydro power (<10 MW)	
Large scale hydro power (>10 MW)	
Landfill gas	
Sewage gas	
Solar	
Photovoltaics	
Solar thermal electricity	
Tidal energy	
Wave energy	
Wind	
Wind on-shore	
Wind off-shore	

Electricity demand reduction database

The background database for the ***Green-X*** model with respect to electricity saving options is based on existing information, such as on the MURE-II database, the IKARUS database and extended to the assessment of costs for energy saving options. It contains information for the three sectors of industry, households and tertiary, thus covering almost all areas of an economy. Each sector is divided into a number of different sub-sectors, see Table 3.2.

In contrast to the supply side, only data for new DSM options are necessary on the demand side. Key information per sub-technology and sector are:

- investment costs for standard and energy saving technologies
- operation and maintenance costs for standard and energy saving technologies
- electrical efficiency standards for standard and energy saving technologies
- full-load hours for standard and energy saving technologies
- lifetime expectancy for standard and energy saving technologies
- mid-term energy saving potential of energy saving technologies compared to standard technologies

The database containing information with respect to costs and potentials for electricity supply and electricity saving options is independent from the simulated scenario, i.e. data is used independent of the chosen scenario setting. In contrast, other important input parameters depend on the selected scenario. This means the user can select the framework conditions depending on the specific case to be analysed. These parameters are analysed in the following way.

Table 3.2 Considered sectors and sub-sectors for energy saving options

Industry	**Household**	**Tertiary**
Cement	Clothes dryers	Commercial offices
Ceramics	Dishwashers	Education
Chemicals	Freezers	Health
Dairies	Lighting	Hotels and catering
Engineering	Refrigerators	Distribution and warehousing
Foundries	Television	Public building
Glass and glass products	Washing	Retail
Iron & steel		Sports and leisure
Non-ferrous metals		
Other industries		

3.2.3 Framework conditions / exogenous inputs

Two major items are required as scenario-dependent model inputs, namely primary energy prices and electricity demand forecasts, both in a dynamic context. These parameters depend on the macro-economic development and are exogenously given in the ***Green-X*** model – included in the background database as time-series.

In more detail, primary energy prices forecasts up to 2020 are needed for all fossil and nuclear fuel-based supply-side generation options on a country-level. Default figures are available for both biogenic and fossil fuels in the database of the model ***Green-X***. The price forecasts for biogenic energy sources are based on an assessment conducted within the ***Green-X*** project. Fuel Price forecasts for fossil energy have been extracted from the WETO study (WETO, 2003) and the European Energy Outlook 2003 (Mantzos et. al. 2003)

With respect to electricity demand, a default forecast of the gross national electricity demand has to be provided as a model input for the whole investigation-period (i.e. up to 2020). The forecasts are based on two different scenarios (baseline and energy efficiency) made within the Europen Energy Outlook 2003 (Mantzos et. al. 2003a, b). By applying DSM strategies, default figures will be endogenously adapted.

3.2.4 Social and investor behaviour

The impact of both consumer and investor behaviour is, to a certain extend, integrated in the ***Green*-X** computer model.

With respect to the consumer, the willingness to pay for green electricity products like labelling for RES-E (Green Certificates), and combined heat and power is considered. In addition, the price elasticity – determining the reaction of the consumer on electricity price changes with changes in their demand – can be adjusted in the model.

Another important issue in the model ***Green*-X** refers to the investor behaviour. The decision of stakeholders, whether to invest or not into a certain technology depends on in the stability of the planning horizon, the kind of promotion instrument (variation in risk premium) and the technology itself. These parameters are considered by determining the weighted average costs of capital (WACC) in the ***Green*-X** model.

For both consumer and investor behaviour, parameters characterising their behaviour are available as time series in the database.

3.2.5 Policy setting

The setting of the policy instruments represents, beside above explained supply-side and demand-side structural database, the major input for the dynamic simulation model. In more detail, instruments are categorised as follows:

- General taxes including:
  - Energy taxes (to be applied to: electricity, heat, lignite / brown coal, hard coal, gas, fuel oil)
  - Environmental taxes on CO_2-emissions
- Promotion instruments for RES and conventional options in the field of electricity generation - including:
  - Price-driven strategies (feed-in tariffs, tax incentives, investment subsidies, subsidies on fuel input)
  - Demand-driven strategies (Quota obligations based on tradable green certificates (including international trade), tendering schemes)

  Note, all instruments can be applied to all RES and conventional options separately. In addition, separate settings can be selected for combined heat and power. With respect to nuclear power plants pre-defined phase-out scenarios can be also investigated.
- Demand-Side-Measures (DSM): Instruments to reduce the demand for electricity (i.e. quota obligations, tax incentives, investment subsidies) can be applied on a sectoral level, i.e. for industry, tertiary (public and private) and household sector (single and multi-family dwellings)
- Climate Policy: Trading of emission allowances on both the national and international level can be analysed.

Thereby, various instrument-specific parameters have to 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.

Note, all instruments can be set for each country individually. Furthermore, all settings can be changed in a dynamic context (i.e. for each year of the simulation). Of course, all default settings refer to currently implemented energy policy strategies (business-as-usual).

3.2.6 Development of the dynamic cost-resource curve

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 that year and the (policy) framework conditions set for the simulation year. In principle, the approach is carried out in three steps:

- The development of *static cost-resource curves* for each generation and demand reduction option, on a technology and country-level;
- The *dynamic assessment*, including a dynamic assessment of costs as well as of potential restrictions, in order to derive annual dynamic cost-resource curves.
- The derivation of the *dynamic cost-resource curve*.

In the following, the individual steps are described in more detail.

3.2.6.1 Static cost-resource curve

A *static cost-resource curve* describes the relationship between (categories of) technical available potentials (for example wind energy generation, demand reduction from lighting) and the corresponding (full) costs of utilisation of this potential at this point-of-time. This means, that no dynamic effects are included in static cost-resource curves.

On the supply side a distinction between already existing plants and potentially new ones must be made. For existing plants, the economic conditions are given by the short-term marginal costs and the generation potential is given by the installed capacity times the full-load hours. For new plants the long-run marginal costs are relevant. With respect to the potentials, realisable additional mid-term potentials have been assessed for each RES and conventional generation category by country. They represent the maximal additional achievable potential up to the year 2020 assuming that all existing barriers can be overcome in a dynamic context and all driving forces are active.

The static cost curve on the demand side is characterised by the electricity price level at which it is rational to use energy saving technologies compared to a standard technology as well as the long-term potential of electricity saving.

In the ***Green-X*** computer model, for both supply and demand, stepped cost-resource curves are applied. For illustration purpose, on the left-hand side of Figure 3.3 a theoretically ideal continuous static cost-resource curve for the supply side is depicted, taking into account that every location is slightly different from each other and, hence, looking at all locations e.g. for wind energy in a certain geographic area, a continuous curve emerges after these potentials have been classified and sorted in a least cost way. The stepped function, as shown on the right-hand side of Figure 3.3, represents a more practical approach. Thereby, sites with similar economic characteristics (e.g. in case of wind, sites with same range of full-load hours) are described by one band and, hence, a stepped curve emerges.

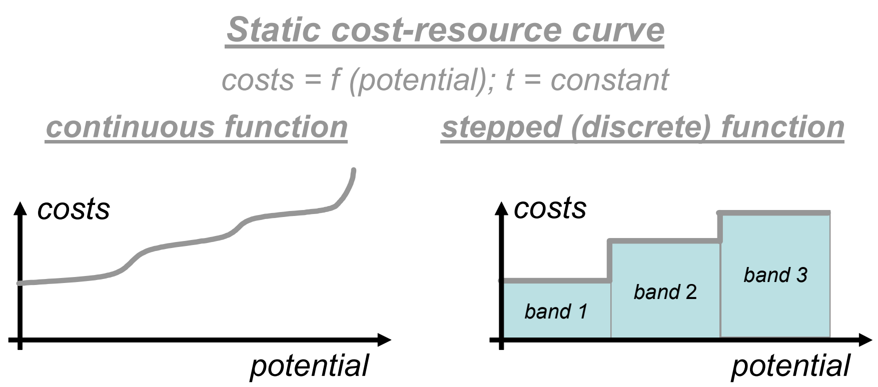


Figure 3.3 Characteristic run of a static cost-resource curve: Continuous (left-hand side) and stepped function (right-hand side)

3.2.6.2 Dynamic assessment

Dynamics are reflected within the model ***Green-X*** on an annual basis. For existing electricity plants and energy saving equipment dynamics is – beside dynamic operation and maintenance costs (fuel prices changes over time according to the selected scenario) – restricted to decommissioning activities of power plants at the end of their lifetime and exchange of energy saving applications, respectively.

For new power plants, dynamic costs and potential information must be derived considering:

- the selected policy instruments;
- investor and social behaviour;
- general framework conditions.

In order to derive dynamic cost-resource curves for each year, a dynamic assessment of the previously described static cost-resource curves is undertaken. It consists of two parts: the *dynamic cost assessment* and the application of *dynamic restrictions*.

Dynamic cost assessment

Forecasting technological development is a crucial activity, especially for the long time horizon. Considerable efforts have been made recently to improve the modelling of technology development in energy models. A rather 'conventional' approach relies exclusively on exogenous forecasts based on expert judgements of technology development (e.g. efficiency improvements) and economic performance (e.g. described by investment and O&M-costs). Recently, within the scientific community, this has often been replaced by a description of technology-based cost dynamics which allow endogenous forecasts, at least to some extent, of technological change in energy models. This approach of so-called technological learning or experience / learning curves takes into account the 'learning by doing' effect.

In general, experience curves describe how costs decline with cumulative production. In this context, the latter is used as an indication for the accumulated experience gained in producing and applying a certain technology. In many cases empirical analysis have proven that costs decline by a constant percentage with each doubling of the units produced or installed, respectively. In Figure 3.4 the characteristic run of an experience curve is illustrated: As indicated, by plotting such a curve on a log-log scale, a straight line occurs. Thereby, the gradient of the line reflects the corresponding learning rate.

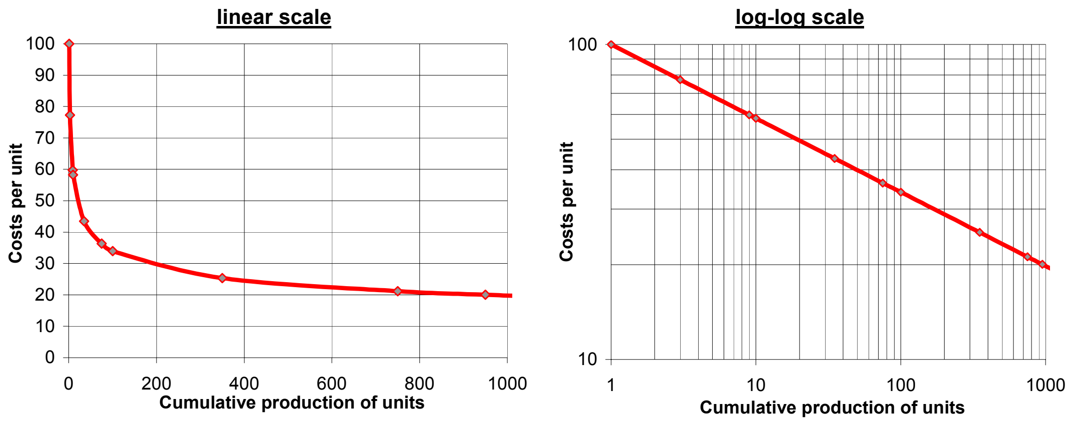


Figure 3.4 Characteristic run of an experience curve: On a linear (left-hand side) and on a log-log scale (right-hand side)

Note: Parameter settings: LR=15%, C0=100.

The chosen approach within the model ***Green-X*** differs by technology. Generally, the model includes these two different approaches – standard cost forecasts or endogenous technological learning. Default settings have been applied as follows:

- For a set of RE technologies like, e.g. wind power or PV, it was decided to adopt the approach of technological learning. Learning rates were assumed at least for each decade separately referring to the global development of the considered technology.[55]
- For conventional power generation technologies as well as some RE technologies, it was decided to adopt well-accepted expert judgements to establish a standard cost forecast.

Dynamic potential assessment

To derive realisable potentials for each single year of the simulation, dynamic restrictions are applied to the predefined additional realisable mid-term potentials. Thereby, a complex procedure is used, which differs by considered restriction. Default figures which can be adapted within the model, are derived from an in-depth assessment of the historical development of the various RES and conventional generation technologies and the corresponding barriers, which are categorised as follows:

- *Social barriers:*

  Social acceptance of additional electricity generation represents an important parameter influencing the penetration of different technologies. In general, a decreasing social acceptance can be observed if penetration of a specific technology increases.[56] For all generation options social acceptance is considered to be technology specific and will vary form region to region in a country.

[55] The existence of a global learning system is preconditioned – i.e. the future development of investment and O&M-costs is pending on the worldwide deployment of the technology. Accordingly, the scenario-specific penetration within all investigated EU 15 countries as given endogenously and for the rest of the world external forecasts (as given by (IEA, 2004)) are summed up to determine the global development in terms of installed capacities year by year.

[56] Note, however that this generally only applies once a certain threshold number of schemes have been installed, as below this level there is likely to be a tendency for low social acceptance for unfamiliar technologies.

Figure 3.5 illustrates the constraint for different barrier levels, which can be edited within the model.

- *Technical barrier:*

For the integration of certain decentralised capacity, e.g. wind power, the existing grid represents an important barrier. Grid restrictions lead to longer project lead times and are considered within the ***Green-X*** model as technology specific dynamic limitations of the yearly realisable potential on a local (i.e. band) level. As with social barriers, technical obstacles increase with the additional deployment.

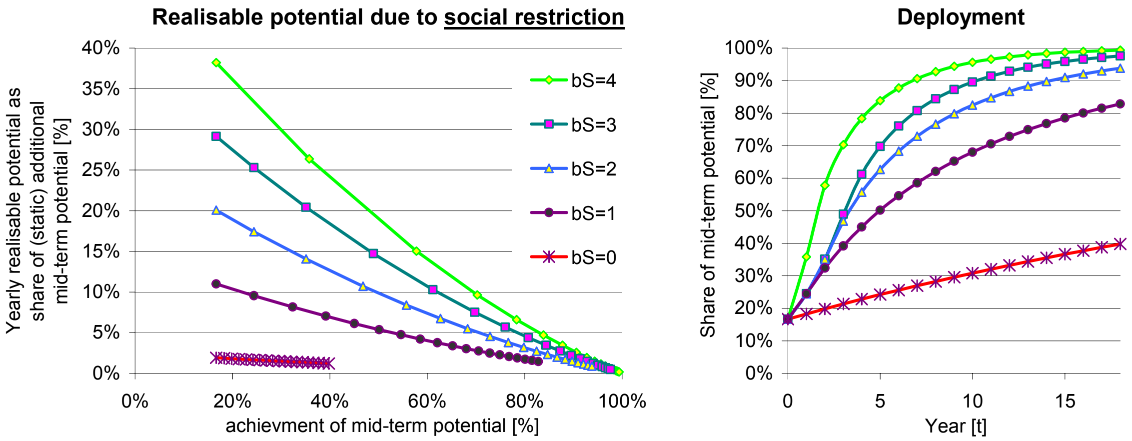


Figure 3.5 Yearly realisable potential due to social restriction, assuming different barrier levels - low barrier if bS is high, high barrier if bS is low (left-hand side) and resulting maximal deployment of the additional available potential due to social restriction (right-hand side)

- *Market and administrative constraints:*

The maturity of the market represents is one of the key issues influencing the penetration of a technology in the future. In accordance with general diffusion theory, penetration of a market by any new commodity typically follows an 'S-curve' pattern, see Figure 3.6. The evolution is characterised by a growth, which is nearly exponential at the start and linear at half penetration before it saturates at the maximum penetration level. With regards to the technical estimate of the logistic curve, a novel method has been employed by a simple transformation of the logistic curve from a temporal evolution of the market penetration of a technology to a linear relation between annual penetration and growth rates. This novel procedure for estimating the precise form of the logistic curve is more robust against uncertainties in the historic data. Furthermore, this method allows the determination of the independent parameters of the logistic function by means of simple linear regression instead of nonlinear fits involving the problem of local minima, etc.

In general, market barriers are closely linked to administrative barriers described above and, hence, are described within the model ***Green-X*** by one specific indicator on a country-level.

The actual technology-specific growth rates of the market are derived by an econometric analysis conducted for each country and RES-E technology within the EU projects 'FORRES 2020' and Green-X. For each RES-E category the 'best practise' market curve is characterised by those (two) countries with the best performance.

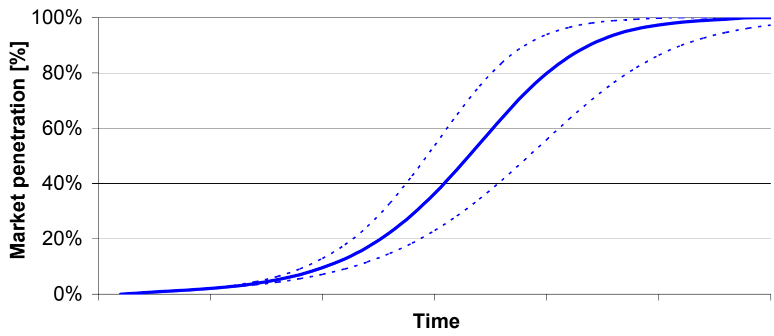


Figure 3.6 'S-curve' pattern: Market penetration of a new commodity

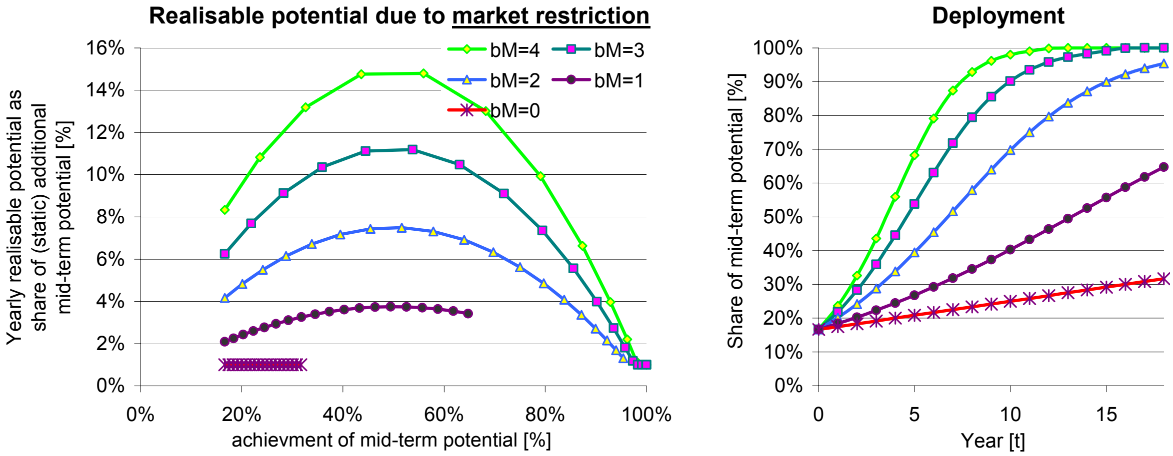


Figure 3.7 Yearly realisable potential due to market and administration restriction, assuming different barrier levels - low barrier if b_M is high, high barrier if b_M is low (left-hand side) and resulting maximal deployment of the additional available potential due to social restriction (right-hand side)

Figure 3.7 illustrates the applied approach for different barrier levels: On the left-hand side resulting yearly realisable potential in relation to the applied barrier level and on the right-hand side related deployment – in case that no other constraint would exist – is depicted.

- *Industrial barriers:*

  In general, the availability of a certain production technology in one country depends on the total global demand. For example, if the (policy-driven) demand for a certain technology, for example wind power plant, would increase rapidly at the international level, then a bottleneck situation might occur with respect to the industrial production of wind turbines. As a result less capacity could be installed also on a country-level. The limitation of a certain technology is considered in Green-X on an international level.

The actual available yearly potential is obtained by combining the different barriers on the band, country and international level. This means, depending on the already achieved deployment rate, different barriers limit the additional yearly available potential.

The assessment on the demand-side is less complex compared to the supply side, because the existing barriers and obstacles are given exogenously in the model ***Green-X***, i.e. they are not derived within the simulation process. Nevertheless, yearly dynamic restrictions of the total technology specific energy saving potentials can vary over time and depend on the already additionally achieved potential of this certain technology in the sector and country.

3.2.6.3 Dynamic cost-resource curve

The technology and country-specific dynamic cost-resources for the simulation year are derived by combining the static cost-resource curves with the dynamic assessment. This dynamic cost-resource curve on the supply side contains information about actual generation costs and the possible potential for electricity generation for various technologies for the simulation year. Figure 3.8 illustrates this procedure for one technology on the supply side.

Similarly, a dynamic cost-resource curve on the demand side contains technology specific information about the electricity price level, at which it is cost efficient to use electricity saving technologies and the possible potential for electricity demand reduction for the simulated year.

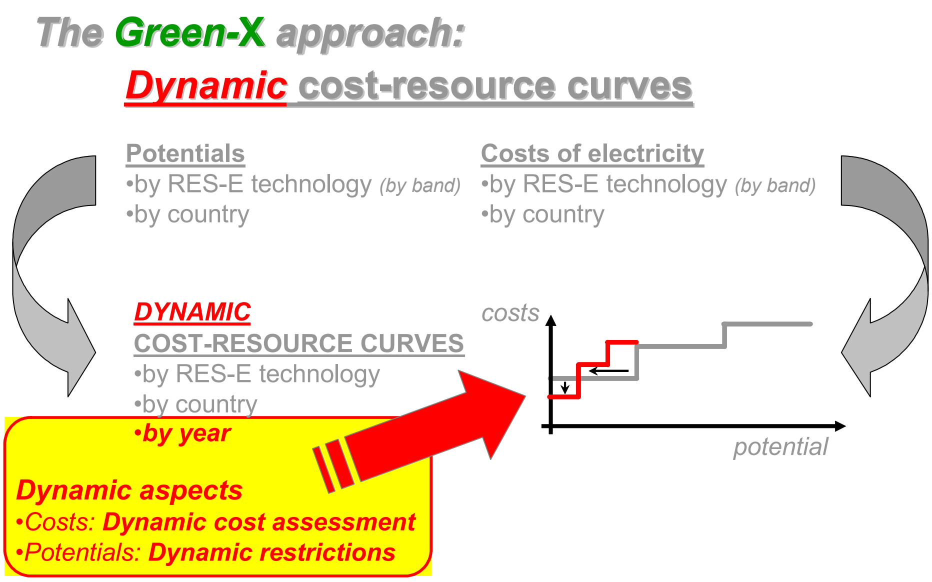


Figure 3.8 Method of approach regarding dynamic cost-resource curves for RES-E (for the model **Green-*X***)

3.2.7 Economic assessment

For the analysis of the interactions of different promotion schemes as well as among different markets and market conditions, a further adaptation of the 'dynamic cost curve' is necessarily both on the supply and the demand side. More precisely, an economic assessment of the dynamic supply and demand reduction curve is made, considering the possible policy support (at the country and technology level).

In general, a (public) support reduces the effective electricity generation costs in the case of supply-side technologies and the electricity price level at which it is economic to use the electricity saving technology in the case of demand side options. Note 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.

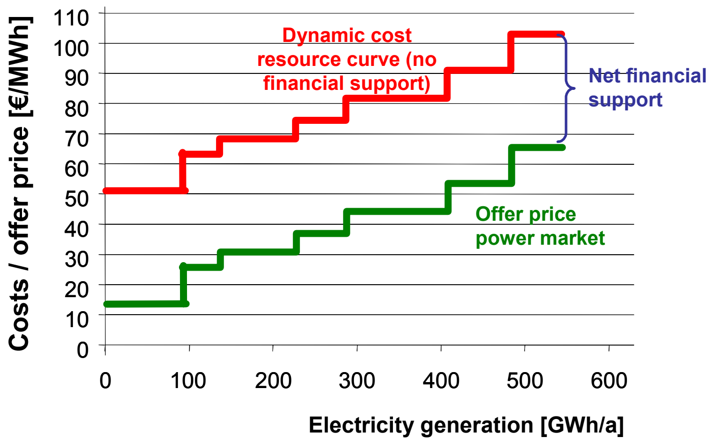


Figure 3.9 Influence of a constant (fixed) premium feed in tariff on the net generation costs / offer price on the power market

Within this step, a transition from generation and saving *costs* to bids, offers and switch *prices* takes place. Figure 3.9 gives an impression of the economic assessment approach via the example of a premium feed-in tariff. As already mentioned, the duration of the tariff influences the 'price reduction', i.e. if the guaranteed duration is rather restricted (lower than the deprecation time), the economic support over the considered depreciation time is lower compared to the case of a high guaranteed duration of the tariff.

3.2.8 Trade-off supply and demand

The general modelling approach is to derive 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 - on a yearly basis. This means that the different technologies are collected within each market and the point of equilibrium varies with the calculated demand. Figure 3.10 illustrates this procedure for a TGC and power markets.

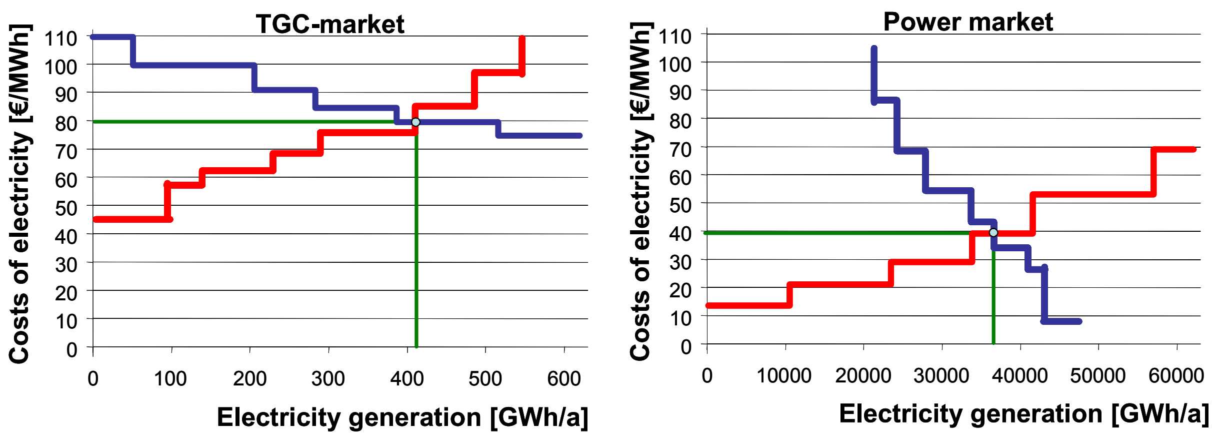


Figure 3.10 Interactions of supply and demand in different considered markets

3.2.9 Model results

After completion of the simulation run, the ***Green-X*** model aims to deliver a broad set of results on a national level as well as per technology for the electricity and – in an extended version – also for the grid-connected heat sector on a yearly basis, i.e. for each year 2004-2020.

In more detail, model outputs can be categorised as follows:

- *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.) [%]
  - 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 CO_2-strategy total [M€, €/MWh]
  - Total (transfer) costs due to the selected support schemes and policy options

Note, as mentioned above all results can be provided on a country and if expedient, – also on a technology level.

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). In addition, intermediate results are also accessible.

3.2.10 Illustration of the computer model *Green-X*

For illustration of the computer model ***Green-X***, some screen shots are copied in Figure 3.11 to Figure 3.18.

Figure 3.11 Starting page **Green-X**

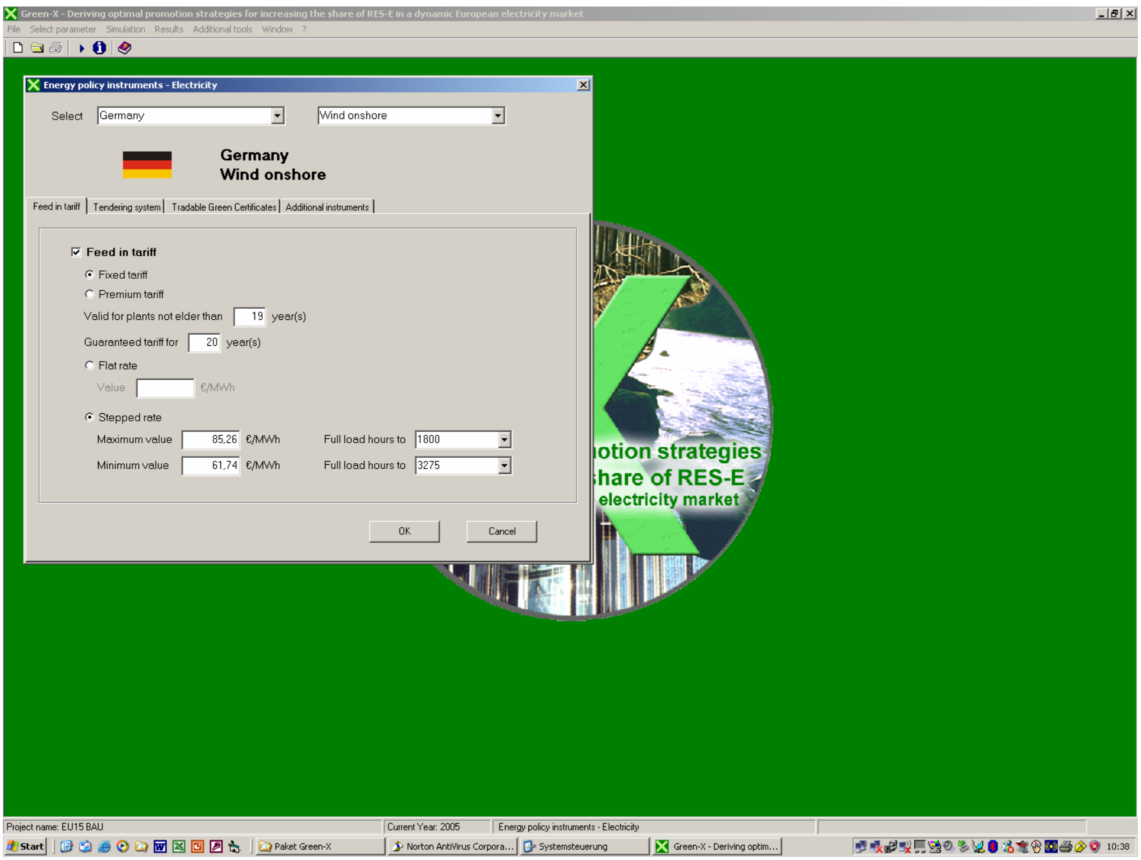


Figure 3.12 Design options in the case of a feed-in tariff

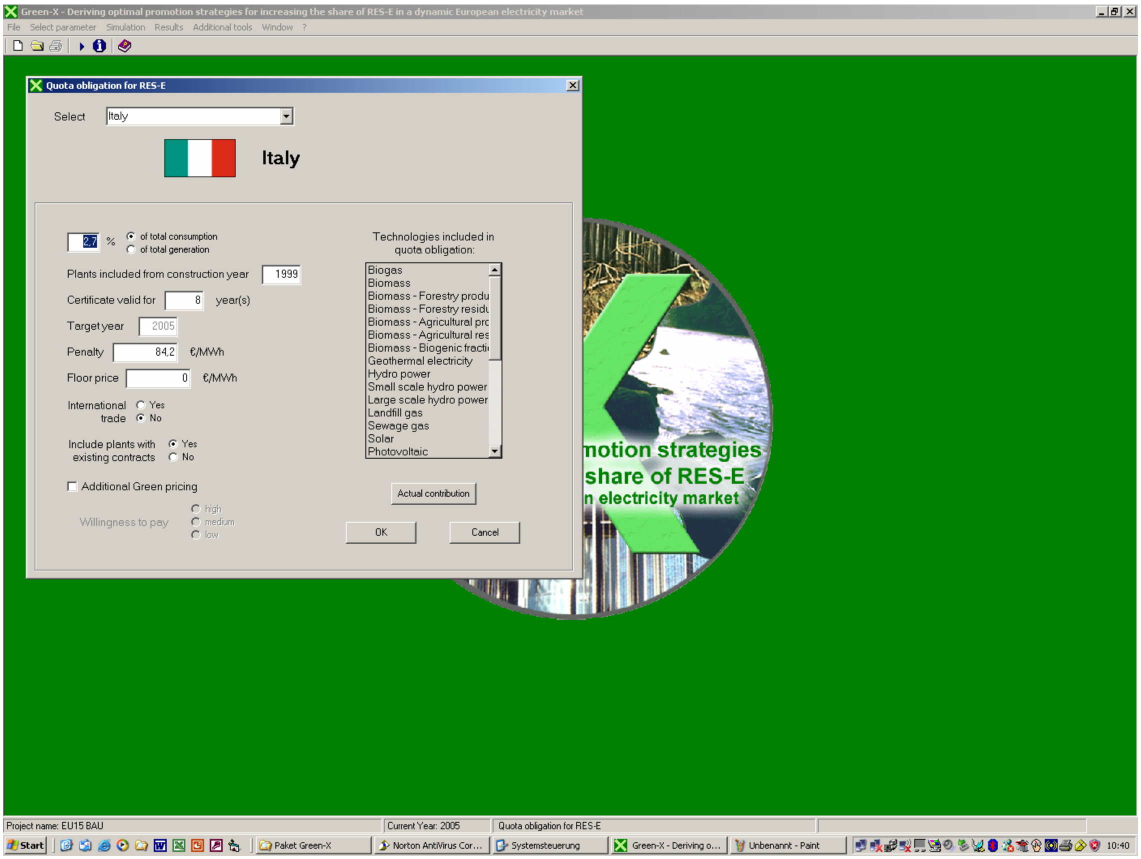


Figure 3.13 Design options in the case of a quota obligation

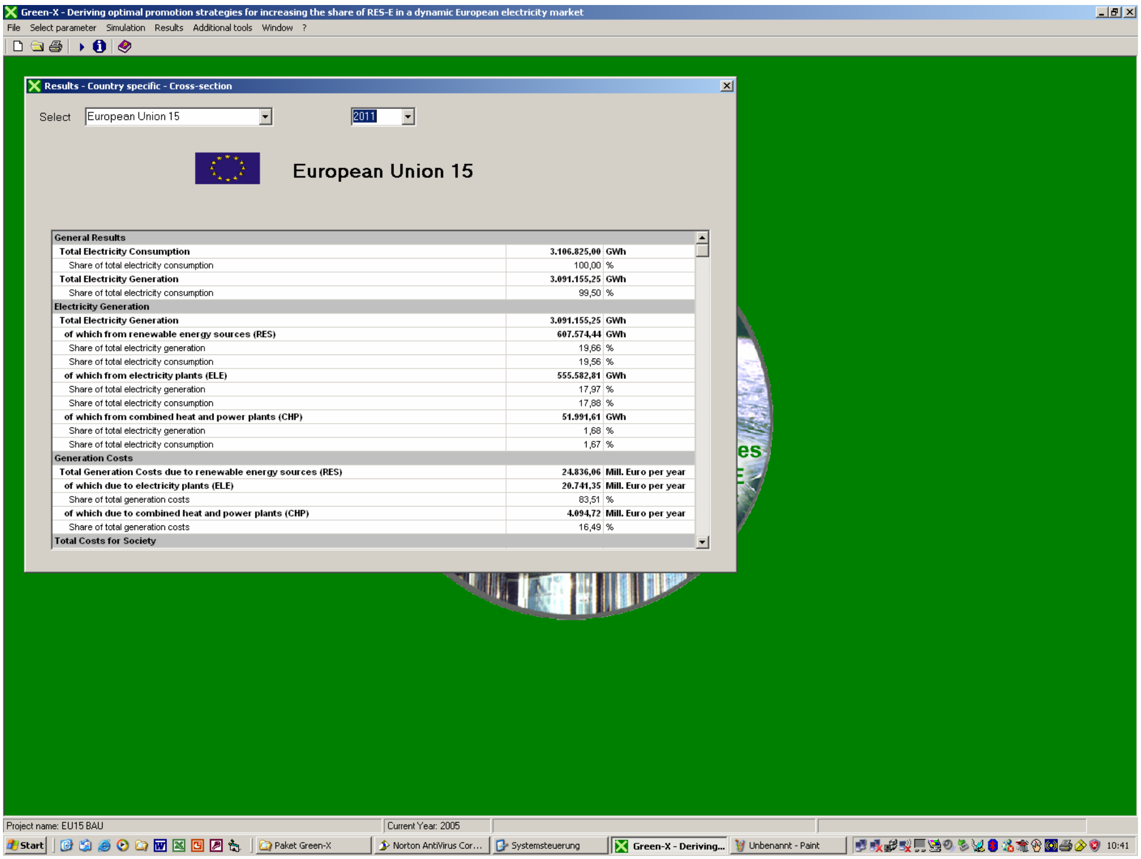
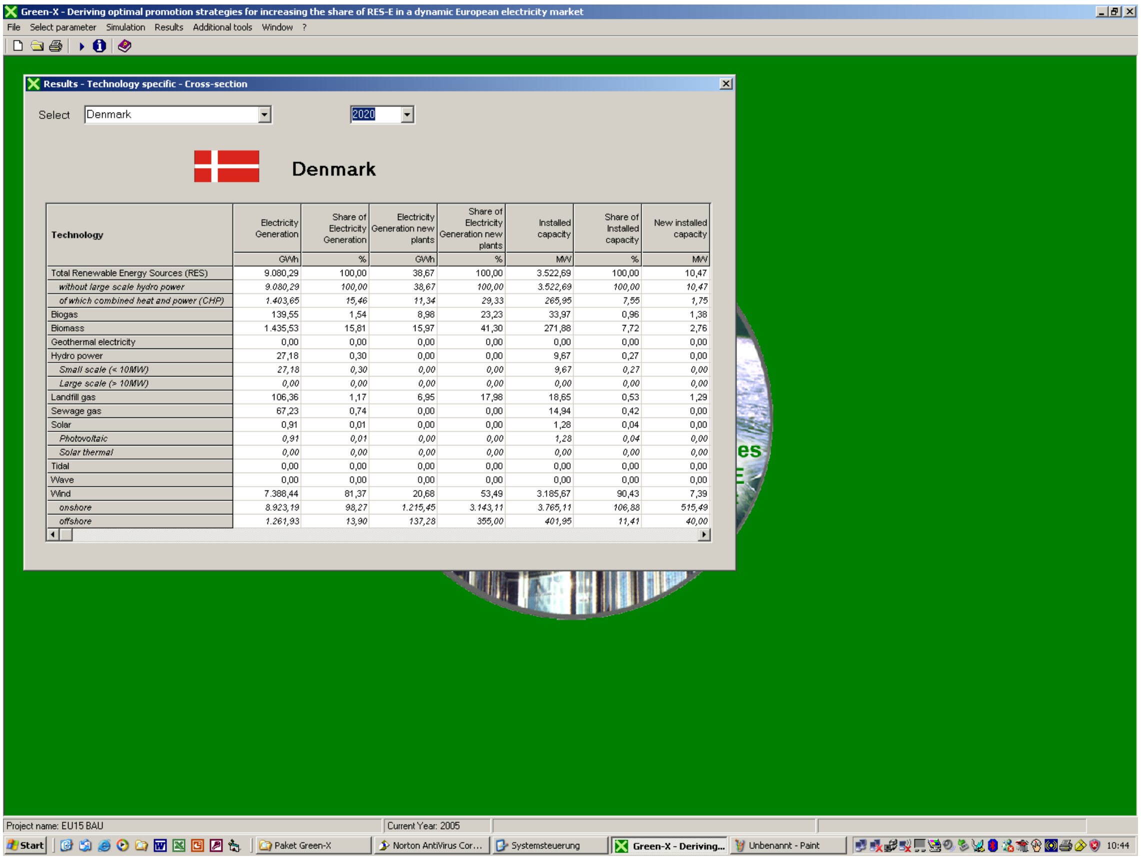


Figure 3.14 Result table - country specific results



Technology	Electricity Generation	Share of Electricity Generation	Electricity Generation new plants	Share of Electricity Generation new plants	Installed capacity	Share of Installed capacity	New installed capacity
	GWh	%	GWh	%	MW	%	MW
Total Renewable Energy Sources (RES)	9.080,29	100,00	38,67	100,00	3.522,69	100,00	10,47
without large scale hydro power	*9.080,29*	*100,00*	*38,67*	*100,00*	*3.522,69*	*100,00*	*10,47*
of which combined heat and power (CHP)	*1.403,65*	*15,46*	*11,34*	*29,33*	*265,95*	*7,55*	*1,75*
Biogas	139,55	1,54	8,98	23,23	33,97	0,96	1,38
Biomass	1.435,53	15,81	15,97	41,30	271,88	7,72	2,76
Geothermal electricity	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Hydro power	27,18	0,30	0,00	0,00	9,67	0,27	0,00
Small scale (< 10MW)	*27,18*	*0,30*	*0,00*	*0,00*	*9,67*	*0,27*	*0,00*
Large scale (> 10MW)	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
Landfill gas	106,36	1,17	6,95	17,98	18,65	0,53	1,29
Sewage gas	67,23	0,74	0,00	0,00	14,94	0,42	0,00
Solar	0,91	0,01	0,00	0,00	1,28	0,04	0,00
Photovoltaic	*0,91*	*0,01*	*0,00*	*0,00*	*1,28*	*0,04*	*0,00*
Solar thermal	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
Tidal	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Wave	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Wind	7.388,44	81,37	20,68	53,49	3.185,67	90,43	7,39
onshore	*8.923,19*	*98,27*	*1.215,45*	*3.143,11*	*3.765,11*	*106,88*	*515,49*
offshore	*1.261,93*	*13,90*	*137,28*	*355,00*	*401,95*	*11,41*	*40,00*

Figure 3.15 Result table - technology specific results on country level

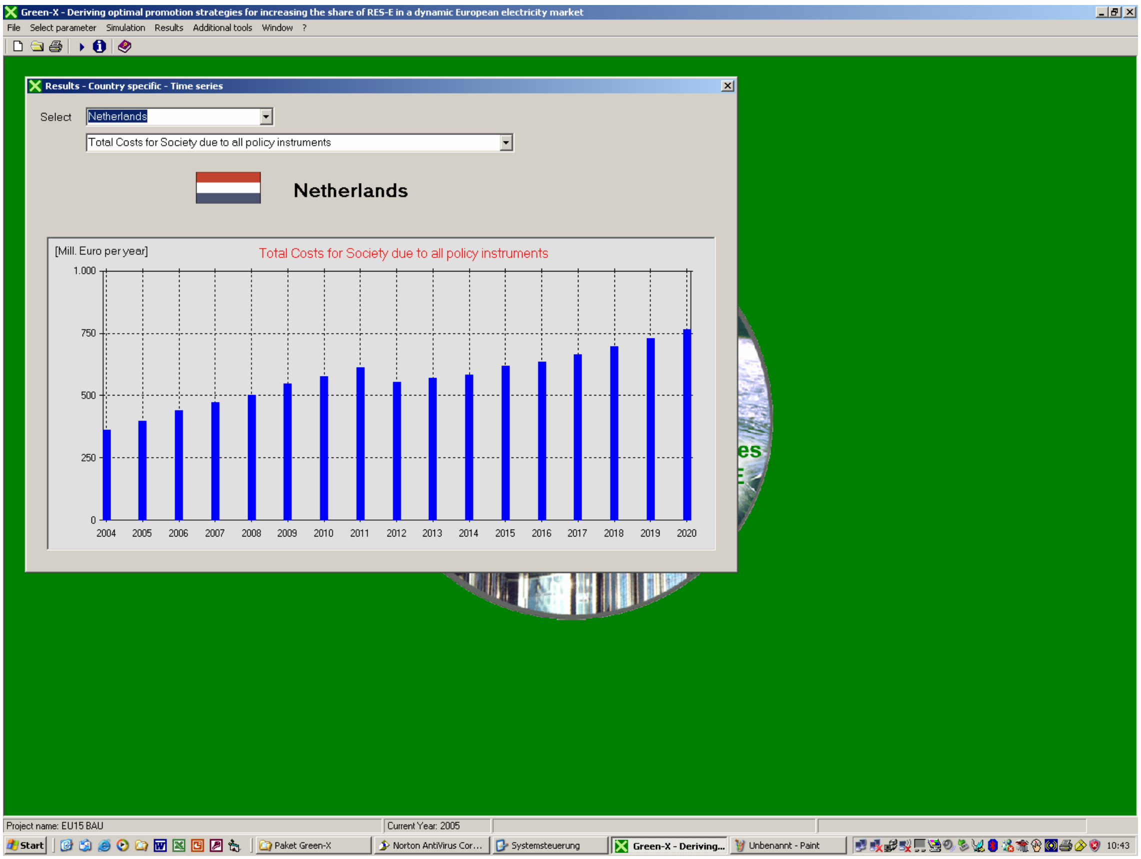


Figure 3.16 Result figure – time series total costs for society

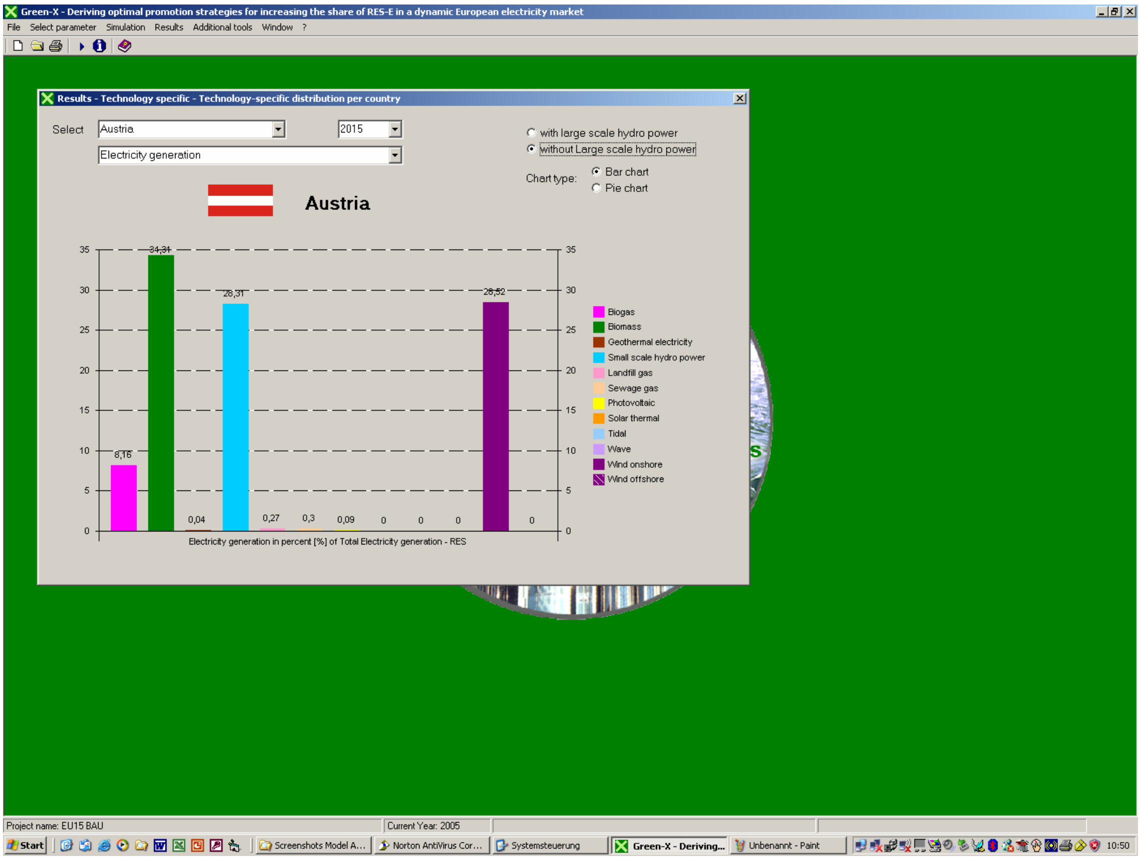


Figure 3.17 Result figure – technology specific distribution per country

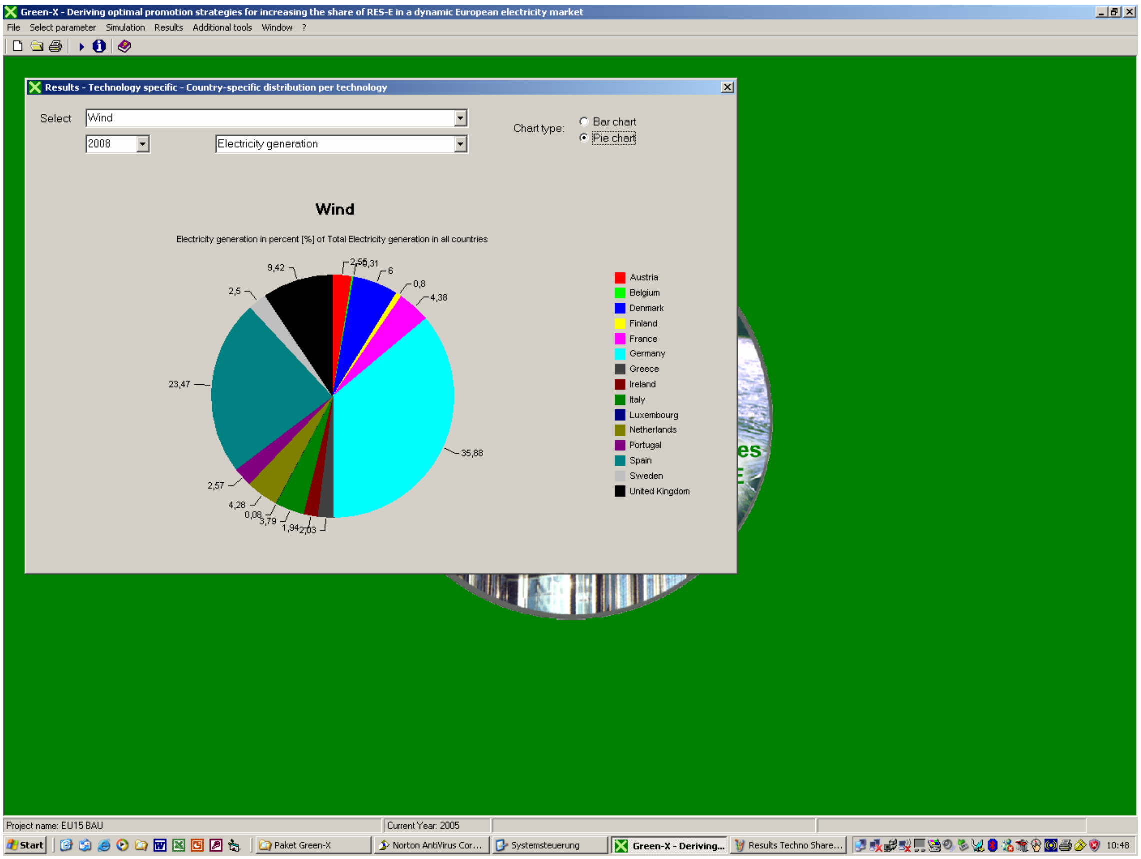


Figure 3.18 Result figure – country specific distribution per technology

4 Evaluation of different policies schemes in a dynamic framework

The aim of this part of the report is to evaluate the different policy instruments and to describe the possible effects. Thereby, general observations as valid for all kind of instruments are depicted first, followed by an in-depth discussion of each instrument – listed in a topical order (i.e. policies for RES-E, GHG-emission reduction, demand side activities (DSM), or combined heat and power (CHP) policy). In addition, as in most cases the impact of the different instruments depends on the level they act, a distinction is made between promotion strategies set at the national and international level. This means the effects of non-harmonised versus harmonised policies are investigated separately, if appropriate. The trade-offs of RES-E policy instruments with respect to the other policy schemes (climate change, DSM, CHP) are described in chapter 5.

