Steering Electricity Markets Towards a Rapid Decarbonisation

Executive summary

International Energy Agency

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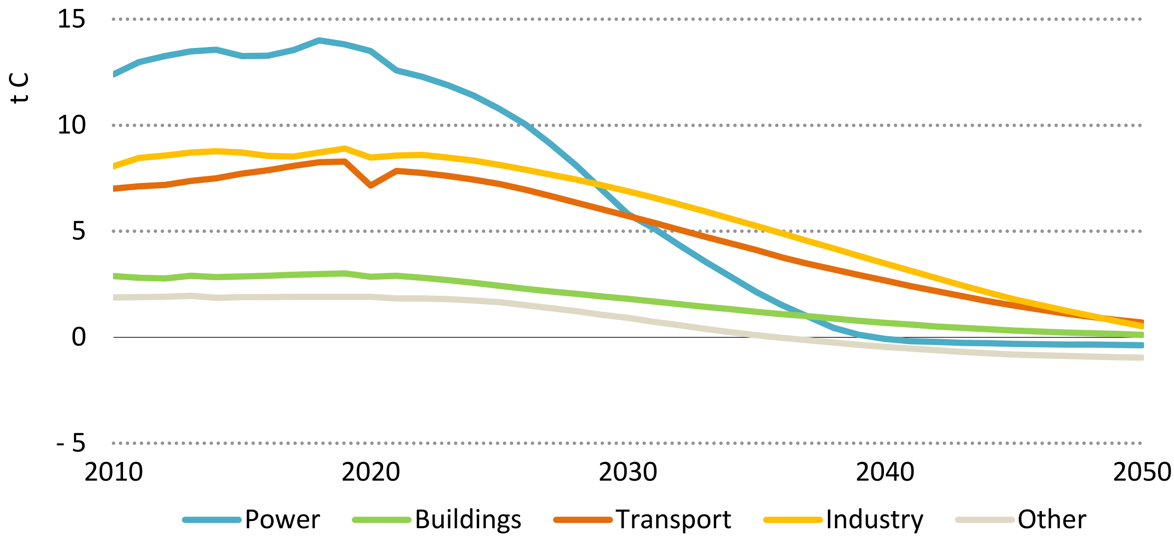
Electricity plays a vital role in achieving net zero emissions by 2050

The electricity sector has grown to be one of the most important sources of energy. In 2020, global electricity demand was 23 230 TWh, 20% of total final energy consumption and its generation produced 40% of total energy-related CO2 emissions globally, making it the single largest source of such emissions.

By 2050, as sectors that currently rely on fossil fuels become electrified, demand is expected to more than double to 60 000 TWh. In light of stated global climate change goals, decarbonising the electricity sector is central to achieving net zero emissions by 2050.

In the IEA's Net Zero Emissions by 2050 scenario, emissions from electricity generation fall to zero (in aggregate) in advanced economies in the 2030s, with emerging market and developing economies achieving this goal around 2040. Making this scenario a reality requires accelerated decarbonisation of the sector.

