

THE STRUCTURE OF AN ELECTRICITY MARKET

Lectures 1-2
in

EG2050 System Planning

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COURSE OBJECTIVE

To pass the course, the students should show that they are able to

- describe the principles of how an electricity market can be organised.



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ELECTRICITY MARKETS

An electricity market is an arrangement to transfer electric energy from producers to consumers.

Transmission of electric energy requires a special infrastructure—a power system.



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ORGANISATION OF THE POWER SYSTEM



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- **Transmission.**
National or international grid—long distance, high wattage
- **Sub-transmission.**
Regional grid
- **Distribution.** Connects the majority of the consumers

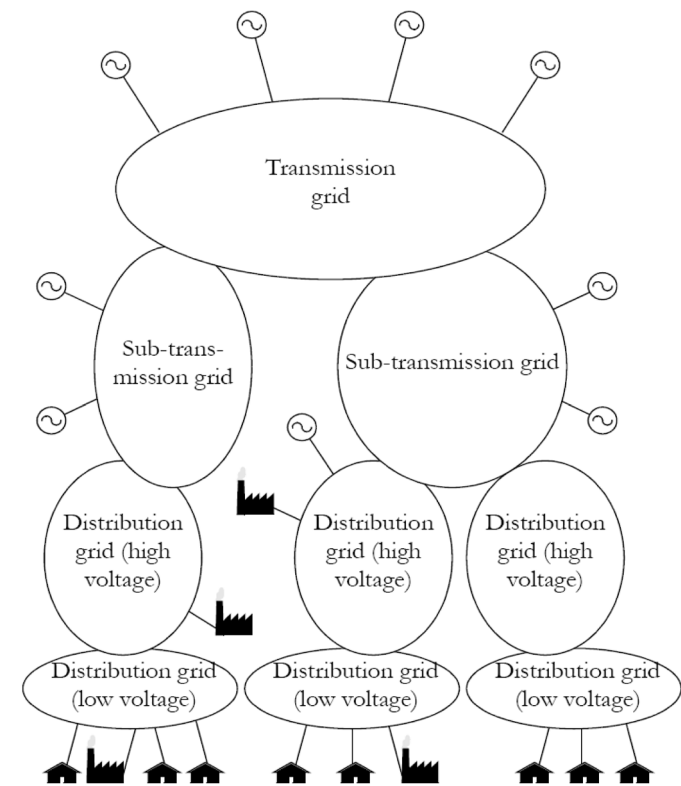
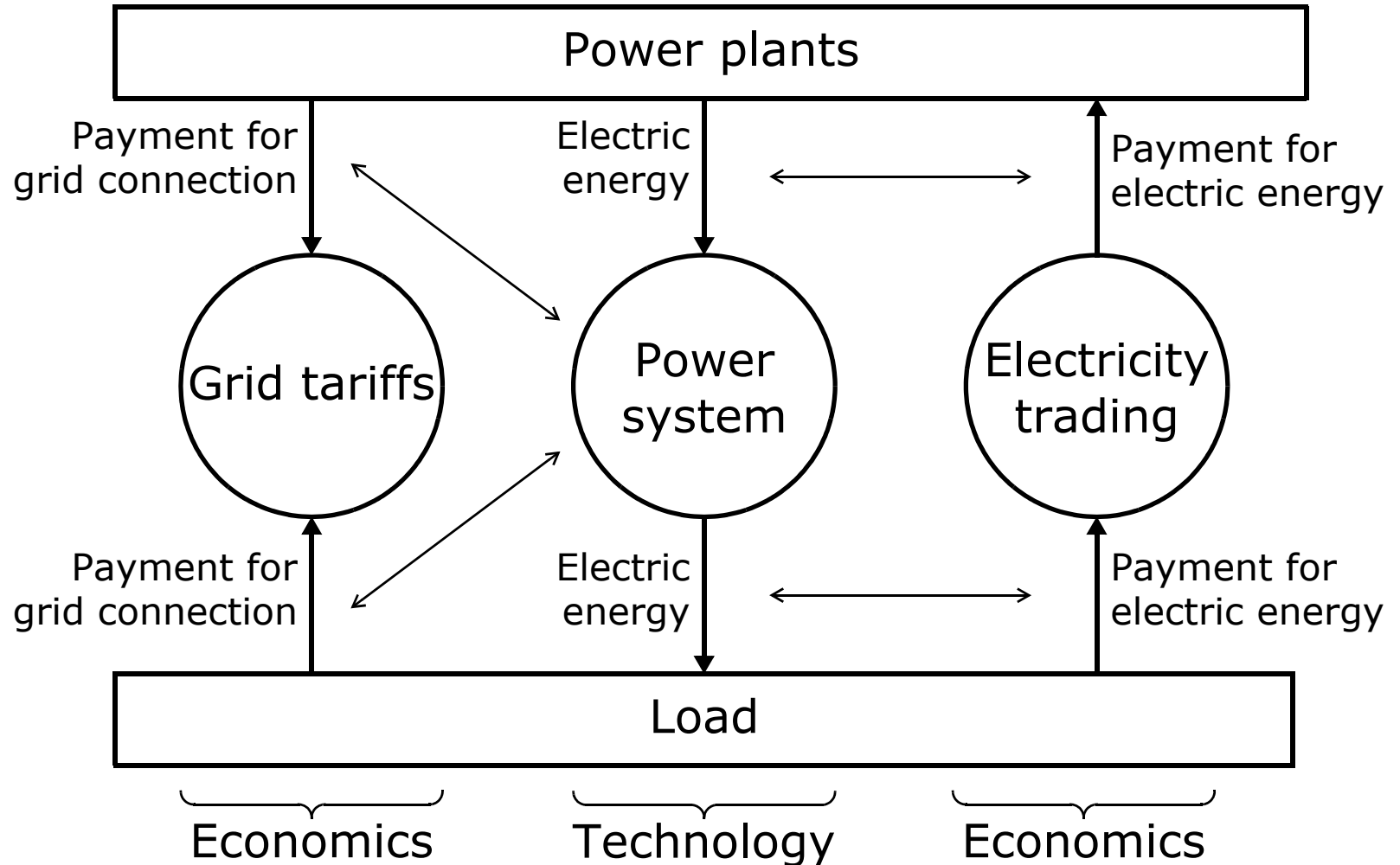


Figure 1.1 The structure of a larger power system.

THE ELECTRICITY MARKET



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FUNCTIONS IN AN ELECTRICITY MARKET

