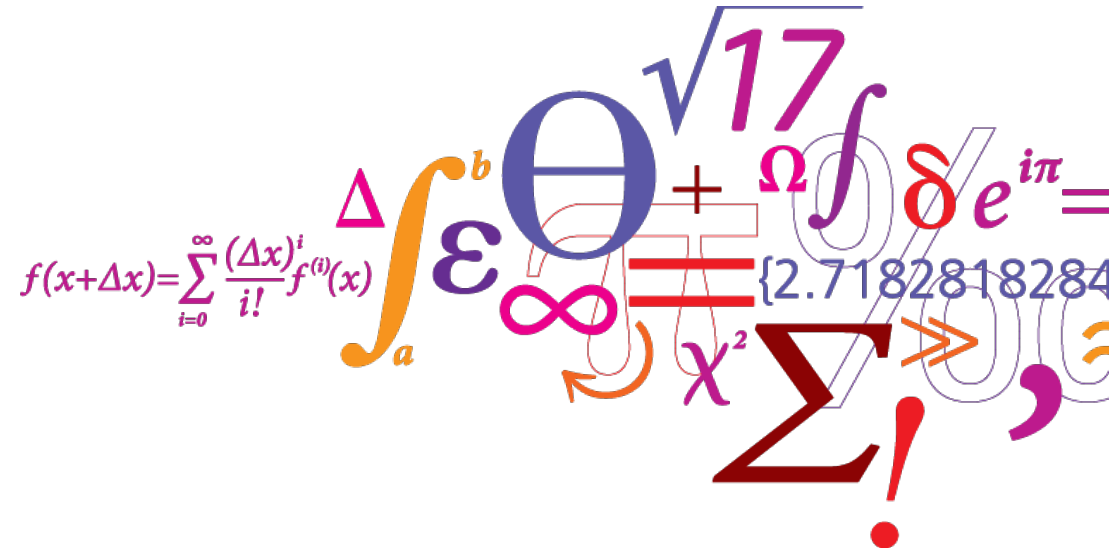


46755 – Renewables in Electricity Markets

Lecture 1: Introduction to electricity markets

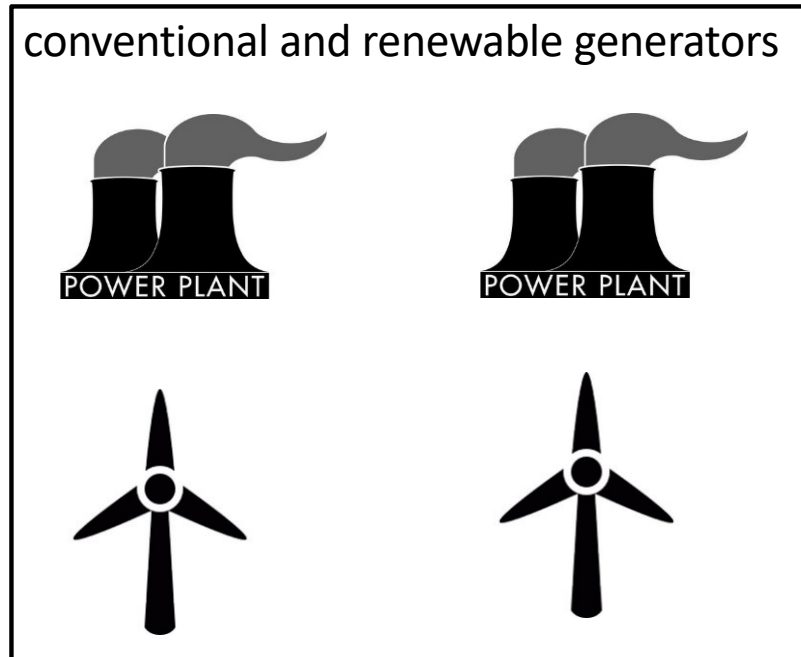
Jalal Kazempour

February 3, 2025



Electric Power Systems

Generators



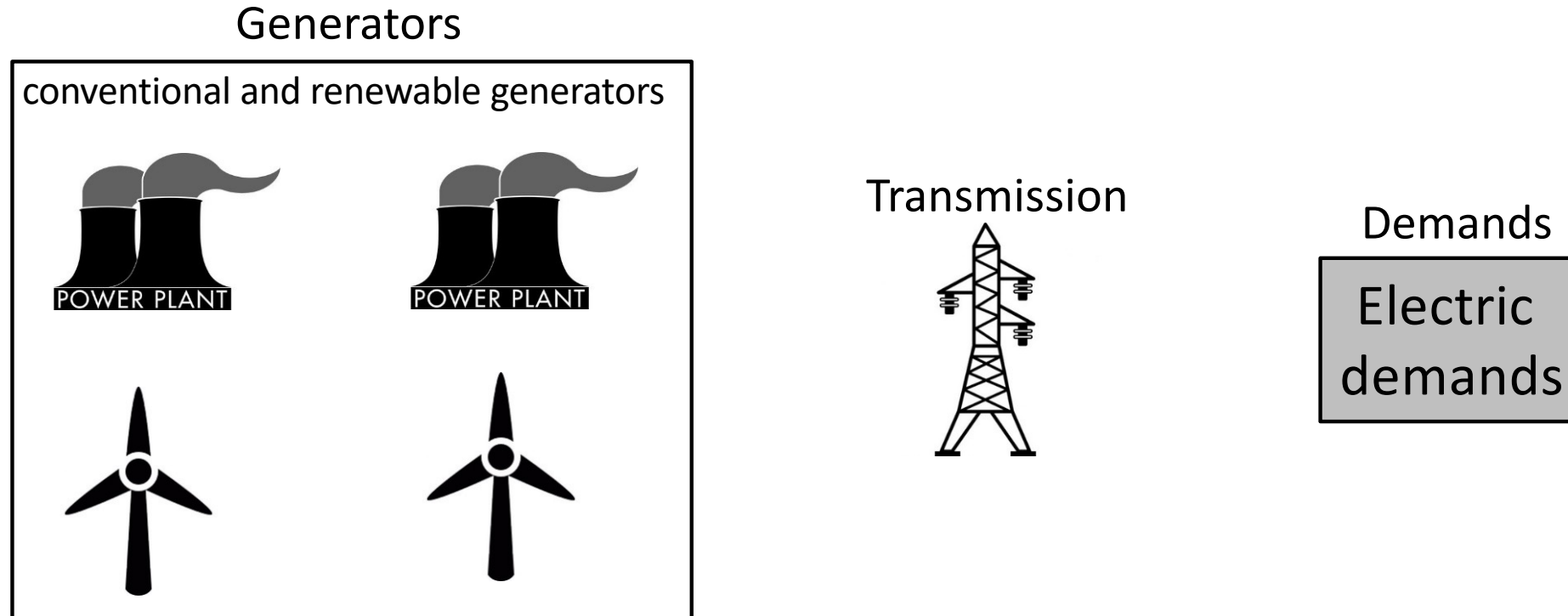
Transmission



Demands

Electric
demands

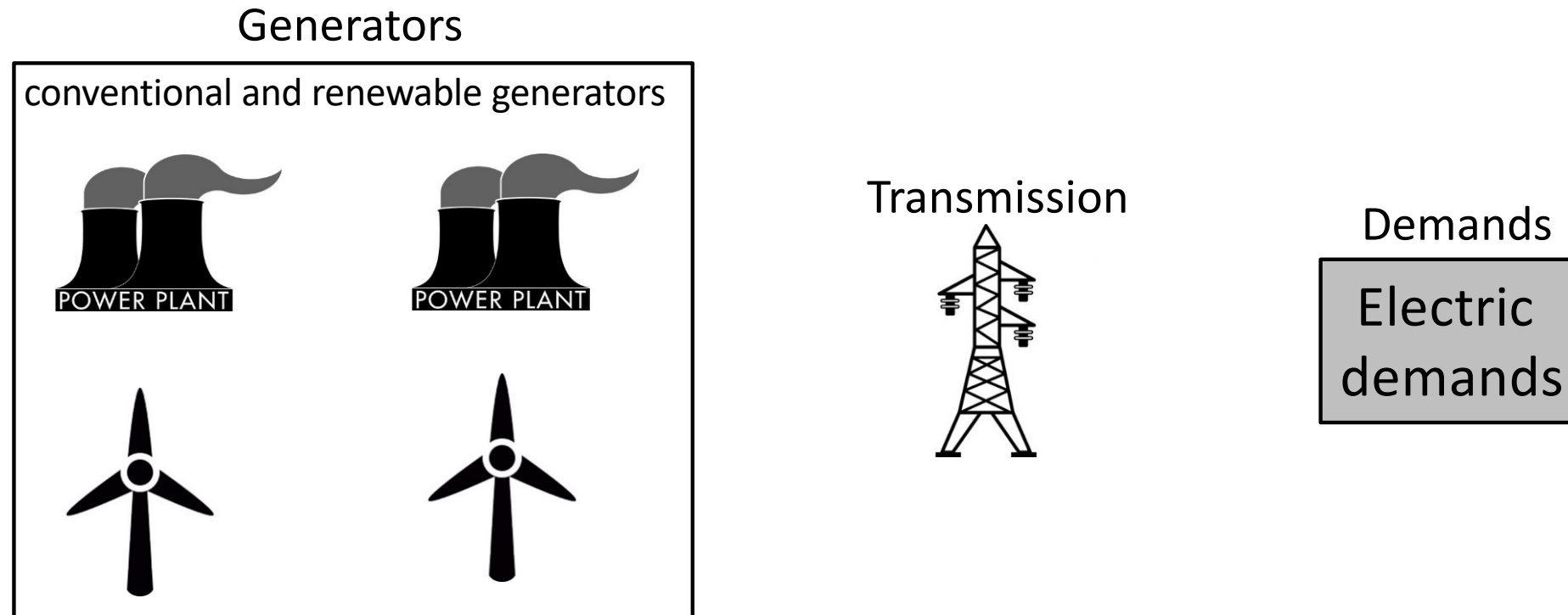
Electric Power Systems



Organizational Structure of Electric Power Systems:

- Centralized Power Systems (no market!)
- Electricity Markets

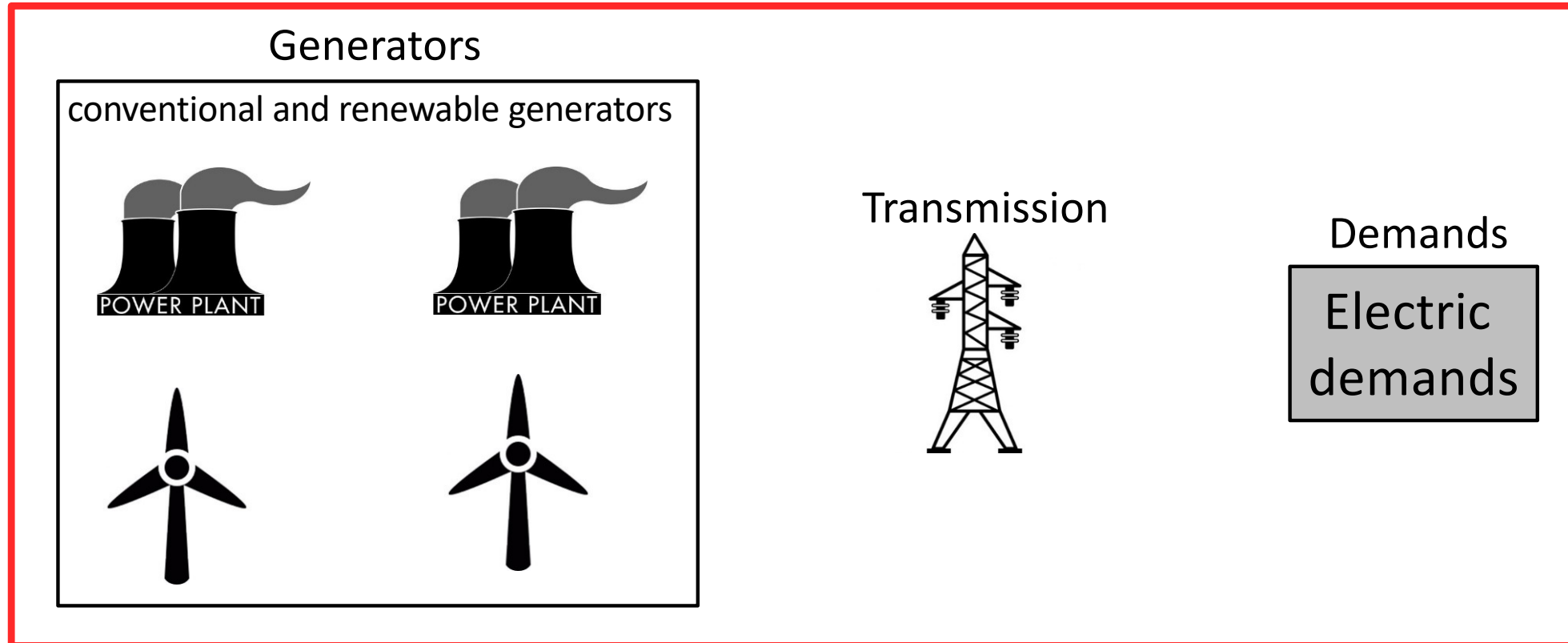
Electric Power Systems



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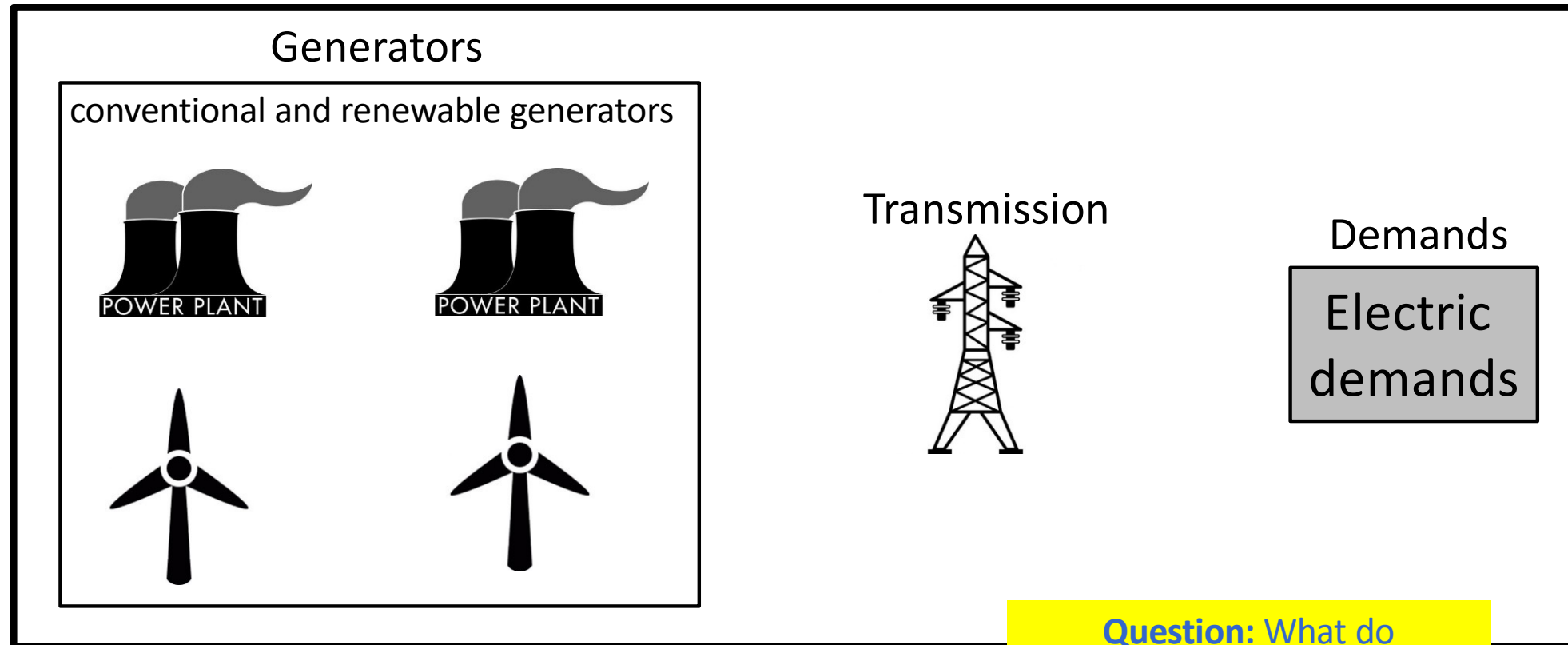
Centralized Power Systems



Centralized power system (no market):

A **single** entity, such as the system operator, is responsible for making all operational and planning decisions for the entire power system.

Centralized Power Systems



Centralized power system (no market):

A **single** entity, such as the system operator, is responsible for making all **operational** and **planning** decisions for the entire power system.

Question: What do
“operational” and “planning”
decisions mean?

Centralized Power Systems

- What is the goal of a system operator when making operational and planning decisions?

Centralized Power Systems

- ☐ What is the goal of a system operator when making operational and planning decisions?

- ✓ To meet the entire demand by dispatching power generators across the network in a **feasible** and **cost-effective** manner.

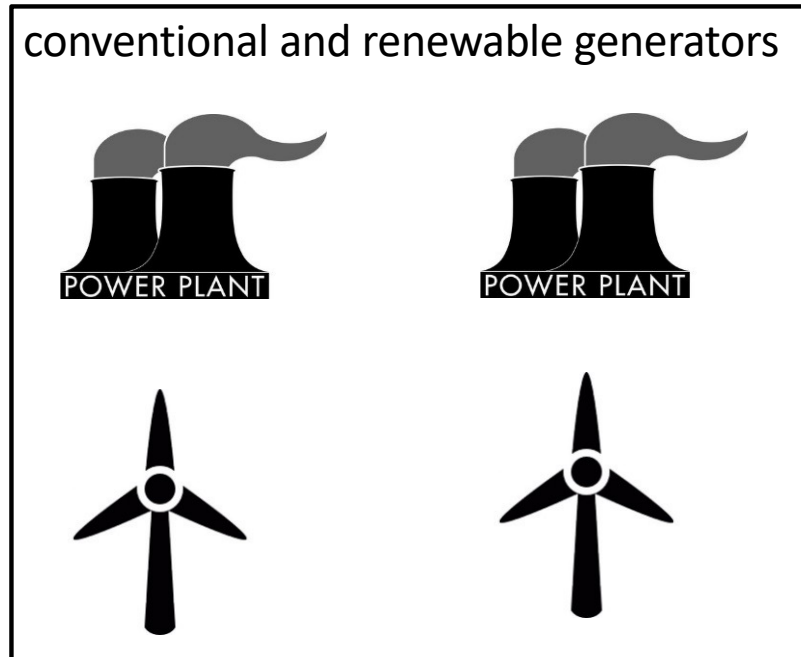
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Electric Power Systems

