Economic integration of renewables in the electricity supply system
RES support models
Anders Plejdrup Houmøller
- The TSO (Transmission System Operator).
- Subsidy systems for renewables
- Feed-in tariffs.
- Auction systems.
- Green certificates.
- Please also refer to the article The Liberalized Electricity Market
  You’ll find the article at the sub-page Facts and findings at www.houmollerconsulting.dk

The TSO (Transmission System Operator)

The TSO is a non-commercial monopolist.
- In the European Union, each TSO has two tasks:
  - Maintains the security of supply in the TSO’s home country.
  - Owns and operates the transmission grid (the high-voltage grid)
    - For example, this means the TSO is responsible for setting the rules for the cross-border trading regime.
  - Most EU countries have only one TSO.
  - However, a few EU Member States have more than one TSO (e.g., Germany).

Electricity market: transportation system
European Union

Environment

Security of supply

Economy

- Transmission System Operator (TSO)
  European Union

- Producers
- Transmission Grid (DK: above 110 kV)
- Distribution System Operators (DSOs) (the grid part of the former distribution companies)
- Distribution Grid (DK: below 110 kV)
- Consumers
Subsidy systems for renewables

In this presentation, *renewables* are facilities producing electricity using renewable energy as input.

Subsidy systems

- Feed-in tariffs.
- Auction systems.
- Green certificates.

Feed-in tariffs in Europe

- During a certain time period, the owner of the renewable gets a fixed price per kWh.
- Previously, this was the dominant system in Europe
  - The TSO had to buy the electricity at the fixed price.
  - Hence, this electricity was not sold at the market.
- Now, even for those European renewables, who have a fixed feed-in tariff, the electricity is normally sold to the market
  - To the local spot exchange.
- If the price at the spot exchange is lower than the guaranteed feed-in tariff, the state or the TSO compensates the owner of the renewable
  - The price transparency provided by the spot exchange is used.
- Hence, at the outset, electricity from renewables is sold at the market.

Usage of the price-transparency provided by electricity exchanges

An electricity exchange provides price transparency for the whole-sale market

From the exchange’s home page, everyone can learn the electricity prices at the whole-sale market.

Feed-in tariffs – 1

For renewables in a country with a electricity exchange

- If your country has a electricity exchange, you may use the exchange price to have a partly market based subsidy for renewables.
- Case: until recently, during the first 7 – 8 years of its lifetime, a Danish on-shore wind turbine would receive a feed-in tariff of
  - (exchange price) + 36.6 €/MWh
  - However, there was a cap of 80.8 €/MWh.

Feed-in tariffs – 2

For renewables in a country with a electricity exchange

- During September 2015, the average electricity price in Western Denmark was 21.2 €/MWh.
  - Hence, for a subsidised wind turbine, the feed-in tariff was about (21.2 + 36.6) €/MWh = 57.8 €/MWh.
- After the 7 – 8 years, the subsidy was reduced to 3.1 €/MWh, which the turbine will receive during the rest of the its lifetime.
  - Apart from the 3.1 €/MWh the wind turbine must manage by selling at the market price.
European auction systems

- To establish a new wind farm, new solar cell farm, etc.
  - The state can operate an auction system.
- The winner of the auction is the company, which is willing to accept the lowest feed-in tariff.
- Often, the fixed feed-in tariff will be granted for the first XX TWh produced by the renewable.
- Normally, the price at the local spot exchange is used as the reference
  - When the spot price is lower than the guaranteed feed-in tariff, the owner of the renewable is compensated.
- You can have technology-neutral auctions
  - And auctions for specific types of renewables
    - Off-shore wind farms, for example.

Auction systems – recent cases

- Case Germany: the German government plans to have 2 auctions per year
  - At the auction April 2018, no wind projects were winners.
  - 32 solar cell projects were winners. The total capacity of all the projects was 200 MW.
  - The average price was 0.0467 €/kWh.
- Case Germany 27 April 2018 – off-shore wind
  - Average price 0.0466 €/kWh
    - The bidders should not themselves pay for grid connection.
- Case India: auction at the start of April 2018 for 2 GW wind capacity
  - Most of the capacity was sold at a price of 2.51 INR/kWh ≈ 0.031 €/kWh.

Statements from IEA’s report Renewables 2017

- Over the period 2017-22 global average generation costs are estimated to decline by
  - 25% for utility-scale solar PV.
  - By almost 15% for onshore wind.
  - By 33% for offshore wind.
- Announced auction prices indicate much steeper possible cost reductions
  - 30-45 $/MWh for solar PV (about 25-38 €/MWh)
    - India, Mexico, United Arab Emirates, Argentina.
  - 35-50 $/MWh for onshore wind (about 30-42 €/MWh)
    - India, Morocco, Egypt, Turkey, Chile.
- Auctions are also proving effective in rapidly reducing costs of offshore wind and CSP (Concentrated Solar Power).