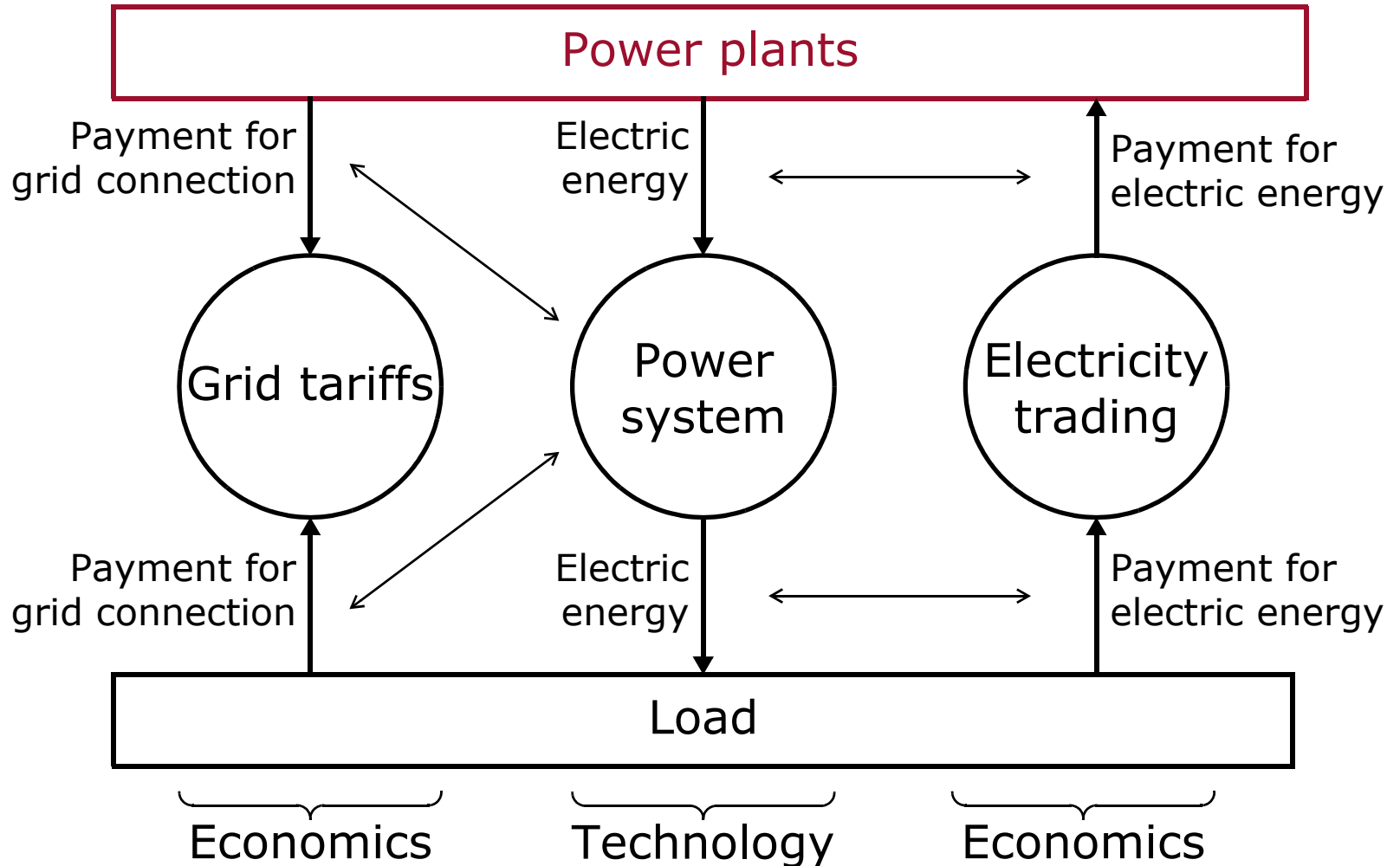


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- Producers
- Consumers
- Retailers and traders
- Grid owners
- System operator
- Balance responsible players

Notice that the same player may have several functions in the electricity market!

PRODUCERS



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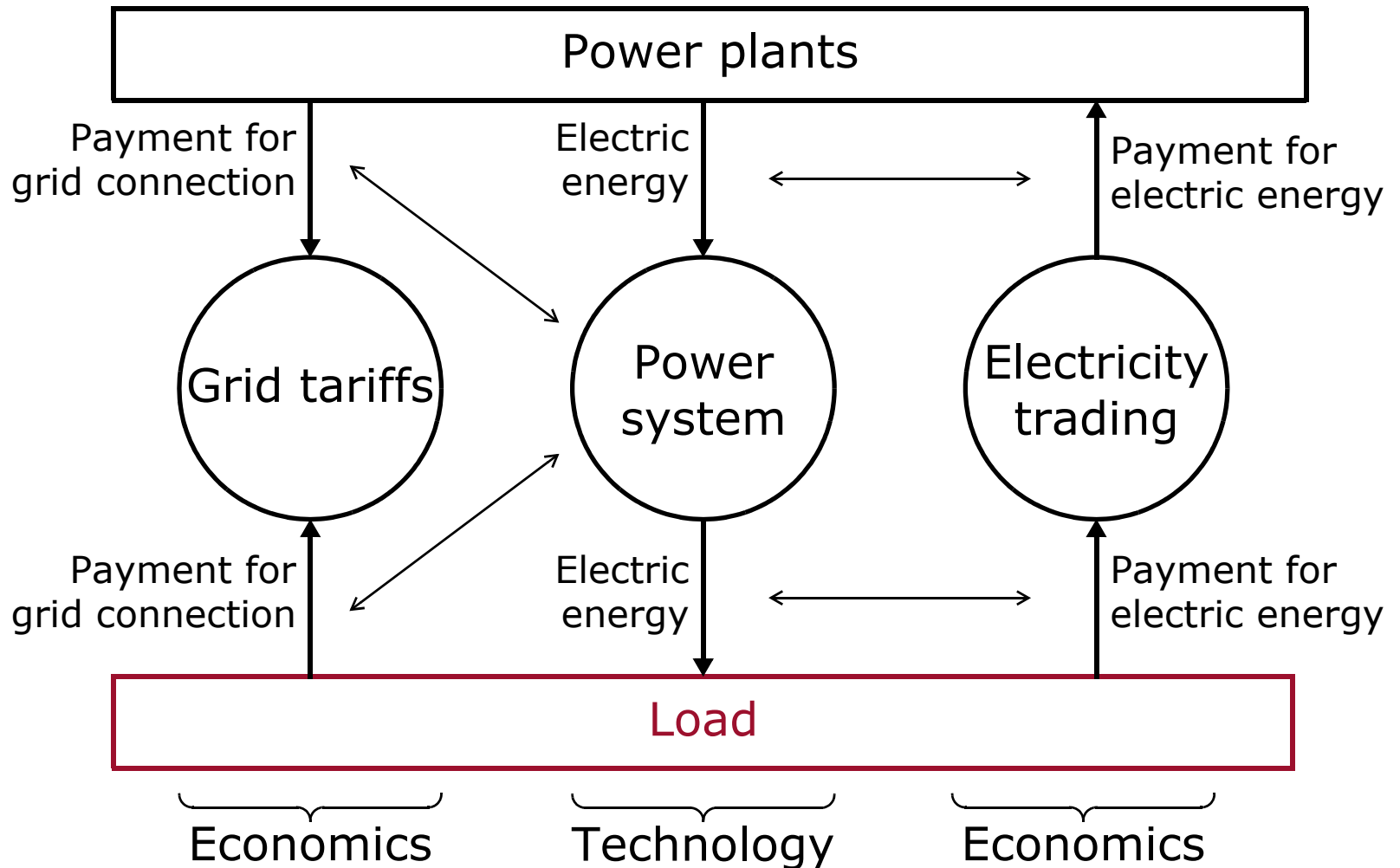
PRODUCERS

- Owns and operates power plants.
- Depending on the organisation of the electricity trading, the producers may sell to
 - local consumers
 - power pool
 - anybody
- Economics of scale \Rightarrow few but large producers



