Briefing

November 2016

European Parliament

Understanding electricity markets in the EU

SUMMARY

The European electricity system is undergoing big changes at present. The transition towards a low-carbon economy means a growing role for renewable energy sources, greater energy efficiency and the electrification of transport and other sectors. It also involves giving consumers a more meaningful role, allowing them to manage their demand actively, produce electricity for self-consumption and feed the excess into the grid. In this context, electricity markets, regulations and technical infrastructures need to be adapted to a world in which large utilities no longer dominate the market. Furthermore, markets need to be redesigned in such a way as to encourage investment in low-carbon technologies, while at the same time safeguarding security of supply and keeping costs for households and industry under control.

This briefing gives an overview of the functioning of the electricity grids and the main features of the EU electricity markets. It aims to provide background information for the ongoing debate about a new electricity market design, which the European Commission is expected to propose by the end of 2016. A European Parliament resolution of September 2016 gives a clear position on various aspects of this design.

In this briefing:

- Trends in electricity supply
- The electricity system
- EU energy market legislation
- Electricity markets in the EU
- Challenges in grid development and market design
- Position of the European Parliament
- Main references

EPRS | European Parliamentary Research Service

Author: Gregor Erbach

Members' Research Service

PE 593.519

EN

Trends in electricity supply

The EU is in the process of transforming its economy with the aim of minimising the emission of greenhouse gases (GHG).[1] Electricity is expected to play a key role in this low-carbon transformation. First, more efficient electricity use and a growing share of electricity from renewable sources will help reduce GHG emissions from electricity generation. Second, the share of electricity in total energy use is expected to grow, especially in the transport sector (electric vehicles) and in heating and cooling (electric heat pumps). Such widespread electrification, in combination with low-carbon electricity production, is seen as a key ingredient for phasing out GHG emissions from fossil fuels by the second half of this century.

Making all of these changes happen requires significant investments in electricity generation, transport and distribution, and in electrical consumer goods. The challenge is how to enable these investments while keeping electricity affordable for both households and energy-intensive industries. Moreover, investments and innovation are needed in order to ensure the stability of the electricity supply in the face of higher demand and an increasingly variable supply from renewable sources that depends on sunlight, wind and rainfall.

Electricity markets need to be remodelled in such a way that would ensure their support for the EU's policy objectives, by:

- encouraging investments in flexible low-carbon electricity generation;
- encouraging investments in a stable and adaptable grid that is fit for a growing share of renewables and for new uses of electricity;
- incentivising the use of energy-efficient equipment and consumer goods;
- providing affordable energy for industry and households.

This briefing offers background information on the current discussions about electricity market design, for which the European Commission is preparing a legislative proposal. It explains how the electric grid works, which players are involved and how electricity markets are organised. It furthermore provides an overview of the principal trends and challenges facing electricity markets over the coming years.

The electricity system

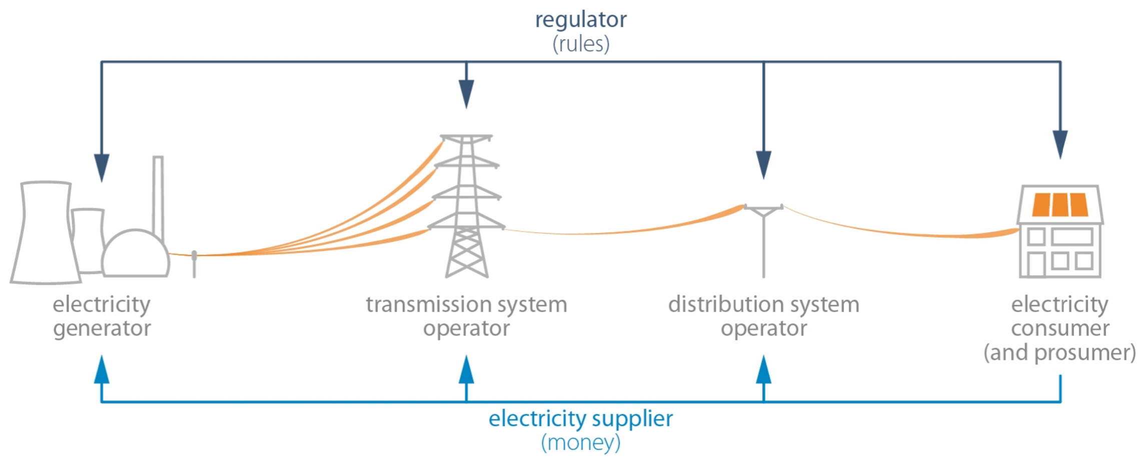
The electricity system consists of the physical infrastructure for electricity generation, transport and use on the one hand, and an organised electricity market on the other (see Figure 1).

