ELEC0018-1 Energy Markets

Lecture 3: From monopolies to markets

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The question of the day

How did the market structure that exists today came to be?

Menu for today

1. Rise of monopolies and liberalisation
2. Actors of the electricity sector
3. Bilateral contracts

An amazing evolution

From [Kirschen]

- For several decades, amount of delivered energy by electricity network **have doubled about every 8 years.**
- In most of the world, average consumer deprived of electricity for **less than two minutes per year.**

How did that come to be ?

The rise of monopolies

In the US:

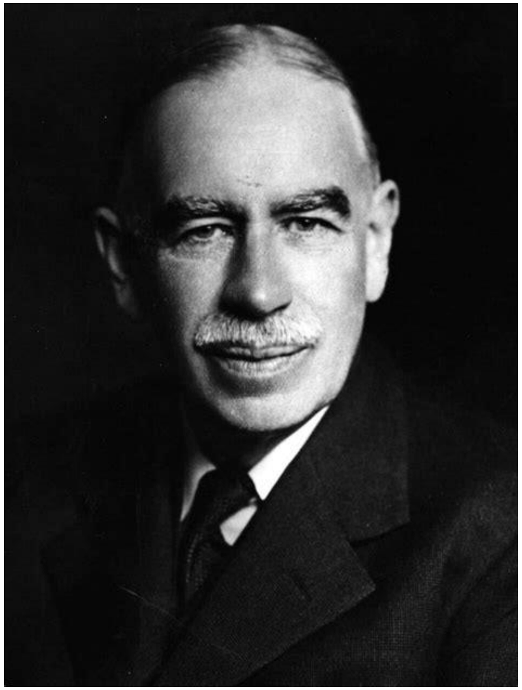
- In 1929, the Great Depression hits the United States
- Capitalism and the market economy - dominant at this time - is pointed as one of the main culprit of this drama.
- Franklin D. Roosevelt just elected in 1933 spoke about 'a cynic and egoist market economy'.
- Put in place a series of measures to decrease the power of private entities and increase the power of the State.

In Europe:

- In the 1950s, Europeans were out of two wars (1914-1918 & 1939-1945) and economic crisis (1920s).
- Same anti-captilastic sentiment
- Strong syndicates and governments push for nationalisation

The rise of monopolies

Supported by the theories of a renown economist of the time: **John Maynard Keynes** (1883-1946)



- Did not believe that there exist a constant equilibrium between demand and offer
- Saw the economy as in constant imbalance rather than as a succession of balanced states
- Promoted a political economy where demand is supported by:
  - large infrastructure work (as done in the US) or
  - public spending (e.g. the social security instaured in Europe)

The rise of monopolies

These political and economic views were to be applied to the electricity sector.

They were also supported by technological advances.

Evolution of production unit size:

- Start of century: ~25 MW
- From 1945 to 1965: increase from 50 MW to 300 MW
- 1970s: nuclear power plants of ~1000MW

Could built bigger, better and less expensive

- Unit cost of production divided by 4 or 5 between 1950 and 1980
- But the total cost of one unit increased as units become bigger

The rise of monopolies

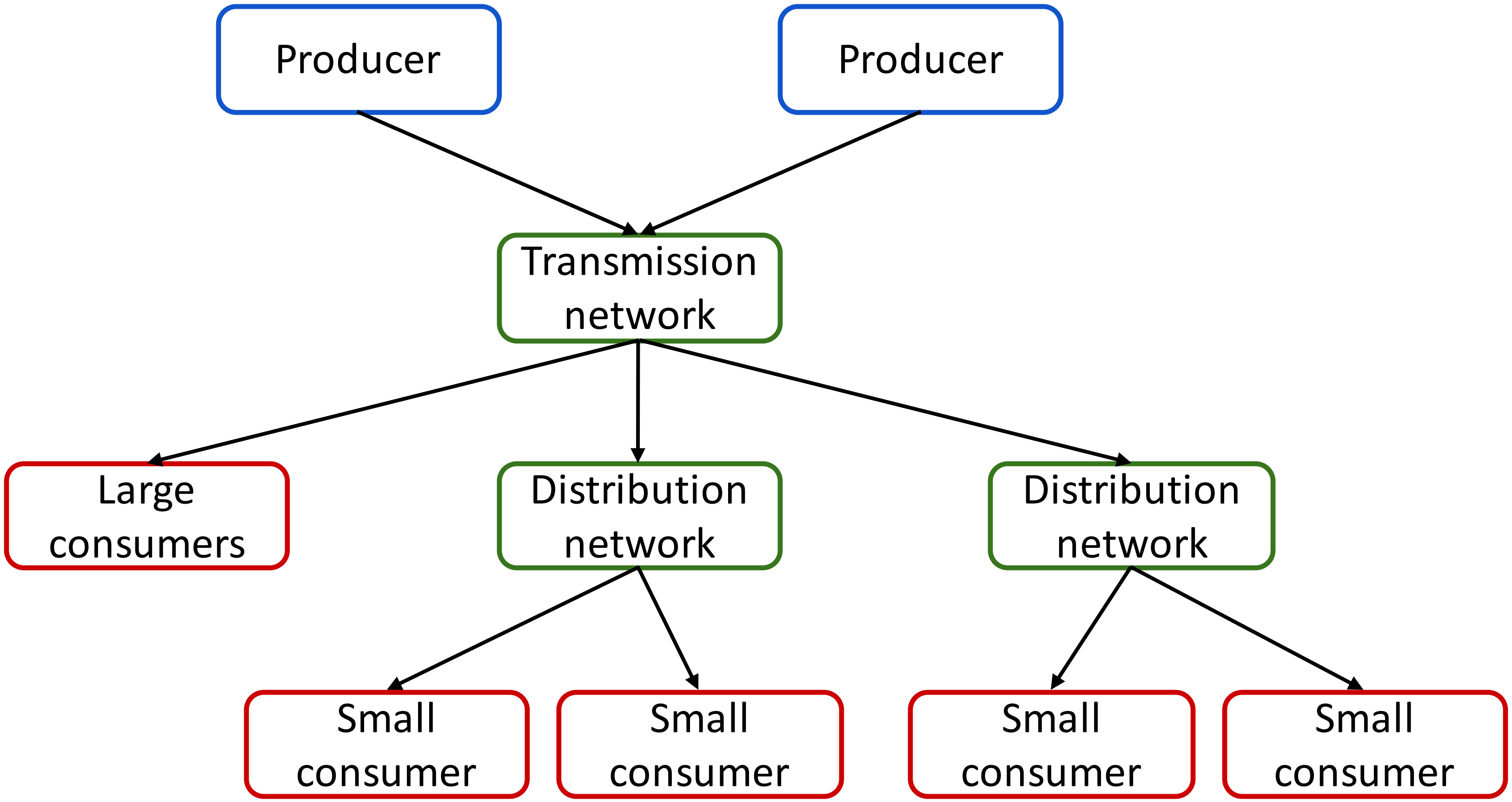
It pushed companies to progressively merge (e.g. In Belgium, a dozen private companies in 1950 and only one in 1990).

As a result, at the end of the 1980s, in most developped economies, the electricity sector was organised as a monopoly.

Vertically integrated structure (monopoly):

The same company produces, transmits and distributes (directly or not) the product to the consumers at a single imposed price.

The flow of energy - Reminder

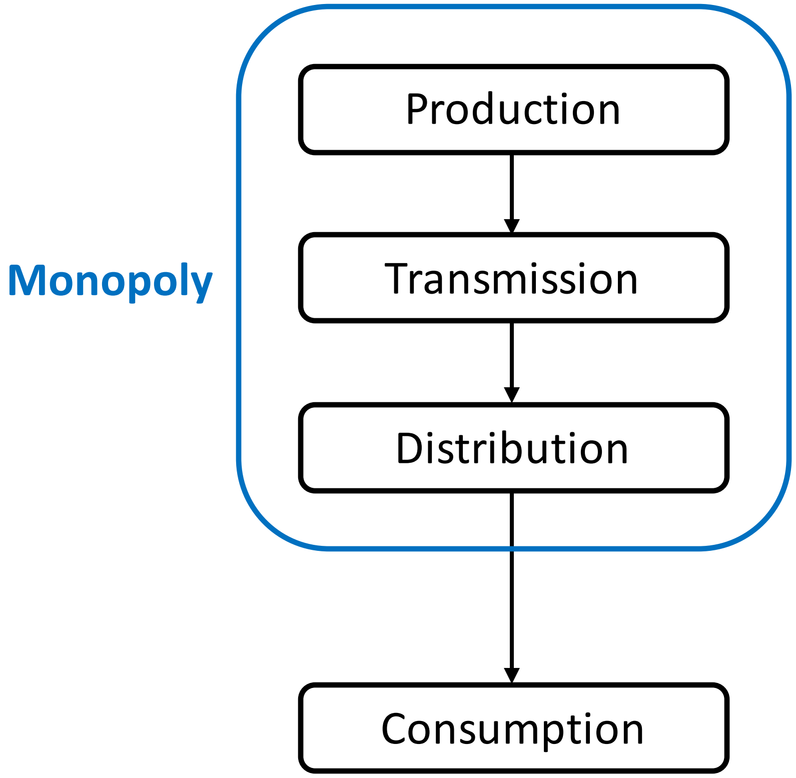


The rise of monopolies

Until the 1980s, no choice when buying electricity, suppliers of electricity had a monopoly over the area where a consumer lived.

