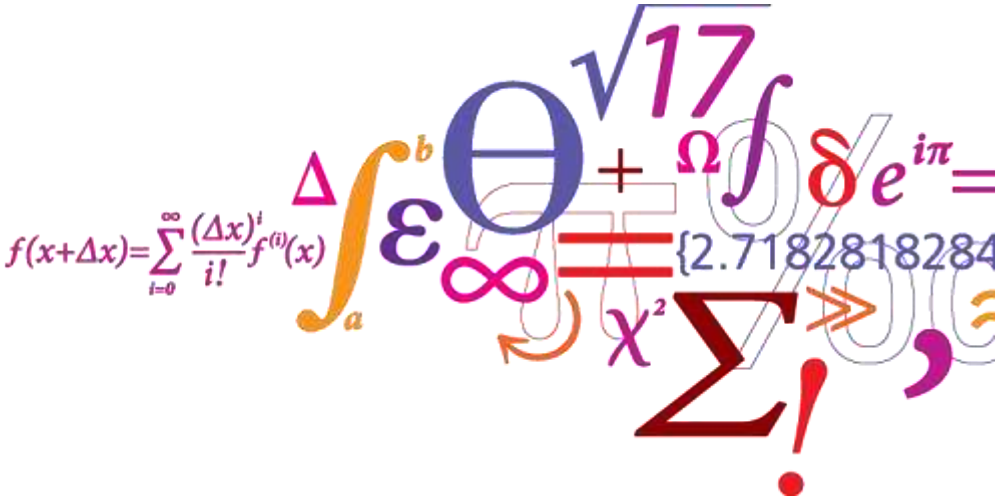
46755 – Renewables in Electricity Markets

Lecture 1: Introduction to electricity markets

Jalal Kazempour



January 29, 2024

Electric Power Systems

Generators

conventional and renewable generators

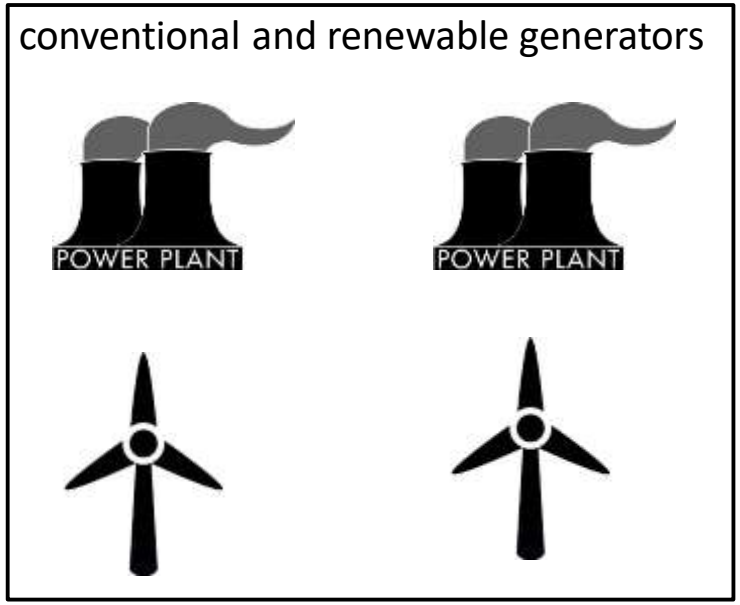
Transmission

Demands

Electric demands

Electric Power Systems

Generators



Transmission

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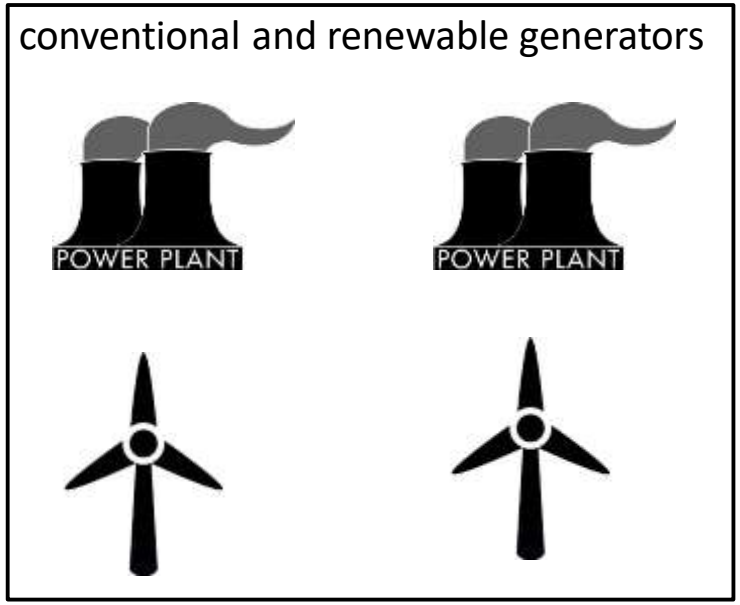
Electric demands

Organizational Structure of Electric Power Systems:

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

Electric Power Systems

Generators



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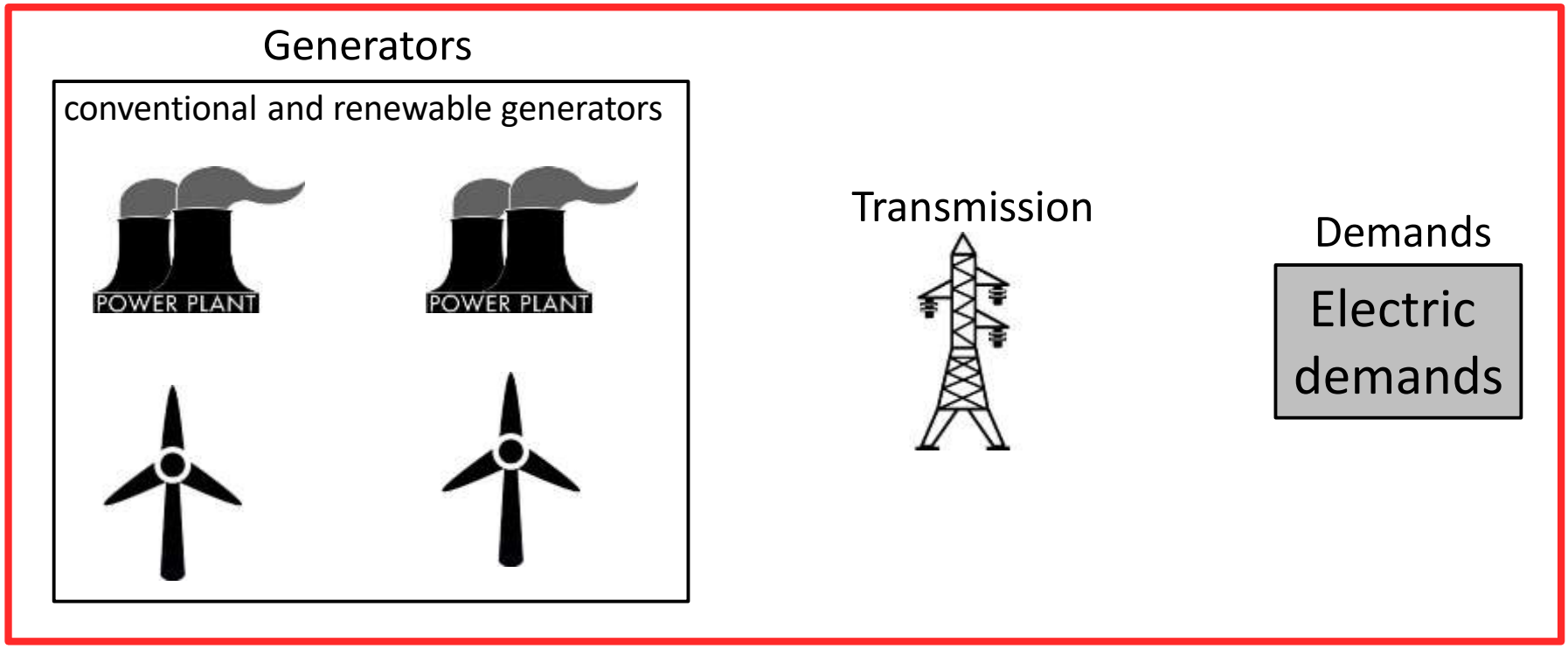
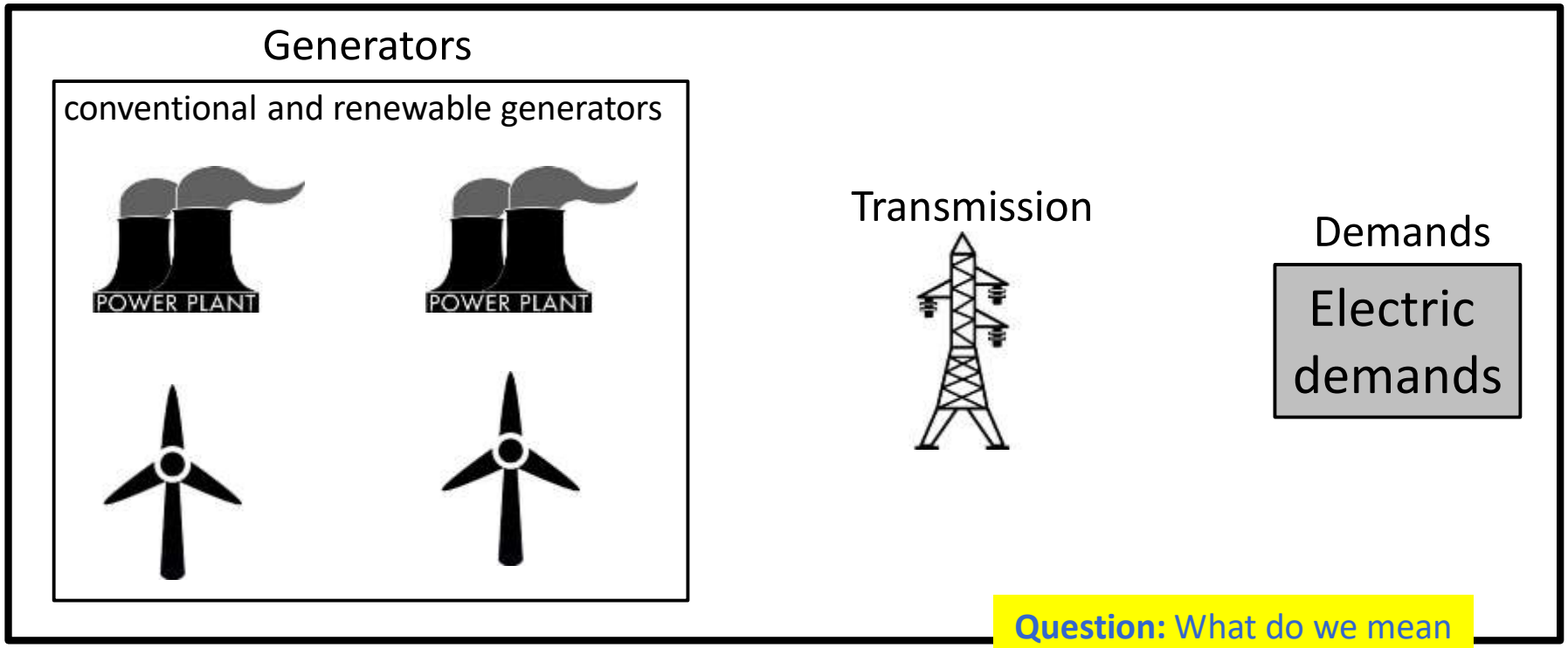
Centralized Power Systems



Centralized power system (no market):

A **single** entity, e.g., the system operator, is in charge of making all decisions (operational and planning) of the entire power system!

Centralized Power Systems



Question: What do we mean by "operational" and "planning" decisions?

Centralized power system (no market):

A **single** entity, e.g., the system operator, is in charge of making all decisions (operational and planning) of the entire power system!

Centralized Power Systems

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

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- ✓ To supply the whole demand through dispatching power generators throughout the network in a **feasible** and **least-cost** manner!

Centralized Power Systems

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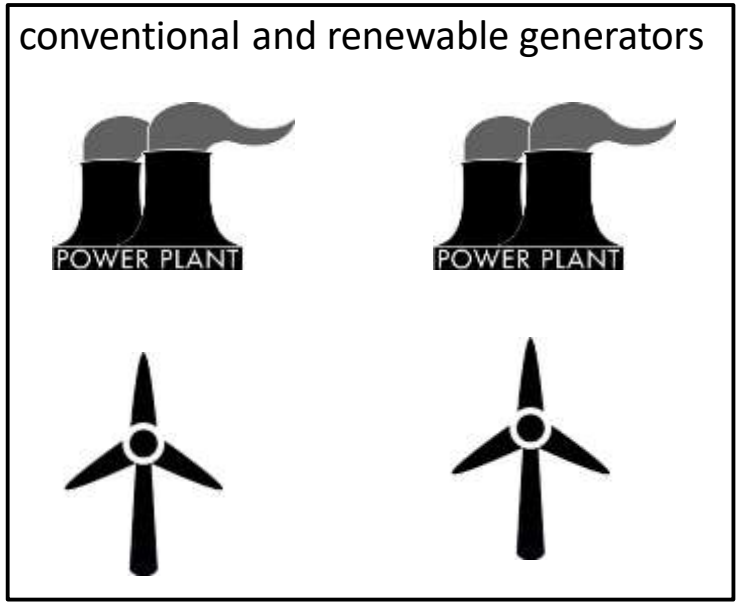
- ✓ To supply the whole demand through dispatching power generators throughout the network in a **feasible** and **least-cost** manner!

Question: What do we mean by “feasibility” and “least-cost dispatch”?

