RECerT

The European Renewable Electricity Certificate Trading Project

Task 1.4.:

Review of the Size and Value of a Tradable Green Certificate (TGC_{el}) Market in an Internal European Electricity Market

Final Report

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BACKGROUND

In the wake of the Kyoto process, globalisation and liberalisation of many markets, tradable permits and credits have been on the rise as environmental policy instruments in many countries and companies. They are also being discussed for use as an alternative, more competition-oriented regulatory measure for the promotion of electricity generation from renewable energy sources (RES-E). Several European countries (the Netherlands, Italy, Flanders, Denmark, the United Kingdom, and Sweden) are about to implement tradable 'green' certificate (TGC) systems[1], mostly in connection with a quantity obligation on a certain group of the electricity supply industry. In other EU Member States (e.g. Austria, Wallonia), the introduction of green certificate systems has recently been put on the agenda. In France, Germany, and Norway, the driving forces for the establishment of such a system are some major energy companies. These companies are members or interested parties in RECS (Renewable Energy Certificates System).

RECS is a platform to meet other parties that work on the international harmonisation of renewable energy certificates. In early 1999, a small group of interested parties in The Netherlands, Denmark and England took the initiative to promote international trade in renewable energy certificates. Since then, representatives from Belgium, Germany, Italy, France, Austria, Norway, and Sweden have joined the process. The RECS now has about 40 members, interested parties, and consultants; 20 of which are major European energy companies, others are representatives from governments, energy associations, and energy agencies. From January 2001 on, a one-year test phase of international certificate trade is being intended with a minimum of three Member States. Major aims of the test phase will be to find out more about the weaknesses and problems in international trade, but also to demonstrate that the mechanism is reliable and fraud-resistant.[2]

So, one can state that the idea of green certificate trade has disseminated rapidly over the past 2 years, and has in the process gained large interest. In combination with the national and even more ambitious European Commission targets (EC-targets) for the growth of renewable sources of electricity, a European market for tradable green certificates could develop soon, if the basic rules can be harmonised.

The following paper is the outcome of a work package in the RECerT project (The European Renewable Electricity Certificate Trading Project), a project partly funded by the European Commission. The European Commission has asked the RECerT project to come up with first rough estimates of the potential size and value of a TGC_{el} market in the European Union. The objective of this document is to present the results of this task and to describe the assumptions and methodology used.

[1] 'Green' certificates are interpreted as representing the environmental benefits of the energy source used. They allow separate trade of service and commodity – 'greenness' and physical power. The separation supports a development where renewable electricity generation takes place at the most economically viable sites and opens a level playing field to traditional market players and newcomers alike.
[2] Refer to the RECS web site at http://www.recs.org for further information.

SUMMARY

Task 1.4 of the RECerT project is dedicated to assessing the potential size and monetary value of a tradable green certificate (TGC_{el}) market in the electricity sector of the European Union. It takes a medium- and long-term view, and determines how such a TGC_{el} market is likely to grow up to 2010.

The basic data used in our analysis was collected in a pragmatic way due to limited resources for this task. The figures are derived from a small number of earlier surveys of the projections we need for our assessment, which are for all EU-15 countries estimates of the technical and market potential for different sources of renewable electricity as well as of the electricity price and consumption development to 2010. Based on the available information, we develop TGC_{el} price-potential curves for each Member State as well as an aggregated curve for EU-15. The base year is 1995.

We present results for 4 TGC_{el}-trade scenarios:

- EU-15, EC-targets scenario: all Member States participate in certificate trading; the 22.1% target of the Commission is reached by Member States accepting the quantitative indications given by the Commission in their recent proposal for a Directive (CEC 2000a);
- EU-15, national targets scenario: all Member States participate in certificate trading; the targets currently set in national legislation and energy programmes (add up to 17% for the whole EU) are reached by 2010;
- EU-5, EC-targets scenario: only the 5 countries at present most advanced with the implementation of a green certificate system (NL, DK, UK, I, Flanders) manage to trade among each other; they accept the targets recommended by the Commission (CEC 2000a);
- EU-5, national targets scenario: only the 5 countries at present most advanced with the implementation of a green certificate system (NL, DK, UK, I, Flanders) manage to trade; they stick to the targets currently laid down in their national legislation or programmes.

For all calculations, we assume that there is only one generic green certificate product, i.e. only one single market develops. Further simplifying assumptions are that there are no trade barriers or other market distortions as e.g. additional promotion schemes for renewable electricity, or upper and lower price limits, i.e. we are in an ideal economic world. Moreover, only renewable energy plants (including large hydro, excluding waste) built after the base year 1995 are eligible for green certificates. Finally, the view we take is mainly static. Production cost effects due to economies of scale or technological progress have been integrated exogenously as averages in the periods 2001-2005 and 2006-2010. Also, the commodity prices are assumed to change in these two periods. Thus, the derived cost-potential curves change in the course of time, they are different for the periods 1996-2000, 2001-2005, and 2006-2010, respectively.

Based on our data and assumptions, green certificates representing 130 TWh RES-E production would be traded cross-border in 2010 under the EU-15, EC-target scenario; this is more than one third of the total certified RES-E production. In our model, this trade volume equals a trade value of about € 3.4 billion; the total TGC_{el} market value is at about € 9.5 billion. Both the estimated trade volume and the estimated market size are about half under the EU-15, national targets scenario. If only the five most advanced countries with respect to TGC_{el} policies started a fully co-operative trading scheme, the international market could still be expected to be sizeable. TGC_{el}s representing more than 30 TWh could be traded between the five countries. (cf. Table 1) Under the EU-5 scenario, Flanders, Italy, and the Netherlands turn out to be

net importers, while Denmark and the UK are exporters of TGC_{el}s due to the assumed substantial offshore wind energy resource.

Table 1: Estimated market size and values under 4 different TGC_{el} scenarios

	TGC_{el} market value (in billion €)			TGC_{el} trade volume (in TWh)			TGC_{el} trade value (in billion €)		
Scenario	2000	2005	2010	2000	2005	2010	2000	2005	2010
EU-15, EC-targets	1.1	3.9	9.5	10	46	130	0.27	1.2	3.4
EU-15, nat. targets	0.15	0.97	1.6	6.8	28	75	0.038	0.31	0.58
EU-5, EC-targets	0.13	0.55	1.6	3.0	15	47	0.037	0.19	0.58
EU-5, nat. targets	0.084	0.35	0.81	1.5	8.4	30	0.012	0.077	0.23

It should be noted that the incentive for green certificate trading comes from international cost/price differentials only, i.e. we are estimating trade volumes and values as a result of relative differences between country-specific renewable energy targets and assumed national resource availability. Further TGC_{el} trades, e.g. within a country or due to arbitrage opportunities at a TGC_{el} exchange, are not considered here.

The results are very sensitive to assumptions about the availability of renewable energy sources, in particular of offshore wind. Therefore, sensitivity analyses have been carried out based on the assumption that only a tenth of the originally assumed amount of the wind offshore potential could be exploited in the medium run. In such scenarios, solar thermal electricity generation in the Mediterranean countries of the EU gets to play a major role in the 2010 TGC_{el} market. Consequently, TGC_{el} transactions from Northern to Southern countries decrease compared to the original scenarios leading to an overall reduction of the trade volume by 20 to 30%. The estimated trade value, however, turns out to be substantially higher than in the original calculations. Due to the fact that, switching from one analysis to the other, comparably cheap offshore wind farms are substituted by more expensive solar thermal power plants, equilibrium TGC_{el} prices rise by a factor 5 to 10 compared to the four original scenarios.

