BALMOREL CASE STUDY 1:

The Baltic Sea Region electricity market and the co-existence of markets for CO_2 emission quotas and renewable electricity certificates

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1. Introduction

Some of the central topics on the energy agenda in the countries of the Baltic Sea Region (BSR) are security of supply, market opening, EU admission, energy supply competition and an increasing environmental concern. Several studies have pointed towards the need for mechanisms supporting the overall regional economic and environmental targets and supporting the substantial need for technological transfer and investments in the new democracies of the BSR.

CO_2 emission targets following the Kyoto agreement are central. Consequently, the discussions of common policy measures for the BSR region have focused on Kyoto follow-up and flexible mechanisms. Such mechanisms will affect the relative competitiveness of fossil-fuel technologies but will also improve the competitiveness of renewable energy source technologies. However, an increase in renewable energy investments seems to be a *complementary target* for all the BSR countries [1]. It is therefore a central question if a carbon trading mechanism sufficiently complies with *both* CO_2 targets *and* renewable energy targets *or* if a complementary financial mechanism is needed for renewable energy. This paper presents the Balmorel model as an instrument of analysing these topics and gives some indications on what to expect.

The Balmorel project[1] is an attempt to provide the region with a common planning tool to be used in future calculations and discussions on energy and environmental policy measures for the region. A need for such a planning tool is among the conclusions of the Baltic 21-Energy project [2]. The project was initiated in the beginning of 1999. An introduction to the methods and to the main mechanisms and assumptions is provided in section 2.

In the next section version 1.01 of the Balmorel model used for the analysis will be outlined. Section 3 describes the scenarios used while section 4 provides the immediate results of the scenario analysis. Finally we will do some concluding remarks.

[1] Kindly supported by the EFP '99 programme of the Danish Energy Agency.

2. Brief description of the Balmorel model

For the analysis version 1.01 of the Balmorel model was used. The Balmorel model is an optimisation model minimising the regional costs of electricity and heat production finding the optimal production of each technology type in each country, the transmission between countries and investments in new production and transmission capacity. The current version of the model includes the areas covered by the Baltic 21 Energy report, which are Norway, Sweden, Denmark, Finland, Estonia, Latvia, Lithuania, and Poland as well as parts of Germany and the north-western part of Russia.

The model is a dynamic optimisation model finding the optimal levels of production and investments in the included countries. The objective function is minimising the operation and investment costs of the whole region. The model is solved for the period 1995 to 2030 and the optimal solution is found each year. In these years new investments in production and transmission capacities, which meet a first-year benefit criterion, can be made. These new investments are then added to the existing ones and give the initial capacities for the next year.

The model can divide the year into subperiods, which can differ with respect to electricity and heat demand as well as in wind and solar production in order to represent seasonal and diurnal variations. All scenarios presented in this paper have 4 subperiods a year being divided into two seasons (summer and winter) each of them having two hour types (day and night).

In general we have used the same assumptions as the Baltic 21 – Energy report, e.g.:

- Initial production capacities in countries
- Growth in consumption and fuel prices
- Water inflow to hydro reservoirs.
- Decommissioning of initial production capacities using a linear function. The last parts are decommissioned in 2030
- Nuclear power is phased out in the period

The initial transmission capacities between countries and the cost of building new capacity are not included in the *Baltic 21 – Energy* report and have been assessed from data from UCPTE [3] and Nordel [4].

The model and a more comprehensive description of the model can be found at the Balmorel project homepage: www.balmorel.dk.

3. Scenario analysis

The purpose of the scenario analysis is to investigate two policy measures that are currently discussed in various European contexts; a regional *carbon trading mechanism* and a *regional certificate-based market for renewable electricity*. These two mechanisms are in most cases discussed independently. However, the section provides an analysis of a liberalised regional electricity market with co-existing markets for carbon emission quotas and renewable electricity certificate.

Mechanisms of environmental trading

Only straight-forward assumptions are made with respect to the *carbon trading mechanim*. E.g. we will only look at CO_2 emission and not other greenhouse gasses, grandfathered emission quotas are distributed to countries based on historical CO_2 emissions (with no fiscal effect), a unique regional and market-based price is assumed on CO_2 emission quotas corresponding to the marginal abatement costs and so forth.

The certificate-based market for renewable energy has received much attention in 1999. The market is based on a *renewable electricity certificate system* (RECS)[2] in which the renewable electricity producer receives a certificate for each unit of electricity from renewable energy sources (RES-E) produced. Electricity is sold at a regional power market whereas the certificates are sold on a separate certificate market. The demand side of the certificate market can be defined as voluntary. However, it is assumed that *demand is based on a legal obligation* specifying that *all consumers must buy certificates corresponding to a certain percentage of annual electricity consumption*[3]. The market price of a certificate will thereby represent the *additional societal value* of RES-E (see also [5] and [6]).

Compliance with national/regional RECS obligations on the demand side allows us to assume that RES-E each year will represent exactly the percentage of aggregate national/regional RES-E production that has been defined by the Government(s).

National Strategy Scenarios

In scenario A1 and A2 the model calculations are made on the basis of national CO_2 goals and national CO_2 compliance.

In the A1 scenario we assume that each country will fulfil the Kyoto CO_2-targets (including EU burden sharing) and will gradually adjust the national emission to this level until the Kyoto goal is

[2] See: www.recs.org

[3] This is the model currently being implemented in Denmark. Equivalent schemes are currently considered in Belgium, the Netherlands, Italy, and UK.

reached in 2012. After 2012 no further CO_2 emission reductions are required. It is assumed that the energy sector should not reduce more than agreed on in Kyoto (i.e. that households, transportation, etc. reduce the same level). No export corrections to the national emissions are made.

In the A2 scenario the countries fulfil the Kyoto goals as in A1 but after 2012 we reduce the allowed CO_2 emission in all countries by 2 percentage points per year of emission allowed by the Kyoto protocol in 2012.