Electric Power Systems

Generators



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Demands

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Organization Structure of Electric Power Systems:

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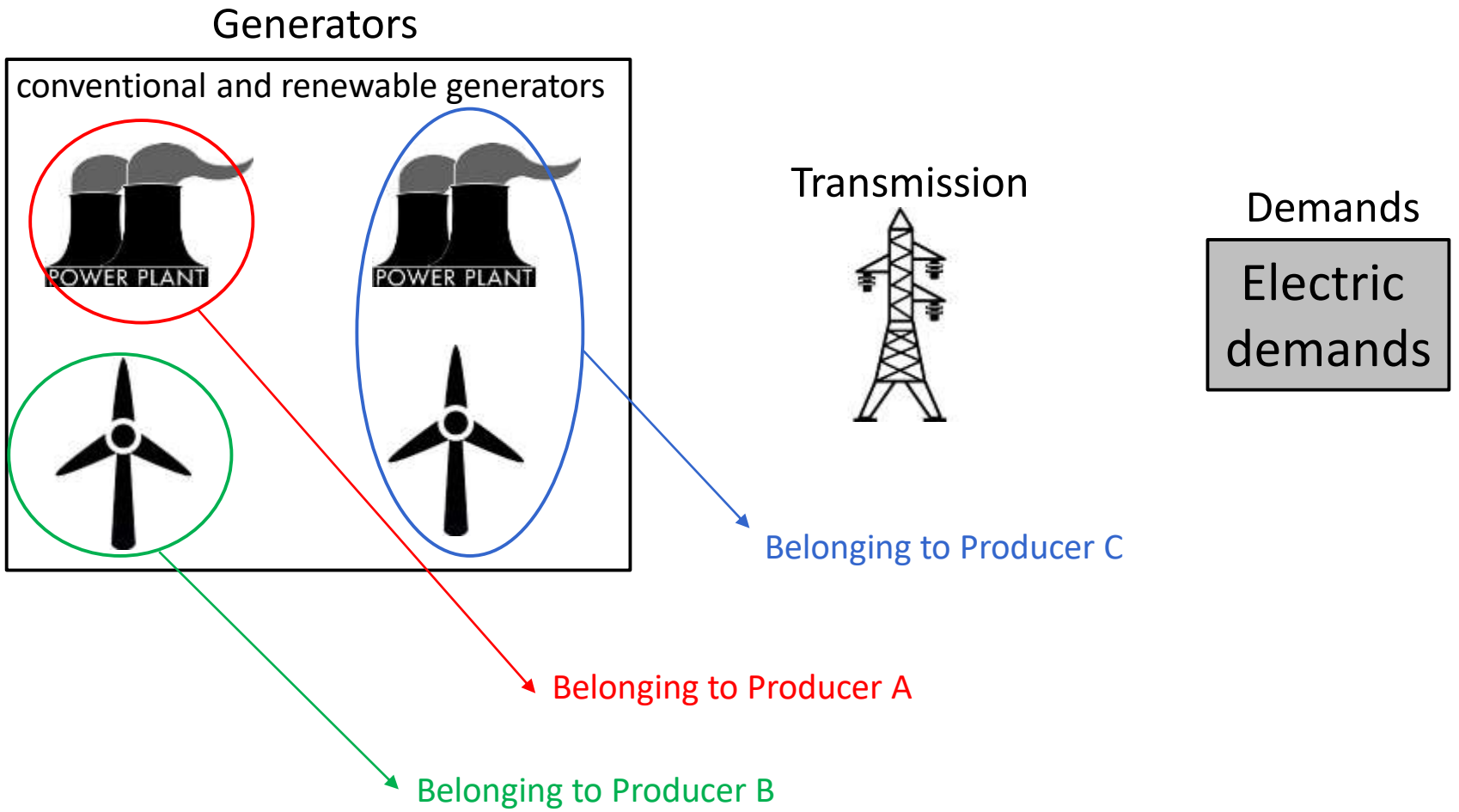
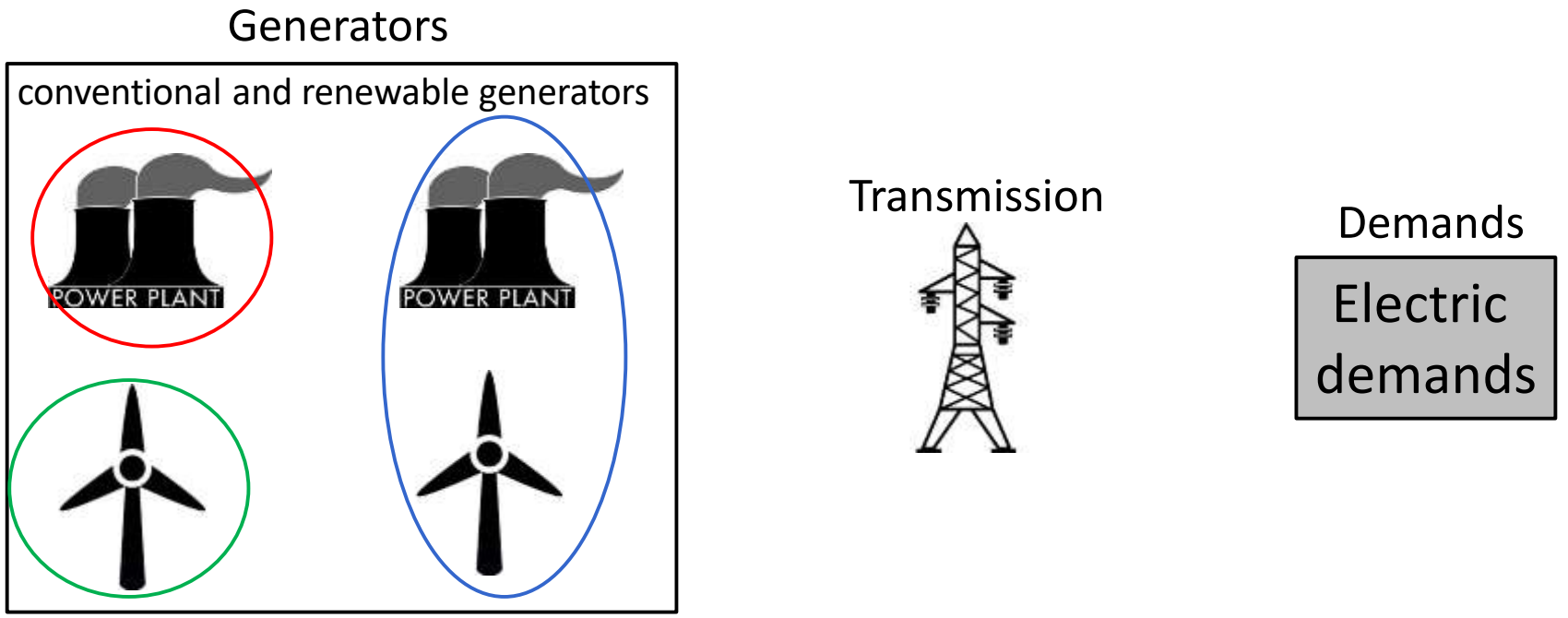
Electricity Markets



Electricity Markets



Electricity Market:

- Each producer seeks to **maximize her own profit** by making optimal operational and planning decisions!
- Unlike centralized systems, there are **multiple** decision-makers!