4.1 The role of risk and risk perception in renewable energy investments

Before the effects of different policy instruments should be evaluated in detail, the general aspect of risk – which is often underestimated in the assessment of support mechanisms – should be discussed.

4.1.1 Risk and upward potential

Risk in relation to investments in RES-E can be described by the negative impact which uncertain future events may have on the financial value of a project or investment. Risks form the counterpart of the upward potential: the increase in value due to future events. It is important to note that *risk* is not identical to *uncertainty*. Uncertainty of the financial value of a project can be both *positive* and *negative* in comparison with the expected value. The term 'risk', however, relates exclusively to the events which might occur and would lower the expected financial value. Events which may take place and would increase the expected value, form the 'upward potential'.

Although both risk and upward potential are related to the uncertainty of future events, risks usually play a more dominant role in investment decisions since investors are risk averse in most cases. When it comes to investment risks for RES, three categories seem to play the most dominant role:

- **regulatory risks** which can be found in project development or are related to possible changes in the financial support for RES-E due to changing government policies
- **market and operational risks** which are related to for instance increasing costs for operation or feedstock, such as biomass
- **technological risks** which follow from malfunctioning of the technology used and potentially can be large for some RES-E technologies since these have entered only recently on the market.

It is important to note that risk is discussed at this place as perceived by stakeholders in RES-E.[57]

[57] This is a different viewpoint than the one taken by Awerbuch et. al. (2003) who have applied portfolio theory to EU electricity planning and policy-making. They remark that adding wind, PV and other fixed-cost RES-E technologies to a portfolio of conventional generating assets serves to reduce overall portfolio cost and risk, even though their stand-alone generating cost may be higher. For energy planning purposes the relative value of generating assets should be determined not by evaluating alternative resources, but by evaluating alternative resource portfolios.

4.1.2 Sources of risk in renewable energy investments

A serious issue in the development of RES projects is how future events affect the value of the project and which risks are involved for the investment planned. Figure 4.1 illustrates the total risk a company in operation may face. Dealing with risk (*i.e.* uncertainties in future developments which have a negative impact on the operation and profit of a company) is a key element when it comes to value a new project and decide on investing in it. This situation applies not only to the actual investor, but also to other stakeholders who are involved, such as banks, insurance companies, suppliers of the technology and the off-takers of the energy. The sources of risk and its impact, however, can differ substantially for each of these stakeholders.

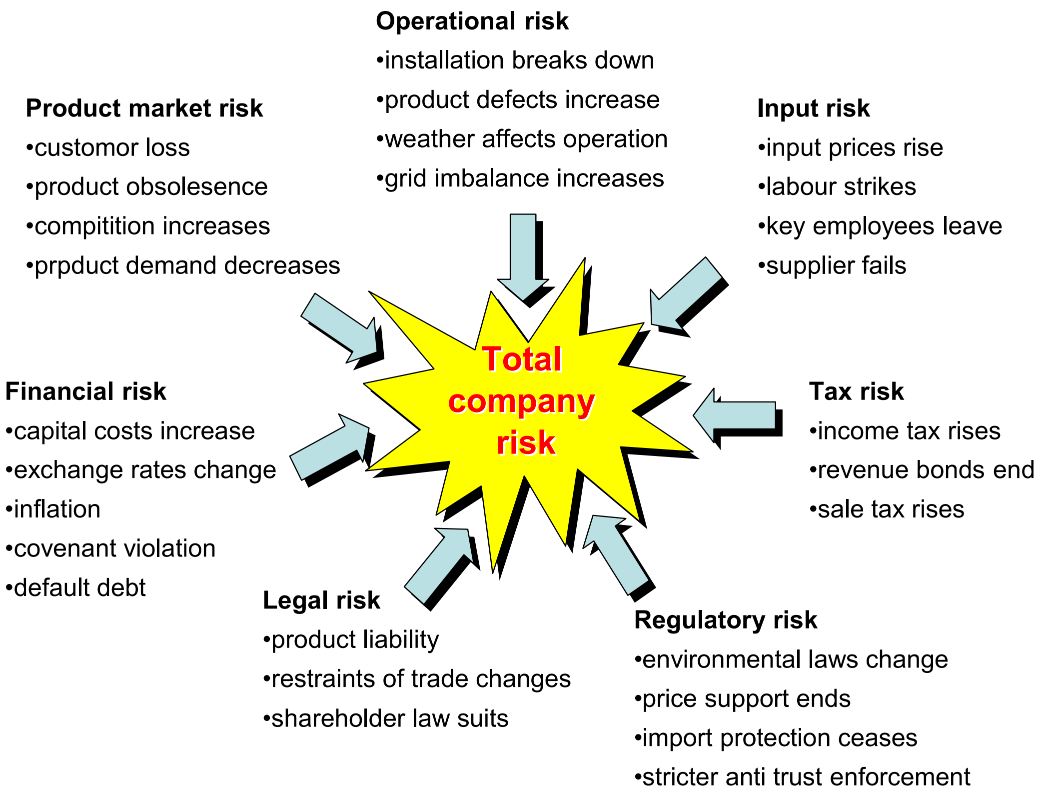


Figure 4.1 A variety of risk sources make up the total risk of a company[58]

The importance of each risk category depends strongly on the nature of the company and the sector and market in which it operates. For trading in green electricity the following risk sources which are relevant for sellers and buyers on the market can be identified, see Table 4.1.

[58] Taken from L. Meulbroek (2000).

Table 4.1 Risk elements which are relevant for producer and buyer of green energy

Risk element	Producer of green energy	Buyer of green energy (in case of a certificate system)
Operational risk	prediction capability of load and grid imbalance is crucial for less mature technology performance is a risk factor	depends on banking strategy of certificates, otherwise possibly relatively low risk
Product market risk	demand expected to rise (favourable), but at same time competition may increase strongly as well	demand expected to rise (favourable), but at same time competition may increase strongly as well
Input risk	bio-energy options: fuel costs important wind and hydro: varies with climate	large profits at risk when long-term contracts are closed and prices change
Regulatory risk	very important: profit strongly depends on price support import protection	very important: profit & sales strongly depend on price support / tax breaks
Financial risk	in particular relevant without long-term contracts and for sources where capital costs dominate (wind, hydro)	depends on inventory size (banking) and portfolio of contracts

4.1.3 Relevance of risks for investors in renewable energy projects

A more detailed overview of risk elements which are relevant for investors in RES-E projects is given in Table 4.2. This overview includes a selection of measures which can be taken to minimise these risks.

For generators trading in green electricity, the following risk sources which directly affect prices (besides other risks mentioned) can be distinguished:

- price development of electricity which is determined by supply and demand of electricity as well as by fossil fuel prices;
- price development of green certificates which is determined in part by supply and demand, but to a large extent also by changes in government policy, subsidies and regulation.

Uncertainties in price developments due to supply and demand are relatively easy to quantify and translate into a risk premium based on historic developments. Fluctuations in prices due to developments on the world's fossil fuel market are more difficult to capture, but a tradition for this has been developed and can be incorporated through different scenarios. Also, for the value of green electricity, such developments are probably of lesser importance.

The most important and most difficult source of uncertainty, in particular for the long-term, concerns the role of government policy. This is most likely to change, as can be learned from the past, but it is difficult to predict when, in what direction and to which extent. However, for the value of green electricity these developments can be crucial.

Table 4.2 Overview of risks with which an investor in renewable electricity is confronted when his installation is in operation.

Note: For every risk we have indicated whether the generator can influence this risks and which measures he can take to limit the risk (within the company or externally on the market)

Type of risk	Description of the risk	Can be influenced	External measure	Internal measure
Operational risks	imbalance in delivery to the grid	yes	outsource load balancing	planning & management load forecasting
	larger maintenance	yes	guarantees equipment supplier	Maintenance strategy
	lower plant availability	yes	guarantees equipment supplier	load management apply conservative budgeting
	lower generation efficiency	yes	guarantees equipment supplier	optimise apply conservative budgeting
Market risks	lower demand	partly	hedging pricing policy	market monitoring marketing pricing policy
	higher fuel purchase prices	yes	contract length & conditions hedging	market monitoring purchase policy
	lower market prices	yes	ditto	market monitoring pricing policy load forecasting
	new entrants	no	ditto	market monitoring
Regulatory risks	change in renewable energy policy	no	long-term contracting fixed pricing	apply risk analysis monitor value-at-risk profit requirements rate of return requirements
	changes in specific regulation	no		
	decrease in financial support	no		

4.1.4 Relevance of risks in buying green energy

Buyers of green energy, such as green suppliers for voluntary demand or suppliers with a government obligation to buy and sell a certain amount, are confronted, like investors in projects, with risks. However, the risk profile can be different. First of all, buyers of green energy are likely to be exposed to risks of the wholesale market for electricity (or heat or gas). Also, regulatory risks due to changes in government policies related to price support of RES apply as well and are equally important and dominating.

In addition, however, green suppliers also face risk on the retail market. This risk is in part determined by changes in government policies to promote and support RES and in part by the dynamics of the retail market. Considering the liberalisation process of the energy market, risk on the retail market can be expected to increase in the near future compared with the present situation. Driving forces for this risk are:

- switching behaviour of customers
- increased competition between suppliers
- new entrants in the market.

The short-term dynamics of developments on the retail market (in e.g. prices, market share, customer preferences) may impose conflicts with the current situation to contract renewable electricity in long-term contracts.

When furthermore regulatory risk comes on top of retail market risk, green suppliers have to consider a suitable bidding and pricing strategy to close long-term contracts with generators. Otherwise their profit-at-risk (PaR) may run out of control and a potential loss-making situation can emerge if certain risks become reality in the future.

4.1.5 Why risks influence cost

On the one hand, the heart of entrepreneur-ship is that there is no financial return without associated risks. On the other hand it does not make sense to take risks if there are no expected returns that can be envisaged are negligible.

The level of risk that a project developer is able and willing to absorb depends on many factors and is difficult to judge. They entail evaluation not just of economic capital capacity, but also liquidity considerations, tolerance for earnings volatility, creditor and shareholder awareness of and tolerance for risk-taking, management capacity to maintain business investment plans, and even on occasion, regulatory acceptance.

Project risk does not come without a price. Project developers have higher financial demands in case of high risk projects, which leads to a risk premium for the energy produced. Bankers, who run the risks that their loans or interested cannot be paid by the borrowers, will charge more for the debt capital they provide or they may require a lower debt to equity ratio.

Long-term subsidies offered by the government may reduce the project developer’s risk considerably, which can even result in a lower subsidy level.

The risk premium is not always made explicit, but is a result of another approach adopted by project developers. For higher risk level a higher rate is used for discounting the future cash flows. Thus, the future cash flows have to increase to obtain the same net present value, which can only be realised when the energy is sold at a higher price.

4.1.6 The relation between support mechanism and project risk

It is generally accepted that risk levels are reflected in the cost of capital required for funding renewable projects. There are two main reasons for this observation:

- Higher project risks limit the amount of debt that can be raised for a project. In general equity is more expensive than debt
- Higher project risks imply that equity providers require higher returns in the project

In the ***Green*-X** project the WACC (Weighted Average Capital Cost) is used as measure for the cost of capital. WACC is composed of the debt interest rates and required returns on equity.

The two predominant support mechanisms in the EU are:

- systems where a guaranteed feed-in tariff is paid for renewable electricity for a period of time
- generators receive TGCs when RES-E is fed into the grid. These TGCs may be sold in the market to (i) offset a RES-E quota obligation or (ii) to provide buyers of electricity with certified green electricity.

In case of feed-in tariffs, the government takes over an important part of the risk a generator faces. A generator receives a fixed price (guaranteed by the government) for the power he generates during a usually fixed period. The height of the feed-in tariff is set by the government and generally determined such that the generator is able to make a reasonable profit taking into account the reduced risk he is exposed to.

In case of a TGC scheme, the price a generator can get for the renewable electricity produced is not fixed. Instead the price is determined by the demand in the market for renewable electricity, which can either be an artificial demand created by either a RES-E quota obligation or by creating generous price conditions for consumers of renewable electricity. The market conditions are reflected in price uncertainty, but the financial return of generators is not limited by price level set by the government. The largest risk a generator faces is the regulatory risk because the market conditions can dramatically change, e.g. in case the governments changes future targets, or new entrants of competing RES-E generators enter the market with competing price offers.

In general it is seen that the cost of capital in TGC markets is higher, because:

- Maximum debt is limited because cash flows are less secure.
- Investors require a higher risk premium because the expected project returns are less certain.

As participants (banks, investors, etc.) build up experience with the market conditions, confidence in the system may grow leading to a decrease in the required risk premiums.

4.2 Evaluation of RES-E policies

In the following, instruments with a clear and direct focus to promote an increased deployment of RES-E are analysed briefly. Thereby, the argumentation derived from the theoretical analysis will be underpinned by simulation results gained from appliance of the computer model ***Green*-X** (mainly on country level).[59] To facilitate understanding these illustrative examples are depicted in boxes, separate from the main text.

4.2.1 General observations

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. Such aspects of importance are discussed in a topical order in the following.

4.2.1.1 Beneficial conditions for investors and stakeholders

- *Appropriate financial support*

  A minimum support level is necessary to overcome economic barriers and, hence, to attract an appropriate number of new investors to the field. The required financial incentive mainly depends on the generation costs of the considered RES-E option. Thereby, the impact of risk differing by promotion instrument in general and its design in detail (e.g. guaranteed duration of financial support) has to be taken into account.

- *High investor confidence*

  The lack of a long-term policy perspective has been and is still one of the main barriers to a stronger deployment of renewable electricity. The effectiveness of various RES-E support schemes largely depends on the stable long term planning security provided by the system. A sta-

[59] Note some of the theoretical investigations – neglecting dynamic effects – had been conducted in a previous EU research project - namely *El*Green (Huber et. al., 2001) – and were extended herein to take into account dynamic considerations and more detailed investigations.

ble planning horizon is important to create a sound investment climate and to lower social costs due to lower risk occurring for investors. Investor confidence depends on the expected continuity of the scheme influenced by its political foundation. Long-term stability, especially for independent power producers, is important to offer an acceptable risk-return profile.

- *Simple and transparent design and implementation*

  A support scheme that is transparent and easy to understand and handle ensures low transaction costs for developers and investors as well as low administrative costs of public bodies.

- *Continuous RES-E policy*

  A continuous and mid to long-term oriented energy policy scheme is important

  – to attract the interest of potential investors in RES-E technologies;

  – to increase the confidence of bank institutions, leading to lower interest rates for loans for investments (risk premium);

  Such a policy can be implemented, for example, by defining long-term RES-E targets (such as those implemented in the UK or Germany). Accordingly, also every fundamental change of the promotion policy causes a leap time in RES-E deployment as project investors / developers have to get familiar with the new instruments and regulations applied.

4.2.1.2 Beneficial conditions for society and policy

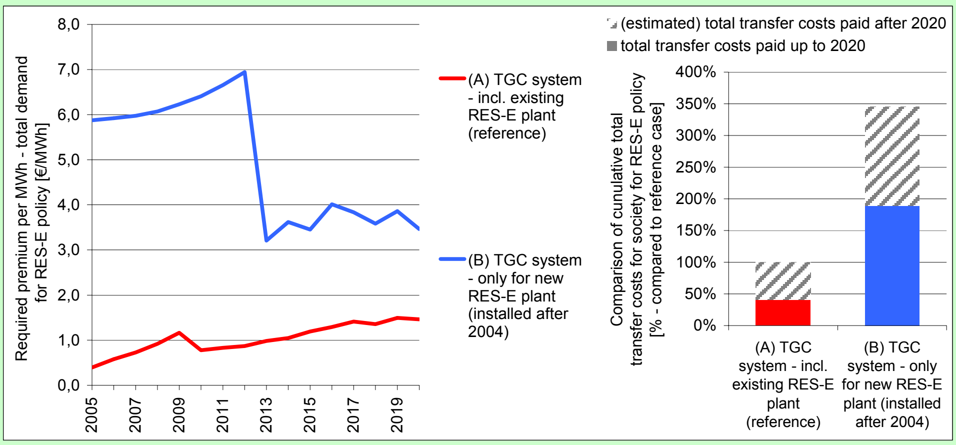
- *Low premium prices (due to the RES-E policy) for power consumers*

  To avoid an over-subsidising of RES-E represents a crucial task for policy maker. It is necessary to keep societal transfer costs as low as possible and, consequently, to ensure a high public acceptance for the applied RES-E policy. Lower generation costs of RES-E should be reflected in prices paid by consumers. With respect to the costs for society, the careful design of the strategy is at least as important as the question of which policy instrument should be implemented.

  The following design criteria help to bring down costs for consumers:

  – Within any support mechanisms, **existing and new capacities should not be mixed**. Support should no longer be provided to plants that are fully depreciated or those that were adequate financially supported in the past;

Box 4.1 Transfer costs for society including / excluding existing capacities in a new promotion scheme



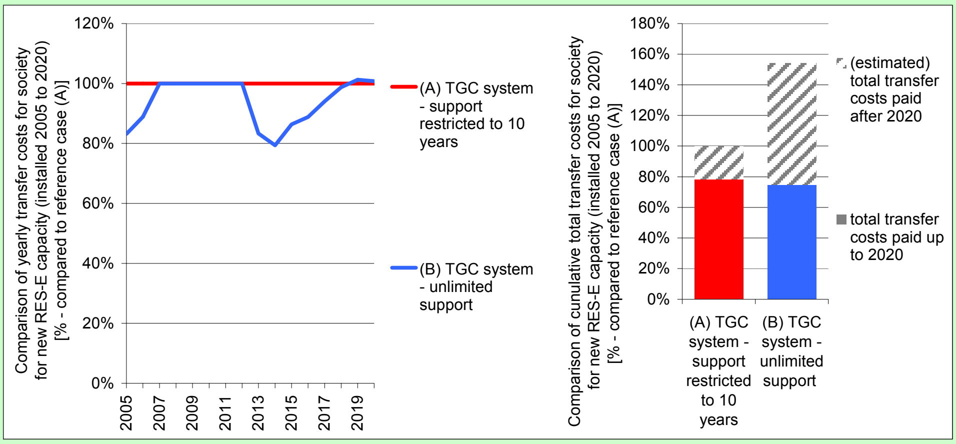
The figure above shows the impact of including / excluding existing RES-E plant in a promotion scheme on resulting total transfer costs for society. In this illustrative example it is assumed that a

TGC-system (covering all RES-E options) is introduced in 2005 in France in order to achieve a rather moderate RES-E target of 19% (on total demand) in 2020. Two variants are investigated: (A) applying the new promotion scheme only to new capacities (installed after 2004) and keeping the already existing ones in their old scheme; and (B) including in the new TGC-system both new and existing plant.

The resulting impact can be interpreted as dramatic: The necessary transfer costs – expressed as premium per MWh total demand for the period up to 2020 on the left-hand side in the figure above – are more than three times higher during the whole period if existing plant are included in the new scheme. Taking into account also the (estimated) residual costs for the years after 2020 a similar result occurs: As depicted on the right-hand side total transfer costs are in size of more than 350% compared to the reference case where the new policy is solely applied to new to-be-built capacities.

– The **time frame for a particular financial support mechanism should be restricted.** The duration should depend on the policy instrument (e.g. development of the TGC price), on the maximum of yearly transfer costs (due to RES-E policy) that can be imposed on society, and on the dynamic of the RES-E target (over time). In addition, it also depends on some characteristics of the envisaged technology, such as their maturity. This means that the level of maturity of the technology (learning curve) should also be taken into account;

Box 4.2 Transfer costs for society in the case of a restricted duration versus an unlimited support



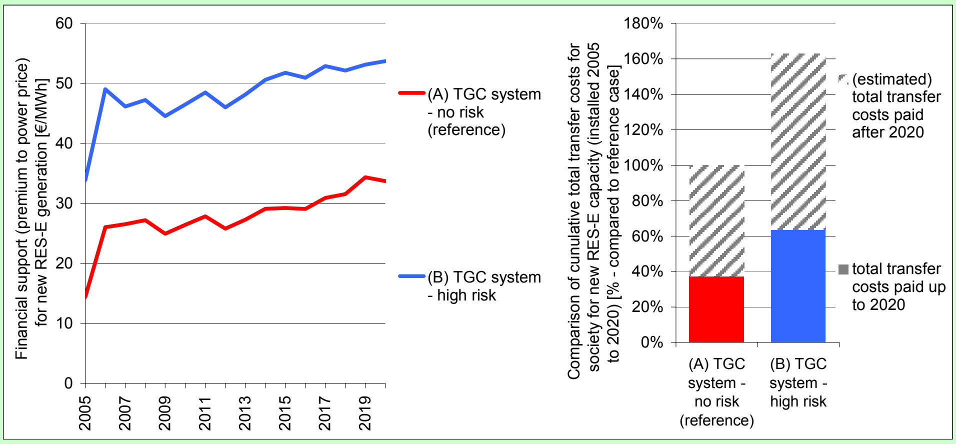
This example illustrates the effects of restricting the duration of financial support versus providing support over the whole lifetime of a RES-E plant. Assuming a TGC-system is introduced in 2005 in Germany for the promotion of new RES-E capacities to achieve a comparable ambitious RES-E target of 24% (on total demand) in 2020. Two variants are investigated: (A) restricting the duration of support to the first 10 years of the lifetime; and (B) granting unlimited support - i.e. a case where RES-E producer are allowed to produce and sells TGCs during the whole lifetime of their plant.

On the left-hand side the dynamic development of the necessary transfer costs for society up to 2020 is shown – expressed as premium per MWh total demand. Due to the fact that support can be received over a longer period in case of variant (B), bid prices of RES-E producers and, consequently, societal transfer costs are slightly lower compared to variant (A) in the early years. Hence, in the later phase societal costs rise as a higher amount of RES-E has to receive support. Hence, for this illustrative case total costs as depicted on the right-hand side of the figure above are by roughly 50% higher if support is not restricted to a certain period of time.[60]

– **Provide a stable planning horizon**. The lack of a stable planning horizon increases the risk for potential investors and, hence, increases the costs for society (significantly) due to the higher necessary internal rate of return demanded by investors.

[60] Although cumulated transfer costs up to 2020 are in case of unlimited support (variant (B)) by 5% lower compared to variant (A) with the restricted duration, but taking into account also the (estimated) residual costs for the years after 2020 (i.e. the dashed bars on the right-hand side of the figure in Box 4.2) the situation changes dramatically: Total transfer costs are for variant (B) more than 50% higher compared to variant (A).

Box 4.3 Transfer costs for society in the case of stable versus an unstable planning horizon



The figure above shows the impact of providing a stable verus an unstable planning horizon on resulting total transfer costs for society. Assuming a TGC-system is introduced in 2005 in Sweden with a rather moderate RES-E target for 2020 in size of 8% (on total demand) for electricity produced by new RES-E capacities (installed 2005 to 2020). Two variants are investigated: Variant (A) represents the case where a stable planning horizon is provided; and variant (B) which is characterised by unstable conditions from an investors point-of-view. Within the simulation runs the stability of the planning horizon is described – in accordance with section 4.1 and 6.2.4 – by differing weighted average cost of capital (WACC) applied in the database for new RES-E options. In principle, these WACC's illustrate the differing risks of potential investors. More precisely, for variant (A) the default figure of 6.5% is used, whilst for variant (B) the WACC is set to 12%.

The resulting impact can be interpreted as huge: Financial support (i.e. the required premium to power price) for new RES-E generation is 60 to 90% higher during the investigated period up to 2020 (see left-hand side of figure above) in case of an unstable planning horizon. Consequently, total transfer costs as expressed on the right-hand side above increase by roughly 60% compared to the reference case.

– **Admitting least cost technology options of RES-E** may contribute to reduce the additional transfer costs for society. For example, co-firing of biomass in thermal power plants or retrofit of large-scale hydropower plants are two of the commercially most interesting cost-efficient options. From a society point-of-view the use of the full basket of available RES-E technologies is highly recommended. The effects of neglecting some technologies – especially 'cheap' options – increase both generation costs and costs for society.[61]

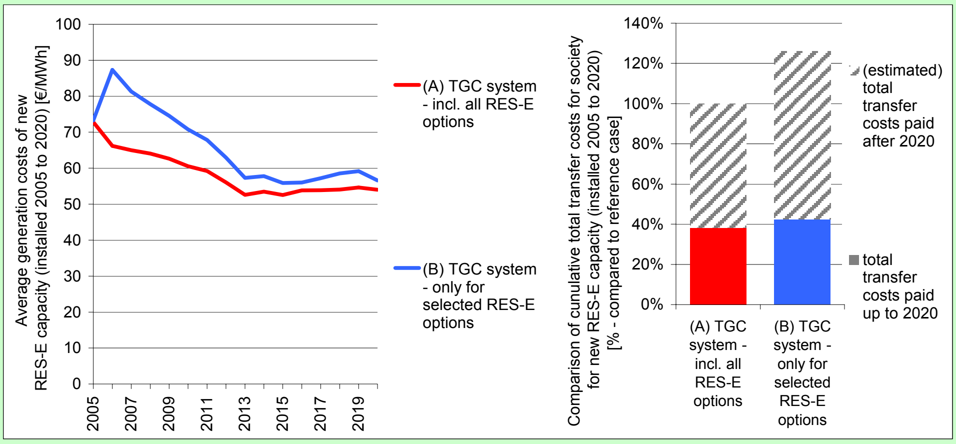
Box 4.4 Effects of including / excluding least cost RES-E options (i.e. co-firing of biomass, biowaste and large hydropower) in a TGC-system

The example below describes the effects of admitting least cost RES-E options (i.e. co-firing of biomass, biowaste and large hydropower) in a TGC-system compared to the case where these technology options are excluded. Thereby, it is assumed that a TGC-system is introduced in 2005 in France with a rather ambitious RES-E target for 2020 in size of 11% (on total demand) for electricity produced by new RES-E capacities (installed 2005 to 2020). In more detail, variant (A) refers to the case where these options are included; whilst variant (B) describes the case where they are excluded.

On the left-hand side of the figure below the dynamic development of the average generation costs of new RES-E capacities (installed 2005 to 2020) is depicted. As long as the potential of these cheap options is not fully exploited, generation costs are on a higher level if they are excluded from the promotion system (as described by variant (B)). In the long run, differences on average costs become comparable small. A similar result occurs for total transfer costs: As depicted on the right-hand side of the figure below total transfer costs are – in order to achieve a similar RES-E target – by roughly 25%

[61] But be careful to support only new capacity, otherwise the inclusion can be counterproductive, e.g. including (large)-scale hydro power plants instead of supporting the retrofit of old plants only.

higher if support is restricted to only a set of RES-E options, where especially cheap options are excluded and hence, consequently, contribute much less to achieving the overall target.



– **Applying differentiated tariffs or support prices to different RES-E technologies** might decrease the cost of reaching a certain amount of RES-E due to different supply costs between the technologies, i.e. the cheaper technologies can be promoted by a lower tariff.[62] The impact of considering / neglecting technology-specific support is explained e.g. in Box 4.8

- *Increasing public acceptance of RES-E technologies*

  In the medium to long-term, the public acceptance of RES-E technologies represents one of the driving forces behind a continuation of RES-E deployment. As they have to bear the additional costs occurring by the extension of RES-E capacity policy makers sensitively react on the society's acceptance. The support schemes as well as their design, influence the public acceptance of RES-E technologies significantly. Some support schemes hinder, while others facilitate the acceptance of renewable technologies. In general, the following issues influence the acceptance:

  – Additional costs for RES-E paid by the final consumer, which depends on the RES-E targets, the support scheme, the design and the administration costs as well as the transparency of these costs
  – The stability of premium costs to consumers over time. If transfer costs increase abruptly, pressure to change the promotion strategy (or the announced and planned RES-E targets) will increase. Such conditions lead to a lower stability and confidence in the system, with the consequences of higher risk (and, hence, higher costs for society)
  – Investment structure (public and regional involvement)
  – Portfolio of RES-E technologies (a broad mix of technologies better than full development of a certain technology)
  – Regional distribution of RES-E technologies (harmonised distribution within a country versus hot spots in development at a national or international level)
  – Regional side-effects, such as encouragement of local and regional development, employment and income generation
  – National energy and environmental benefits, such as greenhouse-gas reduction and higher security of supply

[62] In the case of a feed-in tariff and – to a less extent – for a tender scheme, the creation of a technology specific support does not represent a huge problem in practise. In the case of a TGC-system the application of separate quotas for different RES-E technologies only makes sense if the market volume is big enough. However, applying a technology specific setting requires a benchmarking process, which is not easy to implement and costly.

- A transparent and continuous RES-E policy helps to strengthen public awareness of energy and sustainability issues;

- *Encouraging local and regional benefits*

  The development of RES-E technologies has a significant impact on local and regional areas, both due to their installation and manufacturing – of course, these impacts like employment, rural development etc. differ by RES-E technology. Avoiding a stop-and-go policy will help to build up a national RES-industry.

- *High effectiveness in deployment of RES-E*

  A particular scheme should be fast and effective in increasing the capacity of renewable energy technologies.

4.2.1.3 Beneficial conditions for the market

- *High conformity with the power market and with other policy instruments*

  EU member states are to an increasing extent liberalising their power markets, and new policies such as emissions trading, and other Kyoto instruments will be introduced in the EU. The RES-E policy scheme should be compatible with, or at least should not hinder the integration of the liberalised power market, and its effectiveness in functioning together with existing and new policy instruments. In general, the following criteria should be considered:

  - Free entrance to the grid
  - Free entrance to the power market (no discrimination)
  - No distortion for new entrance with respect to administrative procedures
  - Equal burden on all suppliers (utilities) or consumers in a country

- *Separation of support schemes in the transition process*

  In practice it is unavoidable that over a long-time horizon support schemes for RES-E have to be adapted or replaced by other promotion mechanisms. The transition phase between the new support scheme and the replacement of the existing one is important as distortions may occur. In this respect the following should be taken into account – see also Figure 4.2:

  - A clear starting point for a new support scheme has to be defined. From then on, during the transition period two independent schemes should exist in parallel. This issue may be in conflict with administrative simplicity and low transaction costs.
  - All new and retrofitted capacities, but no existing capacities should be included into the new scheme.
  - The support for already existing plants should be phased out continuously over time. This means that there is no need to change the strategies for existing RES-E capacity. Note, it is important to keep the old support scheme for not fully depreciated RES-E capacity otherwise instability of the planning horizon with its negative effects like higher costs (due to higher risk premiums), lower installed capacity etc. occur.

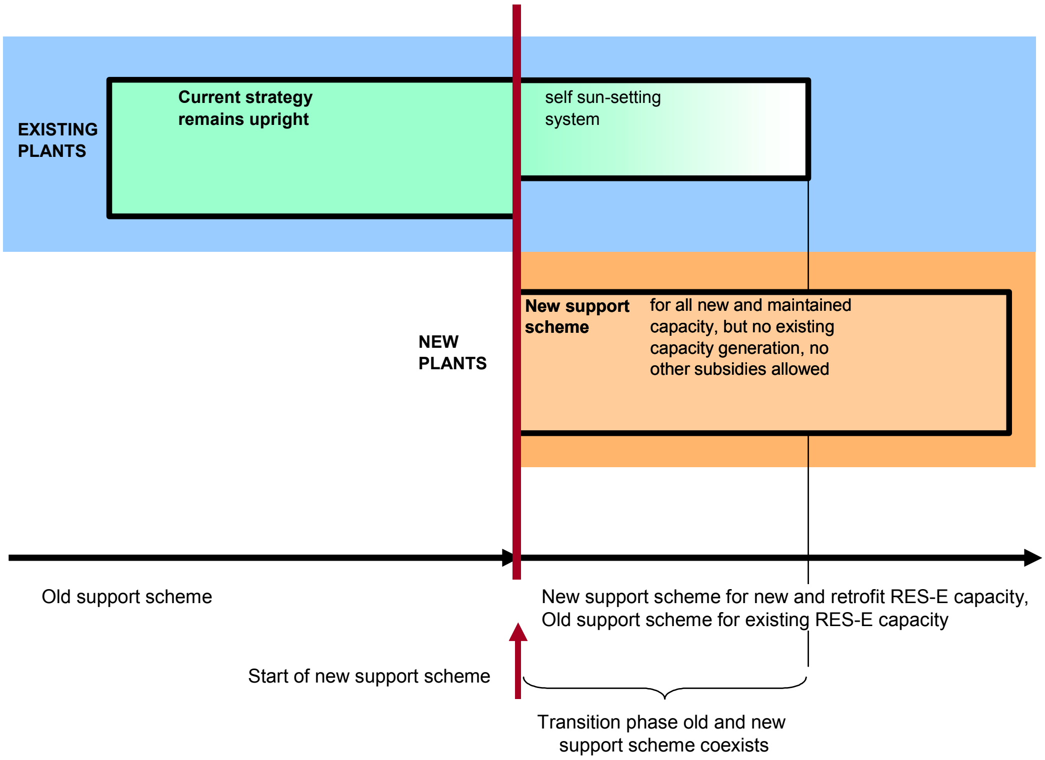


Figure 4.2 RES-E support in the transition period

4.2.1.4 Beneficial conditions for long term strategies and technological development

- *Comparable support provided for a diverse range of technologies*

  Some support schemes tend to support only the cheapest, more mature RES-E technologies disregarding the development of innovative, initially more expensive RES-E technologies. However, in the long-term these novel technologies can play a significant role. In this context, the following issues should be considered in the design of a new support scheme:

  – The promotion of currently less cost effective technologies helps to reduce generation costs in the long term as costs may drop (significantly) due to technological learning / progress (learning by doing, learning by using and economics of scale);

  – The RES-E support structure should also be directed to support small-scale projects, as these small-scale projects – with a rather short lead-time – could contribute crucially to increase RES-E capacity in the short-term, entail additional benefits related to distributed generation and, hence, reduce capacity shortage in the electricity supply. Of course, in general, costs for small-scale projects are comparably higher than for large-scale;

  – It is useful to build up a broad portfolio of different technologies. The preparation of market conditions for less matured technologies is essential, especially if the policy target is ambitious. Small-scale projects demonstrating the utilisation of these technologies are helpful to increase experience and confidence in new technologies and, consequently, path the way for market maturity (necessary for financial risk assessment, learning from administrative burdens, etc). E.g. Box 4.11 illustrates the impact of this issue on transfer costs for society.

- *Encouraging lower manufacturing costs*

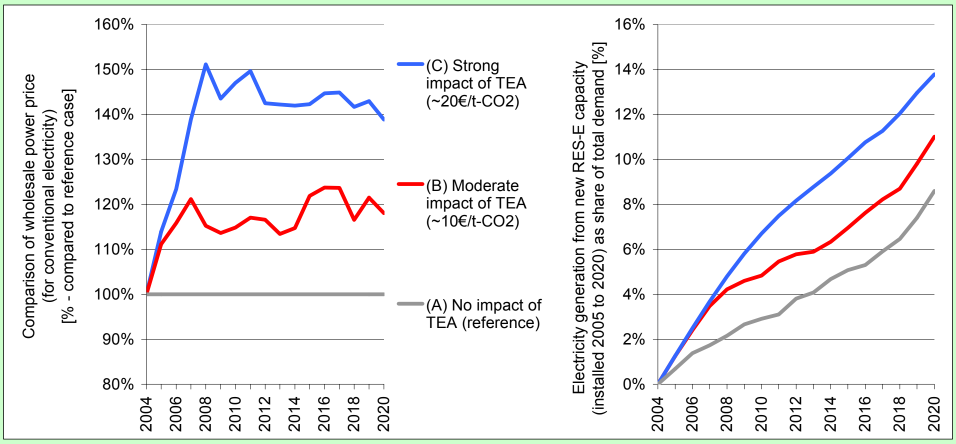
  In the longer run, it is the objective to make renewable technologies fully competitive with conventional ones. Therefore, a particular scheme should encourage competition among manufacturers, so helping to drive down the costs of RES-E. In a dynamic context (at least) two options exist:

– Support current already most cost-efficient technologies: Following this strategy no support for these technologies should be necessary in the future;
– Promote currently less cost-efficient technologies: In this context, a high decrease of investment costs seems likely in case of less matured technologies.[63] Consequently, this will lead to lower system costs in the future.

- *Integration of other policies*
  – **Climate policy**

RES-E and climate policy are closely linked with each other. One the one hand, RES-E policy has a positive impact on GHG emissions. On the other hand, a strategy for GHG reduction leads generally to an increase of the costs of conventional power and, consequently, increases the economic efficiency of RES-E and, in addition, reduces the societal transfer costs due to the promotion of RES-E.

Box 4.5 The impact of TEA on RES-E deployment (due to an increase of the wholesale price on the conventional power market)



This example illustrates the (indirect) impact of a climate policy based on tradable emission allowances (TEA) to achieve a reduction of GHG emissions on RES-E deployment. Thereby, Spain has been selected as a country case – taken from the BAU forecast as presented and discussed on a European level in chapter 6. This BAU-forecast describes the development of RES-E under the assumption that currently implemented policies remain available (without any adaptation) until 2020.

In general, TEA have an indirect impact on RES-E deployment due to an increase of the wholesale price for (conventional) electricity – which leads to an increased competitiveness of RES-E options on the electricity market. For a country like Spain, where currently RES-E are promoted via a premium-FIT scheme – i.e. where RES-E producer receive a guaranteed premium tariff in addition to the revenues from selling the electricity on the conventional market – the increase of the wholesale price is directly reflected in a higher financial incentive for RES-E.

In more detail, three variants have been investigated: (A) represents the reference case where no impact of TEA on the future development of electricity prices can be observed. Variant (B) describes a moderate impact of TEA on the electricity price – i.e. where within the emission trading scheme a certificate price of roughly 10 € per ton CO_2 occurs. Finally, variant (C) is based on a price assumption of 20 €/ton-CO_2 within the market for TEA – equal to a strong impact on future electricity prices.

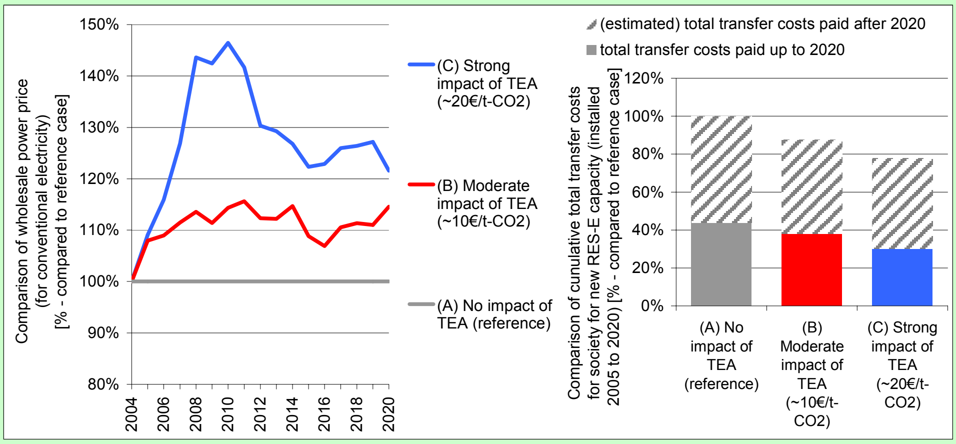
The impact on the wholesale power price for the period up to 2020 is illustrated on the left-hand side above. As there can be seen, for Spain a moderate impact of TEA is characterised by a price increase in size of roughly 20% over the investigated period compared to the reference development. In contrary, a assuming a strong impact TEA would occur, prices would rise by 40 to 50%.

[63] In general, less matured technologies are characterised by higher learning rates (compared to already matured options). In addition, following the approach of technological learning, less deployment (in terms of capacity) has to take place to achieve a doubling of installed units.

The resulting impact on RES-E deployment is shown on the right-hand side of the figure above. In the reference case electricity generation from new RES-E capacities (installed 2005 to 2020) achieves a share on total demand in size of 8.6% in 2020. For variant (B) this share rises to 11% and, hence, for variant (C) a share of 13.8% occurs.

In contrast to the 'extreme case' of Spain (due to the direct impact of TEA-prices on the financial incentives for RES-E) on a European Union level, in particular for the EU-15, the impact of TEA on RES-E deployment is not as impressive: For the EU-15 the reference case shows a share of 12% (electricity generation from new RES-E capacities (installed 2005 to 2020) as share of total demand in 2020), whilst assuming a moderate impact of TEA RES-E deployment rises to 12.5% and, finally, a strong impact of TEA results in a share of 13.2%.

Box 4.6 The impact of TEA on (additional) transfer costs for society for (direct) RES-E policies



This example illustrates the (indirect) impact of a climate policy based on tradable emission allowances (TEA) to achieve a reduction of GHG emissions on the (additional) transfer costs for society due to the (direct) promotion policies for RES-E. Thereby, similar to Box 4.5 (see above) a country case – i.e. Germany – is taken from the BAU forecast as presented and discussed on a European level in chapter 6. This BAU-forecast describes the development of RES-E under the assumption that currently implemented policies remain available (without any adaptation) until 2020.

In general, TEA have an indirect impact on transfer costs for society (related to direct promotion policies for RES-E) due to an increase of the wholesale price for (conventional) electricity – which helps to reduce the gap in terms of costs / prices between RES-E and conventional options. For a country like Germany, where currently RES-E are promoted by feed-in tariffs the increase of the wholesale price is directly reflected in a lower burden for the society due to the promotion of RES-E.

Again, three variants have been investigated: (A) represents the reference case where no impact of TEA on the future development of electricity prices can be observed. Variant (B) describes a moderate impact of TEA on the electricity price – i.e. where within the emission trading scheme a certificate price of roughly 10 € per ton CO_2 occurs. Finally, variant (C) is based on a price assumption of 20 €/ton-CO_2 within the market for TEA – equal to a strong impact on future electricity prices.

The impact on the wholesale power price for the period up to 2020 is shown on the left-hand side of the figure above. For Germany a moderate impact of TEA is reflected in a price increase in size of on average 11% over the investigated period compared to the reference development, whilst a strong impact TEA is characterised by price increase in size of 30% in the short term, dropping to roughly 25% for the second decade up to 2020..

The resulting impact on transfer costs for society – due to the applied RES-E policy for new RES-E capacities (installed 2005 to 2020) – is shown on the right-hand side above. Compared to the reference case total costs decrease to 85% for variant (B), whilst for variant (C) these societal costs drop to a level of 78%.

In contrast to the 'extreme case' of Germany (due to the direct impact of TEA-prices on societal transfer costs for RES-E policies), for the EU-15 the impact of TEA is not as impressive: Assuming a moderate impact of TEA societal costs drop to 93%, and a strong impact of TEA results in a decrease to a level of 87% - both compared to the reference case (i.e. no impact of TEA).

– **Agricultural policy**

  Integration of agriculture and energy policies is one element that might largely enhance the opportunities for biomass. The formal integration of agricultural and energy policy, if supported at the highest level, could assist a more rapid deployment of affordable RES

– **Lower energy consumption**

  The achievement of most policy targets for RES-E as well as the accompanying societal costs is closely linked to the development of the electricity demand. Therefore, besides setting incentives on the supply-side for RES-E, accompanying demand-side measures would help to minimise the overall societal burden.

– **Industrial policy, employment policy, rural and regional development.**

  Of course, energy policy should be linked to other policy issues like industrial and regional development, employment, etc..

Note that some of the above mentioned criteria are in conflict with other issues. Therefore, compromises and cut-backs are necessary to reach an appropriate overall solution.

4.2.2 Evaluation of a feed-in tariff scheme

4.2.2.1 Introduction

Feed-in tariffs (FITs) permit independent producers of RES-E to feed (export) electricity into the grid and to receive therefore a minimum price (the feed-in tariff), usually for a specified period of time. Such tariffs should in theory relate to the long-term marginal generation costs and are set by a regulatory authority.[64] Usually the feed-in tariffs differ between various technologies, depending on the different production costs.

One core argument for feed-in tariffs is to reduce the financial risk of independent power producers by guaranteeing a secure revenue for them over a specified period, e.g. 10 or 15 years.

The amount of electricity generated from RES will depend mainly on the magnitude of the feed-in tariff and its guaranteed duration. Of course, if the tariff and its guaranteed duration are both set high enough, the policy instrument gives a strong incentive to invest in RES. If it is low, only a moderate expansion can be expected.

4.2.2.2 Main conclusion

The main conclusions with respect to the application of a guaranteed tariff scheme are:

(a) Proven to be successful and effective

  FITs have been successful for triggering a significant increase of RES-E technologies in almost all countries where they have been introduced.[65]

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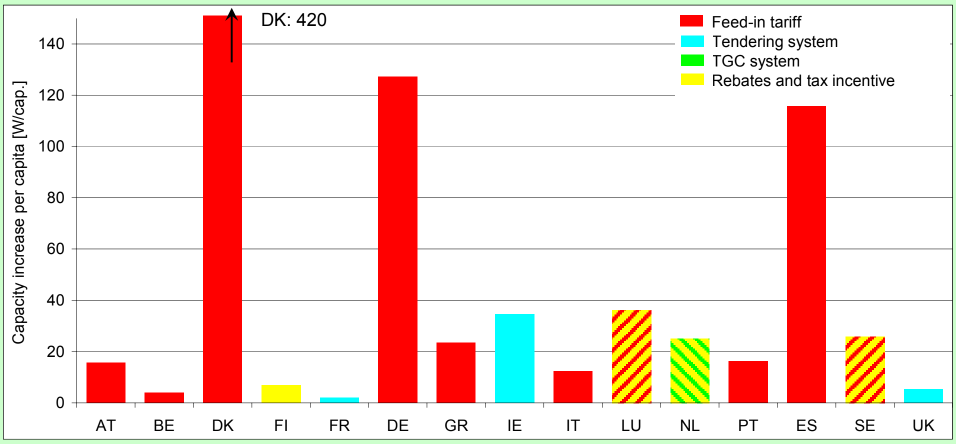
[64] In some cases feed-in tariffs are designed to reflect not only long-term marginal generation costs, but also a ‘reasonable profit’ in order to make it particular attractive to invest.

[65] With the exception of Greece – a country where RES-producer have faced comparable high administrative barriers in the past.

Box 4.7 Comparison of historical wind deployment in countries with FITs vs. other promotion instruments



Please note, this illustrative example is not based on a simulation run of the **Green-X** *model. It represents an outcome of the evaluation of empirical data.*

The figure above shows the increase in wind plant capacities in the period 1997 to 2002 in EU-15 countries. As there can be seen – indicated by the red bars above – FITs have proven to be successful in promoting wind energy in utmost all countries where they have been applied.

Source: Eurostat (2003), own investigations.

(b) RES-E target cannot be exactly reached - flexible in use and time

A guaranteed tariff system can be applied in a flexible way by adapting the tariff level for new contracts over time (e.g. on a yearly basis), is relatively easy to install and to replace. This is important for changing (e.g. harmonising) the RES-E policy as the conditions for the transition period are easy to implement. However, a given RES-E target cannot be exactly reached as the incentive refers to the supply and not the demand.

(c) Low (to medium) administration and transaction costs

In general both administration and transaction costs are low. Nevertheless, administration efforts rise with an intensive benchmarking of RES-E to define the 'correct' tariff levels. Consequently, administrative (as well as transaction) costs might rather rise to a medium level in case of a complex tariff scheme.

(d) Does not encourage competition among investors

One disadvantage of a feed-in tariff scheme is that it does not encourage competition among the investors in the early phase, i.e. as long as enough low cost (potential) options are available.[66] On the one hand the full potential of cost reduction of the single components will not be fully used and on the other hand the gap in the investment cost reduction will be – to a certain extend – compensated by an increase of other 'additional' costs (e.g. rent and lease costs) due to strategic reactions of other involved groups (e.g. farmers). Hence, it does not force the full reduction in the unit price of electricity.[67]

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[66] For example if enough good wind sites with high wind speeds are available.

[67] Costs could be reduced to a higher degree if the feed-in tariff scheme were designed in such a way that the guaranteed tariffs decrease over time. For more detail see point (g).

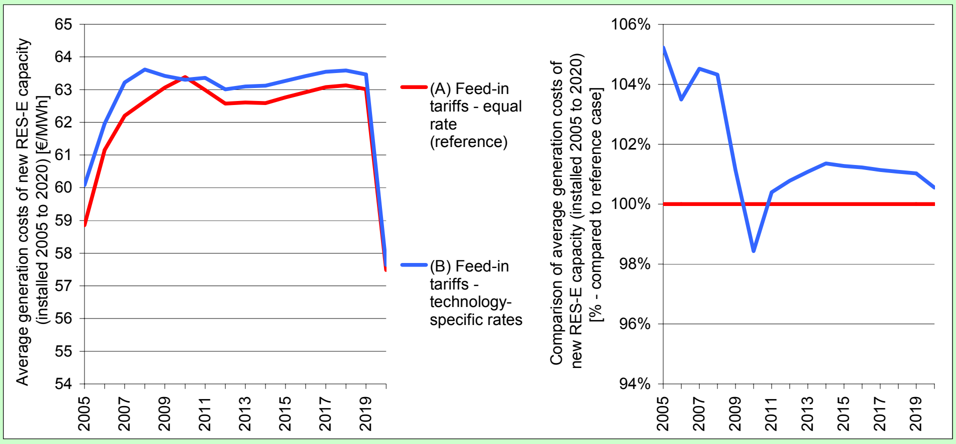
(e) Helps to develop high-quality components

In the case where a longer duration of the tariff is guaranteed, e.g. 20 years in Germany, the development of components with a higher technical efficiency or a longer lifetime compared to the situation of full competition can be encouraged.[68]

(f) Does not necessarily lead to minimisation of generation costs (if RES-E specific tariffs are applied)

Under the assumption that technology-specific tariffs should be offered, total generation costs may not be minimised in the early phase of policy appliance as distortions among the different technologies may occur.[69] More precisely, where these technologies receive a too high tariff, they are 'overrepresented' in the RES-E portfolio compared to technologies receiving less support. Of course this issue depends on the technology specific tariff setting.[70]

Box 4.8 Comparison of generation costs applying technology specific versus equal tariffs



The figure above shows the impact of applying technology specific versus equal feed-in tariffs on resulting generation costs. Assuming enhanced FITs are introduced in 2005 in Italy in order to achieve an ambitious RES-E target for 2020 in size of 12% (on total demand) for electricity produced by new RES-E capacities (installed 2005 to 2020). Two variants are investigated: Variant (A) represents the case where an equal tariff is applied for all RES-E options; and variant (B) characterised by a FIT scheme where technology specific tariffs are set. Note, in both cases the overall target is met and both schemes are based on dynamically decreasing tariffs.

