ADMIRE-REBUS: Modelling the European market for renewable electricity

B.W. Daniels, M.A. Uyterlinde, ECN Policy Studies, the Netherlands

Abstract

ADMIRE REBUS is a dynamic simulation of the international market for green electricity. It pays explicit attention to trade barriers, discriminative support policies, risks and other imperfections that are inherent to a market in transition. The model matches national supply curves (based on costs and potentials) with policy-based demand curves in a way that takes into account the discriminative characteristics of some policies, and the ability of producers to choose whether they produce for the domestic market or wish to trade their production. Because of the different levels of national support schemes, different sub markets emerge with local equilibrium prices.

1 Introduction

Many EU countries have considered renewable, "green" electricity production as an attractive way of reducing CO2 emissions, decreasing the dependency on foreign fossil energy supplies and generating domestic employment. Ever since the beginning of the 1990s, many countries have had national programmes for the stimulation of renewable electricity production. By adopting the Renewables Directive in October 2001, the EU Member States have agreed on a target of 22% renewable electricity consumption by 2010 (European Commission, 2001). This overall share has been translated into indicative targets for the individual Member States according to their potentials and ambition levels. In accordance with the principle of subsidiarity, Member States are free in their choice of policy instruments to achieve these targets. The EU focus on consumption targets rather than production targets allows countries to meet their targets by trade. This trade may result in a considerable cost reduction compared to a situation in which each country has to meet its target by domestic production.

As most renewable production capacity is not yet competitive on the "grey" electricity market, meeting the targets requires an additional reward for the "greenness" of the renewable electricity. The most obvious basis for such a green price is a set of appropriate policies, be it national or EU-wide. Although the Renewables Directive sets a time path that may lead to the introduction of a EU wide harmonised support framework in the next decade, nearly all Member States still continue with the existing wide variety of national support schemes or add new ones. As a consequence, one of the main uncertainties for the period towards 2010 and further is the extent to which the EU countries will harmonise their support schemes, and as a result, what the role of trade will be in the achievement of EU and Member State targets. Another important uncertainty is the extent to which the current and forth-coming national support schemes are capable of realising the targets.

A thorough analysis of these matters requires a model that is capable of grasping the full complexities of the development of renewable potential in coherence with the current tangle of support policies and the possibilities for trade. For this purpose, the ADMIRE REBUS model has been developed as a successor of the REBUS model, which covered the potential for renewables deployment in a transparent harmonised market, but did not incorporate the large variety of current support policies (Voogt et al, 2001). In addition to policies, Admire Rebus incorporates a representation of the barriers involved in the development of renewables potential, leading to lead times and transaction costs, as well as a vintage approach for new and existing capacity, resulting in a truly dynamic simulation tool for the green electricity market. The resulting model is capable not only of giving insight in the functioning of a mature market for renewable electricity, but also in the transition path towards such a market. Thereby it offers a powerful tool for policy makers and investors in renewable capacity alike.

This paper is organised as follows. Section 2 starts with giving an overview of the way the model is set up. Section 3 further elaborates on the different components of the model. Next, Section 4 presents the results of a case study using the model, focusing on the indicative targets in the Renewables Directive. Finally, Section 5 gives some conclusions.

2 Overview of model functionality and structure

The very heart of the model, the core module, matches demand for renewable electricity with supply options in a simulation of the green electricity market. The functioning of this core module is described in the next paragraph. Figure 2.1 gives an overview of the overall functionality of the model, with the relevant factors. The basic building blocks of the model are supply options and policy based demand sections.

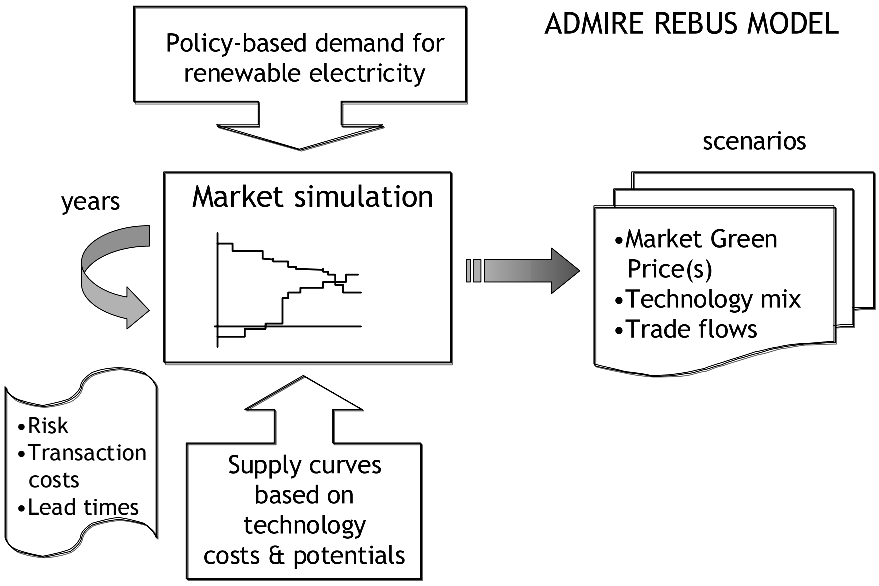

Figure 2.1 Overview of the ADMIRE REBUS model

In brief, the potential and costs characteristics at the supply side are achieved at as follows:

1. Future potentials are estimated for all technology bands within a country, based on a consistent approach, which allows for technology development and learning effects through time. The model converts these potentials to realizable potentials, taking into account all restrictions except economic ones. These restrictions include lead times, the success rate of passing planning and permitting procedures, the production capacity of the capital industry and investor behaviour.
2. An endogenous cost calculation module determines the costs of renewable technologies, expressed in terms of the Required Green Price, see 3.2.1. This calculation includes all costs and revenues expected over the lifetime of a technology, and thus incorporates the effect of different support policies in a straightforward way. Based on technology, market and political risks, the cost calculation applies a technology and country-specific discount rate.

