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Redesigning the European electricity market

An overview of policy options and their implications

Thomaßen, G.K., Chondrogiannis, S., Flego, G., Vitiello, S.

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Contact information
Name: Georg Thomaßen
Address: Via Fermi 2749, 21027 Ispra, Italy
Email: georg.thomassen@ec.europa.eu

EU Science Hub
https://joint-research-centre.ec.europa.eu

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Contents

Abstract

Russia's invasion of Ukraine has sent gas prices to unprecedented highs. These price spikes spilled over to the electricity sector due to the marginal pricing mechanism – which mandates that the highest cleared bid sets the price in each market session. As prices rose much faster than operational costs, the President of the European Commission Ursula von der Leyen announced a complete overhaul of the current market structure in an address to the European Parliament, "adapting it to the new reality of dominant renewables".

The reform proposals that are discussed range from the expansion of market-based instruments to a complete abolishment of marginal pricing, replacing it with pricing based on average production costs. We take up the ongoing discussion to explore possible market architectures. To this aim, we compare two extreme scenarios – a free market and an auction-based monopsony – with the current market architecture based on their ability to deal with energy crunches and to achieve decarbonisation.

Therefore, we outline the main market design elements:

- Reduce windfall profits in crisis situations through the expansion of two-sided CfDs for producers of low-carbon electricity: two-sided Contracts for Difference (CfDs) allow to achieve reliable revenues for renewable generation, while increasing the price resilience of the system if revenues during price spikes are handed back to the consumers.
- Redesigning auctions to drive the transformation towards carbon neutrality: a stronger reliance on auctions requires a better process to select projects. Auctions should therefore be reformed to take into consideration the grid infrastructure, multiple technologies, as well as larger geographic areas, up to a pan-European auction mechanism.

We conclude that a reform is more promising than setting up a completely new market architecture, as there are already in the current system instruments to achieve price resilience and a fast response in energy crises.

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Authors

Georg Thomaßen, Stamatis Chondrogiannis, Gianluca Flego, Silvia Vitiello

Executive summary

Energy prices dynamics have generated factions with completely opposite opinions on the foreseen reform of the wholesale electricity market. The role of the JRC is that of an impartial technical advisor to the European Commission's services in this delicate matter of reconciling decarbonisation and low prices.

This report presents the JRC's work supporting the Directorate-General for Energy of the European Commission on framing some of the questions to be answered by the reform of the wholesale electricity market design. The reflections included in the report are relevant not only for the discussions that led to the reform proposal[1] issued by the Commission on March 14th, 2023, but also for its future amendments in the Parliament and the Council and eventually for its implementation.

Policy context

During the COVID-19 pandemic electricity demand in Europe hit its lowest level and therefore wholesale electricity prices went down. In summer 2021 however prices have started to increase again, pushed among others by the increasing demand due to the resumption of industrial activity. The European Commission, to shield European consumers from these price increases, launched in October 2021 a toolbox with suggestions to Governments about possible actions to undertake.

Later in February 2022 an additional shock struck the energy markets: the Russian invasion of Ukraine, casting a shadow of uncertainty on the delivery of Russian gas, determined a further increase in the wholesale electricity market, where gas is often the marginal technology setting the price. It was then clear that a reform of the electricity market was required to cope with both the immediate gas-led crisis and the medium-long term need to integrate significantly more Renewable Energy Sources into the power system.

Key conclusions

The cost-optimising nature of **marginal pricing** is forcing the wholesale electricity market to evolve towards the technology mix that achieves the **lowest cost possible to supply electricity**, yet this process takes time and produces high costs to be borne by the consumers in the meantime. From the analysis conducted to support the Directorate General for Energy of the European Commission, the JRC pinpointed some key elements for consideration in the structure of the European electricity market:

— **The suitability of prices alone to resolve crisis situations** and to steer the power system's transformation towards climate neutrality **might be limited**, as the price signals necessary to achieve a quick reaction are likely a too extreme burden for consumers. In hybrid markets, i.e. markets where elements of free competition and of regulated markets co-exist (the dominant design in the EU), wholesale electricity price signals might be undermined by parallel auction schemes, which promise a lower-risk environment to investors.

— An implementation of **average-cost pricing would require effective bid control** and that **investments are refinanced through secondary financing mechanisms,** such as auctions. In such a system, the State has to take on the role of a system planner, implementing additional auction schemes or switching to an auction scheme for several technologies at once.

— Options to increase the **price-resilience against future shocks** within the current hybrid-market system already exist. Governments can negotiate switching existing remuneration schemes to **two-sided Contracts for Difference for Renewable Energy Sources**, and potentially include **other carbon-neutral technologies like nuclear power**.

— The implementation of some features of locational marginal pricing, **e.g. including locational information in auctions for RES,** limits the contagion effect of fuel prices on electricity prices. More spatial granularity in the market clearing process may reduce the area in which one power plant sets the price, also reducing windfall profits for that particular plant. This can lead to more diversity among prices setting technologies. End-consumers costs are reduced through a more efficient dispatch (savings on total system costs through lower redispatch) and lower infra-marginal rents for price-setting producers.

[1] COM(2023) 147 final and COM(2023) 148 final

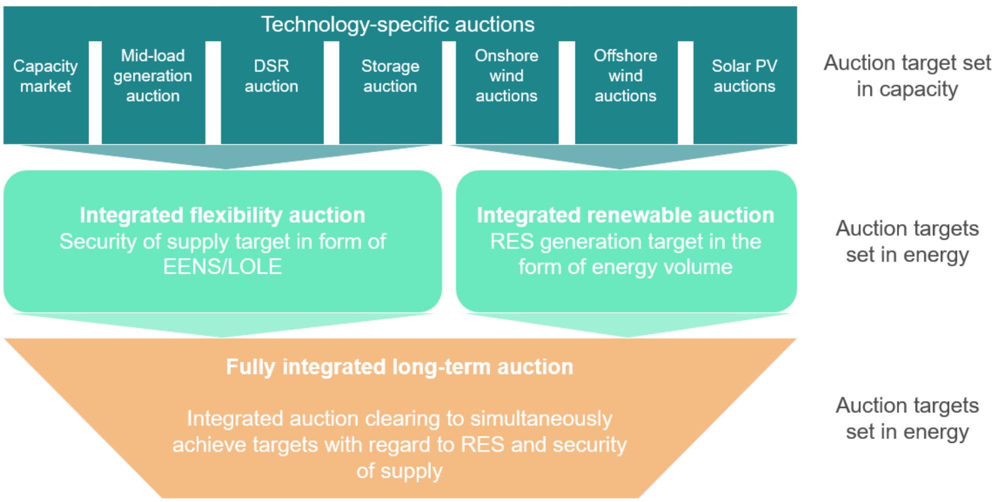
Main findings

The greatest downside of the marginal-pricing system is related to situations when the boundary conditions change suddenly, such as fuel price shocks. In these conditions, markets with marginal pricing are thrown out of balance, which they regain by increasing the infra-marginal rents of those technologies which are beneficial to resolving the crisis. In these situations, consumers pay a high price: the mechanism is slow as relief usually requires new investments which materialise only with several years delay. Further, with the challenge of achieving climate neutrality by 2050 ahead, the market signals necessary to achieve this transformation might be too extreme to maintain a political consensus. It could therefore be warranted that investment into power system infrastructure is steered through secondary financing mechanisms, as this is the safest way to ensure that the necessary infrastructure is being built. Moreover, renewables are becoming the most competitive technology in terms of LCOE, reducing the need for high infra-marginal rents for their deployment, while their capital intensiveness favours de-risking investment mechanisms, such as auctions.