The resulting impact on the dynamic development of generation costs of new RES-E capacities (installed 2005 to 2020) is shown in the figure above – in absolute terms on the left-hand side and in relative terms depicting the deviation to the reference case (A) on the right-hand side.

In the short term differences are comparatively higher for variant (B) (i.e. +4% in the period 2005 to 2008) as due to the technology-specific promotion distortions among the different technologies occur – although costs are still in a similar range. Up to 2020 the differences disappear over time –resulting in less than 1% deviation in 2020.

[68] The provision of more efficient components for wind plants partly explains the low cost reduction of wind turbines in Germany.

[69] In the later phase low generation costs may occur also for initially less mature RES-E options due to the cost reduction stimulated by technological learning.

[70] Under the assumption that the less mature technologies are not supported extensively, total generation costs can be minimised too. Under this constraint the entity of a FIT is similar to a TGC system.

(g) Leads to low costs for society

Transfer costs for society can be reduced if:

(i) **Stepped feed-in tariffs are applied** (as far as possible)

Stepped FITs appear to be a proper tool to reduce the producer surplus and, consequently, the societal burden. A stepped FIT is characterised by a decreasing tariff with increasing 'efficiency' – according to a well-defined benchmark criteria which has to be defined by RES-E technology. It requires an in-depth benchmark of the technological development of each envisaged RES-E option. Stepped FITs will – of course – only be beneficial for the consumer, as premium prices due to the promotion of RES-E decrease. In the 'real' world, stepped FITs are mainly technologically determined guaranteed tariffs that are applied in order to avoid 'gold plaiting' of cheap options.

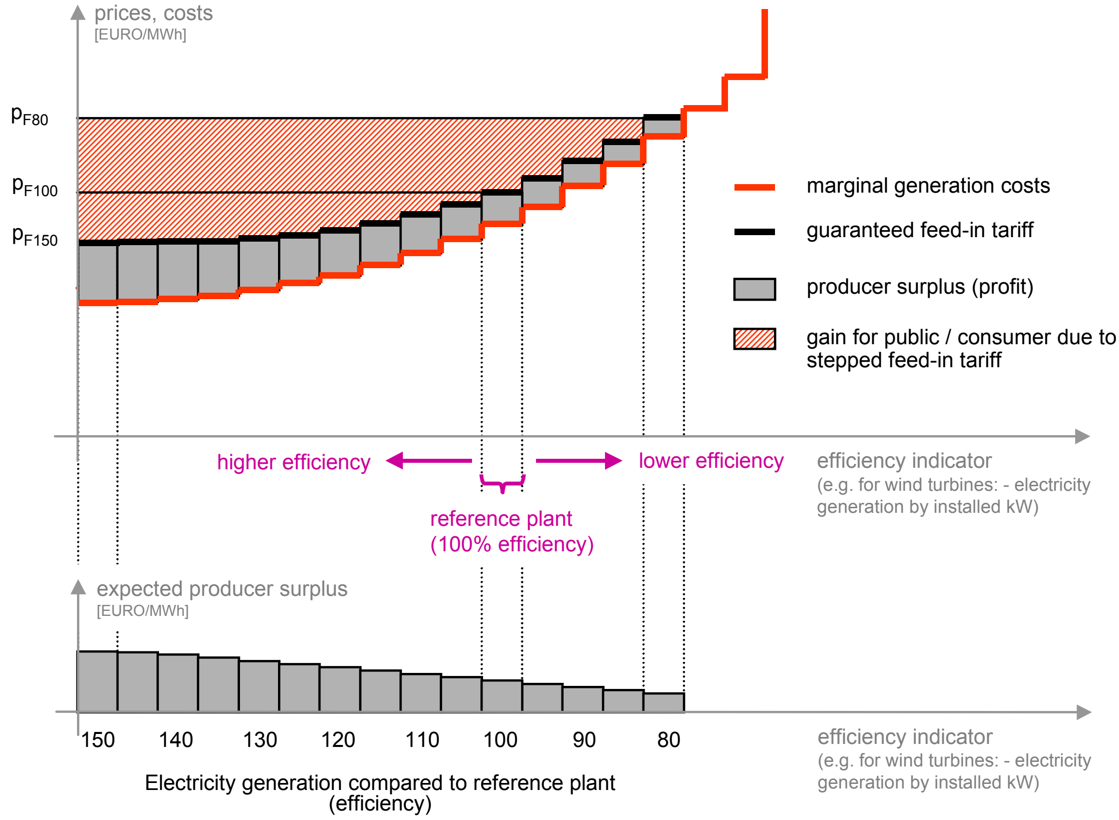


Figure 4.3 Optimal (static) incentive-compatible feed-in system

Note: lower part of figure – producer surplus according to standardised baseline; upper part – transfer of the incentive-compatible contract to the feed-in tariff scheme.

Source: Huber et. al. (2001a)

To maintain an incentive for investors to still implement the most cost-efficient options – characterised by efficient technologies, locations or / and preferable plant-sizes – the decline of the tariff for efficient plants must be less than the total revenue that can be gained if such an efficient option is chosen. In other words, the net profits must be still higher choosing most cost efficient options.

It is essential that the baseline (benchmarking the cost efficiency) of the RES-E technology can be standardised and verified to be able to apply a stepped feed-in tariff design. Depending on the technology the following baselines are feasible:

- Full load hours

- Fuel input
- Combined heat and power
- Plant-size
- Technological option
- Environmental conditions

Table 4.3 summarises possible criteria to determine the baseline conditions for different RES-E technologies. Note, for some technologies no simple and clear measurable rules can be found. For example generation costs for (solid) biomass depend on at least fuel input, plant-size and technological option. Accordingly, administration and transaction costs to determine and prove the baseline increase with the complexity of the evaluation criteria. In principle, however, it is still feasible to create an incentive compatible tariff. [71, 72] Of course, additional costs, which occur due to the expansion of tariff bands, must be weighted up carefully against the gains for consumer arising from reducing producer surpluses.

Table 4.3 Baseline options for different RES-E technologies

Technology	**Full-load hours**	**Fuel input**	**CHP**	**Plant-size**	**Techno-logical option**	**Envi-ronmen-tal con-ditions**
Biogas			X	X		
Solid biomass		X	X	X	X	
Geothermal electric-ity				X	X	
Hydro-power				X		X
Sewage / landfill gas			X	X		
Solar electricity	X			X	X	
Wave / tide	X					
Wind	X					

Box 4.9 Comparison of transfer costs for society applying a stepped versus a flat tariff for wind onshore

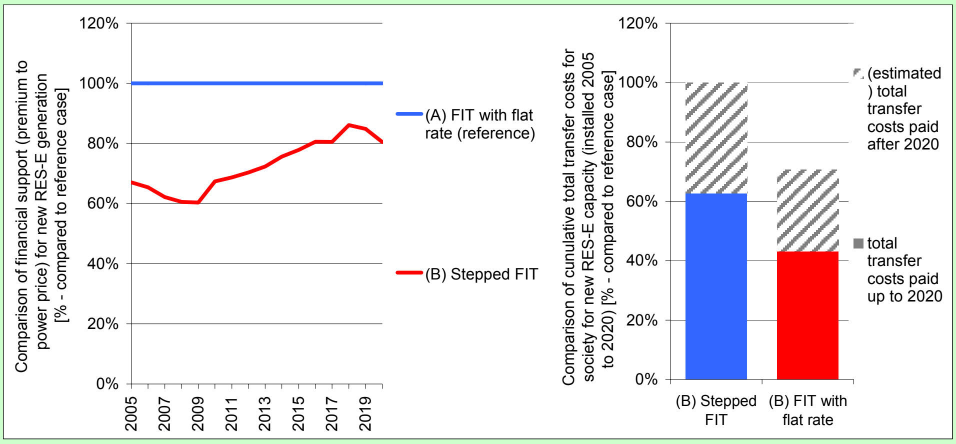
The example below describes the effects of applying a stepped versus a flat feed-in tariff for wind on-shore with respect to the resulting transfer costs for society. Thereby, it is assumed that enhanced FITs are applied in 2005 in the United Kingdom to promote wind on-shore. In more detail, variant (A) describes the case where a flat tariff is applied; whilst variant (B) refers to the case of a stepped FIT. Note, in both cases in 2020 a similar deployment of wind on-shore occurs and both schemes are based on dynamically decreasing tariffs.

On the left-hand side of the figure below the dynamic development of the necessary financial support (i.e. the premium to the power price) for new RES-E is illustrated in relative terms – depicting the deviation to the reference case (A). As there can be seen, in the short term huge differences (up to 40% below the reference) appear, which in the later phase decline to 20%. A similar result occurs for total

[71] For example in the case of biomass tariffs depends on the plant size (lower if size is high) and the fuel input (e.g. forestry production, forestry residues, agricultural products and residues (sawmill, etc.) and biowaste). In addition a distinction between CHP and non-CHP electricity generation is conceivable.

[72] In the case where only a few single sites can be applied – e.g. for hydro power or big off-shore wind parks – a tender system, where the sit, the size, the environmental and grid conditions are predetermined seems to be a better alternative. For more details see section 4.2.4 – dealing with tender systems.

transfer costs: As depicted on the right-hand side of the figure below total transfer costs are – in order to achieve a similar deployment – by roughly 30% lower if a stepped tariff is used compared to the case where a flat FIT is applied.



(ii) **Feed-in tariff rate for new contracts rate decreases over time**

This means that the guaranteed tariff for new facilities and, hence, new contracts will be adapted periodically (e.g. every year). The decrease depends on the drop of the investment costs due to technological learning. Therefore, the reduction should be technology specific and approximately in line with the learning curve of this technology. Of course, strategic reactions of the different 'agents' (manufacturer, investors, farmer, etc), which try to cover the actual cost reduction must be counterbalanced. One solution is to use an exogenous benchmark to determine the cost reduction. This means that the decline in costs is based on an international developments basis instead a national deployment.

In a dynamic environment it is important that the contracts are incentive compatible such that most efficient options are used first. This means that the structure must be design in a way that an incentive for investor exists, both over the efficiency classes as well as over time, to implement the currently most cost efficient technological generation options for each specific RES-E technology. In general, a complex scheme emerges as the following dynamic variables must be considered:

- Electricity generation costs due to technological learning
- Dynamic restriction of available yearly potential; new tariff setting over time depends on the possible yearly deployment of the RES-E technology

In the following the principle of an *advanced dynamic stepped feed-in tariff system* is explained in more detail. Figure 4.4 depicts the procedure for setting an effective and efficient stepped FIT over time.[73] For different moments of time (i.e. t_1, t_2, t_3, t_4) the guaranteed tariffs as well as the marginal generation costs (MC) for a certain RES-E technology are plotted. Thereby, four different efficiency classes (i.e. *A*, *B*, *C* and *D*) of this technology are highlighted in the drawing. *A* represents the highest efficiency class, characterised by the lowest marginal generation costs, followed by *B*, *C* and *D*. The corresponding producer surplus is shown in Figure 4.5 in dependency of the efficiency (upper part) as well as over time (lower part). It can be clearly seen that the incentive compatibility constraint to use efficient technology options is fulfilled for all moments of time as profits are higher for more efficient options compared to less efficient ones.

[73] As already depicted in Figure 4.3, a stepped FIT should be designed in such a way that the guaranteed tariff corresponds with the generation cost, i.e. a low tariff is granted if electricity production is efficient.

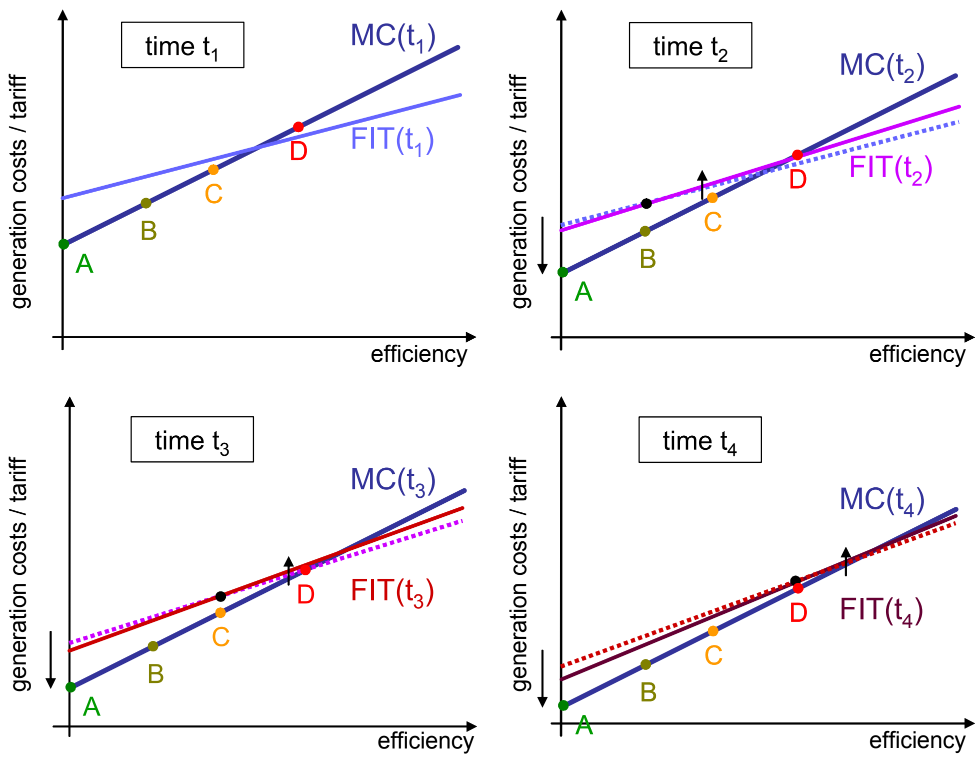


Figure 4.4 Optimal dynamic incentive-compatible feed-in system

In more detail, the setting is done as follows: The starting point as depicted in the upper part on the left-hand-side of Figure 4.4 represents time t_1. Thereby, in order to receive smooth but full penetration of a technology up to the mid-term[74], it does not make sense to promote also less efficient options in the early phase. So, a FIT is introduced which make investments up to efficiency class C profitable. Nevertheless, at time t_1 it is 'optimal' to invest in the most efficient locations first (class *A*) as producer surplus are at the maximum there.

The tariff adjustment over time is implemented as follows: For those generation options, which are more efficient than the currently optimal[75] level – e.g. at time t_2 the efficiency class *B* – the granted tariff should be reduced more than the cost reduction, which occur due to technological learning. In contrary, for the less efficient options (compared to the optimal level) the tariff should be reduced less than the decline of the generation costs. At the optimal level the tariff scheme should be changed in the same way as generation costs drop due to technological progress.

This means that for time t_2, the tariff drops more for efficiency class *A* than the (marginal) generation costs are reduced[76]. The tariff remains constant for *B* in relative terms and is reduced less compared to the reduction of the (marginal) generation costs for *C* and *D*. With respect to the producer surplus (PS) this means that PS drops for *A* at time t_2 compared to t_1, remains constant for *B* and rises for *C* (and *D*), compare Figure 4.5.

At time t_3, efficiency class *C* represents the optimal level. This means that the tariff decreases more than the (marginal) cost reduction for efficiency class *A* and *B* and less for level *D*.[77] As

[74] Such a deployment would follow a typical 'S-curve' pattern – see also section 3.2.6.

[75] Note over time less efficient options must be used, as most efficient ones are already implemented. Applying an optimal tariff scheme, theoretically, the full potential of all more efficient generation options should already be used. In other words, the optimal level is characterised as the most efficient, up to now not used potential.

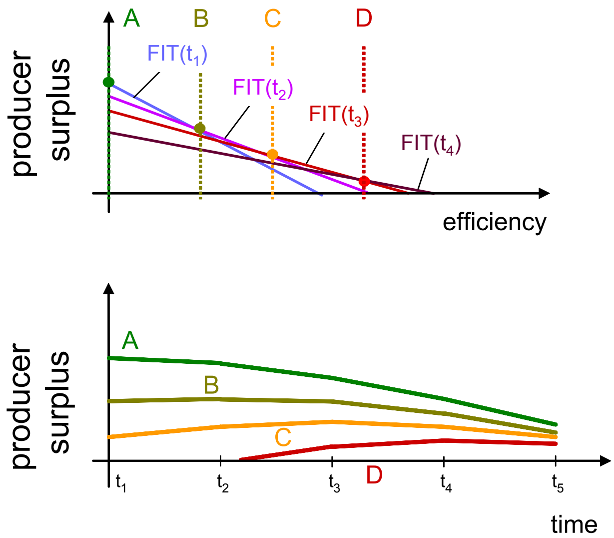
[76] The same relative conditions at time t_2 as under t_1 are depicted by the dotted line.

[77] For *C* the change in the guaranteed tariff is equivalent to the marginal generation cost deployment from t_2 to t_3.

the producer surplus for *A* and *B* drops from t_2 to t_3, investors of plants with the efficiency level *A* and *B* have no incentive to postpone their investments. In contrary to them, investors of plants with efficiency *C* have a full incentive to invest now as the producer surplus reached the maximum value.

Similar, at time t_4 – where *D* characterises the optimal level that should be implemented – guaranteed tariffs for new contract are reduced more than the marginal generation cost drops for A, B and C. Investors in plants of class *D* have an incentive to build their plant now.

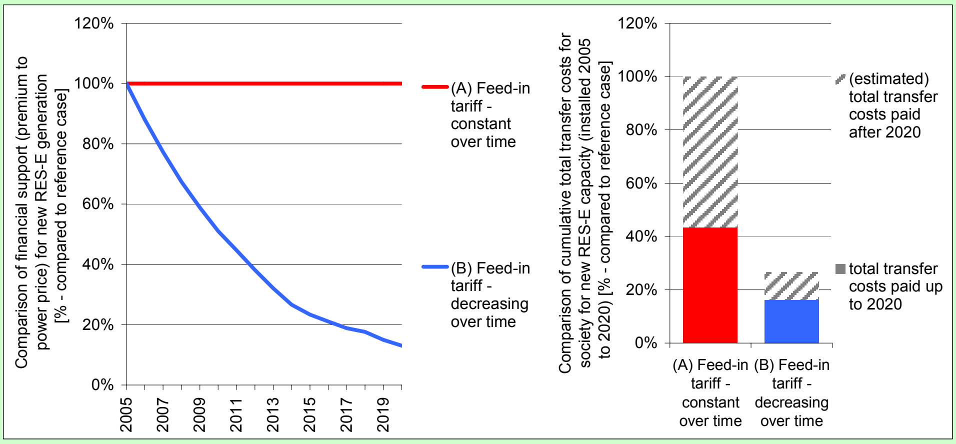
Summing up, in the case that the reduction is well designed, investors have less or no incentive to postpone their investments.



<u>Note:</u> Different scale compared to Figure 4.4!

Figure 4.5 Producer surplus under an optimal dynamic incentive-compatible feed-in system

Box 4.10 Comparison of transfer costs for society applying a dynamic constant versus a decreasing tariff scheme



The example above shows the impact of applying a dynamic constant versus a decreasing feed-in tariff for an emerging new technology option on the resulting transfer costs for society. Thereby, it is assumed that FITs are applied in 2005 in Portugal to promote wave power. In more detail, variant (A) refers to the case of a FIT (with an financial incentive as currently actually imposed) which is kept constant over time; whilst variant (B) describes the case where this tariff decreases over time. Note, in both cases the resulting deployment of wave energy in 2020 is equal.

On the left-hand side of the figure above the dynamic development of the necessary financial support (i.e. the premium to the power price) for new plant is illustrated in relative terms – as comparison with *the reference case (A). As there can be seen, up to the year 2020 huge differences occur. In 2020 within case (B) financial support is only in size of less than 15% compared to the reference variant. Consequently, as shown on the right-hand side of the figure above total transfer costs are only roughly 25% in case of a decreasing tariff. Of course, such huge gains from the appliance of decreasing tariffs can only be expected for new technologies in the early phase of market deployment as cost reductions due to technological learning are expected to be comparatively high.*

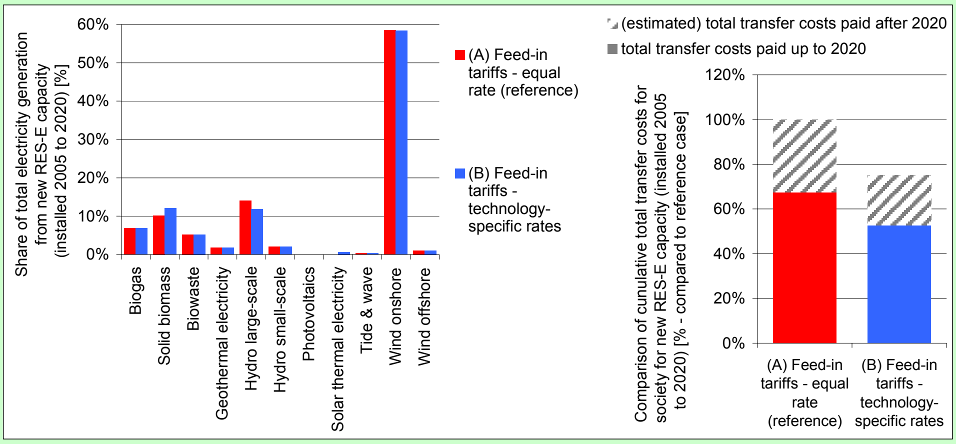
(h) Helps to promote a specific portfolio among different RES-E technologies

By offering technology specific guaranteed tariffs it is feasible to reach a more homogenous distribution or particular target portfolio.[78] Applying such a scheme, the development of currently non cost efficient RES-E technologies can be promoted in a simple way. In a dynamic context this is essential as a dynamic process can be started for non mature technologies. This development come to the consequences that, firstly, generation costs (significantly) decrease in the future[79] and that, secondly, a higher yearly potential is available in the following years.[80]

The stimulation of these technologies at an early phase is useful as this technology can contribute in the future by a higher degree (higher yearly available potential due to the reducing of existing barriers) and to lower electricity generation costs.

Such a strategy is especially of relevance if the medium to long-term target for RES-E is ambitious, i.e. the target exceeds the total available potential of currently cheap RES-E technologies. In time, the promotion of currently non-mature technologies can dramatically reduce costs for society over a period.[81]

Box 4.11 Comparison of RES-E portfolio (and transfer costs for society) applying technology specific versus equal tariffs



The example above shows the impact of applying technology specific versus equal feed-in tariffs on the resulting RES-E portfolio as well as on the accompanying total transfer costs for society. Similar to Box 4.8 it is assumed that enhanced FITs are introduced in 2005 in Italy in order to achieve an ambitious RES-E target for 2020 in size of 12% (on total demand) for electricity produced by new RES-E capacities (installed 2005 to 2020). Two variants are investigated: Variant (A) represents the case where an equal tariff is applied for all RES-E options; and variant (B) characterised by a FIT scheme

[78] For example the tariff for wave energy is higher compared to wind on-shore plants.

[79] Due to the stimulation of technological learning and confidence into the technology (reducing the risk premium for potential investors).

[80] In practice, it can be observed that the yearly available potential follows an inverted U-curve. This means, a low yearly potential is available if the technology is only exploited to a small extent (high barriers), a higher availability if the technology is already mature and the additional total potential is still 'huge', and a low availability in the case of a mature technology but only little additional potential that can be exploited (higher barriers and satiation effect).

[81] A technology specific promotion (additional scheme for currently less mature technologies) is more important for a TGC system than for a FIT or a tender scheme as usually only one price signal exist.

where technology specific tariffs are set. Note, in both cases the overall target is achieved and both schemes are based on dynamically decreasing tariffs.

The impact on the resulting RES-E portfolio is illustrated on the left-hand side above. Due to the ambitious target and the enhanced FITs applied, respectively, differences are rather small. Nevertheless, it can be seen that in case (B) – compared to case (A) – solid biomass contributes to a larger extend and solar thermal electricity also enters the market, whilst wind onshore and large-scale hydropower contribute less.

The impact on the accompanying transfer costs for society due to the RES-E policy is depicted on the right-hand side of the figure above. Thereby, the indicated gains from applying technology-specific incentives are impressive: Total societal costs are roughly 75% compared to the case where equal tariffs are applied.

(i) Helps to reach an area or plant-size specific distribution of a RES-E technology

Similar to the technology specific adjustment, feed-in tariffs schemes can be used to promote a (more) homogenous distribution of a certain RES-E technology over an area or plant size. On the one hand, a more homogenous distribution leads to a better public acceptance, as firstly, more people have the possibility to build up a relationship with the technology and, secondly, the density in hot spot areas is lower. On the other hand, this positive effect over time must be compensated by present economic distortions. This means that currently total generation costs are higher compared to an equal support. [82]

Similar to the technology specific promotion an area or size specific scheme helps to reduce dynamic barriers. This means that these technologies can contribute to a higher share in the future. Again, the criteria for differentiation should be clear and simple, otherwise higher administration and transaction costs occur.[83]

(j) The RES-E deployment is (mainly) independent from the development of the total electricity demand

A guaranteed price scheme leads to market separation – a protected market for RES-E and a remaining market supported by conventional power plus those RES-E options not included in the feed-in tariff scheme, TGC system or tender procedure. As the tariff directly effects supply, RES-E deployment is (mainly) independent from the total electricity demand.[84] This means that RES-E demand depends only on the price level of the guaranteed tariff – a higher tariff entails a higher demand.

An independent RES-E demand results in a higher price elasticity of the remaining demand that must be covered by the free market (spot market, wholesale market or long-term contracts). In this case, the spot market reacts more sensitive to price changes compared to the case of no promotion of RES-E technologies.[85]

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[82] Furthermore, by granting a 'marginal' higher profit if investor choose an efficient plant, a compromise between cost efficiency (and the disadvantage of location hot spots) and homogeneous distribution (and the disadvantage of economic inefficiency) can be adjusted.

[83] In the case that the criteria for a stepped feed-in tariff are the full-load hours (e.g. for wind energy, solar) usually variations among the areas exist. Hence offering a tariff scheme with a higher slop is sufficient fulfilling this constraint.

[84] Of course only if the share of the electricity supported by a feed-in scheme is lower than the total electricity demand, i.e. total demand is higher than the 'effective' total RES-E supply. In the case of wind energy or other predictable and fluctuation technologies a maximum share depends on the total electricity supply.

[85] Assuming that the additional costs due to the implementation of the feed-in tariff are directly imposed on the power price for the consumer and not financed by the public budget, a higher demand reduction compared to the application of a premium feed-in tariff scheme or a TGC system occurs.

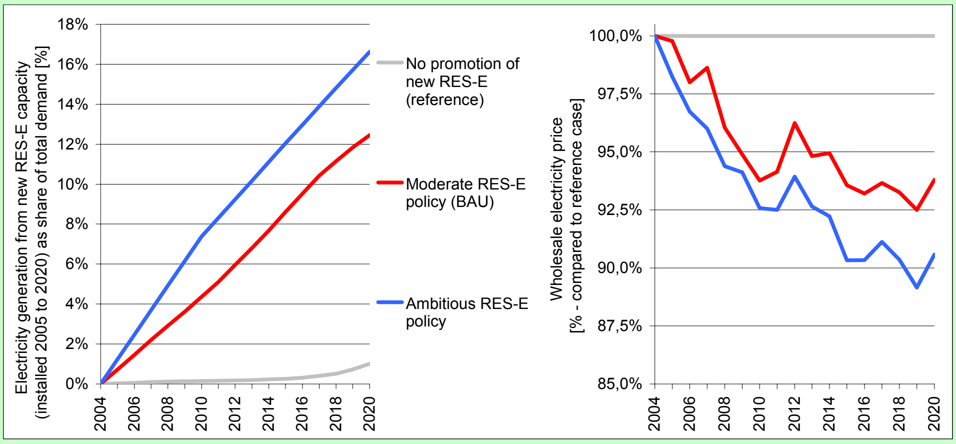
Implementing a premium feed-in tariff scheme instead of a 'fixed' tariff causes different effects on electricity demand and price, namely.

- Firstly both supply and demand on the spot market are higher. The reason is that under this scenario no market separation takes place. This can be essential if the power market is small, as the degree of competition rises due to the higher trading volume;
- Secondly, as the revenues for RES-E are more uncertain than under a 'fixed' feed-in tariff scheme, investors will require a higher risk premium, leading to a lower RES-E deployment;
- Thirdly, in the case of an increasing conventional power price producer surplus for RES-E generators rises too. On the contrary, by applying a fixed feed-in scheme the gap between the (rising) power market and RES-E generation costs decreases - instead of being constant in the case of a premium design - leading to lower costs for society. On the other hand, additional costs occur if the conventional power price drops.[86]

(k) The power market price decreases

The question of the electricity price is closely linked with electricity demand – see point above. Demand on the free electricity market drops if a larger part of the demand is already covered by the larger supply of prioritised electricity from RES. This leads to the consequence that the power market price drops.[87] Total costs for consumer due to the promotion of RES-E can be both higher or lower compared to the situation of no additional RES-E support. They are higher if the premium costs for RES-E exceed the price reduction on the power market and are lower if the reverse it true.

Box 4.12 Comparison of conventional power price with and without promotion of RES-E



This example illustrates the impact of a RES-E policy on the price development on the conventional electricity market. Thereby, results on EU-15 level are taken from the scenarios as presented and discussed briefly in chapter 6. In more detail, three variants are depicted: (i) The reference case describes the future development if no promotion of new RES-E is foreseen from 2005 onwards. (ii) The BAU-forecast, indicating a moderate RES-E policy, describes the development under the assumption that currently implemented individual policies of the Member States remain available (without any adaptation) until 2020. (iii) As a representative of an ambitious RES-E policy the scenario of harmonised enhanced feed-in tariffs has been chosen (i.e. described as 'H3' in section 6.1). Note, for all variants a moderate impact of TEA on the electricity price is assumed – i.e. where within the emission trading scheme a certificate price of roughly 10 €/ton-CO_2 occurs.

[86] This is, however, very unlikely considering current price developments of fossil energy, the increasing shortage of power capacity and the climate change policy (e.g. European Emissions Trading system, Kyoto target).

[87] Conventional power will be substituted by RES-E.

In principle, a RES-E policy has an indirect impact on the development of wholesale power prices on the conventional electricity market as due to an increased RES-E deployment the remaining demand to be covered by conventional options is getting smaller. Consequently, a more cost efficient options may set the marginal price leading to a price reduction compared to the case where no RES-E policy is applied.

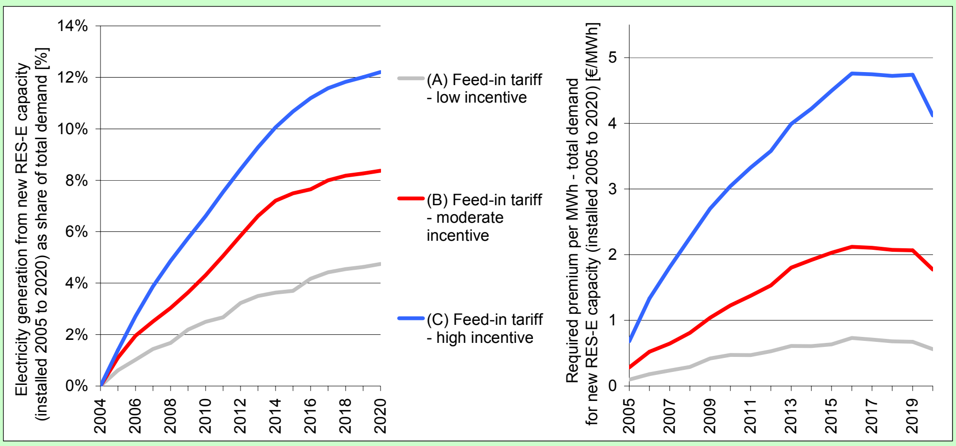
On the left-hand side of the figure above electricity generation from new capacities (installed 2005 to 2020) – expressed as share of total demand - is depicted for the three variants. Even in the reference case a small deployment of new RES-E capacities takes place – achieving a share of roughly 1% in 2020. In the BAU-case a share of 12.5% is indicated for 2020, whilst with ambitious RES-E policies this figures rises to more than 16.5%.

The impact on the wholesale power price for the period up to 2020 is illustrated on the right-hand side above. As there can be seen, on European average a decrease compared to the reference development by -7% up to 2020 is shown for the BAU-variant, whilst with ambitious RES-E policies and the accordingly higher penetration of RES-E a decrease by roughly -10% occurs for 2020. Please note, this indicated cost reduction of the power price has to be compared to the transfer costs due to the promotion of RES-E – for a more detailed discussion of this topic see section 6.7.

(I) 'Relative' homogenous premium costs for society over time

A feed-in tariff scheme is – in contrast to a quota obligation system based on tradable green certificates and (to a certain extend) a tender scheme – designed in such a way that guaranteed tariffs drop over time or at least do not rise to the same degree as under the other schemes.[88] This means that higher 'relative' higher costs arise at the beginning of the system (compared to the other schemes).[89] The reason is that, due to the technology specific tariff-setting, not only most cost efficient technologies can be supported in the early phase of the programme.[90] Hence, the burden on the electricity consumer from the promotion of RES-E is more homogenously distributed over time.

Box 4.13 Transfer costs for society due to the promotion of RES-E technologies over time – in case of FITs



The example above illustrates the resulting transfer costs for society due to the promotion of RES-E technologies over time – in case of applying technology-specific FITs. Thereby it is assumed that FITs are introduced in 2005 in Italy. Note, in all cases the promotion scheme refers solely to new RES-E capacities (installed 2005 to 2020). Three variants are investigated: Variant (A) represents the case where

[88] Otherwise the incentive compatibility constraint cannot be maintained over time, leading to a delay in actual generation.

[89] Of course, they can still rise over time.

[90] This is also the reason why a feed-in tariff can have a different dynamic with respect to the RES-E deployment compared to a quota system for all technologies. In the later case, the RES-E portfolio is restricted as existing barriers for currently not cost efficient technologies cannot be reduced in the start phase.

a rather low incentive is set; variant (B) is characterised by a moderate incentive and variant (C) describes the case of providing high incentives.

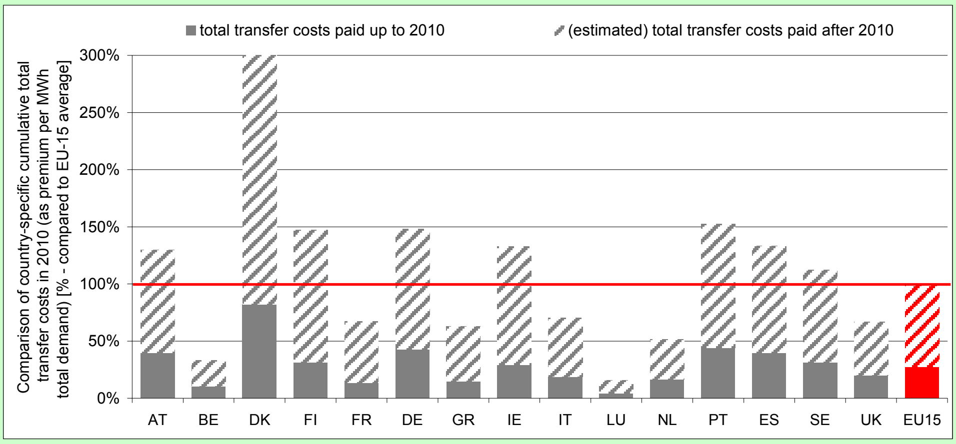
The impact on the resulting RES-E deployment is illustrated on the left-hand side above: In 2020 within variant (A) new RES-E capacities contribute to a share of 4.7% on total demand, whilst with moderate incentives a share of 8.4% can be achieved and, finally, by setting high incentives a share of 12.2% occurs.

(m) The impact on the dynamic development of the accompanying transfer costs for society due to the RES-E policy is depicted on the right-hand side of the figure above. Thereby, in case of low to medium incentives a rather homogenous premium occurs, whilst in case of high incentives a steep rise and decline can be observed. *National burden depends on the actual national RES-E deployment – a homogenous burden sharing at an international level is difficult*

The premium costs due to the RES-E deployment that have to be born by the consumer depend on actual RES-E development. They can significantly vary between countries, because of differed feed-in tariffs among countries. However, even under harmonised conditions, i.e. the same feed-in tariff is applied in all countries, a huge variation in the total consumer costs can occur. The reason is that the RES-E potential and the cost structure differs between the countries and only actual (national) RES-E deployment is relevant for consumer costs. National costs are high in countries with a high share of RES-E and low in countries with less RES-E exploitation.[91]

A homogenous distribution among the countries is difficult to achieve. One, albeit, currently unrealistic solution is to grant the feed-in tariff at the EU rather than at a national level via an EU support programme.[92]

Box 4.14 Comparison of transfer costs for society in different Member States fulfilling the indicative RES-E target 2010 (on EU level) – in case of FITs



This example provides a comparison of resulting transfer costs for society in different Member States fulfilling the indicative RES-E target 2010 on an EU-15 level. These results refer to the scenario of harmonised enhanced feed-in tariffs as presented and discussed briefly in chapter 6 (i.e. named as 'H3' later on). Please note, in this scenario a RES-E share of 22% on total demand – in accordance with the target set by the 'RES-E directive' will be met on European level solely. The achievement of the indicative targets as set for each Member State is not feasible under the scenario conditions as it based on the assumption that harmonised FITs are applied in all countries in 2005. Consequently, the deployment of RES-E on country-level appears in accordance with the resource conditions which do differ to a large extend from country to country.

[91] Note: In a TGC system the national consumer costs depends on the height of the obliged quota and not on actual national RES-E generation. Hence, in such a scheme the consumer costs can be more easily set on the same level by imposing the same quota obligation in all countries.

[92] In this case, differing additional benefits from RES-E development at national level must be counter-calculated.

The resulting country-specific total transfer costs in 2010 are depicted in the figure above. Thereby, both the cumulative paid costs in the period 2005 to 2010 as well as the estimated residual costs which are still to pay in the period after 2010 are indicated. As there can be seen huge differences occur by country. Member States which are characterised by proper resource conditions of RES-E contribute most for achieving the overall EU-target, whilst others with less attractive RES-E potentials achieve only a moderate deployment and accordingly lower costs. Nevertheless, with the exception of four countries total transfer costs appear in a range from 50 to 150% compared to the EU-15 average. Above the 150% border Denmark and Portugal are the ones which have comparatively large and cheap RES-E options available and are therefore faced with high transfer costs. Below the 50% border Belgium and Luxembourg can be found – both characterised by rather poor RES-E resources.

4.2.3 Evaluation of a quota obligation with tradable green certificates

4.2.3.1 Introduction

To promote electricity from RES, a mandatory 'artificial' demand may be set by government via quota obligations (i.e. legally enforceable orders to producers or consumers for specified amounts of RES-E to be sold / bought). The main objective of such a quota system is to secure pre-defined amounts of RES in a liberalised electricity market. Often, tradable green certificates (TGC) are used to both facilitate the fulfilment of the quota obligation, and to increase the economic efficiency of the promotion strategy.[93] Trade could be allowed at the national or international level. In the later case, TGCs must be approved by the participating countries and broadly harmonised.

The obligated parties can be generators or any other 'actors' in the electricity chain (e.g. transmission and distributor companies, suppliers, brokers or consumers). To fulfil the obligation, each obligated actor may either produce RES-E himself or buy TGCs from other suppliers. The revenue obtainable to the RES-E producer for the renewable energy based electricity will be the sum of the market-based power price for physical power and the price of the tradable green certificates.

To the extent that consumers (producer) do not fulfil their purchase commitments for green certificates (quota obligation), they have to pay a penalty fine for the missing number of certificates, i.e., for each MWh for which they should have purchased (sold) green certificates but failed.

4.2.3.2 Main conclusion

The main conclusions with respect to the application of a quota system in combination with tradable green certificates are:

(a) Must be proven to be successful and effective – this mainly depends on the applied design criteria

Up to now, there is no rigorous and comprehensive publication which assesses the performance of TGC schemes. Perhaps it is too early to determine (except in those cases where it has become manifestly clear that a TGC system has not worked). In most cases narrow markets emerge as the real problem. Some evidence from the regional systems in Belgium and Austria shows that this might already present a problem there. Mitchell and Connor (2004) show several problems already appearing in the ROC system in the U.K. For the Swedish case penalties that have been set

[93] A TGC is used to represent the 'marginal added value' or 'greenness' of one pre-defined unit of electricity produced from renewable energy source (RES). As a result, under a TGC system, each producer of RES-E is producing two goods:

- physical electricity, which is fed into the grid and is sold at market prices for conventional electricity;
- TGC, which represents the added value of the 'greenness'.

too low proved to be the main problem. Although the production was actually higher than the quota in 2003 the quota fulfilment was only 77%, since many of the electricity suppliers chose to pay the penalty and to bank their certificates for 2004. Therefore the penalty determined the cap price. In the Italian case a feed-in tariff has been replaced by a quota obligation. The quota obligation has two major disadvantages in this case. First only the very cheapest technologies are currently constructed hampering the diffusion of more technologically sophisticated sources. Secondly the current price of certificates, e.g. for wind energy, is about twice as high as the feed-in tariff in the former system.

The success of a TGC system depends on the right design, including admitted technologies, validity of the certificates, penalty, market volume, stability of the conditions, etc.

(b) RES-E target can be reached exactly - effective if penalty is set correctly but less flexible

One main advantage of a quota obligation is that the target will be reached exactly under the assumption that a sufficiently high incentive is set. This means that the penalty for not purchasing a certificate is higher than the investment needed to meet the quota. As the penalty serves as the price ceiling for TGCs, the lowest penalty level must exceed the expected marginal generation costs (minus market price for conventional electricity) within the system. This is also of great importance when implementing an international trading scheme. If at least in one country the penalty is set incorrectly, i.e. it is lower than the marginal generation costs (minus the power price), the common target will not be reached.

In a dynamic context it is important to mention that the total RES-E deployment proceeds slower than under a RES-E system that pursues the development of different technologies simultaneously. This means if no additional support is granted for currently more expensive technologies, an ambitious RES-E target is more difficult to reach under a TGC system.

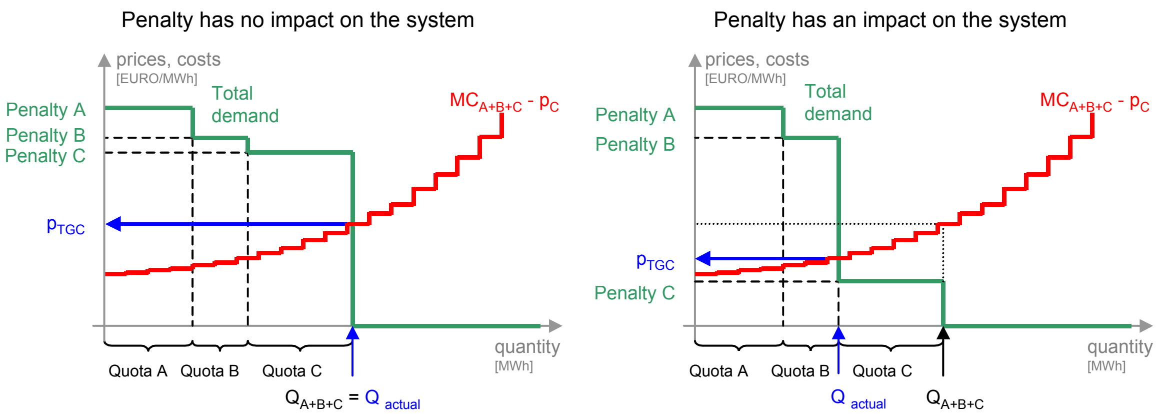


Figure 4.6 Influence of the penalty on the electricity generation: high penalty (left) and low penalty (right); Source Huber et. al. (2001a)

Adapting an existing TGC system can cause problems. The inclusion of additional technologies or the extension of the market (an international TGC scheme) is problematic, as such actions may influence the price level of the TGCs dramatically and, hence the support for RES-E. If the framework conditions are not set clear by the policy, a higher risk for investors results, leading to higher costs for the consumer.

(c) Medium to high administration and transaction costs, especially if system should be flexible (different systems work at the same time)

To be able to use a TGC system, a market structure has to be developed. This means a trading platform, a monitoring system, etc must be implemented. Therefore, depending on the actual implementation, medium to high administration costs and transaction costs occur. Administration costs are – in relative term – high if the market is small. This is the case if it is implemented at the (sub)national level and or it includes just one or two technologies.

(d) Competition among investors

In general, due to the establishment of a market structure where prices are determined by supply and demand competition among investors occurs. The level of competition depends on the market structure. Preconditions are completely full liquid and transparent market for TGCs characterised by many sellers and buyers and, usually, the absence of market power. In countries with a high market volume or if the market is based at the international level these conditions are fulfilled. However, implementing a TGC system in a small size (i.e. in only one small country or where the system is restricted to one RES-E technology) should be pursued with caution. [94]

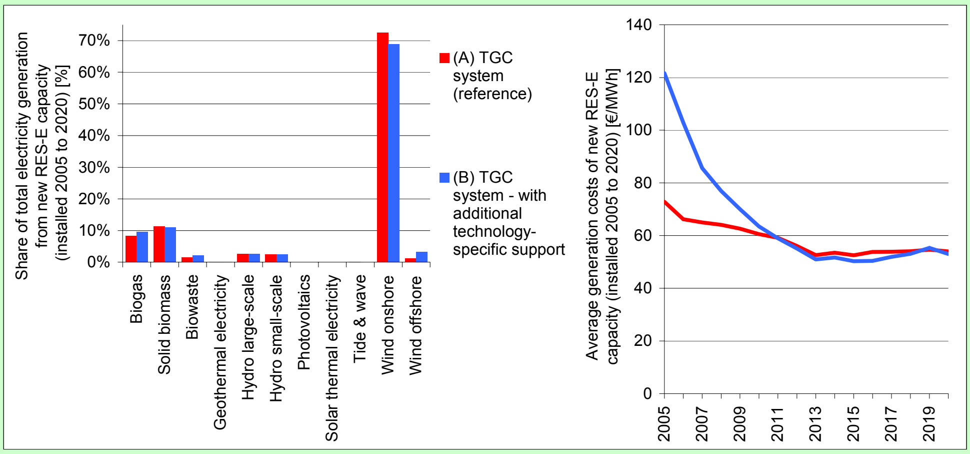
(e) Helps to reduce costs for RES-E technologies

On the one hand, competition entails pressure on manufacturers to reduce the investment costs or on other involved parties to decline their respective cost components. On the other hand, the need to reduce costs can lead to the development of a less efficient and long-lived product.

(f) Leads to minimisation of generation costs (if just one RES-E target)

A quota obligation system based on tradable green certificates leads to minimal total RES-E system costs. This means, a TGC system is cost efficient with respect to the installed RES-E capacity. A TGC-scheme will ensure that the RES-E deployment is made at locations where it is most efficient and profitable. In the case that the TGC system is introduced on international level, "hot spots" due to the high total demand are feasible.[95]

Box 4.15 Comparison of generation costs applying a TGC system without additional technology-specific support versus allowing such support



The figure above shows the impact of applying a TGC system without additional technology-specific support versus allowing such support on resulting RES-E portfolio and accompanying generation costs. Assuming a TGC system is introduced in 2005 in France in order to achieve an ambitious RES-E target for 2020 in size of 11% (on total demand) for electricity produced by new RES-E capacities (installed 2005 to 2020). Two variants are investigated: Variant (A) represents the case where no additional support is applied; and variant (B) refers to a TGC system where in addition technology specific investment incentives are implemented. Note, in both cases the overall target is met.

[94] One example of such an implementation scheme was the quota obligation for small scale hydro power in Austria in the period 2001-2002, which has been replaced by a feed-in tariff scheme since 2003.

[95] Of course, in a national scheme with ambitious RES-E targets the same situation can occur.

The impact on the resulting RES-E portfolio is illustrated on the left-hand side above. Due to the ambitious target differences are rather small. Nevertheless, it can be seen that in case (B) – compared to case (A) – biogas, biowaste and wind offshore contribute to a larger extend, whilst biomass and wind onshore penetrate less.

The resulting impact on the dynamic development of generation costs of new RES-E capacities (installed 2005 to 2020) is shown on the right-hand side of the figure above. In the short term differences are comparatively higher for variant (B) (i.e. +40% in 2005) as due to the technology-specific promotion distortions among the different technologies occur. Up to 2011 differences disappear and, hence, after 2011 it can be observed that generation costs in case of variant (B) are slightly less than in case of a pure TGC system as described by variant (A)

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

Despite the fact that tradable green certificates lead to minimal total RES-E system costs, it is likely / possible that costs for society are not minimal. This means, a TGC system is cost efficient with respect to the installed RES-E capacity but not with respect to the cost that must be born by the society. The reason is that the producer can absorb most of the efficiency gains.