In parallel, each Member State renewable electricity support policy is translated into a demand section consisting of a demand size (in GWh) and a bid price. Demand sizes are either derived from explicit statements in the policies, or by summing up the aggregate supply potential eligible. In the latter case, the available supply is the main restriction. The derivation of bid prices depends on the type of support policy. Its base may be a feed-in tariff, penalty tariff or consumer subsidy.

Further, based on the technologies eligible and further discriminatory provisions of policies, the model determines which demand-supply combinations are allowed. As a consequence, the model accounts both for the discriminative characteristics of policies, and for the ability of producers to choose whether they produce for the domestic market or wish to trade their production. Due to the incorporations of different levels and conditions of national support schemes, the model generates local equilibriums for different sub markets rather than a single equilibrium price for one market.

For each sub market, the ADMIRE REBUS model calculates the Market Green Price (MGP) for renewable electricity[1]. The Market Green Price is the price at which the supply and demand curves of each sub market meet, in order words, the price of the marginal supply option. Note that the assumption is made that trade flows are 'virtual', i.e. trade is facilitated by using tradable green certificates (TGCs), and therefore the market green price can be interpreted as the TGC price.

The simulations can be done for several target years up to 2030, taking account of various other factors that complicate investment in renewables, such as (political) risks, transaction costs and delays due to planning and permitting processes (Uyterlinde et al, 2003). These factors contribute to a realistic simulation of the effectiveness of different policy instruments.

The next paragraphs will deal with the central market match algorithm, the demand sections and supply options in more detail.

3 Matching demand and supply

This section describes the algorithm developed for simulating the market matching. First, it is important to note that in ADMIRE REBUS, the familiar concept of predefined separate demand and supply curves is rather deceptive. The model generates both demand and supply curves as an integral part of the central algorithm, which is of a greedy heuristic type. Beforehand, there are no well-defined demand and supply curves[2]. Likewise, the resulting curves shown after a model run only contain those demand sections and supply options that actually participate in the green market, not the demand sections for which there is no supply or the supply options that do not produce. However, both for the supply options and for the policy derived demand there are well-defined building blocks that are calculated prior to the execution of the central algorithm. In case of the supply options, this concerns supply potentials and the Required Green Price; for the demand sections this concerns the demand size and the bid price.

In calculating the Market Green Price, the main challenge for the ADMIRE REBUS model is to account for the assumed restrictions on trade of green electricity before 2010 and the variety in country specific support schemes. One approach to calculate the MGP for these situations would be the construction of partial markets. ADMIRE REBUS would then calculate a price for each of these markets. However, in this approach the fact that many options are available on different markets presents major problems. The various markets will compete for these shared options, and it is not possible to allocate them beforehand.

Instead, the model applies an alternative approach that circumvents this problem by attaching the various restrictions to both the demand side and the supply options. The model clears the markets by matching the most powerful[3] demand segment not yet satisfied with a supply option still available for this particular demand segment (see Figure 3.1). From those supply options, the one with the lowest cost is chosen first. If a particular supply option is too small to satisfy the complete demand size, the model looks for the next lowest cost supply option to satisfy the remainder of the demand segment. If the particular supply option is larger than the demand segment, the remainder of the supply option will be available for the next demand section. In this way, the model generates demand-supply matches and clears the market, and as a consequence the presented demand and supply curves represent results rather than inputs.

[1] In addition to the electricity commodity price. Often, support policies allow trade of the "greenness" of electricity separate from its physical delivery.

[2] The ask price of a particular supply option may vary between demand sections, due to differences in transaction costs, opportunity costs and the duration for which a demand section offers a particular bid price. Therefore, it is not possible to speak of predefined supply curves without taking into account a particular demand segment.

[3] The demand power of a market segment depends on both the actual bid price and the local equilibrium price achieved in the previous year. Actually, the latter is better indicator for the attractiveness of a market segment for producers than the bid price, which merely presents an upper bound to the equilibrium price.

