Electricity market design options for promoting low carbon technologies

Lead author: *Rupert Hartel (KIT)*

Authoring team: *Wolf Fichtner & Dogan Keles (KIT)*

Reviewers: *Alberto Ceña (KIC InnoEnergy expert); Antoni Martinez (KIC InnoEnergy)*

Executive summary

The increasing share of electricity production from renewables is achieved by political promotion strategies like feed-in tariffs, which foresee payments for renewables outside of the electricity market. Assuming a phase out of the existing promotion strategies, the question arises if other or additional market design options for promoting low carbon technologies are necessary. In this paper, we have made an assessment based on the literature to identify possible market designs that are focusing on the promotion of low carbon technologies. The discussed options for altering the current market design range from providing greater certainty for future carbon prices, over capacity mechanisms for conventional as well as for renewable energy to a complete restructuring of the market design. The study shows that there seems to be three main tendencies to promote low carbon technologies, namely existing EOM with market add-ons for low carbon technologies, a separate market for low carbon technologies or an overall single market based on levelized costs.

Introduction

An important goal of the European Member States is the limitation of the global temperature change to no more than two degrees above pre-industrial levels. To achieve this goal, different approaches are being implemented. One of them is the European emission trading system (EU-ETS), which is a "cap and trade" system for GHG emission allowances. Another approach is to increase the share of renewable energy sources (RES) in (gross) final energy consumption. This is achieved by different political instruments such as fixed quotas or feed-in tariffs for electricity production from RES. Figure 1 shows the classification of promotion strategies for renewable energy. These strategies have led to an increasing share of renewable energy, especially wind and solar power. Due to the increasing feed-in of electricity from intermittent renewables, the number of operating hours of conventional power plants is decreasing. Therefore the revenue situation, especially for base load power plants, is worsening. As large amounts of electricity from RES, such as wind and solar power, feed into the energy-only-markets (EOM), the price tends to decrease, since these technologies have marginal costs of zero (merit-order effect). Only during periods when RES are not operating at full capacity and the demand is covered at least partly by conventional generating capacity, the price will be set by the marginal costs of the fossil-fuel generators. In summary, higher prices are set by fossil-fuel generators if intermittent RES are not covering the full load. Therefore these RES are not or only partly gaining profits from high prices.

The INSIGHT_E project is funded by the European Commission under the 7th Framework Program for Research and Technological Development (2007-2013).

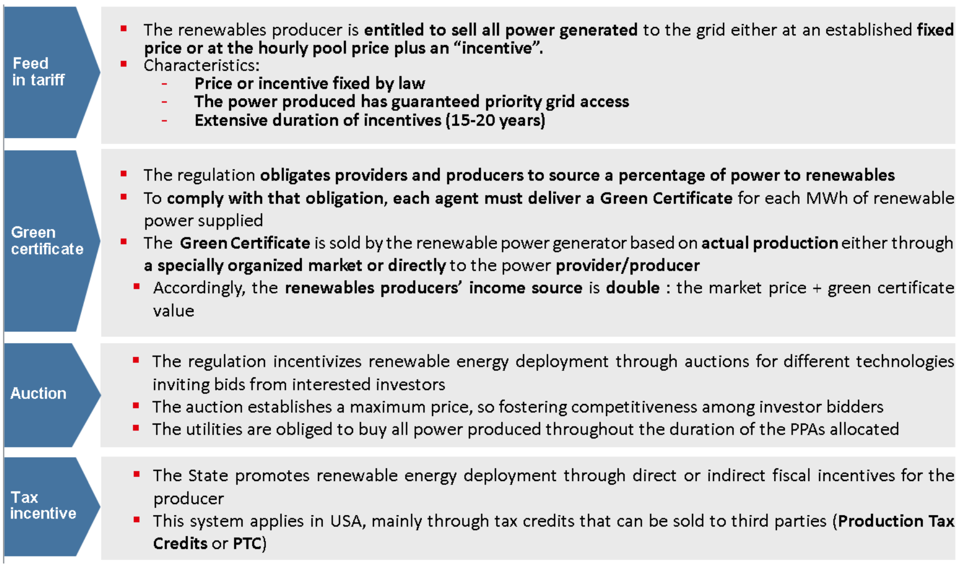

Figure 1: Classification of promotion strategies for RES (Source: A. Ceña, KIC InnoEnergy)

Additionally, the overall target of reducing GHG emissions is not directly considered in the EOM. The price for the GHG emission allowances is reflected within the marginal costs of conventional electricity generation. However, it is unclear to what extent intermittent RES would benefit from higher electricity prices caused by EU-ETS for the same reasons as mentioned above.