Electricity Markets

How to operate an electricity market wherein every market participant (e.g., generators) makes her own profit-maximizing decisions?

Electricity Markets

How to operate an electricity market wherein every market participant (e.g., generators) makes her own profit-maximizing decisions?

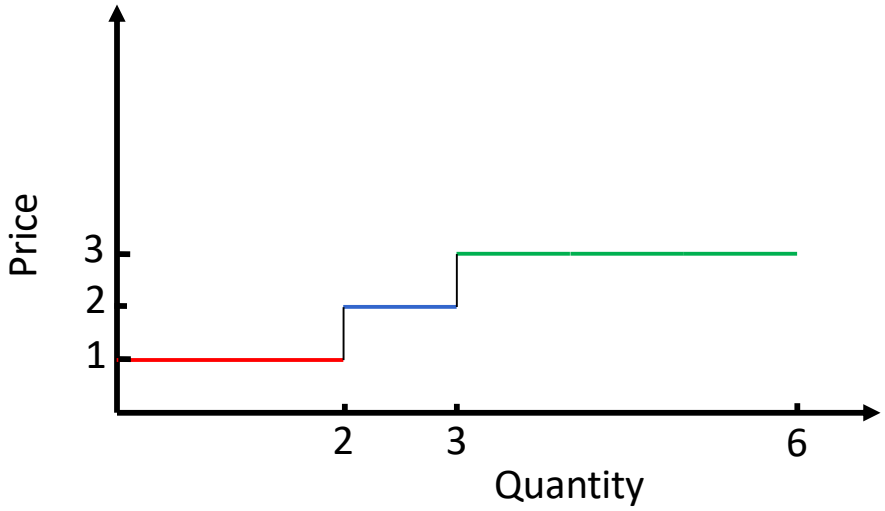
For clarity, let us consider an apple market!

Market

Assume there is an apple market with several 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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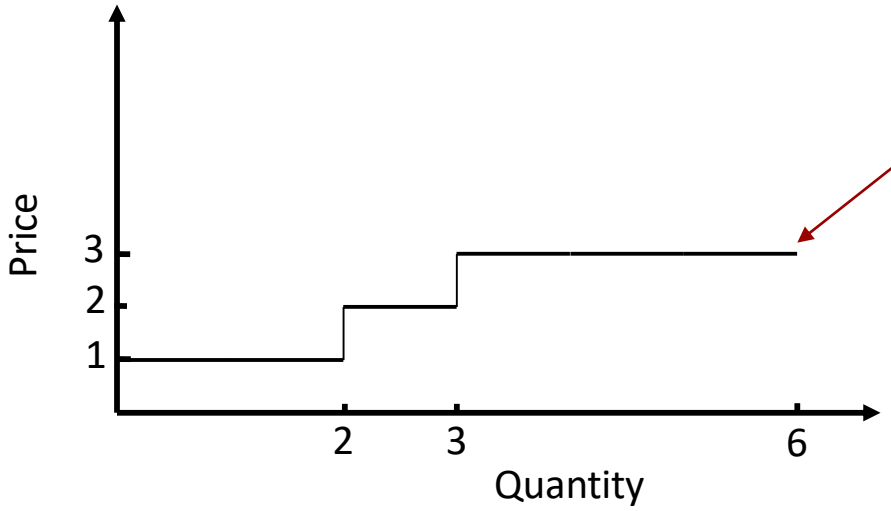


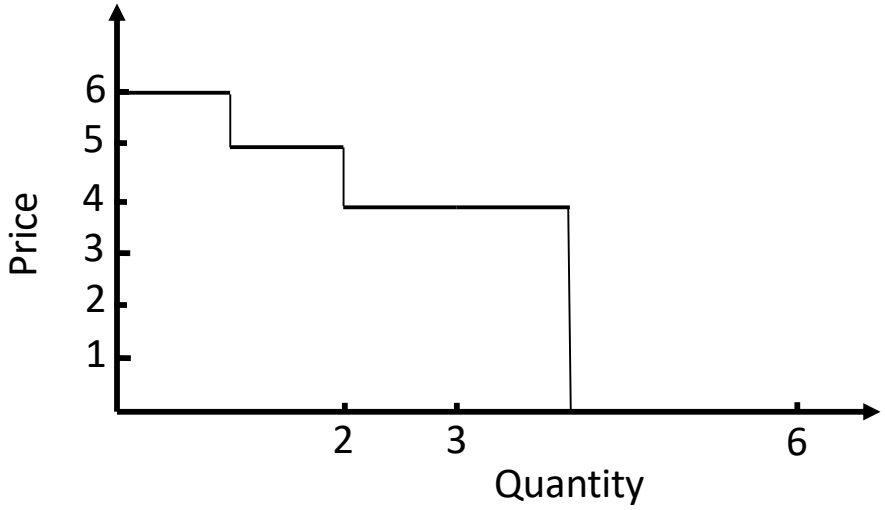
Supply curve:
a non-decreasing curve where sellers are ranked based on the least-cost "merit order principle"!

Market

Assume there is an apple market with several 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.