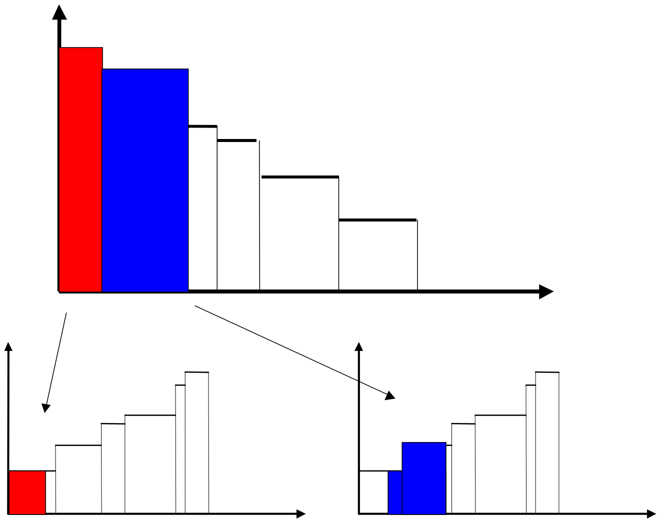

Figure 3.1 The combination of demand curve segments with available supply options

A major advantage of this approach is that there is no need to discern partial markets beforehand. If the barriers for a particular area or demand section are sufficiently large, the ask price of the marginal option will reflect this. This will be higher than that of the marginal option traded between countries on the European green market. The algorithm requires that for both demand and supply additional data are available on discrimination between options and areas, and between areas. This requires a translation of the data on policies into indicators for discrimination.

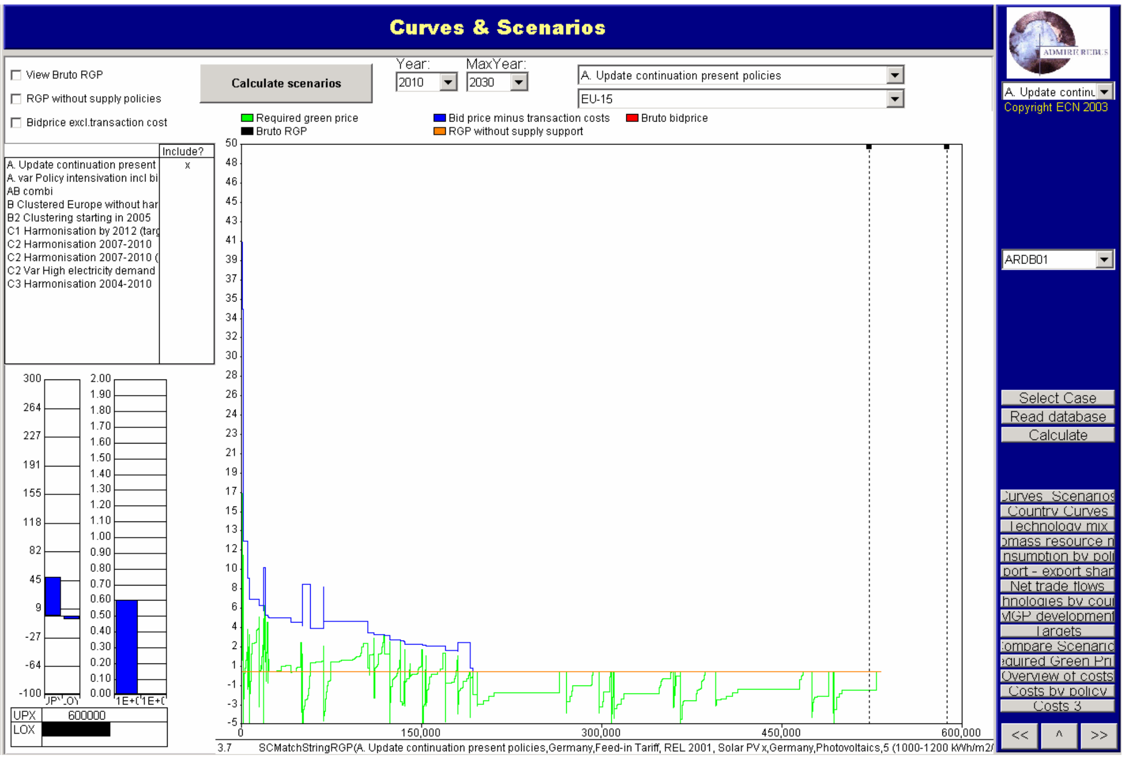

Figure 3.2 Example of a demand and supply curve

3.1 Constructing policy based demand sections for renewable electricity

As stated before, the concept of a demand curve may be confusing, as it is not the familiar predefined continuous curve based on price elasticity. Instead, it is better to speak of discrete demand sections with a uniform bid price for each section. Actually, as each demand section applies its own terms with regard to the eligible technologies and regions of origin, each demand section is in effect a demand defined sub market that competes with other demand sections for supply options that are eligible for both demand sections. The extent to which the eligible supply overlaps may vary from zero to 100%. The model orders the demand sections into a curve resembling a piece-wise demand curve, based on the relative demand-pull, deduced from bid prices and local equilibrium prices in the previous year. This ordering determines the share of supply each demand section manages to attract. For each country, several demand sections may be included, based on specific policies. The required data for the construction of a demand section include both a size in GWh, and the bid price. A relatively easy to translate example is the UK Renewables Obligation, with year-to-year obligations for suppliers, combined with penalty tariffs. The penalty tariff minus transaction costs would directly translate into the bid price of the accompanying demand section, while the obligation would translate into the demand section size.

Various policy measures contained in the policy database play a role in the generation of the demand curve. The way in which policy measures are translated into demand curve sections will vary, depending on both the nature of the measure and the information contained in the policy database. The current section describes the generation of demand curve sections for various cases with regard to the nature of the policy measure, and the available information. However, prior to treating specific cases, it is useful to describe the general approach to deduce level and size of the demand curve sections.