Strategies to promote renewable energy increased the share of RES, while at the same time this market externality influenced the EOM in a way that prices strongly decrease with high levels of electricity feed-in from RES (the so-called merit order effect). The price decrease leads to lower revenues for conventional generators. Assuming that the promotion of renewable energy is phased out, the question is whether investments in RES would reduce or not.

Therefore, the key question is whether there is a "missing-money-problem"[1] for new investments in low carbon technologies[2], and how this can be mitigated by altering the market design.

[1] The term "missing-money-problem" is normally associated with conventional capacities and actually stands for "missing investment incentives".
[2] Within this publication low carbon technologies cover RES, nuclear power plants, and conventional power plants with carbon capture and storage (CCS)

Is there a "missing-money-problem" for low carbon technologies?

The increasing RES capacity in the system has been driven by political promotion strategies to date, guaranteeing sufficient revenue streams for these technologies. The presence of these strategies indicates that RES technologies are not able to refinance themselves on the energy-only-market due to their high investment costs. What is evident is that schemes have led to decreasing material cost and an improvement of the efficiency of RES technologies, which in turn have reduced the associated investment costs and therefore the levelised costs of electricity (LCOE).

Figure 2 shows a comparison of the levelised costs for different production technologies. While RES technologies are still higher than conventional generators, in some cases, notably solar photovoltaic (PV) and onshore wind, the costs are in the same range. This leads to the question of whether RES are competitive in an energy-only-market, if the promotion strategies are phased out, or if there is also a "missing-money-problem".

As previously mentioned, RES with low or zero variable costs tend to decrease the electricity price in an energy-only-market based on marginal costs. The price reduction effect is increasing with an increasing RES capacity [Kopp 2012]. Due to this price reduction effect, RES are probably not able to recover their capital investment under the current market design, leading to the "missing-money–

problem". An analysis by Kopp (2012)] shows that intermittent RES cannot refinance on the energy-only-market in the long run, even if their LCOE fall below the LCOE of conventional power plants. This is also the case in scenarios where a high CO_2 price and increasing fuel prices are assumed[3].

The price reduction effect of RES, often called the merit-order effect, is also reducing the revenue streams for conventional power plants as well as for other low carbon generators, like nuclear. With an increasing share of renewable energy sources it is likely that there will be a "missing-money-problem" for all low carbon technologies.

In the following section, we provide an overview of possible market designs that address this issue. We focus on the studies by Baker (2010) and HM (2010) to analyze possible market designs for low carbon generators in general, and Winkler (2012), Öko-Institut (2014) and Kopp (2013) regarding market designs for renewable energy sources.

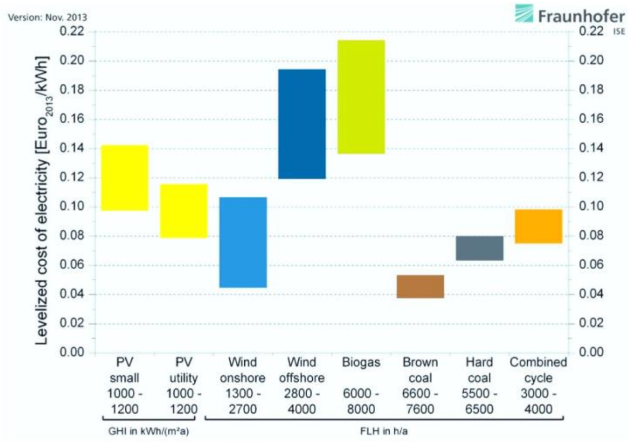

Figure 2: LCOE of renewable energy technologies and conventional power plants at locations in Germany in 2013 (Source [Kost 2013])

Possible market designs

Table 1 gives an overview of the market design options that are considered in this paper. Some of the presented options are quite similar but are presented in the literature in a different context. Therefore the options can be distinguished by their aim. Options 1-7 focus on a market design for low carbon technologies (section A), while options 8-11 evaluate market design options for a completely renewable energy system (section B). Finally, options 12-13 focus on the promotion of RES (section C).