The physical grid, that is, the flow of electricity, consists of electricity **generators** and electricity-transport systems, which are usually subdivided into systems for **transmission** over long distances and systems for **distribution** to residential and industrial **consumers** of electricity.

The electricity market, that is the flow of money, consists of:

- electricity suppliers, who buy electricity from generators and sell it to consumers;
- consumers, who use electricity and pay suppliers via their bills;
- transmission system operators (TSO), who are paid for the long-distance transport of electricity and for ensuring system stability;
- distribution network operators (DSO), who are paid for delivering electricity to consumers; and
- regulators, who set rules and oversee the functioning of the market.

Figure 1 – Schematic overview of the electricity system



Graphic by EPRS.

The electric grid

The electric grid (which the US National Academy of Engineering considers the greatest engineering achievement of the 20th century) is a network connecting electricity generators and consumers via the transmission and distribution networks.

The electric grid has two fundamental technical properties, which also have an impact on electricity markets:

- Supply and demand of electricity in the grid must always be balanced, otherwise failures (blackouts) will occur.
- The flow of electricity in the grid cannot be controlled. It simply follows the path of least resistance, so that consumers receive electricity from mixed sources.

Electricity generators

Electricity generators[2] come in various sizes, starting from rooftop solar panels or small waterwheels (with a generation capacity starting from around 1 kW) to large hydro-electric dams, nuclear or coal power stations (with capacities of several gigawatts).

A **watt (W)** is a unit of power. Running an energy-efficient light bulb takes about 5 watts; a kettle uses about 2 000 watts (2 kilowatts, kW); and an aluminium smelter can use more than a billion watts (gigawatt, GW). A medium-sized power station produces a gigawatt of power.

A **watt-hour (Wh)** is a unit of energy (**power**[3] over time). A watt-hour could be one watt for one hour or 20 watts for 3 minutes. The average EU household uses 10 kilowatt-hours (10 000 watt-hours) per day.

A **volt (V)** is a unit of electric tension, roughly comparable to the pressure of water. In Europe, electricity is delivered to households at 220 V; higher voltages (up to 1 million volts) are used for transporting electricity over long distances.

Generators are rated by their generation capacity, that is, the maximum power they can produce. **Firm-capacity** generators can be switched on or off on demand (see Table 1 for examples). **Variable-capacity** generators are dependent on factors like wind or sunshine and are therefore only able to generate certain amounts at certain times.[4]

Generators also differ with respect to the flexibility with which they can be operated. Some generation technologies, such as nuclear, are well-suited for producing a stable amount of electricity over longer periods, while others can change production more rapidly to adapt to fluctuations in electricity demand and in production from variable sources. Hydro-power is the most flexible (only a few seconds to switch on or off); gas and (to a lesser extent) coal offer some flexibility (minutes to hours, depending on technology and operation); while nuclear is the least flexible form of generation technology.

Coal and natural-gas generators use **fossil fuels** – the remains of living organisms which have been subjected to geological processes over millions of years. Fossil and nuclear fuels are non-renewable: their reserves are expected to last tens to hundreds of years. By contrast, renewable energy sources are available year after year over a very long time.

The burning of fossil fuels and biomass (such as trees) for energy releases carbon dioxide (CO_2), while the growth of biomass removes CO_2 from the atmosphere. Nuclear and renewable energy sources are considered low-carbon energy sources.

In 2013, total electricity generation in the EU-28 amounted to 3.1 billion kWh, corresponding to an average power of 700 watts per capita.

