FACULTY OF ELECTRICAL ENGINEERING
Czech Technical University in Prague

DEPARTMENT OF ECONOMICS, MANAGEMENT AND HUMANITIES
Faculty of Electrical Engineering

Recent developments on EU electricity markets

Research fellow: Dr. Nikolaos E. Koltsaklis

E-mail: koltsnik@fel.cvut.cz, nikkoltsak@gmail.com

Czech Technical University in Prague, Faculty of Electrical Engineering, Technická 2, 166 27, Czech Republic

Outline

- Challenges of the power sector
- Introduction to competition
- **Market Structure and Participants**
- Markets for Electrical Energy
- RePower EU
- Power prices
- Exercises

Challenges of the power sector – Introduction to competition

Challenges of the power sector

- For about a hundred years, the electricity supply industry: **vertically integrated monopoly utilities**.
- Engineers treated the management of this industry: **challenging optimization problems**.
- Optimization problems **grew in size, complexity and scope**.
- **New algorithms** were developed, and ever more powerful computers: planning and the operation of the power systems.
- **Competition** in the electricity supply industry: **Multiple actors** with divergent or competing interests must interact to deliver electrical energy
- Conventional optimization problems are often no longer relevant: dozens of **new questions are being asked about** - old issues must be addressed in radically new ways.
- To stay in business, new companies must maximize the value of the service they provide. **Understanding the physics of the system is no longer enough. <u>We must understand how the economics affect the physics and how the physics constrain the economics.</u>**

Why Competition?

- For most of the 20th century, when consumers wanted to buy electrical energy: **buy it from the utility that held the monopoly**
- Some of these utilities **vertically integrated**: generated the electrical energy, transmitted it from the power plants to the load centers, and distributed it to consumers.
- In other cases: **responsible only for its sale and distribution in a local area**. This distribution utility in turn had to purchase electrical energy from a generation and transmission utility that had a monopoly over a wider geographical area.
- These utilities**: regulated private companies or public companies or government agencies**. Irrespective of ownership and level of vertical integration, geographical monopolies were the norm.
- Electric utilities operating under this model made truly remarkable contributions to economic activity and quality of life. For several decades, **the amount of energy delivered by these networks doubled about every 8 years.** At the same time, advances in engineering improved the reliability of the electricity supply to the point that in many parts of the world the **average consumer is deprived of electricity for less than 2 min per year.** These achievements were made possible by ceaseless technological advances.

Deregulation process

- In the 1980s: arguments that this model had run its course - **monopoly status of the electric utilities removed the incentive to operate efficiently and encouraged unnecessary investments**.
- **cost of the mistakes that private utilities made should not be passed on to the consumers**. Public utilities were often too closely linked to the government. Politics could then interfere with good economics.
- Suggestions that **prices would be lower and the overall economy more efficient if the supply of electricity was subjected to market discipline rather than monopoly regulation or government policy**.
- This proposal was made in the context of a general deregulation of Western economies that had started in the late 70s. Before attention turned toward electricity, this movement had already affected **airlines, transportation and the supply of natural gas.**

Competition and Challenges

- Regulated market or monopolies had previously been deemed the most efficient way of delivering the “products” to the consumers - **special characteristics** made them unsuitable for trading on free markets.
- Not insurmountable obstacles and that they **could and should be treated like all other commodities.**
- If companies were allowed to compete freely for the provision of electricity - **efficiency gains** benefit the consumers.
- Competing companies - **different technologies**. It was therefore less likely that the consumers would be saddled with the consequences of unwise investments.
- However, despite recent technological advances in electricity storage and micro-generation, this concept is **not yet technically or commercially feasible**.
- The **reliable and continuous delivery** of electrical energy still **requires large generating plants** connected to the consumer through transmission and distribution networks and careful attention must be paid to reliability.

Market Structures and Participants

Market Structures and Participants

Traditional Model

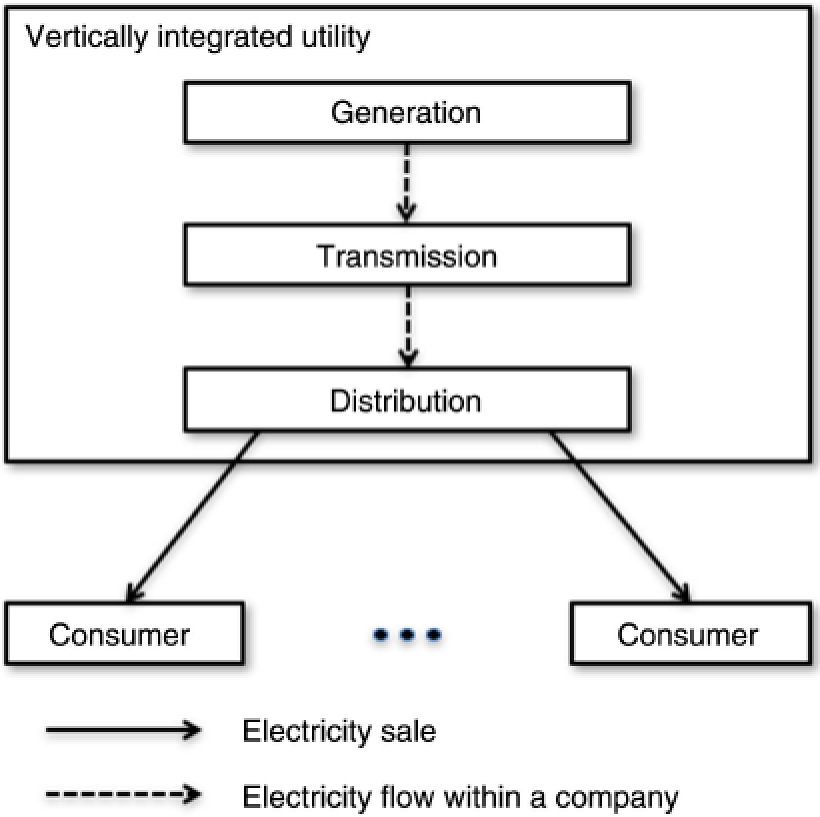


Figure 1: Traditional model of electricity supply

- ✓ In the ***traditional market model***, trading is **limited to consumers** purchasing electricity from their local electric utility – 2 main characteristics.
- ✓ First, it has a **monopoly for the supply of electricity** over its service territory. If consumers want to purchase electricity, they do not have a choice: they have to buy it from this utility.
- ✓ Second, the **utility is vertically integrated**. This means that it performs all the functions required to supply electricity: ***building*** – ***operating*** - ***billing*** the consumers for the service provided.