Table 1: Overview of possible market design options

Nr.	Possible market designs	Aim
1	Greater carbon price certainty	Promote low carbon technologies [HM 2010] [Baker 2010]
2	Support low-carbon investments in current markets	
3	Regulate to limit high-carbon generation	
4	Separate low carbon market for electricity	
5	Single buyer agency	
6	Capacity obligations on suppliers	
7	Capacity obligations on system operator	
8	Change the pricing system to pay-as-bid	Develop a market for a completely renewable electricity system [Winkler 2012]
9	Dispatch based on marginal costs and pricing on LCOE	
10	Market premium	
11	Technology-specific auctions	
12	Capacity market	Promote renewable energies [Kopp 2013] [Öko-Institut 2014]
13	Competitive premium system	

A. Promote low carbon technologies

Using the example of the United Kingdom, Baker (2010) concludes that there appears to be an emerging consensus: the existing market design is unlikely to provide the necessary investment incentives in low carbon technologies to satisfy the UK's climate change goals. The Energy Market Assessment (EMA) by the HM treasury/DECC (HM 2010), which is the basis for the analysis carried out by Baker (2010), discusses the five possible models for altering the current design of the UK electricity market (as is shown in Figure 3). In addition Baker (2010) discusses two capacity based market options.

1. <u>Greater carbon price certainty alone (Option A in Figure 3)</u>: A competitive market framework, where all generators sell their electricity in a wholesale market, is the basis of this concept. The support schemes for RES would remain in place. The government would increase the certainty on future carbon prices to encourage investments in low carbon technologies. This could be conducted for example with an additional payment, paid by the government to low carbon generators as soon as the carbon price falls below a certain level.

[3] However, different literature sources state that this is strongly dependent on the development of the market framework. In a model based analysis, Höfling (2013) shows that a capacity scarcity or an increasing demand can lead to investments incentives in new capacities in an EOM. For further studies on the market value of RES, refer to Hirth (2013) and Nicolosi (2012).

2. Support low-carbon investments in current markets (Option B in Figure 3): In this concept a competitive wholesale market for all technologies is again the basis. The government would intervene by giving additional payments to low carbon generators beside the additional payments mentioned in option A, if the electricity price falls below a certain level. This could be done by obligations, feed-in tariffs and additional payments. This approach provides for higher and more certain revenues.
3. Regulate to limit high-carbon generation (Option C in Figure 3): Another option to achieve the climate change goals via regulatory intervention. The government would by law limit the amount of high carbon generation units that can be built and/or limit the full load operation hours of existing plants (HM 2010).
4. Separate low carbon market for electricity (Option D in Figure 3): This option guarantees a revenue stream which is separated from the existing wholesale market. The price could be determined by competitive tendering, being set by the government or by the regulation of an appropriate return.
5. Single buyer agency (Option E in Figure 3): In this model a central agency needs to be established and acts as the only buyer of electricity from the utilities. The agency would identify the need for low carbon technologies based on the GHG emission reduction goal. If the generating capacity was procured on the basis of levelised costs and not on variable costs, the single buyer model could transform the nature of the electricity market (Baker 2010). Due to their high levelised costs, there would be no reason to dispatch low carbon emission capacities on the basis of submitted bids via a spot market. Therefore, the dispatch is instead determined on basis of a carbon emission hierarchy and between plant technologies on basis of marginal cost. This approach will improve the investment climate by providing investors with confidence through guaranteed income streams. Furthermore this will lead to a reduction of capital costs since the price uncertainty and volatility is decreasing (Baker 2010).

