Energy Economics

Energy market module (focus on electricity markets)

Roberto Bianchini (roberto.bianchini@polimi.it)

Textbook: Perez Arriaga, Regulation of the power sector, pp.341-379

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Unconstrained market clearing

Wholesale electricity market: system marginal price auctions

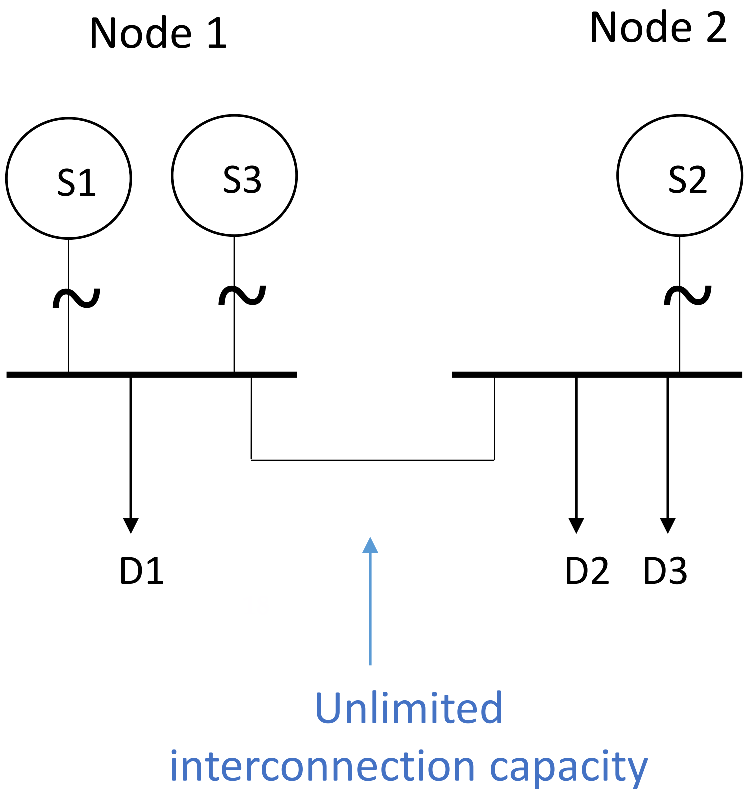
- Bids and offers for each delivery period are submitted by a specified deadline
- **Each power plant** submits a bid (p, q) for each hour:
  - p: minimum price at which the power plant is willing to sell
  - q: maximum quantity the power plant is willing to sell
- **Each buyer** submits a bid (p, q) for each hour:
  - p: maximum price at which the buyer is willing to buy
  - q: maximum quantity the buyer is willing to sell
- Market administrator (MA) grades the bids according to an economic merit order (taking into account constraints)
- Matching of demand and supply establishes the winners (on the supply side, the plants that are dispatched) and the Hourly Equilibrium Market Price
- Different type of bids:
  - Simple hourly bids
  - Block bids
  - Complex bids
  - ….