The premium costs for society mainly depend on:

- RES-E target: In general an ambitious target exploiting a high share of the available potential leads to higher premium costs compared to e.g. a feed-in tariff scheme, as the producer surplus significantly rises;
- Market conditions: As TGC price developments are uncertain and difficult to forecast, investor risks are higher compared to a feed-in tariff or a tender programme. The risk premium leads to higher costs for society. Risks can be reduced by a guaranteed floor price or allowing banking and borrowing of TGCs, but risks remain higher compared to other support schemes, compare also Cleijne et. al. (2004).
- The additional support schemes: Details see below

Under the following conditions the direct premium costs for the consumer can be diminished:

(i) TGC system is standardised. Standardisation of TGCs becomes important within a mandatory system. If there is just one kind of certificate, no separate TGCs markets occur, leading to the following consequences:

- a higher market transparency
- an increased trading volume
- more reliable / robust price signals
- lower generation cost (in the early phase)
- higher windfall profits for most cost efficient technologies[96]

(ii) International TGC system

International trade between countries with mandatory quota obligations increase the efficiency of the entire system. One important precondition is that the national TGC systems are mutually recognised. If the obliged parties in both countries have to fulfil their quotas, the total production of RES will not be influenced by the international trading activity, only the distribution of total generation and costs / profit in the two countries would change. Countries with high mar-

[96] A split into 2 or 3 technology specific quotas (e.g. one quota for wind energy) can reduce the windfall profits and, hence the transfer costs for society. However, a split is only helpful if other criteria (i.e. market transparency, trading volume, competition) are still fulfilled (e.g. within an international market). At national level other instruments giving additional support (investment incentives, tax relief, etc.) are more appropriate.

ginal generation costs (due to a low potential for RES or due to a high obligation) will be net importers, and countries with low marginal generation costs will be net exporters.[97]

International trade between countries with a quota obligation and countries without a regulatory quota creates an implicit asymmetry. This is especially problematic if installed capacity of RES-E in the country with a voluntary system has been promoted by an investment subsidy and low voluntary demand so that the price that can be received from RES-E is similar to the price of conventional electricity. By receiving higher prices, generators will export their "green" electricity to the country with the quota obligation. Of course, this is only possible if interconnection between the countries is not a problem. Thus, significant supply of TGCs occurs in the country with the mandatory obligation contributing to a decrease in the price of TGCs. This flow will make it easier to achieve the obligation.[98]

From an international perspective, countries with a mandatory quota system might not want to accept TGCs from countries with only a voluntary demand approach. TGCs from a country without an obligation should only be accepted if it is proved that the plant is implemented due to the stimulation of the trading system. This means that TGCs must be created from newly installed RES.

(iii) Additional support scheme or different technology specific targets in the case of an ambitious RES-E target

In the case of higher targets an additional technology specific support mechanism helps to reduce costs for consumers, i.e. windfall profits for cheap technologies remain lower. Appropriate additional support schemes are investment subsidies (designed as percentage of investment costs, fix amount or preferable as tender procedure), tax relief or soft loans. In this case, however, additional administrative costs appear due to the introduction of a second instrument.

Note that when implementing an international trading scheme it is especially important to avoid discrimination between countries and technologies. This means that additional support mechanisms in all countries must be known. Otherwise the option of TGC trading will be an additional subsidy instead of a cost efficient way to promote RES. If the additional support differs among the countries, then distortions will occur, because marginal generation costs also differ among the countries. The consequence is that producers in countries with higher subsidies will increase their generation, and producers with lower additional support will decrease generation compared to the optimal case. However, the governments, and indirectly the taxpayers and electricity consumers, of the countries with higher additional promotion scheme support not only RES-E deployment in their own country but also in all other countries. This means that subsidies granted in one country lead to a lower price in other countries, even if support schemes exist in those countries.

Box 4.16 Comparison of transfer costs for society applying a TGC system without additional technology specific support versus allowing such support

The figure below shows the impact of applying a TGC system without additional technology-specific support versus allowing such support on transfer costs for society. Similar to Box 4.14 it is assumed

[97] As already mentioned, not only the TGC system among countries should be adjusted, the (financial) incentive for fulfilling the quota obligation must also be set at a such a high level in all participating countries (penalty) that the compliance of the target in all countries is not jeopardise. In addition, to increase the efficiency of the trading system, it is important that no hidden market barriers exist, e.g. the condition that only TGCs can be imported if the physical electricity is also imported.

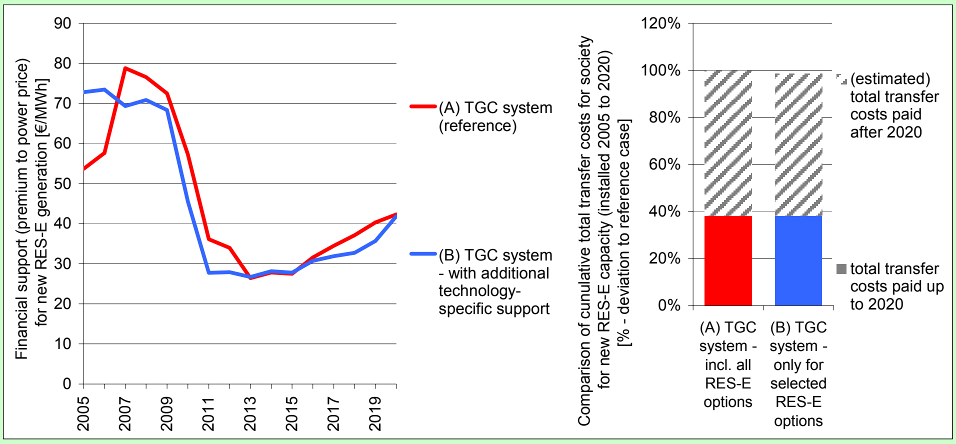
[98] However, the other benefits related to RES-E development of increased employment and industrial development will only be gained by those countries actually implementing the renewable technologies independent of the RES-E quotas in the individual Member States.

that a TGC system is introduced in 2005 in France in order to achieve an ambitious RES-E target for 2020 in size of 11% (on total demand) for electricity produced by new RES-E capacities (installed 2005 to 2020). Two variants are investigated: Variant (A) represents the case where no additional support is applied; and variant (B) refers to a TGC system where in addition technology specific investment subsidies are implemented. Note, in both cases the overall target is met.

Although investment subsidies in size of up to 30% are applied for selected RES-E technologies, the impact on the overall resulting transfer costs is comparatively low. More precisely, the depicted dynamic development of the leveled financial support for new RES-E (i.e. expressed as premium to power price) shows that only in the early phase the pure TGC system of case (A) beats the case where in addition to the TGC system technology-specific support is applied (i.e. variant (B)). In contrary, in the period 2007 to 2020 the mixed system leads to overall lower societal costs – although differences are small.

Total transfer costs are shown on the right-hand side of the figure below. Of course, again, differences are small. Nevertheless it can be observed that variant (B) leads to slightly lower (i.e. -2%) societal transfer costs compared to the pure TGC system of variant (A).

Note, the deviation of a pure TGC scheme to a mixed system is highly influenced by the RES-E target as well as the design of the additional support scheme- A "bad" design leads to higher, a "good" design to lower transfer costs for society compared to a pure TGC scheme. The result underpins the importance of applying technology-specific support - which led in this example to lower TGC-prices and, consequently, helped to reduce producer surpluses compared to the pure TGC scheme.



(h) Helps to promote currently most cost efficient RES-E technologies

Within a single TGC system all RES-E technologies compete on the same TGC market. Hence, only the currently most efficient RES-E options will be chosen to generate electricity, i.e. currently more expensive technologies will not be promoted. The consequences are:

- This scheme facilitates the economic competitiveness of cheap RES-E technologies compared to conventional electricity generation options in a lower period of time.
- Currently less efficient – but for the future promising and necessary – technologies are less promoted. Hence, the economic gap among the different RES-E technologies rises as different incentives are set for already cheap and currently still more expensive technologies[99]

[99] Pursuing a(n ambitious) long-term RES-E policy it is important to give a stimulus for non-mature technologies already in an early phase, as the promotion of currently non-mature technologies in time can dramatically reduce costs for society over a dynamic period. This issue is especially important in the case of a TGC system, where the marginal generation costs of the marginal plant (technology) determines the additional revenue of all contributing technologies. A technology-specific promotion (additional scheme for currently less mature technologies) is more important for a TGC system than for a FIT or a tender scheme. Moreover, such a policy helps to reduce barriers of envisaged technologies in the mid-term, so additional potential is available in the future.

Summing up, the provisions of additional strategies for less mature technologies within or in addition to the TGC system must be considered. Additional strategies could be:

(i) Favours the development of RES-E 'clusters' and hot spots areas

One disadvantage of a trading scheme – especially if it is implemented at the international level - is that if favours geographical and technological hot spots. This means a certain technology at an optimal location will be extensively used. The negative environmental impact[100] must be set against the benefits of income for those regions.

(j) The RES-E deployment interacts with the development of the total electricity demand

A TGC system leads to market separation. One TGC market for RES-E technologies to cover the 'artificial' demand given by the quota and one conventional market providing electricity from conventional power and RES-E not included or applied in the TGC system. Note that, obviously, total electricity will be sold at the spot market. The market price, however, will only be determined by the marginal conditions of the conventional electricity part.[101]

Assuming a relative quota - in percentage of total electricity supply or demand – these two markets are linked by the total electricity demand.[102] An increase (a reduction) in total demand leads to a more (less) ambitious deployment of RES-E deployment.

In addition, the method of imposing the premium costs arising from the RES-E deployment influences the RES-E development – in absolute terms – within a TGC system.

– In the case where the additional costs are directly imposed on the electricity price, total electricity demand diminishes.[103] Total national electricity generation drops due to lower demand. Hence, the total electricity generation from RES-E decreases too, because the ratio between RES-E and conventional power is defined by the quota obligation and is, hence, constant;

- an additional support (e.g. investment subsidies prescribed by the public body or via a tender system) for less mature technologies within the TGC system
- a split of the TGC market in sub-markets, e.g. one market for 'mature' technologies and one for currently 'non-mature' technologies. However, if separate technology-specific TGC systems are applied in small countries, market volumes might appear to be too small, implying that no 'real trade' occurs.
- technology specific support schemes (e.g. TGC system for cheap technologies, feed-in tariff or tender scheme for non-mature technologies) outside of the TGC scheme.

Which option is appropriate depends on the country and policy specific conditions and must be carefully analysed in more detail.

[100] For example the visual intrusion of extensive wind power development in areas of high wind speed.

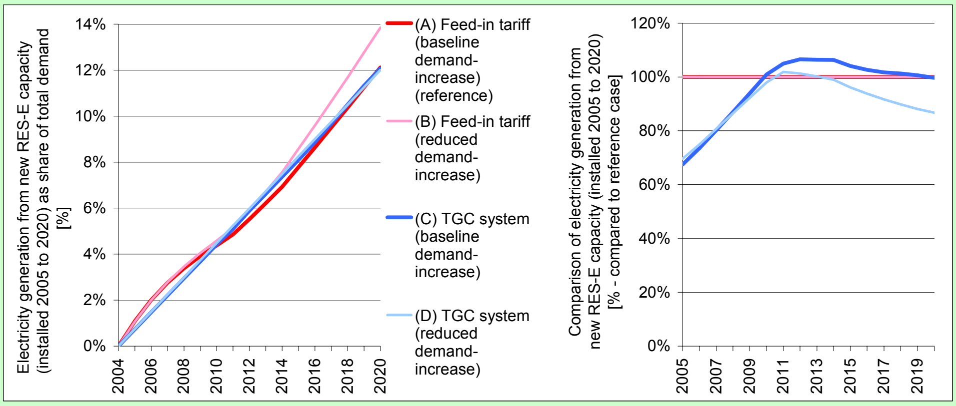
[101] Observe that in the case of a quota system electricity from both conventional and renewable sources will be sold at the spot market. The actual marginal generation cost for RES-E, however, will not be reflected at the spot market. More precisely, RES-E can ever be offered below or at least at the spot market price. The reason is that the difference between the marginal generation costs and the spot market price will be fully compensated by the TGC price. That means that changes in the spot market price are reflected immediately and totally in the TGC price. In this sense, just the marginal generation costs for conventional power production determines the spot market price. Of course, in the case that the actual amount of RES-E generation is higher than the RES-E quota – this could be the case if the quota obligation is low or if a high potential of cheap RES-E production is available – RES-E technologies also determines the spot market price for conventional electricity. This situation is characterised by a high economic cost efficiency of RES-E technologies - at least a higher share than indicated by the quota is cost efficient – and indicated by a TGC market price of zero.

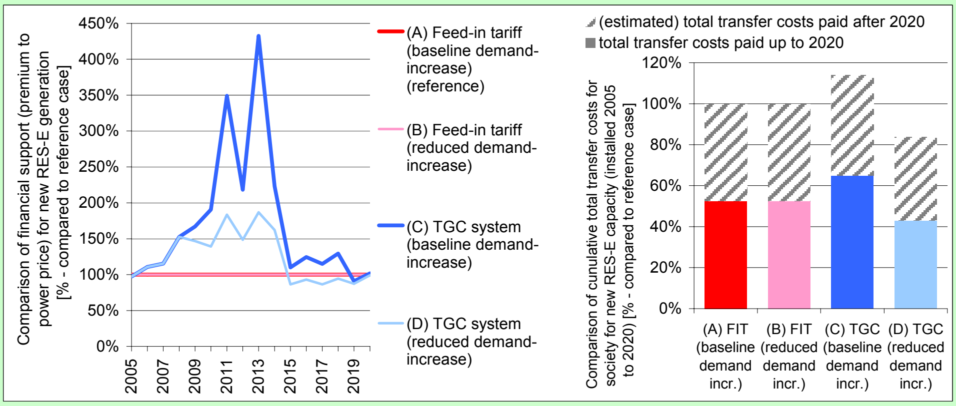
[102] An alternative to the relative target is to impose an absolute amount of electricity generation from RES-E, e.g. x TWh from RES-E in 2020. Such an implementation can have advantages for formulating (high) long-term targets. The reason is that the RES-E deployment is independent from the development of total future supply and demand (e.g. for 2020), leading to less risk about TGC price development. However, under these conditions, DSM activities cannot be used as policy strategy to achieve a higher share of RES-E, because no link between RES-E target and electricity demand exists.

[103] The premium costs are determined by the TGC price times the amount of the quota obligation.

– In the case where the public pays the additional costs via general taxes and duties, the price signal of the electricity price is even lower compared to the case of no quota obligation. The lower market price leads to a higher electricity demand and, hence, to higher electricity generation from both conventional power and RES-E. In other words, if the additional costs are not directly imposed on the electricity price a higher absolute RES-E capacity is necessary to reach the quota target. Conventional electricity production, and hence, CO_2-emissions rise too.

Box 4.17 Comparison of RES-E deployment (transfer costs for society) in dependency of the electricity demand within a TGC system and a FIT





The example above illustrates the impact of the development of the electricity demand on RES-E deployment and resulting transfer costs for different policy options. More precisely, it allows a comparison of the effects for a FIT scheme and a TGC system. In general, it is assumed that either FITs or a TGC system is applied in 2005 in the Netherlands to meet an ambitious RES-E target in 2020 of (as default) 12% (on total demand) for electricity produced by new RES-E capacities (installed 2005 to 2020). In addition, two demand forecasts are considered: A default BAU-forecast and a 'efficiency'-forecast assuming a slower demand growth up to 2020. These assumptions are reflected in the four different variants (A) to (D) as indicated in the figures above.

The impact on the resulting RES-E deployment is illustrated in the upper figure - on the left-hand side expressed as share of total demand and on the right-hand side as comparison to the reference case (i.e. variant (A) – based on a FIT system in combination with the BAU demand forecast). As usual differences occur with respect to the dynamic deployment between the FIT- and the TGC-variants due to the differing mechanisms of either setting prices or demand.

For 2020 the following can be observed: In case of FITs a higher deployment in 'relative terms' – i.e. a higher share of RES-E on total demand - occurs if demand is reduced. Although in 'absolute terms' deployment is similar, i.e. produced GWh or installed MW. In contrary, in case of a TGC system a similar penetration can be observed in 'relative terms', but installed capacity or generation is lower if the demand is reduced.

Total transfer costs as depicted in the lower figure follow more or less the RES-E deployment in 'absolute terms'. I.e. a reduced RES-E demand in GWh in case of a TGC system leads to lower total societal transfer costs. In case of a FIT system total costs are independent from the demand development. Obvi-

ously, the required premium per MWh total demand would be higher if a demand reduction takes place. Note in the case of a FIT scheme also a higher RES-E deployment occur.

(k) The power market price decreases

Similar to the situation implementing a feed-in tariff scheme, the spot market price decreases due to the market separation. Total conventional power demand is reduced according to the total RES-E quota. Hence, the power price is reduced accordingly.

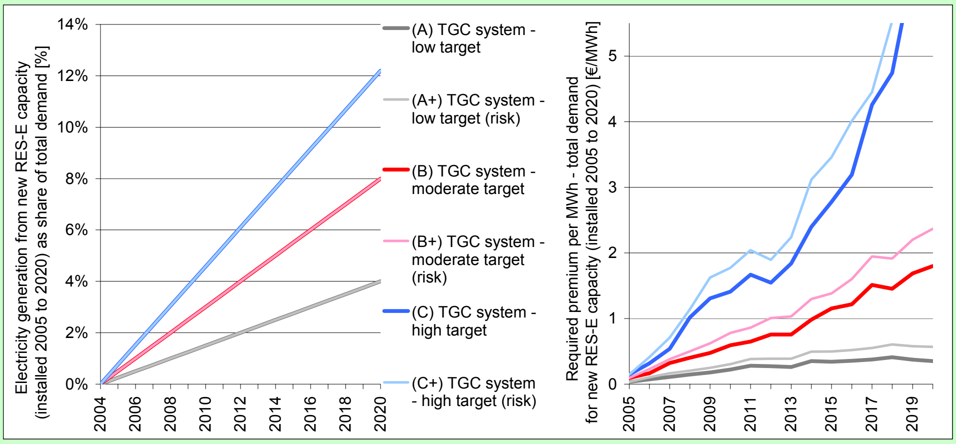
The net effect for both, electricity generator and consumer is ambiguous, depending on the net price effect. In the case that the premium costs from the promotion of the RES-E are smaller than the power price reduction due to the market separation[104], consumer gains from the introduction of a quota obligation.

(l) 'Low' premium costs for consumer in the early phase of the quota obligation - costs for society increase over time

The additional costs for the consumer are low at the beginning of the TGC system. Reasons are:

- low TGC volume in the initial stage.[105]
- low TGC price as most cost efficient generation options will be exploited first. But these costs increase by the end of the period (depending on how ambitious the target is).

Box 4.18 Transfer costs for society due to the promotion of RES-E technologies over time – in case of a TGC system



The example above illustrates the resulting transfer costs for society due to the promotion of RES-E technologies over time – in case of applying TGC systems. Thereby it is assumed (i) that these schemes start in 2005 in Italy, and (ii) that they refer solely to new RES-E capacities (installed 2005 to 2020). In total six variants are investigated: Variant (A) and (A+) represent the case where a rather low target is set; variant (B) and (B+) describe the case of a moderate target and variant (C) and (C+) refer to ambitious RES-E goals. As in case of TGCs investor's risk represents an important issue, for each target a variant (i.e. A+, B+, C+) is applied differing to the default case by a higher WACC (8.6% instead of 6.5%).

The impact on the resulting RES-E deployment is illustrated on the left-hand side above: In 2020 within variant (A) new RES-E capacities contribute to a share of 4% on total demand, whilst with moderate targets a share of 8% can be achieved and, finally, by introducing high targets a share of 12.2% occurs.

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[104] This means that the total electricity price including additional costs due to the RES-E support is lower than the initial power market price.

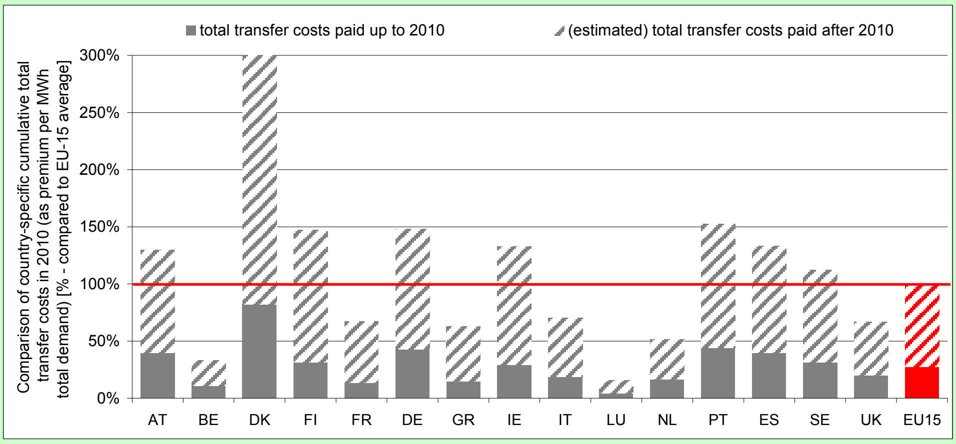
[105] Assuming that a TGC system for new capacity starts in 2005 and should reach a level of 12% in 2010. In the start phase – from 2005 to 2010 – the quota, and hence the number of certificates, have to increase every year by 2%. After 2010 – assuming a constant target of 12%– the total TGC volumes remains more or less constant –only few new certificates are necessary covering the increase of the electricity demand.

The impact on the dynamic development of the accompanying transfer costs for society due to the RES-E policy is depicted on the right-hand side of the figure above. For the low target a rather homogenous premium occurs. In case of a moderate target transfer costs rise continuously up to 2020. Finally, for the ambitious target a dramatically steep rise can be observed. With respect to the 'risk'-variants the deviation depends on production level and varies over time.

(m) The national burden depends on the national RES-E target – a homogenous, unique burden sharing at the international level is easy to implement

As already mentioned, the net benefit of introducing a TGC system for both, electricity generator and consumer is ambiguous, especially considering an international system. The premium costs for the consumer depend on the RES-E target (quota) and not on the actual national RES-E generation. This means the burden might differ between Member States since the quota targets differ.[106] Therefore, it is likely, that the introduction of an EU wide TGC market will lead to a reduction of consumer prices in Member States with non-ambitious RES-E quotas, and vice versa in Member States with ambitious RES-E quotas, i.e. the consumer prices will increase in these countries. A unique burden sharing - that is that the transfer costs for society due to the EU wide RES-E deployment per kWh electricity consumption should be equal in all countries – can easily be implemented by setting the same quota target in all countries.[107]

Box 4.19 Comparison of transfer costs for society in different Member States fulfilling their indicative RES-E target 2010



This example provides a comparison of resulting transfer costs for society in different Member States fulfilling the indicative RES-E target for 2010 both in case of a national and an international TGC system. These results refer to the scenarios of national and international TGC systems as presented and discussed briefly in chapter 6 (i.e. named as 'H4' and 'H5' later on). Please note, in case of a national TGC system the overall EU-15 wide RES-E target of 22% will not be met as not all countries can met their country-specific indicative goals

The grey and the dashed grey bars in the figure above describe the total transfer costs in 2010 in case of TGC systems introduced on national level. As there can be seen, huge differences occur. For four countries costs are more than twice as high as the European average. In contrary, four other countries would face costs in size of less than 50% of the average.

In case of implementing an international TGC system a similar burden occurs for all Member States (neglecting additional transfer payments for existing capacities installed before 2005). This burden is in size of 70% compared to the European average in case of national trading schemes.

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[106] Consumers in Member States with a relative small quota, will enjoy the benefit of the international power and TGC price and only experience low extra costs of buying TGCs. Consumers in Member States with a relative ambitious target, will also enjoy decreasing power and TGC prices too, but will have a larger share of the TGCs price included in the consumer price.

[107] In this sense the entire promotion is shifted on the EU level.

4.2.4 Evaluation of a tender system

4.2.4.1 Introduction

In a tender system, potential generators of RES-E bid to a public authority with a price per MWh they require to generate electricity from RES or an investment subsidy to make an investment economically.[108] It is likely that there will be legally enforceable obligations for RES associated with such programmes. If a proposal is considered viable and competes successfully on price terms against other potential generators, a contract is offered. In the case of a price bid, this requires each selected generator to sell the electricity to a local utility. In return the generator receives a guaranteed price per unit of output (usually the bid price) for a defined period as arranged by the authority. The premium price, i.e. the difference between price paid to the generator and the market price, is reimbursed from a fund or levy. Normally there are separate tenders for different RES-E technologies within different technology bands. In the case of a tender with respect to required investment costs, the winner are supported with the claimed support per MW installed capacity.

4.2.4.2 Main conclusions

The main conclusions with respect to a tender system are:

(a) Must be proven to be successful and effective – mainly depends on avoiding a stop and go nature

Tender systems used to promote RES-E have been used in France (for wind energy) UK and are still in place in Ireland. Experiences with competitive tender schemes have shown that cost reductions are a key success factor of well-designed tender procedures. In practice long lead times between successful tendering and start of production have resulted in higher transaction and administrative costs then required in a more optimal situation. Effectiveness is greatly influenced by its design, especially with respect to pre-arranged planning permission, resulting prices and the number of bidders. The uncertainty in resulting deployments of tendering policies represents a huge barrier for potential investors. Especially for new market entrants the investor certainty can be low and transaction costs are often perceived as too high to prepare actual bids

(b) RES-E target cannot be exactly reached but uncertainty is low - flexible in use and time

A tender scheme is a flexible instrument increasing the RES-E capacity. Independently of the design it is easy to install and to replace. As the economic support of the individual RES-E plants refers to the year of the tender, either in form of a guaranteed price or an investment subsidy, no major problems in changing the system (transition period) occur.

In the case that certain capacities are invited for a tender, the RES-E target can be reached with a (relative) certainty.[109] Under the assumption that the tender scheme is budget restricted[110], a higher uncertainty about fulfilling the RES-E target exists.

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[108] Another option is that potential generators of RES-E bid to a public authority for investment subsidies they require to generate electricity from RES in an economically feasible way.

[109] Of course, only if the approved project will actually be implemented, which, however, is not ever the case in practice.

[110] For example 30 million € are available for a wind on-shore tender.

(c) Low to medium administration costs, medium to high transaction costs

On the one hand, competitive tendering schemes have relatively low administrative costs. Administrative costs are mainly limited to staff time to run the tendering process and for monitoring the resulting projects. On the other hand, costs for investors (transaction costs) are high, as the project planning must be made before the tender takes place. This means that issues concerning finance structure, technology type, site, grid connection, etc must be answered by each bidder. These costs, preventing or at least diminishing competition can be reduced by technology and location specific tenders. This is the case if e.g. the site of a wind off-shore plant is already defined and grid connection agreed, before the tender procedure starts. This system, however, is just applicable for some technologies – wind off-shore, co-firing of biomass, hydropower and to a certain extent wind on-shore. The reduction of the transaction costs are partly compensated by higher administration costs.

(d) Competition among the investors – if tender is not split into to much technology specific tenders

A tender procedure represents an efficient instrument, based on competition among RES-E investors. This requires – similar to market size in case of technology specific quotas within a TGC system – a sufficient size of capacity announced.

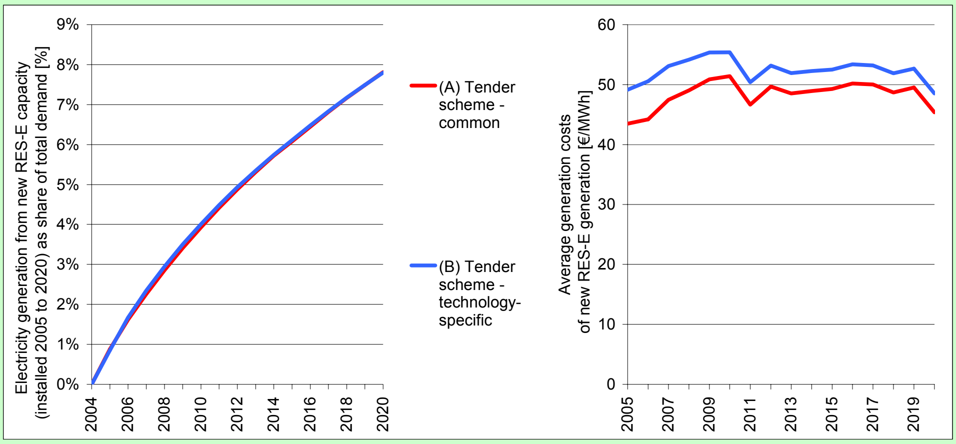
(e) Helps to reduce costs for RES-E technologies

Similar to the quota obligation based on TGCs, full competition entails that the cost components are as cheap as possible.

(f) Does not necessarily lead to minimisation of generation costs

Distortion between technologies may occur, if technology specific tenders are launched. Therefore, total generation costs are not necessarily minimised within such a scheme. [111]

Box 4.20 Comparison generation costs applying technology specific tender scheme with a tender including all RES-E technologies



The figure above illustrates the impact of applying technology specific tender schemes versus a tender including all RES-E technologies on resulting generation costs. In more detail, it is assumed that tender systems are introduced in 2005 in Portugal in order to achieve a moderate RES-E target for 2020 in size of 7.8% (on total demand) for electricity produced by new RES-E capacities (installed 2005 to 2020). Two variants are investigated: Variant (A) refers to common tender system covering all RES-E options; and variant (B) describes a tender system where technology specific tenders are set. Note, in

[111] Assuming that one tender is launched for all technologies, total generation costs will be minimised. Under this condition, however strategic bidding can occur – see below.

both cases the similar overall target is met and as depicted on the left-hand side above, also a similar dynamic development occurs.

The resulting impact on the dynamic development of generation costs of new RES-E capacities (installed 2005 to 2020) is shown on the right-hand side of the figure above. Over the whole period costs are by roughly 5% higher in case of variant (B) – i.e. the technology-specific tender – compared to variant (A) – i.e. the common tender systems.

(g) Leads to low costs for society

In theory, a tender procedure is a good instrument to minimise costs for society. Producer surplus can be reduced, due to competition among the investors. In practice, the selection of the single tender portfolios must be made with caution as, on the one hand, a too large diversification can lead to oligopolies and, on the other hand, the absence of a technology split favours strategic bidding. In general, tender procedure lead to low costs for society if the following issues are considered:

(i) Avoid monopoly and oligopoly structures

If the tender is split into to many technology specific tenders oligopoly structures occur – especially in small countries - leading to higher bids and, hence, higher costs for society.

(ii) Minimise strategic bidding

If no technology diversification takes place and the RES-E target is ambitious, a too high capacity volume is launched within one tender. Such a system, however, invites investors to bid strategically. More precisely, if an investor knows that the generation costs are (much) lower than the marginal bid that will still be accepted (win), he can increase his offer strategically, i.e. the offer price will be a bit lower than the expected marginal offer.[112] In general, the potential for strategic bidding rises with the information level of the potential investors, i.e. over time. One remedy to reduce strategic bidding is to introduce a technology specific splitting and / or ceiling price, i.e. only bids under this price will be considered in the tender.

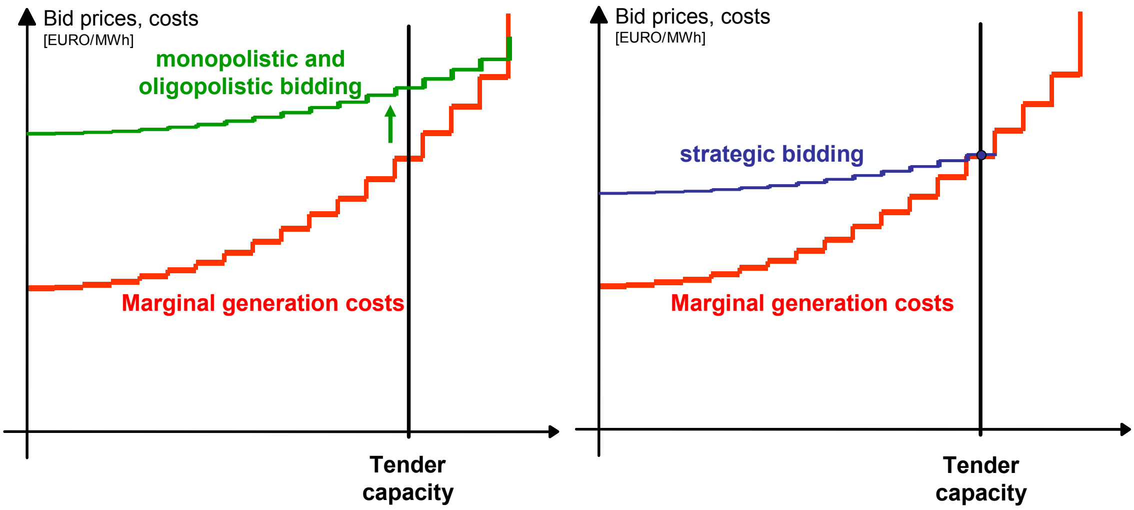


Figure 4.7 Comparison of monopolistic / oligopolistic bidding with strategic bidding

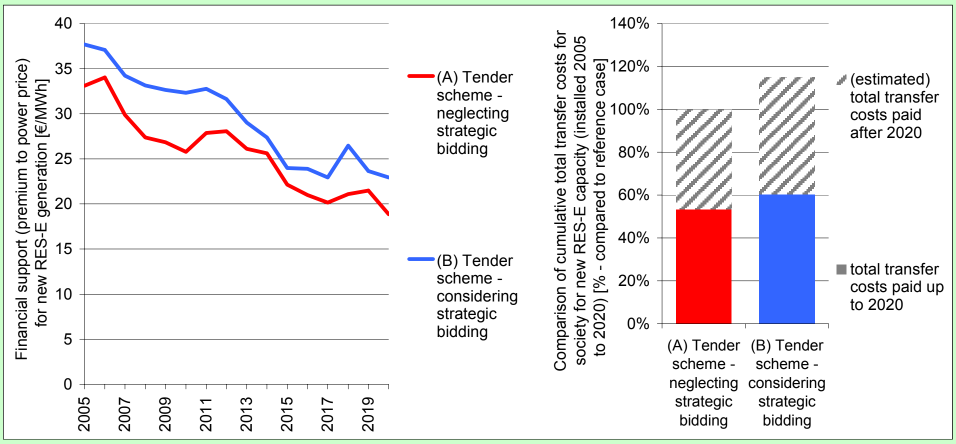
[112] Note that such behaviour differs from oligopolistic or monopolistic behaviour as in the latter case the general bid level rises, i.e. also the marginal bid!. In the case at issue only the bids lower than the unaffected marginal bid are influenced by strategic behaviour.

Box 4.21 Comparison of transfer costs for society considering / neglecting strategic bidding within the tender procedure

The figure below illustrates the impact of strategic bidding (as likely in case of tender systems) on transfer costs for society. For Portugal it is assumed that tender systems are introduced in 2005 in order to achieve a moderate RES-E target for 2020 in size of 7.8% (on total demand) for electricity produced by new RES-E capacities (installed 2005 to 2020). Two variants are investigated: Variant (A) represents the case where strategic bidding is neglected; and variant (B) refers to a tender system where investors act 'strategically' and, consequently, set strategic bids.

As depicted on the left-hand side of the figure above the dynamic development of the leveled financial support for new RES-E (i.e. expressed as premium to power price) shows that over the whole period higher costs occur for the case where strategic bidding is considered.

A similar result occurs with respect to the total transfer costs as illustrated on the right-hand side of the figure below. Similar to the dynamic interpretation on the left-hand-side it can be observed that variant (B) – i.e. the case where strategic bidding is considered - leads to higher societal costs (i.e. +17%) compared to the variant (A) in which strategic reactions are neglected.



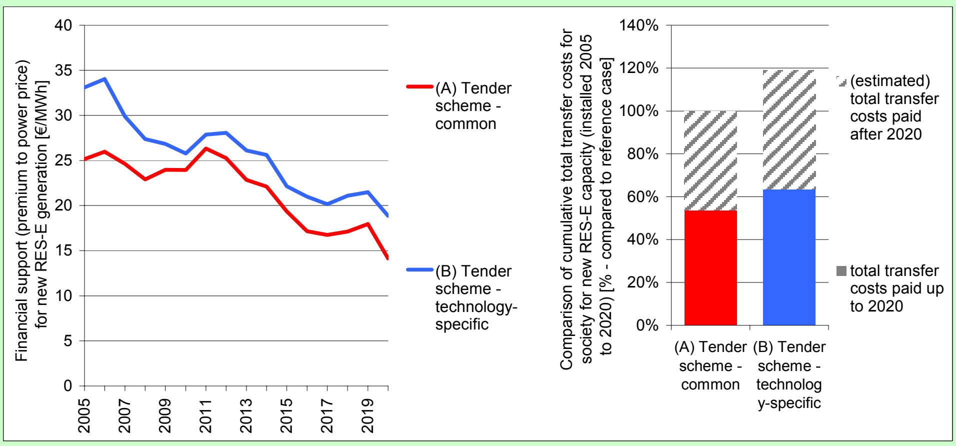
(iii) Call for tender take place continuously

Continued calls for tender are important to stimulate RES-E deployment and to stimulate competition.

(h) Helps to promote a specific portfolio among different RES-E technologies

A tender scheme is a suitable instrument to stimulate a certain RES-E deployment, i.e. reach a specific RES-E portfolio in the long-term. A higher split leads, on the one hand, to more specific calls and hence a more diversified RES-E deployment, but, on the other hand, reduces the cost effectiveness among the different RES-E technologies.

Box 4.22 Comparison of transfer costs for society applying technology specific tender scheme with a tender including all RES-E technologies



The figure above illustrates the impact of applying technology specific tender schemes versus a tender including all RES-E technologies on transfer costs for society. Thereby, as already described in Box 4.20 it is assumed that tender systems are introduced in 2005 in Portugal in order to achieve a moderate RES-E target for 2020 in size of 7.8% (on total demand) for electricity produced by new RES-E capacities (installed 2005 to 2020). Two variants are investigated: Variant (A) represents the case where only one common tender is applied covering all RES-E options; and variant (B) refers to a tender system where technology specific tenders are set. Note, in both cases the similar overall target is met.

As depicted on the left-hand side of the figure above the dynamic development of the leveled financial support for new RES-E (i.e. expressed as premium to power price) shows that over the whole period higher costs occur in case of technology-specific tenders.

By considering both the cumulative paid costs in the period 2005 to 2010 as well as the estimated residual costs which are still to pay in the period after 2010, total transfer costs are illustrated on the right-hand side of the figure above. Similar to the dynamic interpretation left it can be observed that variant (B) – i.e. the technology specific tenders - leads to higher societal costs (i.e. +18%) compared to the common tender system of variant (A).

(i) Helps to reach an area or plant size specific distribution of a RES-E technology

The promotion of RES-E technologies in a certain area or for specific technology sizes is easy to implement. In contrast to a feed-in scheme, no or only lower additional administration costs occur. Again, care must be given to maintain a competitive investment structure.

(j) The RES-E deployment is (mainly) independent from the development of the total electricity demand

For a tender procedure based on guaranteed prices, in principle, the same effects as for a 'fixed' feed-in tariff occur, namely:[113]

- Market separation – technologies covered by the tender procedure versus residual electricity market
- RES-E deployment is (mainly) independent from total electricity demand
- Higher price elasticity on the spot market
- In the case that the tender is based on investment subsidies investors have to consider a higher risk premium.

(k) The power market price decreases

Again, the effects are similar to those that can be observed in the case of a feed-in tariff scheme and a quota obligation. Under a tender scheme the power price drops due to the market separation.

(l) 'Low' premium costs for consumer in the early phase of the quota obligation - costs for society increase over time

It can be expected that premium costs for consumer due to the tender procedure rise over time. The reasons are:

- Lower total capacity that must be supported in the initial stage.
- Relatively low bid price as most cost efficient generation options will be exploited first

A more homogeneous premium cost development over time can be reached if:

- a higher share of tender for less mature technologies is launched in the early stage;[114]

[113] Compare also section on feed-in tariffs.

[114] Especially considering that the costs for the non-mature technologies can be reduced in the future, leading to a lower burden for society.

– the tender procedure is based on investment subsidies.

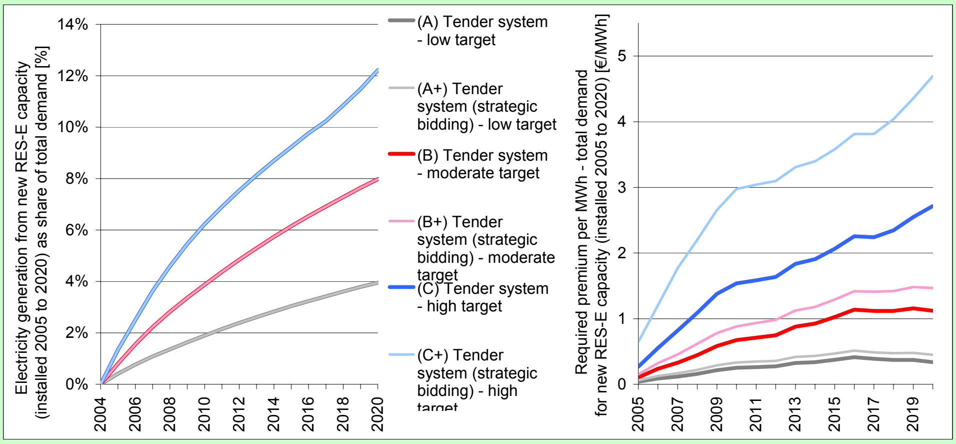
This means that there are realistic options to avoid a high burden in the later phase of a promotion scheme. The development depends on the technology portfolio and on the capacity that is invited to bid over time.

Box 4.23 Transfer costs for society due to the promotion of RES-E technologies over time – in case of tender systems

The example below describes the dynamic development of resulting transfer costs for society for different RES-E deployments – in case of applying tender systems. Thereby it is assumed (i) that these schemes are applied in 2005 in Italy, and (ii) that they refer solely to new RES-E capacities (installed 2005 to 2020). In total six variants are investigated: Variant (A) and (A+) represent the case where a rather low target is set; variant (B) and (B+) describe the case of a moderate target and variant (C) and (C+) refer to ambitious RES-E goals. To get aware of the likely impact of strategic bidding (of investors) for each target a variant (i.e. A+, B+, C+) is applied differing to the default case by the fact that strategic bidding is considered.

The impact on the resulting RES-E deployment is illustrated on the left-hand side above: In 2020 within variant (A) (as well (A+)) new RES-E capacities contribute to a share of 4% on total demand, whilst with moderate goals a share of 8% can be achieved and, finally, by setting high targets a share of 12.2% occurs.

The impact on the dynamic development of the accompanying transfer costs for society due to the RES-E policy is depicted on the right-hand side of the figure above. For the low to medium targets rather homogenous premium costs occur. In case of a high target transfer costs rise continuously up to 2020. With respect to the strategic bidding it can be clearly seen that in case of ambitious targets it represents a crucial issue – leading to societal costs utmost twice compared to the default case where this likely issue is neglected. Similar to a TGC scheme the deviation of a pure tender scheme to a mixed system is highly influenced by the RES-E target as well as the design of the additional support scheme- Again, a 'bad' design leads to higher, a 'good' design to lower transfer costs for society.



(m) National burden depends on the actual national RES-E deployment – a homogenous burden sharing at the international level is difficult

The distribution of the consumer costs among the countries differs. Similar to a feed-in tariff scheme the burden depends on the actual national RES-E deployment. Hence a homogenous burden sharing is difficult to implement. A unique burden can be reached by setting the tender at the EU level.

4.2.5 Combining different RES-E strategies

It is also possible to mix the different system. In the following section a combination of the most important strategies is briefly analysed.

4.2.5.1 Combining TGCs with feed-in tariff scheme or other subsidy system

It is feasible to let some (less mature) RES-E technologies receive a feed-in tariff in addition to the TGC price. This means, these technologies will receive the politically determined tariff instead of the power price.[115] In the case where the quota is unchanged compared to a TGC system without feed-in tariffs or other subsidies, the effect on the power price is unchanged. The introduction of additional feed-in tariffs only affects the TGC market. Some of the RES-E technologies are replaced by the RES-E technologies that receive the feed-in tariff as the latter are more competitive due to the additional support from the feed-in tariff. A further consequence is that the TGC price decreases.

The introduction of a feed-in tariff interferes with the functioning of the TGC market. However, it is also a way of ensuring a political determined diversity of RES-E technologies, and thereby hinders lockout of promising RES-E technologies. Similar effects occur applying an investment subsidy or a tax relief instead of a feed-in tariff scheme if both promotion schemes can be used simultaneously.

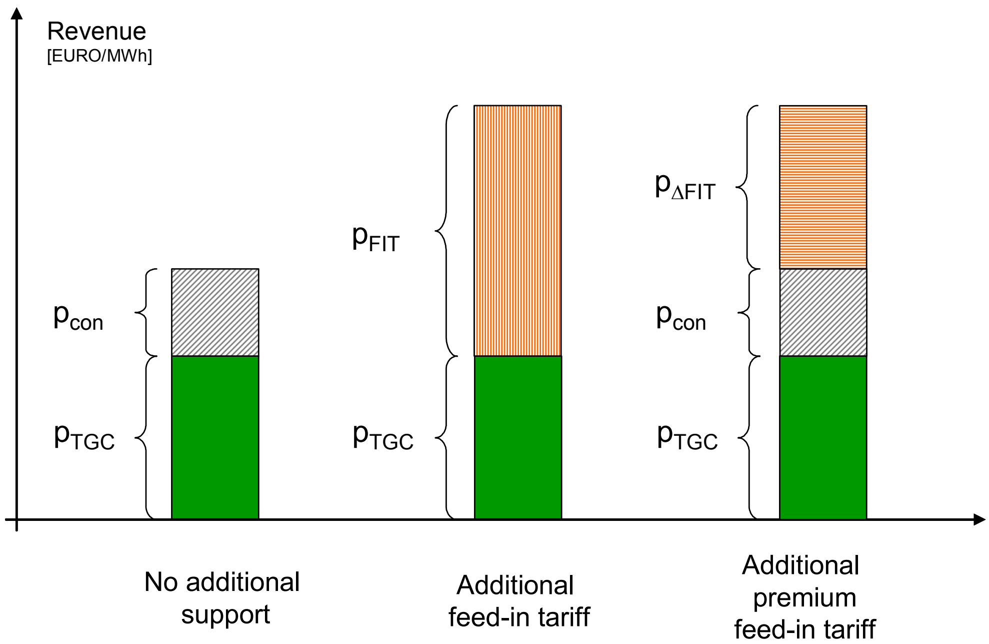


Figure 4.8 Comparison of revenues: TGC system, TGC plus FIT, TGC plus premium FIT

4.2.5.2 Combining TGCs with tender procedure

When applying a tradable green certificate system together with a tender procedure based on guaranteed prices, the market volume must be considered.

- In a small country the use of a comprehensive tender procedure, together with a green certificate market should be done with caution. Large tender-projects, like big off-shore wind parks, will not be small marginal ones compared with the quota. Therefore, they will have to be planned and implemented outside the scheme. Otherwise the consequences might easily be that the price-determination on the certificate market is heavily influenced by the tendering projects, jeopardising the confidence of other actors at the market. Moreover, the tendering projects will gain little or no benefits from the certificate system, because the prescribed quotas cannot be the driving force

[115] It is also possible to give these technologies a feed-in tariff in addition to the TGC and power prices. Implementing such a system leads to an increase of the transaction costs of the investor (3 different systems), the core result, however, remains unaffected.

behind large tender-projects, these ones having to be planned and implemented outside the system anyway. In addition, the tender procedure should be designed to attract a large number of bidders, the major requirements focusing on the needs for competencies with operations and constructions, implying that a considerable number of actors should be on hand. Nonetheless, it is recommended that specific sites for establishing the future big projects are chosen (implying that no free entrance will exist).

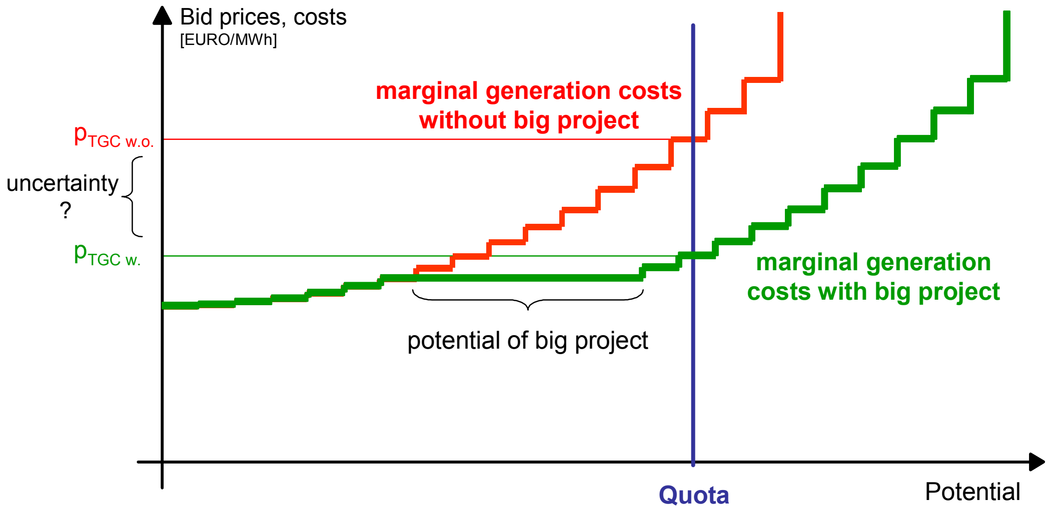


Figure 4.9 Effects of big projects on (market) price for TGCs

- In larger countries most renewable projects – even large offshore wind farms – will be marginal, not having any significant impact on fulfilling the quota obligation. Therefore, it might be relevant to utilise the tendering system to selectively promote those RES-E projects that are interesting in the long-term, but are presently not economically attractive in a TGC scheme.

The combination of a TGC system and a tender procedure based on investment subsides causes no problems at the national level. On the contrary, cost development is more transparent if a quota system is integrated with an investment subsidy based on a tender procedure than without the tender. The reason is that the bid price for the tender of this technology can be directly observed – important to observe the cost development over time. In the case of a TGC system and fixed investment subsidies, i.e. they are not based on a tender – the cost development of this technology cannot be directly tracked as only the TGC price signal is known. At the international level, it is critical to combine an international TGC system with national tenders based on investment subsidies. The reason is that this additional support may differ among the countries, i.e. while in one country a higher share will be promoted another country may significantly restrict the additional budget for investment tenders. The consequences are that those countries giving less additional support (via the tender) gain from such a combined scheme. They receive cheaper TGCs on the (subsidised) international TGC market without adequately contributing to the price reduction. In other words, strategic reaction at the national level cannot be avoided.

4.2.5.3 Combining feed-in tariff schemes with tender procedure

The mechanism behind a tender scheme is similar to a stepped feed-in tariff. The main difference is that the granted (guaranteed) price for RES-E will be determined by the market itself and not by a regulatory authority. Hence, the different systems interact in a fairly straightforward way.