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CONSUMERS



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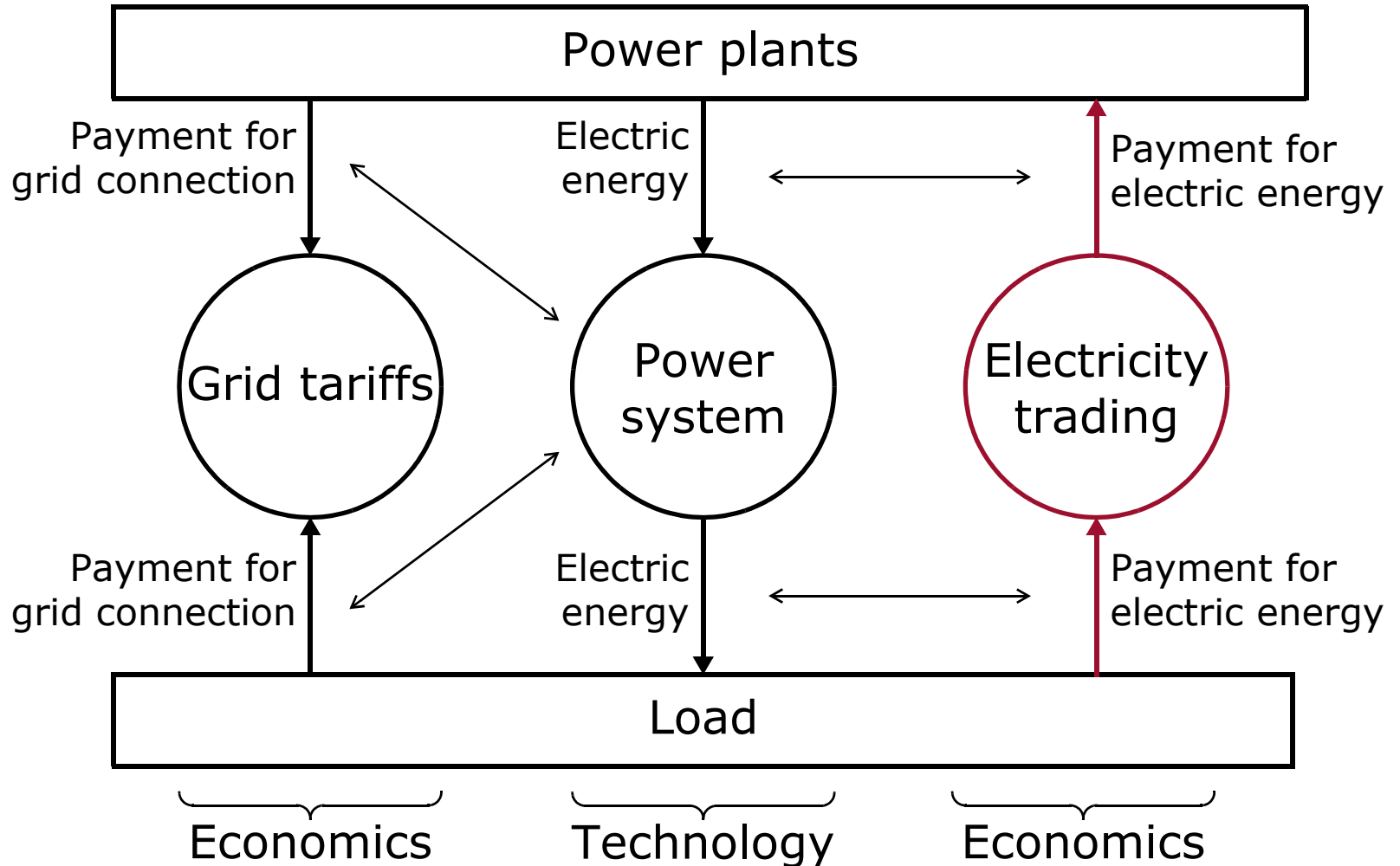
CONSUMERS

- End-users of electricity.
- Depending on the organisation of the electricity trading, the consumers may buy from
 - local power company
 - power pool
 - anybody
- Large variation in size.



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RETAILERS AND TRADERS



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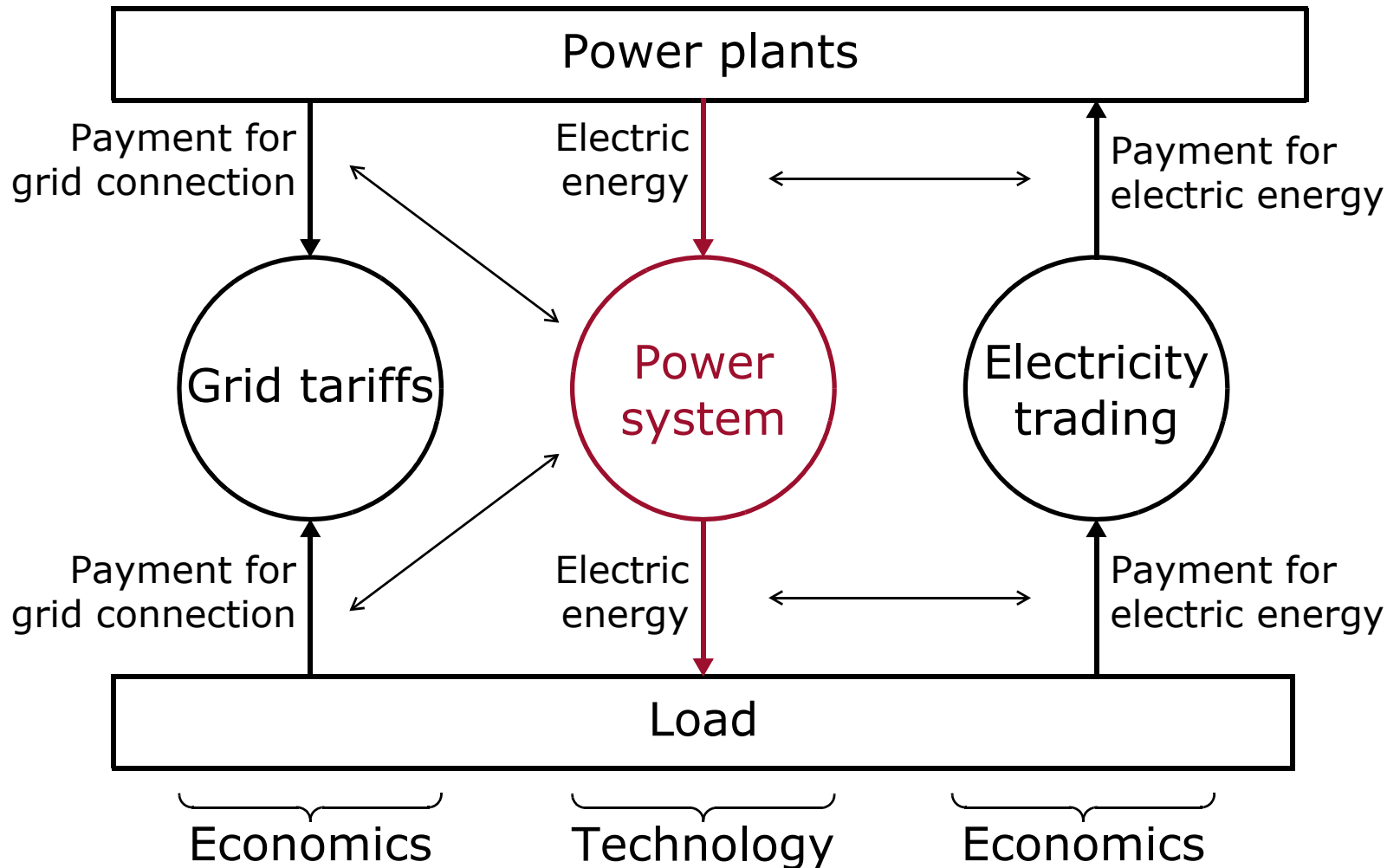
RETAILERS AND TRADERS

- Buys from producers (or other retailers) and sells to consumers (or other retailers).
- Can provide a price insurance to the consumers.
- Can increase competition in the electricity market.
- Might be subject to large economical risks.