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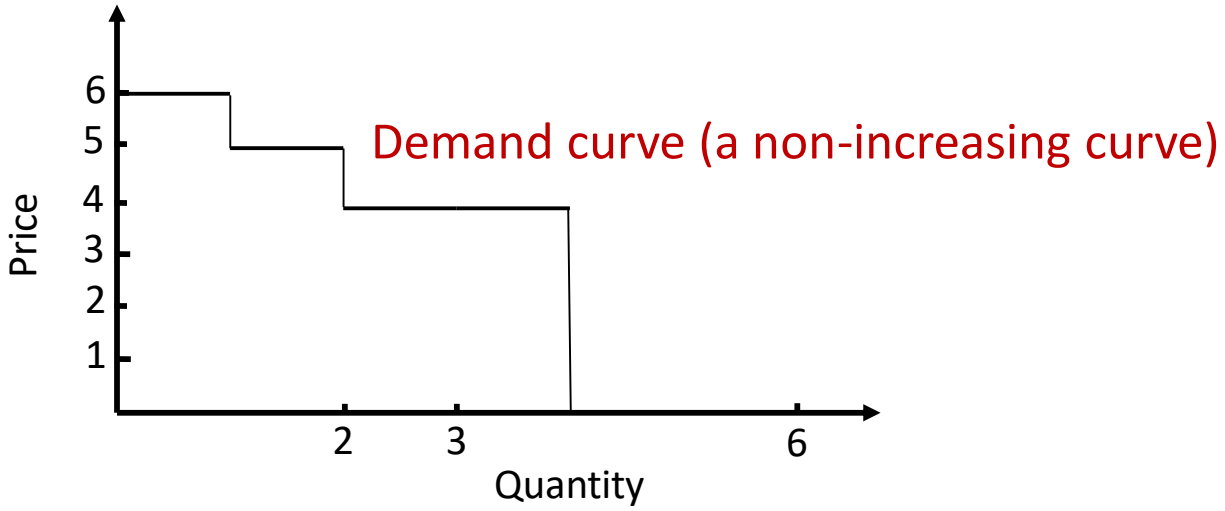
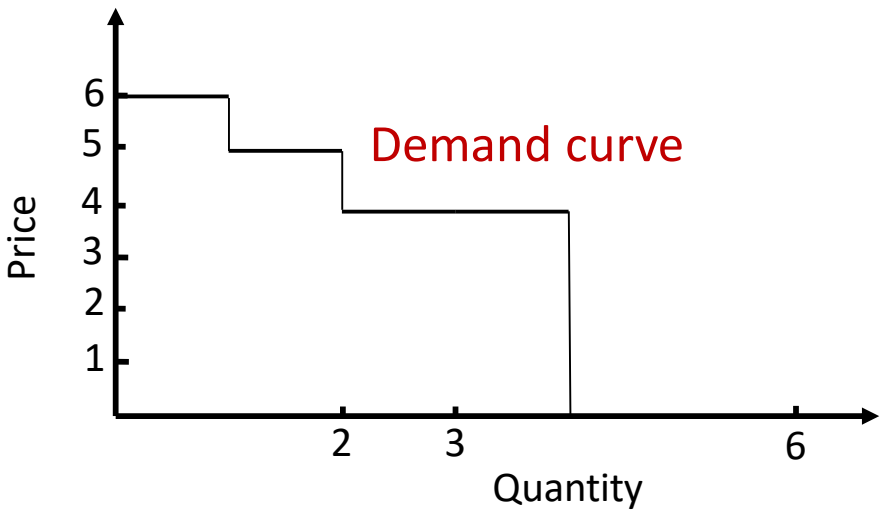
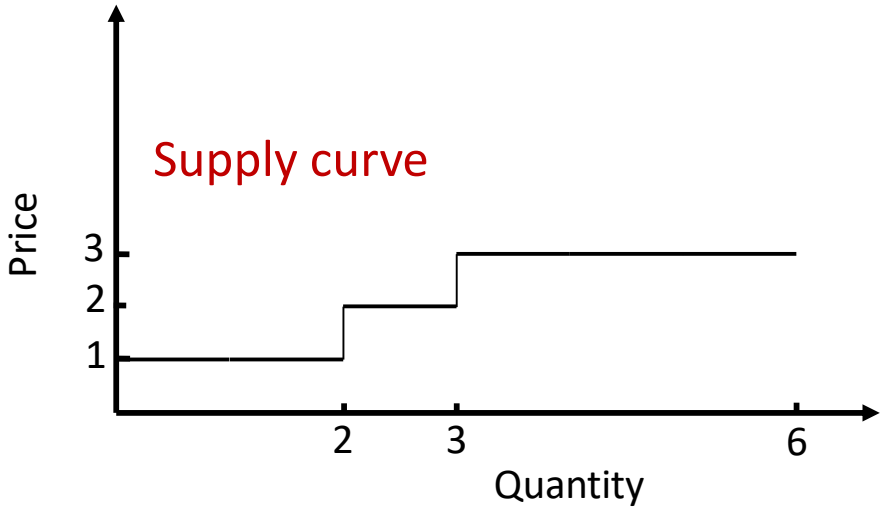


Market

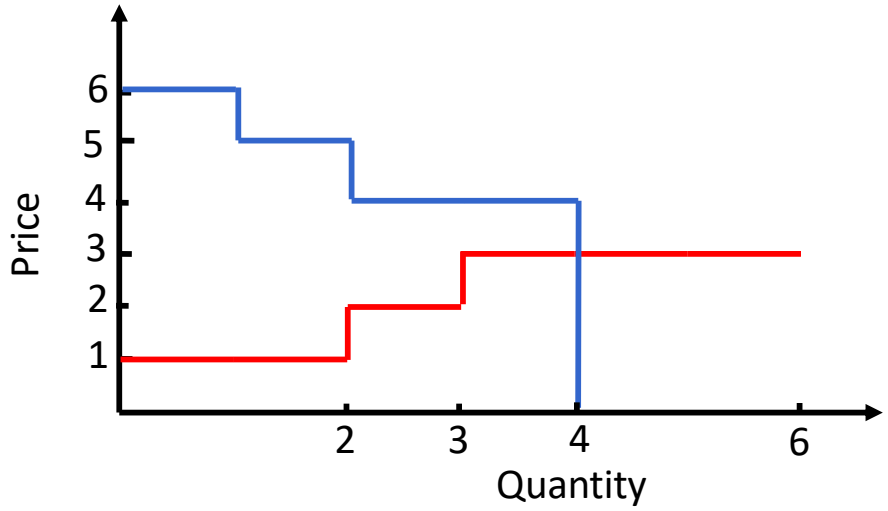




We now have both supply and demand curves. Let us find their intersection!

