ELEC0018-1 Energy Markets

Lecture 2: Energy Markets Overview

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Menu for this lesson

1. The flow of electrical energy
2. Liberalisation of the electricity industry
3. Structure and timeline of the electricity markets
4. Forward/Future electricity market
5. Day-ahead electricity market
6. Intraday electricity market
7. Balancing electricity market
8. Ancillary services
9. Electricity markets coupling

The flow of energy
- How electricity reaches you

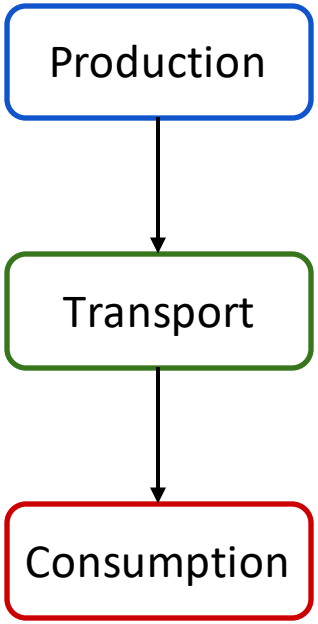
When you plug an electrical device in, electricity flows in.

How?

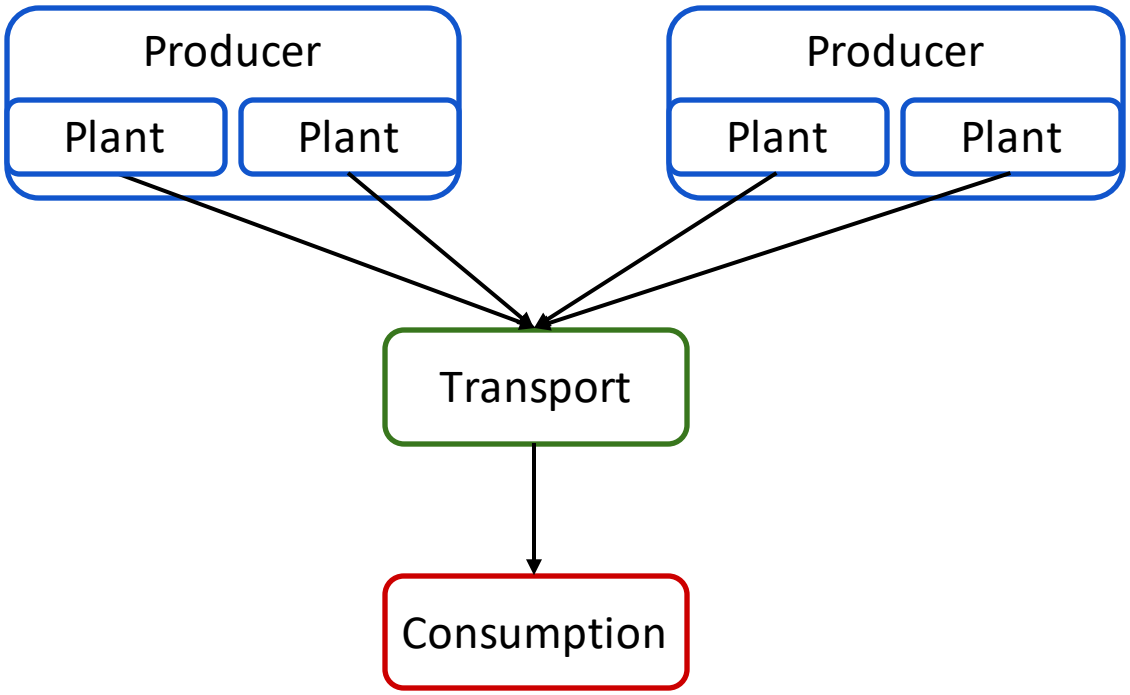
Quick overview of the three main components of the electricity network:

- Production
- Transport
- Consumption

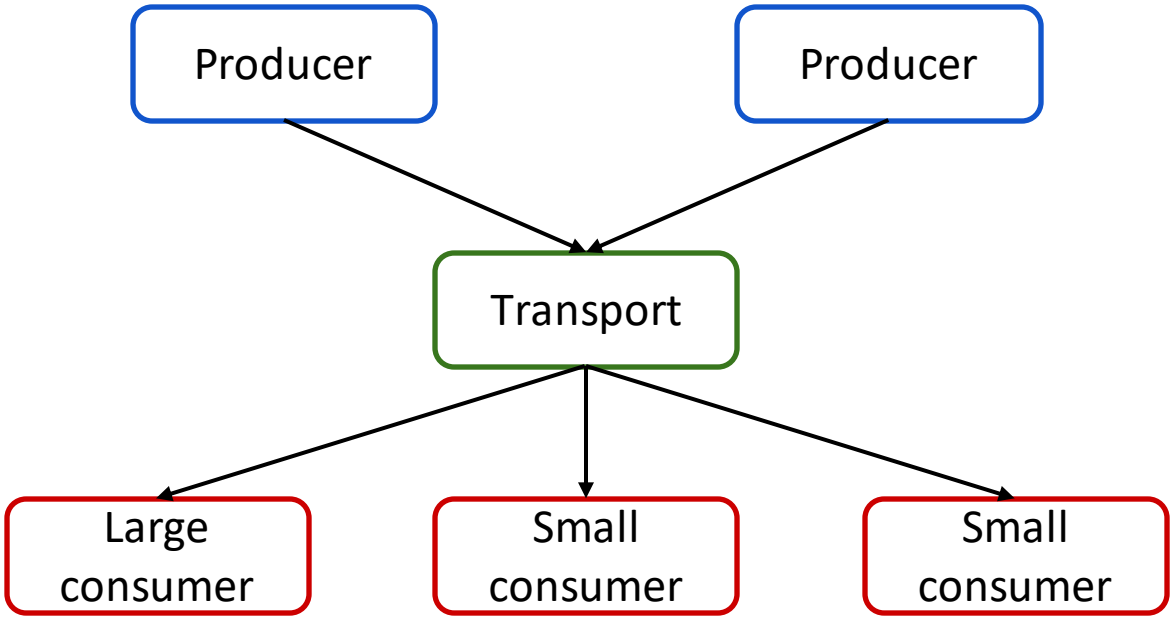
The flow of energy
- 3 main components



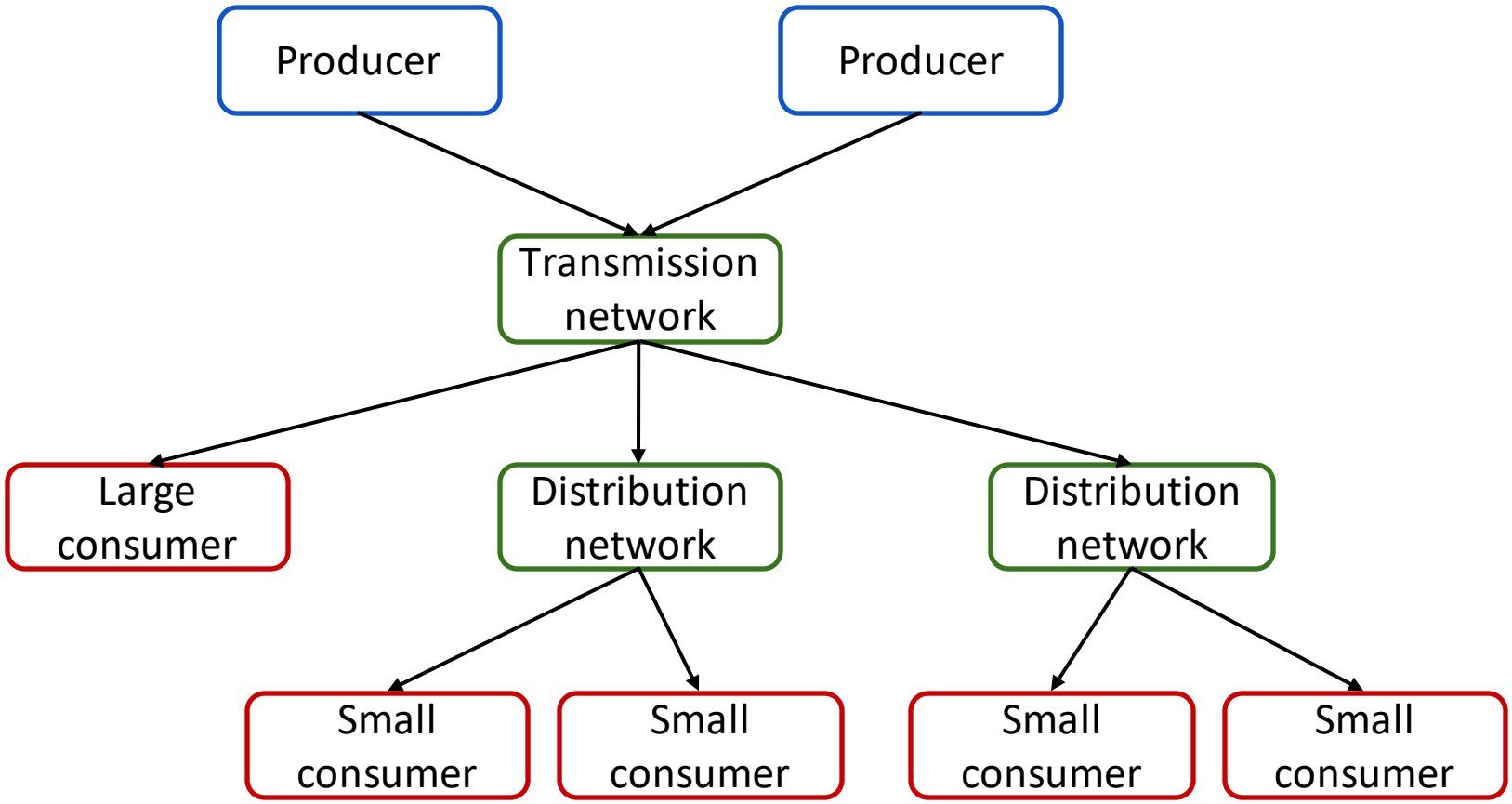
The flow of energy - Production



The flow of energy - Consumption

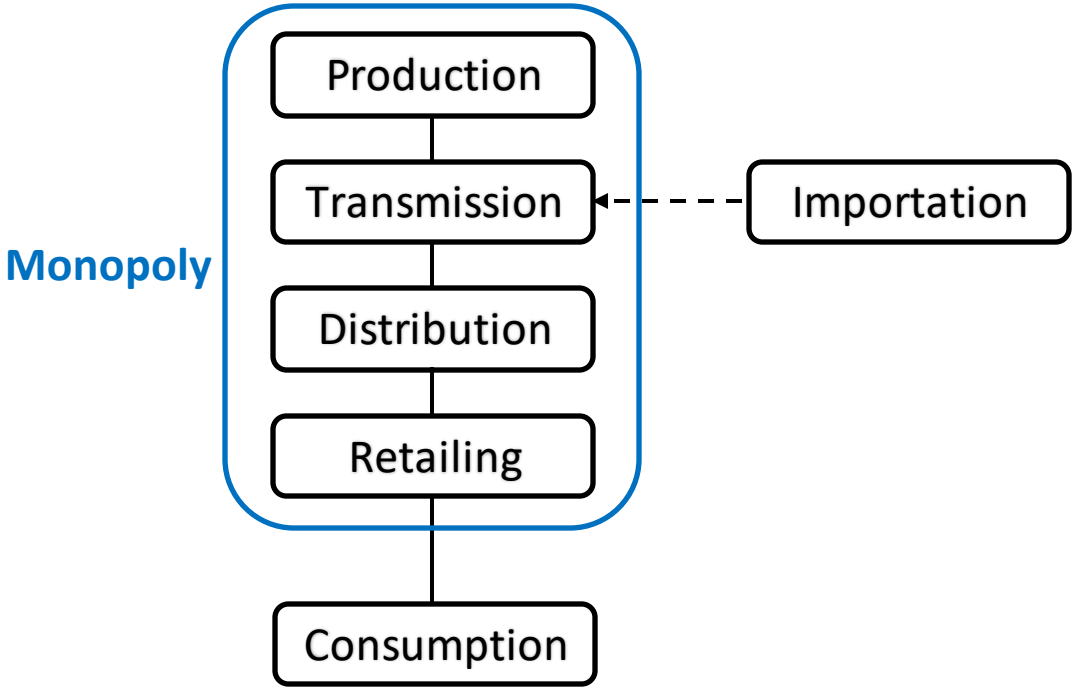


The flow of energy - Transport



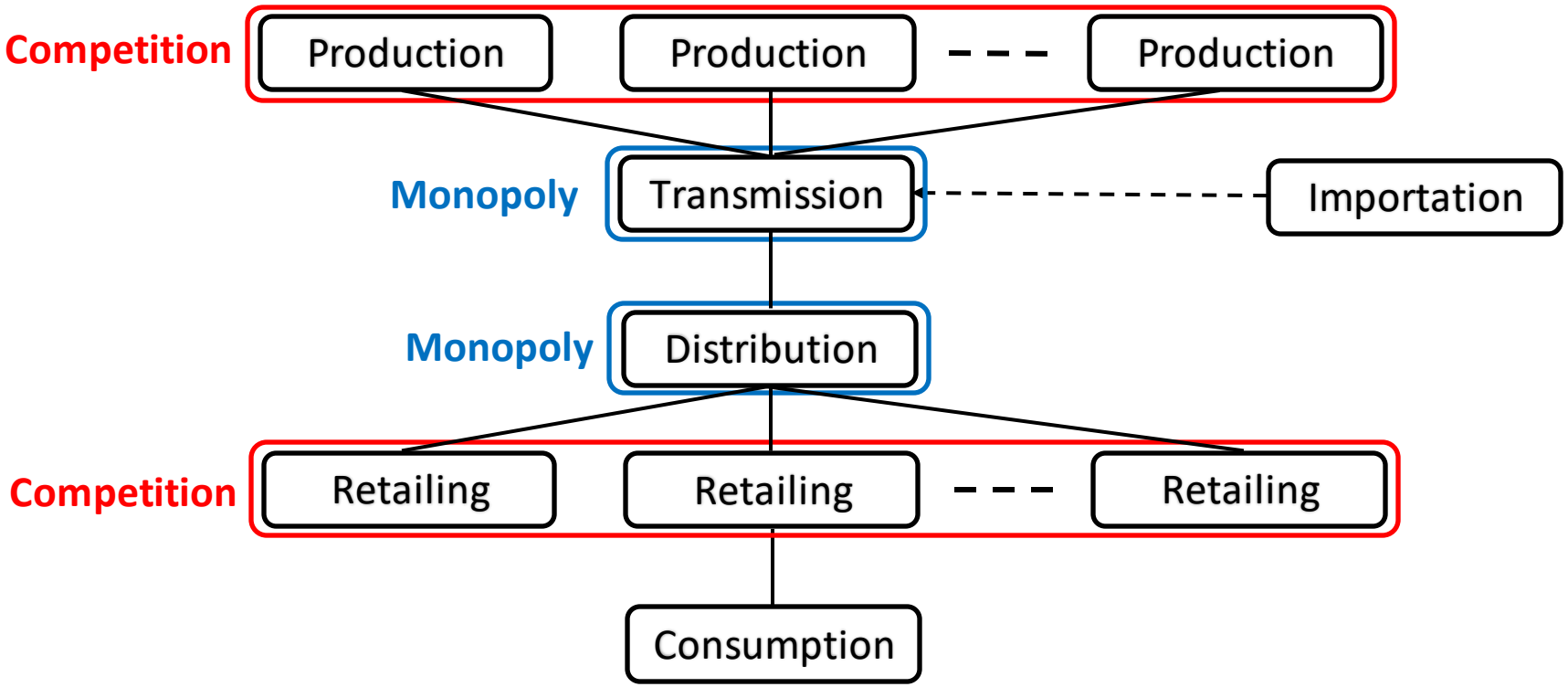
Electricity Industry - Monopoly

Historically, the electricity industry was organised as a **monopoly**:



Electricity Industry - Liberalisation

Nowadays, the electricity industry is significantly **liberalised**:



Electricity industry – Entities

Transmission System Operator (TSO): Operate the electricity transmission network.

Distribution System Operator (DSO): Operate the electricity distribution network.