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SYSTEM OPERATOR



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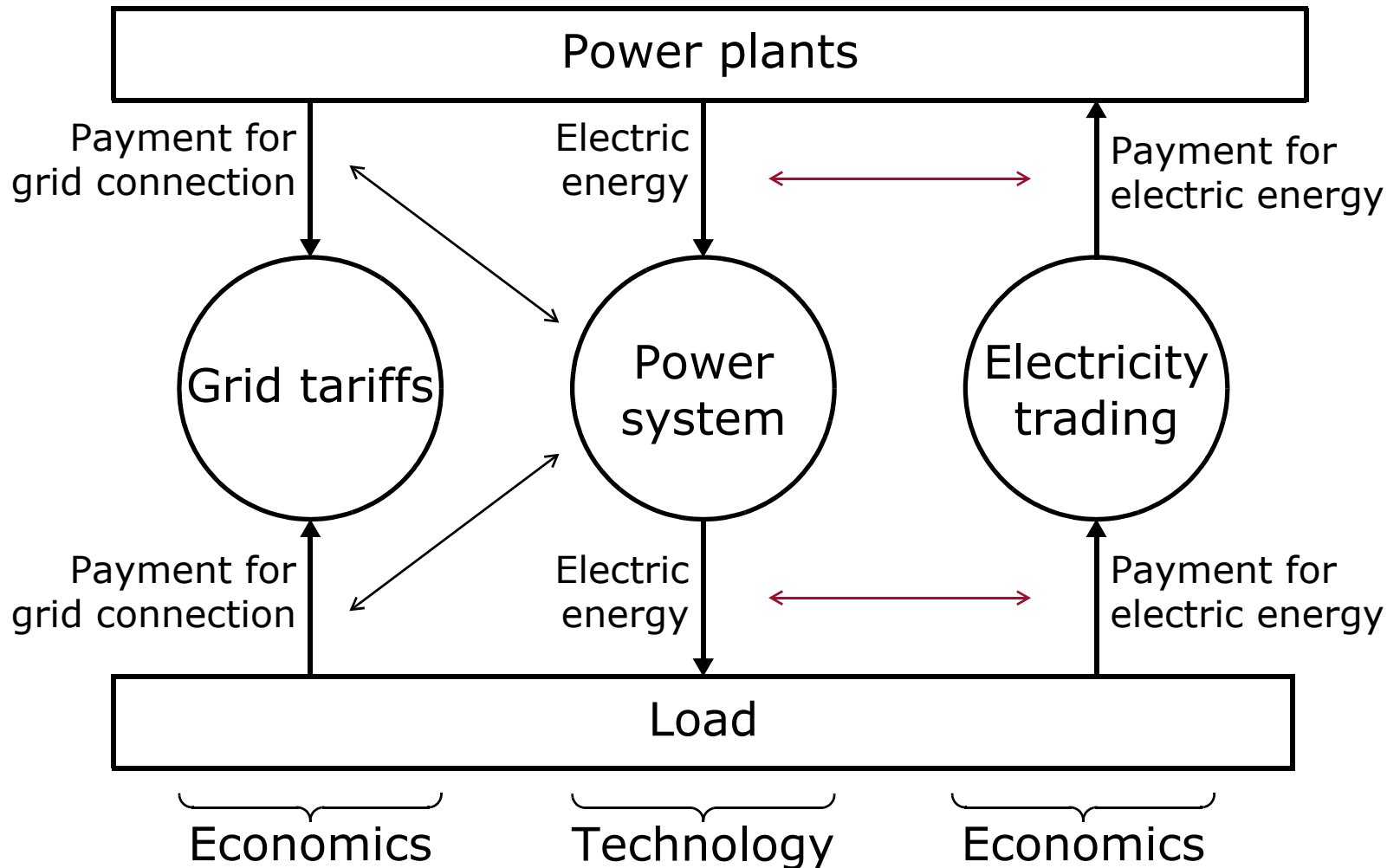
SYSTEM OPERATOR



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- Responsible for safe operation of the power system (technically responsible for balance between generation and consumption).
- Should be independent from producers, consumers, etc. (Therefore sometimes referred to as **I**ndependent **S**ystem **O**perator, ISO.)
- In many cases also owner of the transmission grid. (Therefore sometimes referred to as **T**ransmission **S**ystem **O**perator, TSO.)

BALANCE RESPONSIBLE PLAYERS



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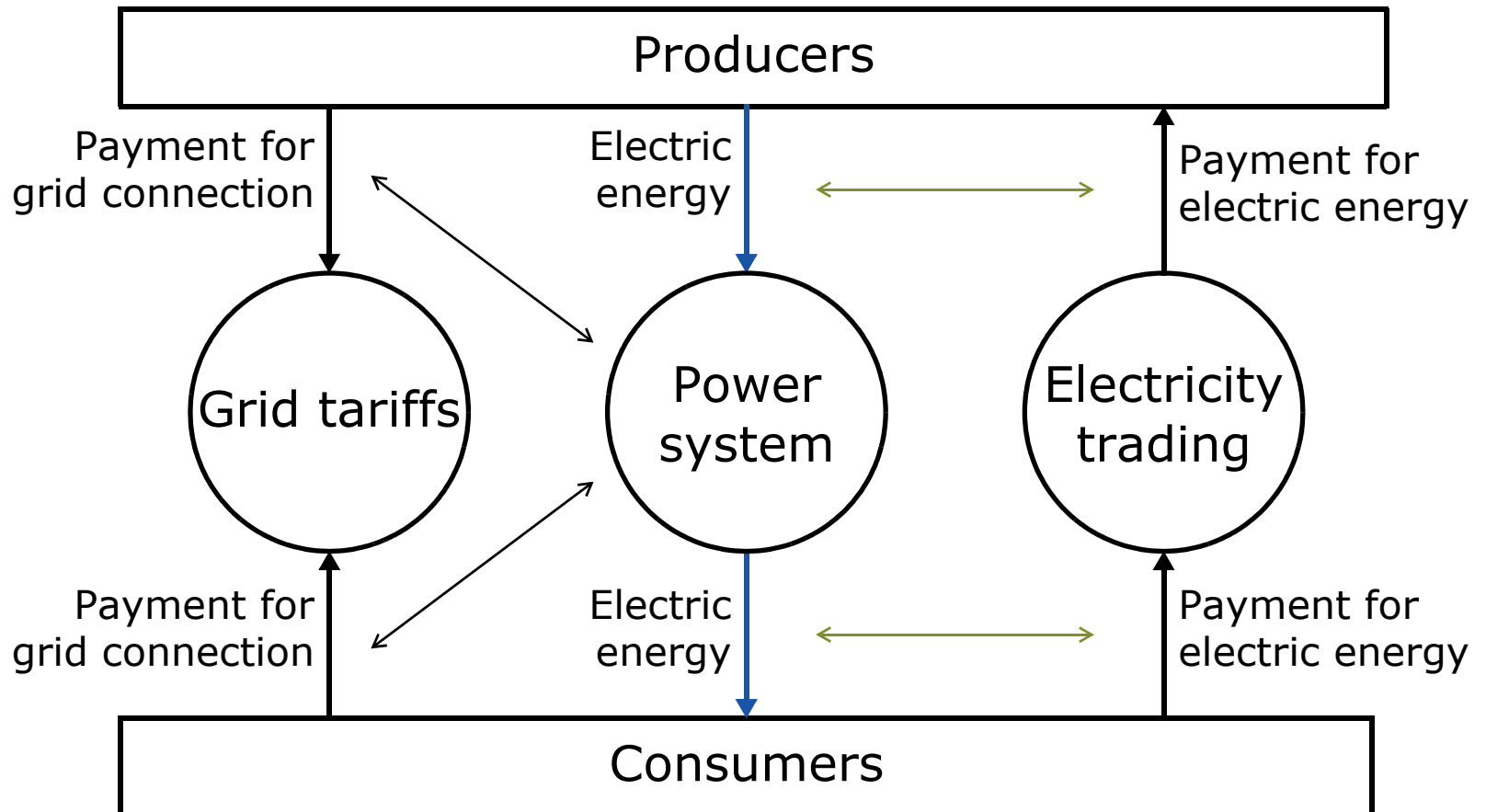
BALANCE RESPONSIBLE PLAYERS



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- Financially responsible for the balance between generation and consumption.
- All producers, consumers and traders are required to either be balance responsible themselves or arrange for some other player to be balance responsible on their behalf.
- The balance responsible players do not have to be power producers or consumers.