Market Structures and Participants

Variant on the traditional model

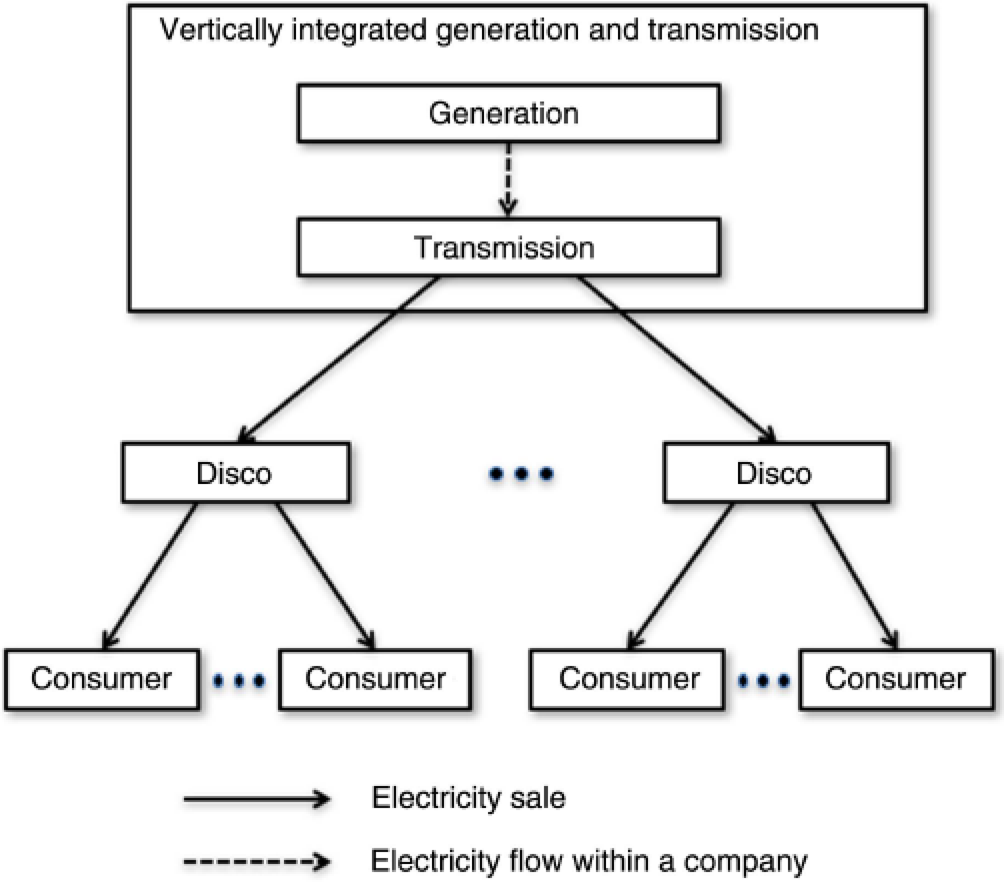


Figure 2: Variant on the traditional model of electricity supply.

- ✓ **Variant of the traditional model** - vertically integrated utility is split in two parts. One organization **generates and transmits electricity over a fairly wide area and sells it to several distribution companies** (**Discos**), each of which has a local monopoly for the sale of electricity to consumers.
- ✓ Because monopolies could take advantage of the fact that their customers do not have a choice to choose supplier and could charge them extortionate prices, they must either be **government entities or be subject to oversight by a government department (the regulator)**.
- ✓ In the traditional model - **regulatory compact**. This is an agreement that gives a utility a **monopoly for the supply of electricity** over a given geographical area. In exchange, the utility agrees that (i) its prices will be set by the regulator, (ii) supply all the consumers in that area, and (iii) certain quality of service.

Traditional model synopsis

- This model **does not preclude bilateral energy trades** between utilities operating in different geographical areas. Such trades take place at the wholesale level
- The problem with the traditional model and its variant is that monopolies - **inefficient** because they do not have to compete with others in order to survive.
- Furthermore, because their operations are rather **opaque**, regulators have difficulties assessing where improvements could be made.

Introducing Independent Power Producers

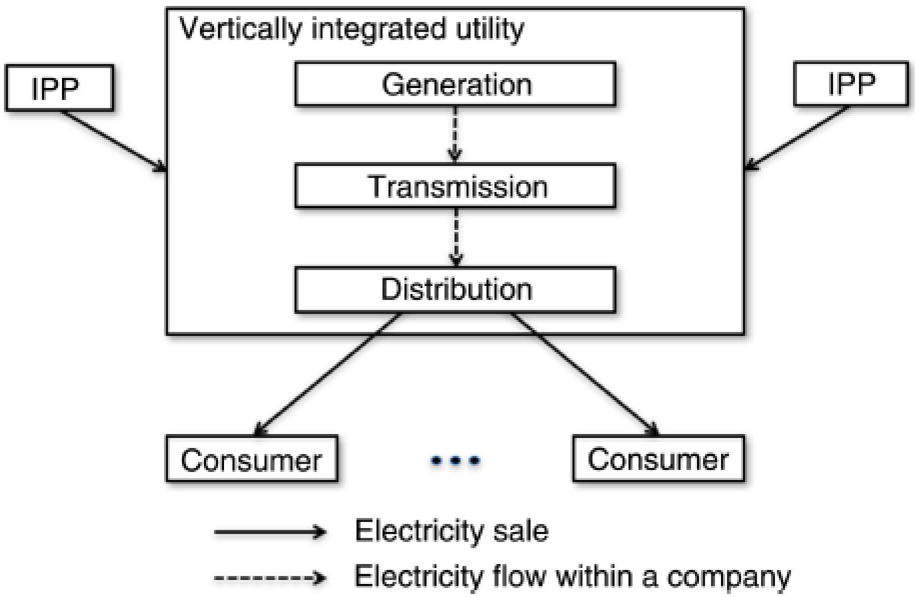


Figure 3: Incumbent vertically integrated utility with independent power producers (IPPs).

- ✓ More competitive industry structure consists in **allowing other companies** (called **independent power producers or *IPPs***) to **produce part of the electrical energy** that the incumbent vertically integrated utility must supply to its customers.
- ✓ **Degree of competition** at the generation level, it does not provide a mechanism for discovering cost-reflective prices in the same way that a free market does.
- ✓ The **incumbent utility** would like to pay **as little as possible** - discourage them from expanding their generation capacity. It must therefore be forced by law to buy the power produced by the IPPs.
- ✓ Given this guarantee that their production will be purchased, the **IPPs** will try to get **as high a price as they can**.
- ✓ **Regulator** – decision what an equitable price would be.
- ✓ Limited detailed and reliable information - **economically inefficient**.