Generators



Transmission



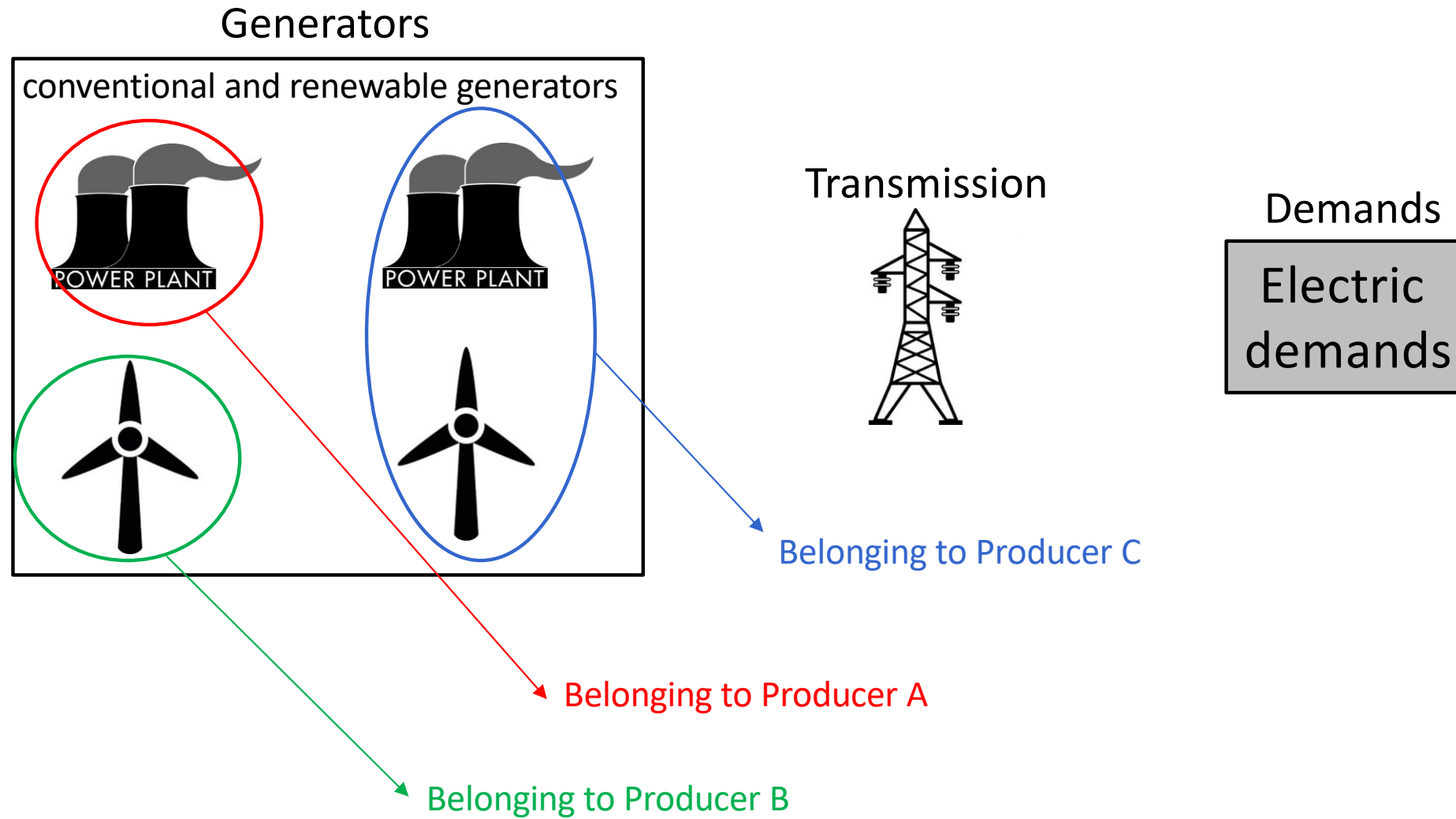
Demands

Electric
demands

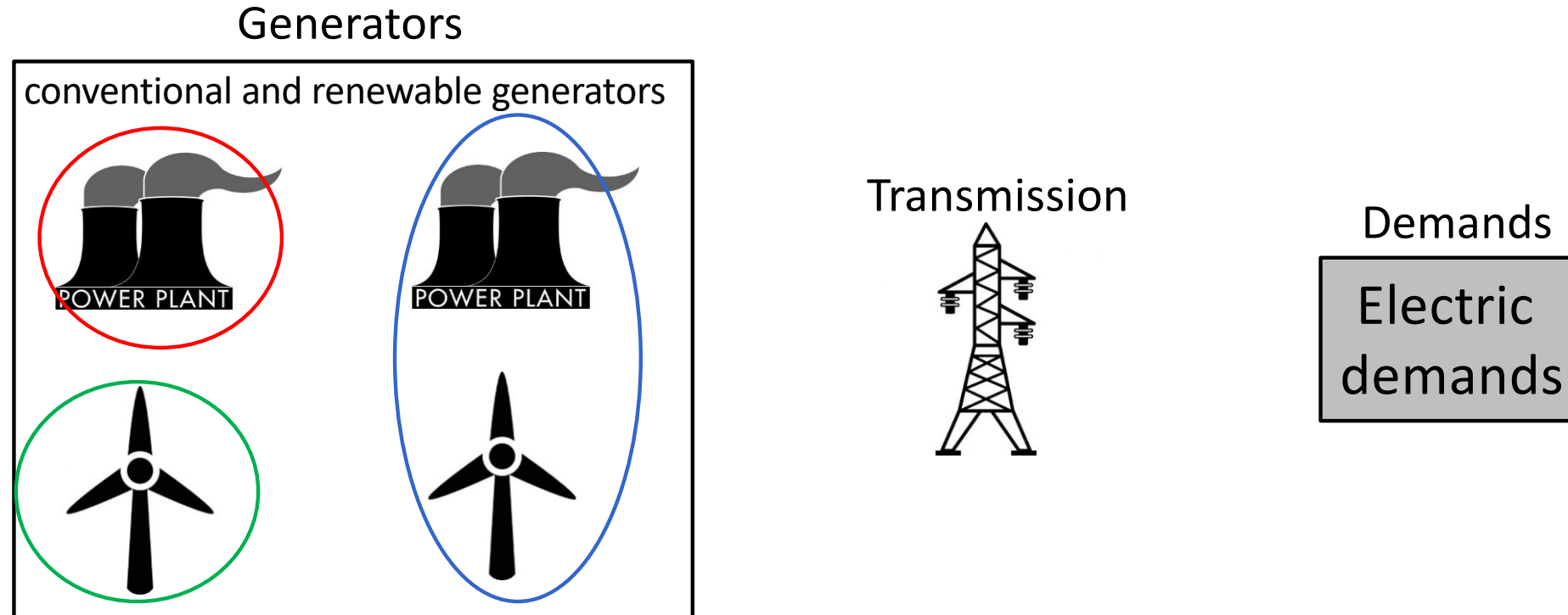
Organization Structure of Electric Power Systems:

- Centralized Power Systems (no market!)
- **Electricity Markets**

Electricity Markets



Electricity Markets



Electricity Market:

- Each producer aims to maximize their own profit by making optimal operational and planning decisions.
- Unlike centralized systems, there are multiple decision-makers involved.

How can an electricity market be operated where each market participant (e.g., generators) makes their own profit-maximizing decisions?

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For clarity, let us consider an apple market!

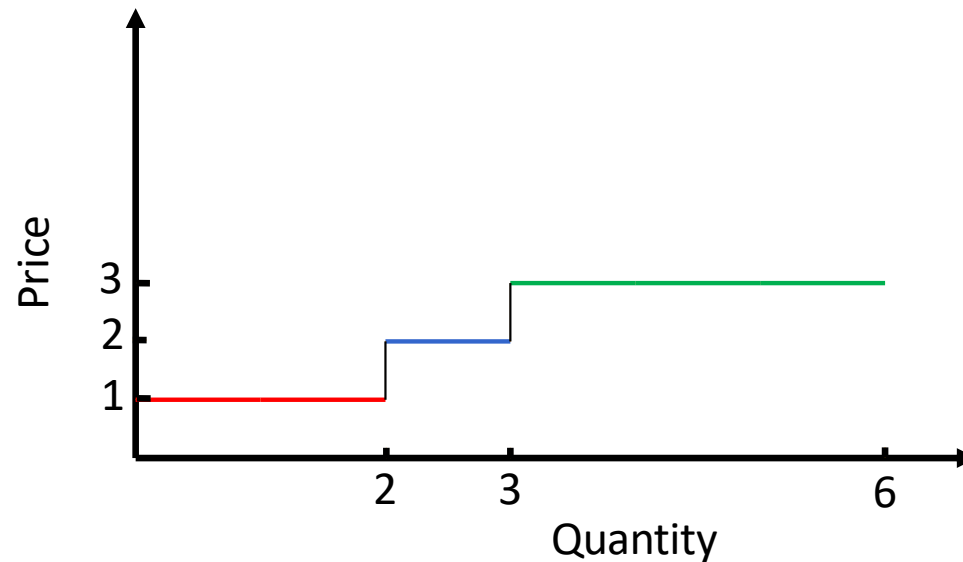


Market

Assume there is an apple market with multiple sellers and buyers:

Sellers:

- **Seller A** sells 2 apples at a price of \$1 each.
- **Seller B** sells 1 apple at a price of \$2.
- **Seller C** sells 3 apples at a price of \$3 each.

