Support Schemes for Renewable Energy

A Comparative Analysis of Payment Mechanisms in the EU

Supported by the European Commission

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Contents

List of tables 2

List of figures 3

List of abbreviations 4

1. Background 5
1.1 Objective 6

2. Current status of renewable electricity in the EU 7

3. External costs 10
3.1 The ExternE project 11
3.2 A comparison of the social costs of electricity from wind, coal and gas 14
3.3 "External benefits" of renewables not accounted for 15
3.4 Avoided emissions and external costs by utilising wind power 16
3.5 Avoidable emissions and external costs by wind power in 2020 19
3.6 Policy instruments and external costs in practice 20

4. Promotion instruments 22
4.1 Environmental taxes 22
4.2 Payment mechanisms 24
4.2.1 Historical background 25
4.2.2 Voluntary systems and green marketing 26
4.3 Support schemes for renewables in the EU 27
4.4 Fixed price systems 30
4.4.1 Investment subsidies 30
4.4.2 Fixed feed-in tariffs 31
4.4.3 Fixed premium systems 32
4.4.4 Tax credits 32
4.5 Fixed quantity systems 33
4.5.1 Tendering systems 33
4.5.2 Tradable green certificate systems 34
4.5.3 Indirect promotion strategies 38

5. Evaluation of support schemes 41
5.1 Evaluation criteria 41
5.1.1 The EU Directive on renewables 41
5.1.2 The evaluation criteria 42
5.1.3 The weights of each criterion 45
5.2 The generic and improved support schemes 46
5.3 Results of the survey evaluating support schemes 48
5.3.1 Unweighted scores of support mechanisms 48
5.3.2 Average weighted scores 49
5.4 Detailed survey results 49
5.4.1 Investment subsidy 49
5.4.2 Feed-in tariff 50
5.4.3 Premium 51
5.4.4 Tendering procedure 52
5.4.5 Green certificates 53

5.5 Variability of results 54
5.6 Conclusions on the survey 56
5.7 Incorporating externalities in support schemes 57
5.7.1 Conclusions and recommendations on externalities role in RES-E policy 59

6. Computer simulations of support mechanisms 61
6.1 Green-X model assumptions 61
6.2 Simulation run results 63
6.2.1 Results – BAU-scenario 63
6.2.2 Comparison of the advanced support schemes 64
6.2.3 "Generic" versus "advanced" schemes 68
6.2.4 Sensitivity investigations – the impact of high fossil fuel prices and externalities 69

7. Conclusions and recommendations 71
7.1 Little evidence of effectiveness beyond feed-in tariffs and premiums 71
7.2 Voluntary best practice design guidelines 71
7.3 Real competition in power markets 72
7.4 Payment mechanisms and externalities 72
7.5 A harmonised system for promoting renewables 73

ANNEX 1: Integration of RES-E in the electrical system: issues and recommendations 74

For an electronic version of this Report, the Overview and the Internet based background documents, please visit http://www.ewea.org/06projects_events/projects.htm

List of tables

Table 3.1 12
Damage from air pollutants on human health

Table 3.2 13
Specific external cost of energy
Damage in eurocents/(kWh of electricity supplied)

Table 3.3 14
Specific social costs of electricity from coal and gas power systems
Social Cost (Internal + External)

Table 3.4 15
Specific social (total) cost of wind energy per kWh electricity generated

Table 3.5 18
Avoidable external cost, in eurocents per kWh electricity generated, by the use of wind energy in 2000

Table 4.1 23
Specific national tax incentives for renewable energy

Table 4.2 25
Historical overview on promotion strategies for electricity from RES in European countries

Table 4.3 28
Fundamental types of promotional strategies

Table 4.4 29
Current end 2004 promotion strategies for RES-E in EU-15 countries

Table 4.5 35
Overview of various certificate models

Table 4.6 38
Energy taxation with exemptions for RES in various EU-15 countries

Table 5.1 45
The main results of the questionnaire

Table 5.2 46
Generic and advanced support schemes

Table 5.3 49
The main results of the questionnaire

Table 6.1 62
Policy-specific settings with respect to the WACC

List of figures

Figure 2.1 7
EU-25 Electricity Production Mix 2003

Figure 2.2 7
Electricity generation from RES in EU-15 countries from 1990 to 2004

Figure 2.3 8
National electricity generation from RES (including large hydro) in EU-15 countries in 2004, for comparison with total national electricity consumptions

Figure 2.4 8
EU-15 countries ranked by the proportion of RES-E (with large hydro) within total electricity consumption in 2004; also shown, the proportions without large hydro

Figure 2.5 9
Technology-specific breakdown of RES-E generation (excl. large hydro) in 2004: Electricity generation by RES-E category in absolute terms by country and relative terms by country, and for total EU-15

Figure 3.1 10
Specific social cost of energy

Figure 3.2 13
Average external costs of electricity production, per kWh of electricity generated from all supplies of the specified countries

Figure 3.3 15
Specific social cost of electricity from coal, gas and wind

Figure 3.4 17
Specific avoidable CO_2 emissions in g/(kWh electricity generated) by wind energy in 2000, within the electricity supply systems of the named countries

Figure 3.5 17
Specific avoidable SO_2 and NO_x emissions in g/(kWh electricity generated) by wind energy in 2000; within the electricity supply systems of the named countries

Figure 3.6 18
Avoidable specific external cost, in eurocents per kWh electricity, by the use of wind energy in 2000

Figure 3.7 19
Avoided total external costs per country by the use of wind energy in 2000 (low, medium and high range calculations, see text)

Figure 3.8 20
Uncertainty abatement and damage curve

Figure 4.1 22
Comparison of historical (1997) and present penetration (2004) and future targets according to the 'RES-E Directive'

Figure 4.2 26
Results of the survey relating willingness to pay more for energy produced from renewable sources

Figure 4.3 30
Feed-in tariffs for electricity from new onshore wind plant in EU-15 countries (at end 2004)

Figure 4.4 38
ROCs issued in the period October 2002 to February 2003 by technology and country

Figure 5.1 45
Average and standard deviations calculated for the answers of the questionnaire

Figure 5.2 48
Respondent's occupation

Figure 5.3 48
Average scores for each of the five support schemes in a generic and an advanced version

Figure 5.4 49
Average weighted scores for each of the five support schemes in a generic and an advanced version

Figure 5.5 50
Detailed results for the evaluation of investment subsidies in the generic and advanced version

Figure 5.6 50
Detailed results for the evaluation of a feed-in tariff in the generic and advanced version

Figure 5.7 51
Detailed results for the evaluation of a fixed premium scheme in the generic and advanced version

Figure 5.8 52
Detailed results for the evaluation of a tendering procedure in the generic and advanced version

Figure 5.9 53
Detailed results for the evaluation of a green certificate scheme in the generic and advanced version

Figure 5.10 54
How the responses on Investor Confidence are distributed on scores for each of the support schemes

Figure 5.11 55
How the responses on Effectiveness are distributed on scores for each of the support schemes

Figure 5.12 59
Feed-in tariffs based on external cost

Figure 6.1 61
Computer Simulation Scenarios

Figure 6.2 63
Development of total RES-E generation in the period 2004 to 2020 on EU-15 level in the BAU scenario

Figure 6.3 64
Total investment needs in the period 2005-2020 within the EU-15 in the BAU scenario

Figure 6.4 64
Development of necessary consumer expenditure on EU-15 level in the BAU scenario

Figure 6.5 65
Comparison of cumulative electricity generation from new RES-E plant (installed 2005 to 2020) on EU-15 level for the advanced support schemes

Figure 6.6 65
Comparison of electricity generation from new RES-E plant (yearly) on EU-15 level for the advanced support schemes

Figure 6.7 65
Technology-specific breakdown of RES-E generation from new plant (installed 2005 to 2020) in the year 2020 for the advanced support schemes

Figure 6.8 66
Comparison of the required consumer expenditure due to promotion of RES-E in the period 2004 to 2020 on EU-15 level for the advanced support schemes

Figure 6.9 66
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 advanced support schemes

Figure 6.10 67
Comparison of necessary cumulated consumer expenditure (in 2020) due to the promotion of new RES-E (installed 2005 to 2020) for the advanced support schemes

Figure 6.11 68
Development of total RES-E generation in the period 2004 to 2020 on EU-15 level for all investigated cases

Figure 6.12 68
Electricity generation versus cumulative consumer expenditure in 2020 for new RES-E plant (installed 2005 to 2020) for all investigates cases

Figure 6.13 70
Comparison of the resulting (reference) yearly average wholesale electricity price on EU-15 level for the sensitivity cases

Figure 6.14 70
Electricity generation versus cumulative consumer expenditure (for the period 2005 to 2020) in 2020 for all RES-E plant – for all sensitivity variants

Figure Annex 1 74
Power flows in the past and in the future

List of abbreviations

€c	Eurocent
AER	Alternative Energy Requirement (Ireland)
BAU	Business As Usual
CCL	Climate Change Levy
CHP	Combined Heat and Power
CSF	Community Support Framework (Greece)
DKK	Danish Krone
DSM	Demand Side Management
ETS	European Union Greenhouse Gas Emission Trading Scheme
FITs	Feed-in Tariffs
GBP	British Pound
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
kWh	kiloWatt hour
LECs	Levy Exemption Certificates
MAPE	Measure for Supporting the Use of Energy Potential (Portugal)
MSW	Municipal Solid Waste
MW	MegaWatt
MWh	MegaWatt hour
NFFO	Non-Fossil Fuel Obligation
NFPA	Non-Fossil Purchasing Agency
OFGEM	Office of Gas and Electricity Markets
PBEDL	Plan Bois Energie Développement Local
POE	Operational Programme for Economical Development
PPA	Power Purchase Agreement
PTC	Production Tax Credit
PV	Photovoltaics
REB	Regulatory Energy Tax (the Netherlands)
RES	Renewable Energy Sources
RES-E	Renewable Energy Sources - Electricity
RO	Renewables Obligation
ROC	Renewables Obligation Certificate
RPS	Reneweables Portfolio Standard
SEK	Swedish Krone
TGC	Tradable Green Certificate
TWh	TeraWatt hour
VSL	Value of Statistical Life
WACC	Weighted Average Cost on Capital
YOLL	Years of Statistical Life

1. Background

According to the Kyoto protocol, the European Union has committed itself to greenhouse gas (GHG) reduction of 8% within the EU by the years 2008-12, as compared with 1990. Renewable energy sources (RES) are expected to play an important role in the implementation of these GHG-targets. In its White Paper on a strategy for the development of renewable energy, the European Commission has set a goal of supplying 12% of the European Union's energy consumption by the year 2010 (a doubling from the 6% level in 1997) from renewable sources, mainly from biomass, hydropower, wind power, and solar energy. Biomass and wind power are expected to be the main sources of growth (European Commission, 1997).

Within these total energy targets, the generation of electricity is a key factor. In 2001, after more than four years of negotiation, an EU Directive (2001/77/EC) on the promotion of electricity from renewable energy sources (the Renewables Directive) was adopted. Accordingly, each Member State should have a specified proportion of electricity generated from renewables in 2010, as related to each country's consumption of electricity. Although not binding, it seems that these targets are now accepted by the EU Member States.

The Commission is prepared also for new mandatory targets if the overall indicative target seems unlikely to be met. The Directive not only indicates that renewable energy technologies are serious options for achieving the targets for GHG-reduction, but it also recognises other benefits of renewables, as quoted below:

"The potential for the exploitation of renewable energy sources is underused in the Community at present. The Community recognises the need to promote renewable energy sources as a priority measure given that their exploitation contributes to environmental protection and sustainable development. In addition this can also create local employment, have a positive impact on social cohesion, contribute to security of supply and make it possible to reach Kyoto targets more quickly. It is therefore necessary to ensure that this potential is better exploited within the framework of the internal electricity market."

(...)

"The promotion of electricity produced from renewable energy sources is a high Community priority as outlined in the White Paper on Renewable Energy sources for reasons of security and diversification of energy supply, of environmental protection and economic cohesion."

According to Article 4 of the Renewables Directive, the European Commission shall, no later than October 2005, evaluate the support mechanisms used to promote renewable technologies in Member States. This evaluation will detail the successes, including cost-effectiveness, of the various support systems and will, if necessary, be accompanied by a proposal for a community-wide framework for support schemes for RES electricity. According to the Directive, any proposal for a framework should:

(a) Contribute to the achievement of the national indicative targets;
(b) Be compatible with the principles of the internal electricity market;
(c) Take into account the characteristics of different sources of renewable energy, together with the different technologies, and geographical differences;
(d) Promote the use of renewable energy sources in an effective way, and be as simple and, at the same time, as efficient as possible, particularly in terms of cost;
(e) Include sufficient transitional periods for national support systems of at least seven years and maintain investor confidence.

According to Article 8 of the Renewables Directive, the European Commission shall, no later than 31st December 2005, present a summary report to the European Parliament and the European Council on the implementation of the Directive. The report shall:

- consider the progress made in reflecting the external costs of electricity produced from non-renewable energy sources and the impact of public support granted to electricity production,
- take into account the possibility for Member States to meet the national indicative targets established in Article 3(2), the global indicative target referred to in Article 3(4) and the existence of discrimination between different energy sources,
- if appropriate, the Commission shall submit with the report further proposals to the European Parliament and the Council.

During the many years of negotiations that led to the final adoption of a Directive for the promotion of electricity from renewable energy sources, the issues of harmonisation and choice of mechanism were keenly debated. That debate is expected to reawaken in the second half of 2005 with the publication of the European Commission's article 4 and article 8 reports.

Other important regulations are the Community guidelines on State aid for environmental protection (2001/C37/03). These determine the conditions under which State aid may be regarded as necessary to ensure environmental protection and sustainable development, including rules and options applicable for renewable energy sources. The current guidelines will come to an end on 31 December 2007.
Article 6 of the Treaty establishing the European Community, the 'EC Treaty', establishes that environmental protection requirements must be integrated into the definition and implementation of the Community policies and activities, in particular for promoting sustainable development. The term sustainable development is generally defined as *"development that meets the needs of future generations without compromising the ability of future generations to meet their own needs"* (Brundtlandt 1987).

Furthermore, it is established in article 174 of the EC Treaty, that the Community bases its policy for the environment on the principles that (i) preventive action should be taken, (ii) environmental damage should, as a priority, be rectified at source and (iii) the polluter should pay. Applying these principles to electricity generation, the implications are that the production of electricity should not pollute and that it is the electricity producers' responsibility to prevent pollution. If the producers do pollute, they should pay an amount equal to the costs of the damage the production causes to society as a whole. The concept of 'internalisation of costs' means that all environmental costs associated with production should be included in company production costs and consequently the prices companies charge should reflect these costs.

1.1 Objective

The main objective of the RE-XPANSION project is to evaluate the various support schemes for RES, including, inter alia, the impacts of such schemes on the development of renewable technologies. Thus, the project is intended to provide valuable background information in the form of economic analysis in assisting the European Commission in its evaluation process.
The expansion of RES-E in Europe will entirely depend on the conditions in place at national level and EU level. Unless stable conditions for investments exist, it will be impossible to meet the EU's goals. As the EU is gradually moving towards the creation of an Internal Market for RES-E, the need for harmonisation and removal of barriers to trade becomes increasingly evident. RE-XPANSION is trying to bridge the gaps between the theoretical economic analysis of possible European-wide systems, the regulatory framework and the participants in the renewable energy industries.

Increasing the amount of RES-E in the EU is a great challenge, considering the need for compatibility with the emerging Internal Electricity Market, itself characterised by market failures, oligopolistic behaviour and trade barriers. The main objectives of the RE-XPANSION project are to:

- Analyse current and needed regulatory environment, and identify trade barriers.
- Simulate the effects on RES-E development of a European-wide framework based on various support mechanisms such as investment subsidies, fixed feed-in tariffs, fixed premium, taxes, tendering and Tradable Green Certificates.
- Analyse the investment behaviour of stakeholders such as developers, financiers and manufacturers and derive requirements for stable conditions in the RES-E market.
- Evaluate how a European-wide framework for promotion of RES-E could develop, while taking into account the EU's intention to internalise external costs of electricity generation, and meets its targets.
- Identify pitfalls and recommend best practice guidelines for the development of a European-wide framework.
- Develop an action plan for practical implementation of selective support mechanisms, taking into consideration existing trade barriers and stakeholder behaviour and requirements.
- Disseminate results and recommendations.

2. Current status of renewable electricity in the EU

Figure 2.1

EU-25 Electricity Production Mix 2003[1] (proportions of total electricity dispatched)

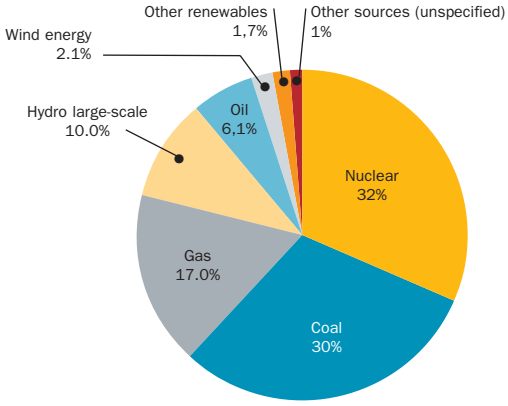
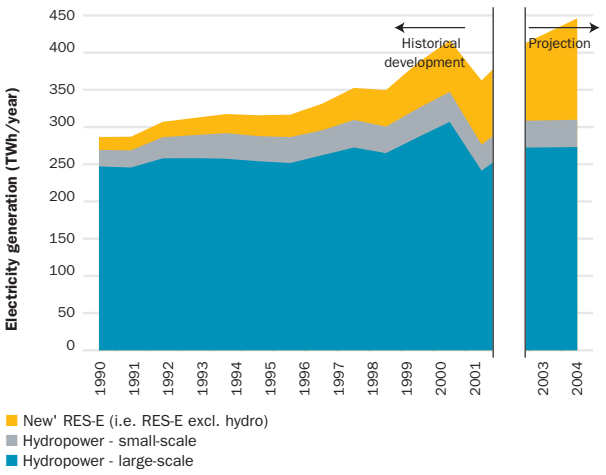


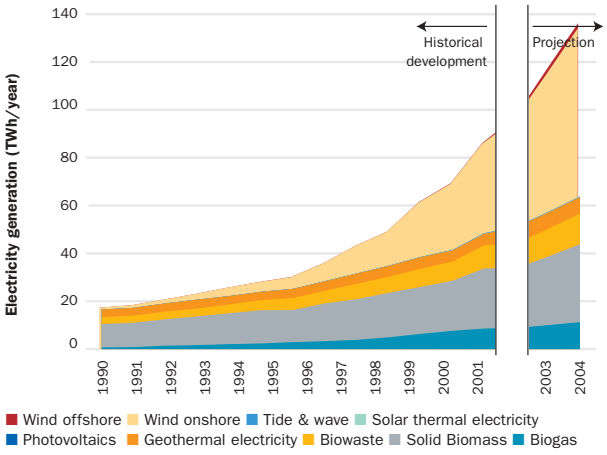
Figure 2.1 illustrates the proportions of electricity sent out in the EU's electricity market in 2003, according to the various types of generation. Electricity from renewable energy sources (RES-E) accounts for at least 13.8% in the enlarged European Union (EU-25).

At an EU-15 level, Figure 2.2 indicates the historical development of RES-E from 1990 to 2004, with (left) & without (right) hydropower; this shows that large-scale (> 10 MW) hydropower is the dominant supply, as predominantly established before the 1970's. Figure 2.2 shows the quantity of RES-E supplied, which varies according to both the capacity installed and the annual meteorological conditions. Noteworthy are (i) the natural variations in annual RES-E supplied, e.g. hydropower[2] , and (ii) the large yearly growth rates of electricity from new RES-E technologies, such as wind power (by 2004 wind power accounted for 53% of all non-large hydro renewable electricity, 16% of total renewable production, including large hydro, and 2.6% of total electricity consumption.

Figure 2.2

Electricity generation from RES in EU-15 countries from 1990 to 2004 – including (left-hand side) & excluding (right-hand side) hydro





Source: Green-X model run; Own investigations; Eurostat (2003).

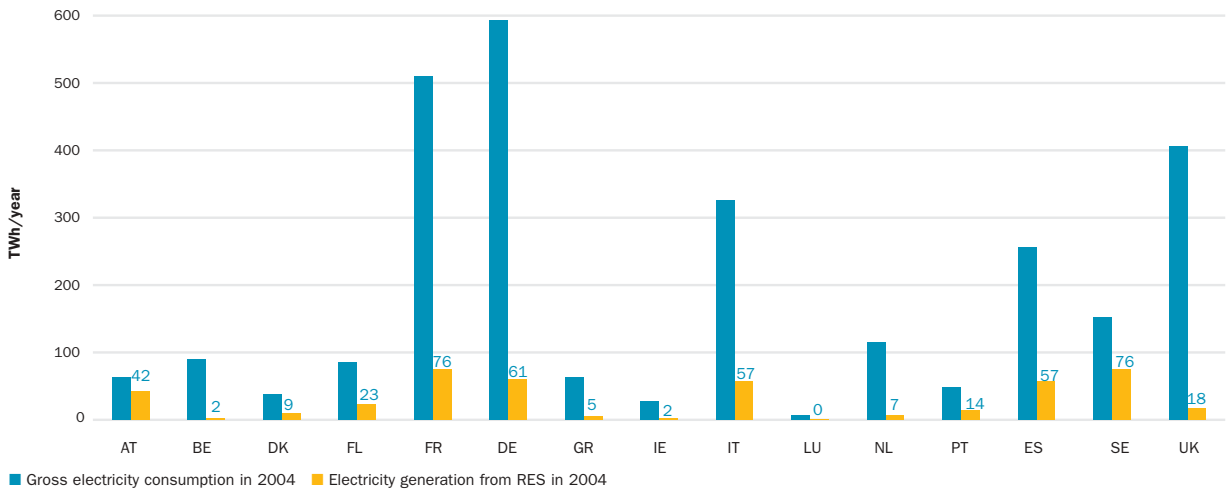
The following figures provide some insights into the country-specific situation. For each EU-15 country in 2004, Figure 2.3 compares (i) the total electricity consumption, and (ii) the amount of electricity generated from RES-E. In Figure 2.4, the countries are

1 Compiled by EWEA using data from the European Commission, COM(2004)366; Eurostat; IEA World Energy Outlook 2004; EWEA.
2 Compare, e.g. the decrease of electricity generation from hydropower on EU-15 level from 2001 to 2002 as depicted in Figure 2.2 (above). In contrast to generation, installed capacity has grown slightly in the same period.

ranked by their share of RES-E (N.B. in effect, this relates to *per capita* consumption of electricity, which is a more meaningful presentation than is national totals, since the latter ignores population size). Two countries, Austria and Sweden, generate more than a third of electricity from these sources; while in other Member States RES-E represents a much smaller proportion.

Figure 2.3

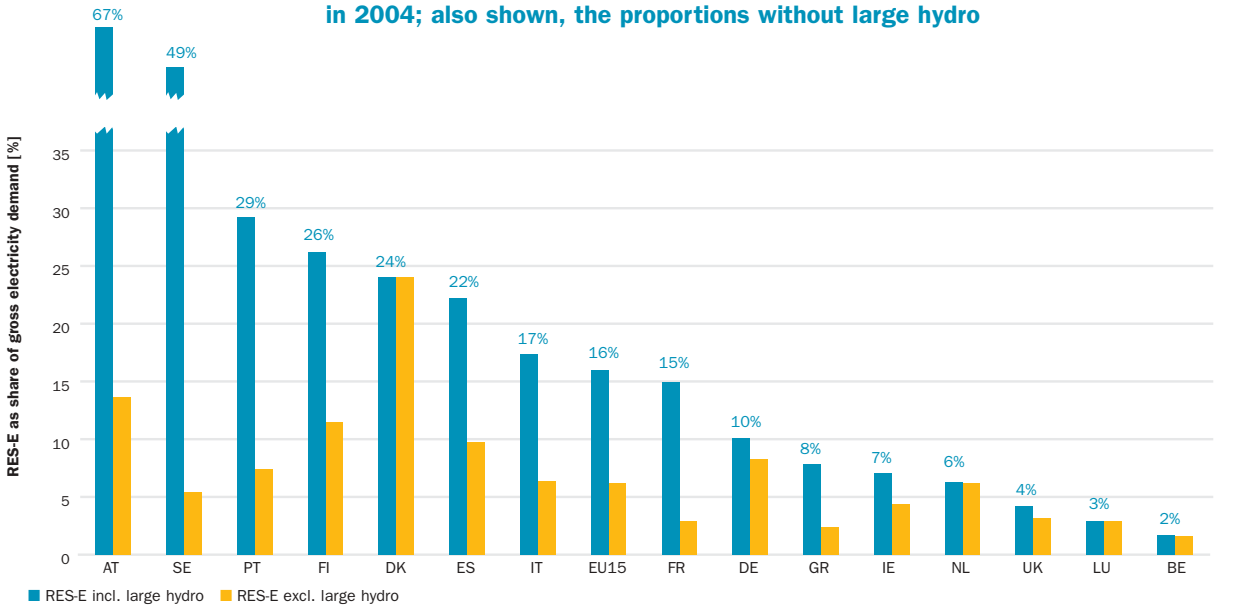
National electricity generation from RES (including large hydro) in EU-15 countries in 2004, for comparison with total national electricity consumptions



Source: Green-X model run; Own investigations; Eurostat (2003); Mantzos et al. (2003).

Figure 2.4

EU-15 countries ranked by the proportion of RES-E (with large hydro) within total electricity consumption in 2004; also shown, the proportions without large hydro



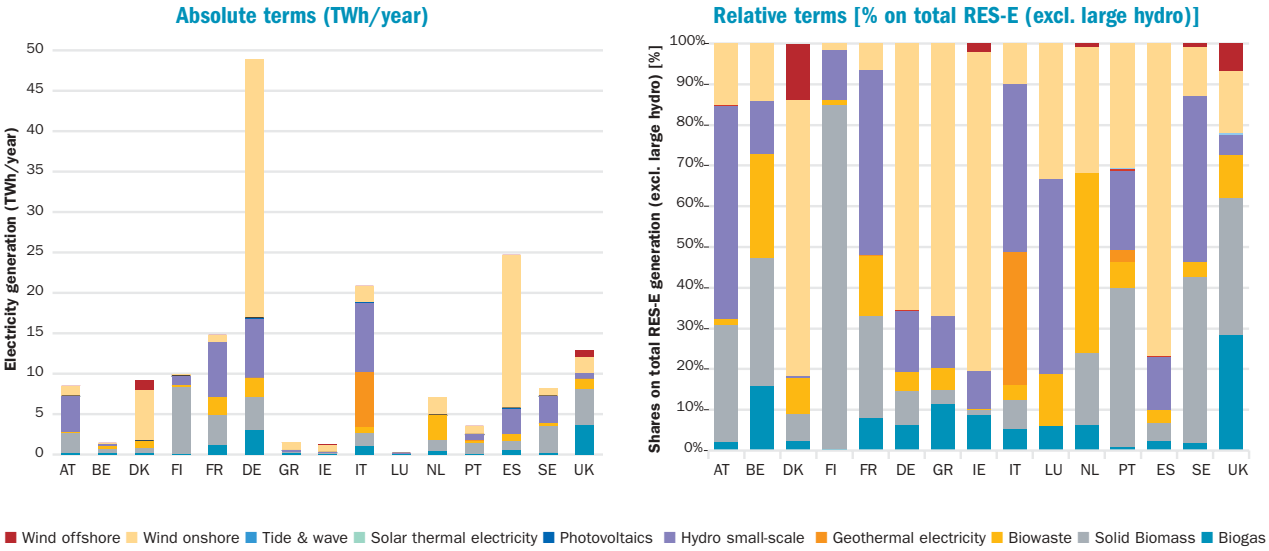
Source: Green-X model run; Own investigations; Eurostat (2003); Mantzos et al. (2003).

A detailed breakdown of RES-E generation in 2004 (excluding large hydro) is depicted in Figure 2.5. This shows the proportions of generation from the various technologies in absolute (above) and relative (below) terms, both by country and (right) for the total EU-15. Wind (onshore), small hydro, biomass and (the biodegradable fraction of) municipal solid waste (MSW) were the most significant in 2004 at national scale.

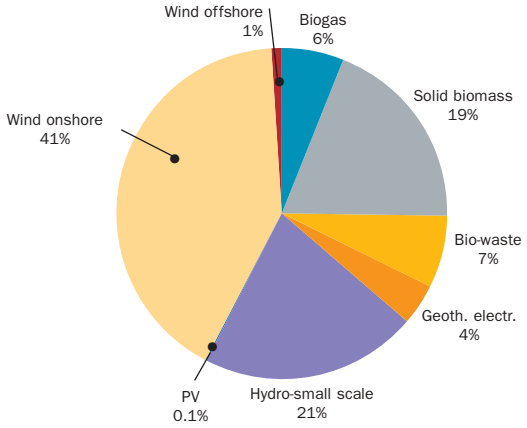
Note (i) the large proportions of wind power in Denmark, Spain, and Germany, (ii) the significant contribution of geothermal power in Italy, and (iii) the relatively large proportion of RES-E generated from biomass in Finland and Sweden, (iv) the dominance of small-scale hydropower in Austria, Italy and Luxembourg.

Figure 2.5

Technology-specific breakdown of RES-E generation (excl. large hydro) in 2004: Electricity generation by RES-E category in absolute terms by country (left) and relative terms (right) by country, and for total EU-15 (below)



TOTAL EU-15:
Share on total RES-E generation (excl. large hydro) in 2004 [%]



Source: Green-X model run; Own investigations; Eurostat (2003).

3. External costs

No electricity generation technology exists that completely avoids pollution or negative environmental impact. Thus, the production of renewable energy impacts the environment to some extent, which may have negative effects. If there are financial impacts on any citizen, it is ethically reasonable to make electricity generators (and hence their customers) pay for the negative environmental impacts they cause. However, such impacts may be difficult to quantify (see the section of this report considering external costs) and even more difficult to compensate to individuals. How do we pay the cost of lost coastal ammenities due to sea-level rise from climate change, on deteriorating health from air pollution or reduction in value of property near a power plant?

This section illustrates how the theory of external (social) costs and their internalisation may be used to rank energy supply systems, with the aim of creating a 'level playing field' for the competition between renewable and conventional energy sources.

Energy supply impact on the environment, e.g. from emissions of chemical pollutants into air, water and soil, both at construction and during operation. Many of these emissions cause accountable damage, such as to human health, natural ecosystems and the built environment. Such damage is termed the 'external effects' of the energy supply, since the associated 'external costs' are not paid for by the owners of the energy system, and hence are not passed on to the consumers. Nevertheless, there is real expenditure involved with the impacts, which has to be paid by those affected. Such costs represent a cost to society that are not paid for by the polluter that causes the emissions (e.g. companies operating power plants). Economists talk about "market failure" when such unpaid external effects exist, because the market fails to match socially desirable level of production due to "false prices".

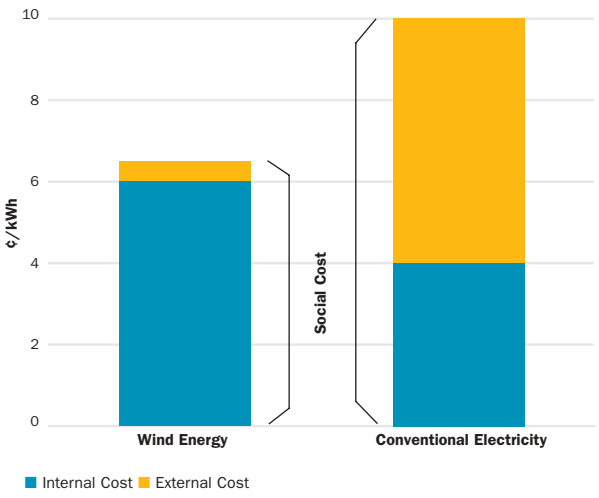
If the polluter does pay adequately for the damage caused, then this is referred to as the 'internalisation of external costs'. As long as external costs are not internalised, the market mechanism cannot secure an optimal allocation of resources. The prices of goods with high associated external costs, are less than if such costs were internalised, so there is over-consumption of these goods, as compared to the optimal consumption for the welfare for society. Thus, the internalisation of external costs is a necessary precondition of an optimal allocation of resources.

Figure 3.1 illustrates a substantial difference in the specific external costs of competing electricity generating technologies (e.g. wind power per kWh and conventional electricity generation per kWh). Consequently, the apparently least-cost technology (i.e. without internalising externalities) may actually have the largest social costs (i.e. with externalities internalised).

Economists argue that if external costs exist, public authorities should make the producers incorporate external costs in their (internal) production cost accounting, in order to improve the welfare of society by an improved resource allocation, i.e. the internalisation of external effects.

Figure 3.1

Specific social cost of energy (eurocent/kWh electricity supplied)



Source: Wind Energy The Facts, EWEA, 2004.

A number of policy instruments exist so external effects can be internalised and consequently producers of goods reduce their emissions to the optimal social welfare level. When this level is achieved, the market will allocate energy supply technologies according to their social costs. The price for the good (e.g. electricity) will then reflect its "true cost".

3.1 The ExternE project

Much emphasis was placed on external costs in the 5th Environmental Action Programme launched in 1992 by the European Commission. In this programme, external cost analysis was mandated before implementation of policies of any kind. In its approach for "getting the prices right", the programme states:

> "Economic valuations can help economic agents to take environmental impacts into account when they take investment or consumption decisions. Where market forces are relevant, process should reflect the full cost to society of production and consumption, including the environmental cost." (European Commission Official Journal of the European Communities, 1993. p.70).

The Fifth Environmental Action Programme formed the environmental agenda for the last decade. Two major principles underpin it (European Commission, 2003):

> "First, the integration of the environmental dimension in all major policy areas is a key factor. Environmental protection targets can only be achieved by involving those policy areas causing environmental deterioration".

> "Secondly, only by replacing the command-and-control approach with shared responsibility between the various actors, e.g. governments, industry and the public, can commitment to agreed measures be achieved".

The White Paper on growth, competitiveness and employment, and the White Paper on energy, also show the growing interest in external cost analysis to assist policy and decision making (European Commission, 1997. p.8).

As a collaborative project between the EC and the US Department of Energy, a joint research project was launched in 1991 to assess the external cost of fuel cycles. From the European side this project is known as ExternE project, co-financed by the EC's JOULE program.

The principle objectives of the ExternE project were (European Commission, 1994.):

- To develop a unified methodology for quantifying the environmental impacts and social costs associated with the production and consumption of energy
- To use this methodology to evaluate the external cost of incremental use of different fuel cycles in different locations in the European union
- To identify critical methodological issues and research requirements.

The European Commission's ExternE project on external costs estimated that the cost of producing electricity from coal or oil in the EU would double, and the cost of electricity production from gas would increase by 30%, if external costs, in the form of damage to the environment and health, were taken into account. This study assumed average electricity production costs in the EU were €0.04 per kWh. The study further estimated that the external costs amounted to 1-2% of EU GDP or between €85 billion and €170 billion, not including the cost of global warming and climate change.

The effects of pollution on human health make up for the second largest portion of external costs (after climate change). The results directly depend on the population exposed. In Table 3.1 it can be seen that countries of the EU, such as Austria, Belgium, France, Germany, and Italy, and to a lesser extent Spain and the UK, are exposed to the largest damages (evaluated as € per tonne of pollutant emitted), whereas Scandinavian countries have the least values.

Table 3.1

Damage from air pollutants on human health

Country	SO_2 €/tonne	NO_x €/tonne	Particulates €/tonne
Austria	9,000	9,000 - 16,800	16,800
Belgium	11,388 - 12,141	11,536 - 12,996	24,536 - 24,537
Denmark	2,990 - 4,216	3,280 - 4,728	3,390 - 6,666
Finland	1,027 - 1,486	852 - 1,388	1,340 - 2,611
France	7,500 - 15,300	10,800 - 18,000	6,100 - 57,000
Germany	1,800 - 13,688	10,945 - 15,100	19,500 - 23,415
Greece	1,978 - 7,832	1,240 - 7,798	2,014 - 8,278
Ireland	2,800 - 5,300	2,750 - 3,000	2,800 - 5,415
Italy	5,700 - 12,000	4,600 - 13,267	5,700 - 20,700
The Netherlands	6,205 - 7,581	5,480 - 6,085	15,006 - 16,830
Portugal	4,960 - 5,424	5,975 - 6,562	5,565 - 6,955
Spain	4,219 - 9,583	4,651 - 12,056	4,418 - 20,250
Sweden	2,357 - 2,810	1,957 - 2,340	2,732 - 3,840
United Kingdom	6,027 - 10,025	5,736 - 9,612	8,000 - 22,917

Source: European Commission, 1999.

The overall range from air pollutants in Europe is 1,027 to 15,300 €/tonne SO_2, 852 to 18,000 €/tonne NO_x and 1,340 to 57,000 €/tonne particulates.

The fossil fuel cycles present the larger specific external costs (coal & lignite, peat, oil, orimulsion and gas), of which gas makes up the least. Electricity generated from renewable energy and nuclear fuels were calculated to have less specific external costs than from fossil fuel generation.

Concerning the nuclear cycle, the ExternE study assumed, contentiously, that radioactive waste management and other potentially hazardous impacts are well managed, so having small external cost now. As the results on nuclear power plants are based on calculations done for the ExternE Project, and as the calculation of the underlying accident probabilities and source terms have never been revealed to third parties for analysis, these figures cannot claim similar credibility as other estimates of external costs, where all assumptions of the calculations are revealed, e.g. the ExternE numbers seem to contradict the results found in the German reactor safety study phase B, that gives rather considerable source terms and accident probabilities for severe core melt down accidents with containment rupture. (Gesellschaft für Reaktorsicherheit, 1989). No assessment of external costs was made regarding the military, terrorist and security aspects of the nuclear fuel cycle, and neither were delayed costs on future populations included. Table 3.2 shows the main results of the ExternE study in relation to the external cost of various energy sources as eurocents/kWh.