International Strategy Scenarios

Calculations are also made on 3 variations of A1 and A2. The first variation introduces a regional CO_2 market such that the marginal cost of CO_2 reduction will be the same in all countries. These scenarios have the postfix C. The second variation introduces a regional renewable electricity market, i.e. the RECS scheme defined above. These scenarios have the postfix RE. Finally a combination of the two markets is included. These scenarios have both postfixes.

For the economic assessments we compare the results with a reference *business-as-usual* scenario (BAU), where no reductions are required.

To sum up, the scenarios in the analyses are:

Scenario:	**Short name:**
Business as usual - no reductions	BAU
Kyoto	A1
Kyoto + CO_2 market	A1-C
Kyoto + RES-E market	A1-RE
Kyoto + CO_2 and RES-E markets	A1-RE-C
Further reductions	A2
Further reductions + CO_2 market	A2-C
Further reductions + RES-E market	A2-RE
Further reductions + CO_2 and RES-E markets	A2-RE-C

Size of RE targets

Only a few of the included countries have specified targets for the RES-E percentage of total electricity demand. However, all countries have specific objectives related to renewable energy and provide a number of different promotion programmes [1].

In the RE scenarios we assume a regional goal of 10% RES-E in 2000, which increases 1 percentage point per year to 40% RES-E of the total electricity demand in 2030. These targets are based on the following definition of RES-E:

- 10% of the hydropower capacity are RES-E (representing small scale hydropower)
- 80% of electricity produced by waste are RES-E
- All windpower and biomass are RES-E

The definitions above were made in order to ease the implementation of the RE certificate market. In order to create an efficient market all existing large-scale hydropower plants (i.e. bigger than 10 MW) are excluded, since they can compete on the real power market and do not need the additional income of a RE-certificate to be cost efficient.

Size of CO_2 targets

Targets concerning the CO_2 emission levels are based on those given in the Kyoto Protocol. They are calculated using the 1990 emission level from the IEA statistics. For the countries, which before 1992 were a part of the Soviet Union, the emissions in 1990 are found using the emission the countries had in 1992 as weights for the 1990 emission of the total Soviet Union.

4. Evaluation and comparisons

In the following section the results of the scenarios will be analysed.

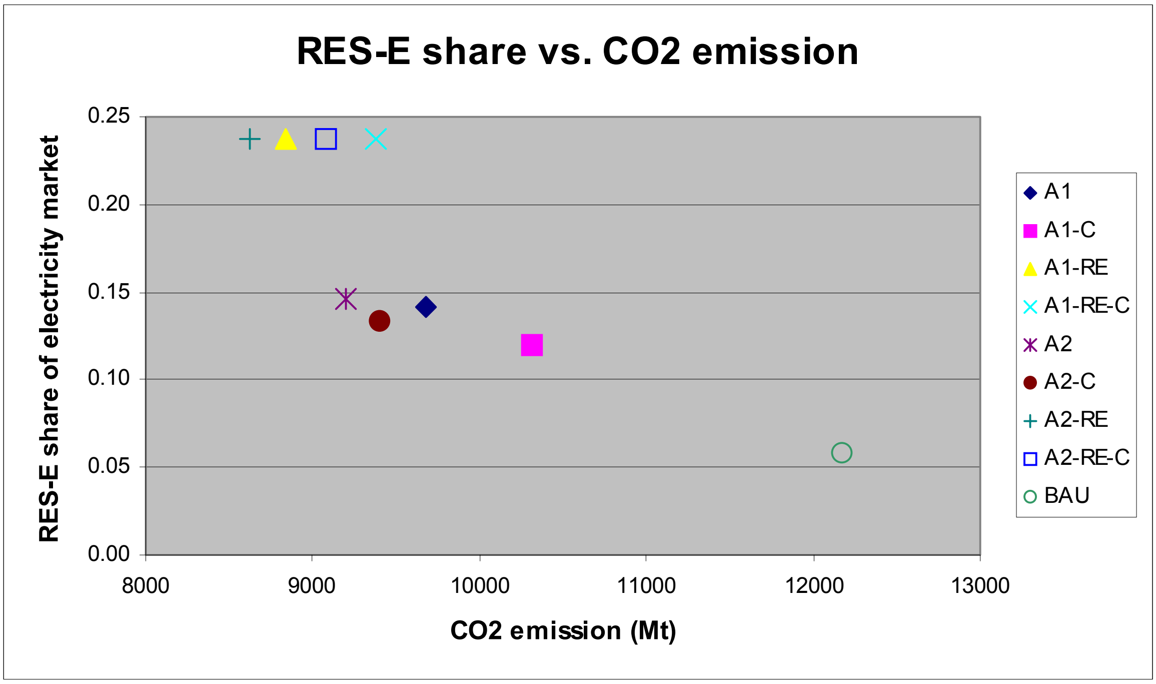


Figure 1 - The trade-off between promoting RES-E and reducing CO_2 emission

Figure 1 shows how different markets (CO_2 and RES-E) lead to different achievements in CO_2 reductions, share of renewable fuels, and the cost of reducing the emission.

We see that the national quotas (in A1 and A2) are stronger than regional ones (A1-C and A2-C) since the national strategies will not permit the individual countries to sell unused parts of their quotas to other countries. And it do appear that some countries with most certainty will have relative large unused parts of their quota, which they in the regional CO_2 trading scenarios could sell and thus increase the CO_2 emission compared with the pure national emission quotas in A1 and A2. The extent of this "hot air" problem though will not be analysed further in this paper.

Table 1 shows the total system costs (fuel, operation and maintenance, investments in production and transmission capacity) in the whole period.

We see that the system costs when having a regional CO_2 market and regional CO_2 emission target are less than system costs based on national goals, as expected.

