1. Introduction

The aim of the paper is to present a detailed analysis of the key influencing factors of investment decisions in a certificate market for renewable energy, like the Polish one.

Green certificate markets are based on the political definition of a minimum market share of green energy in final consumption. Producers of energy from renewable sources receive green certificates from the regulator. Suppliers of energy are obliged to fulfil a certain quota of green certificates according to the stipulated market share. On the certificate market, producers will sell their green certificates to suppliers and receive revenues that are additional to the value of the produced “black”. Thus, green certificates provide an essential incentive to invest in renewable energy sources. Suppliers will allocate the additional cost to their clients. At the end, the final energy consumer will pay for the cost incurred by green certificates. In order to limit these costs in periods where the minimum market share is not reached, and demand for green certificates will not be met, the regulator sets a price cap. In periods with coverage of minimum demand, the certificate price will fall to the price that will result from the merit order of renewable energy sources or to a floor price, which might be set by the regulator.

Investors on such markets have to face – in difference to markets with feed-in tariffs like Germany – price uncertainty. This price uncertainty results from the fact that investors cannot be sure about, if the required market share will actually be reached in future and what price of certificates can be expected.

For this reason, they have to presume the actions of other market participants: Can it be expected that other potential investors utilize their investment opportunity? Can it be expected that due to these anticipated investment decisions other investments will be delayed or even not realized? Might it even be expected, that risk-averse investors will refrain from additional projects if the price of green certificates might fall and that the minimum market share will never be reached after all?

For this problem, we prepared a simplified agent-based model, which simulates investment decisions on basis of the assumption that the behaviour of other agents is built on past development trends.

The model allows for the simulations of possible scenarios of certificate prices and investment development in the respective technologies of renewable energy production, i.e. biomass co-firing, wind, water, biomass, and biogas.

We investigated the investment decisions of several types of investors. As we will see for the case of the Polish market, we may expect that the quota for renewable energies will hardly ever be reached and that as a result, the price will be constantly close to the price cap.

1 All: DREBERIS GmbH, Gostritzter Str. 63, D-01217 Dresden, Germany
2. Main assumptions for the Polish electricity market

Poland will face a significant increase of final electricity demand. This forecast is based on the assumption of constant economical growth on the one hand and continuous increase of energy efficiency on the other hand. This rise of electricity demand shall be accompanied by a dynamic growth of the share of Renewable Energy Sources (RES) (ref. Figure 1).  

![Figure 1: Development of final electricity demand and production of electricity from RES (source: Energy Policy 2009)](image)

3. The promotion scheme for RES in Poland

In Poland, regulations concerning remuneration of power from RES were established by the Energy Law\(^3\) and several ordinances by the Council of Ministers. A separate law for the support of RES technologies does not exist.

A quota obligation system was implemented in 2000. Electricity suppliers delivering electricity to end customers were obliged to generate a certain share of electricity supplied from RES. Electricity suppliers have two possibilities to cover this quota – by producing power from RES on their own, or by purchasing TGCs (so-called świadczenie pochodzenia - certificate of origin). The main regulatory office, URE, delivers one tradable green certificate (TGC) per MWh produced.

The obliged quotas increase according to the following chart:

\(^2\) For a detailed overview on assumptions ref. to Energy Policy 2009.
\(^3\) Ustawa z dnia 10 kwietnia 1997 r. - Prawo energetyczne, Dz.U. 1997 nr 54 poz. 348.
However, due to a lack of penalties, the quota system did not work in the beginning. Only when the Energy Law was amended in 2005, penalties were introduced for companies that did not meet the targets. The amount of the penalty also provides the maximum price for TGCs.

The Polish quota system specifies two income sources for producers of power from RES:

1. The price for produced electricity, calculated as the average market price in the previous year.
2. The price for the TGC, which can be sold via the Warsaw Energy Stock Exchange or in bilateral contracts.

There are no differences between the prices of energy produced using different technologies. Of course, the price for the TGC depends on the market situation. However, until now the quota was never covered (ref. Figure 3).