It will not generate specific problems to introduce a tendering system for some technologies alongside to (pure) feed-in tariffs applied for other technologies. While some technologies receive a feed-in tariff, other technologies are supported by a tender procedure based on guaranteed prices. In particular, it can be useful to apply a tender procedure for non-mature technologies in order to be able to observe the cost development due to technological learning.

Combining both instruments for one technology does not lead to huge advantages – two different procedures must be applied, leading to higher administration costs. Nevertheless for specific project where the general conditions are already predefined (e.g. the capacity, site, and grid connection) tender schemes in parallel with a feed-in tariff schemes may provide some advantages.[116]

4.2.6 Comparison of instruments and general effects of the promotion of RES-E technologies

Please note, the main effects of the most important promotion schemes – feed-in tariff, quota obligation based on tradable green certificates and a tender system – are summarised and compared in Table 4.4 in a comparative way.

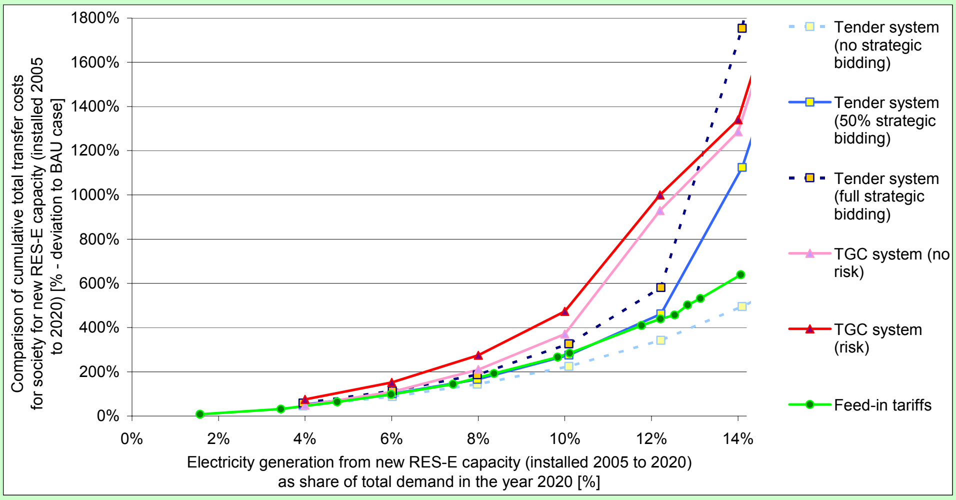
Box 4.24 Comparison of total transfer costs for different instruments in dependence of the envisaged RES-E target

This example provides a sound comparison of RES-E targets and resulting transfer costs for different promotion instruments. This comparison is conducted on a country level – where Italy has been selected as representative of EU Member States without any striking characteristics of its RES-E resource. In more detail, the following instruments are applied: (i) Technology-specific feed-in tariffs, (ii) TGC systems – considering / neglecting higher (investor) risks, and (iii) Tender systems - considering / neglecting strategic bidding. Note, within all scenarios it is assumed that instruments are solely applied to new RES-E capacities (installed 2005 to 2020).

The figure below illustrates the resulting total transfer costs for the instruments applied in dependency of the achieved RES-E deployment. Thereby, the following can be observed:

- *In case of low incentives / targets only small differences can be observed among the instruments.*
- *In case of moderate to high incentives / targets huge differences between the applied instruments appear.*

Please note, a qualitative comparison of the instruments is given in the general text of this section!



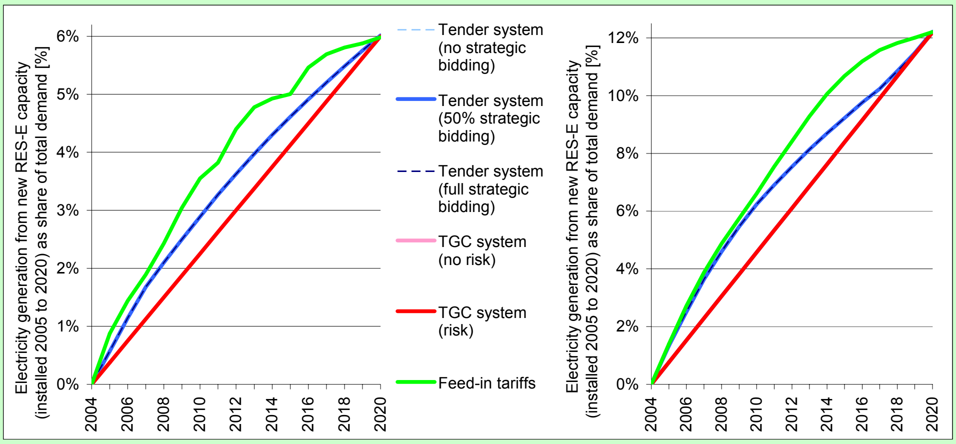
[116] Of course, the size of the investor market must be considered. It could lead to problems in small countries / big tender projects.

Box 4.25 Comparison of promotion instruments for achieving a moderate and an ambitious RES-E target in the mid-term

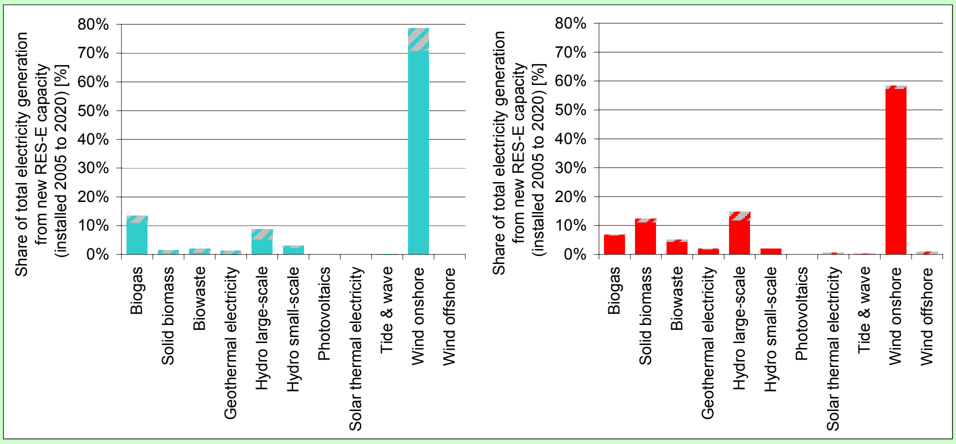
Accompanying to the example of Box4.24 two specific RES-E targets – i.e. a moderate in size of 6% and an ambitious in size of 12.2% - are selected for an in-depth comparison of various issues:

In more detail, based on the comprehensive comparison of policy instruments on a country level as undertaken for Italy various results are depicted in the following. In more detail these are: (i) RES-E deployment over time, (ii) the resulting RES-E portfolio in 2020, (iii) generation costs, and (iv) the necessary financial support for new RES-E over time.

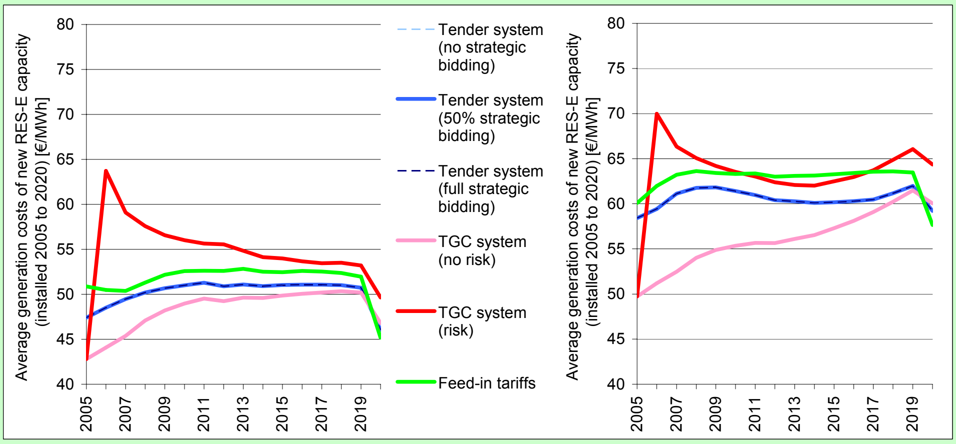
(i) RES-E deployment over time



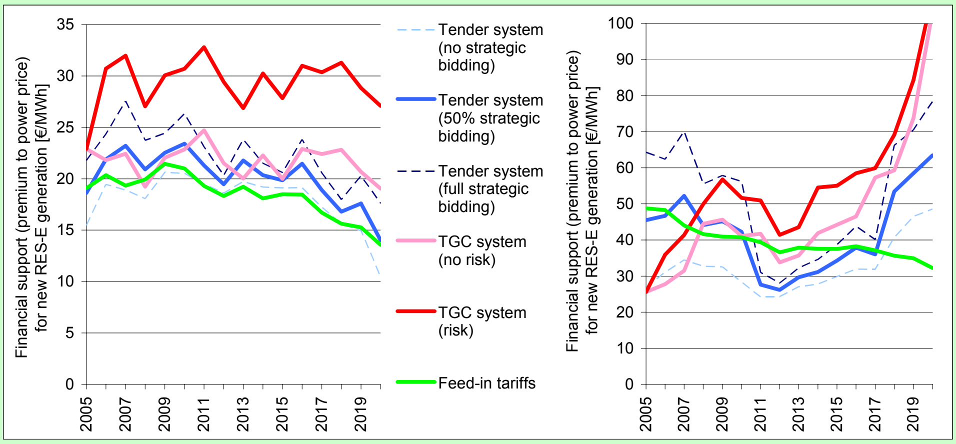
(ii) the resulting RES-E portfolio in 2020



(iii) generation costs



(iv) the necessary financial support for new RES-E over time



There is no clear favourite support scheme; each instrument has its pro and cons. The **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:
  - In the case of 'low' targets[117] 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. [118]
- 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. 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;
- Introducing a tender system alongside a feed-in tariff or a TGC system will not create specific problems in large markets (or for small tender schemes). The different systems interact in a fairly straightforward way. The advantage of tendering is the ability to support specific technologies at specific points in time and thus in many ways this system is complimentary to more general support systems, such as feed-in tariffs and TGCs. Of course, to guarantee an effective RES-E development within a tendering system – equal to a feed-in tariff or TGC – stop and go strategies must be avoided.

[117] Normally these conditions are represented by a flat RES-E supply curve.

[118] Usually under these conditions the RES-E supply curve is steep, allowing a higher producer surplus if the instrument is not well chosen.

- Generation costs can be minimised by avoiding a differentiation among the promotion of the different RES-E technologies. In practise, a TGC system fits best due to the competitive character.
- A quota obligation based on TGCs is less efficient with respect to the transfer costs for society compared to other instruments analysed, as, firstly, a higher risk must be born by the generator, and, secondly, the efficiency gains achieved by implementing this instrument are absorbed by the producer (high producer surplus) and not by the consumer.
- 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.
- In addition, 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 more simple implementation or a TGC system.
- Assuming a medium to high RES-E target, transfer costs for society are more flat over time under a feed-in tariff scheme, followed by a tender procedure compared to a quota obligation – leading to higher public acceptance.
- One advantage of an international TGC system is that a homogenous distribution of the RES-E costs among the countries (consumer) is easy to implement. Under the assumption that the level of the quota obligation is unique among the Member States, the same burden on consumer occurs. In the case of a feed-in tariff scheme or a tender procedure, the premium costs for consumer depend on national RES-E generation, i.e. if the actual deployment is high, the burden is high too. Hence, it is difficult to reach a harmonisation among the countries. Of course, considering additional benefits from RES-E (rural development, job creation etc.), which occur in the country that actually developed the technologies, differences in the burden are – to a certain degree – justified.
- With respect to the generation structure (of RES-E and conventional power) and CO_2 emissions similar developments can be observed independent of the applied promotion instrument, if comparing a TGC system, a harmonised feed-in tariff (where the guaranteed price is set equal to the spot market price plus the TGC price) or a general tender scheme (which includes all technologies in a single tender).

As already discussed the different promotion instruments for RES-E technologies have an impact on the (conventional) power market and their greenhouse gas abatement too. The generation structure for RES-E and conventional power (including GHG emissions) depends – in principle – on the design criteria of the different instruments. This means that with all discussed support schemes the same capacity deployment and the same reduction in CO_2 emissions can be reached.[119]

[119] For example, a unique feed-in tariff for all RES-E technologies (the guaranteed price is set equal to the power market price plus the TGC price) or a tender scheme, which includes all technologies within one tender have the same effect as a joint quota obligation for all RES-E technologies.

Most important **general effects** of RES-E policies are in this context:

- All (analysed) main instruments – fixed feed-in tariff scheme, TGC system and tender procedure - give priority rights to a certain amount of RES-E. This implies that the power market is split (divided) between a priority market and a 'free' competitive market. The promotion of RES-E technologies will displace a corresponding amount of conventional power by lowering the demand for conventional power. The market price of power will decrease when support schemes for RES-E are introduced assuming a competitive market and increasing marginal cost of conventional power;
  - In a closed economy with no international power trading increased RES-E production will totally replace domestic conventional power and thus an equivalent emission reduction will be achieved;

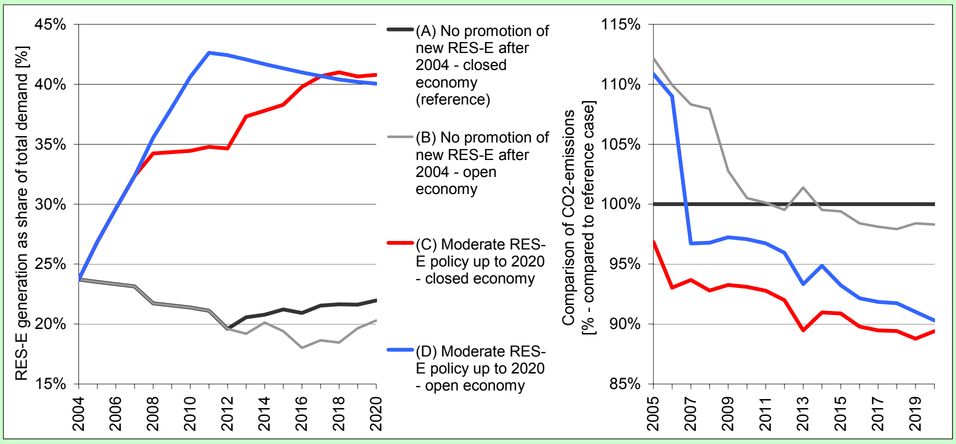
Box 4.26 Comparison of CO_2-emissions with and without RES-E policy in a closed / open economy

The example below provides a comparison of CO_2-emissions with and without RES-E policy in a closed as well as an economy. Exemplarily Denmark has been chosen for this investigation. In total four variants are investigated:

- *Variant (A) represents the reference case where it is assumed that after 2004 no RES-E policy is applied to promote new RES-E options; and variant (C) describes the development of RES-E if a RES-E policy setting moderate incentives would be in place up to 2020. Note, for these both cases it is further assumed that the national electricity market is not linked to the international market – i.e. representing a closed economy.*
- *Supplementary to above variant (B) and (D) represent similar cases as above assuming an open economy – i.e. the European electricity market with its interconnections between the countries as it does exist today.*

The resulting RES-E deployment is illustrated on the left-hand side below: In 2020 within variant (A) and (C) the share of RES-E on total demand is decreasing until 2020 – to a level of 22% within the closed market (variant (A)) or even to 20% in case of international trade (as power prices are slightly lower in variant (C)). In contrast, with moderate RES-E policies as assumed for variant (B) and (D) RES-E achieves a share of roughly 40 to 41% in 2020. Thereby, RES-E can contribute faster in the short-term in case of an open market as technical restrictions (grid limitations and balancing) for RES-E are on a lower level.

On the right-hand side of the figure below, the impact on the development of CO_2 emissions (referring to the national power market) is illustrated. Thereby, the deviation to the reference case (variant (A) - i.e. no promotion of new RES-E after 2004 within a closed market) is depicted. With moderate RES-E promotion incentives in a closed market as assumed for variant (C) CO_2 emissions will decrease to a level of roughly 89% in 2020 compared to the reference. For an open market the impact on national reduction is ambiguous as the actual reduction depends on the conditions on the international spot market. Hence, with similar RES-E policies the resulting reduction of CO_2 emissions within Denmark is lower – compare the blue line (variant (D) – open market) with the red line (variant (C) - closed market) on the right-hand side of the figure below!



   - In an open economy with international power trading and sufficient interconnections among the countries an ambitious national RES-E policy does not automatically replace domestic conventional power and, consequently, does not lead fully to a national reduction in CO_2 emissions. In an open economy, the distribution of the national conventional electricity reduction is independent from the total national RES-E generation. The national conventional electricity production depends only on the conditions on the international spot market (marginal generation plant). As CO_2 emissions are related to power generation, the same conclusion is valid for national CO_2-reduction: how the total increase in RES-E generation itself is distributed among the countries has no influence upon the realised CO_2-reduction in each of the countries. (Morthorst, 2003);

- The total consumer expenses for electricity due to the introduction of a fixed feed-in scheme, a TGC system or a tender procedure can increase or decrease as the additional costs for RES-E due to their promotion are counteracted by the decreased market price of conventional power.

Table 4.4 Comparison between feed-in tariff scheme, quota obligation based on TGC and tender procedure

Criteria	**Feed-in tariff**	**Quota system**	**Tender scheme**
Is instrument successful and effective with respect to RES-E deployment?	Proven to be successful and effective	Must be proven to be successful and effective (depends on the design criteria)	Must be proven to be successful and effective (depends on the design criteria)
Can a certain deployment be guaranteed and is instrument flexible in use?	RES-E target cannot be exactly reached – instrument is flexible in use and time	RES-E target can be exactly reached - but instrument is less flexible	RES-E target cannot be exactly reached but uncertainty is low – instrument is flexible in use and time
How high are administration and transaction costs?	Low (to medium) administration and transaction costs	Medium to high administration and transaction costs, especially if system should be flexible	Low to medium administration costs, medium to high transaction costs
Does instrument encourage competition among the generator?	No, does not encourage competition	Yes, competition among the investors	Yes, competition among the investors (if oligopoly structure can be avoided)
Which effect does instrument have on technological development?	Helps to develop (more) efficient components	Help to reduce costs for RES-E technologies	Help to reduce costs for RES-E technologies
Does instrument lead to minimisation of generation costs?	No, if RES-E technology specific tariffs are applied	Yes, if all RES-E technologies are covered by one quota obligation (at least in the short- to medium-term)	No, if technology specific tenders are launched
Does instrument lead to low costs for consumer?	Yes, lead to low costs for society if instrument is well design	No, leads to higher costs for society (if no RES-E specific targets) and targets are ambitious	Yes, lead to low costs for society if instrument is well designed
Is instrument appropriate to promote specific RES-E technologies?	Yes, helps to promote a specific portfolio among different RES-E technologies	No, helps to promote currently most cost efficient RES-E technologies	Yes, helps to promote a specific portfolio among different RES-E technologies
Is instrument appropriate to favour a specific site or plant size?	Yes, helps to reach an area or plant size specific distribution of a RES-E technology	No, promote currently most efficient plants and, hence, favours the development of RES-E 'clusters' and hot spots areas	Yes, helps to reach an area or plant size specific distribution of a RES-E technology
Does instrument react on electricity demand?	No, RES-E deployment is (mainly) independent	Yes, RES-E deployment interacts with the development of the total electricity demand	No, RES-E deployment is (mainly) independent
Does the power price decrease due to the RES-E promotion?	Yes	Yes	Yes
How does the burden for consumer look like over time?	'Relative' homogenous premium costs for society over time	'Low' premium costs for consumer in the early stage, but costs increase over time	'Relatively' homogenous premium costs for society over time, but higher than under a feed-in tariff scheme
Is international burden sharing easily to reach?	No, as national burden depends on the actual national RES-E deployment	Yes, as national burden depends on the national RES-E target	No, as national burden depends on the actual national RES-E deployment

4.3 Evaluation of CO_2 policies – tradable emission allowances

Tradable emission allowances (TEAs) are designed to help in achieving a given emission target at minimum costs, but they can also be used to advance the RES-E deployment.[120] In general the following effects occur when introducing a TEA system:

- *Conventional supply costs increase.*

  Under a TEA carbon-intensive plants face higher relative increases in marginal production costs than less carbon intensive power producers, i.e. the merit order of conventional plants may change *and* the supply curve is now at a higher level. The additional costs depend on the marginal costs of CO_2-reductions, that is the emission allowance price.

- *The price on the power spot market increases unambiguously* (unless the marginal producer is generating is carbon free)

  The reason is that the costs of reducing CO_2 emissions rise. The magnitude of the increase depends on the
  - GHG goal
  - available portfolio of electricity plants
  - other GHG reduction options, the TEA price depends on all possible options that can be used to reduce the GHG emissions (including a reduction in output)
  - price elasticity of power demand[121];
  - Other factors such as regulatory pricing mechanisms, available generating capacity, competitive pressure, price elasticity of demand, market concentration and allowance allocation method

- *The TEA differ between a national and an international scheme*

  The TEA price under a national TEA system will generally differ from the price under an international TEA system. Depending on the CO_2 reduction options within the markets, the TEA market price can be both, higher or lower within a national TEA system compared to an international implementation scheme.

- *A TEA favours all economically measurable CO2 reduction options in the same way.*[122] This means a TEA scheme induces a stronger development of:
  - RES-E technologies[123];

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[120] Note that emissions are reduced via target setting and not the trading scheme.

[121] Likewise, the consumer price will increase when a TEA system is introduced.

[122] This means, not directly measurable benefits from the different options are not considered such as increased diversity of national power supply, increased security of supply, avoided pollution associated with conventional electricity generation, added value of developing new industries (e.g. new jobs, service skills, diversity of rural employment, export and manufacturing capacity).

[123] For the following groups different incentives exist using RES-E technologies:

- Renewable electricity from independent producers

  This is the case of RES-E generators entirely and exclusively dedicated to the generation of RES-E. That means they do not produce electricity from conventional sources. Thus, they do not have a CO_2 emission target to comply with and neither are CO_2 allowances allocated to them under a grandfathering scheme nor would they have to buy allowances under an auction system. However, these firms would benefit from a TEA system since they would receive a higher price for the electricity they sell on the market.

- Renewable electricity from conventional producers.

  - fuel switching options (to less carbon intensive production);
  - efficiency improvements on the supply side;
  - options to reduce the electricity demand (DSM).

- *Introducing a national TEA market in a (small) country with an international power market leads to the following effects:*
  - The power price will be (mainly) given exogenously to the (small) country, i.e. the TEA system has only a marginal effect on the power price. Therefore, implementing a national TEA system in a country with an international power market (interconnections are available) only provides a marginal stimulus for national RES-E deployment;
  - The international competitiveness of the thermal power supply sector in the small country is (dramatically) reduced. The country increases its share of electricity import or reduces its share of electricity export compared to the situation before introduction of the national TEA system.
  - The CO_2-emissions will be actually reduced within the country

- *Introducing an international TEA market within an international power market leads to the following effects:*[124]
  - The new and higher level of the consumer power price will be the same for all consumers within the liberalised power market;
  - The higher spot price will induce a development of RES-E technologies in all countries, although RES-E will not be specifically favoured compared to other CO_2 reduction options. Both, RES-E and conventional power production will be developed where it is most efficient.
  - An international TEA market may – in reality – lead to market separation due to different power generation structure and the limited interconnections

- *The type of TEA allocation* - independently if in combination with a RES-E promotion scheme or not (compare also chapter 5.1 "The relationship between RES-E (FIT, TGCs) and CO2 (TEAs)") - *is important for implementing an international TEA scheme for both producers and consumers:*
  - If Member States have different quotas for CO_2 emissions, total (but not marginal) costs for power producers will be biased if the TEAs are grandfathered[125] to the companies covered by the TEA system. The higher the quota compared to the available CO_2 reduction options the better off they will be. Thus, in countries where the government wants to achieve significant

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Conventional electricity results in the emission of carbon dioxide. If a cap is put on those emissions, which is the case under a TEA scheme, conventional generators would have to give the pertinent environmental authority a quantity of CO_2 allowances at the end of the compliance period for every ton of CO_2 emission discharged. As renewable electricity does not emit CO_2, conventional generators do not have to keep allowances for the RES-E fed into the grid. In other words, by generating a combination of renewable electricity and conventional electricity, generators may provide the same amount of electricity to the market. But they would only have to submit allowances for the amount of electricity produced by conventional CO_2 emitting sources, not for the renewable electricity. This means that a lower amount of allowances is thus necessary. These extra allowances can be sold in the market getting revenues in return. Or it may mean that the conventional generator does not need to buy these allowances in order to comply with its CO_2 quota. It is quite clear that this benefits renewable electricity insofar as this electricity does not have to be covered by allowances. Also, since the conventional generator would have lower abatement costs if RES-E is deployed, this would be an attractive option.

[124] The same effects occur when implementing a(n inter)national TEA scheme in an isolated power market.

[125] They are distributed free of charge depending on historic emissions or a benchmark system.

CO_2 reductions by means of the TEA scheme (low quota for all installations), the power producers will be hurt economically, compared to companies in countries with less ambitious CO_2 reductions (high quota for all installations). Hence, differing rents in the electricity sector occur implementing a grandfathering system. As for consumer costs, under ideal conditions it does not matter whether the allowances are given away for free or auctioned off or sold at a fixed price.

– If allowances are allocated via an auction[126] there will be no bias between power producers, even when countries have different quotas for CO_2 emissions, because the additional costs due to the GHG restrictions are already included in the (rising) conventional electricity price. This means the agreed quota of each country leads to no distortions within the electricity supply industry. However, under these conditions distortions among the consumer may occur which is of especially importance for the competitiveness of the industry. Total additional electricity costs are low for consumers in countries with a less restrictive GHG target compared to consumers in countries with a more restrictive goal. The reason is that in the first case more revenues received from selling tradable GHG emission permits can be reimbursed (from the state) to the consumer.

– An equal burden sharing among Member States in determining the quotas (that is the same relative reduction compared to previous emissions) will imply the same (relative) economic effects on power producers no matter whether a grandfathering or an auction scheme is used to allocate allowances.

4.4 Evaluation of DSM policy

The consequences of supporting activities to reduce the electricity demand mainly depend on the structure of the national power market, i.e. to which extent it is integrated into an international system. In the following the effects of the two extreme cases are discussed, namely: a fully isolated market without interconnection of other electricity markets and a fully integrated market without import / export restrictions.

The main effects of the DSM support scheme within a national isolated electricity system are:

- the national electricity demand drops[127];
- the national power price decreases;
- the national electricity production declines[128];
- the national CO_2-emissions go down[129].

The consequences for the various parties involved are:

- *Electricity consumers applying DSM measures[130]:*

  They gain twice from DSM measures: Firstly, they reach the same service output by consuming less electricity and, secondly, they benefit from lower electricity prices.

[126] Here TEA must be purchased.

[127] The reduction is calculated by the difference between demand reduction due to the DSM and the increase of service demand due to the lower electricity price.

[128] In general both conventional power and RES-E could be reduced, depending on the marginal conditions.

[129] Of course, only under the assumption that the (marginal) substituted power plants are fossil fuel-based ones.

[130] With respect to society, a distinction between the group of consumers actually implementing DSM activities and the group of customers not directly implementing demand-side measures must be made.

- *Electricity consumer not applying DSM measures:*

  The benefit for this group is ambiguous. On the one hand, they gain from the electricity price drop. On the other hand, they co-finance the DSM support scheme. Hence, the net effect for all customers due to DSM can be both, either positive or negative.

- *National electricity generators:*

  The net effect on the national electricity generators is negative for two reasons: Firstly, due to the lower electricity demand, and, secondly, due to the drop in the electricity price.

- *Total national effect:*

  The total effect of DSM support measures for both - electricity producer and consumer - is negative. This means that the gains due to lower power price cannot fully compensate the necessary additional financial support for implementing DSM activities. Of course, this conclusion is only true if and only if external effects from the electricity generation and/or climate change targets are neglected.[131]

In the case of an international power system, the following effects can be discerned:

- the national electricity demand drops[132];
- the power price decreases less, if DSM measures are only implemented in (some) small countries[133];
- the national electricity generation decreases less than the national demand is reduced. Parts of the "free" electricity capacity will be used to export power or reducing the import of electricity, respectively[134];
- only parts of the total CO_2-emission reductions due to the DSM activities remain in the country, the other reductions take place abroad[135];
- the net effects for consumer and producer in the country implementing the DSM are mainly negative
  - consumers actually implementing the measure can gain, but can also lose; the actual effect depends on the share of the additional expenditures necessary to implement the measures;
  - consumers not implementing the measure probably lose as only low positive effects due to the slightly power price reduction can be expected;
  - the electricity generators lose compared to no activities, but gain compared to a national market. The reasons are, firstly, the power price remains higher, and, secondly, the national production level is higher (share of export increases);
- the net effects for consumer and producer in the country not implementing the DSM are ambiguous

[131] Note that a similar result occurs with respect to the promotion of RES-E technologies and all other strategies promoting a specific technology.

[132] A higher national demand reduction occurs compared to the case of a national power market assuming the same financial support. The reason is that in the latter case the service levels increase more strongly due to a lower power price.

[133] The reason is that the international supply curve is flat compared to the national one. This means that a demand reduction has less influence on the price structure. Assuming that a small country is only a price taker, no price reductions occur.

[134] The reason is that the actual electricity generation in one country depends totally on the marginal electricity conditions on the spot market and not on the distribution of the national demand relations. Hence, DSM measures may only have small impacts on national electricity generation.

[135] Again, the actual reduction depends on the marginal conditions of the electricity generation structure.

– all consumers abroad gain from the expenditures made in the country implementing the DSM activities. This means that this country subsidises the consumers in all other countries due to the (slightly) lower power price;
– all producers loose a little due to the slightly lower power price.

Summing up, consumers in the country carrying out an active DSM policy, subsidise the consumers in all other countries due to the lower electricity price and 'free' CO_2 reduction. Hence, DSM measures at a national level are no adequate policy for national CO_2 reduction within a liberalised power market.

4.5 Evaluation of CHP policy (general observations)

Combined Heat and Power (CHP) saves primary energy and exhibits much lower CO_2-emissions than the separate production of electricity and heat in fossil-fuelled power plants and boilers. These emission savings tend to be in the range of 20-50%. The EU, therefore, wants to increase the share of electricity from CHP from 9% in 1994 to 18% by 2010. Although the potential for CHP is substantial, liberalisation in the electricity and gas markets has resulted in an economically difficult situation for CHP in most EU Member States. In addition, support programmes for electricity from renewable energy sources make RES-E more attractive relative to electricity generated by CHP plants (CHP-E). Thus, without support programmes for CHP, only little additional CHP-E may be produced in the near future. Likewise, whether the European Emissions Trading System (EU ETS) will push or harm CHP-E depends on the actual design of the system, in particular, on the treatment of CHP within the primary allocation of allowances in the so-called National Allocation Plans.[136] In the following, we summarise the effects of a particular additional support measures for CHP. It is assumed that a tradable certificate system for CHP-E is implemented.

Introducing a quota for CHP-E as a share of total electricity production leads to the following effects[137]:

- the electricity market is split into a market for CHP-E on the one hand and into a market for electricity from other, say, conventional technologies on the other hand
- the additional costs for CHP-E are levied on conventional electricity
- the production of CHP-increases (assuming the quota is binding)
- the electricity production by other technologies decreases
- the prices and profits producers of CHP-E receive increase
- the prices and profits producers of conventional electricity receive drop
- the effect of the CHP-quota on the consumer price is generally ambiguous, i.e., it can either be higher, the same or lower compared to the electricity price without a CHP-E quota
- total costs of production will be higher than before, because CHP-E is more expensive than the conventional power, which is substituted by CHP-E

[136] An initial analysis of the NAPs shows that Member States differ considerably in the way they treat CHP. Some MS provide no additional support (i.e. extra allowances) to CHP plants, some only for new CHP plants, and some for both new and old CHP (Betz et al. 2004).

[137]Demand is assumed to be fairly inelastic, that is for a long-run analysis output effects would have to be taken into account as well.

5 Trade offs of RES-E with other policies

5.1 The relationship between RES-E (FIT, TGCs) and CO_2 (TEAs)

In the following the effects of a coincide use of two policy goals - the promotion of RES-E technologies and the fulfilment of a GHG-target (in combination with TEA) - are investigated with respect to market price development, RES-E deployment, GHG emissions and costs for society and producer.

5.1.1 Efficient strategies reaching a RES-E, a CO_2 target or both goals simultaneously

- *Both a TEA system and RES-E policy schemes can be used to reach RES-E deployment goals and emission reduction targets.*

  The application of either a pure RES-E policy or a pure GHG-target to reach both objectives, the promotion of RES-E and the restriction of GHG emissions, can be understood as the corner approach of the simultaneous use of the two instruments.[138]

  – **Pursuing only a RES-E deployment, the application of a pure RES-E policy is favourable from the consumer's point-of-view**

    An introduction of a TEA system alone will increase the power price and thereby also the consumer price, whereas an effective RES-E strategy in some cases will lower the total costs for consumer. Thereby, it is always better, with respect to minimise the burden for consumer, to use a RES-E strategy instead of both a RES-E policy and a TEA scheme or only a TEA scheme.

  – **Pursuing only a GHG reduction, the optimal choice of instruments depends on the correlation between the total consumer price and the RES-E policy.**

    In the case that total costs for the consumer decreases if RES-E instruments are used (negative correlation)[139], it is optimal to apply a pure RES-E policy despite that only a GHG-target must be reached. In the case of a positive correlation, however, it is optimal to use the TEA system. Note that the power market structure is important in this context. Assuming that an ambitious RES-E policy is applied on national level only, i.e. other countries do not pursue an active RES-E policy and the power market is liberalised, the power price only marginally drops compare to a harmonised RES-E policy on international level. Under this assumption the correlation is probably positive, and the application of the RES-E to reduce national GHG emissions is less effective. Despite high costs for society, only a low national GHG emission reduction may occur. National power producer will increase their export rate or reduce their imports,

[138] On the one hand, similar to an application of a RES-E policy (feed-in tariff scheme, a tender procedure or a quota obligation), total electricity demand will be separated into two parts: A demand for RES-E generation from promoted RES-E technologies[138], and a demand for conventional power and non supported RES-E, supplying the spot market. On the other hand, equivalent to the case of a pure TEA system, the additional CO_2-costs must be considered in the marginal supply curve for the conventional electricity part. With a coincide use, however, these costs depend on the RES-E deployment.

[139] Negative correlation means that the costs for consumer drop if a RES-E policy is applied. In this case, the additional costs caused by the promotion of RES-E are lower than the gain for the consumer due to the decrease of the power market price. Simply spoken, a higher RES-E deployment leads to lower costs for society. It the correlation is positive or negative depends on the assessment of additional benefits, which occur from the RES-E deployment.

respectively.[140] In other words, within a liberalised electricity market a national RES-E policy can not be used to reduce national GHG emissions in an efficient way.

– **Pursuing both goals simultaneously, the optimal choice of instruments again depends on the correlation between the total consumer price and the RES-E policy.**

  In the case of a negative correlation between the promotion of RES-E and the consumer price, only a RES-E policy instrument should be used to reach both goals. If a positive correlation exists, it is optimal to use both instruments.[141]

  Considering only economic costs of RES-E generation, in reality it is probably that a positive correlation between RES-E deployment and costs for society exists. This means that it is optimal to use a TEA system and a separate RES-E instrument to guarantee the important goals for the EU, the exploitation of RES-E and the fulfilment of the GHG target. This means that it is inefficient to replace a separate RES-E policy with a TEA system if the deployment of RES-E is still a political goal. This is especially true if the power market is open and other countries are pursuing a different policy. An ambitious climate policy in a (small) country, which is connected to an international electricity market, can only contribute marginally to national RES-E exploitation.

  However, it is a priori not clear, which share of RES-E minimise the total cost for the consumer. The consumer costs consist of the conventional electricity price and the additional costs due to the RES-E support. One the one hand the conventional electricity price decrease with a higher share of RES-E. On the other hand the additional costs for the customers rise with the increase of the promotion of RES-E.[142]

5.1.2 Effects of RES-E policy on power generation, price, emissions and costs

In general, the effects of the RES-E policy on the GHG policy and the power market are independent from the kind of RES-E instrument, i.e. only the total amount of RES-E generation is relevant. However, the effects are influenced if the RES-E policy is implemented on national or international level. General effects are:

- *The promotion of RES-E leads to a decrease of both power price and TEA price*

  In general, the additional CO_2-costs for conventional power decrease with an increasing share of RES-E. The reason is that a higher share of conventional electricity will be substituted by CO_2-free electricity from RES-E and, hence, the demand for conventional electricity will be decrease. Due to the lower demand in combination with the same (constant) total CO_2-target the necessity to reduce the specific CO_2 emissions per MWh diminishes, which leads to a reduction of the TEA price. Therefore, the marginal conventional supply curve is a function of the RES-E achievement. A lower share of RES-E - equivalent with an increasing pressure to fulfil the CO_2-target despite a high amount of fossil power plants - favours plants with low specific CO_2-emissions. As the TEA price indicates the additional CO_2-costs, the TEA market price is high in this case. Furthermore, as the marginal conventional electricity generation costs (including additional CO_2-costs) determine

[140] The condition, whether to produce electricity from conventional plants depends only on the international spot market price level. As long as the interconnections are available, the national production is (mainly) independent from the national RES-E policy, especially in a small country.

[141] For more analytical discussions, see (Jensen and Skytte 2003).

[142] The TEAs do not directly affect the consumer costs. The CO_2-restriction, however, is internalised in a higher conventional electricity price. In addition, the allocation of the TEA influences the consumer costs. In the case that the TEAs are sold via an auction system – and reimbursed to the customers – consumer costs are lower compared to a free allocation of TEAs.

the spot market price, the electricity price is high too. On the contrary, if the RES-E deployment is high, the TEA price and the spot market price are low.

- *RES-E policies, which give priority to a certain amount of RES-E, will displace a corresponding amount of conventional power by lowering the demand for conventional power.*
- *Total electricity generation costs rise due to the application of a RES-E policy*

  Total electricity generation costs increases with the promotion of RES-E technologies. The reason is that distortions to other CO_2 reduction options occur, i.e. an active RES-E policy favours the development of RES-E compared to other CO_2-reduction options. Purely seen from the perspective of the CO_2-reduction, other efficient options (like efficiency improvement or fuel switching) will not be used adequately.[143]

5.1.2.1 RES-E policy is introduced on national level (no harmonisation)

- *Higher power price reduction can be gained if the power market is isolated.*

  The extent of the price reduction depends on the market structure of the electricity sector. Within a national isolated market, a RES-E deployment leads to a higher drop than within an internationally embedded market. In addition, the more competitive the market is, the more likely it is that a reduction in costs will be drive down prices
- *High reduction of the CO_2 emissions occur if the market is isolated*
  - In a closed economy with no international power trading increased RES-E production will totally replace domestic conventional power and thus an equivalent emission reduction will be achieved.
  - In an open economy with international power trading and sufficient interconnections between countries an ambitious national RES-E policy does not automatically replace domestic conventional power and thus does not lead to a full national reduction in emissions. Other potential benefits related to the renewable development such as increased employment and industrial development, however, also accrue in the case of an international power market to the country implementing the RES-E technologies.
- *Higher benefits (for consumer) occur within an isolated power market*

  If consumers have to pay for the increase in RES-E the effect on total transfer costs for consumer is ambiguous: the increased costs for RES-E are counteracted by the decreased market price of conventional power. This means that a RES-E policy in a country with a less interconnected power system effects higher benefits than in countries which are embedded in an international power system.

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[143] In a static short-run consideration, RES-E can not fully compete with *all* other GHG-emission reduction options. Nevertheless, beside the cost advantages for the customers that can be occur due to the promotion of RES-E, renewables has other assets too. For example: increased diversity of national power supply, increased security of supply, avoided pollution form “conventional” electricity generation, added value of developing new industries (e.g. new jobs, service skills, diversity of the rural employment, export and manufacturing capacity).

Considering a dynamic technological development stimulated by the promotion of RES-E, in the long-run, RES-E generation may be a better answer to the climate problem and to a sustainable energy system than the adaptation of conventional electricity plants also with respect to minimise generation costs. Hence, to secure the development of RES technologies by using a separate promotion scheme for RES - beside pure climate change policy – makes sense.

5.1.2.2 RES-E policy is introduced on international level (harmonisation)

Introducing an EU wide ambitious RES-E policy will have the following effects [144]:

- *Power price drops also if power market is liberalised*

  As in a national system the development of RES-E technologies will lead to lower prices on the power spot market, assuming increasing marginal supply costs for conventional power plants and no market power. Under a coordinated scheme, however, the power price actually also drops if the power market is interconnected as total electricity demand for conventional power is reduced

- *Domestically achieved CO_2 emission reduction depends on power market structure*

  As part of a liberalised power market the domestically achieved emission reductions will depend on the marginal conditions on the power market. Thus the nationally achieved emission reductions will have to be shared among those countries participating in the power market. The emission reduction is independent of the actual distribution of RES-E generation among the countries.

- *Other benefits related to actual national RES-E deployment*

  The other benefits related to RES-E development, i.e. increased employment and industrial development will be gained by those countries actually implementing the renewable technologies independent of the RES-E quotas in the individual Member States.

- *Despite harmonised conditions on RES-E and power market benefits differs between the countries*

  Even though the power price is determined on a common power market, the effect on consumer prices might differ between the Member States since the green quotas differ. Consumers in Member States with a relatively small green quota, will enjoy the benefit of the decrease in the power price and only experience low extra costs of buying TGCs. Consumers in Member States with a relatively large green quota, will also enjoy decreasing power prices, but will have a larger share of the TGC price included in the consumer price. Therefore, it is likely, that the introduction of an EU wide TGC market will lead to a reduction of consumer prices in Member States with small green quotas, and to the opposite effect in Member States with large green quotas, i.e. the consumer prices will increase in these countries. Note that an equal burden sharing, that is the same relative quota in all countries, will lead to the same consumer price in all countries.

5.1.3 Effects of a TEA system on RES-E, power generation, price and costs

Although mainly focusing on CO_2 reduction options in general, the introduction of a system of tradable emission allowances (TEA) will also have an a positive effect on the promotion of RES-E technologies:[145]

- **The price at the power spot market will unambiguously increase** because of the cost of reducing CO_2 emissions. The supply curve for power will be shifted upwards corresponding to the marginal cost of CO_2 reductions, i.e. to the emission allowance price. The resulting increase in the power price will depend on the price elasticity of power demand. Again, the benefit depends on

[144] Note that for most of the described effects it is not as important to use the same instruments as to agree on the same level of effort pursuing a RES-E deployment. For example, the power price actually drops if all countries implementing an active RES-E policy compared with the case that such a policy will be implemented exclusively in a (small) country.

[145] In the case of no additional RES-E policy. The effect of a TEA scheme on RES-E policy depends mainly on the kind of RES-E support scheme, see below.

the power market structure. In a closed economy prices will rise (much) more than within an international environment, if other countries are pursuing a less ambitious or no climate policy.[146]

- Likewise, **the consumer price will increase when a TEA system is introduced**, leading to a reduction of the electricity demand
- **The higher spot price will induce a stronger development of RES-E technologies**, although RES-E will not be specifically favoured compared to other CO_2 reduction technologies like fuel switching to less carbon intensive production or efficiency improvements on both the supply and the demand side.
- **Different CO_2 quotas leads to economic distortions among the power producer**

  If the Member States have different quotas for CO_2 emissions the costs for power producers will be biased if the tradable emission allowances are grandfathered (distributed free of charge depending on historic emissions) to the companies covered by the TEA system. The higher the quota is compared to the available CO_2 reduction options the better off they will be. Thus, in countries where the government wants to achieve significant CO_2 reductions by means of the TEA scheme (low quota for all installations), the power producers will be hurt economically, compared to companies in countries with less ambitious CO_2 reductions (high quota for all installations). If allowances are allocated via an auction there will be no bias between power producers, even when countries have different quotas for CO_2 emissions.

  An equal burden sharing among Member States in determining the quotas (that is the same relative reduction compared to previous emissions) will imply the same (relative) economic effects on power producers no matter whether a grandfathering or an auction scheme is used to allocate allowances.

In contrast to the effects of RES-E policy on power price and CO_2 emissions, the effects of a GHG policy on RES-E policy schemes are ambiguous and depend on the kind of RES-E promotion scheme.

- *A TGC system, a premium tariff scheme, investment subsidies or tax relief reacts on GHG policy*
  - **RES-E deployment (slightly) drops in the case of a quota obligation.**

    A TEA system influences the RES-E deployment based on a quota obligation in both, a positive and a negative way. On the one hand, the absolute RES-E generation drops compare to the case of no GHG policy. The reason is that higher power price leads to a reduction of the electricity demand. As the demand is directly linked to the RES-E quota, a lower amount of RES-E generation – in absolute terms – is necessary.[147] On the other hand, the quota obligation is easier and cheaper to achieve. Note the higher power price has no influence on the RES-E deployment and the gains for the producer, because this price increase will be fully compensated by a reduction of the TGC price.[148] In total, the same revenue for the RES-E generator occurs than without a TEA scheme;
  - **RES-E deployment rise in the case of a premium feed-in tariff scheme, investment subsidies or tax relief**

    Under these schemes, the effects on RES-E deployment are contrary to those under a quota obligation. If the additional support is constant – i.e. they will not adapted due to the existence of the TEA scheme -, a higher RES-E deployment occur compare to the case of no TEA

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[146] In an open economy and international TEA scheme the new and higher level of the consumer price of power will be the same for all consumers within the liberalised power market.

[147] Of course, in relative terms the quota remains constant.

[148] TGC-price is given by marginal generation costs minus conventional market price.

scheme. The reason is that a higher power price (caused by the GHG-constraint) increases the competitiveness of the RES-E technologies, because the additional support for RES-E is independent from the higher spot market price. Those technologies, which are already competitive (with the help of the RES-E support) are now over-subsidised, leading to higher costs for consumer.

- *A feed-in tariff scheme and a tender procedure are independent from the GHG target*

  In contrast to the RES-E instrument discussed above, a feed-in tariff and a tender scheme based on guaranteed tariffs are independent from the GHG-policy. Note, the reverse, however, do not hold, i.e. these RES-E policies influenced the GHG-policy! In other words, the RES-E instrument directly influences the GHG policy (e.g. the TEA price), but the climate change policy do not have any direct effect on the deployment of RES-E as the RES-E deployment is independent from both electricity demand and electricity price.[149]

The impact of a tradable emissions allowance scheme on the singe RES-E support schemes are summaries in Table 5.1.

Table 5.1 Impact of TEA on RES-E support instruments

Impact on / of	Issue	RES-E instrument: TGC	RES-E instrument: FIT / tender	RES-E instrument: 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

5.1.4 Effects on consumer, power producer and RES-E generator combining RES-E and GHG policy

The effects for consumer, power producer and RES-E generator combining RES-E and GHG policy can be summarised as follows:

- **Consumer:** As already explained, a joint strategy reduces costs for society if RES-E generation and net consumer price have a positive correlation (which is probably the case neglecting external costs from the RES-E deployment).[150] The optimal promotion level for RES-E depends on the marginal conditions for RES-E generation, spot market and TEA price, and can not determined easily;

[149] Of course, only as long as the GHG-target is not as ambitious that the power price exceeds the guaranteed feed-in tariff or that the bids within a tender would drop to zero. Obviously, under this assumption a separate RES-E policy does not make any sense, as no additional RES-E capacity will be installed.

[150] And both, a RES-E and a GHG-target should be reached by the policies.

- **Power producer:** A decrease of the TEA costs leads to a reduction in compliance costs. However, if total producer surplus rise or drops due to the possibility to buy cheaper TEA depends on their portfolio of power plant technologies and on the marginal conditions on the different markets. [151]
- **RES-E generator:** In the case of a feed-in tariff, tender scheme or quota obligation, RES-E generators are unaffected. The reason is that under these schemes, the revenue from RES-E generation is independent from the power market price. In the case of a quota obligation, the lower TGC price will be compensated by a higher power price. Using a premium feed-in tariff, an investment subsidy scheme or a tax relief, RES-E generators gains, if the additional revenues from the higher spot market price will not be compensated by a lower premium.

Summing up, in principle, there seems to be no major obstacles for combining both strategies; of course caution must be given on the level of RES-E promotion.

5.2 Evaluating the relationship between RES-E (FIT, TGCs), CO_2 (TEAs) and DSM

5.2.1 General interaction RES-E policy and DSM

In general the following interactions between RES-E and DSM activities can be observed:

- Depending on the support instrument, **the use of DSM activities can have significant impacts on electricity demand, power prices and thus on RES-E capacity development**, especially if the power market is less open.
- **Pursuing an active national DSM policy in an international power market leads to a smaller power price reduction** (, especially if it is a small country). In addition, the national electricity generation decreases less than the national electricity demand drops, as parts of the “free” electricity capacity will be used for exporting power. Hence, only part of the CO_2 emission reductions due to DSM activities remains in the country. This means that consumers in this country subsidise the consumers in all other countries due to the (slightly) lower power price.
- **An implementation of DSM activities at the international level leads to higher power price reductions** compared with the situation where the measure is only implemented in one (small) country, assuming an international power market[152]. Consequently, the RES-E policy is influenced to a higher degree by DSM.
- With respect to the transfer costs imposed on consumers a clear answer can be given as, whether the net cost effect is positive or negative depends on the marginal conditions of RES-E and conventional power generation as well as on the marginal costs of electricity demand reduction.

[151] Assuming that the additional costs for reaching the GHG target can be fully imposed on the power price (full competition and no political price setting), generator from less CO_2-emitting plants (e.g. gas-fired power plans) lose if the additional CO_2-costs drops (and coal fired plants are the marginal power plants).

[152] This assumes that the power price decrease under international conditions (harmonised DSM policy and liberalised power market) compared with a national DSM strategy within an (mainly) isolated market depends on the country specific conditions, i.e. the electricity generation structure.