Scenario	**Cost (bill. US$)**	**Cost index (B=100)**
BAU	443.52	100.00
A1	462.18	104.21
A1-C	450.51	101.58
A1-RE	471.51	106.31
A1-RE-C	461.77	104.11
A2	471.25	106.25
A2-C	454.07	102.38
A2-RE	479.20	108.04
A2-RE-C	461.98	104.16

Table 1 – Total cost of the different scenarios

From the emission values in figure 1 and the cost values above we can compute the average (both average in the period 1995-2030 and terms of the countries) costs of reducing the CO_2 emission when comparing with the reference scenario. These reduction prices, which are shown in table 2, is thus lower than the prices of the emission permits, which should have a price equal to the marginal reduction cost.

The average reduction cost when allowing regional emission trading is, as expected, lower than the cost when not allowing emission trading. But we also see an indication of the reduction costs of the RECS scenarios is higher than the non-RECS scenarios.

Scenario	Average reduction costs (US$/t)
A1	7.48
A1-C	3.76
A1-RE	8.40
A1-RE-C	6.53
A2	9.32
A2-C	3.81
A2-RE	10.06
A2-RE-C	5.96

Table 2 – The average CO_2 reduction costs for different scenarios

Table 1 and 2 provide the immediate conventional and non-conventional results of the model calculations:

- a regional CO_2 market and a regional CO_2 goal are more cost-efficient ways of reducing the CO_2 emission than working nationally.
- RE market seems to be a costly way of reducing CO_2 – i.e. if the CO_2 target is the *only* target, only a regional CO_2 market should be promoted!
- there is a trade-off between compliance with the targets of RE and CO_2

As indicated above all countries have *separate/independent* targets for the deployment of renewable energy sources for reasons of CO_2 but also based on other values (emissions of acid, job creation, security of supply, diversification etc.).

The relation between policy measures and the CO_2 and RE targets will be analysed further on the next pages.

The next 4 figures show the electricity production in the BSR by fuel usage. We see that the choice of fuel is very dependent on whether a CO_2 market or a market based on RECS is chosen.

