Green Certificates and Emission Permits in the Context of a Liberalised Electricity Market

*By Stine Grenaa Jensen**

Introduction

In Denmark a comprehensive legislative restructuring of the electric power industry was completed in 1999 ("Elreformen", 1999). This Danish Electricity Act provides a fast schedule for liberalisation including a restructuring of the organisation of the Danish power sector.

As the power market is being liberalised, additional markets are introduced. This includes a framework for a separate green market for renewable electricity production. The main objective of introducing this type of market in Denmark is to secure the development of renewable energy technologies, including contributions to greenhouse gas reductions. Finally, a green market will enable these renewable technologies to be partially compensated for environmental benefits which they generate compared with conventional power production. According to Danish electricity reform a share of 20 percent of total electricity consumption has to be covered by the end of 2003. (See the burden sharing within the EU in COM(2000),2000)

Furthermore, to assist Denmark in complying with commitments under the Kyoto-protocol, tradable CO_2 permits are introduced in a bubble consisting of the power industry. The targets for CO_2 emission are set according to the agreed burden sharing within the EU, where Denmark has agreed to reduce emissions by 21% compared to an import adjusted 1990 emission level. (See the burden sharing in Boots et. al., 2000, page 20).

Increased use of renewably based power production will also lower thermal production on the power market and thereby decrease total emissions arising from power production. Therefore, besides ensuring a desired percentage of renewable energy, the green quota has the positive effect that a smaller percentage of power production emits green house gasses, thereby achieving the goals in the Kyoto agreement. The green quota will, therefore, to some extent, lower the emission level and consequently indirectly work as the emission quota.

Likewise, introduction of an emission quota would favour renewably based power, since it would increase the cost of thermally based power. As a result, renewably based power would become more competitive on the common power market and thereby lead to higher sustainability in power production.

Based on the Danish regulation set up, this paper analyses the equilibrium effects of introducing emission permits and green certificates as regulatory mechanisms, to reduce emissions and ensure a certain deployment of renewable energy, respectively. The analyses in this paper will be based on a small System Dynamics model and they will be theoretical only. Simulations will show the equilibrium effects of letting the planner use both the green quota and emission quota at the same time in order to reach the two goals. The quotas are thus the regulation instruments, whereas the certificates and permits are the means used by the market to fulfil the quotas.

Tradable Green Certificates

The main idea of a market for green certificates is to ensure a politically planned deployment of renewable energy technologies, with the idea of a liberalised energy framework and maintaining low consumer prices. Compared with other methods of promoting development and deployment of renewable energy, green certificates deal with energy that is actually produced and not merely capacity that is available. Each time a green power producer sells electricity to the grid, he receives a corresponding number of green certificates. These certificates are financial assets and tradable. In addition to the physical power market, they can be sold in an organised, financial market established for green certificates thereby providing an additional payment to the producer for each unit of electricity generated. As a result of this, the price obtainable by the producer of the renewably based electricity will be the sum of the market based settling prices for physical electricity and the price of a green certificate.

The demand for green certificates is determined politically. It can be, for example, a purchase obligation on the production side like in Italy or on the consumer side as in Denmark. In any case, a desired share of renewable electricity can be obtained by setting the appropriate quantity of green certificates that will be issued. This quota is called the green quota. (see Morthorst, 1999, Schaeffer et. al., 1999 (1) and Schaeffer et. al., 1999 (2) for more information on the green certificate market.)

Tradable Emission Permits

Another regulation instrument in the new Danish electricity reform is the tradable emission permit scheme. As part of the Danish Electricity Act, tradable CO_2 emission quotas have been introduced in the power sector. If the CO_2 quotas are violated a penalty of approximately 5,5[1] Euro per ton CO_2 emitted must be paid. If the fine is set too low producers will pay the fine rather than actually reduce emissions. Thereby the emission quota will have the effect of an emission tax. The target in Denmark is to reduce emissions by 21% compared to an import adjusted 1990 emission level.