POWER SYSTEM BALANCE

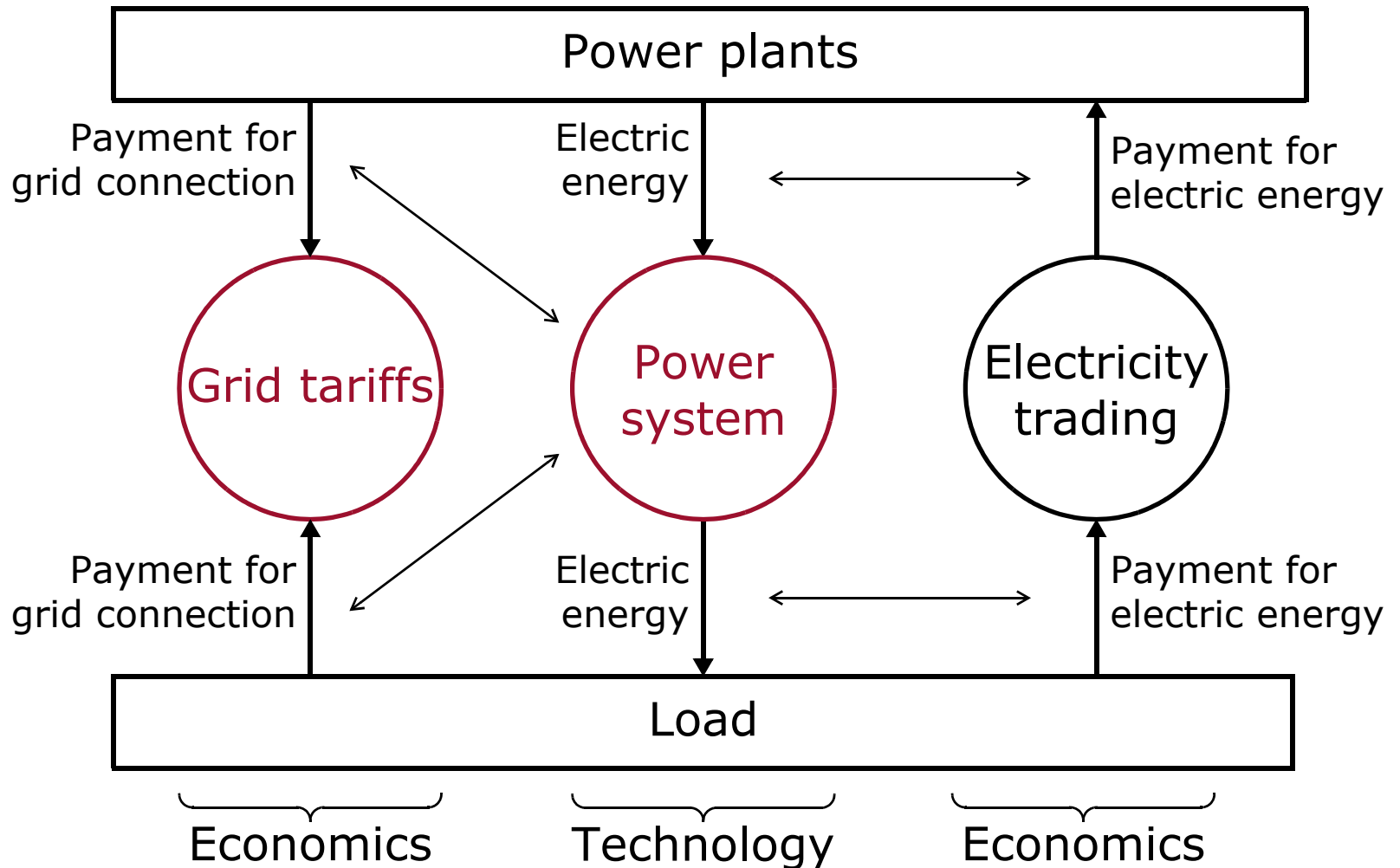


— System responsibility — Balance responsibility



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GRID OWNERS



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GRID OWNERS

- Transmission and distribution are so-called **natural monopolies**.
- Grid owners build, operate and maintain the grids.
- Grid owners are responsible for power quality and metering.
- Grid owners might have to buy electricity to cover losses in the grids.



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GRID TARIFFS

There cannot be an electricity market without a grid. Who should pay for the construction, operation and maintenance of the grid?

Generally, the grid tariff have several components, for example

- energy fee
(applicable to losses)
- congestion fee
(applicable to temporary transmission limitations)
- capacity fee
(applicable to investment costs)



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GRID TARIFFS

As the grids are operated by monopolists, the tariffs are usually regulated.

- **Cost-based regulation.** The tariff is determined by how much the grid is costing the company to build, operate and maintain.
- **Performance-based regulation.** The tariff is determined by the service provided by the grid company.



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ELECTRICITY TRADING

There is a need for an arrangement to guarantee that

- producers are paid for the energy they feed into the power system
- consumers pay for the energy they extract from the power system



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ORGANISATION OF THE ELECTRICITY TRADING



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- There must be a formal procedure for how electricity is to be traded.
- This procedure is quite simple in a small stand-alone systems, where the power company acts as producer, grid owner, system operator and retailer.
- Several possible procedures are feasible for large interconnected systems.

ORGANISATION OF THE ELECTRICITY TRADING

What are the special properties of electricity trading?

- Electric energy **cannot be stored!**
- Production and consumption must be balanced continuously.
- The producers do not know exactly when their customers are consuming electricity.

This problem could be solved by introducing a very complex information system. Would such a solution be beneficial to the society?



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ELECTRICITY TRADING - Trading period

The electricity trading is divided in periods, which we refer to as **trading periods**.

Most electricity markets use a trading period of one hour, but some markets use half-hour periods.

- The physical balance between production and consumption within the trading period is the responsibility of the system operator.
- The balance responsible players only have to balance their total production/purchase and total consumption/sales for each trading period.



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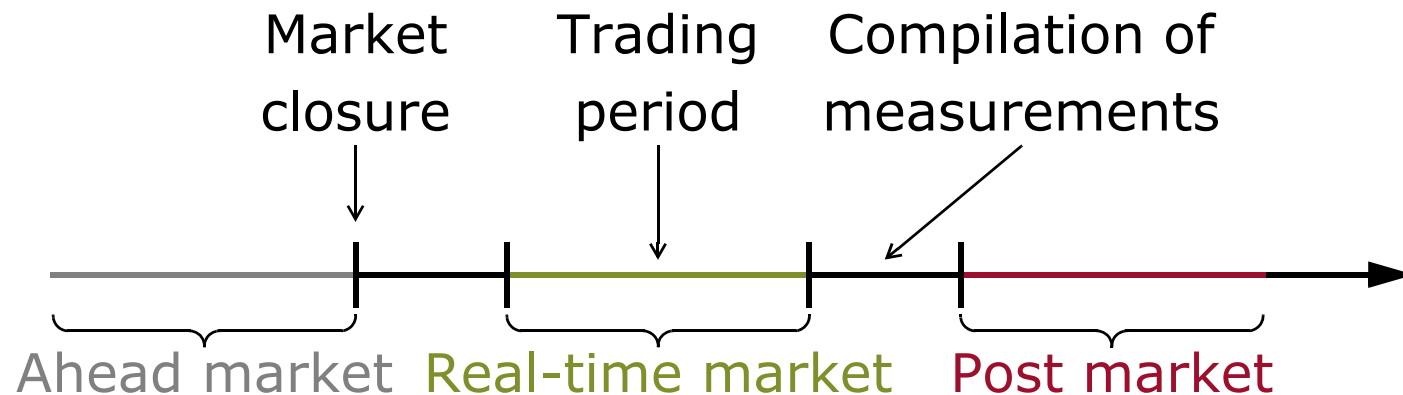
ELECTRICITY TRADING - Timeline

The introduction of trading periods results in a division of the electricity trading into certain phases:

- ahead market
- real-time market
- post market



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THE AHEAD TRADING

In the ahead trading, the players try to balance their **forecasted** production/purchase and consumption/sales. The ahead trading involves many kind of contracts.