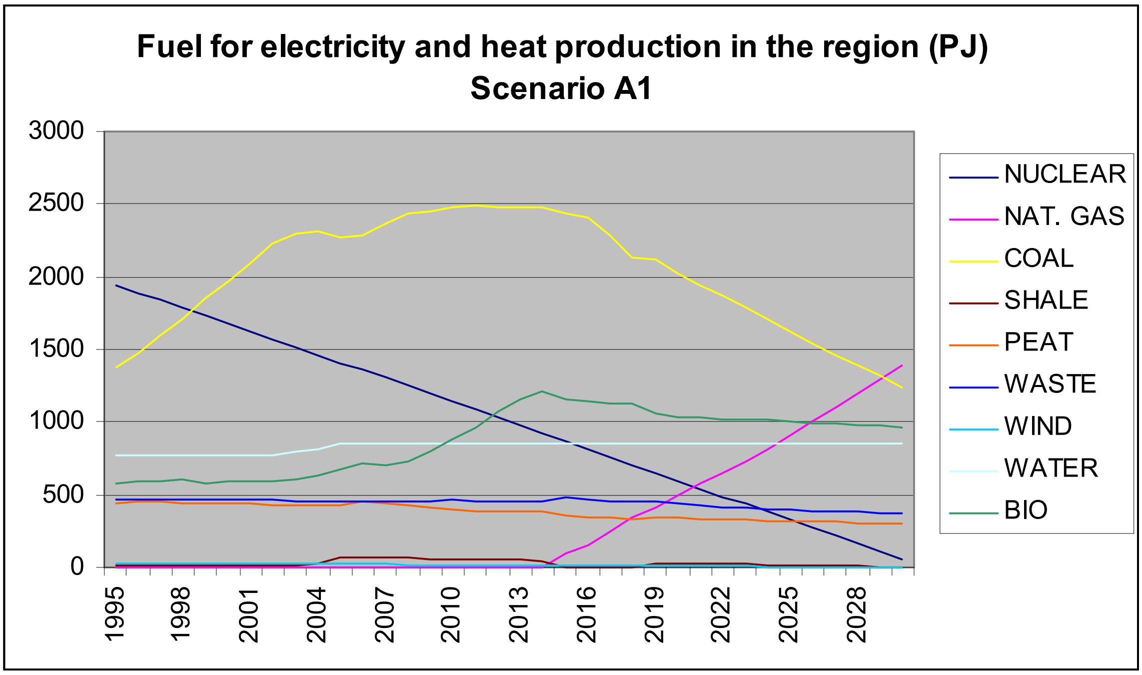


Figure 2 – Electricity production by fuel in scenario A1

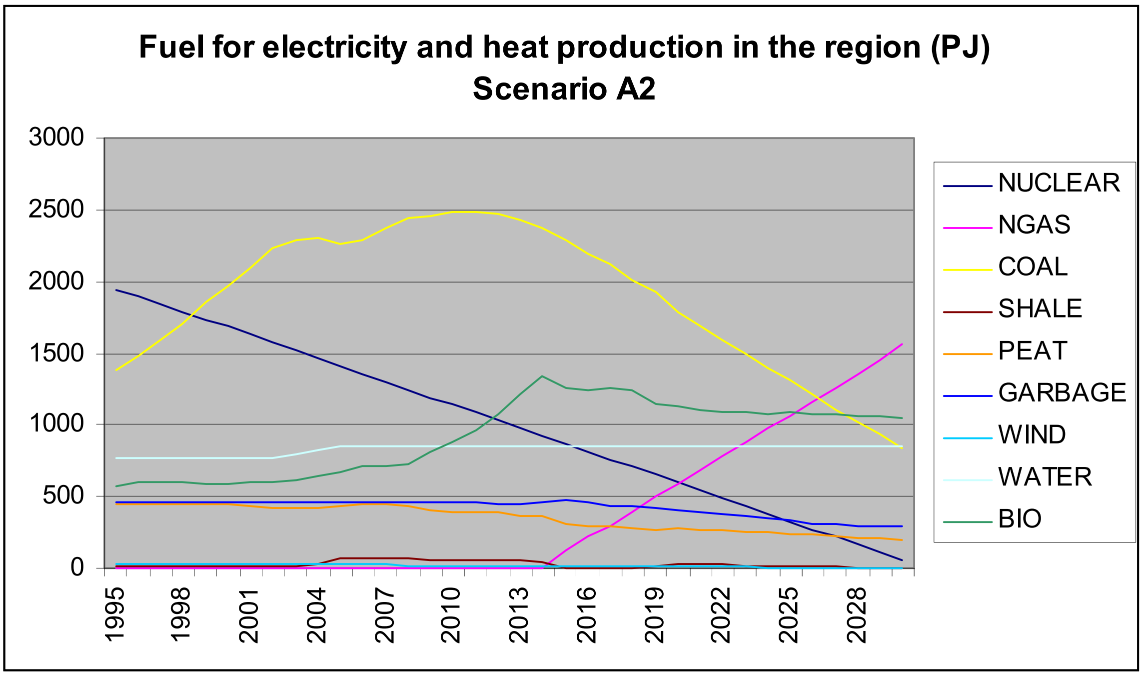


Figure 3 – Electricity production by fuel in scenario A2

From figures 2 and 3 we see that a further reduction in the CO_2 quotas nationally will mainly lead to an increased substitution of coal by natural gas, which turns out to be the cheapest way to reduce the CO_2 emission.

Figures 4 and 5 show the effect of implementing either a regional market for CO_2 emission permits or for RES-E. Compared to the A1 scenario we see that implementing a regional market for CO_2 emission permits as in A1-C will lead to a greater use of the fuels with high CO_2 emission, peat and coal, and less of the low CO_2 emission fuels, gas and biomass. So once again we see that the national goals are tighter than regional goals (but more expensive also), since the reductions in the former case do not necessarily take place in the country where it is cheapest.

