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Evaluation of different feed-in tariff design options - Best practice paper for the International Feed-in Cooperation

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AT:	Austria
AET:	Average electricity tariff (Spanish reference electricity price)
BE:	Belgium
CZ:	Czech Republic
CHP:	Combined heat and power
DE:	Germany
DK:	Denmark
EE:	Estonia
ES:	Spain
EU:	European Union
EU-10:	The 10 countries that joined the European Union on May 1st 2004: Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia
EU-15:	15 countries joining the European Union before the expansion in May 2004: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and the United Kingdom
EU-25:	All Member States of the European Union after May 1st 2004.
FI:	Finland
FLH:	Full-load hours
FR:	France
GR:	Greece
GWh:	Gigawatt-hour
HDR:	Hot-Dry-Rock (Geothermal resource)
HU:	Hungary
IE:	Ireland
IT:	Italy
kW:	Kilowatt
kWh:	Kilowatt-hour
LA:	Latvia
LT:	Lithuania
LU:	Luxembourg
m:	meter
m/s:	meter per second
MT:	Malta
MVA:	Mega volt ampere
MW:	Mega watt
NL:	Netherlands
O&M costs:	Operation and maintenance costs
PL:	Poland
PSO:	Public Service Obligation
PT:	Portugal
PV:	Photovoltaic
RES:	Renewable energy sources
RES-E:	Electricity from renewable energy sources
s:	second
SE:	Sweden
SK:	Slovakia
SI:	Slovenia
UK:	United Kingdom

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1 Introduction

The European Union has the objective to increase the share of electricity generated from renewable energy sources (RES-E) to 21 % of the total electricity consumption in the 25 EU Member States by 2010. This is the core element of Directive 2001/77/EC, which requires each Member State to apply appropriate instruments in order to achieve the national target for RES-E. In the past years several instruments to support the electricity generation from renewable energy sources have been implemented in the EU countries, where the overwhelmingly most frequent measure is the *feed-in tariff design,* which allows RES-E generators to sell their electricity at a fixed price per kWh. Among others, Spain and Germany have been applying feed-in tariff systems during the last years very successfully, which led to a large increase of RES-E plants in both countries. In the year 2004 the governments of Spain and Germany initiated the *International Feed-in Cooperation* in order to promote the exchange of experiences and to improve the feed-in system design in EU and other countries.

This report is written in the framework of the *International Feed-in Cooperation* with the goal to describe and analyse the feed-in tariff designs applied in the Member States of the European Union. Innovative design options to reduce the electricity generation costs as well as the costs for society are presented and investigated. Furthermore the questions of distributing the costs of RES-E support and how to improve the integration of RES-E into the electricity grid are covered. Best practice examples are analysed and their consequences for RES-E generators and electricity consumers are described.

Before the different feed-in tariff designs are illustrated, *renewable energy sources* are defined and the development of RES-E generation in Europe is outlined. Furthermore the *International Feed-in Cooperation* is described.

This paper is not exhaustive, but it intends to show the wide range of different feed-in tariff designs applied in the European Union. Changes in the legislation of Member States until the end of September 2006 are taken into account in this report.

2 Overview

2.1 Definition of renewable energy sources

According to the EU Directive 2001/77/EC[1] renewable energy sources (RES) include the following, non-fossil energy sources:

- Wind power (onshore and offshore)
- Solar power (photovoltaics and solar thermal electricity)
- Geothermal power
- Hydro power (small scale and large scale)
- Wave power
- Tidal power
- Biomass
- Biogas (including landfill and sewage gas)

RES can not only be used to generate heat and electricity, but also as a fuel in the transport sector. However, this report focuses on feed-in tariff designs for electricity generation based on renewables and therefore does not consider technologies for heat generation or biofuels in the transport sector. The different types of renewable energy sources are defined in detail in Appendix A. The following section will outline to what extent the different technologies are used for electricity generation in the 25 Member States of the European Union.

2.2 Present status and historic development of RES-E in the EU

In the year 2005 an amount of 437 TWh of electricity was generated with renewable energy sources in the EU-25 countries. The historical development of the RES-E production is shown in Figure 2.1.

[1] [The European Parliament and the Council of the European Union 2001, Art. 2]

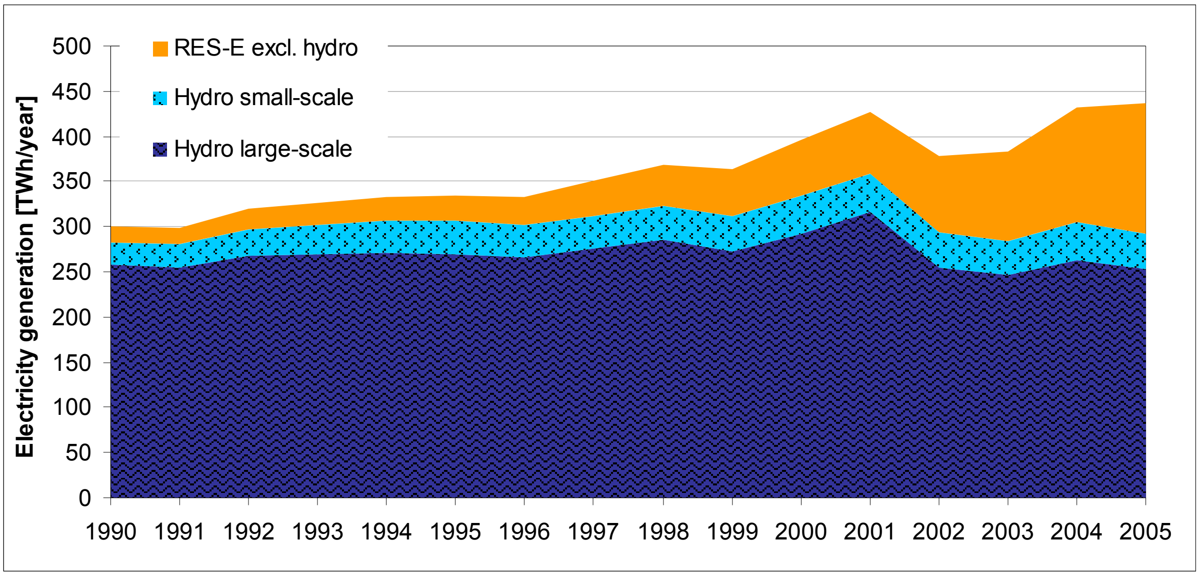

Figure 2.1: Historical development of electricity generation from RES in the EU-25 countries from 1990 to 2005[2]

Figure 2.1 illustrates that the largest share of electricity from RES has been generated with hydro energy. The amount of electricity produced by hydro power plants has remained on a constant level since 1990; the fluctuation is due to a varying precipitation. In contrast, the amount of electricity generated from other sources, such as wind energy or biomass has constantly increased during recent years, as shown in Figure 2.2.

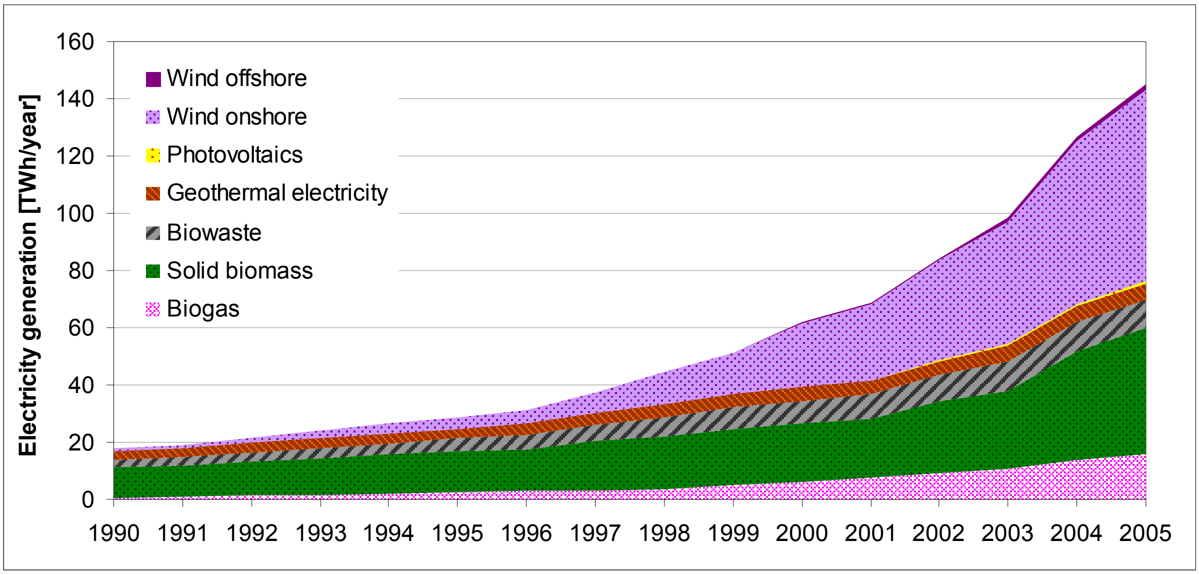

Figure 2.2: Historical development of RES-E excluding hydro power in the EU-25 countries from 1990 to 2005[3]

Regarding Figure 2.2 it should be noted that the amount of electricity produced from biomass, biogas and wind onshore technologies has been increasing significantly during the

[2] Based on EUROSTAT data. Figures for 2005 are not yet confirmed [Eurostat 2006].

[3] Figures for the year 2005 represent estimates or provisional figures for some countries.

past 16 years. The shares of PV and wind offshore energy are still small, but have been increasing as well.

To get a better impression of RES-E generation in the different EU Member States, Figure 2.3 and Figure 2.4 show the breakdown of RES-E in the year 2005 for each country.

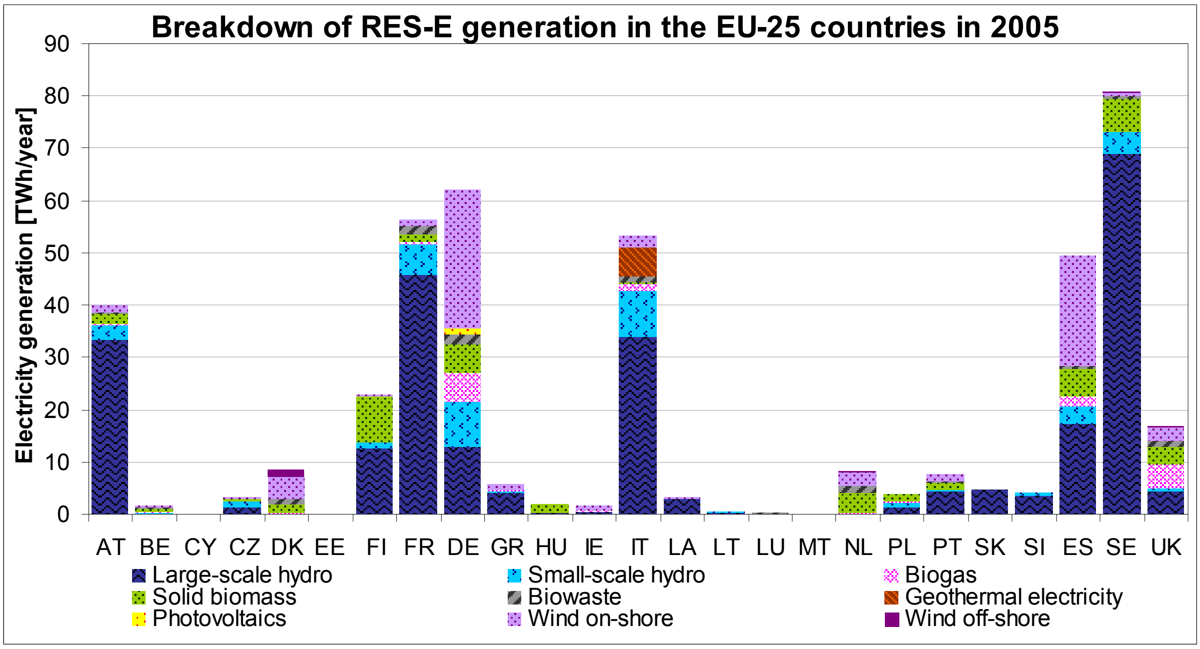

Figure 2.3: RES-E generation in the 25 EU Member States in 2005

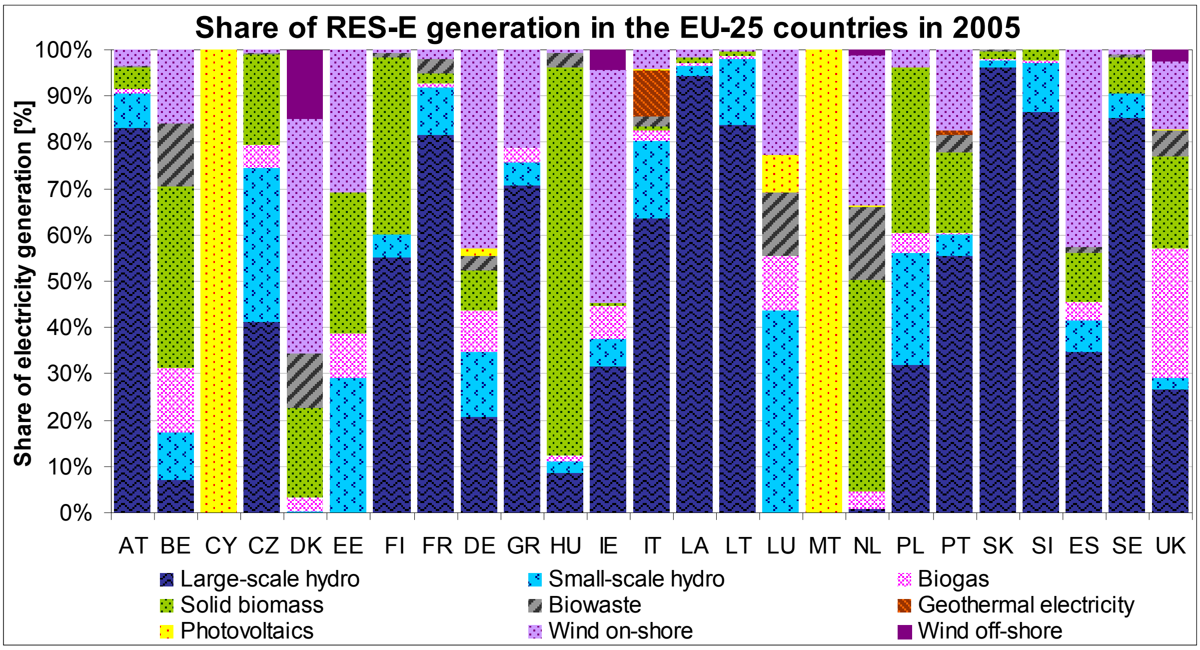

Figure 2.4: Share of RES-E generation in the 25 EU Member States in 2005

The two figures illustrate, that large-scale hydro power is the most important renewable energy source for electricity production in most European countries. Countries that have increased non-hydro renewables significantly in absolute terms are Denmark, Germany, Finland, Hungary, Ireland, the Netherlands, Spain and the United Kingdom. Wind energy is especially important for Denmark, Germany, Ireland and Spain.

2.3 Motivation to support RES-E and Member State targets

The main reasons for supporting RES-E can be summarised as follows:

- Environmental protection, reduction of greenhouse gas emissions (Kyoto protocol), (environmental) risks involved with nuclear power
- Enhancing energy supply security, reducing import dependence of the energy system, coping with the scarcity of fossil and nuclear fuels
- Enhancing economic competitiveness, creation of jobs, creation of lead markets (technological leadership)

These motivations were the main drivers for the *Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market* published by the European Parliament and the EU Council in 2001. In this directive the target to cover 22% of the total electricity consumption of the EU-15 Member States by the year 2010 was set, as well as a national target for each EU country. Transferred to the EU-25 countries, the overall target makes up 21% of total electricity consumption. In addition to the target for 2010 some Member States set national RES-E targets for the year 2020. Both are illustrated by Table 2.1. Figure 2.5 compares RES-E penetration in 1997 and 2004 with the targets set for the year 2010. As can be observed only Denmark, Germany, Hungary, the Netherlands, Spain and Slovenia have made significant progress in reaching the targets set in the Directive.

Table 2.1: National targets for the share of RES-E in 2010 and 2020

Country	Target 2010	Target 2020
Austria	78.1%	
Belgium	6.0%	
Cyprus	6.0%	
Czech Republic	8.0%	15.0 – 16.0%[1)]
Denmark	29.0%	
Estonia	5.1%	
Finland	31.5%	
France	21.0%	
Germany	12.5%	20.0%
Greece	20.1%	29.0%
Hungary	3.6%	
Ireland	13.2%[2)]	
Italy	25.0%	
Latvia	49.3%	
Lithuania	7.0%	
Luxembourg	5.7%	
Malta	5.0%	
Netherlands	9.0%	10.0%[3)]
Poland	7.5%	
Portugal	39.0%	
Slovakia	31.0%	
Slovenia	33.6%	
Spain	29.4%	
Sweden	60.0%	
UK	10.0%	20.0%[4)]

1) Target by 2030

2) Ireland increased its target to 15% by 2010.

3) Target: 10% RES share of total energy consumption

4) The UK Government has stated that it wants to have a 20% target in place in 2020, but it has not yet been formally confirmed.

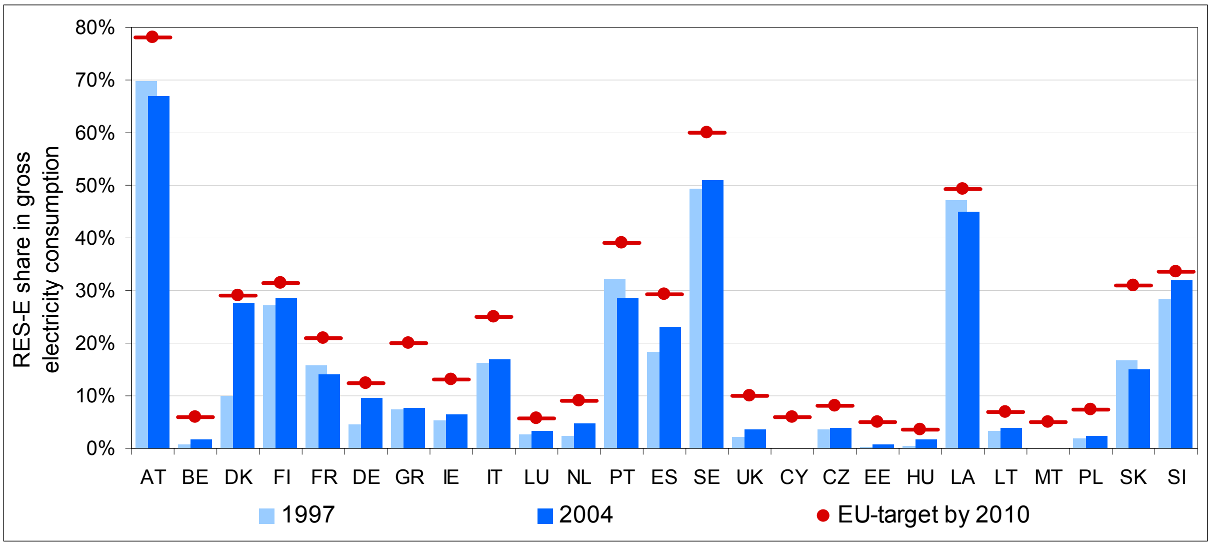

Figure 2.5: RES-E penetration in 1997 and 2004 and national target by 2010 in the EU-25 countries

2.4 Instruments to support RES-E

The current discussion within EU Member States about various renewable promotion schemes focuses on the comparison of two systems, the *feed-in tariff (FIT) system* and the *quota regulation* in combination with a *tradable green certificate (TGC)* market. The system of fixed feed-in tariffs allows electricity generators to sell RES-E at a fixed tariff for a determined period of time. Alternatively, the feed-in tariff can be paid in the form of an additional premium on top of the electricity market price. Currently FITs are applied by 17 of the 25 EU Member States as main instrument to support the generation of RES-E and by 1 country (Italy) only for electricity generation from PV energy.

The quota obligation based on TGCs is a relatively new support scheme and has replaced other policy instruments in Belgium, Italy, Sweden, the UK and Poland in recent years. The basic element of the system is the obligation for a particular party of the electricity supply-chain (e.g. consumers, suppliers or generators) to provide a specified minimum share in total electricity consumption from renewable energy sources. Besides the quota target, a market for renewable energy certificates is established. By giving RES-E producers the possibility to sell certificates on the market, they receive financial support in addition to the electricity sales on the power market.

Other policy instruments such as tender schemes, which grant financial support to projects with the lowest generation costs following a bidding round, are no longer used in any European country as the dominating policy scheme. However, there are instruments like production tax incentives and investment incentives, which are frequently used as supplementary measures. Only Finland and Malta employ these as their main support scheme. Figure 2.6 gives an overview of the currently dominating support schemes in the EU.

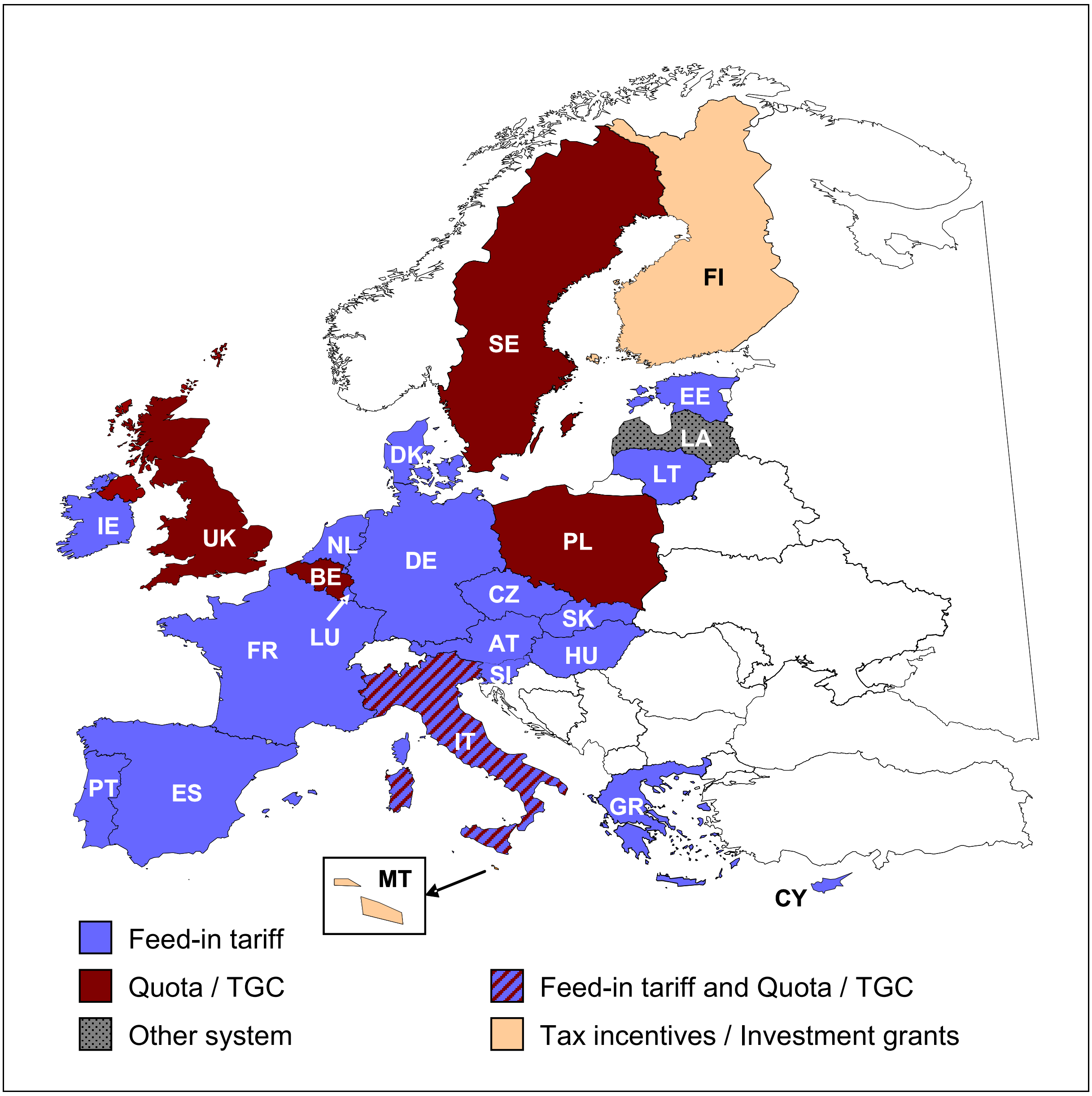

Figure 2.6: Currently applied schemes for the support of electricity from RES in the EU-25 countries[4]

[4] Note: Latvia has provided support for RES-E in the form of fixed tariffs until the year 2001. Since 2002 a system with maximum quotas for renewable energy development has been in force [Ministry of Economics of the Republic of Latvia 2005, pp. 14].