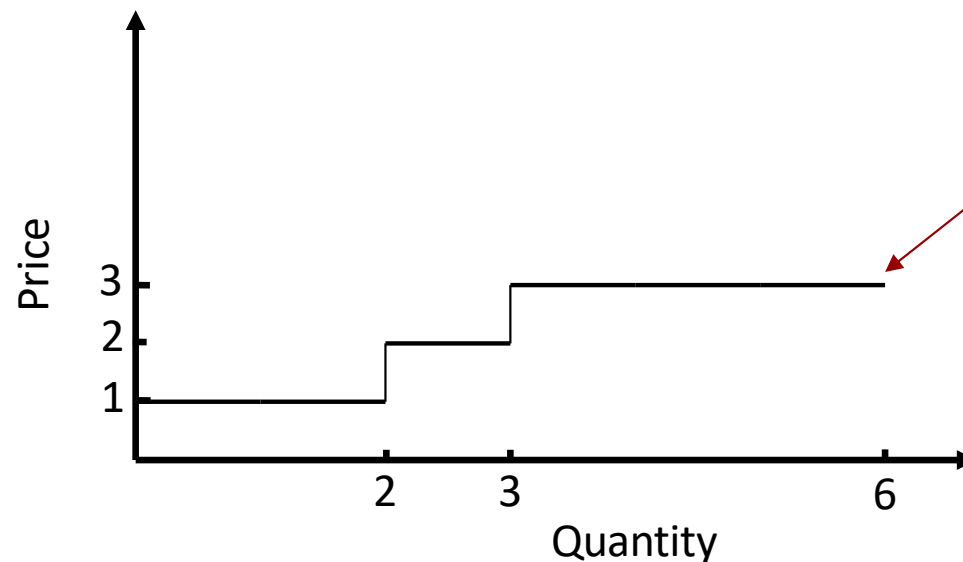


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Supply curve:

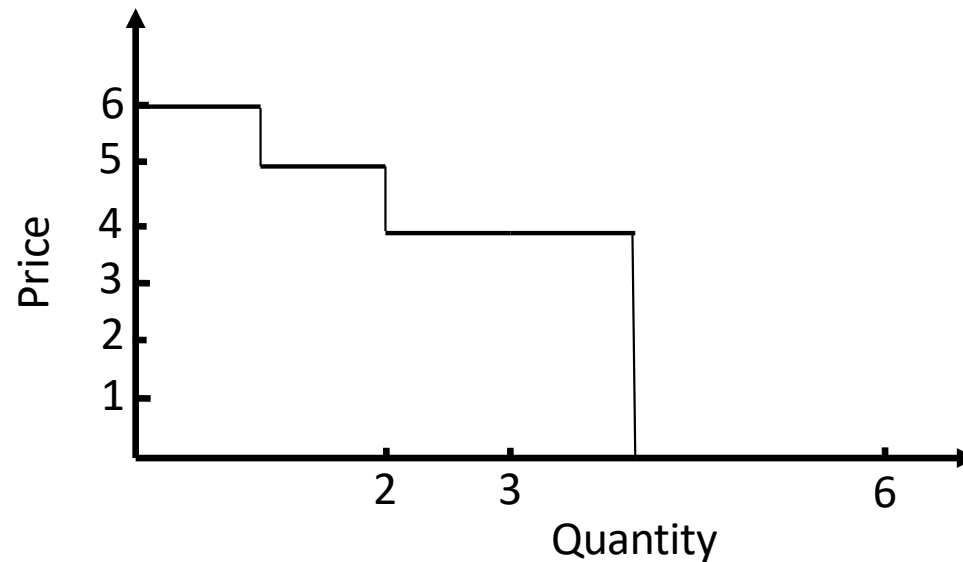
a non-decreasing curve where sellers are ranked based on the least-cost “**merit order principle**”!

Market

Assume there is an apple market with multiple sellers and buyers:

Buyers:

- **Buyer A** buys 1 apple at a price of \$6.
- **Buyer B** buys 1 apple at a price of \$5.
- **Buyer C** buys 2 apples at a price of \$4 each.

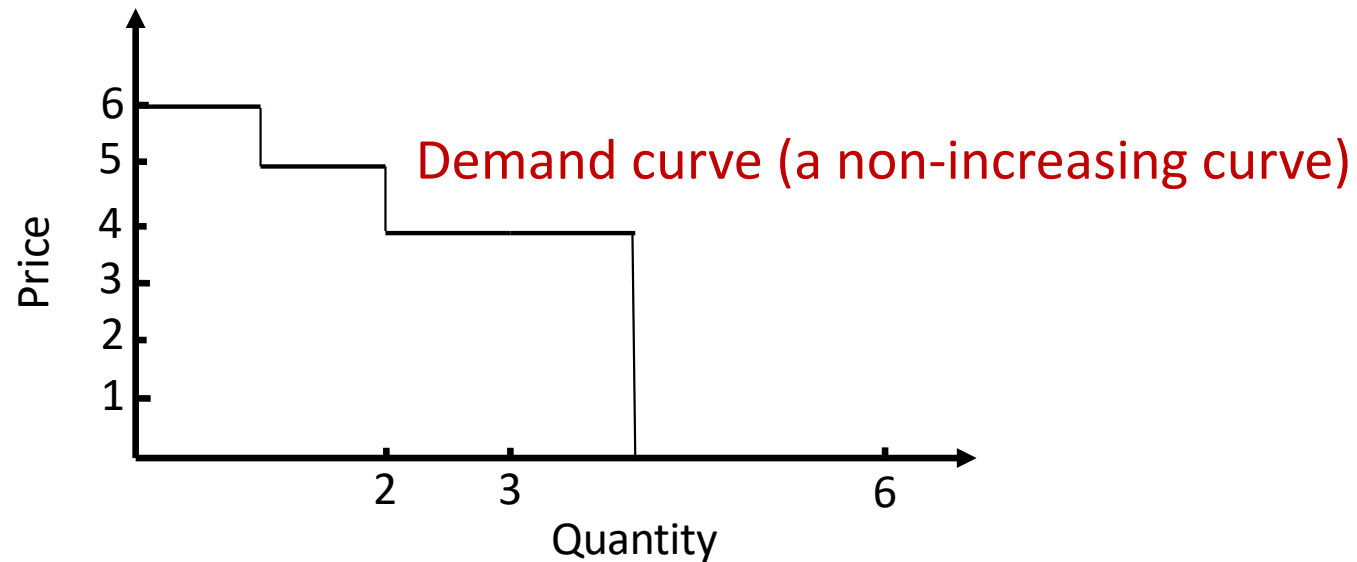


Market

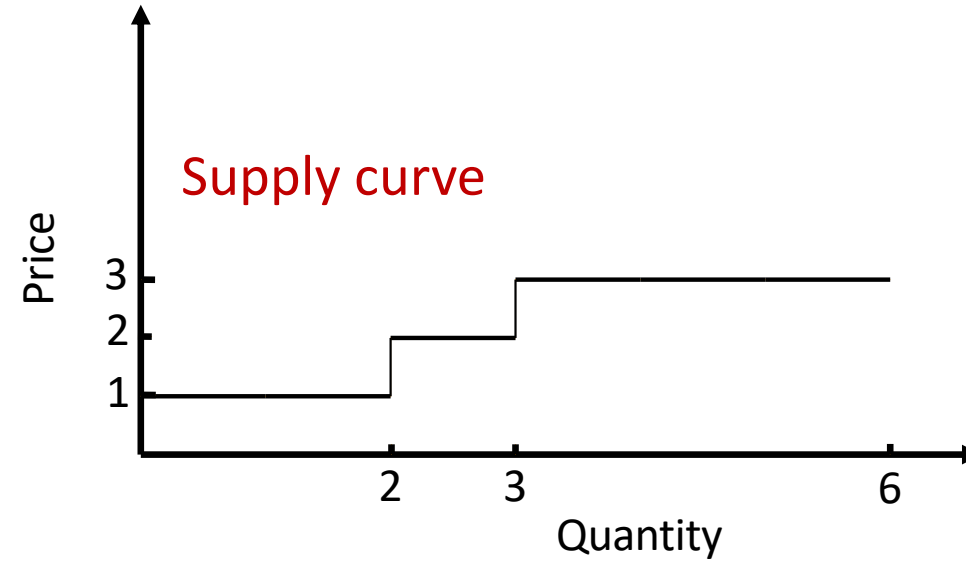
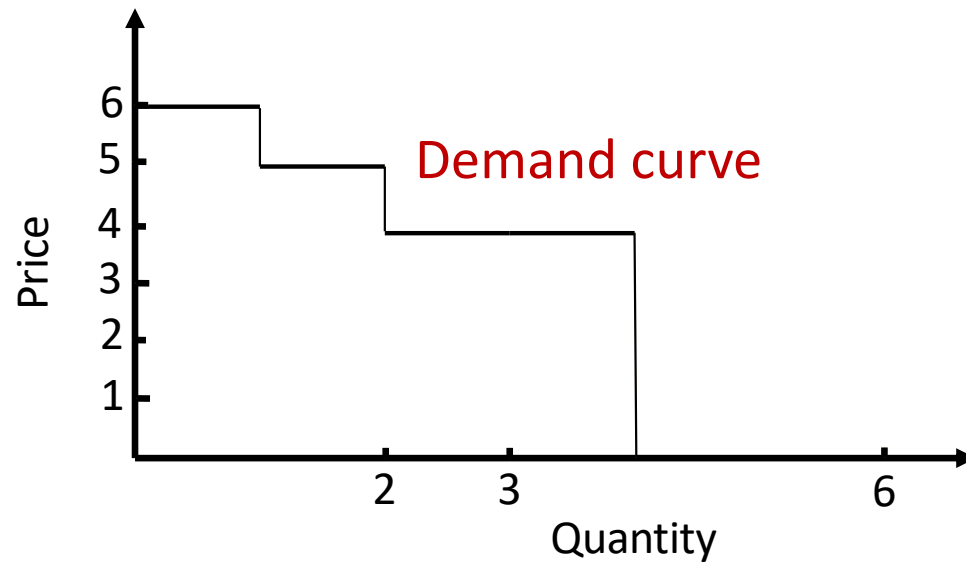
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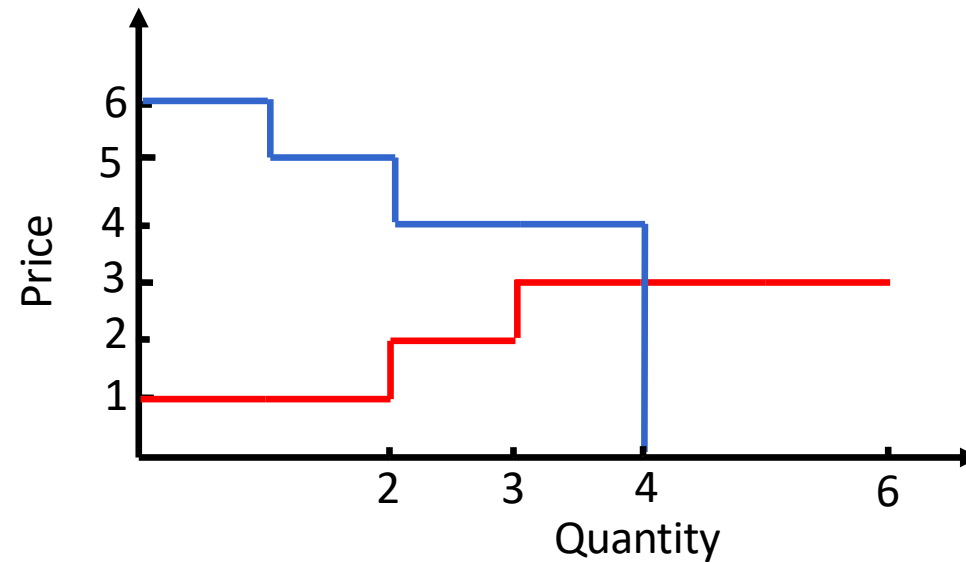