The bid price level (€ct/kWh) of a demand curve section originates from the demand-pull effect of the accompanying set of policy measures. Market conditions may play an important role in determining the part of the demand-pull effect that materialises into a bid price. The size (GWh) of a demand curve section may arise from explicit limits included in the policies, such as fixed quota, capacities or shares of total consumption, but also from market related limitations, such as the demand size of a specific market party the policy aims at. In addition, the origination process of policy-induced markets may play an important role for the year-to-year level and size of the demand curve sections. In some cases, there are identifiable limits determining which supply is eligible. Examples include the restriction to domestic supply, or the exclusion of specific options. In case it is not possible to define any upper limits to the demand size from the information in the policy database, the available potential or the size of the target are used as a basis for estimating the demand size.

3.1.1 Obligations on green electricity consumption, with penalties

Obligations combined with penalties are most easy to translate into demand curve sections: the obligation translates into the size, and the penalty tariff into the bid price. For practical reasons, government will usually lay obligations upon large parties such as suppliers. In this case, an immediate response to policy measures is likely and dynamic limits are of no practicable importance. The inherent inclusion of a demand limit means that the risk for market imbalances is low.

Obligations for suppliers on green electricity consumption, with penalties

Item	Description
Impact on:	Suppliers
Other parties involved:	-, maybe traders
Mechanism:	Specified (year-dependent) quota with penalties
Demand limits (policy):	Obligation size
Other demand limits:	-
Supply limits (policy):	e.g. exclusion of options, limitation to domestic producers, import

	capacities (none of these should be below the quota)
Other supply limits:	-
Dynamic limits:	Not likely. The supplier companies will probably respond very quickly and accurately to obligations, if the penalty level is sufficient high. It is however probable that both the penalty and the quota follow a path leading to the 2010 European target.
Practical approach	- Level: penalty (year-dependent) - Size: quota (year-dependent)

3.1.2 Feed-in tariffs

The ease of translation of feed-in tariffs into demand sections depends on the actual implementation. One main difference between feed-in tariffs and other support policies is that in the case of feed-in tariffs, producers benefit from nearly the whole support level, regardless of the equilibrium price. Other support systems and obligations offer more opportunities for other parties to draw advantages from the difference between the support level and the costs of the marginal option. For this reason, the demand-pull of feed-in tariff based systems is rather strong compared to other support systems, the bid price rather than the price of the marginal option being the appropriate indicator.

Feed-in tariffs for producers of green electricity

Item	Description
Impact on:	Producers
Other parties involved:	e.g. suppliers
Mechanism:	Premium on green electricity production
Demand limits (policy):	e.g. quota, import capacities, budgets
Other demand limits:	-
Supply limits (policy):	e.g. exclusion of options, limitation to domestic supply, differentiation by option or region
Other supply limits:	-
Dynamic limits:	Not likely. However, budgets or quota may be year-dependent, and tuned to the estimated possibilities for capacity growth
Practical approach	- Level: feed-in tariff (year-dependent) - Size: based on available potential, unless quota or budget limitations are specified

3.1.3 Consumer premiums on green electricity consumption

Consumer premiums on green electricity are quite difficult to translate into bid prices and demand sizes. Premiums on green electricity will lead to a smaller cost disadvantage of green electricity, or even to a cost advantage. The actual advantage for the consumers not only depends on level of the demand support, but also on the share of the support that goes to the producers and traders. This means that the support level is not the same as the price obtained by the producers. Because of the role of consumer behaviour, there are many uncertainties with regard to the actual policy derived demand size. The model applies the most practical approach, by allowing the user to define the assumed development of the demand size.

Consumer premium on green electricity consumption

Item	Description
Impact on:	Consumers
Other parties involved:	e.g. traders, suppliers
Mechanism:	Premium, exemption from energy taxes
Demand limits (policy):	e.g. Quota, import capacity
Other demand limits:	e.g. limitations to specific consumer categories

Supply limits (policy):	e.g. exclusion of options, limitation to domestic producers
Other supply limits:	-
Dynamic limits:	Gradual growth of green electricity market, with development from immature oligopolistic markets to more mature markets with more fierce competition. This development results in a growth of the demand size.
Practical approach	- Level: premium, energy tax; minus demand side transaction costs - Size: Scenario for dynamic limitations with split-up in smaller demand sections reflecting the variance in consumer WTP, upper limits because of specific limitations

3.1.4 Supplier premiums on green electricity delivery

Supplier premiums are less complicated than consumer premiums. The indolence of suppliers is likely to be much less than that of consumers, which results in a more immediate response to policy measures. Therefore, dynamic limits are of less, often negligible practicable importance. Another difference is the smaller role for mediators, if any. Suppliers are more likely to search for supply of green electricity themselves. A major consequence of this is that ill-defined policies will result very soon into market imbalances. If there are insufficient explicit or implicit limits on the allowed supply, countries are likely to get swamped by foreign supply.