2.5 The International Feed-in Cooperation

Since the European Commission considers a common and harmonised policy framework within the EU to be premature, there is instead a request for a "*coordination of the existing systems based on two pillars: cooperation between countries and optimisation of the national schemes, which will likely lead to a convergence of the systems*" [European Commission 2005, p. 4]. There is a good match between these policy goals and the main objectives of the *International Feed-in Cooperation*, which was initiated by Germany and Spain at the International Conference for Renewable Energies (renewables2004) in Bonn and is part of the International Action Program that was adopted at the conference. Thereafter, a joint declaration between the governments of Spain and Germany, giving the basis for the cooperation, was signed on October 6, 2005 in Madrid. A new Joint Declaration, which will be in its contents and wording very close to the existing one from 2005, will enable other countries to become member of the Cooperation.

Objectives of the International Feed-in Cooperation

Based on the fact that renewable energy sources contribute to pollution reduction and security of energy supply, Spain and Germany "*express their determination […] to promote an increase in the share of renewable energies in the overall national and global primary energy supply*" [MITYC and BMU 2005]. Among other goals, it is the explicit intention of the *International Feed-in Cooperation* to promote the exchange of experiences between Spain, Germany and others as well as to improve the feed-in system design in each country. Therefore it is necessary to specify the design criteria for a successful policy implementation and it is intended to identify best practice examples throughout Europe. As we have learned from the results of various research projects, a feed-in system seems to be one of the most appropriate policy instruments for promoting RES-E at present. The *International Feed-in Cooperation* now aims at pointing out the evident advantages of a feed-in system. In this context, Germany and Spain want to stimulate the enhancement of feed-in tariffs worldwide by including other countries in their information exchange process. For instance, existing knowledge and experiences gained in the two countries are supposed to serve as information input for other countries planning the introduction or further development of feed-in tariffs.

3 Feed-in tariff design options

Currently 18 of 25 Member States of the European Union apply a variety of different feed-in tariff designs. The differences range from the fact whether or not a purchase obligation exists to the method used for the determination and the adjustment of the tariff level. Distinct concepts are applied to account for different generation costs within one technology (such as stepped tariff designs). Some of the Member States apply a tariff degression to take technological learning into account and to avoid overcompensation. These concepts are described and compared in this chapter. At the end of each section, the advantages and disadvantages of the design options are summarized. Table 3.1 shows the different FIT designs that are used in the EU Member States.

Table 3.1: Feed-in tariff designs in the EU Member States

Country	Purchase obligation	Stepped tariff	Tariff degression	Premium option	Equal Burden Sharing?	Forecast obligation
Austria	x	x	-	-	x[1)]	-
Cyprus	x	x	-	-	x	-
Czech Rep.	x (for fixed tariff)	x	-	x	x	-
Denmark	x (except for wind onshore)	x	-	x (wind)	x[1)]	-
Estonia	x (for grid losses)	-	-	x (new draft)	x	x (new draft)
France	x	x	x (wind)	-	x	-
Germany	x	x	x	-	x[1)]	-
Greece	x	x	-	-	x	-
Hungary	x	-	-	-	x	-
Ireland	x	x	-	-	x	-
Italy	x	x	x (PV)	-	x	-
Lithuania	x	-	-	-	x	-
Luxembourg	x	x	-	-	x	-
Netherlands[3)]	-	x	-	x	[2)]	-
Portugal	x	x	-	-	x	-
Slovakia	x (for grid losses)	x	-	-	x	-
Slovenia	x (for fixed tariff)	x	-	x	x	x
Spain	x (for fixed tariff)	x	-	x	x	x

1) Austria, Denmark and Germany apply an equal burden sharing with advantages for electricity intensive industries (see Chapter 4 on page 57).

2) In the Netherlands each electricity consumer contributes the same amount of money to RES-E support, regardless of the amount of electricity consumed (see Chapter 4 on page 57).

3) In the Netherlands no FITs are paid for electricity from RES-E plants that applied for support after the 18th of August 2006.

3.1 General conditions of a FIT design

In this section we describe ways of determining and revising tariff levels as well as the concept of a purchase obligation.

3.1.1 Determining the support level

One of the most important aspects of a feed-in tariff design is the determination of the tariff level and the duration of support. One possibility is to set the tariff level based on the **electricity generation costs** from renewable energy sources. Alternatively, the support level of RES-E can be based on the **avoided external costs** induced by electricity generation using renewable energy sources. Subsequently, these two concepts will be explained.

Tariffs based on electricity generation costs

As the electricity generation costs vary according to the RES-E technology, a feed-in tariff design should provide technology-specific tariff levels. The following factors influence the power generation costs and therefore should be taken into account when the tariff levels are determined:

- Investment for the plant
- Other costs related to the project, such as expenses for licensing procedures
- Operation and maintenance (O&M) costs
- Fuel costs (in the case of biomass and biogas)
- Inflation
- Interest payments for the invested capital
- Profit margins for investors

According to the expected amount of electricity generated and the estimated lifetime of the power plant, a level of remuneration can be fixed.

Most EU countries that apply feed-in tariffs use the concept based on electricity generation costs to determine the tariff level.

Including avoided external costs in the determination of the tariff level

Besides the electricity generation costs, other factors, such as the avoided external costs, can be considered when fixing the level of remuneration. External costs arise *"when the social or economic activities of one group of persons have an impact on another group and when that impact is not fully accounted, or compensated for, by the first group"* [European Commission 2003, p. 5].

Among others, the following possible external costs can be taken into account for electricity generation[5]:

- Climate change
- Health damage from air pollutants
- Agricultural yield loss
- Material damage
- Effects on the energy supply security

Besides the external costs, those expenses can be taken into account that would occur, if RES-E plants did not exist and the electricity would have to be generated in conventional power plants.

Since the Portuguese concept to determine the tariff levels is based on the avoided costs due to RES-E generation, it is explained in this section.

Portugal

In **Portugal** RES-E producers receive a monthly payment that is calculated by a special formula. The elements of the formula represent different factors that influence the costs avoided due to the electricity generation from RES-E. The following factors are included in the formula:

- A fixed contribution on the plant capacity to reflect the **investment for conventional power plants** that would have to be built, if the RES-E plant did not exist
- A variable contribution per kWh of electricity generated that corresponds to the **power generation costs** of those hypothetical conventional power plants
- An environmental parcel corresponding to the **costs for CO_2 emissions** prevented due to RES-E generation, multiplied by a technology-specific coefficient
- Different tariff levels for electricity generated during **day and night time**
- Adjustment to **inflation**
- A factor that represents the avoided **electrical losses in the grid** due to the RES-E plant

The formula and its elements are explained in Appendix B on page 74.

Evaluation of the different concepts to determine the tariff level

It has been shown in the past that the level and the guaranteed duration of support as well as investment security have been crucial to attract investors and to increase the exploitation of RES-E. Since the power generation costs of different RES-E technologies vary, a successful FIT design should provide technology-specific tariff levels. The remuneration should cover

[5] For more detailed information about external costs of electricity generation see for example [Krewitt et al. 2006].

the electricity generation costs and provide a reasonable profit margin. On the other hand the costs for RES-E support have to be covered by somebody. Typically these costs are included in the electricity price and therefore are transferred to the electricity consumers. High FITs lead to benefits for the investors, but also to a higher burden on society (e.g. the electricity consumers). In Chapter 4 on page 57 different concepts to distribute the costs for the RES-E support are be presented.

It is a challenge for the energy policy to determine an appropriate level of FITs which leads to new installations of RES-E technologies and at the same time keeps the burden on the electricity consumers at a moderate level.

The advantages and disadvantages of the Portuguese concept of determining the level of remuneration is summarized in Table 3.2.

Table 3.2: Evaluation of the Portuguese way of determining tariff levels

Advantages	Disadvantages
• Not only electricity generation costs are taken into account, but also other factors, such as CO_2 emissions. • Due to the possibility to have a higher tariff during daytime than at night, the system is demand orientated. (More electricity is demanded during the day.)	• The tariff level is very difficult to determine. This causes high administrative complexity and low transparency. • Uncertainty for investors and plant operators, because the level of remuneration depends on many parameters and the tariff level is difficult to predict.

Most of the EU countries with feed-in tariffs apply the technology-specific option of feed-in tariffs. Table 3.3 shows the remuneration levels and the period of guaranteed support in the EU countries. In the case of the premium option the overall remuneration, which consists of the market electricity price and the premium tariff is shown in order to be comparable to the fixed tariff. The tariffs are valid for RES-E plants commissioned in the year 2006. Since some countries undertake a further differentiation of tariff level within one technology due to different framework conditions, ranges of remuneration levels are shown. In the case of stepped tariff designs (wind energy in Cyprus, Germany, France and in the Netherlands), the tariff level during the first year of operation is considered. The Czech Republic, Hungary and Portugal apply different tariff designs according to the time of day or season of the year. It is assumed that electricity generation in these countries has the same share in the different time bands. For the Czech Republic, Slovenia and Spain, all countries which offer a premium tariff, an electricity price of 5.56 € Cents/kWh is assumed. In the Netherlands RES-E generators negotiate an electricity price per kWh with the grid operators or electricity distributor, which is assumed to be 5 € Cents/kWh. On top of this negotiated price they receive a premium. For Portugal the tariff ranges are not available, therefore the average tariff levels are shown [Ecofys 2006].

Table 3.3: Level and duration of support for RES-E plants commissioned in 2006

Country		Tariff level in 2006 [€ Cents/kWh] and duration of support for different technologies[1)]						
		Small hydro	Wind onshore	Wind offshore	Solid biomass	Biogas	PV	Geothermal
Austria		3.8 - 6.3 *13 years*	7.8 *13 years*	-	10.2 - 16.0 *13 years*	3.0 - 16.5 *13 years*	47.0 - 60.0 *13 years*	7.0 *13 years*
Cyprus		6.5 *no limit*	9.5 *15 years*	9.5 *15 years*	6.5 *no limit*	6.5 *no limit*	21.1 - 39.3 *15 years*	-
Czech Republic	**fix**	8.1 *15 years*	8.5 *15 years*	-	7.9 - 10.1 *15 years*	7.7 - 10.3 *15 years*	45.5 *15 years*	15.5 *15 years*
	premium	10.5 *15 years*	12.5 *15 years*	-	10.0 - 12.0 *15 years*	9.9 - 12.5 *15 years*	49.0 *15 years*	18.0 *15 years*
Denmark		-	7.2 *20 years*	-	8.0 *20 years*	8.0 *20 years*	8.0 *20 years*	6.9 *20 years*
Estonia		5.2 *7 years*	5.2 *12 years*	5.2 *12 years*	5.2 *7 years*	5.2 *12 years*	5.2 *12 years*	5.2 *12 years*
France		5.5 – 7.6 *20 years*	8.2 *15 years*	13.0 *20 years*	4.9 – 6.1 *15 years*	4.5 - 14.0 *15 years*	30.0 – 55.0 *20 years*	12.0 – 15.0 *15 years*
Germany		6.7 - 9.7 *30 years*	8.4 *20 years*	9.1 *20 years*	3.8 - 21.2 *20 years*	6.5 – 21.2[2)] *20 years*	40.6 – 56.8 *20 years*	7.2 – 15.0 *20 years*
Greece		7.3 - 8.5 *12 years*	7.3 - 8.5 *12 years*	9.0 *12 years*	7.3 - 8.5 *12 years*	7.3 - 8.5 *12 years*	40.0 – 50.0 *12 years*	7.3 - 8.5 *12 years*
Hungary		9.4 *no limit*	9.4 *no limit*	-	9.4 *no limit*	9.4 *no limit*	9.4 *no limit*	9.4 *no limit*
Ireland		7.2 *15 years*	5.7 - 5.9 *15 years*	5.7 - 5.9 *15 years*	7.2 *15 years*	7.0 - 7.2 *15 years*	-	-
Italy		-	-	-	-	-	44.5 – 49.0 *20 years*	-
Lithuania		5.8 *10 years*	6.4 *10 years*	6.4 *10 years*	5.8 *10 years*	5.8 *10 years*	-	-
Luxembourg		7.9 – 10.3 *10 years*	7.9 - 10.3 *10 years*	-	10.4 - 12.8 *10 years*	10.4 - 12.8 *10 years*	28.0 - 56.0 *10 years*	-
Netherlands		14.7 *10 years*	12.7 *10 years*	14.7 *10 years*	12.0 - 14.7 *10 years*	7.1 - 14.7 *10 years*	14.7 *10 years*	-
Portugal		7.5 *15 years*	7.4 *15 years*	7.4 *15 years*	11.0 *15 years*	10.2 *15 years*	31 - 45 *15 years*	-
Slovakia		6.1 *1 year*	7.4 *1 year*	-	7.2 - 8.0 *1 year*	6.6 *1 year*	21.2 *1 year*	9.3 *1 year*
Slovenia	**fix**	6.0 - 6.2 *10 years*	5.9 - 6.1 *10 years*	-	6.8 - 7.0 *10 years*	5.0 - 12.1 *10 years*	6.5 - 37.5 *10 years*	5.9 *10 years*
	premium	8.2 - 8.4 *10 years*	8.1 - 8.3 *10 years*	-	9.0 - 9.2 *10 years*	6.7 - 14.3 *10 years*	8.7 - 39.7 *10 years*	8.1 *10 years*
Spain	**fix**	6.1 - 6.9 *no limit*	6.9 *no limit*	6.9 *no limit*	6.1 - 6.9 *no limit*	6.1 - 6.9 *no limit*	23.0 - 44.0 *no limit*	6.9 *no limit*
	premium	8.6 - 9.4 *no limit*	9.4 *no limit*	9.4 *no limit*	8.6 - 9.4 *no limit*	9.4 *no limit*	25.5 *no limit*	9.4 *no limit*

1) For the countries using a different currency than Euro, the exchange rate of the 1st of January 2006 is used [OANDA Corporation 2006].
2) The maximum value given for Germany is only available if all premiums are cumulated. This combines the enhanced use of innovative technologies, CHP generation and sustainable biomass use.

For a better comparability, the FIT levels for small-scale hydro power, wind onshore, biomass, biogas and PV energy are shown in the following figures. The tariffs are normalised to a lifetime of 20 years and discounted with a rate of 6.6% to the year 2006. If the period of guaranteed support is less than 20 years, it is assumed, that the RES-E generators sell the electricity on the spot market receiving the market price until the plant has been operating for 20 years. The remuneration of the premium option in the Czech Republic, Slovenia and Spain, includes the electricity market price and the premium (see Section 3.4). The market price for the period from 2006 to 2020 is based on results of the model *Green-X*. For the years 2021 to 2025 the price of 2020 is assumed [Green-X 2006].

In Slovakia the Decree 2/2005, which entered into force in June 2005, guarantees support for only one year. However, a change in legislation with longer support periods is planned and a duration of 15 years is assumed [Suliková 2006].

In Hungary the Decree Law 78/2005 does not fix a support period. Currently the tariffs will be paid until 2010. However, a law with a fixed guaranteed support period is planned. For the figures shown below, a duration of 15 years is assumed [Kovács 2006].

The bars symbolise the average level of remuneration per kWh of electricity generated, the ranges illustrate the maximum and minimum FIT level paid for a technology, if further tariff differentiation is undertaken within one technology.

Figure 3.1 illustrates the level of remuneration in the different EU countries applying feed-in tariffs for electricity from small-scale hydro power plants.

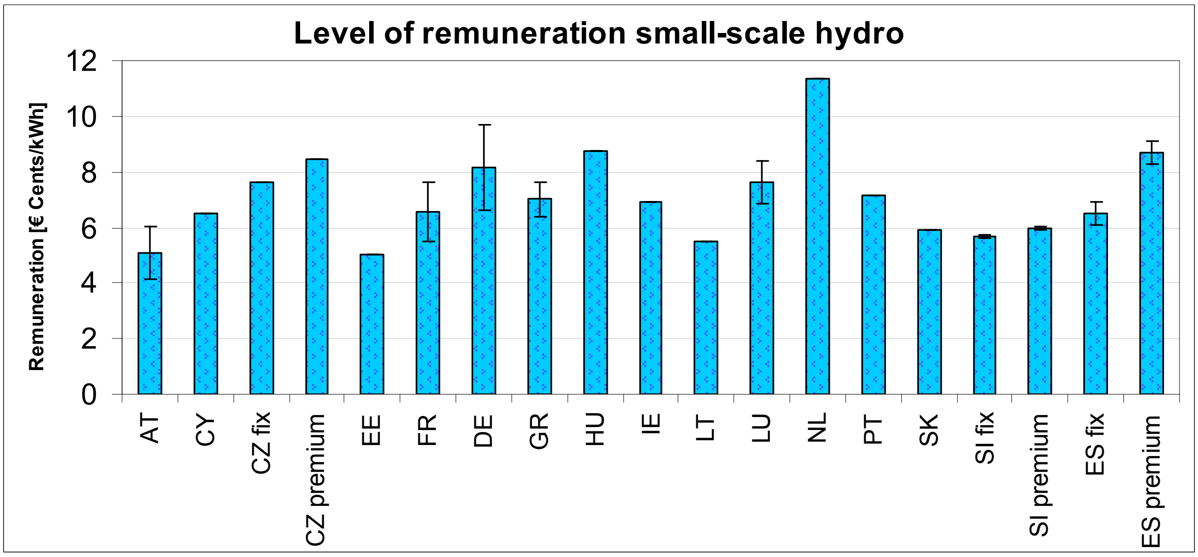

Figure 3.1: Feed-in tariff level for electricity from small hydro. If support level is not fixed at a single value, support ranges with maximum and minimum support level are indicated.

The tariffs range from 5.0 € Cents/kWh in Estonia up to 11.3 € Cents/kWh for hydro power plants in the Netherlands. However, the potential of hydro power is very limited in the Netherlands. The definition of a *small-scale hydro power plant* is not uniform in all EU countries. Typically plants with a capacity of up to 10 MW are considered being small-scale and receive support. However, in Spain for example, hydro power plants up to 50 MW are supported with feed-in tariffs.

In France, Germany, Luxembourg, Slovenia and Spain tariffs are differentiated according to the installed plant capacity. In Austria different FITs are paid according to the overall amount of electricity which is generated by the plant. In Greece higher tariffs are offered for installations located at the autonomous islands, which are not connected to the electricity grid of the mainland.

Figure 3.2 shows the level of remuneration for electricity from onshore wind power.

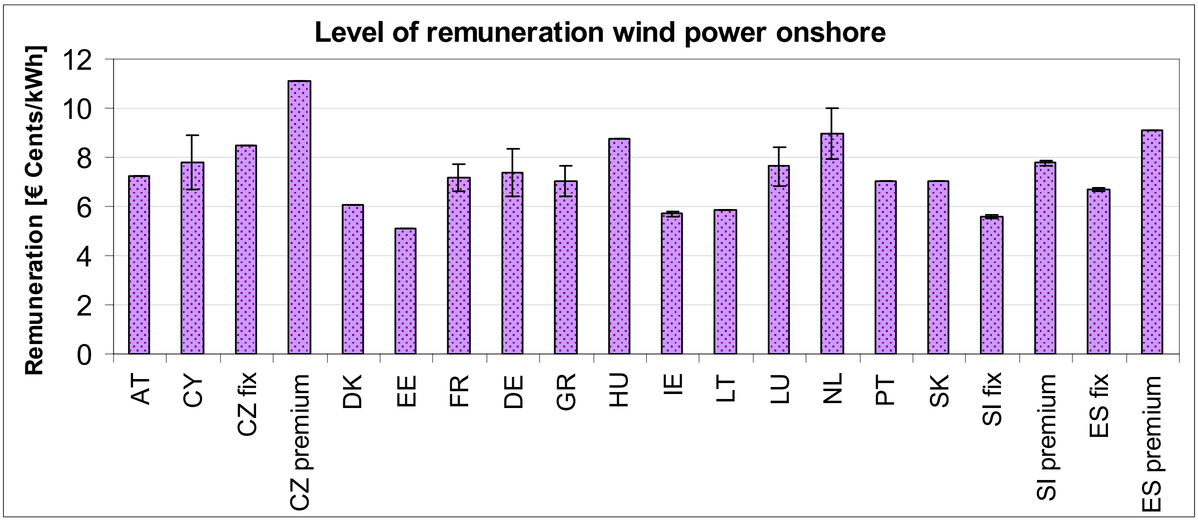

Figure 3.2: Feed-in tariff level for electricity from wind power onshore. If support level is not fixed at a single value, support ranges with maximum and minimum support level are indicated.

The tariff ranges are larger than in the case of small-scale hydro power. Whilst the turbine operators in Estonia only receive 5.1 € Cents/kWh, the ones in the Czech Republic receive 11.1 € Cents/kWh, if they sell their electricity directly on the market using the premium option. In order to judge the suitability of the tariff level, which means, that it is sufficient to cover the electricity generation costs, the specific wind conditions have to be taken into account. The tariff level in Ireland is rather low (5.6 – 5.8 € Cents/kWh, depending on the capacity of the wind turbine), but wind conditions are very favourable and therefore the low tariff is sufficient to cover the generation costs at many sites in Ireland. In Estonia, however, the tariff level is even lower than in Ireland and the wind conditions are worse.

The different tariff levels are distinguished as explained below. The tariff range in Greece shows the difference between the tariff on mainland and autonomous island. Cyprus, France, Germany and the Netherlands apply a system, where the tariff level varies according to the wind yield (see Section 3.2.1). For Ireland, Spain, Slovenia and Luxemburg the tariff levels depend on the plant size.

The level of remuneration for electricity from solid biomass is shown in Figure 3.3.

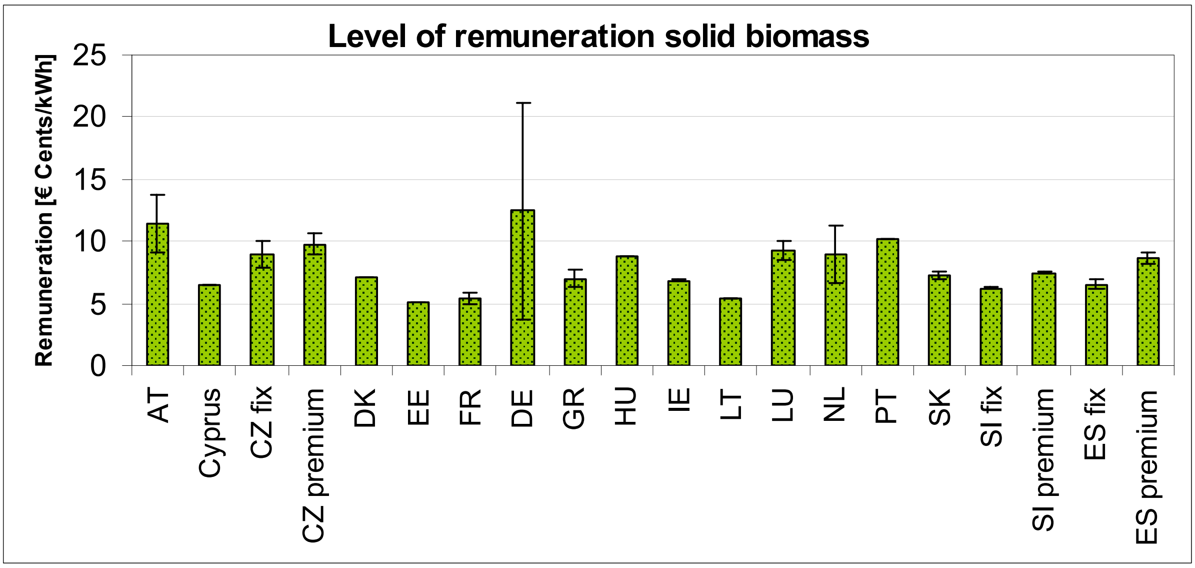

Figure 3.3: Feed-in tariff level for electricity from biomass. If support level is not fixed at a single value, support ranges with maximum and minimum support level are indicated.

Regarding Figure 3.3, it can be observed that both, the lowest and the highest tariff level are paid in Germany, where biomass electricity is remunerated with at least 3.8 € Cents/kWh for power plants using waste wood and can theoretically amount up to 21.2 € Cents/kWh. The support level for biomass in Germany is differentiated according to various plant characteristics, such as the applied technology, plant size, fuel type, etc.. For a detailed description of the German tariff components for biomass support see also Section 3.2.3.