Wholesale Competition

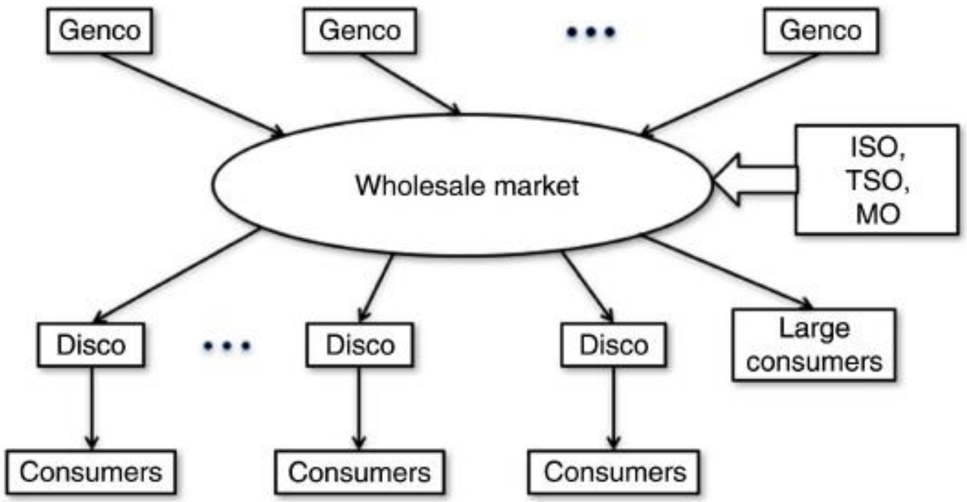


Figure 4: Wholesale electricity market structure

- ✓ Competitive electricity markets consists in **getting rid of the incumbent utility**.
- ✓ All the companies that own large generating plants (***Gencos***) then **compete on an equal basis** to sell electrical energy. **Distribution companies** purchase the electrical energy consumed by their customers on this wholesale electricity market.
- ✓ The **largest consumers:** participate directly in this market.
- ✓ This wholesale market: **centralized manner** or **bilateral transactions**.

- ✓ In this model, the **wholesale price of electricity: interplay of supply and demand**. On the other hand, the **retail price of electrical energy must remain regulated** because each distribution company: local monopoly over the sale of electrical energy flowing through its network.
- ✓ Centralized manner: an organization called **independent system operator** (***ISO***) must be created. This ISO has two main functions. First, it must manage the market in an **impartial and efficient manner**. Second, it is responsible for the **reliable operation of the transmission system**. To ensure the fairness of the market, the ISO has to be **institutionally independent from all market participants**.
- ✓ Bilateral wholesale market: **one or more market operators** (***MOs***), whose role is to facilitate commercial transactions between buyers and sellers of electrical energy, and a **transmission system operator** (***TSO***), who keeps the system in balance and operationally reliable.
- ✓ While TSOs often **own** the transmission assets, ISOs usually do not.

Retail Competition

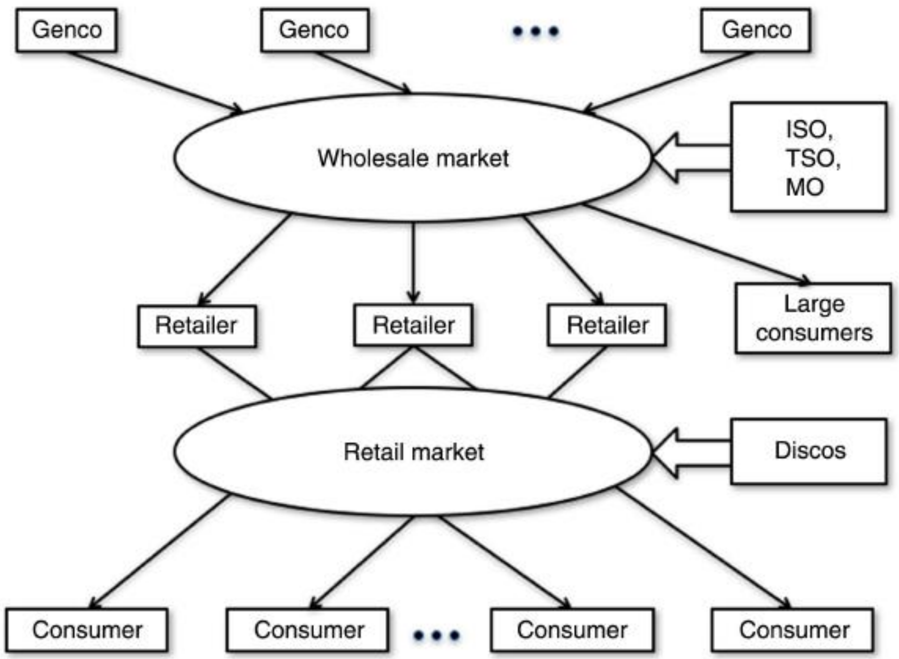


Figure 5: Market with retail competition

- ✓ Competition: **retail market**.
- ✓ In this structure, **retailers purchase electrical energy in bulk on the wholesale market** and resell it to small-and medium-size consumers.
- ✓ In this model, the "wires" activities of the distribution companies are normally separated from their retail activities because they no longer have a local monopoly for the supply of electrical energy in the area covered by their network. **One can view the wholesale market as operating over the transmission network while the retail market takes place over the distribution network.**

- ✓ **Building and operating the transmission and distribution networks remain monopoly activities:** building competing sets of wires would be wasteful.
- ✓ Regulator: **what investments in network assets** are justified and how the **cost of these investments should be allocated to the users of the networks**.
- ✓ Once sufficiently competitive markets have been established, the **retail price no longer has to be regulated** because small consumers have the option to change retailer if they are offered a better price or better service.
- ✓ **Market interactions lead to the discovery of economically efficient prices**.

Renewable and Distributed Energy Resources

- Public policies: aimed at **reducing carbon emissions** to mitigate climate change have significantly altered the **mix of generation technologies** in many parts of the world. Because wind and solar generation now contribute a substantial fraction of the overall production of electrical energy, ***electricity markets have had to adapt to their intermittent and stochastic nature***.
- **Larger imbalances** between generation and load that RES generation causes, **markets operate on a much shorter time frame than before**.
- **Increasing reliance on flexibility from the demand side** to help maintain this balance. Marshalling demand-side resources is challenging because they tend to be small and distributed throughout the system.
- Direct participation in the wholesale electricity markets by **DERs** (demand response, small-scale energy storage, and photovoltaic generation) is not possible because it would vastly increase the number of market participants and render these markets unmanageable.
- Rules of the wholesale markets are complex and the requirements for participation are strict, making the **transaction costs** prohibitively expensive for small participants. To overcome this problem, new entities called ***aggregators*** are emerging - **commercial and technical intermediary between the wholesale markets and the owners of DERs** who could contribute to the economic efficiency of the overall system.

Markets for Electrical Energy

Markets for Electrical Energy (1)

- Development of electricity markets: electrical energy can be treated as a commodity. **However, there are important differences between electrical energy and other commodities such as bushels of wheat, barrels of oil, or even cubic meters of gas.**
- **Supply of electrical energy is inextricably linked with a physical system and that its delivery occurs on a continuous rather than a batch basis.** If this balance is not maintained, or if the capacity of the transmission network is exceeded, the system collapses with catastrophic consequences. Such a breakdown is intolerable because it is not only trading that stops.
- An entire region or country may be without power for many hours because restoring a power system to normal operation following a complete collapse is a **very complex process** that may take 24h or longer in large industrialized countries
- **System-wide blackout:** no sensible government would agree to the implementation of a market mechanism that could significantly increase the likelihood of large supply interruptions.
- Balancing the supply and the demand for electrical energy in the short run is thus a process that simply cannot be left to an unaccountable entity such as a market: **a single organization must ultimately be responsible for maintaining this balance at practically any cost.**
- Difference between electrical energy and other commodities is that the **energy produced by one generator cannot be directed to a specific consumer.** Instead, the power produced by all generators is pooled on its way to the loads. This pooling is possible because units of electrical energy produced by different generating units are indistinguishable. It is also desirable because pooling produces valuable economies of scale.