Independent System Operator (ISO): Secure the entire electricity power system.

Generator: Produce electrical energy and sale in the wholesale market.

Retailer: Purchase electricity in the wholesale market for their customers (consumers).

Consumer: Purchase electricity in the wholesale or retail markets (depending on the consumption).

Market regulator: Define market rules and monitor potential abuse of market power.

Market operator: Operate the energy markets (matching, clearing, settlements).

Electricity industry – Main actors in Belgium

Transmission System Operator (TSO): Elia.

Independent System Operator (ISO): Elia

Distribution System Operator (DSO): ORES, RESA, Sibelga, Eandis, …

Generator: Engie Electrabel, EDF Luminus, Lampiris, Eneco, …

Retailer: Engie Electrabel, EDF Luminus, Lampiris, Eneco, Mega, …

Market regulator: CREG, CWaPE, BRUGEL, VREG.

Market operator: EPEX SPOT, EEX, ICE Endex, …

Electricity – A particular commodity

- Guaranties required by the electricity **demand** (must-serve nature).
- **Essential** element of any industrial activity nowadays (quite inelastic good).
- Difficulties associated with **storage** (mainly uneconomical nowadays).
- **Physical constraints** related to the power grid to be respected.
- Power **generation** = power **consumption** at all times.

Electricity Markets – What is traded?

The **atomic unit** traded in the electricity markets is generally a **power** *P* over a certain **period of time** *T* :

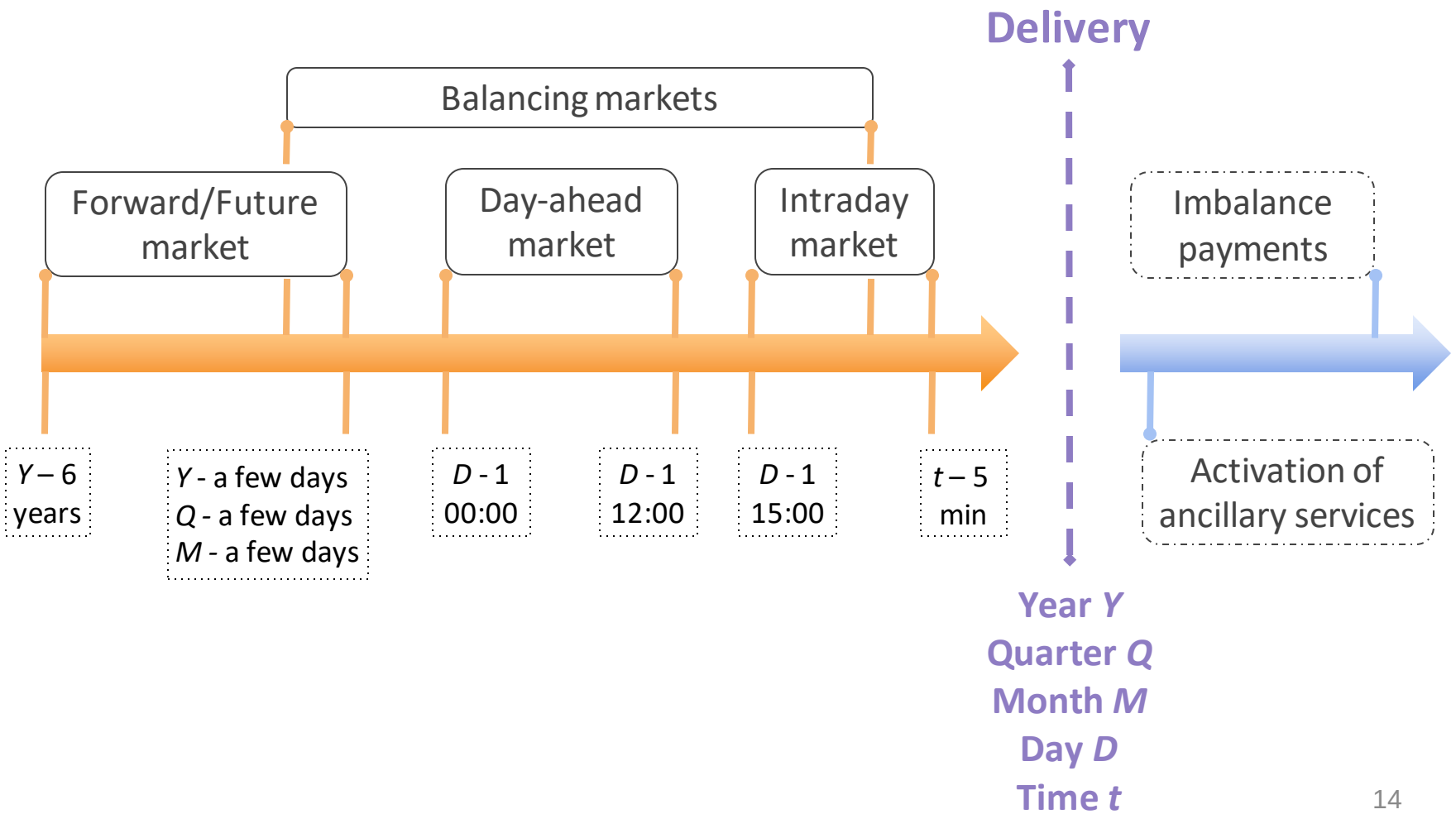
- The (electrical) power is expressed in **Watts (W)**.
- The time period is a duration expressed in **seconds (s)**.