Emission permits are issued based on the emission source and ignore the effect emissions may have on different receptor points. Permits issued to electricity generators allow them to emit up to a specified level of emission, with the total number of issued permits equal to the national limit on emissions. Generators that reduce emissions below their allowed level can sell excess emission permits, which can be purchased by other generators for whom it is more cost-effective to purchase permits at the prevailing market price than to reduce emissions.

In the Danish system, CO_2 emission permits are expected to co-exist with a green certificate market, thereby presenting an interaction between the two markets. But while tradable emissions permits will influence the emissions of greenhouse gases directly, the certificate market will only indirectly

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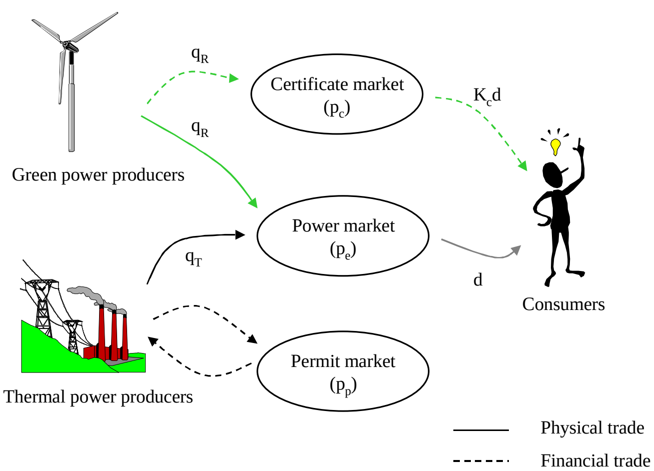
[1] See footnotes at end of text.

influence emissions. Counterwise the green certificate market will influence renewable electricity production directly, while the emission permit system affects it indirectly.

Model Description

The model used to carry out the analyses is a small System Dynamics model, which involves the market participants, illustrated in Figure 1. The renewable producer is acting on the power market and the green certificate market. The thermal producer is acting on the power market and the emission permit market. And finally the consumer is acting on both the power market and the green certificate market.

Figure 1
Actors in the Different Markets.



The consumer will purchase physical power on the power market and certificates on the certificate market. The green producers deliver certificates to the green certificate market corresponding to the amount of electricity produced, which is sold at the power market. The thermal producers likewise deliver physical power to the power market, but they are also obliged to obtain a number of emission permits corresponding to the amount of emissions accompanying their electricity production. These emission permits can be purchased in the permit market when there is a need for additional permits, and sold in the case of a permit surplus.

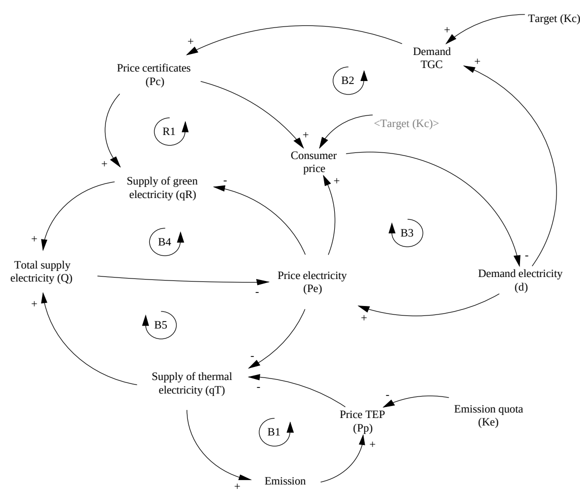
This leads to a model, where all three market participants deal on the power market and one additional market. These interconnections lead to an interaction between the different price determinations, and a change in market conditions on one market will thereby indirectly affect all three markets.