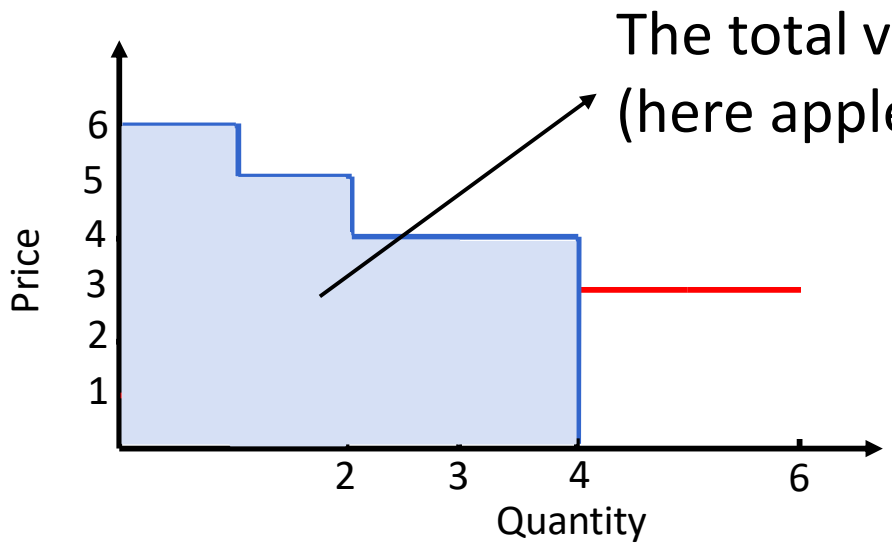
Market

Supply-demand curve

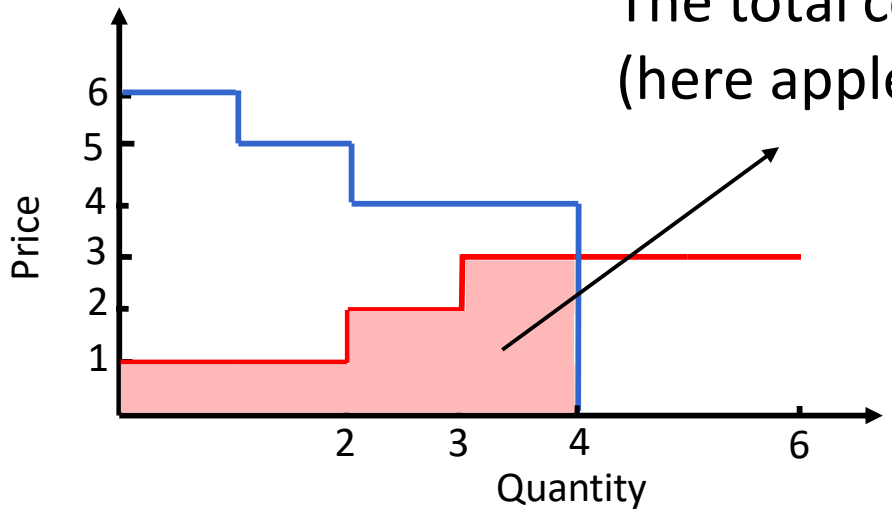


This is the so-called "**market-clearing**" procedure, to be carried out by a non-profit entity, namely the market operator!

Market

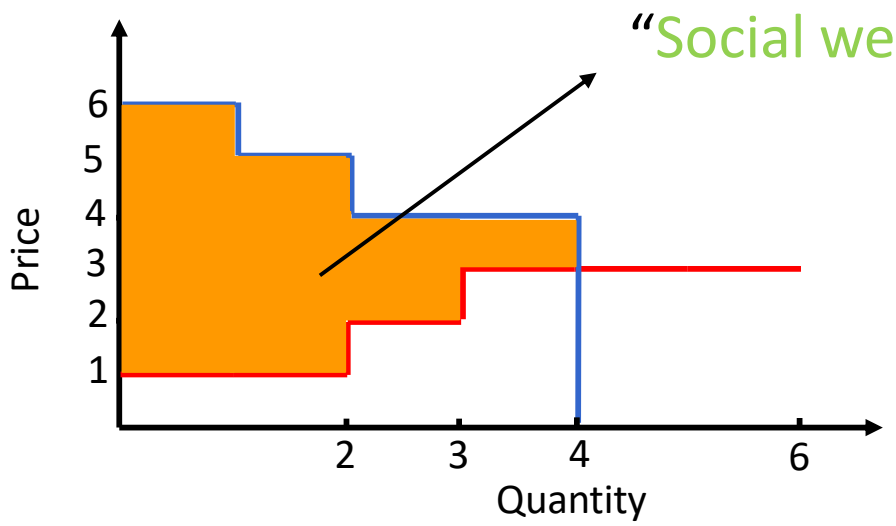

The total value of commodities
(here apples) for the consumers
Price
6
5
4
3
2
1
2
3
4
6
Quantity

Market



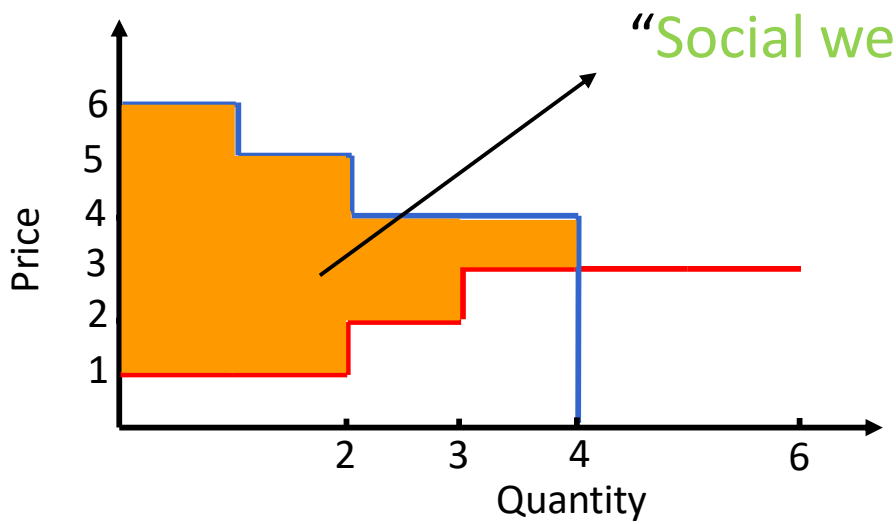
The total cost of commodities (here apples) for the suppliers

Market



The market operator clears the market by ***maximizing*** "social welfare", i.e., the region between supply and demand curves!

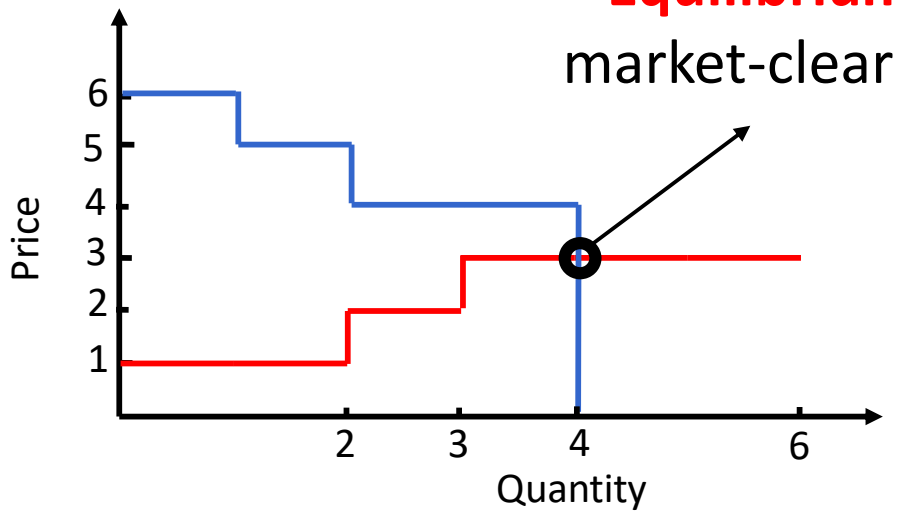
Market



The market operator clears the market by ***maximizing*** "social welfare", i.e., the region between supply and demand curves!

- By maximizing the social welfare, the total value of commodities for demands is being maximized while the total cost for suppliers is being minimized → both demand and supply sides are happy!