Increasing centralization

Option A Greater carbon price certainty alone	Option B Support low carbon in the current market	Option C Regulate to limit high carbon generation	Option D Separate low carbon market	Option E Single buyer agency
Minimum carbon price guarantee at currently expected level Competitive market framework as today	Additional incentives for low carbon generation price above carbon price Competitive market framework as today	Regulate to drive decarbonisation Competitive market framework as today	Long term payments to low carbon generators to provide revenue certainty Conventional plant trades in competitive market framework	Single agency is the only purchaser of electricity generation – existing and new low and high carbon- and only seller of this on to suppliers

Figure 3: EMA market reform options ([Baker 2010] based on [HM 2010])

6. Capacity obligations on suppliers: The underlying idea is to concentrate on low carbon capacity rather than on the output. Several examples exist where obligations are placed on suppliers to procure sufficient generation capacity (Baker 2010). These obligations mainly focus on the security of supply. To support low carbon technologies these obligations need to be defined as technology-specific ones. In general, it would be possible to achieve investments in low carbon technologies and security of supply. This could be conducted in terms of capacity certificates. Suppliers would need to purchase these certificates, with the proceeds distributed to the certificate holders. These certificates need to consider the carbon intensity of different

technologies by premium payments for low carbon technologies. Another possibility is a bid system on the basis of carbon intensity and bid price (Gottstein 2010).

7. Capacity obligations on the system operator: Another option is to place an obligation on the system operator rather than on the supplier. Again, several systems already exist with the focus of establishing a generation capacity requirement. These capacity markets are technology-neutral and are focusing only on the security of supply. However, there is no reason why a capacity market could not be designed in a way that the carbon intensity of generation is considered. So both could be achieved - security of supply and carbon emission reduction goals (Baker 2010). The system operator is to be preferred as the obligated party, because of his ability to anticipate further system needs, such as the optimization of the generation portfolio. However, it is unclear how a non-market based requirement could co-exist with investments on a commercial basis (Baker 2010).

B. Develop a market for a completely renewable electricity system

In Winkler (2012), market design options are further analyzed, particularly for a completely renewable power sector in Germany. The study differentiates between changes applied to the power system and to the market design. The changes applied to the market design can be distinguished in three ways; changes to the current market design, add-ons to the current market design and more radical market changes. Winkler (2012) analyzes how the market rules can be changed to address the challenges of generating investment incentives and cost recovery.

8. Change the pricing system to pay-as-bid: The change of the current pricing system to a pay-as-bid pricing is one proposal analyzed. Auction winners would get paid their bid price instead of the most expensive bid price that is accepted. It is to assume that market participants would bid with their fixed operation costs and variable costs to assure cost recovery. This is not necessarily the case, since plant operators need to dispatch more often to at least partly recover costs. in particular, plants with high capital costs and low marginal costs will try to dispatch as often as possible.
9. Dispatch based on marginal costs and pricing on LCOE: Another way of changing the pricing in the electricity spot market is by allowing more complex bids. The system operator would be informed of the marginal as well as the average production costs of the market participants. The dispatch of the plants would be organized according to rising marginal costs, whereas payments would be based on the average production costs. This approach could lead to different problems. *"The information asymmetry between the generators and the market operator can be used for influencing the prices"* according to Winkler (2012)[4]. This complex bidding system could also lead to inefficient plant dispatch and a disproportional increase of technologies with low marginal costs.
10. Market premium: A further add-on to the market design can be the introduction of a market premium. In a completely renewable electricity system a market premium can support intermittent RES and reduce investment uncertainty by using a "cap and floor" system. Similar to fixed feed-in tariffs, the government or the system operator is challenged to set the right level for the market premium to ensure sufficient investments and to avoid windfall profits for generators.
11. Technology-specific auctions: Technology-specific auctions and long term contracts could also be possible changes to the market design. An example of such a system can be found in Brazil. Similar to capacity markets the generator is paid a price for the capacity, but in addition, intermittent sources are paid a long term payment for electricity generated, similar to feed-in tariffs. The prices for the payments are determined via an auction. Such a system would solve the problem of cost recovery and investment incentives but incorporates other potential drawbacks. A central instance needs to define the capacity need for each technology, which

[4] Plant operators could bid with lower marginal cost to get a guaranteed dispatch while at the same time bid with higher LCOE as they actual have.

can lead to technology lock-in or disregard for alternative technologies[5].

C. Promote renewable energies

Similar to the capacity obligations discussed by Baker (2010) under option 7, Öko-Institut (2014) proposes a market model for the reform of the German energy-only-market. It particularly addresses the need for RES, but recognizes that the technologies will probably not be able to refinance themselves on the actual EOM. This proposal is more detailed than the analysis carried out by Baker (2010) and is therefore included here within in a separate subsection.