Total CO2 emissions per sector, Net Zero Emissions by 2050 Scenario, 2010-2050

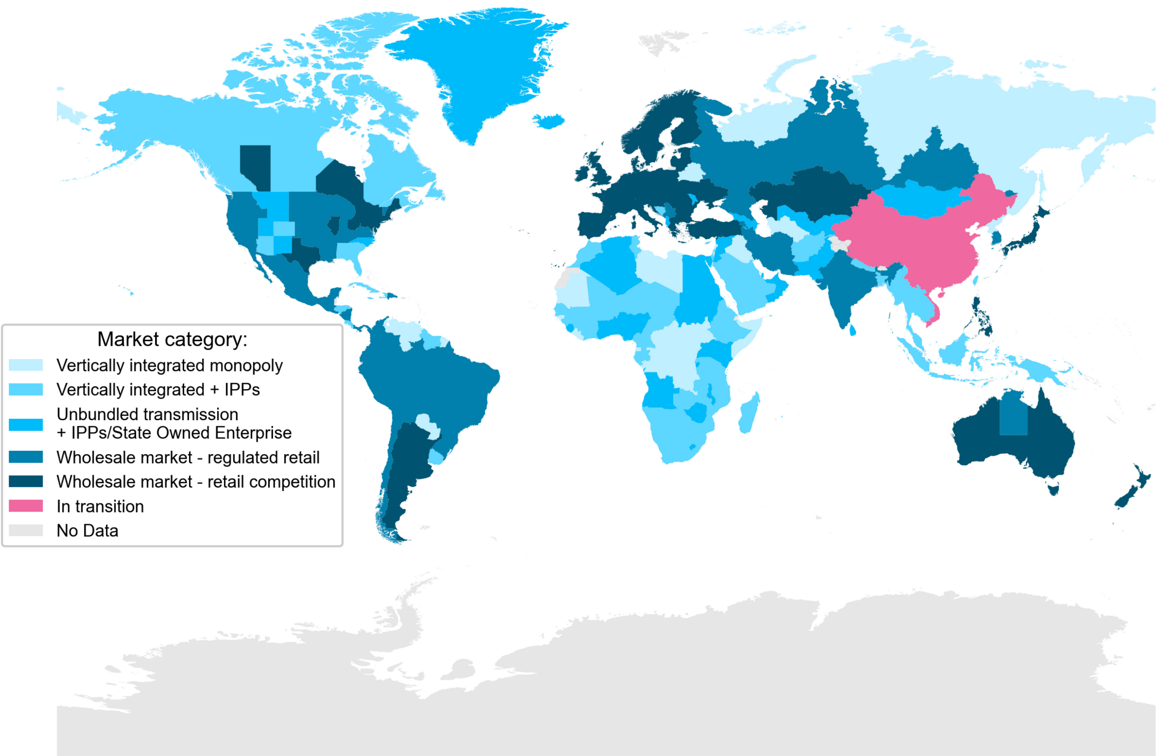


Expansion of generation from renewables is expected to contribute the most to decarbonisation of electricity, output from these sources almost tripling by 2030 and growing eightfold by 2050 – driven mostly by significant deployment of variable renewable energy (VRE) such as solar photovoltaics (PV) and wind. Other low-carbon generation (such as nuclear and hydrogen) and flexibility-providing technologies (e.g., battery storage systems and demand response) will also play lead roles in the path towards net zero emissions.

Electricity markets are central to decarbonising the sector

At present, around 50% of electricity in the world is generated in power systems relying on liberalised markets; this will increase to approximately 76% once China completes implementing power markets. As such, much of the accelerated decarbonisation will have to be stimulated in the short and medium term in systems that rely on electricity markets to minimise operation costs and – to varying degrees – to attract investments.

Status of electricity markets around the world in 2022



Market forces can support decarbonisation of the power sector when guided and complemented by the implementation of policies designed to match net zero ambition, including effective investment frameworks, carbon pricing and other decarbonisation instruments.

As in any other market, a socially optimal equilibrium can only be achieved if all participants are made responsible for all costs and benefits arising from their actions. This is the mechanism by which markets can provide price signals that function as incentives (or disincentives) to guide the decisions of market actors. In the context of decarbonisation, such price signals are not yet optimally aligned. In most power systems in the world, whether co-ordinated by electricity markets or by vertically integrated utilities, externalities due to CO2 emissions are not completely included as part of power sector costs.

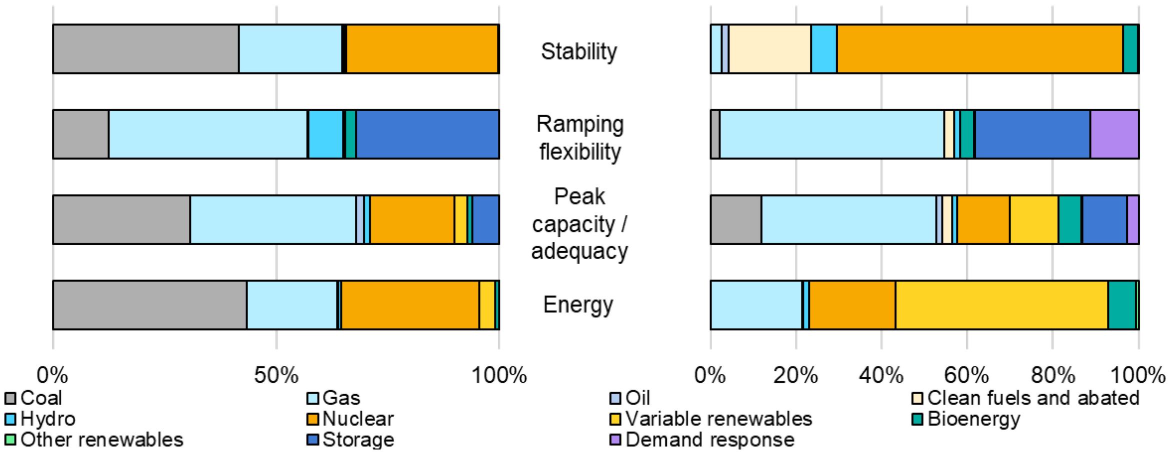
This creates substantially distorted price signals that make investments in and operation of carbon-intensive technologies more profitable than they should be, and do not properly recognise the value of low-carbon technologies.