Markets for Electrical Energy (2)

- The demand for electrical energy exhibits predictable **daily and weekly cyclical variations**. **Small short-run price elasticity of demand: matching supply and demand requires production facilities capable of following the large and rapid changes in consumption that take place over the course of a day.** However, not all of these generating units will be producing throughout the day. When the demand is low, only the most efficient units are likely to be competitive and the others will be shut down temporarily. These less efficient units are needed only to supply the peak demand.
- Marginal producer changes: marginal cost of producing electrical energy (and hence its spot price) to vary over the course of the day. **Such rapid cyclical variations in the cost and price of a commodity are very unusual.**
- Trading in gas also takes place over a physical network where the commodity is pooled and the demand is cyclical. However, pipelines store a considerable amount of energy in the form of pressurized gas. An imbalance between production and consumption of gas therefore has to last much longer before it causes a collapse of the pipeline network. It can therefore be corrected through a market mechanism.
- The only energy that is actually stored and readily available in the power system resides in the rotating masses of synchronized generators. Since this stored kinetic energy is quite small**, a sudden deficit in generation would deplete it quite quickly, causing a drop in frequency that could not be corrected sufficiently fast by a market mechanism.**

Trading Periods (1)

- Electricity is fully characterized by several physical variables: voltage, current, power, and energy. **While all of these matter in the operation of the system, the quantity that best defines a tradable commodity is clearly the energy supplied.**
- **Power system got its name from the fact that it is designed to supply energy on a continuous basis, i.e. power.** Electricity is therefore not traded in terms of energy but rather in terms of power over a certain interval of time.
- **Designing an electricity market therefore involves choosing a time interval that serves as a trading period.** Power is then translated into tradable energy by integrating it over each time interval.
- Short time interval (say 5 min), trading reflects more accurately the instantaneous conditions in the physical system because the actual power generated or consumed will not deviate significantly from its average over each trading period.
- **Systems with a significant amount of wind or solar generation** because of the rapid and unpredictable changes in supply that these renewable sources can cause.

Trading Periods (2)

- Trading over many short time intervals is not always practical.
- If a generating company has the ability to produce a large amount of power for a period of hours or a retailer must supply a constant base load, they probably do not want to trade in 5-min intervals. **They would rather agree on a quantity and price that remain fixed over a much longer period because it reduces their risks.**
- **Electricity trading is organized as a sequence of forward markets with progressively shorter trading periods and a spot market. Forward markets handle trading in large amounts of energy over long periods of time.** They operate slowly and close far in advance of the beginning of the delivery period (also known as "real time").
- **Markets for smaller amounts of energy to be delivered over shorter time periods operate faster and can therefore operate much closer to real time.**
- The **spot market is the market of last resort and thus operates closest to real time -** small fraction of the overall energy needs - market participants manage their risks - gives the system operator time to identify conditions that might affect the operational reliability of the system.

Forward Markets (1)

- **Forward markets:** substantial number of bids to buy and offers to sell. Over time, repeated interactions between the participants, leading to **bilateral trades**, clear the market.
- **Decentralized model - centralized approach**

Depending on the **amount of time available** and the **quantities to be traded**:

- **Customized long-term contracts:** The terms of such contracts are negotiated privately to meet the needs and objectives of both parties and are thus very flexible. They usually involve the sale of large amounts of power over long periods of time. Negotiating such contracts carries **substantial transaction costs**: worthwhile only when the parties want to trade large amounts of energy.
- **Trading "over the counter":** These transactions involve smaller amounts of energy to be delivered according to a standard profile. This form of trading has much **lower transaction costs** and is used by producers and consumers to refine their position as the time of delivery approaches.
- **Electronic trading:** Participants use electronic trading platforms to advertise offers to sell or bids to buy energy. All participants in such a computerized marketplace can observe the quantities and prices submitted by other parties but do not know the identity of the party that submitted each bid or offer.

Forward Markets (2)

- The essential characteristic of bilateral trading is that the price of each transaction is set independently by the parties involved. **There is thus no "official" price and trading can be described as "decentralized."**
- While the details of negotiated long-term contracts are usually kept private, independent reporting services gather anonymized data about over the-counter (OTC) trading and publish summary information about prices and quantities in a form that does not reveal the identity of the parties involved.
- This type of market reporting and the display of the last transaction arranged on the electronic marketplace enhance the efficiency of electricity trading by giving participants a clearer idea of the state and direction of the market.

Spot Markets (1)

- Retailers and large consumers: needs for electrical energy consumption – no perfect accuracy. Similarly, generators cannot guarantee that they will be able to produce the exact quantity that they have sold on forward markets
- **At the time of delivery, any market participant who has more or less energy than it needs or has contracted to buy or sell must be able to trade on the spot market to cover the difference.**
- **The physical counterpart of an imbalance between demand and supply is an imbalance between load and generation, which must be covered very rapidly if the power system is to remain stable.** In the current state of the technology, it is difficult to conceive a mechanism where enough generators and consumers would have the ability and the inclination to process this information sufficiently fast to enter into trades that would restore the balance between load and generation in a reliable manner.
- **The market of last resort for electrical energy is therefore not a true spot market. It is instead what one might call a "managed spot market" because the system operator is counterparty to all trades.** This means that market participants do not buy or sell from each other but deal only with the system operator, who decides how much power it needs to buy or sell to maintain the system's stability.
- **The spot price is then calculated based on the bids and offers submitted by the market participants and selected by the system operator.** Any difference between what a market participant was contractually committed to do and what it actually did is settled at the spot market price.

Spot Markets (2)

- E.g., a generator had sold 100 MW to various retailers but produced only 97 MW during a given spot market trading period. The generator is deemed to have purchased the corresponding amount of energy at the spot price.
- Similarly, a retailer who contracted for 100 MW but consumed only 96 MW during a trading period is deemed to have sold the difference at the spot market price.
- Being out of balance may be unavoidable for producers and consumers, but it should not be cost-free. **To encourage efficient behaviour, producers and consumers who are in imbalance must pay the true cost of the electrical energy that is bought or sold on the spot market to restore the balance between load and generation.** Note that if a market participant is out of balance but in the opposite direction of the system as a whole, it should be rewarded for that.
- Depending on the jurisdiction, the spot market is called “real-time market,” “balancing market,” “intraday market,” or “balancing mechanism” and the trading period ranges from 1 h to 5 min.

Gate Closure (1)

- Forward markets must close at some point before real time to give the system operator control over what happens in the system. **How much time should elapse between this gate closure and real time depends on the perspective that one has on the market.**
- **System operators prefer a longer interval because it gives them more time to develop their plans and more flexibility in their selection of balancing resources.**
- **Generators and retailers, on the other hand, usually prefer a shorter interval between gate closure and real time because it reduces their exposure to risk.** A load or wind generation forecast calculated 1 h ahead of real time is usually much more accurate than a forecast calculated 4 h ahead.
- If a generating unit fails after gate closure, there is nothing that its owner can do except hope that the spot market price will not be too high. On the other hand, if it fails before gate closure, its owner can try to make up the deficit in generation by purchasing at the best possible price on the electronic exchange. **Market participants would therefore prefer to trade electronically up to the last minute to match their contractual position with their anticipated load or production.** This is considered preferable to relying on the spot market where participants are exposed to prices over which they have no control.