Supplier premium on green electricity consumption

Item	Description
Impact on:	Supplier
Other parties involved:	-
Mechanism:	Premium on green electricity delivery
Demand limits (policy):	e.g. explicit (year-dependent) limits, import capacities, shares
Other demand limits:	e.g. specific delivery categories
Supply limits (policy):	e.g. exclusion of options, limitation to domestic producers
Other supply limits:	-
Dynamic limits:	Not likely. The trader companies will probably respond very quickly and accurately to stimulating measures.
Practical approach	- Level: premium-advantage minus transaction costs - Size: depends on actual specifications

3.1.5 Bidding Systems

Tenders may exist in numerous constructions. For the model, three main variants are relevant, with different degrees of freedom in the terms of the tender. For all variants, construction of demand curve sections is the easiest and most elegant way to model. After all, tendering is a competition-based policy instrument.

Location, capacity and technology specified.

In the first variant, most characteristics of the capacity are beforehand known. In terms of the model, the country, technology, band, and supply size are specified. The implementation in the model is a demand curve section for which only one technology-band combination is allowed. The main advantage of this approach is that there is no need to specify additional policy-based bands for the technology. Another advantage is that in case the terms of the tender are not attractive enough to investors, there may appear no investor prepared to do a bid. This means that the particular technology-band combination of the tender will not produce.

Technology (and maximum capacity) specified

The second variant has less detailed terms. Only the technology and maximum capacity are specified, but the choice of a location within the country is open to the investor. The implementation in the model is a demand curve section for which only one technology is allowed, but with all relevant bands. Again, a main advantage is that there is no need to specify additional policy-based bands for the technology. This avoids the problem of allocating the tender capacity beforehand to the available bands. Another advantage is that the model gives an indication of how much capacity for is placed under the tender construction, for what RGP and how much capacity derives its revenues from alternative sources.

Only green GWh specified

The third variant offers maximum freedom. Investors just compete for the delivery of green electricity and may do so with all kinds of technologies. This kind of tender may even act via an international TGC market. The implementation in the model is a demand curve section for which in principle all technologies are allowed. In case of discriminatory terms, selected areas or technologies may be excluded.

Bidding systems

Item	Description
Impact on:	Producers
Other parties involved:	-
Mechanism:	Bidding system with specified capacity and maximum budget
Demand limits (policy):	Specified capacity
Other demand limits:	-
Supply limits (policy):	e.g. exclusion of options, limitation to domestic producers
Other supply limits:	-
Dynamic limits:	Not likely. The terms of a tender will usually be case-specific and well-defined.
Practical approach	- Level: maximal fee (year-dependent) - Size: specified capacity (year-dependent)

3.2 Constructing supply sections based on costs and potentials for renewable electricity

A supply section is defined by its costs and size of potentials. In a traditional supply curve, such information is valid for the entire demand curve. In ADMIRE REBUS, the latter is not the case. Both the asking price and the supply size are specific for each combination of a supply option and a demand section. The specificity is necessary because of the restrictions that may be attached to the demand sections. These restrictions may apply to the benefits of alternative financial support and the incidental coupling of green trade to physical trade of electricity. Other restrictions apply to the place of origin, demands with regard to reciprocity or discrimination of specific technologies. This means that only for a specific demand section, the model can order the available supply options into a supply curve according to their ask price. Ultimately, the required green price is the base for the ask price, but in specific cases, other factors such as opportunity costs may prevail.

3.2.1 Costs: calculation of the Required Green Price

The potentials of the various renewable electricity options and the *Required Green Price* (RGP) of these options define the supply of capacity. This Required Green Price consists of the average minimal green price that the investor has to or wants to obtain from the market over the lifetime of the production capacity in order to make the construction of additional green capacity (or the production with existing capacity) attractive. This means that the RGP incorporates the investment and production costs minus those and only those revenues, including those from support policies that the producer expects to obtain outside the green electricity market.

The model calculates the costs using the NPV method with cash flow analysis. The aim of the NPV=0 calculation is to express the RGP as a function of the other parameters. It means that all the other parameters must be known beforehand; they are based on expectations or defined within the scenarios. Note that, apart from these parameters, the RGP of an investment project cannot vary over time, therefore RGP is assumed constant, i.e. the average, over the depreciation time t = 1..n for a given investment. The formula below shows the basic calculation of the RGP in dependence of various factors. The model applies a more complex version, incorporating taxes, lead times and transaction costs; see (Uyterlinde et al, 2003).

$$RGP = \left[(C - IP) + \sum_{t=1}^{n} \frac{RC_t + (VC_t - (PE_t + PP_t))Q_t}{(1+i)^t} \right] \Big/ \sum_{t=1}^{n} \frac{Q_t}{(1+i)^t}$$

n	Lifetime of the project
i	discount rate
t	year
C	Investment Costs
IP	Investment support (subsidies on new capacity)
RC_t	Fixed production costs at t[4]
VC_t	Variable production costs at t
PE_t	Reference electricity price at t
PP_t	Production support level per unit production at t
Q_t	Production at t

Note that production support generally is not included in the RGP calculation, because this is likely to act via a green electricity market, and the RGP should include only those revenues that the producer expects to obtain *outside* the green electricity market. The RGP definition includes the commodity price[5], which means that the bid price is purely for the green value of the electricity. Usually, the commodity price is the one of the supplying country.

3.2.2 Calculation of realisable potentials

The realisable potentials, used in the supply curves, are calculated from year to year in the Dynamic module of the ADMIRE REBUS modelling system. The Dynamic module is the link between the past and the present. It generates a starting situation for the initial calculation year and translates the results of the past year into relevant information for the present year.