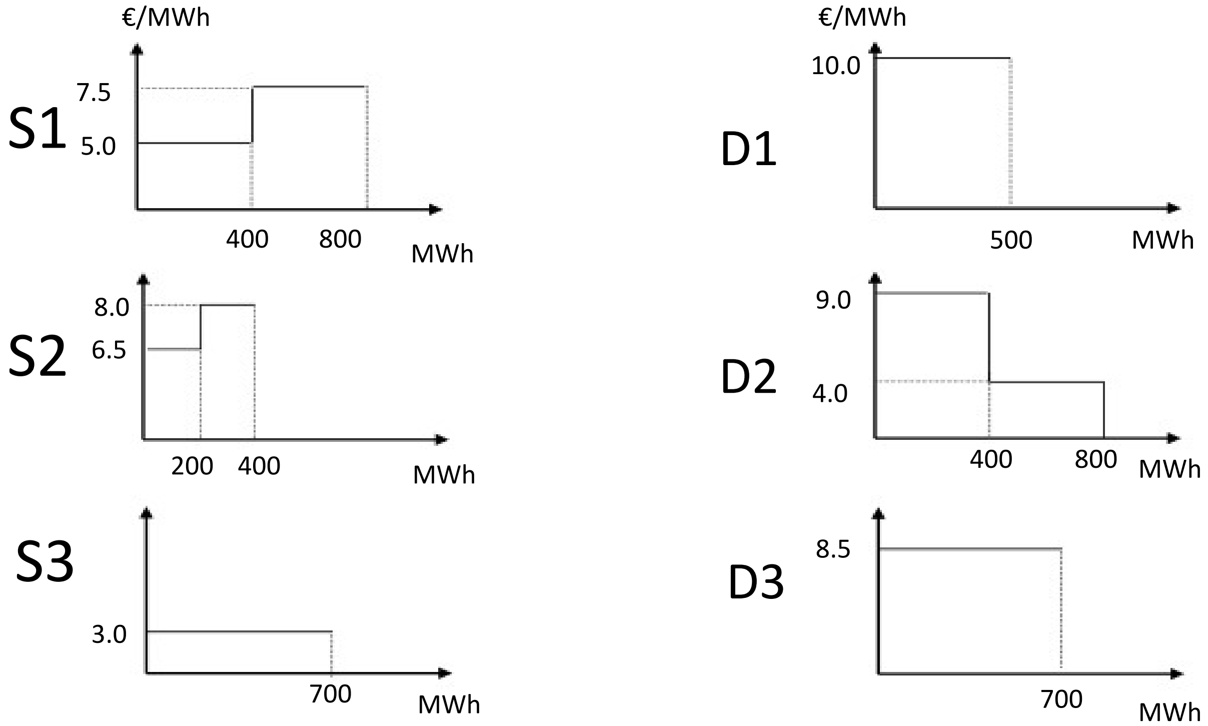
Unconstrained SMP mechanism

Hypotheses:

- No transmission constraints
- Perfectly competitive market:
  - Seller offers represent marginal costs of generation (P)
  - Buyer bids represent Willingness To Pay (WTP) for energy purchased
- MA clears the market: finds price(s) and quantities ((i.e. successful offers and bids)
- Criterion: economic dispatch
  - Less costly generators first
  - Consumers with higher WTP first
- Mathematically: constrained optimization problem
- Economic objective: gain from trade maximization

Unconstrained SMP mechanism



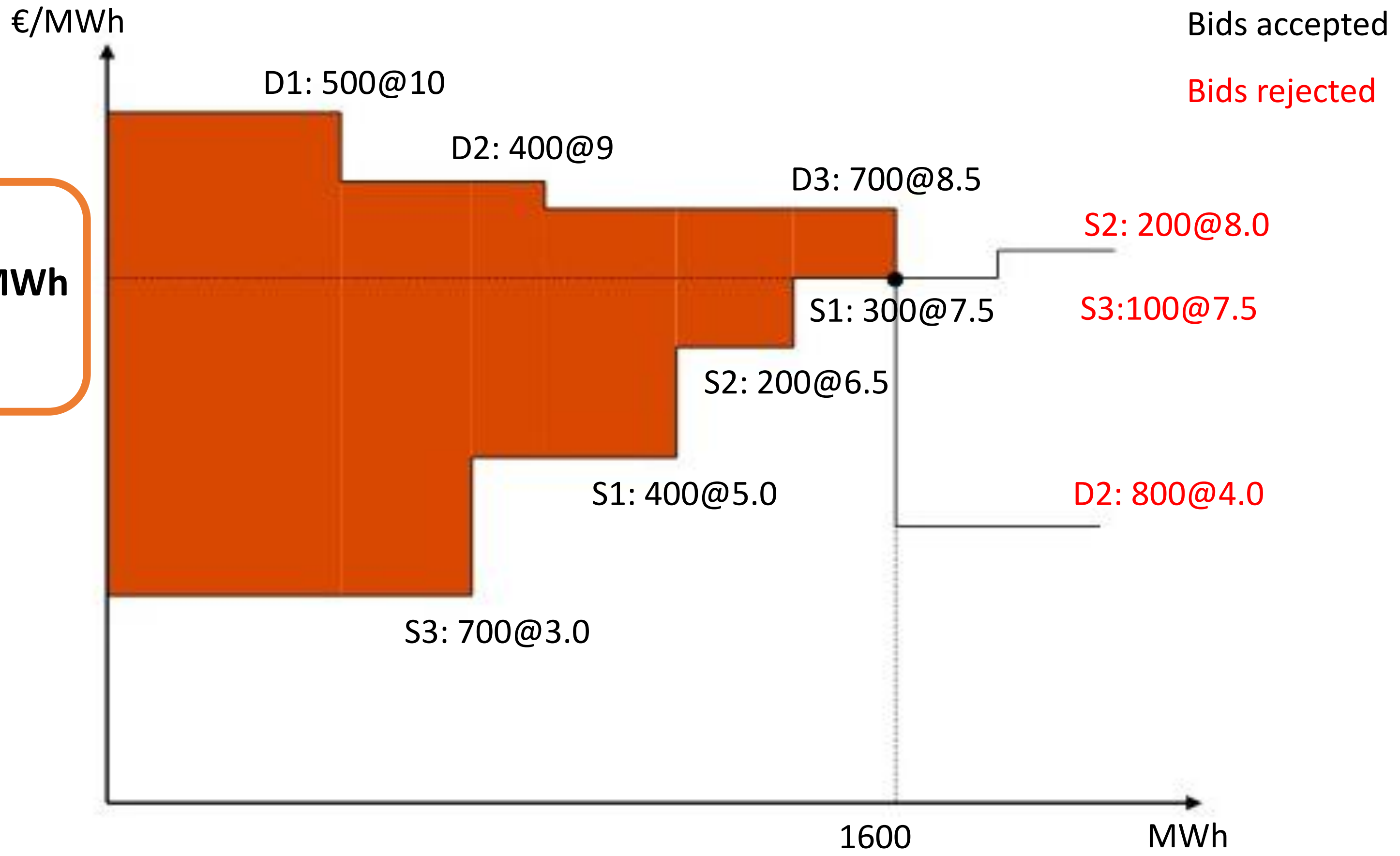


Unconstrained SMP mechanism

System marginal price:

- Each seller receives SMP and each buyer pays SMP
- The SMP is different from the offer/bid of nearly every player

System marginal price 7.5 €/MWh



Unconstrained SMP mechanism

Player	Accepted quantity (MWh)	Out of merit order (MW/h)	Revenues (€)	Costs (€)
S1	700	100	5250	
S2	200	200	1500	
S3	700	-	5250	
D1	500	-		3750
D2	400	400		3000
D3	700	-		5250
Total	1600		12000	12000

Why this equilibrium is not realistic in a «real» electricity market?

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Unconstrained SMP mechanism: optimization problem

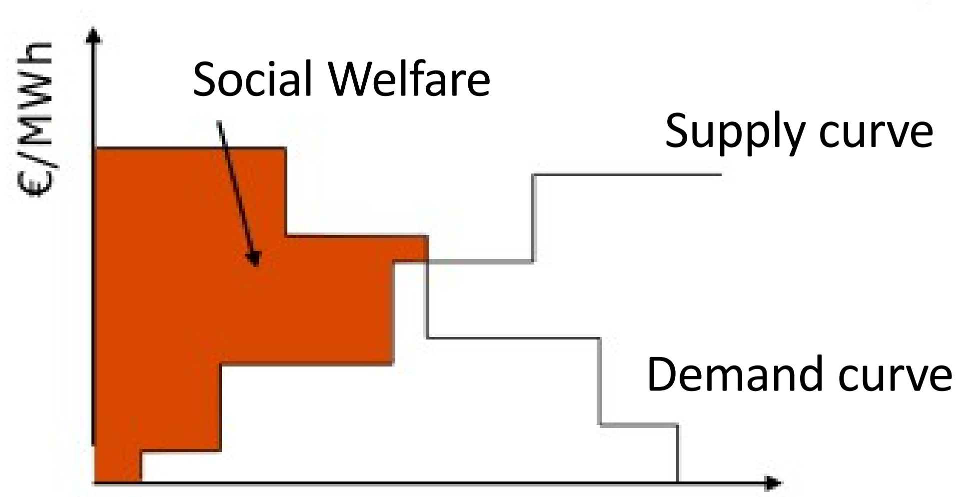
$$Max\ Total\ Surplus\ (TS) = \sum_{i=1}^{n} WTP_i(Q_{Di}) - \sum_{j=1}^{m} P_J(Q_{SJ})$$

s.t.

$$\sum_{i=1}^{n} Q_{Di} = \sum_{j=1}^{m} Q_{Sj}$$ Supply-Demand balance

$$Q_{Di}^{min} < Q_{Di} < Q_{Di}^{max}\ \forall i$$

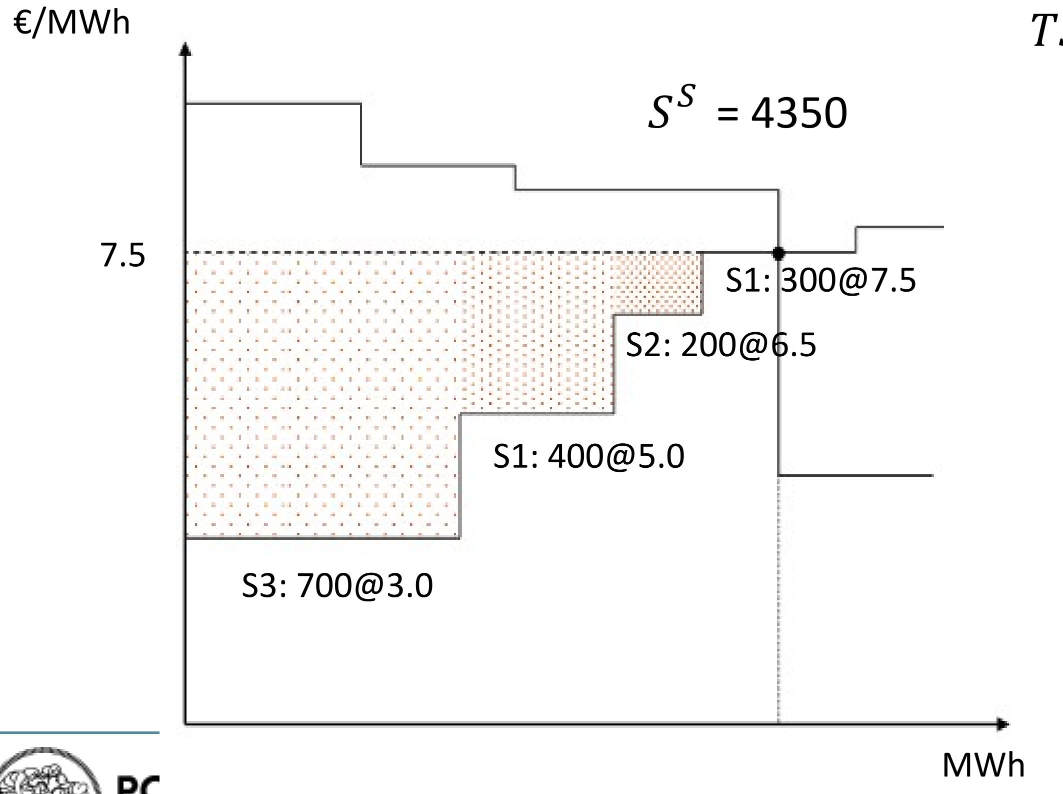
$$Q_{Si}^{min} < Q_{Si} < Q_{Si}^{max}\ \forall i$$ Quantity constraints