Gate Closure (2)

- **At gate closure, the producers and the consumers must inform the system operator of their contractual positions**, i.e. how much power they intend to produce or consume during the upcoming trading period. **The system operator combines that information with its own forecast of the total load to determine by how much the system is likely to be in imbalance.** If generation exceeds the load, the system is said to be **long**. If the opposite holds, the system is **short**. The system operator must then decide which balancing bids and offers it will use to cover the imbalances.

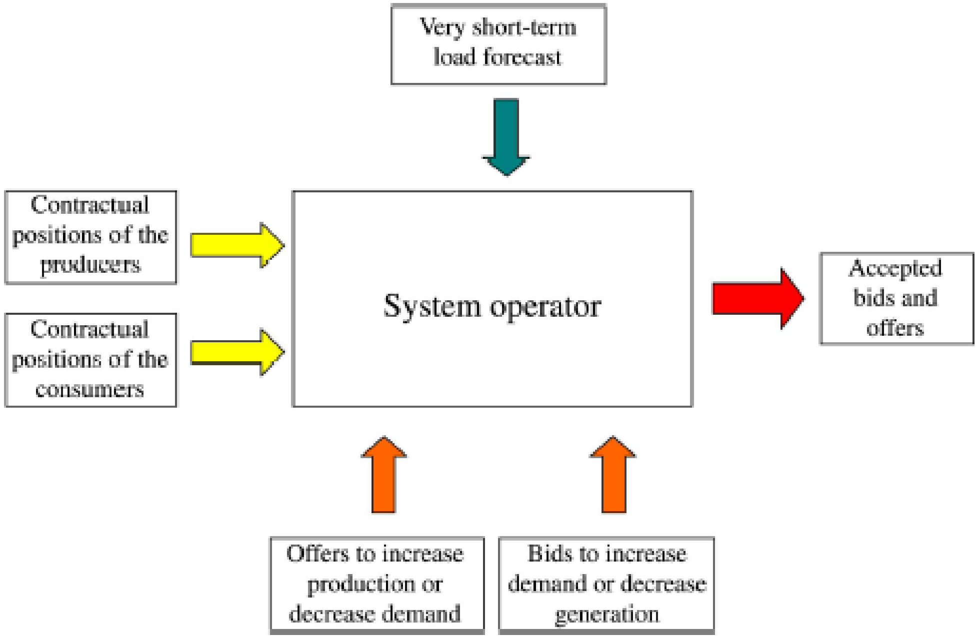
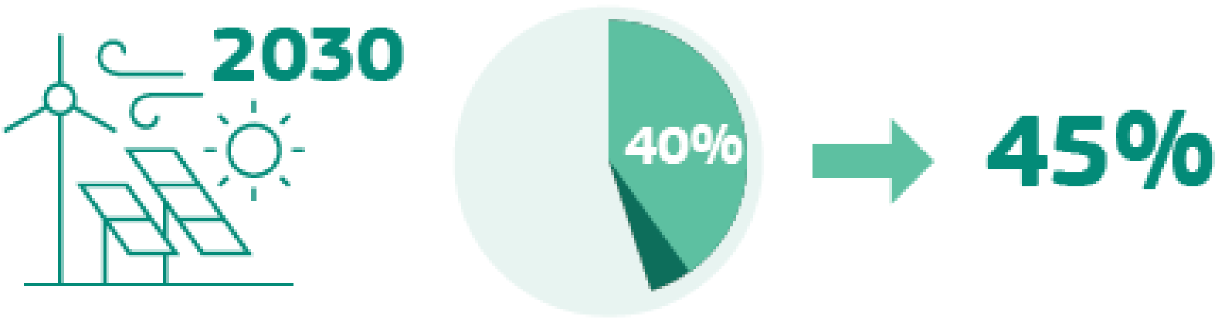


Figure 6: Schematic diagram of the operation of a managed spot market for electricity.

REPowerEU Plan

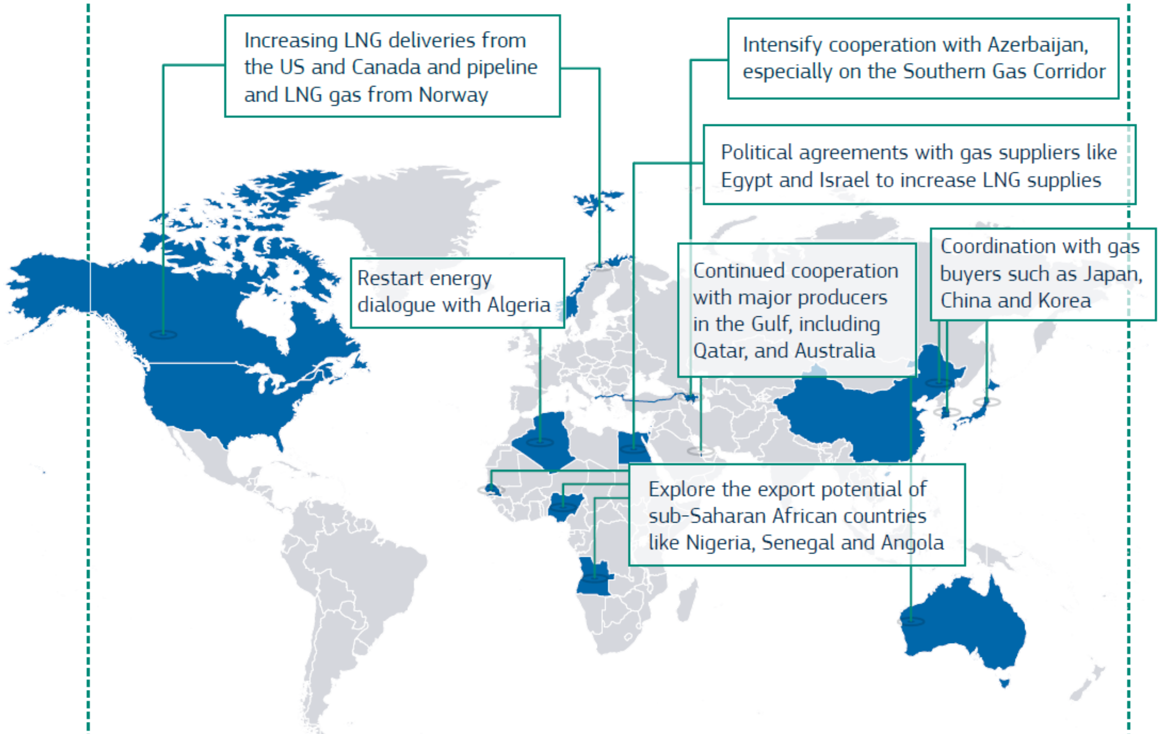
REPowerEU with Clean Energy

- Ending the EU's reliance on Russian fossil fuels: **massive scale-up of renewables** as well as **faster electrification** and replacement of fossil-based heat and fuel in industry, buildings and the transport sector. The clean energy transition will help over time lower energy prices and reduce import dependency.
- Renewables are the cheapest and cleanest energy available, and can be generated domestically, reducing our need for energy imports. The Commission is proposing **to increase the EU's 2030 target for renewables from the current 40% to 45%.** The REPowerEU Plan would bring the total renewable energy generation capacities to 1236 GW by 2030, in comparison to 1067 GW by 2030 envisaged under Fit for 55 for 2030.