The main issue with the current marginal pricing approach is that it produces high infra-marginal rents at disequilibria states. This is a signal to direct investment where it is profitable, yet it is a costly one, putting a heavy burden on end consumers in crisis situations. In addition, the current hybrid system might further undermine these price signals with respect to renewables.

The JRC's analysis of design options for the electricity market, summarised in the figure below, identified the **improvement of auctions** as one of the key aspect that could be implemented in the reform of the European wholesale electricity market.

Figure 1. Design options for auctions, differentiated according to the level of integration.



Source: JRC, 2023

Related and future JRC work

The JRC, the in-house science service of the European Commission, is working on the European electricity market since 2014, delving into specific issues like Adequacy, Bidding Zones definition, transparency and monitoring of the wholesale market. Such activities are done in support of colleagues in the Directorate General for Energy and in the European Agency for Cooperation of Energy Regulators – ACER.

Quick guide

In this report the JRC presents its analysis of the policy options to reform the European wholesale electricity market, considering current technologies as they are today. The question answered is: what level of regulation in the European electricity sector is most suitable to achieve the EU's policy goals? We compared two extreme regulatory scenarios – a fully deregulated "free" market and a fully regulated auction-based monopsony – against the current setting. We concluded that adapting the current hybrid system could be the most promising approach, rather than a complete overhaul of the existing market rules.

1 Introduction

The current energy crisis, following Russia's invasion of Ukraine, has sent gas prices to unprecedented highs. This affects EU consumers not only through their gas bills, but also through their electricity bills, as gas and electricity prices are closely correlated under the current market structure ("Target Model", (European Commission, 2017)). The surge in electricity has been disproportionately higher than the share of gas in the electricity mix would suggest. This is due to the fact that during each trading interval at the EU's wholesale markets, the highest accepted bid sets the market clearing price. Applying this marginal pricing mechanism means that if gas-fired power plants are needed to satisfy even only the very last bit of demand, the market clearing price will be at least as high as their operational costs, even if there is only a very minor share of gas in the respective hour's electricity mix, and every generator whose bid have been accepted will gain that price.

Accordingly, the suitability of this market clearing mechanism, called marginal pricing has been questioned by several Member States, as spot market prices rise much faster than the operational cost of the system, especially in countries with a large share of generation with low operating costs, such as wind, solar and nuclear power. Instead, electricity could be priced based on average operating costs, so the proposal, which would allow consumers to benefit from already-deployed low-cost electricity.

In this report we account for the support provided to the European Commission's Directorate General for Energy to frame the ongoing discussion on a market redesign, and outline two different extremes within the range of possible market structures that are currently debated, and contrast them to the current market design. In all three cases, we analyse how short-term operations are scheduled, and how the necessary long-term investment signals are generated to achieve decarbonisation and reliability targets. We further compare the three market design archetypes based on their resilience against price shocks and bad planning decisions, their technological response to crises, and their suitability for the transformation towards climate neutrality. Based on this analysis, we discuss what measures might be suitable to increase the system's resilience, while simultaneously making it fit for rapid decarbonisation.

2 Methodology: The free-market setting – energy-only market plus cap-and-trade mechanism

The pure energy-only market (EOM) is commonly understood as a market setup, where electricity is traded in several sessions defined by different time horizons, for example day ahead, intraday and balancing in the European power system. Derived products such as futures for energy or capacity exist, and offer traders the possibility to hedge financially against high power prices in the future, yet they are traded on a completely voluntary basis. The market described in this section is an abstract image to convey one extreme of a broad range of potential electricity-market structures. In the real world, there is no power system that implemented this structure to one-hundred percent, as to the knowledge of the authors[2].

2.1 Short-term operation

Marginal prices set effective incentives for an efficient operation of the power system. During each trading interval, all accepted offers receive the price of the most expensive offer that was accepted. This sets an incentive for power plant operators to bid their true operating costs: If they place a bid higher than their marginal production cost, which ends up exceeding the market clearing price, they are not being dispatched. If, however, they place a higher bid which is below the market clearing price, they get the same price, and therefore the same revenue as if they had bid their marginal production cost. One exception to this rule is during times when generation capacity is scarce, when operators can add a mark up to their production costs, as all capacity is needed to satisfy the demand. Therefore, competition during these time periods is lower or does not exist.

2.1.1 Storage and demand response

In addition, marginal prices set efficient incentives for storage operation and demand response (DR). If different technologies set the price in a limited amount of time, the price fluctuates between the different marginal costs. This creates arbitrage between the different hours, which is an incentive for storage operators to buy electricity when it is cheap and resell at higher prices. Similarly, DR has the incentive to shift demand from time periods with high prices to those with low prices.

2.2 Long-term infrastructure planning

In the longer run, marginal pricing is also providing long-term investment signals: if an investor builds a new plant, it must operate at production costs which are lower than the market clearing price during a sufficient number of hours. In these time periods, the plant generates revenue streams, which are necessary to cover the initial investment, as well as all fixed operating costs. A long-term equilibrium is reached when the market generates exactly the right number of hours with prices above their marginal cost of each participating resource to refinance the initial investment.

If a fuel sees a sudden and unexpected price increase, the long-term market equilibrium shifts away from this fuel and towards more competitive technologies. This mechanisms is, however, much slower since new investments in more competitive resources need to be made. In this situation, the market remains at a partial disequilibrium, as the market prices would warrant the entry of new generation assets based on other fuels, yet the time for permitting procedures and construction might take up to several years. Full relief will only materialise once the new power plants are coming on line. Even under the most benign regulatory circumstances, the inevitable technical build-up lags translate into a barrier to market entry, making the convergence path of prices to average total costs excruciatingly long and winding. True, the so-generated short-, or rather medium-run extra profits create a powerful and valuable signal for investment. There is no denying the informational import of this – indeed, it's what would drive the adjustment under a pure free-market setting: muffling it needs thinking through. Yet its value is not infinite, and should be weighed up against the social deadweight loss that these profits create.

[2] Even the most liberalized markets rely, for example, on the system operator procuring balancing capacity to keep markets for balancing energy sufficiently liquid to safeguard the operation of the system. Other monopsonistic elements are centralized capacity auctions, or auctions for renewable capacity.

The reverse effect might, however, be problematic as well, once supply constraints ease and fuel prices come back down: The adjustment towards different technologies will come at the cost of much of the initial generation being kicked out of the market. A normalization in prices could potentially reverse these effects. A technically-adjusted system may well have enough staying power, but this, at the moment, is anybody's guess.

2.2.1 Decarbonisation

Climate targets in a free-market setting are usually pursued through carbon pricing, ideally a cap-and-trade mechanism, which allows emitters to trade emission rights, finding the most economical solution to achieve a certain carbon reduction, given the assumption of complete markets. In the EU, this corresponds to the EU Emission Trading System (ETS), which translates the carbon budget into carbon prices. The price on carbon adjusts the short-term equilibrium to favour low-carbon technologies over carbon-intensive resources by making polluters pay for the social cost of the carbon emissions they release in the atmosphere, so to increase their production costs. This rearranges the merit order, dispatching low-carbon resources first. At the same time, it increases the long-term competitiveness of low-carbon resources, as they can expect more revenue from spot markets – giving them more bargaining power to fetch better long-term prices, too. This shifts the long-term equilibrium towards these technologies. A credible carbon-price path can therefore trigger the expansion of low-carbon infrastructure years before it is actually profitable, as investors can anticipate future profitability, and are enabled to build infrastructure proactively.