Suppliers :

1. were vertically integrated
2. imposed a single regional price.



The rise of monopolies

Benefits:

- Contributed remarkably to economic activity and quality of life
- For several decades, amount of delivered energy by electricity networks doubled about every 8 years.
- Average consumer deprived of electricity for less than two minutes per year (in 2004)

Main problem: not considered to be economically efficient

- No incentives to operate efficiently
- Encourages unnecessary investments
- Government interfering in public entities
- **Higher prices** than in a market

Liberalisation ⇒ lower prices!

Liberalisation

In 1973, first oil crisis:

- oil price multiplied by 4 and again by 2 in 1979
- electricity prices go soaring after decades of decline

Created in Europe a loss of faith in the institution for the poor management of this crisis

Results:

- Election of Margaret Tatcher who launched a massive wave of privatisations
- Europe pushed for the 'Single market' and competition as a way to revive the old continent

Liberalisation

The new UK prime minister was inspired and supported by Friedrich Hayek (1899-1992)

- Proposed an alternative way of managing the economy (i.e. liberalism) shared by people like Milton Friedman and the Chicago Boys (Chili)
- Believed that the state should not take part in economic life
- Saw market as a tool to oppose any governmental planning or control
- Acquired a rising influence since the 1930s

Liberalisation

As for the nationalisation wave, liberalisation was supported by technological changes.

In the 1980s, development of a new production technology: **combined cycle gas turbine (CCGT).**

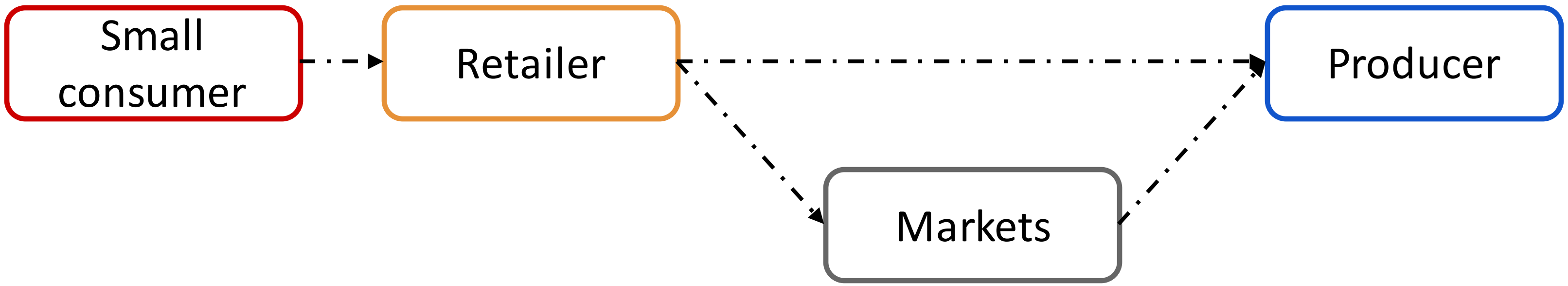
These units were able to use both gas and vapor to run turbines which produced electricity, thus obtaining efficiencies comparable to those of large production unit with unit of much smaller sizes (300 MW, even 50 MW).

Their size made them easy to deploy, thus removing barriers to entry that were protecting monopolies, while eating some of their added value.

They will be joined a few years later by the new renewable energies that enjoy the same modularity.

How to liberalise the electricity sector

1. Open production to competition
2. Introduce a new actor: the **retailer** (or provider)
   - Intermediary between producer and small consumer
   - Protect small consumers from price variation
3. Retailers buy electricity from producers
   - Bilateral contracts
   - Centralized market → operated by a **market operator**



Towards liberalisation

4. Open transmission and distribution to competition?

→ **No** ⇒ electricity transport is a **natural monopoly**

At the national level

→ transmission network operated by the **TSO** (Transmission system operator)

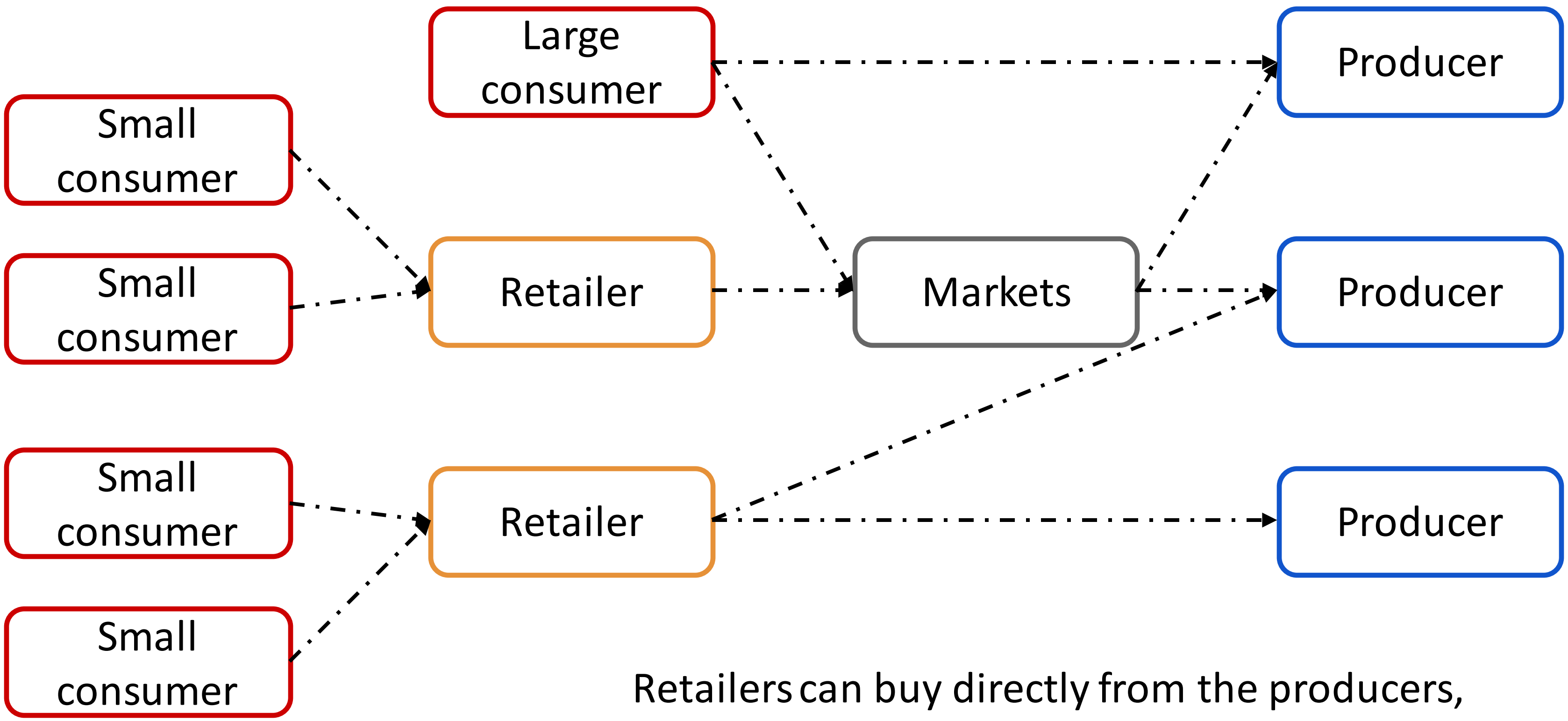
At the regional level

→ distribution network operated by the **DSO** (Distribution system operator)

5. Introduce the **ISO** (Independent system operator)

- Responsible for maintaining the security of power system operation
- Can be managed by the **TSO**

The flow of money



Retailers can buy directly from the producers, from the market, or a mix of the two.

The flow of money

Note that this is still a **very simplified view** of money flows.