The differences in tariffs paid within one country are explained as follows. Some of the countries classify the support level for electricity generated from biomass depending on more than one criterion, among them Germany and Austria. Both countries take into account the plant size as well as the fuel type used. Luxemburg, the Netherlands and Slovenia distinguish the tariff level according to plant capacity. The tariff ranges in the Czech Republic, Ireland, Slovakia and Spain are motivated by the fuel type. France applies a tariff classification based on the energy efficiency of the power plants (see Section 3.5.1).

Figure 3.4 shows the tariff levels for electricity from biogas.

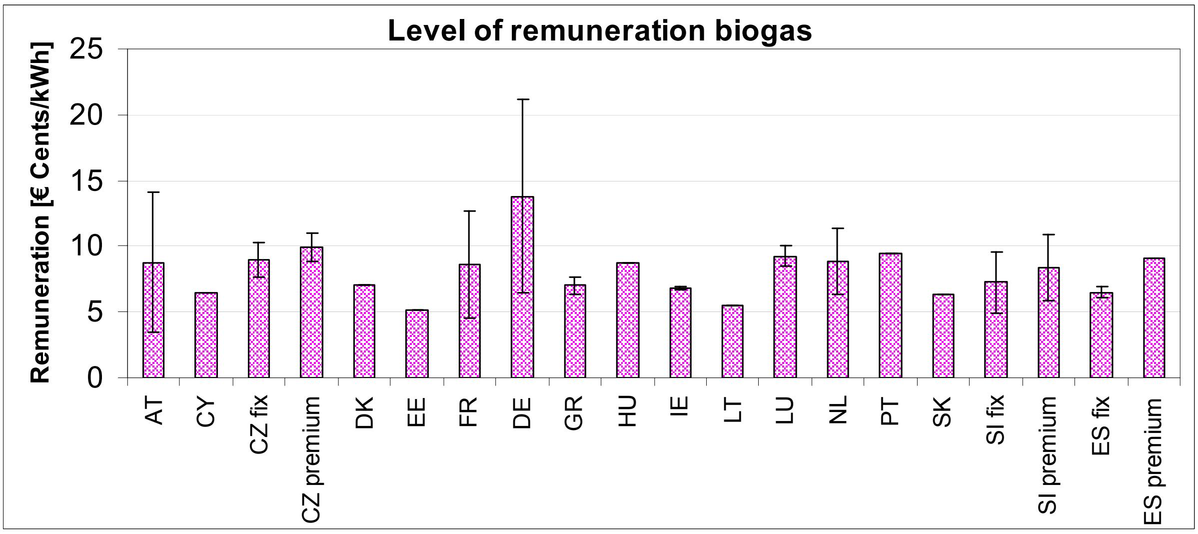

Figure 3.4: Feed-in tariff level for electricity from biogas. If support level is not fixed at a single value, support ranges with maximum and minimum support level are indicated.

In the Estonia power generation from biogas is supported with 5.1 € Cents/kWh. In Germany the tariffs range up to 21.2 € Cents/kWh, if the biogas plants fulfil certain characteristics and the biogas is generated from sustainable biomass (see Section 3.2.3).

For Estonia, Lithuania, and Slovakia the support level is at the lower end of the tariff range. In Austria the tariffs (paid for plants authorised until the end of 2004 and installed until December 2007) are relatively high since the aim is to support small scale agricultural applications as compared to large centralised plants. A similar argument holds for Germany.

In Austria, France and Germany the remuneration for electricity from biogas varies according to the plant size and the fuel type. The tariff ranges in the Czech Republic, Ireland, the Netherlands, Slovenia and Spain are motivated by the type of biogas used. The size of the biogas plant has an influence on the level of remuneration in Luxemburg, the Netherlands and Slovenia. In France the tariff additionally varies due to the energy efficiency of the power plant. As explained before, Greece distinguishes power plants located on the mainland from the ones installed at autonomous islands.

The tariff levels for electricity generated with PV plants is illustrated in Figure 3.5.

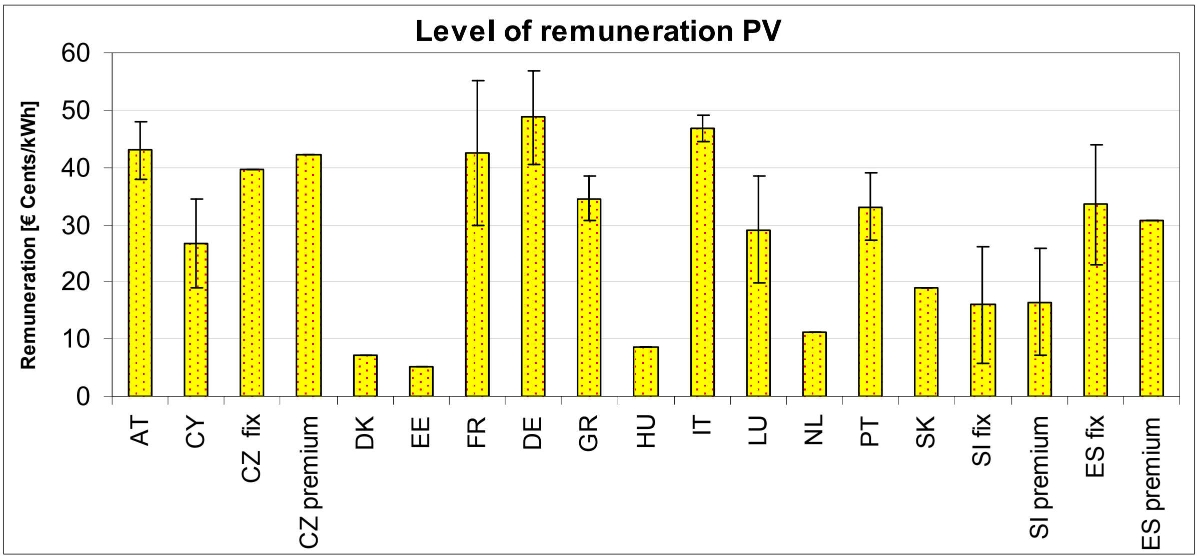

Figure 3.5: Feed-in tariff level for electricity from PV. If support level is not fixed at a single value, support ranges with maximum and minimum support level are indicated.

A large range of remuneration can be observed. In Estonia the FIT for electricity from PV is only 5.1 € Cents/kWh. In Germany a tariff of 56.8 € Cents/kWh is paid for PV devices with a capacity of up to 30 kW that are integrated in the facade of a building. The high level of remuneration led to a large capacity of PV devices installed in Germany. Comparing the level of feed-in tariffs for PV in the different EU Member States, it has to be denoted, that some countries offer further financial support within other policy instrument than the FIT-system. The most prominent example are investment subsidies in order to compensate the high capital costs. These measures are not considered in Figure 3.5.

Due to the low solar radiation in Northern countries like Denmark or Estonia, it may be reasonable to focus the support on other RES-E technologies than PV. Therefore a low tariff level for PV electricity may be appropriate.

In Italy a tariff of 44.5 € Cents/kWh is paid for electricity from PV plants with a capacity between 1 and 20 kW. This tariff is increased by the electricity market price through a *net metering mechanism* ("scambio sul posto"), which leads to an overall support of about 60 € Cents/kWh. The high support level combined with the favourable solar radiation provides good conditions for the application of PV technologies in Italy.

The Czech Republic offers the highest remuneration of the EU-10 countries. The tariff is even situated in the upper range of tariffs of all EU Member States. Since the legislation is from the year 2005, success still has to be proven.

The tariff ranges observed in Figure 3.5 in the different countries are explained as follows. Austria, Germany, Italy, Luxemburg, Portugal, Slovenia and Spain apply different tariff levels according to the plant capacity. In Germany and France the tariffs are increased, if the PV devices are building integrated. In Cyprus the FIT level depends on whether or not an investment subsidy is granted for the PV device. In Greece the ranges show the difference between the tariff on mainland and autonomous islands.

3.1.2 Revision of tariffs

FITs have to be revised regularly in order to check, if the tariffs are still on an appropriate level to reach the energy policy goals. Furthermore the power plant prices, which have a major impact on the electricity generation costs, may undergo unexpected changes due to varying input prices (e.g. for steel or silicon) or a technology breakthrough.

Different methods to revise the level of remuneration are applied:

- Periodical revision and adjustment of tariffs
- Capacity dependent adjustment of tariffs.

Furthermore it has to be decided if the adjustment of the tariff level is just applied for new installations or also for the existing ones. A further question is whether the tariffs are adjusted to inflation.

Periodical revision and adjustment of tariffs

Most countries revise the feed-in tariffs periodically. The examples of the Czech Republic and the Netherlands are assessed in more detail.

Czech Republic

In the **Czech Republic** the level of remuneration for new installations is set annually by the Energy Regulatory Office. These tariffs cannot decrease by more than 5% in relation in relation to the level of those plants that started operation in the previous year. This rule causes stability and investment security [Parliament of the Czech Republic 2005, p. 6].

Netherlands

In the **Netherlands** the tariffs are revised annually, taking into account the decline in costs caused by the technological learning. During these reviews the tariffs are usually set for the next two to three years for new installations. In 2004 for instance, the tariffs were set for the years 2006 and 2007. However, it is possible that the tariffs are changed in the short term. In August of 2006 the feed-in tariffs were set at 0.0 € Cents/kWh for power plants applying for support after the 18th of August 2006 [EnerQ 2006b] and [International Energy Agency 2004, p. 475].

Capacity dependent adjustment of tariffs

Portugal

Portugal applies a system, wherein the tariffs for a RES-E technology are revised when a certain capacity of power plants is reached nationwide (PV: 150 MW, Biomass: 150 MW, Biogas: 50 MW). The tariffs for existing plants are adjusted to inflation. [Ministério das Actividades Económicas e do Trabalho 2005, Anexo II, 18].

Spain

Spain applies a mixture of the two systems. The level of remuneration is determined by the so called *average electricity tariff* (AET or "tarifa eléctrica media o de referencia"). The electricity of each RES technology is remunerated with a certain percentage of this AET, which is set annually by the Spanish Ministry of Industry, Tourism and Trade according to the development of the gas and electricity price (and the interest rate). However, a maximum level of variation of 2% in relation to the previous year is fixed in the Royal Decree 1432/2002, which leads to a stable system with high investment security. The changes of the reference price affect both, existing and new RES-E plants. [Ministerio de Economía 2002, Art. 7 and 8].

The technology-specific percentages of the AET, which are fixed in the Royal Decree 436 are revised every four years and additionally if a certain capacity is installed in Spain, similar as in Portugal. The capacities are shown in Table 3.4.

Table 3.4: Capacities of RES-E technologies in Spain after which the tariffs and premiums are revised

Technology	Capacity
Solar energy	PV: 150 MW or Solar thermal: 200 MW
Wind energy	13000 MW
Small hydro (≤ 10 MW)	2400 MW
Biomass, biogas	3200 MW
Treatment of waste	750 MW
Cogeneration with treatment of waste:	750 MW

Source: [Ministerio de Economía 2004, Art. 32 - 39]

Note: In June 2006 the Royal Decree 7/2006 was introduced, which abolishes the connection of the tariffs and premiums for RES-E with the reference electricity price (see also Section 3.4).

Evaluation of the revision of tariffs

Among other factors, a stable policy framework with long periods of fixed FITs may lead to high investment security and to high exploitation of RES-E, as has been seen for example in Spain, Germany and Denmark in the last years. However, in order to guarantee the flexibility of the system to react fast enough to changes in the costs for a technology or in the electricity price periodic revisions are foreseen in most feed-in systems. It is a challenge to have a system that is flexible enough but also leads to high investment security.

3.1.3 Purchase obligation

The concept of a *purchase obligation* implies that electricity grid operators, energy supply companies or electricity consumers are obliged to buy the power generated from RES. Most EU Member States provide a purchase obligation, however, in some countries the following exceptions are applied:

- No purchase obligation for electricity offered on the spot market
- Purchase obligation only to the extent of electricity network losses

No purchase obligation for electricity offered on the spot market

Spain, the **Czech Republic**, **Slovenia** provide the possibility of selling the electricity from RES directly on the spot market. In addition to the market price, the RES-E generators receive a premium per kWh of electricity. This concept, called *premium tariff design*, is used as an alternative to the *fixed tariff design* and the RES-E producers can choose one of the two options. Both concepts are explained in Section 3.4 on page 43. While a purchase obligation is provided in these countries for the fixed tariff design, there is no purchase guarantee in the case of the premium tariff design[6]

In **Denmark** operators of wind onshore turbines (connected to the grid since 2003) have to sell the generated electricity according to a premium tariff design without a guaranteed purchase and there is no alternative fixed tariff option offered [Danish Energy Authority 2006b].

Purchase obligation only to the extent of network losses

In **Estonia** a system is applied, where the grid operators only have to purchase the electricity from RES-E plants up to the level of their transmission and distribution losses. One reason for this rule is that not every network operator has a licence to sell electricity. Therefore those network operators without any licence cannot buy more electricity than the amount of their network losses. The losses in the grid are very low in times of low electricity consumption (for example in summer nights) and thus the purchase obligation is low as well, which especially affects wind farms. This legislation causes uncertainty for the investors. However, the Estonian government introduced a new draft amending the *Electricity Market Act (RT I 2003, 25, 153)*, which provides a premium tariff design, allowing the RES-E generators to sell the electricity directly on the market [Government of Estonia 2005].

In **Slovakia** a similar legislation is applied where the law does not foresee a purchase obligation for the total amount of electricity from RES, but the operators of transmission and distribution networks have to purchase electricity from RES-E plants up to the level of their transmission and distribution losses [Government of the Slovak Republic 2005].

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[6] Sources: [Parliament of the Czech Republic 2005], [Ministerio de Economía 2004] and [Republic of Slovenia - Ministry of the Economy 2006]

Evaluation of a purchase obligation

A purchase obligation is a possibility to provide investment security and to attract investors. The administrational complexity of this instrument is relatively low. Without a guaranteed purchase the investors request a higher return on investment to cover the increased risk. One objection with respect to the purchase obligation is the fact that it does not represent market compatibility, because the electricity has to be bought independently from the demand. The premium option without a purchase guarantee is an attempt to enhance market compatibility. Typically such mechanisms to raise the market compatibility lead to an increase of tariff levels. The evaluation of a purchase obligation is summarized in Table 3.5.

Table 3.5: Evaluation of a purchase obligation

Advantages	Disadvantages
• Guarantees investment security • Low administrational complexity • Was leading to high RES-E deployment in several countries in the past years	• Limited market compatibility, because the electricity has to be bought independently from the demand.

3.2 Stepped tariff designs

As we have seen in Section 3.1, most EU countries apply distinct tariffs for different RES-E technologies in order to reflect the technology-specific generation costs. However, power generation costs may also differ between plants within the same RES-E technology due to the plant size, the type of fuel used, or the diverse external conditions at different sites, like wind yield or solar radiation. Especially the costs of electricity from wind energy vary significantly depending on the wind yield, as Figure 3.6 illustrates. The difficulty to set the appropriate FIT level will be explained on the example of wind energy.

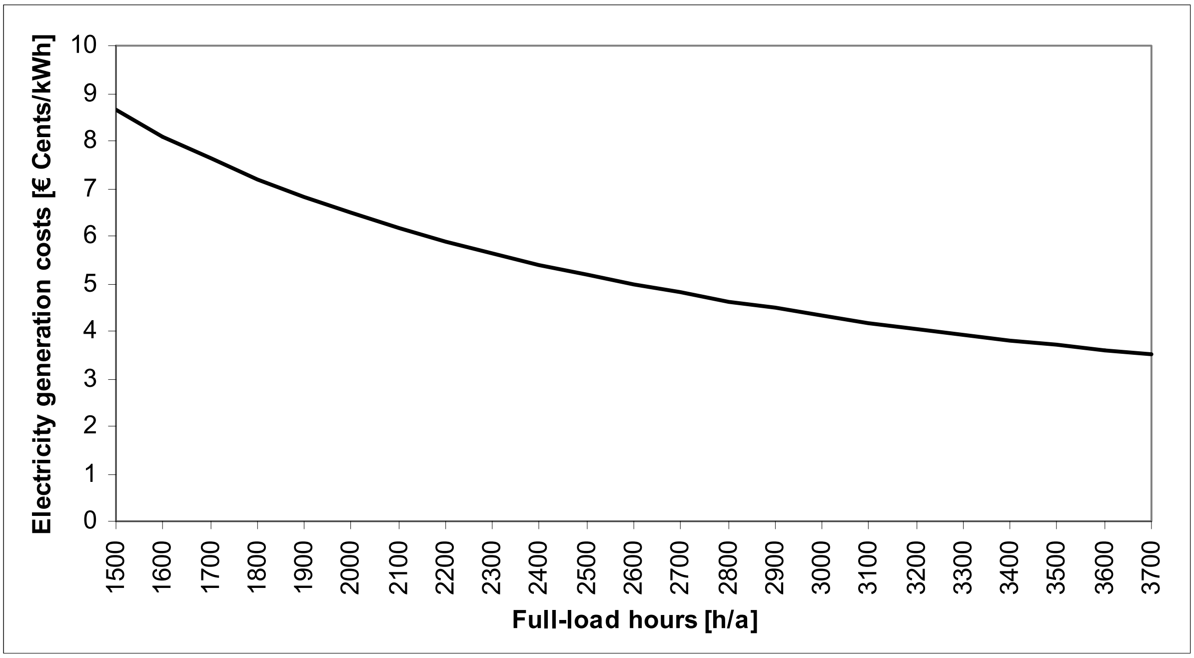

Figure 3.6: Electricity generation costs of wind energy in Germany[7]

Figure 3.6 shows the electricity generation costs for an onshore wind turbine installed in 2006 in Germany. The energy yield of the wind turbine is measured in full-load hours (FLH). A turbine with a capacity of 2 MW that works for 2000 FLH per year generates 4000 MWh of electricity annually. The higher the wind speed and the longer the periods of wind, the higher the electricity yield.

The specific electricity generation cost are decreasing with an increasing amount of FLH per year. While the average costs at a site with 1500 FLH are 8.6 € Cents/kWh, they decrease down to 3.8 € Cents/kWh in the case of 3400 full-load hours. The main reason for the decreasing costs is that a large share of the generation costs is independent from the amount of electricity generated. The investment and installation costs as well as large parts of the operation costs and of the expenses for service and maintenance do not depend on the amount of electricity generated. If only one tariff level is applied for all wind turbines, the

[7] Assumptions: Investment¨1067 €/kW, Lifetime: 20 years, Interest rate: 6.6%, O&M costs: 3% of investment

question is at what level to set the tariff. Figure 3.7 shows a situation, where a high tariff level is applied.

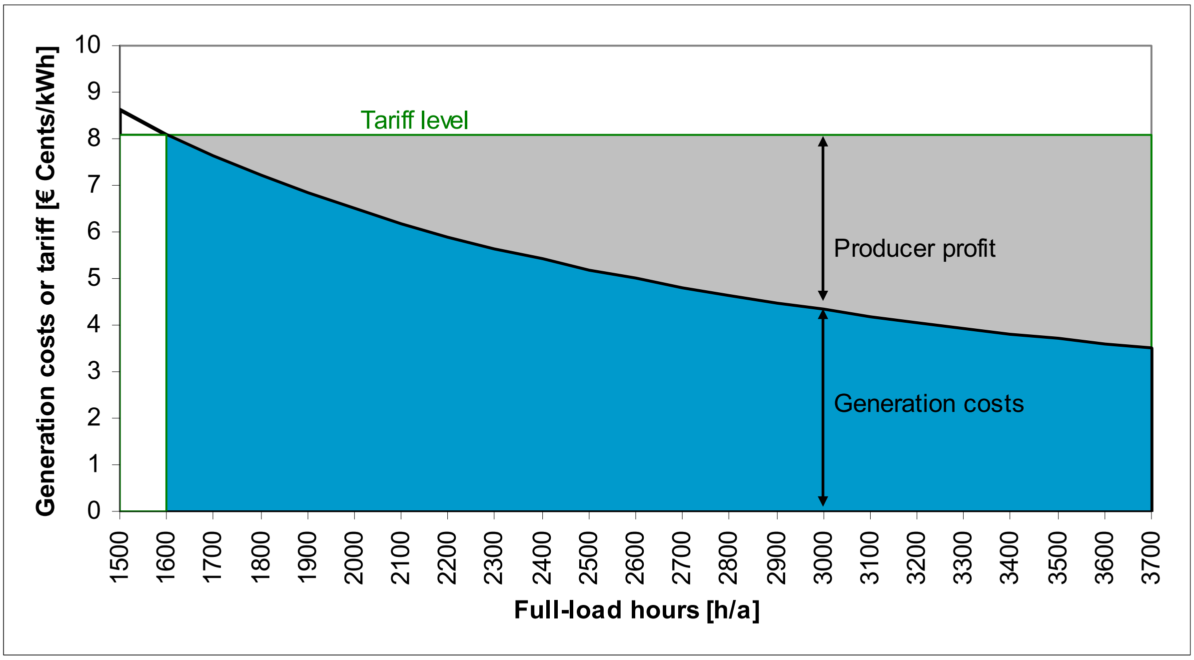

Figure 3.7: High level of remuneration per kWh

In this example, a feed-in tariff of 8.1 € Cents/kWh is chosen. It should be observed that based on this tariff level a site with 1600 full-load hours or more is profitable to exploit. The advantage of a high feed in tariff is that many locations are applicable for wind turbines and that many investors are attracted. This leads to a high exploitation of wind energy. However, the disadvantage is that plants at sites with a high wind yield are over-subsidized. Operators of plants that generate 3000 full-load hours would have a profit of 3.8 € Cents/kWh. This profit has to be typically paid by the electricity consumers.

In order to keep the producer profit on a low level, a lower feed-in tariff could be set, as illustrated in Figure 3.8.

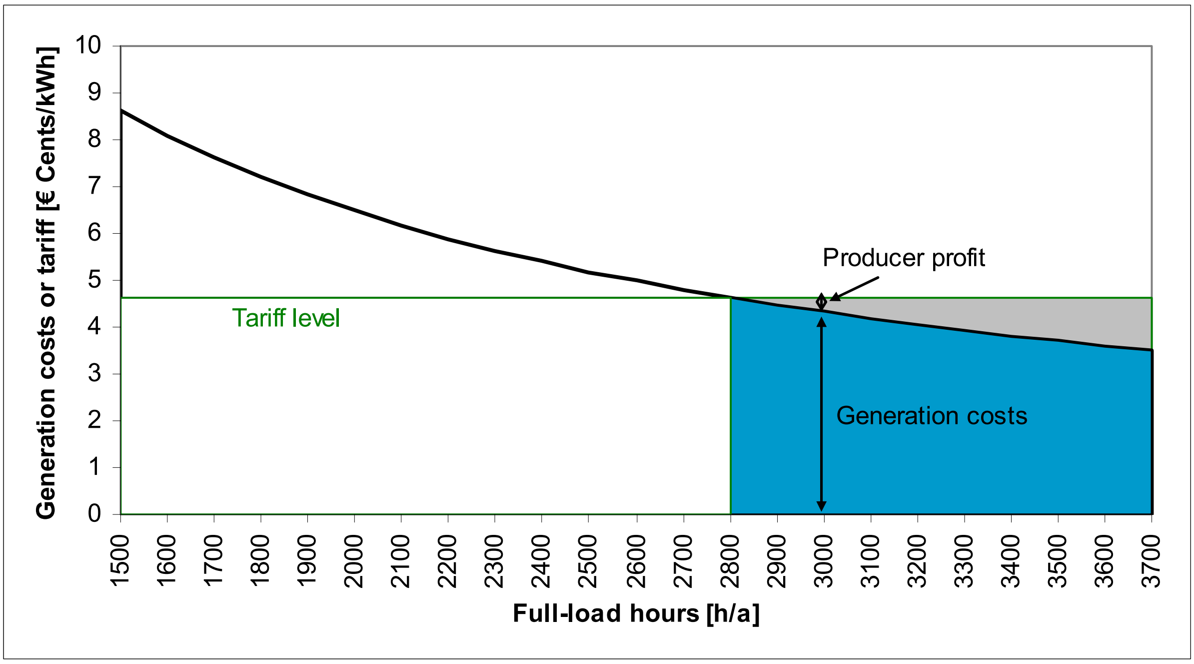

Figure 3.8: Low level of remuneration per kWh

In this graph, a situation with a tariff level of 4.6 € Cents can be observed. At a site with 3000 FLH annually, the producer profit would be 0.3 € Cents/kWh. Compared to Figure 3.7 this profit is a lot smaller and therefore the burden on the electricity consumers due to RES-E generation is smaller as well. However, as the graph illustrates, it is only profitable to exploit sites, where 2800 or more full-load hours are generated annually. This restricts the use of wind turbines significantly.