Table 3.2

Specific external cost of energy
Damage in eurocents/(kWh of electricity supplied)[a]

Country	Coal & Lignite	Peat	Oil & Orimul.	Gas	Nuclear	Biomass	Hydro	PV	Wind	Waste
AT				1.1-2.6		2.4 -2.5	0.004			
BE	3.7-15			1.1-2.2	0.4-0.47					
DE	3.0-5.5		5.1-7.8	1.2-2.3	0.44-0.7	2.8-2.9		0.14-0.33	0.05-0.06	
DK	3.5-6.5			1.5-3.0		1.2-1.4			0.09-0.16	
ES	4.8-7.7			1.1-2.2		2.9-5.2[b]			0.18-0.19	1.5-2.4
FI	2.0-4.4	2.3-5.1				0.8-1.1				
FR	6.9-9.9		8.4-10.9	2.4-3.5	0.25	0.6-0.7	0.6			6.7-9.2
GR	4.6-8.4		2.6-4.8	0.7-1.3		0.1-0.8	0.51		0.24-0.26	
IE	5.9-8.4	3.3-3.8								
IT			3.4-5.6	1.5-2.7			0.34			4.6-7.7
NL	2.8-4.2			0.5-1.9	0.74	0.4-0.5				
NO				0.8-1.9		0.24	0.23		0.05-0.25	
PT	4.2-6.7			0.8-2.1		1.4-1.8	0.03			
SE	1.8-4.2					0.27-0.3	0.004-0.7			
UK	4.2-6.7		2.9-4.7[c]	1.1-2.2	0.24-0.27	0.53-0.57			0.13-0.15	

a. Subtotal of quantifiable externalities (public health, occupational health, material damage, global warming)
b. Biomass co-fired with lignite
c. Orimulsion: 3.1-5.2

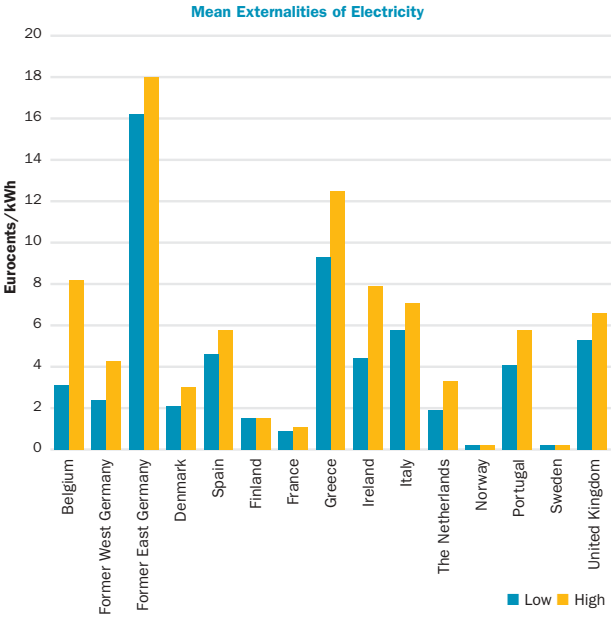
Source: European Commission, 1999.

The ExternE results show that the assessed external costs of negative impacts vary substantially between countries. It is impossible to decide if these differences are real, or due to differences in the methods of calculation or to actual error in calculation.

Figure 3.2 shows aggregated average specific external costs (per kWh of all electricity produced from all types of generation), for every country. Countries relying on fossil fuels have larger specific costs. Large values occur where densely populated areas are affected.

Figure 3.2

Average external costs of electricity production, per kWh of electricity generated from all supplies of the specified countries



Source: European Commission, 1999

The study showed that fossil fuel cycles have significant specific external costs, within which category the gas fuel cycle has the least costs. In comparison with electricity generation from any fossil fuel, generation from renewable energy has less specific external cost. Therefore countries or regions using much fossil generated electricity have large specific external costs, as with the former East Germany. These results give guidance for energy policy decisions, showing that fossil fuels contribute to the majority of the health and environmental damages.

3.2 A comparison of the social costs of electricity from wind, coal and gas

The results of the external cost analysis have generally shown small specific external costs of renewable technologies and substantial specific external costs for fossil fuel generation technologies. We may define the 'internal' costs as those costs presently recognised in the market price of a good, i.e. costs that have been internalised. Then by adding both the external and the internal costs, we obtain the social costs. It is then possible, for instance, to compare the social costs of wind and conventional power. The comparison is based on the ExternE results for the specific external costs, despite our reservations, previously expressed, about the calculations regarding the full life-cycle costs of nuclear power. Internal costs stem from other sources which are cited at the appropriate stage of analysis.

The specific external cost of wind energy from ExternE ranges from 0.05 to 0.26 eurocents/kWh (see Table 3.2), i.e. less than one third of one eurocent per kWh for the highest values.

In contrast, conventional fossil fuel technologies are associated with substantial specific external costs. Considering the coal fuel cycle, the values calculated are of the same or double the order of magnitude of the internal electricity cost of these technologies, which are about 3 eurocents per kWh. The lower and upper values of the coal specific external cost are between 1.8 and 15 eurocents per kWh (see Table 3.2).

Assuming that the internal cost of producing a kWh of electricity from coal is about 3 eurocents/ kWh on average, the addition of the external costs from coal production increases the specific social cost to between 4.8 and 18 eurocent/ kWh, so resulting in significantly larger 'true' costs of electricity to society. Table 3.3 shows the specific social cost of coal and gas power systems for Spain, Denmark and Germany (multiplying these specific costs by the national kWh consumption of electricity gives the total national social costs). As can be seen, the specific external cost for coal is larger than the internal cost by 60% to 500%. For the case of gas, the specific external cost is less than the specific internal cost.

Table 3.3

Specific social costs of electricity from coal and gas power systems

Social Cost[a] (Internal + External[b])

	Coal			Gas		
Costs	Spain	Denmark	Germany[c]	Spain	Denmark	Germany[c]
Internal cost[d] €cent/kWh	3.9	3.4	3.1	5.2	5.2	2.9
External cost €cent/kWh	4.8 – 7.7	3.5 – 6.5	3.0 – 5.5	1.1 – 2.2	1.5 - 3.0	1.2 – 2.3
Total 'social' cost €cent /kWh	8.7 – 1.6	6.9 – 9.9	6.1 – 8.6	6.3 – 7.4	4.7 - 8.2	4.1 - 5.2

a. Figures in the below table are given to 2 significant figures, although accuracy is probably no more than about +/- 10%.
b. The external cost was not converted into 2001 prices.
c. Germany coal and gas (combined cycle) cost is the calculation of this report. Source: Hohmeyer, 2000.
d. Projected avoided cost of conventional power includes 25% capacity credit for wind power, i.e. the intermittent wind power allows the requirement for conventional capacity to be reduced by 25% of the wind power capacity.

Source: Coal prices from IEA/OECD updated to 2001 Euro prices

Production costs of wind energy are available for Denmark on coastal and inland sites for a 600 kW and 1000 kW wind turbine in constant 2001 prices. The resulting specific social costs of wind energy in Denmark are displayed in Table 3.4. The specific external cost values are taken from Table 3.2.

Table 3.4

Specific social (total) cost of wind energy per kWh electricity generated

Wind energy Specific Cost	Turbine Size 600 kW	1000 kW
Internal € cent/kWh	4.4	4.1
External € cent/kWh	0.09 – 0.16	0.09 – 0.16
Total, Social Cost	4.5 – 4.6	4.2 – 4.3

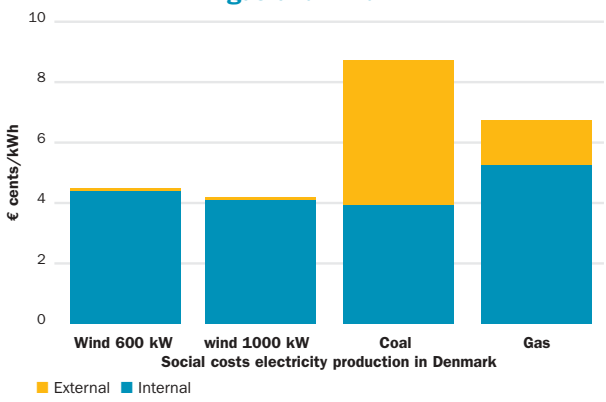
1. The external cost was not converted into 2001 prices.
2. Social costs are given to 2 significant figures.

Source: 'Wind energy the facts', EWEA, 2004

Within the accuracy of the data (about +/- 10%), the specific social costs of wind power are unchanged by the inclusion of the very small external costs. Based on this total social cost comparison, one can say that the total social cost of wind energy is definitely competitive, and usually much less, as compared with the total social electricity costs from conventional power plant. The social cost of coal for Denmark, as shown in Table 3.3, ranges from 6.9 to 9.9 euro cent/kWh. Figure 3.3 illustrates social costs estimated for coal, gas and wind in Denmark. (Note, Denmark does not have nuclear or hydroelectric indigenous power).

Figure 3.3

Specific social cost of electricity from coal, gas and wind



If externalities were incorporated in the current market prices, the perceived cost of renewable energy would be practically unchanged, whereas the perceived low cost of conventional technologies based on fuel cycles would increase dramatically with the incorporation of their external costs. Consequently the renewable (clean) technologies would become competitive in the energy market. The external cost of energy gives the correct strategic indicators for energy policy decisions, recognising that fossil fuels contribute to the majority of the health and environmental damage.

3.3 "External benefits" of renewables not accounted for

Current energy supply systems rely to a great extent on non-renewable (i.e. finite) primary fuels (fossil fuels and uranium). Consequently, the security and reliability of present-day national energy supplies depends predominantly on a steady supply of non-renewable primary fuels. The very limited internalisation in electricity prices of the external costs mentioned above, and the failure to include full life-cycle costs for the nuclear cycle, constitute a market failure which puts renewal electricity production at a competitive disadvantage as compared with fossil and nuclear fuels.

In addition, renewable energy sources are further disadvantaged because the full benefits that RES-E production causes are not internalised in the price paid to producers either. Examples of these are: (i) the overall strategic benefit of adding technologies with zero or very small fuel price risk to an otherwise risky electricity portfolio, (ii) avoided GDP loss from the oil-GDP effect (Awerbuch 2003 and 2004), and (iii) the benefits to society in the form of reduced electricity prices from adding more small marginal-cost (zero fuel cost) technologies.

Fuel price volatility can adversely affect security of supply and the functioning of economic systems. Therefore, the risk of fuel price volatility and its possible impacts should also be incorporated into external cost analysis. Because renewable energy technologies do not rely on fossil fuels, they are not impacted by volatility in fuel prices. Adding this risk premium on current costs of fossil energy generation changes the perception of renewable energy being an expensive investment (Awerbuch, 2003).

Furthermore, research (Awerbuch 2004[3]) suggests that abating fuel imports by substituting renewable energy supplies avoids significant 'loss' of GDP. Awerbach calculated that a 10% increase in renewable energy avoids GDP losses in the range of $29-$53 billion over the lifetime of the plant in the USA and the EU, and $49-$90 billion for the OECD all together. For the USA, the data suggest that each additional kW capacity of renewables, on average, avoids $250-$450 in GDP losses. The offset is worth about $200/(kW capacity) for wind and solar, and about $800/(kW capacity) for geothermal and biomass.

Finally, society benefits generally (and consumer's benefit individually) from cheaper electricity prices when large amounts of low marginal cost (zero fuel cost) renewable electricity is produced. An example occurs in Denmark, regarding wind turbine owners operating in the NordPool power market (i.e. owners of turbines older than ten years). It is estimated[4] that the average market price paid to these owners is 10% less than the average power price when wind power is not available. This is because general market prices decrease when the conditions are windy, due to the extra competition from wind power.

These examples of "external benefits" (or "negative external costs") of renewable energy technologies, i.e. benefits to society of installing renewable energy which do not generate income to the renewable producers but give benefits to society, are not considered further in this project. However, further insight into these macroeconomic benefits of renewables should be subject for further research. Thereafter, it should be a minimum requirement to include these factors in evaluations of both the costs and the benefits of increasing RES-E.

3.4 Avoided emissions and external costs by utilising wind power

In practice, renewable generated electricity replaces electricity generated by conventional fossil sources. The benefits of renewables are the avoided damages that result from avoided emissions from conventional energy sources due to the replacement by renewables.

The avoided damages are from air pollutants, such as SO_2 and NO_x, and from anthropogenic climate change resulting from CO_2 and other emissions. The benefits of this avoidance can be estimated by means of an external cost analysis. Thus, the benefits of renewables today and the potential benefits in the future can be estimated.
If the amount of electricity produced by conventional energy systems that was replaced by electricity generated from wind turbines is known, it is possible to calculate the cost of the avoided damage. The benefits of wind energy equal these avoided costs.

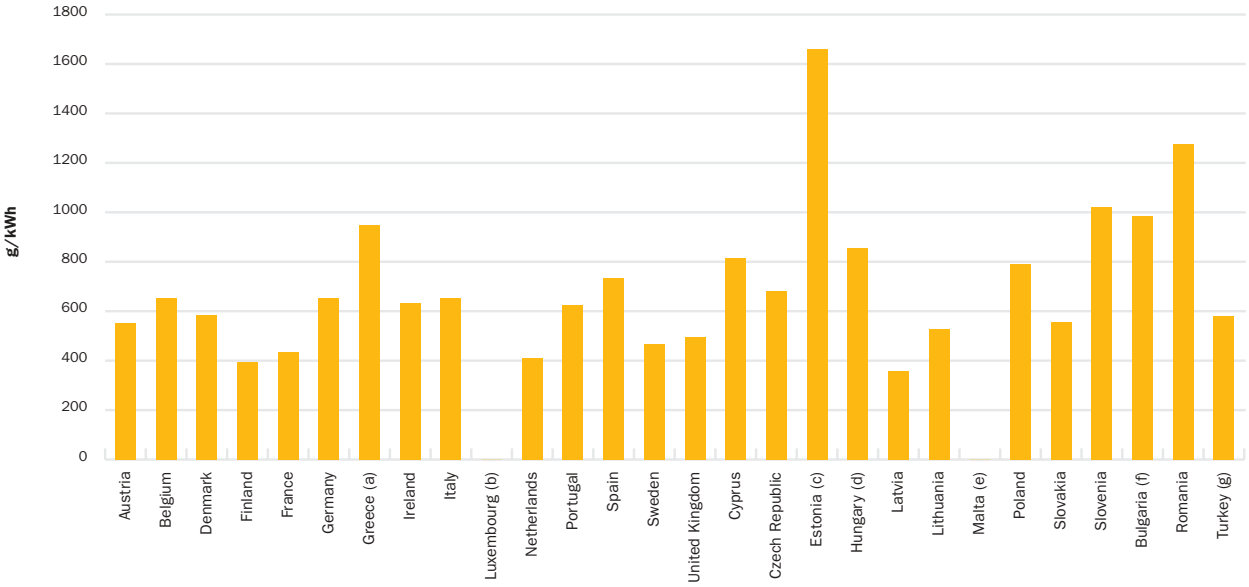
By linking (i) the reported total electricity generation, (ii) the electricity generation from wind energy of each country and (iii) the conventional electricity generation that, e.g. wind production replaces in the intermediate load segment, the total avoided emissions (in kt/a) by wind energy can be calculated.

Figure 3.4. and Figure 3.5. show specific avoidable emissions by wind energy in 2000. The specific emissions are large in countries with much generation from coal, and small where there is significant hydro or nuclear power.

3 exploiting the oil-GDP effect to support renewables deployment, Shimon Awerbuch, 2004.
4 "Vindmøller og dansk klimastrategi - 2005 udgave": ECON Analyse for Danish Wind Turbine Owners' Association, 8. april 2005.

Figure 3.4

Specific avoidable CO_2 emissions in g/(kWh electricity generated) by wind energy in 2000, within the electricity supply systems of the named countries

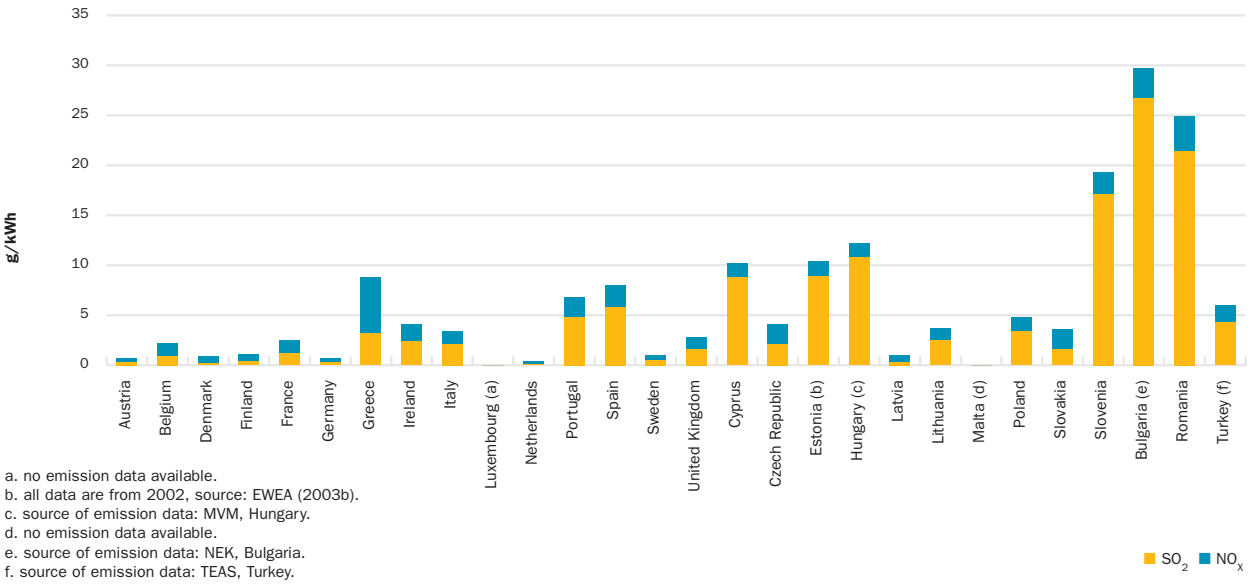


a. Source of CO_2 emission data: Ministry of Environment and Physical Planning: "National Programme for the Reduction of Greenhouse Gas Emissions", Athens (2002).
b. No emission data available.
c. All data are from 2002, source: EWEA (2003b).
d. Source of emission data: MVM, Hungary.
e. No data available.
f. Source of emission data: NEK, Bulgaria.
g. Source of emission data: TEAS, Turkey.

Source: EURELECTRIC (2002), Hohmeyer.

Figure 3.5

Specific avoidable SO_2 and NO_x emissions in g/(kWh electricity generated) by wind energy in 2000; within the electricity supply systems of the named countries



a. no emission data available.
b. all data are from 2002, source: EWEA (2003b).
c. source of emission data: MVM, Hungary.
d. no emission data available.
e. source of emission data: NEK, Bulgaria.
f. source of emission data: TEAS, Turkey.

Source: EURELECTRIC (2002), Hohmeyer et al.

Figure 3.6 gives an overview of the avoidable external costs by wind energy per kWh electricity generated; there is a noticeable difference between the countries. In particular, some new Member States have a large proportion of their electricity supply from plants with very large specific emissions; consequently their external costs of electricity generation are large. The exact values of the avoidable external costs are shown in Table 3.5. The ranges (low, medium and high) relate to the lower (low), central and upper value of the specific externalities per kWh electricity shown in Figure 3.6.

Figure 3.6

Avoidable specific external cost, in eurocents per kWh electricity, by the use of wind energy in 2000

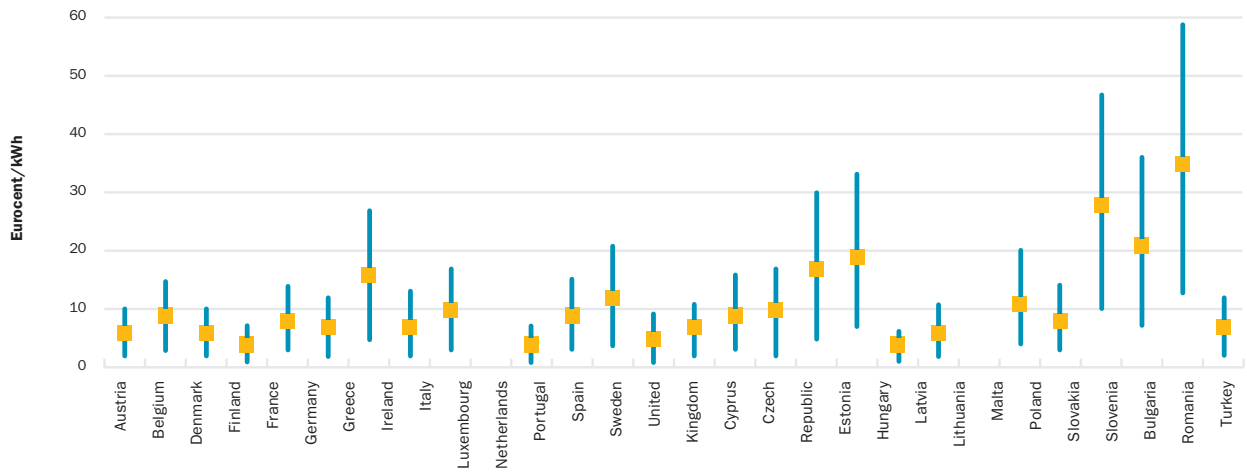


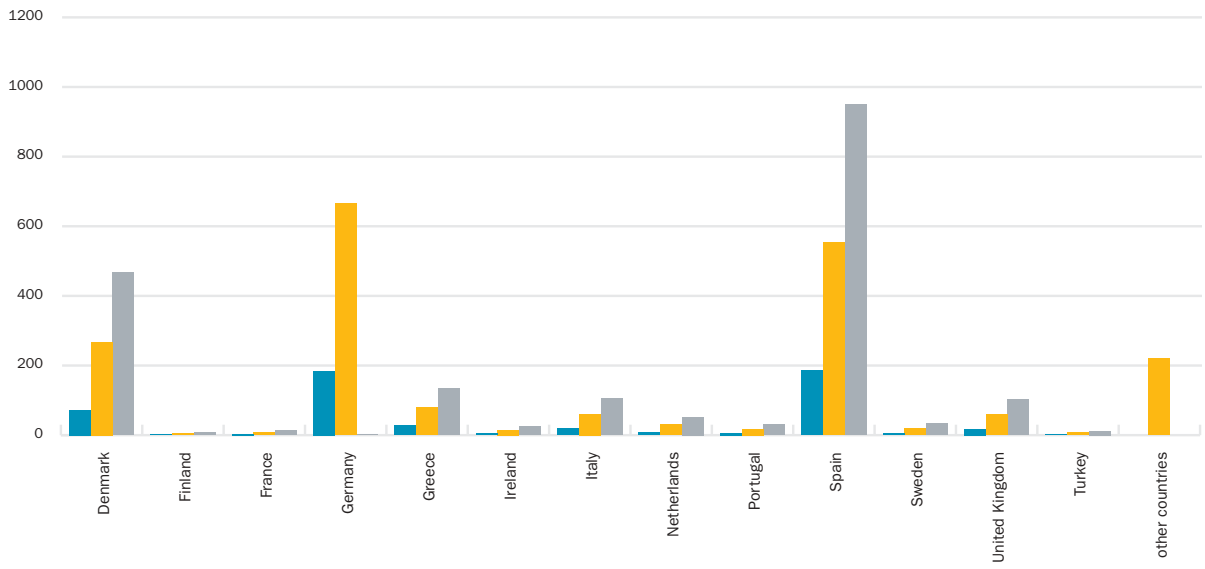
Table 3.5

Avoidable external cost, in eurocents per kWh electricity generated, by the use of wind energy in 2000

	Austria	Belgium	Denmark	Finland	France	Germany
Low	1.69	2.70	1.59	1.02	3.00	1.96
Medium	6.05	8.71	5.97	3.90	8.47	7.07
High	10.50	14.96	10.38	6.81	14.36	12.27
	Greece	**Ireland**	**Italy**	**Luxembourg**	**Netherlands**	**Portugal**
Low	5.36	2.09	3.35		1.16	2.76
Medium	15.79	7.29	10.19		4.27	8.78
High	26.87	12.62	17.46		7.42	15.11
	Spain	**Sweden**	**United Kingdom**	**Cyprus**	**Czech Republic**	**Estonia**
Low	4.13	1.32	2.01	2.52	3.28	4.58
Medium	12.31	4.89	6.57	9.03	10.12	17.13
High	21.09	8.50	11.32	15.70	17.37	29.85
	Hungary	**Latvia**	**Lithuania**	**Malta**	**Poland**	**Slovakia**
Low	7.04	0.98	1.84		3.61	2.71
Medium	19.42	3.66	6.30		11.36	8.33
High	33.29	6.37	10.91		19.60	14.26
	Slovenia	**Bulgaria**	**Romania**	**Turkey**		
Low	10.34	7.47	12.96	2.06		
Medium	27.67	21.04	34.54	7.02		
High	47.35	36.16	58.95	12.15		

Figure 3.7

Avoided total external costs per country by the use of wind energy in 2000 (low, medium and high range calculations, see text)



By multiplying the avoidable specific external costs by the amount of electricity produced by wind energy, the avoided total external costs can be calculated. These are displayed in Figure 3.7. Nearly €1.8 billion was avoided over all the countries by the use of wind energy electricity generation in 2000. Most of this applies to Germany (38%), Spain (31%) and Denmark (15%).

It should be noted that the figures calculated above are based on the 2000 wind energy production which was 22 TWh. In 2004, wind power produced some 65 TWh of electricity in the EU (EWEA, 2005) suggesting avoided external costs of some €5 billion for 2004.

3.5 Avoidable emissions and external costs by wind power in 2020

Specific avoidable emissions per kWh will decrease from 2000 to 2020. This is mainly due to two factors. Firstly, the fuel mix is going to change in the coming decades in most of the countries covered by this analysis. In many cases, high pollutant-emission fuels will be partly replaced by those with less pollutant emissions. For instance, the share of fuel oil and especially natural and derived gas will increase strongly to replace coal. Therefore, the amount of electricity generated by hard coal and lignite will decrease or stagnate. This will lead to less specific avoidable emissions per kWh by wind energy in 2020 compared with 2000.

Secondly, there will be a significant improvement in the efficiency and pollution-removal technologies of fossil fuel based electricity generation. The Eastern-European states, in particular, will up-grade their technology by fitting SO_2 scrubbers and improving combustion processes to reduce NO_x emissions.

For 2020, a total wind power production of 425 TWh/a is forecasted by EWEA (2003) for the EU-25 countries. For EU-28, this implies a forecast of more than 450 TWh/a in 2020.

Calculations (Hohmeyer, 2005) indicate total avoidable external costs by wind power in 2020 are much larger than in 2000; they are expected to increase from €1,8 billion/year in 2000, to more than €25 billion/year in 2020, due to the assumed increase of electricity generation by wind energy from 22 TWh/a in 2000 (65 TWh/a in 2004) to more than 450 TWh/a in 2020. While electricity generation by wind energy increases 20-fold from 2000 to 2020, the avoidable external costs will increase approximately 14-fold.

3.6 Policy instruments and external costs in practice

The background document to these guidelines (work phase 3) show that environmental policy instruments such as emission charges, subsidies[5] and tradable permits allow us to find the extent polluters[6] should reduce their emissions in order to maximise society's welfare and thereby, enabling internalisation of external effects in order to reach a given level of emissions at minimum costs for society (E_{OPT}). The emission standard is inferior in this regard, as it leads to larger costs to society and is therefore only appropriate in cases where urgent restriction of emissions is required. As the bulk of external costs from energy production in the EU are not caused by pollutants needing urgent restriction, but from pollutants with effects demanding a long-term reduction strategy, the emission standard is not adequate to internalise the external costs from energy production[7].

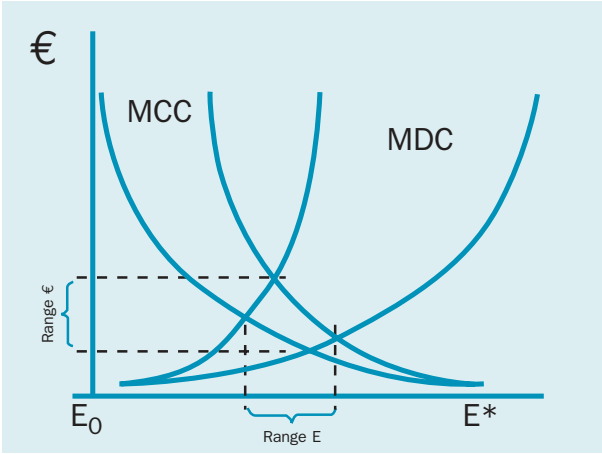
In addition, the internalisation of external costs by means of the policy instruments requires a precise knowledge of the damage costs caused by the emission of pollutants, together with a precise knowledge of the abatement costs. Otherwise E_{OPT} cannot be determined. Hence, the question arises whether current knowledge allows us to determine the optimal level of pollution in practice.

The broad ranges of external costs quantified in different studies provide a good indicator for the uncertainty associated with the "real" shape of external cost curves. However, it must be pointed out that, with the exemption of nuclear power and climate change, the current specific external cost values for 'classical' pollutants (SO_2, NO_x, particulates) provide a good approximation of real marginal damage costs. Consequently, external cost analysis and the internalisation of external costs is able to provide a substantial improvement compared to a situation where external costs are ignored.

In addition to the external costs, the pollution-reduction control costs also involve relatively large uncertainty. This is because the cost for emission abatement is the private information of the polluters which they either do not reveal or do not know. However, the uncertainty about the level of abatement costs is in general less than the uncertainty about damage costs, since a good approximation of costs can usually be acquired from research institutions and from companies selling emission control equipment. However, the estimation by research institutions can be a complex, research-extensive and costly procedure. Thus, it is impossible for public authority to determine the optimal level of emissions precisely.

Figure 3.8

Uncertainty abatement and damage curve



This is illustrated in Figure 3.8, where the uncertainty of the marginal control and damage cost curves is depicted as the difference between the lower and the higher curves of MCC and MDC. The aggregate uncertainty in the MDC curve is larger than the MCC curve. The area A represents the region in which the optimal emissions level can be located with maximum and minimum values as depicted in the figure (ranges) but which cannot be exactly determined by the public authority. Therefore, every emission charge or tradable permit system, when applied in practice, cannot reach E_{OPT} exactly, since the determination of the optimal tax or the optimal quantity requires full information. They can only aim to reach E_{OPT} as closely as possible.

5 In the remaining part of this chapter any statement on emission charges also holds for subsidies as we have shown that they have equal effects on the reduction strategy of the polluters.

6 Environmental policy instruments for the energy sector are usually concerned with pollution control. As emissions such as CO_2, SO_2, NO_X and particulates are the major source of external costs from electricity production we will also use the term "emissions" as a substitute for "pollution". The entity (e.g. a firm) that causes the emissions will be referred to as "polluter".

7 One could also say that the pollutants from energy production that demand urgent restriction have already been successfully restricted by existing command and control instruments.

It is worth noting that the uncertainty varies depending on the pollutant in question. In particular, we have shown that the damage cost curve of CO_2 comes with a high degree of uncertainty, whereas the damage costs of other classical pollutants are more accurately known. Environmental economists therefore suggest that the design of the environmental policy instruments should be differentiated according to climate change and non-climate change emissions.

For climate change emissions, it is suggested that, instead of determining E_{OPT}, public authorities should let scientists determine the level of emissions which prevents catastrophic damage from climate change in the long-term ('dangerous anthropogenic interference with the global climate system', in the words of UNFCCC). Based on such estimates, the authorities can allocate permits to each polluter and subsequently the level of emissions suggested by science is reached. The target emission level can be adjusted if science gains new knowledge about the level of emissions that prevents catastrophic damage.

For impacts other than climate change, most environmental economists in this field suggest that the information about cost curves is sufficient to determine an emissions charge which, when levied, will produce an emissions level close to the optimal level of pollution. Because of the remaining uncertainties, the emission charge has to be set according to the available information in a "trial and error"-process. The charge needs to be adjusted when more information is available. YOLL and VSL approaches may lead to substantially different results of monetised human health damages. Deciding which approach to use is a value judgement, based on society's underlying value system. Thus, calculations of external costs of human health damages should always give both measures and leave it up to the reader or the policy-maker to decide which approach they think is most appropriate. Also inflationary trends in the economy may have an effect on a static charge, making it insufficient to reach the environmental goals. Mechanisms need to be introduced to assure that the charge can be adjusted according to the alterations of economic and environmental conditions.

In section 5.6 we will examine which of the current promotion strategies for renewable energy sources have the best potential to establish a level playing field between all electricity generating technologies through the internalisation of external costs.

4. Promotion instruments

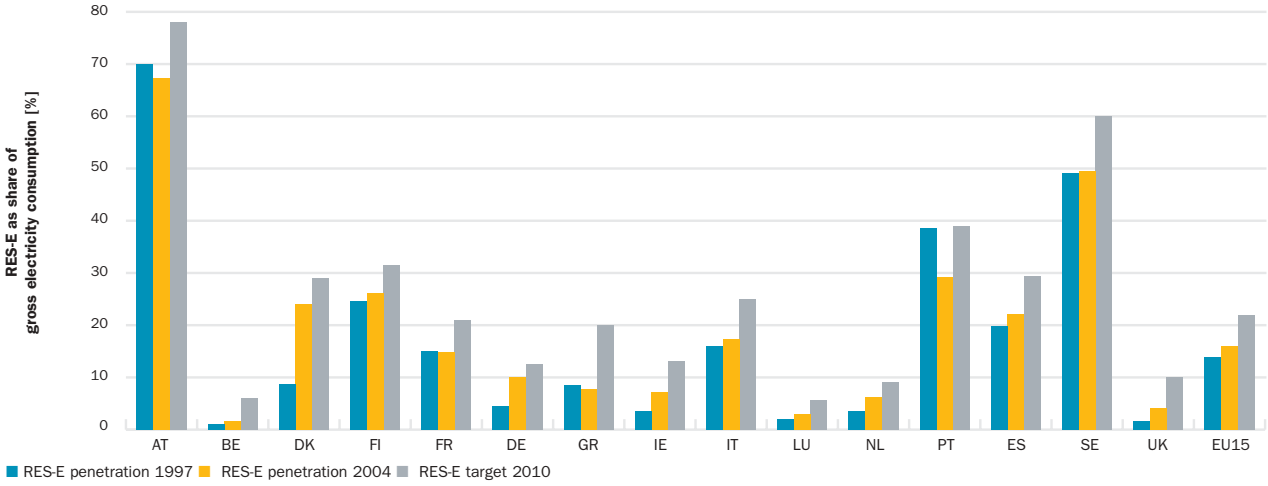
Article 3 of the Renewables Directive as well as its Annex refer to national indicative targets for RES-E. The overall indicative target for the penetration of RES-E is to meet 22% of EU-15's electricity consumption by 2010 (for EU-25, the share is 21%). Indicative targets consequently set for Member States in accordance with the reference values listed in the Annex of the Directive.[8]

It is important to note that:
- national targets are 'indicative' and not 'regulatory binding' – but in accordance with Article 3 of the 'RES-E Directive' "If (…) national indicative targets are likely to be inconsistent" the European Comission "shall address national targets, including possible mandatory targets, in the appropriate form.";
- all targets are related to the total electricity consumption of the 'target' year 2010.

The Annex of the Directive lists the reference values for Member States' national indicative targets. Both the targets for 2010 and the achieved progress in the period 1997 to 2004 are indicated on Figure 4.1 for each Member State as well as for total EU-15.

Figure 4.1

Comparison of historical (1997) and present penetration (2004) and future targets according to the 'RES-E Directive'



Source: European Parliament and Council, 2001; Green-X model run; Own investigations; Eurostat (2003).

4.1 Environmental taxes

As mentioned under chapter 2, harmonised energy taxes, reflecting the actual environmental impact of each electricity production technology is an effective way of internalising external costs. They could make the full production costs of electricity generation transparent, level the playing field in a future Internal Electricity Market and introduce fair competition between renewables and conventional power technologies. This is recognised by the European Commission. In a Communication to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions in February 2001 the Commission states:

"Environmental taxes and charges can be an appropriate way of implementing the 'polluter pays' principle by including the environmental costs in the price of goods and services and by this means internalising external costs. The White Paper emphasised that the environmental benefits of renewable energy justify favourable financing conditions, e.g. through tax exemptions in products from RES."

After 6 years of negotiations, a landmark EU directive[9] setting minimum tax rates for energy products came into force on 1 January 2004. However, as a result of numerous compromises between the Member States,

8 In Article 3 (2) of the 'RES-E Directive' (European Parliament and Council, 2001) it is outlined, that the EU Member States have to adopt and publish a report setting national indicative targets for future consumption of electricity produced from renewable energy sources in terms of a percentage of electricity consumption for the next 10 years. This has to be done not later than 27 October 2002 and every five years thereafter. To set these targets until the year 2010, the Member States shall take account of the reference values in the Annex of the Directive. Furthermore, they have to ensure that these targets are compatible with the climate change commitments according to the Kyoto Protocol.
9 Directive 2003/96/EC of 27 October 2003.

the level of the minimum energy tax rates are close to being the lowest common denominator for the Community and are considerably lower than originally proposed by the Commission (1997) and the Parliament (1999). For electricity, the Directive introduces minimum taxes of Euro 0.5/MWh for business and Euro 1/MWh for non-business. Due to the low minimum tax levels, the many general exemptions and the lack of mandatory exemptions for renewables, the effect of the Directive on wind power will be insignificant in the short term. However, the importance of reaching a final agreement cannot be underestimated, as it emphasises the political will in EU to contribute to the polluter pays principle established in Article 174 of the Treaty Establishing the European Community.

Meaningful environmental taxes are an effective way to level the playing field in the electricity markets but are difficult and time consuming to agree upon at the EU level. The same is true for the removal of state aid to conventional power production technologies. Efforts must be made to remove harmful subsidies to mature electricity technologies based on fossil fuel and nuclear, as suggested by an OECD study on improving the environment through reducing subsidies. The higher the subsidies to polluting technologies, the higher the costs to society will be of introducing clean technologies.

OECD argues that «support is seldom justified and generally deters international trade, and is often given to ailing industries». It further argues:

«This policy [state aid] is often both costly and ineffective in the long run. Technological change and the development of new product markets will generally lead to an even further loss in the competitiveness of the supported industry. As a result, larger amounts of support will be required in order to maintain the industry. (…) In many cases, support is used to prop up declining industries, merely postponing their certain demise at the expense of tax payers and consumers.»

The OECD also argues «that support may be justified if it lowers the long-term marginal costs to society as a whole. This may be the case with support to 'infant industries', such as producers of renewable energy».

The problem with subsidies is that once introduced, they are difficult to remove. The existence of environmentally damaging state aid to mature industries such as coal and nuclear will inevitably lead to higher environmental policy costs.