A **financial contract** (futures, forwards etc.) is simply speaking a price insurance.

A **physical contract** is an undertaking by the seller to deliver the contracted energy during one or more specified trading periods.

All physical contracts are reported to the system operator and will be accounted for in the post trading.



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THE AHEAD TRADING

There are many ways to organise the ahead trading.

Three major categories of electricity markets can be identified:

- Vertically integrated electricity market
- Centralised electricity market
- Bilateral electricity market

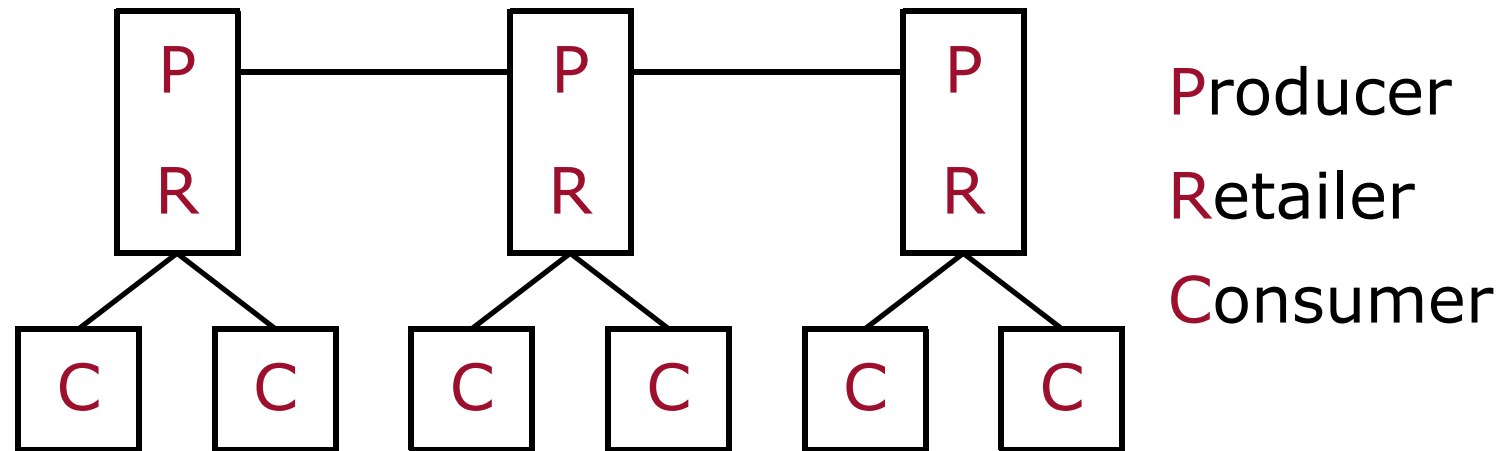


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VERTICALLY INTEGRATED ELECTRICITY MARKET



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- Consumers have to buy from the local power company.
- Power companies may trade freely.

VERTICALLY INTEGRATED ELECTRICITY MARKET



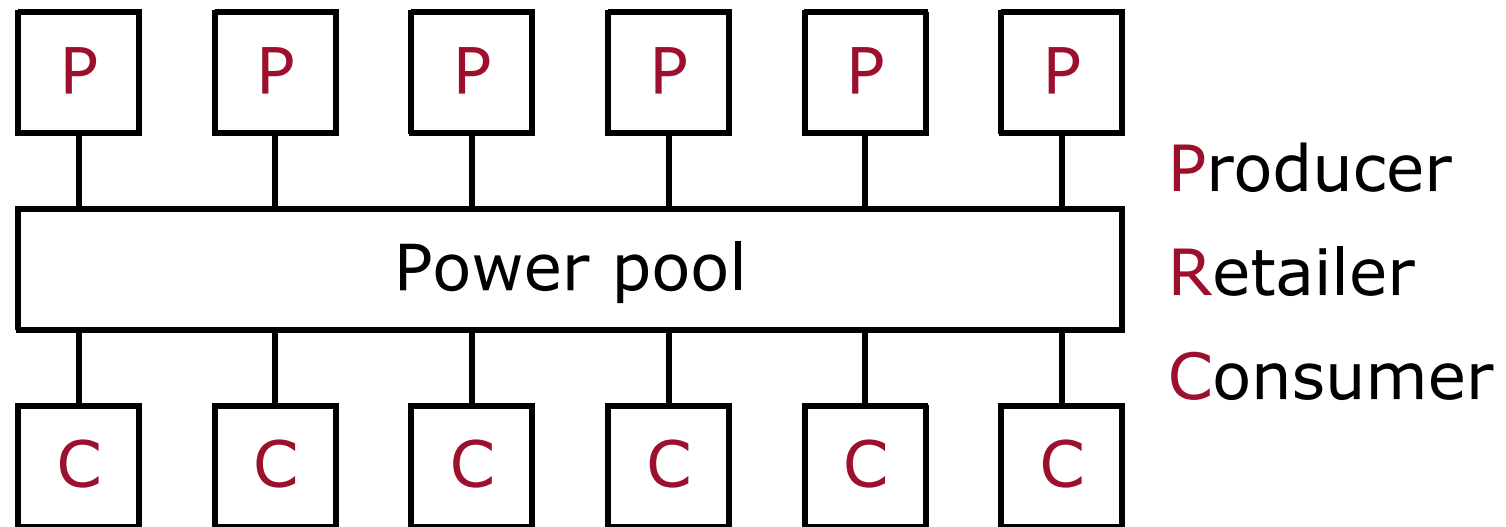
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- The power companies combine the functions of **producers, grid owners, retailers** and **balance responsible player**.
- In interconnected power systems, one power company can be the system operator, or each power company can be system operator for their own local area.

CENTRALISED ELECTRICITY MARKET



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- All producers sell to the power pool.
- All consumers buy from the power pool.

CENTRALISED ELECTRICITY MARKET



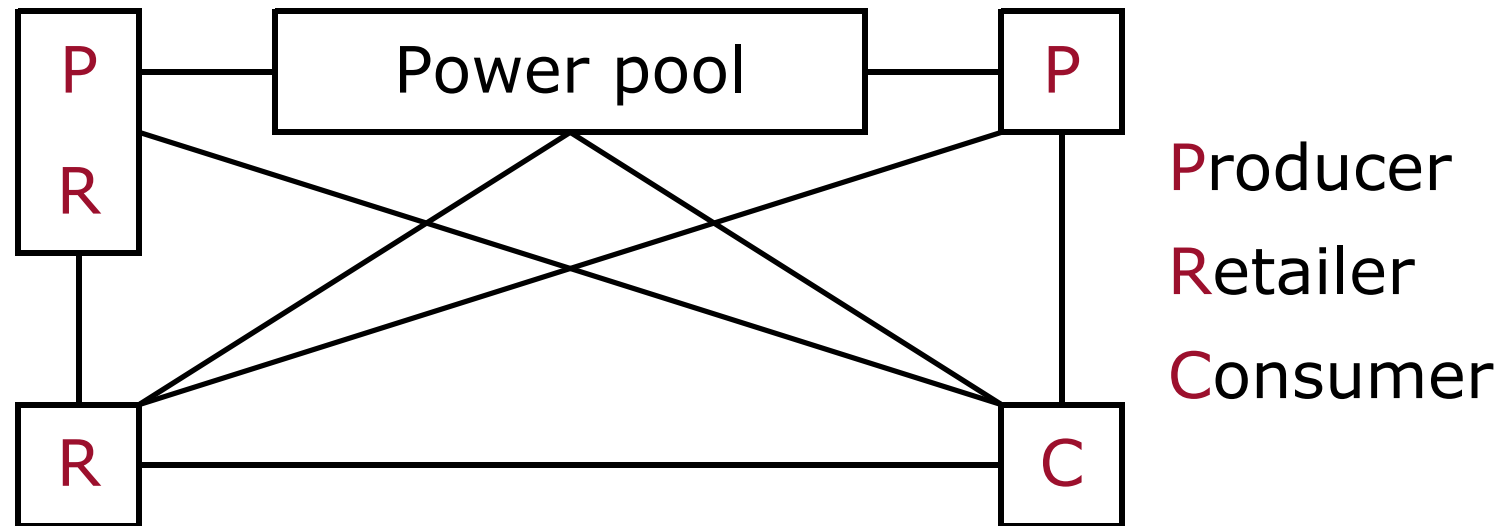
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- Usually the power pool is operated by the **system operator**, who then also acts as **trader** and **retailer**.
- The pool can also be **balance responsible** for the consumers.
- The system operator is also usually a **grid owner**.