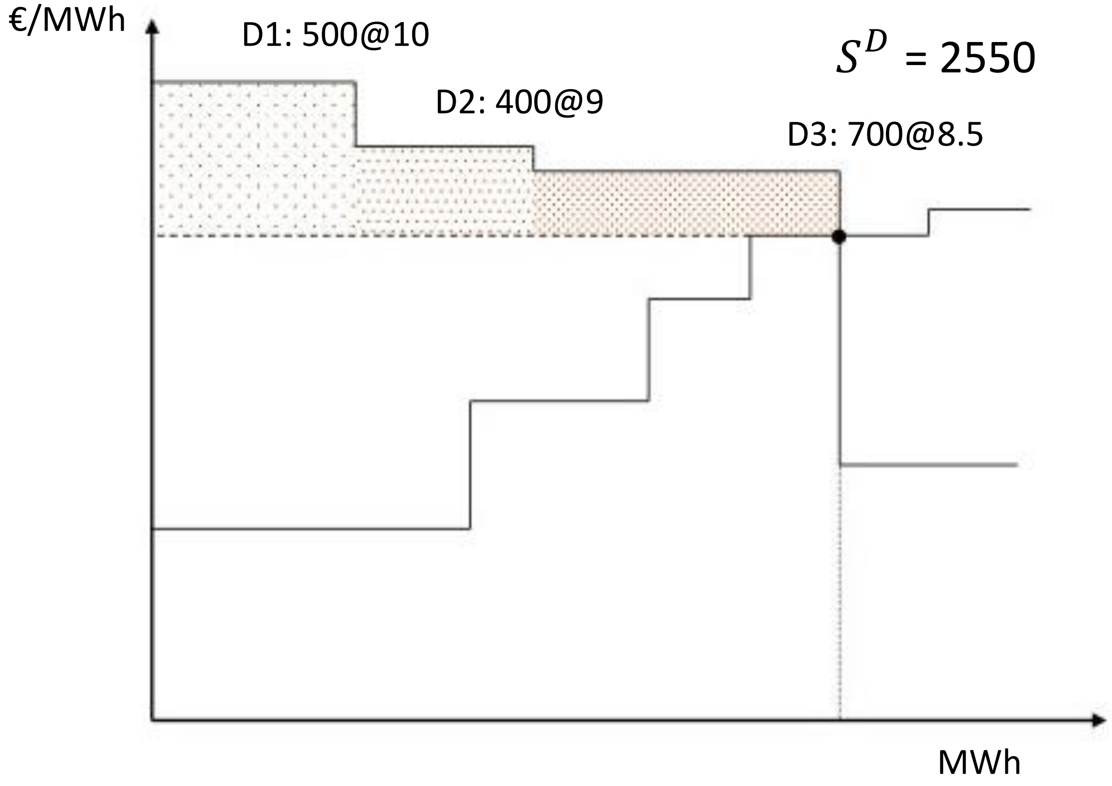


Unconstrained SMP mechanism: optimization problem

$$Max\ Total\ Surplus\ (TS) = \sum_{i=1}^{n}(WTP_i - SMP) * (Q_{Di}) + \sum_{i=1}^{m}(SMP - P_J)(Q_{SJ})$$

