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Energy systems modelling

Tutorial 4

Iegor Riepin

Slightly more complex situation

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- There is a set of power plants [P] in 3 different countries [N]

Power plants	Countries	Technology	Capacity [MW]	VC [$/MWh]
P1	FR	Nuclear	700	20
P2	FR	OCGT	250	55
P3	GER	Lignite	750	30
P4	GER	CCGT	250	40
P5	GER	Wind	300	0
P6	NL	CCGT	400	40
P7	NL	OCGT	200	55
P8	NL	Wind	200	0

Slightly more complex situation

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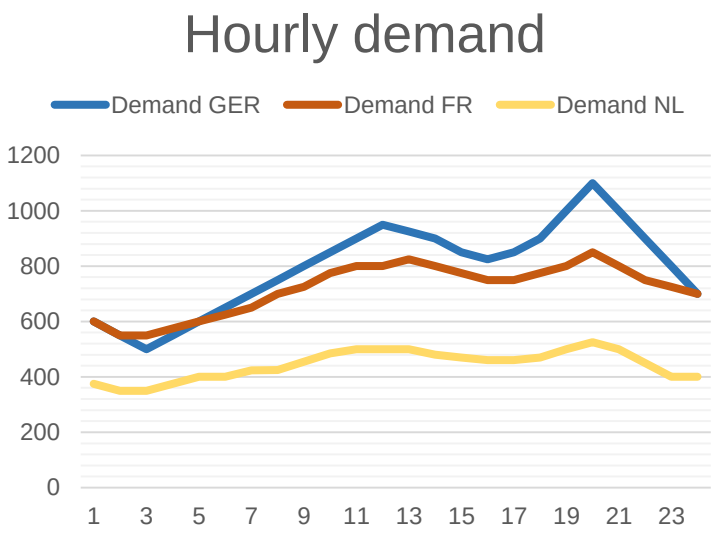
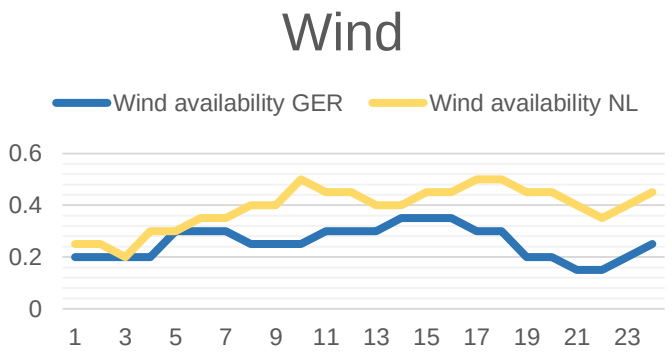
- Time series data is as follows:

Hours	Demand [MW]			Wind availability factor	
	GER	FR	NL	GER	NL
1	600	600	375	0.2	0.25
2	550	550	350	0.2	0.25
-	-	-	-	-	-
-	-	-	-	-	-
23	800	725	400	0.2	0.4
24	700	700	400	0.25	0.45
Max	1100	850	525	0.35	0.5
Min	500	550	350	0.15	0.2
Capacity all	1300	950	800		
Capacity conv	1000	950	600		





Model formulation

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- Minimize the total cost function

$$\min_{G_{p,n,t}} COSTS = \sum_{p,n,t} G_{p,n,t} * vc_p$$

- The demand has to be covered *in each* country *at every* hour

$$demand_{n,t} = \sum_{p} G_{p,n,t}$$

If $G_{p,n,t}$ is a generation of power plant ***p*** in a country ***n*** at time ***t***