After all, the following conclusions could be drawn from our analyses:

1. A substantial TGC_{el} market size and cross-border trading volume can be expected under both EU-15 and EU-5 trading schemes (in the light of the ambitious RES-E targets formulated by the European Commission as well as by the national governments).
2. If the national targets indicated by the European Commission in the recent proposal for a Directive were implemented, the EU Member States Austria, Finland, Luxembourg and Sweden could fail meeting these targets without TGC_{el} trade.
3. Since the national governments' targets and the EC-targets do not reflect the distribution of RES-E potentials across the EU, there seems to be a need for trade. Our sensitivity analysis shows that the estimated trade volumes can be considered as robust. Our market and trade value estimates, in contrast, are very sensitive to assumptions, in particular concerning the exploitation rates of the wind offshore resource.
4. We find that the assumed annual exploitation rates of renewable resources have a crucial effect on TGC_{el} prices. Therefore, a more general conclusion is that European and national policies should also focus on facilitating the development of renewable resources (e.g. by infrastructural measures) and on making obligations more flexible to fulfil (e.g. via instruments like banking and borrowing of TGC_{el}).

1 INTRODUCTION

The feasibility of an international tradable green certificate (TGC_{el}) market with standardised trading rules and products, transparent market prices, and internationally harmonised certification procedures heavily depends on the overall volume and value of the traded certificates.

Therefore, the following paper is dedicated to assessing the potential size and monetary value of a TGC_{el} market in the electricity sector of the European Union. It takes a medium- and long-term view, and determines how such a TGC_{el} market is likely to grow up to 2010.[3] Information for this first rough assessment has been drawn through a specific literature- and data-survey of ours (see references).

The results should be carefully used as the data set involves quite a few uncertainties and assumptions. Furthermore, the conclusions should be regarded as provisional, since the data set may be updated in the course of the project. The latter respects the fact that the whole (renewable) electricity sector is very fast-moving. An example: according to recent information, the Swedish government is planning a proposal to the parliament before summer for introducing a green certificate trading system that is fully operational beginning 2002. This development has not yet been incorporated into our selection of scenarios.

We very much welcome feed-back on the plausibility of the country-specific data used and the results computed. Please, check the information and results for your country in the following tables and feel free to send comments to us. Your comments will improve this paper and will be included in updated versions of Task 1.4 in the course of the RECerT project.

2 SCENARIOS, DATA AND ASSUMPTIONS

For an assessment of the potential future size and value of a TGC_{el} market, we have chosen the years 2000, 2005 and 2010 (base year 1995).

Data collection has comprised:

- Inventory of official national targets for renewable electricity up to 2010; comparison to the indicative Commission target laid down in the White Paper (CEC 1997), and those national targets which the Commission has recently suggested in connection with the proposal for a renewable electricity Directive (CEC 2000a).
- Survey of technical and market potentials in EU Member States for different renewable sources of electricity (wind onshore and offshore, small and large hydro, photovoltaics, solar thermal electricity and biomass (co-firing of biomass as well as electricity generation from wood, biogas and energy crops)). Our technical potential figures are mainly based on papers by the LTI-Research Group (LTI 1998), LTI being a research project that was in part funded by the European Commission in the framework of the APAS programme. The cost potentials have been obtained from several studies (BMU 1999, Kaltschmitt/ Wiese 1997, Matthies et al. 1995, Semke/ Markewitz 1998) and supplemented with own esti-

[3] Refer to RECerT revision Annex of October 1999 (Section 5.1.4.), and RECerT Annex I Part B of Dec. 6, 1999 (Section 4.4.1) for a brief outline of the task.

mates where necessary.
- Review of electricity market projections for EU-15 countries with the help of the Shared Analysis Project (CEC 1999c); as the base year of that project is 1995, we have also chosen 1995 as base year for estimating the future size and value of TGC_{el} markets. Estimations of the price development for electricity have been drawn from Schlesinger/ Schulz (2000) as well as Dany et al. (2000).

Two high estimates for the potential size and value of a future TGC_{el} market are derived from the available data, information, and our model:

1. We assume that the maximum RES-E market size is given on reaching the 'quantitative indications' set by the Commission in the recent proposal for a Directive to ensure that the EU renewable electricity use arrives at a 22.1% share by 2010 (*EU-15, EC-targets scenario*).
2. A second high estimate results from calculations presuming that the market size in 2010 will get to the volume linked with the official national targets for RES-E set today (*EU-15, national targets scenario*).

For both scenarios, we assume that all Member States fully participate in TGC_{el} trading.

The low estimates for the future TGC_{el} market are based on an assessment of the current state of renewable electricity policies in EU Member States. As a minimum of 5 countries is in the process of introducing some type of TGC_{el} system, the two low estimates are:

3.+4. estimates of the market size and value of a TGC_{el} market between the Netherlands, Italy, Flanders, Denmark and the UK, either with the Commission targets (*EU-5, EC-targets scenario*) or with nationally set targets (*EU-5, national targets scenario*).

Many basic assumptions underlie the calculations and results. Most of them had to be made for simplification and in order to attain first rough estimates at all.

- There is only one generic green certificate product, i.e. only one single market and TGC_{el} price develops in the model.
- Only renewable energy plants (including large hydro, excluding waste) built after the base year (1995) are eligible for green certificates. Older plants may be subsidised under other RES-E promotion schemes.[4]
- There are no trade barriers or other market distortions like additional promotion schemes for (eligible) renewable electricity, upper and lower price limits, etc., i.e. we are in an ideal world except for limits set on the annual exploitation of the technical potentials.
- Technical progress and economies of scale are taken into account to some degree. Production costs are reduced exogenously at two points in time (2001 and 2006). Other market dynamics have not been included.
- Technical potentials (except offshore wind up to 2005) can be exhausted at an annual rate of 2% which is a rate slightly higher than the current exploitation rate in the European onshore wind sector.
- Our power production costs and the commodity prices are different for different renewable sources and technologies. Yet, the technology-specific costs and prices are presumed to be identical all over the EU.

In this paper, the terms 'trade volume', 'trade value', and 'market volume/ value' are defined in the following way:

[4] The question of eligibility is a question of policy objectives. In the public debate, it has often been linked with debates on transitional regimes. Possible pro and con arguments have been listed in diverse research papers. In the end, the eligibility question is usually being decided politically.

- The trade volume is equivalent to the sum of all TGC_{el} exports (or imports) in a certain year.
- The trade value is obtained from trade volume multiplied by the equilibrium TGC_{el} price in the period under analysis.
- The TGC_{el} market value equals the total amount of certified RES-E production in a certain year (market volume) multiplied by the TGC_{el} price at that point in time.

3 The Current Renewable Electricity Market[5]

In EU Member States, the only renewable source of energy which had been exploited on a significant scale before 1990 was (large) hydro power. During the nineties, growth rates have mostly been two-figure for non-hydro renewable energies due to a diverse range of renewable electricity promotion policies by national governments and the European Community. Yet, the importance of renewable electricity is still very diverse in different European countries (s. Table in Annex II). The growth rates differ a lot depending on the source and Member State.

In 1997, electricity generation in the EU reached 2,400 TWh, showing an average growth of 1.7% per year since 1990. Despite a limited increase in generating capacity since 1990, hydro and wind power together had increased their production by 2.2% per year on average since 1990 to generate 13% of the total in 1997. Since 1990, wind production has multiplied by 10. It is the fastest growing renewable source of electricity, but its contribution still only represented 0.3% of the total production even though some European countries are amongst the largest world contributors (CEC 2000b, 57).

Today wind energy projects across Europe produce enough electricity to meet the domestic needs of 5 Mio. people. Latest figures show that close to 9,000 MW of wind energy capacity were installed in the countries of the EU at the end of 1999. This is an increase of more than 2,000 MW in a single year, a percentage growth of over 30%, three quarters of that additional capacity were installed in Germany, a fifth in Spain and in Denmark, respectively (http://www.ewea.org).