12. Capacity market: The new proposed model is a combination of EOM and capacity market. In general all new capacities - conventional and renewable - are facing the electricity price signals of the EOM. *"The standard option for this is the mandatory direct sale introduced with the 2014 amendment of the German EEG"*. In addition to the achieved revenues from the EOM, all new capacities are rewarded with capacity payments. This payment is determined ex ante and is fixed on a long term. For intermittent producers, the capacity payment is made on basis of a reference capacity credit that is compatible with the needs of the future electricity system and is determined by the mean feed-in for the middle eight deciles of the hours of a year. Dispatchable capacity, renewable as well as conventional, is priced by its nominal capacity. This approach guarantees a fixed revenue stream and reduces the price uncertainty. In addition to the capacity payments, a risk margin mechanism accompanies the model to account for unexpected high revenues. If the revenues for each technology group exceed a strike price, the plant operator must pay a corresponding cash settlement. This payment is set off against the capacity payment. To achieve special targets this model foresees additional payments. Figure 4 illustrates the proposed mechanism.

Another possible market design to promote RES is proposed by Kopp (2013) and is similar to market premium (option 10) proposed by Winkler (2012). Kopp (2013) identifies six possible options to promote renewable energies. Three options are based on feed-in tariffs and premiums and would be guided by the government. The remaining three options are dependent on a competitive market design. Three out of the six options are combined to form the new market design.

13. Competitive premium system: This concept is based on two revenue streams for RES:
    - Revenues from decentralized trading of the produced electricity on the energy-only-market.
    - An additional long-term payment of a fixed premium over a period of 15-20 years. The level of the premium is determined through an auction.

    The direct trading on the EOM guarantees that the electricity production from RES reacts on market signals and therefore will lead to an efficient plant operation (Kopp 2013). The additional premium makes it possible for plant operators to recover their capital costs.

    In an auction the government defines a financing budget for RES. Auction participants would apply for a part of this budget by indicating their full costs over the contract duration e.g. 20 years. Alternatively they could bid for support needed (difference between market price in the hours they produce and their full costs), which would better reflect the different market value of the different technologies. The lowest bids are awarded first with the level of their bid (pay-as-bid). This is carried on in an ascending order until the budget is exhausted. The bids can either refer to capacity (MW) or to production (MWh) with a limited number of full load hours. The auction can be technology unspecific, meaning one budget for all renewable technologies applying, or technology specific, where the budget for each technology is set individually.

[5] Germany and other European countries are about to introduce systems that are based on auctions for RES.

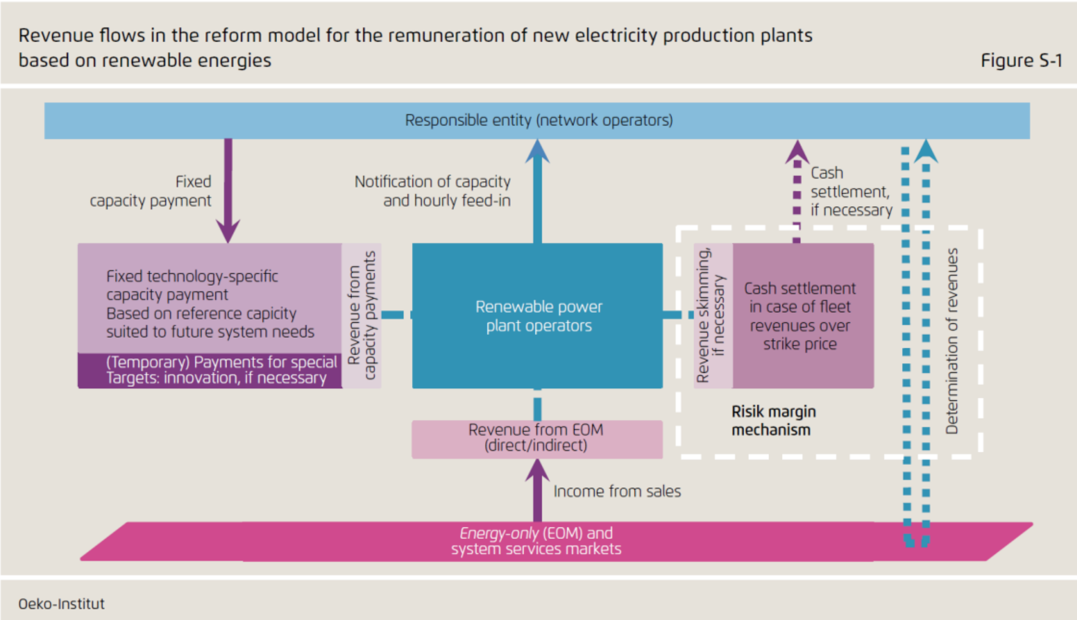

Figure 4: Market model proposed by [Öko-Institut 2014]