Market design needs to be able to adapt to changing landscapes

Over the past several decades, liberalisation of electricity markets has been used as a mechanism to ensure efficient dispatching of resources in line with demand and to obtain benefits from competition in system operation and investment. Since the creation of the first liberalised electricity market – in 1982 in Chile – the design of markets has continuously evolved and matured. This does not mean electricity market design has been solved or that any solution could be static in nature. Ongoing changes in policy and technology require that markets be designed to adapt to new landscapes. This is particularly true in the context of short- and medium-term acceleration of decarbonisation of the electricity sector.

Procurement of system services is an example of this change. As electricity systems transition away from fossil fuel generation to higher shares of VRE, ensuring secure system operation will need to be based on a different configuration of different components. The fundamental services of energy, flexibility, peak capacity and stability will have to be procured to sufficient levels by using all available technologies. In turn, the assets needed and their respective value to systems will evolve. VRE for instance, can provide substantial volumes of clean, low-cost energy but contributes much less to firm capacity. In contrast, despite not providing a net-positive energy contribution, energy storage can contribute to ramping flexibility and adequacy.

Power system services in highly decarbonised scenarios, Korea Announced Pledges Scenario, 2020 and 2035



Note: Stability is represented by system inertia.

Experience shows how electricity market design can be changed to help decarbonisation

Although there is no perfect market, several experiences indicate the main elements of market design that can bring the power sector on track to achieve net zero emissions.

- Re-design of short-term wholesale markets to integrate large shares of VRE and open opportunities for modern technologies to provide flexibility.
- Creation or re-design of investment frameworks and policy instruments to enable deploying larger amounts of low-carbon electricity generation and to enable new technologies to participate in the markets.
- Introduction of carbon pricing to correct distortions due to the lack of recognition of the costs created by greenhouse gas (GHG) externalities. In most systems, this signal is still very low compared to estimates of the actual social costs created by GHGs.
- Strengthen adequacy mechanisms, providing incentives to all resources capable of delivering energy in times of distress of the system

This report collects evidence from electricity markets around the world to identify several innovations in market design and investment frameworks that provide policy makers with immediate actionable ideas to support a transition to a flexible, decarbonised and affordable power sector. It also draws attention to approaches that synergise with decarbonisation in other sectors. These experiences represent examples of one or more of the previously mentioned fundamental elements.

Individually and collectively, they provide powerful tools that will hopefully empower policy makers to match pledges with actions.

Provided that all governments strengthen their energy and climate policies to meet climate ambitions, electricity markets could function as a tool to significantly support decarbonisation pathways, particularly when synergised with a broader portfolio of policies and regulations.

Market design will need to keep evolving and to be revised to stay on the path towards net zero emissions by 2050. We hope that the experiences presented here will serve as the building blocks for rapid decarbonisation of electricity systems.

Short-term wholesale market design is first step towards establishing efficient price signals

Wholesale markets enable the trading of energy between market players at different time scales; as such, they are the cornerstone of successful market design. Well-designed, short-term wholesale markets are fundamental to being able to leverage the advantages of competition in electricity production and consumption while synergising with and supporting accelerated decarbonisation of the sector.