Interspatial effects

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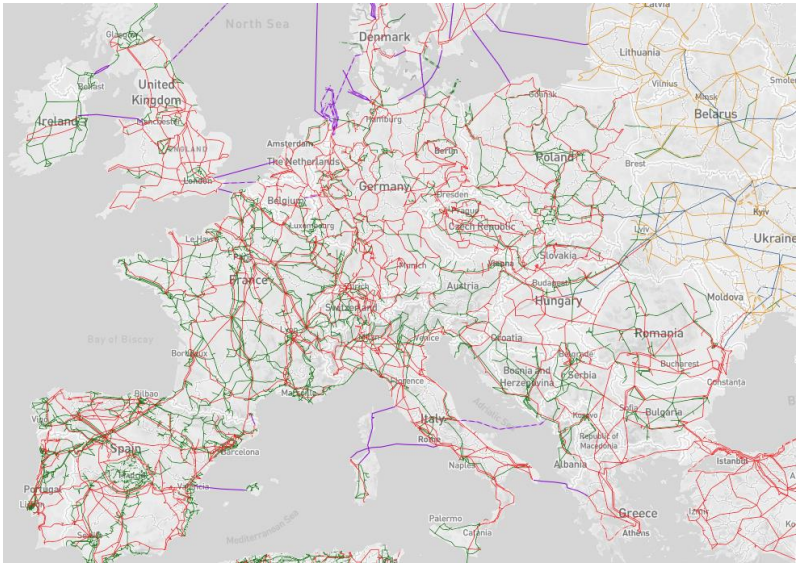
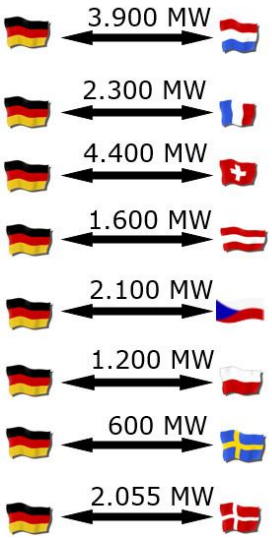
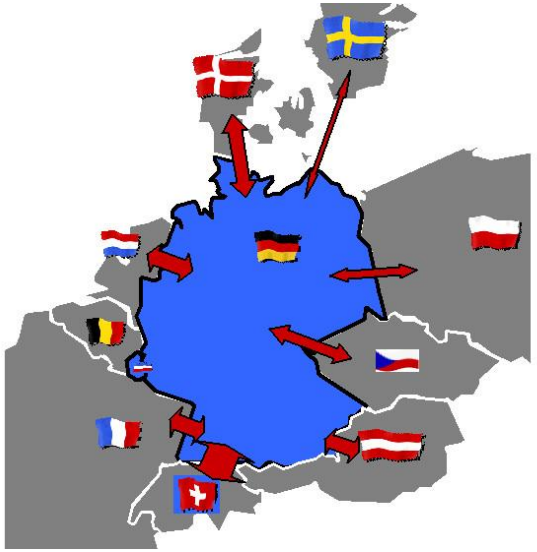
- European electricity markets are highly interconnected







NTC values Summer 2010 in MW
Source: entsoe.com

Generalize main equations

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- Minimize the total cost function

$$\min_{G_{p,n,t}} COSTS = \sum_{p,n,t} G_{p,n,t} * vc_p$$

- The demand has to be covered *in each* country *at every* hour

$$demand_{n,t} = \sum_{p} G_{p,n,t}$$

If $G_{p,n,t}$ is a generation of power plant ***p*** in a country ***n*** at time ***t***

$$-\sum_{nn} FLOW_{n,nn,t}$$ export of country n to nn

$$+\sum_{nn} FLOW_{nn,n,t}$$ Imports from nn to n

Node interconnections

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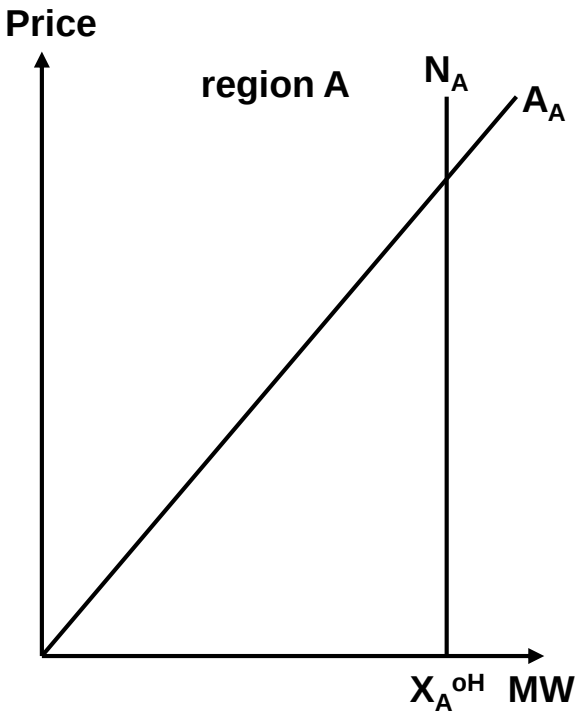
- $FLOW_{n,nn,t}$ is constrained by the net transfer capacity ($ntc_{n,nn}$):