BILATERAL ELECTRICITY MARKET



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- All players may trade freely.

BILATERAL ELECTRICITY MARKET



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- The power pool can be operated by the **system operator**, but it is also possible to have several competing pools.
- The system operator is also usually a **grid owner**.

POWER POOLS

- Physical trading, i.e., reported to system operator and accounted for in the balance for the post trading.
- Players must submit bids in a certain time before the trading period.

Example: Both Nord Pool Elspot and European Energy Exchange requires bids to be submitted no later than 12:00 the day before the trading period.



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POWER POOLS - Bids

- **Sell bid:** Quantity (MWh), time (trading period), minimal price (€/MWh).
- **Purchase bid:** Quantity (MWh), time (trading period), maximal price (€/MWh).
- Some power pools supports special bids as for example
 - **Block bids:** Bid must be accepted for several consecutive trading periods.
 - **Convertible block bids:** Can be converted to single bids if prices are higher (sell) or lower (purchase).
 - **Conditional bids:** Only valid if another bid has been accepted.



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POWER POOLS - Pricing

- **Spot market.** Accepted bids and prices are determined by the power pool in a process that starts after the closure of the bidding. The most common arrangement is to use a price cross.
- **“Clic market”.** The players see a list of all available bids and if a bid seems profitable, they can accept that specific bid. This means that all transactions will have an individual price.

BILATERAL TRADING

- Physical trading, i.e., reported to system operator and accounted for in the balance for the post trading.
- Direct contract between two players.
- Two typical contracts are
 - **Firm power.** A specified quantity during a specified time interval (in general several trading periods).
 - **Take-and-pay.** The buyer may during a specified time interval (in general several trading periods) consume as much as needed up to a specified maximal power.



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FINANCIAL TRADING

- Price insurance.
- Not reported to system operator; hence, not accounted for in the balance for the post trading.
- Direct contract between two players.



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FINANCIAL TRADING

- Contracts

- Two typical contracts are
 - **Options.** Company B buys power from the spot market. If the price exceeds X €/MWh then company A **pays** company B the difference between spot price and X . Company B pays company A for this agreement.
 - **Futures.** Company B buys power from the spot market. If the price exceeds X €/MWh then company A **pays** company B the difference between spot price and X . If the price is less than X €/MWh then company A **receives** the difference between spot price and X from company B.



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REAL-TIME TRADING

During the trading period, players are supposed to act according to the agreements from the ahead market.

However, unexpected events may require generation/consumption changes.

The system operator is responsible for the changes, and activates them using real-time trading.

- Real-time balancing market
- Central dispatch



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REAL-TIME BALANCING MARKET - Bids

- **Up-regulation.** Bidder is willing to sell energy to the system operator. Bids consists of maximal up-regulation (in MW) and minimal price (in €/MWh).
 - Producers increase generation.
 - Consumers decrease consumption.
- **Down-regulation.** Bidder is willing to buy energy from the system operator. Bids consists of maximal down-regulation (in MW) and maximum price (in €/MWh).
 - Producers decrease generation.
 - Consumers increase consumption.

REAL-TIME BALANCING MARKET

- Operation

- When necessary, the system operator will activate the least expensive up-regulation bid or the best paying down-regulation bid.
- Activated bids should be carried out within a specified time interval.



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REAL-TIME BALANCING MARKET

- Pricing

- All activated bids may receive the price requested in that specific bid ("pay-as-bid").
- All activated up-regulation bids receive the same price and all activated down-regulation bids receive the same price ("uniform pricing").
 - The **up-regulation price** is equal to the highest requested price in the activated up-regulation bids.
 - The **down-regulation price** is equal to the lowest requested price in the activated down-regulation bids.



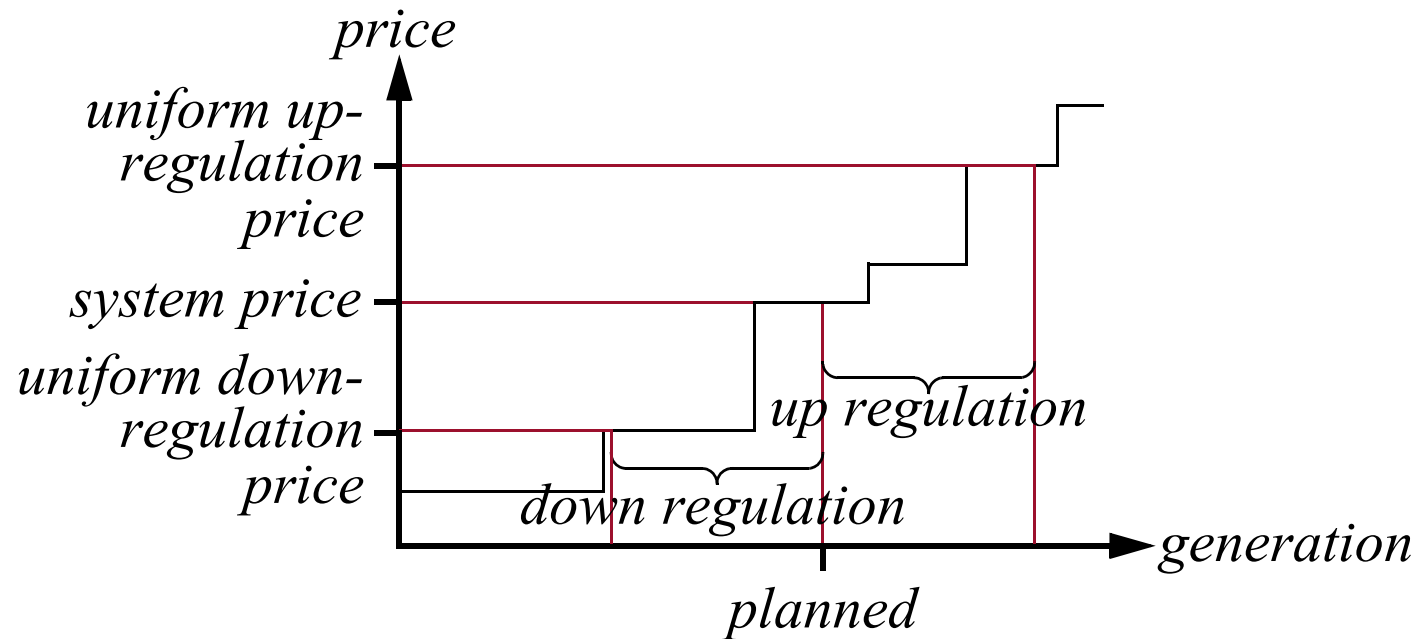
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REAL-TIME BALANCING MARKET

- Pricing



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CENTRAL DISPATCH



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- The system operator solves a short-term planning problem based on bids submitted to the ahead trading. The power system is dispatched according to the solution of this problem.
- Players may readjust their bids to compensate for forecast errors.
Sometimes readjustments must be properly motivated!
- Real-time prices are obtained from the solution to the central dispatch.