In the presented example the situation of wind energy is shown. However, the same principle can be applied to other technologies, where different electricity generation costs are caused by the capacity of a power plant or the type of fuel used.

A possible solution to take these differences in the costs of electricity generation within the same RES-E technology into account is a *stepped tariff design*, which implies, that different levels of remuneration are paid for electricity of the same RES-E technology. The opposite of a stepped tariff design is called a *flat tariff design*. In this case the same level of remuneration is paid for all plants of the same technology without considering the electricity generation costs.

The following three groups of stepped tariff designs are outlined in this paper:

1) Tariff level depending on location
2) Tariff level depending on plant size
3) Tariff level depending on fuel type

In the following passage the three possibilities of stepped tariff designs will be discussed and examples will be given for each type of design.

3.2.1 Tariff level depending on location

In the Netherlands, Portugal, Denmark, France, Cyprus and Germany concepts are applied where the FIT level depends on the local conditions at the plant site.

Netherlands

In the **Netherlands** RES-E generators conclude a long term contract with the electricity distributor or network operator, fixing the price per kWh of RES-E fed into the grid. In the following example, a price of 5 € Cents/kWh is assumed. On top of this price, the RES-E generators receive a premium set by the government. For electricity from onshore wind turbines installed in the first half of 2006, this premium amounts to 7.7 € Cents/kWh[8]. The premium is paid for 10 years or for the first 18,000 full-load hours of electricity generation. Together with the assumed electricity price, a total remuneration of 12.7 € Cents/kWh is paid to the turbine operator. After 10 years are over, or when the 18,000 FLH are used up, the turbine operators receive the negotiated electricity price without the premium payment [International Energy Agency 2004, p. 486] and [Ministerie van Economische Zaken 2004].

Figure 3.9 illustrates the generation costs and the support level for an onshore wind turbine in the Netherlands installed in the first half of 2006. A lifetime of 20 years is assumed. For a plant with an average annual electricity generation of 1800 FLH or less, the operator receives the premium payment for 10 years. Wind turbines with a higher amount of electricity generated will be supported for a shorter period.

The stepped tariff design is compared to a hypothetical *flat tariff design*, which implies that a remuneration of 12.7 € Cents/kWh is paid for a duration of 10 years and for the following 10 years the generated electricity is sold on the spot market. This leads to an average tariff of 9.1 € Cents/kWh for the assumed lifetime of 20 years.

[8] Note: In August 2006 the Dutch government set the premiums for new RES-E plants to 0.0 € Cents/kWh, because the Ministry of Economic Affairs expects the target of covering 9% of the electricity demand by 2010 with RES to be fulfilled and the costs for RES-E support were higher than predicted. Therefore, plants that are applying for support since the 18th of August 2006 will not receive any subsidies. At the time of writing (October 2006) there is no law following up the old legislation [Steenaert 2006].

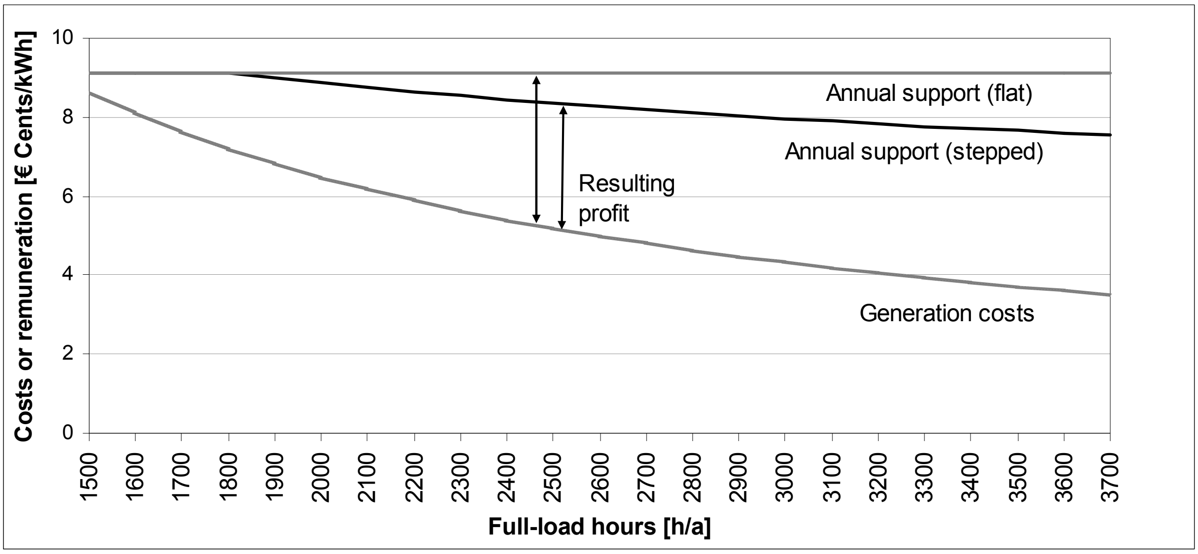

Figure 3.9: Electricity generation costs and annual support for wind onshore turbines in the Netherlands in 2006[9]

It should be noted that the specific generation costs are decreasing with an increasing amount of electricity generated (measured in FLH per year). The difference between the *generation cost curve* and the *support level curve* is the resulting producer profit. Up to an amount of 1800 FLH annually, the *flat* and the *stepped* tariff design lead to the same result. However, if the wind turbine generates more than 1800 FLH of electricity per year, the average level of remuneration per kWh for the stepped tariff design decreases with an increasing amount of electricity produced. This implies that also the increase in the producer profit per kWh of electricity is levelled off, as shown in Figure 3.10. The lower producer profit of the stepped tariff design causes a reduction in costs for the electricity consumers.

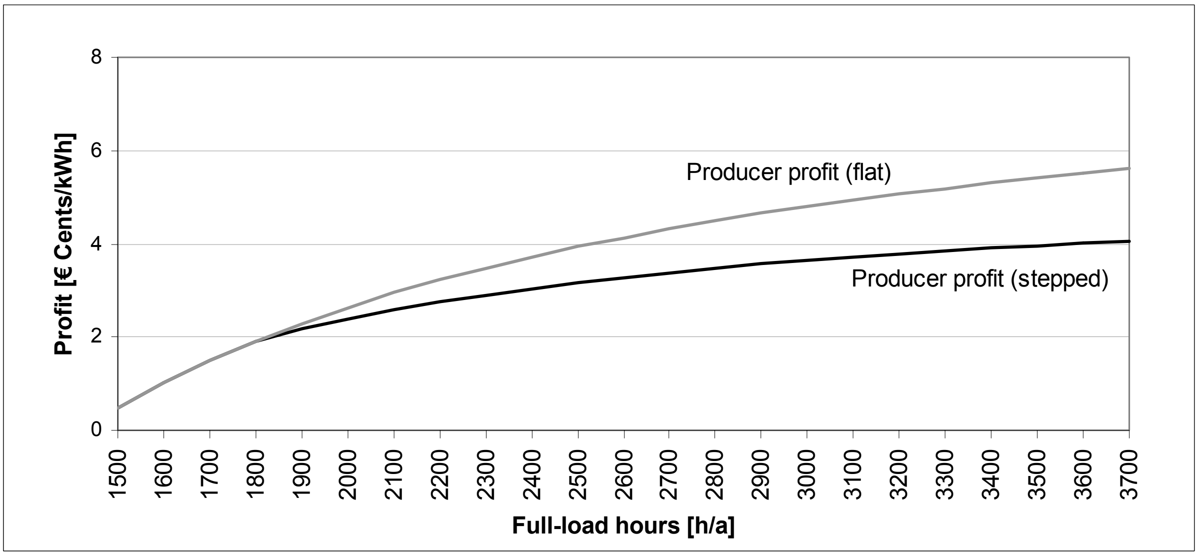

Figure 3.10: Producer profit for electricity from onshore wind energy in the Netherlands in 2006

[9] Assumptions: Lifetime: 20a; Interest Rate: 6.6%; Investment: 1,067 €/kW; O&M Costs: 3% of Investment; Inflation rate: 2.4%, Electricity price: 5 € Cents/kWh

Portugal

In **Portugal** the operators of wind-, hydro-, and PV-power plants receive fixed FITs for the first 15 years or for a certain amount of electricity generated per MW of plant capacity. Even though the legislation is slightly different from the Dutch system, the consequences are identical. Table 3.6 shows the amount of electricity (measured in MWh/MW of capacity), that is remunerated with the fixed FITs [Ministério das Actividades Económicas e do Trabalho 2005, Anexo II].

Table 3.6: Amount of electricity remunerated with fixed FITs in Portugal

RES-E technology	Amount of supported electricity [MWh/MW capacity]
Wind	33 000 MWh/MW
Small hydro	42 500 MWh/MW
PV	21 000 MWh/MW

Denmark

Until the end of 2002 **Denmark** applied a similar system for onshore wind energy, where a certain amount of full-load hours was remunerated with a higher tariff than the rest of the electricity generated. However, since 2003 a premium of 1.34 € Cents/kWh is paid on top of the market price for electricity from onshore wind turbines (see also Section 3.4 on page 48).

France

In **France** operators of onshore wind turbines receive fixed feed-in tariffs for a time-frame of 15 years. During the first 10 years of operation a tariff of 8.2 € Cents/kWh is paid. For the remaining 5 years of support the level of remuneration is determined by the average amount of electricity generated during the first 10 years (measured in full-load hours per year), as shown in Table 3.7. According to this amount the tariff level varies between 2.8 and 8.2 € Cents/kWh for the rest of the support period [Ministère de l'Économie, des Finances et de l'Industrie 2006].

Table 3.7: Range of feed-in tariffs for electricity from onshore wind energy in France

Average annual full-load hours during the first 10 years of operation	Tariff level for year 11 to 15: [€ Cents/kWh] (linear interpolation in between)
< 2400	8.2
2400 to 2800	6.8 – 8.2
2800 to 3600	2.8 – 6.8
> 3600	2.8

In Figure 3.11 the annual support for wind turbines is illustrated for the *stepped tariff design* and a hypothetical *flat tariff design*. Additionally the diagram shows the electricity generation costs.

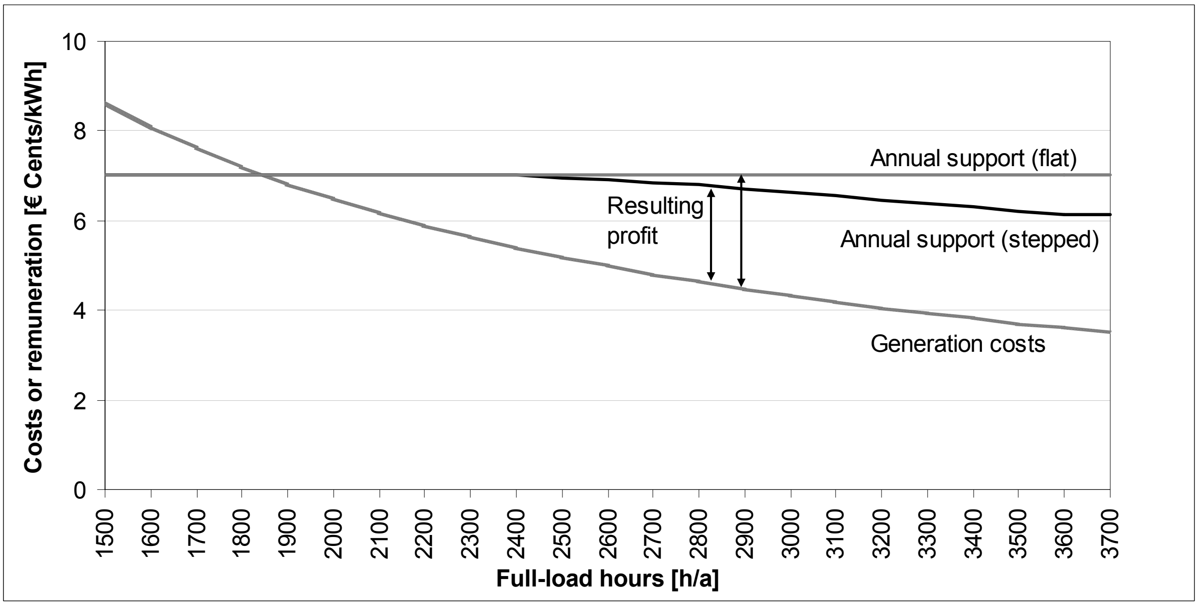

Figure 3.11: Electricity generation costs and annual support for onshore wind turbines in France in 2006[10]

Figure 3.11 illustrates that the *support level curve* with a stepped tariff design is decreasing with an increasing amount of annual electricity generation. The resulting producer profit for a flat and a stepped tariff design is shown in Figure 3.12.

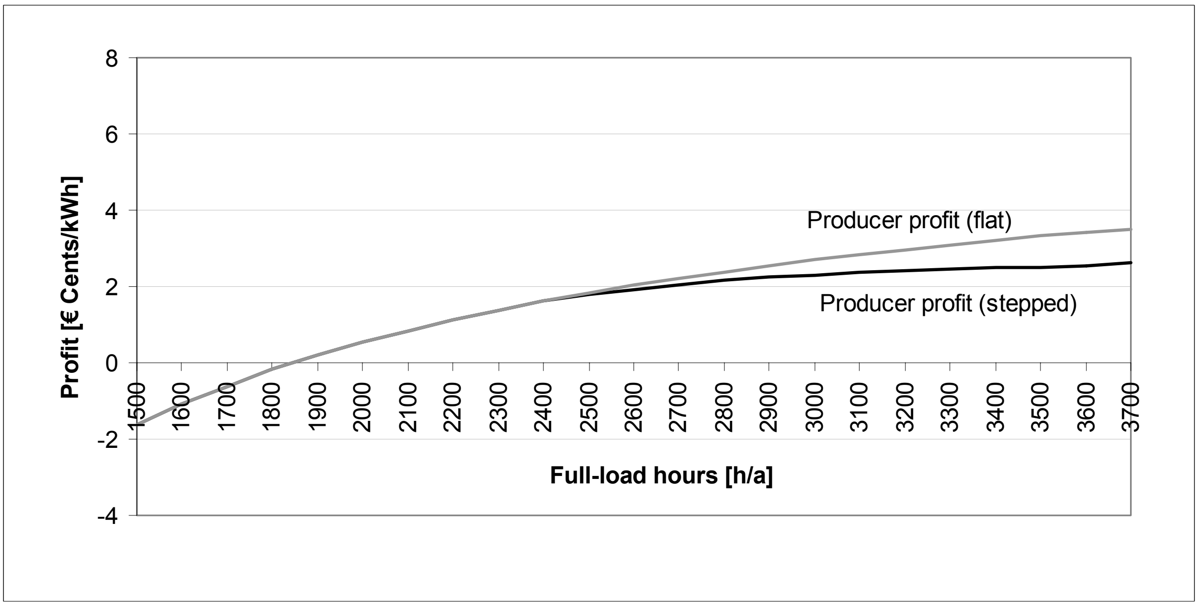

Figure 3.12: Producer profit for electricity from onshore wind energy in France in 2006

It should be observed in Figure 3.12 that in the case of a flat tariff design the producer profit per kWh electricity generated increases with the number of full-load hours per year. Whereas, the profit curve of a stepped design shows that an increasing profit for locations

[10] Assumptions: Lifetime: 20a; Interest Rate: 6.6%; Investment: 1,067€/kW; O&M Costs: 3% of Investment; Inflation rate: 1.6%

with favourable wind conditions can be levelled off. Consequently, the reduction of the producer profit leads to lower costs for the electricity consumers.

These tariffs were introduced in July 2006. Before this, the legislation was similar. The difference is that a tariff of 8.38 € Cents/kWh was paid for 5 years and the remuneration for the remaining 10 years of support was determined by the electricity generation during the first five years, as shown in Table 3.8 [Ministère de l'Économie, des Finances et de l'Industrie 2001, Annexe 1].

Table 3.8: Feed-in tariff range for onshore wind energy in France according to the old law from June 2001

Average annual full-load hours during the first 5 years of operation	Tariff level for year 6 to 15: [€ Cents/kWh] (linear interpolation in between)
< 2000	8.38
2000 to 2600	5.95 – 8.38
2600 to 3600	3.05 – 5.95
> 3600	3.05

The French legislation for offshore wind energy is likewise, but the support period is 20 years. During the first 10 years a remuneration of 13 € Cents/kWh is paid and during the following 10 years the tariffs vary between 3 and 13 € Cents/kWh according to the local wind conditions [Ministère de l'Économie, des Finances et de l'Industrie 2006].

Cyprus

In **Cyprus** operators of wind turbines with a capacity of more than 30 kW receive 9.48 € Cents/kWh for a period of 5 years. During the following 10 years the level of FIT depends on the local wind conditions and ranges between 4.91 and 9.48 € Cents/kWh[11]. Similar as in France, the tariff level is determined by the amount of full-load hours that the wind turbine was operating during the first five years, as shown in Table 3.9 [Pharconides 2006] and [Ministry of Commerce, Industry and Tourism 2003, pp. 13].

Table 3.9: Feed-in tariffs for electricity from wind power in Cyprus (turbine capacity > 30 kW)

Average annual full-load hours during the first 5 years of operation	Tariff level for year 6 to 15: [€ Cents/kWh]
< 1750	9.48
1750 to 2000	8.77 – 9.48
2000 to 2550	6.49 – 8.77
2550 to 3300	4.91 – 6.49
> 3300	4.91

[11] The tariff lies between 2.8 and 5.4 Cyprus Cents/kWh. Exchange rate on January 1st 2006: 1 Cyprus Cent = 1.75488 € Cents [OANDA Corporation 2006].

Germany

In **Germany** the support system for wind energy is a little different from the ones already described. Operators of onshore wind turbines receive a fixed FIT during the first five years after the plant has started operating. The German Renewable Energy Act ("Erneuerbare-Energien-Gesetz", EEG) defines a *reference wind turbine*, which is located at a site with a wind speed of 5.5 m/s in an altitude of 30 meters. This reference turbine would generate a so-called *reference yield* in a five-year-period. If a wind turbine produces at least 150% of this reference yield within the first five years of operation, the tariff level will be reduced for the remaining 15 years of support. However, for each 0.75% the generated electricity stays below the reference yield, the higher starting tariff will be paid for two further months. This means that the use of wind energy to generate electricity is not restricted to locations with very good wind conditions but that sites with less favourable conditions can also be exploited.

Offshore plants, starting to operate before the end of 2010, receive a higher starting remuneration for the first 12 years. This period will be extended, if the wind turbine is positioned more than 12 nautical miles away from the coast line and if the water is more than 20 meters deep. For each mile the distance to the coast line exceeds 12 miles, the period of higher remuneration will be extended by 0.5 months. For every meter of water depth that exceeds 20 meters, it will be extended by 1.7 months. Consequently higher expenses for constructing wind turbines at a greater distance from the coast line or in deeper water and for their connection to the electricity grid are taken into account [Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit 2004, § 10 and Anlage].

3.2.2 Tariff level depending on plant size

For many RES-E technologies the specific electricity generation costs per kWh differ according to the plant size. The second group of stepped tariff designs takes this into account. Almost all EU countries applying feed-in tariffs use different levels of remuneration according to the size of a RES-E plant. In most of these cases capacity scopes (for example PV plants with a capacity from 5 to 100 kW) are used to determine the level of FITs. Portugal and Luxembourg deploy systems that are a little different. Consequently these concepts are explained.

Portugal

In Portugal the tariff level for hydro power plants with a capacity between 10 and 30 MW ranges between 5.91 and 7.04 € Cents/kWh[12]. While the electricity of a 10 MW plant is remunerated with 7.04 € Cents/kWh, the level is reduced in a linear way to 5.91 € Cents/kWh for plants with a capacity of 30 MW, as shown in Figure 3.13 [Ministério das Actividades Económicas e do Trabalho 2005, Annexo II].

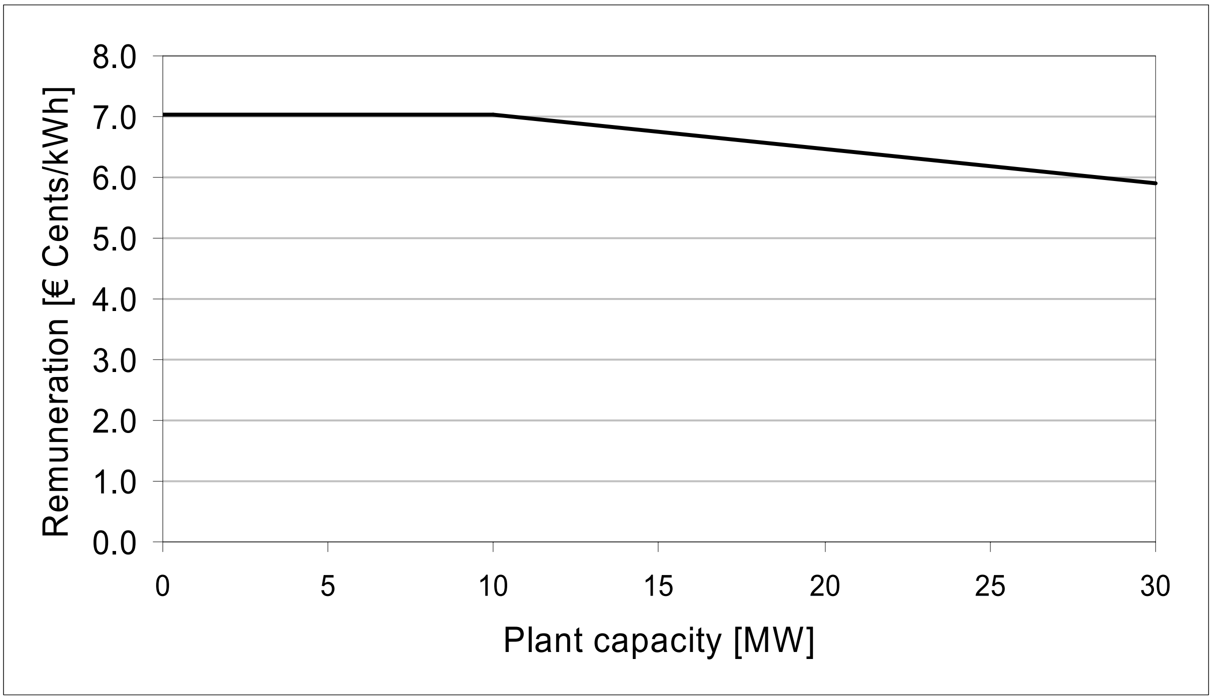

Figure 3.13: Remuneration for electricity from hydro power plants in Portugal[12]

The figure illustrates that the tariff level stays constant for plants with a capacity up to 10 MW. For larger plants the remuneration decreases in a linear way. Applying this legislation, lower electricity generation costs due to economies of scale can be taken into account.

[12] Assumptions: During day and night time the same amount of electricity is generated. The fixed parcel and the adjustment to inflation are not included in this tariff. See also Appendix B on page 74.

Luxembourg

Luxembourg applies a similar system: Electricity from wind-, hydro-, biomass-, and biogas-power plants is remunerated with a certain tariff according to the plant size. In the *Règlement grand-ducal* from October 14th 2005 two different plant sizes are distinguished: plants with a capacity between 1 and 500 kW and plants with a capacity between 501 kW and 10 MW. The level of remuneration is fixed to 7.76 € Cents/kWh for electricity from plants that belong to the first group. The tariff level for plants with a capacity between 501 kW and 10 MW is determined by the plant size according to Formula (3.1) and ranges between 5.41 and 7.76 € Cents/kWh. The tariffs for biomass and biogas plants are increased by a premium of 2.5 € Cents/kWh [Ministère de l'Economie et du Commerce extérieur 2005, Art. 5].

$$M = \left(1.95 + \left(\frac{500}{P}\right)^{0.75}\right) \times 2.63 \qquad (3.1)$$

M: Remuneration per kWh electricity generated

P: Capacity of the hydro power plant

Figure 3.14 illustrates the remuneration for electricity from wind-, biogas-, biomass-, and hydro-power plants according to the capacity.