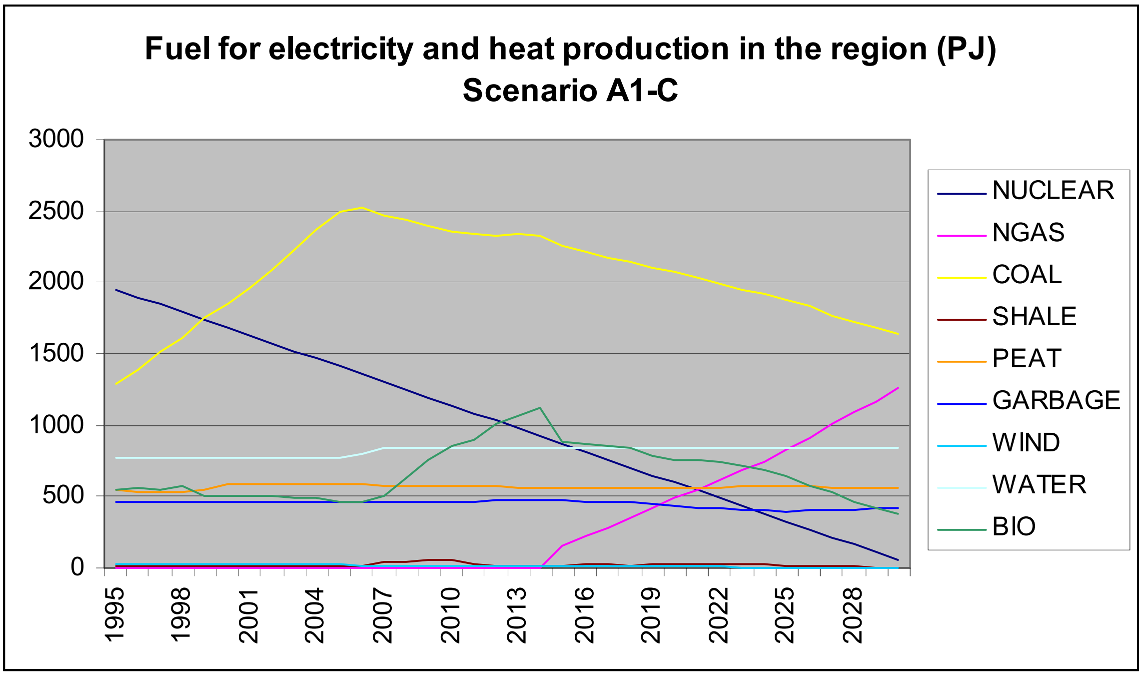


Figure 4 – Electricity production by fuel in scenario A1-C

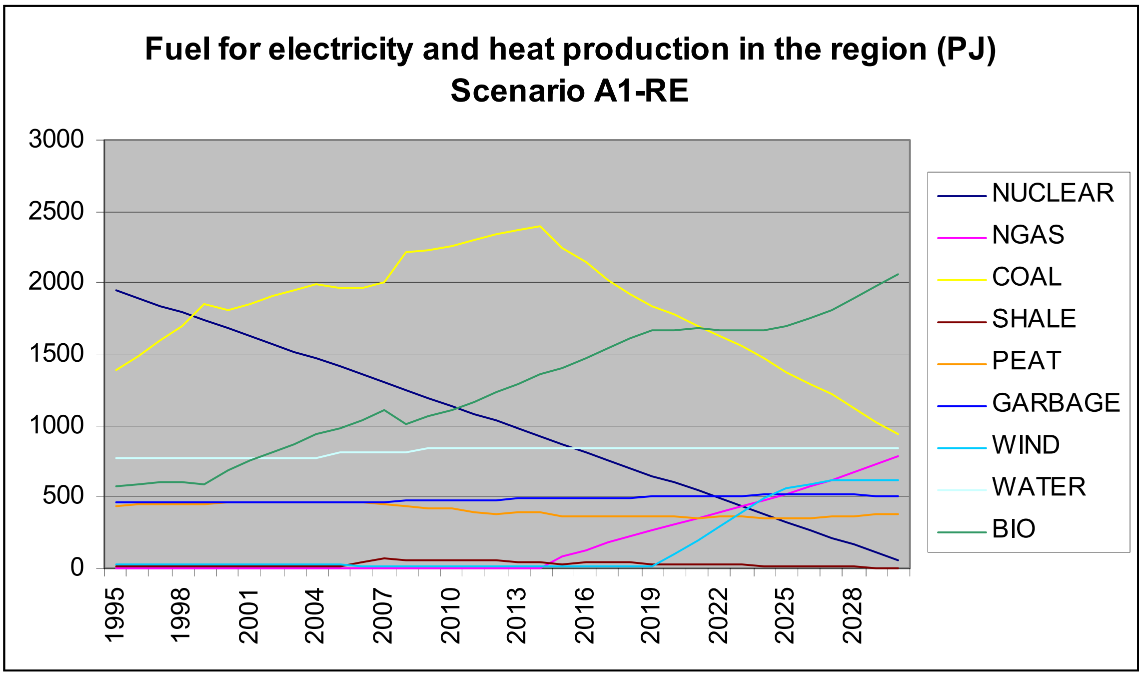


Figure 5 – Electricity production by fuel in scenario A1-RE

Implementing a regional market for RES-E as in scenario A1-RE leads to greater investments in RE technologies, which we did not see in the other scenarios. Thus, 200 TWh of the electricity consumed will in 2030 come from biomass fueled power plants, while windmills will provide another 50 TWh. The cost though is high when compared to achievements in reducing the CO_2 emission, so implementing a market for RES-E should only be done in order to reduce the use of fossil fuels resources pursuing the goal of sustainable energy development.

Having both the CO_2 and the RES-E markets will not change the fuel usage for electricity production much compared to only having the RES-E market. As seen in figure 1 and table 1 though the CO_2 emission is higher but the cost of reduction lower.

In all scenarios we see full utility of the nuclear power plants, which with the related costs in this model are very competitive with other technologies and fuels.

Now we will look on the electricity market price as it is in Denmark, Latvia, and Norway as well as and the price of CO_2 emission permits and RE certificates. The prices show in the graphs in figures 6 – 9 are average prices in each year weighted by the length of the subperiod.

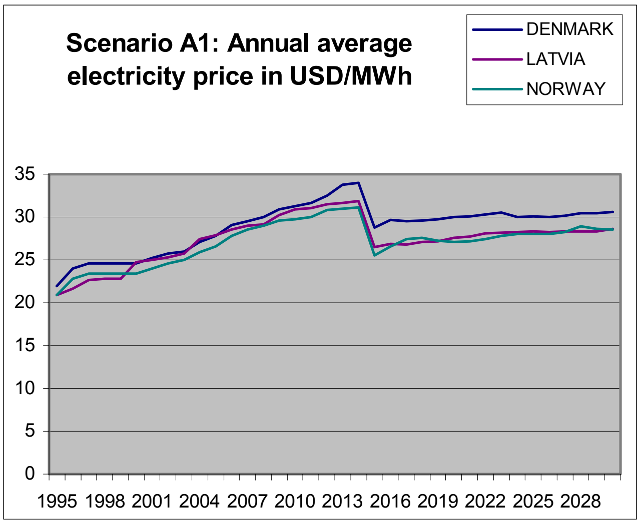


Figure 6 - Electricity price, A1

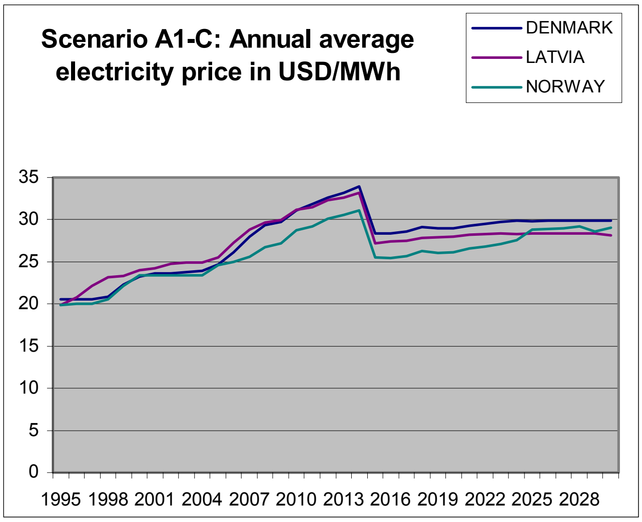
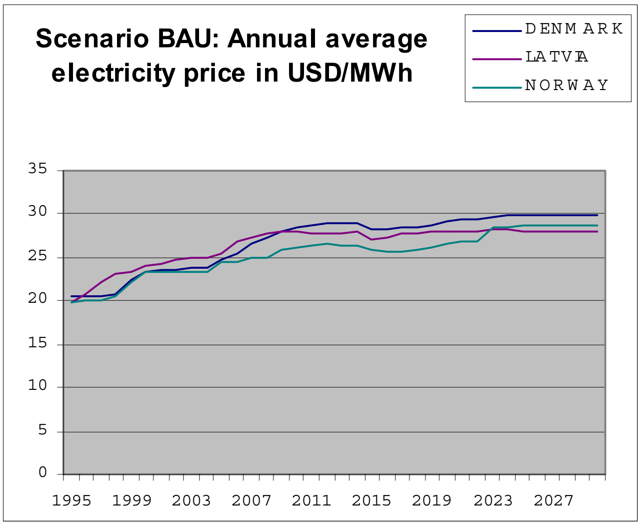


Figure 7 – Electricity price, A1-C

Firstly we see, that the price in Denmark is higher than the price in Norway (no cheap hydropower), and the price difference between the two countries is due to transmission constraints. Otherwise it looks like creating a market for CO_2 emission permits will cause slightly lower prices at some points compared with using national goals with no way of trading emission. The “jump” in 2015 is due to new and better technologies, which are assumed to become available in this year.