Assessment of the market designs presented

Based on the market designs reviewed there are different options to modify the electricity market design. The options presented differ regarding their focus, complexity, the degree of change to the wholesale market and the instruments that are used to achieve the goal of the market design reform. Table 2 evaluates the market designs according to the above mentioned characteristics. Guaranteeing higher certainty over future carbon prices will probably not solve the problem for RES to refinance on a market, based on marginal cost, according to Kopp (2012).

Assumed small changes like changing the pricing mechanism of an electricity market, as presented by Winkler (2012), to a pay-as-bid auction may not solve the problem of achieving investment incentives for low-carbon generators. Greater changes to the pricing mechanism based on average production costs, would imply a higher degree of complexity (Winkler 2012). This change would also mean a re-ordering of the plant dispatch. A further inclusion of the carbon intensity into the dispatch as proposed by Baker (2010) would result in an environmental feature into the market design. However, it is unclear how to implement a concrete GHG emissions reduction goal in such a mechanism and therefore the degree of complexity will probably further increase.

Add-ons to the current market, like capacity mechanisms or feed-in premiums, which are already applied in some countries, could be a further option. Öko-Institut (2014) presents how such a system could be implemented in the German electricity market. The focus of the system is on RES and therefore it is not promoting all low carbon technologies. The question remains whether such systems could be extended to include low carbon generators in general. Baker (2010) mentions that the carbon intensity could be considered in capacity mechanisms, to promote low carbon generation in general. However, this again will increase the complexity of an already complex system.

Table 2: Evaluation of the characteristics of the presented market design options

NR.	Focus	Complexity	Changes to EOM	Instrument	Goal
1	Low carbon	Low	None	Payments	Price certainty
2	Low carbon	Low	None	Payments	Price certainty
3	Low carbon	Medium	None	Regulation	Limit GHG emission
4	Low carbon	Medium	None	Payments	Revenue certainty
5	Low carbon	High	Pricing/ dispatch	Market change	Limit GHG emission
6/7	Low carbon	Medium	None	Capacity Payments	Revenue certainty
8	RES	low	Pricing	None	Revenue certainty
9	RES	Medium	Pricing/ dispatch	Market change	Revenue certainty
10	RES	Medium	none	Payments	Revenue certainty
12	conventional /RES	Medium	None	Capacity Payments	Revenue certainty
11/13	RES	Medium	None	Auction	Revenue certainty

The assessment further shows that there are three main tendencies of market design reforms:

- Keep the existing EOM and market add-ons for low carbon technologies;
- The establishment of a separate market for low carbon technologies;
- An overall single market based on levelised costs of electricity production and plant dispatch based on marginal costs or carbon intensity.

In Table 3 we make our own assessment of each option to one of the three main tendencies. Additionally, each option is evaluated regarding whether it provides investment incentives and if the system is dependent on additional payments.

Market design options which are based on additional payments would probably lead to a higher investment incentive for market participants. The overall single market is the option that does not include additional payments for low carbon technologies. This market design option might lead to investments in inefficient technologies. A pricing system centered on LCOE can provide investment incentives but as long as the dispatch is based on marginal cost or carbon intensity there will be no incentive for technologies with low marginal cost and zero CO_2 emissions to improve the efficiency of the market, since their dispatch is guaranteed.