5.2.2 Effects of DSM on RES-E policy

As already mentioned measures reducing the electricity demand have different effect on the effectiveness and efficiency of RES-E policies. In the following the interactions are described for each main RES-E support scheme:

- *Effect of DSM policy on a TGC scheme*

  The interactions between DSM measures and a quota obligation for RES-E can be summarised as follows:

  – DSM activities reduce both the demand for conventional power and the demand for TGCs. The reason is that the share between RES-E and conventional power is (usually) directly linked via the quota obligation. Hence, DSM helps to reach the RES-E quota, i.e. the application of demand reducing activities represents an option to fulfil the quota obligation. In this sense, these two instruments works well together;

  – Consequently, the total electricity generation from RES-E decreases;

  – The TGC price (probably) increases compared to the case of no DSM. However, producers are neither negative nor positive affected from the increase of the TGC price, i.e. the RES-E generators receive the same revenue for the same amount of electricity fed into the grid.[153]

  – It is ambiguous if the DSM activities in combination with the TGC system lead to lower total costs for the consumer or not. The application of DSM influences the premium costs for RES-E positively – an electricity demand reduction leads to a lower RES-E demand and hence a decrease in premium costs. Consumer gains, if the additional costs caused by the DSM activities are less than the gains from the lower electricity price and the diminished premium costs for RES-E[154] due to the demand reduction.[155]

- *Effect of DSM policy on a feed-in tariff or a tender scheme*

  The following effects can be discerned:

  – In the case of a feed-in tariff or a tender scheme, the amount of RES-E generation retains unaffected from the introduction of a DSM policy. The reason is that, in contrast to the quota obligation, the RES-E demand only depends on the level of the guaranteed price – a high feed-in tariff entails a high demand. As these two instruments are not directly linked, no joint adjusted and balances policy is needed and / or possible.[156]

  – DSM activities fully reduce the conventional power generation. Hence, the demand for conventional power is more elastic than in the case of a quota obligation, due to the inelastic RES-E demand. Hence, the conventional power generation reacts more sensitive on price changes.

  – The net effect for the consumer is ambiguous. The introduction of a DSM policy has no effect on the RES-E deployment and hence the costs (for society) from RES-E policy. Under this as-

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[153] The lower revenues on the spot market are fully compensated by a higher revenue on the TGC market. Of course, less new RES-E capacity will be built due to the lower demand, leading to a lower absolute RES-E target. In this sense, new RES-E investors are (slightly) negative affected.

[154] Cost diminishes due to a lower absolute amount.

[155] The effects are highly influenced by the power market. Within a liberalised system (interconnection are available) power price only drops marginal due to a national DSM activity.

[156] Neither positive - e.g. DSM can be used to facilitate the fulfilment of the RES-E target (as in the case of a quota obligation) - nor negative effects - e.g. that DSM reduce the RES-E deployment in absolute terms (as in the case of a quota obligation) - occur.

sumption the consumers gain from the introduction of a DSM if costs for promotion DSM are lower than the cost reduction on the power market; [157]

- *Effect of DSM policy on a a premium feed-in tariff, an investment subsidy or a tax relief*

  The economic efficiency of new RES-E technologies will be reduced due to the power price reduction caused by the lower total conventional electricity generation, i.e. the gap between the conventional generation costs and RES-E costs increases. Hence, in the case of premium feed-in tariff, an investment subsidy or a tax relief, the competitiveness of the RES-E technologies drops, leading to a lower RES-E deployment. Of course, the effect depends "only" on the reaction of the electricity price. The elasticity is low in an international embedded liberalised market compare to an isolated one. In addition, by adapting the premium support, this effect can be avoided.[158]

The effects of measures reducing the electricity demand on the singe RES-E support schemes are summaries in Table 5.2.

Table 5.2 Impact of DSM activities on RES-E support instruments

Impact on / of	Issue	RES-E instrument		
		TGC	FIT / tender	premium FIT, investment incentives, tax relief
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

5.2.3 Interactions of TEA scheme and DSM policy

TEA and DSM policies mutually influence each other in a positive way. On the one hand, the introduction of a TEA scheme leads to an increase of the power price, and subsequently, a higher consumer price. This encourages the consumer to reduce their electricity demand. In addition, a rise in the power price makes DSM more cost efficient. Therefore, lower (financial) incentives are necessary to promote efficiency improvements on the supply side or a higher demand reduction can be reached, assuming that the financial incentive remains constant.[159]

On the other hand, an effective DSM policy reduced the electricity generation (both national and international, depending on the marginal generation conditions and interconnections) and hence the CO_2-output. A lower emission level, however, reduces the TEA price and the costs for (producer and) consumer.

[157] In contrast to a quota system DSM can not help to reduce additional costs for RES-E deployment.

[158] In this case – and in contrast to a quota obligation – the existence of a liberalised power market structure has a positive impact on RES-E deployment. However, negative effects with respect to national GHG emissions.

[159] This, of course causes higher costs for consumer.

If the net effect with respect to the costs for society is positive or negative depends on the following conditions.

- Additional costs for DSM policy
- Reduction of the TEA price
- Reduction of the electricity price due to DSM and lower TEA premium. The costs depend mainly on the market structure (isolated market versus liberalised market) and the level of DSM (and climate) policy (national promotion versus harmonised policy).

Summing up, independent if a RES-E policy exist or from the kind of RES-E or climate policy, in a liberalised market DSM measures should be harmonised on an international level.

5.3 The relationship between RES-E (FIT, TGCs) CO_2 (TEAs) and CHP

5.3.1 Effects of RES-E support schemes and TEA system on CHP deployment and policy

The effects of RES-E support schemes and climate change policies have that following effects on the development of CHP generation:

- **It is possible that the production of power from CHP will increase in response to the introduction of RES-E policy.**
  - The introduction of a TGC system where the share of RES-E is based on total electricity production will displace electricity produced from CHP, if CHP is the marginal power producer[160]
  - The introduction of a TGC system, where the share of RES-E is based on conventional electricity production (without CHP-E) the effects on CHP-E are ambiguous. Thus, it is possible that the production of power from CHP will increase in response to the introduction of a TGC system.
- **It is ambiguous whether any emission reductions at all are achieved when supporting RES-E technologies in a CHP system.**
- **The effects of a TEA system on CHP-E will depend crucially on the allocation of allowance.** If the cost increase for CHP-E is higher compared to other production technologies, CHP-E will decrease. Likewise, if the cost increase for CHP-E is lower compared to other production technologies, the production of CHP-E will increase.

Introducing a quota for CHP-E and a quota for RES-E (as a share of total electricity production) simultaneously has the following implications:

- the market is split in a market for CHP-E, in a market for RES-E and in a market for conventional electricity production
- the additional costs for both, CHP-E and RES-E, are levied on conventional electricity
- production of conventional power will be substituted for RES-E and CHP-E
- the prices and profits producers of CHP-E and of RES-E receive increase

[160] Of course, if it is difficult to substitute electricity generation from CHP – for example the heat demand must be covered by CHP plants -, no or only a marginal reduction of the electricity price occur.

- the prices and profits producers of conventional electricity receive decrease
- the effect of the CHP- and RES-E-quotas on the consumer price is generally ambiguous, i.e., it can either be higher, the same or lower compared to the electricity price without CHP-E and RES-E quotas
- total costs of production will be higher than before, because CHP-E and RES-E are more expensive than the conventional power, which is substituted by CHP-E and RES-E

5.3.2 Effects of CHP policy on RES-E support schemes

The effects of a CHP policy on RES-E deployment is significantly influenced by the kind of RES-E policy and whether the CHP quota is based on total electricity generation or on conventional electricity generation only.

- **Power price drops due to CHP policy**

  Due to promotion of CHP the demand for pure conventional power is reduced. Hence, the power price drops. The price reduction is higher if the strategy is implemented internationally compared to the case of a national CHP policy (and a liberalised power market).

- **Depending on support scheme share of pure RES-E plants may drop**

  The promotion of CHP leads to diminished electricity generation from pure RES-E plants in the case of a TGC system, a premium feed-in tariff scheme, an investment incentive or a tax relief and remains unaffected in the case of a feed-in tariff or a tender scheme.

- **Share of RES-E CHP plants may rise**

  Depending on the design of the CHP policy, the share of RES-E production from CHP may increase. Hence, the net effect with respect to total electricity generation from RES-E is ambiguous.

- **Effects on consumer price is ambiguous**

  Depending on the design of the RES-E instruments, promoting CHP might result in ambiguous effects on consumer prices and on the volume of deployed RES-E and CHP.

Table 5.3 summarised the impact of CHP production on the different RES-E support schemes.

Table 5.3 Impact of CHP policy on RES-E support instruments

Impact on / of	Issue	RES-E instrument		
		TGC	FIT / tender	premium FIT, investment incentives, tax relief
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

5.4 The relationship of RES-E (FIT, TGCs), CO_2 (TEAs) and Kyoto Mechanisms

5.4.1 Introduction

International agreements have an impact on renewable electricity deployment. In this chapter, the effects of the Kyoto Protocol (KP) on the development of RES-E in Europe are analysed.

In order to help industrialised countries achieve their Kyoto Protocol targets in a cost-effective manner, the KP[161] allows industrialised countries to use three international "flexible mechanisms":

- International Emission Trading (IET);
- Joint Implementation (JI);
- Clean Development Mechanism (CDM).

The later two instruments involve the realisation of emission reduction projects in foreign countries. Emission reduction credits are awarded to those companies carrying out projects abroad. These projects include a wide variety of possibilities, including energy efficiency and renewable energy projects.

5.4.2 Impact of Kyoto mechanisms assuming no RES-E policy

First, the interactions of CDM/JI projects with an EU tradable emission allowance scheme are discussed. Analysing this is important, since policy trends in the EU point in the direction of coexistence between both instruments, as envisaged in the "Linking Directive". Both instruments have different goals but mutual effects. The discernable effects on RES-E generators, conventional generators, emissions and consumers' welfare if CDM/JI projects are:

- **Kyoto mechanisms make it easier and cheaper for EU power producers to comply with the given EU emission quotas**

  The acceptance of emission reduction units (ERU) and certified emission reductions (CER) as given by the CDM/JI-schemes to replace tradable emission allowances in the EU TEA scheme will make it easier and cheaper for EU power producers to comply with the given EU emission quotas. The introduction of CDM/JI projects would have significant price effects on both the electricity and the TEA markets. A reduction in compliance costs causes a lower CO_2 allowance price (TEA price) and a lower TEA price put a downward pressure on the price of electricity. This means the price of electricity would also tend to go down compared to a situation in which CDM/JI projects can not be used. The extent to which it will go down depends on the market structure of the electricity sector. The more competitive the market is, the more likely it is that a reduction in costs will drive down prices.

- **Kyoto mechanisms leads to a lower RES-E deployment in Europe**

  In general, a lower compliance cost for conventional electricity will boost cost-competitive technologies, allowing them to take a higher share of the electricity market. Only the expensive con-

[161] The KP sets an overall quota for the emission of GHG from industrialised countries ("Annex I Parties") which agreed to reduce the emissions from a basket of six greenhouse gases in 2008/2012 by 5,2% against 1990 levels. The EU accepted a legally binding emissions reduction target of 8% by 2008-2012. An agreement on differentiated burdens per Member State was also reached.

ventional electricity would not enter the market. The lower power market price will result in a lower (or even non-existing) deployment of renewable electricity in Europe.[162]

- Conventional producers generating also renewable electricity might consider abandoning some RES-E plans. Of course, this would depend on how they produce renewable electricity. The decision will be based on a comparison between the marginal costs of renewable energy deployment (which allows conventional generators to reduce CO_2 emissions) and the cost of CO_2 allowances. The higher the former and the lower the latter, the less attractive is the deployment of renewable electricity;
- In the case of pure RES-E producer the costs remain unaffected from the lower TEA price, but the revenues from the lower electricity price drops;

- **CDM /JI projects could be very beneficial for the deployment of RES-E outside of the EU**

  It should be noted that the above discussion focuses on the effects of CDM/JI projects on RES-E deployment in Europe. Of course, CDM/JI projects could be very beneficial for the deployment of RES-E in less developed countries (hosts). It could also have a beneficial effect for Annex I countries since these could export their RES-E technologies to the host countries finding a market for their technologies. In general, it would be attractive for companies to deploy electricity from RES in a CDM/JI project up to the point where an additional kWh of RES-E costs more than the price of allowances (as CERs/ERUs are turned into allowances). If it costs more, it would not be profitable to produce an additional kWh, because it would then be more beneficial for the company to buy allowances in the market place.

- **Total CO_2 emissions is neutral (if the baselines are correct)**

  Although there is less pressure to shift the power industry to a low carbon emitting (e.g. gas) or CO_2-free technologies (RES) and to increase the efficiency on both supply and demand side in the Member States than before, the firms have contributed in the same amount to reduce CO_2 emissions by buying CO_2 allowances (formerly CERs and ERUs) from CDM/JI projects). More CO_2 emissions would take place in the country but, since CO_2 is a global warming gas, it does not matter, because those additional emissions will be made up by the CDM/JI projects. Instead of reducing CO_2 emissions through a higher deployment of renewable electricity in the country, the company/country complies with their emission quota by buying allowances in the international market, stimulating thus the implementation of CDM/JI projects.

- **This combination of changes in prices would have a positive impact** (welfare improving) **for consumer, ambiguous effects on conventional electricity generators and negative effects on RES-E generators.**
  - The lower spot power price will be beneficial for EU power consumers, because consumers / suppliers pay the electricity price, and this goes down due to lower prices for CO_2 allowances;
  - The possibility to buy cheaper CO_2 leads to a reduction in compliance costs for these actors. If the total producer surplus increase of drops depends on the competition, the own power structure, the TEA target and allocation.
  - RES-E generator do not benefit at all from the reduction in the CO_2 allowance price, because neither they are allocated free allowances (under grandfathering) nor will they have to buy al-

[162] According to Criqui and Kitous (2003), taking into account the Acceding Countries in the EU trading scheme results in an allowance price of 26 €/tCO_2. Unrestricted opening of the EU ETS to JI and CDM credits would lead to an allowance price of around 5 €/tCO_2. A 6% limit on the import of credits done by the enlarged EU ETSe (meaning that 6% of the requested objective can be fulfilled by such credits obtained through JI and CDM) would result in an intermediate allowance price of 12 €/tCO_2.

lowances in the market (auction). Therefore, their costs remain the same but, since the electricity price has gone down, their revenues are lower[163].

5.4.3 Impact of Kyoto mechanisms assuming an active RES-E policy

The interactions of CDM and JI with an EU tradable emission allowances scheme and RES-E policies can be summarised as follows:

- **RES-E policy helps to reach GHG target**

  The additional RES-E support makes it easier and cheaper for EU power producers to comply with the GHG-target compare to the situation without a RES-E policy. Thus both, the TEA price and power market price drops.

- **An ambitious RES-E policy in Europe makes CDM/JI projects less attractive.**

  As the TEA price drops with an increase of RES-E only cost efficient CDM/JI projects (with lower costs than the TEA price) will be implemented.

- **A very ambitious RES-E policy even can be critical.**[164]

  In the case that the RES-E policy reduces the TEA price under the level of the international price for ERU/CER, the EU will be a net exporter of certificates - via the international emissions trading scheme. This means that the European citizens would subsidies the international climate policy via RES-E generation in Europe! This, of course, is very expensive and economically inefficient.

- **The RES-E deployment depends on the kind of promotion instrument.**

  The following effects with respect to the development of RES-E technologies compared to a situation without interactions with Kyoto-instruments occur:[165]

  – applying a quota obligation, the RES-E deployment (slightly) rise

  – applying a fix feed-in tariff scheme or a tender procedure, the RES-E deployment remains unaffected

  – applying a premium tariff scheme, an investment subsidy or a tax relief, the RES-E deployment drops

- **CO_2 emission level in the EU drops**

  Global CO_2-emissions remain constant; the emissions in Europe will be reduced due to the RES-E policy compared to the case of no additional RES-E support.

- **Distortions between CO_2 reduction options occur**

  From the pure perspective of a cost efficient CO_2-reduction, the promotion of RES-E causes distortions compared to other reduction options like efficiency improvement (on both supply and demand) and fuel switching.

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[163] Note that, of course, there would still be more deployment of renewable electricity in Europe in a situation with a TEA market and CDM/JI projects than without these measures being implemented, the reason being that a TEA market with a target on conventional CO_2 polluting electricity provides a strong incentive for renewable electricity.

[164] Currently, the RES-E policy within the European Union is fare away from this point.

[165] The interactions are reveres to those of the introduction of a coincide TEA and RES-E strategy (compare chapter 5.1).

- **This combination of changes in prices would** (mainly) **have different impacts on all the actors considered**, i.e. RES-E generators, conventional electricity generators and consumers.

  Similar to the case described before, some power producer will gain other lose from the linkage.
  - A combined strategy for RES-E and GHG-reduction reduced costs for consumer (see also chapter 5.1 ".
  - The possibility to buy cheaper CO_2 leads to a reduction in compliance costs for the electricity generator.
  - In the case of a feed-in tariff, tender scheme or quota obligation, RES-E generators are unaffected.[166] Using a premium feed-in tariff, an investment subsidy scheme or a tax relief, RES-E generators loose as the reduced revenues from the lower spot market price will not be compensated.

5.5 Summary interactions

Table 5.4 Overview interactions of RES-E, power market, TEA, DSM and CHP

Impact on of	Policy			
	conventional power	TEA	DSM	CHP
RES-E	generation drops; price drops; CO_2-emissions drops	lower TEA price; CO_2-target easier to reach	lower demand	generation ambiguous
TEA	generation drops; price drops; CO_2-emissions drops		lower demand; DSM more cost-efficient	generation ambiguous, depending on the allocation
DSM	generation drops; price drops; CO_2-emissions drops	lower TEA price; CO_2-target easier to reach		generation drops
CHP	generation drops; price drops; CO_2-emissions increase in power sector, (probably) decrease over all sectors	ambiguous, depending on allocation; CO_2-target in power sector harder to reach; on (inter)national level easier to reach	ambiguous	

Most relevant interactions among the different investigated policy schemes, i.e. RES-E, power market, TEA, DSM and CHP as depicted in Table 5.4.

The effects of other policy instruments on RES-E deployment and transfer costs depend on the RES-E instrument itself.

Table 5.5 gives an overview about GHG policy, DSM activities and the promotion of CHP on RES-E support schemes.

[166] Applying a feed-in tariff or a tender, the revenue from RES-E generation is independent from the power market price, in case of a quota obligation, the lower power price will be compensated by a higher TGC price.

Table 5.5 Impact of GHG policy, DSM activities and promotion of CHP on RES-E support schemes

Impact on / of	Issue	RES-E instrument: TGC	RES-E instrument: FIT / tender	RES-E instrument: 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.

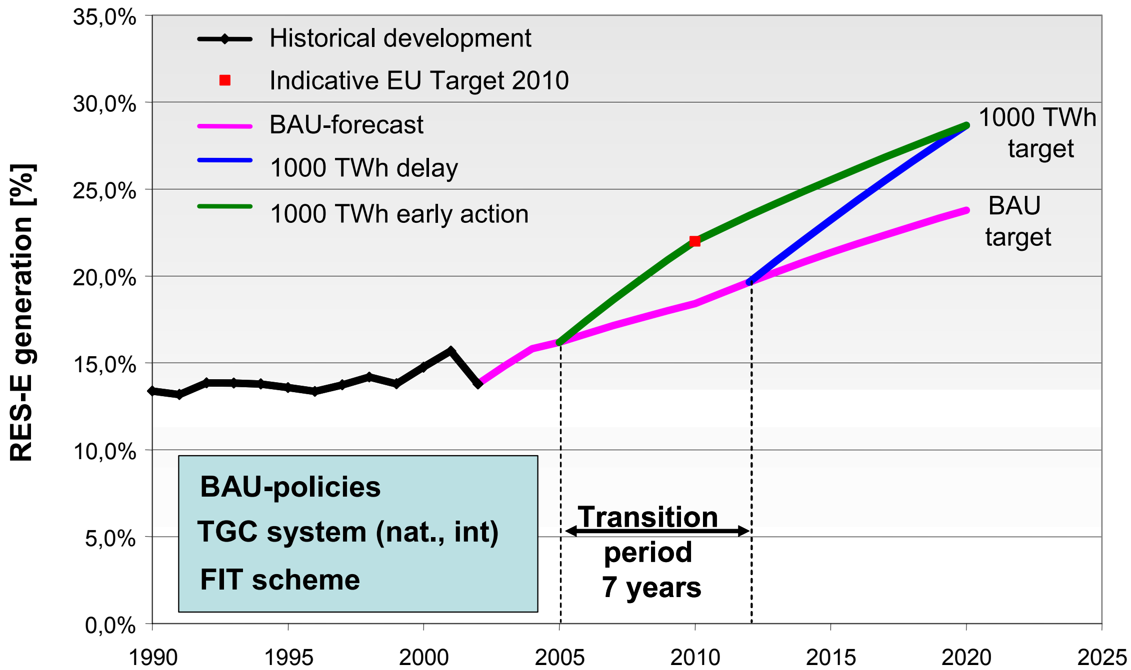

Figure 6.1 Investigated cases

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) – business as usual **(BAU) forecast**
- 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
  - International TGC system
  - National TGC system
- 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
    - International TGC system
    - National TGC system
  - 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.

Figure 6.1 to Figure 6.3 gives an overview of the investigated scenario paths.

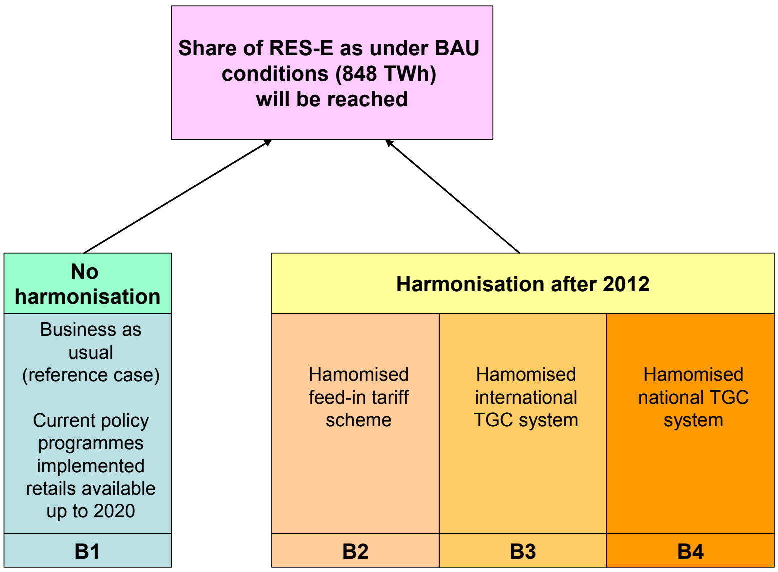

Figure 6.2 Overview of investigated cases BAU TWh target

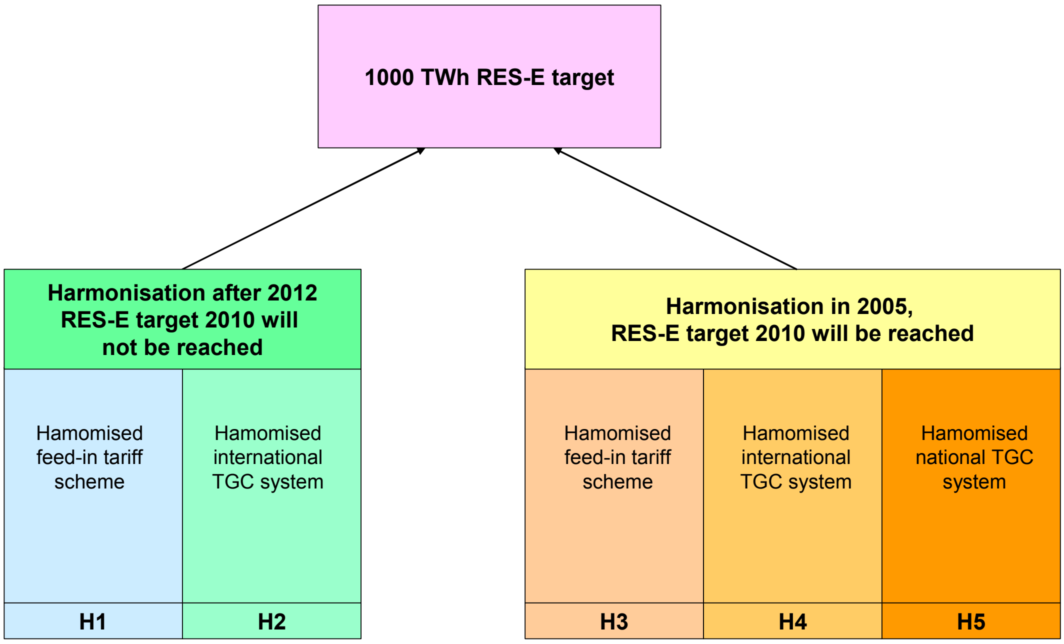

Figure 6.3 Overview of investigated cases 1000 TWh target

6.2 Scenario assumptions

6.2.1 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

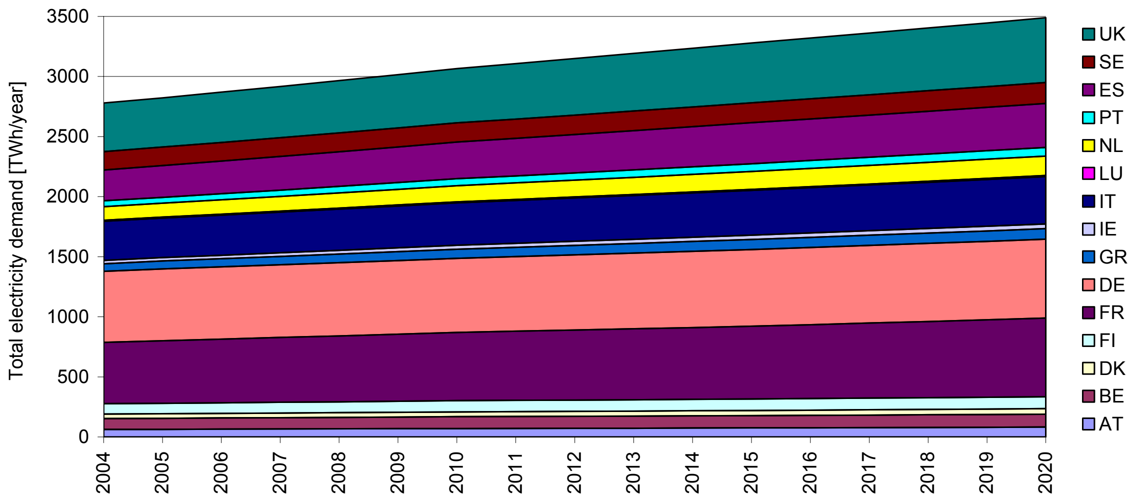

Figure 6.4 Electricity demand forecast within the EU 15 (2005-2020) according to Mantzos et. al (2003)

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.

6.2.2 Primary energy prices for biomass products

Figure 6.5 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.

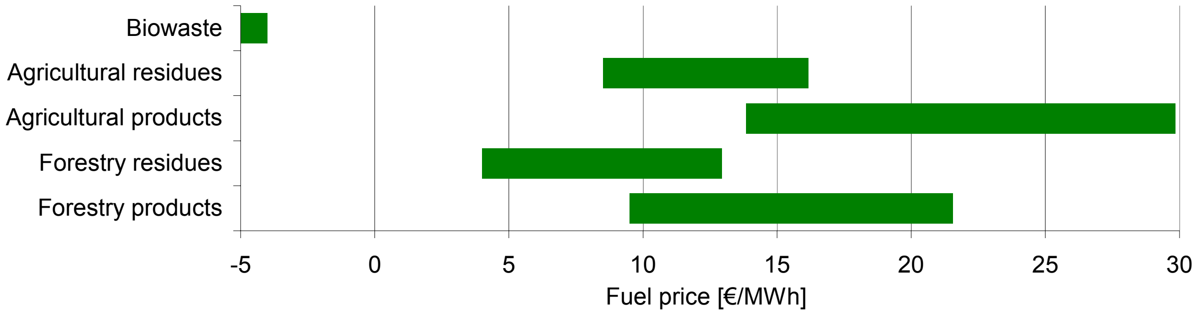

Figure 6.5 Variation of the prices for the different biomass products in EU 15

6.2.3 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**. Figure 6.6 compare this cost forecast with other relevant projections (DGTREN Energy Outlook 2030 (Mantzos et. al., 2003), Enquete commission of the German Bundestag (Enquete, 2002)
- **Different CO_2-policy assumptions**[167], namely
  - No-CO_2 constraint
  - Medium CO_2 constraint (assuming an increasing tradable emission allowance price up to 10 €/t-CO_2)
  - High CO_2 constraint (assuming an increasing tradable emission allowance price up to 20 €/t-CO_2)
- **RES-E policies are as described in chapter 6.1**. Note, RES-E policy significantly influences the power market price.

[167] 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.

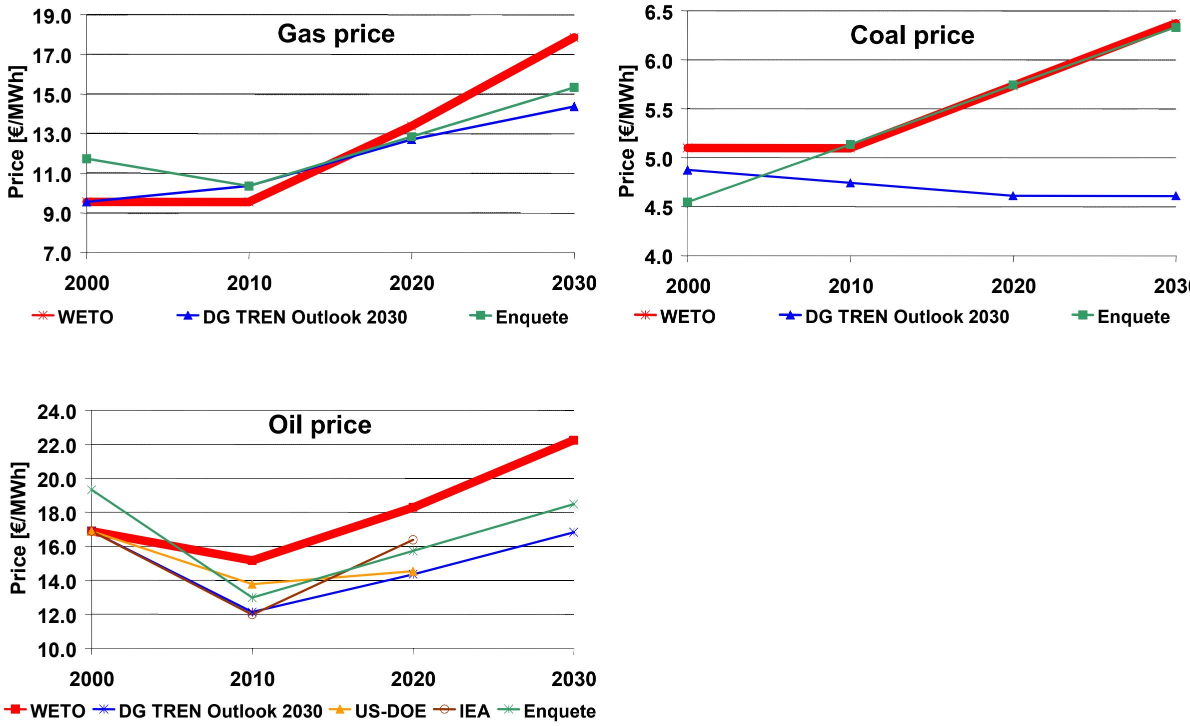

Figure 6.6 Projects of international gas, coal and oil price for Europe 2000-2030

6.2.4 Weighted average cost of capital

The determination of the necessary rate of return is based on the weighted average cost of capital (WACC) methodology. WACC is often used as an estimate of the internal discount rate of a project or the overall rate of return desired by all investors (equity and debt providers). This means, the WACC formula[168] determines the required rate of return on a company's total asset base and is determined by the Capital Asset Pricing Model (CAPM) and the return on debt. Formally, the pre-tax cost of capital is given by:

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

Generally two different WACC options are considered in the analysis; one standard risk level and a higher risk level characterised by a higher expected market rate of return. The first value is used as the default value; the second 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). (TGC system). All relevant values are summarised in Table 6.1. 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. [169]

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

[169] 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 Value setting WACC calculation:

	Abbreviation / calculation	Default risk assessment		Higher risk assessment	
		Debt (d)	Equity (e)	Dept (d)	Equity (e)
Share equity / debt	g	75.0%	25.0%	75.0%	25.0%
Nominal risk free rate	r_n	4.1%	4.1%	4.1%	4.1%
Inflation rate	i	1.9%	1.9%	1.9%	1.9%
Real risk free rate	$r_f = r_n - i$	2.0%	2.0%	2.0%	2.0%
Expected market rate of return	r_m	4.3%	7.1%	4.3%	11.0%
Risk premium	$r_p = r_m - r_f$	2.3%	5.1%	2.3%	9.1%
Equity beta	β		1.6		1.6
Tax rate (corporation tax)	r_t		30.0%		30.0%
Post-tax cost	r_{pt}	4.3%	10.2%	4.3%	16.6%
Real cost	$r = r_{pt} * (1+r_t)$	4.3%	13.2%	4.3%	21.5%
Weighted average cost of capital	*WACC*	6.5%		8.6%	

6.2.5 Future cost projection – technological learning

Forecasting technology development is a crucial activity, especially for a long time horizon. 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)

Table 6.2 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%

For most technologies the investment cost forecast is based on technological learning, see Table 6.2. As learning is taking place on the international level the deployment of a technology on the global level must be considered. Within the ***Green-X*** model 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 IEA World Energy Outlook 2004 (IEA, 2004).

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.

6.3.1 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. The effects of less efficient design options are already demonstrated in chapter 4 (see e.g. the various Boxes). 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** [170]

  The effectiveness of various RES-E support schemes largely depends on the stable long term planning security provided by system. A stable planning horizon is important to create a sound investment climate and to reduce transfer costs for society as a result of a lower risk premium. Investor confidence depends on the expected continuity of the scheme, as well as the political risk. Long-term stability, especially for independent power producers, is important for achieving an acceptable risk-return profile;

- **Continuous RES-E policy / long term RES-E targets**

  A continuous and medium to long-term focussed energy policy scheme is important to attract the interest of potential investors in RES-E technologies as well as to increase the confidence of bank institutions. Such a policy - characterised by long-term RES-E targets or RES-E policy schemes - leads to lower loans for investments;

- **Clear and well defined tariff structure / yearly quota for RES-E technologies**

  If the support structure is well known and designed for investors it can be expected that delays for investments in new plants can be reduced;

- **Reduced investment and O&M costs, increased energy efficiency over time.** For more details see chapter 6.2.5.;

- **Reduction in barriers and high public acceptance in the long term.**

  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;

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**

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

[170] For more details see chapter 4.

- **Restriction of the duration in which investors can receive the** (additional) **financial support**

  By restricting the duration of the possible public support, transfer costs for society can be reduced. In the model runs it is assumed that the time frame is restricted to 15 years. This value fits with a stable planning horizon.

6.3.2 Scenario conditions assuming a quota obligation[171]

- **Tradable green certificates are standardised**

  It is assumed that just one kind of certificate exists, with reciprocity of approval of certificates for international trade

- **Full competition**

  Within the TGC system it is assumed that

  – a high level of market transparency exist;

  – an appropriate level of trading volume is available;

  – investors are seeking the most efficient RES-E resources

  leading to an idealised, fully competitive TGC market;[172]

- **Additional support for less mature RES-E technologies does not exist**

  An additional support system may help – especially in the case of the 1000 TWh RES-E target - to reduce the transfer costs for society as the windfall profits for "cheap" technologies can be reduced significantly. In the sensitivity analysis, the effects of "good" and "bad" designed additional support settings are shown, see also Boxes;

- **Constant yearly interim targets**

  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);

- **Penalty for not fulfilling the quota obligation are set to high amounts up to 200 €/MWh.**

  For the fulfilment of the obligation it is important that the penalty for not purchasing a TGC is higher than the investment needed to meet the quota, i.e. the lowest penalty level must exceed the expected marginal generation costs within the system. Investors have an incentive to build plants with long-term marginal cost up to 200 €/MWh plus conventional power price to reaching the quota obligation. As the penalty serves as ceiling price for TGC, the maximum TGC price is restricted by the penalty minus the expected power price.

6.3.3 Scenario conditions assuming a feed-in tariff scheme[173]

- **Guaranteed tariffs are technology specific,**

  This means the guaranteed tariffs (can) vary between the different (sub)-technologies.

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

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

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

- **Tariffs are set as low as is reasonable.**

  The goal has been to set the tariff as low as possible without causing a lower deployment rate over the RES-E portfolio, i.e. tariffs are set such that they reflect the long-term marginal generation costs. If the deployment of a certain RES-E technology was insensitive to a feed-in tariff level of 60 €/MWh, 70 €/MWh or 100 €/MWh, the 60 €/MWh level was selected. Otherwise, higher transfer costs for consumers occur without any additional RES-E deployment. In practice, RES-E deployment rates are sensitive to the tariff level. Hence a compromise between possible reduction of the tariff and the lower RES-E specific deployment must be made;[174]

- **Guaranteed tariffs decrease over time** or at least remain constant for certain RES-E options

  This means that the tariffs for new facilities and, hence, new contracts, is changed every year. The decrease depends on the reduction in investment costs due to technological learning. By employing such a procedure, investors have a reduced incentive to postpone their investments;

- **Tariffs for wind energy are designed as a stepped feed-in tariff** [175]

  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;[176]

6.4 Results – current situation up to the end on 2004

In order to assess the amount and the value of RES-E technologies in EU 15 up to 2020 it is important to have a look at the current situation with respect to RES-E generation. Figure 6.7 compares the expected amount of electricity production from RES-E with the total electricity consumption for each EU country. The historical RES-E data is based on a comprehensive data collection (Eurostat (2003), IEA (2002) and statistical information gained at the national level). Regarding the years 2003-2004 (very little data is available at the country and technology levels) the "forecast" is based on a model ***Green-X*** run under the assumption that the currently implemented promotion scheme also remains available in 2004.

Three countries, Austria, Sweden and Portugal, 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[177], as is evident from Figure 6.8. Such plants were mostly established before the post-1980's "new" RES-E. The shares of the other "new" RES-E technologies are depicted in more detail in Figure 6.9. It shows that small hydro, biomass, municipal solid waste (MSW) and wind are currently the most significant. 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 relatively high proportion of RES-E generated from biomass in the UK (including landfill gas, municipal waste and sewage gas), Finland, Sweden and Germany.

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[174] Attempts have been made to find a low tariff level over the whole RES-E portfolio. The magnitude of the tariff, however, is not optimised in a way that transfer costs for society are minimised. This means that an additional reduction of the transfer costs is feasible, but requires a more detailed analysis.

[175] As an example a stepped tariff is implemented in Germany.

[176] Profits will thus be higher at more cost effective sites.

[177] Installed capacity is above 10 MW.

Figure 6.10 shows the corresponding development of “new” RES-E over time (1990-2004), with (left hand side) and without (right hand side) hydropower.

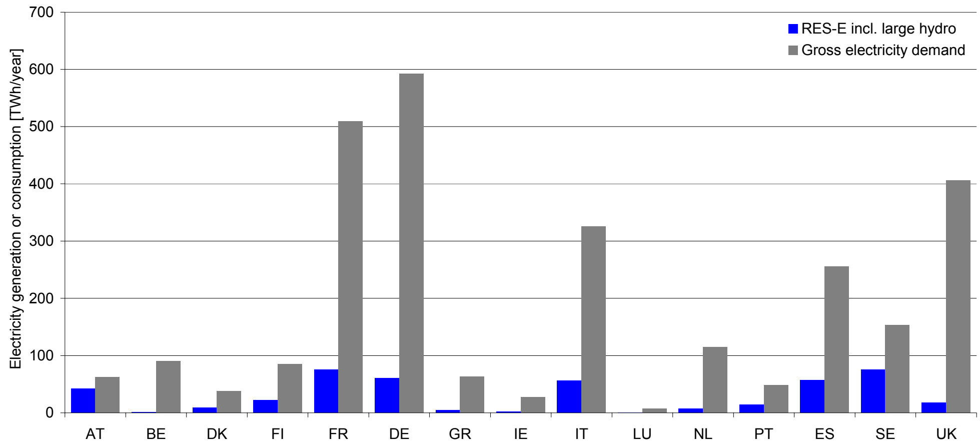

*Figure 6.7 Electricity generation (achieved potential) from RES and gross electricity consumption in EU countries in 2004. Source: Own investigations; Eurostat, 2003, **Green-X** model run.*

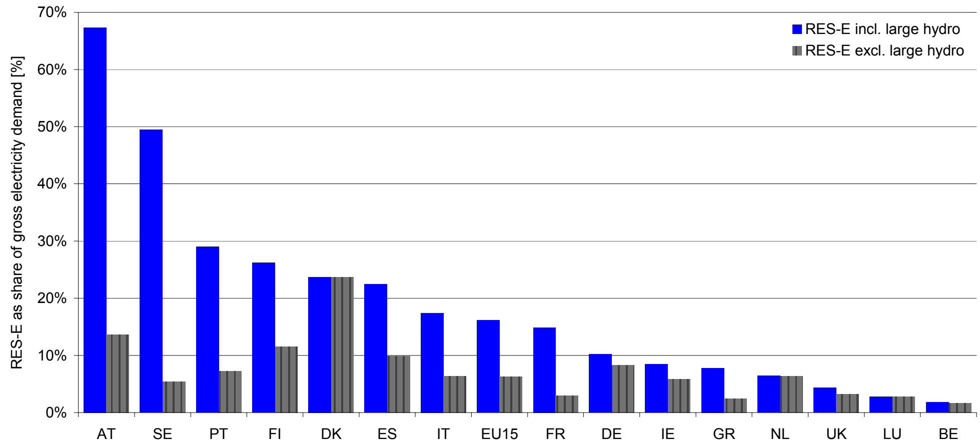

*Figure 6.8 EU-15 countries ranked by the contribution of RES-E (with and without large hydro) to gross electricity consumption in 2004. Source: Own investigations; Eurostat, 2003, **Green-X** model run*

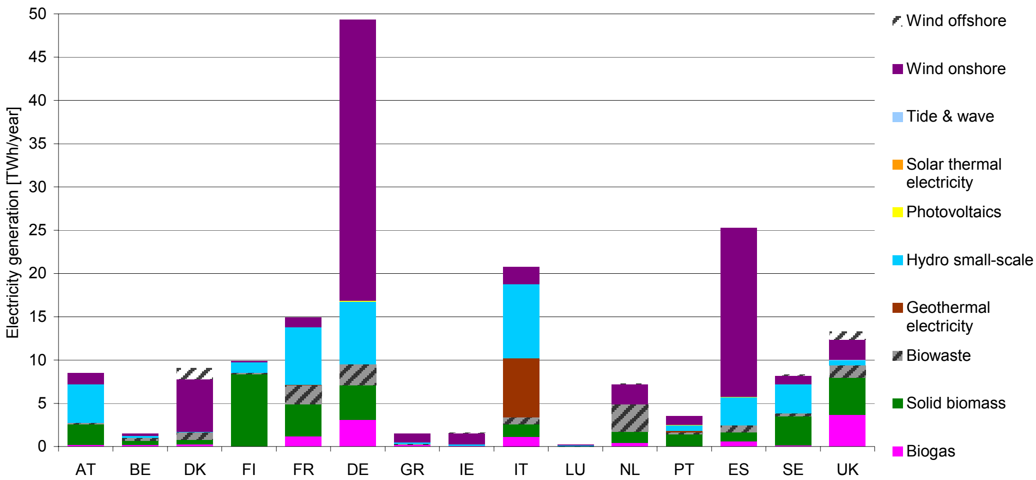

*Figure 6.9 Electricity generation (achieved potential) from various RES in EU countries in 2004. Source: Own investigations; Eurostat, 2003, **Green-X** model run*

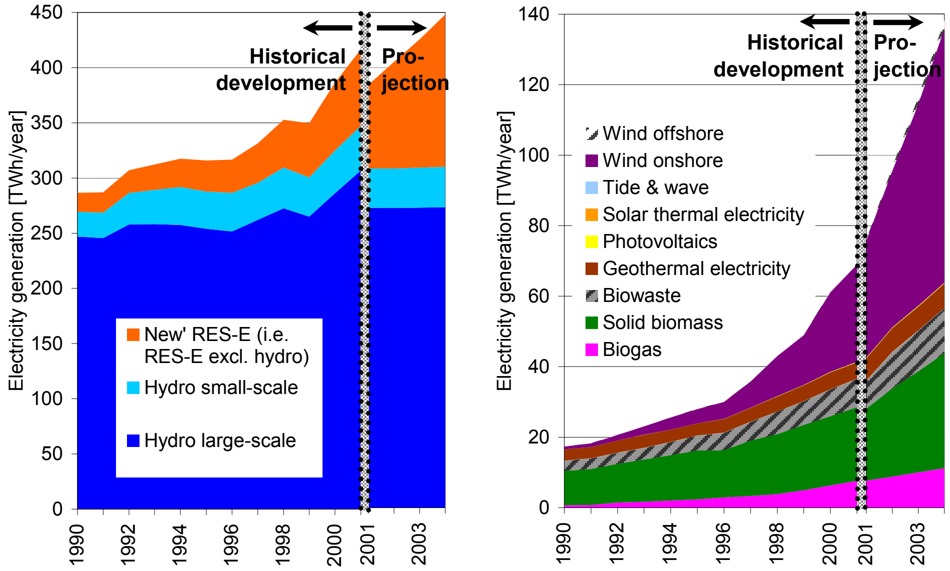

Figure 6.10 Electricity generation from RES in EU-15 countries from 1990 to 2004 – including (left hand side) & excluding (right hand side) hydro.
Source: Own investigations; Eurostat, 2003, ***Green-X*** *model run.*

The relative share of individual RES-E technologies is depicted in Figure 6.11. Currently (large-scale) hydro power is the dominant renewable generation technology - around 60% comes from large and 8% from small scale. Due to the restricted potential and / or social acceptance the share, however, has, in the past, continuously been decreasing. Based on the high deployment rates in recent years wind energy substantially increased its contribution to electricity generation from RES.

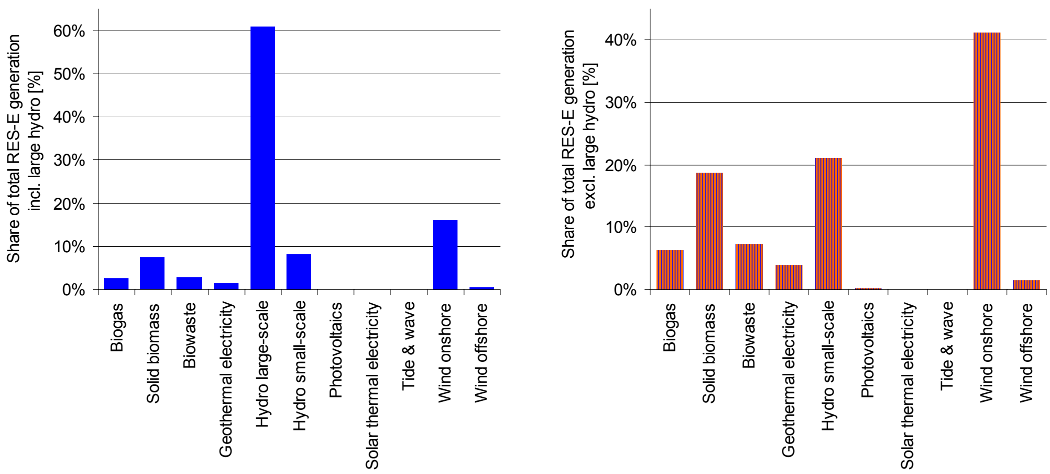

Figure 6.11 Share of electricity generation from RES in the entire EU 15 in 2004 (technology level) - including (left hand side) & excluding (right hand side) hydro.
Source: Own investigations; Eurostat, 2003, ***Green-X*** *model run.*

An overview on the different RES-E options available in total EU-15 up to 2020 is given in Figure 6.12. The achieved potential, i.e. the existing plant, for RES-E in EU-15 countries has been derived within the project ***Green-X***. In the EU 15 the already achieved potential for RES-E equals 448 TWh[178], 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 on a large commercial scale in the EU 15.

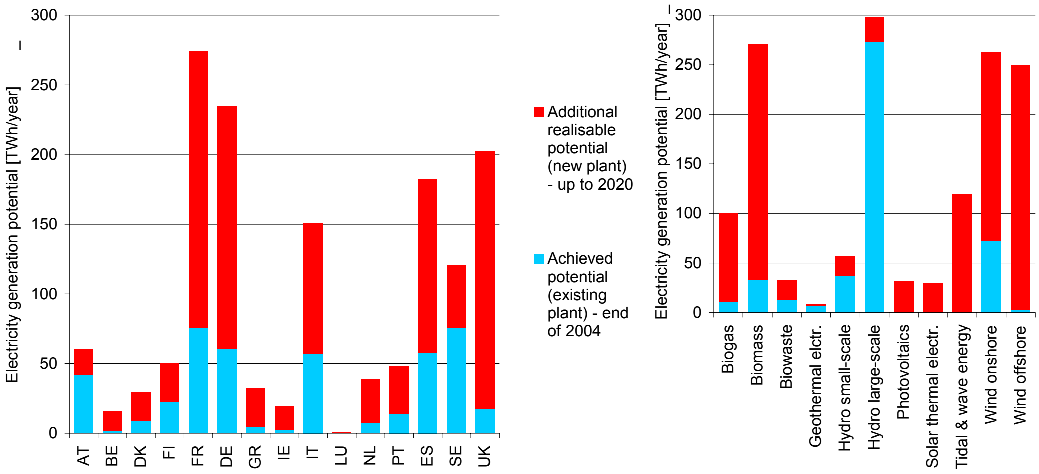

Figure 6.12 Achieved (2004) & additional mid-term RES-E potential (up to 2020) in EU-15 countries
*Source: Own investigations; Eurostat, 2003, **Green-X** model run.*

6.5 Results - BAU target in 2020

Total amount of RES-E generation within the EU 15 was around 449 TWh/a in 2004.[179] 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).[180] 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.

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[178] 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 the case of hydropower, the normal hydrological conditions, and furthermore, not all plants are installed at the beginning of each year.

[179] 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.

[180] 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.