Removing state aid to fossil fuels, nuclear and other mature and environmentally damaging industries has many attractions. Not only would it contribute towards a more level playing field in the electricity markets and create less biased market conditions, it would also save large amounts of money currently spent on unproductive state aid schemes, and finally make it considerably cheaper to develop the environmental technologies that are a precondition to securing the European Union's indigenous supply of electricity and meeting its climate obligations. Removing environmentally harmful subsidies should ideally be supplemented by energy taxes. Taxation can be an effective tool in energy policy if it internalises the costs to society of environmental degradation, and contributes to the polluter pays principle.

Several EU countries have introduced specific tax incentives for renewable energy. These are summarised in

Table 4.1

Specific national tax incentives for renewable energy

Country	Investment-based tax incentives
Austria	Private investors get tax credits for investments in using renewable energies (personal income tax). Note, the amount is generally limited to about 3,000 € per year.
Belgium	13.5 – 14% of RES-investments deductible from company profits, regressive depreciation of investments. Reduced VAT on building refurbishing if energy efficiency is included (6% instead of 21%).
Denmark	The first 3,000 DKK of income from wind energy are tax free.
France	Deduction of 15% investment costs with a maximum of 3000 € per person. Reduced VAT (5.5%) on renewable equipment (not applicable to installation costs).
Germany	Losses of investments can be deducted from the taxable income. This fact increases return on investments into wind projects.
Greece	Up to 75% of RES-investments can be deducted.
Ireland	Corporate Tax Incentive: tax relief capped at 50% of all capital expenditure for certain RES-investments.
Portugal	Up to 30% of any type of investments on RES can be deducted with a maximum of 700 € per year. Reduced VAT (12%) on renewable equipment.
Spain	Corporation Tax: 10% (up to 20% in some autonomous regions) tax liability instead of 35% for investments in environment friendly fixed assets.
The Netherlands	EIA scheme: RES-investors (most renewable energy systems) are eligible to reduce their taxable profit with 55% of the invested sum. Lower interest rates from Green Funds: RES-investors (most renewable energy systems) can obtain lower interest rates (up to 1.5%) for their investments. Moreover, dividends gained are free of income tax for private investors.

Source: EEG

4.2 Payment mechanisms

The present situation is that environmentally harmful practices are accepted, and indeed often subsidised, and there are few environmental taxes that fully reflect the external costs of electricity production. Therefore, the market will not respond to external costs, since they are not charged at source. Without mechanisms to fully internalise externalites, a second best solution for a level playing field in the electricity markets is for Member States (and potentially the EU) to enable adequate incentives to increase the proportion of RES-E. Thus, incentive mechanisms should be viewed as compensation for the lack of internalisation of external costs in power production. This is also the overall rationale given in the Community guidelines on State aid for environmental protection (2201/c 37/03).

For renewables, the amount of the incentive usually depends on the production cost of wind power compared to other technologies and the market price for electricity. As a result of the gradual liberalisation of electricity markets, competition should be increasing in the European electricity sector. Some concern, however, can be raised that Europe is moving from a situation of national electricity monopolies to private monopolies or oligopolies, rather than perfect competition. Increased competition, in combination with the present over-capacity in most European electricity generation, will probably, in the short term, make conditions more difficult for wind power and other renewables as wholesale electricity prices decrease. The price reduction can be expected to continue until generating companies close down their oldest power plants and new capacity is needed.

Several types of incentive have been used to promote the increased deployment of wind power. These can be grouped into three main categories:

- Voluntary Systems where the market determines the price and the quantity of renewable energy (Green marketing)
- Systems where the government dictates the electricity prices paid to the producer and lets the market determine the quantity (Fixed prices)
- Systems where the government dictates the quantity of renewable electricity and leaves it to the market to determine the price (legally obligated quotas)

Fixed price systems and obligated quotas for renewables are ways of creating a protected market, separate from the open electricity market where electricity from new renewable energy sources would have difficulties competing with existing, already depreciated nuclear and fossil based power plants. There are also ways of offsetting (fully or partly) the competitive disadvantage arising from the market's neglect of the external environmental costs and benefits of energy production, as described in section 2.

It is often argued that systems where the government fixes the quantity of renewable electricity demand (e.g. renewables quotas with green certificate trading) is more "market oriented" than systems where governments fix the price (see for example 'Eurelectric and RECS: "Integrating Renewable Energy Sources into the Competitive Electricity Market –a Shared Vision", November 2004'). But a system where the government fixes quantity and leaves it to the market to determine the price is unlikely to be more "market oriented" than a system where the government fixes the price and leaves it to the market to determine the quantity. However, the economics of the two methods are different and, in practice, the capacity of renewables installed under the mechanism may be significantly different.

Few would argue that the oil cartel OPEC is a market oriented mechanism because the members have chosen to control the market (prices) through quantities rather than directly through prices. The reason is that oil quantities are easier to administer. In the World Trade Organisation (WTO), quantitative restrictions are generally banned, while tariffs are accepted to some degree because quotas are regarded as more market distorting than tariffs.

The main purpose of the wide range of available economic measures to support renewable energy technologies is to provide incentives for technological improvements, increased renewables capacity and cost reductions of environmental technologies. That will ensure that we will have cheap, clean technologies available in the future as competitive alternatives to conventional power sources. It is less important that markets are controlled through prices or through quantities. What matters is that control is achieved in a rational and effective manner.

The main difference between quota based systems and price based systems is that the former introduces competition between the electricity producers (e.g. wind turbine operators). Competition between manufacturers of plant (e.g. wind turbines), which is crucial in order to bring down production costs, is present if government dictates either prices or quantities.

4.2.1 Historical background

In the early 1980s, financial incentives in the form of capital grants (i.e. investment subsidies), loans or reduced taxes, were a common way of encouraging investments. The most successful examples are from Germany and Denmark, where, for instance, it was possible to obtain preferential real estate loans for wind turbines.

In the mid-1990s, in various European countries, promotional programs based on regulated tariffs for the purchase of electricity from specified renewable sources became more common. The most important models in this context were (fixed) feed-in tariffs and fixed premium systems. Meanwhile competitive tendering, was introduced in the UK.

In recent years, another type of instrument emerged, at least in the political discussion process. This obligated quotas for RES-E, perhaps associated with Tradable Green Certificates, introduced in some Member States. In the UK this type of promotion instrument replaced the former tendering system (the Non-Fossil Fuel Obligation) in 2002, with the tradable certificates termed 'ROCs' (Renewable Obligated Certificates).

Table 4.2 summarises the most important historical steps for promotional strategies in Europe.

Table 4.2

Historical overview on promotion strategies for electricity from RES in European countries

Year	Country	Type of strategy	Programme name	RES-E Technologies addressed
1978-1985	DK	Investment subsidies		Wind
1989-1993	DE	Investment subsidies plus feed-in tariffs	"1000-Dächer-Program"	PV
1990-1999	UK	Tendering system	NFFO / SRO / NI-NFFO	Selected technologies
1990-present	DE	Feed-in tariffs	"Einspeisetarif"	PV, Wind, Biomass, Small hydro
1992-1994	AT	Investment subsidies plus feed-in tariffs	200 kW PV-Program	PV
1992-2000	IT	Feed-in tariffs	"CIP 6/92"	All technologies
1991-1996	SE	Investment subsidies /Tax relief		Wind, Solar , Biomass
1992-1997	DK	Feed-in tariffs / Tax relief		Wind, Biomass
1992-1999	DE, CH, AT	Feed-in tariffs	"Kostendeckende Vergütung"	PV
1994-present	GR	Investment subsidies	1994-1999": Operational Program for Energy" 1999-now: "Operational Program Competitiveness"	PV, Wind, Biomass, Small hydro, Geothermal
1994-present	ES	Feed-in tariffs or fixed premium systems	"Royal Decree 2366/1994" resp. "R.D. 2818/1998"	All technologies (except Large hydro)
1996-present	DE, CH, NL, AT, UK	Voluntary green tariffs	Various brands	Selected technologies
1996-present	CH	Voluntary stock exchange	"Solarstrombörse"	PV
1997-present	FI	Tax incentives	Energy Tax	Wind, mini hydro (<1MW), wood based fuels
1998-present	DE	Labelled "Green Electricity"	TÜV, Grüner Stromlabel e.V., Öko-Institut	PV, Wind, Biomass, Small hydro
1999-present	DE	Soft loans	"100,000 Dächer-Programm"	PV
1999-2000	NL	(Voluntary) Green certificates		All technologies (exept municipal waste incineration)
2000-present	DE	Regulated Rates	"Renewable energies law"	Selected technologies
2001-present	IT	Rebates	"Tetti fotovoltaici"	PV
2002-present	IT, UK, BE	Quota obligation with Tradable Green Certificates		All technologies (wave, waste and large hydro depend on the country)
2003-2004	AT	Feed-in Tariffs	"Ökostromgesetz"	All technologies
2003-present	SE	Quota obligation with Tradable Green Certificates		All technologies. No waste.
2003-present	NL	Mixed Strategy (Feed-in tariffs, tax incentives, green certificates)	MEP (Environmental Quality of Power Generation) + REB (Regulating energy Tax) + Green Certificates	All technologies except hydro and "non pure" biomass

4.2.2 Voluntary systems and green marketing

In theory, voluntary demand could provide a market for wind power and other renewable energy technologies independently of government policy. However, experience with voluntary systems or "Green Marketing Programmes" to date clearly suggests that voluntary green power schemes, purely based on customers' willingness to pay extra for green electricity i.e. without additional measures, has had only small and not significant impact on the deployment of renewable energy sources.

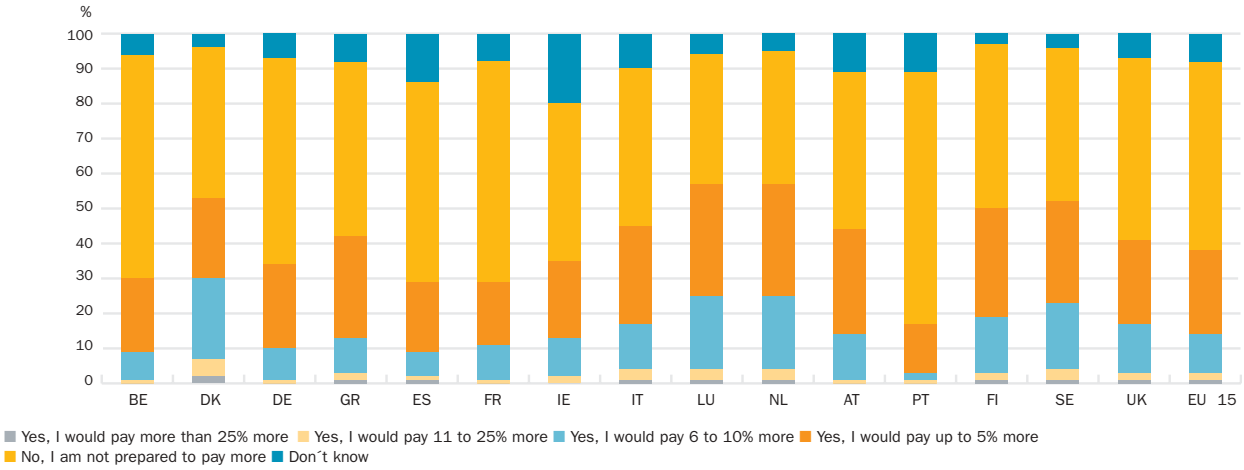
A survey by The European Opinion Research Group from 2003 shows that some willingness exists among Europeans to pay more for energy produced from renewable energy sources (see Figure 4.2).

However, the number of customers signing up for green marketing programmes cannot be directly translated into support for renewables, as most products contain less than 100% renewables. In Pennsylvania, USA 60,000 out of 80,000 customers signed up for a "green" electricity product that had a renewable energy content of less than 1%.

Much research into voluntary green electricity systems has been conducted in the USA where approximately 40% of the households have access to a green power product. One study[10] conducted by Lawrence Berkeley, National Laboratory at University of California, shows that 0.6% of the residential customers with access to voluntary green electricity products have signed up

Figure 4.2

Results of the survey relating willingness to pay more for energy produced from renewable sources: "Would you be prepared to pay more for energy produced from renewable sources than for energy produced from other sources? (If yes) How much more would you be prepared to pay?"



Source: The European Opinion Research Group (2003)

10 Wiser, Bolinger and Holt, Customer choice and green power marketing: A critical review and analysis of experience to date (University of California: Lawrence Berkeley National Laboratory).

(2000). In Denmark, only 0.5% of the customers of a Copenhagen-based supply company have decided to buy its green electricity product. For comparison, a majority of 58% of the Danes answered yes to the question: "Would you consider buying more environmentally friendly electricity, when it becomes possible?" in a survey by Ramboll.

The Lawrence Berkeley study suggests that the collective impact of green marketing schemes on renewable electricity generation has been very modest. The study concludes that there is a considerable difference in consumers' stated attitudes toward environmental products and the actual demand for them[11].

Schemes referred to as "Shareholder Programmes", "Contribution Programmes", "Ethical Trusts", "Green Electricity Tariffs" or "Green Electricity Labels" are frequently referred to as voluntary schemes, because customers of their own free will decide to sign up for a service. However, in most cases where voluntary schemes are perceived to be successful (in terms of many subscribers), the driving force behind the increase in "green" customers is the politically determined framework for investments in renewables rather than high voluntary demand for clean power.

In the UK, the electricity supply company 'Good Energy' markets only green electricity (RES-E) at tariffs some 10% more expensive than from conventional suppliers. The company has an increasing number of customers (7,000 in Dec 2003, increased to 13,000 in Dec 2004). However, in general, there is insufficient renewable capacity to meet the UK Government's obligated quota, hence triggering 'let-out' mechanisms.

Voluntary demand systems must be designed in such a way that customers who are willing to behave "greener than the rest", do not merely reduce the overall mandatory obligation. So far there are no European or national structures in place that can guarantee such purchases actually lead to more renewable power production.

4.3 Support schemes for renewables in the EU

RES-E from renewable energy technologies is becoming increasingly competitive with electricity from conventional sources. However, it is likely that some form of incentive will be required for a foreseeable future until either (a) environmental costs are fully internalised or (b) increased economies of scale and technological development makes renewables fully competitive with conventional sources such as coal and gas, without considering externalities. However, there is no guarantee that the second option would happen in a time to abate climate change and other negative impacts.

If the environmental costs of power production were reflected in the European power prices, wind power and many other renewable energy technologies would not need support, as pointed out in chapter 3 and in the European Commission's Green Paper on Security of Supply[12].

The EC's Green Paper states that wind energy can fully compete with combined cycle gas if externalities are taken into account. Furthermore, both wind energy, biomass, small hydro, photovoltaics and geothermal are significantly cheaper for society than coal if externalities are included. The social cost of coal generated electricity is almost twice as expensive as wind and biomass (1998 figures), according to the Green Paper.

There are currently five main mechanisms to support electricity from renewable energy sources in the Member States: Investment subsidies, fixed price mechanisms, fixed premium mechanisms, quota systems based on auctions or tradable green certificates. The aim of all these mechanisms is to offset some of the competitive disadvantage for renewables as a consequence of electricity markets neglecting the external costs of electricity production. Low electricity prices are of little benefit if they lead to high social costs to society.

Table 4.0 provides a classification of existing promotion strategies for RES-E support mechanisms. An explanation of the terminology is given below.

11 "Customer Choice and Green Power Marketing: A Critical review and Analysis of Experience to date"; Wiser, Bolinger, Holt; Lawrence Berkeley National Laboratory; University of California, USA.
12 Green Paper on Securing future…."; European Commission 2001.

Table 4.3

Fundamental types of promotional strategies

		Direct		Indirect
		Price-driven	Quantity-driven (quotas)	
Regulatory (obligated)	Investment focussed	• Investment subsidies • Tax credits	• Tendering system	• Environmental taxes
	Generation based	• (Fixed) Feed-in tariffs • Fixed Premium system	• Tendering system • Tradable Green Certificate system	
Voluntary	Investment focussed	• Shareholder Programs • Contribution Programs		• Voluntary agreements
	Generation based	• Green tariffs		

Voluntary approaches

This type of strategy is mainly based on the willingness of consumers to pay premium rates for renewable energy. There are two main categories:

- Investment focused: Shareholder Programs, donation projects and ethical thrusts.
- Generation based: Green electricity tariffs, with and without labelling.

Regulatory price driven strategies

Generators of electricity from RES receive financial support in terms of a subsidy per kW capacity installed or a payment per kWh produced and sold.

- Investment focused: Investment subsidies and Tax credits.(€ per unit of generating capacity)
- Generation based: Fixed Feed-in tariffs (FITs) and Fixed Premium systems (€ per unit of generated energy) – with flat rates or a stepped design.

Regulatory quantity driven strategies (quota based mechanisms)

The desired level of generation or market penetration of electricity from RES is set on by a government decision, i.e. commonly named as *Quota obligation* or *Renewable Portfolio Standard*. The price is in principle set through competition between generators. Most important are:

- Tendering systems / bidding,
- Tradable Green Certificate (TGC) systems

Indirect strategies

RES-E can also be promoted by means of indirect strategies, for example CO_2 (Climate Change) taxes, GHG emission trading or removal of subsidies previously given to fossil and or nuclear generation.

In Table 4.4 an overview is provided on current (i.e. as implemented at the end of 2004) promotion schemes for RES-E in EU-15 countries - listing countries, strategies and the technologies addressed.

Table 4.4

Current end 2004 promotion strategies for RES-E in 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. No decision yet on follow-up support after 2004.	FITs for waste with a high biodegradable fraction
Belgium	Quota/TGC + Guaranteed Electricity Purchase	No		Federal: The Royal Decree of 10th July 2002 (operational from 1st of July 2003) sets minimum prices (i.e. FITs) for RES-E.[13] On regional level promotion activities include: Wallonia: Quota obligation (TGC-system) on electricity suppliers – increasing from 3% in 2003 up to 12% in 2010. Flanders: Quota obligation (TGC-system) on electricity suppliers – increasing from 3% (no MSW) in 2004 up to 6% in 2010. Brussels region: No support scheme yet implemented.	
Denmark	Fixed Premiums	No		Act on Payment for Green Electricity (Act 478): Fixed premium prices instead of former high FITs. Guaranteed for 3 (biogas) to 20 (wind) 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: 49-70 €/MWh, biogas: 46-58 €/MWh, geothermal: 76-79 €/MWh, PV: 152.5-305 €/MWh; landfill gas: 45-57.2 €/MWh; wind[14]: 30.5-83.8 €/MWh; hydro[15]: 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		Renewal of German Renewable Energy Act in 2004: FITs guaranteed for 20 years[16]. In more detail, FITs for new installations (2004) are: hydro: 37-76.7 €/MWh; wind[17]: 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)[18] 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	Tendering System	No		Tendering scheme - to be replaced by FITs in 2005. The last tendering competition, No AER VI, took place in 2003: It included technology bands and price caps for small wind(<3 MW), large wind (>3 MW), small hydro (<5 MWp), biomass, biomass CHP and biogas.	No
Italy	Quota/TGC			Quota obligation (TGC-system) 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[19]; penalty in size of 84.2 €/MWh (2004) but market distortions appear[20]. Investment subsidies for PV (Italian Roof Top program).	
Luxembourg	Fixed Premiums	No	No	FITs[21] 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
The Nether-lands	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[22]: 43-83 €/MWh; wave: 225 €/MWh; PV[23]: 224-410 €/MWh, small hydro: 72 €/MWh.	No
Spain	FITs or Fixed Premiums	Depending on the plant size[24]		FITs (Royal Decree 436/2004): RES-E producer have the right to opt for a fixed FIT or for a premium tariff[25]. Both are adjusted by the government according to the variation in the average electricity sale price. In more detail (only premium as valid in 2004 for plant < 50 MW): wind, small hydro, geothermal, tide & wave: 42 €/MWh; solar thermal & PV[26]: 194 €/MWh, biomass: 35-42 €/MWh. Moreover, soft loans and tax incentives (according to "Plan de Fomento de las Energías Renovables") and investment subsidies on regional level.	Premium FIT: 17 €/MWh
Sweden	Quota/TGC	No		Quota obligation (TGC-system) 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"[27]) are available.	No
United Kingdom	Quota/TGC	No		Quota obligation (TGC-system) 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

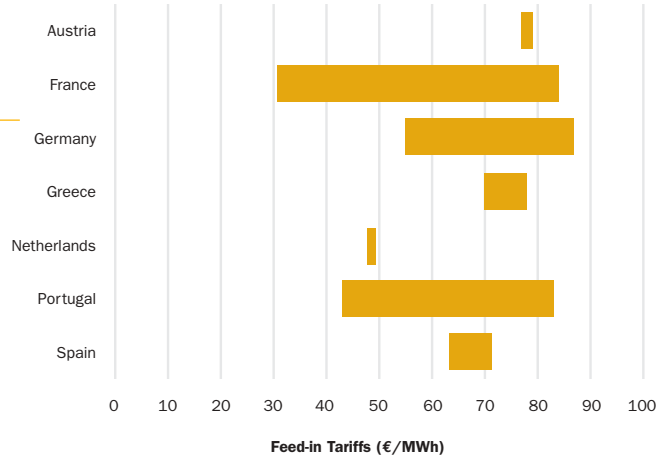
The classification of promotional instruments shows that a broad set of strategies now exist. However, most attention has been concentrated on five of these (investment subsidies, feed-in tariff schemes, fixed premium schemes, obligated quotas, tendering and tradable green certificate systems), and no single instrument has been applied broadly across the EU. Four of these main instruments are discussed in more detail in the following. The internet based background report "A Review of Promotion Strategies" available at www.ewea.org provides detailed tables on the actual levels of support applying to all renewable energy sources.

4.4 Fixed price systems

3 shows the feed-in tariffs for onshore wind energy in the EU15 as of 2004[28].

Figure 4.3

Feed-in tariffs for electricity from new onshore wind plant in EU-15 countries (at end 2004)



In France, Germany, Greece and Portugal, the tariff is related to the siting (production) of the turbine (sometimes referred to as a "stepped feed-in tariff"). In strong wind areas, the tariff is less than in weak wind areas; this is to avoid that the development of wind turbines being concentrated in the very windy areas of a country. In Spain, wind turbine operators can choose between a fixed tariff per kWh or a premium increment above the market fluctuating price for electricity.

4.4.1 Investment subsidies

In the early days of wind power development, investment subsidies where often used as an incentive to investors. We will consider these with examples from wind power (although the mechanisms apply to many other renewable technologies).

A common investment subsidy is a grant for the installation of capacity. This is normally given on the basis of the rated power capacity (in kW) of the generator. It is generally acknowledged that systems that relate the grant to the capacity of the wind turbine, rather than the annual energy production of the electricity, is unadvisable because it encourages less efficient turbines. The incentive should be related to the production of electricity from efficiently operated plant, rather than just the installation of plant capacity that may remain poorly managed.

In the 1990s, India gave a subsidy to wind turbine owners based on the rated capacity of the wind turbines. That proved less successful than hoped because a subsidy was given whether or not production was efficient. The scheme resulted in poor siting of wind turbines, and manufacturers followed customer demands to use disproportionably large generators, which improved project profitability but reduced production and also attracted manufacturers with highly dubious products. India has since corrected the inherent flaws of its incentive scheme and the market has started to develop again. For wind energy, the global trend is to reject

Notes Table 4.4

13 FITs are guaranteed on national level for the first 10 years of operation, e.g. in case of offshore wind in size of 90 €/MWh. Note, they can only be claimed exclusively – in other words, they cannot be claimed if support is given by the regional TGC-systems.
14 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.
15 Producers can choose between four different schemes. The figure shows the flat rate option. Within other schemes tariffs vary over time (peak/base etc.).
16 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.
17 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.
18 Depending on location (islands or mainland) and type of producer (independent power producers or utilities).
19 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).
20 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).
21 Only valid for plants up to 3 MW (except PV: limited to 50 kW).
22 Stepped FIT depending on the quality of the site.
23 Depending on the size: <5kW: 420 €/MWh or >5kW: 224 €/MWh.
24 Hydropower plants with a size between 10 to 25 MW receive a premium of 42 €/MWh, larger plants (25 to 50 MW) can opt for a premium of 35 €/MWh.
25 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.
26 In case of PV the expressed premium tariff refers to plant > 100 KW. For small-scale plant (<100 kW) a fixed FIT in size of 414.4 €/MWh is applied.
27 Decreasing gradually down to zero in 2007.

Notes from p 30

28 Internet based background report "A Review of Promotion Strategies" for the other renewable energy technologies, available at www.ewea.org.

investment subsidies as the only means of encouraging wind power investments, because it is considered economically inefficient as illustrated by the India case.

However, investment subsidies can be effective if combined with other incentives as it is seen in the UK. In order to take account of the higher cost of offshore wind power compared to onshore, the British government offers investment grants to offshore projects to complement the ROC system (an obligated renewables quota system). In the absence of such investment grants, only onshore development would be likely, or it would be necessary to create two separate ROC markets – one for onshore and one for offshore, assuming that both are a priority for the government.

4.4.2 Fixed feed-in tariffs

Mechanisms based on fixed feed-in tariffs (FIT) have been widely adopted throughout continental Europe. Operators of wind farms are paid a fixed price for every kWh of electricity they feed into the grid. The extra cost of the mechanism, if defined by the difference between the level of the tariff and the market price of electricity, is borne by the taxpayers or the electricity consumers.

The structure of the mechanism makes it impossible to predict the total amount of the support per kWh. If the value of the tariff remains constant, the amount of support will change as a result of changing wholesale electricity prices. The level of support per kWh could become effectively negative if wholesale electricity prices were to rise above the value of the tariff. Such a situation has occurred in Scandinavia. In recent years, electricity prices on the Nordic power exchange Nord-Pool has periodically increased dramatically as a result of low levels of water in the Norwegian and Swedish hydropower reservoirs (hence reduced electricity supply) combined with increasing power demand. Sometimes this has led to the somewhat paradoxical situation that owners of coal power plants received higher prices for their electricity supply than owners of wind turbines.

As a rule of thumb, in Germany, the additional cost of the feed-in tariff adds about 1 Euro to the average household electricity bill per month, but as indicated above, the exact amount is difficult to establish when power prices fluctuate. Large German electricity users effectively receive a discount on the feed-in tariff contribution by purchasing electricity at reduced prices.

FIT systems have been highly effective at attracting wind power investments in Denmark, Spain and Germany. Other countries that have feed-in tariffs are Austria, France, Greece, Luxembourg, the Netherlands and Portugal. The main determinant of whether a FIT model is successful at attracting investments is the value of the tariff. Of course, the payment mechanism has to be supplemented by adequate grid connection conditions and a well functioning planning framework that allows distributed generation. The main benefit of a FIT is that it is simple and often encourages better planning. FIT is not associated with a formal Power Purchase Agreement (PPA) and has no definite term. In principle, therefore, the level of the tariff can be changed at any time or removed by repealing the Law. The main disadvantage of FIT is the political risk inherent in the system should general consumers object to paying the levy for the subsidies.

The political risk of the feed-in tariff in **Spain**, seen from a RES-E investor's point of view, is perceived to be somewhat reduced, since the government has given assurance that changes in the tariffs will not bankrupt existing projects built under previous conditions. However, the risk of political change is not eliminated in Spain, and investors can only guess for how long the tariff will continue and at what level. Investors in RES-E plant therefore have to include a risk premium when planning the financial soundness of projects, which eventually leads to higher cost to the consumer than in a situation with less political risk.

Germany has been able to reduce much of the political risk by guaranteeing payments to distributed renewables generators for 20 years. In 2003, the government realised that if the tariff should reduce dramatically, this would have a highly negative effect on the market for new renewables capacity in Germany. However, those who have already invested will not be affected, unless the government decides otherwise. Some political risk is still inherent in the German system, as it is considered less risky for investors to enter into long-term power purchase agreements enforceable under civil law than relying on the good will of a government or parliament.

Greece is a good example that a sufficiently high feed-in tariff does not guarantee development of wind energy. The feed-in tariff (90% of the consumer price or approximately 5.75 cent/kWh – app. 7 cents/kWh if there is no grid access) is supplemented by up to 40% capital grants. That level should be sufficient to develop wind energy taking into account Greece's wind resources. Still development is not taking off in Greece. The main barrier lies in the local government planning and electricity grid authorisation system rather than in the value of the tariff.

France is faced with much of the same problem as Greece. The financial incentive (feed-in tariffs for projects smaller than 12 MW and auctions for larger projects) seems adequate but little development is taking place. The main barrier in the past has been grid and, especially, planning barriers.

The political risk of feed-in tariffs is usually the risk that the government will change the policy, i.e. reduce the tariff if wind power becomes cheaper as the technology develops. But there is also a potential risk that the government will take no action if a feed-in tariff is no longer sufficient to attract investments under the overall economic climate.

Fixed-price systems are rather rigid when it comes to adjusting tariffs, whether increasing or decreasing, as production costs of wind power change. Note also that the inflation risk of the mechanism may be avoided by including an automatic inflation adjustment to the mechanism, as is done by the United States' production Tax Credit.

4.4.3 Fixed premium systems

A "Fixed Premium" or "Environmental Bonus" mechanism is another variant of the fixed price system. Rather than fixing the price, government fixes a premium to be added to the varying market price of electricity. The cost per kWh of the system is, contrary to the fixed feed-in tariff, predictable, although the total costs to society depends on capacity developed. From the perspective of a wind-turbine owner, the total price received per kWh (electricity price plus the premium) is less predictable than under a feed-in tariff, since the total changes with electricity market conditions.

In principle, a mechanism that is based on a fixed premium / environmental bonus that reflects the external costs of conventional power generation could establish fair trade, fair competition and level the playing field in the Internal Electricity Market between renewable energy sources and conventional power sources. Together with taxing conventional power sources in accordance with their environmental impact, fixed premium systems are theoretically the most effective way of internalising external costs.

From a market development perspective, the advantage of a price premium is that it allows renewables to penetrate the market if their costs are less than the sum of the premium and the normal electricity wholesale price. Obviously the amount of the premium will relate to the rate of new renewables capacity; a large premium will increase renewables capacity rapidly and vice versa. Therefore, if the premium is set at an attractive amount (theoretically equal to the abated external costs of conventional power), it allows renewables to compete with conventional sources, without the need for obligated quotas.

In practice, however, basing the mechanism on the environmental benefits of renewables is challenging. Very ambitious studies, such as the European commission's Extern-E project, of the external costs of power generation, have been conducted in both Europe and America. These have illustrated that establishing the exact costs is very complex, as illustrated in chapter 3. In reality, fixed premiums for wind power and other renewable energy technologies, such as with the Spanish mechanism, are based on estimated production costs and comparison with the electricity price, rather than attempting to evaluate the environmental benefit of the renewable energy.

4.4.4 Tax credits

A tax credit is another variant of the fixed price mechanism. Whether an incentive is a tax credit or a cash payment is immaterial from a socio-economic or investor perspective. However, politically it can be important whether an incentive is paid by the electricity consumer as a levy or by the taxpayer within general taxation. If small, levies on regular payments are not noticed, whereas tax increases may become political nightmares.

The largest wind power market to make use of a tax credit is the United States. Also Canada is considering introducing a tax driven system. The US market is driven by the federal Production Tax Credit (PTC), which is worth approximately 1.8 cents per kWh. It is adjusted annually to take inflation into account. However each annual assessment may become politically fraught.

In recent years, there have been three separate phases of the US PTC. The first PTC ended on June 30th 1999, and was not renewed until January 1st 2000. That new PTC expired on December 31st 2001. Again, there was a gap before its extension was announced in March 2002, and this third PTC continued until December 2003. At present (March 2005), the tax credit has again been extended until the end of 2005 and it is difficult to say, if it will be further extended.

As a result of the short lifetime of each individual US PTC, the market has been very volatile and characterised by "boom-bust"-cycles. Activity is usually picking

up dramatically prior to the end of a PTC. There was much activity in late 1998 and early 1999, but almost no activity in 2000, and a great deal of activity again in 2001. Activity was picking up again prior to the December 2003 deadline, although 2004 was a year with low development in the US. At the time of writing (March 2005) it seems that 2005 will be a very busy year for wind power sector in the US. For both investors and manufacturers, these boom-bust cycles are very problematic because it makes planning very difficult. Most European wind turbine manufacturers have plans to start local production in the Unites States but are reluctant to implement them until more long-term stability is secured. It should be emphasised that the boom-bust cycles associated with the annual review of the US PTC are not unique to tax credits. Boom-bust cycles can appear with any mechanism that has short period review and thus is an effect of unstable policy, rather than of a particular mechanism per se.

4.5 Fixed quantity systems

In fixed quantity systems or "Obligated Renewable Quota" systems (in the United States: Renewable Portfolio Standards), the government sets a quota for the amount of renewable energy that should be produced or traded in specified time intervals (e.g. per year). It is then up to the market forces to determine the price. Nevertheless, some form of regulation is needed. Two types of mechanisms have been used to control the uptake of capacity to meet the aims of the renewable quota systems, namely : Tendering and Green Certificates.

4.5.1 Tendering systems

Tendering or competitive bidding is used to promote forms of RES-E in the Republic of Ireland, France (for wind farms larger than 12 MW) and was previously used in the UK (Scotland, Northern Ireland, England and Wales). Developers submit their wholesale sale price for electricity, so bidding for a limited wind energy capacity in a given period. The companies that bid to supply electricity at the lowest costs win the contracts to do so. Usually 15-20 year power purchase agreements are entered into. The difference in price between the contracted tariff and the wholesale price of conventional power is paid to the developers/owners from a levy, which represents the additional cost of producing green electricity.

In practice, one of the major drawbacks of the tendering mechanisms is the encouragement to 'play games' within the system. For instance, wind energy is a technology that becomes cheaper with time. Therefore, a contract holder may delay as long as possible to build a project. Partly because of this inherent flaw, the UK NFFO (Non-Fossil Fuel Obligation) tender system did not result in many projects being build. Another flaw of the NFFO model was that it did not penalise developers if they failed to install the capacity for which they had secured a power purchase contract. In principle anyone was free to make an unrealistic low and unprofitable bid, win the contract and not develop the project. The ineffectiveness of the British NFFO system led the government to abandon the model and introduce a new system based on tradable green certificates (see below). Another unfortunate result of tendering, especially for wind power, is that sites are selected without regard for environmental impact. For instance tendering in the UK encouraged wind turbine sites on hills in 'wilderness' regions, which provoked opposition from the public, especially against the visual impact. In practice, the Feed Law mechanisms have had a much softer impact.

The UK NFFO has been heavily criticised for its failure to deliver, and the British experience has discredited tendering systems substantially. The NFFO had obvious flaws, as described above, but that does not necessarily mean that tendering systems cannot function if they are designed better than the NFFO. The problem with falling production cost over time could have been overcome by introducing deadlines and penalties. The model should be combined with a performance bond and meaningful penalties for failing to meet the contract. Finally, local planning procedures in the UK allow opposition to delay or prevent projects, despite the intentions of central government, which contributed to the disappointing performance of the NFFO.

If designed correctly, tendering systems may work. One of the main attractions of the model is that the 15-25 year power purchasing contracts that bidders compete for are enforced under civil law. From an investor risk perspective, long contracts are very attractive, since it minimises risk. A second attraction of a well-designed tendering system is that the government, (as well as electricity users and taxpayers) do not have to make best guesses about the cost development of producing wind power. The political risk of not controlling subsidies with tendering systems is less than with fixed price systems. However, investors are faced with another risk element under tendering. All developers that enter a bid risk losing the planning costs if the bid is not accepted or if planning permission is not eventually given for the development

project. Of course, other mechanisms can also have long-term contractual arrangements, which is always favourable.

Following the UK NFFO experience, most countries have disregarded tendering procedures. At present Ireland continues its competitive bidding procedure through the AER, but is considering changing its system. The overall objective of the AER is for 500 MW of new renewable energy capacity in the period 2000 to 2005. The winners of tenders are awarded power purchase agreements for 15 years.

Denmark has a tendering procedure for its future offshore wind power development. The country, which already generates about 20% of its electricity from wind power (2004), is following a strategy that future development of wind power should be offshore, combined with repowering of onshore wind energy. The 2004 tender sought two offshore wind farms, each with a capacity of 200 MW, and the results of the tenders were expected in 2005.

If designed correctly, tendering systems could be designed to function, just as with offshore oil and gas leases. However, it still remains to be proved in reality that the system can be effectively applied to significant RES-E power investments. The sunk planning cost risk described above will also have an effect on the ownership structure in the RES-E energy market. For example, as projects increase in size, the wind power sector is already witnessing a shift in ownership away from individual ownership towards larger developers and power companies. The popular element of the early days of wind power co-operatives and individual ownership will probably vanish unless new collective project development institutions are developed. Another effect of the tendering system would be that development is likely to be concentrated in the windiest areas, as found in the UK. That could be desirable from an economic efficiency perspective (although it would have a negative effect on the geographical spread needed to smooth wind power intermittency), but may have implications for planning and public opinion.

The model is probably better suited for large offshore wind farm projects than onshore wind power. But the planning issues must be dealt with, deadlines must be in place and there should be meaningful penalties for not building. Imposing price caps seems to be incompatible with the basic idea of tenders, so the market provides price signals for the RES-E generation.

4.5.2 Tradable green certificate systems

Tradable Green Certificate Systems (TGC) is a mechanism that in some ways resembles the tendering system. The main difference is that the price for the power and certificate is settled at a daily basis on the electricity market and a separate market for tradable certificates (tendering systems are typically based on 15-25 year power purchase agreements). With daily settling of prices, the TGC model is more risky for the investor unless effective markets for long-term power purchasing contracts and certificates contracts (probably based on financial futures or options) are in place.

If a tradable green certificate market works effectively, the price of a certificate would reflect the difference between the market price of electricity and the generation costs of new renewable generating capacity. The value of a certificate thus represents the additional cost of producing renewable electricity compared to conventional sources. That value, it should be noted, will only by coincidence be equal to the abated external costs of conventional power, i.e. the environmental benefits of renewables.

In theory, for to date there is not a settled TGC market for RES-E, the TGC mechanism works as follows: (i) the government sets a specific and gradually increasing quantity, or minimum limit, for the amount of renewable electricity in the supply portfolio; (ii) an obligation is placed on either the electricity suppliers or end users of electricity (it is of little importance who has the obligation); (iii) the generators (producers), wholesalers, retailers or consumers (depending on who is obligated in the electricity supply chain) are obligated to supply / consume a certain percentage of electricity from renewable energy sources; (iv) at the settlement date, the operators have to submit the required number of certificates to demonstrate compliance.

Those obligated obtain certificates in three ways:

- they can own and operate renewable energy plant;
- they can purchase certificates from another renewable energy generator.
- they can purchase certificates from a generator or broker, i.e. purchasing certificates that have been traded independently of the power itself.