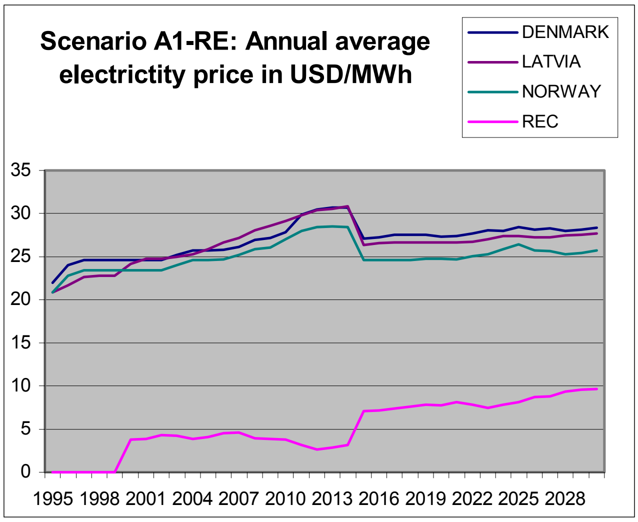


Figure 8 - Electricity price, BAU

Figure 9 – Electricity price, A1-RE

In figures 8 and 9 we see that imposing a market for RES-E will lead to higher market prices initially, but the market price actually ends up lower in the A1-RE scenario than in the BAU scenario. This can happen because the fixed share of the total demand that RES-E should have moves the intersection of the supply curve S (which in the figure below is made of the capacity of non-RE technologies and the capacity left of RE-technologies, after the RES-E target has been met) and the demand curve left, since the "free" market demand D_2 is now less than before D_1. The price may therefore drop as indicated from P_1 to P_2. Note that the demand curve is vertical since demand is assumed to be unelastic in the model.

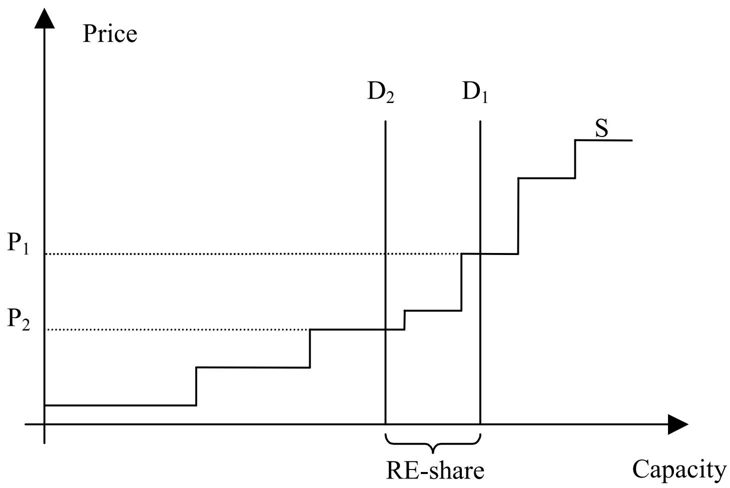


Figure 10 – The supply and demand intersection

The REC price shown in figure 9 was derived from the shadow price of the RES-E restriction. This price should be added to the market price to show the whole sale price. This is shown in figures 11 and 12 below.

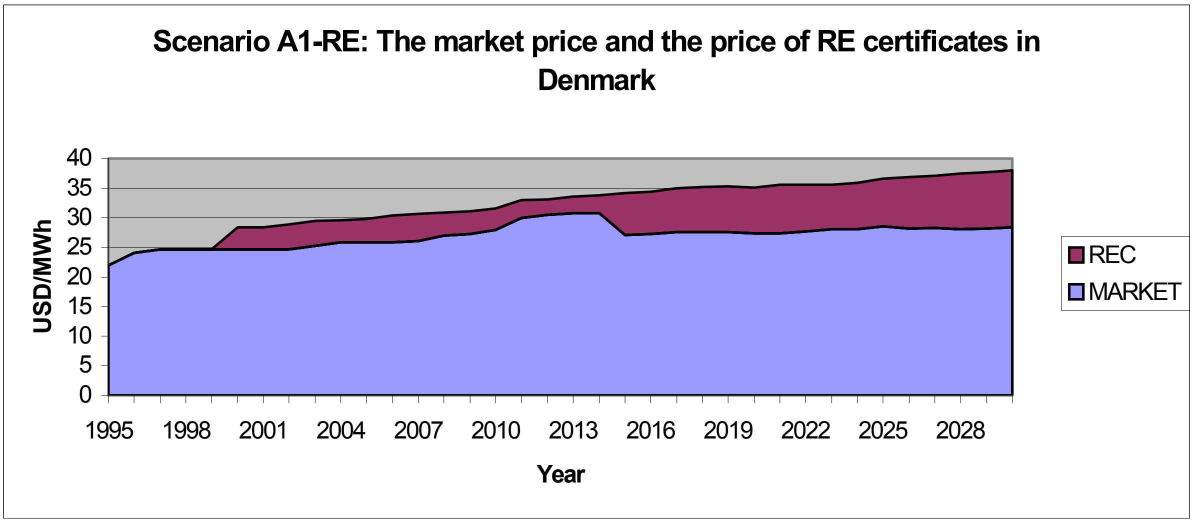


Figure 11 – The price of electricity in Denmark in the A1-RE scenario

We see that the price increases from the year the RES-E market is started. The price increase though is only on the RE-certificate. The total price will increase steadily totally levelling out the jump caused by the availability of new technologies. The reason is that no new RE technologies enter in 2015 – only conventional, so the same "old" RE technologies keep being the marginal one. We end up with a price on the RE certificates of approximately 10 USD/MWh.