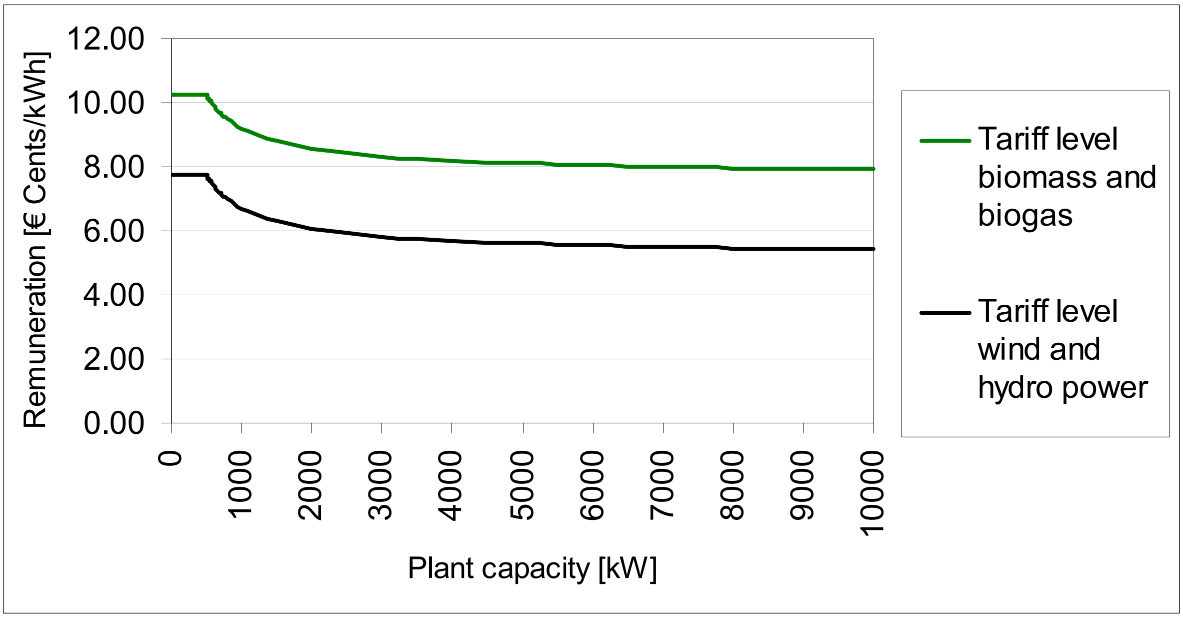

Figure 3.14: Remuneration for electricity from wind, hydro, biomass and biogas in Luxembourg

It should be observed that the remuneration remains on a constant level for plants with a capacity between 1 and 500 kW. The tariff for larger plants is decreasing with an increasing plant size. The exponent of 0.75 has a strong influence on the tariff. This causes a remuneration of less than 6 € Cents/kWh (or 8.5 € Cents/kWh, respectively) for plants with a capacity of slightly more than 2000 kW. However, the economies of scale of RES-E technologies are typically smaller than suggested by this exponent. In addition to the feed-in tariffs, operators of biomass, biogas, wind and hydro power plants receive an extra premium of 2.5 € Cents/kWh, called *grüner Franken* (see also Section 3.5.1 on page 51).

3.2.3 Tariff level depending on fuel type

The electricity generation costs may vary due to the type of fuel used. This is the case for biomass and biogas power plants. Depending on the fuel price, the power generation costs differ. Waste with a large biogenic fraction has a limited energetic potential. Depending on the ambition level of the RES target it will be necessary to grow biomass for the purpose of electricity generation, in order to use the whole potential of biomass. However, the biomass grown as fuel (such as crops) has a higher price than the biogenic fraction of waste. Furthermore producing biogas from animal residues is more expensive than the generation of landfill or sewage gas. These factors are for example taken into account by Austria, Germany, Spain and Portugal.

Austria

In **Austria** the tariff level for electricity from biomass and waste with large biogenic fraction varies according to the fuel type. Electricity from pure solid biomass (such as forestry residues) is remunerated with a higher tariff than electricity from waste with a large biogenic fraction. Furthermore different types of this waste are distinguished. This leads to three different levels of remuneration for electricity from waste with large biogenic fraction. The tariffs vary not only according to the type of fuel used, but also due to the plant size. Four capacity scopes are distinguished. Table 3.10 illustrates the tariff levels for electricity from biomass and waste with large biogenic fraction in Austria [Austrian Energy Agency 2006] and [Nationalrat 2006, Anlage 1].

Table 3.10: Remuneration for electricity from solid biomass and waste with large biogenic fraction in Austria

Plant capacity	Pure solid biomass [€ Cents/kWh]	Waste with large biogenic fraction [€ Cents/kWh]		
		Group 1 (FIT reduction: 20%)	Group 2 (FIT reduction: 35%)	Group 3
Up to 2 MW	16.00	12.80	10.40	2.70
More than 2 MW up to 5 MW	15.00	12.00	9.75	2.70
More than 5 MW up to 10 MW	13.00	10.4	8.45	2.70
More than 10 MW	10.2	8.16	6.63	2.70

Group 1: Residues from wood where a biological utilization is not preferable or possible.
Group 2: Other residues from wood (where a biological utilization is preferable or possible)
Group 3: Other types of waste with a large biogenic fraction, such as residues from food or from waste water treatment.

Germany

In Germany the level of remuneration for electricity from biomass and biogas depends on different characteristics of the power plant as well as on the fuel type. Similar as in Austria, four different capacity ranges are distinguished. Furthermore the tariff level is increased, if the biomass has not been treated before it is used as fuel and if the power plant fulfils certain criteria as illustrated in Table 3.11 [Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit 2004, §§ 7,8].

Table 3.11: Tariff level for electricity from biomass and biogas in Germany in 2006

Plant capacity	Pure solid biomass	Premium for untreated biomass[1)]	CHP premium[2)]	Premium for innovative technologies[3)]
Up to 150 kW	11.16	6.0	2.0	2.0
More than 150 kW up to 500 kW	9.61	6.0	2.0	2.0
More than 500 kW up to 5 MW	8.64	4.0	2.0	2.0
More than 5 MW up to 20 MW	8.15	-	2.0	-

1) The premium for untreated biomass is paid if the electricity is generated from agricultural, forestry or horticultural residues (that were not treated before being used as fuel) as well as from liquid manure.

2) The CHP premium is available, if the electricity is generated in a *combined heat and power* (CHP) plant.

3) The premium for innovative technologies is paid for certain power plant designs, for example *Fuel cells, Organic Rankine plants, Kalina Cycle technologies* or *Stirling engines.*

The following exceptions of the specified tariffs are applied:

- If waste wood is used in a biomass plant, the feed-in tariff is reduced to 3.78 € Cents/kWh.
- If electricity is generated by the combustion of wood in a biomass plant with a capacity between 500 kW and 5 MW, the tariff level is increased by 2.5 € Cents/kWh. However, the premium for untreated biomass is not applicable in this case.
- Electricity generated from landfill and sewage gas is remunerated with a tariff of 7.44 € Cents/kWh if the plant capacity is up to 500 kW and with 6.45 € Cents/kWh in the case of larger plants up to 5 MW. The premium for innovative technologies is also applicable for these cases.

Spain

Also in **Spain** the level of tariffs for biomass plants depends on the type of fuel used. Biomass from energetic cultivation, garden, forest, and agriculture waste is supported with a higher tariff than residues from industrial installations in the agricultural and forestry sector, for example the remains from production of olives [Ministerio de Economía 2004, Art. 37 and Annexo II].

Portugal

In **Portugal** biomass power plants that work with forestry residues receive a lower remuneration than plants that use animal residues [Ministério das Actividades Económicas e do Trabalho 2005, Annexo II].

3.2.4 Evaluation of a stepped tariff design

This section illustrates different possibilities to take into account varying electricity generation costs that occur due to the size of a RES-E plant, the type of fuel used or the conditions at the site of a plant. The examples of the Dutch, French and German systems to support wind energy show that it is possible to level off an increasing producer profit at locations with a higher wind yield. This way costs for the electricity consumers can be kept at a moderate level. Furthermore this legislation makes it possible and profitable to exploit sites with less favourable conditions. However it has to be kept in mind, that it makes sense to exploit the sites with the most favourable conditions first. Therefore energy policy should provide incentives to exploit the most efficient sites first and also to use in each region the kind of RES which is most suitable under the local conditions. Thus a system with FITs should be organised which renders the return on investment slightly higher for plants at cost efficient locations compared to sites at locations with less favourable conditions [Resch 2005, p. 78]. Table 3.12 summarizes the advantages and disadvantages of these systems.

Table 3.12: Evaluation of a stepped tariff design

Advantages	Disadvantages
• Differences in power generation costs due to the plant size or the fuel type can be taken into account • Local conditions can be considered and reflected in the tariff level • Not only the sites with most favourable conditions can be exploited • Risk of over-compensating very efficient plants is minimised • Producer profit is kept on a moderate level at favourable sites. Therefore the burden on electricity consumers is lower. • Higher electricity generation costs for example due to deeper water or a large distance to the coast line (in the case of offshore wind turbines) can be taken into account	• The system can lead to high administrative complexity (e.g. for defining a reference turbine as in Germany). • Many different tariff levels within the same technology may lead to less transparency and uncertainty for the investors. • If the tariffs for plants with a low capacity are significantly higher than for larger plants, it could be economically feasible to construct two small plants instead of a large one, even though larger plants might be more efficient. This decreases the overall efficiency of the system.

3.3 Incorporating technological learning in RES-E policy

One goal of energy policy should be to provide incentives for technology improvements and more efficient solutions in order to reduce the electricity generation costs of RES-E technologies. The largest share of these costs is maid up by the price of the power plant itself and the installation costs. This is especially the case for technologies that do not require any expenses for fuel, such as wind power, PV, geothermal energy or hydro power. The price for power plants and the installation costs tend to decrease as a technology is applied due to the so-called *experience curve effect* or due to *technological learning*. The decreasing costs should be reflected by the support policy. This can be done by reducing the FIT level for new installations during the revision and adjustment of tariffs (see Section 3.1.2). Another possibility is a predefined *degression* of the tariff level by a certain percentage per year for new installations. The concept of the experience curve and the tariff degression are explained in this section.

3.3.1 The concept of experience curves

An experience curve describes the relation between the total costs that are associated with a technology (including labour, capital, administrative costs, research and marketing costs, etc.) and the cumulative output. In many industries it has been observed that with every doubling of the cumulative output the total costs per unit decrease by a fixed and predictable percentage, the so-called *learning rate*. The unit costs after cumulated output has doubled can be referred to as *progress ratio.* A learning rate of 20% (implying a progress ratio of

80%) for example means that the unit costs decrease by 20% (down to 80%) when cumulative output is doubled.

The main factors that are made responsible for the reduction in costs are:

- Learning process
- Economies of scale
- Technical Progress
- Rationalisation

For a more detailed explanation of the experience curve effect, see for example [Breit 1985, pp. 125] and [Neij 1999, pp. 21].

3.3.2 Tariff degression

The system of a tariff degression can be described as follows: The tariff level depends on the year, when the RES-E plant starts to operate. Each year the level for new plants is reduced by a certain percentage. However, the remuneration per kWh for commissioned plants remains constant for the guaranteed duration of support. Therefore the later a plant is installed, the lower the reimbursement received. The tariff degression can be used to provide incentives for technology improvements and cost reductions. Furthermore it minimizes the risk of over-compensation. Ideally the rate of degression is based on the empirically derived progress ratios for the different technologies. Germany, France (for wind energy) and Italy (for PV) apply a support system for RES-E with a tariff degression. Subsequently these concepts will be described.

Germany

According to the German Renewable Energy Act, the tariffs for electricity from RES are reduced annually. Depending on the type of technology the FITs for new installations decrease by 1% for small hydro plants up to 5% for building integrated photovoltaic systems. If the PV devices built on the ground, the degression is even 6.5%. This way cost reductions due to the experience curve effect are included in the policy and a continuous incentive for efficiency improvements and cost reductions for new plants is offered [Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit 2004, §§ 6-11].

Figure 3.15 illustrates the development of the experience curve of wind turbines as a relation between the cumulative installed capacity and the specific price of wind turbines expressed in € Cents/kWh*a. The specific price of a wind turbine is calculated as follows: The price per kW of a wind turbine is divided by the average amount of electricity generated in one year at the reference location according to the German Renewable Energy Act. At this location the wind speed is 5.5 m/s in an altitude of 30 m. A 1.5 MW turbine with a tower height of 100 m generates about 4.5 million kWh electricity per year [Institut für Solare Energieversorgungstechnik 2005].

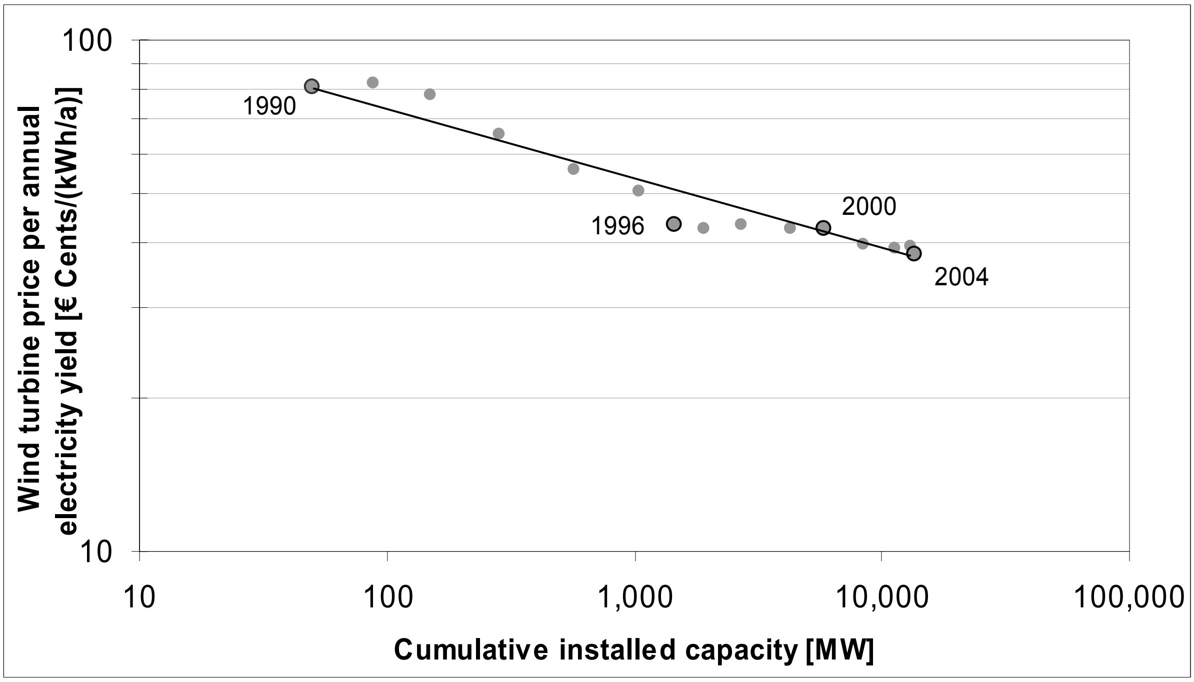

Figure 3.15: Experience curve of onshore wind turbines in Germany

It should be observed that the price for wind turbines as ratio of the annual electricity yield decreased from 80 to 38 € Cents/(kWh/a) between 1990 and 2004. This implies a reduction of 53% in total and an average learning rate of 5.2% per year. Figure 3.15 also shows that after stagnation of generation costs between 1990 and 1992, a strong decrease followed between 1992 and 1996. In the second half of the 1990s until 2004 costs only decreased very little. The slower decrease is caused by different factors. The development of wind turbines with a capacity of more than 1 MW led to high costs for the turbine producers from 1996 on. Furthermore the steel price has been increasing in the past years, as well as the demand for wind turbines on the world market. However, technical improvements and more efficient solutions still led to a decrease in the specific electricity generation costs [Bundeskabinett 2002, p. 17].

In order to analyse the instrument of *tariff degression*, the illustrated experience curve is compared to the development of the support level for electricity from wind energy. Figure 3.16 shows the tariff level for the period from 1991 until 2004.

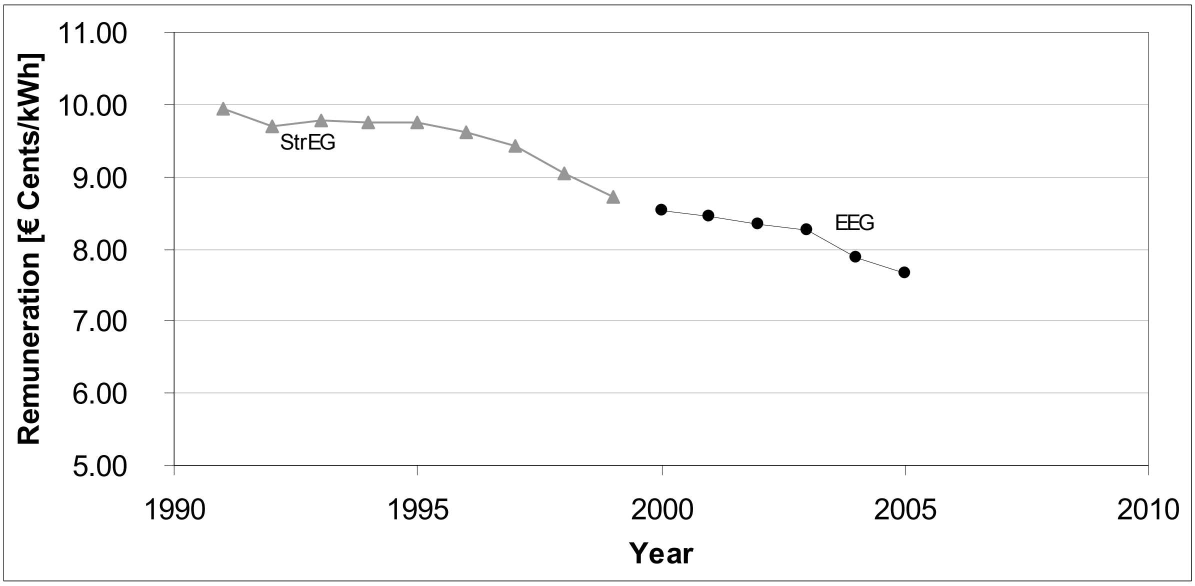

Figure 3.16: Development of the remuneration of electricity from onshore wind energy in Germany

Figure 3.16 illustrates the level of remuneration according to the *Stromeinspeisungsgesetz (StrEG)* for the time from 1991 to 1999, and the *Erneuerbare-Energien-Gesetz (EEG)* for the period from 2000 to 2005. For the time from 2000 to 2005 the real average remuneration at the reference location was taken as a basis. The FITs are corrected for inflation whereas the reference year is 2000. The graph shows that the remuneration went down from 9.95 € Cents/kWh in the year 1991 to 7.65 € Cents/kWh in 2005. This implies a reduction by 23% [Institut für Solare Energieversorgungstechnik 2006].

The tariffs for new installations are reduced by 2% annually. Furthermore, the FITs fixed in the EEG do not include an inflation correction leading to a real reduction of the tariffs. The implementation of a tariff degression for new installations leads like a stepped tariff design to an adequate adjustment of the support level to the generation costs.

In the PV industry a similar development as in the wind industry could be observed with even stronger cost reductions. The price for a PV module decreased from 90 US$ per W_{peak} in the year 1968 down to 3.50 US$ per W_{peak} in 1998. This implies a learning rate of 20%. The prices of PV devices in Germany continued to decrease until the end of 2003. However, a fast growing PV market led to a shortage in the supply of silicon, which is used to construct PV modules. This shortage was increased by a growing semi-conductor industry, that uses silicon as well. Therefore the silicon price went up from 30$ US$ per kg in 2003 to 60 US$ per kg in 2005. About 10% of the price for PV modules is made up by the price of silicon, therefore the PV plant prices increased as well in the years 2004 and 2005. In order to solve the shortage problem of silicon, the producers have been increasing their capacity from 14000 up to 30000 tons per year globally; however the extension of the silicon production requires high investments and takes a long time.

Technological improvements and product innovations in the PV module production combined with an emerging release in the silicon supply is recently causing decreasing PV device prices. Since the end of 2005, the wholesale prices of PV modules have been decreasing by

5%. For the year 2007 a similar rate of decrease is expected, which goes along with the tariff degression of 5% suggested by the German Renewable Energy Act [Körnig 2006].

France

In **France** a tariff degression of 2% annually is applied for electricity from new wind turbines from the year 2008 on [Ministère de l'Économie, des Finances et de l'Industrie 2006].

Italy

Italy applies a similar legislation for PV. From 2007 on the level of FITs for electricity from new PV plants will be reduced by 2% annually [Ministero delle attività produttive 2005, Art. 5].

3.3.3 Evaluation of a tariff degression

We have seen that a tariff degression can be used to incorporate technological learning in RES-E policy. The predetermined percentage of degression causes higher transparency and security for potential investors than reducing the tariff level during a periodical revision, as described in Section 3.1.2. However, rising prices of input factors like steel for wind turbines or silicon for PV devices may lead to an unexpected increase in the price of RES-E plants. In order to maintain RES-E projects attractive for investors, the price development of the most important input factor could be taken into account to determine the tariff level. On the other hand this could lead to increased plant prices, if the plant producers know that the degression rate is variable.

The advantages and disadvantages of a tariff degression are summarized in Table 3.13.

Table 3.13: Evaluation of a feed-in tariff design with a tariff degression

Advantages	Disadvantages
• Investment security • Transparency • Incentives to build a plant early in time, because the level of remuneration is decreasing along with the plant prices • Incentive for technological improvement • Lower burden on electricity consumers	• If the degression rate is set for many years, the system is not very flexible, in the case of varying technology prices due to structural changes, e.g. increased prices of steel or silicon. • It is difficult to set an appropriate degression rate, due to the difficulties in predicting technological learning, which is for example related to the cumulative amount installed capacity

3.4 Premium versus fixed tariff design

A feed-in tariff can be paid to RES-E generators as an overall remuneration (the *fixed tariff*) or alternatively as a premium, that is paid on top of the electricity market price (the *premium tariff*). In the case of a fixed tariff design, RES-E producers receive a certain level of remuneration per kWh of electricity generated. In this case, the remuneration is independent from the electricity market price. In contrast, the development of the electricity price has an influence on the remuneration level under the premium option. Hence, the premium tariff represents a modification of the commonly used fixed tariff towards a more **market-based** support instrument.

Currently, most of the European countries with feed-in systems opted for the fixed tariff model. Premium tariffs are only applied in **Spain**, the **Czech Republic**, **Slovenia**, the **Netherlands** and **Denmark** (for onshore wind energy). According to a new draft, amending the **Estonian** Electricity Market Act, premium tariffs are also considered for the RES-E support in Estonia. Subsequently the systems of the six countries are be described and compared to the fixed price option.

Spain

In **Spain** the Royal Decree 2818 of 1998 introduced a system offering RES-E producers to choose between a *fixed tariff option* and a *premium option.* The choice is valid for one year, after which the generator may decide to maintain the tariff option or change to the alternative option. In the case of the fixed tariff option, the electricity from RES is purchased by the electricity distributor, who pays a fixed remuneration per kWh to the RES-E generator.

RES-E producers who choose the *premium option* still sell their electricity to the distributor and receive a premium on top of the final average hourly market price *(precio final horario medio)*. A modification of the Spanish tariff system, which was introduced by the *Royal Decree 436* in March 2004, replaced the existing premium option with a stronger market-orientated one. However, the former premium option is still available as a transitional alternative until 2007. According to the new premium option, RES-E generators can sell their electricity on the market in a bidding system, which is managed by the Spanish market operator (OMEL). Furthermore the electricity can be sold directly to other customers through bilateral contracts or to electricity traders through forward contracts. The overall remuneration consists of the market electricity price (or the negotiated price, respectively) and the additional tariff components including a premium and an incentive for participation in the market [Ministerio de Industria y Energía 1998, Art. 23ff] and [Ministerio de Economía 2004, Art. 22ff].

Figure 3.17 illustrates which one of the two options the RES-E producers chose from January 2004 to July 2006 and how the average hourly market price developed.