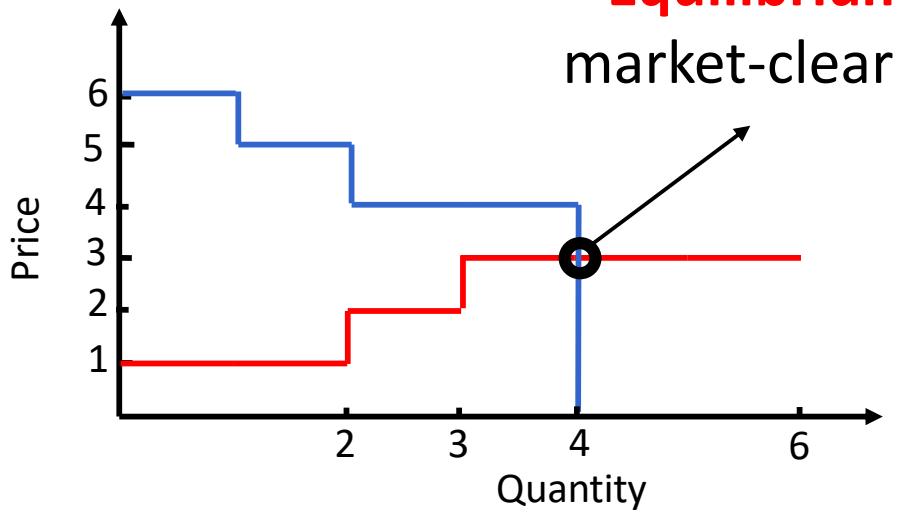
Market



Equilibrium point: yielding the market-clearing price and quantity

Market

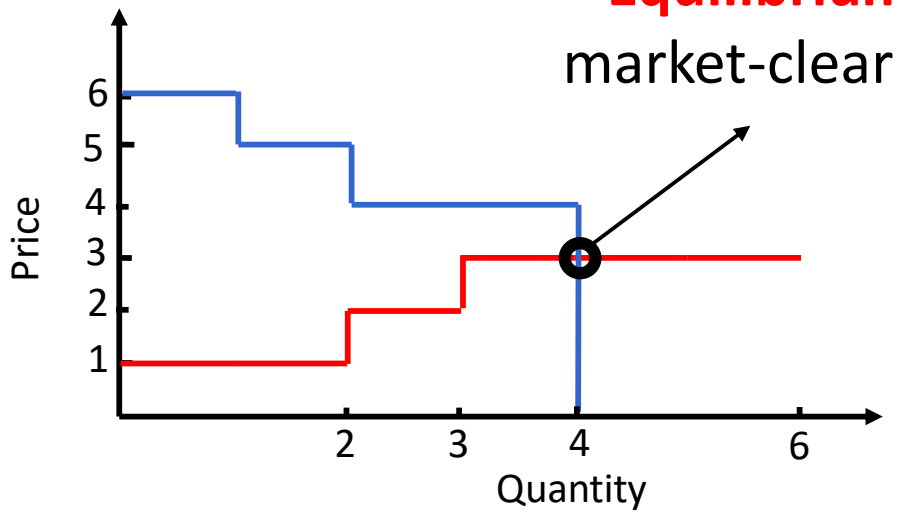
Equilibrium point: yielding the market-clearing price and quantity



- In the equilibrium point, the social welfare is the maximum.

Market

Equilibrium point: yielding the market-clearing price and quantity

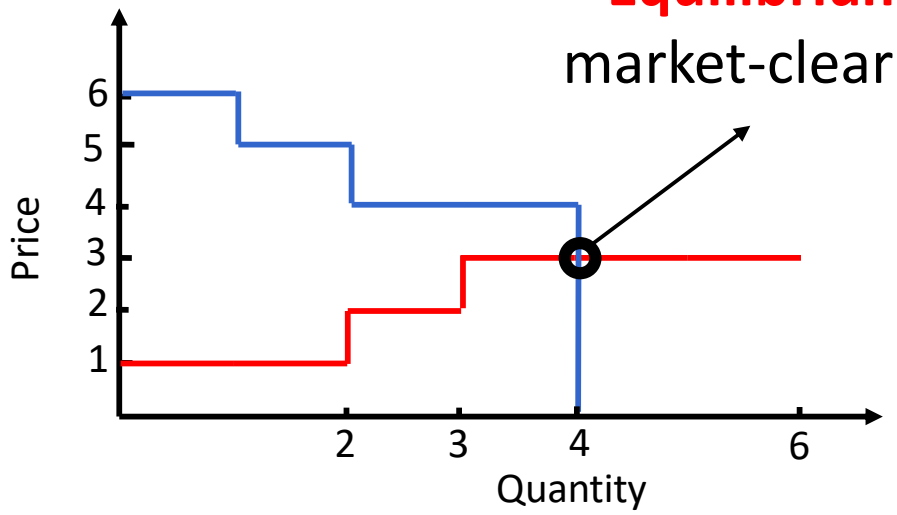


- In the equilibrium point, the social welfare is the maximum.
- Based on the equilibrium point achieved, four apples are traded, at the price of $3 each (uniform pricing)!

Market

Question: Based on uniform pricing, is any buyer (seller) necessarily pays (is paid) at the price she submitted to the market?

Equilibrium point: yielding the market-clearing price and quantity



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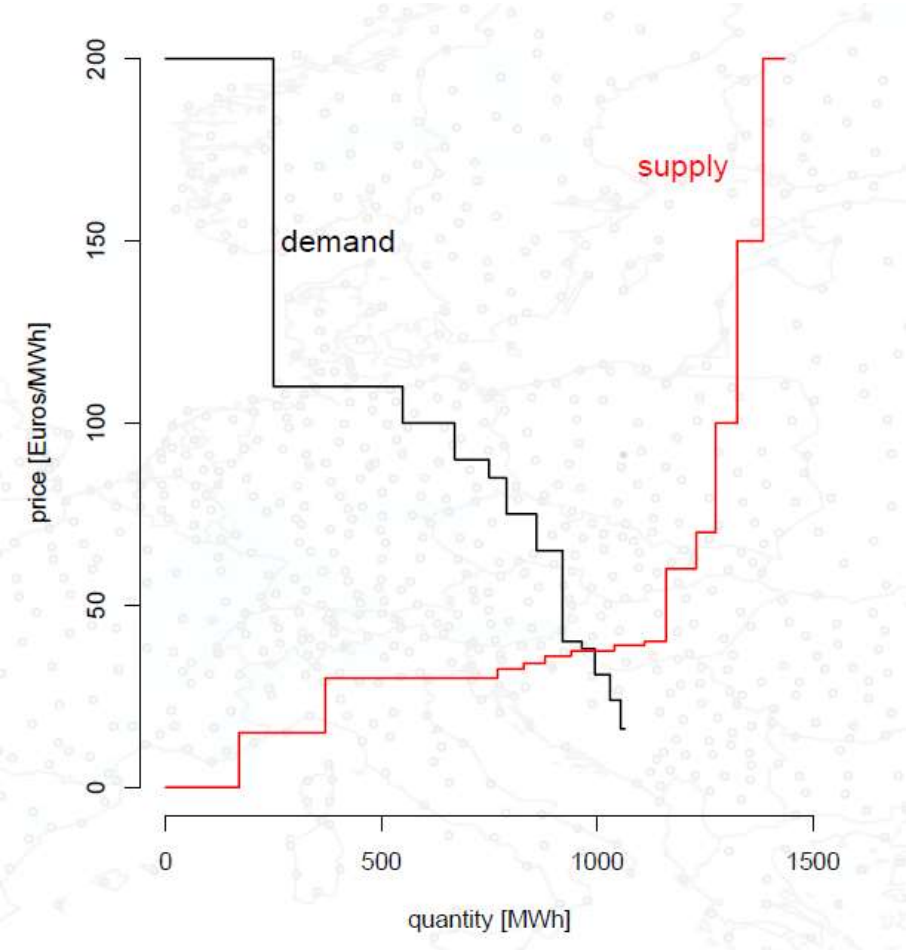
Electricity Markets

Electricity market is a commodity (like apple), and its clearing algorithm is similar!