Table 3: Assessment of the 14 market design options

	Greater carbon price certainty alone	Support low-carbon in current market	Regulate to limit high-carbon generation	Separate low carbon market for electricity	Single buyer agency	Capacity obligations on suppliers	Capacity markets
Focus of study	low carbon	low carbon	low carbon	low carbon	low carbon	low carbon	low carbon
Provide investment incentives	unlikely	unlikely	unlikely	likely	inefficient invest.	likely	likely
Separate market for low carbon	NO	NO	NO	YES	NO	NO	NO
Market with add-ons	YES	YES	NO	NO	NO	YES	YES
Overall single market	NO	NO	YES	NO	YES	NO	NO
Additional payments	YES	YES	NO	YES	NO	YES	YES

	Change the pricing system to pay-as-bid	Dispatch based on marginal costs and pricing on LCOE	Market premium	Technology-specific auctions	EOM and capacity market	Competitive premium system
Focus of study	RES	RES	RES	RES	RES	RES
Provide investment incentives	inefficient invest.	inefficient invest.	likely	likely	likely	likely
Separate market for low carbon	NO	NO	NO	NO	NO	NO
Market with add-ons	NO	NO	YES	YES	YES	YES
Overall single market	YES	YES	NO	NO	NO	NO
Additional payments	NO	NO	YES	YES	YES	YES

Conclusion

The cost recovery of RES in an EOM is a controversial question. There are indications that a fixed-charge coverage on an electricity market, which is based on marginal cost, is unlikely for renewable energy sources at this point of time (Kopp 2012). With an increasing share of RES and due to the merit-order effect, this is also likely for other low carbon technologies, which have high capital and high variable costs. Therefore, it is likely that there will be a "missing-money-problem" for low carbon technologies. This leads to the question how the market design could be transformed to promote low-carbon technologies.

The presented options for altering the market design to promote low carbon technologies have up- and downsides and differ in their degree of complexity. A future market design should be as simple as possible, as an increasing degree of complexity could also lead to higher uncertainty for market participants, besides the uncertainty that would arise due to the market change. The introduction of a market premium instead of feed-in tariffs or auctions for RES, which are recommended in the EU guidelines (EC 2014), for example could help to bring renewable energy technologies closer to the market, while keeping the changes to the market to a minimum. This will improve the understanding on how renewable energy technologies will participate in the market. However it is unclear in which way these instruments need to be transformed to include low carbon technologies in general.

A change in the pricing system from marginal cost to LCOE and a changed dispatch would mean a restructuring of the market design. Different aspects need to be considered to guarantee a level playing field for the different technologies. But the question remains how a completely new system can be implemented and it is questionable if it is necessary at this point.

The assessment further shows that there seem to be three main tendencies for altering the market design to promote low carbon (existing EOM with market add-ons for low carbon technologies, a separate market for low carbon technologies or an overall single market based on levelised costs). The establishment of a separate market for low carbon technologies or a change in the pricing system are complex instruments and an implementation seems unrealistic. However, further research is needed to be able to identify which of the tendencies is suitable to satisfy the needs of the future electricity system.

Sources :

Baker, P.E., Mitchell, C.,Woodman, B.: "Electricity Market Design for a Low-carbon Future"; THE UK ENERGY RESEARCH CENTRE, 2010

European Commission: Guidelines on State aid for environmental protection and energy 2014-2020, 2014/C 200/01

Gottstein, S. (2010). The Role of Forward Capacity Markets in Increasing Demand-Side and Other Low Carbon Resources: Experiences and Prospects;

Hirth, L.: The market value of variable renewables: The effect of solar wind power variability on their relative price, Energy Economics, Volume 38, July 2013, Pages 218–236

HM Treasury. (2010). Energy Market Assessment.

Kopp, O., Eßer-Frey, A., Engelhorn, T.: "Können sich erneuerbare Energie langfristig auf wettbewerblich organisierten Strommärkten finanzieren". Zeitschrift für Energiewirtschaft (2012)36:243-255

Kopp et al. (2013): Wege in ein wettbewerbliches Strommarktdesign für erneuerbare Energien, Mannheim 2013.

Nicolosi, M.: The economics of renewable electricity market integration. An empirical and model-based analysis of regulatory frameworks and their impacts on the power market, Ph.D. thesis, University of Cologne, 2012

Öko-Institut (2014): Erneuerbare-Energien-Gesetz 3.0 (Langfassung). Studie im Auftrag von Agora Energiewende.

Winkler, J., Altmann, M.: "Market designs for a completely renewable power sector" Z. Energiewirtsch (2012) 36:77-92

For further reading or information, please visit www.insightenergy.org