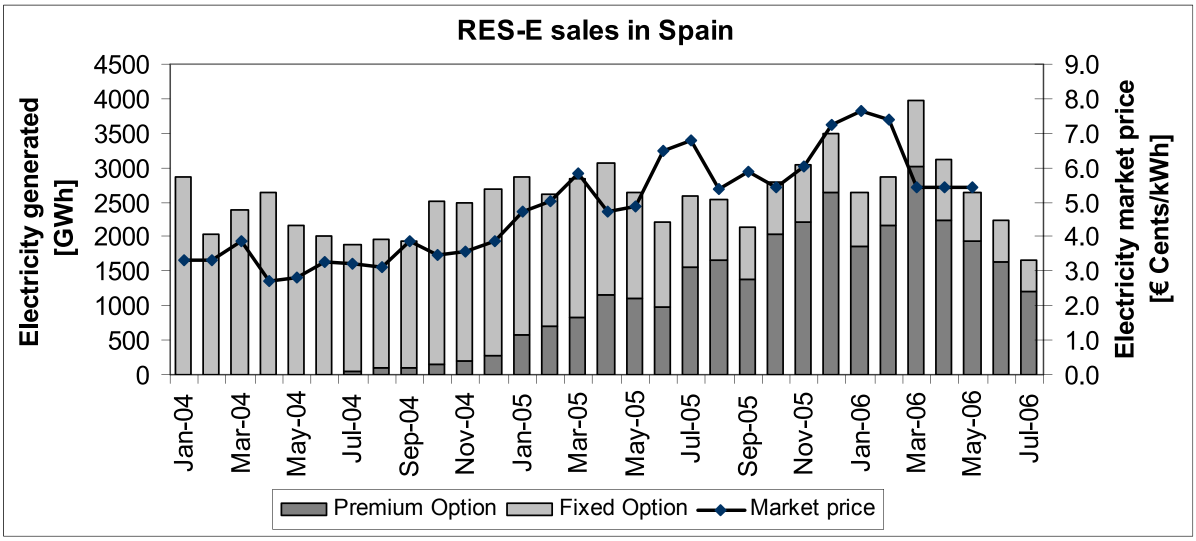

Figure 3.17: Electricity sold through the fixed and the premium option and electricity market price in Spain from January 2004 to July 2006

As Figure 3.17 shows, the electricity market price went up from 3.3 € Cents/kWh in January 2004 to 5.4 € Cents/kWh in May 2006[13]. The highest price of 7.6 € Cents/kWh could be achieved in January 2006. Due to the increasing price, the share of electricity sold with the premium option increased from 0% in June 2004 up to 72% in July 2006. Figure 3.18 shows this share for the different technologies.

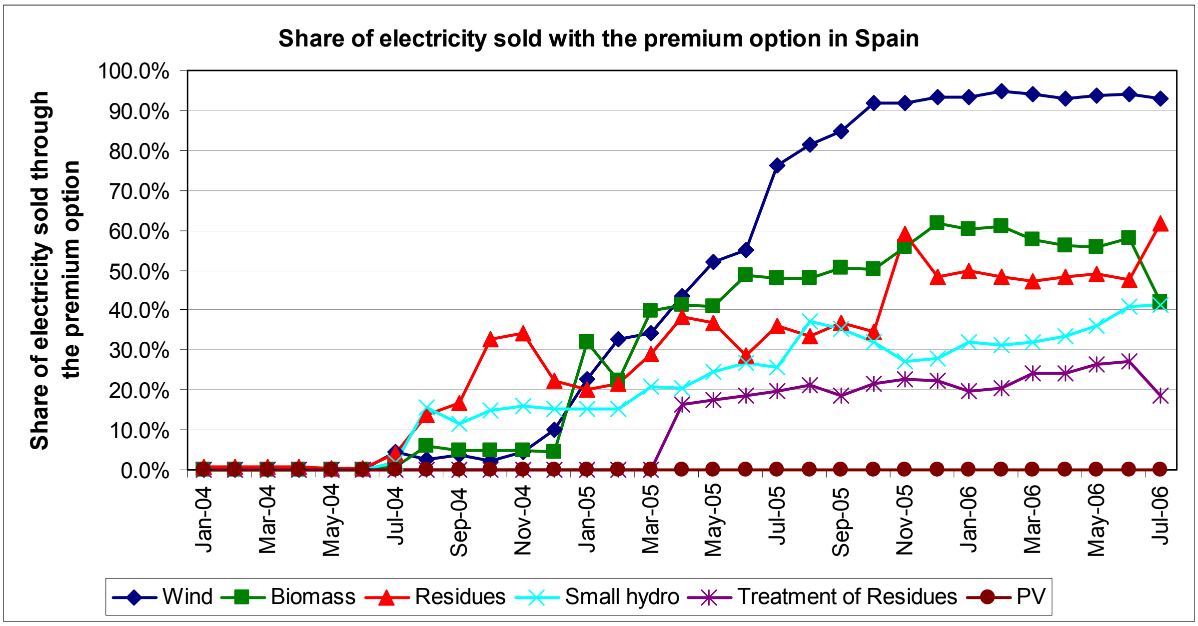

Figure 3.18: Share of electricity sold with the premium option in Spain from January 2004 to July 2006[14]

[13] For June and July 2006 the market price is not available.

[14] *Residues*: Plants using residues as primary energy (group c); *Treatment of residues*: Plants using cogeneration for the reduction or treatment of residues (group d) [Ministerio de Economía 2004, Art. 1].

It should be observed that the share of electricity sold with the premium option increased for all RES-E technologies, after the new premium option was introduced in March 2004. Only the operators of PV plants have not been selling their electricity directly on the market. (The main reason for this is that the premium option is only available for PV plants with a capacity of more than 100 kW, most PV plants are smaller.) Since the share of electricity from wind energy sold with the premium option shows the largest increase (from 0% in June 2004 to 93% in July 2006), this technology will be analysed closer subsequently.

Figure 3.19 shows the remuneration for both possibilities, the fixed and the premium option.

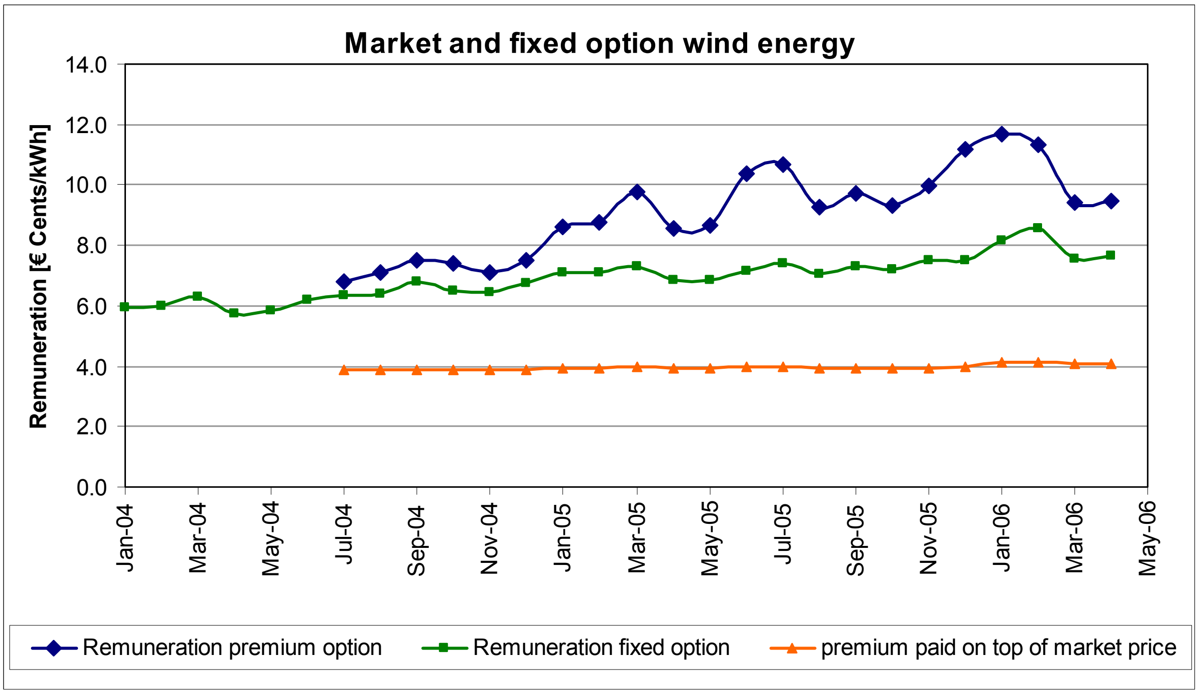

Figure 3.19: Remuneration for electricity from wind energy in Spain from January 2004 to April 2006

Regarding the premium option, the orange curve represents the premium plus incentive paid over market price for electricity generated from wind energy. This premium only changed slightly from July 2004 until April 2006 according to the adjustment of the average electricity tariff. The green curve in the middle shows the average overall tariff per kWh that is paid in the case of the fixed option. The blue curve on top illustrates the total remuneration per kWh for the premium option, as the sum of the premium and the electricity market price[15]. As the figure illustrates, the premium option offers a higher support level than the fixed-price regulation and that the difference in the level of remuneration between both options has been increasing since June 2004. Therefore the share of electricity from wind energy that is sold through the premium option has been increasing constantly during the last two years, as demonstrated in Figure 3.20. Furthermore the possibility of selling the electricity directly through bilateral contracts or via a system of forward contracts introduced in March 2004 by the Royal Decree 436 has made the premium option more attractive for RES-E producers.

[15] 63% of the electricity from wind energy sold with the premium option were taken into account to determine the total remuneration in the case of the premium option. Furthermore the penalty, which has to be paid for deviations from the predicted amount of electricity fed into the grid, is not included.

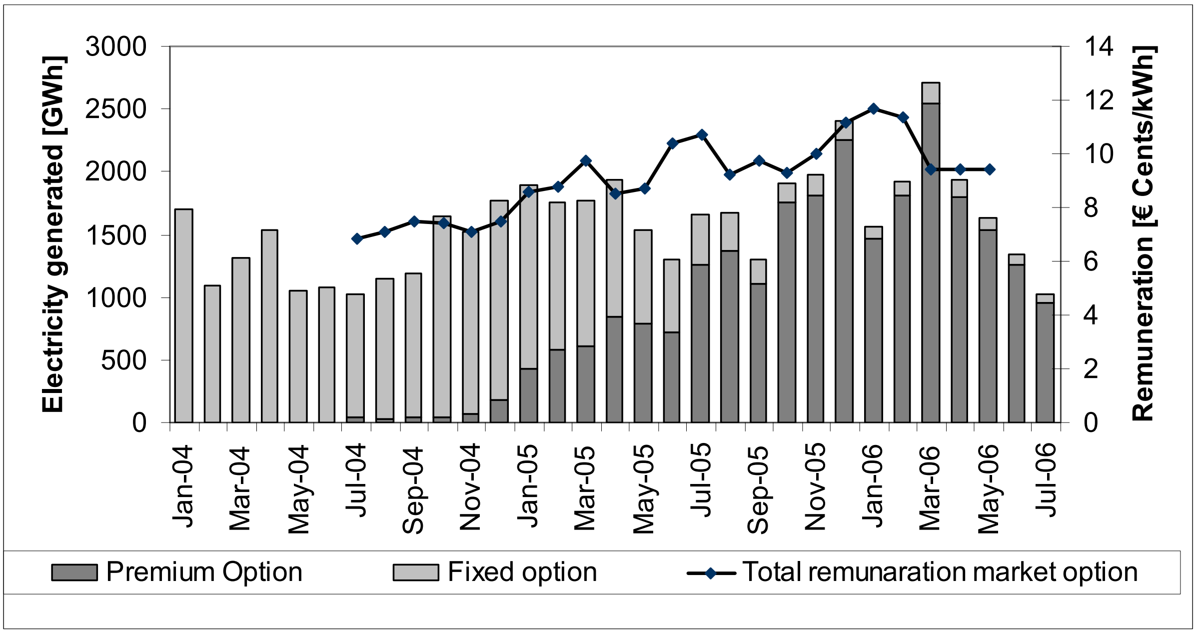

Figure 3.20: Electricity from wind energy sold with the fixed and the premium option.

Figure 3.20 shows that until June 2004 the total amount of electricity from wind energy fed into the Spanish electricity grid, was remunerated according to the fixed option. In July 2004 5% of this electricity was offered on the market. The number of wind turbine operators, who chose the premium option constantly rose and a 93% share of the electricity from wind energy was sold through the premium option by July 2006 [Comisión Nacional de Energía 2006].

As mentioned above in Section 3.1.2, the tariff levels and premiums were fixed as a percentage of the reference electricity price, which was set annually by the Spanish Ministry of Industry, Tourism and Trade. The Royal Decree Act 7/2006, passed in June 2006, abolished the linkage of the FITs and the premium payments to the reference electricity price. The main reason for the change in law was, that the reference electricity price, which also determined the maximum price the consumers had to pay per kWh of electricity, could only vary by 2% annually. Since the oil and gas prices have been increasing significantly in recent years, the electricity generation costs have been rising faster than the electricity price, leading to a *tariff deficit*, which amounted 3.81 billion € in 2005. In order avoid this deficit during the next years, the consumer electricity price will rise according to the actual costs from June 2006 on. If the premiums and tariffs of RES-E were still linked to the reference electricity price, the rising electricity prices would cause rising remunerations for RES-E as well. However, due to the change in legislation, this is not the case. Until the tariffs are revised and adjusted (the latest legal point of time for this is the 23rd of December 2006) those tariffs are valid, that were paid in June 2006 [Ministerio de Industria, Turismo y Comercio 2006] and [Gellings 2006].

In the past years the total costs for RES-E support in Spain have been increasing. The main reason for this is a higher amount of RES-E generation. However, in 2005 and during the first months of 2006 not only the total costs for RES-E support have been rising, but also the average costs per kWh of RES-E, as illustrated in Figure 3.21 This increase in costs, which was a lot higher than expected by the Spanish government, also led to the Royal Decree

Law 7/2006. The change in legislation causes uncertainty for the investors, because the level of remuneration for new RES-E plants is not clear in advance [Comisión Nacional de Energía 2006].

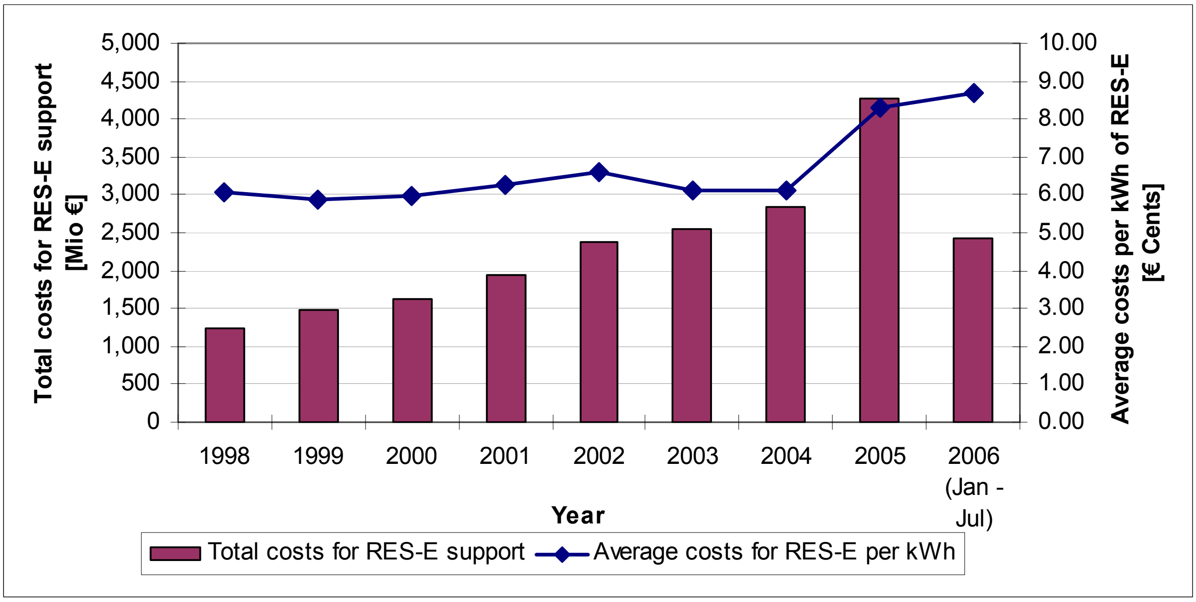

Figure 3.21: Development of the total costs for RES-E support and the average costs per kWh in Spain

Czech Republic

In August 2005 the **Czech Republic** introduced a *premium option* as an alternative to the already existing *fixed feed-in tariff*. Since January 2006 RES-E generators can decide to sell their electricity to the grid operator, receiving a fixed overall tariff, or alternatively offer their electricity directly on the market. In this case, a premium called *green bonus* is paid on top of the market price. For power plants using co-firing of biomass and fossil fuels only the new premium option is applicable. The decision to use one of the alternatives is valid for one year. In order to encourage participation in the market, the level of the premium is chosen in a way that the overall remuneration of this option is higher than in the case of a fixed tariff option. The fixed tariffs and the green bonus are adjusted annually by the *Energy Regulatory Office*, which takes into account the development of the different technologies and the market needs. [Energy Regulatory Office 2005] and [Parliament of the Czech Republic 2005].

Slovenia

Another country that applies a system with fixed tariffs as well as premium tariffs is **Slovenia.** However, there are two differences to the concepts described above: RES-E generators may sell a part of their electricity on the market receiving a premium on top of the market price and another part to the grid operator receiving fixed tariffs. The second difference is that the overall remuneration is supposed to be on the same level for both, the *premium* and the *fixed* option [Republic of Slovenia - Ministry of the Economy 2006, p. 9].

Estonia

The current law in **Estonia** only provides the fixed tariff option. However, there is a new draft introducing a premium tariff design in addition to the existing fixed tariff. The premium together with the market price is supposed to be higher than the FIT of using the purchase obligation (5.81 € Cents/kWh in comparison to 5.18 € Cents/kWh[16]), in order to encourage participation in the market [Government of Estonia 2005, pp. 19].

Denmark

In 1999 it was decided to change the feed-in tariff system in **Denmark** into a quota system with tradable green certificates. However, due to a significant opposition of major interest groups as well as parts of the parliament against these plans, the Danish government decided to keep the fixed FITs as a transitional solution. For electricity from wind onshore energy, a premium tariff was introduced. Operators of plants that were connected to the grid after the 31st of December 2002 have to sell the generated electricity on the market and are responsible for the related costs (e.g. balancing energy). In addition to the market price they receive a premium of 1.3 € Cents/kWh[17] and an allowance of 0.3 € Cents/kWh for offset costs. For plants connected to the grid in 2003 and 2004, the premium depends on the level of the electricity market price and is adjusted, if the price rises above 3.49 € Cents/kWh in a way that the sum of market price and premium does not exceed 4.83 € Cents/kWh. For plants that were connected to the grid since 2005, this cap was abolished and the operators of those plants receive a premium of 1.34 € Cents/kWh independently from the electricity market price [Danish Energy Authority 2006b].

One reason for the abolishment of the cap was that the adjustment of the premium could be considered as a tax of 100% on electricity sales from wind energy, if the spot market price rises. Furthermore the newly installed capacity of onshore wind turbines in Denmark has been decreasing rapidly since 2000, as shown in Figure 3.22 (the intermediate increase of installed capacities in 2002 was reached by an extra repowering scheme in this year).

[16] The remuneration in the case of the fixed option is supposed to be EEK 0.81/kWh and in the case of the premium option EEK 0.91/kWh. Exchange rate: 1 EEK = 0.06390 Euro (01.01.2006).

[17] Exchange rate: 1 DKK = 0.13405 € (1.1 2006) [OANDA Corporation 2006].

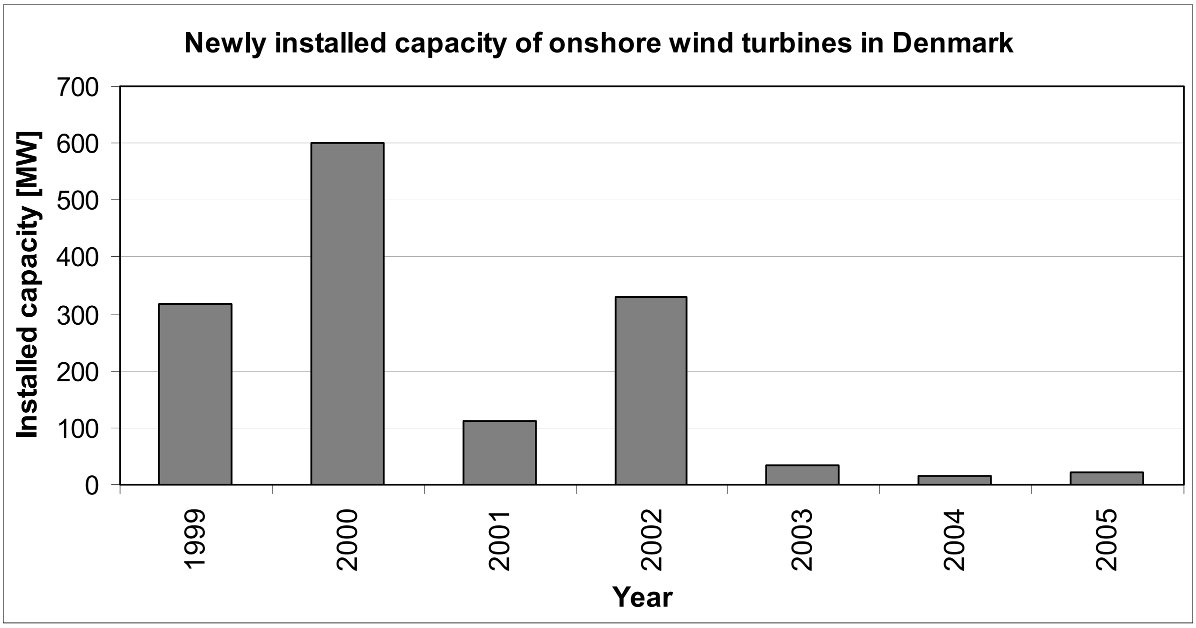

Figure 3.22: Newly installed capacity of onshore wind turbines in Denmark

In the year 2000 onshore wind turbines with a capacity of 601 MW were connected to the grid. This number decreased down to 36 MW in 2003 and to 15 MW in 2004.

So far the abolishment of the cap has not been leading to significantly higher rates of newly installed wind turbines. In 2005 turbines with a capacity of 22 MW were connected to the grid. The main reason for this low figure is, that the overall remuneration for electricity from onshore wind energy in Denmark is too low to attract investors [Danish Energy Authority 2006a] and [Holst 2006].

Netherlands

Electricity from RES-E plants approved before August 18th 2006 is remunerated with the electricity price, paid by the network operator / electricity distributor and a technology-specific premium fixed by the government. The electricity price is negotiated between the RES-E generator and the network operator or electricity distributor and a contract fixes this price various years. The Netherlands do not offer a fixed feed-in tariff as an alternative to the premium tariff design.

Evaluation of the premium tariff versus fixed tariff

The premium option shows a higher compatibility with the liberalised electricity markets than fixed feed-in tariffs. This involves a better and more efficient assignment of the grid costs, particularly as regards the management of the alternative routings and supplementary services. The risk for the RES-E producers is larger in the case of the premium option, because the total level of remuneration is not determined in advance and there is no purchase obligation as is typically the case with the fixed option. Therefore the remuneration of the premium option has to be higher than the one of the fixed tariff option in order to compensate the higher risk for RES-E producers (if the same investments in new installations should be achieved). Nevertheless, the higher support level also implies higher costs for the electricity consumers, especially if the remuneration levels of fixed and the premium option differ significantly, as we have seen in the Spanish example. One possibility to avoid these large differences and the extra costs for electricity consumers could be a premium varying with the electricity market price, as applied in Denmark or a top limit for the overall remuneration paid in the case of the premium option. A bottom limit could be introduced as well, in order to compensate falling electricity prices. However, if varying premiums or limits are applied, some advantages of the premium option are no longer valid, for example the incentive to feed electricity into the grid in a moment of high demand (and a high price). On the other hand, the possibilities for operators of wind and solar power plants to feed the electricity into the grid at defined times are limited.

Table 3.14 summarizes the advantages and disadvantages of a premium tariff design in comparison to a fixed tariff design.

Table 3.14: Evaluation of a premium tariff design compared to a fixed tariff design

Advantages	Disadvantages
• More market orientated and less market distortion • More demand orientated • Provides an incentive to feed electricity into the grid, in times of peak demand	• No purchase guarantee, therefore less investment security • Most likely higher costs for electricity consumers, especially if the market price rises • Operators of wind and solar power plants can hardly influence the time of electricity generation and therefore are not able to take advantage of feeding electricity into the grid at peak demand

3.5 Additional incentives for innovative features

In this section additional measures are described that are used in the Member States of the EU along with feed-in tariffs, such as additional premiums for RES-E generators, if the power plants fulfil certain criteria, incentives for repowering or incorporating demand orientation in the feed-in tariff level.

3.5.1 Additional premiums for RES-E generators

Different premiums and incentives are applied in Germany and France for the following features:

- Building integrated PV
- High efficiency of plants
- Regular electricity production

Germany

In Germany the FIT level for a PV plant commissioned in 2006 is 40.6 € Cents/kWh. However, this tariff is increased, if the PV device is installed on top of a building or on a noise barrier, as shown in Table 3.15.

