Market4RES

D6.2 Guidelines for implementation of new market designs in Europe with high shares of RES-E penetration (post-2020)

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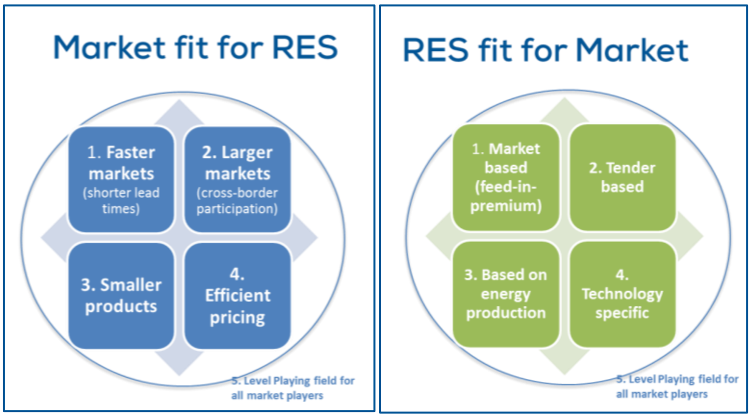
EXECUTIVE SUMMARY

The current energy market is in need of a more suited design, that reflects the dynamics of a fast changing landscape, with higher contribution of variable energy sources, which come with very low marginal generation costs but high initial investments, and that can coop with a number of persisting market failures, such as the incapability to properly reflect technologies environmental impact cost (e.g. very low CO2 prices).

As the penetration of renewables increases, market instruments to support their deployment need to become more market based, increasing competition and reflecting short-term market signals, as already reflected in today's state-aid regulation from the European Commission. In parallel, it is of critical importance that the (energy) market in which renewable players participate are better suited for the intrinsic characteristics of variable energy sources, allowing a level playing field among all participants. This is the approach followed in this report, providing a set of recommendations that will make the market fit for RES and at the same time will ensure that RES are fit for the market.



Market fit for RES

1. Faster markets

In a future power system dominated by wind, solar and other variable renewables, the timing of markets should evolve to allow faster changes in system conditions, which are largely caused by weather patterns (e.g. renewable generation, heating/cooling demand, etc.). Concretely, this means that the time point at which Transmission System Operators receive schedule generation and take control to ensure security (gate closure time) should be pushed back as close as possible to real time giving market players with variable generation the option to self-balance their deviations via the market. Not only would this maximize the value of existing renewable generation, but also minimize the impact of uncertainty provoked by non-dispatchable generation, thereby the need for flexible resources.

2. Larger markets

Wind and solar power output is smoother when aggregated over several sites and across large geographical areas, many of which may or may not be located within the same grid, market, or control area. In order to couple cross border markets at all timeframes (day-ahead, intraday, balancing), the available transmission capacity for trading needs to be clearly defined. Traditionally, this is calculated before final flows are known, one border at a time and without considering bilateral trading impacts on neighbouring systems (*available transmission capacity* (ATC) method). This causes TSOs to frequently prioritise flows inside zones over flows across borders under different security standards, even when restrictions are not justified by the physical flows of power.

TSOs would thus need to use more sophisticated methods (flow-based transmission capacity allocation) and make use of a Common European Grid Model. This approach take into account the relationship between commercial flows and physical congestion on affected transmission network elements, maximizing the use of the existing infrastructure.

Increasing cross-border interconnection capacity, as well as the capacity to transport electricity across the same bidding area is crucial to allow further integration of renewable energy sources. Such increased capacity is the basis to ensure cross-border competition in the various markets (e.g. intraday and balancing).

3. Smaller products

Smaller timeframes for the products are positive for the participation of variable renewables generation units. This is very much related to forecasting and predictability of renewable generation assets and their possibility to adjust to demand ramp up/down periods. The use of shorter products will need to be combined with larger ones to find a balance between liquidity in the markets and cost of implementation. Moreover, the procurement rules associated with the specific products have a key impact on the participation of renewables, especially for balancing markets.

The introduction of 15-min products in the German intraday market in 2011 has been hailed as a success for handling variability of renewable energy, compared to the traditional hourly based contracts. And although product volumes remain relatively low, they will most likely become automatically higher as the share of renewables increases.

4. Efficient pricing

Prices in the wholesale power market are the main reference for operational choices and investment decisions for all generators. Therefore, they must be transparent and should not be kept artificially away from revealing scarcity. This means that price volatility and spikes should be seen as positive outcomes of a market that signals when investments are needed, in capacity and/or in flexibility.

Prices in the wholesale market should also relate solely to the marginal costs of producing electricity. The entire rationale of a cost-efficient short-term dispatch of energy relies on ensuring that the most competitive generators are the first to serve demand. Marginal pricing (pay as cleared) therefore, should be considered as the common norm across all time frames, with the exception of continuous intraday trading, where continuous offers (pay-as-bid) should be combined with discrete auctions (pay-as-clear).

Restoring today's depressed low wholesale prices will therefore be a matter of ensuring that the right signals come out of the market itself.

5. Level-playing field

Above all, for renewable energies to fully contribute to a functional energy market, the design and rules have to be adapted to a level-playing field for all generators. Market access, increased transparency of operational procedures, a polluter pays principle guiding dispatch and a complete phase-out of environmentally damaging subsidies are paramount for strengthening the market towards a more sustainable future.

- **Balancing responsibilities and the market.** The Electricity Balancing Guideline[1] aim to standardize and harmonize to a large extent the national terms and conditions for balancing services providers (BSPs) and balance responsible parties (BRPs). In that context, the guideline foresees responsibilities for all market players, as this seems an important condition for a well-functioning electricity market, allowing effective system balancing. Balancing responsibilities for all parties should, however, be accompanied by the existence of markets that allow trading close to real time (specially the intraday market with short gate closure times and with a sufficient level of liquidity) to minimize forecast errors and markets that have fair access rules to balancing markets for all market parties.

- **Priority dispatch.** Increased transparency on operational procedures leading to curtailment of wind and solar energy and remuneration of these events as system services are needed in order to progressively phase-out the priority dispatch provisions introduced in the 2009 renewable energy directive. Needless to say, in order to achieve a level playing field, priority dispatch for conventional generators shall also be eliminated.

- **Non-internalized environmental costs.** In today's power market, the cost of polluting air, water and soil while generating electricity is not taken fully into account in producers' costs. Without a meaningful price of CO2 and other pollutants, competitive conditions are too good for polluting sources of generation. A major revision of the EU ETS is needed to establish a meaningful price of CO2.

- **Subsidies to conventional technologies.** While today's discussion is centred on the support for renewable energy sources, conventional technologies continue to receive direct or indirect support at national and European level. Historically, technologies such as nuclear

[1] It is also known as the Electricity Balancing network Code (still draft under comitology process by June 2016)

and coal have received direct support several orders of magnitude higher than the support provided today to the various renewable energy sources. Indirectly, still today nuclear energy receives) more support for research and development (focus on safety) from European funds (Euratom- Horizon 2020 than the support allocated to all other low-carbon technologies (including renewables, CCS, smart grids and energy efficiency). Therefore in order to guarantee a level-playing field, continued support to conventional technologies needs to be addressed in parallel to the reform of market design rules and the revision of state-aid guidelines for environment and energy.

RES fit for the market

Depending on the full set-up of markets (including acceptance for scarcity pricing and possible capacity markets) market framework might still not be sufficient to guarantee an adequate return on investment for renewable generation characterized by high upfront investments (CAPEX) and low marginal costs. Supplementary national regulatory mechanisms could be needed to ensure a business case for renewables even in an almost fully decarbonized power system. These market instruments should evolve based on the technology market penetration/maturity as well as on the situation of market (whether the market is fit for RES). When introducing a RES market mechanism, a careful balance needs to be found between investment risk, overall policy cost and impact on short-term market signal.

1. Market based support schemes

Wholesale prices could be complemented with long-term price signals that create a stabilisation of revenue. These signals can take various forms, such as a feed-in-premiums. Feed-in-premiums can be designed in various form (floating, fix), exposing producers to different levels of market risk and leading to various results in term of impact to dispatch decision. The scheme should ensure that market risks are limited to ensure financing cost to be as low as possible given that most of the lifetime generation cost of the technologies is associated to the CAPEX.

2. Tender based support schemes with careful design consideration

As far as the limited recent experiences can tell, design parameters play a crucial role and practices currently vary substantially across the different EU countries. The use of tenders can lead to market efficiency, but for this to happen, the tender design options need to be carefully defined. Tenders present participants with higher risks (costly applications, uncertainty over project selection and guaranteed remuneration) which are internalised in bids and could temporally result in higher support costs.

There is no tender design system that is a complete success story because tenders are subject to continuous adaptation of both design elements and participants behaviour. For a tender to be effective, it has to achieve competitive prices (cost-competitiveness criterion) and high realisation rates (efficiency criterion). It is very important that the tenders are not applied to all market participants (e.g. small players to be excluded), given the transaction costs associated with a tendering process.

This reports talks about the lessons learnt with current experience and presents a set of detail design parameters necessary for a successful scheme.

3. Support scheme should reward energy production

While various support schemes are presented in this report as potentially viable solutions, support schemes that reward energy production instead of capacity seem to be a more suitable solution to reach the various energy policy goals.

The consortium recommends a *floating price premium as the instrument with the highest potential*. In this system, a price premium (€/MWh) is provided on the top of electricity prices for a supported volume of energy. The *supported volume* for a given RES producer is determined by the amount that can be produced, account taken for availability of capacity as well weather conditions. Thus, it should not be based on the actual generation (reducing interference with short-term price signals). For wind- and solar-power this means that a voluntary reduction in output because of negative prices or provision of negative balancing energy in real time, will not have any impact on the volume supported.

The level of the premium is adjusted regularly (e.g. annually) so that the total price for RES generation (i.e. electricity price plus price premium) is in accordance with a target value (resulting from a competitive tender), reducing investment risk and ensuring revenue stability in the long term.

4. Technology specific support

Technology neutral schemes might provide, in the short term, the least-cost solution for implementing a given amount of renewables in a well-functioning market. However, to encourage investments in wider range of technologies with high potential (both in terms of energy and cost-reductions through learning-by-doing effects), technology-specific support types are needed as well. In the long-term, a wide portfolio of complementing technologies could provide the most cost-effective solutions from a market and system-wide perspective. The so called cannibalization effect for every single technology would be reduced and challenges linked to system integration could be more easily addresses (correlation of production between PV solar and wind energy).

The Way forward

The European Commission guidelines on state-aid support for environment and energy should be continued after 2020, in line with the current framework, building on increasing experience from tender systems, and premium-based schemes. It would be important to re-assess the default condition of technology neutrality and further investigate the implication for small players in auction schemes, based on our recommendations.

The full Implementation of market network codes (Balancing, Capacity allocation and congestion management) should take place in due course to expedite many of the needed design aspects reflected in this document. It will be important, however, that member states follow closely all the principles and rules put forward, avoiding derogations, exclusions and excuses in order to ensure Europe can create a level playing field across borders.

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1 INTRODUCTION

1.1 Role of WP6 in the Market4RES project

This report is part of the Work Package 6 (WP6), providing the concluding part of the Market4RES project. In this WP, the results from previous work packages are analysed and gathered into a set of conclusions and recommendations. Additional elements from external literature are also presented to contextualize conclusions. Its major objective is therefore to recommend the steps towards a practical implementation of policy, legislation and regulations for renewable electricity generation in order to secure a robust evolution of the EU Target Model (TM) beyond 2020.

The Market4RES project addresses market design issues via two separate work streams:

- **Work Stream 1:** Assuming the current generation fleet as an input and current implementation status of the target model, the focus is on determining appropriate, yet novel, instruments (and their subsequent accompanying national energy policies) for increased renewable electricity generation in support of the 20/20/20 targets;
- **Work Stream 2:** Assuming the future generation fleet (beyond 2020) as a result of current market designs, and taking into account possible future changes in market design beyond the existing TM, the focus is on developing necessary additions or complementary instruments to the current design, which will induce investment incentives and phase out support schemes in the long term without compromising system adequacy or security of supply.

This report focuses on the second work stream. It therefore addresses the time horizon beyond 2020, building on the analysis and conclusions provided in reports D6.1.1 and D6.1.2.

1.2 Purpose and structure of this report

The purpose of this report is to deliver policy recommendations on market design aspects beyond 2020 that can help driving investments in an electricity market characterised by large shares of renewable energies. Against this background the project has been structured in two main pillars:

- **Market fit for RES:** Assessing the current implementation of the European target model and assessing the pre-conditions needed to facilitate renewables market integration. Recommendation are presented for all short-term markets timeframes (day-ahead, intraday, balancing).
- **RES fit for the market:** Given the obligation to move towards market-based schemes, what will be the impacts of this change on short-term markets? Which proportion of wind and solar capacities should be concerned by these new schemes? How shall the market-based schemes be configured?

For both topics, the recommendations that are being delivered in this report are based on work performed within previous work packages of the project, namely WP2, WP3 and WP5:

- WP2 has made a diagnosis of the Target model and gives a state of play of its implementation. In addition, it assess the impact of RES support schemes on market dynamics, and the (lack of) participation of demand in the different market time frames;
- WP3 has studied in a qualitative manner developments affecting the design of short-term markets and long-term markets, including RES support schemes design;
- WP5 has studied in a quantitative manner, among others, the impacts on short-term markets of different options regarding RES support schemes, the impact of different design configurations for balancing markets and long-term cost options for energy/capacity markets beyond the 2020 horizon.

2 RATIONALE FOR AN EVOLVING MARKET DESIGN WHICH ENABLES RENEWABLE ENERGY GROWTH

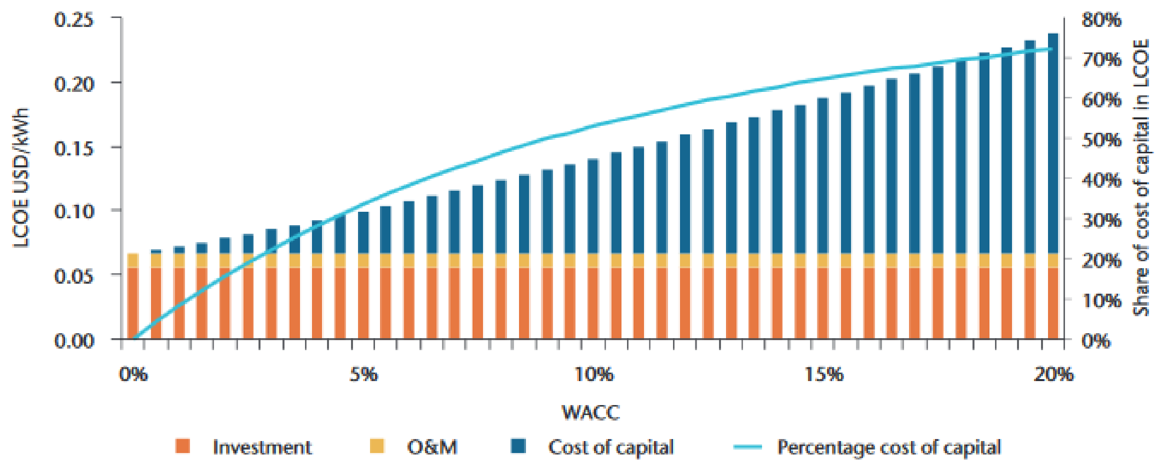
2.1 Reducing market risk by the use of enabler policies and market instruments

The rapid and successful market uptake of renewables into European Energy markets is mainly due to three factors:

- The first one was the **introduction of support schemes** that would **hedge investors against market price risk**. With the introduction of Feed-in-tariffs (FiT) in Europe in the early 2000's, investors would receive a fix remuneration from each kWh generated for as long as 20 or 25 years. These type of mechanisms (compared against an investment subsidy) would encourage producers to generate as much as possible in order to increase revenue, but would not hedge them against volume risk.
- The second one, was the **provisions for priority dispatch**. Priority dispatch is an obligation on transmission system operators to schedule and dispatch energy from renewable generators ahead of other generators as far as secure operation of the electricity system permits. Wind and solar PV energy in particular, having variable output and being very flexible (since their power output can be dispatched down to zero in few seconds without significant cost for ramping up/down and start-up), risk being the first to be curtailed in power systems with low flexibility. As curtailing variable generators would be the easiest solution to solve grid congestion in such systems, mostly characterised by a lack of infrastructure and sophisticated operational practices or both, the RES-E Directive puts a requirement on the system operators to reduce curtailment of RES-E generation. In addition, in some cases curtailment is compensated (WindEurope, 2016a). **Priority dispatch thus hedge investors significantly against market volume risk.**
- Additionally, although not so critical as previous elements, the **exemption from balancing responsibilities** would ensure that the remunerated price would not be affected (reduced) due to deviations from the forecasted production. These deviations are generally penalized with a (imbalance) charge, and can be significant for renewable producers, if the energy is to be sold uniquely in the day-ahead market. **The exemption from balancing responsibilities thus would hedge investors against market price risk**

These three elements, along with national targets for renewables that give investors certain visibility on the regulatory framework, improve the competitiveness for RES-E projects, and help to reduce investment risk significantly, bringing down the cost of capital and allowing an effective deployment of the technologies. For technologies such as wind and solar, which run fuel-free and have high investment cost, the cost of capital (financing cost) is a key parameter that will determine whether a project is bankable. The cost of financing should therefore be taken into account when considering the cost-effectiveness of implementing new support systems that transfer risk from the central authority to generators/investors.