On the other hand, the EOM setting presents some inherent drawbacks for the deployment of decarbonised power sources, even under the current context where such sources present the cheapest technologies in both short-term operational costs and levelised cost of electricity (LCOE):

A. Whenever a certain technology is highly profitable in a certain setting, additional deployment will eventually reduce the number of hours that more costly generation sets the price. Thus, if investors invest in too much capacity, they ruin the revenues they need to refinance their investments. This situation will not improve until capacity exits the market, electricity demand increases – creating new demand for generation capacity – or economic parameters, for example, carbon price or fuel prices change. Until then, the profitability of all plants of this technology suffers.
   While this generally applies to all kinds of technologies, this is particularly relevant for renewables, as this is the type of generation which is the backbone of most climate neutrality scenarios, and therefore requires the highest rate of expansion. With increasing renewable deployment, this *cannibalisation* can become worse, i.e. capture prices dropping more quickly than wholesale prices on average (Hirth, 2013), necessitating a disproportionate increase in CO_2 prices to re-establish a long-term equilibrium (Brown and Reichenberg, 2021).
B. Uncertainty about the future electricity mix can create price volatility in the EOM, which – in turn – increases risk premiums. The impact of the latter on investment decisions depends on the cost structure of the different technologies and affects most technologies with a high share of capital costs (as opposed to operating costs). This applies to the most competitive low-carbon power generation technologies, such as solar, wind (and nuclear), as they are characterized by very low operating costs. On the contrary, the cost of fossil-fuel power technologies is much more defined by their operational costs.

2.2.2 Security of supply

Resource adequacy in EOMs is maintained through scarcity prices, which occur when demand exceeds the available supply. In these situations, voluntary or involuntary demand curtailments set the market clearing price, exceeding the marginal production cost of the last plant in the merit order (Cramton, Ockenfels and Stoft, 2013). If there aren't enough consumers that agree to reduce sufficient volumes of demand voluntarily, the price rises to the upper price cap and the system operator curtails load to balance load and generation. These time periods – which rarely occur – are of great importance to investors in generation assets, as they form the major contribution to refinancing the initial investment. Accordingly, there is a direct relationship between the upper price cap and the number of hours during which involuntary load shedding occurs: if the price cap is high, a low number of hours with scarcity prices is sufficient to generate enough revenue to refinance investments in peak generation plants at the end of the merit order. If it is low, more hours with scarcity need to occur, as the revenue generated during each hour is much less. Therefore, investors have an incentive to invest in less capacity if a low price cap is introduced, as they need to ensure that a sufficient number of scarcity prices occurs (Stoft, 2002; Thomaßen, Redl and Bruckner, 2022).

Strictly speaking, this principle is already a deviation from a pure market perspective, as the price cap does not reflect each consumer's value of lost load (VOLL). One approach is to estimate a system-wide VOLL, yet this remains only an imperfect proxy, as the value of involuntarily-shed load will vary with each consumer, and over time, depending on the associated processes behind the desire to consume electricity[3].

2.3 Key for a functioning system: free price formation

2.3.1 Credibility

As outlined above, prices are the major instrument steering investments in new infrastructure, such as power plants, storage and DR. Prices have to be credible and reliable for this mechanism to work, as investors have to believe they can predict how the market will evolve, and what assets will be profitable in the future (Edenhofer *et al.*, 2021). The more uncertainty about the future development of the market remains, the more risky investing in such a market becomes. Uncertainty can be induced by unpredictable fuel-price developments, uncertainty about the ambition level of climate policies, as well as market-inherent factors such as the variability of renewable generation (Tietjen, Pahle and Fuss, 2016; Edenhofer *et al.*, 2021).

The riskier the investment is perceived, the higher the return must be to persuade investors to invest. Some risk-averse investors might cede to invest altogether, as they are only willing to invest in low-risk environments with predictable returns. Others need to be sure that the market is allowed to play out freely, and that policy makers will not intervene, no matter the market outcome. Only if investors believe that carbon prices will be allowed to determine the cost of abatement in the market without intervention will they invest in low-carbon technologies based on spot market prices (compare section 2.2.1). Similarly, investors will only invest in peaking plants if they have confidence that scarcity prices of several thousand EUR/MWh are allowed to occur freely in the market (compare section 2.2.2). This may come in contrast to the policy goal of affordability (and industrial competitiveness) in cases of energy crunches due to external factors (e.g. of geopolitical nature). It questions whether the EOM is *resilient* against external pressure.

2.3.2 Implications for the energy transition

The importance of letting the pricing mechanism work freely has major implications for the transformation of the power system towards climate neutrality. *In theory*, every transformational speed – given that it can be physically achieved – can be realised within a free-market setting. *In practice*, however, this relies on letting the market send the necessary signals in the form of prices. In the period until markets have adjusted, while the market is at disequilibrium, this can result in an immense burden on consumers. A new decision, for example, to tighten the carbon budget in an existing cap-and-trade mechanism, would first trigger higher carbon prices, leading to higher electricity prices, and thereby increasing the competitiveness of low-carbon resources. Consumers would have to pay these extra costs for as long as it takes until new investments in low-carbon generation were realised. A side effect is that during the period of disequilibrium, existing low-carbon resources receive additional infra-marginal rents, which were not anticipated before the respective final investment decision at this point in time[4].

[3] For instance in terms of number of hours per year (essentially, ACER's 2020 "methodology for calculating the value of lost load, the cost of new entry and the reliability standard" displays the very same approach: The problem here is that the Value of Lost Load rises disproportionately with the scale of outage, above a certain threshold relating to the preservation of the quintessential public good of law and order. In other words, the distribution of outage costs is long-tailed, even if the distribution of outage durations may not be. Also, imputing the exact cost of a very rare disaster is more of a gut-feeling than a rational-expectations affair: by definition, it is something we are going to avoid on most years – on all years, if we are lucky. The definition of VOLL, in such cases, takes on an inevitable public policy dimension that simply cannot be estimated via customary VOLL surveys.

[4] Generally, investors in low-carbon resources will generally expect higher infra-marginal rents due to high ETS prices. It is, however, unlikely they expected this already in the year 2022, but rather later in time when the ETS budget is much smaller than today.

3 Auction-based monopsony – a potential implementation of average cost pricing

The most radical alternative to the free-market setting is a state-run monopsony based on out-of-the market financing mechanisms for all those power-system components whose cost recovery would rely on market revenues in the free-market setting. Such a system would effectively decouple short-term operational incentives from long-term investment signals, and steer capacity expansions primarily through secondary mechanisms, such as auctions[5], to refinance the investment.

3.1 Short-term operation

Covering the investment costs of the different system components through auctions is a *precondition* to changing the pricing rules in the energy market.

A simple switch to a pay-as-bid mechanism would be ineffective to reduce costs, as market participants would try to guess the highest clearing bid and place a bid at a marginally lower price. An average-pricing mechanism could, however, be combined with effective bid control. In this case, the market operator would assess the cost of production of each generator, based on current fuel prices, power production efficiencies and other technical and economic parameters. Then, each dispatched generator would receive a payment that covers these production costs for the produced electricity. Consumers would pay a price that reflects the weighted average of all production costs, i.e. the average production cost of electricity during the trading interval in question.

Such an approach could even result in a dysfunctional system, since there would be no opportunity to refinance investments into power system infrastructure, likely leading to widespread bankruptcies of utilities. If the cost of the investment is, however, covered through an additional auction mechanism, it allows more degrees of freedom in the way energy is priced, opening up the possibility of implementing average-cost pricing. Similar mechanisms are common practice in US markets to mitigate bids of large generators, if they are suspected to make use of market power. In this case, the system operator estimates their “real” marginal costs based on fuel prices and technical indicators of the plant. Then, the bid is lowered to the estimated marginal cost plus a modest adder (Hogan and Pope, 2017). To achieve an effective average-cost pricing regime, such a *cost-plus* mechanism would need to apply to all generators to achieve lower average prices than a marginal-pricing approach. It would likely be necessary to combine it with regulation that mandates offering all available capacity for dispatch, as the financial incentive to operate the plant on its own could be too low.