Figure 2 below shows the major feedback loops in the model, i.e., the connections between the three markets and their entrants. The figure provides an overview of the components in the model, incorporating equilibrium assumptions. In the diagrams, the arrow linking any two variables, x and y, indicates a causal relationship exists between x and y. The sign at the head of each arrow denotes the relationship between the two variables as follows:

$$x \xrightarrow{+} y \Rightarrow \partial y / \partial x > 0 \quad \text{and} \quad x \xrightarrow{-} y \Rightarrow \partial y / \partial x < 0$$

The description of the interconnections assumes that all other variables are constant. The description thereby illustrates the reaction pattern in the model, without saying anything about the final simulation results.

Figure 2
Feedback Loops in the Model



Loops connecting demand and supply exist through both of the supply functions. The balancing loop (B4) indicates that an increase in green production leads to a decrease in the power price, which again leads to a decrease in green power production. This case corresponds to the loop showing the thermal case. These loops illustrate the adjustment between the two suppliers of power in response to the power price, in order to bring total power supply in line with demand.

The balancing loop (B1) represents the market clearing mechanism in the emission permit system. An increase in supply leads to an increase in emissions, which yields an increase in the emission permit price. This way the supply level declines and production is balanced, leading to an equilibrium price for emission permits. Likewise the balancing loop (B2) illustrates the market clearing mechanism in the green certificate system and the equilibrium price on green certificates.

The market clearing mechanism loop in electricity price determination (B3) could by initialised by unfulfilled demand. Unfulfilled demand generates an increase in prices, which again leads to further production to fulfil the demand, and when this level is reached the price level returns to normal.

The only major reinforcing feedback loop (R1), in the model, is the one able to raise demand again and again. This is the loop showing the renewable producer's advantage, when the green quota is raised. When the supply of green electricity rises, the price of electricity decreases, the demand for electricity increases, and thereby the demand for certificates increases. This leads to an increase in the green certificate price and finally the supply of green electricity raises to a new level. This could generate a spiral, where the part of the market allocated to the green producers keeps rising, if no other effects follow to stop it.

Model Assumptions

This section describes some of the assumptions made in the model in order to carry though the simulations. The

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determination of demand is based on consumer elasticity[2] for electricity and the expected consumer power price. The elasticity is set to 0.01 and is, therefore, quite inelastic, according a smaller variation in demand than in price.

The price determinations of the green certificate price and the power price are found through the supply and demand differences in order to set equilibrium prices. An increase in price is caused by excess demand and likewise a decrease in price is caused by excess supply. This leads to an equilibrium situation in the long run, where demand equals supply at equilibrium price.

The green quota is set at 20 percent. No additional consumption of green certificates is allowed, i.e., demand for certificates has to equal one fifth of total consumption. The model omits both upper- and lower price-bounds of certificates.

The emission quota in the model is set subjectively at 9 million tonnes CO_2. This corresponds roughly to a decrease of 50 percent from the 1990 level in the Danish electricity industry. The price determination of emission permits is through the disparity of the actual emission level and the emission quota, which will lead to an equilibrium emission permit price.

Simulation Experiments

Three different situations will be considered in order to illustrate the effect of either an emission quota or a green quota:

- Reaching an emission goal
  - Emission quota: 9 million tons CO_2
  - Green quota: NONE
- Reaching a green quota
  - Emission quota: NONE
  - Green quota: 20% renewable energy
- Comparison of co-operative versus non co-operative decisions
  - Non co-operative
    - Emission quota: 9 million tons CO_2
    - Green quota: 20% renewable energy
  - Co-operative
    - Emission quota: NONE
    - Green quota: 30% renewable energy

The first case shows the different effects of using an emission quota or a green quota in order to reach an emission goal. In the second case the goal is to get sustainable electricity production in the form of renewable produced electricity. The third and last case has the objective of illustrating the difficulties of using two instruments to reach two different goals without co-operation, when the instruments interact through the power market.