According to ADEME, the operational peak capacity of photovoltaic installations in the world at the end of 1998 can be estimated at 600 MW, for an annual energy production of 500 GWh. EurObserv'ER has worked on an estimation which, on the basis of trends recorded over the past few years, comes to a figure of approximately 124 MW_p for installed PV capacity in the European Union at the end of 1999. That equals a 19% growth rate for 1999. PV electricity production for the EU in 1998 is approximated at 80 GWh (Photovoltaic barometer in Systèmes Solaires N^o 136, 2000).

The 1997 White Paper of the European Commission (CEC 1997) set out an indicative target for the Community as a whole of doubling the share of renewable energy from 6% to 12% of the gross inland energy consumption by 2010. This overall objective has been translated into a 22.1% RES share in the electricity sector for 2010. The recent proposal for a Directive on the promotion of RES-E (CEC 2000a) once more emphasises the importance of this policy field for the EU. However, it also stresses that additional efforts are necessary at the Commu-

[5] For a more detailed overview on the current situation and policies for renewable sources of electricity in the European Union, you are referred to the country reports written within the RECerT project for each EU Member State and also summarised for EU-15. Visit http://recert.energyprojects.net for further information.

nity level as well as in Member States in order to achieve the objective. Tradable green certificates are seen as one possible policy instrument to facilitate the medium-term significant increase in RES-E within the EU. In the following, we assume that the introduction of TGC_{el} support schemes is harmonised between those countries that opt for it.

4 MARKET PENETRATION TARGETS FOR RENEWABLE ELECTRICITY

In the light of EU policy, many Member States have formulated a market penetration target for renewable sources of energy in 2010. Intermediate and technology-specific targets are often fixed as well, but for different points in time and different technologies. Not all national targets are consistent with the White Paper, that mainly is, they are not as ambitious as in the White Paper. Some Member States have not at all set national targets for the domestic future consumption of RES-E. To ensure that the level of RES-E develops in conformity with their 22% objective and that each Member States contributes its portion, the Commission has proposed 'indicative' targets for each Member State.

Table 2: EC and national targets for RES-E in EU-15

	RES-E share 1997 (in %)	**'EC-targets' for RES-E in 2010 (in%)**	**(in TWh)**	**Increase 1997-2010 (in TWh)**	**'National Targets' for RES-E until 2010* (in % and year)**	**(in TWh)**
Austria	72.7	78.1	55.3	15	3% (non hydro) in 2005 (non-large hydro)	+2 (+0.11)
Belgium	1.1	6.0	6.3	5.4	Flanders: 3% in 2004 5% in 2010 Wallonia: 8% in 2010	Fla.: 0.9 1.8
Denmark	8.7	29.0	12.9	9.7	20% in 2003 30% in 2010	7.5 13
Finland	24.7	35.0	33.7	16	Doubling bt. 1990-2010	32
France	15.0	21.0	112.9	47	No Target	0
Germany	4.5	12.5	76.4	52	10-12% in 2010	61
Greece	8.6	20.1	14.5	11	No Target	0
Ireland	3.6	13.2	4.5	3.8	5.1% in 2000 20% in 2010	1.2 6.8
Italy	16.0	25.0	89.6	43	+2% in 2002 Doubling until 2010 ?	+4.5 78
Luxembourg	2.1	5.7	0.5	0.4	No Target	0
Netherlands	3.5	12.0	15.9	12	8.5% in 2010 17% in 2020	11
Portugal	38.5	45.6	28.3	14	500 MW small hydro, 47 MW biomass, 290 MW wind by 2006	+3
Spain	19.9	29.4	76.6	40	12% in 2010 (non-large hydro)	62
Sweden	49.1	60.0	97.5	26	+1.5 TWh/a bw. 1998 and 2002	79
UK	1.7	10.0	50.0	44	5% in 2003, 10% in 2010	21 50
EU-15	13.9	22.1	675	339		

*Please, comment on these numbers. As the RES-E world is moving fast, they might not be up-to-date.

Sources: Columns 1-3: CEC (2000a), column 4: own calculations based on CEC (1999b), columns 5+6: compilation from & calculations based on RECerT & InTraCert country reports

Table 2 shows the Commission's ideas as to what extent the individual Member States should contribute to the renewable electricity target for the whole EU ('EC-targets') and compares them with the actual targets formulated by Member States' governments in official documents ('National Targets'). For countries like Austria, France and Portugal they differ considerably, whereas the targets set by Denmark and the UK exactly correspond with the goals of the Commission. In the last column "+" stands for additional production compared to the 1997 level.

Under the EC-targets scenarios, France, Germany, Italy, Spain, Sweden, and the United Kingdom would obviously need to contribute the most to future European RES-E development in absolute terms.

To approximate the potential renewable energy market sizes in 2000, 2005, and 2010, we partly needed to calculate fictitious goals by forward or backward projections of the targets actually fixed nationally. Table 3 summarises the additional RES-E production envisaged by the Member States for 2000, 2005, and 2010 according to our calculations that are built on the baseline figures (cf. Table 4) and the targets in Table 2. The assessment demonstrates that the national targets scenario would only result in an overall increase of the RES-E share in EU-15 electricity consumption from 13% in 1995 to 17% in 2010, whereas the Commission strives at 22.1% in 2010.

Table 3: Derived national targets for additional RES-E production in EU-15 (in TWh/a)

	1996-2000	**2001-2005**	**2006-2010**	**1996-2010**
Austria	0.060	0.048	0.16	0.27
Belgium	0.21	0.71	0.92	1.8
Denmark	0.57	4.9	6.3	12
Finland	4.1	4.1	4.1	12
France	no target	no target	no target	no target
Germany	4.5	12	23	39
Greece	no target	no target	no target	no target
Ireland	0.52	1.2	4.2	6.0
Italy	3.9	9.1	27	40
Luxembourg	No target	No target	no target	no target
Netherlands	0.59	2.8	7.2	11
Portugal	0.49	2.6	4.8	7.9
Spain	3.4	4.8	9.3	18
Sweden	4.5	5.4	6.5	16
UK	4.6	11	29	44
TOTAL	27	59	120	210
White Paper and Directive Total	*42*	*106*	*215*	*363*

It must be noted that the target path for an EC-targets scenario (last row in Table 3) is already an outcome of the calculations described later on (in Chapter 7). It was chosen under the assumption that in the case of a TGC_{el} trading regime, TGC_{el} prices might need to be more or less constant over time (1996-2010), or at least not decrease rapidly, in order to avoid large stranded investments. Due to decreasing production costs and increasing exploitable offshore wind energy potentials over time, stable TGC_{el} prices require an exponentially growing RES-E market, and thus exponentially growing RES-E targets. If a fully co-operative EU-15 TGC_{el} market was started in 1996, slightly more than 10% of the 2010 targeted RES-E production should be striven for in the first 5-year period. The intermediate target for 2005 should be fixed to contribute another 30% to the final RES-E target, and between 2006 and 2010 the major part (60%) of additional RES-E production should enter the market. These considerations are reflected in the target paths for the EC-targets scenarios.

To derive absolute figures for the future RES-E market size (as in Tables 2 and 3), it is necessary to consider the development of the European electricity market up to 2010. We have used the figures of the Shared Analysis Project (CEC 1999c) to which the European Commission refers as well in their Directive proposal (cf. Table 4). As indicated by their projections, the European electricity market is expecting substantial growth rates until 2010. Thus, even if the RES-E shares in the EU member countries were to remain on their 1995 levels, a considerable increase in renewable power generation would be necessary until 2010.