Generally, the dispatch optimisation would need to move away from simply selecting the lowest bids that satisfy the demand. It would require a more comprehensive optimisation approach which takes into consideration operating costs and technical characteristics, not only of power plants, but also of storage and DR. Average prices on their own would be insufficient to incentivise the optimal use of these technologies as the price differences between trading intervals would be much lower than in a marginal pricing system. For optimal storage operation, this would require knowledge of charging, discharging and storage capacities and efficiencies, among other technical specifications. In the case of DR, detailed knowledge of how much demand can be shifted within and during which time periods is essential, as well as the associated costs. In general, the dispatch can then be optimised, taking into consideration cost and technical constraints. Based on these, an average cost can be calculated which would constitute the price charged to consumers.

For as long as the switch to average-cost pricing occurs simultaneously throughout the whole European power system, market coupling is not an issue either. Schedules can be determined through optimisation, as outlined above, which determines also the use of interconnector capacity. The exchanged flows can then be priced either at their marginal cost (implicitly assuming that the generation to provide the flow through the interconnector is additional and should therefore be fully paid by the recipients), or priced at the average generation cost of the supplying zone (which would mean that consumers in the receiving zone are treated in

[5] Generally, other mechanisms, such as feed-in tariffs, can also be suitable for selective technology classes. All suitable mechanisms have in common that the state acts as a single buyer for capacity of different technology classes. Since auctions (for renewables or firm capacity) are the predominant form in the Energy Union, we will use auctions as a placeholder for similar mechanisms, which are more or less interchangeable.

equal those in the supplying zone). Market coupling would, however, be much more difficult to realise, if only some Member States switched to average-cost pricing, while others kept a marginal-pricing approach.

3.2 Long-term infrastructure planning

In such a system, the investment in power system infrastructure needs to be steered through auctions or similar mechanisms, as the market revenue is insufficient to refinance the initial investment costs. This massively reduces the investment risk, as the revenue is guaranteed through the auction result, while the operation of the infrastructure is merely compensated on a cost-plus basis. It implies a risk transfer from utilities, and other investors in the electricity sector, to the state. Since market participants do not have to predict anymore what is profitable in the market, but merely react to the state's auction targets, the state has to adopt a new role of a system planner. Auctions would become the only instrument to shape the system. The basis for such a system should therefore be a comprehensive target scenario, which includes detailed information on aspects such as expected demand characteristics – such as the total demand and its flexibility – and annual capacity targets for different technology classes.

Moving efficiently towards this target picture requires likely a redesign of auction mechanisms, for example to steer investments to locations where they are needed most, and to differentiate more closely between different technology classes. The first option would be to continue the current auction mechanisms and supplement it with additional auctions when the elimination of the market threatens to leave a gap. The alternative is a fundamental reform of auctions, creating a mechanism that includes all technologies within one single systemic auction. Option B could be considered an evolution of Option A, while several intermediate forms could be imagined.

3.2.1 Option A – several parallel auctions to achieve the target picture

3.2.1.1 Decarbonisation through auctions for renewables

Carbon pricing in the power sector would lose its purpose to incentivise low-carbon investments as it does not increase rents for low-carbon technologies: In an average-cost-pricing world, every producer receives their production cost, while no producer gains an additional incentive to invest based on short-term operational remuneration. The remaining purpose would be, on the one hand, operational – to dispatch low-carbon resources first and create arbitrage opportunities for storage. On the other hand, it would incentivise consumers to use energy more efficiently, as power prices would rise if too many carbon-intensive resources were used for power production. This effect, however, would also be mitigated by the average-cost pricing mechanism, i.e. the incentive for energy savings would be stronger in a system with marginal pricing as the impact on end-consumer prices would be larger. Auctions for renewables would therefore be the primary driver to decarbonise the power sector, by expanding the generation of green electricity. Changes in auction design would be necessary: Instead of competing for a top-up of market revenues, such as a one-sided contract for difference (one-sided CfD)[6], the entire investment would need to be covered through the auction: This could lead to a price increase in some auctions, which do not rely on two-sided CfDs or feed-in tariffs (FITs). This increase is, however, expected to be small, as recent auction results suggest[7].

3.2.1.2 Security of supply

To safeguard the operation of the power system, the system needs sufficient amounts of firm capacity. As these technologies will not enter the market based on spot prices, they need a financing mechanism which ensures profitability for enough capacity to meet the desired level of reliability during peak-load periods. An auction for firm capacity, i.e. a capacity market as implemented in several European and US power systems, could fulfil the function of attracting the necessary investments to maintain adequate levels of capacity.

[6] A one-sided CfD uses a strike price to top up payments whenever the market price is lower than the strike price. In these cases, the plant operator receives an additional payment based on the difference between the strike price and the market price.

[7] In the UK, auctions cleared at similar rates as on the European main land, even though the UK system relies on two-sided CfDs, where the plant operators are effectively guaranteed a fixed rate per MWh they produce, as they need to pay back the difference between the market price and a predetermined strike price when the market price exceeds the strike price. https://www.sse.com/news-and-views/2022/07/cfd-contract-secured-for-viking-energy-wind-farm/

The basis for such an auction is a resource adequacy assessment, assessing the investment needs to safeguard a certain reliability standard. Based on this assessment, a capacity target can be derived, taking into consideration the contribution of renewables, storage and DR. This capacity target is then acquired in an auction.

3.2.1.3 (Low-carbon) dispatchable generation

In addition to a conventional capacity market, a second financing mechanism targeted at dispatchable generation would likely be necessary to maintain the necessary amount of mid-load generation in the power system. Mid-load plants – such as CCGT units or coal-fired power plants – usually have a higher efficiency or lower fuel costs, leading to lower marginal costs than peaking plants. Under average-cost pricing, however, this is not a competitive advantage anymore – as everyone is only compensated for their operating costs, no matter how high. In the capacity market, on the other hand, peaking plants with high operating costs but low investment costs have a competitive edge, as they are cheaper to build. For as long as mid-load generation can be provided by existing power plants, this issue is less severe. Existing plants remain highly competitive in capacity markets, as they only have to refinance their fixed operation and maintenance costs. Since mid-load generation will, however, be still needed in the medium to longer term, new low-carbon technologies might become necessary to provide these services with a lower carbon footprint than the existing plants. Additional mechanism, such as a special capacity auction targeted at mid-load generators could therefore become necessary.

3.2.1.4 Flexibility

If electricity is priced by the average-cost of production, it removes – to a significant extent – the business case for storage and DR deployment based on market prices alone. Operators generate contribution margins by exploiting arbitrage, yet arbitrage is drastically reduced through the change of the pricing mechanism. Since the operation of storage and DR is beneficial to the system – reducing its cost and improving the stability of the system – it makes sense to set up auctions to fill this gap, and incentivise system-optimal storage and DR deployment. In the case of storage, these would primarily be necessary to cover the initial cost of the investment. In the case of DR, which has much lower investment costs than storage or dispatchable generation, a fixed remuneration could be agreed on, which covers the cost of each individual shift of demand.