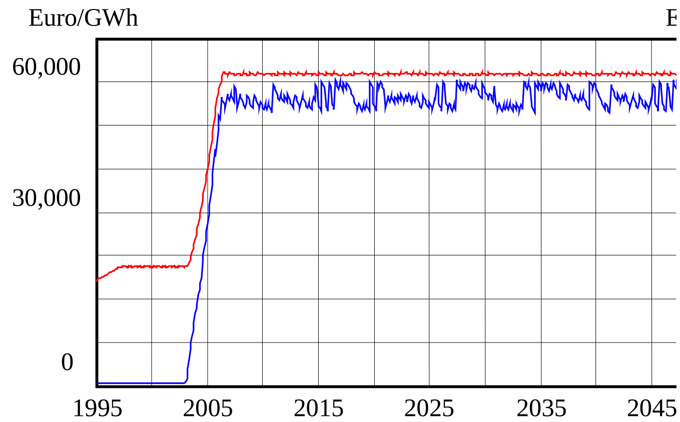
The simulations should show different implications, when introducing one or several mechanisms in order to reach different goals, with respect to the long run equilibrium case.

Reaching an Emission Goal

The emission goal can be reached either by the use of an emission quota, a green quota or by a combination of both. One needs to regulate if the emission goal is lower than the amount of emission that occurs without regulation.

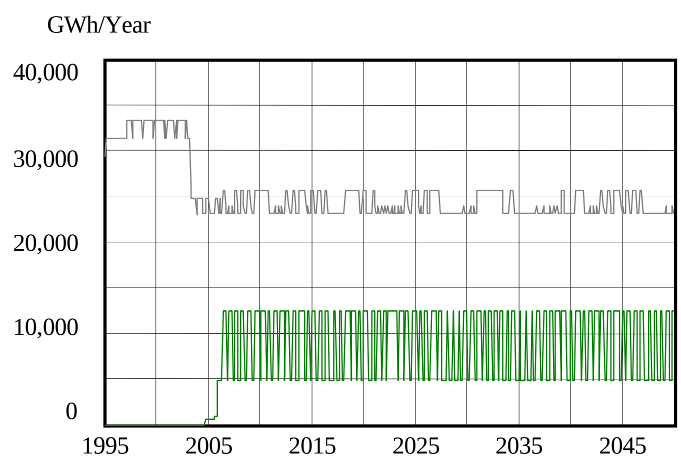
If the planner uses only the emission quota and not the green quota, the result will be a positive equilibrium price for emission permits at a level that illustrates the cost of reducing one unit of emission. The price of certificates will be zero, provided that there is no binding green quota (Figure 3).

Figure 3
Power Price (top) and Emission Permit Price (bottom), Introduction of Emission Quota When t=2003.



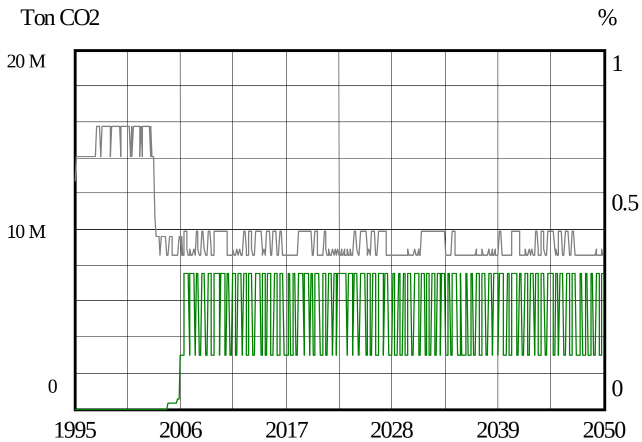
With an increase in the emission permit price and an increase in the electricity price, the producers of renewably based electricity will get better market conditions and the production of “green” electricity, therefore, increases; counterwise thermal production decreases resulting from the additional costs from the emission permits (Figure 4).

Figure 4
Power Production (Thermal-top line and Renewable-bottom line), Introduction of Emission Quota When t=2003.



The effect of the emission quota is, of course, seen on the actual emission level, which falls to the desired level of 9 million tonnes CO_2 on average over a year (upper line in Figure 5). At the same time the percentage of renewable produced electricity increases to 23 percent on average as a result of the power price effect following the introduction of the emission quota (lower line in Figure 5).