Among others, this **does not show**:

- Payment of taxes and network fees. These are included in the price paid by the small consumers to the retailers which then pay those taxes and fees.
- Buying from producers/selling from retailers. Sometimes, as we will see later, producers (retailers) can be incentivised to buy (sell) energy, instead of selling (buying) it.
- Balancing fees
- Payments for capacity mechanisms
- Guarantees of Origin

The last actor

The **regulator**:

- Determines or approves the electricity market rules,
- Investigates the suspected cases of abuse (market power),
- Sets or controls the prices of products and services in the case of monopolies (e.g. distribution network fees)

Actors recap and examples

Generating company/producers:

1. Own one or several power plants
2. Sell electrical energy produced by these plants
3. Can also compete to sell ancillary services

Generation companies having assets in Belgium:

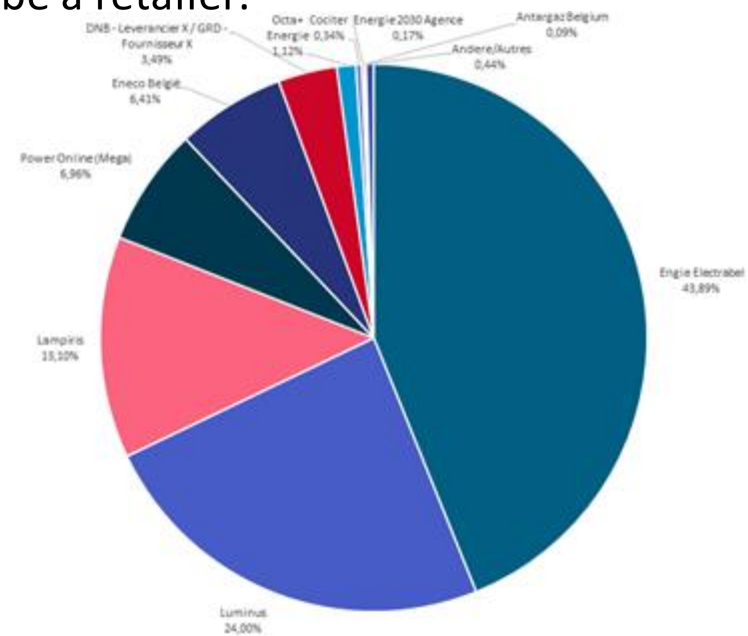
- Engie Electrabel
- EDF Luminus
- Eneco
- Lampiris (now TotalEnergies), Ecopower, Energie 2030 and Wase Wind

Actors recap and examples

Retailer:

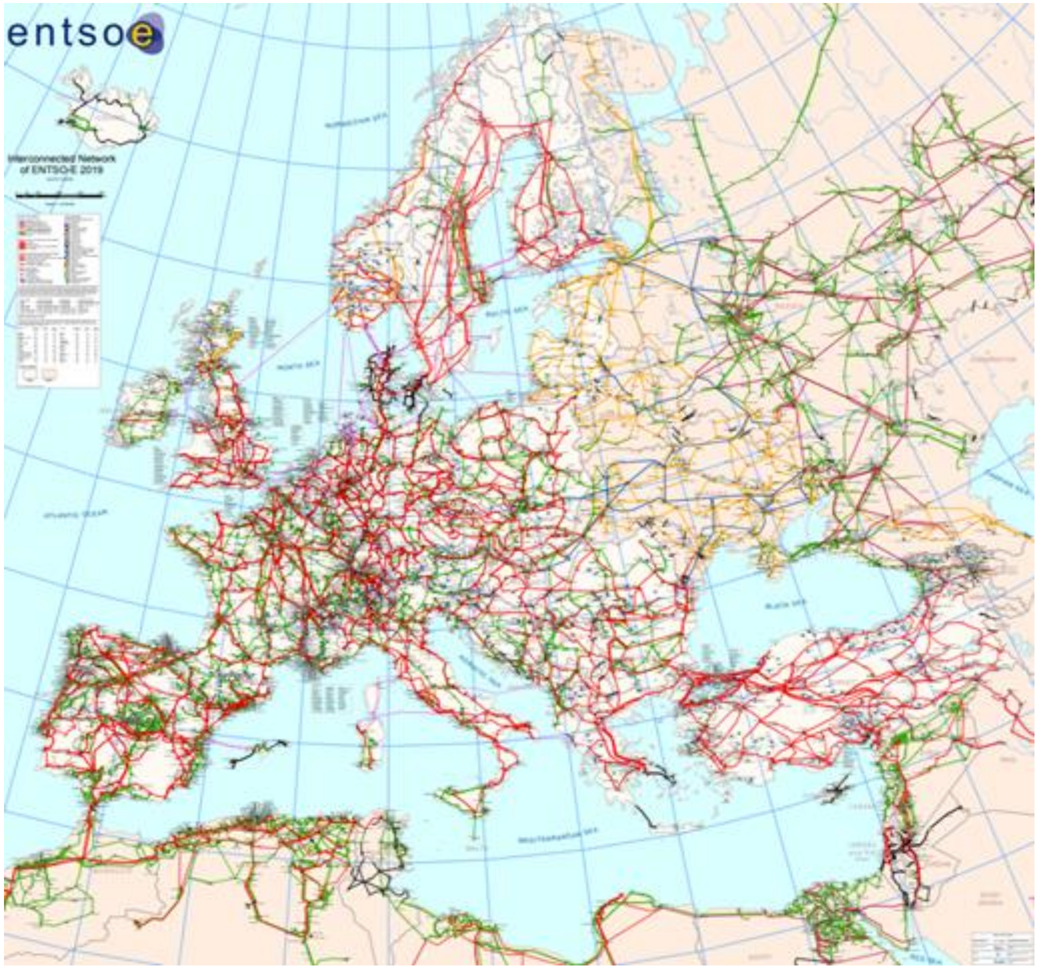
- Sell electricity to small consumers through a **retail market**
- Buy electricity from producers on the **wholesale market** (or directly from the producers)
- A generation company can also be a retailer.

Market share of retailers in Wallonia (Belgium)



Source: https://www.creg.be/fr/consommateurs/le-marche-de-lenergie/parts-de-marche-des-fournisseurs-denergie (Wallonia October 2021)

The Belgian example – Note on the European network



Source: https://www.entsoe.eu/data/map/ (November 2021)

Actors recap and examples

TSO - manages the transmission network
ISO - maintains the security of the network:

- In Belgium, TSO = ISO → Elia

At European level:

- **ENTSO-E** – European network of transmission system operators for electricity

Actors recap and examples

Several **DSO**s for the three Belgian regions:

- *Wallonia*: Ores, Resa, Régie de Wavre, AIESH, AIEG
- *Brussels-Capital region*: Sibelga
- *Flanders*: Eandis, Infrax

Source: http://www.elia.be/en/about-elia/electricity-market-players
Image source: Damien Ernst Facebook

Actors recap and examples

1 country, 4 **regulators**:

1. *National* : CREG – Commission de Régulation de l'Electricité et du Gaz
2. *Wallonia* : CWAPE – Commission Wallonne Pour l'Energie
3. *Brussels-Capital* : BRUGEL – Brussels Gaz and Electricity
4. *Flanders* : VREG – Vlaamse Regulator van de Elektriciteits- en Gasmarkt

CREG

brugel

LE REGULATEUR BRUXELLOIS POUR L'ENERGIE

ACER

European Union Agency for the Cooperation of Energy Regulators

CWaPE

Commission Wallonne pour l'Energie

vreg

VLAAMSE REGULATOR VAN DE ELEKTRICITEITS- EN GASMARKT

Actors recap and examples

Market Operator

- Matches generating bids (from sellers) and consumption offers (from buyers)
- Takes care of the settlement of the accepted bids and offers

The market operator depends on the type of market.

Moreover, most European markets have been integrated.

Typical market operators include EPEX SPOT, EEX and ICE Endex.

Open questions about liberalisation

Main benefit of monopoly utility model: the operation and development of the power system was taken within a single organisation

As it is not the case anymore with liberalisation:

1. Is it possible to coordinate the different entities to achieve least cost operation? (e.g., maintenance of transmission system done jointly with the maintenance of operation line, coordination of long-term development in generation and in transmission, etc.)
2. Will free markets ensure that generation will always match demand?
3. How to optimize future investments?