The impact of the financing cost (expressed in this example as the weighted average cost of capital-WACC) upon the Levelized cost of energy (LCOE) of solar and wind has been shown in many studies. An illustrative example taken from (IEA, 2014a) is shown hereafter:



Notes: This example is based on output of 1 360 kWh/kW/y, investment costs of USD 1 500/W, annual operations and maintenance (O&M) of 1% of investment, project lifetime of 20 years, and residual value of 0.

KEY POINT: When the WACC exceeds 9%, over half the LCOE of PV is made of financial expenditures.

Figure 1. Effect of financing costs on the levelised cost of energy of Solar Photovoltaics. Source: IEA, 2014

With respect to this, the [IEA] states that: *"For a given site and irradiation, setting aside performance ratio and its evolution over time, the most important levers for cost reductions are capital expenditures and costs of capital [...]. When the weighted average capital cost WACC exceeds 9%, more than half the LCOE represents the burden of financing. [...]. More optimistic assumptions lead to lower costs."*

Similarly, a recent published report (Agora-Energiewende-C, 2016), provides the following example with regard to the impact of the WACC upon wind generation assets: *"For two technologies, where one is capital-intensive but without fuel cost (e.g. onshore wind project, 80 percent capital cost) and the other is less capital intensive with fuel cost (e.g. CCGT technology, 20 percent capital cost), a rise in capital costs by 1 percent due to revenue risks (e.g. from 6 to 7 percent) would lift the LCOE of the wind project by about 8 percent and the LCOE of the CCGT project by only 2 percent. This means the wind project would have to generate substantively higher revenues in the same market to be profitable, as compared to the CCGT project."*

In light of the above, although not discussed in depth in this report, long-term binding targets provide a number of additional benefits that should not be underestimated. For instance:

- They provide long-term certainty to energy regulators and system operators and industry to make the necessary level of investments in transmission and distribution infrastructure.

- They provide visibility to industry to tap into the benefits of economies of scale by increasing manufacturing capacity, optimizing the value chain and investing in capital-intensive infrastructure (e.g. new vessel for installing offshore platform, larger testing site, etc.)
- They also provide long-term stability to energy regulators to define adequate market rules adapted to the upcoming technologies.

2.2 RES fit for the Market AND market fit for RES

Evolving RES support instruments

With the successful deployment of renewable energy technologies in Europe and their fast cost reduction, their impact on the operation of the market and the energy system has been the subject of numerous studies. In most parts of Europe, renewable electricity has been supported by FiT, which guarantees a fixed price for all electricity produced. Whereas this system was perfectly fit initially, there are now increasing challenges of having those systems: Low (and even negative) and extremely volatile wholesale prices, and conventional electricity generation have difficulties to recover their costs.

Thus, there is a general agreement on the need to progressively expose renewable energy producers to market signals. This is also reflected in the new European State-aid guidelines for energy and environment that were approved in 2014 and are entering into force in 2016. A deeper analysis of this regulation is provided in (Market4RES-D6.1.1, 2016). They push governments to make use of market based support mechanisms when driving the deployment of supporting renewable energies, as well as making use of tenders to allocate the specific support to market parties in a more transparent and competitive manner. A report of this project (Market4RES-D3.2, 2015) has detailed the process of adapting support schemes to market based mechanisms, as a first step on the market integration of renewable energies.

Section 4 of this document assess the various market-based support schemes, and provides guidance on how this should evolved overtime, as renewable energy is deployed.

Evolving energy market

The movement to more market-based instruments for RES support needs to be accompanied by an evolution of the electricity market in various aspects. Without this simultaneous adaptation, renewable energy producers will be faced with market arrangements that implicitly and/or explicitly penalize non-dispatchable weather dependent technologies, exposing them to uncompetitive market situations. Thus, if market-based instruments are implemented without evolving the market to fit better for RES, investment risk will increase considerably, leading to higher financing costs for investors and society. As a consequence, the growth of renewable energy sources in Europe could be jeopardized. The market needs to gradually adapt to new technologies that are more variable, with low running costs and that do not use fuels that can be stored (at least not in a very competitive way so far). Thus the market needs to lead to full utilization of their variable output while ensuring secure operation of the system and leading to an efficient dispatch (market signals, namely market prices that could even be negative, play a very relevant role in this regard). Among the parameters that need to be improved, the timeframes for trading, the geographical scope of the market, access to the balancing market and design of reserves are among the key ones that urgently need to evolve. Section 3 of this report presents how the Energy-only Market could get fitter for RES.

Evolving external factors and markets

Finally, the ultimate goal of a liberalized energy market is to allow renewable energy technologies, as well as any other type of technology, to compete on a level playing field, leading to the necessary investments in environmentally friendly technologies, and ensuring that security of supply targets are fulfilled. Independently of the evolution and future need of explicit support instrument in the long term, a number of action need to take place to create a level playing field. Concretely:

- Complementary markets, such as the Emission Trading scheme (ETS), need to readjust their emissions cap to reflect current economic activity, emissions reduction targets and the influence of energy efficiency and renewables,
- Remaining subsidies to fossil fuels, either through direct subsidies in producing countries, tax exemption regimes and/or targeted payments for capacity need to be properly addressed,
- External environmental costs should be internalized. Today EU lacks a common approach to reduce air pollution or internalize it in technology costs; the cost for nuclear energy plants decommission and waste disposal are generally socialized through citizens taxes, thus not being reflected in the technology capital cost (IRENA-ReMAP, 2016).

While these factors are not directly addressed by the energy market rules, they do impact its functioning and thus they need to be considered by policy makers when discussing its optimal design. The deliverable 6.3 of this project (Market4RES-D6.3, 2016) developed extended views on these factors. (Ecofys-B, 2014) has made an extensive assessment of external cost of energy technologies, presenting their real cost in terms of €/MWh. Not surprisingly, technologies such as coal present values 10 to 20 times higher than those for Solar PV and wind power.

The previous three main areas of work that will have an impact on the effective deployment of renewable technologies is depicted in Figure 2.

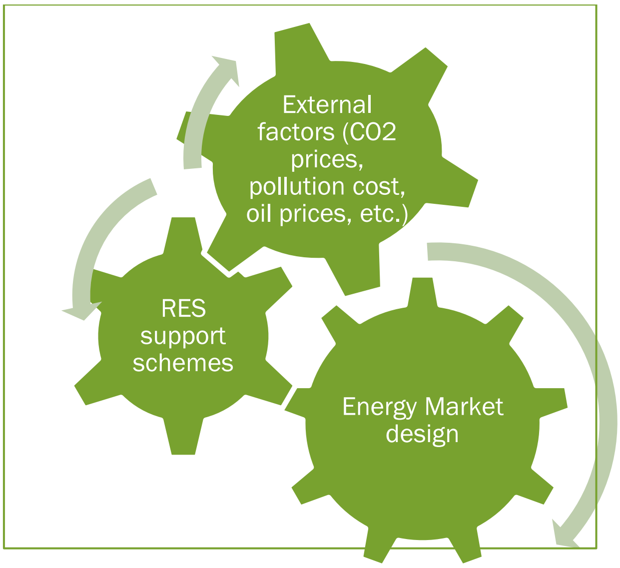


Figure 2. Main areas influencing the design of policy

3 KEY MARKET DESIGN FEATURES TO FACILITATE RENEWABLES MARKET INTEGRATION

The following section (3.1) summarize the key design features that are critical for the successful participation and integration of renewable energy producers in a fully liberalized and competitive market place at all timeframes (day-ahead, intraday and balancing). These features are organized in five areas/aspects, as presented in Figure 3. Afterwards, sections 3.2 to 3.4 address specifically each of the market timeframes.

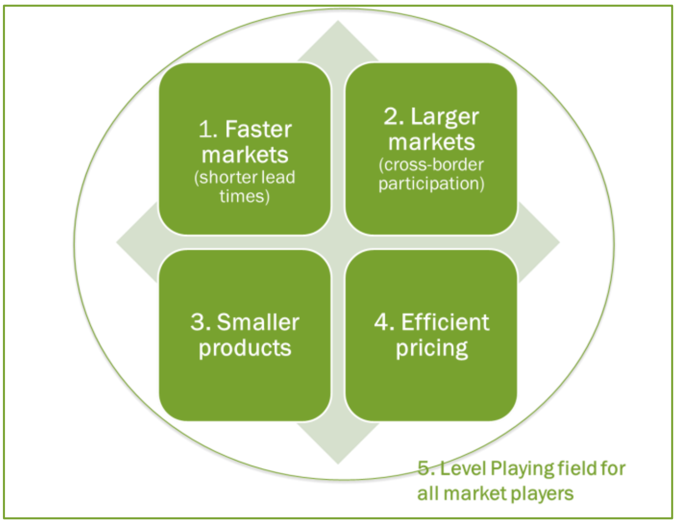


Figure 3. Key market features for successful integration of RES in all market timeframes

3.1 Common key design market features

3.1.1 Timing of Markets

The real-time operation of a power system must always be centrally coordinated ahead of delivery time to ensure a continuous match between supply and demand. However, the liberalization process has provided market places with a prominent role in contributing to this balance.

With the growing penetration of renewables generation, there is a consensus reflected in the network codes that the timing of markets should evolve to allow faster changes in system conditions, which are largely caused by weather patterns (e.g. renewable generation, heating/cooling demand, etc.).

Concretely, this means that the time point at which Transmission System Operators receive schedule generation and take control to ensure security should be pushed forward back as close as possible to real time giving market players with variable generation the option to self-balance their deviations via the market. Not only would this maximize the value of existing renewable generation, but also minimize the impact of uncertainty provoked by non-dispatchable generation and thereby the need for flexible resources.

Figure 4 shows the sequence of the various markets, from forward markets that can set energy bids in the long term, to close to real time like the balancing market. It can be observed that the procurement of balancing capacity can happen in the very long term. The figure tries to depict that the gate closure time for balancing energy should always be after the gate closure time for the intraday market (this is not the case in all European countries).

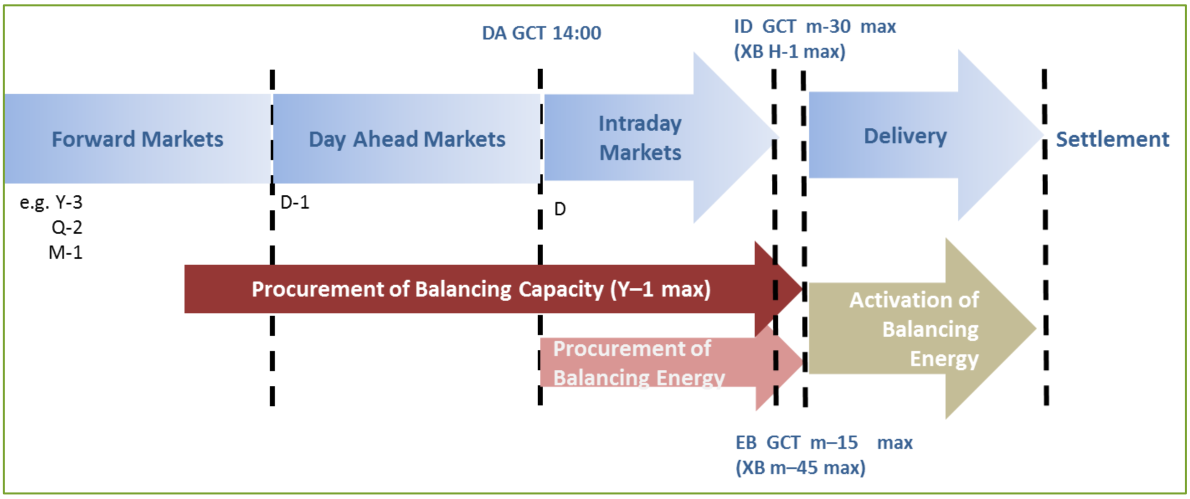


Figure 4 Sequence of markets and Interface between the timeframes. Source: WindEurope

3.1.2 Size of markets- geographical scope

The starting point for a pan-European market where electricity can move freely across borders is to define the available transmission capacity for trading. Traditionally, this has been calculated before final flows are known, one border at a time and without considering bilateral trading impacts on neighboring systems (*available transmission capacity* (ATC) method). This causes TSOs to frequently prioritise flows inside zones over flows across borders under different security standards, even when restrictions are not justified by the physical flows of power.

This can be alleviated by better coordination between TSOs, notably by harmonizing transmission capacity calculation and allocation methods that use a **Common European Grid Model in which flow-based transmission capacity allocation can be carried out**[2]. This method builds on technical power flow optimization models that take into account the relationship between commercial flows and physical congestion on affected transmission network elements (cf. critical branches). The benefits include:

- Increases in the capacity offered to the market participants,

[2] Except in cases where the electricity networks are not meshed and where such a method would not add value compared to a coordinated Net Transmission Capacity scheme

- Improvements in price convergence and higher the social welfare by allocating capacity where it is most valuable[3].
- The potential to significantly reduce unscheduled power flows (loop flows) through neighboring systems,
- The possibility of linking dynamic grid management (cf. dynamic line rating) with the market to maximize the use of new and existing assets.

By 2020, transmission capacity calculation should be performed in all timeframes, including intra-day, following the implementation of the capacity calculation requirements (CACM regulation)[4].

Increasing cross-border interconnection capacity, as well as the capacity to transport electricity across the same bidding area is crucial to allow further integration of renewable energy sources. Such increased capacity is the basis to ensure cross-border competition in the various markets (e.g. intraday and balancing). This will impact positively the liquidity in the market and could reduce prices for consumers.

3.1.3 Product design

Smaller timeframes for the products are positive for the participation of variable renewables generation units. This is very much related to forecasting and predictability of renewable generation assets and their possibility to adjust to demand ramp up/down periods. The use of shorter products will need to be combined with larger ones to find a balance between liquidity in the markets and cost of implementation. The project has assessed product design aspects for the day ahead, the intra-day and the balancing market (see sections 3.3 and 3.4).

Moreover, the procurement rules associated with the specific products have a key impact on the participation of renewables, especially for balancing markets.