A quantity of **energy** *E*, expressed in **Joules (J)**, is the multiplication of a power by a certain time duration:

$$E[\mathrm{J}] = P[\mathrm{W}] \times T[\mathrm{s}]$$

In energy markets, quantities of energy are generally expressed in (kilo k, mega M, giga G, tera T) **Watt-hour (Wh)** instead of Joules.

Electricity Markets - Overview



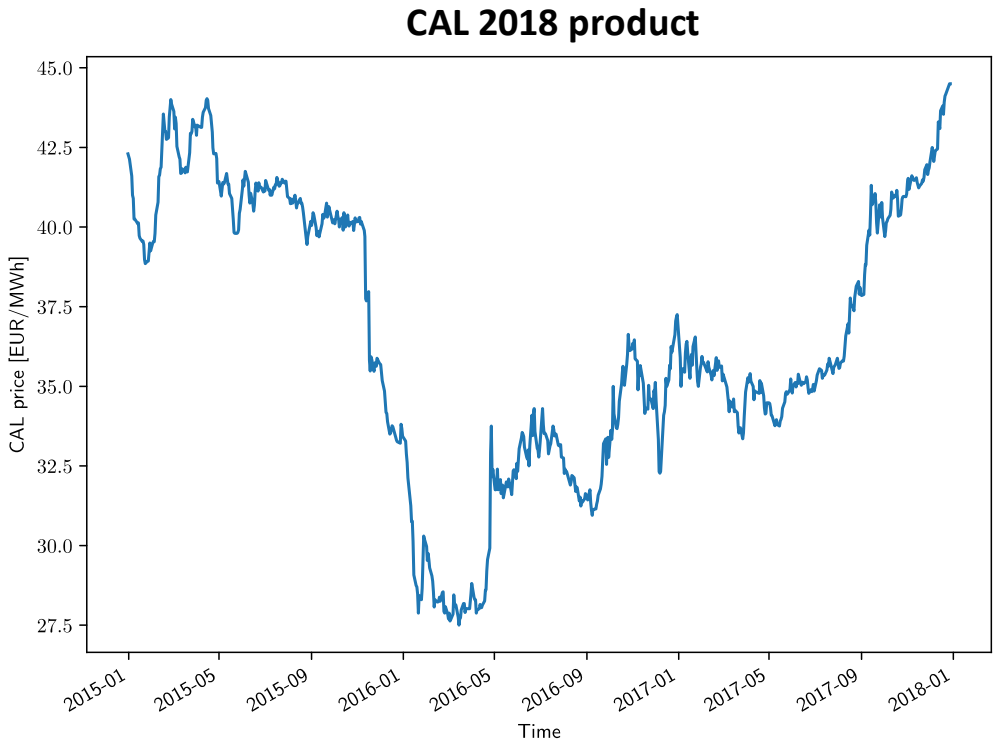
Forward/Future market - Presentation

- Electricity market based on **long-term financial bilateral contracts** between producers and consumers (generally retailers) of electricity.
- Diverse products available: yearly, quarterly or monthly base-load products.
- Trading horizon from **6 years up to a few days ahead** of the product first delivery day.
- Opportunity for the market participants to perform price hedging and risk management, to avoid the short-term higher price volatility.
- The Forward/Future price represents the **expected price** to be observed on the day-ahead market for the time period considered.
- Market operator: EEX, ICE Endex.