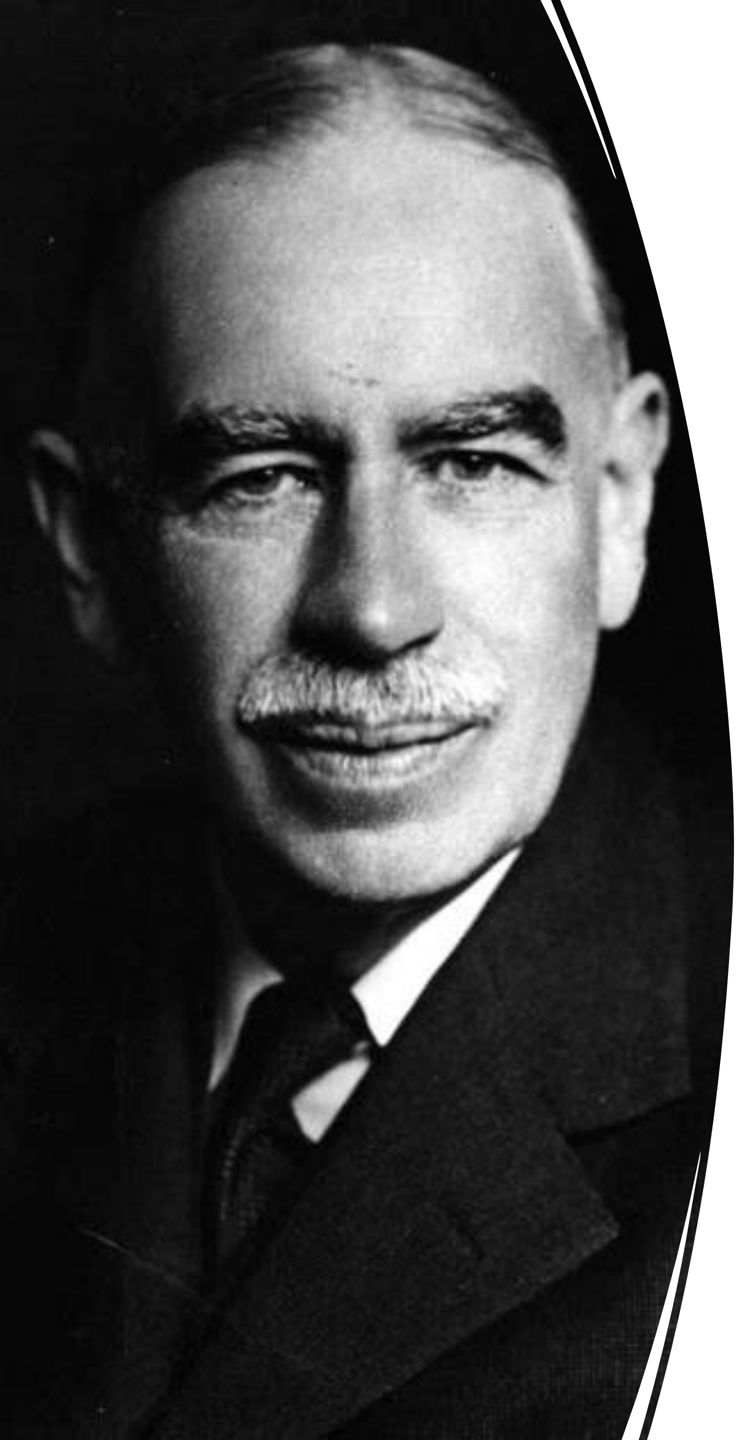
Remark about liberalisation

Most of the economic laws supporting the push for liberalisation suppose a market with perfect competition.

But it is far from being the case in electricity markets.

Typically, in France, EDF – the former national monopoly – still owns most of the production assets.

To ensure fair competition, Europe imposed correcting mechanisms such as ARENH (Accès Régulé à l’Electricité Nucléaire Historique) which imposes to EDF to sell part of its production to its competitors at a regulated price.



“The ideas of economists and political philosophers, both when they are right and when they are wrong are more powerful than is commonly understood. Indeed, the world is ruled by little else. Practical men, who believe themselves to be quite exempt from any intellectual influences, are usually slaves of some defunct economist.”

John Maynard Keynes

Let us zoom on two actors

1. Producers
2. Retailers

Producers

The goal of producer is to maximise their profit.

Their profit is equal to their revenues minus their costs.

Revenues are simply equal to the quantity of energy they sell times the price to which it is bought.

Costs are generally divided into two categories:
1. Long-term costs: investments and maintenance costs
2. Short-term costs: costs of operations, of fuels, ...

Another important cost is the **marginal cost** of production. It is the cost of producing the last unit of energy.

A simplified view of the producer

Let us consider a generating company that tries to maximise the profits Ω_i it derives from a single generating unit called unit i .

Mathematically, this resolve in solving the problem:

$$\max \Omega_i = \max(\pi P_i - C_i(P_i))$$

where P_i is the power produced, π the price at which this production is sold, and $C_i(P_i)$ is the cost of producing this power.

Optimality when $\frac{d\Omega_i}{dP_i} = \frac{d(\pi P_i)}{dP_i} - \frac{dC_i(P_i)}{dP_i} = 0$

First term = **marginal revenue** of unit i, equal to the price π
Second term = **marginal cost** of production of unit i

For optimality, production must be increased until the marginal cost is equal to the price on the market.

Example

Consider the unit with the inverse production function (quantity of fuel needed to generate P_1) $H_1(P_1) = 110 + 8.2P_1 + 0.002P_1^2$ MJ/h with a minimum stable generation is 100 MW and a maximum output of 500 MW.

Cost of fuel F = 1.3 €/MJ.

Questions:

A. What is the power that should be generated by the unit to maximise profit if electricity can be sold at 12 €/MWh?

B. At which electricity prices should the unit operate at maximum output?

C. What is the electricity price below which the unit cannot make any profit?

Example – Solution

A. Cost of production if F is cost in fuel per €/MJ: $110F + 8.2P_1F + 0.002P_1^2F$ €$/h$

Since $F = 1.3€/MJ \rightarrow C_1(P_1) = 143 + 10.66P_1 + 0.0026P_1^2$ €$/h$

Optimality condition: $\frac{dC_1(P_1)}{dP_1} = 10.66 + 0.0052P_1 = 12\,€/MWh \rightarrow P_1 = 257.7MW$

Solution valid because between minimal (100 MW) and maximal output (500 MW).

B. $\frac{dC_i(P_i=500)}{dP_i} = \pi \rightarrow \pi = 13.26\,€/MWh$

C. Can be computed by solving the following minimisation problem:

$$\min_{\pi, P_1} \pi$$
$$\text{subject to} \quad \pi * P_1 - H_1(P_1) \geq 0$$
$$100 \leq P_1 \leq 500$$

More realistic scheduling

The production profile needs to be optimised over several market periods rather than one due to (among others):

Start-up costs: costs of starting units. Diesel generators and open cycle gas turbines = low start-up costs. Large thermal units: large amount of heat energy before the steam is at a temperature and pressure that are sufficient to sustain the generation of electric power. They have large start-up costs.

Dynamic constraints: Limits placed on the variation of production of a generator to avoid mechanical stress (mainly of the prime mover) and all the problems related to gradients in temperature.

Environmental constraints: E.g.: rate at which a certain pollutant is released in the atmosphere is limited (or total over one year); constraints on the use of water for hydro plants.

How can we measure the cost of producing electricity?

The Levelised Cost of Electricity (LCOE) - or Levelised Energy Cost (LEC) is often taken as a measure for defining the cost of electrical energy.

It is the net present value of the unit-cost of electricity.

LCOE is often taken as a proxy for the average price that the generating asset must receive in a market to break even over its lifetime.

It is a first-order economic assessment of the cost competitiveness of an electricity-generating system that incorporates all costs over its lifetime: initial investment, operations and maintenance, cost of fuel, cost of capital.

LCOE – Mathematical formulation

Mathematically, LCOE is computed as:

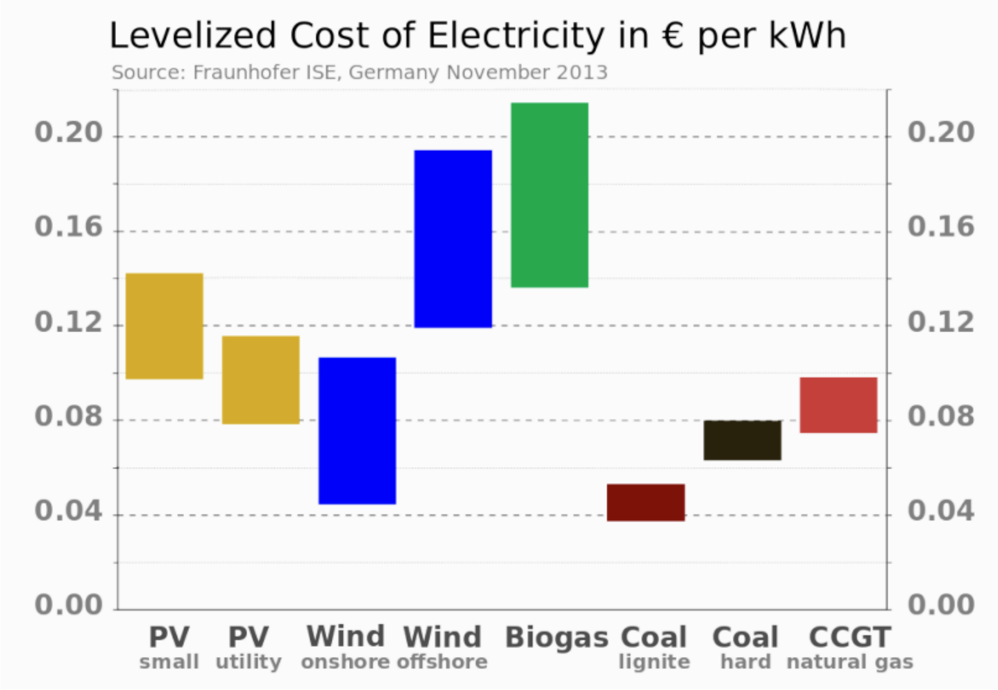
$$LCOE = \frac{cost}{electricity} = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

where:

- I_t = Investment expenditures in the year t
- M_t = Operations and maintenance expenditures in the year t
- F_t = Fuel expenditures in the year t
- E_t = Electricity generation in the year t
- r = Discount rate
- n = Life of the system

LCOE - Example

The LCOE for some newly built renewable and fossil-fuel based power stations in €/kWh in Germany (estimation done in 2013 by the Fraunhofer Institute):



Net Present Value

To evaluate the profitability of a project, producers can use the net present value. The net present value (NPV) of a project for electricity generation is defined as:

$$NPV(r) = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t}$$

where C_t is the cash flow during year t.

$$C_t = R_t - M_t - F_t - I_t$$

where R_t are the revenues generated by the power plant during year t.