3.2.2 Option B - fully integrated auctions

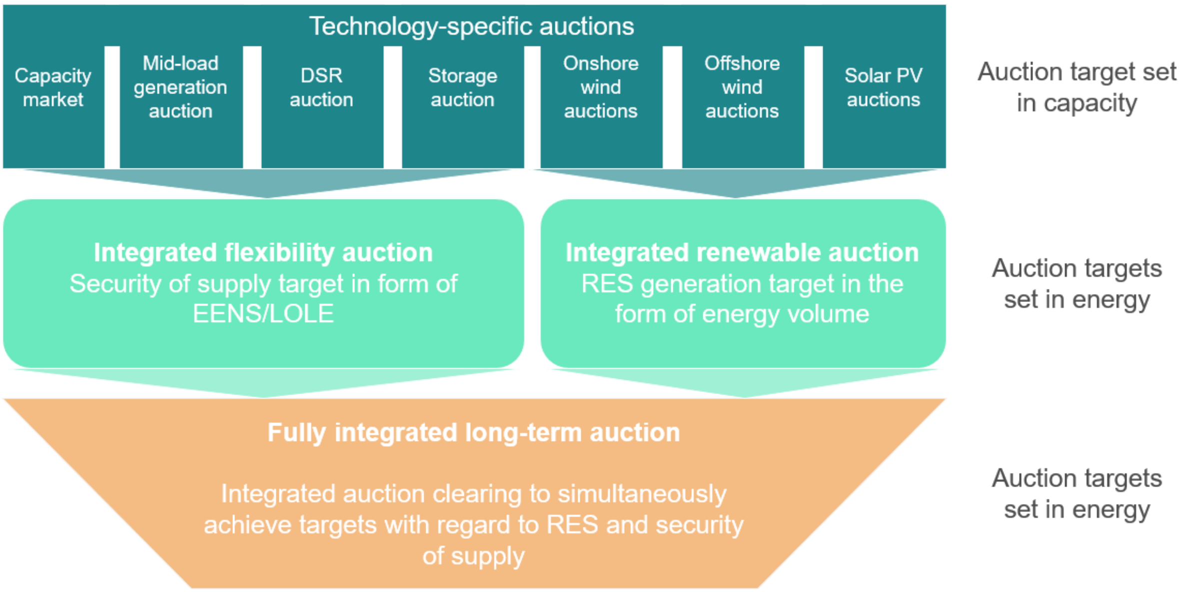
As the previous subsections show, a fully monopsonistic system could become rather fragmented, as a lot of different system services need to be considered, meaning that capacity for each of these needs to be acquired in a separate auction. In this situation, it could be preferable to move towards a more integrated auction design. Integrated auctions could award contracts for several technologies at once, up to one holistic auction which determines the winning bids for all relevant technologies.

This is depicted in **Error! Reference source not found.**. Instead of having specific auctions for each type of technology, a first step would be to integrate those technologies together which generate renewable energy, and those who provide flexibility, i.e. peak and mid-load generation, DR and storage. Since different types of capacity would be represented in the same auction, this would require setting decarbonisation and resource adequacy targets at a higher level, i.e. a target for total generation from renewable sources, as well as a maximum allowable amount of expected energy not served (EENS) or a maximum loss of load expectation (LOLE).

After all bids are submitted, a capacity expansion model would then determine the optimal selection of bids to achieve these targets. Such a design would have the advantage that it considers to what degree one technology class can substitute another. For example, a lack of bids for firm capacity might lead to more storage bids being accepted to achieve the same adequacy level. At the same time, it avoids having to "translate" the capabilities of one technology, in this case storage, into a different category (firm capacity). Instead of estimating capacity credits per technology, as is common in capacity remuneration mechanisms, the capacity expansion model would simply pick the combination of new investments which achieves the targets at lowest cost.

Technology-specific auctions could still be warranted in addition to more integrated auctions, for example to develop strategically important technologies before they become competitive in an integrated auction. This could, for example, apply to hydrogen-fired power plants, which are basically non-existent in the EU power system, yet play a major role in decarbonisation scenarios (see, for example, (IEA, 2021)).

Figure 2. Design options for auctions, differentiated according to the level of integration.



Source: JRC, 2023

3.3 Key for a functioning system: consistent and forward-looking planning

The largest risk in a monopsonistic auction-based system lies in the way that auction targets are derived. For example, if each change in government could lead to a complete revision of target scenarios, with completely different technology targets than the previous one. Rather, an existing or newly-established agency should be charged with the exercise of conducting the necessary assessments, to establish a target scenario based on their outcome, and to hold the corresponding auction(s) to achieve the targets. Ideally, this exercise would be organised on a larger scale, for example the regional level to coordinate the transformation of the power system and harvest synergies. More aspects of auction design are discussed in section 6.2.

4 (A multitude of) Hybrid markets – the current system

The European electricity market is neither a fully liberalised market, nor an auction-based monopsony, but rather a hybrid form between the two: Renewable expansion is commonly steered through an auction mechanism, and several Member States introduced capacity auctions to maintain resource adequacy, yet the trade of electricity is coordinated through spot markets which apply a marginal pricing rule to price electricity. Further, a carbon budget is enforced through a cap-and-trade mechanism, the EU ETS, which translates the annual budgets into a price on carbon emissions. While the latter is a true pan-European mechanism, the specific designs of renewable financial support schemes and capacity remuneration mechanisms lead practically to a multitude of specific hybrid designs in the EU. This might cause inefficiencies, distortions and regulatory arbitrage opportunities.

4.1 Short-term operation

Short-term operations are very much in line with the principles of a fully liberalised market. Electricity is traded in market sessions, namely day ahead, intraday, and balancing, on which markets for derived financial products are based. In addition to these market-based mechanisms, several Member States implemented mechanisms to safeguard the operation of the system in tight conditions, such as strategic reserves, interruptibility schemes, or market-wide capacity auctions. The first two are activated outside the market to ensure a safe operation of the system, in case the market alone is not able to satisfy the entire demand.

4.2 Long-term infrastructure planning

In the long run, market signals are expected to signal the need for new investments. In addition, however, several auction mechanisms are in place to correct the market signal, in case they are deemed necessary to mobilise the investments needed to achieve climate and reliability targets.

4.2.1 Decarbonisation

The primary instruments to achieve climate targets in the EU's electricity sector convey the double structure in place: It relies both on free-market elements, as well as on monopsonistic elements where the state acts as a single buyer. In this system, the EU ETS is in place to enforce the overall carbon budget primarily for the energy and the industry sector. In addition, each Member State holds auctions for the deployment of renewable capacity to increase the share of renewable generation in the European grid. This double structure achieves, on the one hand, a steady ramp-up of renewable electricity in the system, allowing for technology learning, which reduces the cost of deployment, as well as low-risk financing of renewable projects (Mazzucato, 2013; Đukan and Kitzing, 2021). In contrast, a system purely relying on the EU ETS would see renewable deployment only when carbon prices were sufficient to rectify investments in renewable capacity. Before this tipping point was reached, renewable deployment would not be profitable. As soon as it was reached, production capacities and other infrastructure would likely not be in place to react to the sudden surge in demand for renewable electricity. This would lead to a delay in deployment and to high carbon prices in the meantime (compare section 2.2 on market disequilibrium).

The EU ETS triggers additional carbon reduction measures – such as a reduced generation from carbon-intensive sources by shifting them back in the merit order – and can also serve as a corrective to renewable auctions: If auction volumes are set at too low levels, carbon prices will rise and trigger not only additional carbon reduction measures in other areas, but can incentivise market-based deployment of renewables. In the longer run, ETS prices might even be the key to integrate renewables fully into the market, when market value of renewable electricity is higher – due to high carbon prices – than the price paid in renewable auctions (Brown and Reichenberg, 2021; Thomaßen, Redl and Bruckner, 2022).

4.2.2 Security of supply

Theoretically, resource adequacy in the European power system is very much left to the markets: Articles 10 and 20 of the Electricity Regulation demand that technical bidding limits are chosen in a way that do not restrict trade, and that all price caps should be lifted before additional capacity remuneration mechanisms, such as capacity markets or strategic reserves, can be established. This is reflected in a mechanism that raises the technical bidding limits in the European day-ahead markets by 1000 EUR/MWh as soon as the market price surpasses 60% of the existing day-ahead bidding limit (ACER, 2017)

In practice, however, the security of supply is monitored closely through short-, medium- and long-term resource adequacy assessments. Building on these, resource adequacy concerns are tackled through additional mechanisms, such as capacity markets, or out-of-the-market mechanisms, such as interruptibility schemes, or strategic reserves (see (ENTSO-E, 2021) for a detailed list).