Table 4: Assumed development of European electricity markets (in TWh)

	Total electricity production				**Total electricity consumption**			
	1995	**2000**	**2005**	**2010**	**1995**	**2000**	**2005**	**2010**
Austria	55	58	62	68	53	61	66	71
Belgium	74	87	93	101	78	89	98	105
Denmark	37	40	42	44	36	39	42	44
Finland	64	76	84	91	71	81	90	97
France	490	544	575	588	420	471	511	538
Germany	532	546	570	606	536	552	577	613
Greece	41	52	61	71	42	52	61	72
Ireland	18	24	30	34	18	24	30	34
Italy	237	273	307	335	275	301	331	359
Luxembourg	1	1	2	3	5	6	7	8
Netherlands	81	93	106	129	93	105	118	133
Portugal	33	41	54	63	34	42	53	62
Spain	165	192	219	250	170	200	229	256
Sweden	148	157	162	161	147	154	162	163
UK	333	380	431	483	349	398	450	500
EU-15	2308	2563	2799	3028	2327	2576	2823	3054

Source: CEC (1999c)

5 TECHNICAL AND MARKET POTENTIALS FOR ELECTRICITY SUPPLY FROM RENEWABLE SOURCES OF ENERGY

There are several studies on the technical potential of renewable energies. The LTI-Research Group has comprised these studies and come up with ranges for technical potentials of renewable energies in the 15 EU countries. We largely base our calculations on the work of that group with the following additional assumptions:

- The annual exhaustion rates of the source-specific potentials are limited. Due to several restrictions to the renewable energies market development that have been observed in the past we assume that a maximum of 2% of the technical potential can additionally be used per year to increase the market share of renewable electricity.
- With respect to offshore wind energy, we assume that wind farms might enter the electricity market at a maximum annual rate of 1% of the technical potential not starting before 2001. After 2005, the offshore wind energy potential is treated like the other sources of energy.

  Since it turns out that the penetration of offshore wind energy is crucial in our scenarios with respect to determining TGC_{el} prices, we also provide results assuming that the off-shore wind energy potential can only be exploited at a one-per-thousand rate between 2001 and 2005 and a two-per-thousand rate between 2006 and 2010.

The structure of gathered information on country-specific technical potentials is shown in the following table.

Table 5: The accumulated technical potential for RES-E in EU-15 (in TWh/a)

EU-15 – Technical Potential					
WIND ENERGY					
Wind: onshore	*Wind speed*	*7.5m/s*	*6.5m/s*	*5.5m/s*	
		38	124	209	
Wind: offshore	*Water depth*	*10m*	*20m*	*30m*	*40m*
		601	935	944	570
HYDRO ENERGY		Large hydro	Small hydro		
		138	16		
SOLAR ELECTRICITY		Photovoltaics	Solar thermal		
		432	1404		
BIOMASS ELECTRICITY		Fuel switch	Wood	Biogas	Crops
		58	32	56	37

Source: Compilation from LTI (1998)

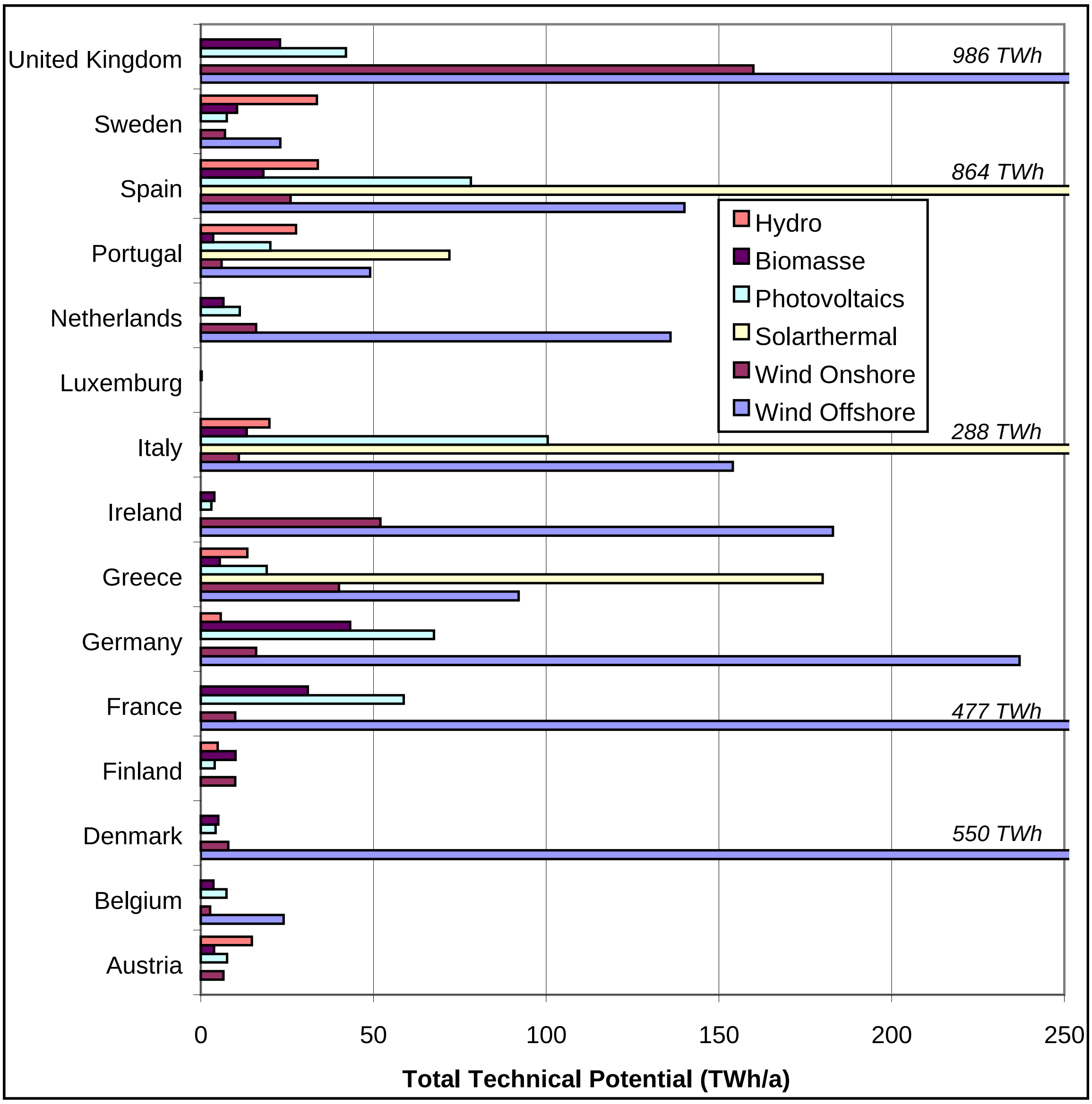
Table 5 illustrates the aggregated RES-E potential of all 15 EU Member States differentiated according to renewable energy source and technology. The wind potential has been split into several categories depending on average wind speeds (onshore) or different water depths (off-shore). In addition to common biomass potential studies it is assumed that the co-firing of biomass will play a role in renewable energy market development. Based on data from CEC (1999c) we assume that 10% of the fossil fuels used as input for electricity generation can be replaced by biomass. In addition, we assume that all other type of biofuels are converted to energy in CHP plants with a fuel efficiency of 65% on average. 33% of the remaining useful energy is assumed to be converted to electricity.

The above mentioned restrictions concerning exploitation rates shall be explained here with the large-hydro potential serving as an example. 2% of the large-hydro potential mean that a maximum of 2.8 TWh of additional large-hydro electricity can penetrate the European electricity market annually. In the five-year time periods considered here, this translates into an exploitable European large-hydro potential of 14 TWh in the period between 1996 and 2000. For the following periods, the overall large-hydro potential is reduced by the part of the potential that was realised between 1996 and 2000.