<table>
<thead>
<tr>
<th>Year</th>
<th>Electricity price (PLN/MWh)</th>
<th>Maximum price TGC (penalty fee)</th>
<th>Total (PLN / MWh)</th>
<th>Exchange rate</th>
<th>Total (EUR / MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>117.49 PLN</td>
<td>240.00 PLN</td>
<td>357.49 PLN</td>
<td>3.90</td>
<td>92 EUR</td>
</tr>
<tr>
<td>2007</td>
<td>119.70 PLN</td>
<td>242.40 PLN</td>
<td>362.10 PLN</td>
<td>3.78</td>
<td>ca. 96 EUR</td>
</tr>
<tr>
<td>2008</td>
<td>128.80 PLN</td>
<td>248.46 PLN</td>
<td>377.26 PLN</td>
<td>3.52</td>
<td>ca. 107 EUR</td>
</tr>
<tr>
<td>2009</td>
<td>155.44 PLN</td>
<td>258,89 PLN</td>
<td>434.33 PLN</td>
<td>4.33</td>
<td>100 EUR</td>
</tr>
<tr>
<td>2010</td>
<td>n.s.</td>
<td>267,95 PLN</td>
<td>n.s.</td>
<td>4,07</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

Table 1: Development of price components of RES in Poland 2006-2010 Source: Regulatory office URE, Polish power exchange, Deutsche Bank research.
Due to the fact that Poland chose a “market oriented” promotion scheme for RES, prices are not stable, which is described in Figure 4.

Figure 3: Demand vs. realisation of RES production (source: URE, ordinance)

Figure 4: Prices of Green Certificates 2006-2009 (source: Polish Power Exchange)
4. **Price forecast for Green Certificates**

In order to develop a forecast of future production of RES (and thus the offer of Green Certificates) we prepared a microeconomic model. This model simulates the investments into new RES capacities on behalf of the investment decisions of representative investors („agents“).

We separate the following technologies and their respective cost structure:

- Wind – onshore
- Wind – offshore
- Hydro
- Biomass cofiring
- Biogas

The model shows the interaction of investors in the different technologies on the background of a politically defined demand for Green Certificates (i.e. quota).

An representative investor decides to invest into new capacity, if on behalf of his expectations he sees a positive NPV of his project, i.e. if his projection of remuneration for „green electricity“ will cover his investment costs.

He forecasts the production of all different RES on base of historical trends.

This allows a simplified investment calculation based on the following parameters:

- Investment costs of each technology
- Lifetime 20 a
- Assumptions of Full Load Hours
- Expected remuneration and production of electricity/ green certificates
- Variable and fixed operational costs
- CIT of 19%
- WACC 7% (real)

If the NPV of an investment into one of the mentioned technologies is – from the point of view of a representative investor - positive, the model calculates for the respective year an investment into this technology. We assume asymmetric information of the investors. The Agent sees only the past years, but not the current actions of his competitors.

The total (aggregated) investment is limited by a technically feasible upper limit for each technology („technical potential“).
The model assumes that in a given year the technical limit of a technology is realized in case that the agent decides for an investment.

This decision is repeated as “rolling plans” for the years 2009 to 2030. The aggregation of the capacity development gives a macroeconomic forecast of electricity generation from RES and the resulting offer of Green Certificates.

**Figure 5: Mechanism of investment projection**

- Period n
  - Demand projection agent 1 to m

- Period n
  - Price projection agent 1 to m

- Period n
  - Investment decision agent 1 to m

- Period n
  - Aggregation of all agents’ investment decisions

- m agents – each represents one renewable energy technology

- Merit Order of technologies according to their full costs

- In case of overfulfillment of quota, each agent expects the price fall to a level that is defined by demand and merit order.

- If expected NPV<0 → agent will not invest.

- Marginal investments will in general not be realized.
**Figure 6: Mechanism of price projection**

<table>
<thead>
<tr>
<th>Technology</th>
<th>2008 (Installed Capacity)</th>
<th>2009 - 2020</th>
<th>2021 - 2030</th>
<th>2030 (Installed Capacity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydro</td>
<td>928.73</td>
<td>120</td>
<td>200</td>
<td>1.248.73</td>
</tr>
<tr>
<td>Wind onshore</td>
<td>525.7</td>
<td>5.450</td>
<td>5.000</td>
<td>10.975.7</td>
</tr>
<tr>
<td>Wind offshore</td>
<td>0</td>
<td>300</td>
<td>3.000</td>
<td>3.300</td>
</tr>
<tr>
<td>Biogas</td>
<td>52.47</td>
<td>730</td>
<td>600</td>
<td>1.382.47</td>
</tr>
<tr>
<td>Biomass</td>
<td>41.8</td>
<td>475</td>
<td>400</td>
<td>916.8</td>
</tr>
<tr>
<td>Biomasse Co-Firing</td>
<td>0</td>
<td>45</td>
<td>0</td>
<td>45</td>
</tr>
<tr>
<td>Total</td>
<td>1.548.7</td>
<td>7.120</td>
<td>9.200</td>
<td>17.868.7</td>
</tr>
</tbody>
</table>