The (gradually increasing) obligation creates a demand for TGCs. It is left to the market to deliver the supply of certificates. TGCs are issued to producers of renewable electricity in proportion to the volume of green electricity they generate. A TGC serves as evidence that a

specific amount of green power has been produced and fed into the grid. If demand for certificates exceeds supply, the amount of renewable electricity produced tends to be less than the government quota so the market price of certificates increases. The price will continue to increse until the price satisfies the investors' requirements for return and new capacity will be installed to meet the quota. In practice, as in the UK, a cap is set for the maximum TGC price by allowing obligated companies to pay a 'fine' (buy-out price) for lack of compliance. The money of these 'fines' is, in the UK, recycled to the RES-E suppliers, which further encourages new RES-E capacity.

Table 1.5 gives an overview of various certificates models

Table 4.5

Overview of various certificate models

	Denmark (Abandoned. Never operational)	UK	Belgium (Flanders region)	Belgium (Wallonia)	Italy	Sweden
Period	**Abandoned**	**Start 2002**	**Start 2002**	**Start 2002**	**Start 2002**	**Start 2003**
Obligated capacity or share of total supply	20% by end 2003 (proposal abandoned)	3% in 2002; 4.3% in 2003; 10.4% in 2010; 15% in 2015	1.2% (2003), 2% (2004) increasing to 6% in 2010	3% in 2003 increasing up to 12% in 2010 From September 2010 onward, the quota will be multiplied by a factor of 1,01	2% in 2002 and will be increased annually by 0.35% between 2004 and 2008	7.4% in 2003, 16.9% in 2010
Obligation on	End-user	Supplier	Supplier	Supplier	Producers and importers	End-user
Technology bands (baskets) within overall quota	No	No	No	No	No	No
Technologies involved	small hydro, wind, biomass, solar -, geothermal energy, no waste	small hydro, wind, biomass, photovoltaic, wave, but, not waste combustion	all renewables, no solid municipal waste	all renewables and high quality CHP	all renewables (incl. large hydro), facilities not older than 8 years	small hydro (<1,5 MW), large hydro (only in some cases), wind, biomass, geothermal, wave energy
International trade allowed	No	No	No	No	Yes, but only in exchange with physical electricity	Trading scheme with Norway planned
Floor price	14 €/MWh	Not planned.	Floor prices set at federal level: From 1st of July 2003 onwards the grid operator has the obligation to buy TGC issued anywhere in Belgium for the minimum prices per TGC (in size of 1MWh) of: offshore wind 90 €, on-shore wind 50€, hydro: 50€, solar energy: 150€, biomass: 20€ Within Wallonia, RES-E producers may exchange their TGC for a subsidy at a fixed price of 65 €.		n.a.	Floor prices are planned for the introductory phase: 6.6 €/MWh in 2003; 5.5 €/MWh in 2004; 4.4 €/MWh in 2005; 3.3 €/MWh in 2006; 2.2 €/MWh in 2007; from 2008 onwards no floor price is planned.
Penalty	37 €/MWh	The Buy out price is £30,51/MWh (for 2003/2004) (~45 €/MWh)	75 €/MWh (75€ per missing certificate in size of 1MWh) in 2003; 10 €/MWh in 2004; and 125 €/MWh in 2005	From 1st of April 2003 onwards: 500 €/MWh (100€ per missing TGC in size of 1MWh)	84 €/MWh (2004)	150% of the market price – but with a maximum of about 19 €/MWh in 2004, respectively 26 €/MWh in 2005
Trading scheme		Stock exchange	Stock exchange	Open, trading and direct support	Free or in the power pool.	Open

Comments: **Denmark:** The TGC was initially proposed in 1999 but was abandoned before ever becoming operational. **UK:** As per 2004, the certificate price is higher than the penalty level / buy-out price. This is because penalties for non-compliance are recycled to the suppliers that have met their obligation. The system is deliberately designed this way to create an additional incentive for early deployment **Belgium:** The green certificate system are administered by the regions who are also responsible for issuing certificates. Only offshore wind energy certificates are regulated at the federal level. **Italy:** In reality the system is a combination of fixed prices and fixed quantities as GRTN (Italian Transmission System Operator), in practice, sets the certificate price. The certificate price is related to the regulated price of the previous system (CIP6)

The TGC mechanism is more complex in operation than other payment mechanisms. RES-E operators have to be active in two interrelated financial markets: one for TGCs and one for power. One of the problems is that there seems to be an asymmetry between the demand and the supply side in the markets. RES-E owners would prefer to have as long contracts as possible to minimise risk, while the electricity companies on the demand side seem to prefer short contracts – also to minimise costs. It is essential that the certificate market is able to attract financial arbitragers and speculators that can allocate risk.

Ideally there should be no floor and no cap on the price of certificates. However, there will need to be a penalty for not complying. As any other penalty, it should ideally be set at a level so high that it need never be enforced. A high penalty is one of the contributors to the successful US sulphur dioxide market. If the penalty is set too low (i.e. too close to the expected market price of the certificates, as in the UK) it will in effect have the characteristics of a price controlling factor, which may delay reaching the target RES-E capacity.

In the ideal market, the price of the TGC and the expected price of electricity will always total what economists call the «long term marginal cost» of producing a product, in this case the costs of adding one more unit, e.g. one more wind turbine, to the generating base. In reality, any change in costs associated with RES-E production will be compensated for by an equal change in the combined income from selling the electricity and selling its accompanying certificate. If, for example, interest rates rise, so will the combined payment. If sites with poorer power potential are used, the combined payment will also rise. And if technology improves, the combined payment falls.

In theory, under an RPS, all changes, or rather all expected changes, in the cost determinants of RES-E investment will be immediately reflected in the combined price of electricity and the price of renewable energy certificates (TGCs). Likewise, a reduction in electricity prices will be accompanied by an equal rise in the price of the certificate.

The role of the TGC market, as any other market, is to establish a price according to the laws of supply and demand. But determining a price is problematic when supply and demand are fixed in the short term (the problem of vertical demand and supply curves). A price cannot be determined if a situation where demand equals supply is an exception. The effect will be that the price will tend to be 'banging' either against the price cap created by the penalty or the price floor (if there is one), and never 'floating' in the mid-range, unless specific design features are applied.

In order to eliminate the price fluctuations caused by the fixed demand and to secure flexibility in payment, a system of «banking» must be available. Certificates will be issued at the time of production of renewable energy and will be destroyed, in accordance with the requirements of the obligation, on delivery to an independent authority. But there will most likely be an imbalance between actual production of RES-E and the quota obligation for any given period. The market must be structured to cope with the imbalance. A banking system could be a solution. Such a system gives consumers the option of buying future production and gives RES-E plant owners the option of selling future production by trading borrowed certificates. This stabilises fluctuating prices by creating a basis for long-term certificate purchase contracts. The system thus allows participants in the market the option of hoarding certificates in the expectation of future price changes, and RES-E plant owners the option of borrowing certificates in case their plant does not produce enough electricity to meet their long term delivery contracts.

For owners of wind turbines and their financiers, it is of paramount importance that any payment system allows reasonable certainty for cash flow projections. In support systems based on fixed price, this tends to be less of a problem. But with selling of both power and certificates on spot markets with fluctuating prices, it could become a problem, which increases the risk and thereby the cost of producing RES-E.

Financial long-term contracts would limit this problem through the establishment of well-functioning futures or options markets. By selling electricity and certificates on long term futures or options contracts, the risk (and the price) can be reduced. Futures and options contracts make it possible to sell or buy certificates for delivery some time in the future at a price that is agreed upon today. Such a market would be helped by an institution to facilitate trade and guarantee delivery if the RES-E generator is unable to deliver.

Another aspect to consider is whether all renewables technologies defined in the Directive on Promotion of Electricity from Renewable Energy Sources should be included in a single «umbrella certificate» or whether a certificate for each technology is the answer. One certificate, however, only ensures development of the cheapest technology, while several certificated technologies will result in a market with dangerously low liquidity, at least in the beginning of development.

One way to deal with the problem is to accept, for example, that photovoltaic power (PV) is 10 times more expensive than wind power and issue 10 times as many certificates to PV producers than to wind producers for the same amount of power. But such a solution brings us back to the problem of the fixed price systems: there is no easy way of estimating the true production costs of the various technologies, which makes it difficult to determine the proportional relationship between the costs of wind and PV. What if the cost of PV decreases 10% from its current high level, and the certificate proportion is not changed quickly enough to reflect the decrease? Investment in solar PV would soar and nobody would invest in cheaper renewables options, even though the latter may be several times cheaper in real terms. Offshore wind, being more expensive than the onshore variety, gives rise to the same problem and a way needs to be found of stimulating its development.

Furthermore, issuing certificates in proportion to estimated production costs requires constant evaluation of the costs of technologies and political intervention in the form of changed certificate proportions. The political risk in such a market would be substantial. One certificate for all technologies (an umbrella certificate) would also make it impossible to determine the price of pollution abatement in relation to the individual technology. Consequently, it would not be possible to determine when a technology no longer needs support. Thus: an umbrella certificate will still have a positive value when the least costly technology becomes competitive. The risk is that support will be given to technologies that no longer need it.

On the other hand, the liquidity problem of having several certificates cannot be ignored. Low liquidity is a problem for efficiency in every market. There are compromise solutions, however. Certificates could be issued to different technologies in exactly the same proportions, with the less competitive technologies receiving additional subsidies. Or instead of granting direct capital investment subsidies, auctions could be held for subsidised contracts, to encourage competitive bids, much along the lines of the British Non Fossil Fuel Obligation legislation. A further alternative is to have obligated quotas divided into technology bands.

Renewable obligation certificates in the United Kingdom

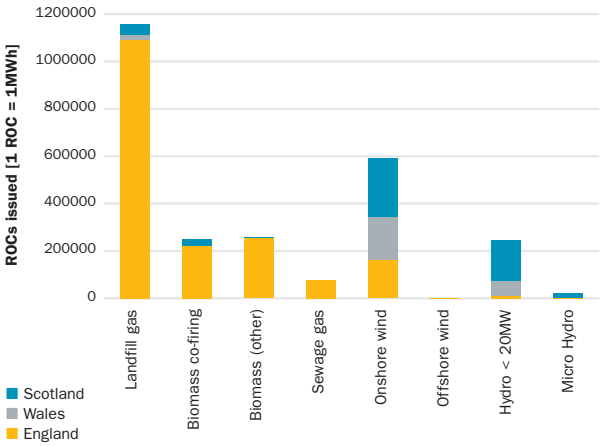
The most important mechanism in the UK for the promotion of green electricity is the *Renewables Obligation (RO)*. This policy scheme came into force in April 2002 and replaced the previous *NFFO (Non Fossil Fuels Obligation)* based on a competitive bidding mechanism. Suppliers have to demonstrate the compliance with the RO through tradable green certificates – the so called *Renewables Obligations Certificates (ROCs)*. Each ROC represents 1 MWh of renewable electricity from eligible generators. OFGEM, the British Regulator, is responsible for the administration of the RO, i.e. for the control of compliance. For the period of 2003/2004 suppliers have to meet an obligation of 3.4% of each supplier's total provided electricity. The quota obligation runs on a yearly basis. The obliged target will increase to 10.4% in 2010/2011. An increase of the quota after 2010 has been agreed in principle.

To meet the RO suppliers have 3 possibilities:

- to pay for the ROCs in association with the supply of renewable energy purchased from eligible generators;
- to buy ROCs from other suppliers or from the NFPA which periodically puts the ROCs (acquired under the existing NFFO contracts) on auction;
- to pay the penalty or "Buy-Out Price" set by OFGEM for the non-compliance of the quota.

Figure 4.4

ROCs issued in the period October 2002 to February 2003 by technology and country (Note: 1 LEC = 1MWh$_{el}$).



Source: OFGEM (2003)

The Buy-Out Price (which is in effect a fine or penalty) is now set at £30.51 per MWh, although it can be varied by the Minister in the future. All penalty payments, representing the shortfall between the obliged and actual presented ROCs, are placed in a central fund. This fund is redistributed only to those suppliers which have met the obligation. The money redistributed is in proportion to the number of ROCs each of those suppliers originally presented. Therefore the real costs for a supplier who is not complying with the obligation are higher than their total Buy-Out Price payments ('fines'), since they forgo the opportunity to be included in the redistribution. In contrast, accomplishing and surpassing the RO target provides additional economic incentives. That explains why ROCs trade at higher prices than the Buy-Out price. That situation can be expected as long as the market is short of the obligated total of RES-E.

Figure 4.4 depicts the number of ROCs (Renewable Obligation Certificates) issued in UK between October 2002 and February 2003 by technology and country.

4.5.3 Indirect promotion strategies

Aside from strategies which directly address the promotion of one (or more) specific RES-E technologies, there are other strategies which may have an indirect impact on the dissemination of renewables.

The most important are:

- Environmental taxes on electricity produced with non-renewable sources;
- Taxes/Permits on CO_2 (Climate Change) emissions;
- Fossil and nuclear subsidy reduction (not exactly renewable promotion, rather this is rectifying a market failure)

To promote RES via energy or environmental taxes, two options exist:

- RES-E can be exempted from taxes (energy taxes, sulphur taxes etc.);
- Or, if there is no exemption for RES, taxes can be (partially or wholly) refunded.

Both measures lead to an improved competitiveness for RES-E on the market and can apply for both established (old) and new plants.

A short summary on existing indirect strategies in EU-15 countries is given in Table 4.6.

Table 4.6

Energy taxation with exemptions for RES in various EU-15 countries

	Taxation with exemptions for RES
Denmark	Carbon-based, sulphur- and energy-taxation: Existing RE-plants (wind, biomass, biogas) are exempt from the CO_2-taxation (1.3 €c/kWh)
Finland	Carbon-based environment tax in force since 1990. Since 1997 an exemption on energy tax for renewables electricity is implemented. The tax is refunded to the producers which use wood-based fuels, wind- and small-scale hydro power.
Germany	1999, „Ökosteuerreform": Energy tax (tax for electricity in 2000: 0.01 €/kWh, increasing yearly. 2003 - Fifth stage: Electricity tax: 2.05 €c/kWh). Electricity from renewables is exempted
Sweden	Carbon-based, sulphur- and energy-taxation: RES-based electricity production is not taxed.
The Netherlands	From January 2003 users of green electricity are partially exempted from paying the Regulatory Energy Tax (REB or Ecotax.). The Ecotax exemption was in 2003 2.9 €c/kWh. (reduced from 6€c/kWh as in 2002) Electricity suppliers can use the green certificates to claim the Ecotax exemption.
United Kingdom	Climate Change Levy (CCL): The tax is to be levied on business customers with effect from April 2001. Carbon neutral fuels are exempted. Current Levy rate is 4.30 GBP/MWh

European Emission Trading Directive

On 23rd of October 2001, the European Commission proposed a Directive on a European Emission Trading Scheme within the Member States. In January 2005 the European Union Greenhouse Gas Emission Trading Scheme (EU ETS) commenced operation as the largest multi-country, multi-sector Greenhouse Gas emission trading scheme world-wide. The scheme is based on Directive 2003/87/EC, which entered into force on 25 October 2003.

The Directive is based on the EU's Kyoto obligation to reduce, by 2010, the emission of greenhouse gasses by 8% compared to 1990. The Directive sets carbon dioxide caps on emissions from numerous industrial sectors (e.g. electricity generation).

Emitters of large amounts of carbon dioxide are allocated emission allowances for free on the basis of national allocation schemes. If they reduce the emissions to less than the quantity assigned to them, they can either sell the surplus allowances to participants that do not fulfil their obligation or they keep surplus allowance for later use. Consequently, enterprises that exceed their freely allocated allowances can purchase emission permits in the market. The scheme consists of two periods: 2005-2007 (pilot phase) and 2008-2012 (first obligation period of Kyoto Protocol).

The importance of the Directive for RES-E is uncertain and very much depends on whether a short-term or long-term perspective is taken. Nevertheless the following aspects can be noted:

- The price of an emission allowance is unlikely to ever fully equal the external costs of the polluting power production.
- The effect of the Emission Trading Scheme on renewables crucially depends on the method of allocation and the reduction target.

Two general misconceptions have evolved about the European Emissions Trading Scheme (ETS):

- Emissions trading will certainly benefit the uptake of renewables
- Emissions trading places an additional cost burden on conventional power production

The ETS is an effective and potentially powerful tool to meet targets for emissions of greenhouse gasses. But its effects on the relative competitiveness between the various power technologies, specifically its relative effects on renewables and non-renewables, are not yet well understood.

In a conventional power market that is characterised by limited competition[29], a conventional power plant operator can gain considerable windfall profits from the EU emissions trading scheme. The reason is that price-fixing in the electricity markets are based on the marginal cost of production, i.e. the cost of the last produced kWh. The cost of an emission allowance will therefore apply to the marginal unit of electricity that sets the price on the market, raising the market price for all kWh produced. So fossil power producers will receive the higher price for each kWh they produce but the cost of buying CO_2 emission allowances will only apply to the very small share of total kWh's produced that are not allocated for free. With limited competition, power companies will be able to pass on the price increase at the margin for the total electricity supplied to consumers.

The higher electricity price is unlikely to have significant short-term effect on the wind power markets (at least those markets where wind turbine owners receive fixed tariffs), as these are sheltered from direct competition with conventional sources. In countries that run mechanisms based on fixed premiums, notably Spain, revenues to wind turbine owners could increase; however the political response would probably be an equal reduction in the environmental bonus, leaving renewable power producers unaffected by the price increase.

One analyst has estimated the windfall profits to European power generators of the ETS to be in the order of €11-12 billion per year, assuming the current relative low carbon prices. With higher prices, the profits are even greater. Pricewaterhouse Coopers, a consultanting company, has surveyed the largest European power producers. A large majority of these responded to the survey by stating that emissions trading will have a positive impact on the valuation of their company, in effect indicating a windfall profit.

But who stands to lose, if conventional power gains and renewable energy producers are left more or less unaffected? The losers are the electricity customers. Due to the limited competition in the wholesale power markets, they have to pay a high price for all the kWh they purchase, although the extra production costs for the power plant only apply to a very little share of total power produced.

29 See e.g. the European Commission's four annual Benchmarking Reports on the Implementation of the Gas and Electricity Internal Market. Fourth report: COM(2004) 863, January 2005.

In the longer term, as the quotas are tightened (and / or free allocation is replaced by auctioning of allowances), wind power and other renewable energy sources could benefit from an increased emissions allowance price and increased alternative abatement costs.

A more significant impact of emissions trading on minimal climate change-emission technologies (renewables and nuclear power) can be expected if the free allocation (grandfathering) method is replaced by 100% auctioning of allowances. That would also create less market distortions between technologies and between new and existing players.

Furthermore, it would remove all the potential competitive distortions resulting from determining the level of free allocation through National Allocation Plans in the Member States, which has characterised the start of the European Emissions Trading Scheme. However, 100% auctioning is unlikely in the short term. The Emissions Trading Directive states that for the period 2005-2007, Member States should allocate at least 95% of emission allowances for free. For the period 2008-2012, 90% of allowances shall be allocated for free.

Emissions trading can – if designed correctly - be a successful tool to reduce greenhouse gas emissions, but it does not serve the same purposes as policies to promote the development of renewable energy sources, and in its current form it works contrary to the overall aim of the Electricity Directive to provide consumers with the lowest possible power costs in order to increase European competitiveness.

5. Evaluation of support schemes

An ideal payment mechanism for development of renewable energy technologies is not by itself sufficient for an extensive deployment of renewable sources. Several other issues have also to be in place, which, if not implemented, means that even the best payment mechanism has little chance of success.

There are four main ingredients in a potentially effective overall promotion strategy for renewables:

1. Well designed payment mechanisms
2. Grid access and strategic development of grids
3. Appropriate administrative procedures and streamlined application processes
4. Public acceptance

Any framework for the development of renewable energy sources has to include the above four components. If one is missing, deployment of renewables will be severely restricted.

RE-Xpansion has focused primarily on the first component – the support scheme. In annex 1, the issue of grid integration is addressed. In the following sections the preconditions for the evaluation of the different support schemes will be discussed, as will the concept of the support scheme itself.

The analyses of support schemes carried out in this report are undertaken under the following preconditions:

- The use of support schemes is considered in the short to medium-term perspective as well as in the long-term perspective. However the harmonisation of RES-E support schemes would likely be a lengthy and complicated process, due to the great differences not only among Member State policy traditions, but also among their goals. Therefore, the evaluation criteria discussed in this paper focus mainly on the medium to long-term perspective.
- It is assumed that barriers such as lack of proper planning procedures, and problems associated with access to electricity grids, are tackled outside the framework of support schemes, and they will therefore be considered here. However, these issues are equally critical when creating well functioning framework conditions for renewable energy deployment.

The main objective of this chapter is especially to evaluate the various support schemes for RES-E that are already in use in the EU Member States, or could be brought into use in the future, based on feed-back from stakeholders. The report handles three main tasks in this part of the project:

1. Identification and discussion of criteria for evaluating support schemes. This part includes a description of each of the chosen criteria and a determination of the weights associated to each criterion based on a questionnaire among selected experts.
2. Definition of the most important generic support schemes and the development of an improved version of these generic schemes with the aim to illustrate the impact of mechanism design improvements. The chosen generic schemes include investment subsidies, feed-in tariffs, premiums, tendering systems and tradable green certificate systems. In the advanced versions, the generic schemes are developed / redesigned according to the flaws identified for each of the criteria.
3. Finally, to carry out a survey to evaluate the various generic and advanced support schemes utilising the expertise of a large number of experts within the energy and RES-E field. Therefore, as part of this project, an Internet-based survey was sent out to more than 500 persons for the purpose of getting their evaluation of the support schemes according to the defined criteria.

In the Internet-based background report[30], the results of the evaluation are presented and discussed.

5.1 Evaluation criteria

5.1.1 The EU Directive on renewables

According to the EU Directive (2001/77/EC) on the promotion of electricity produced from renewable energy sources, the European Commission shall, no later than October 2005, evaluate the support mechanisms used to promote renewable technologies in Member States. This evaluation will detail the successes, including cost-effectiveness, of the various

30 Available at www.ewea.org – "Evaluation of Renewables Support Schemes"

support systems and will, if necessary, be accompanied by a proposal for a community-wide framework for support schemes for RES-E. According to the Directive, any proposal for a framework should:

1. Contribute to the achievement of the national indicative targets;
2. Be compatible with the principles of the internal electricity market;
3. Take into account the characteristics of different sources of renewable energy, together with the different technologies, and geographical differences;
4. Promote the use of renewable energy sources in an effective way, and be as simple and, at the same time, as efficient as possible, particularly in terms of cost;
5. Include sufficient transitional periods for national support systems of at least seven years and maintain investor confidence.

The RES-E Directive is our starting point for the development of criteria for the evaluation of support schemes in this project. These criteria must not only include the above-mentioned requirements (1) to (5) as stated by the EU renewable directive, reflecting political consensus, but should also be open to other issues important from economic and policy standpoints, as well as from an investor confidence viewpoint, reflecting the discursive role of science vis-à-vis policy-making and industrial activity.

5.1.2 The evaluation criteria

With the starting point as the requirements listed in the EU Directive, a short proposal is given below for the criteria to be used to evaluate the support schemes. The list is intended to be comprehensive, while at the same time avoiding overlaps and maintaining simplicity.

The criteria are divided into ten categories:

1. Simple and transparent in design and implementation, implying low administration costs
2. High diversity of the technologies supported
3. High investor confidence
4. Encouraging lower manufacturing costs
5. Capable of reducing the price for power consumers
6. High effectiveness in deployment
7. High conformity with the power market and with other policy instruments
8. Facilitating a smooth transition process
9. Encouraging local and regional benefits
10. Increasing public acceptance of renewable technologies

In addition the mechanisms are evaluated with regards to their ability to internalise external costs, a central EU policy objective laid down in the EC Treaty.

In the following, each of the ten categories is described and discussed in more detail.

Simple and transparent in design and implementation, implying low administration costs

Some support schemes may in theory seem ideal, but in reality they may be costly and difficult to implement. Is the support scheme transparent and easy to understand making it reliable for investors? Is the scheme capable of keeping down the transaction costs for developers/investors, the sunk planning costs as well as the administrative costs of the public bodies?

- Is the functioning of the support scheme transparent and easy to understand, making it conducive for investors?
- Transaction costs for developers and investors (owners) should be kept low. Easy and transparent access to information on investment-related data is important, and the same goes for the operation and administration costs for existing plant.
- The costs for administration of the support scheme itself should be low, regardless of whether the scheme is managed by public authorities, system operators, private companies, independent agencies, or some combination. All administrative costs need to be considered, i.e., also those that arise from RE generators, electricity distributors or electricity consumers.

High diversity of the technologies supported

In general, the aim of the support schemes is to promote renewables in the broad context. The main argument for supporting renewable technologies is to develop these to a stage in the future where they no longer need support. It should never be considered a political goal to pick technology winners and losers, and the cheapest technology today is not necessarily the one that has the most potential for becoming the cheapest in the future. Nevertheless, different schemes and their variations may favour specific renewable technologies. This may not be in accordance with political priorities.

- What diversity of technologies is promoted?
- How is the lock in/lock out problem handled?
- Is the development of pre-market technologies an integral part of the support scheme, or is it to be treated outside the scheme?
- Does the support scheme allow sufficient consideration of differences in the social value of different technologies, for instance, differences in their positive or negative external effects?

High investor confidence

Investor confidence is a question of the level of support and the expected continuity of the scheme. Thus, is the support scheme capable of attracting a wide range of new investors to the field and does it possess a long-term stability that makes it trustworthy for the investors? How well does the scheme fit with the mobilisation of the entrepreneurial, organisational, and financial resources of society, and thereby support and enhance demand for RES-E? What level of risk to the investor is inherent under each scheme?

- Does the scheme attract a good range of manufacturers, developers and service providers, such as insurance companies and finance institutions into the field?
- Does the scheme possess long-term stability characteristics that makes it trustworthy for the investors?
- Is it possible to achieve an appropriate level of profitability of new renewable technologies as seen from the investor viewpoint?
- Risk as perceived by the investors – how much will be added as a risk premium? This risk can be further subdivided into a political, economical and technological risk – the importance of each of these will not only depend on the support scheme itself, but also on the technology in question (maturity). It should be recalled that high investor risk will be passed on to end consumers in the form of higher cost of increasing the share of renewables electricity.
- Risk as perceived by the financial institutions – how does the addition or reduction of risk through the support scheme affect the cost of capital?
- Is the support scheme institutionalised in a way that is legally stable and/or politically trustworthy from the viewpoint of investors? I.e. can it be overturned / altered easily after a change of government, significantly increasing political risk?
- Is the support scheme efficient in the mitigation of investor risk?

Encouraging lower manufacturing costs

It is important that the support scheme is efficient in driving down the costs incurred by all parties contributing to the development of RES-E plant, such as for manufacturers of equipment, component manufacturers, developers, land-owners, providers of ancillary equipment and services, etc. Promotion of competition is not only about creating a level playing field, but also about having a multitude of players. Thus, the important issues are:

- Does the scheme in general encourage competition among manufacturers and service providers?
- How well suited is the support scheme to the reduction of costs to manufacturers? This could be analysed to a degree through the study of RES-E price-trends, supplemented by observed price differences of the same technology among EU Member States depending on the support scheme in question.
- How fast and cheap can the support mechanism establish a “real” market?
- Should different support mechanisms be implemented at different levels of technological maturity?
- What impact does the support scheme have on the international competitiveness of the European RES-E industry?

Capable of reducing the price for power consumers

Although a scheme may in general be efficient in driving down the costs of renewable technologies, such benefits may not necessarily be passed on to power consumers. Undesirable distributional effects between different groups in society might arise:

- Does the scheme possess a strong ability to pass on lower technology costs to the consumers?
- Who will benefit economically and who will lose when one support scheme is utilised over another, and are such distributional effects acceptable for society?
- Does the support scheme include a fiscal burden, i.e., costs that need to be covered by taxes? Or is it independent of the state budget? Are there risks related to the development that is cheaper for society as a whole to bear than for individual project developers.

High effectiveness in deployment

The essential issue is how fast and how effectively does the scheme promote the development and deployment of RES-E. This can be measured quantita-

tively for existing schemes - as we have seen up to the present, feed-in tariff schemes have been very effective in the installation of wind power capacity (Germany, Spain, Denmark), while the initial tendering system in the UK (not continued) proved to be less effective in this regard. Therefore, it is important, when analysing the success or failure of existing or past systems, to establish whether factors not directly covered through a support scheme have influenced the outcome. For example, it is widely recognised that planning procedures, rather than the tendering procedure itself, was a main determining factor of failure in the former UK renewable deployment framework NFFO, and that the original scheme was a chance outcome of a policy to assist nuclear power. RES-E deployment also depends on a number of other criteria, such as the efficiency of the scheme in attracting entrepreneurs and developers.

- Experience until now – where have we seen a fast development of renewables and which mechanisms have been used?
- The support mechanism should encourage efficient, low cost production of renewable energy, not only capacity expansion.
- Does the support scheme promote a particular geographical pattern of RES-E production? Economic and non-economic advantages or disadvantages of this.

High conformity with the power market and with other policy instruments

Through the adoption of the EU Electricity Directive, the EU Member States are in a process of liberalising their power markets and of having new policies, such as emission trading and other Kyoto instruments. Some countries already have fully liberalised power markets including power exchanges, while others are still in transition. Thus, it becomes increasingly important to consider how well a support scheme for renewables fits into a liberalised power market and the eventual development of real competition in the European power markets. Moreover, positive and/or negative synergisms may arise between the support scheme and other existing or planned EU or Member State policy instruments. As is well known, the use of an International Certificate Scheme for renewables may interfere with national strategies for CO_2–reduction and international trading of CO_2 allowances. Similar effects may also be found in the use of other policy instruments. Moreover, a support scheme may interfere with the general efficiency of the energy system, including the use of specific energy conversion technologies, e.g., CHP plants utilising biomass. The following issues should be addressed:

- Does the support scheme encourage competition among producers of electricity?
- Does the support scheme have any impact upon (or make specific demands upon) the technical functionality of the power system within a liberalised power market?
- Does the support system significantly influence the price-determination of the power market, and is this influence beneficial or detrimental? The conditions for the support system may influence how a liberalised power market can "absorb" the quantities of produced renewable power.
- Will the support scheme integrate easily with the EU-wide CO_2 trading scheme?
- How does the support scheme impact on energy efficiency? What impact does the support scheme have on conversion efficiency (mainly in the bio-energy sector) and combined heat and power production?
- What impact does the support scheme have on the general energy system? Does it favour RES solutions that fit well into the energy system, or does it promote less optimal solutions (e.g. issues such as intermittence, power quality, dispatchability)?.
- Does the scheme promote efficient use of grids for electricity, heat and gas transmission and distribution? Or are grid resources regarded as free goods / natural monopolies?
- Does the support scheme fit well with the aim of strengthening the single market (not just the electricity market, but markets for technology, services, labour and capital)?

Facilitating a smooth transition process

- There will be occasions when a new scheme replaces one already in place, and the transition phase between the two is important.
- Is the transition to a new scheme likely to be a simple or complex matter?
- What will be the duration of the transition period?
- Will the transition period have significant impact on the credibility of the old scheme or its replacement?

Encouraging local and regional benefits

The development of renewable technologies can have significant impact on the local or region where it is implemented. Local / regional benefits may be felt,

especially for industrial development, increased employment and local income generation. If such benefits accrue to less developed regions in need of preferential treatment, this would provide an example of a positive synergy between RES-E policy and EU regional policy. Furthermore, positive local effects can provide important public support for the renewable energy policy itself.

- Does the support scheme encourage local/regional development and employment?
- Does the support scheme support local/regional income generation?

Increasing public acceptance of renewable technologies

Some support schemes involve public involvement that may hinder or facilitate the acceptance of renewable technologies. Such involvements may be of a local nature, as in the example of Danish special conditions for co-operatives establishing wind power plants. Others may be more general, e.g., perceived impact of wind power on bird populations.

- Does the scheme itself contain elements that promote or discourage the public acceptance of renewables?
- Does the scheme have impact on the creation of user organisations or other forms of stakeholder involvement?

5.1.3 The weights of each criterion

The relative importance of the ten criteria has been derived through an electronic questionnaire circulated to industry experts[31]. The sum of the weights adds up to 100. Thus the average weight is 10 and the relative importance of each criterion can be assessed by observing if the average is above or below a score (i.e. a mark) of 10. To assess the answers in the questionnaires, the average values and standard deviations of the marks are calculated, where the last-mentioned values (in columns 4 and 5) indicate the variation of marks for that question. Thus a low standard deviation implies that the respondents have agreed well on the importance of a criterion, while a high standard deviation implies a wide spread of answers. Moreover, the maximum and minimum values of marks are shown in Table 5.1.

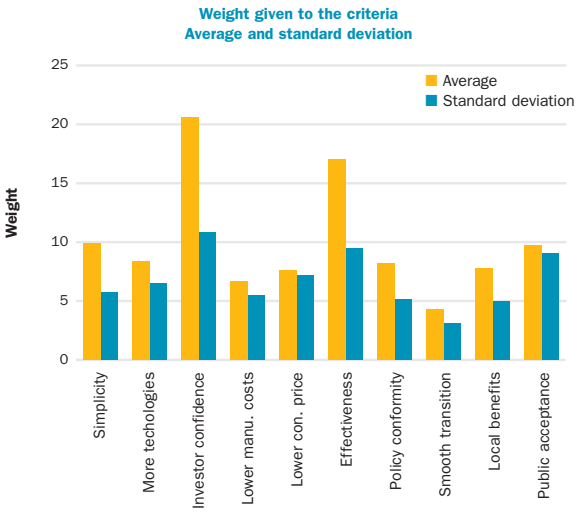
Table 5.1

The main results of the questionnaire

	Average mark	Standard deviation	Std. Dev. (% of mark)	Max mark	Min mark
Simplicity	9.9	5.75	58.3	20	0
Diversity of technologies	8.4	6.50	77.6	30	0
Investor confidence	20.6	10.84	52.7	50	0
Lower manufacturing costs	6.7	5.51	82.6	20	0
Lower consumer price	7.6	7.15	93.9	30	0
Effectiveness	17.0	9.50	56.0	40	0
Policy conformity	8.2	5.15	62.9	16	0
Smooth transition	4.3	3.10	72.3	10	0
Local benefits	7.8	4.96	63.9	18	0
Public acceptance	9.7	9.05	93.1	40	0
Total	100	-	-	-	-

Figure 5.1

Average and standard deviations calculated for the answers of the questionnaire



Two criteria come out with significant higher scores than the other criteria. Investor confidence comes out with the highest score of almost 21, more than double of the average score. As shown in Figure 5.1, Investor confidence also has a fairly small standard deviation, implying that the respondents have a reasonable agreement of this subject. The second highest score is gained by Effectiveness with a relative importance of 17 and as for Investor confidence a fairly small standard deviation. That these two criteria both come out with high scores is even more noticeable, given that respondents could perceive effectiveness as being a function of investor confidence.

31 For full details see RE-Xpansion background report "Evaluation of Renewables Support Schemes"

A large group of criteria comes out at almost the same level ranging from approximately 7 to 10. This group include Simplicity (9.9), Public acceptance (9.7), More technologies (8.4), Policy conformity (8.2), Local benefits (7.8), Lower consumer prices (7.6) and Lower manufacturing costs (6.7). As shown in Table 5.1, high standard deviations are calculated especially for Lower consumer prices and Public acceptance, indicating that the respondents have given quite different answers to these criteria. But also concerning the inclusion of More technologies in the support scheme and Lower manufacturing costs fairly high standard deviations are calculated, indicating a certain disagreement on the importance of these topics. Finally, as the only criteria a Smooth transition process is considered to be of less importance (a score of 4.7) when evaluating the different renewable support systems.

The scores achieved in this questionnaire will be used as the relative weights (indicating their relative importance according to the respondents) when calculating the average scores in the following evaluation of the various generic and advanced support schemes.

5.2 The generic and improved support schemes

As there are wide differences between the design of individual mechanisms, even between mechanisms of the same type, a number of generic and improved (or advanced) support schemes have been defined, which should be evaluated against the criteria defined in section 5.1.2. The definitions of the mechanisms have been chosen, partly to reflect actual schemes and partly to allow us to show some of the theoretical justifications for designing mechanisms in a particular way to better meet the overall criteria. When moving from the generic to the advanced mechanisms the mechanisms should improve in overall performance. However, moving from a generic to an advanced mechanism does not necessarily improve a mechanism's performance on all criteria, e.g. the advanced models tend to be less simple than the generic ones and one would therefore expect these to obtain lower scores on the simplicity criteria.

The definitions of the five generic and five improved support schemes are shown below. For a more detailed elaboration on the assumptions for the defined support schemes, see the Internet based RE-Xpansion report "Evaluation of Renewables Support Schemes".

Table 5.2

Generic and advanced support schemes

Investment subsidies	
Generic	**Advanced**
The current level of support is known up front. Support is defined as a % of the approved investment costs.	Level and duration of support for new installations for the coming five years is announced.
Future price of electricity unknown (spot price known).	Power purchase agreements (PPAs) of maximum three years are available. (Ideally the PPAs should be at least ten years, but this is considered unrealistic to achieve in the short to medium term in all European power markets).
The level of support is the same for each technology and reflects the cost of the cheapest technology.	Support level varies between technologies, reflecting differences in cost structures.
The investment subsidies are paid by the electricity consumer as a levy within power bills.	

Fixed feed-in tariffs	
Generic	**Advanced**
Only Current tariff known, i.e. future changes in level unknown.	Tariffs guaranteed for existing capacity for period sufficient to recover investment (10-20 years depending on technology and the level of the tariff).
Duration unknown.	Tariffs can be changed, reflecting changes in cost structures, but new tariffs only apply to new investments.
The tariff is the same for each technology and reflects the cost of the cheapest technology.	Support level varies between technologies, reflecting differences in cost structures.
The tariff is paid by the electricity consumers.	Tariffs vary according to resource availability on sites (stepped feed-in tariff). The tariff is structured so that it is still more profitable to put turbines in the most resource rich areas.