We can observe that the general approach to resource adequacy follows a similar principal as the approach to decarbonisation, as there are both market elements and elements of a monopsony. Free markets are generally supposed to achieve the right level of adequacy. These are, however, paired with secondary mechanisms to ensure that the necessary level of capacity actually materialises.

4.3 **Key principle: markets and auctions as mutual correctives**

In general, the current market structure can be considered an intermediary design between the two extreme principles. We found double structures in many areas of the current system – both in short-term operations and long-term system planning; in supply security and decarbonisation – that consisted of free market elements, and elements where the state acts as a single buyer. These double structures serve as a safety net to achieve targets with regard to decarbonisation and the safe operation of the system, both with a short- and a long-term horizon.

In this way, auctions serve as a corrective for markets in a hybrid setting, while the converse is equally true: On the one hand, if markets do not achieve policy targets on their own, auctions help to ensure that the necessary investments occur. On the other hand, if auction targets are too low, markets create an incentive to fill the gap: ETS prices can incentivise additional deployment of renewables or change consumption behaviours. High prices during a temporary energy shortage help to mitigate the crisis by signalling to consumers to reduce demand, while offering a strong incentive to mobilise every resource that can be made available.

In this way, double structures cover two of the three energy policy goals: security of supply and decarbonisation, yet not affordability. In fact, the existing double structures come at least partially at the expense of affordability, as additional out-of-the-market measures produce costs which are not necessarily counterbalanced by cost savings in other areas. This can be considered the greatest drawback of the current hybrid structure, that it produces additional costs, while leaving markets vulnerable to price shocks, both at the expense of consumers.

5 Results: Comparison of the three market design principles

5.1 Resilience against unforeseen crisis events

5.1.1 Price response

The cost-optimising nature of marginal pricing is forcing the market to evolve towards the technology mix that achieves the lowest cost possible to supply electricity, yet this process takes time and produces high costs to be borne by the consumers in the meantime. This is a feature of both, the free market as well as the current hybrid market design.

A system with average-cost pricing would be more resilient against price shocks in secondary fuel markets. Hourly prices would only rise proportionally to the share of electricity produced with the fuel in question. The key difference of the monopsonistic system is that investment signals are not generated through higher marginal rents. Since long-term investment signals are completely decoupled from short-term operational remuneration, it further allows more significant policy interventions, as these do not undermine the perspective for long-term investments.

In free-market settings, increased infra-marginal rents are necessary to signal the necessity to invest in beneficial technologies to achieve relief in the medium to long-term. In the current hybrid-market setting, these increased rents still occur, even if the technologies that should primarily react to them are mainly deployed through secondary auction mechanisms – such as renewables. This double structure can even undermine the investment signals stemming from higher marginal rents: if the primary mechanism to deploy renewables is an auction, investors will be reluctant to invest based on anticipated market prices, since these are much less certain than the revenue guaranteed through the auction mechanism. This does not only relate to situations where a support mechanism is in place, but can further already apply, if one is only being debated: In such a situation, investors might delay investments, as they anticipate the introduction of new policies which generate higher revenue and/or reduce the risk of investment[8].

5.1.2 Technological response

At the same time, the system response in a monopsonistic system does not necessarily have to be slower even though the incentives do not exist. On the contrary, a competent system planner with the necessary authority would likely be able to generate a faster response, as auction volumes for beneficial technologies could be increased. It would create low-risk conditions for investing in these technologies, which facilitates a fast and strong response. This applies as well to the hybrid systems, where existing auctions can be adjusted quickly. In a completely free market, the technological response capability is usually lower, as the long-term outlook during crisis events is very uncertain. In the case of a fuel price shock, it must be judged whether this is a temporary spike in prices, or the new normal. This uncertainty could lead to higher financing costs, disincentivising new investments. Only once the situation has stabilised and the longer-term perspective is sufficiently predictable, a reaction from the markets could be expected.

5.2 Foresight

As outlined in section 3.3, monopsonistic systems are most vulnerable to bad planning decisions, as no corrective to these exists. An incompetent planner and/or insufficient authority to design and adjust auctions would lead to suboptimal system design, which will not be compensated through market forces, as no incentive exists to invest outside the centralised auctions. In market-based systems with marginal pricing, the market will still send price signals to achieve decarbonisation or reliability targets, which reward those who invest in the right technologies, while punishing those investing in the “wrong” technologies. In theory, market participants anticipate the evolution of the system and make forward-looking investments. In reality, however, the multitude of possible future scenarios hinders proactive system transformation, since most participants

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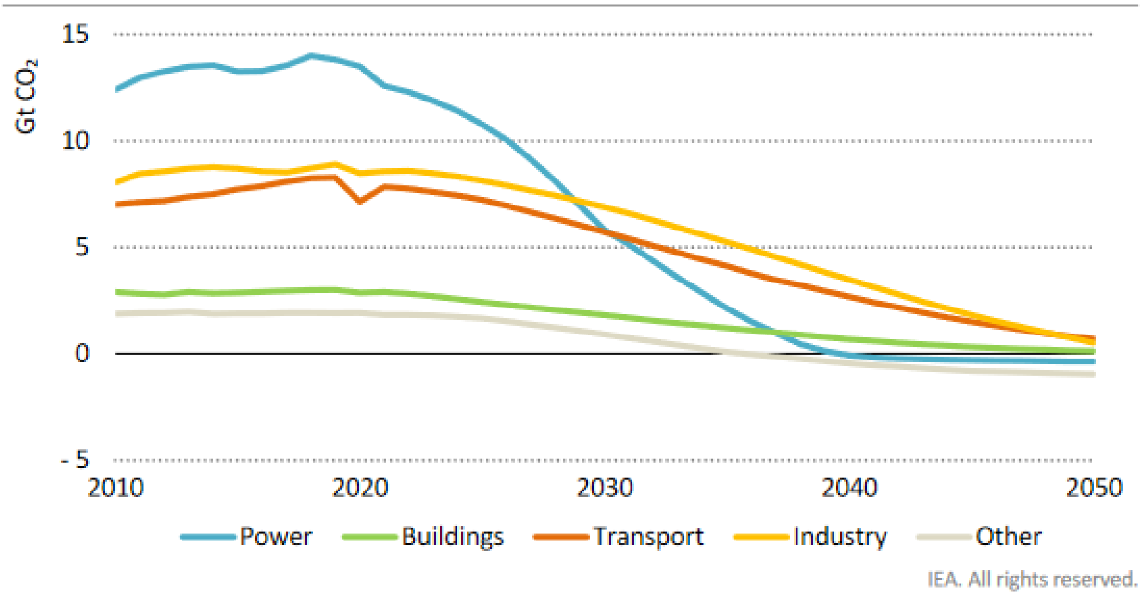
[8] For example, if several scarcity events occurred during one year, the amount of revenue that can be generated during these hours could generally rectify investments into new peak plant capacity. If, however, a capacity market that was introduced after investment decision, would likely reduce scarcity in the market, and therefore negatively affect the profitability of the plant in question. The plant might be able to participate in the capacity market, as these are usually open to existing power plants. Yet existing plants usually receive much shorter contracts (for example one year), compared to new-built plants (for example 15 years).

will only invest once they deem the investment a "safe bet". In a hybrid system these market signals remain generally intact, yet they might be undermined by risk preferences of investors. If auctions for this type of asset generally exist, it is reasonable to go through the auction for new investments, rather than betting on the possibility that insufficient volumes were auctioned off, which leave room for market-based investments. In addition, any correction in future auctions would be detrimental to the revenue earned with the respective market-based investment.