**Table 2: Technically feasible construction of new RES capacities - Source: own forecast based on Stryjecki (2008) et al., Polish Energy Policy**
Table 3: Cost assumptions (different sources)

In future we expect a rise of the quota – this results from the energy policy but also from obligations of Poland towards the EU.

The 20-20-strategy of the EU defines for the respective member states certain minimum share of RES. According to directive 2009/28/EG Poland has to reach a minimum share of 15% of RES in Final Energy Demand.

In order to reach this goal, a share of appr. 24% of final electricity demand should be reached (ref. Table 4).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Final energy demand</td>
<td>61.815</td>
<td>61.316</td>
<td>63.979</td>
<td>69.203</td>
<td>75.480</td>
<td>80.551</td>
</tr>
<tr>
<td>RES in Electricity</td>
<td>371</td>
<td>715</td>
<td>1.516</td>
<td>2.687</td>
<td>3.256</td>
<td>3.396</td>
</tr>
<tr>
<td>RES in heat</td>
<td>4.313</td>
<td>4.482</td>
<td>5.046</td>
<td>6.256</td>
<td>7.049</td>
<td>7.618</td>
</tr>
<tr>
<td>RES in transport</td>
<td>97</td>
<td>549</td>
<td>884</td>
<td>1.444</td>
<td>1.633</td>
<td>1.882</td>
</tr>
<tr>
<td>RES total</td>
<td>4.780</td>
<td>5.746</td>
<td>7.447</td>
<td>10.387</td>
<td>11.938</td>
<td>12.897</td>
</tr>
<tr>
<td>RES-total[%]</td>
<td>7,7%</td>
<td>9,4%</td>
<td>11,6%</td>
<td>15,0%</td>
<td>15,8%</td>
<td>16,0%</td>
</tr>
</tbody>
</table>

Table 4: Share of RES in Final energy Consumption (source: own calculations)
Figure 7: Future Development of Quota (source: own calculations)

The model does not assume a change of investment and full costs for the following reasons:

- Cost reduction would only in the case of a change of merit order lead to a change of forecasts.
- A database for project specific price forecasts in Poland is hard to establish.
- Not only price decrease due to technological progress, but also price increase due to higher project costs (worse locations, higher biomass logistics etc.) might take place.

5. Results

We calculated the results in 3 scenarios.

Scenario 1 – Base Case

The Base Case assumes the RES share according to the Energy Policy. Furthermore we assume a subsidy of 50% of investment costs until 2020. The electricity prices forecast is based on the assumed development of the price set by URE.

Under these assumptions, wind inshore, biomass and biomass cofiring will be developed according to the technical limit. Only within 3 periods an investment into biogas will take place, as investors fear that total remuneration will not cover full costs. There are no investments into hydro and wind offshore.
The quota will not be reached, prices are on the maximum level of 122.16 EUR08/MWh in 2020 and 131.88 EUR08/MWh in 2030.

![Projected RES production in base case](image1)

<table>
<thead>
<tr>
<th>Installed capacity [MW]</th>
<th>2020</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind onshore</td>
<td>5,676</td>
<td>10,676</td>
</tr>
<tr>
<td>Wind offshore</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Biomass</td>
<td>632</td>
<td>1,032</td>
</tr>
<tr>
<td>Biogas</td>
<td>342</td>
<td>342</td>
</tr>
<tr>
<td>Biomass cofiring</td>
<td>584</td>
<td>584</td>
</tr>
<tr>
<td>Hydro</td>
<td>949</td>
<td>949</td>
</tr>
<tr>
<td>Price EUR08/MWh</td>
<td>122.16</td>
<td>131.88</td>
</tr>
</tbody>
</table>

Figure 8: Projected RES production in base case

Table 5: Installed capacity in base case

![Projected payment for RES in 2008 prices](image2)

Figure 9: Projected RES payment – scenario 1

**Szenario 2 – Constant quota after 2017**

We assume that the quota will not be increased after 2017 but stay on the stable level of 12.9%. In comparison with the base case this leads to a demand reduction for green certificates by appr. 50%.
This leads to lower investment into wind (2 500 MW instead of 5 700 MW). For certain periods overinvestments take place which lead to a decrease of total remuneration to the level of marginal costs of biogas.