Table 3.15: FIT level for new PV plants in 2006 installed on top of a building or on a noise barrier

Plant size	Tariff level [€ Cents/kWh]
≤ 30 kW	51.8
30 – 100 kW	49.3
> 100 kW	48.7

If a PV device is installed on the facade of a building instead of on the roof, the tariffs shown in Table 3.15 are increased by 5 € Cents/kWh [Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit 2004, § 11].

France

In **France** the electricity from RES is supported by fixed FITs, but the operators of RES-E plants can receive an additional premium on top of the FITs if their plant fulfil certain criteria. These criteria are shown in Table 3.16 for the different RES-E technologies.

Table 3.16: Extra premiums for RES-E in France

Technology	Conditions	Level of premium [€ Cents/kWh]
Biomass	energy efficiency	0 – 1.2
Biogas, geothermal power	energy efficiency	0 – 3.0
Biogas with methanisation	extra premium for methanisation	2.0
PV energy	building integrated plants	25.0
Hydro power	extra premium for regularity of production during winter time	0 – 1.52

Source: [Ministère de l'Économie, des Finances et de l'Industrie 2006]

Luxembourg

In **Luxembourg** fixed FITs are paid for electricity from RES. These FITs are set by the Ministry of Economy and paid for by the electricity consumers within the power price. In addition to the FITs the operators of wind turbines, hydro, biomass and biogas plants receive an extra premium of 2.5 € Cents/kWh financed from the budget of the Ministry of Environment [Ministère de l'Environnement 2005] The premium, called *Grüner Franken*, is paid to every plant operator, independently from the plant size, the type of fuel or any other conditions. Therefore it is not paid to compensate higher costs for RES-E generators. Instead of applying the premium, which causes extra administrational complexity, the FIT level could be increased by 2.5 € Cents/kWh.

Evaluation of the concepts with extra premiums

If the electricity generation costs increase due to certain power plant designs, and these designs go along with the policy goals it makes sense to pay an extra premium.

An extra premium for a high plant efficiency, as it is paid in France for biogas or geothermal power plants provides an incentive for plant operators to use most advanced and efficient technologies.

Table 3.17: Evaluation of additional premiums for RES-E generators

Advantages	Disadvantages
• Extra premiums provide the possibility to influence RES-E producers in their behaviour decisions	• Additional premiums typically lead to more complexity in a support system

3.5.2 Additional premium for repowering

In **Denmark** and **Germany** an extra premium is paid to wind turbine operators, if old, small wind turbines are replaced by new ones with more capacity. This concept is called *repowering.*

Germany

If new onshore wind turbines replace or renew turbines that started operating before 31.12.1995 and enlarge their capacity by at least three times, the higher starting tariff of 8.36 € Cents/kWh (for plants commissioned in 2006) is paid for two more months for each 0.6% that the yield does not reach the reference yield defined in the Renewable Energy Act [Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit 2004, § 10]. (For further information about the starting tariff and the reference yield, see Section 3.2.1 on page 32.)

Denmark

In Denmark operators of wind turbines that replace a turbine with up to 450 kW receive a *removing certificate*. This certificate guarantees an extra premium of up to 1.6 € Cents/kWh for the first 12,000 full-load hours of electricity generated by the new wind turbine. In order to receive this premium, the old turbine must be decommissioned between December 15th 2004 and December 15th 2009. The premium is varies in relation to the market price as the total of premiums and market price must not exceed 6.4 € Cents/kWh.

Evaluation of the systems to support repowering

Table 3.18 summarizes the positive and negative effects of an extra incentive for repowering.

Table 3.18: Evaluation of an additional premium for repowering

Advantages	Disadvantages
• Incentive to replace old, small turbines • With the same amount of wind turbines a higher electricity yield can be achieved • Old turbines are usually built at sites with favourable wind conditions and might block them for new turbines • A repowering strategy may be used to improve the management of electricity grids • New and modern turbines are better adjusted to the grid management • Modern wind turbines typically rotate slower and run smoother than old turbines.	• Wind turbines that are working well might be replaced before the lifetime is reached

3.5.3 Demand orientation

The demand of electricity varies depending on the time of day and the season of the year. The so-called *load curve* or *load profile* shows the amount of electricity that is demanded during one day. Figure 3.23 illustrates a typical load curve in Germany for a day in summer and in winter time.

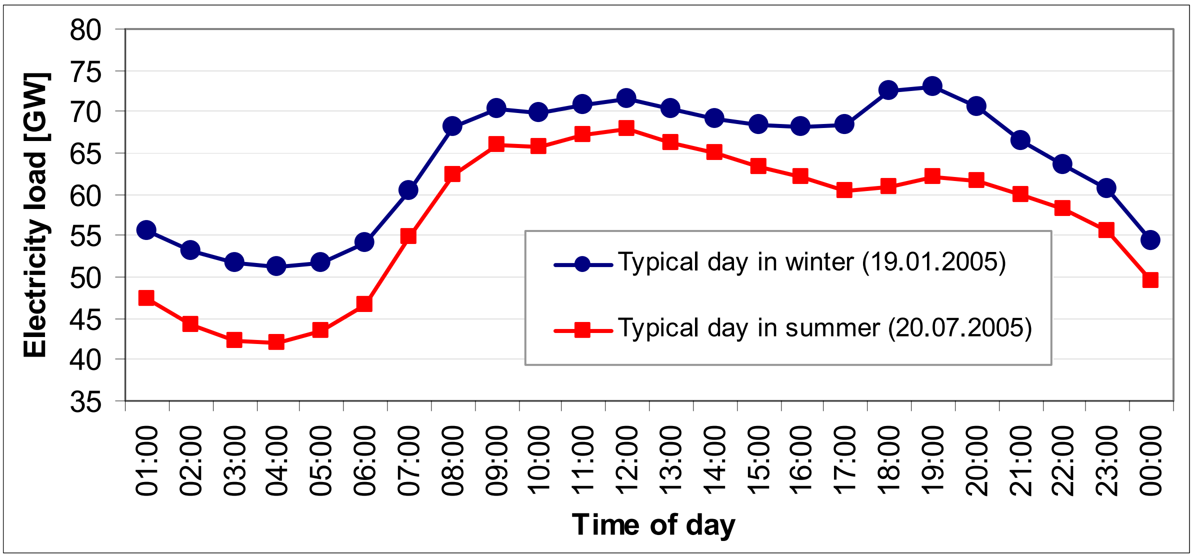

Figure 3.23: Typical electricity load curve

The electricity demand is higher during the day time than during night time. Furthermore there is a difference in the electricity demand during summer and winter time. Lower temperatures and longer nights cause a higher demand for electricity during the winter months than in summer time [Wegner 2006]. Some countries take the time of the day or the season of the year into account when setting the level of FITs. Subsequently, these concepts are explained.

Portugal

The **Portuguese** legislation provides two different levels of FITs for day- and night time. The plant operators can decide if they want to receive the same tariff level independently from the time of day or if they want to receive a higher remuneration for electricity fed into the system during day time than during night time. However, operators of hydro power plants are obliged to receive differing tariffs according to the time of day [Ministério das Actividades Económicas e do Trabalho 2005]. (See also Appendix B on page 74.)

Slovenia

In **Slovenia** RES-E producers can choose between two tariff systems: the *single-* and the *double-tariff*. For the first option the same level of remuneration is paid irrespective of the time of the day or the season of the year. The double tariff option, however, distinguishes three different seasons and two different daily tariffs, as shown in Table 3.19.

Table 3.19: Factors for the double tariff option in Slovenia

	Higher daily tariff item (HDT)	Lower daily tariff item (LDT)
High season (Jan, Feb, Dec)	1.40	1.00
Middle season (Mar, Apr, Oct, Nov)	1.20	0.85
Low season (May – Sept)	1.00	0.70
HDT:	Mon – Sat, 6:00 – 13:00 and 16:00 – 22:00 o'clock (when winter time is used) Mon – Sat, 7:00 – 14:00 and 17:00 – 23:00 o'clock (when summer time is used)	
LDT:	Mon – Sat, 22:00 – 6:00 and 13:00 – 16:00 o'clock (when winter time is used) Mon – Sat, 23:00 – 7:00 and 14:00 – 17:00 o'clock (when summer time is used)	

In the case of the double tariff option, the FITs are multiplied by the factors illustrated in Table 3.19. The lowest tariff is applied from May to September during the night or in the early afternoon, when RES-E producers receive only 70% of the regular tariff level. The highest tariff of 140% is paid from December to February during the morning and during the late afternoon. The result is that the producers of RES-E, who can adapt their operation, are able to achieve a higher price for their electricity and the supply is more demand-orientated. This makes especially sense for biomass and biogas plants [Republic of Slovenia - Ministry of the Economy 2006, pp. 9].

Hungary

In **Hungary** the *Decree Law 78/2005* distinguishes between the RES that depend on the weather (wind and solar energy) and the ones that are (more or less) independent from weather conditions (hydro power, biomass, biogas and geothermal) While the same level of remuneration is paid for electricity from wind and solar energy, three different tariff levels are applied for other RES-E technologies. As shown in Table 3.20, the tariffs for electricity from geothermal, biomass, biogas and hydro power varies according to the electricity demand.

Table 3.20: Tariff levels for the different RES-E technologies in Hungary from January to August 2006[18]

Technology	Tariff level [€ Cents/kWh]		
	peak	off-peak	deep off-peak
Solar, wind	9.44	9.44	9.44
Geothermal, biomass, biogas, small hydro (≤ 5 MW)	10.72	9.44	3.85
Hydro (> 5 MW)	6.90	3.45	3.45

In Hungary the FITs shall only be an intermediate solution. The goal is to introduce a green certificate system, even though no date has been fixed for the introduction so far [Tóth 2005] and [Hungarian Energy Office 2006].

Evaluation of the demand orientated tariff systems

The positive and negative effects of the concepts to take the electricity demand into account are summarized in Table 3.21.

Table 3.21: Evaluation of demand orientated tariff levels

Advantages	Disadvantages
• Good system to take electricity demand into account • More market orientated than just one tariff level • Possibility to make RES-E generators more sensitive for electricity demand • Incentive to feed electricity into the system, when it is needed most	• Higher administrational complexity than one tariff level • RES-E generators might not always know, when the electricity demand is high • Does not make much sense for wind and solar power, because the operators cannot influence the electricity generation

3.6 How to increase the local acceptance of RES

The use of RES-E not only makes sense in large power plants, but also in small devices. Therefore RES-E technologies can be applied decentralized (in contrast to conventional

[18] Exchange rate: 1 Hungarian Forint = 0.003963 Euro (01.01.06) [OANDA Corporation 2006]

power plants such as coal or nuclear power devices). In order to increase the deployment in many different regions, Portugal and Greece developed a concept to increase the local acceptance of RES-E plants.

Portugal

In **Portugal** an incentive for local authorities to support the installation of wind turbines in their territory was introduced in December of 2001. According to the Decree-Law 339-C/2001 the operators of wind turbines have to pay 2.5% of the remuneration they receive for electricity fed into the grid to the municipality where the wind turbine is located [Ministério da Economia e do Ambiente e do Ordenamento do Território 2001, Art. 3].

Greece

The legislation in **Greece** is similar. The law 2773/1999 introduced an annual fee of 2% of the electricity sales to the grid, which RES-E producers have to pay to the local authority where the RES-E plant is located. The authorities are supposed to realise local development projects with this fee. However, the legislation does not have great impact in Greece. Even though opinion polls show a positive public attitude towards RES, increasing local oppositions against wind energy and hydro power projects have been shown in different Greek regions [Greek Association of Renewable Electricity Producers 2004, p. 5].

Evaluation of the concepts to increase local acceptance of RES-E projects

By applying the described concepts, local authorities are interested in an increasing number of RES-E projects in their territory. Furthermore they care about efficient power plants generating a large amount of electricity, in order to raise their income and may even become an active partner in these projects. The revenues of the electricity generation are transferred to the annual budget of the municipality and therefore are used for the welfare of local people. Portugal and Greece apply feed-in tariffs, however their concepts to increase the local acceptance of RES-E might as well be used with other forms of support instruments, such as quota obligations with tradable green certificates. Table 3.22 summarizes the evaluation of the described systems.

Table 3.22: Evaluation of the concepts to increase local acceptance

Advantages	Disadvantages
• Incentive for local authorities to support RES-E projects • Authorities are interested in efficient power plants and sustainable deployment of RES-E • Revenues of electricity generation are used for the welfare of the local people	• Administrational complexity • Increases the costs of the support system

4 Burden sharing

In countries where the electricity from new RES-E plants contributes significantly to the total electricity consumption, the distribution of the costs emerging from the support of renewable energy is a crucial aspect of the feed-in tariff design. Figure 4.1 shows the share of RES-E of gross electricity consumption in the EU countries applying feed-in tariffs. Electricity from large-scale hydro power plants is not supported through feed-in tariff systems and is therefore excluded in the figure.

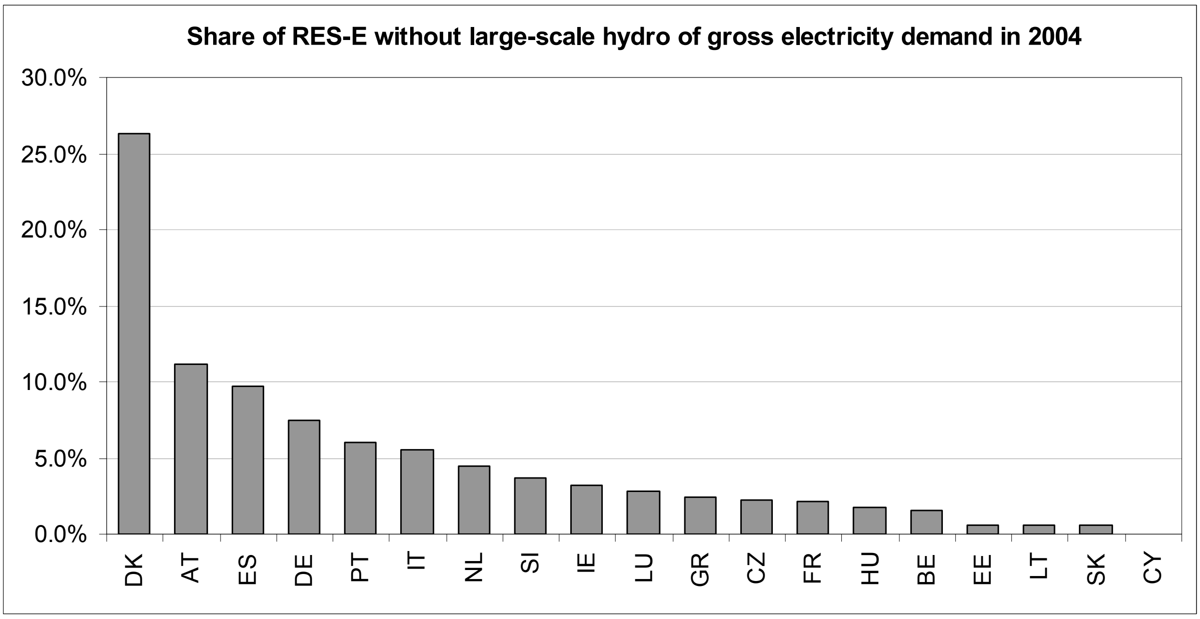

Figure 4.1: Share of electricity from renewable energy sources of gross electricity consumption excluding large-scale hydro power in 2004

Source: [OPTRES 2006]

The figure illustrates that the share of RES-E generation (excluding large-scale hydro power) of total electricity consumption varies significantly. In the year 2004 Denmark had the largest share with 26.3%, followed by Austria and Spain (with 11.1% and 9.8%, respectively).

In most EU countries these costs are distributed equally among all electricity consumers by including them in the power price. However, distinct consumer groups are affected in different ways by the increased power price due to RES-E generation. Especially for electricity-intensive industry sectors the power costs may represent a significant part of their expenses and their international competitiveness might be influenced. In order to maintain the burden for electricity-intensive industries on a moderate level, some European countries have implemented a burden sharing depending on the *consumer type*. Before these systems are explained, different possibilities to define *electricity-intensive industries* and the concept of *competitiveness* are outlined.

Electricity-intensive industries

In order to determine, which industry sectors are affected most by increased power prices due to RES-E generation, the following indicators can be applied among others:

- Total amount of electricity consumption of a company
- Annual costs of electricity consumption in relation to other parameters, such as the *revenues*, the *total costs* or the *gross value added* of a company
- *Voltage level of the grid connection* (Usually a connection to a high voltage grid implies, that a consumer uses a high amount of electricity)

In the report "Belastung der stromintensiven Industrie durch das EEG und Perspektiven", the relation between the *electricity costs* and the *gross value added* is proposed as an appropriate indicator for the electricity intensity of an industry sector, because the power costs are compared to the actual value added accomplished by a company. According to this indicator it can be judged, whether or not the international competitiveness of a company might be influenced in a negative way [Leprich et al. 2003, pp. 22].

Competitiveness

An industry can be considered being *competitive*, as long as an "adequate" value is added to the input factors (capital and land). One possibility to determine the competitiveness of a company is to look at the ratio of *value added to capital and land* to the *gross production value*. This indicator decreases, if the costs for higher electricity prices (due to RES-E support) cannot be transferred to the costumers through the product prices. If the ratio at the current location is considered as "too small", the competitiveness might be endangered and the company might move to another country [Leprich 2005].

Austria, **Denmark**, **Germany**, and the **Netherlands** apply a system, where distinct consumer types contribute differently to the RES-E support. Subsequently these systems will be presented.

Austria

The Austrian electricity network is divided into 7 grid levels for different voltage ranges (from 400 V up to 380 kV). Every electricity consumer has to contribute to the RES-E support according to the voltage level of the grid he is connected to. Until the end of 2006 the costs for RES-E support are distributed to four different tariff groups[19], as shown in Table 4.1.

[19] An exception is the support of small-hydro where the burden sharing is allocated equally to consumers.

Table 4.1: Contribution of the different consumer groups in Austria to RES-E support in 2006

Grid level	Costs for RES-E support
Grid level 1 – 3 (110 - 380 kV)	0.325 € Cents/kWh
Grid level 4 (Transformation from 110 kV to 10-30 kV)	0.382 € Cents/kWh
Grid level 5 (10 – 30 kV)	0.382 € Cents/kWh
Grid level 6 (Transformation from 10-30 kV to 400 V)	0.398 € Cents/kWh
Grid level 7 (400 V)	0.464 € Cents/kWh

The average consumer's contribution in 2006 is fixed at 0.42 € Cents/kWh. Electricity-intensive industries (Grid level 1 – 3) pay 78% of this tariff, whereas households (Grid level 7) are obliged to pay 111%. In addition to this value, there is a charge for electricity traders of 0.06 € Cent/kWh leading to an average burden contribution of 0.48 € Cents/kWh [E-Control 2006b].

According to a new law, the *Ökostromgesetz-Novelle*, which was passed in May 2006, Austria's system of burden sharing will change. From 2007 on, two different ways of financing the RES-E support are applied. Every electricity consumer has to pay an annual charge depending on the grid level he is connected to. From 2007 to 2009 this charge, which is called *Zählpunktpauschale* is fixed to 15 € per year for households (Grid level 7) while electricity-intensive industries have to pay up to 15000 € annually (Grid levels 1 to 4). Compared to the current system the annual charge unburdens the customers using a lot of electricity and increases the burden on the ones with low electricity consumption. About 38% of the support for RES-E[20] and combined heat and power plants shall be covered by this annual charge. The remaining 62% are supposed to be financed by the price that electricity traders have to pay for RES-E. The so-called *Ökostromabwicklungsstelle* purchases the electricity from RES-E producers and assigns a certain amount of it to each electricity trader in Austria. The traders have to pay a special price for this electricity which is fixed according to the predicted support volume for renewable energies. The costs for the electricity from RES are passed on by the electricity traders to their customers. In September 2006 a draft regulation was published by the Austrian Energy Control Commission (E-Control), that sets the price to 10.46 € Cents/kWh [E-Control 2006a].

The legislation for small-scale hydro power plants (with a capacity of up to 10 MW) is different. The price per kWh, that has to be paid by the electricity traders, is supposed to cover the total support volume for these plants. Since the electricity traders pass these costs on to their customers, the burden for the support of small hydro power plants is distributed equally among all electricity consumers. While this price was also 4.5 € Cents/kWh in the year 2006, it will increase to 6.47 € Cents/kWh in 2007, according to the draft regulation of E-Control [E-Control 2006a] and [Nationalrat 2006, § 22].

Netherlands

The **Netherlands** apply a similar system as Austria. Every electricity consumer has to pay an annual charge to finance the RES-E support. However, in the Netherlands the level of the

[20] Subsidies for hydro power plants with a capacity of up to 10 MW are not included.

charge is the same for all consumers; in 2005 it amounted to 52 €. While Austria only finances a share of the RES-E support with an annual fee, the charge in the Netherlands shall cover the total amount of expenses for the support of renewable energies. By the application of this system, consumers who use a lot of electricity are unburdened even more than in Austria and the part of RES-E support that is covered by households is a lot higher [EnerQ 2006a]. Since the costs for RES-E support in the Netherlands were higher than expected during the last years, the annual charge is not sufficient to cover the costs of RES-E generation. Therefore the entire burden for RES-E support will be transferred to the states budget from 2007 on [van Tilburg 2006].

Denmark

In **Denmark** the subsidies for electricity from RES are passed on to the consumers via a so-called *Public Service Obligation* (PSO) tariff on their total electricity consumption. In order to decrease the burden on electricity-intensive industries, the PSO is reduced for customers with a consumption of more than 100 GWh per year. For the part of their consumption that exceeds 100 GWh, these customers only have to pay 37 – 39% of the PSO, depending on their location[21] [Energinet.dk 2006]. Currently there are only two companies in Denmark consuming more than 100 GWh per year [Lawaetz 2006].

Germany

The **German** Renewable Energy Act from 2004 basically fixes an equal distribution of burden sharing, but it also provides possibilities of cost reduction for electricity-intensive industries, if they fulfil the following criteria:

- Their annual electricity consumption has to exceed 10 GWh
- Their electricity costs have to be above 15% of gross value added

For these privileged customers the increase of the electricity price caused by RES-E support is limited to 0.05 € Cents/kWh. The same regulation is applied for track railways. The costs that are saved by electricity-intensive industries and track railways have to be borne by the other electricity consumers. However, the electricity volumes which are transferred to the non-privileged electricity consumers are limited to a maximum of 10% above the share calculated pursuant to the Renewable Energy Act from 2004. In June 2006 a new draft of the Renewable Energy Act was published by the German parliament. This draft proposes to abolish the mentioned 10% cap for non-privileged electricity consumers in order to improve the planning reliability for electricity-intensive industries and track railways as well as their competitiveness [Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit 2004, § 16] and [Bundesregierung 2006, pp.12].

[21] During the third quarter of 2006 (July-August) the regular PSO tariff was 0.63 € Cents/kWh in the Eastern and 0.54 € Cents/kWh in the Western part of Denmark. The reduced PSO was fixed to 0.23 € Cents/kWh in the Eastern and 0.21 € Cents/kWh in the Western part. Exchange rate: 1 DKK = 0.13405 € (July 1st 2006) [OANDA Corporation 2006].

Luxembourg

In **Luxembourg** RES-E support is financed by a special compensation fund. Until the end of 2005 only the electricity consumers that were connected to the grid with a voltage lower than 65 kV had to contribute to this fund. In December 2005 this law was changed and since January 2006 all electricity consumers have to finance the RES-E support. While electricity-intensive industries were privileged in the former legislation, Luxembourg changed to a system where the costs for RES-E support are distributed equally among all electricity consumers [Grand-Duché de Luxembourg 2005p. 6].

Evaluation of the systems of burden sharing

Since the use of RES-E increases with different rates in the Member States, the costs for RES-E support and therefore the burden on the electricity consumers, differs as well. This effects electricity-intensive industries more than other consumers. A burden sharing among all electricity consumers in Europe could be a possibility to solve the problem of international competitiveness. However, this requires a coordination of the support systems for RES-E as well. Otherwise a country could pay very high tariffs to the RES-E producers knowing that the costs are distributed among all electricity consumers in Europe.

5 Grid integration and stability of power supply of fluctuating RES

In the following chapter different concepts to distribute the costs for grid connection are presented. Furthermore systems are described to integrate RES-E power plants in the electricity grid and to implement forecast methods in RES-E policy.