Fixed premium systems	
Generic	**Advanced**
Only current premium known, i.e. future changes in level unknown.	Premium guaranteed for existing capacity for period sufficient to recover investment (10-20 years depending on technology and the level of the premium).
Duration unknown.	Premium can be changed, reflecting changes in cost structures, but new premiums only apply to new investments.
Future prices of electricity unknown (spot price known).	Premium level varies between technologies, reflecting differences in cost structures.
The premium is the same for each technology and reflects the cost of the cheapest technology.	Premium level does not vary according to resource availability.
The premium is paid by the electricity consumers.	Power purchase agreements (PPAs) of up to three years available. (Ideally the PPAs should be at least ten years, but this is considered unrealistic to achieve in the short to medium term in all European power markets).

Tendering systems	
Generic	**Advanced**
The level of support is known up front by the winner of the tender.	The tender is based on an auction over the lowest 15-year Power Purchase Agreement (PPA).
Future prices of electricity unknown.	Deadlines and meaningful penalties for exceeding deadlines.
No technology banding, i.e. the renewable energy technology is not specified in the tender.	Technology banding introduced, i.e. different tenders are announced for each renewable technology.
No penalties / performance bonds.	
No deadlines for construction.	
Is it based on an auction over lowest premium / kWh for 15 years above an unknown future market price for electricity.	
The premium is paid by the electricity consumers as a levy within power bills.	

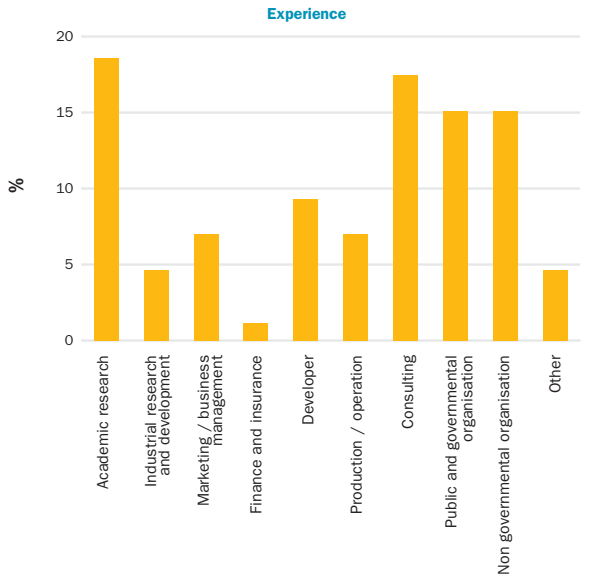
Tradable green certificate systems	
Generic	**Advanced**
Future electricity prices unknown (spot price known).	Power purchase agreements (PPAs) of up to three years available. (Ideally the PPAs should be at least ten years, but this is considered unrealistic to achieve in the short to medium term in all European power markets).
Future certificate prices unknown (spot price known).	Contracts on certificates of up to three years available. (Ideally the certificate contracts for at least ten years should be available, but this is considered even more unrealistic to achieve than for PPAs in the short to medium term in all European power markets).
Duration of scheme unknown.	Long-term (at least 20 years) mandatory targets known.
Mandatory targets setting a gradually increasing quota.	Duration of scheme known.
Penalties for non-compliance.	Gradually increasing quota.
No price cap or floor on certificates.	Technology differentiation.
No technology differentiation.	
The certificate is paid by the electricity consumers.	

5.3 Results of the survey evaluating support schemes

To evaluate the generic and the advanced support schemes, as defined in section 5.1.2, a survey was carried out in the period 17 January to 7 February 2005, reaching a large number of people with knowledge within the energy field[32]. Figure 5.2 shows the respondents'occupation.

Figure 5.2

Respondent's occupation



In the following, the results of the unweighted as well as the weighted ratings (see section 5.1.3) are given. The unweighted averages are as calculated directly on the answers given in this survey. For calculating the weighted averages the weights from section 5.1.3 for each criterion are used.

The RE-XPANSION survey comprised two versions of five types of support mechanisms: Investment Subsidies, Fixed Feed-in Tariffs, Fixed Premiums, Tendering and Tradable Green Certificates.

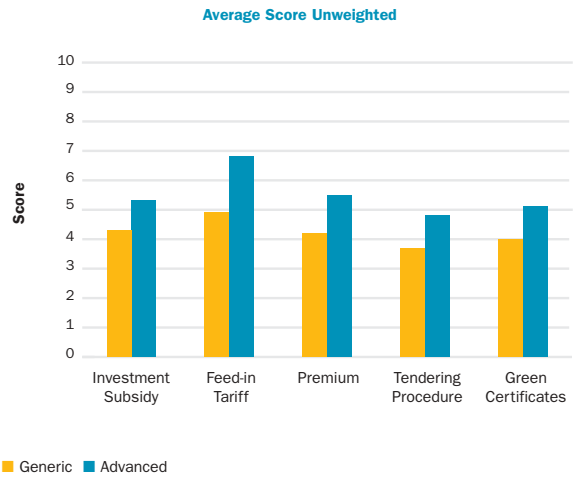
For each support scheme – both the generic and the advanced – the respondents were asked to award a score to 10 different criteria (see section 5.1.2). Zero was the lowest score and ten the highest.

32 See Internet-based background report

5.3.1 Unweighted scores of support mechanisms

Figure 5.3

Average scores for each of the five support schemes in a generic and an advanced version



The average scores calculated on the responses given in the survey for each of the evaluated support schemes are illustrated in Figure 5.3. As shown in the figure, the Feed-in tariff received the highest score, both for the generic scheme and for the advanced scheme. In the generic version, the Feed-in Tariff scored 4.9, compared to a score of 6.8 in the advanced version. As shown on the figure, the Feed-in Tariff is well ahead of the other support mechanisms. For the generic scheme, the Investment Subsidy ranks second, marginally higher then the Premium scheme, while the opposite is the case for the advanced scheme. Finally, the Green Certificate system ranks four for both versions, while the Tendering Procedure gets the lowest scores.

As could be expected, the average unweighted scores for each of the 2 x 5 support schemes is in general higher for the advanced scheme than for the generic one, but the scores follow the same trend. The largest gap between the generic and the advanced version appears for the Feed-in-Tariff, where the score for the advanced version is 6.8 vs. a score for the generic one of 4.9. Thus the design changes considerably improve the Feed-in Tariff, according to the respondents. Tendering Procedure gets the lowest score with 3.7 in the generic version and 4.8 in the advanced version.

5.3.2 Average weighted scores

In the above-mentioned calculations, each criterion gets the same weight, but of course this need not be so. The importance of each criterion was therefore investigated in a questionnaire, as reported above. The outcome of this questionnaire is repeated in Table 5.3, where the determined weight of each criterion is shown in the first column and the standard deviation in the second.

Table 5.3

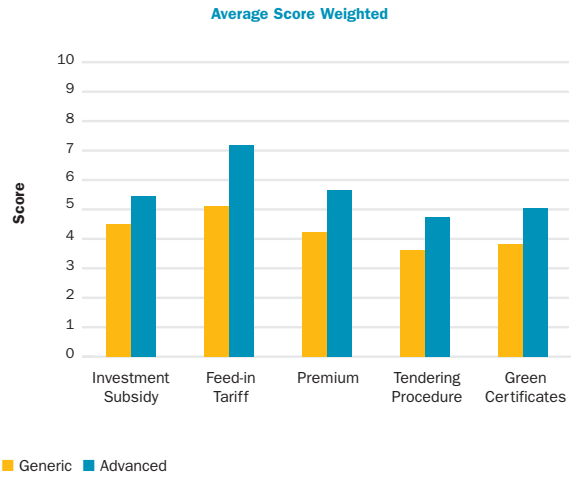
The main results of the questionnaire

	Average weight	Standard Deviation (%)
Simplicity	9.9	58.3
Diversity of technologies	8.4	77.6
Investor confidence	20.6	52.7
Lower manufacturing costs	6.7	82.6
Lower consumer price	7.6	93.9
Effectiveness	17.0	56.0
Policy conformity	8.2	62.9
Smooth transition	4.3	72.3
Local benefits	7.8	63.9
Public acceptance	9.7	93.1
Total	100	-

As shown in Table 5.3, the Investor confidence criterion is the most important issue with the highest weight of 20.6, while the lowest weight is related to the Smooth Transition criterion, which gets a weight of 4.3. These weights are now used in the calculation of the weighted average scores for each of the 2 x 5 support scheme versions. The results are shown in Figure 5.4. This will give an indication of the overall performance of the mechanisms as perceived by the respondents.

Figure 5.4

Average weighted scores for each of the five support schemes in a generic and an advanced version



As it appears on Figure 5.4, the use of the weighted criteria does not change the ranking of the support schemes much. Again the Feed-in Tariff has the highest score, both for the generic version and for the advanced one. The Investment Subsidy ranks two in the generic version, followed by the Premium scheme, however these two change place in the advanced version. However, only marginal differences are found between the scores of the Investment Subsidy and the Premium scheme. The Green Certificates ranks four and the Tendering Procedure has the lowest score of all.

In general, most of the average weighted scores are slightly higher than the average unweighted ones. For the Feed-in-Tariff, the average weighted score in the generic version is 5.1 compared with 4.9 in the unweighted calculation. Correspondingly, the average weighted score in the advanced version is 7.2, compared to 6.8 in the unweighted calculation. The exception is the Green Certificate system that comes out with marginal lower scores in the weighted calculations.

5.4 Detailed survey results

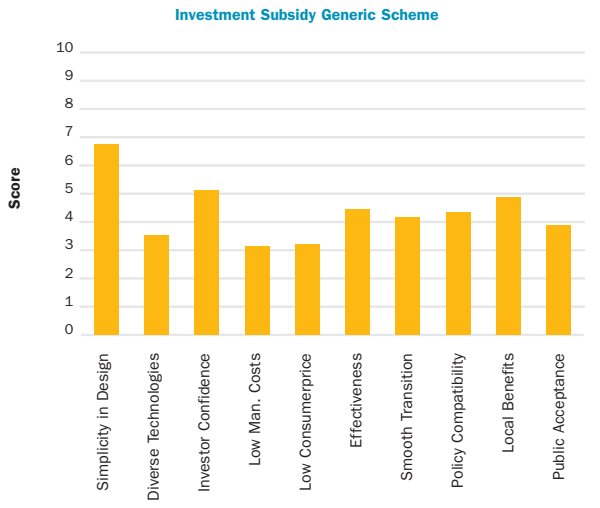
In the following, the scores of each criterion for each support scheme is described and commented on in more detail.

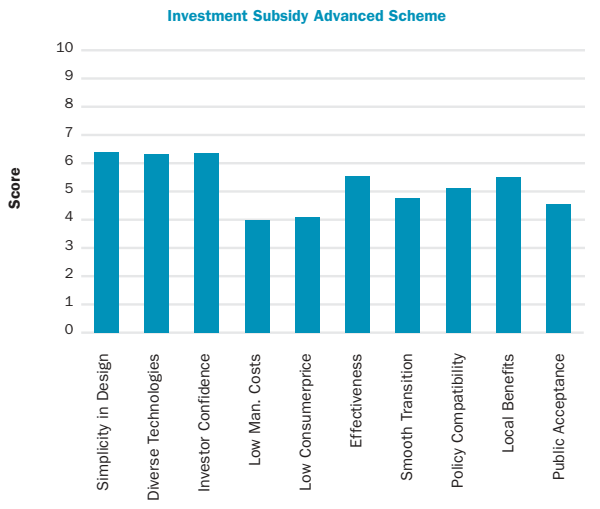
5.4.1 Investment subsidy

For the Investment Subsidy scheme there appears to be quite a difference in the scoring for the generic and the advanced versions as shown on Figure 5.5.

Figure 5.5

Detailed results for the evaluation of investment subsidies in the generic and advanced version





As shown, the advanced version does improve the score according to most criteria, but not to all. For the Simplicity in Design, the generic version scores higher, the advanced version being evaluated to be more complicated than the generic one. In general there are improvements to be found when going from the generic to the advanced version. Significant higher scores are achieved by the advanced version for Diverse Technologies and Investor Confidence The first-mentioned one has a score of 3.5 in the generic version, compared to 6.3 in the advanced one, implying that the advanced version is doing much better in supporting a broad range of renewable technologies. The score of Investor Confidence is raised from 5.1 to 6.4, when going from the generic to the advanced version.

The comments given in the survey to the various criteria focus on:

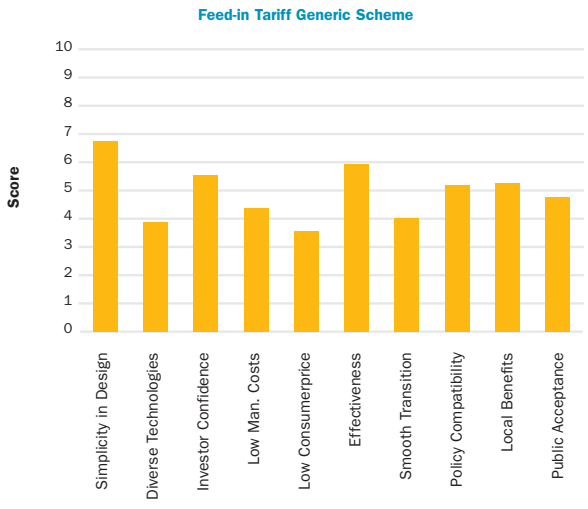
- Regarding Investor confidence, it will depend on the level and timeframe of the subsidy.
- Regarding Manufacturing costs, there will be no effect as the subsidy only will reduce up-front costs. This also goes for Reducing price for consumer.
- Regarding Effectiveness, an investment subsidy is considered a good kick-off mechanism, but again it will depend on the level of the subsidy and the enforcement mechanisms.
- Regarding the Conformity with the power market, it should be coordinated with other policies to give optimal price signals.
- Regarding a Smooth transition, it depends on annual adjustments.
- Regarding Local benefits, its effect depends on local potentials, costs and amount of specific support.

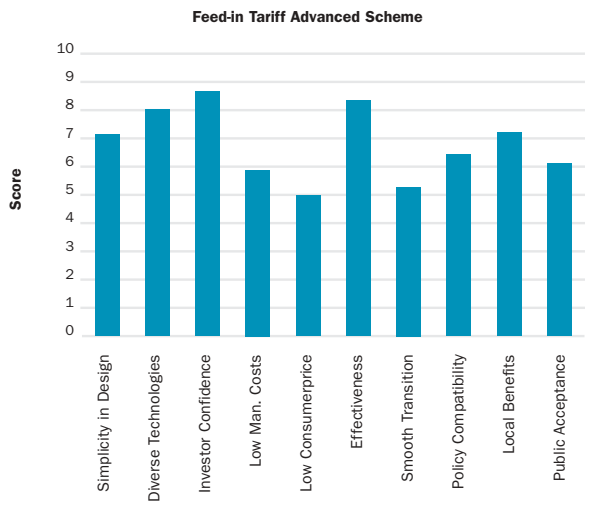
5.4.2 Feed-in tariff

Also for the Feed-in Tariff there appears to be quite a big difference in the scoring for the generic and the advanced versions, as shown on Figure 5.6, indicating the desire for an improved design.

Figure 5.6

Detailed results for the evaluation of a feed-in tariff in the generic and advanced version





For all criteria, a higher score is achieved in the Feed-in Tariff when going from the generic version to the advanced one. Simplicity in Design gets the highest score in the Generic scheme (6.8), while this criterion only gets a slightly higher score in the advanced version (7.1). But significant higher scores are seen in the advanced version in a number of cases: For the ability to handle support to a broad range of technologies (Diverse Technologies), the score is increased from 3.9 in the generic version to 8.0. For Investor Confidence, it is increased from 5.5 (already high in the generic version) to 8.7 and, finally, for Effectiveness it is increased from 5.9 (also very high) to 8.4.

Thus according to all criteria, the Feed-in Tariff actually achieves reasonably high scores both in the generic and the advanced version, with the only exceptions being the Diversification of Technologies and the Lower Consumer Costs for the generic version.

Comments given in the survey to this support mechanism focus on:

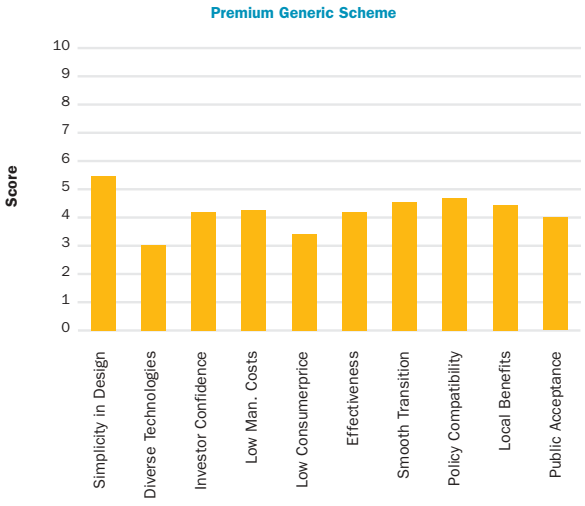
- Regarding Diverse technologies, it would require different tariffs to different technologies.
- Regarding Investor confidence, this support scheme is essential for technologies not that close to the market.
- Regarding Manufacturing costs, it will depend on an effective digression rate.
- Regarding Low consumer price, fixed tariff does not by definition create lower prices.
- Regarding Effectiveness, empirical evidence in countries such as Germany, Spain and Denmark show that the Feed-in Tariff is effective.
- Regarding Conformity with power market, it creates a parallel market for renewables.
- Regarding a Smooth transition, it helps to start up the market and should be revised regularly.
- Regarding Local benefits, there is no direct benefit, but depends on the ownership of the installations.

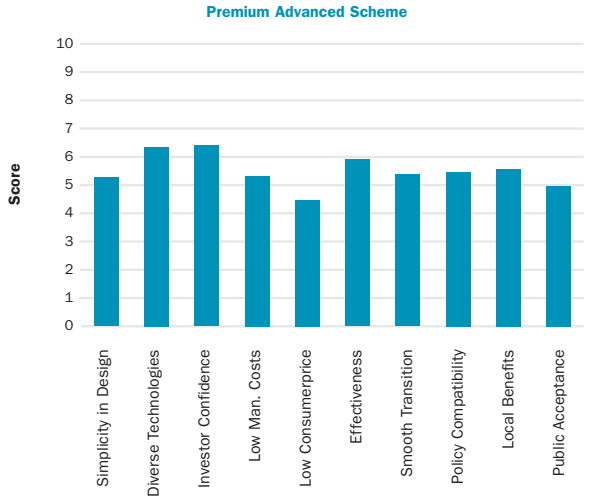
5.4.3 Premium

The Premium support scheme shows for most criteria fairly small variations. For the generic scheme, Simplicity in Design gets the highest score with 5.4, while this criterion gets a slightly lower score in the advanced scheme. But according to all other criteria the scores are higher when going from the generic version to the advanced one. Significant improvements are found for the Diverse Technologies criterion, where the score is increased from 3.0 in the generic version to 6.4 in the advanced one, and for Investor Confidence, where the score is raised from 4.2 to 6.4, see Figure 5.7 for more details.

Figure 5.7

Detailed results for the evaluation of a fixed premium scheme in the generic and advanced version





Comments given in the survey to this scheme concern:

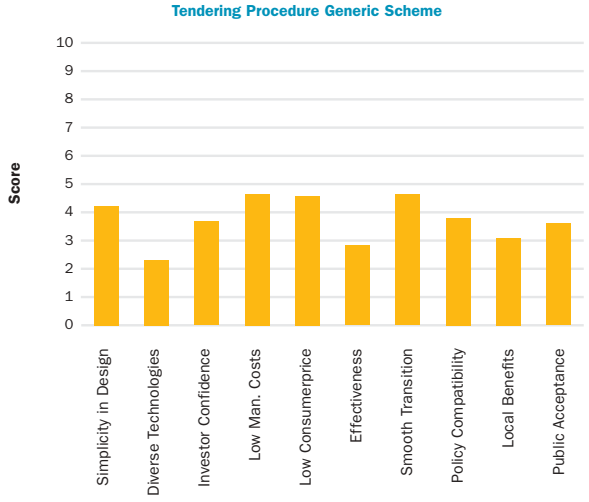
- Regarding Simplicity in design, it is more complicated than fixed tariff systems.
- Regarding diverse technologies, Premiums should be differentiated.
- Regarding Investor confidence, it gives less confidence than fixed tariff systems.
- Regarding Effectiveness, it depends on the level of the premium.
- Regarding the Smooth transition, it will also depend on the frequency in changing the premium.
- Regarding Local benefits, it is closely related to local investments.

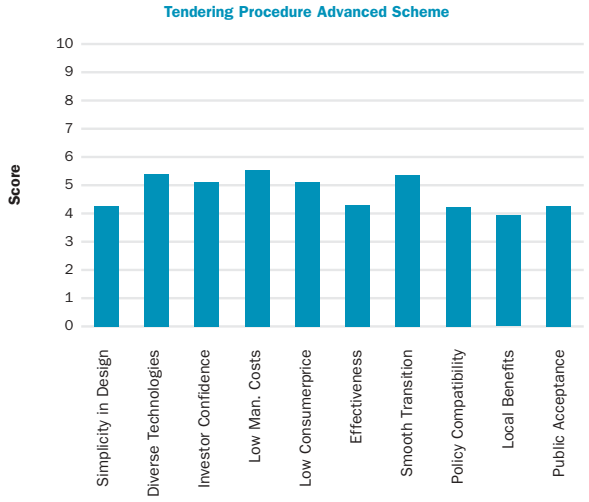
5.4.4 Tendering procedure

The support scheme of the Tendering procedure gets the lowest score of all support schemes and only moderate higher scores are achieved, when going from the generic version to the advanced one. The results are illustrated in Figure 5.8.

Figure 5.8

Detailed results for the evaluation of a tendering procedure in the generic and advanced version





The largest increase in score when moving from the generic to the advanced version is achieved in relation to the ability to support a broad range of renewable technologies (Diverse Technologies) and Effectiveness. For the first-mentioned, the generic version gets a score of only 2.3, which is increased to 5.4 when an advanced version is adopted. Effectiveness also comes out with a very low score in the generic version of 2.8, which is raised to 4.3 in the advanced version – though this is still a low score compared to other support mechanisms. But also Investor Confidence is increased quite a bit, from 3.7 in the generic version to 5.1 in the advanced one.

Comments from the survey to the Tendering procedure focus on:

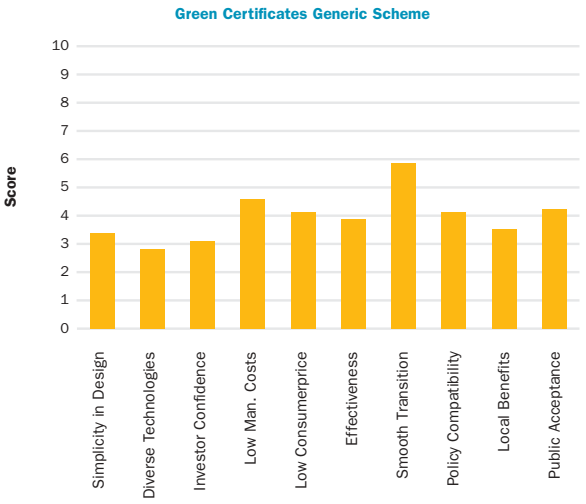
- Tendering systems require strong efforts, and simplicity in design is especially important for a transparent and mature market.
- Regarding Investor confidence, the duration of PPAs is usually approx. 20 years in advanced tendering systems.
- Regarding Effectiveness, it depends on level of penalties and enforcement mechanisms. And anyhow, it has not worked anywhere for wind energy.
- Regarding a Smooth transition, tenders have to be large to be manageable.
- Regarding Local benefits, local investors are usually excluded and local authorities are not involved as producers.

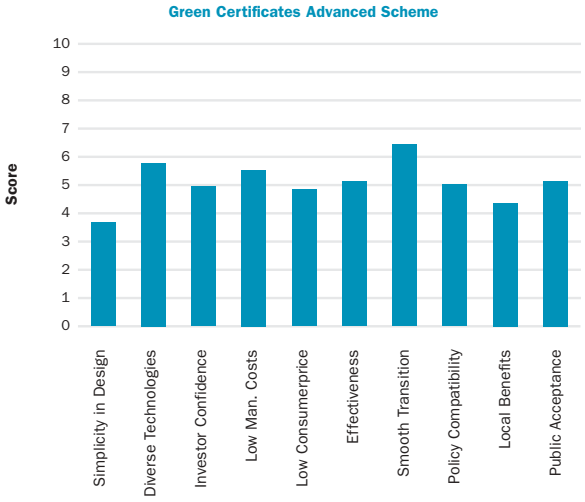
5.4.5 Green certificates

According to the survey, Green Certificate Schemes are perceived to be high cost and inefficient mechanisms. For the Green certificates, the generic and the advanced scheme have quite some differences in the scoring pattern, as illustrated in Figure 5.9.

Figure 5.9

Detailed results for the evaluation of a green certificate scheme in the generic and advanced version





The generic scheme for Green Certificates comes out with very low scores for the criteria on Simplicity in Design (3.4), the ability to support several technologies (2.8 for Diverse Technologies) and Investor Confidence (3.1).

For all criteria we find higher scores when going from the generic scheme to the advanced one. This is especially significant for criteria such as Diverse Technologies, where the score is increased from 2.8 in the generic version to 5.8 in the advanced one, Investor Confidence the score increasing from 3.1 to 5.0 and finally, Effectiveness, where the score increases from 3.9 to 5.1, when going from a generic scheme to an advanced one.

Nevertheless, even in the advanced version of the Green Certificate system low scores are found for the two most important criteria, Effectiveness and Investor Confidence, when compared to other support mechanisms. For Effectiveness the Green Certificate system ranks as number four with a score of 5.1, compared to Feed-in Tariffs with a score of 8.4. Only a Tendering Scheme scores lower than Green Certificates for effectiveness. For Investor Confidence the Green Certificates gets the lowest score of all, only 5.0 compared to the Feed-in Tariffs score of 8.7.

Though, for the criterion on Smooth Transition Green Certificates has the highest score of all, 6.4 compared to the second highest score of 5.4 for Tendering Procedures. In the survey, the score of Green Certificates Lowering manufacturing costs is not outstanding, in general at the same level as Feed-in Tariffs, Tendering Procedures and Premium Tariffs.

Comments given in the survey to this scheme focus on:

- Regarding Simplicity in design, it should ideally be launched on a European market.
- Regarding diverse technologies, it depends on technology differentiation and level of application.
- Regarding Investor confidence, it is less effective than feed in tariff and premium.
- Regarding Effectiveness, it may be effective if well designed.
- Regarding a smooth transition, it is even more facilitated if there are minimum prices for green certificates.
- Regarding Public acceptance, this depends mainly on other factors.

5.5 Variability of results

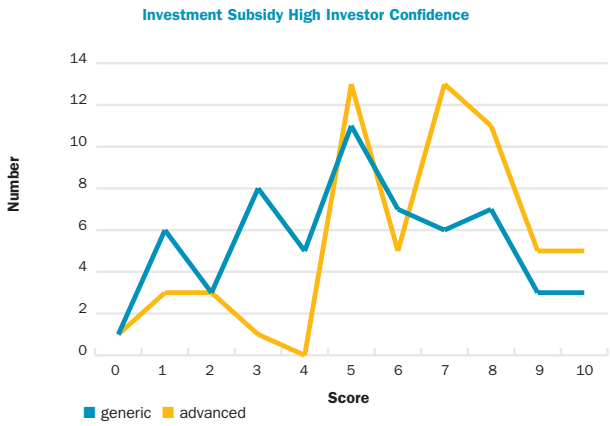
In this section we will illustrate the uncertainty of the results of the survey. For all support schemes and criteria we have found a considerable variability of results, although of course this variability depends on the individual criterion and support scheme. In the following, the variability of the most important criteria, that is Investor Confidence and Effectiveness, will be described in more detail.

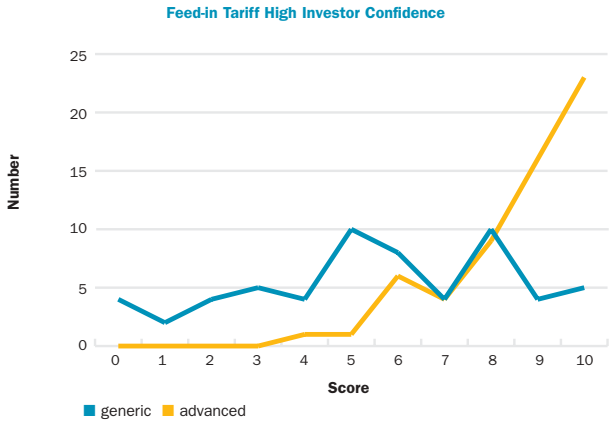
Figure 5.10 shows how the responses on the criterion Investor Confidence are distributed on the different scores from zero to ten.

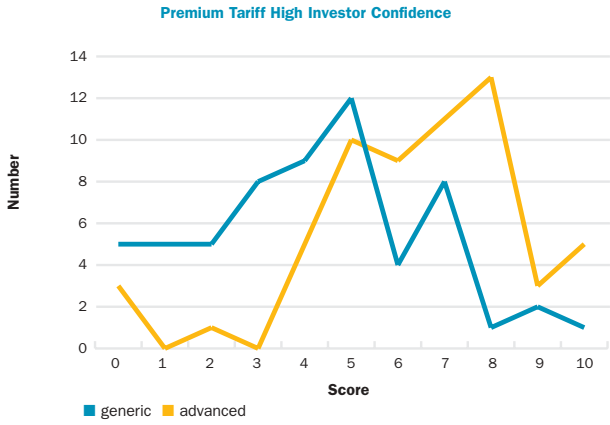
In general we see a spread in the responses; all schemes having scores ranging from zero to ten. But a general tendency is that the scores are pushed to higher levels (the curves are pushed to the left), when going from generic to advanced versions. Thus for Investment Subsidies, we find that the bulk of marks are around five in the generic version, pushed towards higher scores in the advanced version, where most marks are distributed around five, seven and eight. Thus we do only see quite few responses at the low score levels in the advanced version. But still there is quite some variability, though the standard deviation goes down from 51% for the responses of the generic version to 38% in the advanced version[33].

Figure 5.10

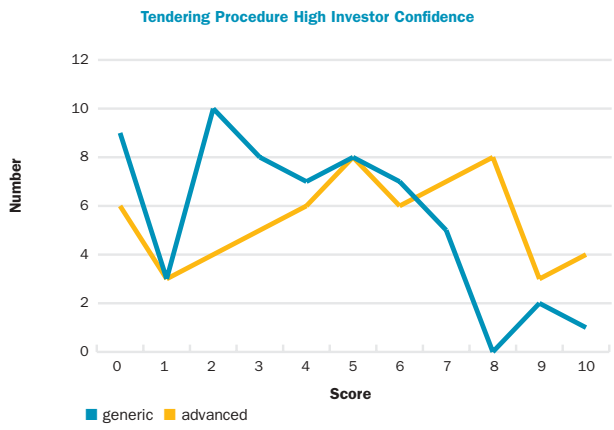
How the responses on Investor Confidence are distributed on scores for each of the support schemes. Observe the different y-axes

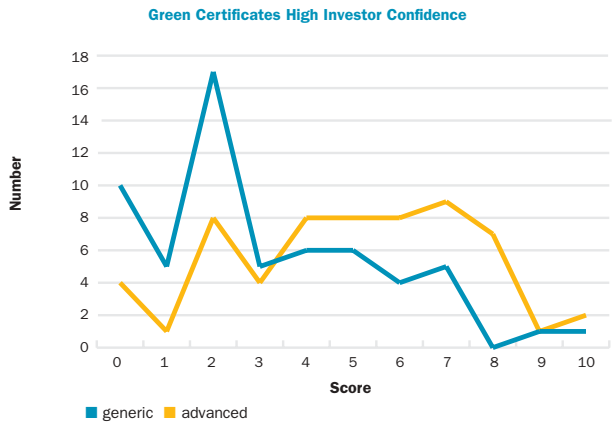






33 The lower the value, the less the responses vary



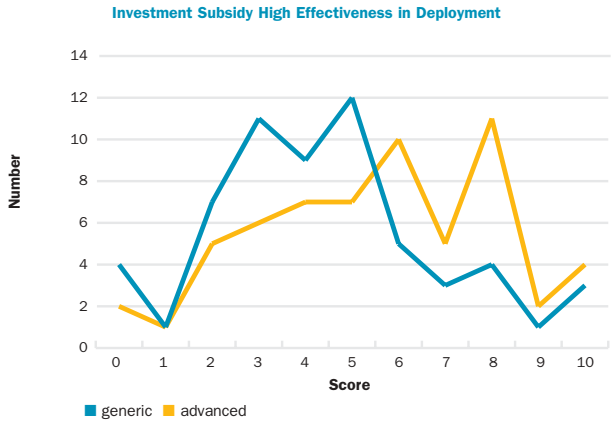


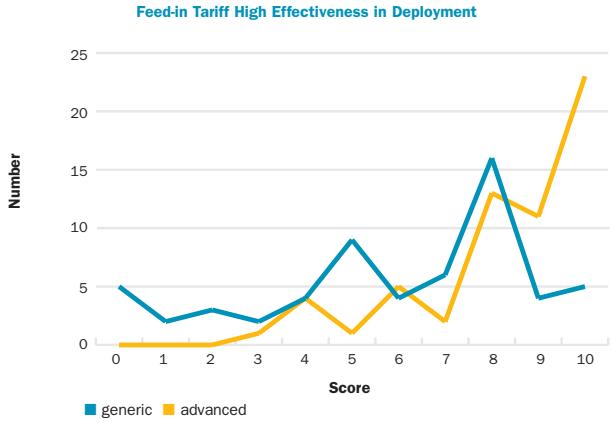
So in most cases, considerable variability is found in the responses. The highest standard deviation is found for Green Certificates of almost 80% in the generic version, reduced to 51% in the advanced one. The Premium Tariff has in the generic version a standard-deviation of 58%, reduced to 35% in the advanced version, while a Tendering Procedure in the generic version has 68% and in the advanced one 57%.

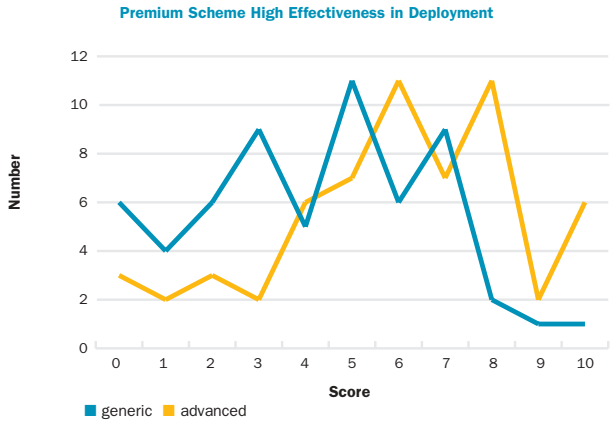
There is one outstanding exception in the variance of results: The Feed-in Tariff in its advanced version has no marks at the lower score levels of zero, one and two, and a very limited number at three, four and five. Almost 40% of all responses rate the advanced Feed-in Tariff to the highest score of ten. The standard deviation of responses of the Investor Confidence criterion is reduced from approximately 50% in the generic version to less than 20% in the advanced one. So in general, the respondents agree significantly on the superiority of the Feed-in Tariff for Investor Confidence.

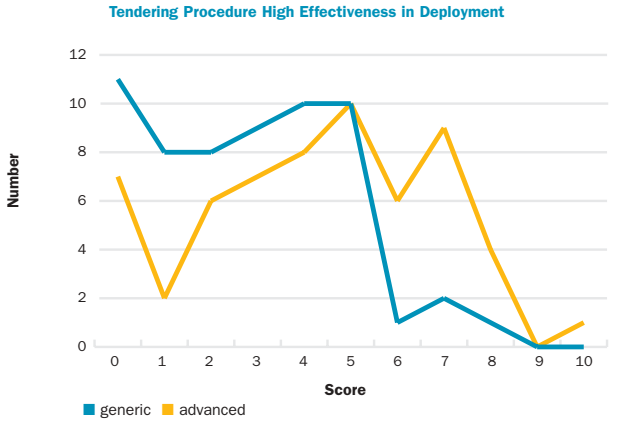
Figure 5.11

How the responses on Effectiveness are distributed on scores for each of the support schemes









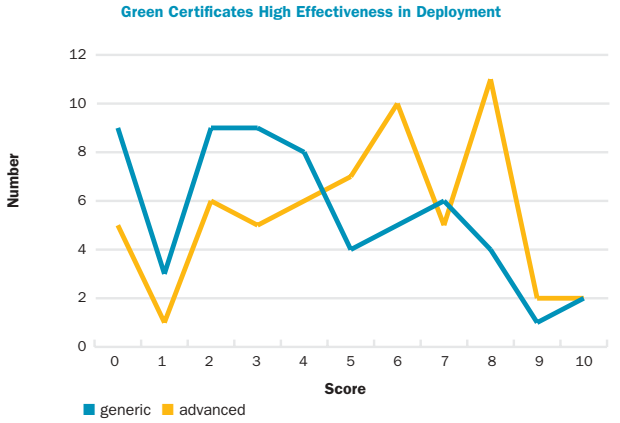


Figure 5.11 shows how the responses on the criterion Effectiveness are distributed on the different scores from zero to ten. Again almost the same picture is seen, as for the Investor Confidence criterion. There is a high spread on the responses for Investment Subsidies, Premium Tariff and Green Certificates with standard-deviations of 56%, 60% and 71%, respectively for the generic version, reduced to 45%, 45% and 53%, respectively in the advanced versions.

The Feed-in Tariff is again exceptional, with no responses at the zero and one score levels and a high number of the nine and ten score levels for the advanced version. The standard deviation for the Feed-in Tariff is calculated to 50% in the generic version and reduced to 23% in the advanced one.

For effectiveness, the Tendering Procedure comes out with very low scores both in the generic version and in the advanced one. In the generic version Tendering has no nine or ten level scores and even in the advanced version only one ten is scored. The standard deviation for the Tendering Scheme is calculated to 74% in the generic version and reduced to 58% in the advanced one. Thus, although there is a significant spread of the responses, in general the respondents agree that the Tendering Scheme is not very effective in the deployment of renewable technologies.

In general, a significant spread is found on the responses to the other criteria of the survey, with the tendency of reducing the variance when going from a generic to an advanced scheme. No specific outstanding results are found on the variability of the responses of the other criteria.

5.6 Conclusions on the survey

This section describes three main tasks:

1. Identification and discussion of criteria for evaluating support schemes.
2. Definition of the most important generic support schemes (e.g. Feed-in Tariff) and development of an improved version of these generic schemes.
3. The survey to evaluate the various support schemes, utilising the expertise of a large number of experts within the energy and RES-E field.