TS = 6900

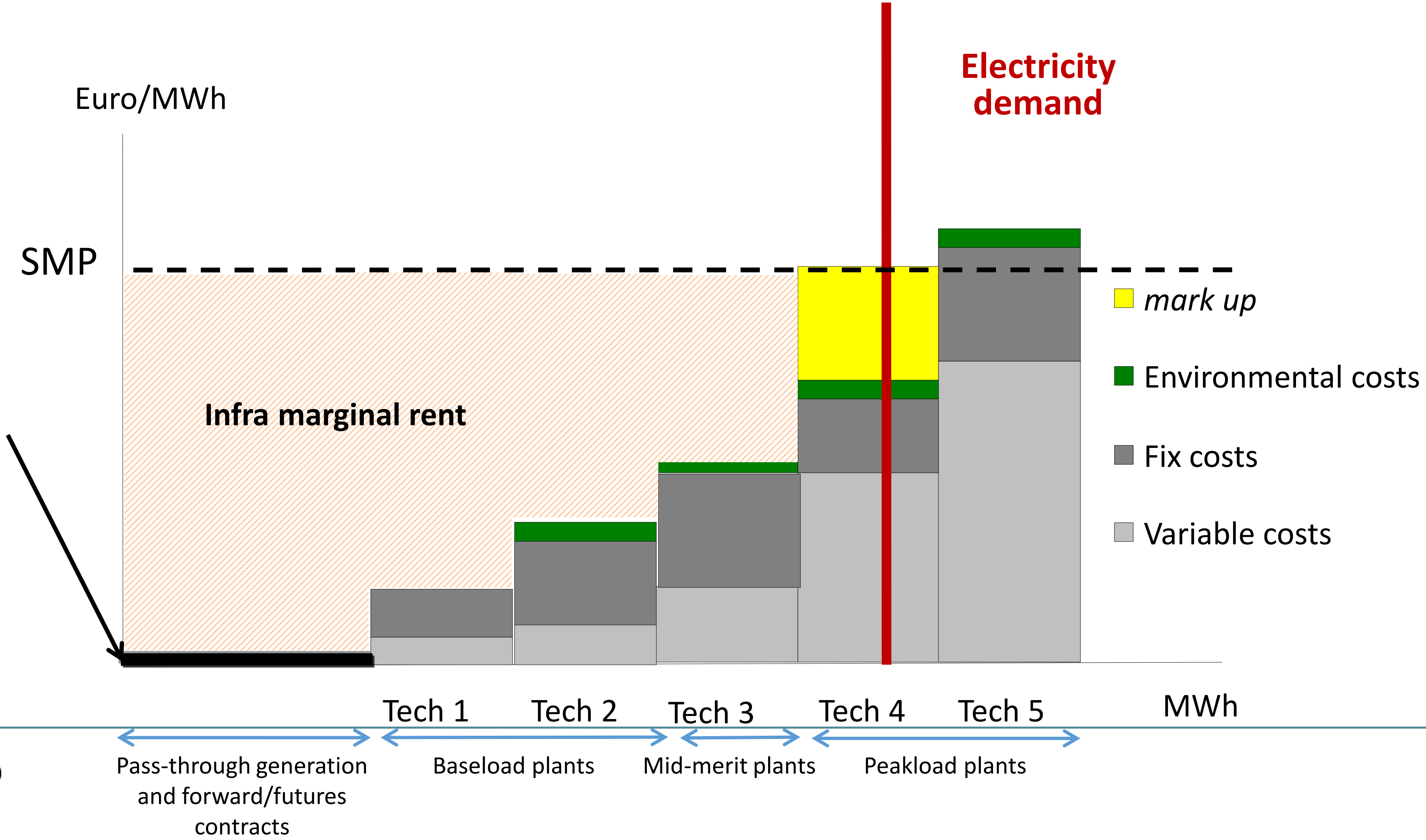




Unconstrained SMP mechanism: fixed and variable costs

Forward/future contracts:

- bids to buy/sell electricity at price equal to zero
- remuneration not determined in the wholesale market



SMP mechanism: pros and cons

Pros

- Positive margin for all infra-marginal suppliers
- Fixed cost paid by market price for all infra-marginal suppliers
- Promotion of operational efficiency: marginal supplier obtains the lowest (zero) operating margin
- Incentive to discover actual production costs
- Strong price signaling effect (oversupply/shortage)