Market



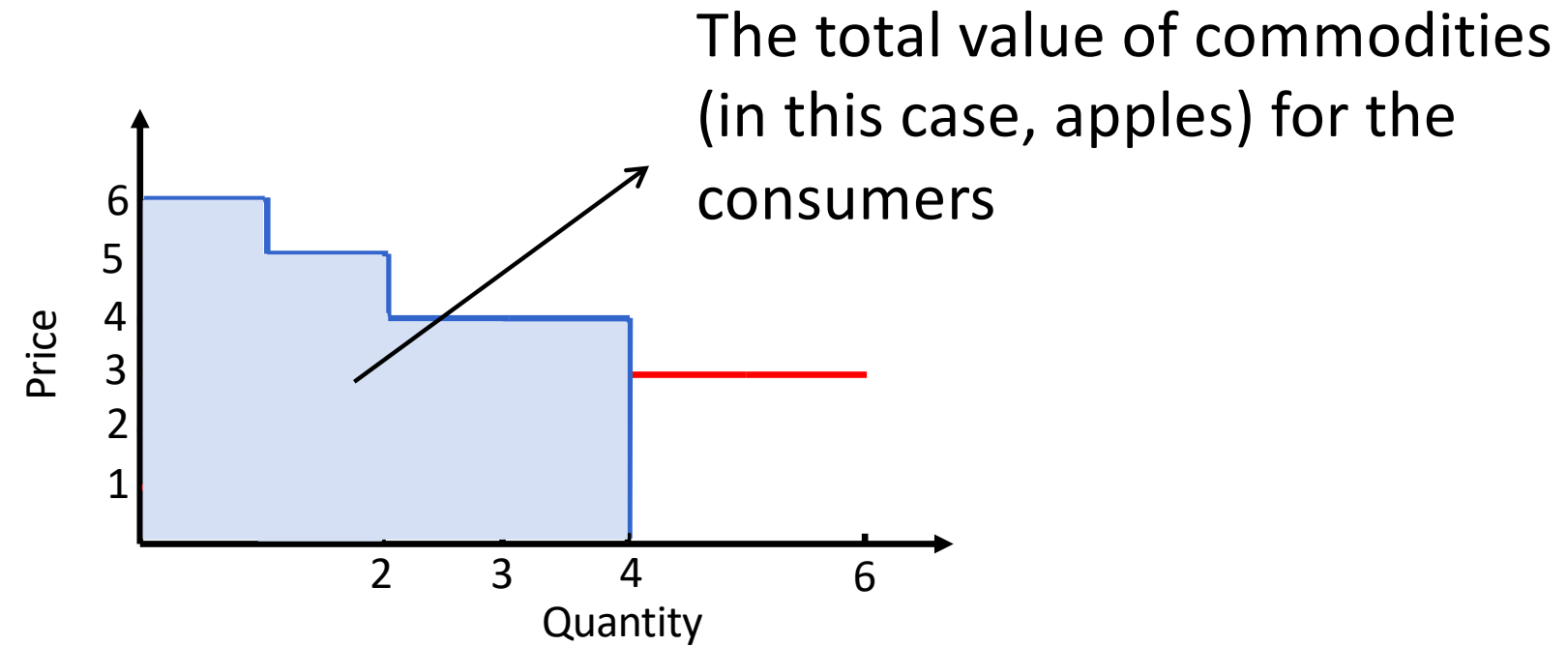
Now that we have both supply and demand curves, let's determine their intersection!

Supply-demand curve

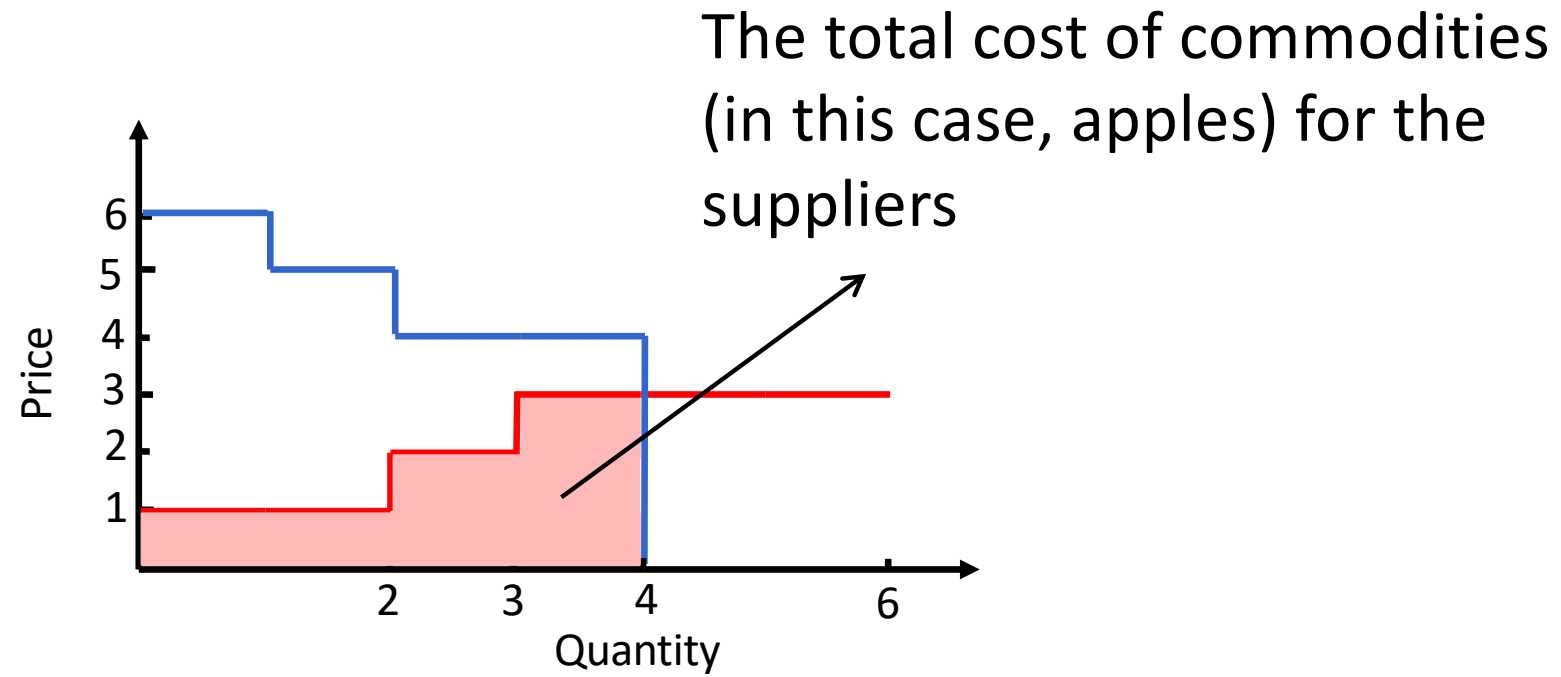


This is known as the “**market-clearing**” procedure, which is carried out by a non-profit entity, the market operator!