In the following, conclusions are drawn on each of these tasks specifically.

Criteria for evaluating support schemes

In the project, ten criteria were identified and defined as the important ones in evaluating support schemes. The list of criteria was intended to be comprehensive, while at the same time effort has been made to avoid overlaps and maintain simplicity. On the bases of the criteria descriptions an electronic questionnaire was designed to determine the importance of each of these criteria. The main results from the questionnaire includes:

- The most important criterion is Investor Confidence, which in the questionnaire recieves a weight of 20.6% (10% is the average).
- The next highest weight is related to the criterion Effectiveness (17%).
- Following these two is a large group of criteria with weights of 7% to 10%, including criteria as Simplicity in Design, the ability to encourage the development of a broad range of RES-technologies and Public Acceptance.
- The lowest weight is achieved by the criterion Smooth Transition with a value of 4.3%.
- The criterion on Lower manufacturing Costs came out with the second lowest value of 6.7%.

In general, all criteria, except the Smooth Transition, were found to be of significance, but with Investor Confidence and Effectiveness accounting for almost 40%. Owing to the importance of covering all aspects of the support schemes, all the ten criteria are used in the following evaluation.

The most important support schemes - generic and advanced versions

In the project, five types of support mechanisms were defined: Investment Subsidies, Fixed Feed-in Tariffs, Fixed Premiums, Tendering, and Tradable Green Certificates. These were all described in two versions: A generic, simplified version and an improved, advanced one. When moving from the generic to the advanced version the mechanisms should improve in most, if not all, issues of performance.

The most important issues identified when moving from a generic to an advanced version include:

- The stability and continuity of the support scheme is improved, e.g. tariffs are guaranteed for a number of years ahead.
- Power purchase agreements for a number of years ahead are made available.
- Support levels vary between technologies, reflecting differences in cost structures.
- For support schemes as Tendering penalties are introduced to ensure that deadlines are not exceeded.

The results of the survey on the evaluation of renewable support mechanisms

To evaluate the generic and the advanced support schemes, a survey was conducted in the period 17 January to 7 February 2005. An Internet-based questionnaire was send to a gross population of 551 experts, of whom 60 responded giving a response rate of 11%. The quality of the answers was excellent, expectedly because no experts were allowed to skip any questions, but were redirected to the unanswered parts of the survey. This in turn can have had a negative impact on the overall response rate, some experts skipping the whole questionnaire because they were not allowed to skip specific questions.

The main results from the survey are the following:

- Both the unweighted and weighted results clearly show that the Feed-in Tariff is the preferred support scheme by the respondents of the survey. This is the case both for the generic version and the advanced one.
- The Investment Subsidy ranks as number two for the generic scheme, marginally higher then the Premium scheme, while the opposite is the case for the advanced scheme.
- The Green Certificate system ranks four for both versions, while the Tendering Procedure gets the lowest scores.
- In the advanced version the Feed-in Tariff ranks high for almost all criteria. For those criteria, identified as the most important ones that is Investor Confidence and Effectiveness, the advanced Feed-in Tariff gets no score below three and for a significant number of respondents it scored at very high levels, nine or ten.
- In general, higher scores are found for the advanced scheme than for the generic one. The largest gap between the generic and the advanced version appears for the feed-in-tariff, where the score for the advanced version is 6.8 vs. a score for the generic one of 4.9 (unweighted). Thus there is seen to be a considerable higher score for the Feed-in Tariff, when the scheme is improved.
- Even in the advanced version of the Green Certificate system, low scores are found for the two most important criteria, Effectiveness and Investor Confidence, when compared to other support mechanisms. For Effectiveness the Green Certificate system ranks as number four with a score of 5.1, compared to Feed-in Tariffs with a score of 8.4. For Investor Confidence the Green Certificates gets the lowest score of all, 5.0 compared to the Feed-in Tariffs score of 8.7.[34]
- In the survey the score of Green Certificates on this issue of lowering the manufacturing costs of new technologies is not outstanding, in general at the same level as Feed-in Tariffs, Tendering Procedures and Premium Tariffs.

5.7 Incorporating externalities in support schemes

In section 3, we examined the issue of externalities. In this section a closer look at existing promotional strategies for renewable energy sources is taken. This is to determine which strategies have the best potential to establish a level playing field between all energy generation technologies by internalising external costs.

What role can external cost analysis play in existing and future renewable energy promotion strategies?

34 Weighted by the weights determined in the formerly applied questionnaire on the importance of the ten criteria.

External cost analysis could serve, (i) as input to assist decisions of policy makers, (ii) as a tool to measure the economic benefits of renewable energy strategies and (iii) as a basis for the design of policy instruments (e.g. internalisation of external costs).

In the first case, a comparison of the external costs of different energy technologies can help to design policies to overcome the disadvantages of clean energy technologies with high internal but low external costs, which have to compete with conventional energy technologies with low internal but often high external costs. Such policies neither need to know the exact differences of the external cost nor do they need to know the exact form of the marginal abatement cost curve for the reduction of pollution. As long as the right order of magnitude of the difference in the external costs is taken into account, such policies may already improve the competitive situation of the different energy technologies. Based on this knowledge technology policies (aiming at research, development and demonstration) or diffusion policies (like investment subsidies or bonus payments) for clean technologies may be guided to overcome the economic disadvantages of clean energy technologies.

In the second case, benefits of renewable energy strategies can be evaluated by measuring the avoided external costs. Such an exercise was described in section 3 of these guidelines for 28 countries in Europe. It presents how much external costs of conventional generation has been avoided by the use of wind energy in 2000 and how much external costs can be avoided under the assumed scenario by the year 2020 (the total avoided external costs in 2000 are 1.8 billion euros and more than 25 billion euros in 2020, due to a larger share of electricity produced by wind energy in the 2020 market. Based on such orders of magnitude, diffusion policies may get some orientation about the order of magnitude of justified financial incentives for clean energy technologies.

The third case deals with the question of how external costs can be incorporated into energy costs. As shown before, reaching an economically "optimal" level of pollution requires authorities to intervene to establish a level playing field. Unlike most of the existing renewable energy promotion strategies, *policy instruments based on external cost analysis have a direct effect on the polluters,* so incorporating the damage costs caused by their pollution into the energy price and according to the kind and quantity of damage. In this way, a level playing field is created and renewable energy systems are competitive due to the internalisation of external costs, i.e. to indirect strategies.

A question arises of the extent to which payment mechanisms for renewables may also lend themselves to internalise external costs, thereby creating a level playing field. To answer this question, fixed and premium tariffs as well as tendering and trading of renewable certificates are further analysed under this perspective.

Fixed and premium tariffs

By means of external cost analysis, the "optimal level of pollution" can be found and translated into a cost per kWh (e.g. tax) to the polluter. Such tax needs to be based on the pollution causing the external costs to be internalised. Thus, it can not be directly linked to the use of renewable energy sources. Nevertheless, attempts can be made to compile all the net advantages in external costs of the use of a renewable energy source such as wind energy, as compared to the conventional energy sources replaced by its use. If an internalisation of all external costs of energy through a tax does not seem feasible, such aggregated net differences in external costs between clean renewable energy sources and conventional energy sources may serve as a basis for the calculation of fixed or premium tariffs.

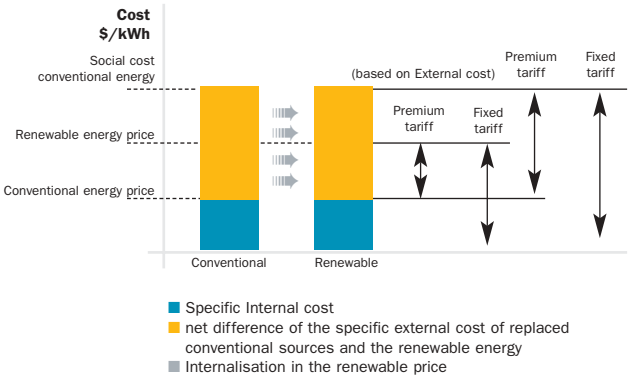
Such a renewable promotion strategy tries to create a level playing field to help renewables access the market without major disadvantages due to differences in external costs. A strategy based on fixed or premium tariffs gives the renewable generator a fixed price per kWh or a premium over the energy market value (based on internal costs) to compensate for relatively higher internal cost of the clean renewable energy. Fixed or premium tariffs can be set making use of external cost analysis. This can be done by giving directly to the renewable energy generator the net difference of the specific external cost of replaced conventional sources and the renewable energy source.

Figure 5.12 depicts how a price-driven mechanism, such as a Feed-in Tariffs, lends itself to being adapted to "internalise" net differences in external costs. In this case the tariff is not designed to match the price per kWh of RES-E, instead the external cost is applied as a contribution to the clean technology. For that reason it could be argued that Feed-in Tariffs are the second

best solution after environmental taxes (the polluter principle) especially fixed premium systems. They are second best price solutions because they only correct the relative prices of the competing energy supply technologies. They do not correct the incorrect relative prices of energy towards any other market activity, such as the use of energy saving technologies. Existing fixed premiums are not based on very detailed assessments of differences in external costs, although, the argument has played a role since the early 1990s.

Figure 5.12

Feed-in tariffs based on external cost



In this report, the avoidable external cost abated by wind energy per kWh electricity generated was calculated, as shown in sections 3.4 and 3.5 and for the years 2000 and 2020. A premium tariff for wind energy based on external cost would be equal to the avoidable specific external cost calculated (see section 3). As an example, a premium tariff for Spain in 2000 would be between 4.13 and 21.09 Eurocents per kWh and a fixed feed-in tariff would need to add the specific internal cost.

Tendering and green certificate systems

Under these strategies, a government sets the quantity of RES-E required for a given period of time (by tender or by obliged compliance with renewable certificates) and leaves it to the market to determine the price by introducing competition between the electricity producers. Thus, the internal cost of expanding renewable capacity is reduced by such competition.

Since these mechanisms are capacity-driven strategies, the cost of a kilowatt-hour can not be directly affected to internalise specific external cost, the renewable energy price is a dependant variable following supply and demand forces. The specific external costs can be reached only coincidentally when either the certificate price or the tariff in the tender is high enough (as the example Figure 5.12). In other words, a capacity driven strategy is not able, by itself, to internalise specific external cost.

In cases where external cost may be almost impossible to estimate, as for long term external costs of global climate change induced by anthropogenic GHG emissions, it can be argued that a 'quantity driven' strategy may still be the best strategy available to secure that critical concentration of greenhouse gases will not be reached. Such strategy would, nevertheless, use quantity regimes for GHGs and not for renewable energy sources.

Summarising the discussion so far, concerning the internalisation of external costs, the promotion of renewable energy technologies can only be seen as an indirect policy, because the direct internalisation would always need to relate to environmental or health damages of polluting technologies and their emissions directly.

5.7.1 Conclusions and recommendations on externalities role in RES-E policy

Based on our considerations concerning the internalisation of external costs in the promotion of renewable energy technologies, a few conclusions can be drawn and some recommendations can be given.

Conclusion 1: Because the policy targets for the introduction and diffusion of renewable energy sources into the market aim for more than the internalisation of external costs, such policies cannot simply rest on the internalisation of external costs.

Conclusion 2: Because the external costs of global climate change due to anthropogenic greenhouse gas emissions cannot be adequately quantified (due to the fact that most damages will happen in 50 to more than 100 years), no optimal emission policy (in the economic sense of the word) will ever be possible. Any policy trying to take global warming into account will need to start from a quantity regime for the limitation of greenhouse gas emissions.

Conclusion 3: Because the external costs of conventional air pollutants, e.g. SO_2 and NO_x can be derived quite accurately, these external costs can be taken into account in the design of environmental as well as energy policies.

Conclusion 4: In general, it is preferable to internalise a known external cost directly via a tax instead of by any indirect application through renewable energy policies, as such taxes (on conventional energy sources) set all relative prices right. Whereas, the internalisation for only renewable energy sources (as through a fixed premium) only corrects the relative prices between the polluting conventional energy technology and the promoted renewable energy technology.

Conclusion 5: As monetary incentives for renewable energy technologies, such as fixed Feed-in Tariffs, Fixed Feed-in Premiums or Investment Subsidies, can be directly related to the net difference in external costs between the renewable energy technology in question and the replaced conventional energy technology, such policies offer an advantage with respect to the internalisation of external costs as compared to quantity regimes. Nevertheless, as long as the external costs due to greenhouse gas emissions cannot be adequately quantified, a major part of the external costs avoided by the use of renewable energy sources cannot be included in such internalisation of renewable energy policies.

Conclusion 6: Quantity-oriented renewable energy policies need to be justified on other grounds than the attributable internalisation of external costs, as such quantity targets cannot be derived from the differences in external costs between polluting conventional and clean renewable energy technologies.

Consequently, the recommendations of this report, in so far as externalities are concerned, are as follows:

Recommendation 1: As far as possible, known external costs should be internalised through appropriate pollution taxes on the polluting energy technologies.

Recommendation 2: The problem of greenhouse gas emissions (GHGs) and the anthropogenic greenhouse effect needs to be dealt with in a quantity regime for GHGs, which can assure the adherence to safe maximum concentrations of GHGs in the atmosphere, without needing to know the long term external costs of possible damages of the anthropogenic greenhouse effect. This is because the latter will never been known sufficiently well for any other internalisation strategy.

Recommendation 3: Specifically if the known external costs of conventional energy technologies are not internalised through appropriate emission taxes, price based mechanisms, such as Feed-in Tariffs or Feed-in Premiums, should be used to internalise the differences in external costs between conventional and renewable energy technologies as a second best solution. A cap for such internalisation, as in the EU Directive, on subsidies for renewable energy technologies, is counterproductive and should not be applied.

Recommendation 4: As long as the quantitative reduction targets for greenhouse gases are far from securing the adherence to safe maximum GHG concentrations, additional provisional measures should be taken to level the competitive playing field for renewable energy technologies.

Recommendation 5: It should never be overlooked that there are other reasons for the promotion of renewable energy technologies than only the internalisation of external costs, e.g. security of national supply, diversity of supply, local employment. Such factors need to be taken into account in the making of renewable energy policies in their own right.

6. Computer simulations of support mechanisms

The evaluation of the different support schemes for RES-E is based on both theoretical analysis and questionnaires. In the following, the computer model Green-X, developed by EEG of the University of Vienna, is used to determine the effects of introducing harmonised versions of the generic and advanced support mechanisms with respect to RES-E deployment, investment required, generation costs and consumer expenditure.

6.1 Green-X model assumptions

The following scenarios (see Figure 6.1) have been investigated with respect to the simulations of support schemes:

- A **reference scenario** has been applied indicating RES-E deployment if no further support applies for new RES-E – i.e. installed in the period 2005 to 2020. This variant indicates the consumer expenditure dedicated to existing plant (installed up to 2004) due to prior support guarantees running out in the coming years.
- No harmonisation, where currently implemented policies remain available (without any adaptation), i.e. **business as usual** (BAU) **forecast**
- **Starting in 2005,** an instant **harmonisation** of the support schemes takes places. This is obviously not practically possible, but is done for illustrative purposes. To be able to analyse the effect of different

Figure 6.1

Computer simulation scenarios

Support schemes in their generic and advanced form

FIXED FEED-IN TARIFFS generic	FIXED PREMIUM SYSTEM generic	TENDERING SYSTEM generic	TGC SYSTEM generic	INVESTMENT SUBSIDIES generic
FIXED FEED-IN TARIFFS advanced	FIXED PREMIUM SYSTEM advanced	TENDERING SYSTEM generic (strategic bidding)	TGC SYSTEM (common) - advanced	INVESTMENT SUBSIDIES advanced
		TENDERING SYSTEM (common) - generic	TGC SYSTEM (techn. sp.) - advanced	
		TENDERING SYSTEM (common) - advanced (strategic bidding)		
REFERENCE (no further promotion of RES-E)		TENDERING SYSTEM (techn. sp.) - advanced		
BAU (continuation of current policies)		TENDERING SYSTEM (techn. sp.) - advanced (strategic bidding)		

(harmonised) policies compared to the status quo (BAU), it is assumed that the same RES-E target as under BAU conditions will be reached by 2020. Thus the initial and final states are the same; it is the *paths* to these states that differ and will be evaluated. Thus, it is important to recognise that the Green-X model runs do not *per se* give us any direct indication whatsoever of whether a harmonised support framework will be effective in increasing renewables as it implicitly assumes that the same deployment as in the BAU will take place. For example, a poor designed mechanism will in the model have the effect of increasing the consumer expenditure (rather than decreasing the deployment) as a result of higher risk premiums. For the same reason, conclusions on the consumer expenditures should be made with care as these depends crucially on the design of the mechanisms and their assumed risk premiums / required rates of return.

- The following policies have been investigated under harmonised conditions:
    - Investment Subsidies
    - Fixed Feed-in tariffs
    - Fixed Premium Systems
    - International Tendering Systems
    - International TGC systems.

To illustrate the impacts of changing the design of mechanisms, instruments are applied with **generic** and **advanced** settings. As there are wide differences between the designs of mechanisms, even between mechanisms of the same type the RE-Xpansion project has defined a number of generic and advanced support mechanisms, which should be evaluated against the defined criteria.

In addition to the broad set of scenarios described above, sensitivity runs have been applied to illustrate the impacts of full internalisation of external costs as described in section 3, as well as a scenario run based on current fossil fuel prices, corresponding to $50 per barrel of oil. More precisely, these sensitivity cases refer to the BAU-scenario – i.e. the continuation of current support schemes.

The determination of the required rate of return is based on the weighted average cost of capital (WACC) methodology[35]. A set of six options are considered in the analysis, varying from 6.5% up to 12%. The different values are based on different risk assessment according to the questionnaire, a standard risk level and a set of risk levels characterised by a higher expected market rate of return. The 6.5% value is used as default for stable conditions as given e.g. under advanced fixed feed-in tariffs and based on the survey conducted within RE-Xpansion (see section 5); whilst the higher values are applied in scenarios with less stable conditions and in cases where support schemes cause a higher risk for the investors (e.g. a TGC system), according to the survey respondents. For a detailed listing of the policy-specific settings see 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[36].

Table 6.1

Policy-specific settings with respect to the WACC

Support scheme	Interest rate / weighted average cost of capital Design criteria are set ...	
	... advanced	... generic
Fixed feed-in tariffs	6.5%	9.1%
Fixed premium systems	7.55%	10.6%
Tendering systems	7.55%	10.6%
TGC systems	8.6%	12%
Investment subsidies	8.6%	12%

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 baseline (BAU, Kyoto-target, etc.) [%]
    - Market price electricity (yearly average price) [€/MWh]
    - Market price Tradable Green Certificates [€/MWh]

35 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).
36 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.

- *Producer expenditure, 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 [M€, €/MWh]
  - Total (transfer) costs due to the selected support schemes and policy options [M€]

For further information on the methodology in the Green-X simulation runs, see the internet based report "Inputs to the Analysis of Support Schemes – Scenarios on the Future Deployment of RES-E & Accompanying Consumer Expenditure" available at www.ewea.org.

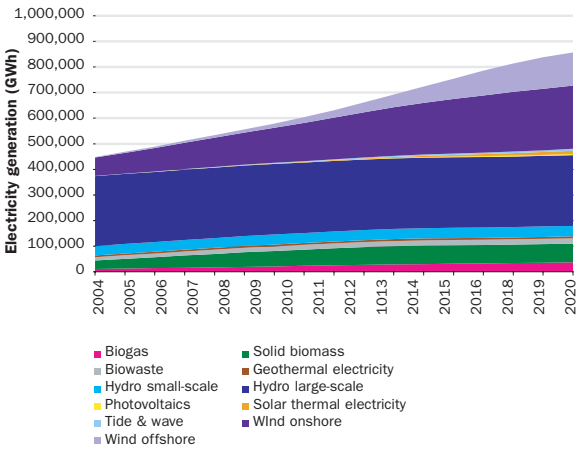
6.2 Simulation run results

Before comparing the scenarios of harmonised support schemes, the BAU-scenario is presented as a base case. The BAU scenario assumes a continuation of current RES-E policies in place up to 2020. This represents the most likely future under non-harmonised conditions in the EU-15 Member States.

6.2.1 Results – BAU-scenario

Figure 6.2

Development of total RES-E generation in the period 2004 to 2020 on EU-15 level in the BAU scenario



The total amount of RES-E generation within the EU-15 was around 446 TWh/a in 2004.[37] Without any changes in the support schemes in each country, the electricity production will rise to about 579 TWh/a in 2010 (19.0%) and 857 TWh/a in 2020 (24.6%). The amount for 2010 is, following the BAU demand projection from Mantzos et al. (2003), around 95 TWh/a; this is 3 %-points less than the indicative target as described in the 'RES-E Directive' (2001/77/EC).

Figure 6.2 shows the dynamic development of RES-E generation for the BAU case. It illustrates the technology-specific development for the EU-15 as a whole. Due to less public support and acceptance, the amount of large scale hydro power plants will increase only marginally in absolute terms[38]. In relative terms, the share drops significantly from around 60% in 2004 to 33% of renewable electricity production in 2020. The 'winner' among the considered technologies is wind energy, both onshore and offshore. It can be expected that around 45% of the RES-E production of plants installed in the period 2005 to 2020 will come from onshore wind, and 25% from offshore. By 2020 wind power's share of total RES-E production will be 45% - 30% onshore wind and 15% offshore wind. Other significant increases can be expected for solid biomass (+ 10%) and biogas (+ 6%).

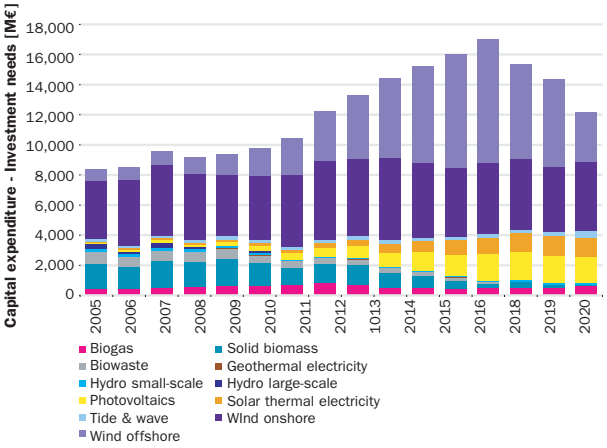
37 Note: RES-E generation in 2004 refers to available potential of RES-E times normal (average) full load hours of the technologies. This means actual generation can differ from this value due to (i) variation of generation from average conditions (e.g. for hydropower or wind) and (ii) new capacity build in 2004 is not fully available for the whole period 2004.
38 Considering the effects of the Water Framework directive (EC, 2000b), the total electricity generation from large scale hydro may be less in 2020 than in 2005.

Large financial resources will be required to construct new capacity.

Figure 6.3 shows the total investment for RES-E over time, assuming BAU policy up to 2020. While necessary investments into wind onshore and biogas plants are relative stable over time, investments into solid biomass plants (including biowaste) mainly occur in the first years (2005-2015) and for wind offshore and photovoltaic mainly after 2010. The investments (within the EU and worldwide) stimulate technological learning, leading to lower generation costs in the future.

Figure 6.3

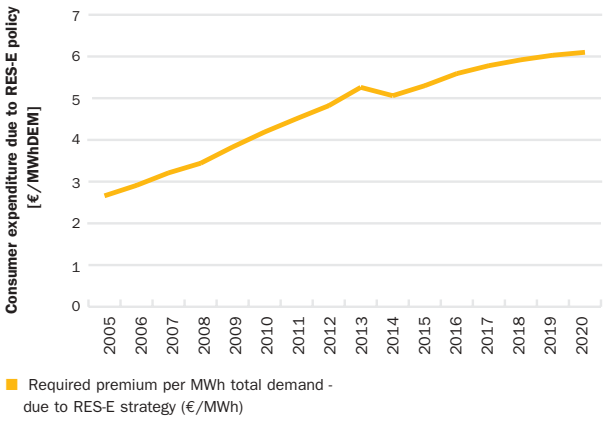
Total investment needs in the period 2005-2020 within the EU-15 in the BAU scenario



The necessary financial incentive for the promotion of RES-E is indicated in Figure 6.4 which illustrates the required yearly consumer expenditure on EU-15 level for the BAU case, expressed as (average) premium per MWh total demand. The consumer expenditure refers to the direct costs of applying a certain support scheme[39]. A steady rise in required expenditures occurs, starting from a level of 2.7 €/MWhDEM in 2005, to about 6.1 €/MWhDEM in 2020[40].

Figure 6.4

Development of necessary consumer expenditure on EU-15 level in the BAU scenario



6.2.2 Comparison of the advanced support schemes

In the following, a comparison of the *advanced* schemes is undertaken briefly[41]. Note that the initial values (as 2005) and final values (as BAU) of cumulative installed RES-E generation are assumed implicitly to be the same for all scenarios; it is the paths between these constraints that differ by scenario – as is evident in Figure 6.5 within all cases a similar RES-E deployment in size of the BAU-target is reached in 2020 – an amount of 857 TWh in total, to which new installations of the period 2005 to 2020 contribute about 440 TWh. Obviously, the dynamic path to achieve this overall target differs by variant, e.g. Figure 6.6. For instance, for investment subsidies more new installations occur in the later years, i.e. after 2012. However, for fixed feed-in tariffs, the amount of new installations decline in the years after 2017. This is mostly caused by the applied design criteria in combination with market diffusion or resource exploitation on country level.

39 E.g. for a fixed feed-in tariff its marginal value per MWh_{RES-E} is calculated by subtracting the reference wholesale electricity price from the guaranteed promotional tariff.
40 Note, these figures represent the average on EU-15 level. On country-level, large differences appear for non-harmonised support (BAU-case). For a detailed discussion of this topic, see Huber et al. (2004).
41 For illustration, the reference case – indicating what would happen if no further support will be given to new RES-E after 2004 – is added in the set of figures depicted in this section.

Figure 6.5

Comparison of cumulative electricity generation from new RES-E plant (installed 2005 to 2020) on EU-15 level for the advanced support schemes

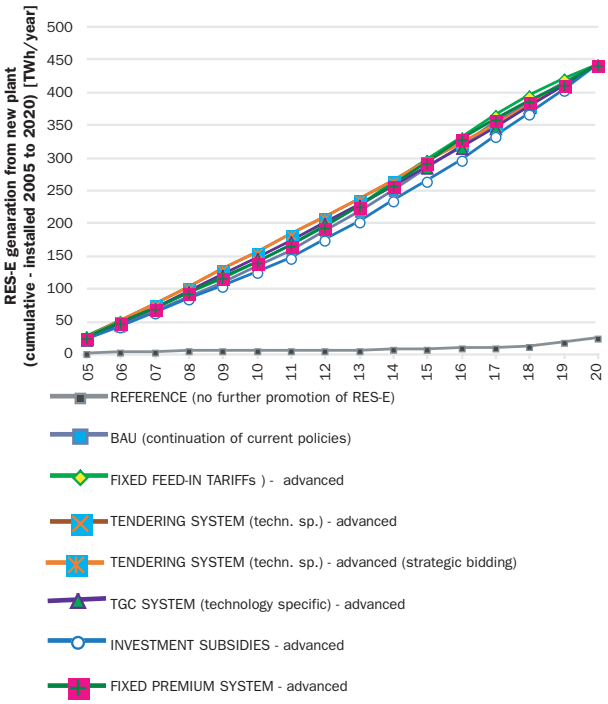
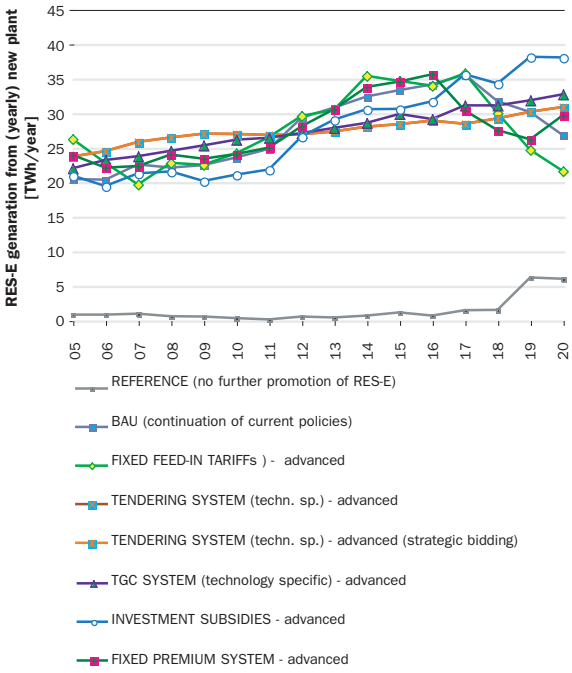


Figure 6.6

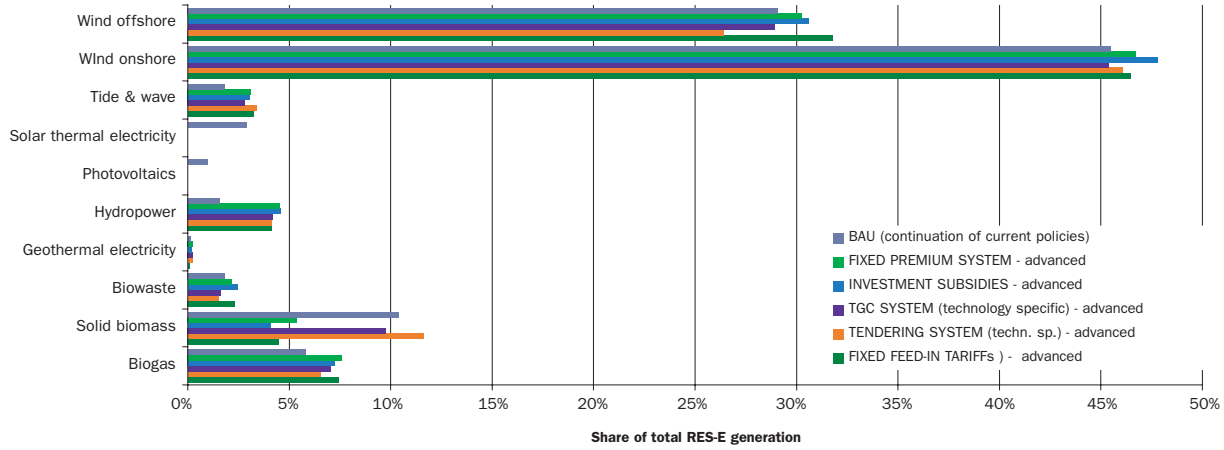
Comparison of electricity generation from new RES-E plant (yearly) on EU-15 level for the advanced support schemes



Next, Figure 6.7 illustrates which RES-E options contribute most in the period 2005 to 2020 within the investigated cases. Wind energy (on- & offshore) dominates this scenario, as with the BAU-case described in the previous section. For low risk support schemes, biomass is reduced, due to its relatively larger fuel costs. Under the implied assumption of the model to minimise consumer expenditure, no contribution can be expected from comparatively expensive RES-E, options, such as PV or solar thermal electricity power in the advanced cases.

Figure 6.7

Technology-specific breakdown of RES-E generation from new plant (installed 2005 to 2020) in the year 2020 for the advanced support schemes



Looking at the financial aspects related to the support of RES-E in the observed period, huge differences become evident. In this context, Figure 6.8 provides a comparison of the required consumer expenditure due to the promotion of RES-E in the period 2004 to 2020. These values are related to demand, in order to give an impression of the required burden for consumers in *per unit* terms (i.e. €/MWh). Note, these figures represent an average premium at EU-15 level; the country-specific situation differs even in case of harmonised promotional settings.

As evident from this illustration, all advanced schemes will lead to less consumer expenditure in total compared to the default BAU-case. This is primarily due to the development of renewable energy in high resource areas. Differences appear also between the various harmonised schemes investigated, primarily as a result of the implied required rate of returns. Investment subsidies cause the largest expenditures in the early years (up to 2009) of implementation, decreasing later to the least level among all scenarios. Tendering systems are preferable if investor's cannot act strategically in setting their bids. If strategic bidding is taking into account, the largest expenditures appear after 2009 for tendering of all advanced schemes. Fixed Feed-in tariffs leads to a small to moderate consumer burden in the observed period. Fixed premium systems cause slightly larger consumer expenditures compared to fixed FITs as an impact of the slightly larger risk from an investor's point-of-view.

Figure 6.8

Comparison of the required consumer expenditure due to promotion of RES-E in the period 2004 to 2020 on EU-15 level for the advanced support schemes

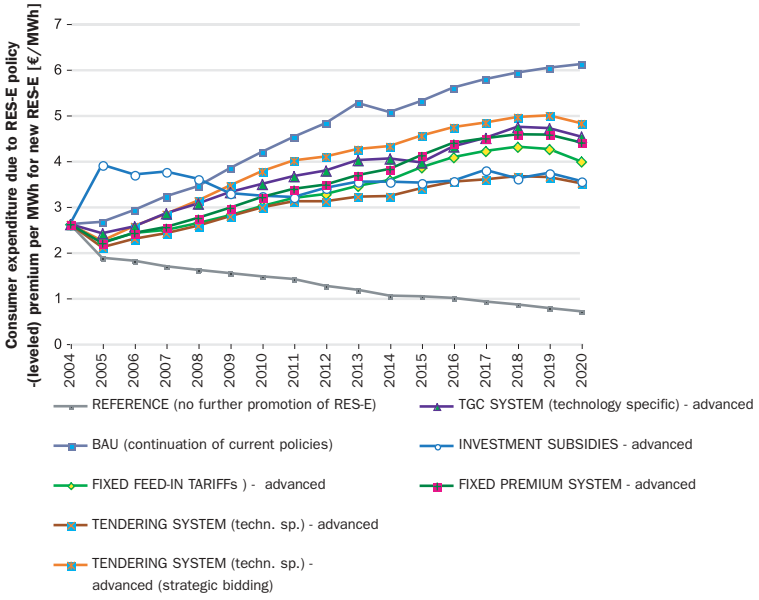


Figure 6.9

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 advanced support schemes

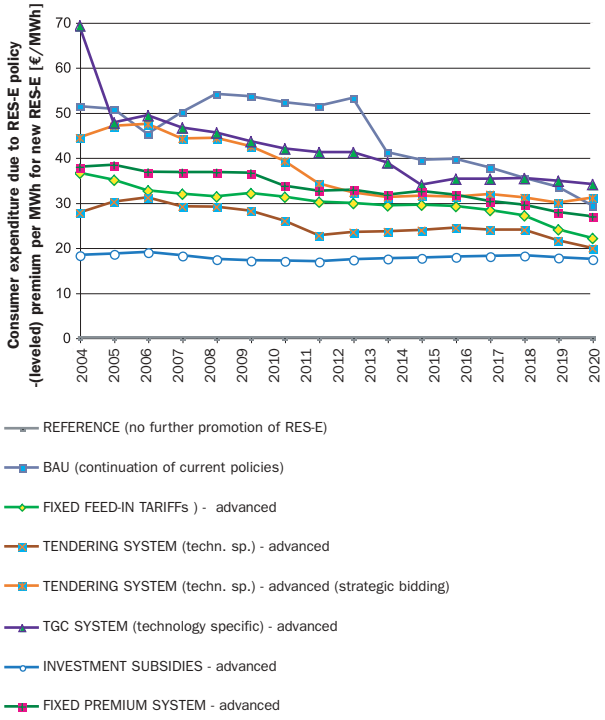


Figure 6.9 indicates the average financial support for new RES-E plant over time. This amount represents, from an investor's point-of-view, the average additional premium on top of the power price guaranteed (for a period of 15 years) for a new RES-E installation in a certain year. From a consumer perspective, it indicates the required additional expenditure per MWh_{RES-E} for a new RES-E plant, compared to a conventional option (characterised by the power price).

As can be seen from Figure 6.9, the required financial support per MWh_{RES-E} decreases in all cases over time. Comparing the different advanced schemes, a similar characteristic compared to Figure 6.7 appears – with one deviation referring to investment subsidies, which require or set, respectively, according to this observation the lowest incentive among all variants. The reason for this is the up-front incentive, which is solely set by this type of scheme.

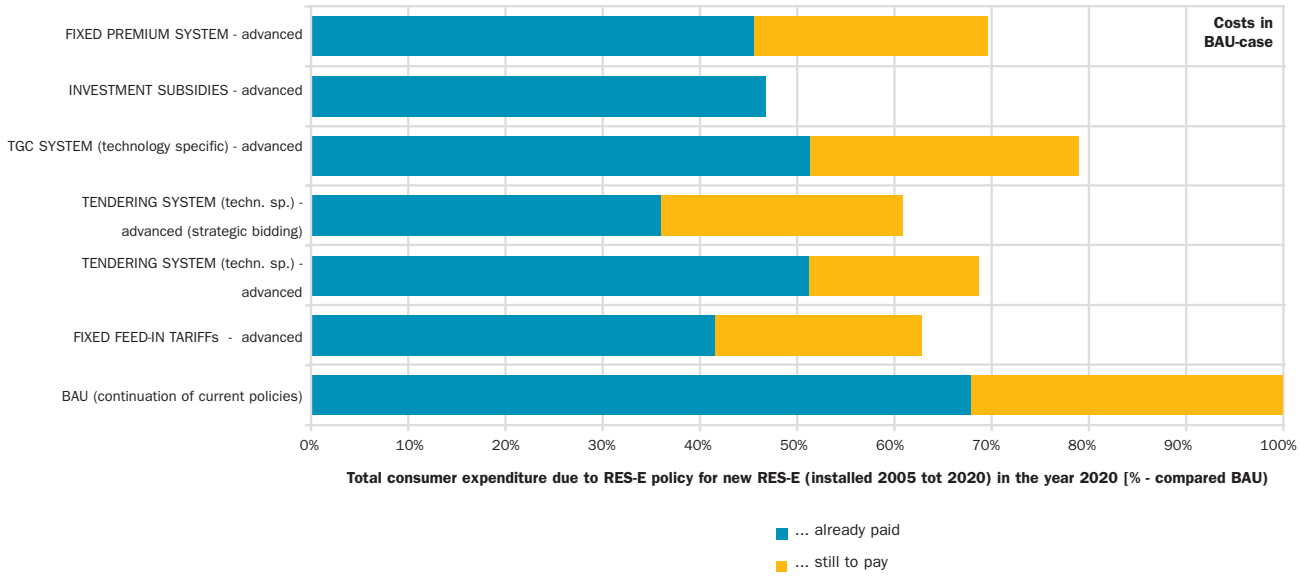
Figure 6.10 shows a comparison of the cumulated consumer expenditure due to the promotion of new RES-E installed in the period 2005 to 2020. It summarises both the cumulated consumer burden *within* the investigated period 2005 to 2020, as well as the residual expenditures for the years after 2020 (dotted area). The calculation assumes that the required yearly consumer expenditure in the period 2005 to 2020 (as illustrated in Figure 6.8), as well as the estimated residual expenditures for the following years after 2020, are translated into their present value in 2020.[42]

As becomes evident from this comparison, total transfer costs for society are least by applying investment subsidies, followed by fixed feed-in tariffs and tendering systems[43]. Next, fixed premium systems appear in order followed by an EU-wide TGC system[44].