Prices will be the same like in the base case, which means 122.16 EUR08/MWh in 2020 and 131.88 EUR08/MWh in 2030.
If we assume that the quota will be kept by 2020 on the level of 23% but afterwards the promotion scheme will be cancelled, then – in case investors presume this development – wind and biomass will be extended to a lower degree, but biomass and cofiring will be extended until 2020.

After 2020 the remuneration decreases to the level of electricity price (i.e. green certificate price equals 0). Prices account to 122.16 EUR08/MWh in 2020 (like in scenario 1 and 2) and 69.92 EUR08/MWh in 2030.
Figure 12: Projected RES production in scenario 3

Table 7: Installed capacity in scenario 3

<table>
<thead>
<tr>
<th></th>
<th>2020</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind onshore</td>
<td>2176</td>
<td>2176</td>
</tr>
<tr>
<td>Wind offshore</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Biomass</td>
<td>632</td>
<td>632</td>
</tr>
<tr>
<td>Biogas</td>
<td>92</td>
<td>92</td>
</tr>
<tr>
<td>Biomass cofiring</td>
<td>584</td>
<td>584</td>
</tr>
<tr>
<td>Hydro</td>
<td>949</td>
<td>949</td>
</tr>
<tr>
<td>Price EUR08/MWh</td>
<td>122.16</td>
<td>69.92</td>
</tr>
</tbody>
</table>

Figure 13: Projected RES payment – scenario 3
6. Conclusions

Poland chose a so called market oriented mechanism which nevertheless leads to investment uncertainties for the investors:

» Electricity price development
» Long term development of the quota
» Technical limits for RES extension
» Cost structure and merit order of alternative technologies.

This leads to higher capital costs.\(^4\) The model is a tool for better understanding of the specific consequences of this investment regime, but also shows that the consumer is confronted with higher prices (higher capital costs, and prices on the level of the upper price cap).

Figure 14 shows the expected consequences for the average electricity price.

As these prices are borne by the consumers, this fact cannot be intended on the long term by the polish energy policy. For these reasons we expect amendments to the current promotion scheme.

\[\text{Figure 14: Projected Promotion}\]

The results provide the following implications for policy making:

\(^4\) Reichel, Wegert, Czambor 2009
Quota systems that are in general seen as a solution for guaranteeing the market share of renewable energy, lead to a non-fulfilment of obligations, at least if there is no satisfying floor price. Not all investments that are politically desired (i.e. within the quota), will in fact be realized.

Prices will be close to the price cap. As the price cap is in general designed as an upper limit, they exceed the production costs of most renewable energy sources significantly. For this reason, the overall price of renewable energy production is higher than it could be in the case of fixed, technology related feed-in tariffs, and society pays too much for renewable energy.

This effect is still underlined by significantly higher capital costs in certificate markets. These capital costs enlarge the production costs of renewable energy, which have to be considered by policy makers in setting the price cap.

In summary, green certificate systems seem to be charming in comparison with feed-in tariffs at first glance. They are seen as a market oriented system for the promotion of renewable energy. But in reality the intended goals can hardly be reached.
7. Literature:

Laws and Ordinances:

Prawo energetyczny - Ustawa z dnia 10 kwietnia 1997 r. (with later changes)

Ustawa o podatku akcyzowym z dnia 23 stycznia 2004 r. (with later changes)

Rozporządzenie Ministra Gospodarki w sprawie szczegółowego zakresu obowiązków uzyskania i przedstawienia do umorzenia świadectw pochodzenia z dnia 14 sierpnia 2008.

Further sources:


European Wind Energy Association, Brussels 2009.


Towarowa Giełda Energii (TGE), Warszawa, 2009.

Urząd regulacji energetyki (URE), 2009.