Establishing efficient price signals can provide incentives to market actors to align their decisions with the needs of the system. The overarching aim is to ensure that price signals represent the reality of the system and that they reward services that provide value to it. These price signals are essential to highlight the needs of the system. Examples of particular value to system decarbonisation include generation at times of high demand, lower carbon emissions and flexibility to modify levels of generation or consumption in response to system needs. As technology evolves and the needs of the system change, it is necessary to adapt the design of the wholesale market to ensure that price signals continue to correctly represent the needs of the system and reward the value provided by different assets.

Wholesale markets should be designed such that price signals ensure improved representation of the time and geographical value of energy. This can be achieved through increased time resolution, moving gate closure times closer to the hour of delivery, and applying a market model that correctly represents the underlying physical infrastructure. Additionally, to ensure efficient system operation, it is important to make sure long-term contracts support risk hedging and investments, but do not impede optimal dispatch on short-term wholesale markets.

Embedding decarbonisation instruments in competitive markets

Among decarbonisation technologies, wind and solar PV have become the most cost competitive. Current electricity markets and regulations, however, have not managed to stimulate sufficient investment. To accelerate deployment of low-carbon electricity, it is necessary to close the investment gap by reflecting the cost of negative externalities and introducing additional decarbonisation mechanisms that are compatible with both wholesale market signals and other policy instruments.

Several decarbonisation instruments facilitate integration with competitive wholesale market revenues while reducing the overall cost burden that gets passed on to consumers. To implement these decarbonisation mechanisms correctly and efficiently, market design needs to balance providing revenue certainty through long-term signals while encouraging efficient integration in day-to-day power system operations.

In the coming years, as VRE comes to account for the majority share in generation, it will be important to introduce market-based instruments to ensure sufficient investment in dispatchable low-carbon assets. To achieve this, policy makers will need to introduce instruments that reward the provision of services such as flexibility and adequacy while maintaining the efficiency of the wholesale market.

Maximising the value of distributed energy resources requires changing current market structures

The diversification and accelerated deployment of distributed energy resources (DER) worldwide is shifting electricity systems. The past model of centralised, large generators connected to transmission networks with little demand-side control is no longer reflective of how modern systems function. The emergence of decentralised systems, with many distributed resources that are smaller and interconnected, allows both end-use devices (e.g., appliances) and consumers to have more active roles.

If deployed efficiently, DER offer large potential to support the integration of VRE, increase system resilience and reduce the need for grid upgrade. In addition to providing demand-side response, some DER assets can supply ancillary services as sources of flexibility, black start services and non-wire alternatives. To maximise the benefits of DER, it is necessary to adapt markets to reward their true value. Indeed, under current market structures in which system operators often lack visibility of DER, its deployment can create issues and incentivise inefficient behaviours by asset operators, particularly considering the increased electrification that results in higher peak loads and congestions of distribution grids.

Ensuring electricity markets are ready to let DER play their role is therefore highly recommended. To make DER visible to system operators, digitalisation should be encouraged. This implies deployment of connected appliances and smart metering infrastructure, supported by effective data exchange structures and appropriate data privacy measures. Digital infrastructure will facilitate the design of electricity tariffs that reflect the locational and time-variant value of electricity and ensure a fair repartition of grid costs, thereby ensuring optimal use of DER. In addition, policy makers should review connection schemes and participation rules and acknowledge the role of aggregators while facilitating their involvement. Lastly, co-operation protocols among stakeholders (particularly transmission and distribution system operators [TSOs and DSOs]) and grid operation processes have to be adapted to the DER-induced shift from the transmission to the distribution system.

Market design must recognise the unique role of storage to leverage its advantages

Cost reductions in energy storage technologies, especially battery storage, have resulted in increased uptake in various domains of the power system. To support its further deployment and ensure the system value of storage is maximised to support decarbonisation, market design changes must consider its unique role and technological advantages.

Storage is unique in its ability to provide flexibility through both load and generation, across a broad range of timescales. As it cannot decarbonise the power system on its own, storage must be part of a package of measures that aims to align market incentives and the generation mix towards decarbonisation to avoid worse emissions outcomes. Taxation and network tariffs must also be adapted to appropriately recognise its role as a flexibility provider, ensuring it is not charged twice as a consumer and as a generator. Finally, specifications for market participation must evolve away from the properties of conventional technologies towards technologically neutral ones that use (and appropriately remunerate) the system services of storage.