Electricity Markets

Discussion:

What aspects of an electricity market do differentiate it from markets for other commodities (like apple market)?

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What aspects of an electricity market do differentiate it from markets for other commodities (like apple market)?

- Electricity market-clearing algorithm should consider physical (Kirchhoff's circuits laws) of electric networks,
- Electricity is a non-storable commodity in large size,
- Electricity demands are usually highly inelastic to price (this is changing though),
- …

Electricity Markets

Market-clearing algorithm

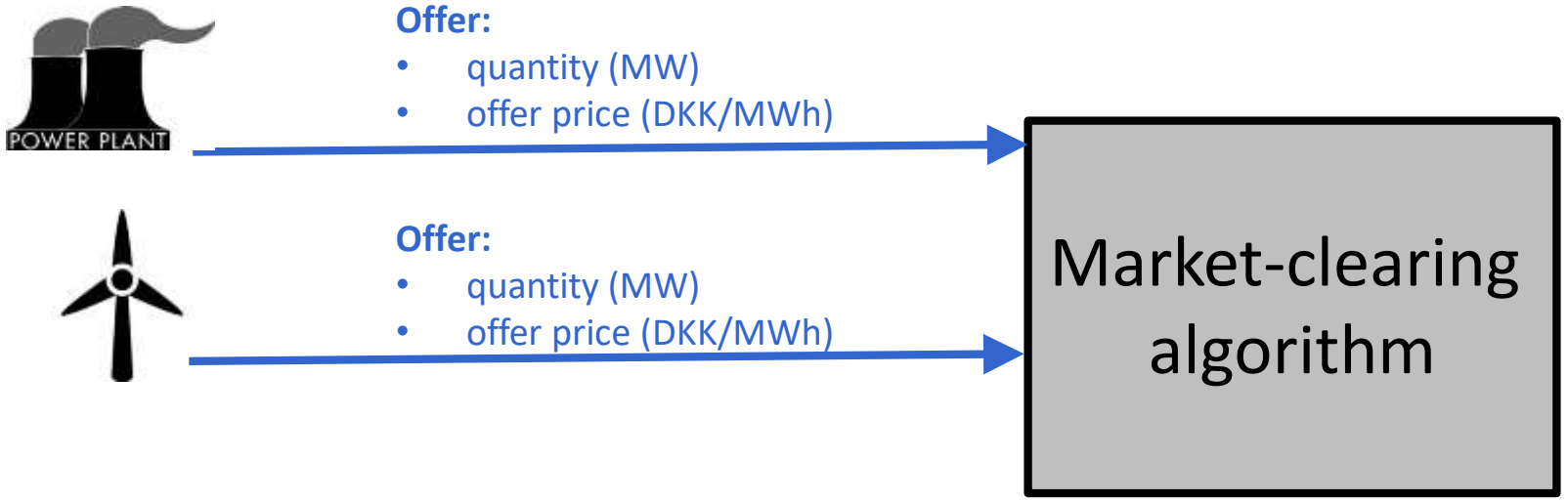
Electricity Markets

Offer:

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

Market-clearing algorithm

Electricity Markets



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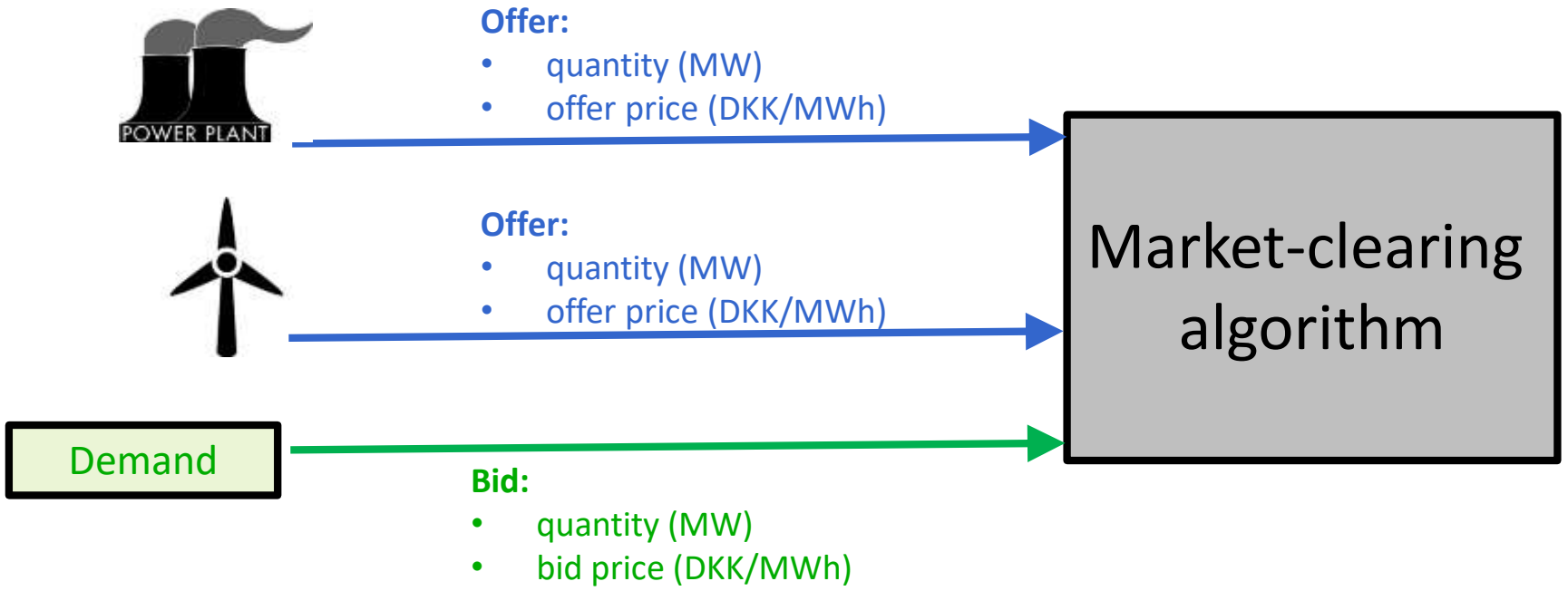

Electricity Markets

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

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Demand

Bid:
- quantity (MW)
- bid price (DKK/MWh)

Market-clearing algorithm

Market-clearing outcomes
- Clearing price (DKK/MWh)
- Generation/consumption level of each producer/demand (MW)

Thanks for your attention!

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