5.3 Suitability for system transformation

The EU's climate neutrality target 2050 will require massive amounts of investments in new infrastructure in the power sector: from renewable generation, storage and grids to carbon-neutral dispatchable generation, such as hydrogen-fired power plants. Many of these technologies have to be in place much earlier than 2050, since other economic sectors will rely on the power sector to decarbonise through electrification – directly and indirectly (through the use of green hydrogen). According to the IEA's Net Zero by 2050 scenario, the global power sector has to be decarbonised by 2040. It is hard to imagine that this infrastructure will be provided within 18 years, only based on electricity-market and ETS prices. Such a strategy would need to allow for the necessary price spikes in the ETS to occur reliably, without the threat of policy interventions. Given the recent interventions as a reaction to the Russian gas crisis, it seems out of the question that market participants would put their trust in free price formation in the markets. This trust is, however, the precondition for proactive power sector investments, at the scale necessary to achieve climate neutrality.

Figure 3. Global carbon budgets per sector according to IEA's NetZero scenario.



Source: IEA, 2021

Auctions will therefore remain necessary, and will likely require an expansion in volume for renewables, as well as an expansion to other technologies which are not yet on track to achieve the necessary market penetration – such as batteries or hydrogen-ready power plants. After all, state-held auctions are the powerful tool to ensure that what is needed is actually being built. In this way, the transformation towards carbon neutrality in itself could require a shift towards a more monopsonistic system structure.

The hybrid-market-inherent double structure, relying on marginal pricing, therefore remains useful. It further achieves that too-low auction volumes will be met with higher ETS prices, which (1) incentivise other reduction mechanisms, and (2) increase political pressure to adjust decarbonisation policies, for example increase auction volumes for renewables.

6 Possible policy implementation

Marginal pricing pushes the system towards energy generation with the cheaper and cheaper operational costs, lowering the market prices over the long run. However, the greatest downside of the marginal-pricing system is related to situations when the boundary conditions change suddenly, such as fuel price shocks. In these conditions, markets with marginal pricing are thrown out of balance, which they regain by increasing the infra-marginal rents of those technologies which are beneficial to resolving the crisis. In these situations, consumers pay a high price, as the mechanism is slow, and relief usually requires new investments which materialise only with several years of delay.

Further, with the challenge of achieving climate neutrality by 2050 ahead, the market signals necessary to achieve this transformation might be too extreme to maintain a political consensus on the current system. Generally, it could therefore be warranted that investment into power system infrastructure is steered more through secondary financing mechanisms, as this is the safest way to ensure that the necessary infrastructure is being built. Moreover, renewables are becoming the most competitive technology in terms of LCOE[9], reducing the need for high infra-marginal rents for their deployment, while their capital intensiveness favours de-risking investment mechanisms, such as auctions. If the system is more and more shaped through a central-planner approach, it makes sense to consider more holistic auctions which cover several technologies and coordinate several Member States, up to a pan-European auction. In this way, auctions could not only ensure that the necessary renewable deployment materialized, but simultaneously ensure that it is accompanied by the necessary deployment of storage and other means of flexibility to integrate the additional volumes efficiently into the grid.

Moreover, a complete redesign of the market takes time, as the legislative process for a complete overhaul of the relevant legislation itself would require several years, not to speak of a downstream effective implementation process[10]. This could waste crucial time in the fight against climate change, and would leave the system vulnerable against price shocks in the meantime. An evolutionary reform of the existing system therefore appears to be the better solution, if it can reach the same objectives, i.e. to protect consumers against price shocks, as well as an efficient transformation of the power system. If this is not possible, the drawbacks of a prolonged reform process need to be carefully weighed against the benefits. In addition, an evolutionary approach would not jeopardise pan-European market coupling, i.e. a single European market for electricity (although still incomplete), which is one of the major achievements of EU energy policy. Still, if the evolutionary policy interventions are delayed, or too timid, market-coupling may be jeopardised by a regression to national priorities in the face of a sustained energy crunch.

In the following subsections, we will outline some reform options that could improve the resilience of energy prices with regards to shocks, and enable to achieve the climate targets. In the last subsection, we will discuss potential improvements to the auction process, as it is foreseeable that their significance in shaping the system will increase in the future. This section deals with extending auctions to more technologies and larger geographical areas, as well as increasing the geographical granularity.

6.1 Reduce windfall profits in crisis situations through the expansion of two-sided CfDs for producers of low-carbon electricity

The main issue with the current marginal pricing approach is that it produces high infra-marginal rents at disequilibria states, which benefit producers that do not need them to refinance their investments, as they didn't factor in these revenues when deciding on the investment (see section 8). This functions as a signal where investment is profitable, yet it is a costly investment signal, which puts a heavy burden on end consumers in crisis situations. In addition, the current hybrid system might further undermine these price signals with respect to renewables and firm capacity (see section 5.1.1). In the worst case, the current system produces costly investment signals, which are ineffective as investors might be unwilling to react to them.

[9] Even though RES deployment might produce additional system-integration costs due to higher balancing needs than conventional technologies and their intermittent production profiles.

[10] In a recent report, the European Court of Auditors noted that significant delays still occur in the implementation of the wholesale electricity market design as defined in the Third Energy Package in 2009 and in the subsequent implementing Regulations. https://www.eca.europa.eu/en/Pages/NewsItem.aspx?nid=17646

Renewable investments decisions are commonly based on winning an auction, and thus being awarded a contract for a remuneration scheme. These volumes of electricity can serve as a cost buffer, if they are remunerated either through a two-sided CfD or a feed-in tariff, as higher market prices will not increase the rents paid to renewable generators. A first step towards increasing the system's resilience against shocks could be the large-scale switch towards two-sided CfDs for renewable auctions: If the market price drops below a strike price, operators receive the difference between the market price and the pre-agreed strike price. If the market price exceeds the strike price, however, the operator pays back the difference between the two. This serves as a buffer against shocks, as spikes in power prices do not benefit renewable generators. Parts of the renewable industry have nonetheless shown a preference for CfDs, which could indicate that this switch would generally be accepted (see for example (Wind Europe, 2022)).

Existing contracts, however, were often not concluded on the basis of a two-sided CfD, therefore, switching the remuneration scheme for new auctions would only have an effect in the long run. In light of the current crisis, it might be rectified that governments enter into negotiations with renewable generators that were awarded a one-sided Contract for Difference to change the basis of these contracts. It would require increasing the rates paid to these producers, as the respective auctions were won with the prospect of additional revenue from the market (even though the revenue to be expected at the respective point in time was admittedly much lower). Given the prospect of a moderate adder as compensation for the missed revenue in the short run, it could be an attractive case for renewable generators, as future price development is very uncertain, while the higher CfD rates would be paid over the remaining duration of the contract.

In this way, the share of electricity that is being paid the market price would be effectively reduced, with only moderate cost increases over a longer period. The generated revenue should then be used by the Member States to reduce the end-consumer costs of electricity, for example by reducing grid tariffs or other taxes and levies that apply to the use of electricity. These price reductions could be calculated on a weekly basis to avoid inter-temporal arbitrage and preserve incentives for efficient storage operation and DR.

This would effectively implement a dual procurement mechanism in the power system, as recently recommended by (IRENA, 2022): (Variable) renewables (and possibly other carbon-neutral technologies like nuclear) would be procured through a long-term mechanism, while the spot markets organise the flexibility to balance the residual load, both positive and negative. Since auctions would award CfDs, i.e. financial contracts, renewables would still be traded on the spot market. This would maintain a common platform to organise the dispatch, and preserve a far-developed environment for electricity trade.