Finance

Levelized Energy Cost (LEC)
Also known as the Levelized Cost Of Electricity (LCOE).

- It is often taken as a proxy for the average price that the generating asset must receive in a market to break even over its lifetime.
- It is a first-order economic assessment of the cost competitiveness of an electricity-generating system that incorporates all costs over its lifetime:
  - Initial investment.
  - Operations and maintenance.
  - Cost of fuel.
  - Cost of capital.
- This can be roughly calculated as:
  - \( \frac{(\text{The net present value of all costs over the lifetime of the asset})}{(\text{The total electricity output of the asset})} \)

LCOE calculation

\[
\text{LCOE} = \frac{\text{sum of costs over lifetime}}{\text{sum of electricity produced over lifetime}} = \frac{\sum_{t=1}^{n} \left( I_t + M_t + F_t + E_t \right)}{\sum_{t=1}^{n} \left( 1 + r \right)^t}
\]

- \( I_t \) investment expenditures in the year \( t \).
- \( M_t \) operations and maintenance expenditures in the year \( t \).
- \( F_t \) fuel expenditures in the year \( t \).
- \( E_t \) electricity generation in the year \( t \).
- \( r \) discount rate.
- \( n \) expected lifetime of asset.
- Why is the energy production discounted?
LCOE in USA  (Numbers in $/MWh)

- OpenEI, sponsored jointly by the US DOE and the National Renewable Energy Laboratory, has compiled a historical cost-of-generation database.
- Because the data is open source it may be subject to frequent revision.

<table>
<thead>
<tr>
<th>LCOE from OpenEI DB as of June, 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant Type</td>
</tr>
<tr>
<td>Wind, onshore</td>
</tr>
<tr>
<td>Wind, offshore</td>
</tr>
<tr>
<td>Solar PV</td>
</tr>
<tr>
<td>Enhanced Geothermal</td>
</tr>
<tr>
<td>Small Hydropower</td>
</tr>
<tr>
<td>Hydropower*</td>
</tr>
<tr>
<td>Natural Gas Combined Cycle</td>
</tr>
<tr>
<td>Coal, pulverized, scrubbed</td>
</tr>
<tr>
<td>Nuclear</td>
</tr>
</tbody>
</table>

*1 Data from 2011

Green certificates
The basics

"Green" electricity
Physical delivery is impossible!

Producers

50 Hz

consumers

Buy certificates corresponding to a given percentage of customers' consumption

Market for green certificates

Retailer

Energy

Market for electrical energy

Green certificate

Sept. 2020

Market for green certificates

The basics of green certificates
Summary

- The target is set politically.
- How the target is met is decided by the market.
- Competition decides:
  - The size of the subsidy.
  - The types of renewable technologies employed to meet the target.
  - For a multinational certificate market: the geographical location of the new renewables is decided by the market.
- This is a tool well suited to an well organized ends-and-means process
- Where a target is first set.
- And the road to the target is then decided
  - In this case: decided by the market.
Spot market for Green Cert.

Sale: 10 MWh € 14.8/MWh
Sale: 10 MWh € 14.8/MWh
Sale: 10 MWh € 15.0/MWh
Sale: 10 MWh € 15.0/MWh
Sale: 10 MWh € 14.8/MWh
Sale: 10 MWh € 14.8/MWh
Sale: 10 MWh € 15.0/MWh
Sale: 10 MWh € 15.0/MWh
Sale: 10 MWh € 14.8/MWh

Buy: 10 MWh € 13.7/MWh
Buy: 10 MWh € 14.8/MWh
Buy: 10 MWh € 14.8/MWh
Buy: 10 MWh € 14.8/MWh
Buy: 10 MWh € 15.0/MWh
Buy: 10 MWh € 15.0/MWh
Buy: 10 MWh € 14.8/MWh
Buy: 10 MWh € 15.0/MWh
Buy: 10 MWh € 14.8/MWh

Database for Green Certificates

Where do you have green certificates today? – 1

- Currently, in Europe, this subsidy scheme exists only in Sweden and Norway.
- Sweden and Norway have a common market for green certificates.
- This may expand to a common market for green certificates for more European countries.