In any given year, the supply curve reflects two types of renewable production capacity.

- The operational capacity inherited from past years and the potential that comes available again by the abandonment of old capacity. This requires the incorporation of a vintage approach to the present capacity.
- Realisable potentials for new capacity, taking into account various limitations due to the limited production capacity of the capital goods industry, the limited speed of opening up the available resources (e.g. biomass), the limited amount of potential entering exploratory courses (pipeline

---

[4] For existing capacity, it is economically attractive to produce if the revenues exceed the variable costs. Especially in the case of biomass options, this may be relevant, because of the relatively high share of fuel costs. Therefore, a formula that discerns between variable and fixed costs is to be preferred.

[5] The theoretical basis for this is that the ADMIRE REBUS model only describes the green electricity market. Mixing up the grey and green markets would give results that are difficult to understand and to explain. The pragmatic basis is that exclusion of the commodity price from the RGP would necessitate the inclusion of it in the bid price. As it is possible that a green producer delivers its electricity and its greenness to different customers, this would require the definition and calculation of separate bid prices for each possible demand supply combination, which would in fact mean the mixing up of the "green" and "grey" customers. The latter would result in higher calculation times and results that are difficult to analyse.

potential) and the limited amount of investment plans passing these courses and the accompanying legal procedures successfully.

In order to account for the effects of the lifecycles of the operational potential, the model incorporates a vintage approach.

4 Case study: will the EU Renewables Directive targets be met?

This section describes a case study that investigates whether the current support schemes are sufficient to meet the EU Renewables Directive targets. For this purpose, a scenario with continuation of current and foreseen support schemes has been analysed. Two policy-intensification scenarios with an obligation system, one without and one with trade provide the required references in order to determine whether mere intensifying of current policies or import offer solutions. The scenario without international trade does allow for imports of biomass (wood) resources to close the present policy gaps.

Table 4.1 presents the indicative targets as specified in the Renewables Directive, ranging from 5.7% in Luxembourg to 78.1% in Austria. As the targets are defined as a share of electricity consumption, projections have been used as a basis for calculating the targets in absolute terms. These electricity demand projections have been based on growth rates in (European Commission, 2000) combined with 1999 realisations (Eurostat).

Table 4.1 Renewable electricity targets in 2010 (targets including large hydro)

	Target 2010 (% of electricity consumption)	Target in GWh
Austria	78,1%	47.686
Belgium	6,0%	5.506
Denmark	29,0%	10.714
Finland	31,3%	27.239
France	21,0%	104.186
Germany	12,5%	66.752
Greece	20,1%	12.043
Ireland	13,2%	3.737
Italy	25,0%	81.573
Luxembourg	5,7%	411
Netherlands	9,0%	11.004
Portugal	39,0%	21.882
Spain	29,4%	70.927
Sweden	60,0%	82.744
UK	10,0%	41.475
EU-15	21,7%	587.879

4.1 Production under continuation of present support schemes

As Figure 4.1 shows, continuation of present policies is sufficient for seven of the current Member States. In the case of the UK and Sweden, a well-designed trajectory of quota obligations leads to an almost exact match. . For Denmark, we have assumed the introduction of the announced quota obligation and TGC system in 2004. However, if the current feed-in tariffs are continued, Denmark is not likely to meet its EU target.

For those countries using a system of feed-in tariffs, there is no direct relationship with the target. The amount of capacity installed is only related to the level of the support compared to the costs of renewables deployment in a specific country. Therefore, the fact that France almost exactly meets its target is merely a coincidence. Three countries, Austria, Greece and the Netherlands show an overshoot. However, this is not sufficient to make up for the eight countries falling short of their targets: as a whole, the EU attains only 91% of the aggregate target.

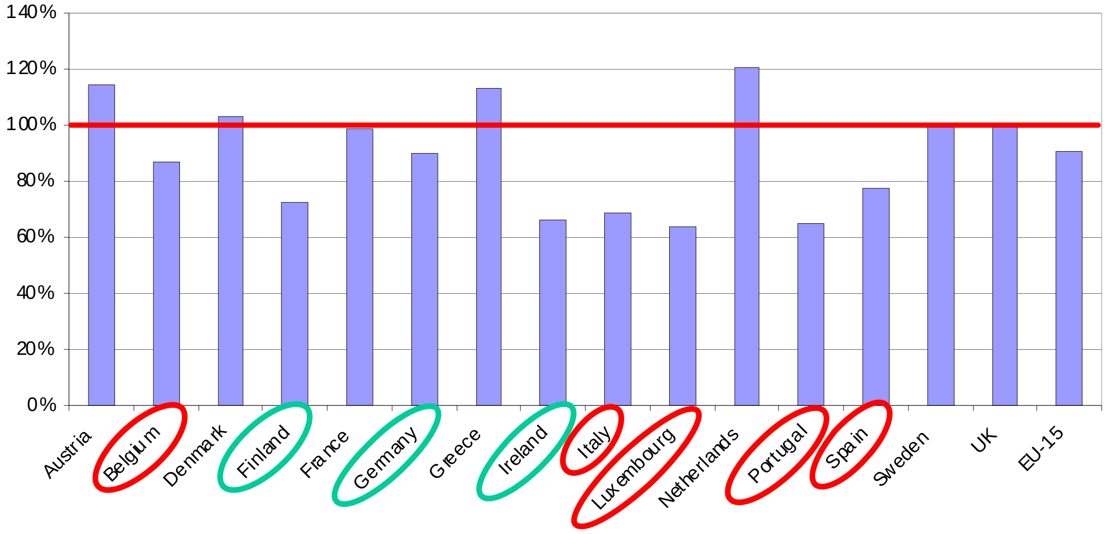

Figure 4.1 Consumption of renewable electricity as a share of national targets in 2010