The internal rate of return (IRR) of a project is the value of r that leads to a NPV equal to 0.

The payback period is the period of time required to recoup funds expended in an investment.

LCOE, NPV & IRR - Exercise

Exercice: Mister X has installed at home 4 kWp of PV panels at a price of 6000 €. His panels have a lifetime of 20 years. This installation generates 3500 kWh of electricity per year.

[A] Compute the LCOE given a discount rate of 0% and 5%.

[B] Assume a retail price for electricity of 23 c/kWh, compute the payback period of the installation.

[C] Given the same retail price for electricity, compute the internal rate of return of the project.

Reminder: $\sum_{k=a}^{b} q_k = \frac{q^a - q^{b+1}}{1-q}$ where $a, b \in \mathbb{N}$ and $q \neq 1$.

Net Present Value - Exercise

[A] We have: $I_1 = 4000€$ and $I_t = 0$ if $t \neq 1$

$M_t = 0, F_t = 0, E_t = 3500\ \forall t$

$n = 20$

If r = 0, we have LCOE = 6000/(3500x20) = 85 c/kWh.
If r ≠ 0, the LCOE can be rewritten as: $q = \frac{1}{1+r}$

$$LCOE = \frac{\frac{600}{(1+r)}}{\sum_{t=1}^{20} \frac{3500}{(1+r)^t}} = \frac{6000 \times q}{3500 \times \sum_{t=1}^{20} q^t} = \frac{6000 \times q}{3500\, \frac{q-q^{21}}{1-q}}$$

where $q = \frac{1}{1+r}$.

If r = 0.05, we have q = 0.952 and LCOE = 5712/(3500x12.42) = 131c/kWh.
If r = 0.10, we have q = 0.909 and LCOE = 5454/(3500x8.5) = 183 c/kWh.

Net Present Value - Exercise

[B] Every year, this installation is generating 0.23 x 3500 = 805 € worth of electricity.

This installation costs 6000 €. The payback time is therefore equal to 6000/805 = 7.45 years.

[C] No closed-loop solutions. How to proceed?

Retailer

The role of the retailers is to buy electricity to producers to sell it at consumers.

The price they offer to their customers is either **fixed** or **variable**, depending if they have less or more aversion to risk, respectively.

Fixed energy price computed as A + X*kWh

- **Constant** during the entire contract duration
- Danger: If the price is high at the contract settlement, it will remain high.

Variable energy price = A + (Index*B+C)*kWh

- The index and thus the price **varies** during the entire contract duration.
- Index may be on the day-ahead or future markets.

In Belgium: 60% of fixed price contracts (*before rise of prices*)

Sources: [Dumas] & https://www.cwape.be/node/138#prix-fixes-et-prix-variables

Retailer

Challenge: to buy energy at a variable price on the wholesale market and sell it a fixed price at the retail level.

The quantity-weighted average price at which a retailer purchases energy should be lower than the rate it charges its customers.

Must forecast very well the consumption of its consumers to reduce its exposure to spot market prices (accuracy usually good if a large group of customers).

Retailers may offer more competitive tariffs to customers which record the energy consumed at every time period.

Retailer – Building offers

The first option to build an offer is to buy directly from the producer.

They can also buy electricity through **a market**.

But what is exactly a market ?

What are electricity market**s**?

What is a market ? [Investopedia]

"Place where two parties can gather to facilitate the exchange of goods and services. The parties involved are usually buyers and sellers. The market may be physical like a retail outlet, where people meet face-to-face, or virtual like an online market, where there is no direct physical contact between buyers and sellers."

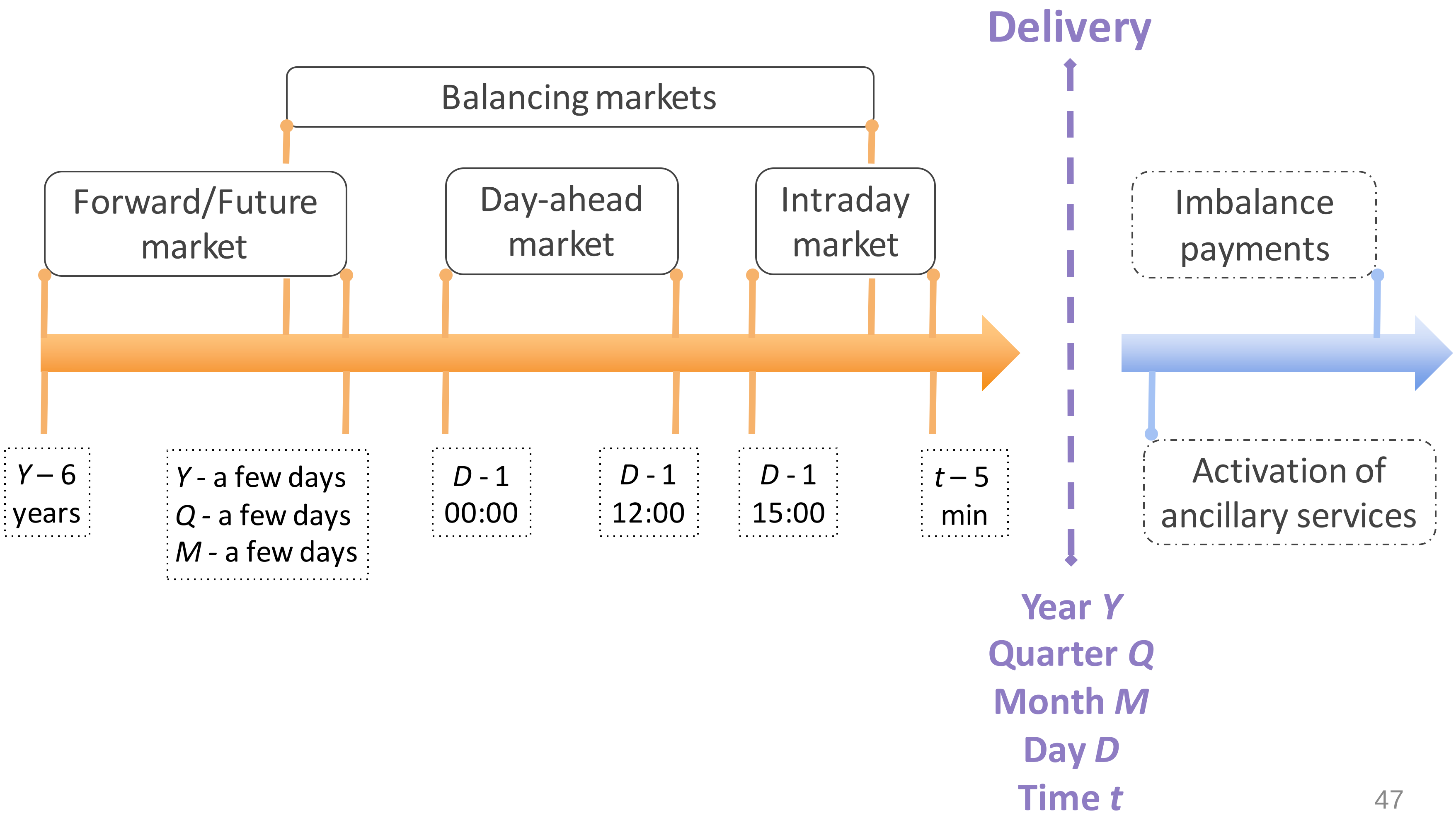
What is an **electricity** market?

- product → electricity (both energy and power)
- buyers → retailers & sellers → producers
- mostly virtual

Why an *'s'* in market**s**?

Electricity has some special properties → several ways to exchange it

Chronology of Markets



Two families of markets

Bilateral contracts

Electricity pools

Bilateral contracts

An exchange of energy between two actors: a buyer and a seller.

Different coexisting forms of bilateral trading depending on the amount of energy to be traded and the time available.

1. Customised long-term contracts: negotiated privately; usually involve the sale of large amounts of energy; large transaction costs
2. Trading "over the counter" (OTC): Involve smaller amounts of energy to be delivered according to a standard profile (how much energy should be delivered during the different periods of the day and the week). Much lower transaction costs; use to refine positions.

Bilateral contracts

3. Electronic trading: Offers to buy energy or bids to sell energy are traded. Bids and offers can be seen by everyone but they are anonymous.
   a. When party enters new bid, the system checks to see whether it matches an existing offer (offer with a price greater or equal to the bid).
   b. If yes, a deal is struck. Otherwise, the bid is added to the list of the bids.
   c. Similar procedure with offers.

Remarks: Electronic trading is fast and cheap. Used to refine positions in the minutes before the market closes

Electricity pools

Electricity naturally pooled when flowing from the generators to the loads
⇒ It was felt that trading could be done in a centralised manner through electricity pools.

No repeated interactions between buyers and sellers to reach the market equilibrium.

A pool provides a mechanism for reaching this equilibrium in a systematic way.