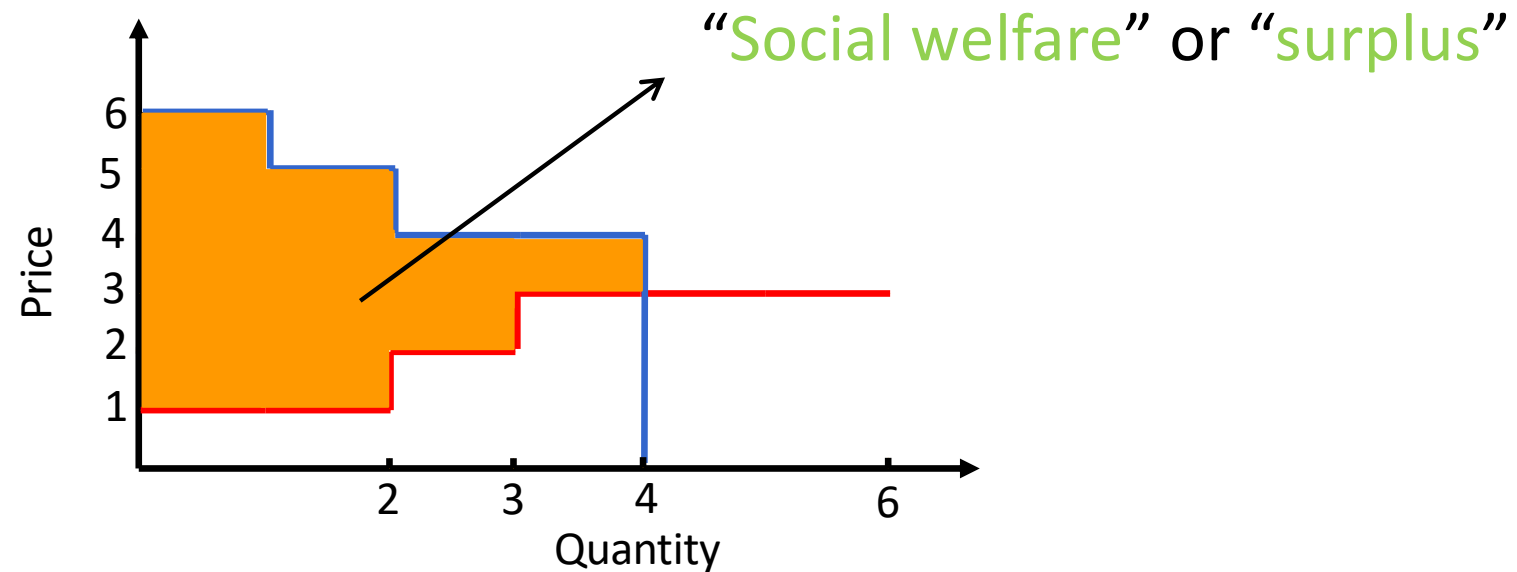
Market



Market



Market



The market operator clears the market by **maximizing** “social welfare”, which is the area between the supply and demand curves!

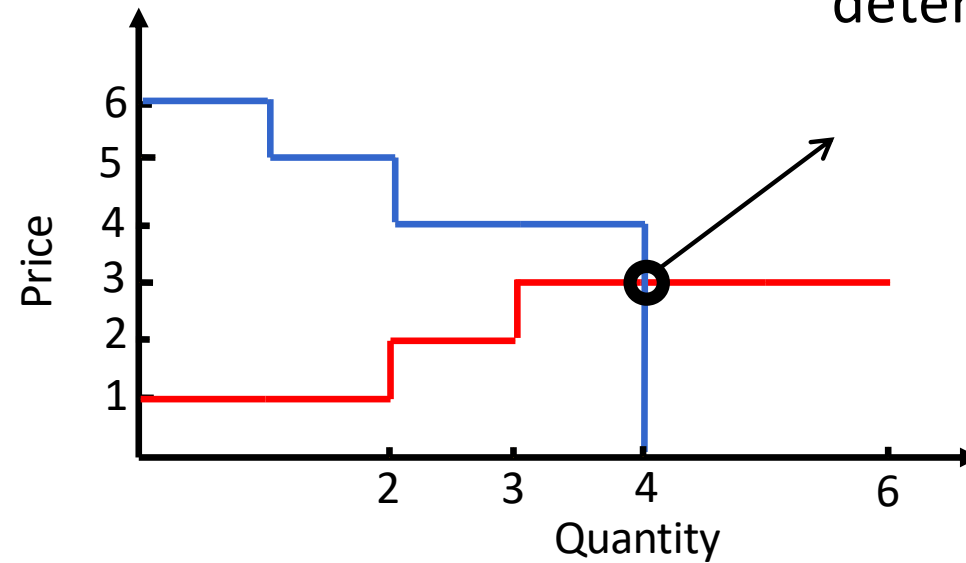


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- By maximizing social welfare, the total value of commodities for consumers is maximized, while the total cost for suppliers is minimized—resulting in satisfaction for both the demand and supply sides!

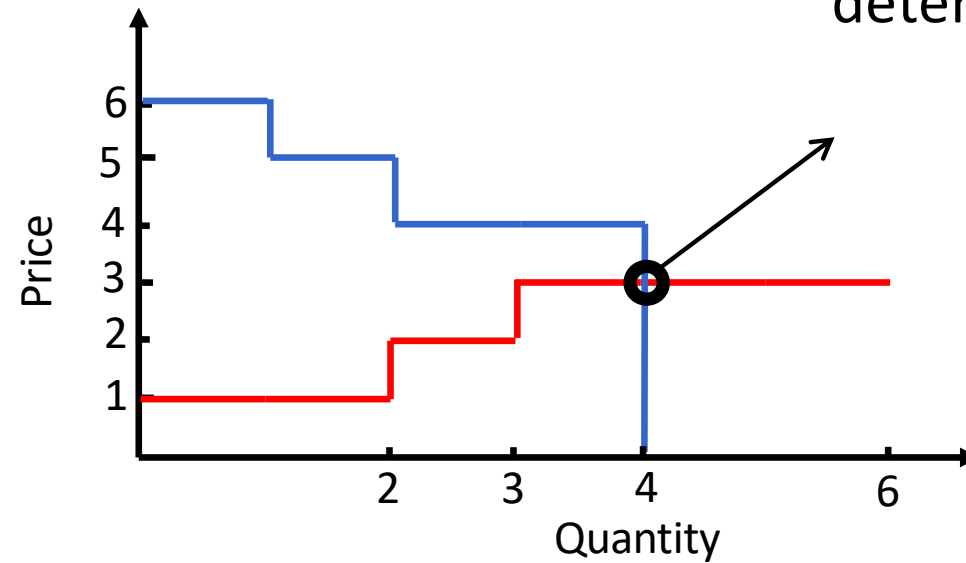
Market

Equilibrium point: The point where the market-clearing price and quantity are determined.



Market

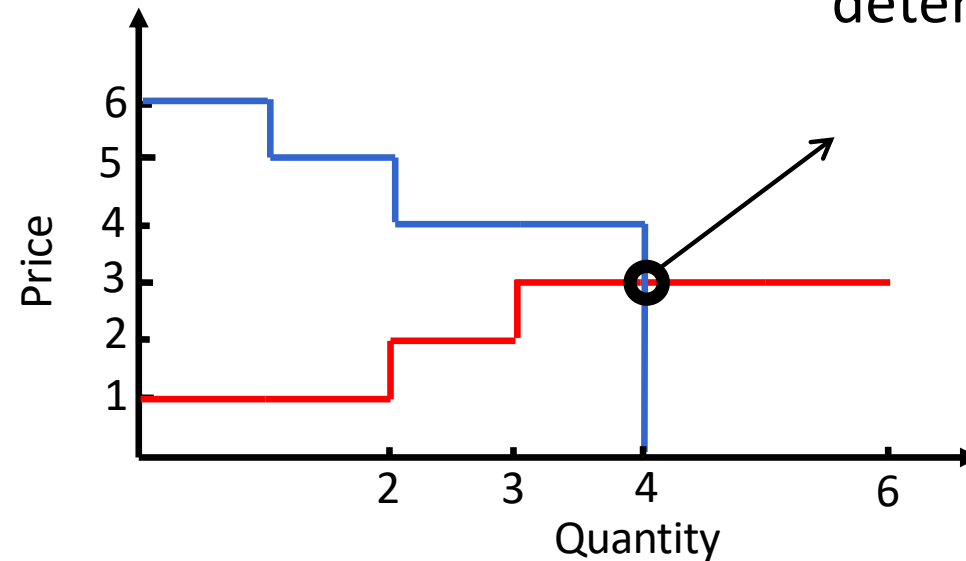
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Market

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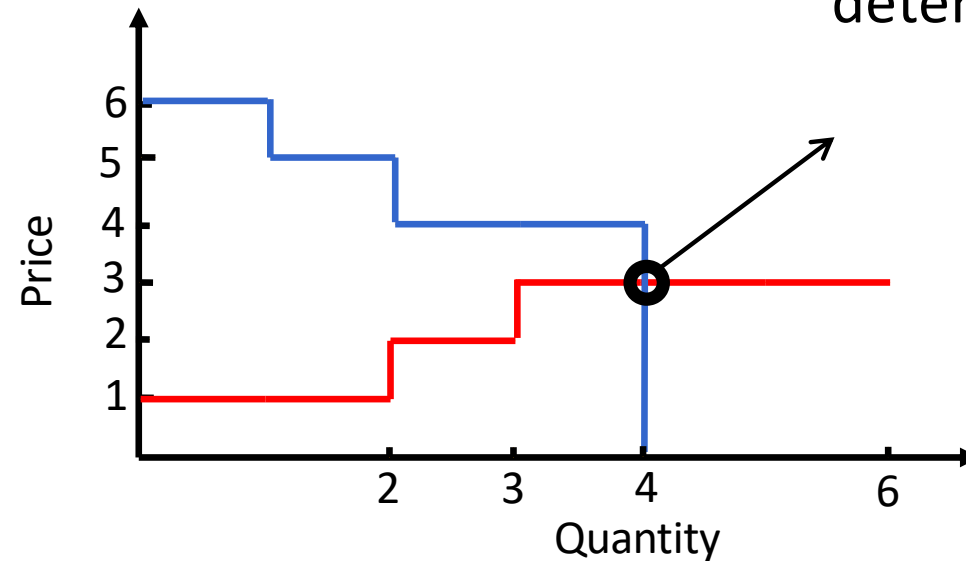


- At the equilibrium point, the social welfare is maximized.
- Based on the equilibrium point, four apples are traded at a price of \$3 each (**uniform pricing**)!