In Ireland, Finland and Germany, marked green in the figure, moderate additional efforts are likely to bring the targets within reach. Ireland has plenty of wind potential, but the successor of the current AER6 programme has not yet been decided on. Probably, it will be sufficient to close the gap. In the case of Finland, there is also a lot of potential, but the current support level is very low, less than 1 €c/kWh. Slight increases of the support levels will make a lot of potential available. Germany is in an entirely different situation. Its gap is only 8%, but its current levels of policy support are already among the highest in the EU. However, the German support is rather selective, and does not cover all kinds of renewable potential. The harmonisation scenarios, in which not only the total amount of renewables changes, but the mix as well, confirm this. More support for especially some biomass options will easily allow Germany to achieve its target.

Belgium, Italy, Luxembourg, Portugal and Spain, marked red in the figure, face more severe problems in attaining their targets. Belgium and Luxembourg require a very large growth of their domestic production, which even more difficult because of the long lead times in these countries. In a situation without international trade, only the imports of additional biomass resource will solve the problem. The latter also offers a solution for Portugal. For the larger countries Italy and Spain, the respective policy gaps of 31% and 23% are even difficult to be closed by way of biomass imports. For these countries, the obvious solution comes from green electricity imports.

Finally, it is important to note that the Netherlands is the only country that partly achieves its target by imports in all scenarios. The Netherlands mainly imports its renewable electricity from countries that have a low domestic support level, such as Finland. If such countries intensify their support, the Netherlands run the risk that it will be no longer capable of attracting sufficient imports. Moreover, the Netherlands' system has to deal with a lot of additional uncertainty, as it acts via the stimulation of a voluntary demand.

4.2 Costs of achieving targets

Apart from the realisations, the costs involved are also important. The total costs of continuation of present policies amount to some 9 billion euro in 2010, but as mentioned this scenario fails to attain the target. Policy intensification without trade, with help of some biomass resource imports to fill remaining gaps, attains the target for some 17 billion euro in 2010. In contrast, the ideal scenario, with international trade starting in 2004, attains the target for 11 billion euro. In this scenario, targets are achieved in the most efficient way, because deployment is made in the cheapest locations. However, in particular in the short term, this scenario is not likely.

The contrast between continuation of present policies and the trade scenario becomes even more striking in a comparison of realisations and cost effectiveness after 2010 (Figure 4.2). In both 2015 and 2020, realisations in the trade scenario are considerably higher than with continuation of present policies. Despite the higher realisations, cost effectiveness is better in the trade scenarios from 2015 onwards. This advantage of the trade scenario is even much larger in 2020. This is not to say that the completely harmonised scenario is by definition the most cost-effective. Tailor-made support schemes that differentiate by technology can be cheaper, as confirmed by the cost-effectiveness in 2010. A uniform renewable support scheme by definition over-supports the cheaper options.

When looking at the benefits of trade for the individual Member States in the longer run, Sweden, UK and Ireland emerge as the main exporters, with considerable export benefits. The countries that benefit by replacing expensive domestic potential by cheaper imports include Belgium, Italy, Spain, Portugal, and the Netherlands.

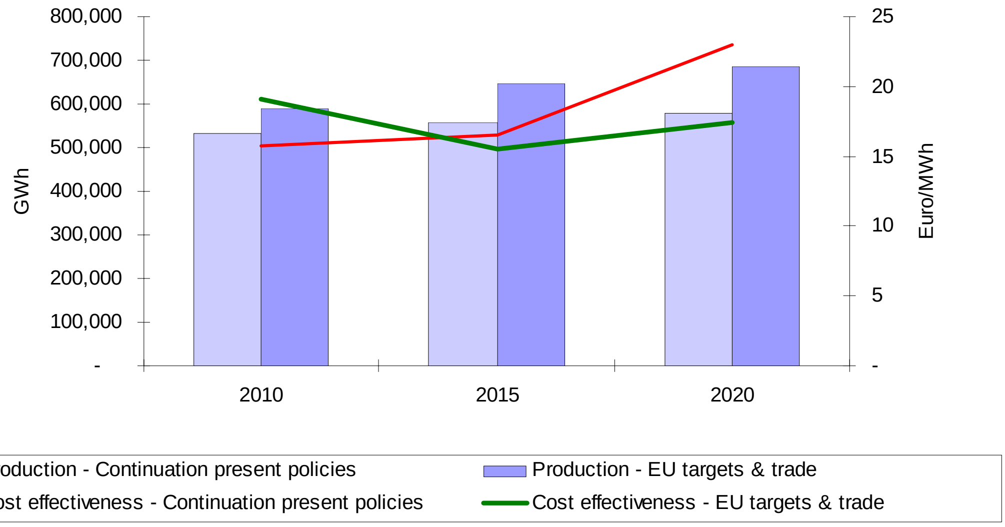

Figure 4.2 Costs of achieving the targets under different scenarios

4.3 Which technologies will contribute to achieving the targets?

Another important result is the deployment of the various technologies. Figure 4.3 shows the shares of the technologies in 2010, compared to a total production of 533 TWh. Large hydro, consisting mostly of existing capacity, is by far the most important technology with 52%. Wind onshore shows the largest growth and has a 19% share in 2010. In the policy intensification scenarios wind onshore and offshore and biomass, in particular biomass cofiring, gain. More ambitious scenarios are especially beneficial for wind offshore, which combines a large potential with relatively high but in the longer term decreasing specific costs.