According to the LTI survey, the EU-15 technical potential is distributed unevenly across the different Member States (cf. Figure 1). Denmark, France and the United Kingdom can make use of a large offshore wind energy potential, whereas Spain, Italy, and Greece could exploit a large solar electricity potential. These two types of renewable energy technologies are dominating the technical RES-E potential in the European Union.

Looking at the data, one can easily find out that the countries with a large targeted RES-E production in 2010 are not necessarily those with the largest renewable energy resource. This fact already gives a hint that RES-E trade will be important when the indicated RES-E targets by the European Commission and by the national governments are turned into serious commitments.

Figure 1: Distribution of the RES-E potential across EU-15 (in TWh/a)



Sources: Compilation from LTI (1998), Semke/ Markewitz (1998)

Estimates of the current and future RES-E production costs are a further essential input variable for a review of the TGC_{el} market development. The results from a little survey of ours are illustrated in Table 6. Based on the cost predictions and the estimates of technical potentials in Figure 1, we can then calculate cost-potential curves for each of the 15 EU countries.

For that purpose, some additional assumptions are necessary. We assume e.g. that the 6.5m/s feasible onshore wind resource of 12.4 TWh between 1996 and 2000 will be exploited at costs linearly increasing from 3.5 c€/kWh to 7 c€/kWh. This method is used for all technology categories. Finally, we obtain the European cost-potential for each of the three time-periods under consideration by accumulating the individual cost-potential curves (also cf. Chapter 7).

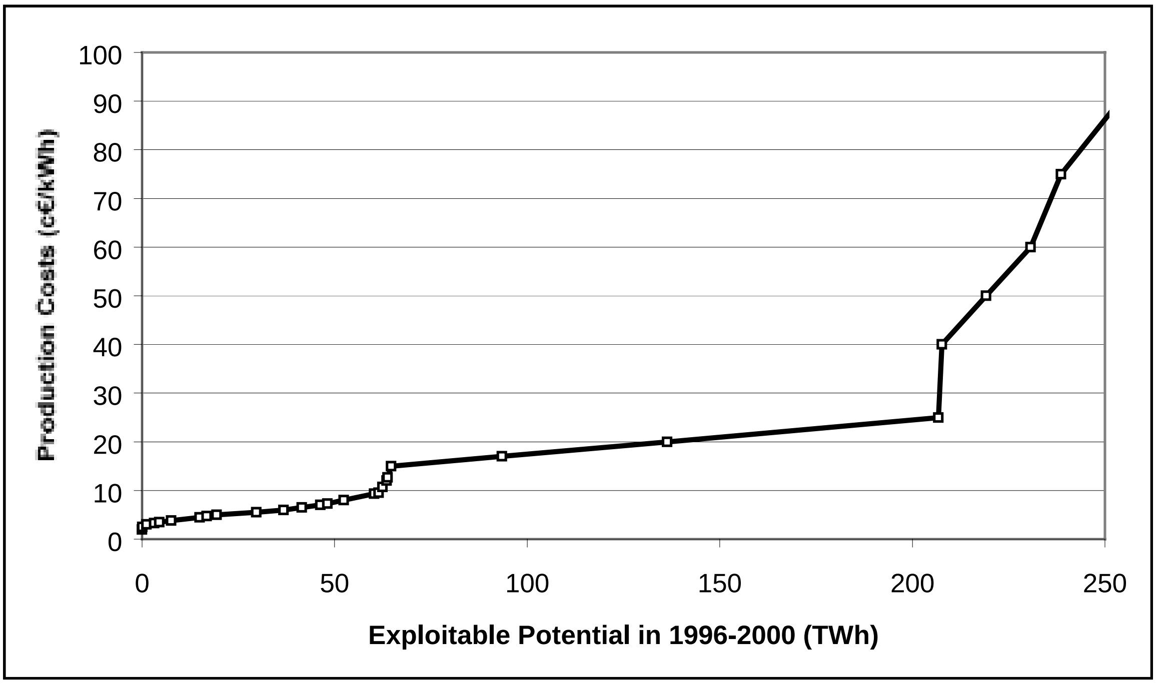
Table 6: Production costs developments of the different technologies (in c€/kWh)

	1996-2000		2001-2005		2006-2010	
	Low	**High**	**Low**	**High**	**Low**	**High**
Wind: onshore						
7.5m/s	2.5	4.5	2.0	4.0	1.8	3.5
6.5m/s	3.5	7.0	3.0	5.5	2.5	5.0
5.5m/s	5.5	9.5	3.5	7.0	3.0	6.0
4.5m/s	8.0	15.0	5.0	11.0	4.0	9.0
Wind: offshore						
10m	3.3	6.0	2.7	5.3	2.3	4.7
20m	4.7	9.3	4.0	7.3	3.3	6.7
30m	7.3	12.7	4.7	9.3	4.0	8.0
40m	10.7	20.0	6.7	14.7	5.3	12.0
Large Hydro	3	6	3	8	3	8
Small Hydro	5	17	5	17	5	17
Photovoltaics						
North	60	90	48	72	38.4	57.6
Central (FR, AT)	50	75	40	60	32	48
South (GR, IT, PO, SP)	40	60	32	48	25.6	38.4
Solar electricity	15	25	12	20	10	15
Biomass electricity						
Fuel switch	5.5	5.5	5.5	5.5	5.5	5.5
Wood	2	20	2	20	2	20
Biogas	6.5	100	6.5	100	6.5	100
Crops	3.8	12	3.8	12	3.8	12

Sources: BMU (1999), Kaltschmitt/ Wiese (1997), Matthies et al. (1995), Semke/ Markewitz (1998) and own estimates

The following figure (Figure 2) shows the accumulated cost-potential curve of EU-15 in the period 1996-2000 based on the assumptions given above. The overall exploitable RES-E potential in that period sums up to about 250 TWh, most of which (about 200 TWh) could be utilised below 30 c€/kWh. However, the national and the derived EC targets for that period are much lower. They amount to 27 TWh and 42 TWh respectively (cf. Table 4). Taking a closer look at that section of the cost-potential curve (1996-2000) reveals that under full co-operation between the 15 Member States, the production costs for reaching the targets would be far less than 10 c€/kWh (Figure 2), according to our data.

Figure 2: Cost-potential curve of EU-15 in the period 1996-2000



6 PROJECTIONS OF FUTURE EU ELECTRICITY MARKET PRICES

In order to be able to estimate the TGC_{el} (and not only the RES-E) market size and value, it is now necessary to make assumptions on the price RES-E producers can achieve for feeding their electricity into the grid (commodity price). The figures in Table 7 present low and high estimates for the development of the commodity prices over the time periods under consideration. They are drawn from two very recent German studies. We make the (strong) assumption that they are valid for all EU Member States alike.