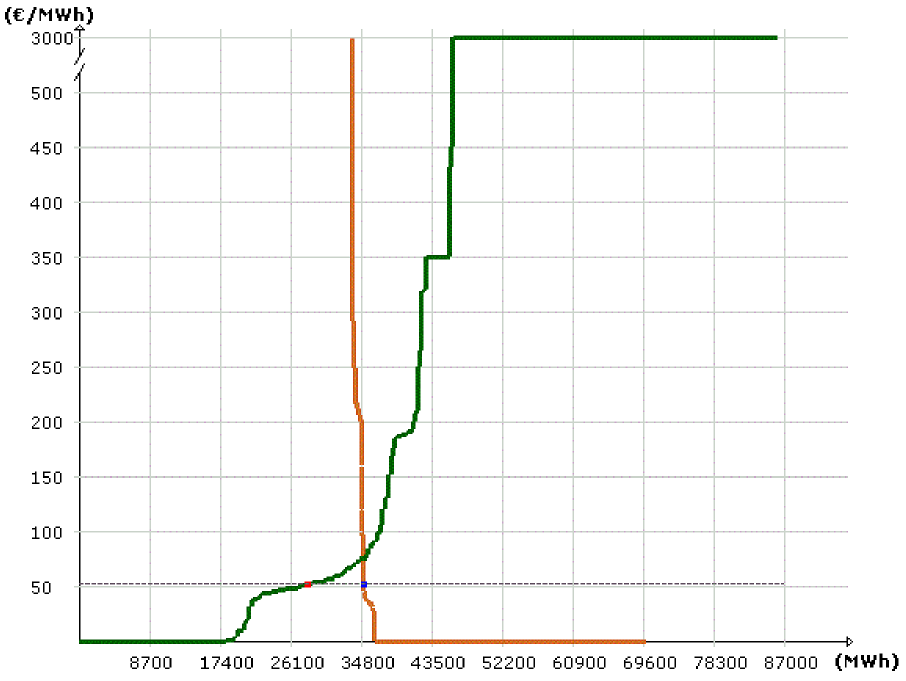
Cons

- Production costs discovering may not be a prevailing behavior
- Strategic behaviors by multi-plants suppliers
- Infra marginal supplier may withhold capacity

Unconstrained SMP mechanism: example - Italian DAM

Market Zone: CNOR; CSUD; NORD; SARD; AUST; COAC; CORS; FRAN; SLOV; SVIZ

Date: 04/03/2019 **Hour:** 12



Accepted offer quantity (28220,125 MWh)
Accepted bid quantity (35069,125 MWh)

Day-Ahead Market-MGP

Day:	Month:	Year:	Time:
04	March	2019	12

Zonal Prices: **nord**

Selling Price (€/ MWh)	Purchases(MWh)	Sales (MWh)
52,46	23.557,06	16.786,40

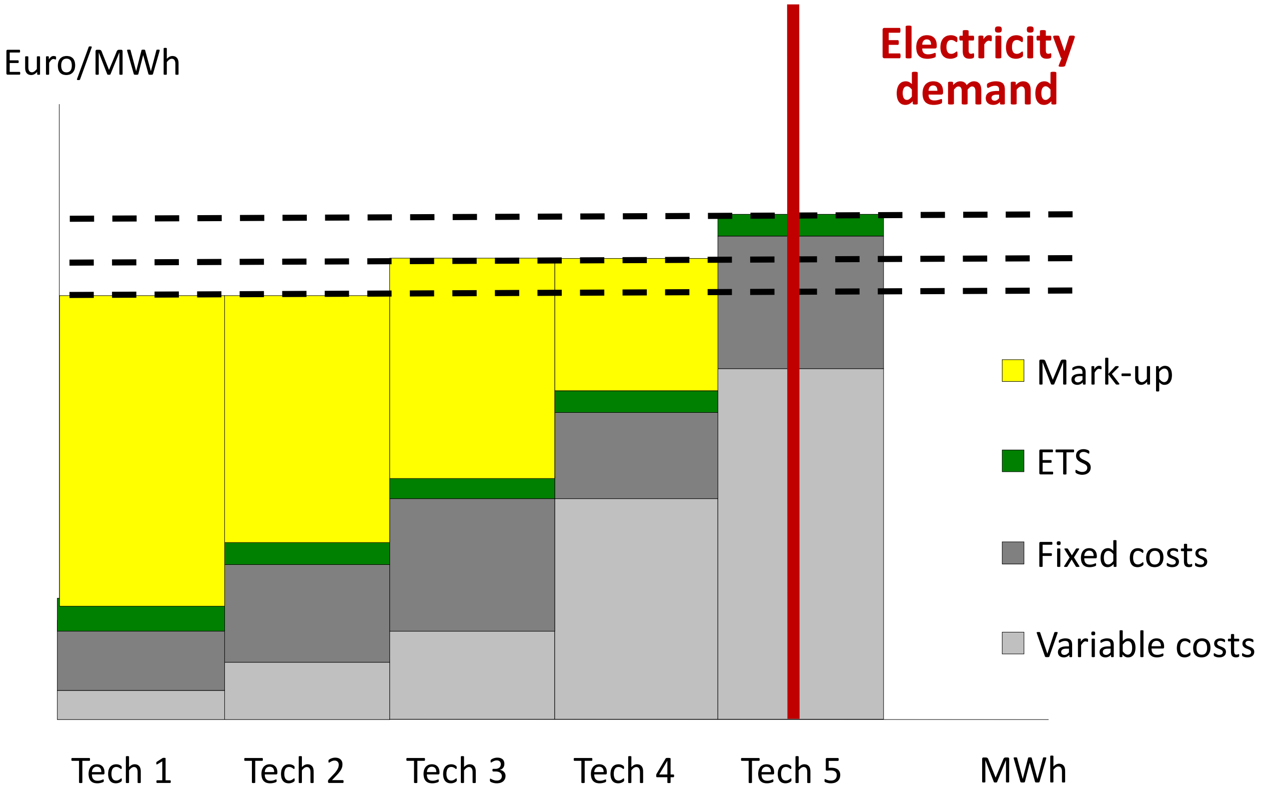
Zonal flow

From	Max Transmission Capacity (MWh)	Flow (MWh)
AUST	10.000,00	00,00
CNOR	2.500,00	-247,34
FRAN	10.000,00	00,00
SLOV	10.000,00	00,00
SVIZ	10.000,00	00,00