By including only expenditures actually appearing in the period 2005 to 2010 (i.e. the filled area in Figure 6.10) a different ranking occurs, where fixed feed-in tariffs and tendering systems are ranked first, followed by fixed premium systems, investment subsidies and TGC systems.

Figure 6.10

Comparison of necessary cumulated consumer expenditure (in 2020) due to the promotion of new RES-E (installed 2005 to 2020) for the advanced support schemes



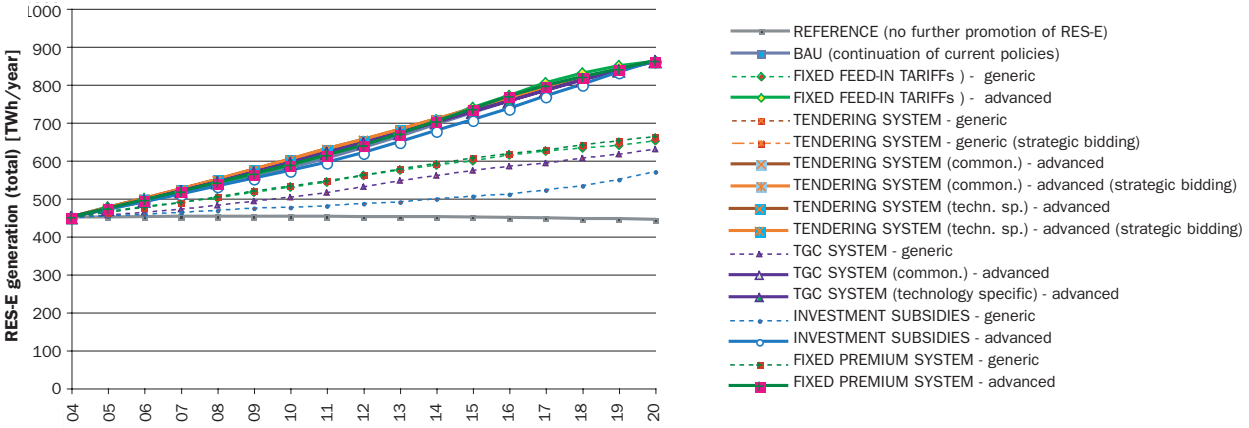
Note: In the case of a TGC scheme, total transfer costs paid after 2020 are estimated assuming that the TGC price in the year 2020 is constant up to the phase out of the support.

42 Thereby, an assumed rate of inflation has been applied of 3%/y on average.
43 In contrast to all other advanced systems, an investment subsidy causes only an up-front support. No generation-based incentive is introduced, which was often a significant hindrance in the past. For a detailed discussion of this aspect, see e.g. Resch et al. (2005).
44 Note, for tendering systems, a range of likely consumer expenditures is taken into account, so both neglecting and considering the impact of investor's strategic behaviour.

6.2.3 “Generic” versus “advanced” schemes

Figure 6.11

Development of total RES-E generation in the period 2004 to 2020 on EU-15 level for all investigated cases



Generic schemes are taken into consideration in the brief investigation of advanced support schemes, as in the previous section. A first impression on the overall resulting RES-E deployment is given in Figure 6.11 for all investigated cases (i.e. both generic and advanced). Generic variants are depicted in dotted lines.

Figure 6.12

Electricity generation versus cumulative consumer expenditure in 2020 for new RES-E plant (installed 2005 to 2020) for all investigates cases

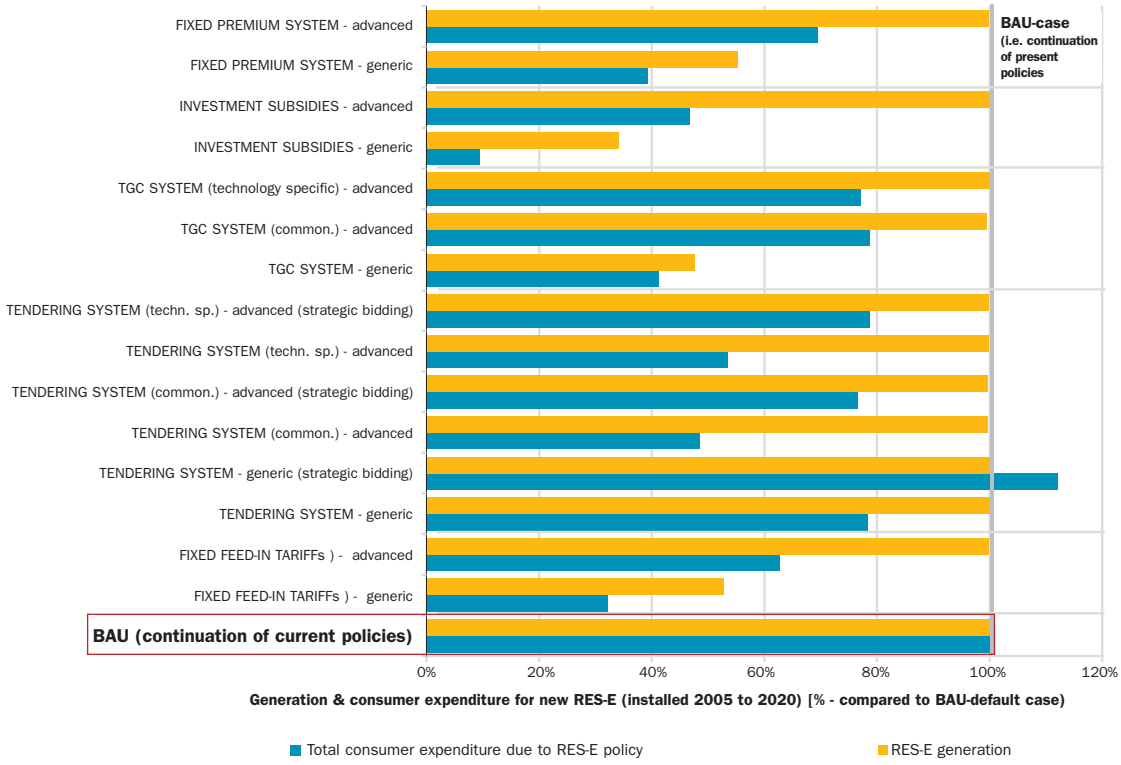


Figure 6.2 depicts RES-E generation and cumulative consumer expenditure (in 2020) for all scenarios. As can be seen, almost all generic variants result in less RES-E deployment than the advanced models. The only exception is the generic tendering system, which is a result of the default settings of the Green-X model – where tenders impose a mandatory demand which would only in case of comparatively higher non-financial barriers not be fulfilled (which are not subject of this analysis).

For *investment subsidies*, the generic variant results in a reduced RES-E deployment by about 76% compared to the advanced variant. Accordingly, consumer expenditure is also reduced by 79%. In comparison with all other cases, this scenario has the least deployment and least consumer expenditure.

The generic variant of *fixed feed-in tariffs* is characterised by a reduced deployment of 48% compared to the advanced, whilst consumer expenditures decrease by 49%.

For fixed premium systems, deployment in the generic variant is less reduced compared to the support schemes discussed above. RES-E deployment is reduced by 45% in the generic version and required expenditures drop as a result by 44%.

In case of tendering systems, as mentioned above, no reduction of RES-E deployment takes place due to the model settings. In contrast, consumer expenditures in the generic version rise dramatically by an average of 45% compared to the advanced mechanism. This is a consequence of the larger risk, due to increased uncertainty, on future earnings in the generic forms.

The generic variant of a *TGC system* results in a reduced deployment in size of 52% compared to the advanced version. Consumer expenditures decrease by 46%.

6.2.4 Sensitivity investigations – the impact of high fossil fuel prices and externalities

The sensitivity analysis serves to illustrate:

- the impact of continued high fossil fuel prices as currently evident, and
- the impact of external (social) costs (based on the reference case – default fossil fuel prices)

on RES-E deployment, in addition to direct consumer expenditure. External (social) costs also paid by the consumer eventually, but indirectly.

Again, the BAU scenario is chosen as the base case, as characterised by a continuation of current RES-E policies up to 2020.

Considering the **increases on fossil fuel price experienced in 2004/5**, the 2004 peak of European average prices have been identified for each fossil fuel type. These data have been included in the database of the model, under the assumptions that these prices will stay constant over the investigated period.

Furthermore, scenarios on external costs are investigated, according to chapter 3, where a re-evaluation as well as an incorporation of **externalities** into energy prices has been undertaken (see Hohmeyer et al. (2004)).
The following scenarios are considered:

- *the external cost of classical pollutants using the 'value of statistical life' approach … (VSL) – medium (average) scenario*
- *external cost of classical pollutants using the 'years of statistical life lost' approach … (YOLL) – low / medium (average) / high scenario*

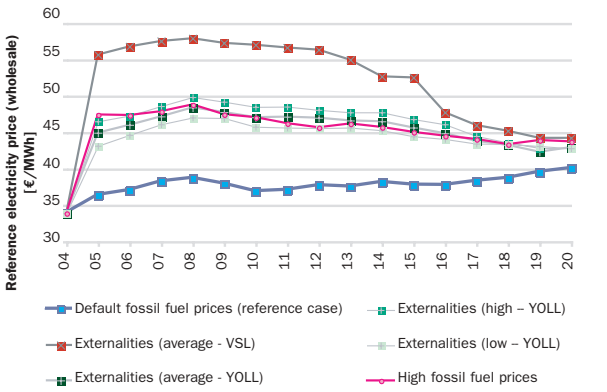
Regarding climate change externalities, the large uncertainty of damage or abatement costs for green house gases emissions (e.g. CO_2) result in a large uncertainty in the external cost as well. Another approach is suggested by e.g. the IPCC studies where scientists have determined the limit level of emissions which could prevents catastrophic damage from climate change in the long-term.

Note that in this external cost scenario cost related to climate change have not been included. Instead the impact of the recently launched EU-wide emission allowance trading scheme is considered as default. (EU trading scheme differs from the level of emissions suggested by the IPCC studies).

As a first result, the impact of externalities and current fossil fuel prices on the resulting power price – representing the EU-15 average – is illustrated in Figure 6.13. These results can be compared with the reference case (grey-blue line) as applied for all previous investigations.

Figure 6.13

Comparison of the resulting (reference) yearly average wholesale electricity price on EU-15 level for the sensitivity cases



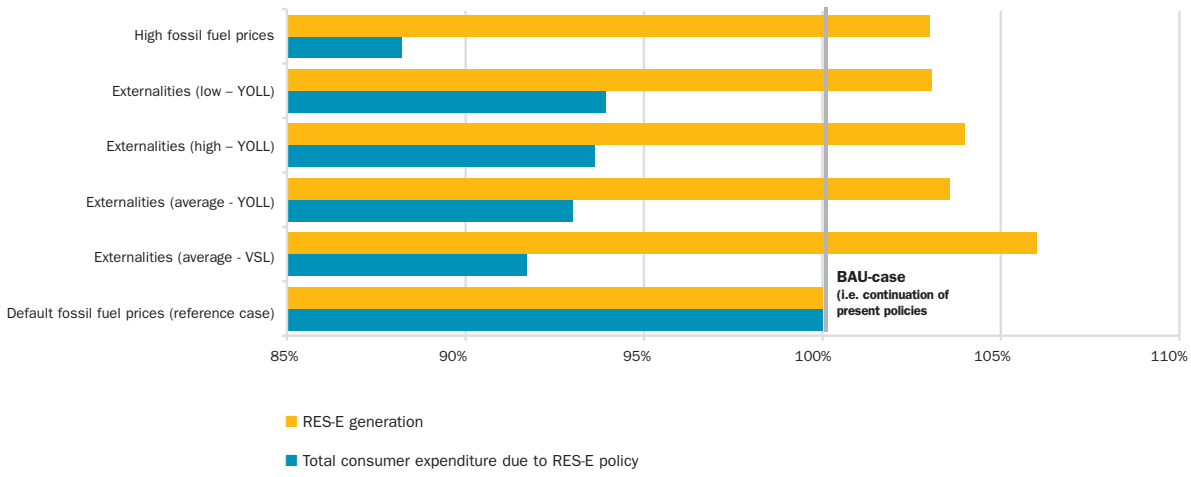
It can be seen that the largest impact on the power market will come from the consideration of external cost of pollutants using the 'value of statistical life' approach. This produces an increase instant increase in power prices of 20 €/MWh above the reference case. A continuation of current high fuel prices would cause an increase of about 10 €/MWh, compared to the BAU-case. The differences become smaller by 2020, as structural changes in the power sector are imposed to reduce pollutant emissions that cause the external costs.

Finally, Figure 6.14 illustrates the impact on RES-E generation as well as cumulative consumer expenditure (in 2020) – both referring to RES-E plant in total – for the two scenarios of assuming current fossil fuel prices and externalities.

Almost all sensitivity variants result in a larger RES-E deployment of between 3% and 4% in total. In the external cost approach according to VSL, a much larger RES-E deployment can be expected, leading to an increase by +6%. In contrast to the RES-E deployment, the required consumer expenditure for the promotion of RES-E drops dramatically with a continuation of 2004/5 high fossil fuel prices, resulting in a reduction of the overall expenditure by 12%. On the first glance one might expect that expenditures are least for the external cost variant according to VSL, which neglects the impact of increasing RES-E deployment and therefore increasing expenditures. All other variants result in a reduction of the consumer burden in a range from 6% to 8%, compared to the BAU-case.

Figure 6.14

Electricity generation versus cumulative consumer expenditure (for the period 2005 to 2020) in 2020 for all RES-E plant – for all sensitivity variants



7. Conclusions and recommendations

It constitutes a market failure that electricity retail prices do not include the full cost to society of electricity production. If environmental costs were levied on electricity generation according to their impact, many renewable technologies would no longer require support. Having harmonised energy taxes, reflecting the actual environmental impacts of each technology, would be an effective and fair way of internalising environmental costs.

If, at the same time, direct and indirect subsidies to electricity generation from fossil and nuclear fuels were removed, the need to support renewable electricity generation would diminish still further.

However, it does not seem politically feasible in the short to medium term to agree on measures to fully internalise external costs in electricity production, or to remove unproductive subsidies to conventional energy sources. Therefore, second-best mechanisms are needed to support RES-E.

Support frameworks as compensation for market failure

Support frameworks for renewable energy sources should be viewed as compensation mechanisms for correcting the market failures. Such support frameworks provide the necessary, yet temporary, support to enable renewable energy technologies to achieve mainstream status, and eventually full competition with conventional electricity production technologies.

While the financial framework, i.e. the payment mechanism for renewables, is vital for increasing the renewable share of the power mix, it is important to recognise that attention must be given simultaneously to the development of appropriate measures in each of four vital areas:

- Well designed payment mechanisms
- Grid access and strategic development of the grids
- Appropriate administrative procedures
- Public acceptance and support

RE-Xpansion has focused on the analysis of payment mechanisms. However, if one of the other three elements is missing from an overall framework, little progress will occur. It is therefore vital that analysis of support mechanisms in the Member States, such as the Commission's evaluations of progress towards meeting the targets, identifies successes and failures; "cause–effect" analysis is essential. Otherwise the assessment of support mechanisms may lead to the wrong conclusions.

7.1 Little evidence of effectiveness beyond feed-in tariffs and premiums

Based on past experience, it appears that policies based on fixed tariffs and premiums can be designed to work effectively. However, introducing them is not a guarantee of success. Most countries with mechanisms to support renewables have, at some point, used feed-in tariffs. However, not all feed-in mechanisms have contributed to an increase in renewable electricity production. It is the design of a mechanism, in combination with other measures that determines its success.

It is too early to draw final conclusions on the potential impacts of the full range of policy options available, since more complex systems, such as those based on tradable green certificates, are at an early stage of implementation and still in an experimental phase. These must be given time to prove their effectiveness. More time and experience are needed to make credible conclusions on their potential ability to attract investments and deliver real growth in renewables capacity.

There is not enough evidence yet that mechanisms other than fixed tariffs and premiums can be effectively applied at Community or national level at this time without dramatically affecting the European market for renewables. Mechanisms, especially complex ones, take time to prove their ability to attract investment, and so increase RES market share.

7.2 Voluntary best practice design guidelines

There are five main payment mechanisms in use in Member States today. These are:

- Investment subsidies (capital grants)
- Fixed feed-in tariffs
- Fixed premiums (environmental bonus systems)
- Auction models / tenders
- Renewables quota obligations (possibly combined with tradable green certificates (TGCs))

However, different variations of these five main systems have evolved in the Member States - systems that are not immediately compatible, which is to say that 25 different variants of the five mechanisms exist in the EU today. Their redesign, in order to facilitate fair trade, would cause widespread investor uncertainty in all markets, if undertaken too quickly.

In order to minimise these disruptive effects and to prepare for a potential Community-wide mechanism, a set of voluntary Best Practice Design Guidelines should be developed in consultation with stakeholders. Such an approach has also been adopted for gas infrastructure and cross-border gas in the context of the European Gas Regulatory Forum (Madrid Forum).

Development of "market clusters"

Best Practice Design Guidelines would indicate to Member States the choices for a future mechanism, and create the opportunity for more coherence among both existing and potential mechanisms.

Rather than introducing dramatic changes in all 25 independent markets, this would lead to gradual alignment of the support mechanisms of Member States that have chosen a similar version of one of the five mechanisms (e.g. tradable green certificates in Sweden, Wallonia, Flanders, Italy and the UK; fixed feed-in tariffs in Germany, France and Portugal; fixed premiums in Spain and Denmark, etc.). Such "market clusters" would increase the ease with which the country of origin of a unit of renewable electricity could be recognised (avoiding 'double counting' issues), and provide valuable insight and experience on which to base a Community decision later on.

The Voluntary Best Practice Design Guidelines should be based on a set of design requirements for support mechanisms. The RE-Xpansion survey analysis was based on ten such design requirements (see section 6, above). The survey results clearly show that the specific design of payment mechanisms has a significant impact on how the performance of a mechanism is perceived, i.e. the "advanced" mechanisms score significantly higher than the "generic" mechanisms.

7.3 Real competition in power markets

The "advanced mechanisms" defined in section 6 assume that certain elements of electricity markets are available, e.g. long-term power purchase agreements, and the existence of long-term contracts for certificates. Another underlying assumption is that real competition exists in the European power markets today. However, some of the elements assumed in the analysis are not present in today's power markets.

The European Commission's four benchmarking reports on the implementation of the EU electricity and gas directives conclude that real competition in the electricity market is still far off. Creating a market for renewables that is compatible with a well functioning internal market should be a goal of the Community.

However, it seems premature to force renewable electricity into an Internal Market framework at a time when competition in the conventional power market is far from being effective and will only exist in theory for many years to come. Due to its interaction with the power market, fair trade in renewable electricity will be impossible to achieve unless distortions in the internal electricity market are overcome e.g. increased concentration, ineffective ownership unbundling, massive subsidies paid to conventional electricity sources and market dominance, and failure to internalise externalities. New renewables (excluding large hydro) account for approximately 5% of EU electricity consumption. Competition in renewables should be preceded by fair and real competition in the remaining 95% of the power market.

7.4 Payment mechanisms and externalities

Article 174 of the Treaty establishing the European Community states that the Community bases its environmental policy on the principles ensuring that preventive action should be taken, that environmental damage should be rectified at source and that the polluter should pay.

If external costs, in the form of damage to the environment and health, were taken into account, the EC-funded ExternE study estimated that the cost of producing electricity from coal or oil would double and the cost of electricity production from gas would increase by 30 %.

The study further estimated that these costs amount to 1-2 % of EU GDP, or between €85 billion and €170 billion, not including the cost of global warming and climate change. The RE-Xpansion analysis shows that wind power alone is expected to avoid external costs of €25 billion/year by 2020[22].

The evaluation and design of payment mechanisms for renewables must also consider mechanisms to internalise external costs for all forms of generation. Only then will an optimal allocation of society's resources be achieved. Therefore, internalising external costs should be an additional design parameter in developing the Voluntary Best Practice Guidelines proposed in section 7.2.

In general, it is preferable to internalise a known external cost directly, e.g. via a tax or levy, instead of indirectly, e.g. through a renewable energy support mechanism. This is because such taxes and levies may establish social costs within the retail prices of both conventional and renewable electricity production. In contrast, the subsidisation of renewable energy sources (through a fixed premium, for example) only corrects the price difference between the polluting conventional energy technology and the promoted renewable energy technology; it does not clarify the true cost of the non-renewable supply.

7.5 A Harmonised system for promoting renewables?

The adoption of the Renewables Directive in 2001 has initiated a positive Europe-wide political process to develop adequate frameworks for renewables. However, in many Member States, these frameworks are still not yet operational, being still in the preparatory phase, but should nonetheless be effective soon. The Commission should encourage these Member States to speed up the process of implementation of national renewables frameworks, specifically in relation to the best design of payment mechanism, and to overcoming administrative and grid barriers.

Any change towards an EU-wide system at present would stall the development of renewable policies in many Member States by at least another 2-3 years - at a critical time for the technologies. The present efforts of Member State would be wasted and such a move could have devastating effects on national markets where signs of activity are at last beginning to show.

Introducing a common system now would be premature

A premature move towards a common approach could stop, or seriously delay, development even before it starts; Member States would fail to meet their national targets and European global leadership in renewable energy technologies would be put at serious risk.

There is much evidence that changes to frameworks - even the discussion of potential change - creates uncertainty for renewables, and introduce an initial adverse impact on renewables markets. The initiation now of a community-wide mechanism would undermine several years of Member State efforts to develop effective mechanisms.

Finally, it is still too early to draw a final conclusion on the relative effectiveness of the various policy options for support mechanisms. While mechanisms based on feed-in tariffs (e.g. the German mechanism) and premiums (e.g. the Spanish mechanism) have proved effective in attracting investments, more complex systems, such as those based on tradable green certificates, are still at an experimental and early stage of implementation.

These more recent mechanisms must be given time to prove their effectiveness before a decision on a common harmonised mechanism is decided. More time and experience are therefore needed to make credible conclusions on the impacts of the full range of options.

A shift to a Community-wide support mechanism for the promotion of renewable energy sources must be well prepared. Preparations could include the development of a set of Voluntary Best Practice Design Guidelines for support mechanisms. These should be based on a set of design requirements, for which the RE-Xpansion project has suggested an approach.

ANNEX 1: Integration of RES-E in the electrical system: issues and recommendations

General

The present amount of RES-E connected to the electric power system shows that it is feasible to integrate renewable energy to a significant extent. The experience shows where bottlenecks are and which kind of problems can occur.

This chapter discusses the major issues specifically related to the equation of RES-E generation and the electric power system, consisting of generation units, transmission and distribution grids, and the end users.

In brief the main issues discussed are:

- Grid connection of RES-E and system stability
- System adequacy issues
- Grid infrastructure issues
- System operation issues
- Market redesign issues.

The observations made in this chapter are to a major extent based on the findings of the RE-Xpansion project. In addition, they are based on results reported in several publications referenced in the Internet based background reports available at www.ewea.org.

Grid connection codes, system stability issues

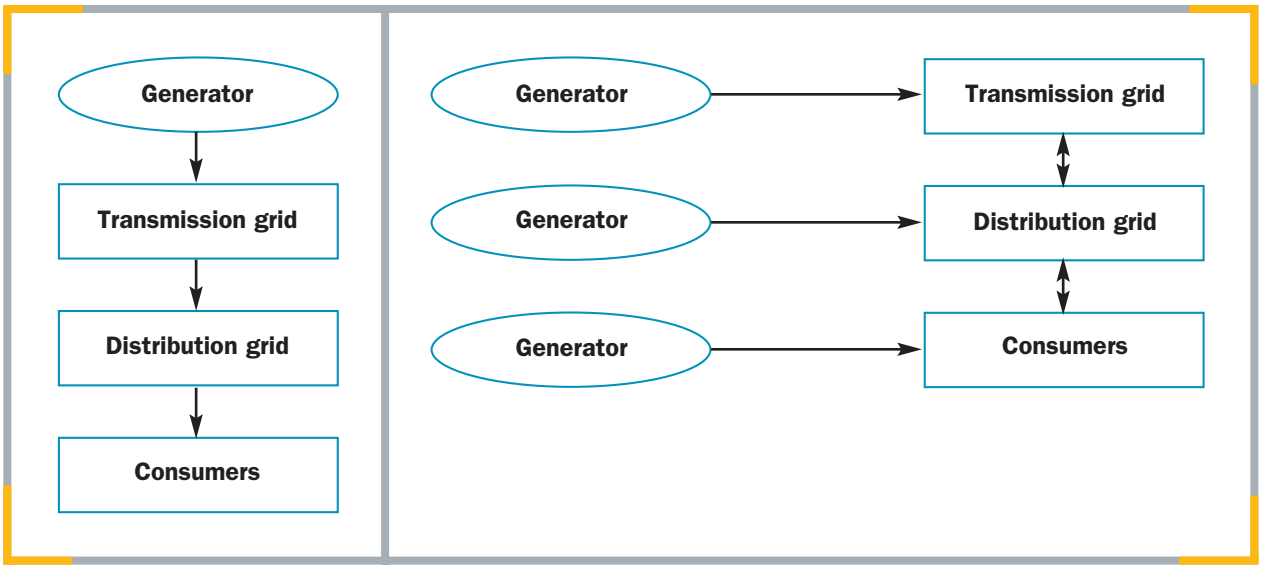
Several impacts (positive and negative) can be identified in the operation of a grid system - both on transmission and distribution level - with a large amount of distributed RES-E generation, such as:

- Voltage changes along the grid, depending on the power produced by the RES-E generators, the load and the impedance of the line.
- Fault levels (short-circuit levels) increase.
- Line losses change as a function of embedded generation and load.
- Congestion in system branches may occur as a function of embedded generation and load.
- Power quality and system reliability may be affected.

In solving these issues it should be borne in mind that the existing grid design standards and regulatory framework are still based on the old paradigm (Figure 1a). However, in practice, the corresponding framework for the future paradigm (Figure 1b) is steadily becoming established as increasing capacities of RES-E generation are permitted.

Figure Annex 1

a) Power flows in the past (left) b) Power flows in the future (right)



Source: Joerss et al. (2002)

In order to avoid negative impacts on the network, especially if there is a substantial amount of distributed and embedded generation, technical criteria (interconnection regulations, grid codes) for grid connection are being applied for most RES-E generation technologies. The detailed requirements that have to be met by distributed generators mostly depend on the voltage at the point of coupling between the embedded generator and the grid infrastructure.

In several EU-countries the interconnection regulations for wind power are being further refined, in order to allow a larger penetration, and at the same time maintain an adequate power supply. The great variety of national regulations is not always an advantage for wind turbine manufacturers. However, a Europe-wide harmonisation of interconnection regulations designed for high penetration situations is also not yet desirable, because some requirements pose an unduly heavy impact on wind turbine design and cost, and hence on the investors and operators of wind farms. It is recommended in the short term to work towards a harmonisation of the regulations on aspects having little impact on the overall costs of wind turbines (e.g. power quality). For other aspects, regulations should take into account specific power system robustness and RES-E penetration levels. Costly technical requirements such as fault-ride-through capability and voltage control possibilities of wind power stations should be included only if they are technically required for reliable and stable power system operation.

Power system adequacy

The issue here is related to the long-term effect of RES-E on the power system, more specifically, the question whether intermittent RES-E such as wind power can replace a part of the conventional capacity – and at the same time enable the power system to maintain adequate power supply at a given moment, even in critical grid situations, with unchanged risk.

The impact of intermittent RES-E wind on the adequacy of power production in the system is determined by the reliability of RES production during peak load situations. From analysis and practical experience it follows that variable sources such as wind power do save and can replace thermal capacity. If system penetration is low, the capacity value of intermittent RES-E generation at critical load situations (also named capacity credit) is equal to the (long-term) average power of the intermittent source. For wind power in a given region, for example, this is equal to the rated power of the total installed wind power capacity in the region multiplied by the average capacity factor (typically 20 – 25 % for a wind power collective consisting mostly out of onshore installations). For example in Belgium, a region with low wind penetration (less than 1 %), the capacity credit of the 100 MW installed wind plants is approximately 20 MW (i.e. the country could safely disconnect 20 MW of the installed thermal power without changing the risk in situations of peak demand). As the penetration increases, the relative capacity credit tails off. In Denmark, for example, where the penetration is much higher (on the average 20 %), the capacity credit of the 3 GW of installed wind power would be around 250 MW.

It is obvious that a geographical dispersion of RES-E generation facilities (which is enhanced by interconnection) and positive correlation between RES-E power and demand increase their capacity credit in the system, and hence the contribution to the system security of supply. In order to assist strategic planning of power systems, a continuous effort is needed in improving insight into the statistical behaviour of intermittent energy sources, e.g. by systematic output monitoring.

The allocation of system capacity cost (for system security) to a single generation technology (e.g. wind) is deceptive, since this ignores the requirements of other generation. In practice, spare controllable capacity is already established for the secure operation of conventional generation plant supplying varying demand. Therefore, the system capacity requirements due to intermittent RES-E (wind) generation cannot be considered on a “MW to MW“ basis, neither now or in the future. In practice, additional system capacity caused by increasing intermittent RES-E (wind) generation does not necessarily come from these new power plants entering the market. For instance, existing conventional and controllable thermal generation units, including peaking generation, and/or existing pumped hydro storage power plants are sufficient for the new intermittent generation also. Therefore, in practice, the socialisation of the costs associated with additional system capacity requirements due to increasing intermittent RES-E generation will be established by the balancing and wholesale electricity markets; these give satisfactory prices signals for the provision of adequate generation capacities.

System operation and balancing

On the generation side: power and energy balancing

Fluctuations in the overall output of RES-E generation place an additional burden on other generation plant in the system and increase requirements for system balancing services, especially when these fluctuations become comparable in magnitude with fluctuations in demand.

Reduction of uncertainty

It is important to stress that system balancing requirements are not assigned to back-up a particular plant type (e.g. wind), but to deal with the overall uncertainty in the balance between demand and generation. Moreover, the uncertainty to be managed in system operation is driven by the combined effect of the fluctuations both (i) in demand, and (ii) in generation from conventional and renewable generation. These individual fluctuations are generally not correlated, which has an overall smoothing effect, with a consequent beneficial impact on the cost.

It has been found in practice in power systems with high penetration, such as Denmark and Spain, that good wind forecasting is critical to successful operation, because it reduces the uncertainty in the balance between demand and generation.

Balancing cost

System balancing requirements and costs are increased by random fluctuations and by forecast errors, both of intermittent RES-E generation and of load, since these are generally not correlated. From various country- and region-specific studies, it can be concluded that the additional costs for increased controllable capacity allocated to wind generation are in the range of 0-3 €/MWh. Modest amounts of wind energy up to 10% of peak demand can be assimilated without incurring additional cost or changing operating procedures. It can be demonstrated that power balancing requirements due to wind mainly address secondary control and reserve power in the system (tertiary control), which in general is offered on the balancing market.

The regulation costs should be allocated to the corresponding balancing markets. In practice, the balancing market prices should send out the correct price signals to the market competitors so the network remains stable.

Avoiding curtailment of RES-E

If wind generation reaches large penetration in a system and with other forms of dispersed embedded generation on line, there may be occasions when the number of conventional large generation units needed to supply the remaining load will be so few, that adequate capacity of central short-term balancing services cannot be maintained. In some situations, renewable generation could, potentially, exceed demand during some periods. A number of actions should be planned to deal with such potential surpluses of renewable generation, as prioritised with respect to cost. The easiest strategy is – interconnection being set aside - to have some renewable plant under central control and for this to be curtailed, as with fossil thermal plant. The least costly options could be to increase demand under 'demand side management', e.g. by additional pumping at pumped storage facilities and water supply reservoirs, or, in future, by hydrogen production. Modern wind turbines will be able to provide response and reserve to at least 10% of their output. If there is still surplus generation left, some of the renewable generation would need to be taken off-line, starting with the technologies with the largest marginal cost, such as biomass.

Ancillary services for generation

Apart from balancing requirements from the energy perspective, the power system requires so-called ancillary services supplied by generators, ranging from operating reserve and reactive power through short-circuit current contribution and black start capability, Intermittent RES-E is not suited for producing such services in a dispatchable, controllable way and in parallel with the implementation of RES-E in the system, appropriate equipment should be maintained to provide the ancillary services.

Transmission & distribution system operation issues

Transmission level

In addition to considerations of managing energy and power balance in the transmission system (discussed above), high levels of intermittent generation also have other implications for the operation of the transmission system. Active voltage control in the system (for example in the neighbourhood of large wind farms) may be required in order to cope with unwanted voltage changes. This voltage support could be supplied by the wind farm itself if adequate wind energy technology is used, otherwise dedicated equipment has to be installed (Static Voltage Controllers SVC's).

Another issue is the management of power flows and possible congestion in the grid. Also for this purpose, TSO's should be provided with high quality wind forecast tools. Forecast errors need to be acceptable up to approximately 12 hours ahead, meaning that the errors are small enough to enable the TSO to cope with the actual situation at acceptable cost.

Distribution level

The addition of RES-E (distributed/embedded generation) to distribution grids creates both difficulties and advantages, for the following principal reasons:

- There is very little so-called "active" management of distribution grids.
- "Distributed generation" adds a further set of circumstances (e.g. changes from full generation to no generation) with which the grid must cope, without reducing the quality of supply seen by other customers;
- The direction and quantity of real (active) and reactive power flows change, which may affect operation of grid control and protection equipment;
- Design and operation practices may no longer be suitable and need modification;
- Weak grids, with reduced voltage under load, can be reinforced by the RES-E;
- Associated power controllers at the embedded generation can improve both active and reactive power characteristics;
- The power from the embedded generation does not entail transmission costs if, as is likely, this power is consumed within the distribution grid network;
- Local 'island' operation may, in principle, be possible in the event of transmission failures;

Distribution grids may have to become more "actively managed". This implies costs, and requires the development of suitable equipment and design principles, but the improved grid yields collateral benefits for the distribution grid operator.

Grid extension and grid reinforcement

A common difficulty concerns the costs of grid extension and reinforcement for integrating large-scale wind power into a grid system. The same difficulty would arise for other embedded generation of similar scale; however wind power is now the most advanced. Should the grid extension cost be charged to the new embedded generator or to the consumers?

The need for extension and reinforcement of the existing grid infrastructure may have a variety of causes. Changes in generation and in load at one point in the network in principle cause changes throughout the system, which may cause power congestion (bottlenecks). It is not possible to identify one (new) point of generation as the single cause of such difficulties, other than it being 'the straw that broke the camel's back'. Therefore, the allocation of changes of load flows in a system to a single new generator connected to the system (e.g. a new wind farm) is ambiguous, since established generators or changes in demand may cause an equal burden on the grid infrastructure.

A number of detailed, published, country-specific studies exist, quantifying grid extension/reinforcement requirements and corresponding cost caused by large-scale grid integration of wind power. The countries include Germany, Island of Ireland, UK, Belgium, Austria, Netherlands and Poland. They are based on comprehensive load flow calculations on the national transmission grids.

The studies quantify grid extension/reinforcement requirements and corresponding costs caused by a variety of factors. These factors include requirements for increases in generation to meet demand (in general) and (in particular) necessary measures and costs for large-scale wind integration. The analyses are based on load flow simulations of the corresponding national transmission and distribution grids that take into account different scenarios of national wind integration, utilising the most favourable sites. The country-specific studies indicate that the grid extension/reinforcement costs caused by additional wind generation are in the range of 0.1 to 5 €/MWhwind, the higher value corresponding to a wind penetration of 30 % in the system (UK). More studies and a harmonisation of methodology is needed to develop a reliable empirical relation between grid extension/reinforcement costs and wind energy penetration. It may, however, serve to identify problems with studies yielding results far from the present results.

Cost allocation principle

In the context of a strategic EU-wide policy for long-term, large-scale RES-E grid integration, a fundamental unbundling discussion is indispensable. A proper definition of the interfaces between the RES-E power plant itself (incl. the "internal grid" and the corresponding electrical equipment), and the "external" grid infrastructure (i.e. new grid connection and

extension /reinforcement of the existing grid) has to be discussed, especially for remote wind farms and offshore wind energy. This does not necessarily mean that the additional grid tariff components due to RES-E grid connection and grid extension/reinforcement have to be paid by local/regional customers only. These costs could be socialised within a "grid infrastructure" component at national, or even at EU level. Of course, corresponding accounting rules would need to be established for the grid operators.

Market redesign, demand side management and storage

In view of the issues discussed above, many European electricity markets still have structural deficiencies and inefficiencies in their balancing and settlement procedures that discriminate against intermittent RES-E generation. Therefore, a re-design of corresponding market structures and procedures is seen as a precondition for integrating significant total capacity of intermittent RES-E into the national and international networks. This especially applies to wind power now, for which there are very large capacity expectations.

Addressing technological development in the short- to medium-term, the implementation of improved forecasting tools will mitigate the intrinsic intermittency of wind generation and, subsequently, reduce corresponding costs for balancing the system. The future role of new, advanced storage technologies, such as battery and fuel cell systems, in providing corresponding balancing services is not yet clear. Therefore their market entry cannot yet be predicted or quantified.

Long-term and fundamental market re-design should focus on having manageable loads on the demand-side. Such loads should change sympathetically with changes in generation, especially of intermittent generation. Such management will reduce both system balancing and system capacity requirements substantially and hence their costs. The preconditions for the significant implementation of demand response applications are (i) the implementation of known and future technologies for communication between supply and demand, (ii) tariffs that encourage rapid and sufficient demand-side load changes in response to the needs of supply, i.e. have minimal transaction cost for consumers.

Nevertheless, the active integration of the demand-side response in overall system operation is indispensable. This will subsequently minimise the additional requirements on the system related to future substantial intermittent RES-E generation.

Literature

1. Auer H., G. Resch, A. Lopez-Polo, C. Obersteiner, J. Twidell: "Evaluating the intermittency of RES-E generation", Report of the project Re-xpansion, Vienna, March 2005.

2. Auer H., C. Huber, M. Stadler, C. Obersteiner, J. Twidell:"Large-scale RES-E Grid Integration: Strategies, Requirements and Cost, Report of the project Re-xpansion, Vienna, March 2005.