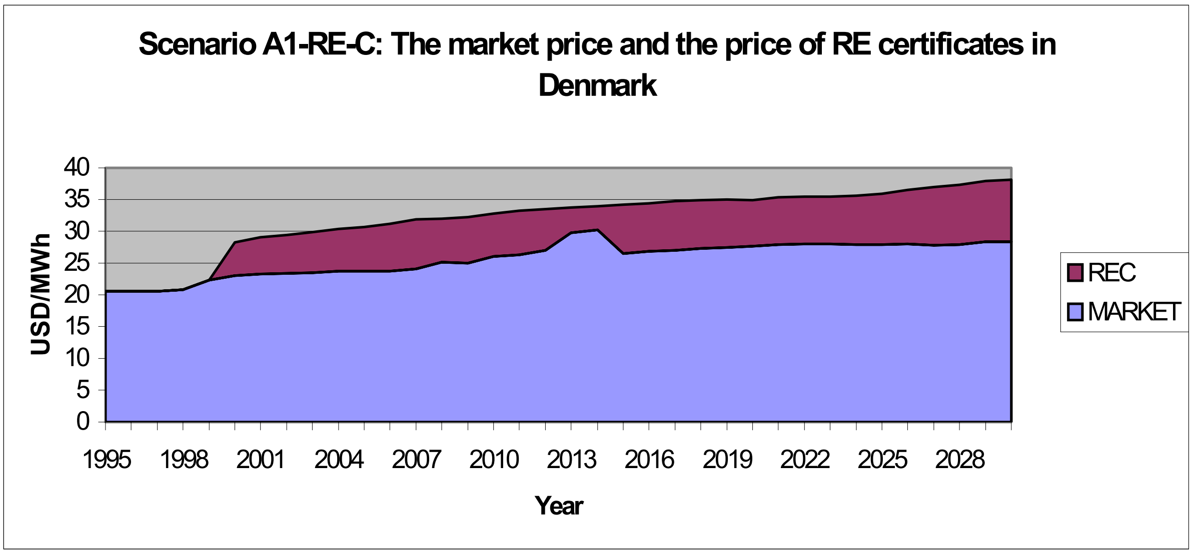


Figure 12 – The price of electricity in Denmark in the A1-RE-C scenario

When looking at the A1-RE-C scenario we get the same picture though the price tends to be a little higher. Both for scenarios A1-RE and A1-RE-C we see a positive price on the RE-certificates, so the price setting technology is a RE technology (otherwise the price would be zero).

When looking at the transmission between countries during the period till 2030 we see that the scenarios differ considerably. Figures 13-15 show the net annual transmission in the scenarios A1, A1-C, and A1-RE. The most visible difference is that the transmission between countries in scenario A1 is a great deal higher than for the other scenarios. The reason is that the price of reducing CO_2 emission is different in the different countries. So the countries with the greater reduction costs and with hard CO_2 targets will generally buy electricity from countries with cheap reduction costs or easy-to-reach emission targets, rather than invest in new and more expensive technologies nationally.