Forward/Future market – Example

Calendar (CAL) product:

- Yearly base-load product (delivery of constant electric power for the entire year).
- Starting 3 years ahead of the delivery year.
- Ending a few days before the first day of the delivery year.



Day-ahead market – Presentation

Also called **electricity spot market**, the day-ahead market is the central electricity market for everyday matching of electricity supply and demand.

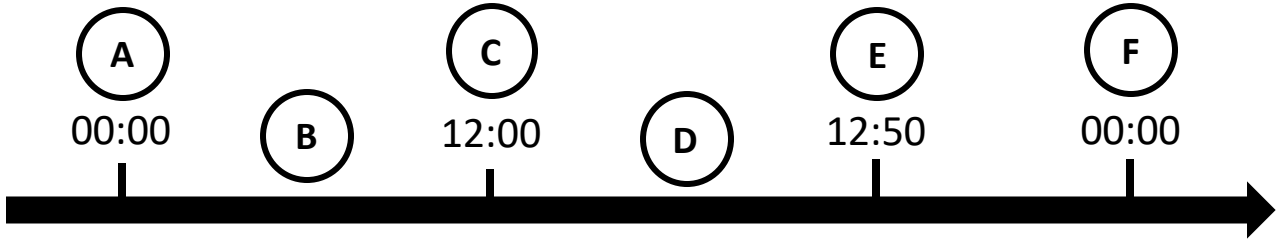
This electricity market is operated once a day for all hours of the following day through a **single blind auction** (hourly resolution).

The day-ahead market is organised as a **pool**:

- All **bids** (buying) and **asks** (selling) orders are considered simultaneously.
- The other market participants' orders are **unknown**.
- A unique price is determined by the **market clearing algorithm** for all participants.

Market operator: EPEX SPOT (originally Belpex).

Day-ahead market – Timeline

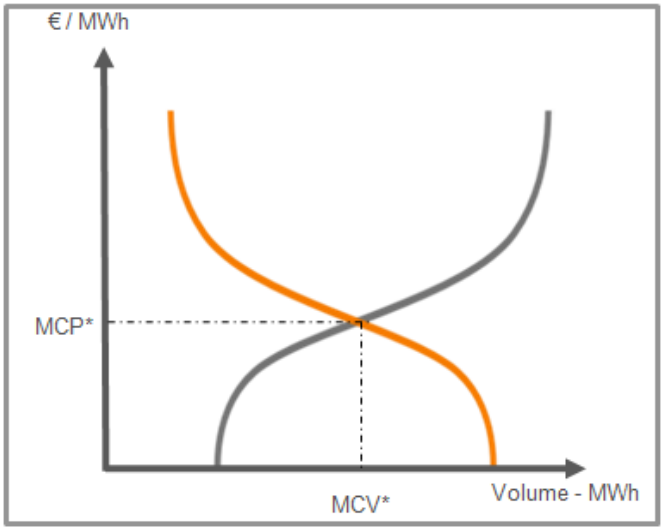


A. Opening of the day-ahead market for all hours of the following day.
B. Market participants submit their bids and asks to the order book (simple orders, block orders, exclusive orders, curtailable orders, …).
C. Closing of the day-ahead market for all hours of the following day.
D. Execution of the market clearing algorithm.
E. Notification of the market participants and system operators about the market clearing outcomes.
F. Beginning of the delivery of electricity for the entire day.

Day-ahead market – Clearing Algorithm

For each hour of the following day:

1. Aggregation of the ask orders submitted to the order book into the **supply curve**.
2. Aggregation of the bid orders submitted to the order book into the **demand curve**.
3. Determination of the **equilibrium point** (intersection of both curves).
4. Notification of the resulting **clearing prices and volumes**.



https://www.epexspot.com/en

This market clearing algorithm maximises the **social welfare** (explained in more details in lesson 4).

Day-ahead market – Potential problem

The clearing of the day-ahead market happens a **fairly long time** before the supply and consumption operations (between 12 and 36 hours).

The actual generation/consumption may **deviate from the original schedule** contracted (different weather forecasts, technical problems, etc.).

Three main solutions are offered to the market participants:

- **Compensate** with other generation/consumption assets within their portfolio.
- Adjust their positions through the **intraday market**.
- Do nothing and be exposed to the **balancing market**.

Intraday market – Presentation

The intraday market allows the market participants to **adjust their positions** through **bilateral contracts**.