Table 1 – Characteristics of the main energy-generation technologies

<table>
<tr><th>Type</th><th>firm / variable</th><th>type of fuel</th><th>flexibility</th><th>low-carbon</th><th>CO_2 emissions[5] (kg per kWh)</th></tr>
<tr><td>coal</td><td>firm</td><td>fossil</td><td>medium</td><td>no</td><td>0.95</td></tr>
<tr><td>natural gas</td><td>firm</td><td>fossil</td><td>high</td><td>no</td><td>0.55</td></tr>
<tr><td>biomass</td><td>firm</td><td>renewable</td><td>medium</td><td colspan="2">yes; regrowth of biomass compensates emissions</td></tr>
<tr><td>nuclear</td><td>firm</td><td>nuclear</td><td>low</td><td colspan="2" rowspan="5">considered as zero-emission energy sources</td></tr>
<tr><td>hydro with dam</td><td>firm</td><td>renewable</td><td>very high</td></tr>
<tr><td>solar</td><td>variable</td><td>renewable</td><td>very low</td></tr>
<tr><td>wind</td><td>variable</td><td>renewable</td><td>very low</td></tr>
<tr><td>geothermal</td><td>firm</td><td>renewable</td><td>high</td></tr>
</table>

Transmission networks

Transmission networks are networked grids of long-distance power lines. High voltages, between 220 kV and 1 000 kV, are used for reducing transmission losses. Traditionally, transmission networks use alternating current (AC), but high-voltage direct current (HVDC) is emerging as an effective alternative.[6] The European transmission grid contains more than 300 000 km of power lines, including 355 cross-border lines.

Transmission networks are run by **transmission-system operators** (TSO). At European level, these are organised in the European Network of Transmission System Operators (ENTSO-E), which draws up 10-year network development plans and participates in the development of network codes (rules for operating the network).

Transmission grids are operated on a sub-national or national level. There are **interconnections** between grids and across national borders to balance supply and demand.

Distribution networks

Distribution networks take electricity from the transmission networks and distribute it to consumers.[7] Distribution networks are managed by **distribution-system operators** (DSO), who connect consumers, install electricity meters and communicate the consumption to the energy suppliers. Electricity from smaller renewable sources, such as solar and wind, is generally fed into the distribution network.

Balancing supply and demand

The electricity supply must be equal to the electricity demand at all times, otherwise the system risks breaking down.[8] Traditionally, non-flexible generators are used for serving the base load (the normal level of electricity use), while flexible generators are used for meeting peaks in demand. The increased share of variable capacity, such as wind and solar, means that more flexible generation capacity is needed to satisfy demand when production from variable generators is low.

To ensure security of electricity supply, enough generation capacity must be available to meet demand at all times.[9] Balancing supply and demand in the short term is done with the use of primary reserves (activated within seconds), secondary reserves (activated within a few minutes) and tertiary reserves (activated within 15 minutes).

However, energy companies may be reluctant to keep in reserve power plants that are only used in cases of peak demand (see section on capacity markets below). Moreover, variable renewable generators, which have priority on the European grid, are producing increasingly often enough electricity to serve most or all of the demand, thus making it more and more difficult for conventional electricity generators to earn money with plants that operate only some of the time.

Demand response – an alternative approach to matching electricity supply and demand – involves reducing electricity demand in times of scarcity. This is dependent on electricity markets that incentivise flexible demand by time-variant pricing (also known as scarcity pricing), and on infrastructure, such as smart grids and smart meters.

Balancing injections (supply) and offtakes (demand) of electricity from/to the grid, normally over quarter-hour periods, is the responsibility of **balance responsible parties** (BRP). Shorter-term fluctuations are managed by the TSO, who will ask operators to increase generation or reduce demand. The TSO will pay for these **ancillary services** and charge the BRP responsible for the imbalance.

Energy storage

Storing energy is another means of balancing supply and demand. In times of low demand and/or high supply, energy is fed into storage, from which it is released at times of high demand and/or low supply. However, storage is expensive and losses of energy occur in the process.

> The adoption of electric vehicles could have significant effects on electricity markets. First of all, moving from fossil fuels to electricity will increase electricity demand. If many users charge their vehicles at the same time, more peaks in demand can be expected. On the other hand, 'smart' electric vehicles may provide storage services to the electricity grid by charging up when electricity is abundant and feeding electricity back into the grid when it is scarce and expensive.

The most common type of energy storage on the electric grid is pumped storage, where excess electricity is used for pumping water from a lower to a higher reservoir (for instance, to a lake on a hilltop), and energy is generated by letting the water flow downhill, driving the turbine of an electric generator on its way.[10] Battery storage is another emerging option; although still expensive, this technology is developing rapidly and costs are falling as companies like Tesla scale up production.