Market

Question: Based on uniform pricing, does any buyer (or seller) necessarily pay (or receive) the price they submitted to the market?

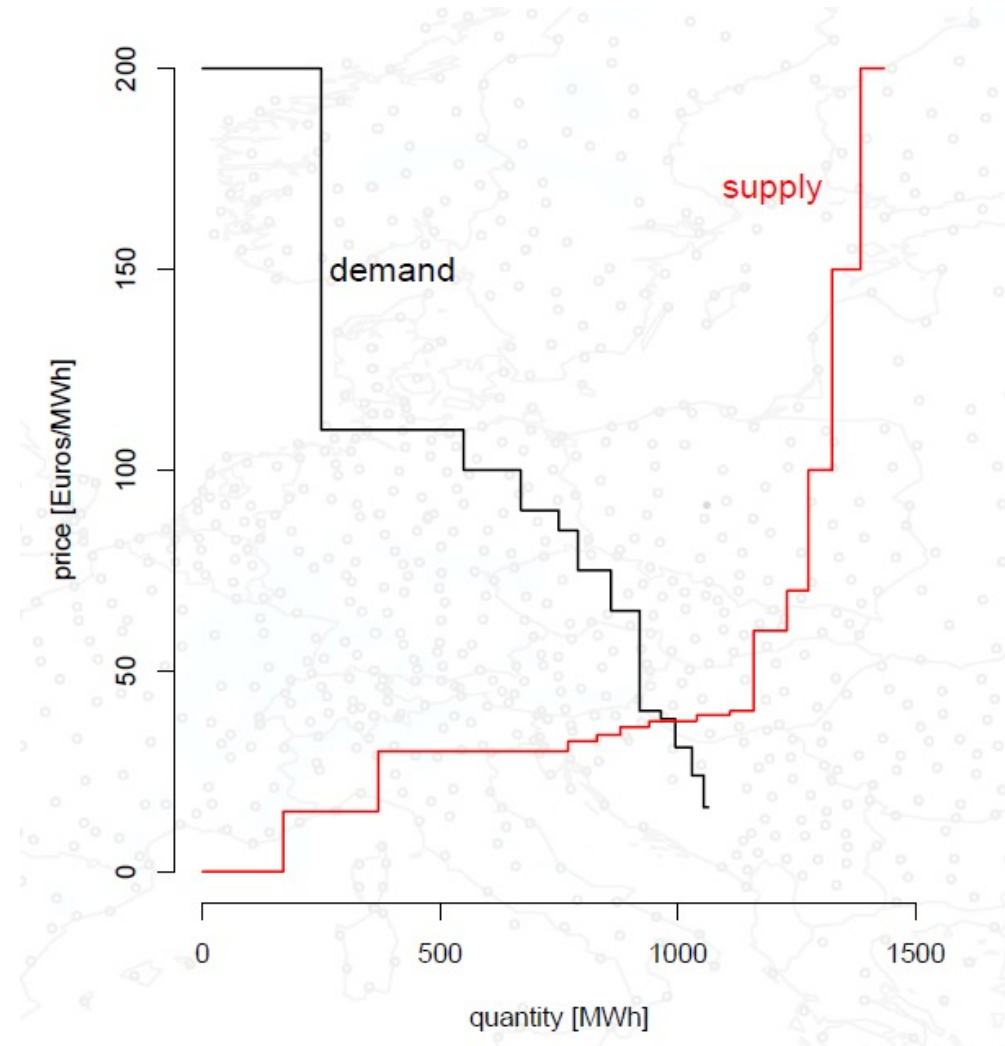
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Electricity Markets

The electricity market also trades a commodity (like the apple market), and its clearing algorithm is similar!



Let's check supply-demand curves in Nord Pool



Auctions ▾ UK Auctions ▾ Intraday ▾ Power system data ▾ Reports ⓘ Map

Settings ▾ Subscribe Log in

Day-ahead

Prices

System price & turnover

Volumes

Capacities

Flows

Scheduled physical flows

Flow-based constraints

Aggregated Bidding Curves

Aggregated Bidding Curves

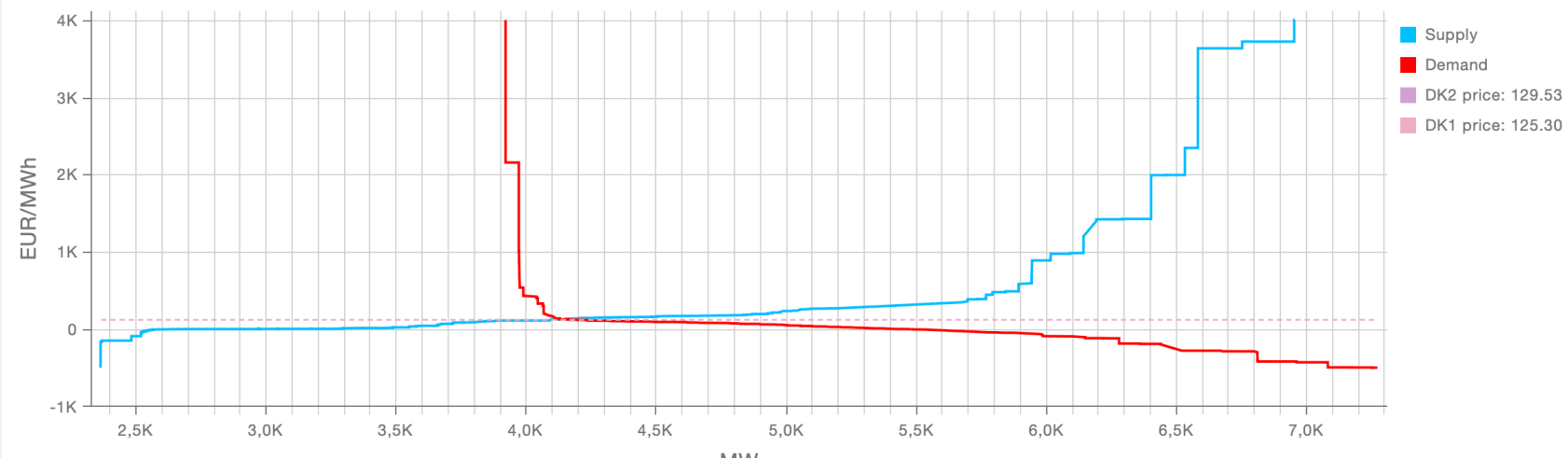
◀ 03.02.2025 ▶ Filters ^

Clusters CWE AT BE DE-LU FR NL PL Nordic **DK** FI NO SE Romania RO BALTIC

Status: **Final**

Aggregated bid curves are based on aggregated demand and supply curves from all participants, across all power exchanges participating in the Day-ahead auction. In addition, realized supply and demand block volumes as well as import and export flows are added on to the curve volumes.

Delivery period: 00:00 - 01:00 (CET)



Link: <https://data.nordpoolgroup.com/auction/day-ahead/aggregated-bid-curves?deliveryDate=2025-02-03&bidCurveArea=DK>

Electricity Markets

Discussion:

What aspects of an electricity market differentiate it from markets for other commodities, such as the apple market?

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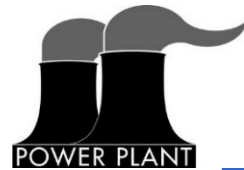
- The electricity market-clearing algorithm must take into account the physical laws of electric networks (e.g., Kirchhoff's circuit laws),
- Electricity is a non-storable commodity on a large scale,
- Electricity demand is typically highly inelastic to price, though this is changing,
- ...