Table 7: Development of commodity prices (in c€/kWh)

	1996-2000		**2001-2005**		**2006-2010**	
	Low	**High**	**Low**	**High**	**Low**	**High**
Wind / Solar electricity	1.53	5.62	1.66	4.60	1.79	5.11
Large hydro	5.11	5.62	3.08	4.60	4.09	5.11
Small hydro	5.62	5.62	4.60	4.60	5.11	5.11
Fuel switch to biomass	5.11	5.62	3.08	4.60	4.09	5.11
Other Biomass	5.62	5.62	4.60	4.60	5.11	5.11

Sources: Schlesinger/ Schulz (2000), Dany et al. (2000)

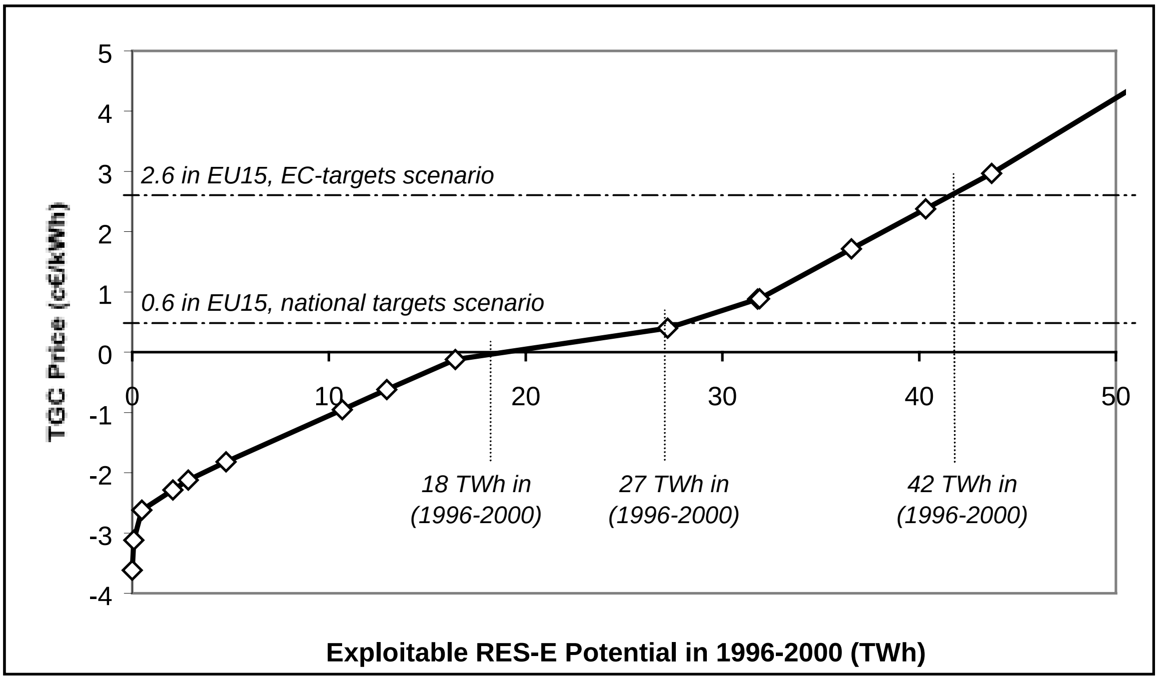
The commodity prices differ subject to the grid level and the value of the delivered electricity. The high estimates reflect the market price for electricity at low voltage levels. The minimum high value is reached between 2001 and 2005 when competition and price dumping due to the existence of over-capacity in the electricity sectors are supposed to have a maximum effect on prices (cf. Schlesinger/ Schulz 2000).

For small hydro and biomass use other than co-firing, we assume that the low voltage grid level is the only feasible to feed in electricity. Accordingly, low and high commodity prices are supposed to match. Due to the fact that delivering electricity from wind energy and photovoltaics at a given date is more uncertain, the value of this intermittent product might be below the low voltage level market price for electricity. Based on Dany et al (2000: 52) we assume the value of electricity from wind energy and photovoltaics to be at least 1.53 c€/kWh. If in the long run capacity effects are fully reimbursed the value of wind and solar electricity is supposed to be 1.79 c€/kWh. The low values for electricity from large hydro and fuel switch to biomass are relevant if the electricity is directly sold to the high voltage grid.

To create TGC_{el} price-potential curves for each country in the European Union, we accept the broadest price range possible. What this means is again exemplified with the wind onshore potential at a 6.5 m/s wind speed in the period 1996-2000. The lowest value of production costs minus the highest possible commodity price is -2.12 c€/kWh (= 3.5-5.62 c€/kWh). We assume that the TGC_{el} price is linearly increasing from that vale to the highest value of 5.47 c€/kWh determined by the high value of the production costs and the low value of the commodity price (= 7.0-1.53 c€/kWh).

Accumulating all country-specific functions we obtain the EU-15 TGC_{el} price-potential curve. For the first period (1996-2000) under analysis, the curve section up to 50 TWh of the total 250 TWh exploitable potential is illustrated in the following figure (Figure 3).

Figure 3: TGC_{el} price-potential curve (up to 50 TWh) of EU-15 in the period 1996-2000



With our figures and assumptions, we must conclude that even without subsidies some 18 TWh of RES-E production would have penetrated the European electricity market. Precondition for that result are the non-discriminatory access to the grid for RES-E and a single market in electricity. A basic assumption on (quota-based) market functioning says that the producer`s cost at the margin (of the quota) determines the market price (cross-section of demand and supply function). Under a fully co-operative EU-15 TGC_{el} trading scheme, the 2000 national target (27 TWh) results in a TGC_{el} price of less than 0.6 c€/kWh, whereas the 2000 EC target (42 TWh) is estimated to be met at about 2.6 c€/kWh in our model (cf. Figure 3).

7 ESTIMATES ON THE POTENTIAL SIZE AND VALUE OF A FUTURE TGC_{EL} MARKET

Based on the information, assumptions and methodology given in the previous chapters, we can now present first rough estimates of the potential size and monetary value of a tradable green certificate market in the electricity sector of the European Union.

We distinguish 4 TGC_{el}-trade scenarios:

- EU-15, EC-targets scenario: all Member States participate in certificate trading; the 22.1% target of the Commission is reached by Member States accepting the quantitative indications given by the Commission in their recent proposal for a Directive (CEC 2000a);
- EU-15, national targets scenario: all Member States participate in certificate trading; the targets currently set in national legislation and energy programmes (add up to 17% for the whole EU) are reached by 2010;
- EU-5, EC-targets scenario: only the 5 countries at present most advanced with the implementation of a green certificate system (NL, DK, UK, I, Flanders) manage to trade among each other; they accept the targets recommended by the Commission (in CEC 2000a);
- EU-5, national targets scenario: only the 5 countries at present most advanced with the implementation of a green certificate system (NL, DK, UK, I, Flanders) manage to trade; they stick to the targets currently laid down in their national legislation or programmes.

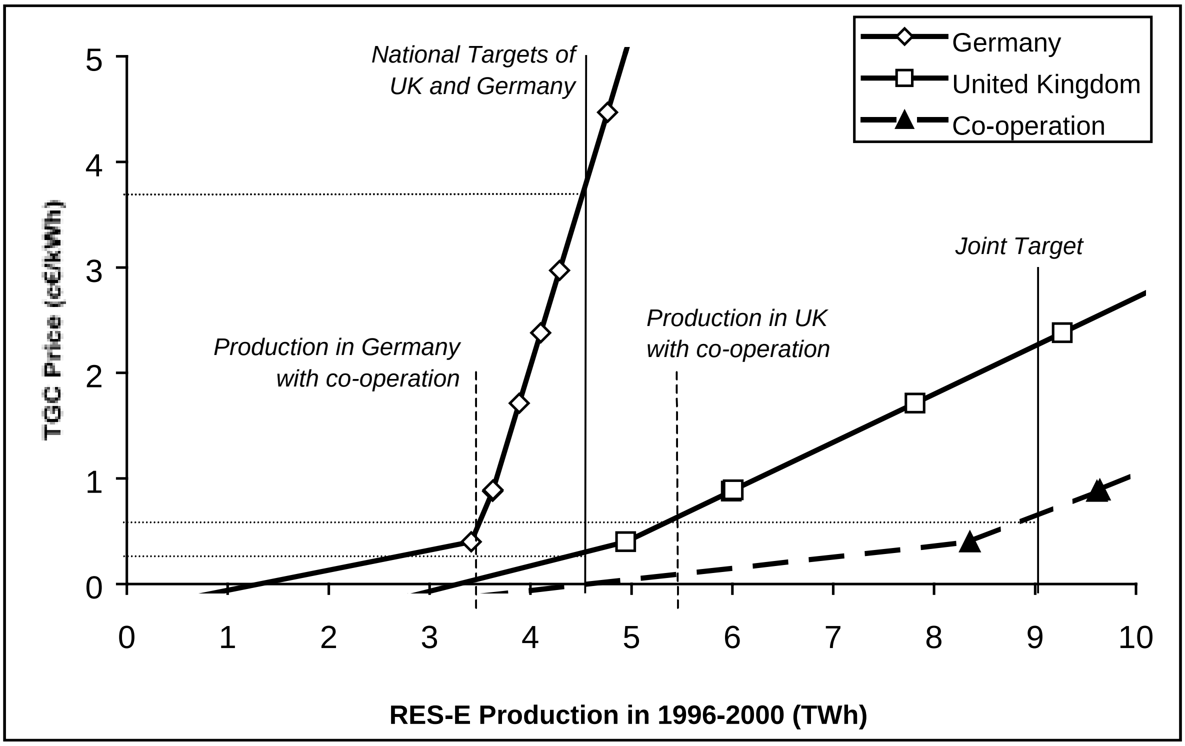
For both sets of targets we calculate the RES-E production in each European country, the trade volume, and the TGC_{el} market price. Thus, we can derive the overall TGC_{el} market volume and the TGC_{el} trade value (cf. Table 8). Detailed results for the described scenarios are given in Appendix I.