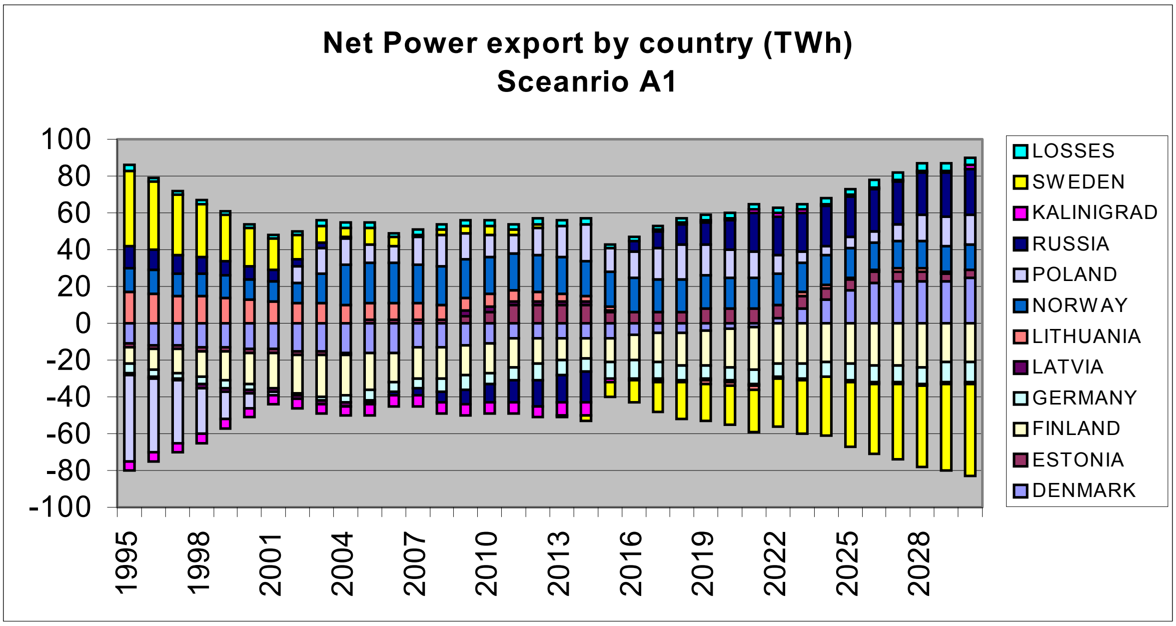


Figure 13 – Net electricity export by country – scenario A1

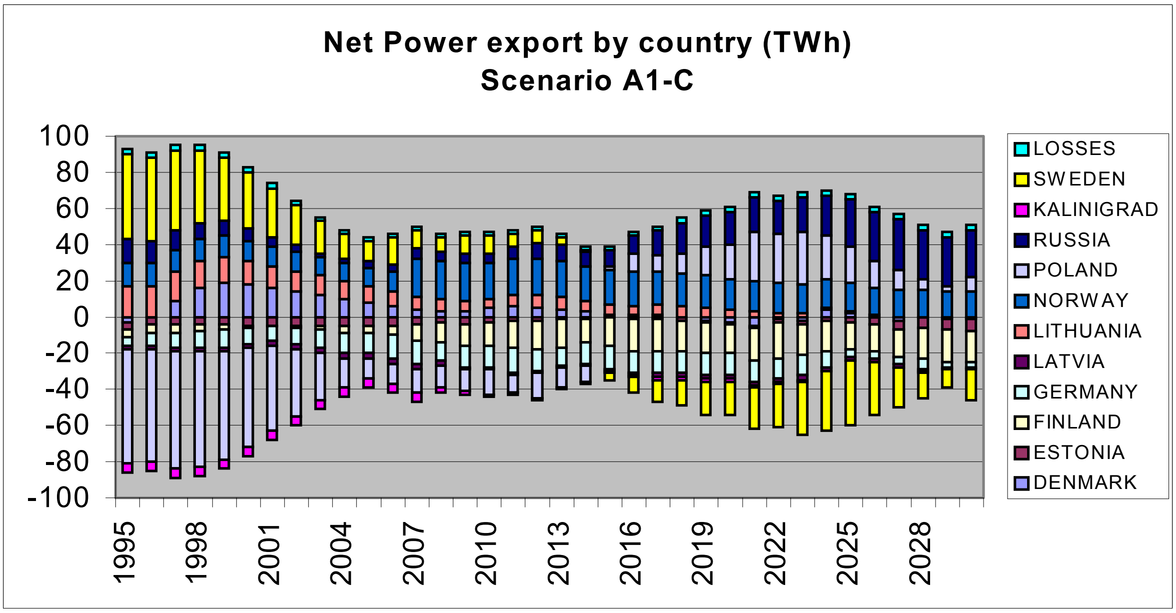


Figure 14 – Net electricity export by country – scenario A1-C

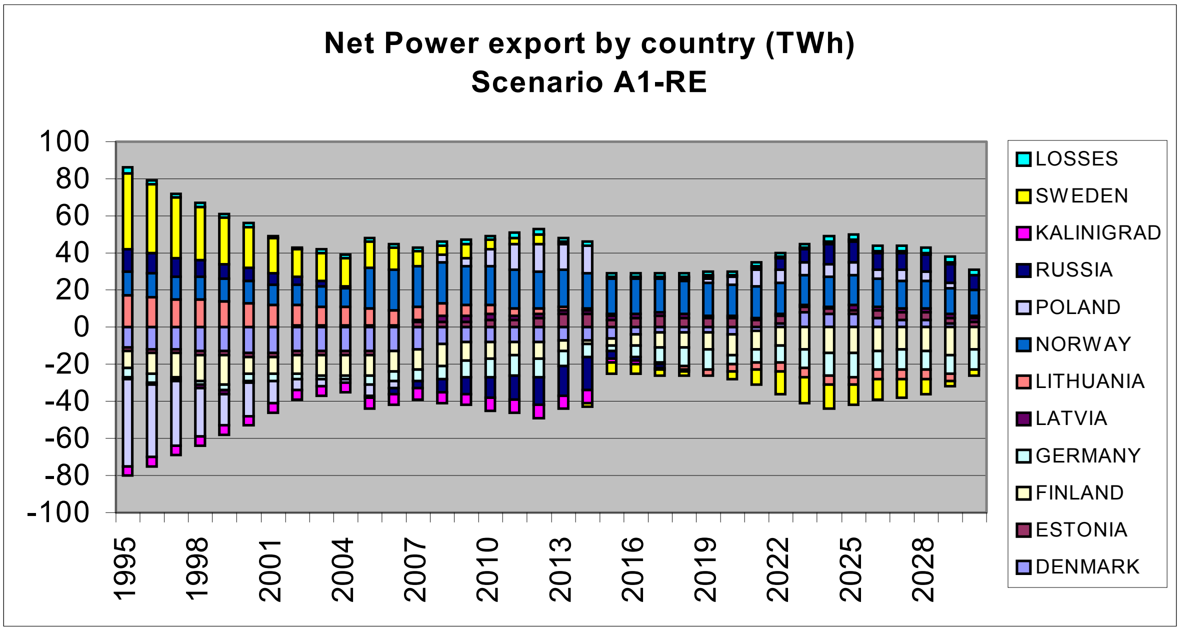


Figure 15 – Net electricity export by country – scenario A1-RE

In figure 15 we see that creating a market for RES-E tends to lower the gain of trading electricity between countries. The main reason for this is that the new RE technologies, which the countries are building, are placed locally. I.e. biomass fueled CHP plants are placed in connection with national district heating systems and windmills are placed in the countries needing them. Note that the efficiency of windmills (and all other technologies) is assumed to be same for all countries in the BSR though the amount of energy produced by a similar mill will vary considerable if placed in different parts of the BSR.

5. Conclusions

The preliminary results of the model indicate that achievements with respect to CO_2 and RE are separate goals. When having national targets, it looks like importing electricity for some countries will be cheapest way of reducing the national emission. This indicates that reductions sometimes can be achieved more cheaply in other countries, either because the have larger potentials of cheap RE productions or because the national emission quota are harder to reach in some countries than others.

This observations tell us that if the goal is to reduce the CO_2 emission globally (and in this case regionally), this is cheapest done by creating a regional CO_2 market for emission permits. But such a market does not support the development of renewable energy technologies like biomass and windpower. Pursuing the goal of making the BSR more independent of fossil fuels will benefit better of creating a regional market for RES-E. As we have seen, such a regional market will lead to a huge increase of renewable energy technologies, which again will ensure that considerable R&D in such technologies will take place.

The quantitative analyses in the paper have been undertaken using the Balmorel model. As the paper has shown, this model is useful for analyzing multi-regional markets as the BSR. However, the model has not been verified by comparing the results with those of other models, but such studies will take place later this year. Until that the results must be regarded as very preliminary.

6. References

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