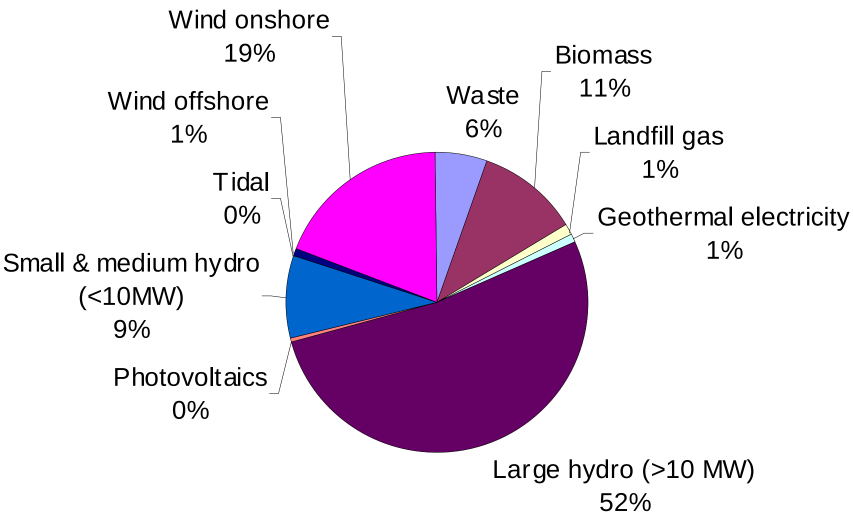

Figure 4.3 Technology mix in 2010 under continuation present policies

5 Conclusions

The case study results reveal only a small part of the complexities of the developing green market. With the current variety of support schemes there is not one single green market. Particularly at first, a gradual harmonisation with an increasing role of trade will result in even more complexities, but full harmonisation will produce a more transparent market in the end. The results indicate that it is unlikely that the present and planned policy schemes are sufficient to attain the overall EU target. For some individual countries, it is even nearly impossible to achieve the targets without trade due to the insufficient amount of domestic potential. For other countries moderate increases of the policy effort are sufficient.

The model is also capable of identifying the countries that benefit most from trade. Here it is important to stress that trade is not necessarily linked to a complete harmonisation of support schemes. The Netherlands is a good example, being currently the only country that accepts imports in some of its support schemes. However, in the current non-harmonised situation, the Dutch import flows are highly uncertain, as they may change due to slight changes in the terms of domestic support schemes in the exporting countries.

Finally, despite the presentation of only a selection of results, it will be clear the ADMIRE REBUS model is well equipped to grasp the full complexities of the developing green market. It accounts for the inherent diversity of policy support systems with their differences in eligibility, support levels and duration and discriminative terms. In addition, it accounts for all other important factors such as the role of risks, lead times, success rates of procedures and industrial production limitations. Therefore, ADMIRE REBUS is a tool suitable for supporting both policy makers in developing and evaluating renewable electricity policy, and investors in identifying market opportunities and analysing price expectations.

6 Acknowledgement

The ADMIRE REBUS project is partially funded by DG TREN (Energy & Transport) of the European Commission under the Altener programme. Project partners:
- ECN Policy Studies – NL (co-ordinator)
- RISOE, Denmark
- ZEW, Germany
- CSIC, Spain
- Observer, France

For further information:
Ms. Martine Uyterlinde
ECN Policy Studies
P.O. Box 1
1755 ZG Petten
The Netherlands
Tel:(+31)224 564369/4347
Fax:(+31)224 563338
E-Mail: uyterlinde@ecn.nl
www.admire-rebus.net

7 References

(European Commission, 2000) EU Energy Outlook to 2020

(European Commission, 2001) Directive 2001/77 of September 27th 2001 on the Promotion of Electricity produced from Renewable Energy Sources in the internal electricity market.

(Uyterlinde et al, 2003) Uyterlinde M A, Daniels B W, De Noord M, De Zoeten-Dartenset C, Skytte K, Meibom P, Lescot D, Hoffman T, Stronzik M, Gual M, del Río P, Hernández P. *ADMIRE-REBUS Assessment and Dissemination of Major Investment Oppprtunities for Renewable Electricity in Europe using the REBUS tool.* Interim Report. ECN, Petten. 2003

(Voogt et al, 2001) Voogt, M.H., M.A. Uyterlinde, et al., *Renewable Energy Burden Sharing - REBUS. Effects of burden sharing and certificate trade on the renewable electricity market in Europe.* ECN-report no. C--01-030, NL, June 2001.