Electricity pools – How they work

Producers submit bids for the period under consideration.

Bids = amount of electrical energy at a certain price. Bids are ranked according to increasing price and a supply curve of the market is built.

Consumers submit offers (amount of energy they are willing to buy at a certain price). A demand curve is built.

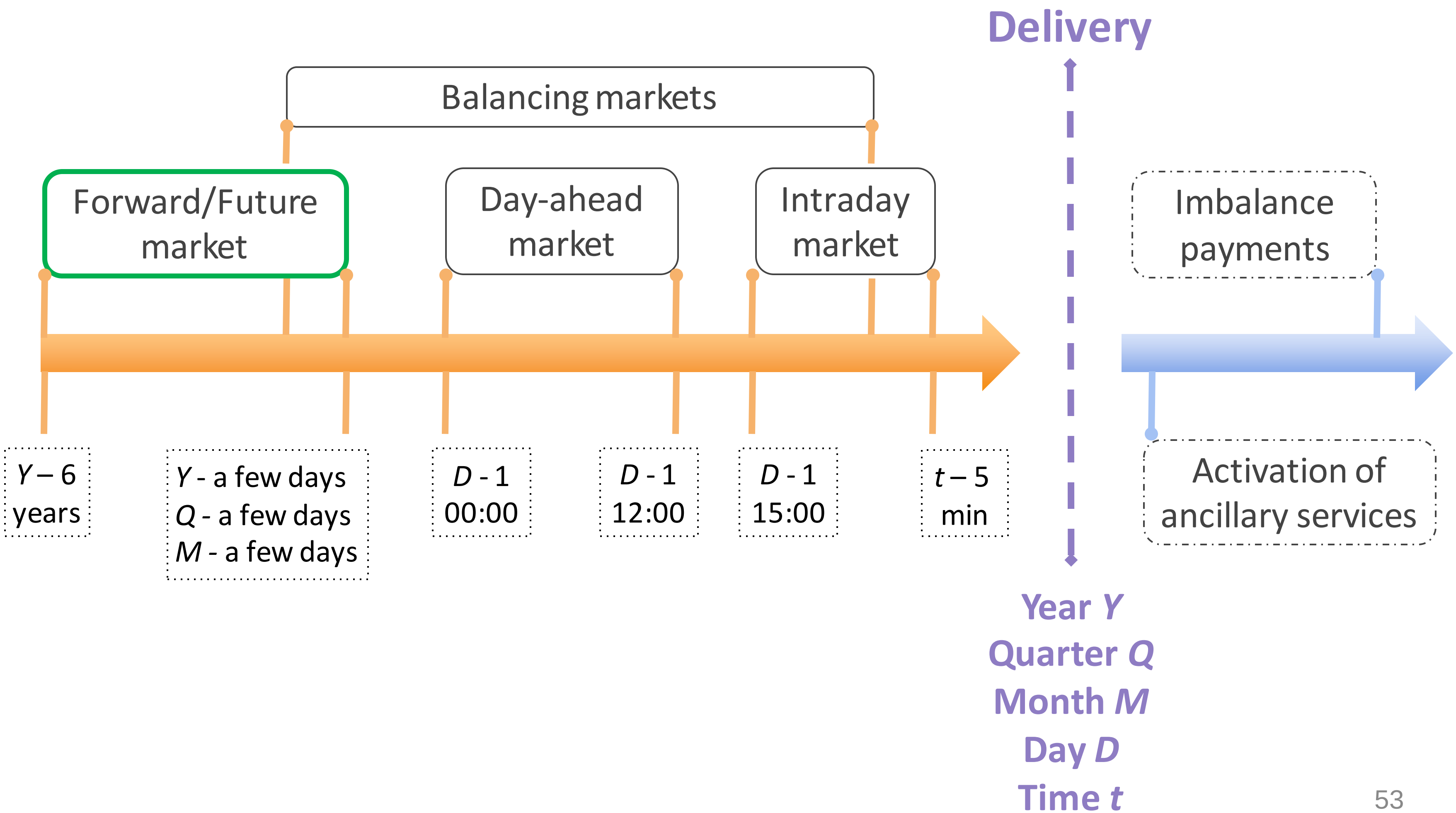
⇒ These two curves define the merit order.

Intersection of demand and supply curves represent the market equilibrium price (also called the system marginal price, SMP).

Bids inferior to the market equilibrium price and offers above this price are accepted.

More information on that subject in the next lesson.

Let us focus on a first market



Hedging

What is hedging? Let us take an example.

A generator is interested in hedging its revenues from producing electricity. It sells 100 MWh of electricity every hour of a year at 50 €/MWh in a forward market:

- '+': it **hedges against the risk** of prices (and revenues) dropping to 30€/MWh.
- '-': it gives up potential additional revenues if prices increase to 100 €/MWh.

An electricity-intensive consumer will also wish to hedge its costs. If the consumer buys that annual 100 MWh contract for 50 €/MWh:

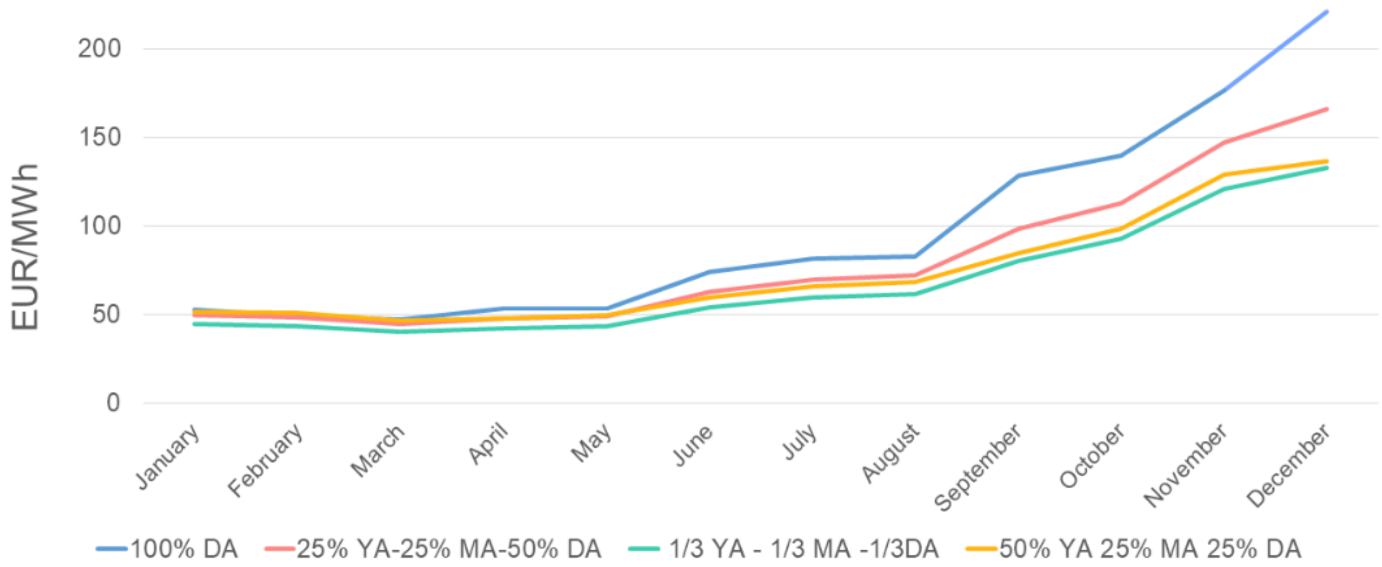
- '+': it **avoids the risks** of losing money if prices increase to 100 €/MWh.
- '-': it gives up on the potential lower cost of 30 €/MWh.

Source: ACER's Final Assessment of the EU Wholesale Electricity Market Design

Hedging

Using proper hedging strategies allows to reduce the cost of energy.

Figure 23: Unit procurement costs (EUR/MWh) of a supplier using diverse hedging strategies in the German electricity market in 2021



Source: ACER based on Platts.

Source: ACER's Final Assessment of the EU Wholesale Electricity Market Design

Forward/ Future market

The forward market is the most prominent electricity market when it comes to the number of transactions (88% of transactions), followed by spot markets covering day-ahead (11%) and intraday (1%) timeframes.

Source: https://www.emissions-euets.com/internal-electricity-market-glossary/1472-forward-electricity-market

Forward contracts and forward markets

A forward contract specifies the following:

1. the quantity and quality of the product to be delivered,
2. the date of delivery,
3. the date of payment following delivery,
4. the penalties if either party fails to honour its commitment, and
5. the price to be paid.

Reduce exposure to the volatility of the spot market.

A forward market gathers producers and consumers interested in trading with forward contracts.

Forward price should reflect **the consensus expectation of the spot price.**

Future contracts and Future markets

Secondary markets where producers and consumers of the commodity can buy and sell standardised forward contracts.

Contract **not backed by physical delivery** ⇒ they are called future rather than forward contracts.

As the date of delivery approaches, the speculators must balance their position because they cannot produce, consume or store the commodity.

May help producers and consumers to manage other risks than the price risk. Increase also the **liquidity** of the market.