Electricity Markets



Market-clearing
algorithm

Electricity Markets



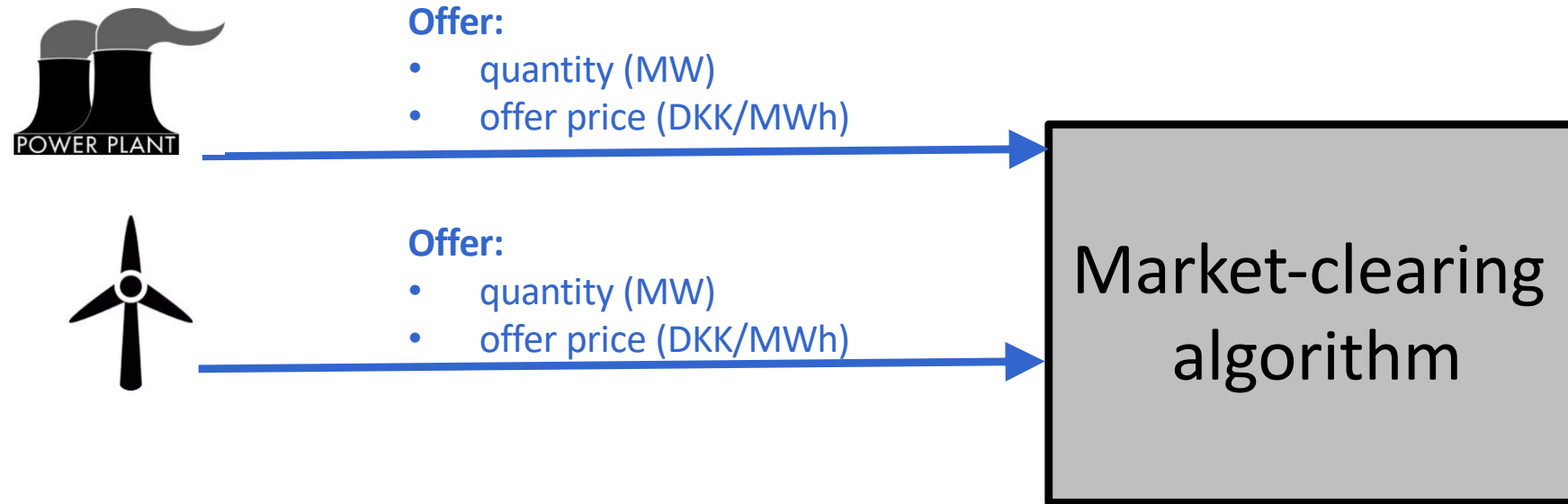
Offer:

- quantity (MW)
- offer price (DKK/MWh)



Market-clearing
algorithm

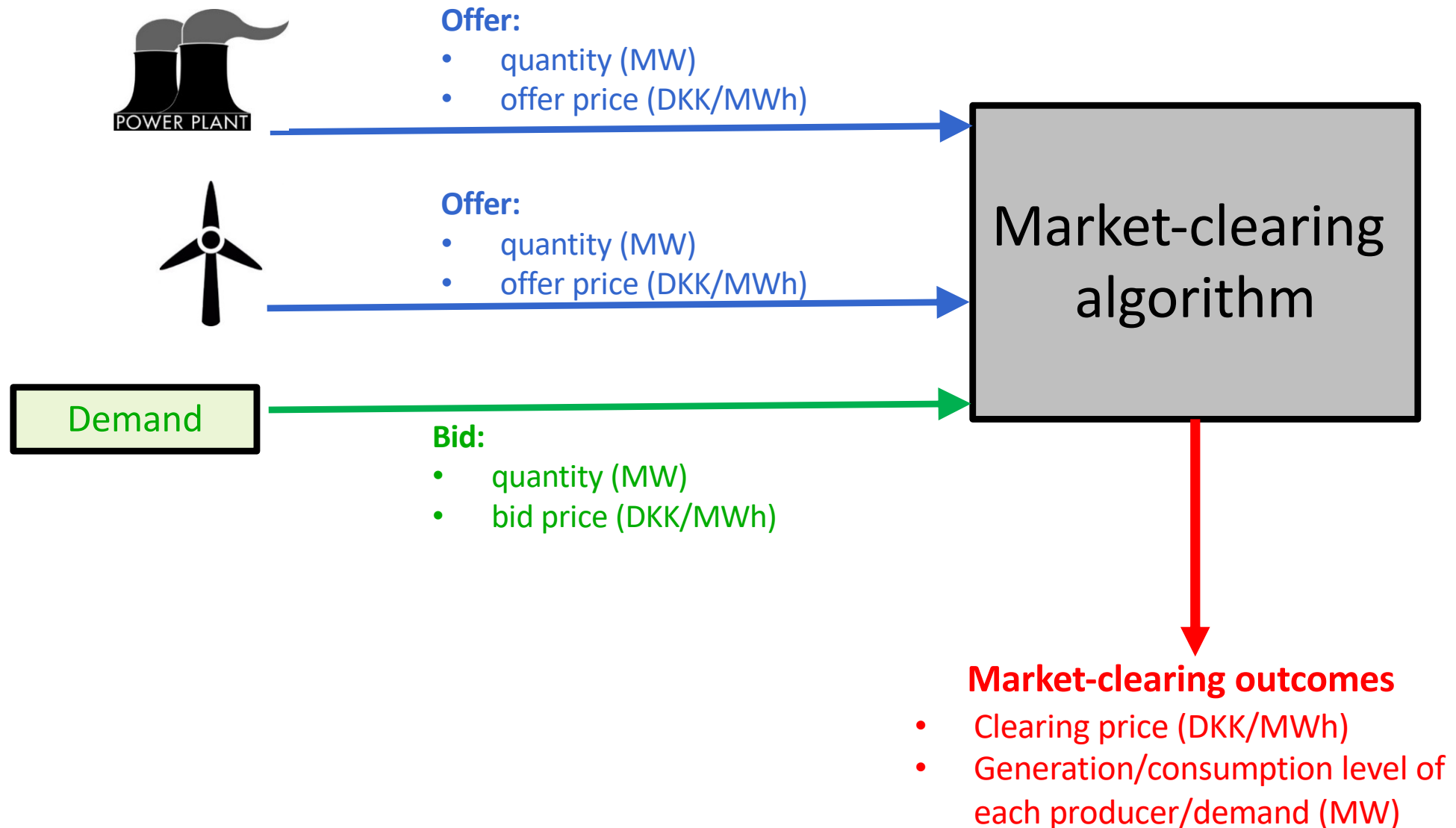
Electricity Markets

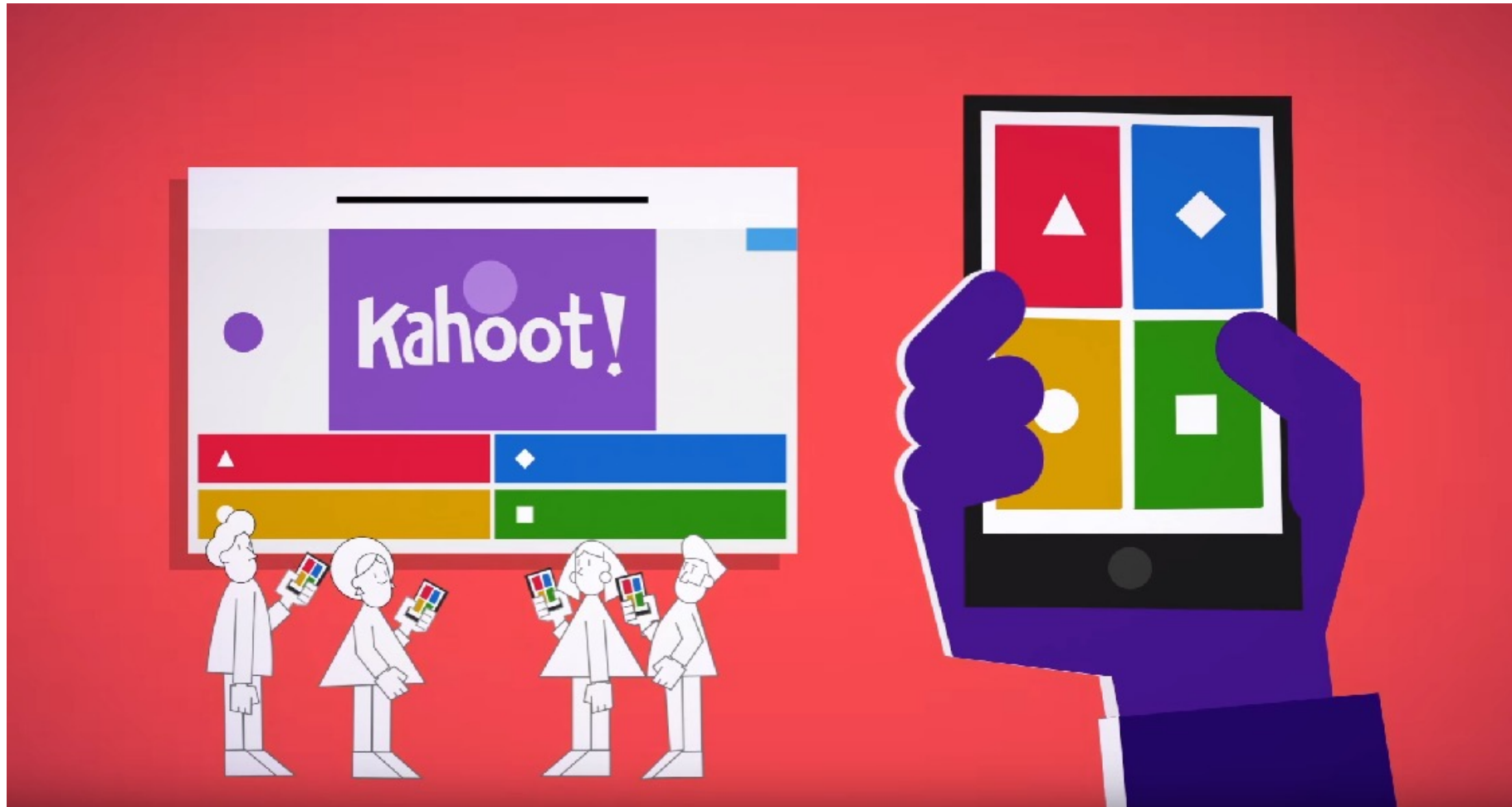


Electricity Markets



Electricity Markets





Thanks for your attention!

Email: jalal@dtu.dk