EU energy market legislation

Thanks to EU energy legislation adopted over the years, EU electricity markets have undergone major changes, involving shifting away from a regulated environment dominated by a few quasi-monopolistic companies, to one that is increasingly competitive. EU energy legislation is based on a 'target design model', where the ultimate goal is the achievement of an increasingly interconnected European electricity market with convergent prices across the EU.

A liberalised internal energy market for gas and electricity has been established through three legislative packages[11] adopted in the 1990s, in 2003 and in 2009. It is founded on the unbundling of supply, generation and networks; on providing market access to third parties; and on ensuring competition on wholesale and retail markets. Other aspects include the obligation to provide a universal service to all households and mechanisms for regulatory oversight, in particular through cooperation amongst energy regulators and the creation of the Agency for Cooperation of Energy Regulators (ACER). The EU internal energy market is still not fully completed by the Member States, as noted in the European Commission's State of the Energy Union 2015 report.

The Renewable Energy Directive obliges Member States to open their power grids to energy from renewable sources and to even give them priority. Other electricity-related EU legislation concerns energy market regulation, security of electricity supply, trans-European networks and the EU emissions trading system. EU competition policy (state aid rules in particular) and tax policies are other important policy areas.

Electricity markets in the EU

Markets by geography, time scale and type of customer

European electricity markets operate on various levels. Wholesale markets are organised differently than retail markets, which cater to consumers. Markets may vary in geographical scope, ranging from local offers on the retail market to transnational wholesale markets. Based on their time scale, wholesale markets range from real-time balancing markets to long-term contracts.

In a liberalised market, different entities are responsible for generating electricity, as well as for operating the transmission system (**transmission system operators**, TSO) and the distribution system (**distribution system operators**, DSO). They are required to provide third-party access to their networks.

The retail market

The actors in the retail market are suppliers, who offer electricity contracts approved by the competent regulator, and consumers, who have the right to choose their supplier. Suppliers buy electricity from generators and sell it to consumers. Suppliers send invoices featuring the price charged for the electrical energy delivered,[12] transmission and distribution, as well as taxes and levies that are sometimes used to support production of renewable energies, protect more vulnerable consumers, or promote other policy objectives. Suppliers differentiate their offers based on price or on the origin of the electricity.[13]

Electricity prices for industrial consumers are generally lower than those for households. Energy-intensive industries often benefit from very competitive prices and may be partially exempted from charges and levies.

The wholesale market

The participants in the wholesale market are generators, electricity suppliers and large industrial consumers.

As noted above, electricity differs from most other goods in that it must be produced at the moment when it is needed, because it cannot be stored easily. Therefore, most electricity transactions involve the delivery of electricity at some point in the future. Depending on the type of contract or market, transactions may cover different periods of time:

- long-term contracts: up to 20 years or more;
- on the forward and future markets: weeks to years in advance;
- on the day-ahead market: the following day;
- on the intra-day market: delivery within a specified time period (for instance, an hour or a quarter);
- on the balancing market: real-time balancing of supply and demand.

Electricity can be traded privately between two parties, as happens in the over-the-counter market. It may also be traded through an **energy exchange**, which brings together more buyers and sellers and offers transparent pricing. Prices on the energy exchange vary with supply and demand: on the wholesale market, they can go beyond €80/MWh in cases of peak demand, or drop to zero or even below[14] in cases of excess supply.

Whenever there is a need to generate electricity, generators are **dispatched** in an order ranging from the lowest to the highest price (**merit order**). They all receive the price demanded by the generator whose offer would satisfy the marginal demand. The application of this principle has led to the 'merit order effect', whereby European wholesale prices fall as a result of the fact that variable generators (wind, hydro and solar) have no fuel costs and can thus offer low prices that determine the price levels for the other generators.

Wholesale markets are integrated on a transnational regional level, as in the case of the central west European region (known as 'market coupling'). Flow-based capacity allocation helps optimise the use of interconnection capacities between grids. In case of sufficient interconnection capacity, prices across the market will converge. When the demand for cross-border trading exceeds the interconnection capacity ('congestion'), electricity cannot flow from a lower to a higher-price area, as a result of which the regions may experience different prices.

Promotion of energy efficiency and renewable energy sources

To achieve EU and national targets, Member States apply various approaches for promoting renewable energy sources. The most common support mechanisms for renewable electricity have been feed-in tariffs and feed-in premiums, but competitive auctions are becoming more and more common. Member States aim to design support schemes that would enable them to encourage the roll-out of new technologies, while phasing out support for mature technologies that are cost-competitive on the market.