Forward/Future market - Reminder

Diverse products available: yearly, quarterly or monthly base-load products.

Fixed amount of energy for the given period

Trading horizon from **6 years up to a few days ahead** of the product first delivery day.

Market operator: EEX, ICE Endex.

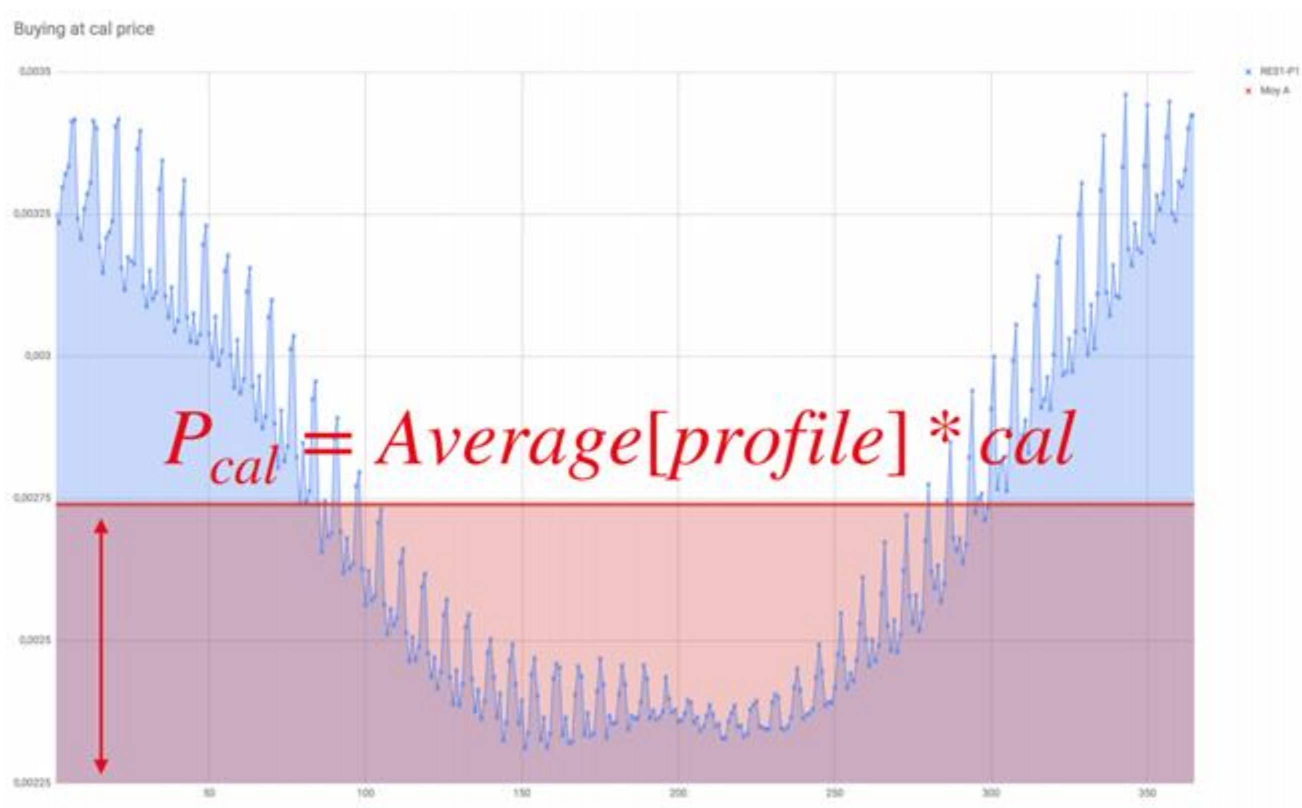
Figure 25: **Relative shares of trading volume per year in the future in Germany (2019 - 2021)**

Source: ACER data.

Note: The blue, yellow and grey bars respectively sum up to 100% (over all timeframes). For 2020 (respectively 2021), Year +1 means products for delivery in 2021 (respectively 2022).

Forward/Future market – Supplier example

How does a supplier buy energy in advance?



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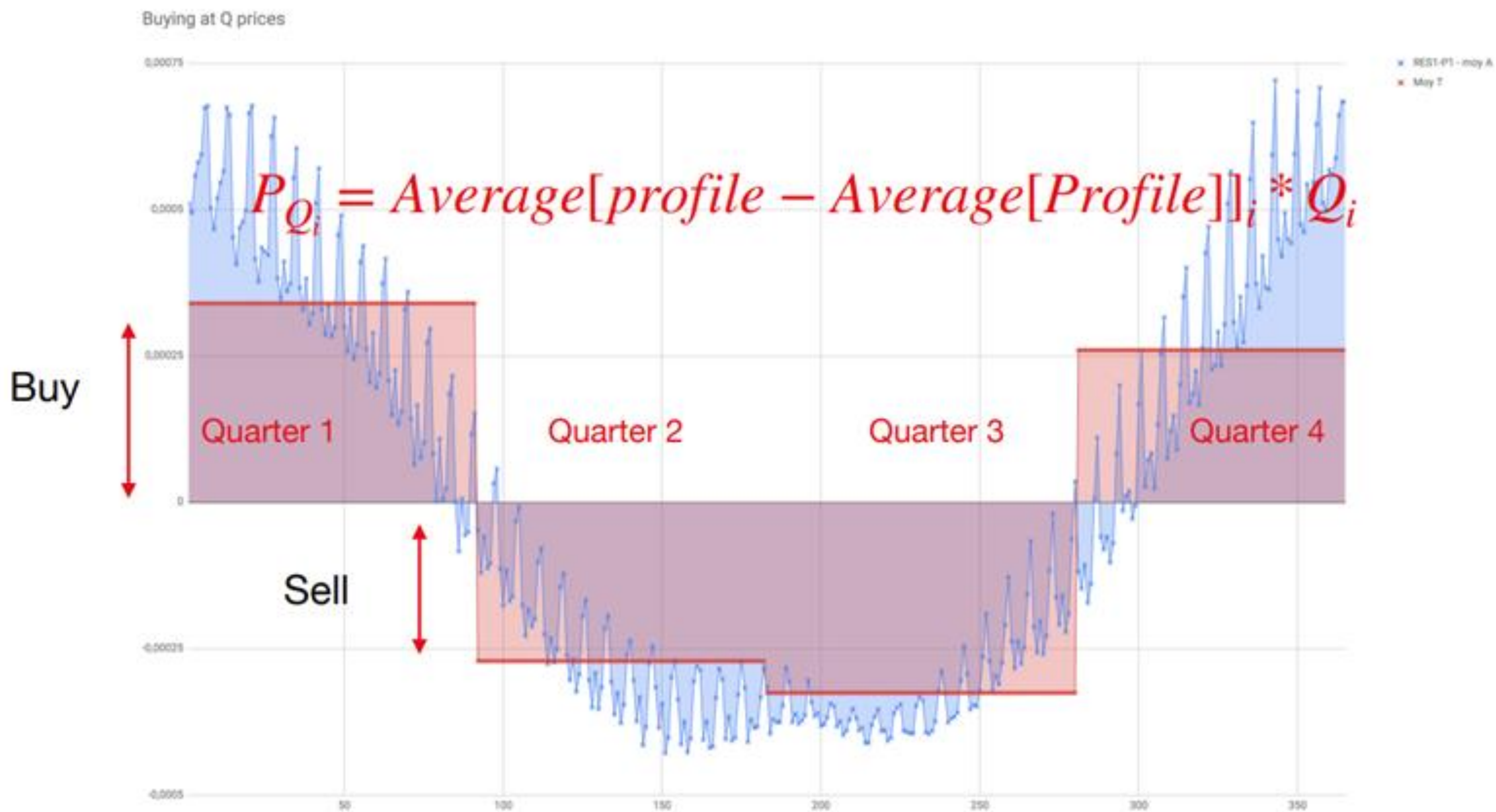