THE POST MARKET



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- The objective of the post trading is to clear all imbalances between what was planned before the trading period and what really happened during the trading period.
- The players involved in the post trading are the **system operator** and the **balance responsible players**.
- Each player in the electricity market must either be balance responsible or have an agreement that somebody else will be balance responsible for them.

IMBALANCE SETTLEMENT

- After the trading period, measurements of actual generation and consumption are collected.
- For each balance responsible player, the system operator calculates a balance, for example as

$$\begin{aligned} \textit{balance} &= \textit{generation} + \textit{purchase} \\ &\quad - \textit{consumption} - \textit{sales}. \end{aligned}$$

Notice that purchase and sales includes both the ahead trading and the real-time trading!



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IMBALANCE SETTLEMENT



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- **Positive balance.** More energy has been inserted to the power system than extracted. The balance responsible player has to sell the excess to the system operator.
- **Negative balance.** Less energy has been inserted to the power system than extracted. The balance responsible player has to buy the deficit from the system operator.

PRICING IN THE POST MARKET

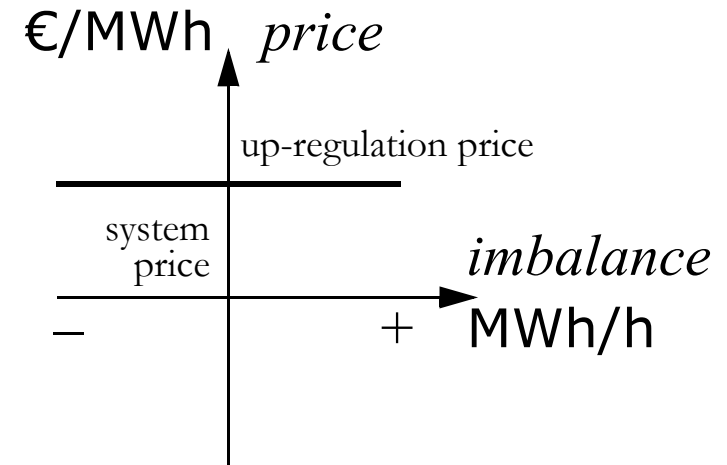
- The imbalance price is based on prices in the real-time trading.
 - Up- and down regulation prices (if there is a balancing market).
 - Real-time prices (if central dispatch is used).
- There are several methods for setting the imbalance price. The two most common methods are
 - **Single-price system.** System operator is buying and selling imbalance power for the same price.
 - **Two-price system.** System operator has one price for buying imbalance power and one for selling.



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PRICING IN THE POST MARKET

Example: Single-price system during an up-regulation trading period.



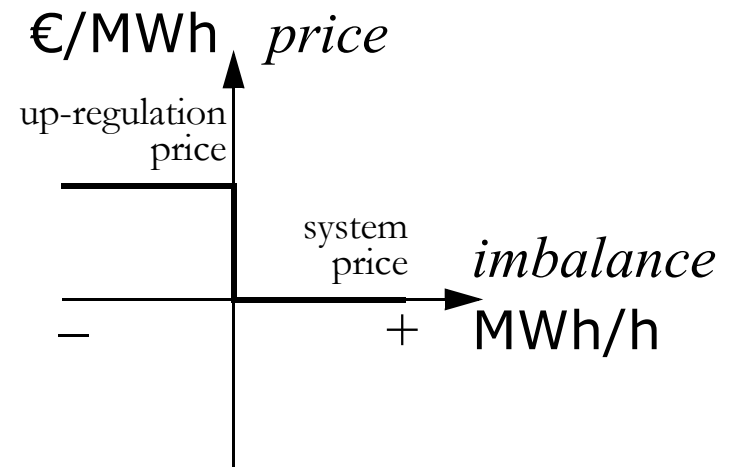
- Player with positive imbalance sells for up-regulation price \Rightarrow better price than in the ahead trading.
- Player with negative imbalance buys for up-regulation price \Rightarrow worse price than in the ahead trading.



PRICING IN THE POST MARKET

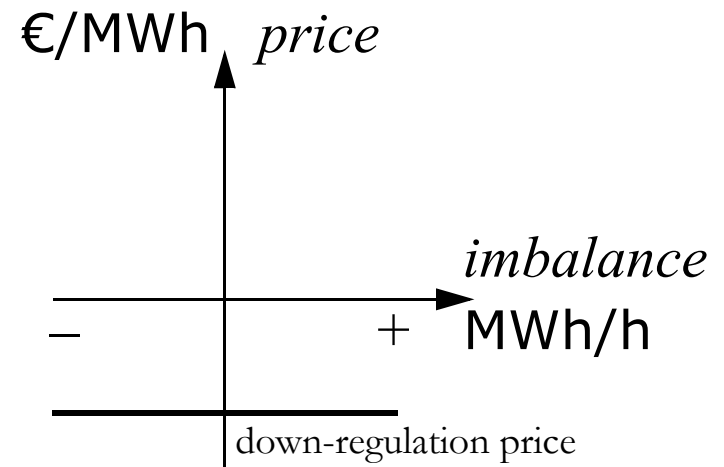
Example: Two-price system during an up-regulation trading period.

- Player with positive imbalance sells for system price \Rightarrow same price as in the ahead trading.
- Player with negative imbalance buys for up-regulation price \Rightarrow worse price than in the ahead trading.



PRICING IN THE POST MARKET

Example: Single-price system during a down-regulation trading period.



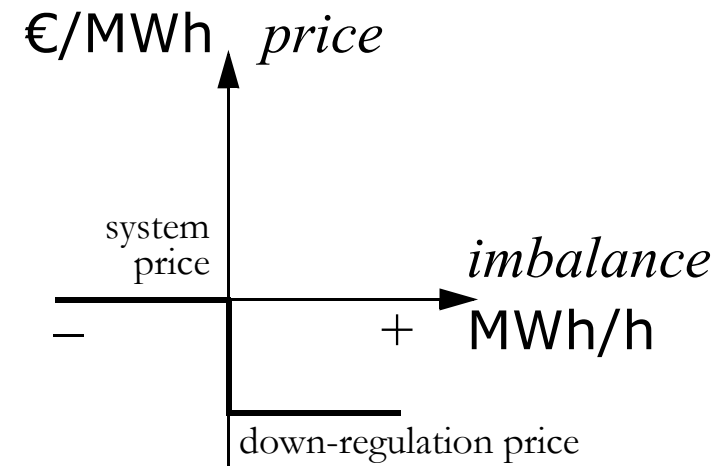
- Player with positive imbalance sells for down-regulation price \Rightarrow worse price than in the ahead trading.
- Player with negative imbalance buys for down-regulation price \Rightarrow better price than in the ahead trading.



PRICING IN THE POST MARKET

Example: Two-price system during a down-regulation trading period.

- Player with positive imbalance sells for down-regulation price \Rightarrow worse price than in the ahead trading.
- Player with negative imbalance buys for system price \Rightarrow same price as in the ahead trading.





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POST TRADING - Consequences

- There is a stronger pressure on balance responsible players to avoid imbalances in a two price system.
- This could be a problem for players having generation or load which is hard to forecast.
 - **Mixed price system.** Balance responsible players who have “helped” the system receives a price which is less favourable than the real-time price, but better than the system price.
 - **Dead-band.** Small deviations are charged the system price, i.e., only large deviations receive a price worse than in the ahead trading.