Figure 5
Total Emission and Percentage of Renewable Electricity, with Introduction of Emission Quota When t=2003.



At the same time the emission goal could be reached using the green quota, as the introduction of more renewably produced electricity would replace the thermal production, which leads to a decrease in emissions. It is, however, much more difficult to find the exact green quota in order to reach an exact level of emission, not knowing the direct effect caused by the price and demand change.

It is also possible to use both instruments in order to reach one desired emission goal. It is, however, difficult to use several mechanisms to reach one goal, when it is possible to use only one. The use of several instruments also requires an insight into the interaction between the two instruments as well as insight into the separate markets. The fact that the emission permit market, the green certificate market, and the power market are coupled has an important effect. This exact case will not be simulated in this paper, but the results are similar to the case of co-operative decisions. (See Jensen and Skytte, 2001 (2) for more detail on the interactions.)

Reaching a Goal of Renewable Energy

In the following section the focus is on the green quota, and there are no direct considerations of emissions. This could correspond to the objective of developing sustainable electricity production. Like the emission goal, this goal can be reached either by the use of one of the markets separately or by a combination of both.

If the planner uses only the green quota to regulate, the green certificate price will reach a level that illustrates the value of a percentage of sustainable power production. The emission permit price will be non-existant. The power price has a negative correlation with the green certificate price, which is why the power price falls with introduction of a binding green quota (Figure 6). An example of an analytical model of the interaction between the power market and the green certificate market can be seen in Jensen and Skytte, 2001 (1) and Jensen and Skytte, 2001 (2).

With a decrease in the power price and a positive certificate price the producers of renewably based electricity will get improved market conditions and the production of "green" electricity, therefore, increases. At the same time the lower power price weakens thermal producers and, therefore, thermal production decreases (Figure 7).

Figure 6
Power Price (bottom) and Green Certificate Price (top), Introduction of Green Quota When t=2003.

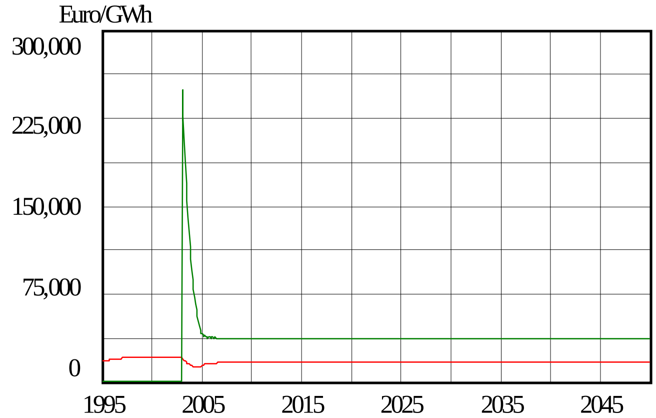
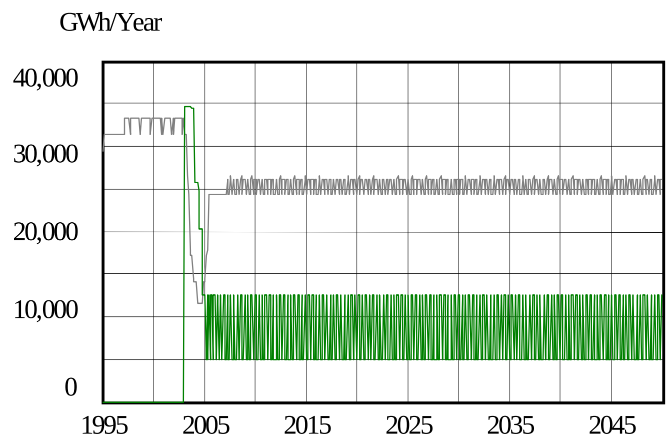


Figure 7
Power Production (Thermal-top line and Renewable-bottom line), Introduction of Green Quota When t=2003.