Where do you have green certificates today? – 2

- Green electricity producers in Norway and Sweden receive one certificate for each produced MWh of electricity.
- The certificates can be sold to companies who are required to source a certain amount of their electricity use from renewables.
- The cancellation figures show how many certificates were actually used in the market.
- For Sweden and Norway 16.2 million green certificates were cancelled in 2013:
  - 16.2 million certificates correspond to
  - 16.2 million MWh = 16.2 TWh.
  - 12.3m were cancelled in Sweden and 3.9m in Norway.
  - In 2013, the consumption excl. grid losses was (in TWh):
    - Sweden 139
    - Norway 128
    (source: ENTSO-E).
- This may expand to a common market for green certificates for more European countries (?)..

The size of the subsidy – 1

For a country (or a group of countries) – assume a target is set:
At the end of a given period, the annual electricity production from renewables commissioned during the period must be a given number E_target.
Assume the target is met by means of four different technologies T_A, T_B, T_C, and T_D where T_A, T_B, and T_C are the most cost-efficient.
For whatever reason, there’s a limit to the capacity, which can be installed by means of T_A, T_B and T_C.

Setting the size of subsidies for renewables

In this case, T_D will be the price-setting technology.
The size of the subsidy – 2
If a feed-in tariff system is used: the politicians must set the feed-in tariff, so the renewables receive the price $P_1$.
However, this requires the politicians to determine the price $P_1$.
With a green certificate system, at the start of the period, the price of the certificates will automatically settle at a level, which grants the renewables the price $P_1$ for their electricity.
The market will do the job of determining $P_1$.

The size of the subsidy – 3
Assume the technology $T_0$ develops: after some time, the price needed to reach the target becomes $P_2$.
With a feed-in tariff system, the politicians should now lower the subsidies.
However, lowering subsidies has proven difficult. The task is made even more difficult, as only an estimate of $P_2$ is available.
With a certificate system, the prices of the certificates will automatically decrease – setting the renewables’ electricity price at $P_2$.

The size of the subsidy – risk allocation
For the renewables commissioned at the start of the period, this potential lowering of the electricity price is the technology risk.
After some time, the technological development may reduce their electricity price from $P_1$ to $P_2$. This may make it difficult for the “old” renewables to make a decent profit.
With a feed-in tariff system, the consumers bear the technology risk: normally the feed-in tariff granted to “old” renewables will not change, even though the technologies have developed.
In a market economy, the producers normally bear the technology risk.

The common Swedish-Norwegian certificate market
The common market was launched 1 January 2012.
Before 1 January 2012, Sweden had a purely domestic certificate market.
No Norwegian certificate market before 1 January 2012.
The target for the common market was derived from the 2020 goal allocated by EU to Sweden and Norway:
By the end of 2020, the electricity production from renewables commissioned in Sweden and Norway after 1 January 2012 should correspond to 26.4 TWh/year.
This was changed by Sweden to a 2020 target of 28.4 TWh.
Swedish electricity consumers will finance 15.2 TWh.
Norwegian consumers will finance 13.2 TWh.
At the outset: after 2020, the certificate system will gradually be phased out.
The common certificate market is a tool to reach a specific target.
The 2020 target for the production from new renewables.

Lessons – 1
For the investors, the technology risk is huge.
On-shore wind turbines is the price-setting technology.
This technology is developing fast.

Price of green certificates
Swedish market only Swedish-Norwegian market
Swedish-Norwegian green certificates
Average monthly prices
Sources: www.skm.se and www.nordpoolspot.com

<table>
<thead>
<tr>
<th></th>
<th>March 2018</th>
<th>March 2018</th>
<th>April 2018</th>
<th>April 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green certificates C/MWh</td>
<td>9.55</td>
<td>9.55</td>
<td>10.27</td>
<td>10.86</td>
</tr>
<tr>
<td>Spot prices Sweden (Stockholm) C/MWh</td>
<td>29.03</td>
<td>29.03</td>
<td>33.14</td>
<td>33.14</td>
</tr>
<tr>
<td>Spot + certificates C/MWh</td>
<td>54.39</td>
<td>54.39</td>
<td>52.87</td>
<td>52.87</td>
</tr>
</tbody>
</table>

The trend is falling prices (overlaid by short-term price volatility)

Lessons – 2
From the Swedish-Norwegian certificate system.
Input from the interviewees. Green colour: my comments

- All the interviewees emphasized the system’s cost-effectiveness.
- For example: during 2013, Swedish electricity consumers paid 3.1 EUR/MWh for the expansion of renewables
  - This price was the lowest for many years in Sweden and among the lowest in Europe, according to the Swedish Energy Agency.

Therefore:

- Green certificates is an economic sustainable route to an environmentally sustainable electricity supply.