3.1.4 Efficient Pricing of products

Scarcity pricing

In a well-functioning electricity market, unhindered price-formation drives operational choices and investment decisions. Transparent and undistorted market prices must be in place in all time horizons. Therefore, price spikes should be treated as a positive sign of an efficient and cost-effective energy system, where market participants are free to choose the level of hedging they prefer to contract, and that reveals the true value of flexibility and energy at all times.

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[3] Welfare increase in 2014 under flow-based market coupling was simulated to amount to 132 million euros, ACER 2014 Market Monitoring Report.

[4] See Deliverable D6.1.2 for further details on current status (Market4RES-D6.1.2, 2016)

Marginal pricing as the common norm

The major problem when clearing electricity markets is that due to non-convexities (start-up, indivisible offers such as the minimum technical output, etc.), it is not possible to obtain an optimal (social-welfare maximising) dispatch that can be cleared with uniform marginal prices since they only include variable production costs.

The project has assessed (Market4RES-D3.2, 2015) the different approaches taken by the EU (uniform marginal pricing) and the US (where additional compensations are allowed for some bids, implying discriminatory remuneration). Results show that there is no perfect design, cf. Figure 5.

		European approach	US approach
Eficiency	Prices (cost reflectivity)	Good	Fair
	Bidding protocols and dispatch	Fair	Good
Robustness	RES penetration	Good	Good
	Market power	Good	Fair
Implementability	Implementability: computability	Fair	Good
	Implementability in Europe	Very Good	Fair

Figure 5. Summary of the assesment made for the EU and US approaches to the design of energy prices and bids

Marginal pricing (pay-as-clear) should not only be applied in day-ahead and intraday markets but should also be the rule for balancing market as it is proved that activation of Reserves (in particular aFRR) with merit order leads to lower balancing costs (eBridge, 2015). While pay-as-bid provides incentives to market parties to submit bids as close as possible to the expected marginal price (e.g. Germany, Belgium, Austria, Italy, Hungary), this is more difficult for small players that do not have the same possibilities to forecast prices, thereby this can act as an entry barrier and undermine competition within balancing markets.

The only exception is the intraday timeframe, where continuous offers (pay-as-bid) should be combined with discrete auctions (pay-as-clear). Including more complex types of orders within these auctions may prove to be a challenge for the short-time period available to clear the market.

3.1.5 Level Playing field

Balancing responsibilities

It appears to be a common understanding that full balancing responsibility for all market participants is an important prerequisite for a well-functioning electricity and thus balancing market, with equal access for all players and a level playing field for all market players. There is wide agreement that the Balance Responsible Parties (BRPs) play an essential role, and that balancing responsibility for all market participants is an important condition for system balancing, for security of supply and efficient market functioning.

The Electricity Balancing Guideline[5] aim to standardize and harmonize to a large extent the national terms and conditions for balancing services providers (BSPs) and balance responsible parties (BRPs). It that context, responsibilities for all market players are foreseen.

Balancing responsibilities for all parties should, however, be accompanied by the existence of markets that allow trading close to real time (specially Intraday market with short gate closure times and with a sufficient level of liquidity) to minimize forecast errors and markets that have fair access rules to balancing markets for all market parties (see section 3.4 for further analysis).

Priority dispatch

Regulatory frameworks will increasingly expose renewables generators to market risks. Today some EU markets which have relatively high penetration rates of renewables, do not offer priority dispatch for renewables producers and this does not place any restrictions on market growth. Besides, these markets offer market-based instruments to allow them to participate in balancing markets and to voluntarily dispatch-down their output.

In general, priority dispatch for any technology should be set according to market maturity and liberalisation levels in the Member State concerned, but it should also take due account of progress in grid developments and should apply the best practices in system operation.

A phase out of priority dispatch for RES could only be conceived if the following cumulative conditions are fulfilled:

- Priority dispatch is removed for conventional generation and all other forms of non-renewables generation
- Existence of functioning intraday and balancing market
- Renewables generators should have full access to balancing markets
- A satisfactory level of market transparency and clear compensation rules for curtailment

Subsidies to conventional technologies

While today's discussion is centred on the support for renewable energy sources, conventional technologies continue to receive direct or indirect support from national governments and the European Commission. Historically, technologies such as nuclear and coal have received direct support several order of magnitude higher than the support provided today to the various renewable

[5] It is also known as the Electricity Balancing network Code (still draft under comitology process by June 2016)

energy sources (Ecofys-B, 2014). Indirectly, still today nuclear energy receives more support for research and development (focus on safety) from European funds (Euratom- Horizon 2020) than the support allocated to all other low-carbon technologies (including renewables, CCS, smart grids and energy efficiency).

And still today, national support to coal, nuclear and gas amounts to over 20bn€ annually just within the European Union (figure from 2012), as presented by the European Commission in (Ecofys-B, 2014).

Continued support to conventional technologies needs to be addressed in parallel to the reform of market design rules and the revision of state-aid guidelines for environment and energy.

3.2 Day-ahead market

Trading renewable energy mostly on day ahead markets prevents the possibility of delivering more accurate power generation, and leads to greater mismatches between scheduling and delivery of energy, which need to be corrected during the day of operation.

Today, most power exchanges in Europe “close” day-ahead trading at 12:00. Then, clearing is performed once per day for all coupled zones around 13:00, this way orders can be matched between markets and cross-border capacity is implicitly allocated. In contrast to conventional power generation (decision for thermal units commitment is generally about 6 to 8 hours ahead), which is demand driven, RES generation is mainly supply driven according to the availability of its energy source. This availability is more accurately forecasted at shorter time scales (around 10% error margin 24 hours ahead of delivery, for wind).

Delaying the day-ahead closure time could therefore result in a decrease in the errors made by RES operators when forecasting their available RES electricity production, as well as a reduction of the error on forecasting demand. More adequate forecasts should lead to less rescheduling (and corresponding transaction costs), and overall allow the system to decrease substantially the size of imbalances they must address in subsequent markets (especially important for RES generators).

To maximize efficiency and avoid distortion, all these tasks before market coupling calculation could therefore be pushed to take place as late as possible. However, for some power system there might be no significant added value to bring it too close to real time. The analyses carried out in (Market4RES-D5.2, 2016) show that bringing closer the day-ahead market to real time only a few hours does not necessarily reduce the dispatch costs of the power system, because the reduction in the wind and solar forecast error is small, as can be seen in Figure 6. In these situations, although more RES is integrated into the power system, the energy produced with thermal units increases. The integration of more RES energy into the system results in some flexible generation plants, largely hydro ones, being no longer committed. Hence, part of the electricity being produced and up reserves being provided by hydro units are now being provided by thermal units. Of course, this only occurs for low levels of reduction of the forecast error.

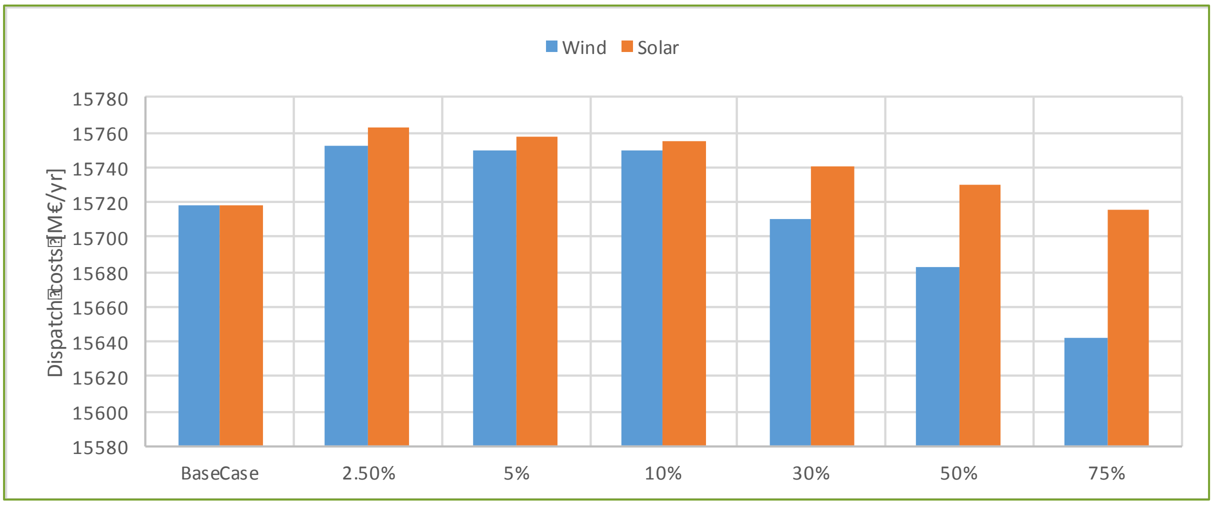


Figure 6 evolution of the generation dispatch costs with the reduction in the wind (blue) and solar (orange) forecast error for the 2030 Spanish system

Figure 6 shows that reducing the forecast error brings significant benefits in the operation of the power system, but only when the error is reduced more than 30% or so. In order to achieve these levels of reduction in the forecast errors, the day-ahead market has to be very close to real-time, as can be seen in Figure 7 for wind. But the lack of flexibility of the generation mix of some power systems would make it inviable to bring day-ahead markets this close to the real time. If the day-ahead market is very close to the real-time, some generation units will not be able to start-up or shut-down in the required time and therefore, they will be automatically out of the market. Power systems with high flexibility in their generation mix, e.g. Nordic power systems, may consider this option.

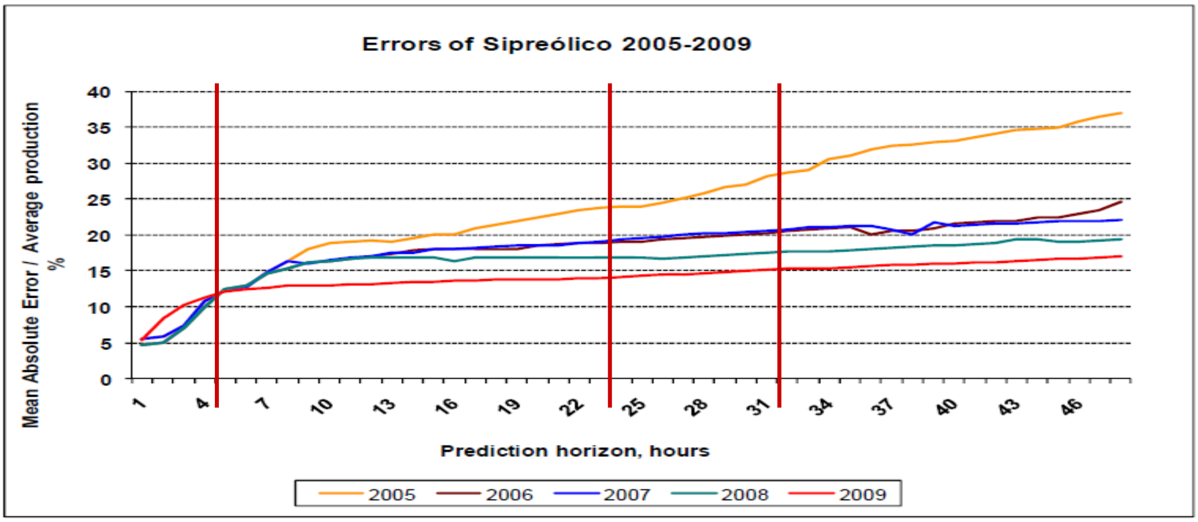


Figure 7 evolution of the wind forecast error based on the forecasting horizon

Regarding the coupling process itself, the efficiency is increased as the total time needed to conduct the associated tasks is shortened (while complying with security criteria). Currently, under normal operational conditions, total time to conduct these tasks takes 42 minutes.

Nevertheless, even after day ahead gate closure, plans generally need to be updated. One of the following events could occur: suppliers or non-physical traders may have forecast their production incorrectly, an updated weather forecast might be available, or there may be an unforeseen down time of a transmission line or an unscheduled outage of a large power plant. Therefore, relying on an intraday market is especially important.

3.3 Intra-day Market

3.3.1 Market timeframe

The intra-day time frame is of significant importance to allow renewable generators to adjust their market position, but also to reduce the amount of balancing operations. An adequately functioning intraday market is a prerequisite to the full implementation of balancing responsibilities for all generators, notably because the correction of imbalance on this market proves to be less costly than through the activation of balancing mechanism, which is generally financed by the market parties out of balance (imbalance charges)[6].

When setting the timing for this timeframe, two major alternatives exist:

- **Continuous trading**, i.e. bids can be submitted and matched by power exchange at any time before final gate closure time. For instance in Belgium, intraday platform becomes available for trading the day before delivery, at 14:00, and closes 5 minutes before is actual delivery.
- **Intraday discrete auctions**, i.e. one or several auctions are called at specific predefined time. For instance, EPEX SPOT launched on German intraday market a complementary 15-min call auction at 3pm allowing market participants to trade the 96 quarters for delivery the next day simultaneously. Then, continuous trading session starts at 4pm until 30 min before delivery time. This examples (presented in Figure 8) shows the interest from participants to make use of 15-minute products

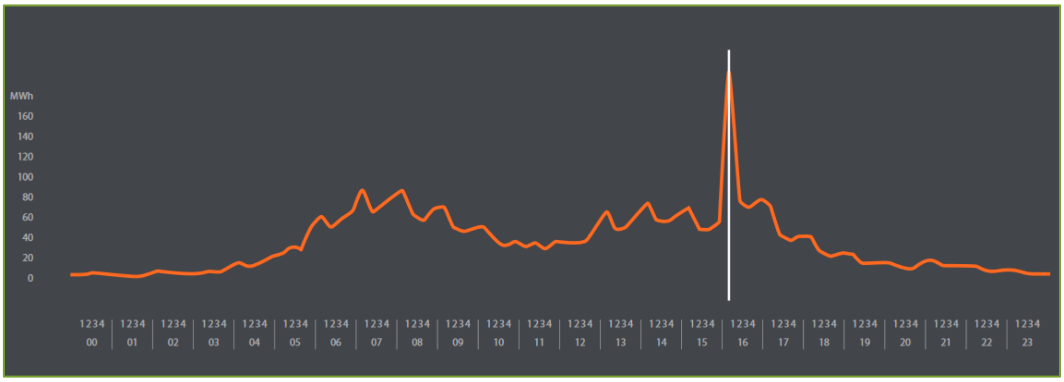


Figure 8 Trading activity on the 15-minute intraday market, EPEX SPOT 2015

[6] The Balancing process is generally financed through imbalance settlement. In some cases, its cost is also shared by all energy consumer through network charge

Continuous markets (pay-as-bid) are simple to implement from a conceptual point of view. At least if only simple price-quantity orders are allowed. Including more complex types of orders may prove to be a challenge for the short-time period available to clear the market. There is a large international experience both at national and regional level with this type of markets (for instance in Northern and Central-West Europe).

Discrete intraday auctions are also relatively simple to implement, but require more regional coordination (at least some homogenization is needed on the decisions on when to schedule discrete sessions of the markets). There is international experience at a national level (e.g. Spain, Portugal and Italy). The experience in the regional context is limited in Europe to the simpler case of two interconnected systems (e.g. Spain and Portugal). However, the processes for intraday auctions are expected to mimic – or at least to be largely inspired by - the day-ahead process, which is already largely implemented in Europe.

There is a possibility to combine both approach into a hybrid design, combining the advantages of both (but also the disadvantages). **The hybrid approach can be expected to be the best design variant** as it achieves the most balanced and therewith best overall-outcomes with regard to the assessment done by the Market4Res consortium (Market4RES-D3.2, 2015).

3.3.2 Enlarging the geographical scope

When coupling cross-border intraday markets regional auctions need to be introduced at large scale; this would require more regional coordination; at least some homogenization is needed on the decisions on when to schedule discrete sessions of the markets and the gate closure times.