Zone: **nord**

to	Max Transmission Capacity (MWh)	Flow (MWh)
AUST	10.000,00	-315,00
CNOR	4.000,00	00,00
FRAN	10.000,00	-3.453,00
SLOV	10.000,00	-630,00
SVIZ	10.000,00	-2.620,00

Unconstrained pay as bid mechanism



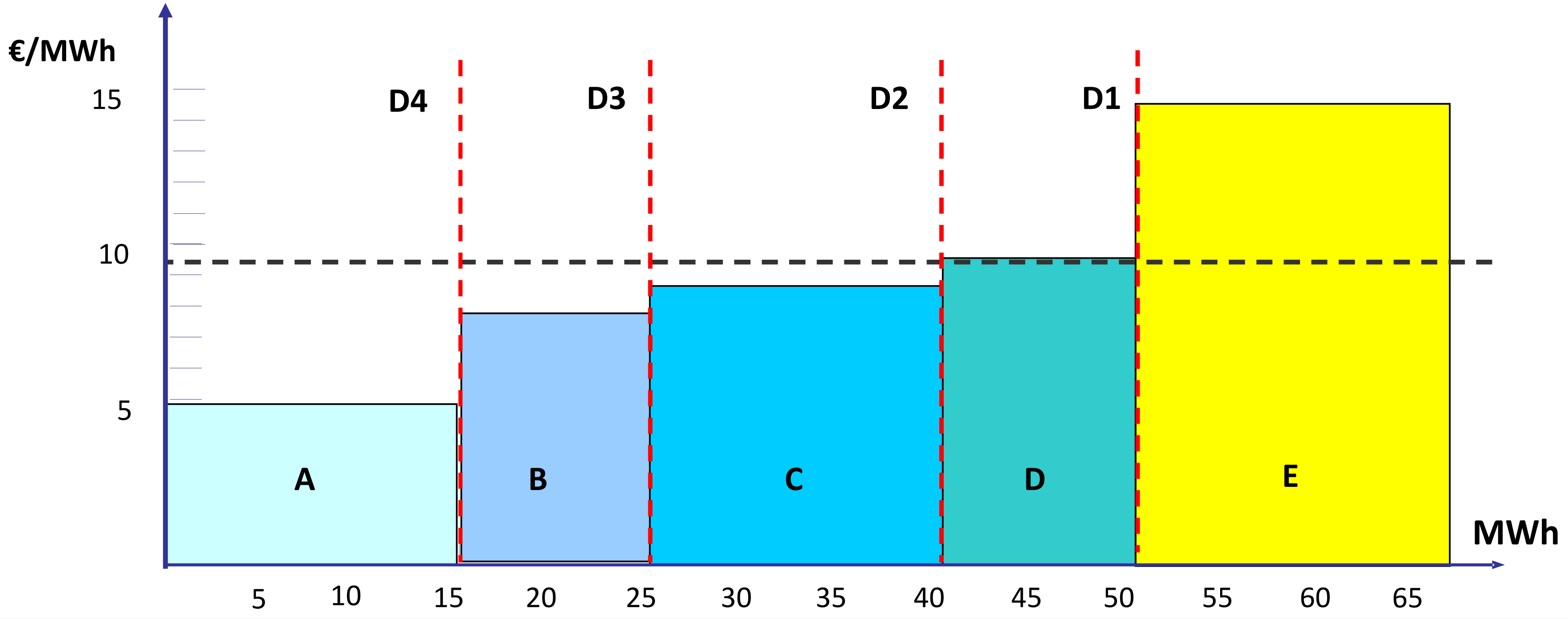
Pay As Bid (PAS)

Each power plant receives a price that is exactly equal to what it has bid. The price paid by consumers is the average of these prices

SMP: exercise

Case study:

- 5 power plants with different production costs
- 4 different demand scenarios



SMP: exercise

Compute power plants' profits in case A and B (assuming bids equal to marginal costs and unit variable costs)

Case A:

- 5 power plants, at initial stage managed by different market players (power plants E is not included in the merit order)
- System marginal price mechanism in a perfect competition market where each player bids at marginal cost
- Plants incur in fixed costs even if they are not dispatched
- Profits determined in 4 different demand scenarios (D1-D4)