The effect of the green quota is seen directly on the percentage of renewable electricity production, which averages 20 percent a year (lower line in Figure 8). At the same time emissions decrease to a level just above 10 million tonnes CO_2 per year. It should be noted that a green quota of 20 percent is not enough to reach the desired level of emissions below 9 million tonnes CO_2 per year (lower line in Figure 5).

Of course, it is still possible to use the emission quota or both instruments in order to reach a desired renewable energy goal, with the same reflections as in the former case.

Comparison of Co-operative Versus Non Co-operative Decisions

In this section two different scenarios will illustrate the difference between co-ordinating the decisions and trying to reach the goals without co-ordination. If the state has both an emissions goal and a renewable energy goal, with two different offices administrating one instrument each, we would get the case without co-ordination. The emissions quota and green quota will both be operating, and all three

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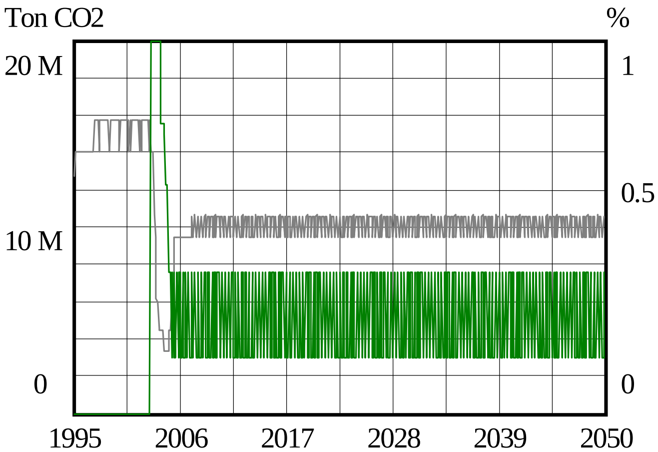
markets are then interacting.

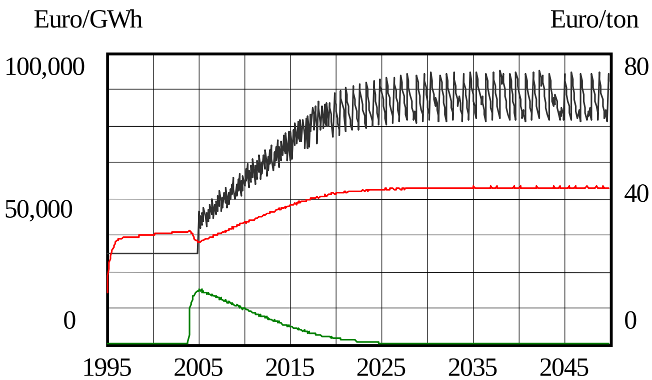
Figure 8
Total Emission (top) and Percentage of Renewable Electricity (bottom), with Introduction of Green Quota When t=2003.



Assume that one office determines an emission quota of 9 million tonnes of CO_2 in order to reach an emission goal. At the same time another office determines a green quota at 20 percent to reach a renewable electricity production. This case is the non co-operative situation illustrated in Figure 9 and partly in Figure 10. It is seen that the green quota is unnecessary to reach a deployment of renewable produced electricity, i.e., the equilibrium certificate price equals zero after a while, but the emission permit price remains positive (Figure 9). This could indicate that it is unnecessary to spend time and money to implement a green certificate system, since the green quota is reached anyway by using only the emission quota.

The power price in the middle of Figure 9 rises caused by the positive correlation to the emission price.

Figure 9
Emission Price (top), Power Price (middle) and Green Certificate Price (bottom) in the Non Co-operative Case.