Last but not least, the persistence of uncoordinated and heterogeneous intraday gate closure times (ID CGT), between but also within bidding zones, is an important barrier to the improvement of liquidity level in intraday markets according to (ACER, 2015). For example, in the Netherlands, the national ID CGT is five minutes ahead of delivery, while different GCTs are in place on their borders (which can be up to 8 hours ahead of real time). According to the CACM regulation, there should be one ID GCT established for each market time unit for a given bidding zone border and this to be at most one hour before the start of this market time unit[7].

3.3.3 Increasing liquidity

The main objective of improving intraday trading within and across border is to boost market parties interest and thus liquidity (relatively low in the majority of national intraday markets). ACER has attempt to assess liquidity in EU markets by assessing various indicators that will unlock market parties participation in this timeframe (see Figure 9)

[7] Regulation 2015/1222. See http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R1222&from=EN

	Nationally specific elements of ID markets						Elements of (national and cross-border) intraday trade that are envisaged in the intraday target model			
Market	Ratio ID volumes/ demand	Intermittent generation (% installed capacity)	ID auctions	Exclusive (no alternative to organised market)	Portfolio bidding/Unit bidding	Market time unit (in the organised market)	Balance responsibility for RES	Implicit allocation of cross-border capacity	Close-to-real-time gate closure (1 hour or less, national market)	Standard and non-standard products available
Spain	12,1%	22%	Yes	Yes	Unit bidding	1 hour	Yes	On one border	No (2-3 hours)	Yes
Italy	7,4%	18%	Yes	Yes	Unit bidding	1 hour	Not fully	No	No (2-3 hours)	Yes
Portugal	7,6%	21%	Yes	Yes	Unit bidding	1 hour	No	Yes	No (2-3 hours)	Yes
Germany	4,6%	28%	Yes (for 15 min. product)	No	Portfolio bidding	1 hour and 15 min	Not fully	On one border	Yes (45 minutes)	Yes
Great Britain	4,4%	12%	No	No	Portfolio bidding	30 min	Yes	No	Yes (1 hour)	Yes
Slovenia	1,0%	7%	No	No	Portfolio bidding	1 hour and 15 min	No	No	Yes (1 hour)	Yes
Belgium	1,0%	19%	No	No	Portfolio bidding	1 hour	Yes	On one border	Yes (5 minutes)	No
Sweden	1,0%	11%	No	No	Portfolio bidding	1 hour	Yes	Yes	Yes (1 hour)	Yes
Lithuania	1,0%	8%	No	No	Portfolio bidding	1 hour	No	Yes	Yes (1 hour)	No
France	0,7%	10%	No	No	Portfolio bidding	1 hour	No	On one border	Yes (45 minutes)	Yes
Czech Republic	0,7%	10%	No	No	Portfolio bidding	1 hour	Yes	No	Yes (1 hour)	No
The Netherlands	0,2%	10%	No	No	Portfolio bidding	1 hour (standard) and 15 min	Yes	On some borders	Yes (5 minutes)	Yes
Poland	0,1%	9%	No	No	Portfolio bidding	1 hour	Yes	No	No (Gate closure at 14:30)	No

Figure 9 Liquidity in organized markets and the main characteristics of market design in a selection of European intraday markets, ACER 2014 Market Monitoring Report

As shown by this analysis, there is an obvious relationship between intraday liquidity and the penetration of renewable-based generation. The presence of intraday auctions as well as obligatory unit bidding seem to play a significant role in increasing liquidity, notably because this latter incentivise renewable generators to adjust their position in this timeframe to avoid important balancing costs.

There is a close interdependency between the use of intraday cross-border capacity and the ability of close-to-real-time trading. It has been observed (ACER, 2015) at some borders that more than half of the intraday cross-border capacity was requested and allocated between one and three hours prior to delivery, proving that well-designed and interconnected intraday markets serve the balancing needs of renewable generators[8].

However, the relatively low utilisation of cross-border capacity in the intraday timeframe (as well as observed intraday price differentials) suggests that there is scope for improvement as regards the reassessment of network conditions after day-ahead gate closure time.

[8] 56% for French borders with Germany and Switzerland in 2014. Source: ACER market Monitoring report

3.3.4 Product design

As for day ahead timeframe, most intraday markets trade standard hourly products. However, the introduction 15-min contracts on German intraday market in 2011 had fostered market participants' interest because it allows them to refine their schedules every 15 min thereby limiting the deviation from their real production compared to an hourly basis. In 2015, EPEX SPOT pointed out that *"since 2011, 15-minute contracts provide greater flexibility to handle intermittency and the daily ramping effects of renewable production, contributing to a more balanced market."* Although that liquidity remains relatively low it most likely becomes automatically higher as the share of renewables in the generation mix is to increase. Additionally, the introduction of an intraday call auction can improve the liquidity by attracting markets players who would otherwise not have access to continuous trading.

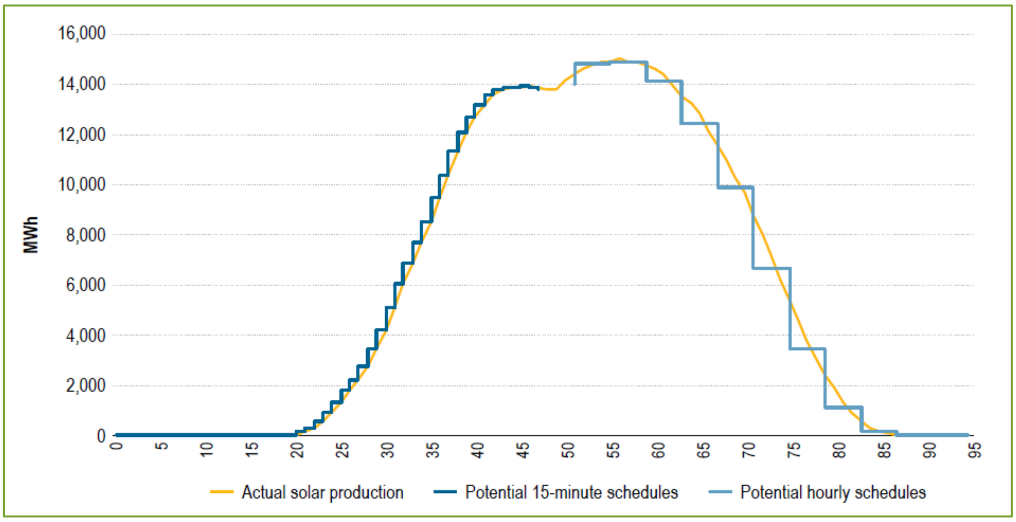


Figure 10. Comparison of potential 15-min schedules vs. hourly schedules of solar production in Germany on 21 June 2014, ACER 2014 Market Monitoring Report

A prerequisite to the introduction of more granular products seems to be consistency between the market time unit in the intraday market and the Imbalance Settlement Period (also 15 min in Germany); this is further discussed in section 3.4.3.

3.4 Balancing market

3.4.1 Market timeframe

Intraday and balancing markets are closely related since the more (or less) BRPs adjust their schedules through the former, the less (or more) balancing actions will be needed in real time. Only imbalances occurring after the closure of the intraday market should be balanced by TSOs within the balancing market timeframe. This can be explained by the fact that preventive balancing actions may compromise liquidity in the intraday market (by moving bids from this market to balancing markets) and, at the same time, increase balancing costs (which could have been minimized through intraday trading).

For the above mentioned reasons, the balancing energy gate closure time (i.e. *bids* for being available for activation in real time) is much linked to the ID gate closure regime and to availability of short term products in the ID market and with the possibility to schedule cross-border trade in the same (short) time unit. Balancing energy gate closure time should not be before ID gate closure time[9]. This would imply that a change in ID gate closure time should be followed by a corresponding change in balancing market energy gate closure time so that market participants have the opportunity to balance their position.

3.4.2 Balancing markets product and their procurement

So far, renewable generators are in most cases only partly allowed to participate in balancing energy markets and often only in providing replacement reserves. Ongoing market reform and network codes should remove existing barriers and provide for balancing market features and products apt for renewable generators participation. The design of products and associated procurement rules are key factor to increase the participation of renewables in balancing markets. The following sections describe some of the most important features, based on the project detailed assessment (Market4RES-D3.2, 2015).

Separated versus joint procurement of balancing capacity and balancing energy products

Firstly, balancing capacity and balancing energy products should always be procured separately in the future. Some countries (e.g. Germany, Denmark and Spain for aFRR) require generators to have a contract for balancing capacity with TSO in order to participate in balancing energy market. The gate closure time for procuring balancing capacity has generally long lead times for which renewable generators cannot secure firm capacity (e.g. year ahead in Finland and the Netherlands, week ahead in Germany). On the contrary, some countries like Belgium or in the Netherlands, market players can bid balancing energy without a contract up to 1h before real time. Moreover, shorter lead times tend to reduce the cost of balancing, as it has been demonstrated by the project consortium (Market4RES-D5.2, 2016). Several lead times have been analysed, e.g. week-ahead, day-ahead, 12 hours-ahead and one hour-ahead. In the simulation cases D to F (see Figure 11) the lead times and product lengths are reduced from day-ahead to hour-ahead. In addition, common procurement by all TSOs is possible in these cases in contrast to the reference case. Therefore, combining common procurement and shortening the timing of balancing products, reductions of 5.6% (day-ahead), 8.4% (12 hours-ahead) and 14.6% (hour-ahead) in terms of total procurement costs of positive and negative balancing capacity products can be achieved compared to the reference case, where week-ahead is assumed, see Case D to F in Figure 11.

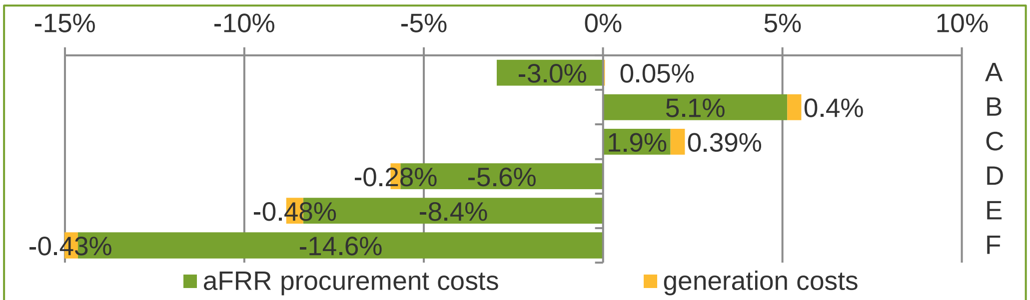
[9] According to the draft NC EB, Balancing GCT needs to be always after ID GCT

Finally, the joint procurement of balancing capacity and energy products could limit up to a great extent the harmonization of balancing markets across borders and, consequently, prevent cross-border trading. This can be explained by the fact that flexibility in balancing capacity markets is much more limited than flexibility in balancing energy markets: while balancing energy is activated to manage imbalances between generation and demand in real time, balancing capacity is procured to guarantee security of supply in longer time frames. Consequently, arrangements for the procurement of balancing capacity can vary greatly depending on each power systems structural characteristics and security of supply needs

Separated versus joint procurement of upward and downward balancing capacity products

Upward and downward balancing products should be split as renewables units would have to produce below their maximum production level. Joint procurement of upward and downward balancing capacity products, as it still applies in many countries, incurs an opportunity cost which corresponds to the revenue that they could obtain from selling the "curtailed" power in the day-ahead or intraday market. Furthermore, symmetric (joint) procurement of positive and negative balancing capacity tend to increase total generation costs and total procurement costs because, typically, the price of the single product is determined by the sub-product (in the case, either upward or downward balancing capacity) of highest cost (the costs of providing upward and downward balancing capacity can vary significantly). This has been demonstrated by the project consortium in (Market4RES-D5.2, 2016) by simulating balancing markets in 2030 (see Figure 11). In Case B (week-ahead) and C (day-ahead) the symmetric (joint) procurement of positive and negative balancing capacity has been applied in contrast to the reference case, where separated procurement is assumed. As it can be seen from the graph the procurement costs are around 5% (for week-ahead and 2% for day-ahead) higher than in the reference case.

Figure 11: Differences of aFRR procurement costs and generation costs compared to reference case.



Duration and size of balancing products

The duration of the products has also high impact on the opportunity for renewables generators to offer balancing services. Balancing energy is generally procured on blocks of 1 hour, although some countries have time frames for Frequency Restoration Reserves as short as 15 minutes (i.e. Italy, France, Belgium). Shorter timeframes can increase participation of renewables generators and are likely to reduce the overall cost of balancing (with shorter products length and procurement times, inter TSO cooperation becomes less relevant- TSO can rely on more balancing capacity within their own control area so there are less reserves exchanged (Market4RES-D5.2, 2016).

The technical characteristic of renewables generators, compared to conventional ones, allows provision of response and reserve on demand, and with fewer inefficiencies (see Figure 12). Advanced control techniques allow them to ramp up or down as required by the system, depending on the availability of their primary energy source at the specific moment. This could offer significant flexibility to the system, allowing TSOs to make use of inexpensive balancing resources. Failure to utilize this capability regularly will increase the cost to the consumer.

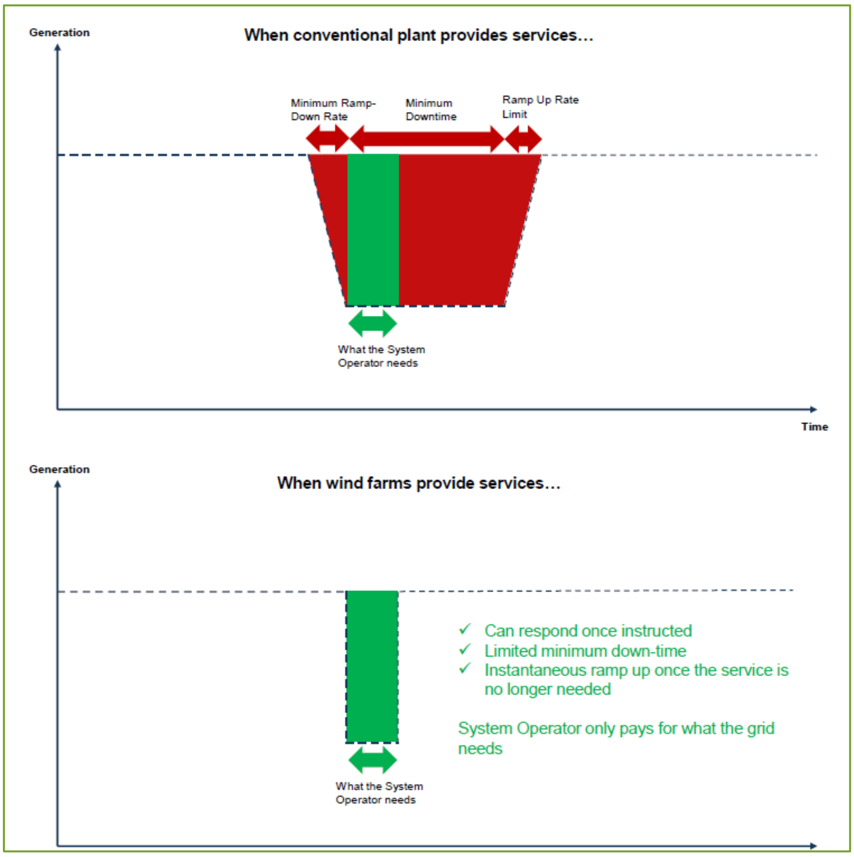


Figure 12. Provision of downward regulation by wind farms is more effective than by conventional generators. Source: DONG energy

Depending on the product minimum bid size, small generation and load units may be prevented from participating in balancing markets if aggregation of individual units' offers (for compliance with minimum bid size) is not allowed[10]. To foster the participation of small units in balancing markets,

[10] In the Spanish case, the minimum bid size for balancing products is 10 MW, while 23% of wind units and 48% of solar units are smaller than 10 MW

smaller minimum bid size should be required and the aggregation of several units should be facilitated. It should be noted that aggregated forecasts are more accurate, which could lead to a more reliable participation of renewable producers in balancing markets.