Regulators

The rules for the operation of electricity markets are set by independent national regulators. At EU level, the Agency for the Cooperation of Energy Regulators (ACER) defines the guidelines for transnational electricity networks and markets, the so-called network codes. These are then further developed by ENTSO-E and approved by Member States' representatives through the comitology procedure.

Capacity mechanisms

Capacity remuneration mechanisms, which have been introduced in an increasing number of Member States, involve payments to electricity generators to keep generation capacity (power plants) in reserve, in order to ensure the stability of the electrical system in case of demand peaks. Depending on the organisation of an electricity market, such capacity payments may be needed to ensure that the provision of reserve generation capacity is economically viable.

There is a debate as to whether capacity markets are necessary or whether an energy-only market with time-variant pricing can provide sufficient incentives for the provision of spare capacity. Another issue is the optimal geographic scope of capacity markets. Cooperation between Member States may increase the efficiency as spare capacity is pooled. An EU-wide capacity mechanism is not feasible as long as only limited amounts of electricity can flow across borders, due to limited interconnection capacities.

The Commission assesses the impact of national capacity mechanisms on competition in the electricity market under state aid rules. It has launched a sector inquiry into national capacity mechanisms and expects to publish its report in late 2016.

Challenges in grid development and market design

The following major trends have an impact on European electricity markets:

- Further electrification of the economy (for instance, electric vehicles in the transport sector and heat pumps in the heating sector) leads to rising electricity demand.
- The share of distributed and variable renewables (solar, wind) is increasing and should increase even more in order to reduce CO_2 emissions from electricity generation. As a consequence, increased transmission capacity is needed to transport electricity from generators to consumers.
- Energy service companies and aggregators (who bundle electricity supply from small generators) can bring innovative business models to electricity markets.
- Support for renewable energy sources has contributed to price increases for households, but at the same time generation from variable sources can lead to very low (even negative) prices in the wholesale market.
- The number of 'prosumers', that is, entities which produce and consume electricity, is growing. Increased self-consumption also means that less electricity is consumed from the grid, resulting in decreased revenues for grid operators, which makes it difficult for them to finance investments. As a consequence, consumers who do not generate their own electricity may face higher network charges.
- As investment in flexible generation capacity is often unprofitable, some Member States have introduced national capacity remuneration mechanisms as a counteractive measure.
- Technological developments, such as smart meters (which enable time-variant pricing), smart appliances and smart grids, electricity storage, electric vehicles and digitalisation, can enable innovation in electricity markets.
- Time-variant electricity pricing ('scarcity pricing') could give consumers an incentive to use less electricity (or even release electricity from storage) at times of peak demand, and to use or store electricity when supply from variable sources is abundant.
- There is a need for building new infrastructure to improve electricity transmission within Member States and interconnections between them, but obtaining authorisation and financing for new infrastructure can face different obstacles.

In order to address these challenges, from July to October 2015 the Commission held a public consultation on energy market design, focussed on the electricity market and the need to integrate a growing share of variable renewables in it. EU energy ministers informally discussed energy markets in April 2016, and the Council presidency issued a statement in May 2016. The Commission's legislative proposal is expected towards the end of 2016.

Position of the European Parliament

Parliament's resolution of 13 September 2016, Towards a new energy market design, addresses the issues raised in the consultation document. It notes that the task of integrating a growing share of renewables and prosumers into the electricity markets, but also of improving the mobilisation of demand response and storage, requires a combination of liquid short-term markets and long-term price signals. It calls for time-varying prices that reflect the scarcity or surplus of supply and provide incentives for storage and demand response, complemented by instruments aimed at mitigating revenue risk over 20-30 years, such as a market for long-term contracts and a regulatory framework for prosumers (self-production and local energy storage). In this respect, the resolution highlights the role of DSOs. The new energy-market design should provide technical and market conditions for energy storage, including the introduction of smart grids and smart meters, as well as digital technologies. Renewables should be integrated into the market and should participate in balancing services, while support for mature renewables should be phased out. Market-based cross-border capacity mechanisms should only be allowed under certain conditions. The resolution emphasises the importance of regional cooperation and calls for ACER to be given additional competences.