References

The references included below have been compiled from the background reports to these guidelines. The background reports are available at www.ewea.org. The references are included here to demonstrate the sources of the overall project. Not all of these references have been used in the drafting of these guidelines.

Ackermann Thomas (ed.), *Wind Power in Power Systems*, Wiley, ISBN 0-470-85508-8, 2005.

Akhmatov, *Variable-speed wind turbines with doubly-fed induction generators*, part III – model with back-to-back converters, Wind Engineeting vol 27, issue 2, pp 79-92, 2003.

Alakangas E., *Renewable Energy sources in Finland 2002,* OPET Report, Finland, 2002.

Almeida A.T. de, P. Fonseca, C.P. Rodrigues, A. Barros, A Jahn and M. Broeger, *Remote metering of electricity as a tool for the promotion of energy efficiency,* ECEEE 2003 Summer School, p. 719-728, 2003.

Alsema E., *PV cost and development* – Presentation at the PHOTEX workshop in Brussels, 4th June 2003, from: Utrecht University, Department of Science, Technology and Society, 2003.

Arbeitsgemeinschaft Erneuerbare Energien, *Ökostromboerse –Förderrichtlinien* [available at www.öekostromboerse.at], 2002.

Auer Hans, *Value and additional cost of large-scale wind integration into the European grids*, Presentation 2004 European Wind Energy Conference, London, 23 November 2004.

Auer H., G. Resch, A. Lopez-Polo, C. Obersteiner, J. Twidell, *Evaluating the intermittency of RES-E generation,* Report of the project Re-xpansion, Vienna, March 2003.

Auer Hans, Gustav Resch, Maria Assumpcio Lopez-Polo, Carlo Obersteiner, John Twidell, *Evaluating the intermittency of RES-E generation*, Report of Work Phase 2 of the Altener project RE-XPANSION, supported by EC-DG TREN, Energy Economics Group (EEG), Vienna University of Technology, Austria 2005.

Auer Hans, Michael Stadler, Gustav Resch, Claus Huber, Thomas Schuster, Hans Taus, Lars Henrik Nielsen, John Twidell, Derk Jan Swider, *Cost and Technical Constraints of RES-E Grid Integration*, WP2-report, August 2004, available for download from the project website www.greennet.at, 2004.

Auer H., T. Faber , C. Huber, G. Resch, C. Obersteiner, *Action Plan for an enhanced least-cost integration of RES-E into the European Grid,* WP10-report, Report on the project GreenNet, Vienna, February 2005, available for download from the project website www.greennet.at

Awerbuch, S., *The true cost of fossil-fired electricity*, Power economics, May 2003.

Awerbuch, S., *Determining the real cost. Why renewable power is more cost competitive than previously believed,* Renewable Energy World March-April 2003. Available from: http://www.jxj.com/magsandj/rew/2003_02/real_cost.html [Accessed 13th October 2003]

Azar and Sterner, *Discounting and distributional considerations in the context of global warming,* Ecological Economics volume 19. pages 169-184, 1996.

Barde, J.-P., *Environmental policy and policy instruments,* In: Folmer, Henk and Landis, H. *Principles of environmental and resource economics,* 2000.

Beurskens L., M. de Noord, *Offshore wind power developments,* Report prepared by ECN (NL), 2003.

Bird L., Wüstenhagen R., Aabakken J., *Green Power Marketing Abroad: Recent Experience and Trends,* Report NREL/TP-620-32155, Colorado, USA, 2002.

BMU, Conference transcript of *Fachtagung Geothermische Stromerzeugung – eine Investition in die Zukunft* (in German). 20-21 June 2002, Landau/Pfalz, published by the German Ministry for Environment, Germany, 2002.

BMU: *Ökologisch optimierter Ausbau der Nutzung erneuerbarer Energien in Deutschland* (in German), Prepared by DLR/ifeu/WI for the German Ministry for Environment, Germany, 2004.

BTM Consult ApS, *International wind energy development – world market update*, Yearly updated reports by BTM Consult ApS (DK), 1999 to 2003.

Bustos M., *The experience of Spanish renewable developers,* Paper from APPA Info Bulletin. Special Edition EWEC 2003, 2003.

Castello S., Personal Information from Mr. Castello, Enea Casacccia Research Center, Italy, 2003.

Center for Energy Policy and Technology, Imperial College, *External cost and environmental policy in the United Kingdom and the European Union.* London, Centre for Energy Policy and Technology. Available from: http://www.british-energy.com/environment/downloadable_items/other/external_cost_and_environmental_policy.doc [Accessed 14th May 2003], 2001.

Christiansen Peter, Knud K. Jorgensen, Aksel Gruelund, *Grid Connection and Remote Control for the Horn Rev 150 MW Offshore Wind Farm in Denmark,* in Proceedings: EWEA 2002 Madrid Conference, 16.-19, June 2002.

Christl Norbert: *Offshore-Windenergienutzung: Wie kommt der Strom aufs Festland?,* Energiewirtschaftliche Tagesfragen, S. 98-103, 53. Jg. Heft 1/2, 2003.

Commission of the European communities, *Progress Report on implementation of the European Community Programme of Policy and Action in relation to the environment and sustainable development "towards sustainability"* Available from http://europa.eu.int/comm/environment/env-act5/prog-rep.htm [Accessed 19th November 2003], 1996.

Consentec, RWTH Aachen, FGH-Mannheim, *Auswirkungen des Windkraftausbaus in Österreich,* Studie von Consentec Consulting für Energiewirtschaft und -technik GmbH, Institut für Elektrische Anlagen und Energiewirtschaft der RWTH Aachen, Forschungsgemeinschaft für Elektrische Anlagen und Stromwirtschaft e.V. im Auftrag der E-Control GmbH, Schlussbericht, Juni 2003.

Connor P.M., *UK renewable energy policy,* Paper from: Renewable & Sustainable Energy Reviews 7, p. 65-82, 2003.

Danish Wind Turbine Owners' Association, *50% af Danmarks elforbrug med vindenergi i 2025,* Danmarks Vindmølleforening (Danish Wind Turbine Owners' Association); March 2005; Web: http://www.dkvind.dk/nyheder/pdf/notat_50procent_vind_2025.pdf, 2005.

Dany Gundolf, H.-J. Haubrich, *Anforderungen an die Kraftwerksreserve bei hoher Windenergieein-speisung,* Energiewirtschaftliche Tagesfragen, S. 890-894, Nr. 12, 2000.

Dena, *Energiewirtschaftliche Planung für die Netzintegration von Windenergie in Deutschland an Land und Offshore bis zum Jahr 2020,* Studie im Auftrag der Deutschen Energie-Agentur GmbH (dena), Konsortium: DEWI, E.ON Netz, EWI, RWE Net, VE Transmission, Februar 2005.

Department of Trade and Industry, DTI, NFFO-News, New Review – The Quarterly Newsletter for the UK New & Renewable Energy Industry, Issue 45, August 2000 – available at http://www.dti.gov.uk/NewReview/nr45/html/nffo_news.html], 2000.

Deutsches Windenergie-Institut Gmbh (DEWI): *Studie zur aktuellen Kostensituation 2002 der Windenergienutzung in Deutschland* (in German), Deutsches Windenergie-Institut GmbH, Germany 2002.

DLR/WI/ZSW/IWR/Forum, *Klimaschutz durch Nutzung erneuerbarer Energien* (in German) – study for the German Ministry for Environment, Germany, 1999.

DTI/ETSU, New and Renewable Energy: Prospects in the UK for the 21st century, United Kingdom, 1999.

DTI/ETSU, *The commercial prospects for Tidal Power,* Report for DTI/ETSU by Binnie, Black and Veatch in association with IT Power, United Kingdom, 2001.

Elsässer Rainer Frank, *Kosten der Windenergienutzung in Deutschland,* Präsentation im Rahmen der Sitzung des Wirtschaftsbeirates der Union, Berlin, 23 Juli 2003.

Enel Green Power, *The Green Label,* Web: www.enel.it,, 2003.

Ener-lure Project Phase III, Various reports - available at www.jrc.es/cfapp/ener-iure/analysis.htm, 2002.

Enquete, *Analysis grid for the German Enquete Commission on Sustainable Energy Policy,* 2002.

ESD/DGXVII, TERES II – *the European Renewable Energy Study,* Report & CD-ROM by ESD et al.– on behalf of the European Commission, DG TREN, 1996.

ETSU/DGXVII, *Atlas Project– Energy technology, the next steps,* THERMIE report, 1997.

EUBIONET, *Various reports (e.g. "Fuel prices in 2002/2003")* on web page www.eubionet.net., 2003.

EURELECTRIC, *Statistics and prospects for the European electricity sector (1980-1990, 2000-2020),* (EURPROG 2000), 2002.

European Commission, *Externalities of fuel cycles "ExternE" project, Summary Report.* Brussels, European Commission, 1994.

European Commission, *Externalities of fuel cycles "ExternE" project. Economic Valuation Report.* Brussels, European Commission, 1994.

European Commission, *Energy for the future: renewable sources of energy. White paper for a community strategy and action plan,* Available from: http://europa.eu.int/comm/energy/library/599fi_en.pdf [Accessed 15th September 2003], 1997.

European Commission, *Extension of the accounting framework. Final report.* Stuttgart, Germany. Available from: http://externe.jrc.es/meth2.pdf [Accessed 15th September 2003], 1997.

European Commission, *ExternE. Externalities of energy. National Implementation.* Volume 10. Belgium, European Commission, 1999.

European Commission, *Towards Sustainability,* The European Community Programme of policy and action in relation to the environment and sustainable development. Available from: http://europa.eu.int/comm/environment/actionpr.htm [Accessed 15th September 2003], 2003.

European Commission, Annual Energy Review, *Forecast 2010: Energy in Europe – European Union Energy Outlook to 2020,* 1999.

European Commission, The European Opinion Research Group, Eurobarometer. *Energy: Issues, Options and Technologies. Science and Society,* European Commission, Luxembourg, 2003.

European Commission, *Green Paper Towards a European Strategy for the security of energy supply,* 2001.

European Parliament and Council, *Directive of the European Parliament and of the Council on the promotion of electricity produced from renewable energy sources in the internal electricity market,* Directive 2001/77/EC - 27 September 2001, Brussels, 2001.

European Parliament and Council, *Directive 2000/60/EC of October 23rd 2000 establishing a framework for Community action in the field of water policy,* 2000.

European Renewable Energies Federation – EREF, *RES-E EU Frameworks Prices,* Report from EREF, First Edition 2003 (March).

Eurostat, Environmental statistics – Yearbook 2001 (CD-ROM), 2002.

Eurostat, Energy statistics – 2002 edition (CD-ROM), 2002.

EWEA, DG TREN, *Wind Energy – The Facts,* Study published by The European Wind Energy Association (EWEA) and the European Commission's Directorate General for Transport and Energy (DG TREN) within the ALTENER Programme of the European Commission, www.ewea.org, 2003.

EWEA, *Wind Power Targets for Europe: 75,000 MW by 2010,* 2003.

EWEA, *Survey for Wind Energy -The Facts,* 2003.

Ewers H-J. and Rennings, K., *Economics of nuclear risks – A German Study,* In: Hohmeyer, O. and Ottinger R.L. Social costs of Energy. Present Status and Future Trends, Springer-Verlag, Berlin, 1992.

FAOSTAT, Food and Agricultural Organization of the United Nations - statistical database (on land use, forestry, etc.), available on the Internet: http://apps.fao.org/, 2002.

Fichtner, *Gutachten zur Markt- und Kostenentwicklung der Stromerzeugung aus Biomasse* (in German). Expertise prepared by Fichtner for Bundesinitiative Bioenergie, Stuttgart (DE), 2002.

Frankl P., Menichetti E., *Policies and Market Developments. Case Study: Spain,* REMAC 2000, Italy, 2002.

Friedrich, L. *et al., Externen Kosten der Stromerzeugung,* 1989.

Fuchs Martin, *Windpower in Germany: present situation and outlook,* E.ON Netz GmbH, January 2003.

Gamberale M., Castello S, Li Causi S, *The Italian Roof Top Program: status and perspectives,* Presentation at the conference "PV in Europe - From PV technology to energy solutions", 7-11 October 2002, Rome, Italy, 2002.

Gardner P., *The Impact of Increased Levels of Wind Penetration on the Electricity Systems of the Republic of Ireland and Northern Ireland,* Final Report for the Commission for Energy Regulation/OFREG NI by Garrad Hassan and Partners Limited, Glasgow, Scotland, 2003.

Garrad Hassan, Germanischer Lloyd, Windtest, *Study of the Offshore Wind Energy in the EC,* 1995.

German Ministry for the Environment, Nature Conservation, and Nuclear Safety, *Richtziel der Bundesrepublik Deutschland für den Verbrauch von Strom aus erneuerbaren Energiequellen im Jahr 2010 und Maßnahmen zur Verwirklichung des Richtziels,* Report of the German Government in accordance with Article 3 of the Directive 2001/77/EC. Berlin, Germany (in German), 2003.

Genennig B. and Hoffmann V.U., *Sozialwissenschaftliche Begleituntersuchung zum Bund-Länder-1000-Dächer Photovoltaik Programm,* Umweltinstitut Leipzig (in German), 1996.

Gesellschaft für Reaktorsicherheit (GRS), *Deutsche Risikostudie Kernkraftwerke Phase B. Eine zusammenfassende Darstellung. 2,* Auflage. Köln, 1989.

Giebel Gregor, *The capacity credit of wind energy in Europe, estimated from reanalysis data,* Risoe working paper, 2001.

Giebel, Gregor, *On the Benefits of Distributed Generation of Wind Energy in Europe,* PhD thesis, Carl von Ossietzky Universität, Oldenburg, VDI_Verlag, ISBN 3-18-344406-2, 2001.

Greenpeace, North *Sea Offshore Wind – A Powerhouse for Europe,* Germany 2000.

Greenprices, Various *Greenprices newsletter.* Web: www.greenprices.com, 2003.

Gutschner M., *Evaluation of the technical potential of building integrated photovoltaic power systems,* Report for the PVPS Task VII, Photovoltaic Power Systems in the Built Environment, Freiburg 2001.

Haas R., *Market deployment strategies for PV systems in the built environment – Report from the IEA PVPS programme* – Task 7, Energy Economics Group, Vienna University of Technology, Austria, 2002.

Haas R., Huber C., Wohlgemuth N., *Financial incentives to promote renewable energy systems in European electricity markets – a survey,* Paper from: International Journal of Global Energy Issues 2001.

Haas R., Ornetzeder M., Hametner K., Wroblewski A., Hübner M., *Sozialwissenschaftliche Begleitforschung zum österreichischen 200 kWp-PV-Breitentest,* BMWV, Vienna, Austria (in German), 1997.

Haidvogl Herbert, *Netzanbindung von Windenergieerzeugungsanlagen (WEA),* Elektrizitätswirt-schaft, S. 20-21, 2002.

Hatziargyriou, *Wind Engineering,* vol. 26 no. 6, 2002; this special issue includes:

Ledesma Pablo and Usaola Julio, *Contribution of variable-speed wind turbines to voltage control*

Michos D., Dialynas E. and Vionis P., *Reliability and Safety Assessment of Wind Turbines Control and Protection Systems*

Haniotis A., Papathanassiou S., Kladas A. and Papadopoulos M., *Control Issues of a Permanent-Magnet Generator, Variable-Speed, Wind Turbine*

Agelidis Vassilios G. and Mademlis Christos, *Technology of Offshore Wind Turbines and Farms and Novel Multilevel Converter-Based HVDC Systems for their Grid Connections*

Schinas N., Vovos N.A. and Giannakopoulos G.B., *Embedded Wind Turbine Generation into AC Weak Distribution Grids*

Kanellos F.D. and Hatziargyriou N.D., *Comparison between Types of Generation for Wind Turbines Operating in Stochastic Wind.*

Häusler Michael, Owan Frederik, *AC or DC for connecting Offshore Wind Farms to the Transmission Grid?,* in Proceedings for the 2002 Workshop on Transmission Networks for Offshore Wind Farms, Stockholm 2002.

Helby Peter, *Rationality of the subsidy regime for wind power in Sweden and Denmark,* University of Lund, Sweden, 1995.

Helby Peter, *Renewable energy projects in Sweden: An overview of subsidies, taxation, ownership and finance,* Mimeo, University of Lund, Sweden, 1998.

Hensing, I et al, *Energiewirtschaft, Oldenbourg Verlag, München-Wien,* 1998.

Hirst E., *Consulting in electric-industry restructuring,* www.ehirst.com, 25/04/2003 [see his reports *Integrating wind output with the BPA Power System, Interaction of wind-farm output with bulk-power systems,* 2003.

Hohmeyer, O et al. (eds), *Social costs and sustainability,* Heidelberg, Spring Verlag Berlin, 1996.

Hohmeyer, O et al. (eds), *Chance Automausstieg. Perspektiven für neue Arbeitsplätze an Atomstandorten,* Hamburg, Greenpeace, 2000.

Hohmeyer, O., *Soziale Kosten des Energieverbrauchs,* Springer Verlag, 1988.

Hohmeyer, O. *Social costs of climate change strong sustainability and social costs,* In: Hohmeyer, O. et al. *Social costs and sustainability,* Heidelberg, Spring Verlag Berlin, 1996.

Hohmeyer, O., *Vergleich externer Kosten der Strömerzeugung in Bezug auf das Erneuerbare Energien Gesetz,* Umweltbundesamt, Berlin, 2001.

Hooft J. L., *Survey of integration of 6000 MW offshore wind power in the Netherlands electricity grid in 2020,* 2003.

Huber, C., T. Faber, *The computer model Green-X,* Presentation at the mid-term workshop of the project Green-X, Brussels, 23 September 2003; Energy Economics Group, Vienna University of Technology. Available at: www.green-x.at, 2003.

Huber C., T. Faber, R. Haas, G. Resch, J. Green, S. Ölz, S. White, H. Cleijne, W. Ruijgrok, P.E. Morthorst, K. Skytte, M. Gual, P. Del Rio, F. Hernández, A. Tacsir, M. Ragwitz, J. Schleich, W. Orasch, M. Bokemann, C. Lins, *Final report of the project Green-X,* Green-X report, Nov. 2004, available at *www.green-x.at.*

IEA, *World Energy Outlook 2004*, International Energy Agency, Paris, 2004.

ILEX Energy Consulting: „Quantifying the system costs of additional renewables in 2020", A report of ILEX Energy Consulting in association with Manchester Centre for Electrical Energy (UMIST) for the Department of Trade and Industry (DTI), October 2002.

International Energy Agency, *Trends in Photovoltaic Applications in Selected IEA Countries between 1992 and 1999*, Report IEA-PVPS T1-08/2000, 2000.

International Energy Agency, *IEA Wind Energy Annual Report 2002,* Paris, France, 2003.

International Energy Agency, *Energy Statistics of OECD countries,* 1997-1998, Paris, France, 2000.

International Energy Agency, *Electricity Information,* Paris, France, 2002.

International Energy Agency, *Renewable Energy Database,* available at: http://library.iea.org/dbtw-wpd/textbase/pamsdb/re_webquery.htm, 2003.

Jackson Jack, *A Cry for Better Forecasters in Denmark,* Windpower Monthly, p. 40-42, Issue 12/2003.

Jensen, P.H., Morthorst, P.E., Skriver, S., Rasmussen, M. et al, *Økonomi for vindmøller i Danmark - Etablerings-, drifts- og vedligeholdelsesomkostninger for udvalgte generationer (in Danish),* Risø, 2002.

Joerss W., B.H. Joergensen, P. Loeffler, P.E. Morthorst, M.A. Uyterlinde, E.J.W. van Sambeek, T. Wehnert, B. Groenenddaal, M. Marin, H. Schwarzenbohler, M. Wagner, *Decentralised Generation Technologies – Potentials, Success Factors and Impacts in the Liberalised EU Energy Markets,* EU-Project DECENT, Final Report, Berlin, October 2002.

Junginger M., A. Faaij, *Cost reduction prospects for the offshore wind energy sector,* Paper presented at the EWEA 2003 in Madrid (June 2003), Department of Science, Technology and Society; Copernicus Institute, Utrecht University, The Netherlands, 2003.

Kaltschmitt M., Wiese A., Streicher W., *Erneuerbare Energien* – 3rd edition (in German), ISBN 3-540-43600-6, Springer-Verlag, Germany.

Knight Sara, *Balancing Cost Halved by Forecast Program*, Windpower Monthly, p. 42-43, Issue 12/2003.

Landberg L., *Prediktor – an Online Prediction System*, EWEA Special Topic Conference in Kassel, 2000.

Landberg et al, *Wind Resource Estimation – An overview*, Wind Energy Journal, Vol. 6, No.3, 2003.

Lee, Russell, *Externalities Studies: Why are the numbers different,* In: Hohmeyer, O. et al. Social costs and sustainability, Heidelberg, Spring Verlag Berlin, 1996.

Lehmann Klaus-Peter, *Strategic options for the wind energy market, Renewable Energy World,* pp. 38-49, May/June 2003.

Leonhard Werner, Kai Müller, *Balancing fluctuating wind energy by controlling fossil power plants* – where are the limits?, EW-Journal, Jg. 101, Heft 21-22, 2002.

Lorenzoni A. (2001): Blue Energy for a Green Europe – final report, EU Altener II Programme, IEFE – Universitá Commerciale L. Bocconi, Milano 2001.

Lundsager Per, Henrik Bindner, *Integration of wind energy into electricity supply systems,* in Proceddings: 1st Risoe International Energy Conference, 19-21 May 2003, Session on Wind Energy, Roskilde, 2003.

Luther Martin, *Grid operation and management with large scale wind generation,* European Conference on Integration of Renewable Energy Sources and Distributed Generation in Energy Systems, Brussels, 25-26 September 2001.

Mantzos et al., *European Energy and Transport Trends to 2030,* On behalf of: European Commission, DG TREN. University of Athens, Greece, 2003.

Mariyappan Jay, *Cost and Technical Opportunities for Electricity Storage Technologies,* WP3-Report of the project "Pushing a Least Cost Integration of Green Electricity into the European Grids" of the 5th Framework Programme, Coordinator: EEG Vienna, Duration: January 2003 - December 2004.

Markard J., *Welchen Beitrag können freiwillige Zahlungen von Stromkunden zur Förderung regenerativer Energien leisten?*, Öko-Institut, Freiburg, Germany (in German), 1998.

Massachusetts Institute of Technology, *The future of nuclear power,* Available from: http://web.mit.edu/nuclearpower/ [Accessed 22nd February 2005], 2003.

McGovern Michael, *Forecasting Focus on Who Pays in Spain,* Windpower Monthly, p. 45-46, Issue 12/2003.

McLeay Keith, David Moretti, Mott MacDonald, *Electrical design for offshore wind,* Journal re-gen, pp. 58-61, June/July 2003.

Menges, R., *Supporting renewable energy on liberalised markets: green electricity between additionality and consumer sovereignty,* In: Energy Policy 31, No. 7 (2003), p. 583-596, 2003.

Metering International, *New approaches to ripple control,* Metering International Issue 4, p 45. [available on internet], 2002.

Meyer N.I., Koefoed A.L., Danish Energy Report: *Policy implications for renewables,* From: Energy Policy 32 p. 597-607, 2003.

Michael P., *DTI Wave Report 2002,* Department of Trade and Industry, United Kingdom, 2002.

Milborrow David, *Forecasting for Scheduled Delivery,* Windpower Monthly, p. 37-39, Issue 12/2003.

Milborrow D., *The real cost of integration wind,* Windpower Monthly, S. 35-39, February 2004, 2004.

Milborrow D., *Impact of Wind on Electricity Systems with Particular Reference to Alberta,* Working Paper, 20 July 2004.

Mitchell C., *Renewable Generation – Success Story?,* in The British Electricity Experiment Privatisation: the Record, the Issues, the Lessons, edited by J. Surrey, Earthscan, 1996.

Morthorst P. E., *Wind power and the conditions at a liberalised power market*, 2003.

Morthorst P.E., K. Skytte, C. Huber, G. Resch, p: Del Rio; M. Gual, M. Ragwitz, J. Schleich, S. White, *Analysis of trade-offs between different support mechanisms,* Green-X Work package 4 report, March 2004, available at www.green-x.at, 2004.

Morthorst P.E., B. H. Jørgensen, G. Resch, D. Mora, O. Hohmeyer, H. Chandler, C. Kjær, P. Helby, J. Twidell, *Evaluation of Renewable Support Schemes,* Re-Xpansion Work phase 2 report, forthcoming – to be published in April 2005.

Morthorst P.E., *The use of policy instruments in the long-term implementation of renewable energy technologies under liberated market conditions,* Risø National Laboratory, Roskilde, Denmark, 1998.

Moths, E., *Internalization of external costs during the crisis of environmental policy or as a crisis for economic policy,* In: Hohmeyer, O. and Ottinger R.L. Social costs of Energy. Present Status and Future Trends. Springer-Verlag. Berlin, 1992.

Neij, L., *Use of experience curves to analyse the prospects for diffusion and adaptation of renewable energy technologies,* Energy Policy, 23(13), 1997.

Neij, L. et al, *Final report of EXTOOL: Experience curves, a tool for energy policy programmes assessment,* Lund, Sweden, 2003.

Neij L., P. D. Andersen, M. Durstewitz, P. Helby, M. Hoppe-Kilpper, P. E. Morthorst, *Experience curves: A tool for Energy Policy Assessment (EXTOOL),* Final report of the project EXTOOL – a European research project funded by the EC, DG RESEARCH; Coordinated by Lund University, Sweden, 2003.

Neubarth J., M. Kaltschmitt, *Erneuerbare Energien in Österreich* (in German), ISBN 3-211-83579-2, Spirnger-Verlag Wien New York, Austria, (in German), 2000.

Nielsen, T.S., A. Joensen, H. Madsen, L. Landberg, G. Giebel, *A New Reference for Predicting Wind Power,* Wind Energy, Volume 1, pp. 29-34, 1998.

Norton R., *The UK renewables market and the implications of the UK´s long term energy policy,* Energy Briefing April 2003.

Norton R., *Wind Power in France,* Energy Briefing, June 2003.

Nowak St., M. Gutschner, G. Favaro, *Impact of Technology Developments and Cost Reductions on Market Growth* – Concentrating Solar Power, Report prepared within the project REMAC2000. NET Ltd., Switzerland, 2002.

Nybroe, Malene Hein, Mikale Togeby, Demand *Response and the need for intelligent appliances,* EEDAL 03 conference, Turin, October 2003.

O'Bryant Mike, *Advantage of Tight Hour Ahead Forecasts,* Windpower Monthly, p. 44-45, Issue 12/2003.

OECD/IEA, *Projected Costs of Generating Electricity – Update 1998,* OECD Nuclear Energy Agency and International Energy Agency, Paris, 1998.

OECD/IEA, *Projected Costs of Generating Electricity – Update 2005*, OECD Nuclear Energy Agency and International Energy Agency, Paris, 2005.

Offer, *Fifth Renewable Order for England and Wales,* [available at http://www.open.gov.uk/offer/offer.htm], 1998.

Official Journal of the European Communities, *Towards sustainability (No C 138)* Available from: http://europa.eu.int/comm/environment/env-act5/5eap.pdf [Accessed 19th November 2003], 1993.

Official Journal of the European Communities, *Community guidelines on State aid for environmental protection (2001/C 37/03)* Available from: http://europa.eu.int/eur-lex/pri/en/oj/dat/2001/c_037/c_03720010203en00030015.pdf [Accessed 19th November 2003], 2001.

OFGEM Newsletter, *Re:source. Renewables*, Update - June 2003

O'Malley M. (Guest Ed), Special issue, with 5 papers, considering the impact of wind power on the Irish supply grid, Wind Engineering vol 28, issue 1, 2004. The papers are:

J. G. Slootweg and W. L. Kling, *Modelling Wind Turbines for Power System Dynamics Simulations: an Overview*

Ronan Doherty, Leslie Bryans, Paul Gardner and Mark O'Malley, *Wind Penetration Studies on the Island of Ireland*

Morgan Bazilian, Eleanor Denny and Mark O'Malley, *Challenges of Increased Wind Energy Penetration in Ireland*

Jane E. McArdle, *Dynamic Modelling of Wind Turbine Generators and the Impact on Small Lightly Interconnected Grids*

Andrew Causebrook and Brendan Fox, *Modernising Grid Codes to Accommodate Diverse Generation Technologies, especially Modern Windfarms.*

OPET Finland, Green Electricity, *Green Certificates and Flexible Mechanism in Finland,* Finland, 2002.

Ottinger, R.L. et al., *Environmental cost of electricity,* Pace University Center of Environmental Legal Studies, New York, Oceana Publications, Inc, 1990.

OXERA Environmental, *Renewable Electricity Entry Scenario,* United Kingdom, 2001.

Pantaleo A., Pellerano A., Trovato M., *Technical issues on wind energy integration in power systems: Projections in Italy,* Proceedings: European Wind Energy Conference 2003, Madrid, 16-19 June 2003.

Parsons B., Milligan M., Zavadil B., Brooks D., Kirby B., Dragoon K., Caldwell J., *Grid Impacts of Wind Power: A Summary of Recent Studies in the United States,* Proceedings: European Wind Energy Conference 2003, Madrid, 16-19 June 2003.

Pechey J., P. Taylor, R. Dixon. M. Lawson and A. Dinning, *The role of medium voltage electrical system design in risk management for offshore wind farms,* Wind Engineering, vol 28, no. 5, pp 489-502.

Persaud, Shashi, Brendan Fox and Damian Flynn, *Modelling the impact of wind power fluctuations on the load following capability of an isolated thermal power system,* Wind Engineering vol 24, issue 6 pp399-416, 2000.

Poussard E, Quantin J., *Collection of European experiences in local investment,* PREDAC, France, 2003.

Public Citizen, Price-Anderson Act: *The billion dollar bailout for nuclear power mishaps,* Available from: http://www.citizen.org/documents/priceandersonbackgrounder.pdf [Accessed 11th February 2005], 2004.

Rabel, Ari, *Discounting of Long Term Costs: What Would future generations prefer us to do?*, In: Hohmeyer, O und Rennings, K (Editors). Man-made climate change. Economic aspects and policy options, Spring Verlag. Heidelberg, 1999.

Ragwitz M., J. Schleich, C. Huber, G. Resch, T. Faber, M. Voogt, W. Ruijgrok, P. Bodo, *FORRES 2020 - Analysis of the renewable energy's evolution up to 2020,* Draft final report of the project FORRES 2020 - on behalf of the European Commission, DG TREN; coordinated by FhG-ISI with contribution from EEG, Ecofys, Kema and REC; Karlsruhe (DE), 2004.

Redlinger R.Y., Dannemand Andersen P., Morthorst, P.E., *Wind energy in the 21st century,* Palgrave 2002.

Rennings, K., *Economic and ecological concepts of sustainable development: External costs and sustainability indicators,* In: Hohmeyer, O. et al. Social costs and sustainability, Heidelberg, Spring Verlag Berlin, 1996.

Resch G., M. Berger, L. Kranzl, *Database for the Model ElGreen, Internal report of the project Organising a Joint European Green Electricity Market (ElGreen),* Energy Economics Group (EEG), Vienna University of Technology, Austria, 2001.

Resch G., T. Faber, C. Huber, *Dynamic cost-resource curves for RES-E,* Presentation at the mid-term workshop of the project Green-X, Brussels, 23 September 2003; Energy Economics Group, Vienna University of Technology. Available at: www.green-x.at, 2003.

Resch Gustav, Thomas Faber, Claus Huber, *Electricity from renewable energy sources in EU-15 countries – Future potential and costs,* Report of Work Phase 1 of the Altener project RE-XPANSION, supported by EC-DG TREN, Energy Economics Group (EEG), Vienna University of Technology, Austria 2005.

Resch Gustav, Auer Hans, Sadler Michael, Nelsen Lars Henrik, and Twidell John, *Pushing a least cost integration of green electricity into the European grid, GreenNet. Dynamics and basic interactions of RES-E with the grid, switchable loads and storages, work package 1,* September 2003, www.greennet.at

Resch Gustav, Maria-Assumpcio Lopez-Polo, Auer Hans, Haas Reinhard, *Electricity from renewable energy sources in EU-15 countries: A review of promotion instruments,* Work Phase 1 report of the project Re-xpansion, Vienna, April 2005.

Resch G., M. A. Lopez-Polo, Auer H., Haas R., Chandler H., Kjær C., Twidell J., *Electricity from renewable energy sources in EU-15 countries – a review of promotion strategies,* Re-Xpansion Work Phase 2 report, June 2004.

Riccio, J. (2001) Risky business. *The probability and consequences of a nuclear accident.* Greenpeace. Available from: http://www.greenpeaceusa.org/multimedia/download/1/573123/0/risky_business.pdf [Accessed 15th March 2005]

RISØ National Laboratory, *European Wind Atlas,* ISBN 87-550-1482-8, Denmark 1998.

RWE, Umweltplus – *Eine Initiative der RWE Energie AG,* Info-homepage from RWE: www.umweltplus.de, Germany, 2003.

Sambeek E.J.W., *The European Dimension of National Renewable Electricity Policy Making.* An analysis, 2002.

Sambeek E.J.W., Thuijl E., *The Dutch Renewable Electricity Market in 2003,* ECN, Netherlands, 2003.

Schaeffer et al., *Learning from the sun – Final report of the Photex project,* Report of the European research project Photex, supported by EC, DG TREN; coordinated by ECN, Netherlands, 2004.

Schneider and Zweifel, *How much internalization of nuclear risk through liability insurance?,* Socioeconomic Institute, University of Zurich. Available from: http://www.vcharite.univ-mrs.fr/idep/Docs/Egrie/zweifel.pdf [Accessed 10th February 2005], 2004.

Seawind, *Guidelines Tool for Planning and Implementation of Costal Offshore Wind Parks,* Summary of Altener Project 4.1030/Z/01-103/2001, August 2003.

Sensfuß F., Ragwitz M., Wietschel M., *Fluktuationen der Windenergie und deren Vorhersagbarkeit bei einem verstärkten Ausbau des Offshore-Anteils in Deutschland bis 2020,* in Proceedings: 3. Internationale Energiewirtschaftstagung an der TU-Wien, 14. Februar 2003.

Spitaleri C., Seminara A., Ceci C., *Sun at School. The Italian PV School Program,* Presentation at the conference PV in Europe-From PV technology to energy solutions, 7-11 October 2002, Rome, Italy, 2002.

Sustainable Energy Ireland, *Results of the sixth Alternative Energy Requirement (AER VI) competition,* Dublin, Ireland - available at: www.sei.ie, 2003.

Swedish Energy Agency, *Electricity Certificates – New legislation for the environment and for the future,* Sweden, 2002.

Swedish Energy Agency, *Energy in Sweden 2002,* Sweden, 2002.

Swedish Energy Agency, *The Electricity Market 2002,* Sweden, 2002.

Thorpe M., *Wave energy review,* United Kingdom, 1999.

Tondi G., Cariello F., Andreozzi M., *The PV Roof Top Program in the province of Florence,* Results and achievements with local administrations, Presentation at the conference *PV in Europe-From PV technology to energy solutions,* 7-11 October 2002, Rome, Italy, 2002.

Twidell John, *Increasing renewables grid generation using sympathetic loads and tariffs,* Working paper, AMSET Center, June 2003.

Tyran, J. and Zweifel, P., *Environmental risk internalization through capital markets: The case of nuclear power,* International review of Law and Economics. Volume 13. pages 431-444, 1993.

UCTE: *"National electricity consumption 2002 and peak load (December 2002),* www.ucte.org, 2002.

UCTE: *"National electricity consumption 2003 and peak load (December 2003),* www.ucte.org, 2003.

Umweltbundesamt, *Vergleich externer Kosten der Stromerzeugung in Bezug auf das Erneuerbare Energien Gesetz,* 2002.

Usaola Julio, Ravelo Oswaldo, González Gerardo, Soto Fernando, Dávila Mª Carmen, Díaz –Guerra Belén, *Benefits for wind energy in electricity markets from using short term wind power prediction tools; a simulation study,* Wind Engineering, vol 28 issue 1, [2004].

UWIG, Wind Power Impacts on *Electric-Power-System Operating Costs,* Summary and Perspective on Work Done to Date from the Utility Wind Interest Group, November 2003.

van Werven Michiel, Beurskens Luuk, van Sambeek Emiel, Roos Clement, *Issues of integrating wind power in EU electricity systems – Economic and technical impacts,* WP4-report, October 2004, www.greennet.at

Varming Soren, Gaardestrup Christian, Eli Nielsen John, *Review of the technical options and constraints for integration of distributed generation in electricity networks,* Report on the project Sustelnet (Policy and Regulatory Roadmap for the Integration of Distributed Generation and the Development of Sustainable Electricity Networks), 2002.

VDEW–Vereinigung Deutscher Elektrizitätswerke, *VDEW-Statistik 1998. Leistung und Arbeit. (CD-ROM),* Frankfurt, VWEW Verlag- und Wirtschaftsgesellschaft der Elektrizitätswerke, 2000.

Verbruggen A. (2004), *Tradable Green Certificates in Flanders,* Belgium, Paper from Energy Policy 32, p. 165-176, 2004 (forthcoming).

WCED – World Commission for Environment and Development, *Brundtland Report*, 1987.

Weinreich, S., *Nachhaltige Entwicklung im Personenverkehr unter Berücksichtigung der externen Kosten,* PhD thesis at the University of Flensburg, 2002.

Wene, C.-O., *Experience curves for energy technology policy,* International Energy Agency, Paris, 2000.

WETO, *World Energy, Technology and Climate Policy Outlook,* ENERDATA et al. on behalf of DG Research, 2003.

Wiser, Bolinger and Holt, *Customer choice and green power marketing: A critical review and analysis of experience to date,* Report elaborated by University of California, Lawrence Berkeley National Laboratory, USA, 2000.

Wright Sally D., Rogers Anthony L., Manwell James F., Ellis Anthony, *Transmission Options for Offshore Wind Farms in the United States,* in Proceedings: 2002 AWEA Conference - Transmission Options for Offshore Wind Farms in the United States, 2002.

Wu, Xueguang, Atputharajah Arulampalam, Changjiang Zha2 and Nick Jenkins, *Application of a Static Reactive Power Compensator (STATCOM) and a Dynamic Braking Resistor (DBR) for the Stability Enhancement of a Large Wind Farm,* Wind Engineering vol 27 issue 2, pp 92-106, 2003.

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