Design changes to reward technological advantages of storage could focus on fast response time and geographic flexibility. Remunerating fast response could be achieved through shorter time periods or new markets focusing on fast frequency regulation. Remunerating geographic flexibility could be achieved through more granular locational signals or new markets for localised system services.

Ensuring system adequacy requires additional measures

Policy makers have the duty to set the desired reliability standard for electricity systems and ensure mechanisms are in place to meet it. If they do not properly value all system services, wholesale markets may not sufficiently provide incentives for the assets needed for secure system operation. Even if restrictions on prices (e.g., price caps) were relaxed in the wholesale market, if the quantity of reserves that needs to be procured is not properly valued, the problem of “missing money” arises and can result in underinvestment.

Three policy instruments can help solve the missing money problem: energy price adders, capacity-based payments and regulated procurement. These instruments can be used in combination – use of one does not exclude use of the others. Energy price adders embed the cost of procuring reserves into the wholesale market by allowing prices to exceed variable costs during periods of reserves shortages (which indicate system stress). Rewarding capacity that directly contributes to security in these periods creates incentive for investment in the types of capacity that can be available when actually needed. Capacity payments directly reward capacity through a long-term payment for their availability, providing a predictable stream of revenue that can encourage some capacity to enter or remain in the market. These payments also effectively reduce the volatility that can occur when energy markets do become stressed. It is important that these payments be designed to ensure performance of the asset when needed. Regulated procurement, under which utilities are mandated to contract in advance enough energy to supply a share of their forecasted demand, can also play a significant role in supporting capacity adequacy by providing longer term incentives.

Retail markets need to encourage efficient behaviour while protecting consumers

Well-functioning retail markets are crucial to ensure that the benefits of liberalised wholesale markets are passed on to final consumers. Given that most retail customers prefer not to interact directly with the price of energy in their daily consumption, retailers serve a critical function in the power sector – i.e., managing and allocating risk on behalf of their clients. New developments are changing the types of risks that retailers face in power markets. Recent events, including the spike in the price of natural gas (which sets the electricity price in many markets), and extreme weather events are leaving consumers and retailers alike exposed to the resulting high prices of electricity.

Retail markets can serve the desire to reduce system costs while also protecting consumers. Innovative tariffs, such as capacity subscriptions, can protect the truly critical portion of a customer's consumption while also leveraging technologies to manage demand during times of stress. These measures can be almost imperceptible to customer comfort, such as smart charging of electric vehicles or activation of appliances. But customers who prefer to completely avoid being exposed to market fluctuations should be able to choose fixed tariffs from financially stable suppliers for this service.

System planning lays the foundation for power markets

Transforming electricity systems is key to a clean energy transition. To meet stated climate goals, systems will need more grids, along with more and better integrated low-carbon resources (including demand-side participation). Developing a vision that sets out clear objectives, provides a realistic view of how systems may evolve and sets a plan for deploying the assets needed to meet the policy objectives is helpful to framing the role of markets. Power sector planning provides information on system needs in the long term and, as such, serves as a guide for competitive investments. Planning also supports policy making as it helps identify necessary enhancements to market design.

Planning is a complex process that requires taking account of a large number of uncertainties; the longer the time horizon, the number and scope of uncertainties tends to increase. Traditional practices were centralised and highly technical; new approaches have evolved to engage (early and often) a wide range of stakeholders in the mission of designing the future system.

Integrated and co-ordinated planning (an emerging practice that must not be confused with central planning) is a collaborative framework bringing together the strengths and information from many stakeholders within the power sector and from other sectors to feed into the plan. It helps ensure robustness in planning and stability in the rules over the long term, thereby supporting decarbonisation of the power system. Key features of effective integrated planning are to consider the power system as a whole (including integration with other sectors); to incentivise all solutions that contribute to policy goals; to be transparent and engage stakeholders; and to aim for robustness with respect to a broad range of futures and uncertainties (including, for example, extreme weather events).

Finally, mechanisms should exist to ensure formalised feedback between planning, policy making and market design (with a clear process for adapting rules over time) so that planning supports increasing ambitions for decarbonisation.

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