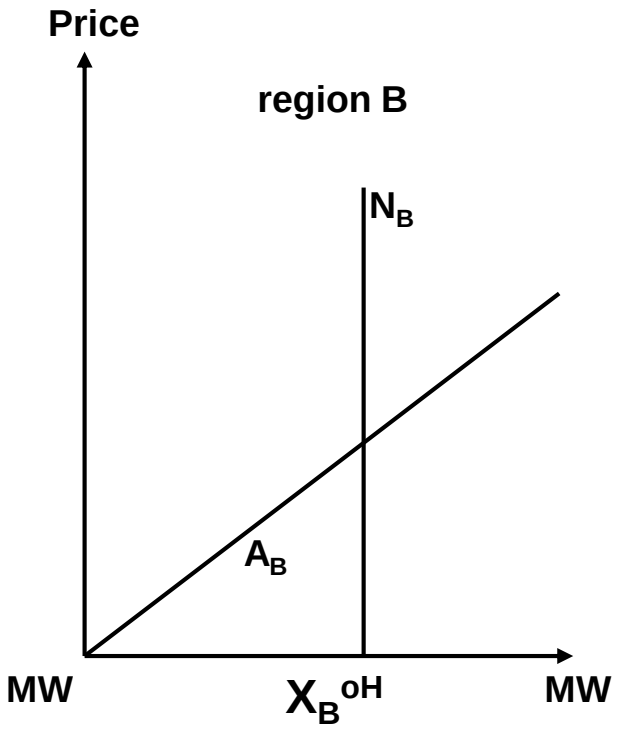
$$FLOW_{n,nn,t} \leq ntc_{n,nn} \qquad FLOW_{nn,n,t} \leq ntc_{nn,n}$$

- The $NTC_{n,nn}$ shows the transmission line capacity in MW:

NTC	GER	FR	NL
GER		300	250
FR	350		220
NL	200	200	

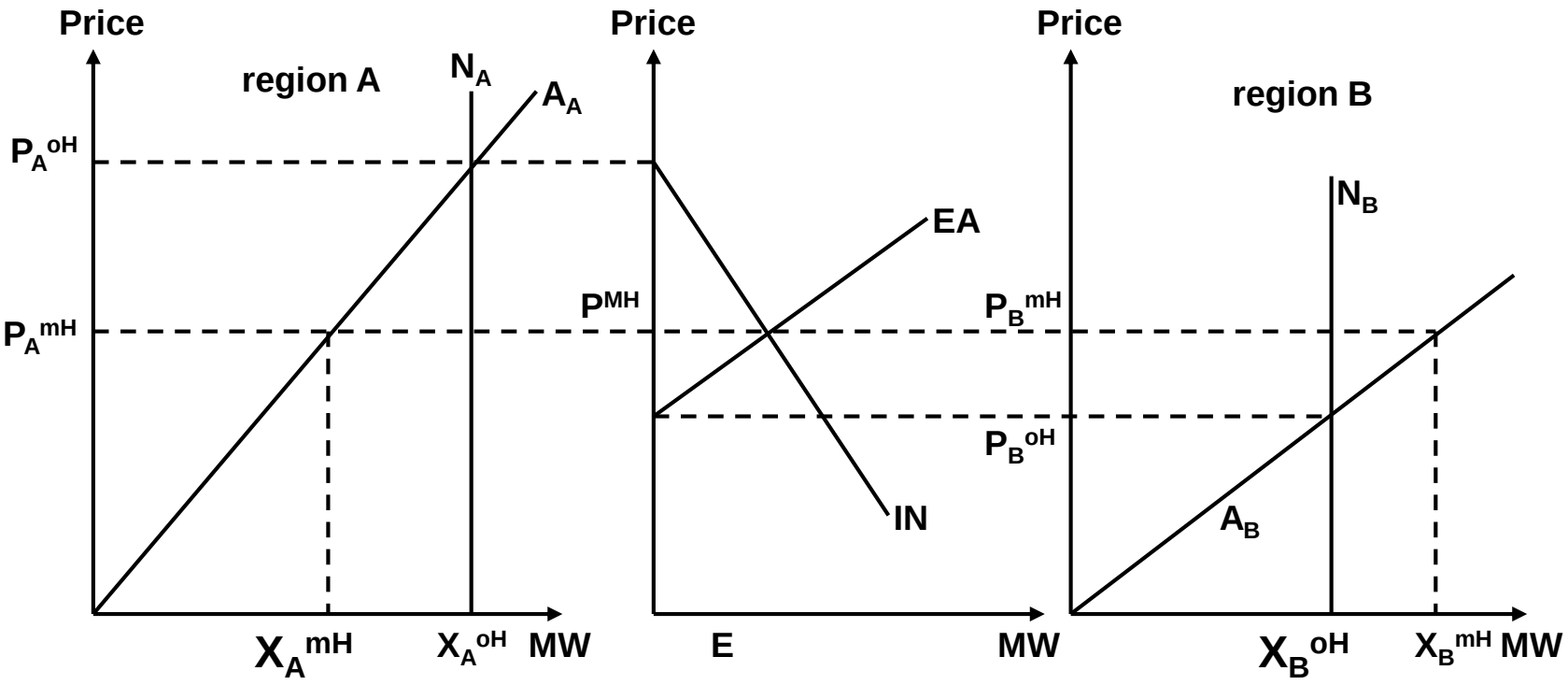
Prices With and Without Congestions





Source: Schwarz and Lang (2006): Europäische Stromerzeugungsmärkte am Beispiel Zentraleuropas: Stand der Integration und Handlungsbedarf

Prices With and Without Congestions



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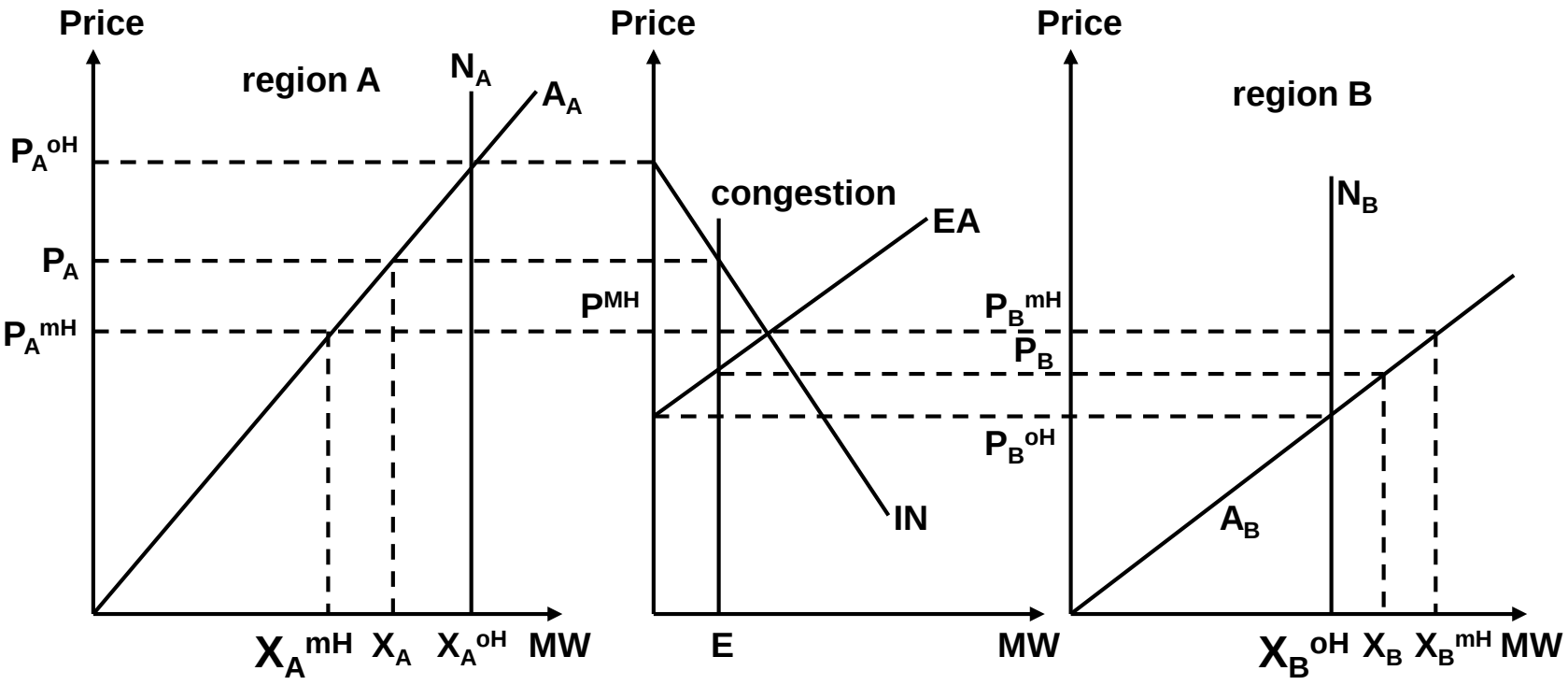