In recent years, Parliament has adopted several resolutions related to energy markets: on making the internal energy market work (10 September 2013), on the energy union, on interconnection targets (15 December 2015), on delivering a new deal for energy consumers (26 May 2016), and on the renewable energy progress report (23 June 2016). To some extent all have addressed issues relating to electricity market design.

Main references

Capacity mechanisms in the EU energy markets: law, policy, and economics, Leigh Hancher et al. (eds.), Oxford University Press, 2015.

Electrical energy generation in Europe: the current situation and perspectives in the use of renewable energy sources and nuclear power for regional electricity generation, Jorge Morales Pedraza, Springer, 2015.

Electric networks and energy transition in Europe, Michel Cruciani, Ifri, September 2015.

EU electricity trade law: the legal tools of electricity producers in the internal electricity market, Petri Mäntysaari, Springer, 2015.

Energy technology perspectives 2016, International Energy Agency, June 2016.

Energy Union: key decisions for the realisation of a fully integrated energy market, European Parliament, DG IPOL, April 2016.

Promotion of renewable energy sources in the EU: EU policies and Member State approaches, European Parliament Research Service, June 2016.

Renewable energy integration in power grids, IEA-ETSAP and IRENA Technology Brief, April 2015.

Re-powering markets: Market design and regulation during the transition to low-carbon power systems, International Energy Agency, February 2016.

[The EU electricity laws](), Pierre Bernard et al., Claeys & Casteels, 2015.

The European power system in 2030: Flexibility challenges and integration benefits, Fraunhofer IWES, June 2015.

Endnotes

[1] The EU's targets and international commitments are for a 20% reduction in GHG by 2020, 40% by 2030, and 80–95% by 2050, using 1990 as a baseline (see EPRS briefings on the high priority for low carbon, the Paris Agreement, the ETS reform, the Effort Sharing Regulation, and on land use and forestry (LULUCF)).

[2] Here 'generator' means an actor who produces electricity, but it can also refer to the equipment that converts mechanical energy into electric energy.

[3] Power, measured in watts, is the rate at which energy is generated or consumed in a given time interval. Note that 'power' is also often used as a synonym for 'electricity'.

[4] A variable generator of a certain capacity will have a lower output than a firm generator of the same capacity. The ratio between the theoretical capacity and the actual output is the capacity factor.

[5] Average emissions of US electricity generators provided by the US Energy Information Administration.

[6] HVDC lines have lower transmission losses than AC lines, but their substations require more expensive power electronics, and it is not as easy to make connections in the middle of an HVDC line.

[7] Some large consumers, such as aluminium smelters, may receive electricity directly from the generator or the transmission network. Some smaller generators, such as solar panels and windmills, feed electricity into the distribution network.

[8] Avoiding the risk of a power losses (*blackout*) requires that the frequency of the electricity on the entire grid be synchronised. Other risks to electricity supply include climate-related water shortages, terrorist attacks, cyber-attacks and electro-magnetic pulses from nuclear devices or solar flares.

[9] Adequacy assessments at national and regional level are used for checking whether supply and demand can be balanced even in cases of unusually high demand or outages of generating stations.

[10] Pumped storage in Europe had an estimated 45 GW capacity from about 170 pumped storage units in 2011; projections indicate that more than 60 new units with a total capacity of some 27 GW should be added by 2020.

[11] For the electricity market, these are Directive 96/92/EC on the common rules for the internal electricity market, Directive 2003/54/EC which enabled new electricity suppliers to enter Member States' markets and allowed consumers to choose their electricity supplier, and Directive 2009/72/EC which further liberalised the market.

[12] In some markets, prosumers only pay for the difference between the energy received from the grid and the energy injected into the distribution network, a practice known as **net metering**.

[13] Specific types of electricity (such as low-carbon electricity or electricity from renewable sources) are only available for sale in the market system. The electricity supplier buys a certain amount of such electricity from a generator and sells it to a consumer. However, electricity from different sources cannot be separated physically in the grid.

[14] Negative electricity prices can occur when high generation from variable renewable sources coincides with low energy demand. Generators of renewable energy, which receive support payments, can be profitable despite the negative prices. For generators that have limited flexibility (such as nuclear power plants), selling electricity at negative prices may be less costly than shutting down and restarting the power plant.

Disclaimer and Copyright

eprs@ep.europa.eu
http://www.eprs.ep.parl.union.eu (intranet)
http://www.europarl.europa.eu/thinktank (internet)
http://epthinktank.eu (blog)