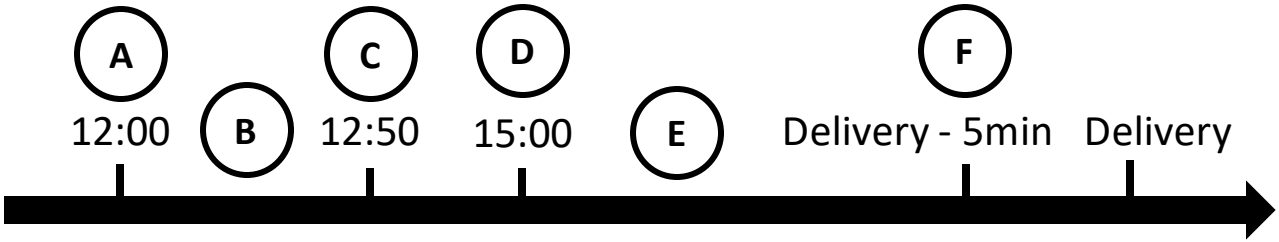
It is the opportunity for producers and consumers to make **last minute adjustments** and balance their positions **closer to real time**.

This electricity market authorises **continuous trading**, meaning that a trade is executed as soon as two orders match (different constraints have to be met depending on the orders types).

Multiple contracts are available: hourly, half-hourly and quarter-hourly.

Market operator: EPEX SPOT (originally Belpex).

Intraday market – Timeline



A. Closing of the day-ahead market for all hours of the following day.

B. Market clearing algorithm execution.

C. Notification of the market participants and system operators about the market clearing outcomes.

D. Opening of the intraday market for the delivery on the following day.

E. Continuous trading on the intraday market.

F. Closing of the intraday market for the delivery period considered.

Intraday market – Fictive example

Context: There is a last-minute update in the wind forecast, and the predicted wind power generation associated with the portfolio of a supplier is suddenly decreased by 50 MWh for the time period 10:00-11:00.

This wind power generator intends to adapt its position on the intraday market, whose state is represented hereafter for that specific time period.

Question: Which actions could be performed by this supplier to avoid any imbalance?

ID	Side	Quantity (MWh)	Price (€/MWh)
G1	Sell	100	35
G2	Sell	80	40
G3	Sell	50	50
G4	Sell	20	65
C1	Buy	10	55
C2	Buy	20	60
C3	Buy	35	65
C4	Buy	110	70

Curtailable orders
(All or None)

Intraday market – Fictive example

1. A first possibility is to buy 50 MWh to G3 and pay 50 x 50 = 2500€.

2. A second possibility is to buy 80 MWh to G2 and sell respectively 10 MWh and 20 MWh to C1 and C2, thus paying 80 x 40 – 10 x 55 – 20 x 60 = 1450€.

3. Other possibilities?

ID	Side	Quantity (MWh)	Price (€/MWh)
G1	Sell	100	35
G2	Sell	80	40
G3	Sell	50	50
G4	Sell	20	65
C1	Buy	10	55
C2	Buy	20	60
C3	Buy	35	65
C4	Buy	110	70

Curtailable orders
(All or None)

Balancing market – Presentation

The balancing stage, occurring close to real-time (after delivery), is of critical importance and enables the transmission system operator (TSO) to **keep the power grid balanced** (generation = consumption) at all times.

The complete balancing stage includes:

- The **balancing market** allows the TSO to acquire **regulating power** from voluntary producers/consumers prior to the time of delivery.
- The **imbalance payments** where the market participants have to **cover the costs** of their contributions to placing the power system off-balance.

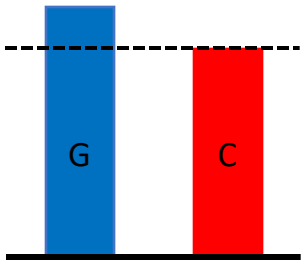
Market operator: TSO (Elia).

Balancing market – Imbalances

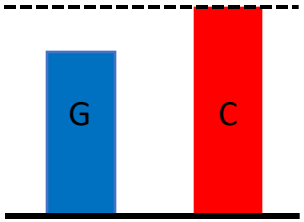
There exist 3 possible situations for the power grid balance:

- **Positive imbalance**: Generation > Consumption (downward regulation required).
- **Negative imbalance**: Generation < Consumption (upward regulation required).
- **No imbalance**: Generation ~ Consumption (no regulation required).

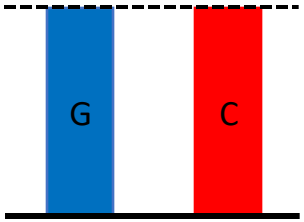
The same reasoning is also valid for a producer/consumer considered individually (contracted production/consumption vs actual production/consumption).



Positive imbalance



Negative imbalance



No imbalance

Balancing market – Simple example

Context:

A generator is scheduled to produce 100 MWh of electricity for 45€/MWh with wind turbines during the time period 10:00-11:00. Because of inaccurate wind forecasts at the time of market clearing (day-ahead market), its actual production deviates from its original schedule. The imbalance price is set to 50€/MWh for this specific time period (negative imbalance for the entire power system).

Questions:

1. What is the revenue of this generator if its actual production is 80 MWh?
2. What is the revenue of this generator if its forecast is correct?
3. What is the revenue of this generator if its actual production is 120 MWh?

Balancing market – Simple example

Answers:

1.