Appendix I also includes the price effects of scenario in which all Member States reach their targets without trade. Assessing prices, the pure national strategies help to explain expected imports and exports of the full-trade scenarios: an exporter of TGCs will meet the national target at costs below the full-trade price level, while importers will not be able to meet their national targets at full-trade prices.

The mechanism is once more described with an example: Suppose Germany and the United Kingdom co-operate in meeting their RES-E targets. Germany has a comparably poor RES-E resource and consequently faces high specific costs to meet its national target. The United Kingdom is able to meet its national target domestically at specific costs far below the calculated German equilibrium TGC_{el} price. With German TGC_{el} prices, the UK could produce at RES-E levels beyond its national targets. Thus, if Germany and the UK co-operated, the equilibrium TGC_{el} price under co-operation would range between the (isolated) national TGC_{el} prices of the two countries. As an effect, Germany buys TGCs in the UK (cf. Figure 4).

The target path designed above (cf. Table 3) for the period 1996 to 2000 presents nearly equal national targets for Germany (4.5 TWh) and the United Kingdom (4.6 TWh). Yet, based on our model, the TGC_{el} price necessary to reach the targets nationally would be about 3.8 c€/kWh for Germany compared with 0.3 c€/kWh for the UK (cf. Table 2 in Appendix I). The broken line in Figure 4 represents the TGC_{el} price-potential curve of Germany and the United Kingdom under full co-operation. The overall 2000 target of 9.1 TWh RES-E could be produced at a TGC_{el} price of about 0.6 c€/kWh. At this price level, about 5.6 TWh RES-E would be produced in the UK and about 3.5 TWh in Germany. Hence, the UK is exporting TGCs equivalent to 1 TWh RES-E production to Germany in this example.

Figure 4: Example of Co-operation between UK and Germany



The amount of TWh covered by the TGCs sold from the UK to Germany (1 TWh) is interpreted as the trade volume. The trade volume is then multiplied by the equilibrium TGC_{el} price (0.6 c€/kWh), the product stands for the TGC_{el} trade value (€ 6 Mio.). The accumulated national targets or the renewable electricity certified in total (market volume of 9.1 TWh) multiplied by the TGC_{el} market price yields the TGC_{el} market value (ca. € 55 Mio.) under full co-operation.

The trade volume in an EU-15 or EU-5 scenario equals the sum of all TGC_{el} exports (or imports) of the 15 (5) co-operating countries in TWh. The market volume is determined on the assumption that only electricity from additional renewable energy plants (base year 1995) is certified and receive TGCs. If plants built before 1995 are eligible to receive TGC_{el} for their production, the market volume may even be larger. But, as said before, this will mainly be a political decision.

In our EU-15, EC-targets, full-trade scenario, an estimated certified RES-E production of 130 TWh (out of 360 TWh) is traded between the EU Member States in 2010; this comes to a market value of about € 3.4 billion (see Table 8). Thus, the EU-wide trade volume amounts to more than one third of the certified RES-E production in 2010. These figures indicate that there is a huge potential for TGC_{el}-trade between the 15 Member States. If the targets formulated by the national governments are implemented (EU-15, national targets, full-trade scenario), the trade volume is estimated to be at about half of the EC-targets case; the TGC_{el} market value in 2010 would be € 1.5 billion, which is still a considerable market size. If only the five most advanced countries with respect to TGC_{el} policies started a fully co-operative trading scheme, the international market could still be expected to be sizeable. TGCs representing more than 30 TWh are expected to be traded between the five countries. Flanders, Italy and the Netherlands turn out to be net importers. Denmark and the United Kingdom are estimated to be exporters of TGCs due to their substantial offshore wind energy resource.

Table 8: Estimated market size and values under 4 different TGC_{el} scenarios

Scenario	TGC_{el} market value (in billion €)			TGC_{el} trade volume (in TWh)			TGC_{el} trade value (in billion €)		
	2000	2005	2010	2000	2005	2010	2000	2005	2010
EU-15, EC-targets	1.1	3.9	9.5	10	46	130	0.27	1.2	3.4
EU-15, nat. targets	0.15	0.97	1.6	6.8	28	75	0.038	0.31	0.58
EU-5, EC-targets	0.13	0.55	1.6	3.0	15	47	0.037	0.19	0.58
EU-5, nat. targets	0.084	0.35	0.81	1.5	8.4	30	0.012	0.077	0.23

The tables in Appendix I also provide the approximated TGC_{el} prices for each Member State if national targets have to be fulfilled domestically, i.e. without cross-border trade. The results reveal that Austria, Finland, Luxembourg and Sweden could have difficulties in meeting the EC-targets without trade. The only country which is, based on the information given, not able to fulfil the RES-E target set by its national government is Finland.

It has already been mentioned before that the results are very sensitive to the assumed production costs and exploitation rates, in particular of offshore wind energy. If we reduce the possible exploitation rate per year to a tenth of the original assumption, the resulting TGC_{el} prices turn out to be 5 to 10 times higher (than those underlying the results presented in Table 8); under such a scenario with EC-targets, the TGC_{el} price is for example expected to reach about 14 c€/kWh. This higher TGC_{el} price is the consequence of solar thermal power plants entering the RES-E market after 2005. TGC_{el} trade, however, decreases by 20 to 30% since RES-E production is increasing substantially in the South of Europe and simultaneously, TGC_{el} transactions from those areas with a large offshore wind potential in the North of the EU can be cut. In total, the estimated value of traded TGC_{el}s exceeds the value of our original calculations due to higher expected TGC_{el} prices by about a factor of five.

After all, the following conclusions may be drawn from our analysis:

- A substantial TGC_{el} market size and cross-border trading volume can be expected under both EU-15 and EU-5 trading schemes (in the light of the ambitious RES-E targets formulated by the European Commission as well as by the national governments).
- If the national targets indicated by the European Commission in the recent proposal for a Directive were implemented, the EU Member States Austria, Finland, Luxembourg and Sweden could fail meeting these targets without TGC_{el} trade.
- Since the national governments' targets and the EC-targets do not reflect the distribution of RES-E potentials across the EU, there seems to be a need for trade. Our sensitivity analysis shows that the estimated trade volumes can be considered as robust. Our market and trade value estimates, in contrast, are very sensitive to assumptions, in particular concerning the exploitation rates of the wind offshore resource.
- We find that the assumed annual exploitation rates of renewable resources have a crucial effect on TGC_{el} prices. Therefore, a more general conclusion is that European and national policies should also focus on facilitating the development of renewable resources (e.g. by infrastructural measures) and on making obligations more flexible to fulfil (e.g. via instruments like banking and borrowing of TGC_{el}).