Finally, technology-specific products that can only be provided by specific agents (e.g. additional upward reserve market in Spain, used to procure replacement reserves capacity, where only thermal units not committed in the day-ahead market are allowed to present bids) should be removed. If a competitive and efficient integrated balancing market is to be achieved, all potential providers should be allowed to participate as long as they comply with the technical requirements for balancing service provision.

3.4.3 Imbalance settlement

Balancing costs (capacity procured + activated energy) should be allocated to imbalanced BRPs through the use of imbalance charges. However, in several countries, one can see that balancing capacity procurement costs are disproportionally high. Possible reasons include that the sizing of reserves is not always optimal, (e.g. conservative application of N-1 rule in small systems) and that Capacity is also contracted to deal with network congestions (e.g. Italy, Great-Britain, Poland, Spain).

Balancing capacity is generally contracted well before and for longer periods than the actual imbalances. Consequently, procurement costs of balancing capacity cannot be directly attributed to imbalanced BRPs. For this reason, balancing capacity costs are, in most cases, socialized among consumers while balancing energy costs are allocated to imbalanced BRPs through imbalance prices. Finally, procurement rules should be optimized to reduce as much as possible the cost of balancing capacity (cf. previous section), and converging the energy balancing cost to the overall balancing cost.

Imbalance charges can be settled under either a single or a dual pricing scheme. A dual imbalance price mechanism is supposed to give stronger incentives to deliver schedules as submitted. However, it could also incentivise strategic gaming behaviour (i.e. bidding towards system imbalance) and may excessively penalise renewables generators, as their forecasts can deviate up or down. Such balancing provisions put them at a disadvantage compared to conventional generators as their forecasts become more accurate closer to electricity delivery, but they have few or no opportunities to use them in real time operation.

Finally, the design of the imbalance settlement has to be a zero sum game for the TSO (not a source of revenues). Where a penalty component is added, this extra income is typically used by TSOs to reduce transmission tariffs, thereby resulting in a transfer of money from wind power generators to average users. This put small players at a disadvantage in comparison to large players which can net their imbalances and face lower imbalance costs.

The impact of shorter imbalance settlement periods has also been assessed by the project (Market4RES-D3.2, 2015), leading to the conclusion that shorter imbalance settlement periods contribute to a more cost-reflective calculation of imbalance prices.

The above mentioned design parameters are summarized in Table 1. A fully-fletched analysis of all these market aspects is provided in (Market4RES-D3.2, 2015).

Table 1. Summary of the assessment of balancing arrangements

Competition among BSPs			
Procurement of balancing capacity and balancing energy products	Joint	Separated	
	Poor	Good	
Procurement of upward and downward balancing capacity products	Joint	Separated	
	Poor	Good	
Existence of technology-specific products	Yes	No	
	Poor	Good	
Minimum bid size	Large (> 5MW)	Medium (1MW-5MW)	Small (≤1 MW)
	Poor	Poor to fair	Good
Pricing of balancing products	Pay-as-bid	Marginal	
	Poor to fair	Good	
Adequate incentives on BRPs			
Imbalance pricing system	Dual	Single	Combined
	Poor to fair	Fair to good	Good
Settlement period	Long (1 hour)	Average (30 min.)	Short (15 min.)
	Poor	Fair	Good
Efficiency in balancing actions			
Balancing & intraday trading (ID)	Preventive balancing actions	All balancing actions after ID	
	Poor	Good	
Balancing & congestion management (CM)	CM affects imbalances	CM is treated separately	
	Poor	Good	

3.5 Brief conclusions on market design features

- **The timing of markets** should be modified to allow their outcome to react faster to changes in system conditions largely caused by renewable generation. Then, day-ahead markets should be called as late as possible (regarding bid submission) while tasks associated with them should be carried out as quickly as possible. In the Intra-day time frame, continuous trading, providing greater flexibility, should be implemented, while in those cases where flexibility is not enough this should be combined with discrete auctions.
- **Intraday market liquidity** is heavily dependent on factors such as: renewables participation, the existence of discrete auction in addition to continuous trading, short gate closure times, balancing responsibilities, the possibility of aggregated bids and intra-day cross border implicit transmission allocations. Balancing responsibility for all parties should be closely linked to the existence of enough liquidity in the intraday market.

- Options for the **procurement of balancing reserves** from the long to the very short term should be made available to **allow all types of resources** to contribute reserves to the extent of their possibilities. Lastly, the gate closure for balancing energy bids should be taken as close as possible to real time, providing, again, more flexibility. The gate closure time of the balancing market should always be after the gate closure time of the intraday market, in order to minimize system balancing cost by maximizing trading in the market.
- **Regarding the energy pricing and bidding protocols**, the EU approach turns out to be most efficient, since prices computed more closely reflect marginal supply costs incurred. On the other hand, the US approach features more flexible bids that can reflect power plant constraints and provides larger certainty of producing a market price and a feasible market dispatch, which is not guaranteed under the EU approach. Given that both approaches have some advantages and disadvantages, preserving the EU approach within Europe seems sensible, thus avoiding large implementation costs, and major changes in market design, which would require a large consensus and would be difficult to achieve.
- **As for balancing markets**, more competition would be achieved if both capacity and energy products and upward and downward reserve are separately procured, all technologies are allowed to participate, minimum size requirements for bids are removed (or aggregation is allowed to take place) and pricing of products is marginal.
- Regarding the **imbalance settlement rules**, if balancing arrangements applied are well suited to single pricing, this settlement scheme should allow prices to reflect the costs imposed on the system by any imbalance and should avoid creating a surplus for the system operator out of the application of the scheme. However, if balancing arrangements do not suit single pricing, this may produce worse results than dual pricing. The settlement period should be as short as possible for imbalances created by each agent to be reflected in payments to be made by it.
- Lastly, **imbalance actions should take place after intra-day markets** and the use of balancing resources for congestion management and balancing purposes should be kept separate regarding the price formation process.

4 RENEWABLE ENERGY MARKET INSTRUMENTS- PREFERRED OPTIONS

4.1 Key design aspects of RES support schemes

Maturing technologies unavoidably need to progressively be exposed to more market risk, allowing a level playing field and facilitating the operation of the power system. As previously discussed, the trend is to rely more a more on market-based support mechanism, such as Feed-in-Premiums (FIPs). However, these are just generic concepts and they depend strongly on the precise design parameters used to define them. The setting of each of the parameter will determine whether the mechanism is effective (leading to investment), efficient (leading to lower financing costs), robust (allowing the scheme a certain degree of flexibility in order to react to changing circumstances but in a predictable way without causing investors unnecessary uncertainty). Table 2 presents some of the key features defining a specific market instrument, in particular for feed-in-premiums and green certificates systems.

The duration of the support is as important as the level of the premium itself. Whether the support is technology neutral or targeted will make a huge impact on the development of different technologies (for instance, the recently tender to access the premium of the Contract for difference in the UK has led to almost only support to onshore projects, neglecting the future potential contribution from other technologies with respect to cost reduction and to complementarity on production profiles).

Table 2. Key design parameters of RES support mechanism. Assessment done by WindEurope

Design parameter	Description	Impact
Premium level	It can be set administratively or based on a tendering process. It is generally based on the estimate LCOE (considering life time of the plant and estimated energy output). Common methodology to calculate LCOE have been proposed by (Ecofys, 2014) It can be also designed to automatically adjust based on actually installations against a projected growth (corridors). Typically used in FIT and FIP. More sophisticated premiums can be introduced (floating premium); being dependent of appropriate return rates and average market prices.	The premium needs to reflect technology cost decrease to avoid windfall profits for the industry. Without priority dispatch for RES, it becomes very challenging to estimate full-operating hours, and thus the level of the premium. Floating premium can lead to very different outcomes depending on its design (further explain in Figure 17).
Volume of supported technology	Quota systems do not set the price but the volume of green certificates that need to be purchased.	The top-down setting of the quota has significant implications on the certificates prices.

	FIT and FIP can be either limited through the size of the tender/auction or by total amount of permits given by the administration per years.	
Floor	They are used to reduce investment risk which can results from low wholesale market prices and/or low green certificate prices. Within a FIP, the can ensure minimum remuneration per kWh. Different floor prices can be set, depending on market situations (season, time of day, etc.)	Floor prices tend to reduce financing cost as price risk is reduced, however they are prone to easier regulatory intervention to reduce overall policy cost.
Cap	Limiting the maximum remuneration from the premium, they help to limit policy cost (support) from consumers). They are usually used for instances when market prices are high enough to provide for investment return. They are also used to eliminate support when market prices are negative, des-incentivising the injection of power in times of low demand.	Given the tendency of decreasing wholesale prices, caps are normally not reached (e.g. wind power support in Denmark). They are being introduced to limit the number of hours with negative prices in the market.
Duration	A key feature of the support is its duration. Traditionally support through FIT has been granted for a period of 15 to 25 calendar years. Today, FIP are moving to shorter period (10 years) or they are based on a defined number of (full-load equivalent) hours.	In markets without priority dispatch, the duration based on full-load hours help to reduce uncertainty on the revenue. However, hourly based remuneration tends to represent shorter timeframes (5 to 10 years equivalent)
Scope (technology specific/neutral)	Most of the existing FIT and FIP in Europe are technology specific to avoid supporting uniquely the most competitive solutions (at a given time).	Technology specific premium can ensure a balance deployment of a wider range of technologies and optimize support to avoid windfall profits.
Scope Minimum threshold	Traditionally, the level of premium and duration of support has been associated to the size of installations as these can present significant differences (e.g. rooftop solar versus utility scale large ground mounted installation). Small plants are generally excluded from tendering processes as these systems require a certain level of financial capabilities.	Exposing all type of support to a tendering process will likely exclude small investors (cooperative, private rooftop installation, etc.). This can reduce the level of public acceptance.
Components for specific technology evolution	Certain countries have introduced additional features in the FIP that will determine the full duration of the premium, based on specific technology characteristics. The Danish FIP for onshore wind power is adjusted depending on the relative size of the rotor to the generator of the wind turbine.	These adjustment can help to shape technology evolution to more system-friendly solution, potentially reducing the overall system integration cost of renewables. These adjustments come at a higher investment cost so

		the final support needs to be carefully defined.
Priority dispatch (purchase obligation)	Certain support schemes such as FIT come with an obligation to the system operator to purchase all electricity generated.	It gives visibility on the total amount of revenues throughout the entire lifetime, decreasing financing cost. However, it leads to market interference, as producers will produce independently of current market prices

4.2 Comparison of revenue support schemes

RES support schemes have been historically introduced to drive the deployment of RES generation in large quantities in order to accelerate the development of specific technologies (by technology development and economies of scale). These incentives have been designed to trigger long-term investment decisions, focusing primarily on reducing the risk for investors and thus achieving significant cost reduction for financing. These incentives however did not pay much attention on how they impact the operation of short term markets, as the share of renewable were still relatively small.

Ideally, short-term market incentives should not be affected by long-term investment instruments. However, a balance needs to be found between the incentive for investment in the long term (which has important implications on investment attractiveness and thus the financing cost) and the effectiveness of the instrument to integrate new technologies to a market which is not yet fully liberalized nor distortion-free.

The Market4RES project has assessed extensively the impact of various support schemes design option on the short term and long term functioning of the system (Market4RES-D3.2, 2015) (Market4RES-D3.1, 2015). A synthesis of this analysis is presented in following sections.

4.2.1 Overall Assessment of support schemes based on their impact to the market functioning

Long-term impact

When assessing support schemes from the point of view of their effects on the functioning of the system in the long-term, the impact on investment decisions was an important criteria. The set of relevant criteria included: **Efficiency** (marginal cost reflectivity, liquidity, diversity of products and market transparency); **Effectiveness** (achievement of policy goals- RES targets); **Robustness** (resilience to changes in fundamentals such as fuel prices and demand) and **Implementability** (simplicity, experience with the implementation and applicability to other contexts).

The assessment carried out in (Market4RES-D3.1, 2015) (see Figure 13) concluded that the design options should be of a market nature in order to increase their efficiency and reduce the possibility that authorities manipulate support payments. Specifically, Long-term clean energy and capacity auctions, Feed-In Tariff or Feed-In Premium both based on auction schemes should all result in the most cost-competitive RES generation that is compatible with the achievement of RES deployment objectives being installed in the system. Besides, some of these mechanisms could be accepted by authorities and stakeholders, since experience exists with the application of some of them throughout the EU.

	ASSESSMENT CRITERIA								
Design Options	EFFICIENCY				EFFECTIVENESS	ROBUSTNESS	IMPLEMENTABILITY		
	Marginal Cost reflectivity	Liquidity	Diversity of Products traded in market	Market Transparency			Simplicity of the market	Experience with implementation	Applicability to other timeframes and contexts
Long-term capacity auctions	Very Good	Very Good	Good	Very Good	Fair	Good	Fair / Good	Poor	Fair / Good
Long-term clean energy auctions	Good	Poor (FIT); Fair (CFD); Good (FIP)	Good	Very Good	Good	Good	Fair / Good	Poor	Fair / Good
Net metering of Demand and Generation per network user for computations of regulated charges	Poor / Fair	Poor	Poor	Fair	Poor	Good (-)	Fair	Good	Very Good
FIT with Regulated Prices	Poor	Poor	Fair	Poor	Fair	Poor	Good / Very Good	Very Good	Good
FIT with Auction	Good	Poor	Fair	Good / Very Good	Good	Good	Fair / Good	Poor	Good
FIP regulated with no price cap and floor	Poor	Good	Good	Fair	Fair	Fair	Very Good	Good	Fair
FIP regulated with overall price cap and floor	Poor	Good	Good	Fair	Fair	Fair	Very Good	Good	Fair
FIP resulting from an auction with no price cap and floor	Good	Good	Good	Very Good	Good	Good	Fair / Good	Good	Fair
FIP resulting from an auction with overall price cap and floor	Fair / Good	Good (-)	Good	Very Good	Good	Good	Fair / Good	Good	Fair
Certificate Schemes with Quota	Good	Fair / Good	Fair / Good	Very Good	Good	Fair	Fair	Fair	Good
No support scheme	Poor	Very Good	Poor	Very Good	Poor	Very Good	Very Good	-	Very Good
Support conditioned to the provision of grid services	Poor	Fair	Poor	Fair	-	Fair	Fair	Very Good	Fair

Figure 13. Summary of the assessment of RES support schemes according to their impact in the long-term

Short-term Impact

Similarly, the short-term impacts of support schemes have been assessed against 4 criteria elements (Efficiency, Robustness, Implementability, and Fairness) following the same approach as done for long-term effects.

Based on the analysis carried out in (Market4RES-D3.2, 2015) (see Figure 14) it can be concluded that: “Net metering of demand and generation”, all types of FITs, regulated FIP and the support conditioned to the provision of grid support services have some serious drawbacks or do not perform well on average terms with respect to short-term impacts.

In the other hand, long term clean capacity auctions and “No support” options perform very well in terms of their impact on the short-term functioning of the market, whereas Long term clean energy auctions, FIP resulting from an auction and Certificate schemes perform well.