In addition, CfDs are ideally designed to distort spot markets as little as possible. Recent proposals to achieve this focus on coupling the CfD not with the physical production of the renewable plant in question, but rather with the production forecast, or a virtual twin, which calculates energy production volumes based on weather data (Schlecht, Hirth and Maurer, 2022; Newbery, 2023).

In a similar way, CfDs could be extended to other forms of low-carbon generation, such as nuclear power. Here, the state could offer a CfD at a rate little above the expected long-term market prices to further reduce the amount of electricity that is affected by the market price. Most of the nuclear plants currently on line have long refinanced the cost of the initial investment, and are furthermore often run by (partially) state-owned companies. It would effectively increase the share of electricity which is unaffected by spot-market prices, and therefore serve as a buffer against future price shocks, while effectively providing relief in the current crisis.

The expansion of two-sided CfDs can be seen as a built-in hedge against unforeseen shocks in the future, reducing the impact of price spikes in the spot market on consumers. They should, however, not replace private-party hedging activities, but rather occur additionally. Renewable PPAs remain important, and retailers should be encouraged to enter into these contracts to further increase their own resilience against price shocks, and thereby the resilience of the system.

6.2 Redesigning auctions to drive the transformation towards carbon neutrality

Given the challenge of climate neutrality by 2050, it is obvious that the future market design has to achieve the transformation as efficiently as possible. This has implications for designing auctions, which are most important in the case of a monopsonistic auction-based system, as they are the main instrument to shape the power system. These aspects are nonetheless also important in a hybrid system, as they can achieve a better auction outcome, i.e. more impact with less financial resources.

Redesigning auctions should focus on three aspects: (1) Increase the geographical scope of the auction, (2) increase the number of technologies in the same auction to allow for substitution between different technologies, and (3) include locational aspects, such as a representation of the grid and local demand to increase the geographical resolution at which bids are cleared.

By directly including the demand and grid in the auction clearing process, the clearing mechanism can also consider the benefit that each bid has to the system. Instead of simply accepting the lowest bids, irrespective of their location, bids would be accepted based on their improvement of the overall welfare.

Increasing the geographical scope and the number of the technologies simultaneously cleared in an auction increases the options to achieve decarbonisation goals or reliability targets. These could be organised involving all the relevant actors (e.g. Regional Cooperation Centres (RCCs), NEMOs, in coordination with ENTSO-E and EU DSO Entity). In the longer run, a pan-European auction could be organised to implement a European approach to infrastructure investments in the power sector.

In practice, a renewable auction could thus be held as follows:

1. A target for new renewable capacity or generation is derived from a target scenario.
2. The respective responsible party (RCCs, for example) runs simulations using several decades of weather years to determine the marginal welfare contribution of each renewable technology at each transmission grid node. From these, indicative de-rating factors for each location can be derived, which are published well in advance to indicate to project developers where renewable projects are especially beneficial to the system, i.e. which locations are promising to win the auction.
3. Bidders can submit their offers to the auction, which consist of a strike price for the CfD, and a geographical location.
4. All offers are included as investment options in a capacity expansion model. A constraint is added to the model that enforces the auction target, i.e. that a certain amount of renewable capacity is built, or that a certain amount of renewable generation is added to the system.
5. The model picks the system-optimal combination of offers to achieve the target. The selected offers constitute the winning bids of the auction.

Similarly, a capacity/reliability auction can be designed. In this case, the RCCs would set a reliability target, for example in the form of an EENS or LOLE[11] value which should not be exceeded. Then, projects for dispatchable generation, storage and DR could compete, while the model selects those offers which fulfil the reliability target at the lowest cost.

Moving towards a European auction scheme is very much in line with the principles of the Energy Union. As auctions become the main mechanism to shape the power system, it is the logical conclusion to strengthen the internal market also on this aspect, and coordinate this mechanism at regional and pan-European level. This allows to find the most effective and cost-efficient solutions to achieve decarbonisation (and potentially resource adequacy) throughout the whole European Union.

[11] Any LOLE target would likely need to be converted into an EENS target, since it is easier to constrain the optimisation to allow only for a certain amount of ENS, rather than to ensure that ENS occurs during a certain number of hours.

7 Concluding remarks

The European gas price shock of 2022 sparked a discussion on whether the current market design, in which wholesale markets determine the market clearing price based on the marginal bid. The suitability of this mechanisms was repeatedly put into question, suggesting that pricing electricity based on the average cost of production could be a more suitable approach. These discussions usually lacked context of what additional measures would be necessary to make market based on average cost pricing work, without risking the security of supply or the European climate targets.

This report provides the JRC's view on the issue, which boils down to the question: what level of regulation in the electricity sector is most suitable to achieve the EU's policy goals? Hence, we analysed two extreme regulatory scenarios – a fully deregulated "free" market and a fully regulated auction-based monopsony. These were compared to the current European system which inhibits hybrid structures – free market elements combined with monopsonistic instruments – in many areas.

The basis for this comparison were three criteria:

- the ability to achieve an **efficient crisis response in a fuel price shock**, i.e. reducing demand and new investments in those technologies that can bring relief, while maintaining socially acceptable prices for end consumers;
- the ability to create a **sufficiently predictable environment to allow for efficient investment** decisions from market participants; and
- the ability to **deliver on the green transition**, which will require massive amounts of new investments into power system infrastructure.

Based on our analysis, we concluded that adapting the current hybrid system could be the most promising approach, rather than aiming for a complete overhaul of the market rules. A completely deregulated approach seems out of question at this point, as free markets rely on a high level of confidence on the investors' side that market prices are allowed to play out freely. A fully regulated approach, however, would take several years to implement and would threaten investor confidence in the meantime, likely leading to a drastic reduction in investment in a time which requires high levels of investment to achieve the EU's decarbonisation targets. The hybrid market could, however, be supplemented by elements which increase price resilience in times of fuel price shocks or other crises and improve the investment in low carbon technologies.

This can be achieved by **(1) switching to two-sided CfDs in renewable auctions** and **(2) improving the auction mechanisms by which these contracts are awarded**, including locational information in the auction system. Two sided CfDs will generate income streams in times with high prices, which, in turn, can be used to relieve customers by lowering their energy bills. As the share of energy in the system will increase, which will mainly be remunerated through a CfD – and therefore much less exposed to market dynamics – this warrants that the states select better which projects are rewarded with a remuneration contract. Auctions should be developed to cover a larger geographical area, and to consider the local grid infrastructure. Ideally, projects are then selected based on system benefit, rather than selecting only the lowest bids, regardless of their location and their temporal correlation with demand.

Implementing these policies will increase the price resilience of European power markets, while achieving investment security for those technologies which are most needed to make the European Green Deal a success story – which are renewables. By improving the auction process, we can further maximize the benefits to consumers and the environment, by placing renewables in those locations where they are needed the most and reap the highest benefits.

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List of abbreviations and definitions

ACER	European Union Agency for the Cooperation of Energy Regulators
CCGT	Combined-cycle gas turbine
CEER	Council of European Energy Regulators
CfD	Contract for difference
DR	Demand response
E.DSO	European Distribution System Operators
EENS	Expected energy not served
ENTSO-E	European Network of Transmission System Operators for Electricity
EOM	Energy-only market
ETS	Emission trading system
EU	European Union
EUR	Euro
FiT	Feed-in tariff
IEA	International Energy Agency
LCOE	Levelised cost of electricity
LOLE	Loss-of-load expectation
MWh	Megawatt-hour
RCC	Regional cooperation centre
US	United States
VOLL	Value of lost load

List of figures

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