- Day-ahead market revenue: 100 x 45 = 4500€.
- Imbalance market revenue: -20 x 50 = -1000€.
- Eventually, the generator's revenue is equal to 3500€ (43.75€/MWh).

2.

- Day-ahead market revenue: 100 x 45 = 4500€.
- Imbalance market revenue: 0 x 50 = 0€.
- Eventually, the generator's revenue is equal to 4500€ (45€/MWh).

3.

- Day-ahead market revenue: 100 x 45 = 4500€.
- Imbalance market revenue: 20 x 50 = 1000€.
- Eventually, the generator's revenue is equal to 5500€ (45.83€/MWh).

Balancing market – Simple example

Remarks:

In the 3rd situation, the positive imbalance of the producer (partially) counters the negative imbalance of the entire power system, resulting in a revenue surplus.

This may encourage speculation on the imbalance side, which is undesired because it could cause important instabilities in the power system.

Solution:

Two-price imbalance settlement (as opposed to **one-price imbalance settlement**):

- Actors contributing to the power system imbalance are penalised (imbalance price).
- Actors unintentionally countering the power system imbalance do not get extra rewards (day-ahead market clearing price).

Balancing market – Settlements

Question:

What is the revenue of the generator in the 3rd situation from previous example if a two-price imbalance settlement policy is considered instead?

Answer:

- Day-ahead market revenue: 100 x 45 = 4500€.
- Imbalance market revenue: 20 x 45 = 900€.
- Eventually, the generator's revenue is equal to 5400€ (45€/MWh).

Contribution	One-price imbalance settlement	Two-price imbalance settlement
Negative (reinforce imbalance)	Imbalance price	Imbalance price
Positive (counter imbalance)	Imbalance price	Day-ahead market clearing price

Ancillary Services - Presentation

Linked to the balancing stage, the ancillary services are all the services necessary for the TSO to **maintain the integrity and stability of the power system**.

The **balancing market** is dedicated to the trading of these ancillary services.

The imbalance price is related to the **price of acquisition and activation** of the ancillary services.

There exist multiples types of ancillary services:

- **Frequency control** (primary, secondary, tiertiary reserves).
- **Voltage control** (primary, secondary, tiertiary controls).
- **System restart** (black start capability).

Operator: TSO (Elia).

Ancillary services – Reasons

There are many causes for the power system to not be balanced:

- The electricity **demand** is particularly **difficult to forecast**. The actual consumption may be quite different from the one foreseen at the time of market clearing (day-ahead market).

- The electricity **supply** may also be **difficult to forecast**, especially for renewable energy sources whose production can significantly vary depending on the weather.

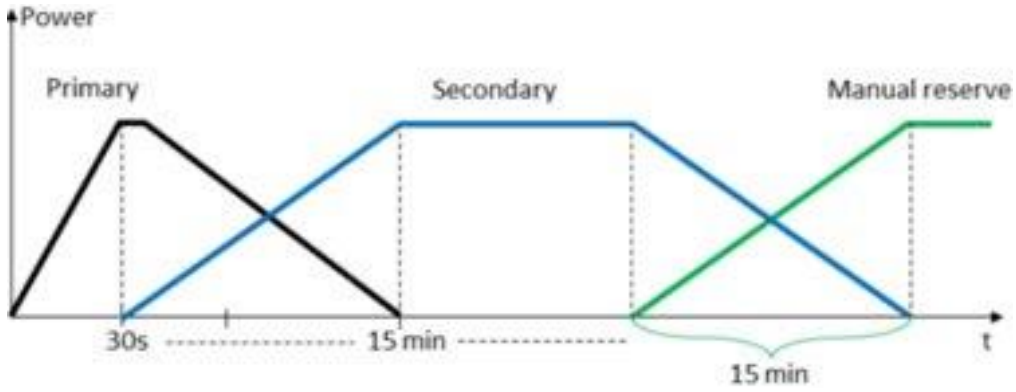
- **Technical problems** may affect both generation and transmission/distribution of electricity.

- **Congestions** may occur internally in important power lines within a zone.

Ancillary services – Reserves

The main ancillary services in Europe are the reserves (frequency regulation):

- **Primary reserve:** Automatically activated within 30 seconds following the incident (frequency deviation), the primary reserve is used to bring back the equilibrium between generation and consumption in order to limit the damages.
- **Secondary reserve:** Automatically activated within 15 minutes following the incident (frequency deviation), the secondary reserve is used to get the power system back to its target frequency (50Hz in Europe).
- **Tertiary reserve:** Contrarily to the first two reserves, the tertiary reserve is manually activated and serves as a backup for the secondary reserve (same goal).



European coupling

There is a **coupling** between the European electricity markets, meaning that power can be traded/exchanged between multiple countries/zones.

The current trend is to reinforce this coupling by **setting up new power lines** between local/regional/national/continental power systems.

The objective is to **distribute more efficiently the electricity** all over Europe (social welfare maximisation).

Coupling power grids is particularly important for the **energy transition** to better exploit the electricity generated by **renewable energy sources** (volatility).

European coupling