Power Plant	Fixed Costs €/h	Variable Costs €/MWh	Power MW		Demand
A	5	5	15		D1: 50
B	2	8	10		D2: 40
C	3	9	15		D3: 25
D	0	10	10		D4: 15
E	4	15	15		

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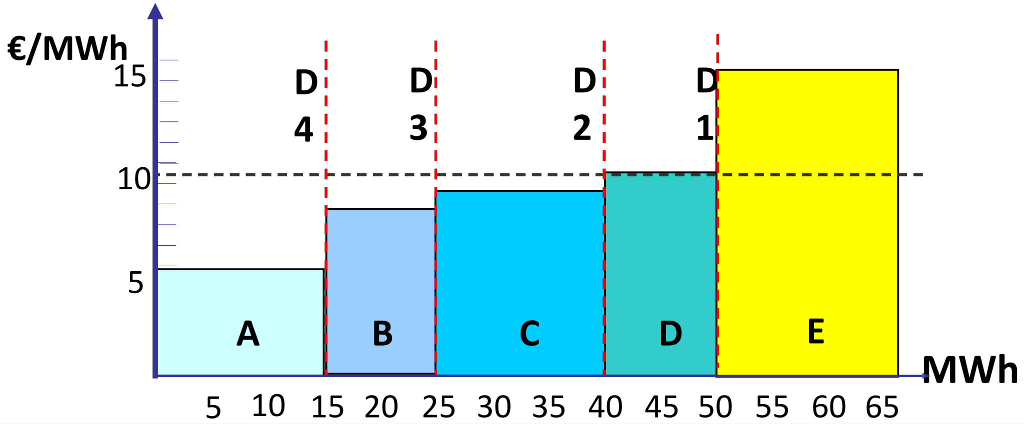
SMP: exercise– case A

7:00

Profits Case A

Power Plant	Fixed Costs €/h	Variable Costs €/MWh	Power MW		Demand
A	5	5	15		D1: 50
B	2	8	10		D2: 40
C	3	9	15		D3: 25
D	0	10	10		D4: 15
E	4	15	15		

Power Plant	D1	D2	D3	D4
A				
B				
C				
D				
E				



Case A

Profits power plants A, C, D, E = ?

SMP: exercise – case B

Compute power plants' profits in case A and B (assuming bids equal to marginal costs and unit variable costs)

Case B:

- Power plants A, C and E owned by the same market player
- Such player does not offer power plant C
- System marginal price mechanism in a perfect competition market where each player bids at marginal cost
- Plants incur in fixed costs even if they are not dispatched
- Profits determined strategically using demand scenario D1

How much do profits increase under the hypothesis of strategic behaviour in demand scenario D1?

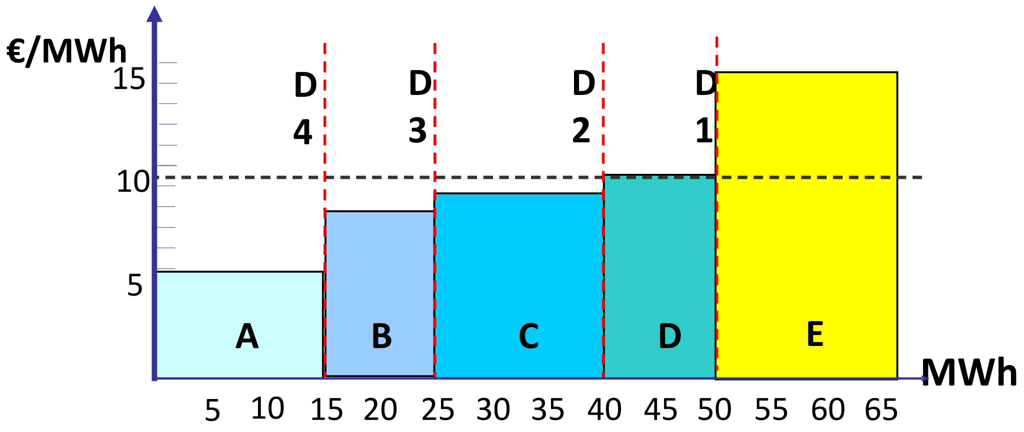
Power Plant	Fixed Costs €/h	Variable Costs €/MWh	Power MW
A	5	5	15
B	2	8	10
C	3	9	15
D	0	10	10
E	4	15	15

SMP: exercise – case B

7:00

Power Plant	Fixed Costs €/h	Variable Costs €/MWh	Power MW		Demand
A	5	5	15		D1: 50
B	2	8	10		
C	3	9	15		
D	0	10	10		
E	4	15	15		

Power Plant	D1
A	
B	
C	
D	
E	



Case B

- **Profits power plants A, B D, E = ?**
- **Comprehensive profit of owner of plants A,C,E in cases A and B?**