RENEWABLE GASES: HYDROGEN AND BIOMETHANE

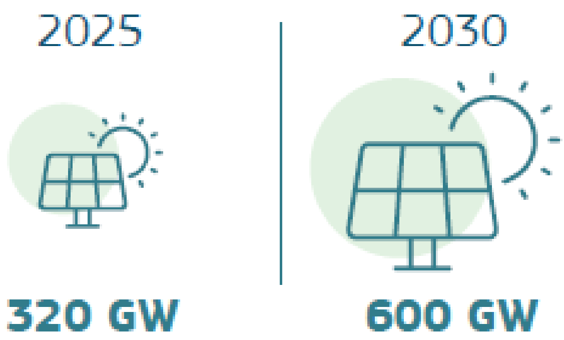
- A new Hydrogen Accelerator to ensure **10 million tonnes of domestic renewable hydrogen production** and **10 million tonnes of renewable hydrogen imports by 2030.**
- The REPowerEU Plan sets out that an additional 15 million tonnes (mt) of renewable hydrogen – on top of the 5.6 mt already planned under the Fit for 55 initiative – **can replace approximately 27 bcm of imported Russian gas by 2030.**
- A dedicated action plan to boost **biomethane production to 35 bcm by 2030**



The new **EU Energy Platform** will play a key role to pool demand, coordinate infrastructure use, negotiate with the international partners and prepare for joint gas and hydrogen purchases.

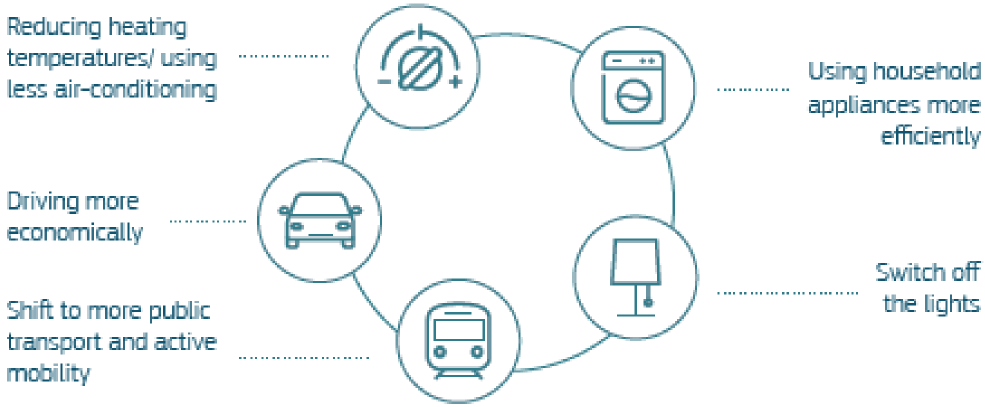
SOLAR ENERGY TO REPOWER EUROPE

- The **EU Solar Energy Strategy** will boost the roll-out of photovoltaic energy. As part of the REPowerEU plan, this strategy aims to bring online **over 320 GW of solar photovoltaic newly installed by 2025**, over twice today's level, and almost 600 GW by 2030. **These frontloaded additional capacities displace the consumption of 9 bcm of natural gas annually by 2027**.
- **A European Solar Rooftops initiative**: a gradual obligation to install solar rooftop panels in certain buildings, combined with renovations, while promoting self-consumption and energy communities
- An **EU Solar PV Industry Alliance** for an innovative and resilient photovoltaic value chain in the EU
- **EU large-scale skills partnership**: to ensure that the deployment of renewables happens smoothly and creates local jobs across the EU

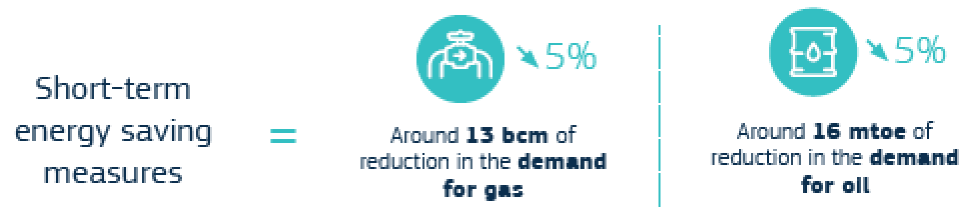


REPowerEU: Energy Savings and Energy Efficiency

There are many ways to **reduce energy consumption** in our **daily lives** by:



Short-term measures:



In July 2021, the Commission proposed an **increase of the EU energy efficiency target of 9% by 2030**, as part of the 'Fit for 55' package. It is now necessary to **go even further.**

REPowerEU: Clean industry

- Replacing coal, oil and gas in industrial processes will help cut the dependency on Russian fossil fuels, while transitioning to cleaner energy sources, strengthening industrial competitiveness and supporting international technology leadership.
- Electrification, energy efficiency and uptake of renewables could **allow industry to save 35 bcm of natural gas by 2030 beyond Fit for 55 targets**
- Largest reductions in gas, almost **22 bcm**, could be made from non-metallic minerals, cement, glass and ceramics, chemicals production and refineries
- **Around 30% of EU primary steel production** is expected to be **decarbonized** on the basis of **renewable hydrogen** by 2030
- The industrial sector will also play a key role in scaling up the production of equipment and components necessary to quickly transform our energy system.

↓

Additional investments of **€210 billion** are needed between now and 2027 to phase out Russian fossil fuel imports, which are currently costing European taxpayers nearly **€100 billion** per year.

Power prices

EU Natural Gas price

Figure 6: EU natural gas price evolution during the last 10 years

- ✓ European natural gas futures settled around €117 per megawatt-hour on Friday (June 17).
- ✓ Gazprom tightened further gas supplies to the EU putting in jeopardy EU's objectives to filling 80% of storage capacity before the next winter heating season.
- ✓ The Russian state-owned gas giant has cut more gas supplies to Italy, with ENI set to receive just half of its requested gas while flows to Germany through the key Nord Stream remained curbed by 60%.
- ✓ Adding to woes, the shipments of US LNG cargoes are set to decline, following an explosion at Freeport LNG, a facility which accounts for roughly 20% of the US total liquefaction capacity. The company said repair works would take months, and the facility would be fully operational by late 2022.

Hard coal price

Figure 7: Hard coal price evolution during the last 10 years

- ✓ Newcastle coal futures, the benchmark for top consuming region Asia, were trading below the $400-per-tonne mark, a level not seen in more than a month, as surging inventories and weaker demand continued to pressure the market.

CO_2 emissions price

Figure 8: EU Carbon Permits price evolution during the last 10 years

- ✓ EU Carbon Permits increased 1.72 EUR or 2.13% since the beginning of 2022

Exercises

Exercise 1

The electricity pool of X market has received the bids and offers shown on the table below for the period between 9:00 and 10:00 A.M. on 20 June.