5.1 Costs for grid connection

Before a RES-E plant starts operation, it has to be connected to the electricity network. The distribution of the costs that occur due to this connection is an important aspect of energy policy. Different costs can be distinguished: first of all the expenses to connect the power plant physically to the electricity grid. Secondly it is possible that the capacity of the local network is not sufficient to accommodate the new power plant. In this case the electricity network has to be reinforced, which causes additional expenses.

According to the *Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources*, the EU Member States have to ensure that transmission and distribution system operators guarantee grid access for electricity generated by RES. Furthermore the grid operators have to publish their standard rules on sharing the costs for grid connection and network reinforcement. Additionally, the Member States may oblige the grid operators to provide *priority access* for RES-E and to cover (part of) the connection and reinforcement costs [The European Parliament and the Council of the European Union 2001, Art. 7].

Within the EU countries several concepts have been developed to distribute the costs that are related to the connection of RES-E plants to the electricity grid. Usually electricity generators have to pay a *connection charge* to the distribution grid operator that covers a part or the total amount of the costs to connect their plant physically to the grid. In some cases the RES-E producer additionally has to pay a contribution to network reinforcement costs that occur as a consequence of connecting the power plant to the grid. Furthermore the grid operator may levy a *use of system charge* that has to be paid by electricity generators when they use the distribution system in order to transport the electricity to their customers. [Knight et al. 2005, p. 6]

Four methods of connection charging can be distinguished:

1) Shallow connection charging
2) Deep connection charging
3) Mixed or shallower connection charging
4) True connection charging

These four possibilities to approach connection charging will be explained subsequently.

Shallow connection charging

When the *shallow* method of connection charging is applied, RES-E generators only have to pay for the costs of the equipment needed to connect their plant physically to the nearest point of the electricity distribution grid (at the appropriate voltage level). Any costs for reinforcements of the network have to be borne by the grid operator, who usually recovers them by applying *use of system charges*.

The shallow connection charging is favourable for RES-E generators, because the costs for the grid connection itself are minimised. Moreover, the system provides a high degree of transparency, because RES-E producers can estimate the level of expenses for the grid connection in advance. By applying use of system charges, the grid operator can pass the reinforcement costs to all customers of the electricity network. However, the shallow method of connection charging has some disadvantages as well. Due to the fact that RES-E producers do not have to pay any network reinforcement costs, they might not consider the capacity of the local network while deciding where to build the power plant. This may lead to an inefficient choice of the plant sites from the perspective of the whole energy distribution system. Furthermore it is likely that the RES-E generator has to pay use of system charges for the using the electricity grid.

Deep connection charging

In the case of *deep* connection charging, RES-E generators have to cover all costs that are associated with the connection of their plant. This includes the expenses for the physical connection to the nearest point on the electricity network as well as any costs for grid reinforcement that arise as a consequence of adding the plant to the network. The advantages of this method are that RES-E generators usually do not have to pay any use of system charges, because the grid operator does not have to recover the expenses for the grid reinforcements. Furthermore the deep concept of connection charging provides strong incentives for RES-E generators to choose a location where the costs for the grid connection and reinforcements are as low as possible. From the perspective of the overall energy distribution system this might lead to a more efficient solution than the shallow method. However, from the perspective of the RES-E generator, the deep connection charging concept has two significant disadvantages: firstly, the costs corresponding to the grid connection are potentially much higher than the equivalent costs determined by a shallow connection method. This may lead to a situation, where RES-E plants are not built because of the high costs of grid connection. Secondly, it is possible, that a single RES-E generator ends up paying for the reinforcement caused by other generators, if each new connection application is treated separately. Therefore it might not be clear in advance, how much a RES-E generator has to pay for network reinforcement, which leads to a lack of transparency.

Mixed or shallower connection charging

Another possibility to approach connection charging is the *mixed* or *shallower* method. This concept is a combination of the deep and the shallow method. The RES-E generator has to pay the costs for the physical connection to the nearest point of the electricity network and additionally a share of the costs of network reinforcements that are necessary due to adding the plant to the electricity network. The crucial point is to fix the exact share of reinforcement costs that has to be borne by the RES-E generator. Therefore clear and transparent rules are necessary. Usually this share is calculated according to the estimated proportional use of the new infrastructure by the RES-E generator. Similar as the deep method, this approach provides incentives for the RES-E generator to choose a location for the plant, where the grid has sufficient capacity to connect the plant or at least where the costs for network reinforcements are minimised. On the other hand the total amount of costs that has to be borne by the RES-E generators may prevent the construction of new plants. Furthermore RES-E producers may have to pay use of system charges.

True connection charging

The forth method is called the *true* connection charging. In this case the RES-E generator has to pay the costs equivalent to the expenses for connecting his plant to the nearest point (and voltage level) on the grid system at which the grid capacity is sufficient to incorporate the plant into the network without reinforcement. The advantage of this concept is that incentives are provided for the RES-E generator to choose an appropriate site for the plant, where the grid connection costs are as low as possible. However, the main problem is that the nearest point of connection, which does not require network reinforcement, could be at a significant distance from the RES-E generator and the costs of this connection may be even higher than in the case of the *deep* charging approach. Therefore it could be more beneficial for RES-E generators to choose a closer connection point and pay for the necessary network reinforcement.

Experiences with connection charging in the EU-15 countries

Table 5.1 shows the different concepts of connection charging in the EU-15 countries. Furthermore the level of transparency of the connection system and the fact, if the cost calculation methods are published in the different countries can be observed [Knight et al. 2005, p. 73].

Table 5.1: Key parameters of network connection charging in the EU-15 countries

Country	Predominant connection charge philosophy	Level of transparency in the system	Are there published cost calculation methods?
Austria	Deep	Low	No
Belgium	Shallow	High	Yes
Denmark	Shallow	High	Yes
Finland	No standard approach	Medium	No
France	Intermediate step between deep and shallow	Medium	No
Germany	Shallow	Low	No
Greece	Deep	Low	No
Ireland	Deep	High	No
Italy	Deep	Low	No
Luxembourg	Deep	Low	No
Netherlands	Shallow	High	Yes
Portugal	Deep	Medium	No
Spain	Deep	Low	No
Sweden	Deep	Low	No
United Kingdom	Intermediate step between deep and shallow	High	Yes

In September 2005 a project team of *ELEP (European Local Electricity Production)* published the report "Distributed Generation Connection Charging within the European Union". In this report several recommendations for connection charging methods are proposed. First of all it is stated that the procedures to connect new power plants to the grid as well as the mechanisms to calculate the connection costs have to be transparent and accessible for future RES-E producers.

In general the shallow connection charging approach is recommended in the report. However, a shallow concept implies that possible network reinforcements are paid by the network operator. Therefore "fair and transparent mechanisms for the recovery of those costs" are necessary [Knight et al. 2005, p. 50]. A concept with *use of system tariffs*, which have to be approved by a regulation authority, is proposed. Furthermore future RES-E generators shall be influenced in the choice of the plant site. By providing financial (or other) signals RES-E generators should be discouraged to construct their plant at a location that would affect the overall efficiency of the electricity system in a negative way.

In **Denmark** an innovative system is used to connect wind turbines to the network. As a shallow approach is applied in Denmark, the operators of wind turbines usually have to pay for the physical connection to the 10-20 kV network. However, *specific planning zones* are created, in which the turbine operators only have to pay the costs for the connection up to the boundary of the zone. This system encourages the construction of wind turbines in certain areas. A similar concept is applied in the **United Kingdom**, where *registered power zones* were introduced by the regulating authority OFGEM. In these areas on the distribution network, the network operators commit to addressing the technical challenges and opportunities of integrating RES-E plants into the network. In return, certain incentives will be applicable for the network operator.

If a pure shallow connection charge approach is not considered acceptable, the report recommends a system, in which RES-E generators pay a share of the network reinforcement costs that corresponds to the capacity of their plant in relation to the capacity of the local electricity network after reinforcement has been completed. The following example illustrates the concept:

A network operator decides to reinforce the local distribution network from a connection voltage of 3 MW up to 10 MW, in order to connect a 5 MW new RES-E power plant. In this case the RES-E generator uses 5 of the 10 MW, therefore he should contribute 50% of the costs for the network reinforcement. By applying this system the RES-E producer only pays for the part of the network reinforcement that represents his proportional use of the grid.

For RES-E generators with very small plants the necessity of a system with simple rules and connection costs is emphasised. In this case, a pure shallow concept should be applied and the RES-E producers should not be charged for any reinforcement.

Besides the costs for grid connection, the timescale between the application for the connection of a new RES-E plant and the quotation of the network operator is a key factor. The ELEP report recommends that the network operator has to submit a connection offer to the RES-E generator including proposals for the costs of network reinforcements that have to be borne by the generator within 60 days after the application for connecting the plant.

5.2 Forecast obligation

For some types of renewable energy sources the amount of electricity generated depends on external conditions like solar radiation, wind speed or the level of water in a river. An integration of the electricity from these RES in the power grids is a lot easier, if the amount of electricity that is generated can be forecasted. The amount of water in a river is predictable rather well and changes are rather slow. Therefore the amount of electricity from hydro power plants is well predictable. The integration of electricity from PV plants does not have great influence on the electricity grid, because the share of PV electricity is still very small.

This is different for wind power, as the wind conditions tend to change very fast and the share of electricity from wind energy is significant in some areas (e.g. 18.8% of Denmark's total electricity consumption in the year 2004 was made up by wind energy) [Danish Wind Industry Association 2006].

In some countries the operators of RES-E plants are obliged to predict the amount of electricity they plan to feed into the grid.

Spain

Spain applies a system with forecast obligation. In the case of the fixed price option, only plants with a capacity of more than 10 MW are affected by the forecast obligation. The RES-E generators have to report to the grid operator the amount of electricity they plan to feed into the system for each hour of the day, at least 30 hours before a day starts. Until one hour before an hourly interval starts, it is possible to correct the predicted amount. If the penetrated electricity differs from the provision by more than 20% in the case of solar and wind energy and by more than 5% in other cases, the operators have to pay a fee of 10% of the reference electricity price for each kWh of deviation.

For those plant operators who choose the premium option, the market rules are applied. Therefore they have to forecast the amount of electricity generated for all RES-E plants (not only the ones with a capacity of more than 10 MW). For deviations a penalty of 10% of the daily market price has to be paid [Bustos 2004, p. 12] and [Ministerio de Economía 2004, Art. 19 and 31].

This legislation facilitates integration of electricity into the grid. Furthermore it provides an incentive to improve the forecast quality, because of the penalty. It has to be stated however, that RES-E producers have the possibility to compensate missing electricity from one wind farm with excess of electricity from another farm. Furthermore electricity from other types of RES can be used to balance the deviation.

Slovenia

In **Slovenia** the producers of RES-E with plants of a capacity of more than 1 MW have to forecast the amount of electricity they want to feed into the grid. They don't have to pay for deviations, though [Government of the Slovak Republic 2005].

Estonia

In the new draft of the **Estonian** law the operators of RES-E plants with an installed capacity of 1 MW or more have to specify the amount of electricity they wish to sell using the purchase obligation [Government of Estonia 2005] (see also Section 3.1.3 on page 22).

6 Summary, conclusion and policy recommendations

In this paper different feed-in tariff designs that are applied in the Member States of the European Union were presented and analysed. The variety of instruments gives many possibilities to improve the FIT design in most countries. However, it has to be kept in mind that a system should remain transparent and should not get too complex. An important aspect is to take the local conditions of a country, such as RES-E potentials, the electricity grid as well as social aspects into account, when the support mechanisms are fixed or changes are made.

Based on the different options for feed-in tariff designs presented in this paper the following policy recommendations are proposed:

- **RES-E support requires continuity and long term investment policy**

  A stable, transparent policy framework is crucial for a successful and continuous exploitation of RES-E. Therefore feed-in tariffs should be accompanied by long term targets and sufficiently long periods for which the tariff is guaranteed. However, the tariffs for new installations have to be revised regularly in order to control, if they are still corresponding to the policy goal.

- **Technology-specific tariff levels should be applied**

  In order to reflect the varying electricity generation costs of the different RES-E technologies, technology-specific tariff levels, sufficiently high to cover the power generation costs should be provided. These tariff levels should ensure to reach the policy goals of a country and incentives should be provided to exploit those RES first, which are most cost efficient at the particular location. On the other hand, technologies that are not ready for the market yet, should be supported as well, in order to allow them acting on the market and to gain experience, which leads to cost reductions in the future.

- **Energy policy should provide mechanisms to ensure the penetration and to improve the integration of RES-E into the grid**

  A feed-in tariff design should provide a purchase obligation or an alternative measure ensuring, that the RES-E generators may sell their electricity on the market receiving a fixed tariff or a premium on top of the market price. A forecast obligation for RES-E may facilitate the integration of the electricity from RES into the grid. However it should be carefully analysed, which market actor should be obliged to forecast fluctuating power generation in order to minimise the costs for the energy system.

- **A premium tariff option can be applied to increase market orientation**

  A premium tariff design allows RES-E generators to sell their electricity directly on the spot market, receiving a premium on top of the electricity market price. Such a system without a purchase obligation may create higher market compatibility than the fixed tariff option. Furthermore it provides an incentive to feed electricity into the grid in the periods of peak demand. One disadvantage is, that the premium option typically causes higher costs than the fixed tariff option and that the costs of the system may increase strongly if the conventional electricity price increases.

- **Tariff degression provides incentives for cost reductions**

  An annual reduction of the tariff level by a certain percentage for new power plants, called *tariff degression*, provides an incentive for cost reductions and technology improvements. Ideally the degression rate corresponds to the cost reduction due to technological learning.

- **Stepped tariffs may be applied to reflect different power generation costs within the same technology**

  Electricity generation costs differ according to the plant size, the type of fuel used or due to local conditions, such as wind yield or solar radiation. In order to enable the exploitation of many sites and fuel types and at the same time to keep the producer profit on a moderate level, stepped tariff designs can be applied. However, it is important that the producer profit is still highest for the most efficient power plant designs and at cost efficient sites.

- **Extra premiums may help to reach policy goals**

  Premiums for additional features like repowering and electricity generation during times of peak demand can be a reasonable measure. On the other hand most premiums lead to extra administrational complexity. Therefore additional premiums should be used only if the transparency of the system is not affected and if their benefits are higher than the additional administrative costs.

7 Appendix A

In this section technologies to generate electricity from renewable energy sources are explained.

Wind energy

Wind turbines convert a portion of the wind's kinetic energy into rotational energy of the turbine blades. The motion of the rotor drives a generator, which produces electricity. The available wind power is proportional to the cube of the wind speed; therefore the electricity generation from wind energy is very dependent on local wind conditions. According to the site of a wind turbine, two different kinds can be distinguished: *Onshore* wind turbines are installed on land, *offshore* turbines are set up in water. A collection of wind turbines in the same location is called a *wind farm* [Kaltschmitt et al. 2003, pp. 267].

Solar energy

Two different ways are applied to generate electricity from solar energy:

- Photovoltaic (PV)
- Solar thermal technologies

A *photovoltaic cell* (solar cell) directly converts solar radiation into electricity. Light falling on a two-layer device of differently doped semiconductors is absorbed due to the *photoelectric effect,* causing an electric voltage between the two layers. If both layers are connected to a consumer, an electric current is available. A combination of these solar cells in serial or parallel groups is called *PV-module* [Kaltschmitt et al. 2003, pp. 197].

Solar thermal power plants convert the solar radiation into heat, which is used in a thermodynamic cycle to generate electricity. Different solar thermal technologies are applied. Most of the power plants use mirrors focussing the sun's radiation on a receiver, where a fluid is heated. This fluid is used to create steam or a hot gas, which drives a turbine connected to an electric generator.

Geothermal power

Geothermal power plants use the heat of the ground to generate electricity. In some cases hot water or steam resources exist in the ground. These resources, called *hydrothermal resources,* can be piped to the surface and used to drive a turbine generator. If no hydrothermal resources are available, other technologies can be applied to use the geothermal power. The so-called *Hot-Dry-Rock (HDR) technology* takes advantage of the heat of deep masses of rock that contain little or no steam or water, and are not very permeable. The rock temperature reaches commercial usefulness at depths of about 4,000 meters or more. To exploit these resources, a permeable reservoir must be created by hydraulic fracturing. Two holes are drilled from the surface down to the rock. Water from the surface must be pumped through the first hole and through the fractures to extract heat from the rock. Once the water is heated up, it can be pumped to the surface through the second hole and may be used to drive a turbine generator.

While hydrothermal resources are already used commercially for the electricity generation, HDR technology is just applied in demonstration projects, because the two holes require a large investment and the costs to exploit the HDR resources increase with their depth [National Renewable Energy Laboratory 2006] and [Kaltschmitt et al. 2003, pp. 487].

Hydro power

Hydro power plants convert the potential or kinetic energy of water into electricity. Two different technologies of hydro power plants can be distinguished:

- Storage systems
- Run-of-the-river systems

Hydro power plants with a *storage system* use water reservoirs created by dams. When the water is released, the potential energy is converted into kinetic energy. The water pressure drives a turbine allocated in a lower altitude than the water surface of the reservoir. The turbine is connected to a generator to produce electricity.

In some cases off-peak electricity is used to pump water from a lower reservoir to an upper reservoir. During periods of high electricity demand, the water is released back to the lower reservoir to generate electricity. This technology is called *pumped storage plant.* The described way of electricity generation is not considered being renewable.

Run-of-the-river systems directly use the kinetic energy of the water to drive a turbine and produce electricity in a generator. These plants do not store the water, therefore electricity generation will vary with changes in the amount of water flowing in a river [Kaltschmitt et al. 2003, pp. 333].

In most European countries *small* (≤ 10 MW) and *large-scale* (> 10 MW) hydro power plants are distinguished. While small hydro power devices receive financial support, the majority of EU countries excludes electricity from large-scale hydro power plants from their support program. The reason is that almost all of the large-scale devices have been in operation for many years and therefore are fully depreciated and do not need additional support for financial viability [Ragwitz et al. 2005].

Wave power

Wave power devices convert the energy from surface waves or from pressure fluctuations below the surface into electricity. The energy in waves can be captured in a number of ways and several types of wave energy devices are under development. Two of the most promising methods will be explained:

- Oscillating water column
- Tapered channel system

The *oscillating water column* consists of a partially filled vertical tube. Above the water a column of air is enclosed in the tube. The motion of the water forces the air back and forth through an air turbine which is connected to an electricity generator. Power from such devices is already sold commercially to the grid in Scotland.

In a *tapered channel system*, the waves flow along a tapered channel rising in height until they enter a reservoir constructed on cliffs above sea level. The stored water flows back into the sea through a turbine generating electricity [Kaltschmitt et al. 2003, pp. 575] and [Ragwitz et al. 2005, p. 97].

Tidal power

The energy contained in moving water mass due to tides can be referred to as *tidal power*. Two different technologies can be applied to use tidal power for electricity generation:

- Tidal barriers
- Tidal currents

Tidal barriers utilise the rise and fall of the tide (the tidal range) to trap sea-water at high tide in a reservoir behind a barrage. As the water leaves and/or enters the reservoir in a constrained duct, submerged hydro turbines generate electricity, as in conventional hydropower.

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

Biomass

Biomass refers to living or recently living organic material, such as forestry and agricultural crops and residues (including vegetal and animal substances) as well as the biogenic fraction of waste. Organic material which has been transformed by geological processes into fossil fuels (coal, petroleum and natural gas) is not considered as biomass. Solid biomass can be burned as fuel to produce steam, which drives a turbine generator. Furthermore it can be converted into other forms of usable energy, such as biogas. The use of biomass is neutral in terms of carbon dioxide emissions, because the organic material takes up carbon dioxide from the air while it is growing and then returns it to the air when it is burned as biomass, thereby causing no net increase [Kaltschmitt et al. 2003, pp. 629].

Since many EU Member States apply different feed-in tariff levels for *solid biomass*, *biogas* and the *biogenic fraction of municipal waste*, these three types of biomass are treated as different categories of RES in this paper.

Biogas

Biogas refers to a gas produced by the anaerobic digestion of organic material, such as agricultural residues or sewage, landfill, and organic wastes, including residues from animals. The gas, which consists of methane (45-70%), carbon dioxide (25-55%), and small amounts of nitrogen, oxygen and hydrogen sulphide, can be collected and combusted for electricity generation. In comparison to solid biomass, higher efficiency can be reached when biogas is used as fuel.

Generating landfill or sewage gas is less expensive than the production of other types of biogas. Therefore electricity from landfill and sewage gas is excluded from the RES-E support or remunerated with a lower tariff in some countries [Kaltschmitt et al. 2003, pp. 629] and [Institut für Energetik und Umwelt 2005, p. 77].

Municipal solid waste

Municipal waste can be used as a fuel to generate electricity. The biogenic fraction of municipal waste is considered as renewable energy source. Therefore the biomass portion of the waste is eligible for support in some countries [The European Parliament and the Council of the European Union 2001, Art. 2].

8 Appendix B

The Portuguese system of RES-E support is based on the prevented costs due to the existence of RES-E power plants. The operators of these plants receive a monthly payment that is calculated by formula (8.1), which will be explained subsequently.

$$VRD_m = KMHO_m \times \left[PF(VRD)_m + PV(VRD)_m + PA(VRD)_m \times Z\right] \times \frac{IPC_{m-1}}{IPC_{ref}} \times \frac{1}{(1-LEV)} \quad (8.1)$$

VRD_m: Monthly payment, which is calculated with the following elements.

$KMHO_m$: The plant operators can choose if they want to receive the same remuneration regardless of the time of day or a higher tariff for electricity generated during the day than during the night. In the first case the coefficient $KMHO_m$ equals 1. In the second case the amount of electricity generated between 8:00 and 22:00 o'clock during wintertime and 9:00 and 23:00 o'clock during summer time is multiplied by 1.25 and the rest of the electricity is multiplied by 0.6. Operators of small hydro plants do not have the possibility of choosing between the two options. For those plants the following rule is applied: The amount of electricity generated during day time is multiplied by 1.15 and during night time by 0.8.

$PF(VRD)_m$: This element, which is called the *fixed parcel*, corresponds to the investment for conventional power plants that would have to be built, if the RES-E plant did not exist. The fixed parcel is determined by the installed capacity and the efficiency of the RES-E plant. According to the Decree-Law 33-A/2005 the fixed parcel is calculated by multiplying the efficiency of the plant (measured in generated electricity divided by the theoretically possible full-load hours per month) by 5.44 € per kW installed capacity. This implies that the more efficient a plant operates, the higher the avoided costs for conventional plants that do not have to be built.

$PV(VRD)_m$: The *variable parcel* is supposed to correspond to the electricity generation of the conventional power plants that do not have to be built due to the existence of the RES-E plant. It is calculated by multiplying the generated electricity by 3.6 € Cents/kWh.

$PA(VRD)_m$: The *environmental parcel* represents the avoided costs due to the prevented CO_2 emissions. According to the Decree-Law 33-A/2005, 370 g CO_2 are avoided for each kWh of electricity generated with RES. The avoided costs are set to 0.00002 €/g emitted CO_2. Therefore the environmental parcel is 0.74 € Cents/kWh.

Z : The environmental parcel is multiplied by the *coefficient Z*, which varies according to the RES-E technology, as shown in Table 8.1. Due to the introduction of this coefficient in 2001 (Decree-Law 339-C/2001) the Portuguese support system for RES-E changed from being only based on the avoided costs due to RES-E generation to a concept that also takes into account different electricity generation costs according to the RES-E technology.

Table 8.1: Coefficient Z in Portugal according to the RES-E technology

RES-E technology	Coefficient Z
Wind	4.6
Hydro (≤ 10 MW)	4.5
Hydro (between 10 and 30 MW)	3 – 4.5 (linear interpolation in between)
PV (≤ 5 kW)	52
PV (between 5 and 35 kW)	35
Biomass (forestry residues)	8.2
Biomass (animal residues)	7.5
Biogas	7.5
Solid urban waste	3.8

$\frac{IPC_{m-1}}{IPC_{ref}}$: Due to this element the FITs are *adjusted to inflation*. IPC_{m-1} is the consumer price index for the month prior to the current one and IPC_{ref} is the consumer price index for the month when the RES-E plant was connected to the grid.

$\frac{1}{(1-LEV)}$: This element corresponds to the *electrical losses* in the transmission and distribution grid that were prevented by the RES-E plant. The value LEV varies according to the size of a RES-E plant, as Table 8.2 illustrates.

Table 8.2: Element corresponding to the electrical grid losses according to the plant size

Plant Capacity	LEV	$\frac{1}{(1-LEV)}$
< 5 MW	0.035	1.363
≥ 5 MW	0.015	1.015

It should be observed that plants with a capacity of less than 5 MW receive a higher remuneration than plants with a higher capacity.

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