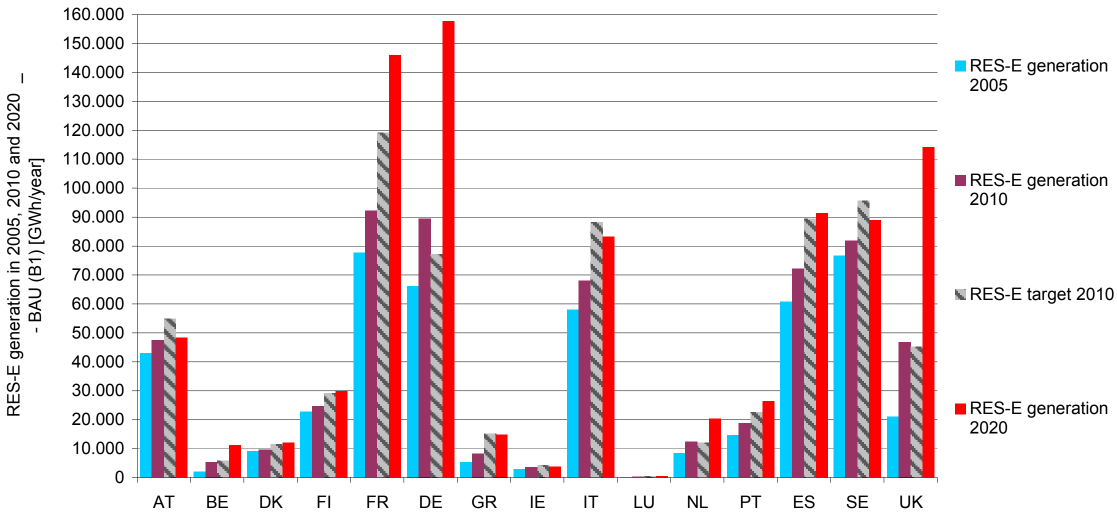

Figure 6.13 Comparison of RES-E generation in 2005, 2010 and 2020 assuming no change in the promotion strategy (B1)

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 that the penalty is binding). Substantial additional RES-E development can be expected in most countries after 2010, compare Figure 6.13.

The dynamic development of RES-E generation and the corresponding new RES-E capacity for the BAU case is depicted in Figure 6.14 and Figure 6.15, respectively.

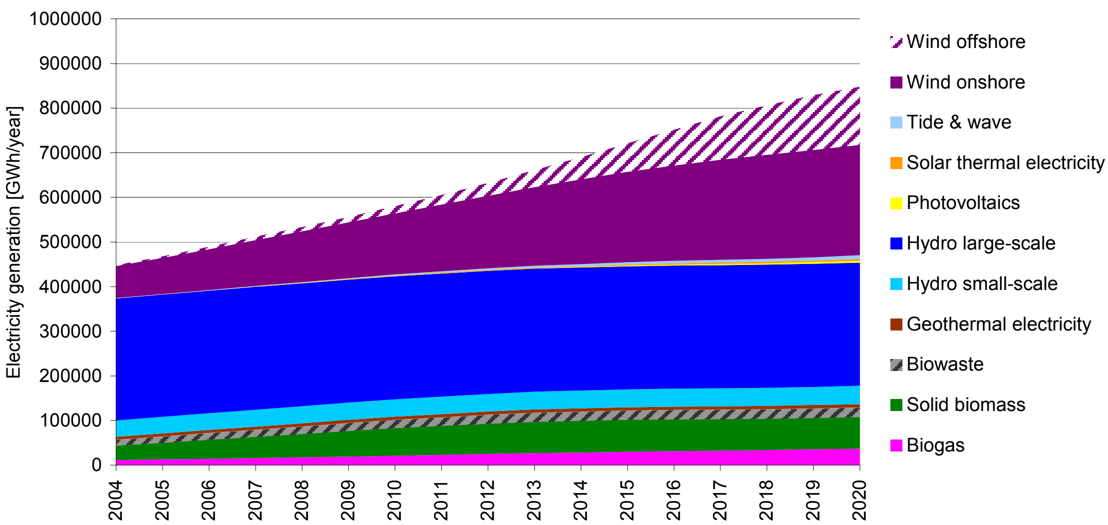

Figure 6.14 Development of RES-E generation 2004-2020 within EU 15 in the BAU scenario (B1)

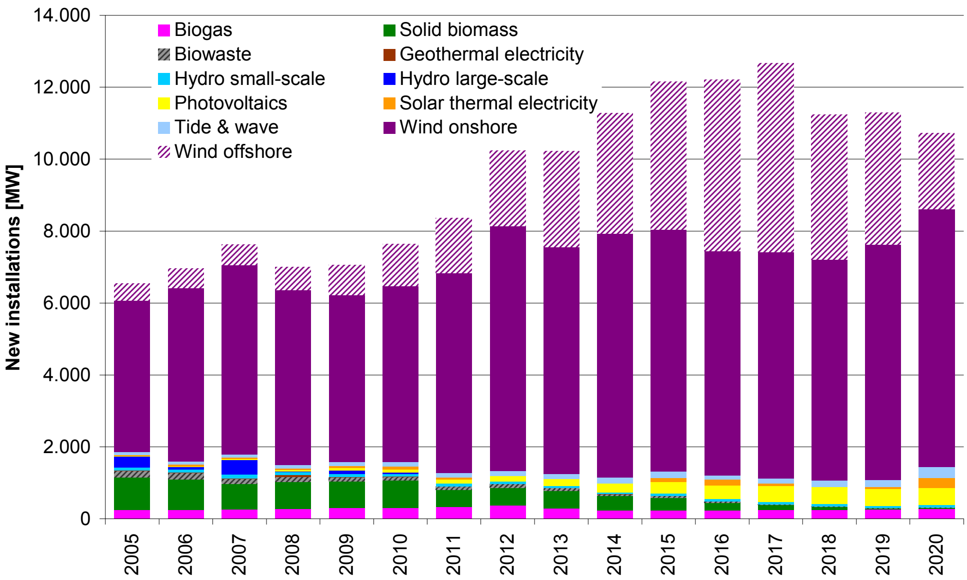

Figure 6.15 New installed capacity within the EU 15 in the BAU scenario (B1)

Due to less public support and acceptance, the amount of large scale hydro power plants will increase only marginally in absolute terms.[181] In relative terms the share drops significantly from around 60% in 2004 to 33% in 2020, compare Figure 6.11 and Figure 6.16. 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 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%).

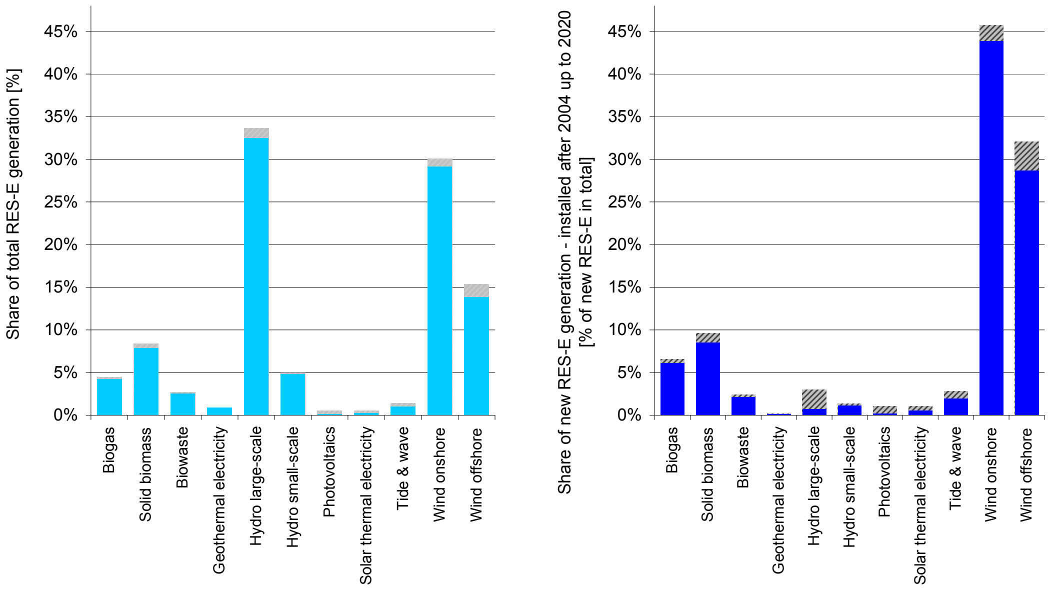

Figure 6.16 Share of RES-E technology on RES-E generation in 2020: From total (left) and new (right) installed capacity. Note: Dotted grey area indicates the variation due to the applied policy strategy in the future (B1-B4)

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[181] 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.

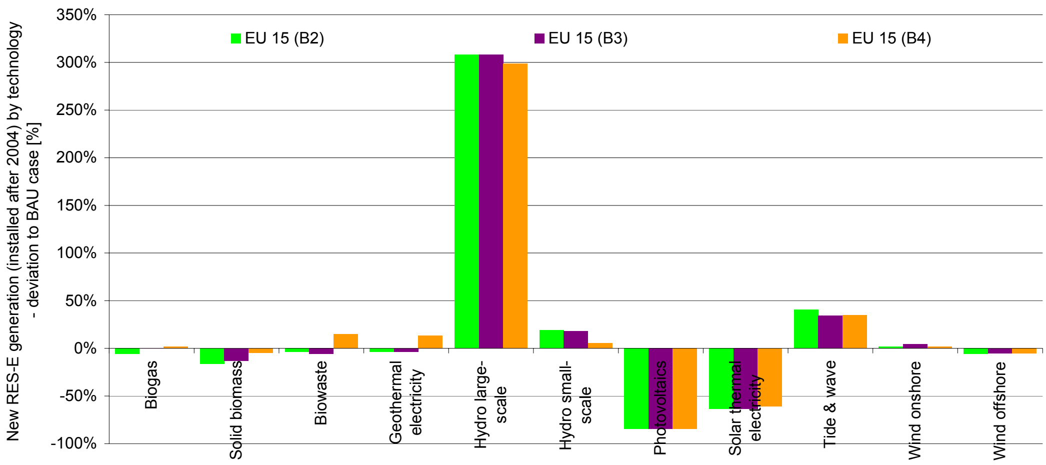

Figure 6.17 Share of RES-E technology on RES-E generation in 2020 compared to BAU forecast (B1)

The kind of public support substantially influences the development of new installed RES-E capacity. Figure 6.17 depicts the electricity generation in 2020 for the single RES-E technologies compared to RES-E generation projection in the case of remaining the current policy on EU 15 level. A higher deployment indicates that the current incentive is too low compared to the cost efficient solution, and a lower share says that the current policy scheme represents a too "high" promotion compared to other RES-E technologies with respect to electricity generation costs.[182]

Beside the support scheme the available potential highly influences the actual RES-E development. The portfolio of RES-E technologies significantly differs among the Member States as can be seen from Figure 6.18.

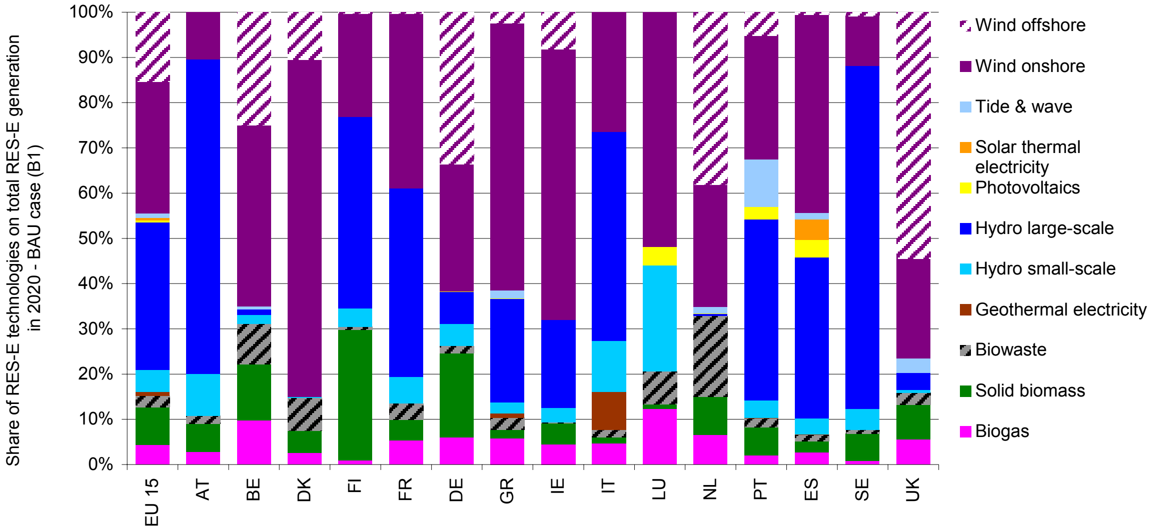

Figure 6.18 Portfolio of RES-E technology on RES-E generation in 2020 among the Member States under BAU conditions (B1)

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[182] As an international TGC scheme minimise generation costs (at least in the short term) a comparison of case B1 (BAU) with B3 (int. TGC) indicates the efficient use of the technologies.

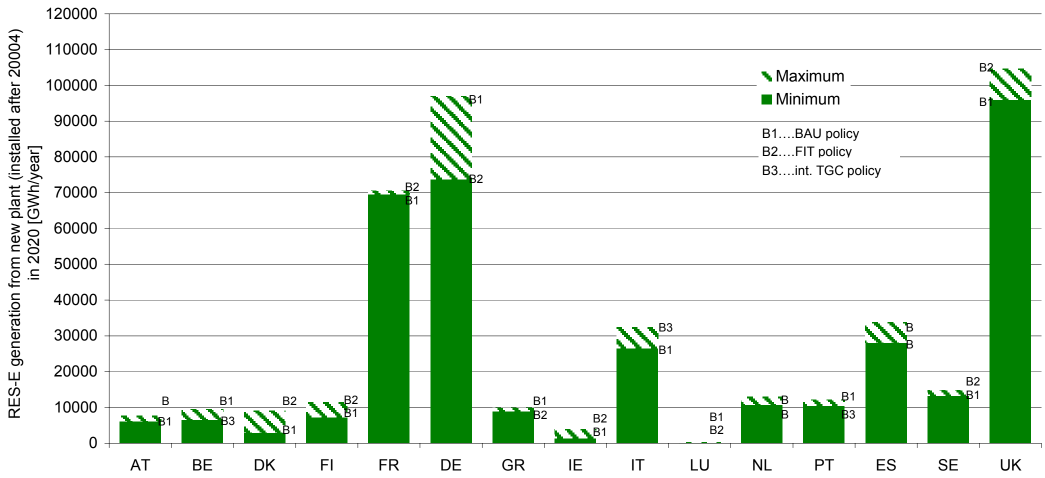

Figure 6.19 Comparison of RES-E generation from capacity installed after 2004 *Note: Dotted grey area indicates the variation due to the applied policy strategy in the future (B1-B4)*

The electricity generation from RES-E plants installed in the period 2005-2020 on country level is shown in Figure 6.19. 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. The actual generation depends on the applied policy and partly varies significantly. Figure 6.20 gives an overview of the electricity RES-E production in 2020 (from new plants 2005-2020) in dependency of the applied policy within the single EU 15 Member States. Similar to the comparison on technology level, a higher deployment under a harmonised feed-in tariff and / or international TGC scheme indicates that the current *average* incentive is lower than the EU average. This, however, does not mean that the current promotion scheme represents a too low incentive *for all* single RES-E technologies. For example in Austria more electricity will come from wind or biomass under the current policy scheme compared to the application of a harmonised feed-in tariff scheme (B2) or international TGC system. The "gap" of RES-E generation in the BAU scenario results from lower production of large and small scale hydro power, which overcompensates the higher generation from the other technologies.

Figure 6.20 Share of RES-E generation in 2020 compared to BAU forecast (B1) on country level

High investments are necessary to be able to build up the new capacity. Figure 6.21 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.

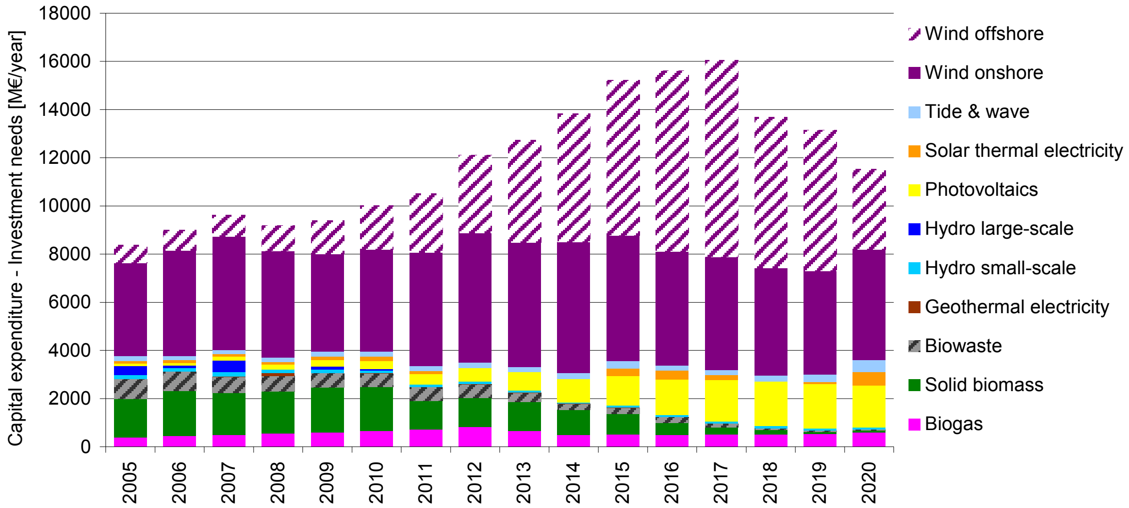

Figure 6.21 Total investment needs in the period 2005-2020 within the EU-15 in the BAU scenario (B1)

The investments (within the EU and worldwide) stimulates technological learning, leading to lower generation costs in the future. Figure 6.22 depicts the expected investment costs for the single RES-E technologies. The highest cost reduction can be expected for tidal & wave energy as well as solar electricity - both photovoltaics and solar thermal electricity production – and wind power.

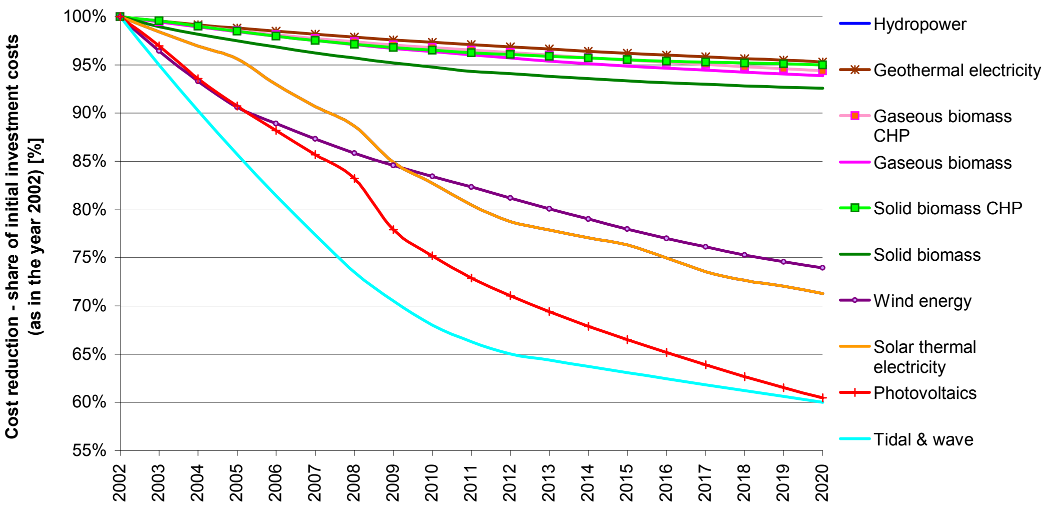

Figure 6.22 Development of the investment costs according to the BAU scenario (B1)

Next, the necessary financial incentive for the promotion of RES-E is discussed. Figure 6.23 compares the average financial support for new RES-E capacity for the four investigated cases B1-B4. The amount represents the additional premium costs for society compared to the power market price.[183] 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.[184] In contrast to this scheme the entity of both a national and international TGC system is to promote currently least cost generation options (only).[185] Hence, in the first year(s) premium costs are low but increase over time as cheap production options are already used.[186] 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 – with the exception of the first year - higher than applying a technology specific well designed feed-in system.[187]

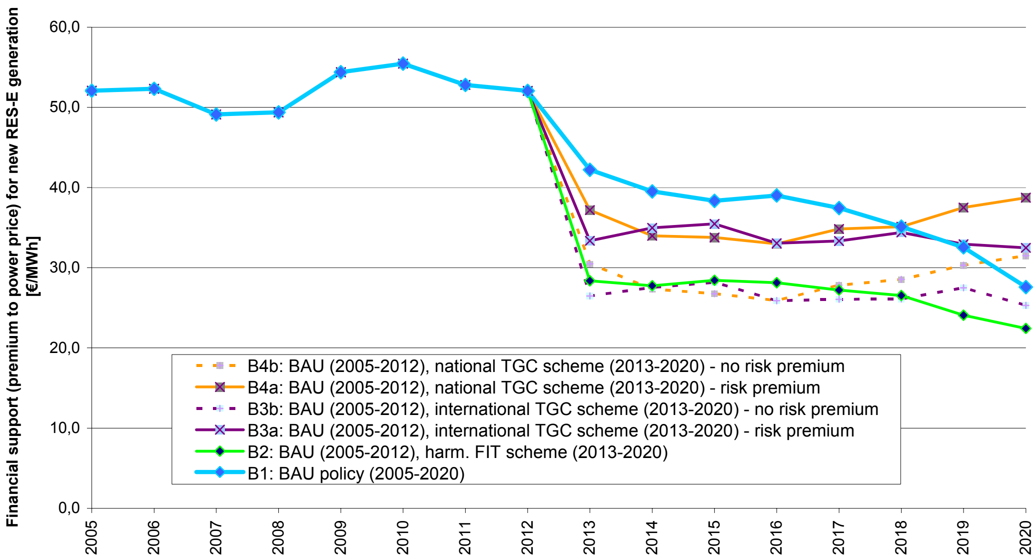

Figure 6.23 Comparison of financial support (average premium to power price) for new RES-E generation on EU 15 level in the period 2005-2020 for the cases B1-B4

The application of current policies lead to a high spread of the granted financial premium costs among the countries, see Figure 6.24.

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

[184] 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.

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

[186] 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.

[187] For comparison purpose, the “necessary” premium for the case of no risk premium is depicted in Figure 6.23 too (dotted lines).

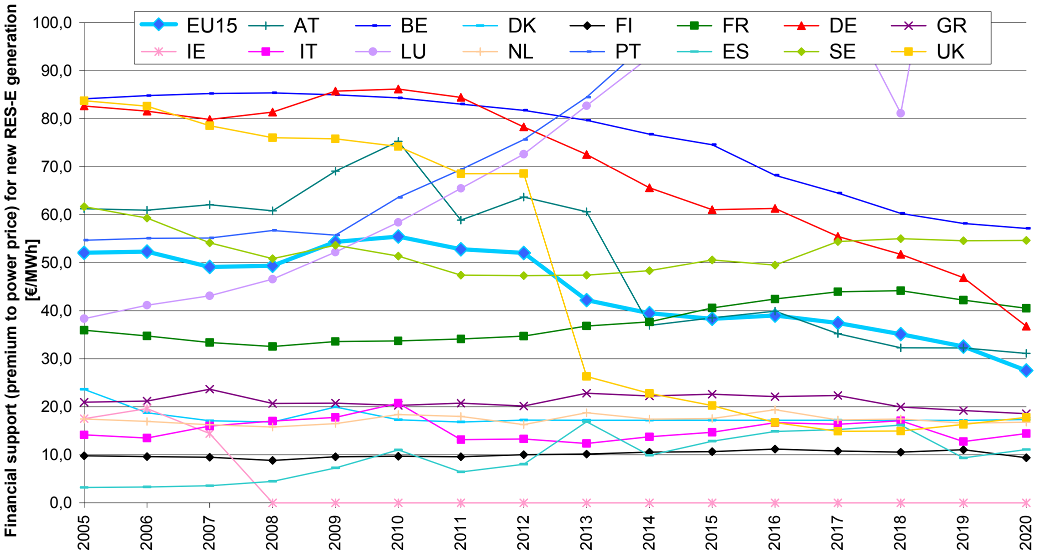

Figure 6.24 Country specific financial support (average premium to power price) for new RES-E generation applying current RES-E policy schemes (B1)

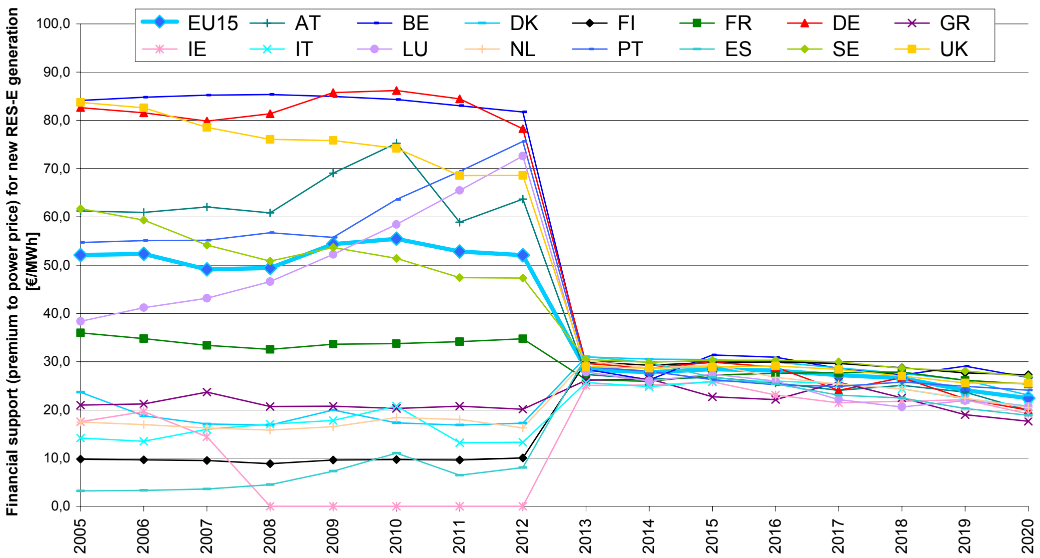

Figure 6.25 Country specific financial support (average premium to power price) for new RES-E generation applying an internationally harmonised feed-in tariff scheme after 2012 (B2)

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 6.25, or fully by applying an international TGC scheme, see Figure 6.26.[188] 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 6.27.[189] The premium depends on the national RES-E target setting.

[188] 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.

[189] 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.

Assuming that the same national RES-E deployment as under the BAU policy should be reached, high distortions between the countries occur.[190]

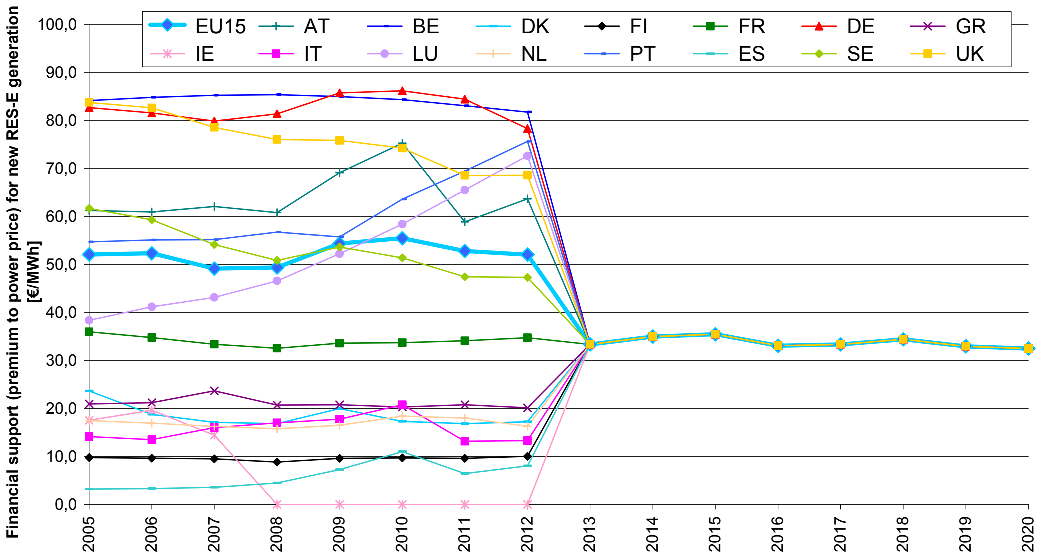

Figure 6.26 Country specific financial support (average premium to power price) for new RES-E generation applying an international TGC scheme after 2012 (B3)

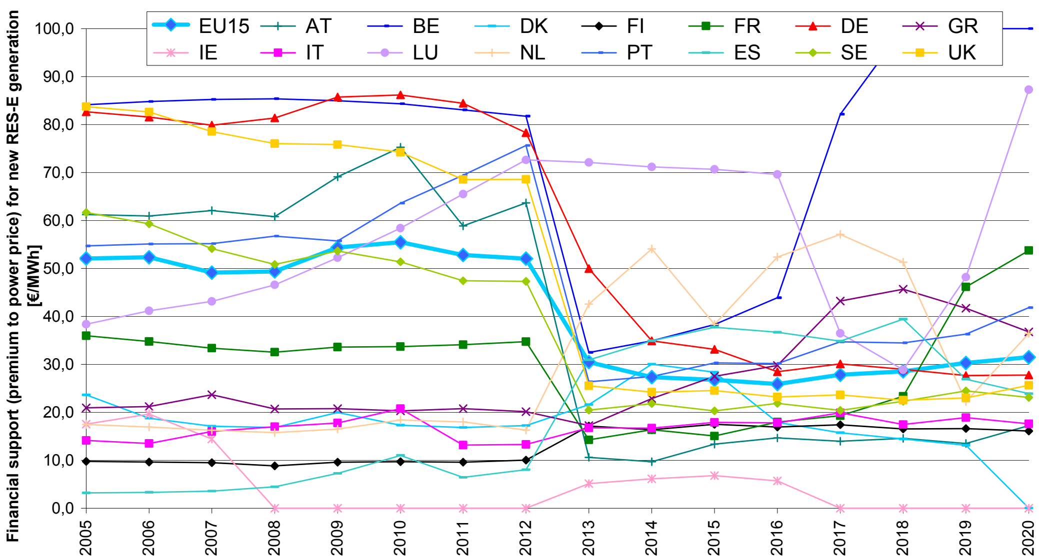

Figure 6.27 Country specific financial support (average premium to power price) for new RES-E generation applying national TGC schemes after 2012 (B4)

Figure 6.28 summarises the average premium support in the period 2013-2020 for the four investigated cases B1 to B4 on country level. On (EU 15) average, the additional financial support necessary to built up the appropriate RES-E capacity can be reduced by harmonising the strategies. By applying technology specific support schemes – in this investigation represented by feed-in tariff schemes – the support can be reduced. In all countries the average support level is lower compared to the application

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

of an international, non technology specific TGC scheme. The effect of national TGC systems is ambiguous: For some Member States necessary premium costs are lower, for other they are higher than applying an international TGC scheme.[191]

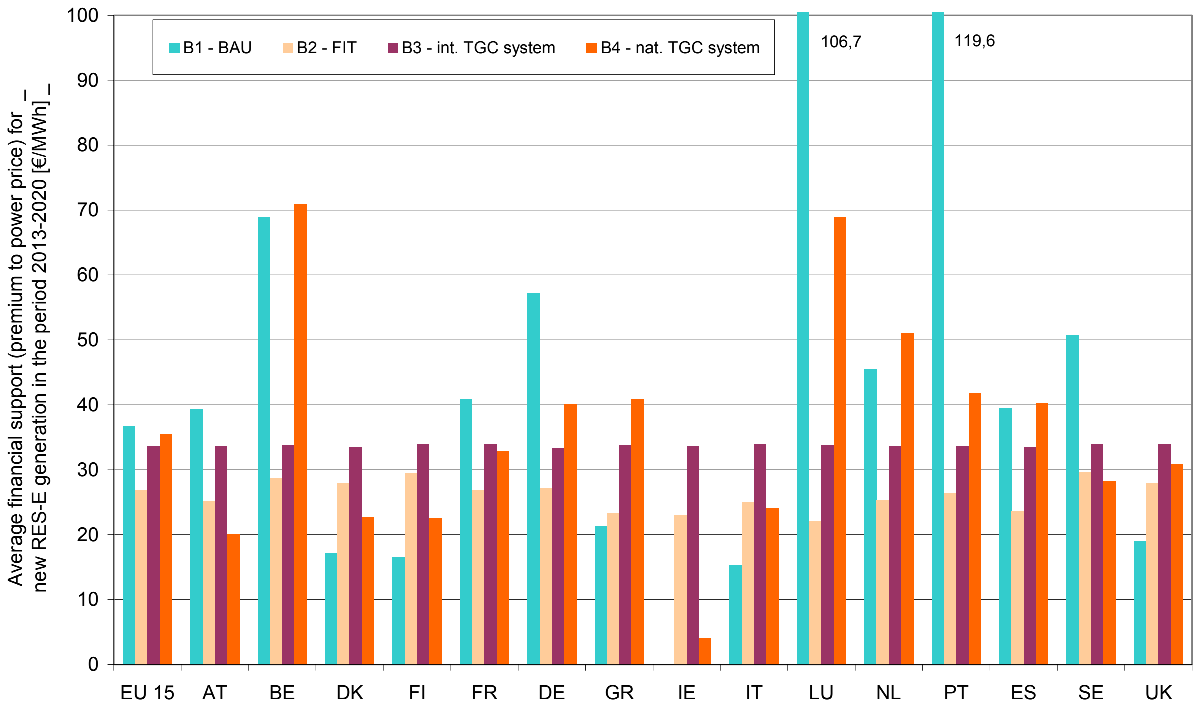

Figure 6.28 Comparison of country specific financial support (weighed average premium to power price) for new RES-E generation in the period 2013-2020 for the cases B1-B4

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.

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 6.29. 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 compare to the 2012 level, but increases over time.

[191] On average (EU 15) premium costs are higher, i.e. the whole system is more inefficient than using an international scheme.

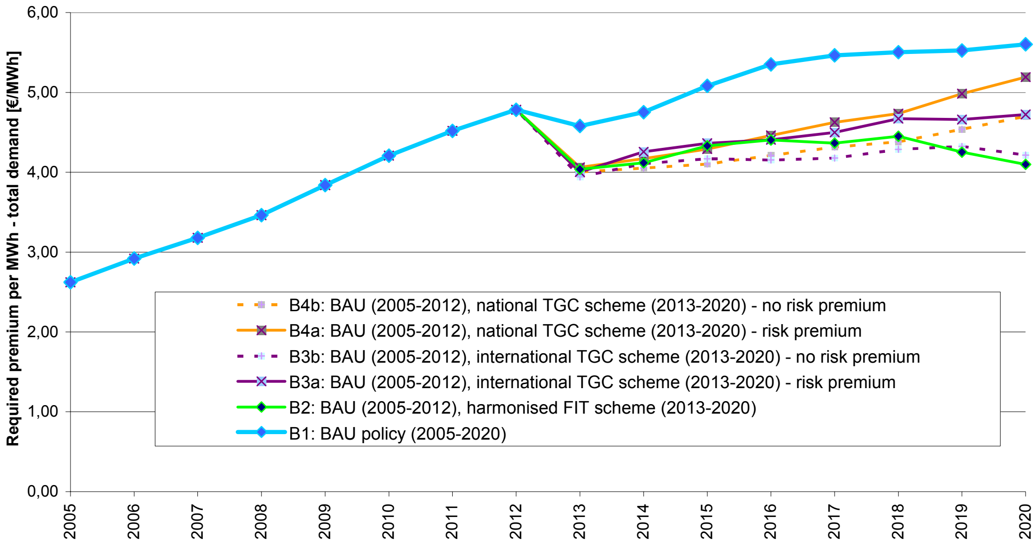

Figure 6.29 Comparison of necessary transfer costs for consumer reaching the BAU target 2020 (B1 – B4)

Figure 6.30 to Figure 6.33 show the required yearly transfer costs for society on Member State level. It can be clearly seen that a harmonisation reduce 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.[192]

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.[193] 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 if it is assumed that existing capacity remains in their old promotion scheme, i.e. the new schemes are applied to new capacity only.[194]

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

[193] 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).

[194] Note: This clear distinction between new and existing capacity is also applied to existing TGC schemes. This e.g. explains the high burden in the UK for the harmonised schemes. It is assumed that the RES-E capacity participated in the "old" TGC scheme up to 2012 receives the TGC price for the year 2012 onward, which is on a high level.

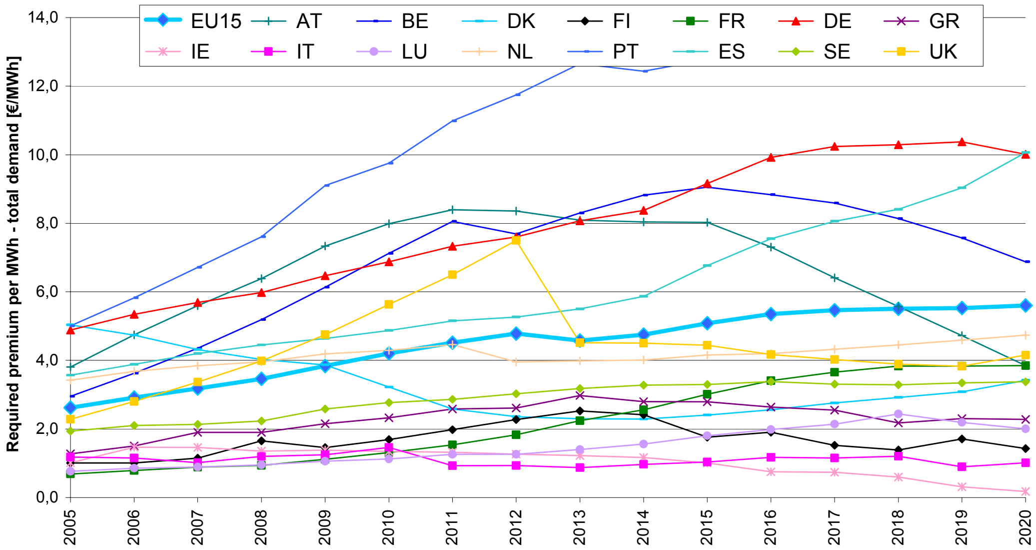

Figure 6.30 Country specific required premium per MWh total electricity demand B1 scenario

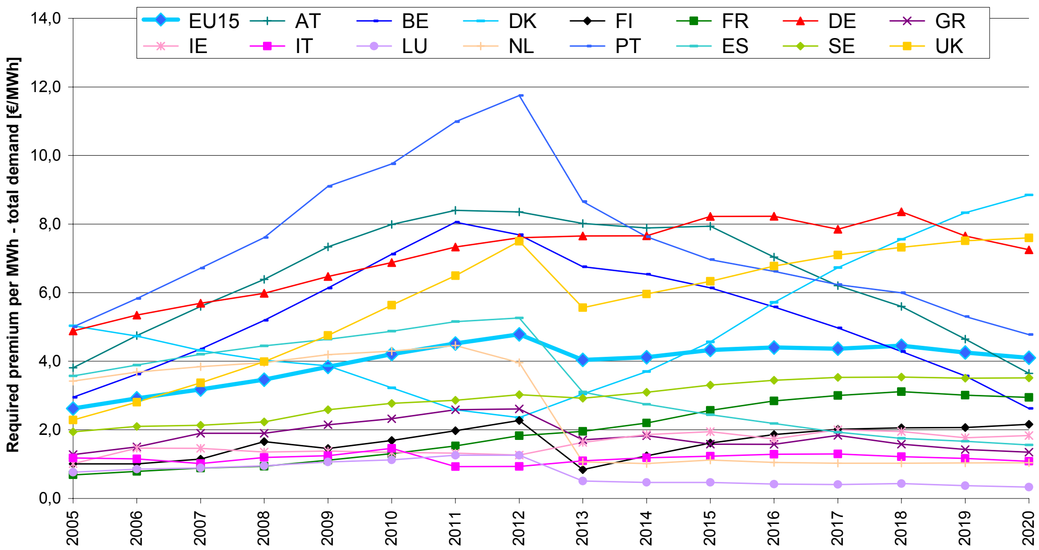

Figure 6.31 Country specific required premium per MWh total electricity demand B2 scenario

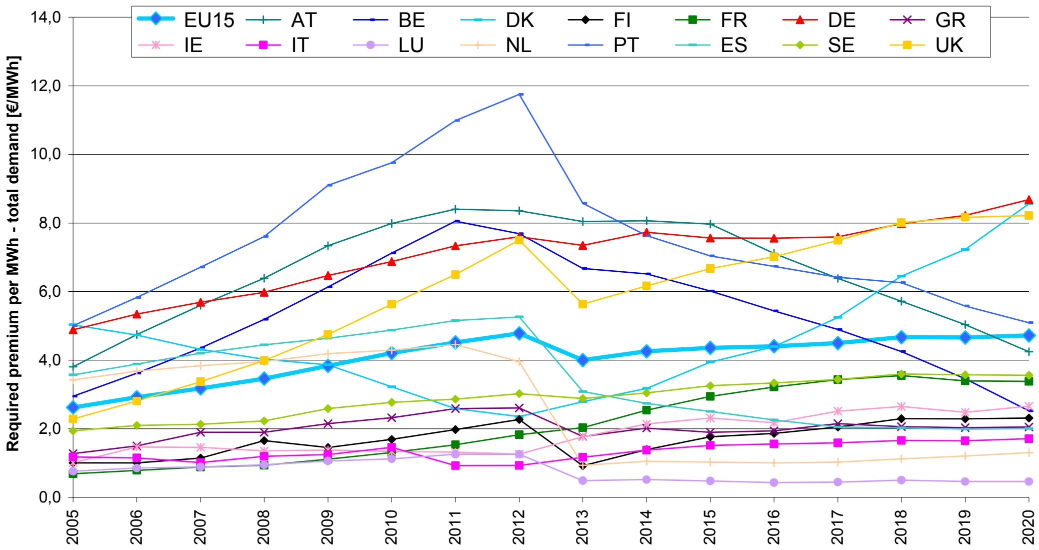

Figure 6.32 Country specific required premium per MWh total electricity demand B4 scenario
Note: Premium costs for society after 2012 depends on the actual allocation of the national quota; high national RES-E target higher premium costs, low RES-E target, lower premium costs:

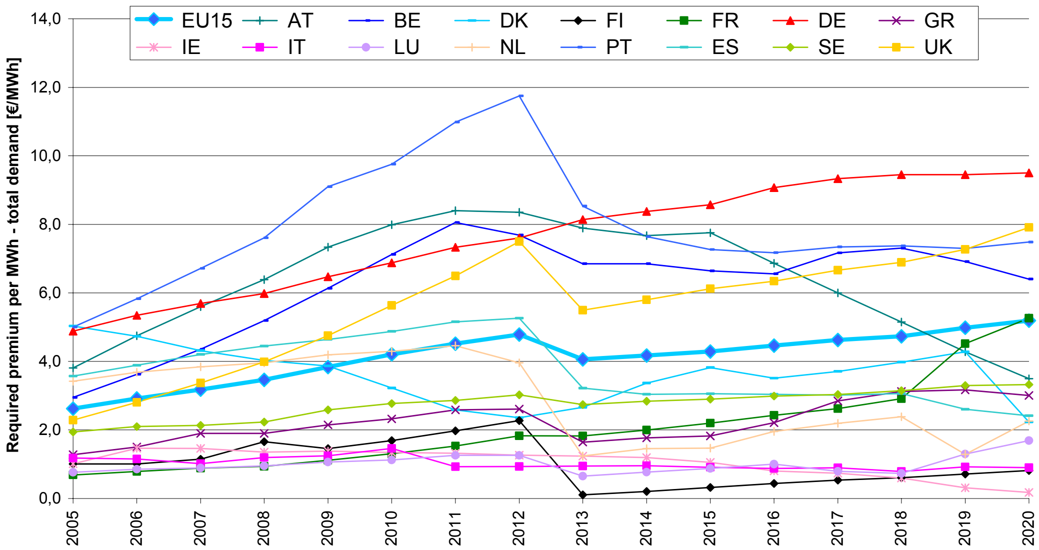

Figure 6.33 Country specific required premium per MWh total electricity demand B4 scenario
Note: Premium costs for society after 2012 depends on the actual national quota; high national RES-E target higher premium costs, low RES-E target, lower premium costs

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[195]. 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 6.29 to Figure 6.33 the *total burden* for the consumer seams to be " much higher" in the BAU scenario than under the other cases as a higher share of the costs are already paid

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

up to 2020.[196] 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 6.34. 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.

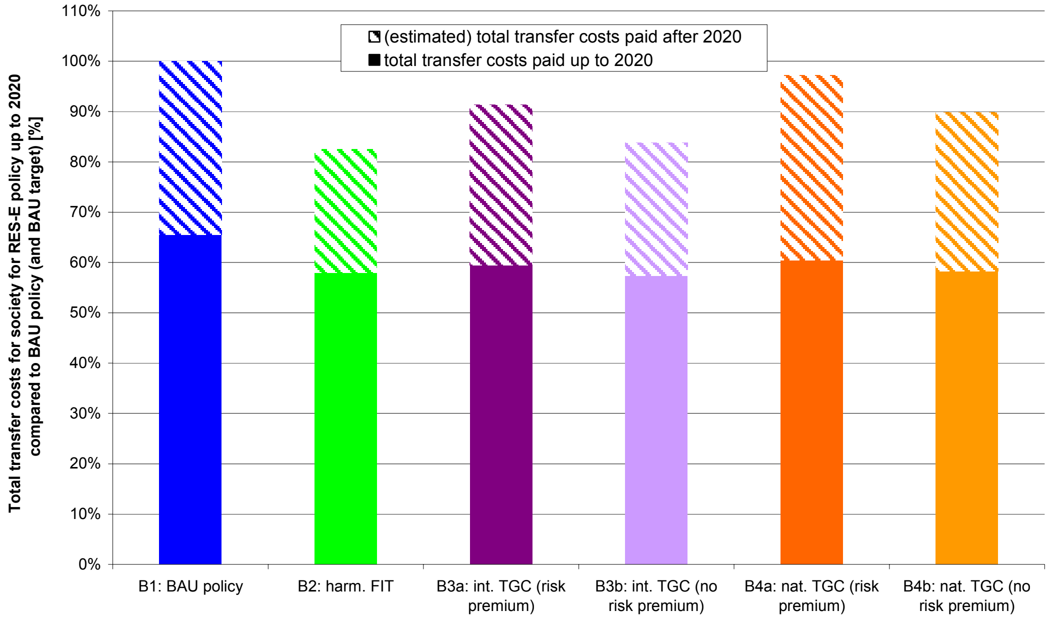

Figure 6.34 Comparison of necessary cumulated total transfer costs for consumer due to RES-E policy up to 2020 reaching the BAU target 2020 (B1 – B4).

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

6.6 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 6.35 depicts the deployment of RES-E generation reaching 1000 TWh in 2020 over time.

[196] 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 6.29 to Figure 6.33, 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.

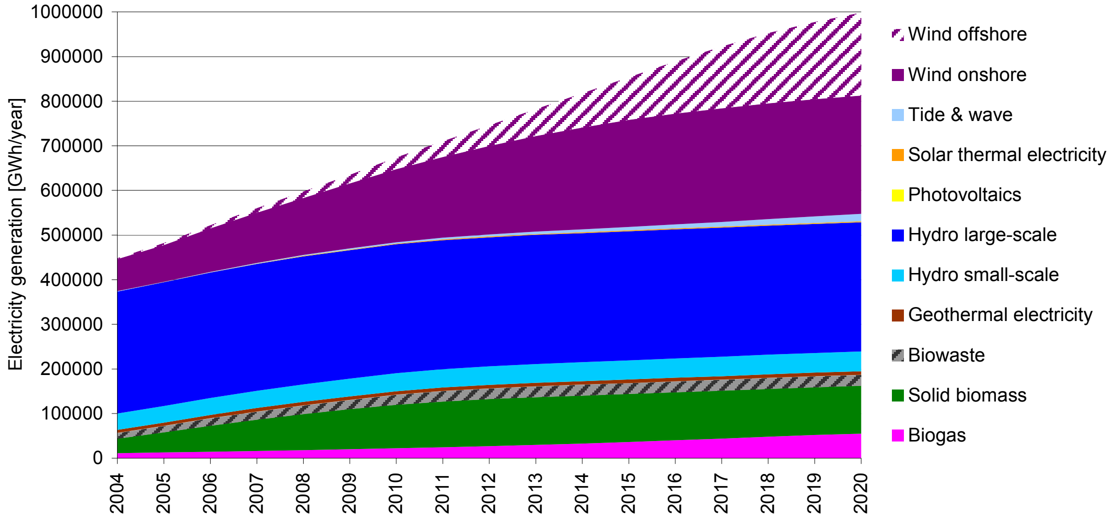

Figure 6.35 Development of RES-E generation 2004-2020 within EU-15 in the 1000 TWh scenario (variant H3)

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%, compare e.g. Figure 6.16 with Figure 6.36. 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 ambitous target, see left hand side of Figure 6.36. The country specific portfolio (for the case of international trade) is depicted in Figure 6.37. 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, see Figure 6.38.