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Appendix I: Scenario Results

EC-Targets	**EU-15: RES-E net export (in TWh)**			**EU-5: RES-E net export (in TWh)**		
	2000	**2005**	**2010**	**2000**	**2005**	**2010**
Austria	0.04	-3.3	-11			
Belgium	-0.33	-1.1	-2.7	-0.23	-1.2	-3.8
Denmark	-0.44	10	38	-0.28	5	21
Finland	-0.20	-3.1	-10			
France	-3.0	-3.0	2.1			
Germany	-2.1	-8.6	-23			
Greece	2.0	3.9	5.8			
Ireland	2.3	8.6	20			
Italy	-3.1	-13	-33	-1.8	-13	-39
Luxembourg	-0.04	-0.14	-0.35			
Netherlands	-0.83	-0.16	1.6	-0.66	-1.6	-3.9
Portugal	-0.02	-3.3	-10			
Spain	-0.25	-8.2	-27			
Sweden	1.4	-2.5	-13			
United Kingdom	4.7	24	63	3	10	26
Equilibrium TGC_{el} price (c€/kWh)	2.6	2.6	2.6	1.2	1.2	1.2
TGC_{el} market value (bill. €)	1.1	3.9	9.5	0.1	0.6	1.6
TGC_{el} trade volume (TWh)	10	46	130	3.0	15	47
TGC_{el} trade value (bill. €)	0.3	1.2	3.4	0.0	0.2	0.6

National Targets	**EU-15: RES-E net export (in TWh)**			**EU-5: RES-E net export (in TWh)**		
	2000	**2005**	**2010**	**2000**	**2005**	**2010**
Austria	0.15	0.41	0.60			
Belgium	0.01	-0.18	-0.01	0.03	-0.23	-0.07
Denmark	0.02	2.9	16	0.06	2.1	15
Finland	-3.0	-6.3	-9.5			
France	0.79	7.1	23			
Germany	-1.1	-8.7	-22			
Greece	2.1	5.2	10			
Ireland	0.81	4.0	8.0			
Italy	-1.7	-7.9	-29	-1.4	-8.0	-29
Luxembourg	0.00	0.00	0.00			
Netherlands	-0.09	0.07	-0.61	-0.03	-0.19	-0.93
Portugal	1.1	-0.23	-2.9			
Spain	1.1	0.31	-2.4			
Sweden	-0.98	-4.3	-8.1			
United Kingdom	0.73	7.7	17	1.4	6.3	15
EU TGC_{el} price (c€/kWh)	0.6	1.1	0.8	0.9	0.9	0.7
TGC_{el} market value (bill. €)	0.2	1.0	1.6	0.1	0.4	0.8
TGC_{el} trade volume (TWh)	6.8	28	75	1.5	8.4	31
TGC_{el} trade value (bill. €)	0.04	0.3	0.6	0.0	0.1	0.2

*n. pos.: not possible based on the assumptions

Appendix II: Renewable Electricity Production in EU Member States

		Austria 1997		Belgium 1998-99		Denmark 1998		Finland 1997		France 1999		Germany 1999		Greece 199?	
Large hydro	in GWh	33,000	66.0%	152	0.2%	0	0.0%	12,000	17.4%	70,000	14.3%	13,000	2.4%	3,900	9.5%
	in MW	11,000	94.7%			0			0.0%	19,000	90.4%	3,100	32.6%	2,800	97.7%
Small hydro	in GWh	2,300	4.6%	186	0.2%	0	0.0%	700	1.0%	8,000	1.6%	6,000	1.1%	120	0.3%
	in MW	600	5.2%			0		10	35.1%	2,000	9.5%	1,500	15.8%	40	1.4%
Wind onshore	in GWh	32	0.1%	13	0.02%	2,700	6.9%	17	0.0%	51	0.0%	5,400	1.0%	50	0.1%
	in MW	20	0.2%					16	56.1%	21	0.1%	4,400	46.3%	25	0.9%
Wind offshore	in GWh		0.0%		0.0%		0.0%		0.0%		0.0%	0	0.0%		0.0%
	in MW		0.0%						0.0%		0.0%	0	0.0%		0.0%
Biofuels	in GWh	75	0.2%	148	0.2%	500	1.3%	8,200	11.9%	1,600	0.3%	1,400	0.3%		0.0%
	in MW		0.0%						0.0%		0.0%	400	4.2%		0.0%
Solar	in GWh	0	0.0%	0	0.0%		0.0%		0.0%	7	0.0%	30	0.0%		0.0%
	in MW		0.0%					3	8.8%		0.0%	100	1.1%		0.0%
Other	in GWh	0	0.0%		0.0%	3,400	8.7%		0.0%		0.0%	0	0.0%		0.0%
Total	in GWh	35,407	70.8%	499	0.6%	6,600	16.9%	20,917	30.3%	79,658	16.3%	25,830	4.7%	4,070	9.9%
Total	in MW	11,620	100%		0%		0%	29	100%	21,021	100%	9,500	100%	2,865	100%
Total electricity productior		50,000		81,000		39,000		69,000		490,000		550,000		41,000	

		Ireland 1998		Italy 1997o.98		Luxemburg 1999		Netherlands 1998		Portugal 1996		Spain 1998		Sweden 1998		UK 1997	
Large hydro	in GWh			33,000	11.0%	21	2.1%	0	0.0%	14,000	40.0%	31,000	16.3%	74,000	47.7%	4,000	1.2%
	in MW			14,000	82.0%	11	23.2%	0	0.0%	4,200	93.5%	16,000	86.4%	16,000	98.9%	1,400	75.4%
Small hydro	in GWh			8,300	2.8%	75	7.5%	110	0.1%	520	1.5%	5,600	2.9%		0.0%	160	0.0%
	in MW			2,200	12.9%	21	44.3%	37	8.8%	240	5.3%	1,500	8.1%		0.0%	56	3.0%
Wind onshore	in GWh			230	0.1%	17	1.7%	640	0.7%	140	0.4%	1,400	0.7%	300	0.2%	670	0.2%
	in MW			160	0.9%	15	31.6%	380	90.3%	50	1.1%	830	4.5%	170	1.1%	140	7.5%
Wind offshore	in GWh			0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	in MW			0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Biofuels	in GWh			300	0.1%	1	0.1%	260	0.3%		0.0%	1,100	0.6%	3,300	2.1%	1,200	0.3%
	in MW			120	0.7%	0.3	0.6%		0.0%		0.0%	190	1.0%		0.0%	260	14.0%
Solar	in GWh			6	0.0%	0	0.0%	4	0.0%		0.0%	15	0.0%		0.0%		0.0%
	in MW			6	0.0%	0.1	0.2%	4	1.0%		0.0%	9	0.0%		0.0%		0.0%
Other	in GWh	1,200		4,200	1.4%	0	0.0%	0	0.0%		0.0%	0	0.0%	0	0.0%	340	0.1%
Total	in GWh	1,200		46,036	15.3%	114	11.4%	1,014	1.1%	14,660	41.9%	39,115	20.6%	77,600	50.1%	6,370	1.8%
Total	in MW	310	0%	17,066	97%	47	100%	421	100%	4,490	100%	18,529	100%	16,170	100%	1,856	100%
Total electricity production				300,000		1,000		90,000		35,000		190,000		155,000		345,000	

Sources: Compilation from InTraCert and RECerT Draft Country Reports