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Modelling a 3-node system (1,2)

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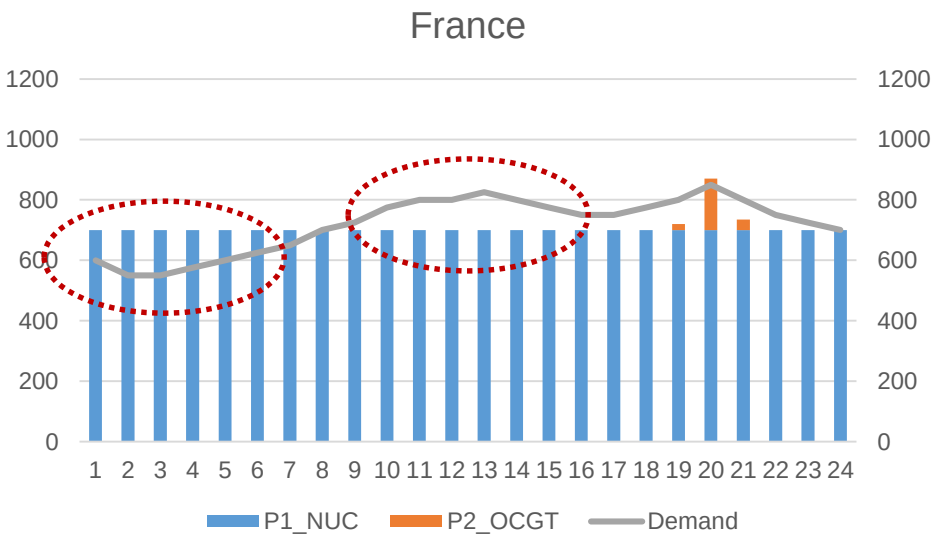
Discussion:

1. How and why do results change with trade allowed? *(independent work)*
2. What drives trade between countries?



Modelling a 3-node system (3,4)

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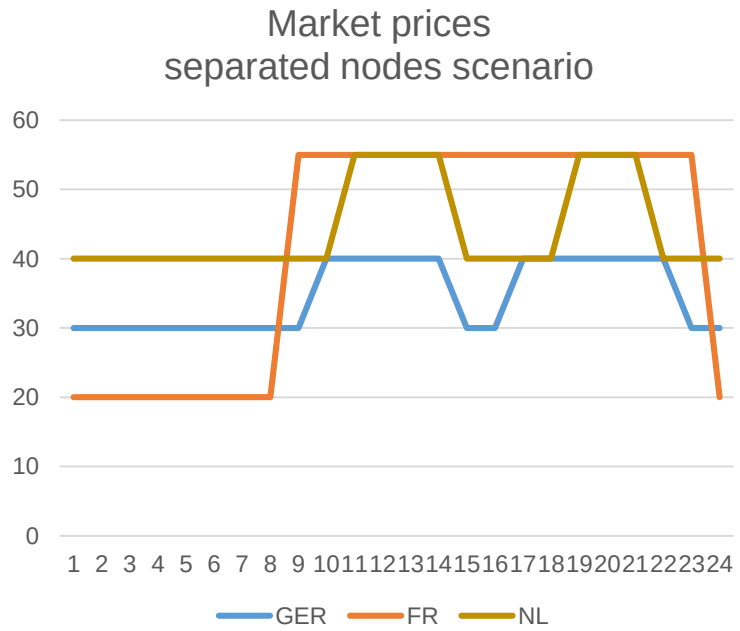
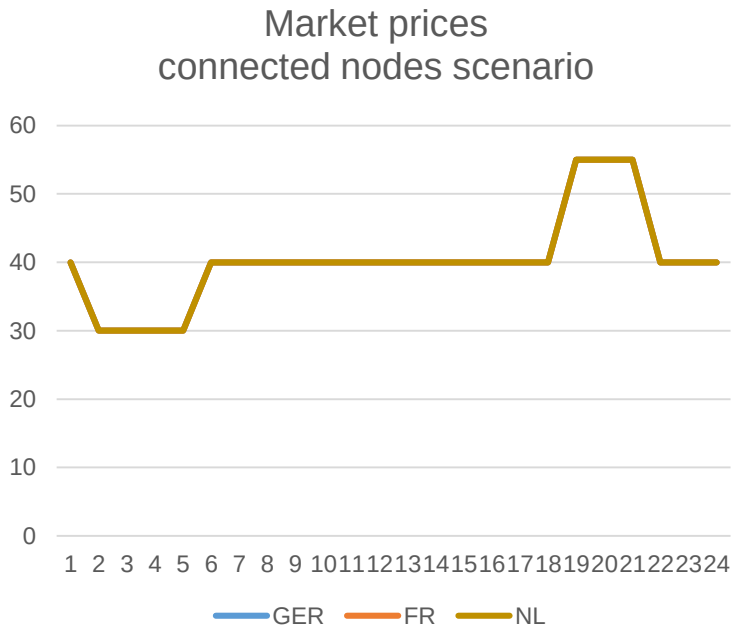
Discussion:

3. How price is formed?
4. Why prices are same in all markets in the scenario with interconnected nodes?





Modelling a 3-node system (5,6)

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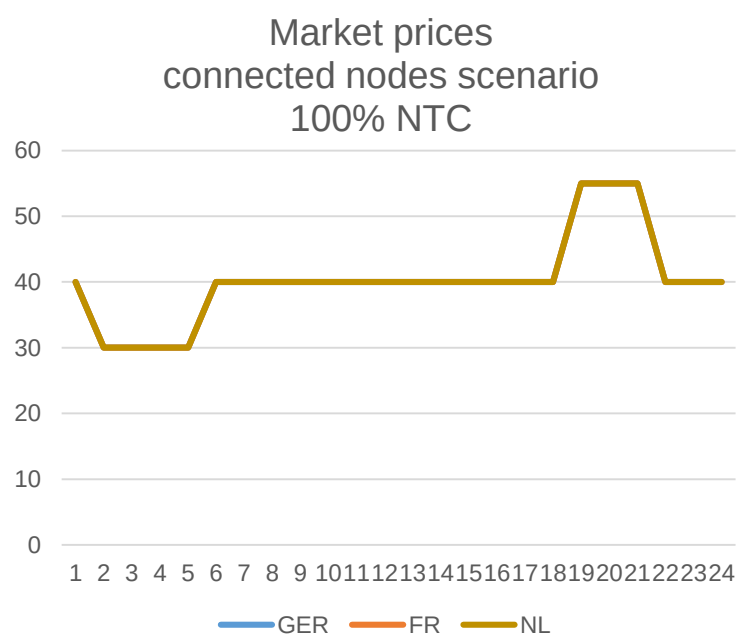
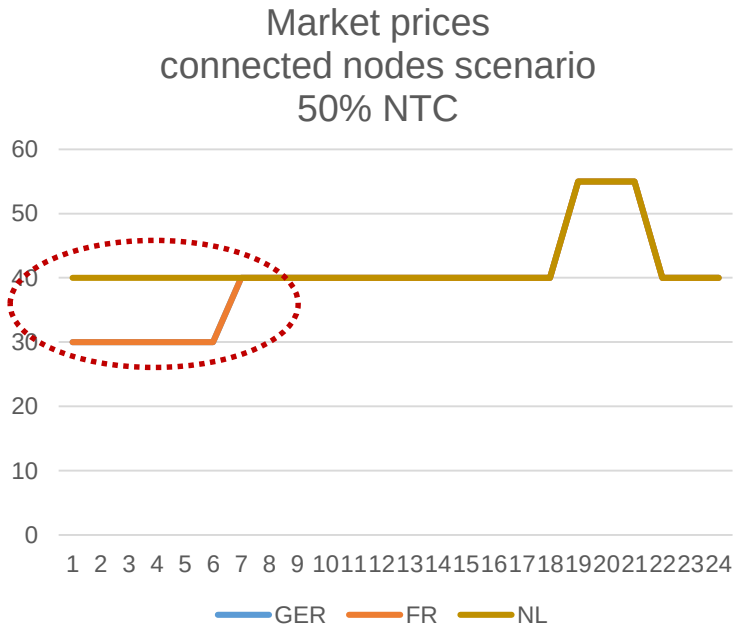
Discussion:

5. What happens with price levels if NTC are reduced by 50%?
6. Is there any evidence that trade is constrained by NTC levels (i.e. congestions)?





Modelling a 3-node system

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Homework

7. Calculate NTC hourly utilization rates.

8. What is the marginal value of NTC constraint? What is the economic meaning of this value?

9. Calculate which power plant owner benefits the most from the trade.

See you next class!