Bids	Company	Quantity (MWh)	Price ($/MWh)
	Red	200	12.00
	Red	50	15.00
	Red	50	20.00
	Green	150	16.00
	Green	50	17.00
	Blue	100	13.00
	Blue	50	18.00
Offers	Yellow	50	13.00
	Yellow	100	23.00
	Purple	50	11.00
	Purple	150	22.00
	Orange	50	10.0
	Orange	200	25.00

1. **How much is the System's Marginal Price (SMP) during that hour?**
2. **How much energy each generator will be instructed to produce and how much energy each consumer will be allowed to draw.**
3. **Calculate the revenues and expenses for each company.**

Exercise 2

The Z Company owns a generating plant and serves some load. It has been actively trading in the power market and has established the following position for 11 June between 10 and 11 am:

- **Long-term contract** for the purchase of 600MW during peak hours at a price of 20.00 $/MWh
- **Long-term contract** for the purchase of 400MW during off-peak hours at a price of 16.00 $/MWh
- **Long-term contract** with a major industrial user for the sale of 50MW at a flat rate of 19.00 $/MWh
- The **remaining customers** purchase their electricity at a tariff of 21.75 $/MWh
- **Future contract** for the sale of 200MWh at 21.00 $/MWh
- **Future contract** for the purchase of 100MWh at 22.00 $/MWh
- **Call option** for 150MWh at an exercise price of 20.50 $/MWh
- **Put option** for 200MWh at an exercise price of 23.50 $/MWh.
- **Call option** for 300MWh at an exercise price of 24.00 $/MWh.

The **option fee** for all the options is 1.00 $/MWh. The peak hours are defined as being the hours between 8:00 am. and 8:00 pm..

The outcome for 11 June between 10 : 00 and 11 : 00 is as follows:

- The spot price is set at 21.50 $/MWh.
- The total load of the Syldavian Power and Light Company is 1200 MW, including the large industrial customer.

• The power plant produces 300 MWh at an average cost of 21.25 $/MWh.

Assuming that all imbalances are settled at the spot market price, calculate the profit or loss made by the company during that hour.

CZ-AT EEG

CZECH-AUSTRIAN ENERGY EXPERT GROUP

Thank you very much for your attention! Questions?

Experience and Open Questions (1)

- In the **monopoly utility model**, all technical decisions regarding the **operation and the development of the power system** are taken within a single organization. In the short term, this means that, at least in theory, the operation of all the system components can be coordinated to achieve least cost operation. *For example, the maintenance of the transmission system can be scheduled jointly with the maintenance of the generation units to cooptimize reliability and economy.* Similarly, the system long-term development can be planned to ensure that the transmission capacity and topology match the generation capacity and location.
- **Introducing competition** implies renouncing centralized control and coordinated planning. A single integrated utility is replaced by a constellation of independent companies, none of which has the responsibility to supply electrical energy to all the consumers. Each of these companies decides independently what it will do to maximize its private objectives. When the idea of competitive electricity markets was first mooted, it was rejected by many on the grounds that such a disaggregated system could not keep the lights on. There is now ample evidence to demonstrate that separating the operation of generation from that of the transmission system does not necessarily reduce the operational reliability of the overall system.
- Having a separate, independent organization in charge of operating the power system has the significant advantage that it makes processes more open and transparent. Buyers and sellers have an interest in exploring how market rules and operational procedures can be improved to reduce costs and improve the profitability of their assets. **This attitude has led to markets operating much closer to real time and to the development of “products” to accommodate the increasing amount of RES as well as new technologies such as demand-side participation and energy storage.**

Experience and Open Questions (2)

- **Electricity** markets have also grown geographically because **bigger markets provide more trading opportunities and are thus more liquid and efficient**. This growth happened either through **additional participants** joining an existing market or through the establishment of **market coupling mechanisms**. Increased trading opportunities result in more frequent and larger transactions between distant generators and loads. Such power flows increase the physical interdependence between parts of the grid that used to be loosely connected. Maintaining the stability and operational reliability of large interconnections under these conditions has forced system operators to enhance the scope and functionality of their data acquisition and analysis capabilities.
- Electricity markets have some unique characteristics that facilitate the **abuse of market power**. Many, if not most, electricity markets therefore have had to deal with the fact that they were often less than perfectly competitive. This has led to a number of inquiries by regulators, the creation of market monitoring bodies, the implementation of price caps, and other less controversial market power mitigation measures.
- In terms of long-term development, the argument in favour of competition is that central planners always get their forecasts wrong. In particular, **monopoly utilities have a tendency to overestimate the amount of generation capacity that will be needed**. Their captive consumers are then obliged to pay for unnecessary investments. With the introduction of competition, it is hoped that the sum of the independent investment decisions of several profit-seeking companies will match the actual evolution of the demand more closely than the recommendations of a single planning department.

Experience and Open Questions (3)

- In addition, underutilized investments by a company operating in a free market represent a **loss for its owners and not a liability for its customers.** Some markets rely entirely on the profits that power plants can obtain from the sale of energy and services to motivate investments in generation capacity. In other jurisdictions, market designers have introduced **additional revenue streams** to ensure that enough generation capacity is available to supply the load in a reliable manner.
- Vertically integrated utilities can plan the development of their transmission network to suit the construction of new generating plants. In a competitive environment, the transmission company does not know years in advance where and when generating companies will build new plants. **This uncertainty makes the transmission planning process much more difficult.** Conversely, generating companies are not guaranteed that enough transmission capacity will become or will remain available for the output of their plants. Other companies may indeed build new plants in the vicinity and compete for the available transmission capacity.
- The **transmission and distribution networks have so far been treated as natural monopolies**. Having two separate and competing sets of transmission lines or distribution feeders clearly does not make sense. **From the economic and the reliability points of view, all lines, feeders, and other components should be connected to the same system.** On the other hand, some economists and some entrepreneurs argue that not all these components must be owned by the same company. They believe that independent investors should have the opportunity to build new transmission facilities to satisfy specific needs that they have identified. Taken individually, such opportunities could be lucrative for the investors. **However, the prevalent view is that such investments must take place within a framework that maximizes the overall benefits derived by all users of the network while minimizing their environmental impact.** Electricity is not a simple commodity whose trading is governed by the principles of classical economics. In addition to the need to maintain reliability, electricity markets are also affected by policy decisions driven by a desire to **promote RES and protect the environment, concerns about energy security and independence**, as well as **subsidies aimed at spurring the development of new technologies or helping a national industry**.