		Long term clean capacity auctions	Long term clean energy auctions	Net metering of demand and generation	FIT with Regulated Prices	FIT with auction	FIP regulated with no price cap and floor	FIP regulated with overall price cap and floor	FIP resulting from an auction with no price cap and floor	FIP resulting from an auction with overall price cap and floor	Certificate Schemes with Quota	No support	Support conditioned to the provision of grid support services
Efficiency	*Marginal cost reflectivity*	Very Good	Fair for FIPs Poor for FITs	Fair	Poor	Poor	Fair	Fair-	Fair	Fair-	Fair	Very Good	Fair+ for FIPs Poor+ for FITs
	Cost causality	Very Good	Good	Poor	Poor	Poor	Good	Fair	Good	Fair	Good	Very Good	Good for FIPs Poor+ for FITs
	Liquidity	N.A.	N.A.	Fair or Good	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Very Good	N.A.	N.A.
	Global coherence	Good to Very Good	Fair for FIPs Poor for FITs	Poor	Poor	Poor	Poor	Poor	Fair-	Fair-	Good	Very Good	Poor to Fair
Robustness		Very Good	Fair	Poor	Poor	Fair	Poor	Poor	Fair	Fair	Fair	Very Good	Fair
Implemen-tability	*Compatibility with regulation*	Good	Fair	Poor	Poor	Fair	Poor	Poor	Fair	Fair	Good	Very Good	Poor
	Relevance of barriers	Good	Fair	Fair	Poor	Poor	Fair	Good	Fair	Good	Good	Fair	Poor
	Level of use of public funds	N.A.	N.A.	Very Good	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Very Good	Very Good	N.A.
	Cost efficiency	Fair+	Fair+	Good	Poor+	Fair+	Poor	Poor+	Fair	Fair+	Fair+	Very Good	Good
Fairness		Fair	Fair	Poor	Poor	Fair	Poor	Poor	Fair	Poor to Fair	Good to Very Good	Good to Very Good	Poor

Figure 14. Summary of the assessment of RES support schemes according to their impact on short-term markets

Combined impact analysis

Taking into account the assessment and ranking made of RES support schemes according to both their short and long term effects, support schemes have been classified into most promising options (Green) and those to be discarded (Red). From the qualitative analysis done in the project, the most promising options are FIP resulting from auctions, long term clean capacity auctions, Long term clean energy auctions, and certificate schemes. This is presented in Figure 15.

Design Options	Weak points (-)	Strong points (+)
✓ Long-term clean capacity auction ✓ Long-term clean energy auction ✓ Certificates ✓ FIP (auction)	• FIP (auction) and Certificates imply some project risk • FIP, Certificates, and energy auction distort short term prices to some extent, and this distortion depends on system conditions • LT clean auction difficult to extend to other markets (involves central buyer) • Relevant amount of support provided • Create some barriers to RES participation in markets	• Tend to reveal the marginal cost of RES capacity in LT procurement schemes for new projects • Effective to meet LT RES targets • Limited distortion of efficient short term signals • Tend to foster both LT and ST liquidity • Certificates promote Cost Causality • Resilient to political intervention
✓ FIP regulated ✓ Net metering ✓ FIT ✓ Support conditioned to the provision of grid support	• May not reflect marginal cost of RES capacity for new projects • Fail to meet LT RES targets • All create relevant distortions of short term prices (FIT-largest, FIP regulated-relevant, Net Metering-localized) • FITs, Net Metering and , and Voltage condition reduce liquidity in short term markets • Prone to political intervention • Regulated FIP and FIT: Large support	• FIP regulated promotes liquidity in short term markets • Low overall support involved in Net Metering • Grid support condition reduces the amount of support mobilized • Experience within the EU • Can be extended to other systems

Most promising design options (overall strong grades) — Discarded design options (overall weak grades)

Figure 15 Overall classification of design options into Strong and Weak ones, considering their short and long term effects, and reasons supporting this

Although the option “no support scheme” has overall strong grades, it would however perform very poorly under the Effectiveness criterion and, therefore, cannot comply with policy objectives set for RES targets in the Long-term.

Market based schemes based on an auction are expected to be extremely sensitive to the design of the auction as described in (IRENA, 2015), (WindEurope-a, 2015), (Agora-Energiewende-a, 2014). A badly designed auction may lead to poor effectiveness. Furthermore it should be noted that the design of auctions is administratively set and may therefore also be subject to “retroactive” changes. Recommendation on tender design parameters are addressed in section 4.4.

4.2.2 Detailed assessment of the preferred support schemes

The original analysis carried out by the project Market4RES has selected 4 type of mechanisms as the most preferred options. In following section, we provide further analysis, complemented with recent external literature not considered before (CEER, 2016), (Diacore-Project, 2016). The following analysis is especially valuable with regard to Feed-in-Premiums, because, as it is shown, multiple configurations (fixed vs floating) can lead to wide range of potentially different solutions on market risk, overall policy support and short term market signal.

4.2.2.1 Fix premium

This is the simplest version, adding a fix premium on top of the market prices. This type of premium results in a high level of certainty regarding the amount of public support, because it is set in advance for the duration of the support. In return, the risk borne by RES producers is relatively high, because their total revenue is directly dependent on the evolution of power prices over the long term (since support is usually granted for 10 to 20 years). Consequently, financing cost for these projects can be substantially higher than in a FIT system. On the other hand, if market prices are higher than expected in the longer term, this design feature is also unfavourable for the rate-payers because the level of support will turn out to be higher than needed for a reasonable return. This form of simple fix premium is not common in member states practices today.

4.2.2.2 Floating premium

In case of a floating premium, a reference value (or strike price) [EUR/MWh] is set either administratively or through a competitive procedure (see Table 2). The reference value represent the income that the investor would need to get a reasonable internal rate of return. The premium [EUR/MWh] is then calculated as the difference between the reference value and the reference market price (this is an average market price- further explain in Figure 17). Whenever the reference market price is above the reference value, the premium would be negative. For this rather unlikely situation, the design can foresee that producers have to pay back this difference (e.g. in UK under the CfD scheme) or the premium is set to zero (e.g. Germany). The introduction of negative premiums (repayment by the producer) can reduce the needed support, when using it for technologies close to market parity (reference value close to expected market price) or if market prices go up unexpectedly.

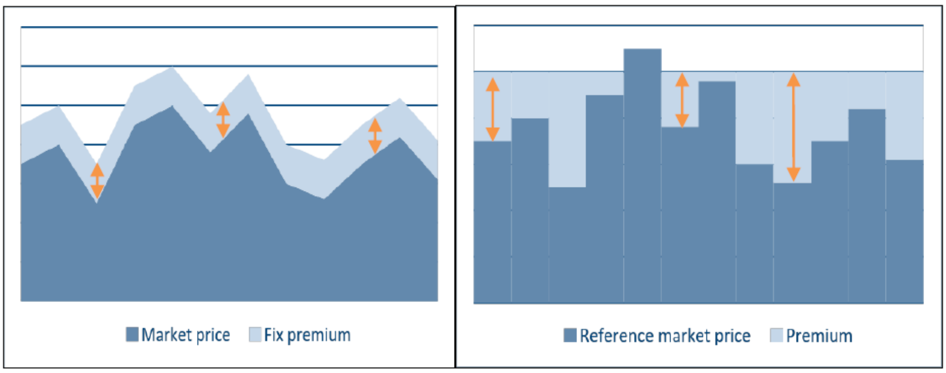


Figure 16. Functionalities of a fix premium and floating premium scheme. Source: CEER, 2016

In a floating premium scheme, the long term revenue of RES producers is guaranteed, but the amount of support to be paid out (and to be refinanced by consumers) is difficult to predict as it depends on the reference market price. Additional parameters such as floors and caps can be introduced to reduce the possible amount of policy support given to the investors (see Table 23). Today, floating premiums are the preferred option in those countries using a FIP scheme.

Reference Market price (floating premiums)

Setting an appropriate timeframe

The reference market price is usually linked to a relevant energy exchange price, and the definition of its timeframe is crucial regarding the exposure of RES producers to market signals and risks:

- **Hourly fixed reference market prices:** The incentive for market integration is basically removed. The producer is interested in finding a better price for that given hour but not interested in scheduling its production according to different prices for different hours. Therefore, the market integration effect of hourly set premiums is equivalent to FIT.
- **Monthly (or longer) fixed reference market prices:** Producers are incentivised to perform better than the average market outcome. The longer the fixed period, the greater the incentive for market integration. If fixed e.g. for one year, producers are incentivised to optimise their output (or sales) across months and seasons. However, the lengthier the timeframe, the higher the risks for the RES producers. Consequently, setting the reference period is a trade-off between achieving higher levels of market integration and transferring a bearable share of risks to the RES producers. In practice, MS have opted for different timeframes, for example a yearly period in the NL, a six-month period for baseload RES generation in the UK, a monthly period in Germany and an hourly basis for some RES technologies in the UK.

Selecting an appropriate set of market prices values

In general an average market price (e.g. an arithmetic average of hourly spot prices) is typically used as reference market value. For variable generation (e.g. wind and PV) however, the average market spot price could be weighted with actual production profiles in order to more appropriately reflect real commercialisation opportunities. RES producers can achieve higher revenues whenever they perform better than the market average. This presupposes the successful adaptation of the production pattern to market signals and the additional revenue being high enough to cover the extra costs needed to provide this flexibility (e.g. adjusted technology, appropriate steering decisions, storage, increased capacity, etc.).

Deciding when to set the reference market price

The reference price can be set ***ex ante or ex post***. Ex ante setting is based on forward prices, while ex post version is typically made by averaging hourly spot prices. Ex ante price setting gives more predictability ahead for the producers, while possibly lowering incentives for risk-averse producers to react to short term market signals as the market outcome is not properly reflected. The risk for over or under compensation is especially relevant in a setting where ex ante reference prices are technology-specific. Ex post price setting provides less predictability and this stimulates more flexibility as risk-averse producers would sell their electricity as well as possible on the day ahead and intraday markets.

Figure 17. Key design elements of a floating premium. Source: CEER

Table 3. Effect of design parameters on floating premium schemes

		Effect on the degree of market integration	Investment risk	Other Implications
Timeframe of the reference market price	Hourly fix	low	Low	
	Monthly	high	medium	
	Yearly fix	High	High	
Setting of the reference market price	Ex-ante	Low	Low	
	Ex-posts	high	high	
Floor & caps	floor	medium	High	Reduced policy support
	cap	low	Low	Reduced policy support
Technology characteristics to highlight market integration value	Adjusted technology (e.g. rotor to generator size)	Medium	low	Higher investment costs
	Onsite storage use	high	Medium	Higher investment cost

4.2.2.3 Long-term capacity auctions

This is a system of long-term generation capacity auctions, whereby support to a predefined amount of RES generation capacity of a certain technology results from bids accepted in the auction and is generally fixed (only depend on the amount of capacity installed).

Revenues from the long-term capacity auction only refer to complementary revenues required by RES promoters to decide to install new generation. The rest of revenues would be earned in the rest of markets. Thus, the stability of revenues depends on long-term evolution of market prices. Still, compared to a fixed feed-in premium, this system gives reduced uncertainty since the income from the support scheme is up-front (neither price nor volume risk). However, compared to a floating feed-in premium the uncertainty is higher.

Short term prices earned by RES are fully reflective of short term marginal supply costs, as the revenue from the capacity payment is independent on market operation.

Therefore, if auctioning capacity has the advantage in terms of effectiveness of being a quantity-based support scheme, it requires to apply an average load factor and this may be a source of some uncertainty[11].

Another important factor is that for most generation technologies (i.e. all except peaking RES technologies), subsidizing capacity introduces a bias on investment decisions with respect to the renewable energy produced by them. When considering the investment options, project developers could choose to install more powerful machines producing less energy (e.g. with oversized electric generator for wind turbine but a smaller rotor, aiming to maximizing their revenues from the support istead of maximizing their production). This behavior would lower the load factor, making it even more difficult to reach policy energy targets and complicating grid integration.

4.2.2.4 Long-term clean energy auctions

Remuneration conditions affecting the compulsory supply of a certain block of clean energy (predefined amount of it) are set through an auction process taking place in the long-term.

Prices earned by RES generation for predefined amounts of the clean energy they produce are largely defined in the long-term. The equivalent price earned by RES generation for this amount of electric energy produced may not be fully fixed (depending on whether a full price, a fix premium, or a floating premium with regards to some reference price level is set in the auction). The amount of power produced that is not covered by the contract would be remunerated according to market prices.

A clean energy auction can be combined with any time of premium system. However, the remuneration is only given to a fraction of all the expected energy produced throughout the lifetime of the power plant (gross energy production). In that sense, the remuneration is not dependent on the energy dispatched.

Alternatively, it could be linked to dispatch electricity, but since the overall amount of full-load hours remunerated is significantly lower than the expected energy produced, energy producers will not be incentivized to generate when prices are below their marginal productions costs.

[11] Simply because it depends on (i) technology and (ii) meteorology or more generally the availability of the inputs and, for dispatchable technologies, of their cost and the wholesale electricity market prices. Thus, although it seems reasonable to evaluate the amount of electricity produced over a year by one GW of wind turbines, it seems much less obvious for biomass-fired thermal plants. This uncertainty is even reinforced in the case of technology-neutral auctions because there are significant discrepancies in the average load factors across technologies

4.2.2.5 Tradable green certificate schemes (TGC)

Under TGC systems, the price of the premium is determined by the market demand/supply. The volume of the market is however determined administratively, by setting purchasing obligations to either electricity suppliers and/or system operators. Quota obligations with Tradable Green Certificate are the high compatibility with market principles and the competitive price determination, however this system face major challenges:

- Regulatory risk as changes to the regulatory framework affect the market for certificates, which creates uncertainties for investors. This uncertainty adds to the uncertainty of wholesale electricity prices. As explained earlier, this generally leads to higher capital costs and thus reduced efficiency of the system.
- Price-risks due to the balance of the system. If the implemented system has a defined duration, prices could drop to zero if there is slight over-investment. On the other hand, peak prices could occur depending on how the penalty for missing certificates are calculated.
- Technology neutral certificates give the least-cost solution for implementing a given amount of renewables in a well-functioning market. However, to encourage investments in wider range of technologies with high potential (both in terms of energy and cost-reductions through learning-by-doing effects), technology-specific support types are sometimes needed. This can be obtained within TGC schemes (by e.g. provided extra certificates per MWh produced) [12].

One possible solution to reduce the risk premium is to introduce cap and floor prices. This solution is hardly distinguishable from a FIP, presenting additional drawbacks (e.g. need to enforce penalties in case of non-compliance with quota obligations).

4.3 Impact of support mechanism design on investment risk

The specific design of market-base support mechanisms (or the lack of it), as well as a number of elements assessed in section 3 such as how priority of dispatch is implemented (i.e. ranking of technologies for dispatch down under events of curtailment, compensation scheme, etc.) will naturally expose generators to market signals at different levels. That level of risk exposure will then lead to an increase/decrease of financing costs which could have significant effects on the viability of projects and the overall policy cost. Exposing investors to higher risks may result on the need for higher premiums to ensure investment attractiveness.

Figure 18 presents an illustration of how various support schemes and their specific design affects the level of investment risk and thus of financing cost. The level of the support within each

[12] Normally, less competitive technology receive more than 1 certificate per MWh generated. Determining how many should receive each technology is challenging and need to be regularly reviewed to reflect on technology reduction costs.

mechanism will determine whether the technology is financed through consumer bills/taxes, or it is rather financed in the market.