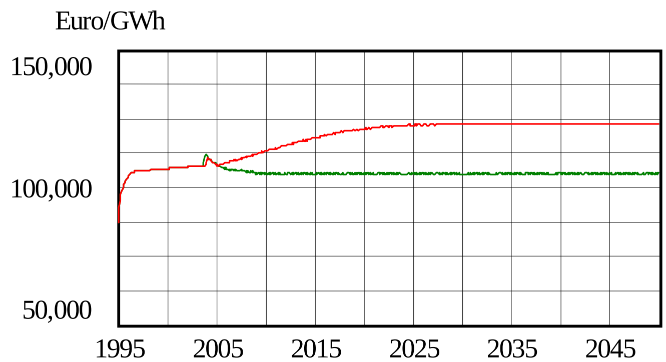


In the co-operative case the offices could, however, consider the correlation between all three prices in the determination of the two quotas. This gives not only a correlation between the power market and the two regulating markets, but also a correlation between the emission permit price and the green certificate price. This correlation exists through the power market and is thereby highly affected by it. The correlation is negative; i.e., an increase in one indirectly leads to a decrease in the other. This negative correlation explains why the two regulatory mechanisms can be used as substitutes for each other. (See Jensen and Skytte, 2001 (2) for more about this correlation.)

The quotas should be set by optimising the social surplus or consumer surplus with respect to the correlations and the desired goals. The simulation shown here does not illustrate an optimised situation, but it does show a combination of quotas that reaches lower consumer prices and thereby lower consumer surplus.

If the planners from the two offices co-operated in the determination of the quotas, they could set the green quota at 30 percent and no emission quota. They could thereby reach a lower consumer price than in the non co-operative solution, and both the goals would still be reached (Figure 10). As a side effect it would only be necessary to implement one additional market, saving the cost of introducing two markets. It should, however, be mentioned that other circumstances, not included in this model, could influence the indirect effect on the emissions, and thereby eliminate the advantage of having only one regulatory mechanism.

Figure 10
Example Consumer Prices in the Co-operative (bottom) Case and Non Co-operative (top) Case.



Discussion and Conclusions

In the light of the recent deregulation in most European countries and the following introduction of market based regulation methods, it has been shown in this article that the interaction between the different coupled markets has impact on the equilibrium results of an implementation of regulatory mechanisms. In order to analyse the considerations to be made, when two regulatory mechanisms are used in combination with a liberalised electricity market, this paper illustrates some of the problems in the coupled markets and separate goals.

A simple System Dynamics model was used to simulate different effects of introducing emission permits and green certificates as regulatory mechanisms. The simulations show how interactions between the green certificate market, the emission permit market and the power market can influence prices and the attainment of desired goals. Due to this interaction the political planner (the state) can use both instruments in order to reach an emission goal or a goal of a certain percentage of renewable energy in electricity production.

The simulations show the importance of knowing the interaction of the different markets, if the plan is to introduce both an emission permit market and a market for green certificates, as in the case of Denmark. Of course, the goal can be reached without co-ordination, but it was shown that it could be reached at lower consumer prices and thereby larger consumer surplus with some form of co-ordination. Further work will look at the effects on the social surplus, to determine the effect from the producer side in the model and find the actual goals in the optimal situation.

It was shown in several simulations, that it is possible to reach an emission goal using green certificates as the regulatory mechanism and likewise using the emission permit system to reach a green quota. Having both an emission goal and a renewable electricity production target does, therefore, not necessarily lead to an implementation of both additional markets, or the planners should at least co-ordinate the quotas in order to reach the most optimal situation for society or consumers.

Quite a large number of problems remain to be investigated on the effect of interactions in regulated and coupled liberalised markets, e.g., effects of uncertainty and the actual development for the present situation. Furthermore, it will be very interesting to watch the actual implementation of the green certificate market in the forthcoming years, and observe if one of the two regulatory mechanisms is unnecessary to achieve the goals, like the simulations in this paper would indicate.

Footnotes

[1] Calculated with an equivalence of 1 DKK = 7,46 EURO.

[2] Price elasticity: $\varepsilon = \frac{-\Delta d}{d} \Big/ \frac{\Delta p}{p}$, where d is the demand and p the price.

References

Contact the author.