Centralized Trading (1)

Principles of Centralized Trading

- Rather than relying on repeated interactions between suppliers and consumers to reach a market equilibrium, a **centralized electricity market** provides a *mechanism for determining this equilibrium in a systematic way*. While there are many possible variations, a centralized market essentially operates as follows:
- **Generating companies submit offers to supply a certain amount of electrical power at a certain price for the period under consideration.** These offers are ranked in order of increasing price. From this ranking, a curve showing the offer price as a function of the cumulative quantity offered can be built. This curve is deemed to be the **supply curve** of the market.
- Similarly, the **demand curve of the market can be established by asking consumers to submit bids specifying the quantity they need and the price that they would be willing to pay.** These offers are then ranked in decreasing order of price to create a demand curve. Since the demand for electricity is highly inelastic, this step is often omitted and the demand is set at a value determined using a forecast of the load. **In other words, the demand curve is assumed to be a vertical line at the value of the load forecast.**
- The **intersection of these constructed supply and demand curves determines the market equilibrium.** All the offers submitted at a price lower than or equal to the market clearing price are accepted, and generators are instructed to produce the amount of energy corresponding to their accepted offers. Similarly, all the bids submitted at a price greater than or equal to the market clearing price are accepted and the consumers are informed of the amount of energy that they are allowed to draw from the system.

Centralized Trading (2)

- The **market clearing price represents the price of one additional megawatt-hour of energy and is therefore called the System Marginal Price or SMP**. Generators are paid this SMP for every megawatt-hour that they produce and consumers pay the SMP for every megawatt-hour that they consume, irrespective of the offers and bids that they submitted.
- The process of finding the intersection between these constructed supply and demand curves emulates the operation of a market and thus **maximizes the global welfare**.
- Paying the SMP for all the accepted generation offers may appear surprising at first glance. Why should generators be paid more than their asking price? Wouldn't paying every generator its asking price reduce the average price of electricity? **The main reason why such a pay-as-bid scheme is not adopted is that it would discourage generators from submitting offers that reflect their marginal cost of production.** All generators would instead try to guess what the SMP is likely to be and would offer at that level to maximize their revenues. Therefore, at best, the SMP would remain unchanged. However, inevitably some low-cost generators would occasionally overestimate the SMP and offer at too high a price. These generators would then be left out of the schedule and be replaced by generators with a higher marginal cost of production. The SMP would then be somewhat higher than it would be if all generators were paid the same price. Furthermore, **this substitution is economically inefficient because optimal use is not made of the available resources.** In addition, generators are likely to increase their prices slightly to compensate themselves for the additional risk of losing revenue caused by the uncertainty associated with trying to guess what the SMP might be. **An attempt to reduce the price of electricity would therefore result in a price increase!**

Comparison of Centralized and Decentralized Trading

- In the early days of the introduction of competition in electrical energy trading, bilateral trading was seen by many as too big a departure from existing practice. **Since electrical energy is pooled as it flows from the generators to the loads, it was felt that trading might as well be done in a centralized manner and involve all producers and consumers.** The adoption of a centralized or a decentralized market model was therefore influenced by history and the character of industry organizations.
- **Day-ahead centralized electricity markets are usually run by the system operator.** This facilitates the integration of forward markets with the needs to maintain the balance of the system and to ensure operational reliability. **This advantage is particularly important in systems where network constraints have a significant impact on the market.**
- Most small and medium electricity consumers have very little incentive to take an active part in an electricity market. Even when they are aggregated, the retailer that represents them has only a limited ability to adjust consumption in responses to changes in prices. The transaction costs are therefore reduced significantly if demand is deemed to be passive and is represented by a load forecast as is the case in many centralized markets. **Many economists are unhappy with this approach because they feel that direct negotiations between consumers and producers are essential if efficient prices are to be reached. Some economists thus dislike centralized markets simply because they are only an administered approximation of a market rather than a true market.**

Comparison of Centralized and Decentralized Trading

- **Centralized markets also provide a mechanism for reducing the scheduling risk faced by generators and hence, hopefully, the cost of electrical energy.** When a generator sells energy for each market period separately on the basis of simple offers, it runs the risk that for some periods it may not have sold enough energy to keep the plant on-line. At that point it must decide whether to sell energy at a loss to keep the unit running or to shut it down and face the expense of another startup at a later time. Either option increases the cost of producing energy with this unit and forces the generator to raise its average offer price. On the other hand, in a centralized market, the generation schedule produced by the **unit commitment calculation** avoids unnecessary unit shutdowns and the market rules typically ensure that generators recover their startup and no-load costs. Since these factors reduce the risks faced by the generators, they should, in theory, foster lower average prices. However, this reduction in risk requires the implementation of more complex market rules. Such rules reduce the transparency of the price setting process and increase opportunities for price manipulations.
- Generators and retailers who participate in a day-ahead centralized market are typically obliged to sell their entire production or buy their total consumption through this market. However, **they usually retain the right to enter into bilateral financial contracts to manage the price risks that they are exposed to in this day-ahead centralized market.**
- Some centralized day-ahead markets also allow bilateral trading. The quantities traded bilaterally are taken into account in the clearing process, but these transactions do not set the market price.

Obtaining Balancing Resources (1)

- If market participants were able to predict with enough lead time and with perfect accuracy the amount of energy that they will consume or produce, the system operator would not have to take balancing actions. The participants themselves could trade to cover their deficits and absorb their surpluses. **In practice, there are always small imbalances and the system operator must obtain adjustments in generation or load.**
- Integrated over time, these adjustments translate into purchases and sales of electrical energy that can be settled at a spot price reflecting the market's willingness to provide or absorb extra energy. **This approach provides the system operator with the widest possible choice of balancing options and should therefore help reduce the cost of balancing.**
- **Balancing resources can be offered either for a specific period or on a long-term basis. Generating units that are not fully loaded can submit bids to increase their output.** A generating unit can also offer to pay to reduce its output. This is a profitable proposition if the price that this generator has to pay is less than the incremental cost of producing energy with this unit. A generating unit that submits such an offer is in effect trying to replace its own generation by cheaper power purchased on the spot market.
- **The demand side can also provide balancing resources.** A consumer could offer to reduce its consumption if the price it would receive for this reduction is greater than the value it places on consuming electricity during that period. Such demand reductions have the advantage that they can be implemented very quickly. It is also conceivable that consumers might offer to increase their demand if the price is sufficiently low.
- Since these offers of balancing resources are submitted shortly before real time, the system operator may be concerned about the amount or the price of balancing resources that will be offered. **To reduce the risk of not having enough balancing resources or of having to pay a very high price for these resources, it can purchase balancing resources on a long-term basis.** Under such contracts, the supplier is paid a fixed price (often called the option fee) to keep available some generation capacity. The contract also specifies the price or exercise fee to be paid for each megawatt-hour produced using this capacity.

Obtaining Balancing Resources (2)

- Imbalances due to forecasting errors by the participants are relatively small, evolve gradually, and have a known probability distribution. On the other hand, imbalances caused by generator failures are often large, unpredictable, and sudden. Many generating units can adjust their output at a rate that is sufficient to cope with the first type of imbalances. **Handling the second type of imbalances requires resources that can increase their output rapidly and sustain this increased output for a sufficiently long time.**
- It is important to realize that all the units of energy that are traded to keep the system in balance do not have the same value. A megawatt obtained by increasing slightly the output of a large thermal plant costs considerably less than a megawatt of load that must be shed to prevent the system from collapsing. **To be able to keep the system in balance at minimum cost, the system operator should therefore have access to a variety of balancing resources.**
- When producers and consumers bid to supply balancing resources, their bids must specify not only a quantity and a price but also **what constraints limit their ability to deliver a change in power injection.**