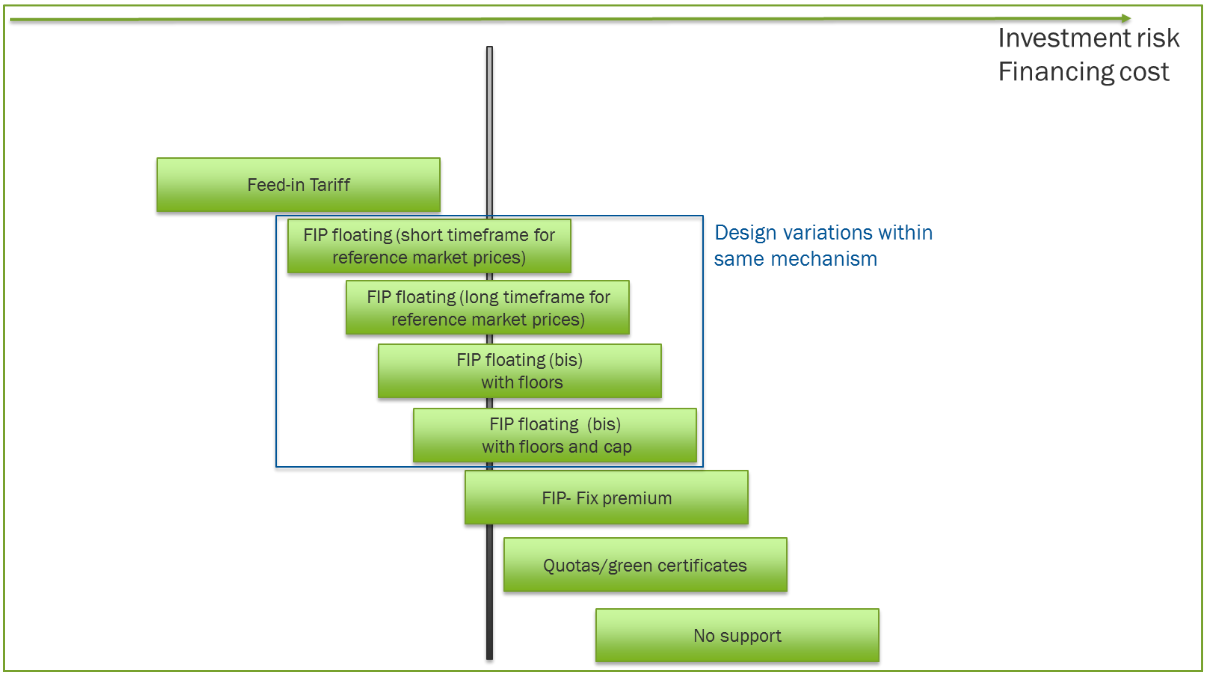


Figure 18. Impact of different support schemes on investment risk and thus financing cost (illustrative). Source: WindEurope.

(Diacore-Project, 2016) has done an extensive analysis of the impact of the various mechanism on investors perception and its final influence on financing costs. The country regulatory framework, along with the specific market instrument lead to important considerations that cannot be neglected when defining the most efficient way to advance RES market integration.

4.4 Design options for auctioning-based mechanisms

Current context

As previously explained (Table 2), the premium can be set administratively or through a competitive bidding process under an auction or tender system[13] . Strictly speaking, tender or auction schemes do not represent a distinct support category, but they are used to allocate financial support to different technologies and to determine the support level of other types of support schemes, such as feed-in systems, in a competitive bidding procedure.

Tenders are increasingly used across the globe as a support allocation mechanism for deploying renewable energies. They are also gaining track under different markets, such as the recent capacity

[13] Auction and tender refer to the same process for the purpose of this report

market in the UK. Experience in Europe is however rather limited, especially with regard to PV. While UK had used tenders already in the 90's to allocate support for non-fossil fuels for capacity[14], it has been only recently that technology-specific tenders have been deployed (including for wind and solar PV). Italy, Portugal, the Netherlands, UK, Poland and Spain have run recent tender rounds for onshore wind. Outside Europe, Brazil and South Africa have been running annual tender since 2009 and 2011 respectively. For offshore wind, Denmark, the Netherlands and France have launched tenders in 2015/2016 (WindEurope-B, 2016). All previous competitive bidding processes allocated either a FIP or FIT.

In the PV sector, experience is even more limited. Europe's largest markets have prepared or are in the process of using tender schemes for large-scale solar PV. In April 2015, Germany started a pilot tender project with three rounds and a total volume of 500 MW for ground mounted systems up to 10 MW each. France has been applying tenders for some time for systems above 250 kW – nearly 70% of all French installations in 2015 belonged to that category.

With respect to the above, it should however be noted that so far the record of installed projects following an auction is limited. This can be attributed to the following:

- Commonly, significant timeframes are allowed between awarding contracts and the actual realisation of a project, which, given decreasing technology costs, provides an incentive to defer installations as a way to increase margins,
- Low experience of players: some may bid at price levels that aim to secure the option to build, but then decide against the investment at a later stage

In addition to the above, a lack of high quality data makes it difficult to assess the real success of tenders. Data available to SolarPower Europe in June 2016 suggest that up to 2016 approximately 7 GW of solar projects have been awarded via tenders globally (note that this figure is attached to uncertainty). However, none of the recent low-price awarded tendered capacities in Peru, Mexico or Dubai have been realized so far. This underlines the necessity to carefully consider provisions that regulate what happens "after the tender".

After 2020

After 2020, all new renewable energy in Europe above a certain size threshold should be granted support through a competitive tendering process, if the principles of the current EU State Aid regulation are to remain. It will all depend on the experience gathered by the implementation of these complex mechanisms in the following years.

As far as these recent experiences can tell, design parameters play a crucial role and practices currently vary substantially across the different EU countries. The use of tenders can lead to market efficiency (Market4RES-D3.1, 2015), but for this to happen the tender design options need to be carefully defined.

[14] Non-Fossil Fuel Obligation - NFFO)

Due to the limited European and international experience with tendering, public authorities will seek the appropriate tender format on a learning-by-doing basis thus challenging the industry (developers, financing institutions, etc.) to adapt business models to frequent changes in tender arrangements. Tenders present participants with higher risks (costly applications, uncertainty over project selection and guaranteed remuneration) which are internalised in bids and could temporally result in higher support costs[15].

Lessons learnt

Serious shortcomings associated with tenders in the past included:

- Investor uncertainty over the price deterred investment;
- Investors bidding too low to ensure they won the tender were not able to develop the project as the economics did not guarantee sufficient returns[16];
- Complex tender procedures and financial risks discouraged small players from participating;
- Sites selected without regard for environmental impacts resulted in public opposition and/or undesired environmental consequences leading to project being blocked;
- Sites selected with little regard for territorial distribution led to certain areas or regions being over-solicited whilst others ignored;
- Where there was little or no competition, there was no incentive to lower prices.

Design recommendation

There is no tender design system that is a complete success story. Tenders are rather subject to continuous adaptation of both design elements and participants behaviour. For a tender to be effective, it has to achieve competitive prices (cost-competitiveness criterion) and high realisation rates (efficiency criterion). Tenders should also incentivise research and innovation efforts and allow for the development of cutting-edge renewable technologies.

The Market4RES project suggests to take a holistic perspective in respect to the sequence of auctions and related topics, a non-exhaustive list of relevant topics is provided in Figure 19.

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[15] Recent pilot experiences for a PV tender in Germany, based on pay-as-bid rules resulted in higher premiums than the premium administratively set (FIT). http://www.rechargenews.com/wind/1419928/ones-to-watch-german-tenders-monitored-across-europe

[16] Recent experience in Spain for an onshore Wind Tender resulted in a premium of zero €/MWh, leading to a very challenging environment (move ahead without additional support or face potential penalties and negative implications for future tenders)

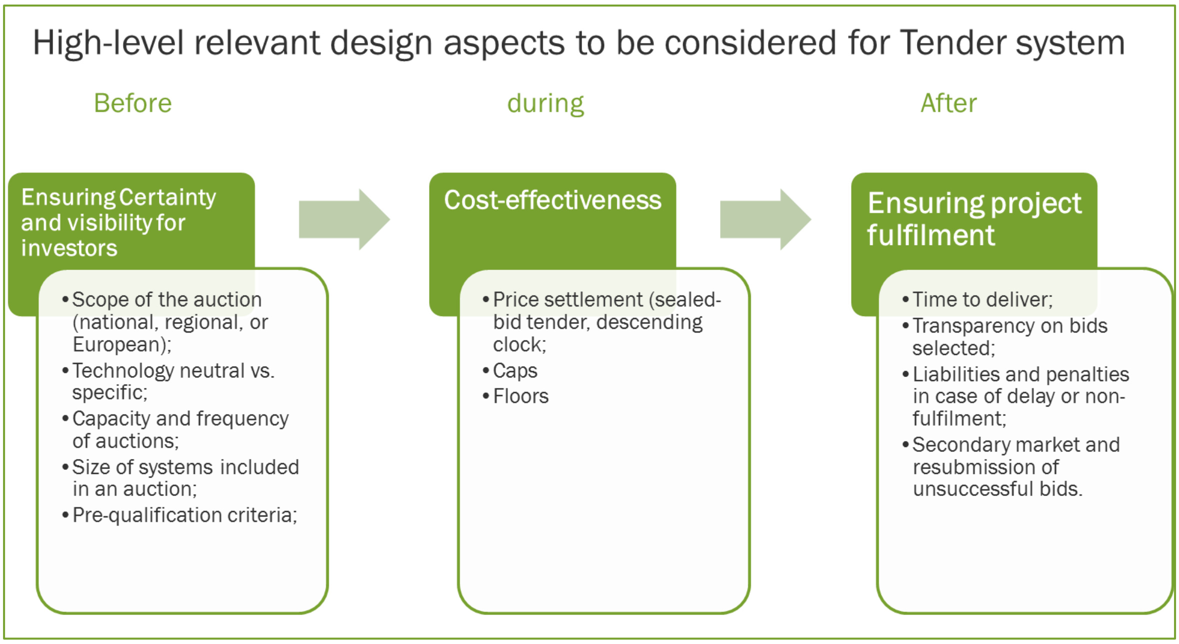

Figure 19 High-level design aspects of a competitive tender scheme

Next to the existing and extensive literature that already exists on auctions (see for instance (WindEurope-a, 2015) (IRENA, 2015) (Agora-Energiewende-a, 2014)), the following highlights additional fundamental issues that should be kept in mind when designing tendering /auction schemes:

- **Toward harmonization:** It is important for applicants to reduce development costs by reducing the variance of tendering schemes across Europe. In theory, European-wide tenders would ensure uniformity in the treatment of bidders and promote the most attractive projects on a European scale. In the short to medium-term, we however consider that for practical reasons and local acceptance issues the direct control by Member States on the tendering process is a more realistic option. Harmonization between Member States' tendering systems should however be pursued in order to facilitate access for a larger number of participants. Similar process designs, comparable participation requirements, streamlined and harmonized administrative procedures as well as a stepwise opening to transnational bidding would all help to promote a real international competition. Such commonalities would contribute to prepare a long-run convergence of cross-border or even EU-wide tenders.
- **A clear framework:** Before entering into a bidding process and with a view to reduce overall costs, applicants need visibility on the following elements:
  - The exact composition of the energy mix which is pursued (technology-specific tender). A technology-specific approach may be more appropriate to take into account particular situations (absence of homogeneous bidding structure) and priorities (local player involvement) at the national level. In a number of leading wind onshore markets (e.g. Germany, Spain, Italy) such considerations include setting up

a realistic annual deployment target that includes both new installation potential and repowering needs of the wind generation fleet.

  - The capacity tendered as well as the frequency of tenders; this is crucial to ensure an efficient planning of project pipelines,
  - The pre-qualification criteria, which should aim to reduce the exposure to unserious players while at the same time ensuring enough competition,
  - The geographical scope of the tender.

- **The Site selection** should be down on a bottom-up approach. Given the decreasing availability of renewables resource sites, project developers are best suited to use their know-how in identifying good sites for technology deployment (special PV and onshore wind). Streamlining planning and licensing procedures should be a priority for national authorities as the numerous permits required impede project development.
- **Smaller players:** Given the transaction costs associated with a tendering process, it is important to maintain the possibility for **smaller projects below 1 MW to be developed via other types of mechanisms (above 18 MW in the case of wind power)**. In addition, pre-qualification criteria should be project-related (provision of building consent, grid-access connection, land acquisition) rather than bidder-specific (experience, project portfolio) to ensure small players participation. Bid bond requirements should be set at a reasonable level to ensure that smaller, yet credible, players can participate in the tender process.
- Finally, in case the market is not considered liquid enough, the **pre-qualification criteria should be adapted or extended** in order to reflect other objectives such as technical or environmental quality.
- Once the preparatory phase is completed, projects developers will have to compete. **Transparency** and **simplicity** should be the main guiding principles during the selection process.

There are different ways to design an auction, but the static sealed-bid and the dynamic descending clock auction or a combination of the two have been used the most to support new RES-E installations. Table 4 present the characteristic and implications of using the different options.

Table 4. Specific design parameter of tenders with respect to price mechanisms .Source: WindEurope, 2015

TENDER PROCEDURE		
Item	**Design Option**	**Assessment**
Price-finding mechanism	**Sealed-bid:** bids are submitted simultaneously and remain undisclosed	Sealed-bid is a static auction because no exchange of information occurs about the price of the auctioned product. In theory, information asymmetry might result in the "winner's curse" whereby the winner underestimates the true value of the auctioned product, underbids in order to win but ends up with an unprofitable price. However, sealed-bid offers low transaction costs and is simple which attracts participants.
	Iterative process: either descending or ascending clock where the auctioneer establishes a price ceiling, which decreases/increases during the iterative bidding process, until a bidder accepts to procure at a certain price level	Iterative bidding procedures are dynamic auctions whereby participants gradually unveil their offers and can adapt them to their competitors' bids. In theory, the possibility of misjudging the true value of the auctioned product, resulting in winner's curse, decreases. However, iterative bidding could potentially involve strategic behavior. A descending clock is most commonly used but competition levels depend upon the ceiling price. If the ceiling price is too low, only a small number of bidders will participate, consequently leading to undersupply and lack of competition. If it is too high, there is a risk of opportunistic bidding.
	Hybrid: two-stage auction combining descending-clock with sealed-bid	Hybrid auctions provide for price discovery during the descending clock at the first tender stage and participants preserve the confidentiality of their bids during a second sealed-bid round. However, this arrangement is quite complex to administer.
Payment arrangement	**Pay-as-bid:** each bidder receives the price he has offered	Pay-as-bid could minimise overall policy costs because bidders only receive the minimum support requested for projects. In theory, however, it might result in low realisation rates due to opportunistic bidding.
	Pay-as-clear (uniform/marginal pricing): all bidders receive the price set by the most expensive accepted bid (marginal price)	Under uniform pricing, bidders may have an incentive to disclose real costs because the final compensation is not linked to individual bids. In theory, strategic bidding could occur as participants bid low hoping to get higher remuneration than needed if the marginal price exceeds their offers.

Outlook for a European roadmap on tenders

The fact that tendering designs vary significantly across Europe limits the opportunities of project developers to reduce their overall cost for participating in multiple tenders. Consequently, a single European-wide tender would offer a number of advantages, as explain the previous section. Such a design however seems unlikely to be implementable within short to medium timeframes due to the fact that aspects such as compatibility with national energy policy and system integration requirements call for a direct control by Member States. With respect to this, a progressive harmonization of tendering design parameters (Figure 20) can be expected to increase the overall efficiency of tenders. Furthermore, the provision of a roadmap and or long-term perspective regarding the volumes to be auctioned would increase investors' confidence. Finally, the creation of a database providing insights on globally tendered and successful connected capacities is recommended.