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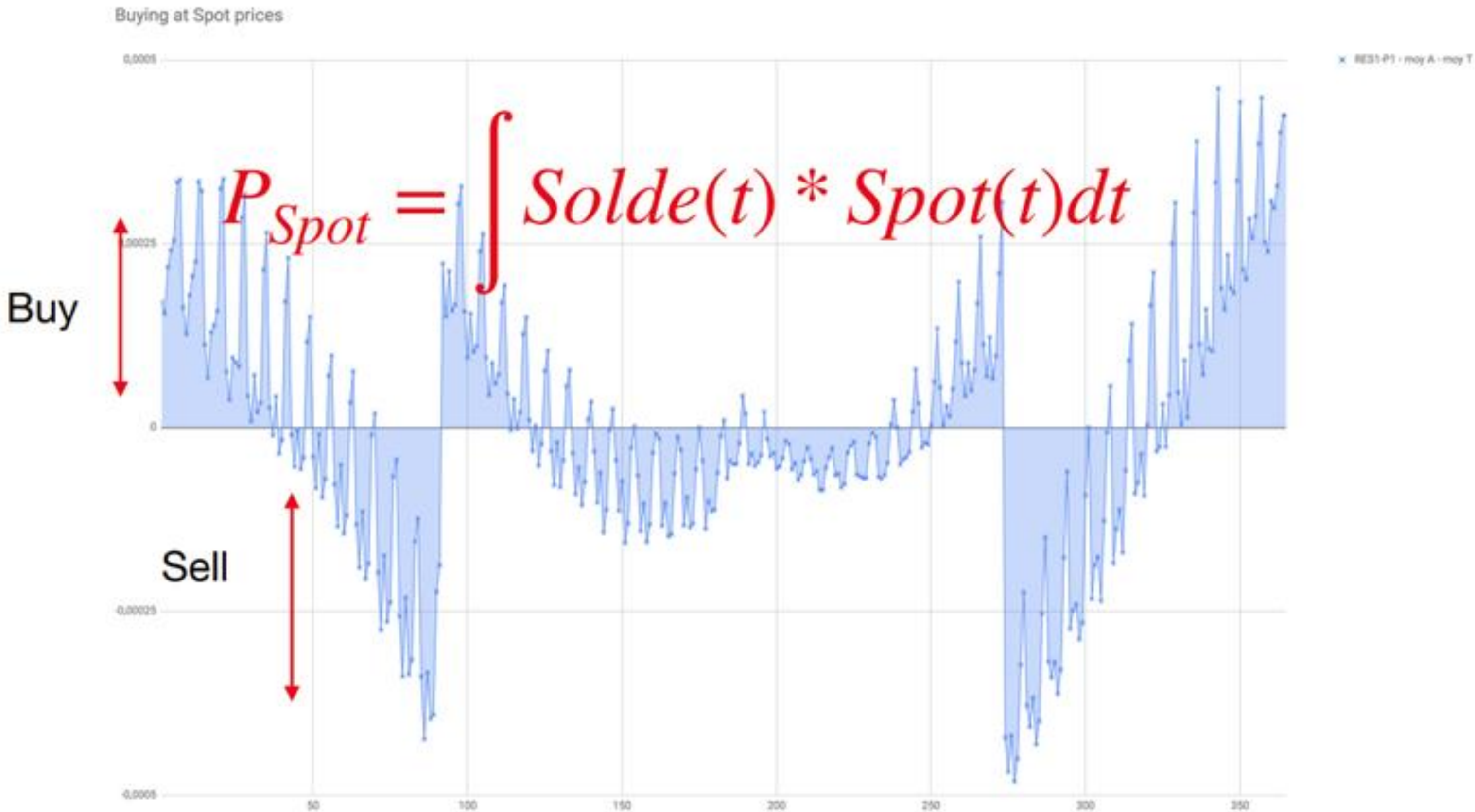


Options

Future and forward contracts are firm contracts, the delivery is **unconditional**. If the seller is unable to deliver the quantity agreed or the buyer cannot take the full delivery → must buy/sell it via some other market (e.g. day-ahead).

Options: Contracts with **conditional delivery:** contracts are only exercised if the holder of the contract is interested in doing so.

Call option: gives the holder the right to buy a given amount of a commodity at a price called the exercise price.

Put option: gives the holder the right to sell a given amount of a commodity at the exercise price.

Contracts for difference

Contracts for difference (or swaps) work in the following manner:

- The two parties agree on a strike price and an amount of commodity for a given period of time.
- The contract is settled in a way that the difference between the strike price and the spot market price, at that time period, times the amount agreed in the contract is paid by the buyer.

For instance, if the spot price is 100€/MWh, the swap price is 75€/MWh and the amount is 20 MWh, the buyer pays 25*20 € to the seller at the given date and time. Of course, if the spot price goes below 75€/MWh, then the seller owns money to the buyer.

Generally, contracts for difference are often grouped for several time periods. For example, peak swaps cover several peak load hours.

More complicated forms of swaps exist (*i.e.* caps, floors and collars, see [Biggar]).

Power Purchase Agreement

A Power Purchase Agreement (PPA) is a long-term (10-20 years) contractual agreement between an energy buyer and seller.

The buyer agrees to buy at a fixed price per MWh (part of) the production of a generation asset for the length of the contract.

This can be a good source of financing for project developers while guaranteeing a protection to investors.

This type of contract can be used for any generation asset but since governmental subsidies for renewable energy projects started to decrease, renewable projects developers have increasingly turned to PPAs for financing.

Source: https://pexapark.com/solar-power-purchase-agreement-ppa/

Collateral

Collateral refers to **money put aside as a guarantee** by the buyer and seller of forward products. This guarantee **covers the risk of failure** of one of the counterparties.

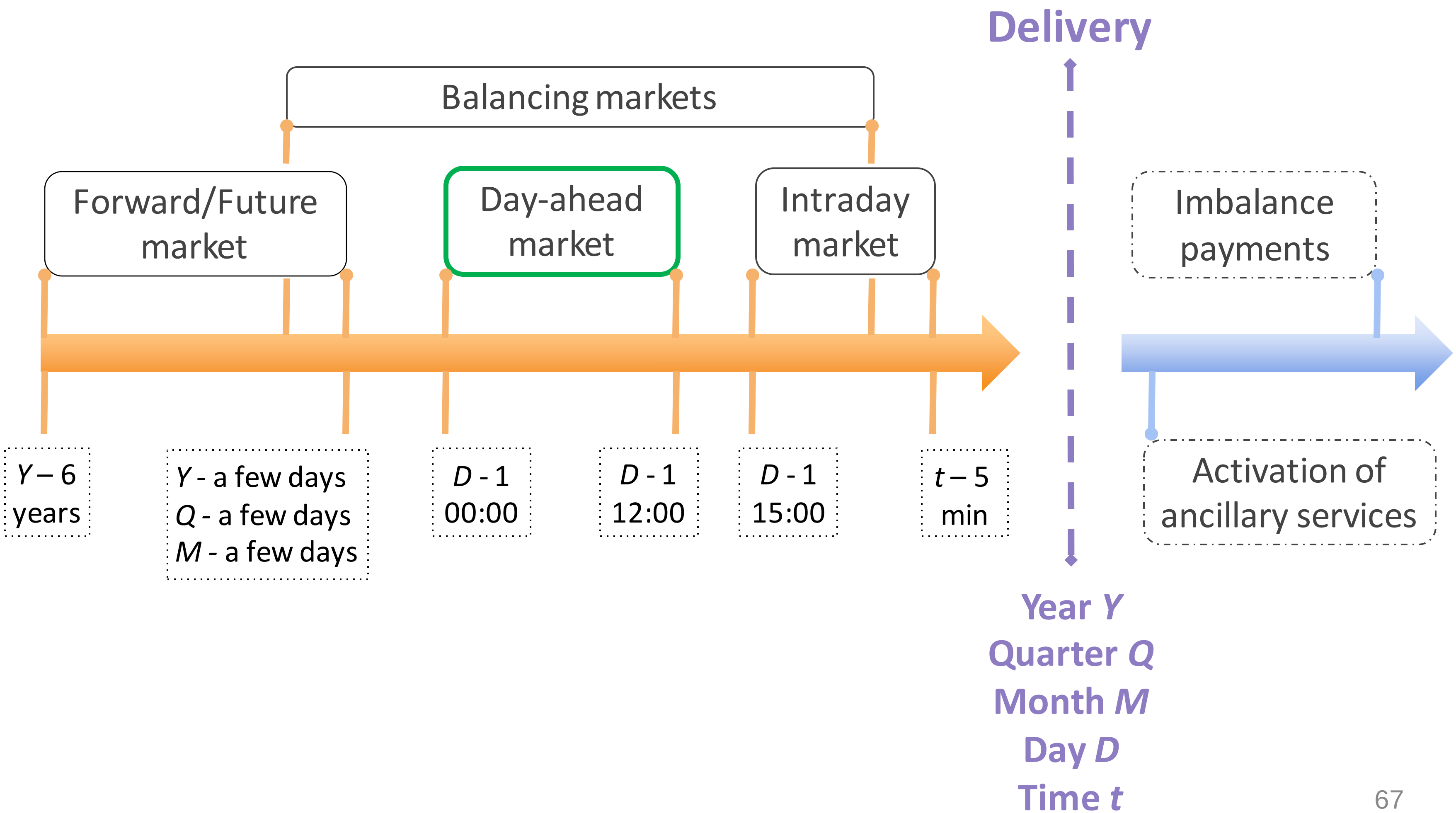
Hedging via trading in **forward and futures markets requires collateral**.

When prices jump and volatility rises, collateral requirements also significantly grow, increasing the financial guarantee that market participants need in order to hedge for future years.

Increase in collateral requirements often implies increased debt which might put some market participants at risk of bankruptcy.

Source: ACER's Final Assessment of the EU Wholesale Electricity Market Design

Next week...


Delivery
Balancing markets
Forward/Future market
Day-ahead market
Intraday market
Imbalance payments
Activation of ancillary services
Y – 6 years
Y - a few days
Q - a few days
M - a few days
D - 1 00:00
D - 1 12:00
D - 1 15:00
t – 5 min
Year Y
Quarter Q
Month M
Day D
Time t