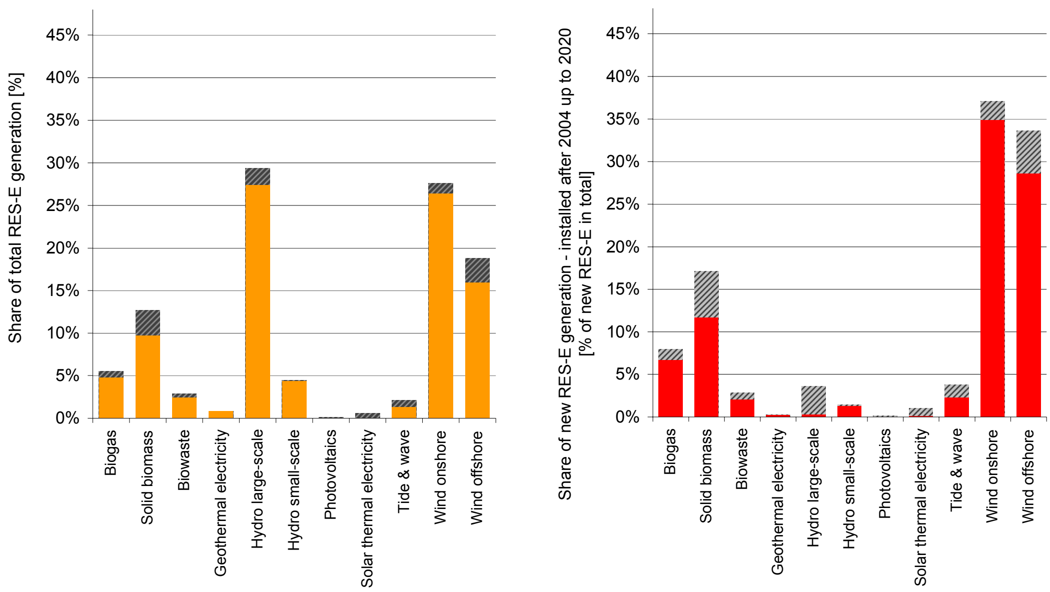

Figure 6.36 Share of RES-E technology on RES-E generation in 2020: From total (left) and new (right) installed capacity

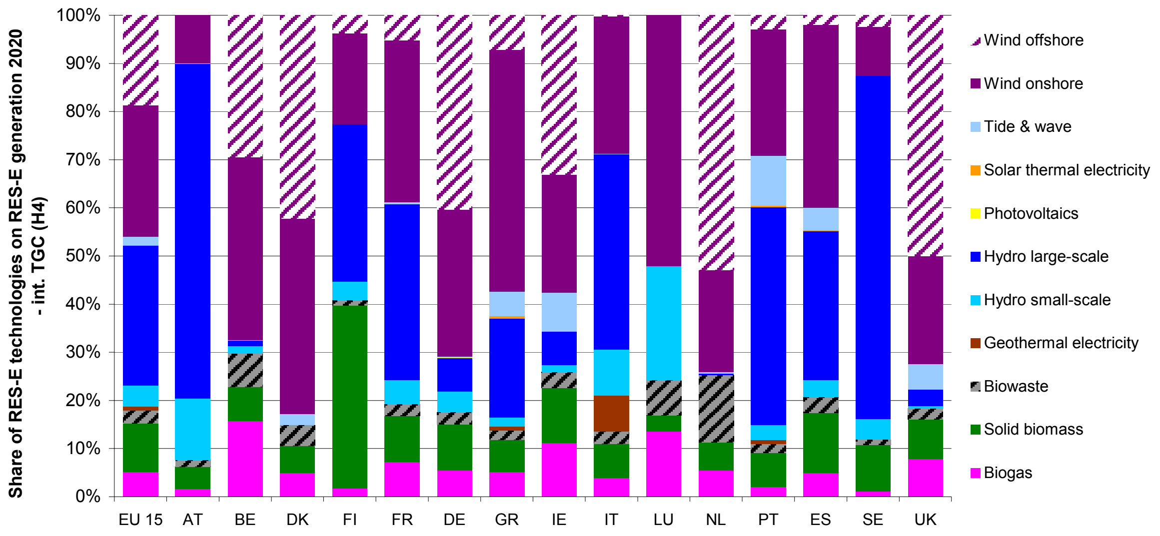

Figure 6.37 RES-E generation from new RES-E capacity 2005-2020 in 2020 (variant H3)

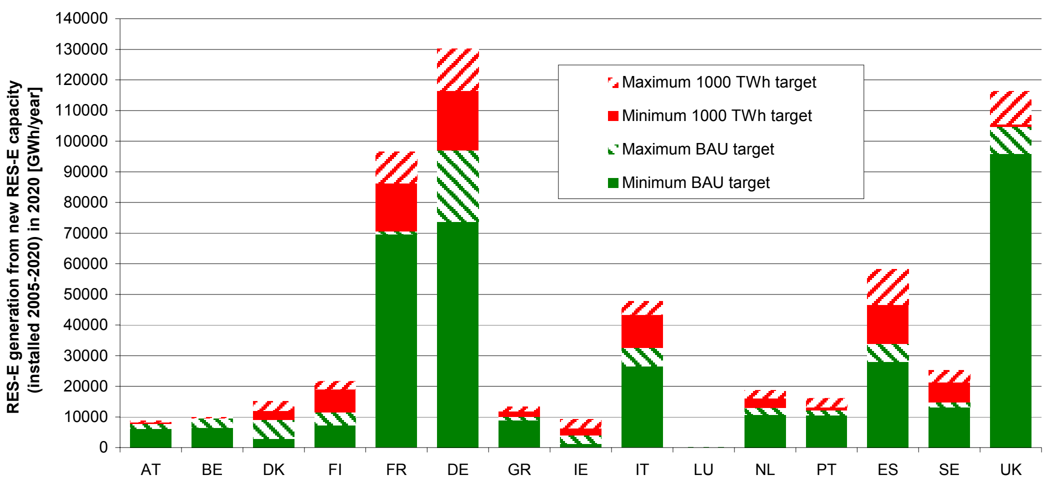

Figure 6.38 Comparison of RES-E generation from capacity installed after 2004

Note: Dotted grey area indicates the variation due to the applied policy strategy in the future (H1-H4)

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, see Figure 6.39.

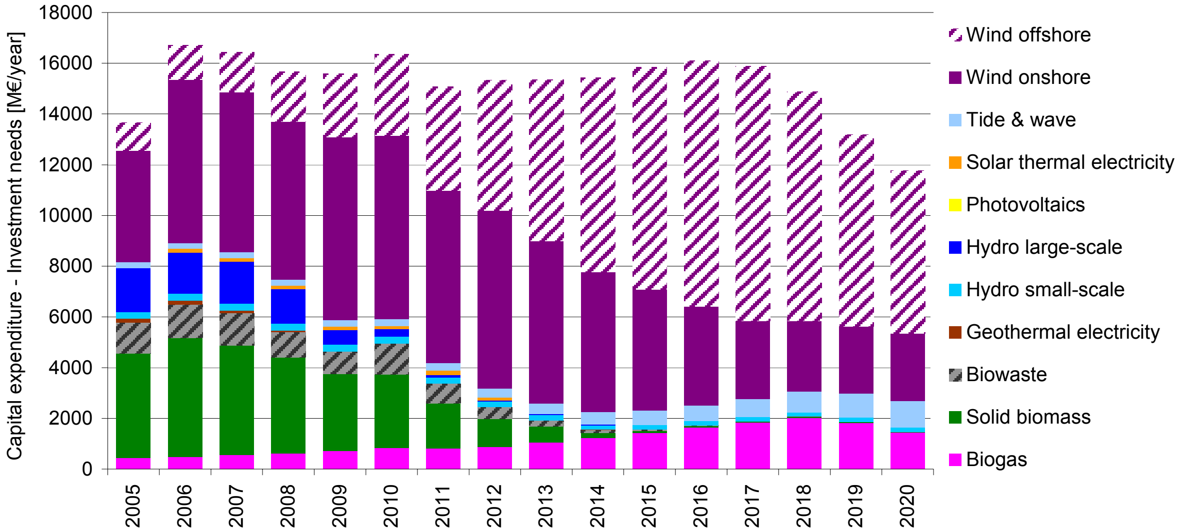

Figure 6.39 Total investment needs in the period 2005-2020 within the EU-15 in the BAU scenario (variant H3)

Figure 6.40 shows the necessary financial support for the two scenarios assuming a harmonised approach after 2012. 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. 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.

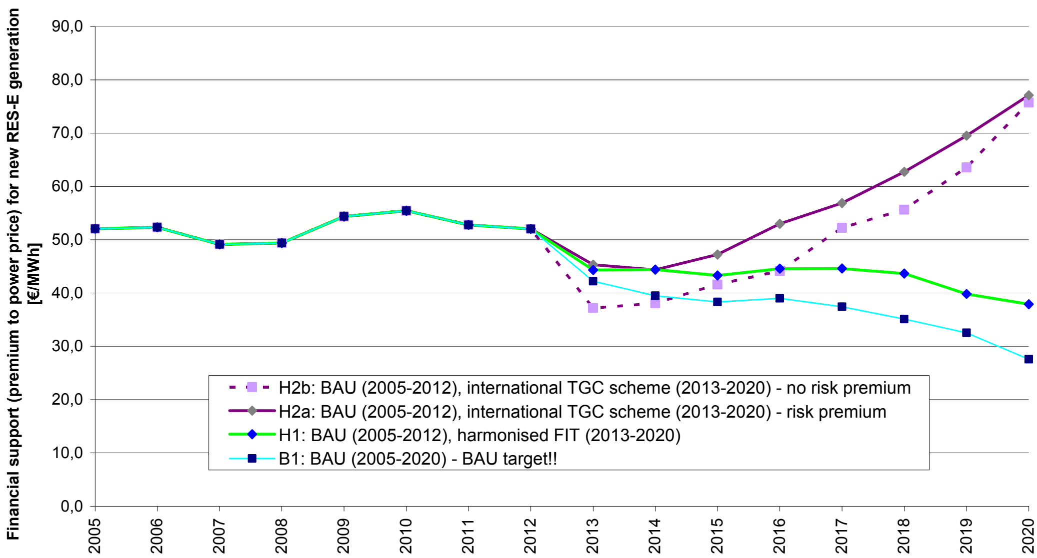

Figure 6.40 Comparison of financial support (average premium to power price) for new RES-E generation on EU 15 level in the period 2005-2020 for the cases B1, H1 and H2

The development of the financial support over time starting with a harmonised strategy already in 2005 is depicted in Figure 6.41. 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 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).[197] 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 - H6 for the case of a feed-in scheme and H7 assuming an international TGC system, see Figure 6.42. It can be observed that the necessary support is lower in the first years, however with a more moderate reduction over time.

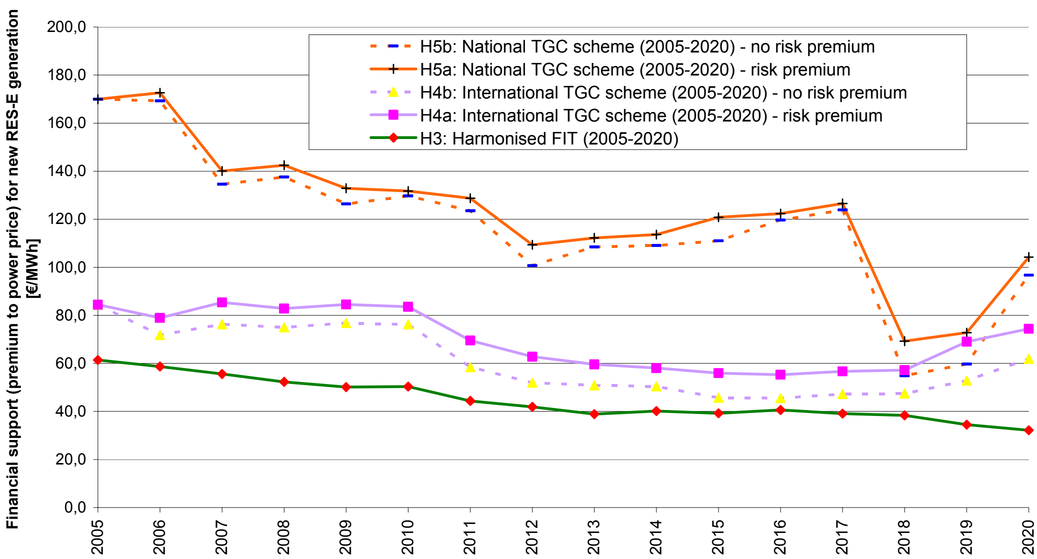

Figure 6.41 Comparison of financial support (average premium to power price) for new RES-E generation on EU 15 level in the period 2005-2020 for the cases H3 – H5

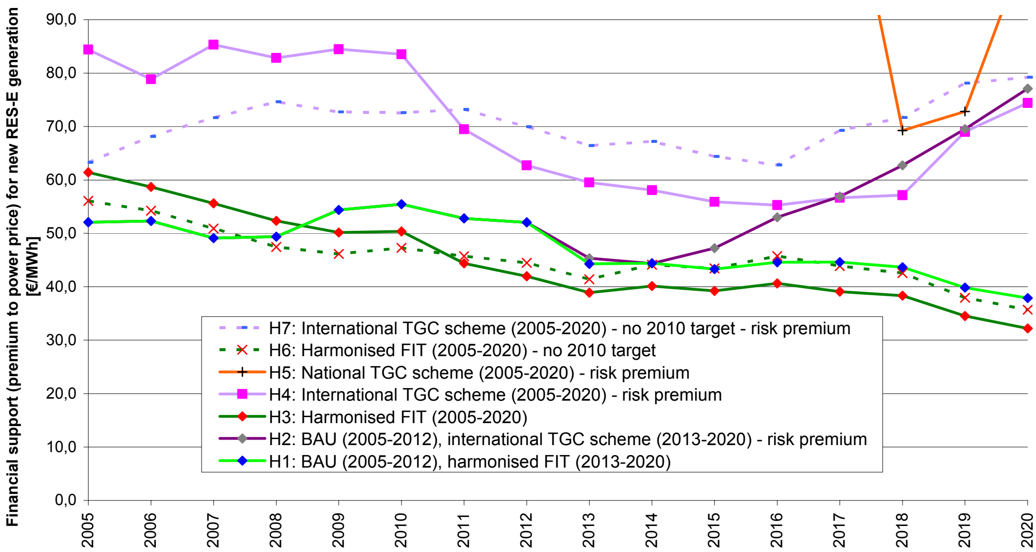

Figure 6.42 Comparison of financial support mechanisms feed-in tariff and international TGC scheme (average premium to power price) for new RES-E generation on EU 15 level in the period 2005-2020

The yearly transfer costs for society for all investigated 1000 TWh cases are depicted in Figure 6.43 to Figure 6.45. The effects with respect to the yearly transfer payments for the consumer / society corre-

[197] 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.

spond 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 higher in the early phase applying a feed-in tariff 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 (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.[198]

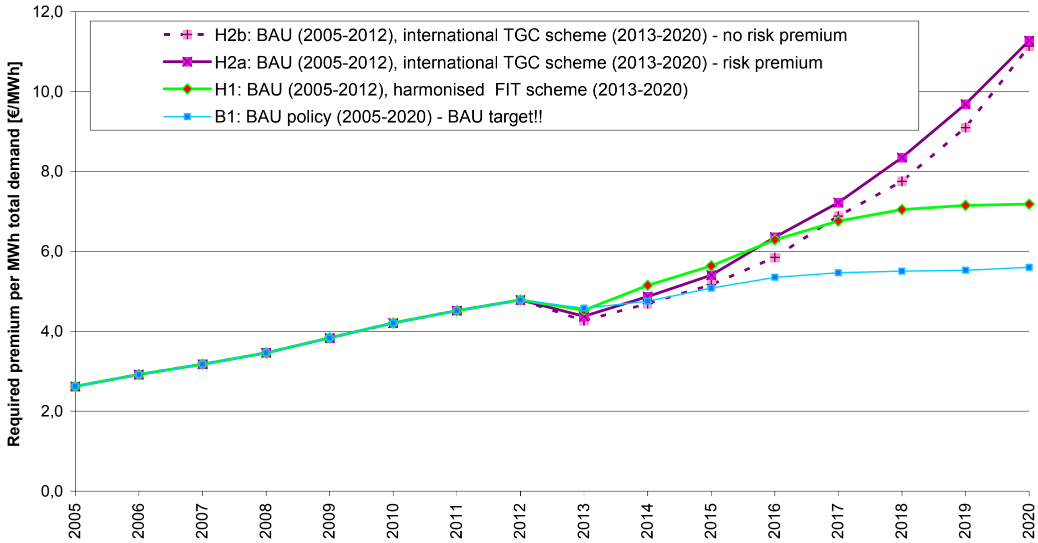

Figure 6.43 Comparison of necessary transfer costs for consumer reaching the 1000 TWh target in 2020 starting with a harmonised approach in 2013 (H1 and H2)

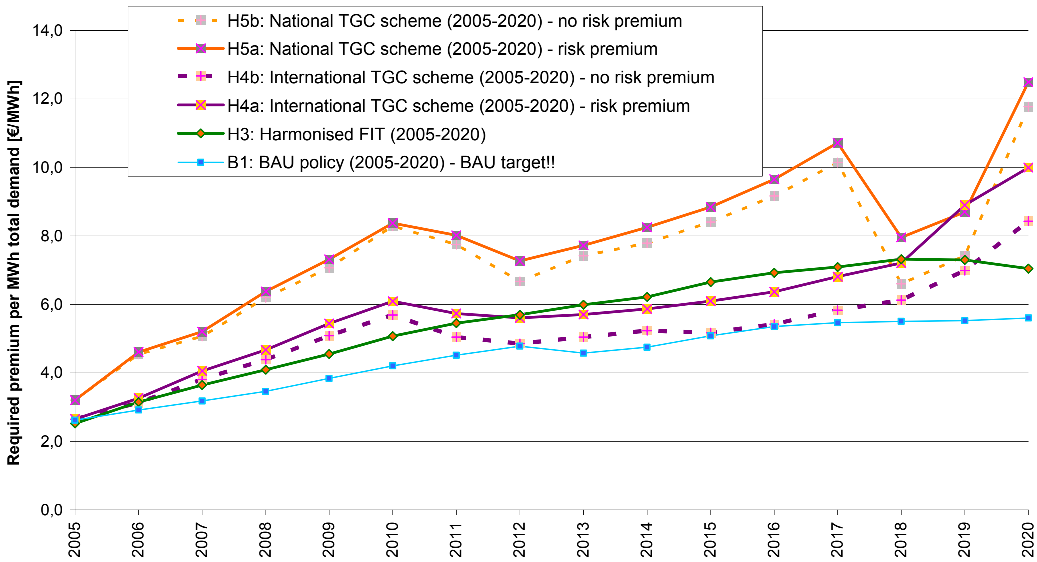

Figure 6.44 Comparison of necessary transfer costs for consumer reaching the 1000 TWh target in 2020 starting with a harmonised approach in 2005 (H3 – H5)

198 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.

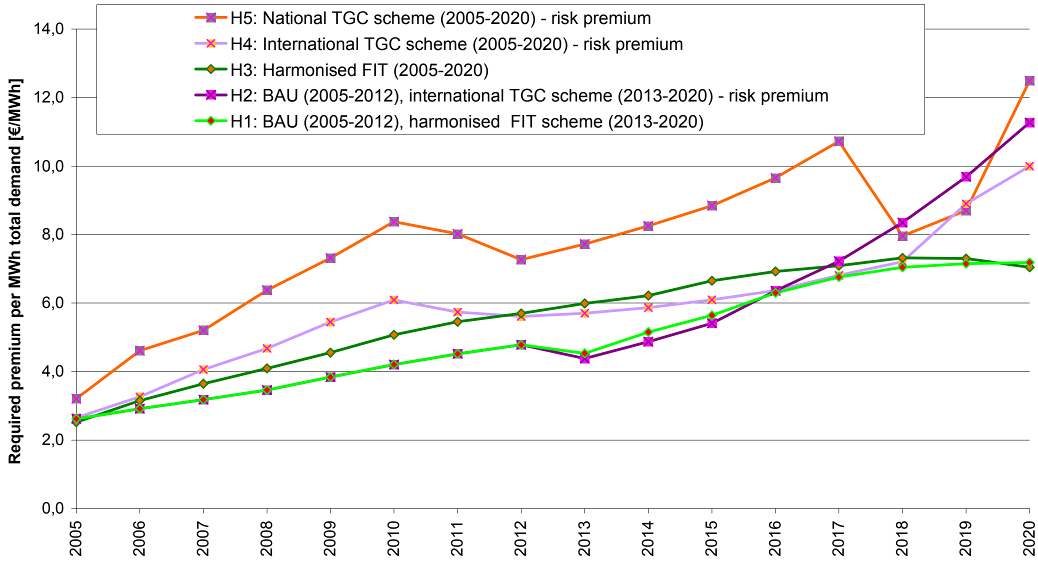

Figure 6.45 Comparison of necessary transfer costs for consumer reaching the 1000 TWh target in 2020 starting 2005 and 2013 with a harmonised approach (H1 – H6)

With respect to the total costs for society – see Figure 6.46 - 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.

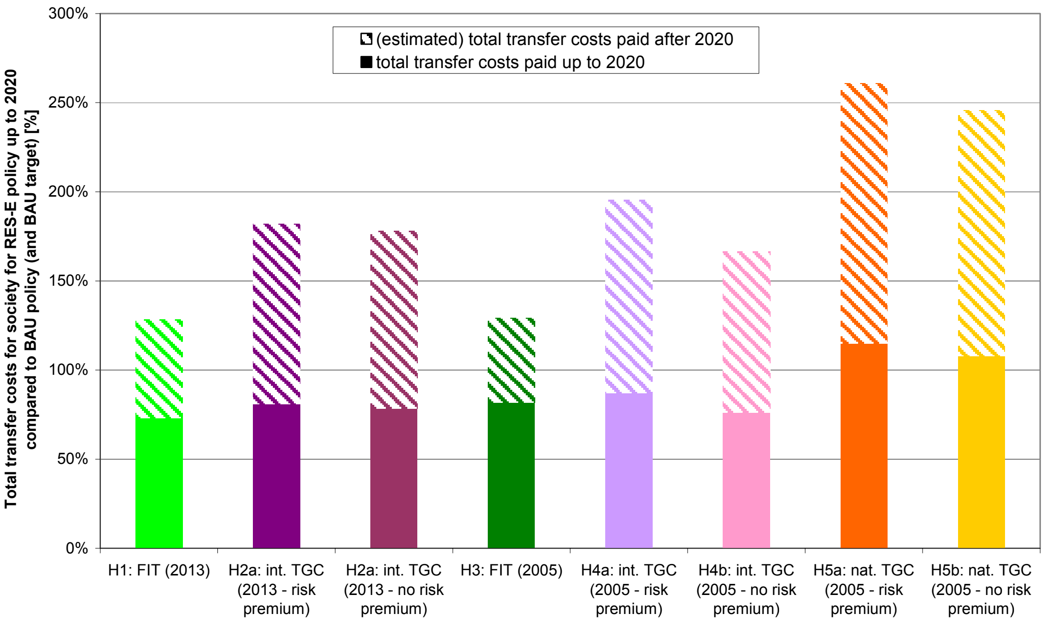

Figure 6.46 Comparison of total transfer costs for consumer reaching

6.7 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 6.47 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.[199] This means that – neglecting possible back-up costs for RES-E – the deployment of RES-E leads to a price reduction on the power market of 5% to 10%. [200]

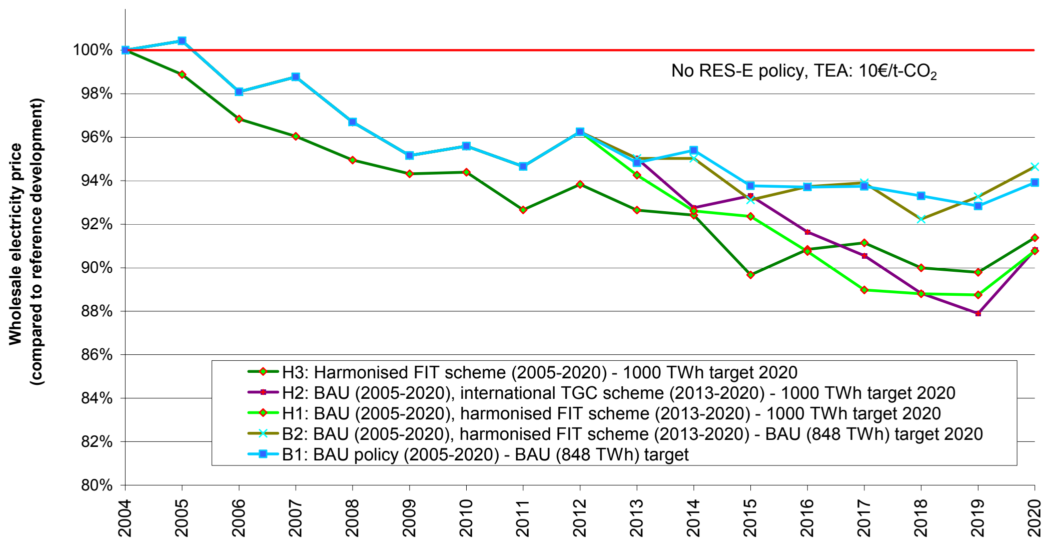

Figure 6.47 Comparison of wholesale electricity price compared to reference development (no RES-E policy and TEA price of 10€/t-CO_2)

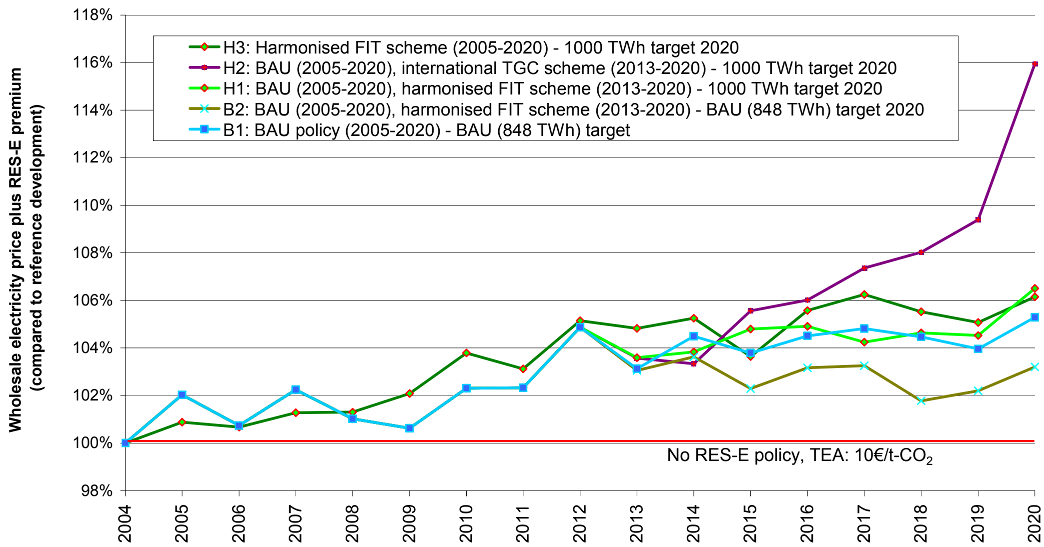

Figure 6.48 Comparison of wholesale electricity price including RES-E premium compared to reference development (no RES-E policy and TEA price of 10€/t-CO_2)

[199] 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,

[200] 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).

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 the case of TGC scheme 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 6.49.

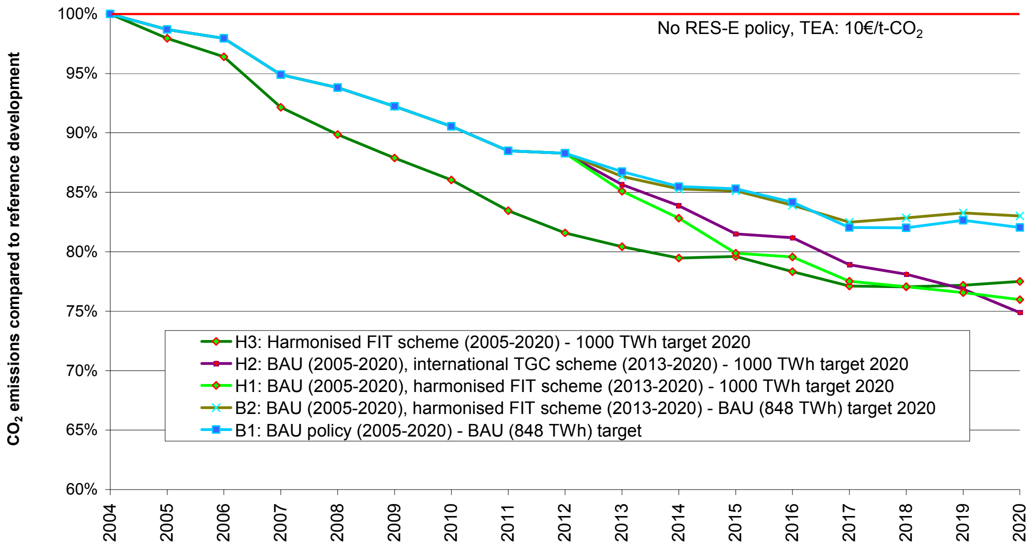

Figure 6.49 Comparison of CO_2-emissions compared to reference development (no RES-E policy and TEA price of 10€/t-CO_2)

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).

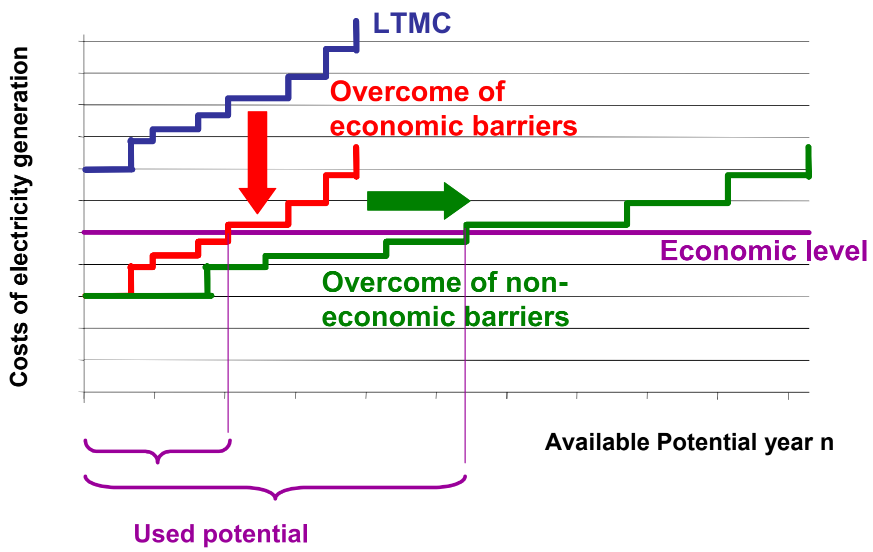

Figure 7.1 Necessary conditions reaching a RES-E deployment

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. The following criteria are necessary to overcome both kinds of barriers:

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 rigorously removed 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 management measures. Renewable energy development and increase of energy efficiency are strongly interdependent. 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.
- *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 addi-

tional costs are a direct burden on electricity generation in the form of additional system operation costs comprising system capacity and balancing costs[201]

- System capacity costs: Due to the limited contribution of intermittent RES-E technologies additional cost for back-up systems are imposed
- Balancing costs: Extra short-term balancing requirements and costs occur due to the intermittency of wind[202]

Remedies to significantly mitigate system operation costs are:

- 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[203];
- 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. [204, 205];
- Special emphasis should be placed on urban areas, where a high proportion of all energy is consumed. Urban areas are characterised by a highly developed infrastructure, which does not always facilitate a rapid increase of the level of renewable energy generation. In general, a future energy infrastructure will, from its conception, have to be designed to effectively accommodate RES to a very high level[206].

- *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 the RES-E targets in the future;

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[201] 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.

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

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

[204] This is mostly not true for onshore or offshore wind energy, where generation and load centres can be far apart, i.e. a zonal pricing system could be a high burden for wind energy. 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)

[205] 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)

[206] Due to the technology’s decentralised character, urban areas can - in some cases - allow a high degree of penetration of PV generators, without changing the existing cabling, transformer stations, etc.

- *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. By including import-substitution of fossil fuels in the mandates for which companies national governments may support, new domestic or established international companies in these new industries would qualify for support.

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.

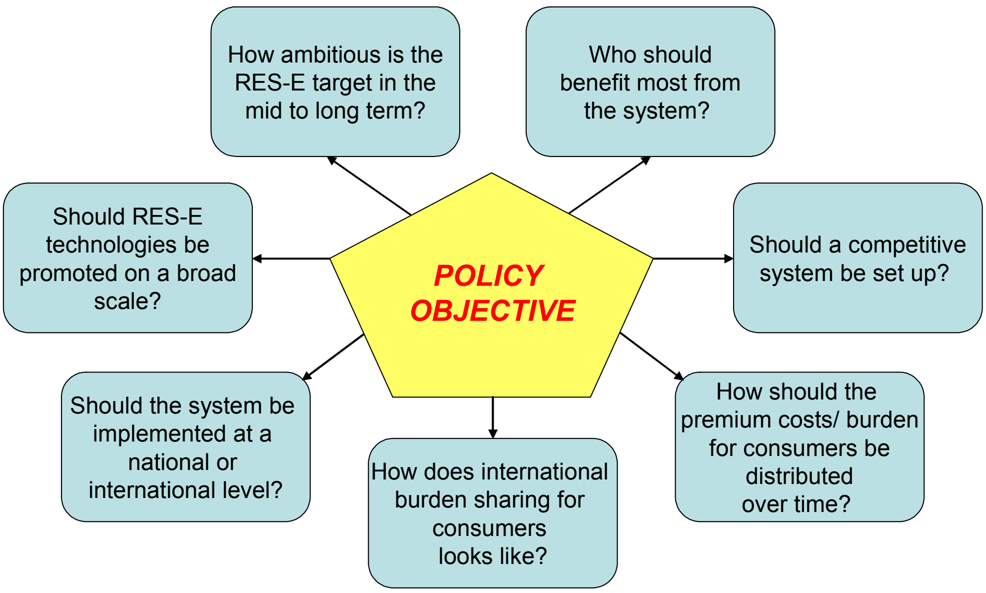

Figure 7.2 Possible policy objectives in choosing the appropriate support scheme

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.[207]

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 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

[207] 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.

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 left hand graph in Figure 7.3.

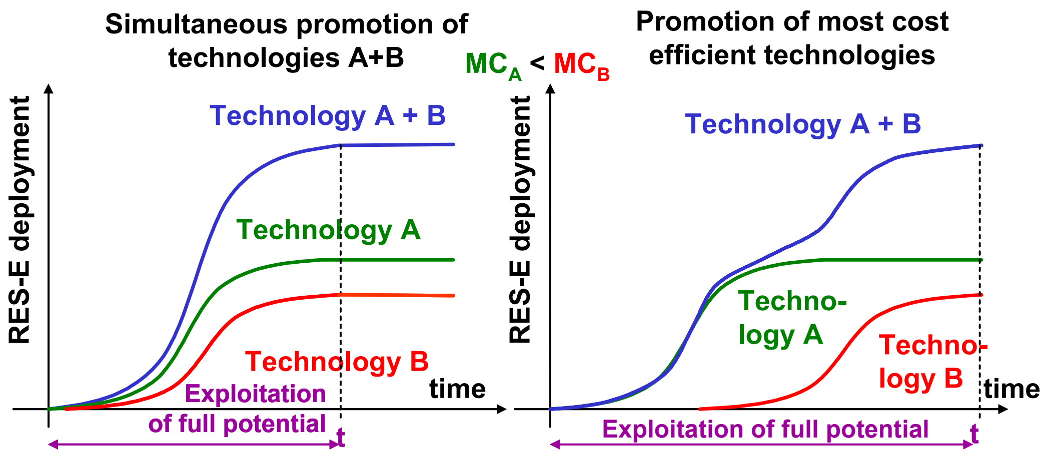

Figure 7.3 Effect of a simultaneous promotion of RES-E technologies versus a serial promotion (according to the cost efficiency) with respect to total RES-E deployment

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 right-hand-side 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 right hand side 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.

7.2.3 Who should benefit from the system, the RES-E industry, the 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;[208]
– 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[209]. In most cases and considered over a certain time frame, a feed-in tariff scheme[210] 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[211].

7.2.4 Should a competitive system be set up?

It must initially be clarified *where* competition should take place within the energy chain from manufacturing to end use. Figure 7.4 gives an overview about the energy chain

– **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 transpar-

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[208] This does not necessarily lead to the conclusion that manufacturers of currently cost efficient technologies prefer strategies that promote only cost efficient technologies. The reason is that under such conditions the danger of overheated markets exists.

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

[210] 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.

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

ency 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.

– **Should competition be enforced between distribution companies?**

  If competition can be introduced, this should improve the position of generators.

– **Should competition be enforced between end user?**

  Competition depends on market transparency, i.e. the offer of green products (green pricing) and guarantees of origin. Competitive pressure also exists if it is assumed that the quota obligation is imposed on the end user.

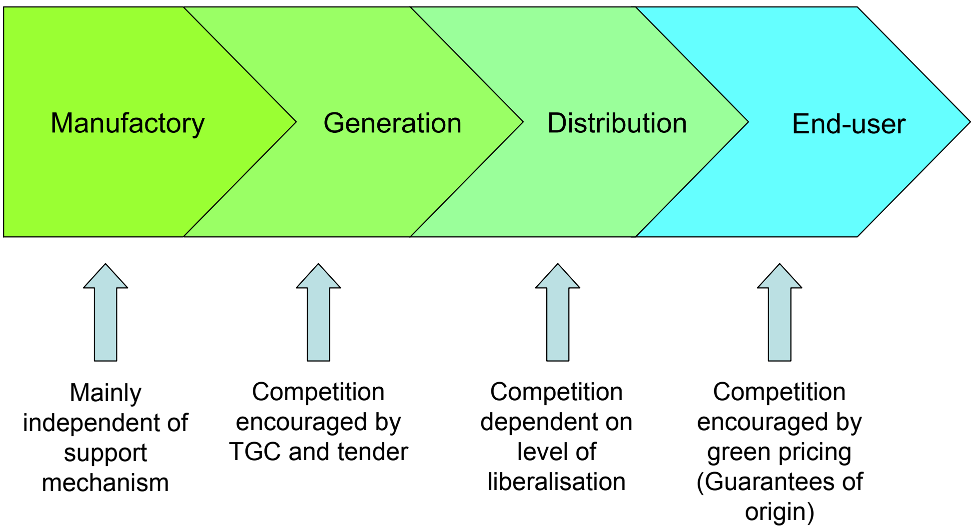

Figure 7.4 Electricity production chain

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[212], maybe not per MWh, but in total as RES-E capacity increase.[213]

[212] 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.

[213] 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.

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.

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[214] 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[215] and

(iii) generation costs of these technologies are lower due to technological learning.

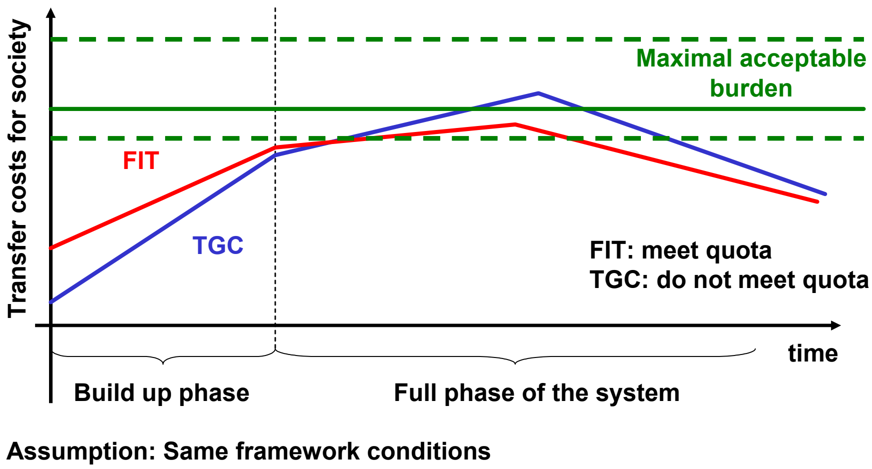

Figure 7.5 Transfer costs for society applying a instrument with simultaneous support (feed-in tariff / FIT) and a mechanism promoting only the currently most cost efficient technologies (TGC scheme)

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 7.5 and “proved” by the simulation results; see e.g. Figure 6.29, Figure 6.44 and Figure 6.45.

7.2.6 What 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.

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

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

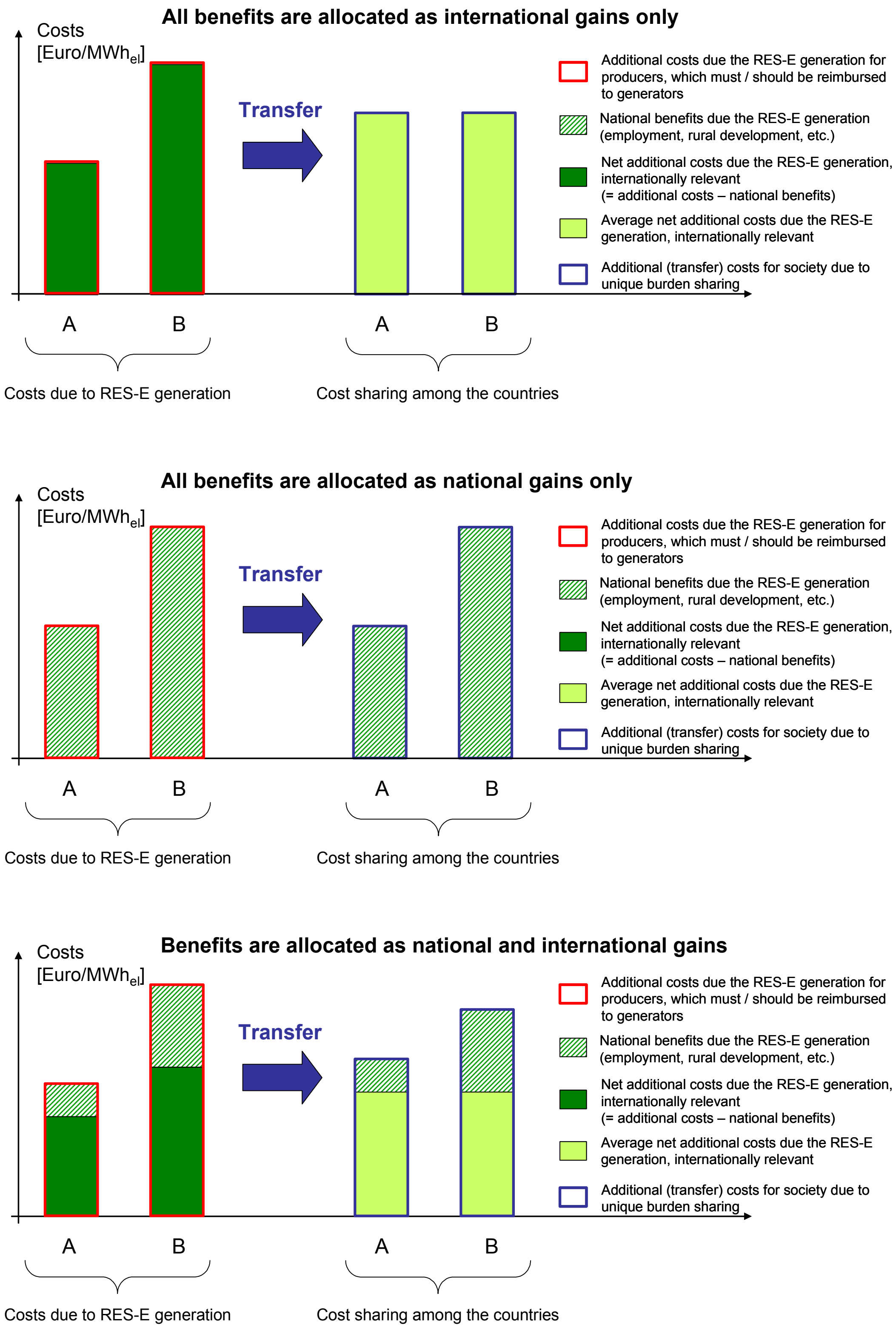

Figure 7.6 Possible allocations of RES-E costs among the countries A and B

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.[216]

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

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 7.6 illustrates the possible allocation in a fictive two country example (country A and B). 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 7.6 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 7.6. 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. [217, 218]

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.

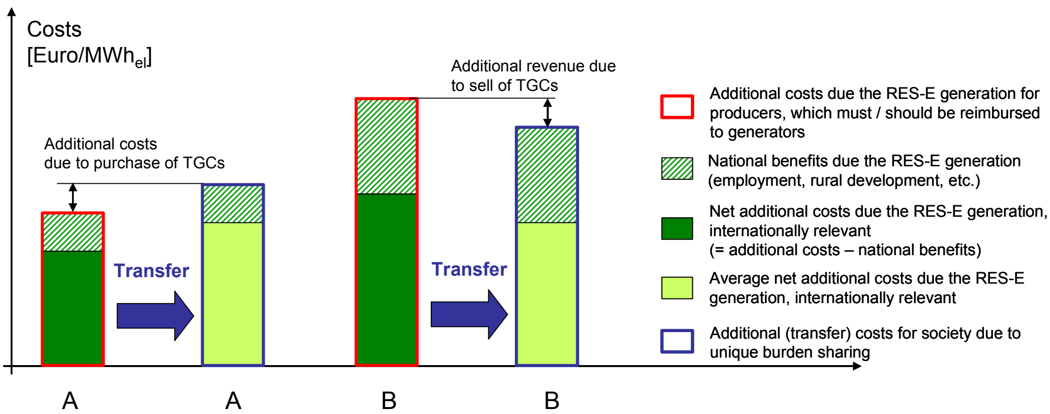

Figure 7.7 Trade-off within an international trading scheme

  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

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

[218] 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.

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.

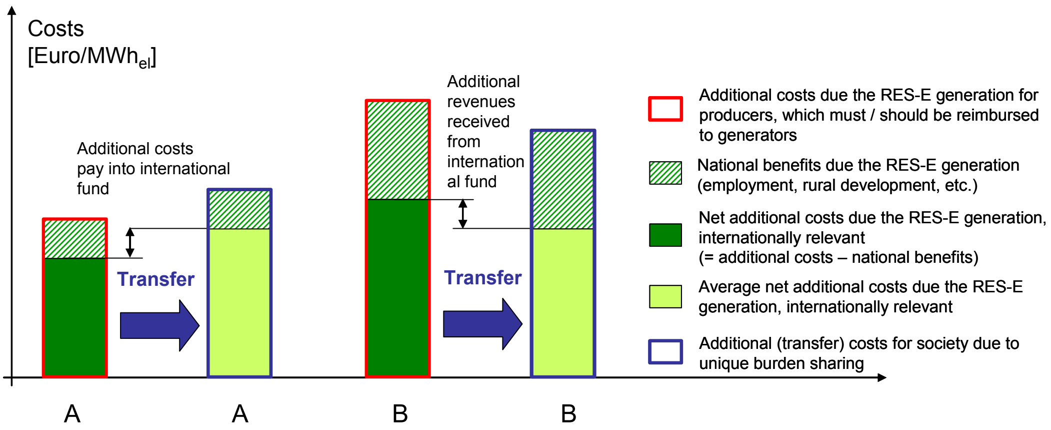

Figure 7.8 Trade-off within a feed-in tariff scheme, a tender procedure, national TGC or other price driven schemes

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 7.8. Hence, in contrast to an international TGC scheme additional administration effort is necessary reaching a "fair" distribution of the costs for RES-E deployment. [219] 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.

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.

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**.

[219] Within an international TGC scheme a comprehensive negotiation process is necessary reaching a "fair" burden sharing agreement between the Member States.

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 decreases with technological progress
- 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)
- 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).

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

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. 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 declines due to technological learning, caused by the RES-E development in the other countries[220].

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.

- **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[221]. Common general rules can reduce distortions among the producer and consumer.

Figure 7.9 provides a suggested design of efficient instruments so as to minimise costs for consumers. For more details with respect to the design, refer to chapter 4.

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[220] 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.

[221] 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.

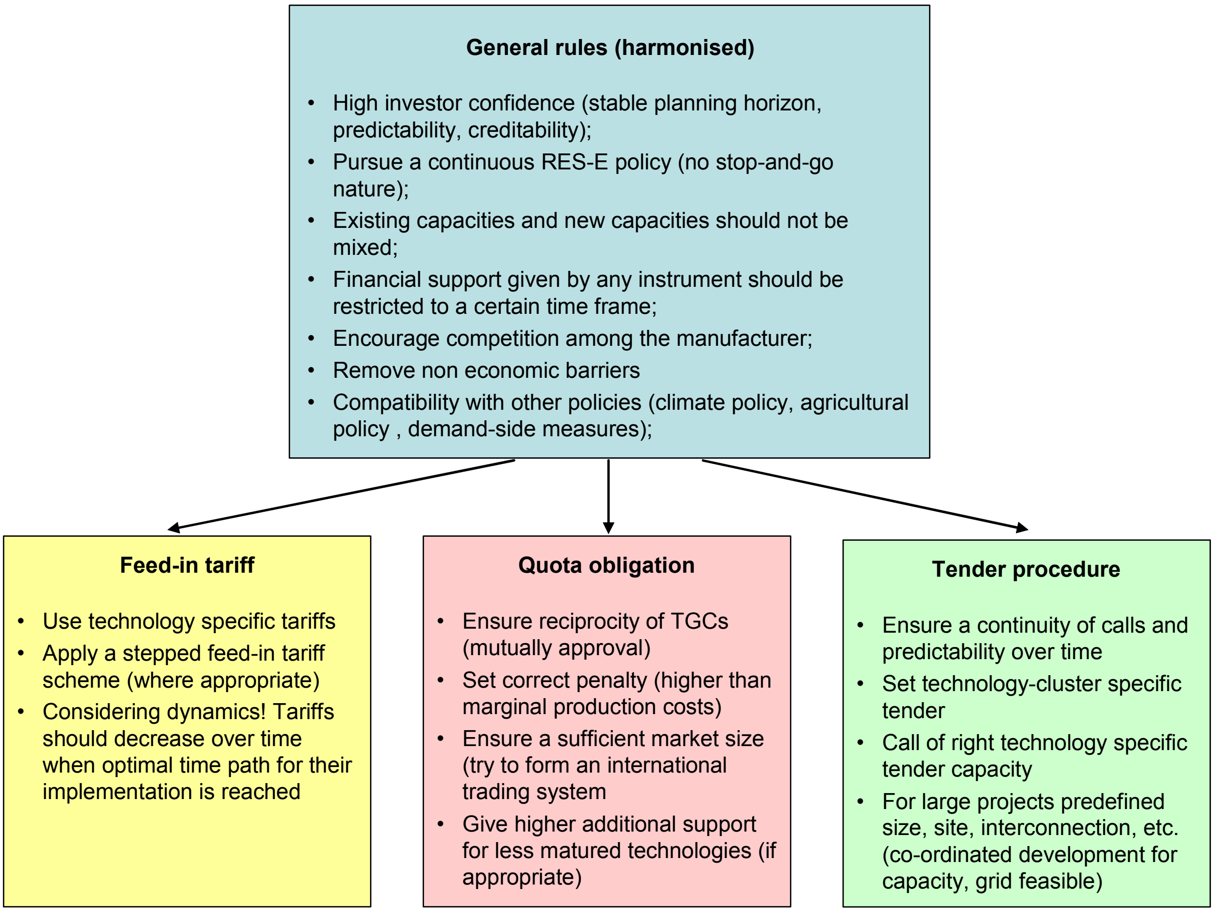

Figure 7.9 Efficient design options for RES-E support instruments from the consumer's perspective

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. [222]
- 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**. Of course, a necessary pre-condition to reach an international agreement is that **a "fair" burden sharing concept is developed, considering both national and international benefits from RES-E generation**
- 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**. 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 **TEA 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.

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

8 References

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