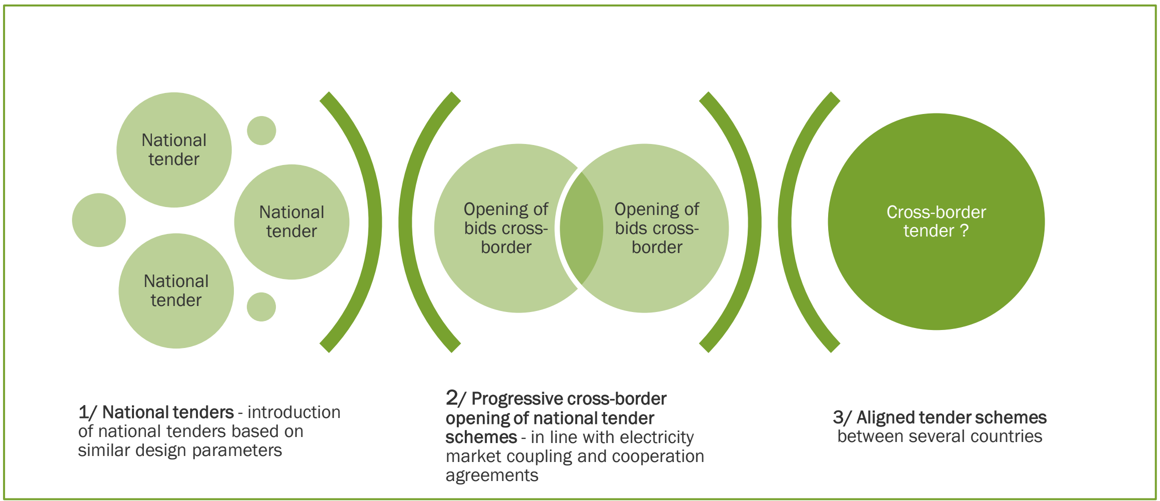

Figure 20. Roadmap on tender design evolution

As illustrated above, the progressive alignment of tendering schemes across Europe will require additional steps: a real market coupling and a fully interconnected electricity grid will be needed before a second phase of convergence can be envisaged.

4.5 Additional considerations

4.5.1 Self-Cannibalization effect. The long-term need to improve market value of the technologies

Decreasing market value of wind and solar energy

Wholesale power price vary hour-by-hour (or minute-by-minute). Power plants that tend to produce in high-price hours have a higher average revenue per MWh – their market value is higher. This is specifically relevant for wind and solar power: their market value used to be high but drops with increasing market share – each MWh becomes less and less valuable as the competition completion among them increase. This is no coincidence: in windy and sunny hours, especially in system with oversupply, little thermal generation flexibility and lack of demand flexibility, the additional supply of power depresses the electricity price. Some call this a "self-cannibalization effect".

By reducing wholesale prices, variable non-dispatchable RES undermine their own competitiveness.

While technology progress has reduced the levelized cost of energy of wind and solar to levels close or even lower than those for conventional generation (see LCOE calculations for PV and wind in for instance (Agora-energiewende-B, 2014) or more recently (Agora-Energiewende-C, 2016). These technologies are still not fully competitive in the wholesale electricity market. As wind and solar contribute to the reduction of the number of high prices (by displacing more expensive technologies in the merit order curve), and they bring down the wholesale electricity prices. As a consequence, under current market condition the needed support to make renewable technologies profitable might increase.

The market value of wind and solar has been subject to several analysis (e.g. (Lion Hirth & Simon Müller, 2016), as presented in Figure 21. This is based on a number of assumptions and system simulations for the Germany system; while the overall concept is right and the tendency of decreasing market value is evident, specific national cases may differ considerably. For instance, in Denmark, with over 40% wind share in 2015, the market value assessed by Energinet.dk is still 0.88-0.92 as compared to the reference case, while the theoretical example shows that with a 13% share it should already be at 0.85.

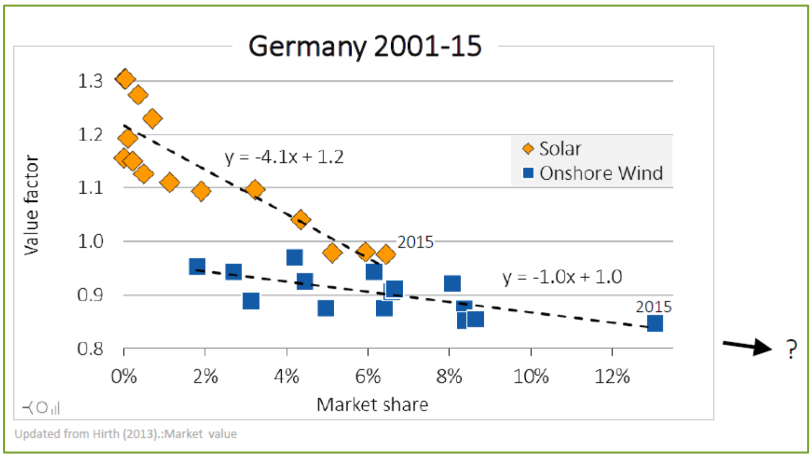

Figure 21. Value Factor = Market value / base price. Each dot is one year. Source: "System-friendly wind power". Leon Hirth 2015

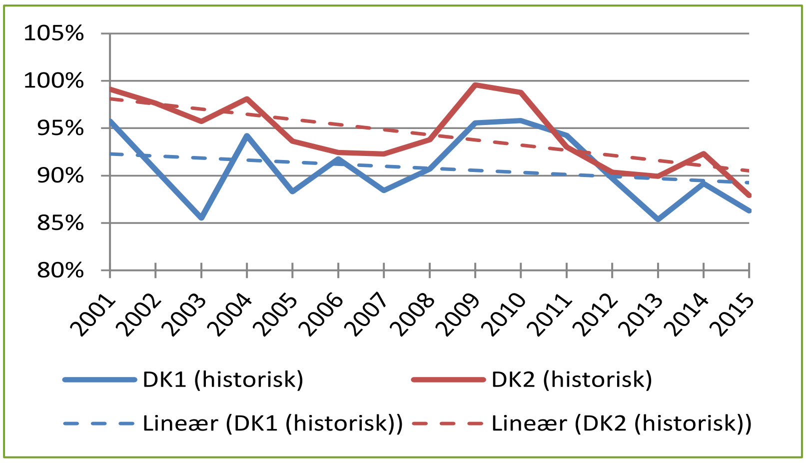

Figure 22. Market value of wind in the Danish system. Source: Energinet.dk , 2015

Technological solutions to increase market value

A number of system solution are known for maximizing the value of variable renewable energy sources in the system (market). Among them, we have demand response, storage, long-distance interconnection, reduction of thermal must-run (CHP, ancillary services), improving the spot and balancing market design.

In parallel, a number of improvements are coming from the renewable technology side: Optimized geographic allocation of VRE generators and increase of capacity factors from both PV and Wind energy. In PV solar systems, East-west oriented solar modules can help increase capacity factors. In wind, new turbine designs can help tapping into low wind speeds, increasing capacity factors. These wind turbines have been called system-friendly turbines. They basically consist of increasing the size of the rotor (higher turbines, larger size of blades) while maintaining the size of the generators. As a results, the power density of turbines decreases (W/m^2), while the capacity factors can increase significantly (from an average of 20-24% up to 40% for onshore wind energy systems), as presented by (Lion Hirth & Simon Müller, 2016).

Higher capacity factors mean that more electricity can be sold in the market at times with low wind speed, when wind energy producers participation is low, and thus market value increases. Additionally, this system can help increasing the overall economic value of wind energy as it leads to a reduction of network costs and of forecast errors. Figure 23 presents an illustration of the additional economic values.

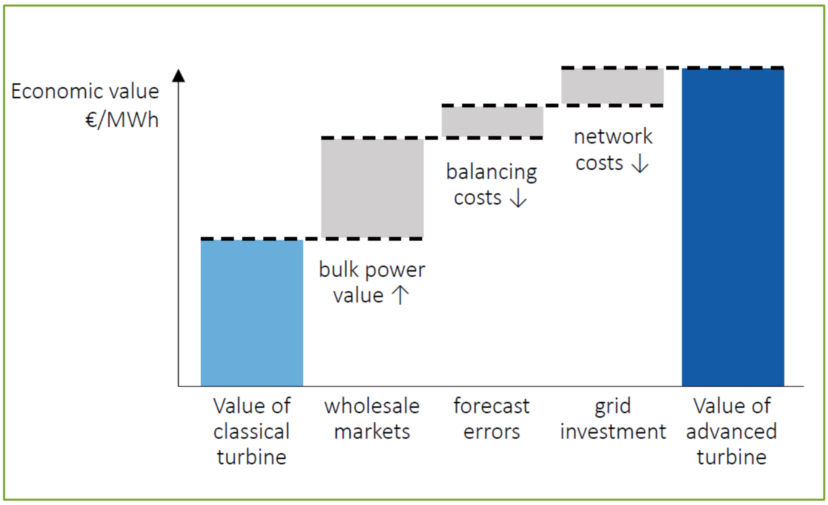

Figure 23. Advanced turbine design: possibly multiple benefits. Boxes are illustrative. Source: S. Muller, IEA, 2016

Policies to reflect the added system value of new technology developments

A number of countries are adapting their market support instruments to incentive the use of system-friendly wind turbines. A clear example is Denmark which uses a fix premium with a cap and has introduced a variation in 2014. While the premium value remains invariable, the number of hours that is granted to producers is significantly influenced by the type of turbine (relationship rotor/generator). Larger rotors, while incurring higher investment costs, can lead to an additional 2-3 years of support (support in Denmark for an average wind resource site is 6 to 8 years).

4.6 Future evolution of market-based support schemes

Support schemes should not be based on the time horizon (before or after 2020) but on market penetration (as share of demand) as well as on the situation of the market (whether the market is fit for RES).

Based on the assessment of markets design aspects (section 3) and on the penetration rates of a certain renewable technology (which is an indicator of technology and market maturity), we provide an illustrative representation of a potential support schemes evolution (see Figure 24).

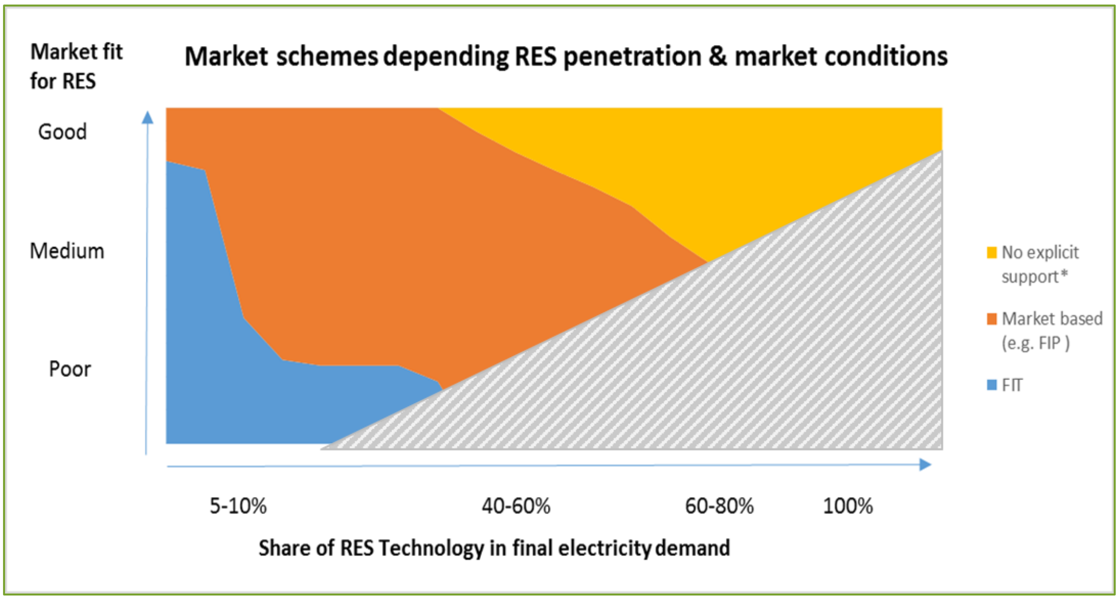

Figure 24. Conceptual illustration of the potential evolution of support schemes based on market design and penetration of a specific RES technology. *Explicit support is needed when other complementary markets do not function correctly and when environmental externalities are not internalized.

In the early stage of market deployment, new technologies that are generally expensive and not yet competitive (but which represent a long-term cost reduction potential) should be supported with instruments that reduce investment risk as much as possible to accelerate deployment at an appropriate cost for society. Only on those cases where the market is adapted for this new technology, the regulatory environment is very stable (including visibility on long-term market prices), could producers be exposed to market prices.

As the technology increases its share in the energy mix, it is important to develop the market instrument, reducing the overall support but also making it more dependent on market dynamics. The better the market situation, the faster this transition can be made.

In well-functioning markets, where there isn't oversupply, electricity prices are stable and short term markets are liquid and distortion free, In these markets RES producers can be financed without explicit support schemes (however, most of the analysis within the project shows that this may not be the most cost-effective solution in the long-term, especially considering the issue of self-cannibalization, as presented in section 4.5.1).

Finally, it is worth explaining that we don't contemplate the possibility to achieve a significant market penetration (e.g. above 10-15%) in a system where the market condition are somehow not adapted to these new technologies (this is represented in the figure by the grey area).

With this background in mind, the European Commission guidelines on state-aid support for environment and energy should be continued after 2020, in line with the current framework, building on increasing experience from tender systems, and premium-based schemes. It would be important to re-assess the default condition of technology neutrality and further investigate the implication for small players in auction schemes, based on our previous recommendations.

4.7 Brief conclusions on support mechanisms

Based on the previous analysis, the following general recommendations for future support mechanisms can be made:

- Support schemes should not be based on the time horizon (pre/post 2020) but on market penetration/maturity as well as on the situation of market (whether the market is fit for RES).
- A careful balance needs to be found between investment risk, overall policy cost and impact on short-term market signal.
- Technology specific support should be allowed.
- Floating Feed-in-Premium schemes with the reference price set ex-ante for long periods (e.g, 1 year) lead RES producers to participate in the market while being shielded, from long term price uncertainty (as long as the market reference price is regularly adjusted (e.g. every 2-3 years). Premiums set ex-post, depending on the electricity infeed could also work as long as premiums are not given in hours of negative prices. The support provided should be independent of the final generation being produced by the generation units, or alternatively the support needs to be conditioned to the times when market prices are not negative. This will provide correct incentives in the short-term markets.
- The level of support should be the outcome of a competitive market process (tender).
- The tender should be technology specific and should not apply to all market parties (e.g. small players to be excluded), given the transaction costs associated with a tendering process.
- The tender pre-qualification criteria should be project-related (provision of building consent, grid-access connection, land acquisition) rather than bidder-specific (experience, project portfolio) to ensure small players participation.

5 CONCLUSIONS

As recently agreed in the Paris agreement, a more ambitious environmental policy is needed to limit global warming and avoid considerable future mitigation costs. Such a policy will involve reducing the number of emission permits or similar measures to increase the cost of pollution. This will then lead to higher costs for fossil-fuel power generation, and higher electricity prices. In that case, where all external cost are internalised and reflected in the market, the share of renewable power generation could increase even without any support mechanisms. However, we are still far from that optimal situation. In the meantime, Europe needs to continue the support to renewable energy technologies and the changes needed in the market, pushing the transition towards a future sustainable energy system.

There is not a one-fit-all solution with regard to market design. However it is important to address the various challenges in parallel, to avoid that market interventions introduced to address market failures do not create new distortions.

The upcoming years will be crucial to put into practice many new market design issues such as the recently approved market codes (balancing, CACM, etc.) and to gain experience from the recently introduced tender mechanisms. The market will also provide clear views on the risk premiums related to the various support schemes. While this report aims to identify the ingredients for a blue print for RES support schemes, it is clear that more practical evidence is needed to better understand investment risk and market dynamics. It is important that small private players, fundamental pieces of the energy transformation, as well as new technologies are not fully exposed to market competition as they will have little or no chance to make their long-term contribution.

The review of the state-aid regulation for environmental and energy support will begin already in 2017. But we should try to gather as much evidence and experience as possible before introducing significant changes to the current and recently introduced framework.

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