



# Low Carbon Ukraine

Policy advice on low-carbon policies for Ukraine

Supported by:



Federal Ministry  
for the Environment, Nature Conservation  
and Nuclear Safety

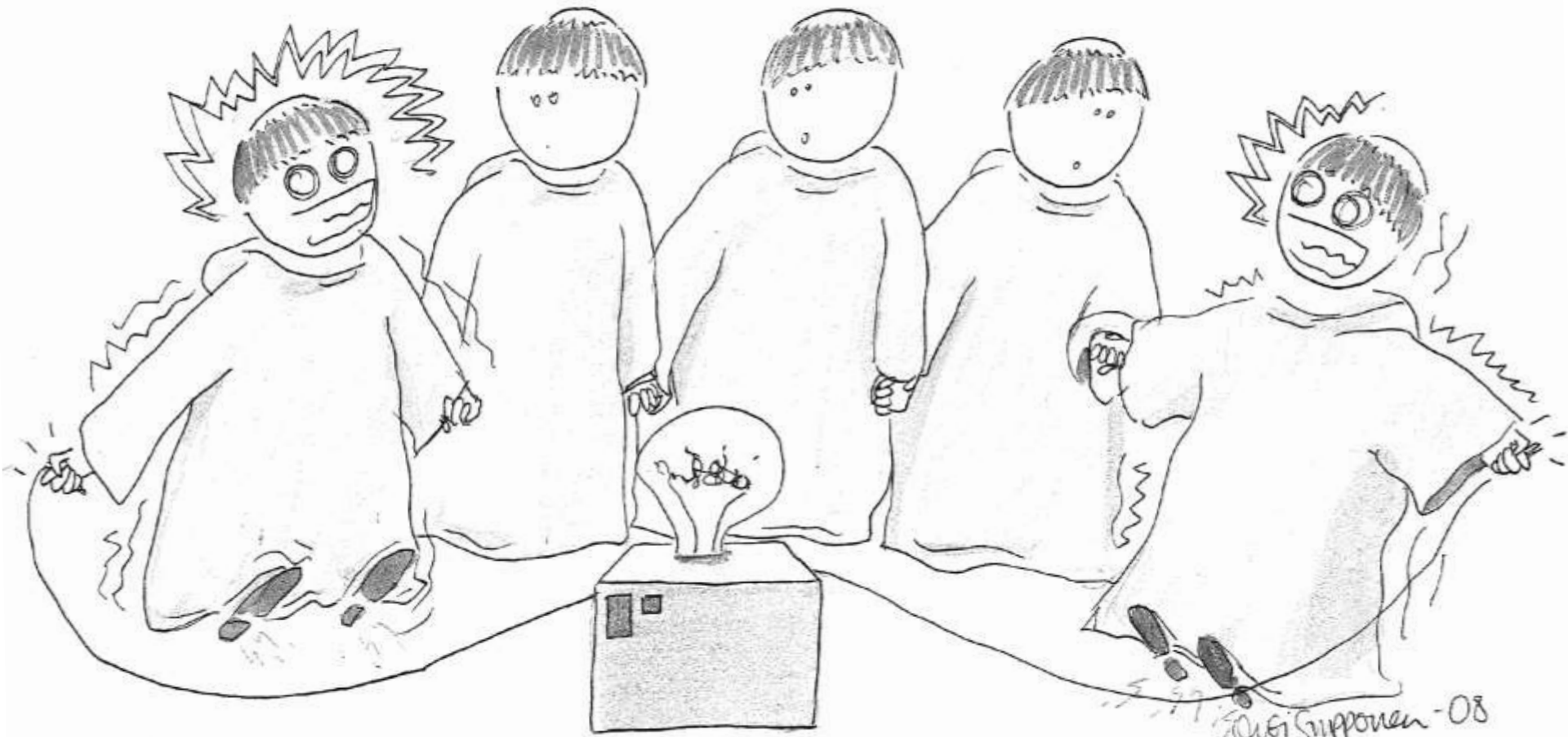
based on a decision of the German Bundestag



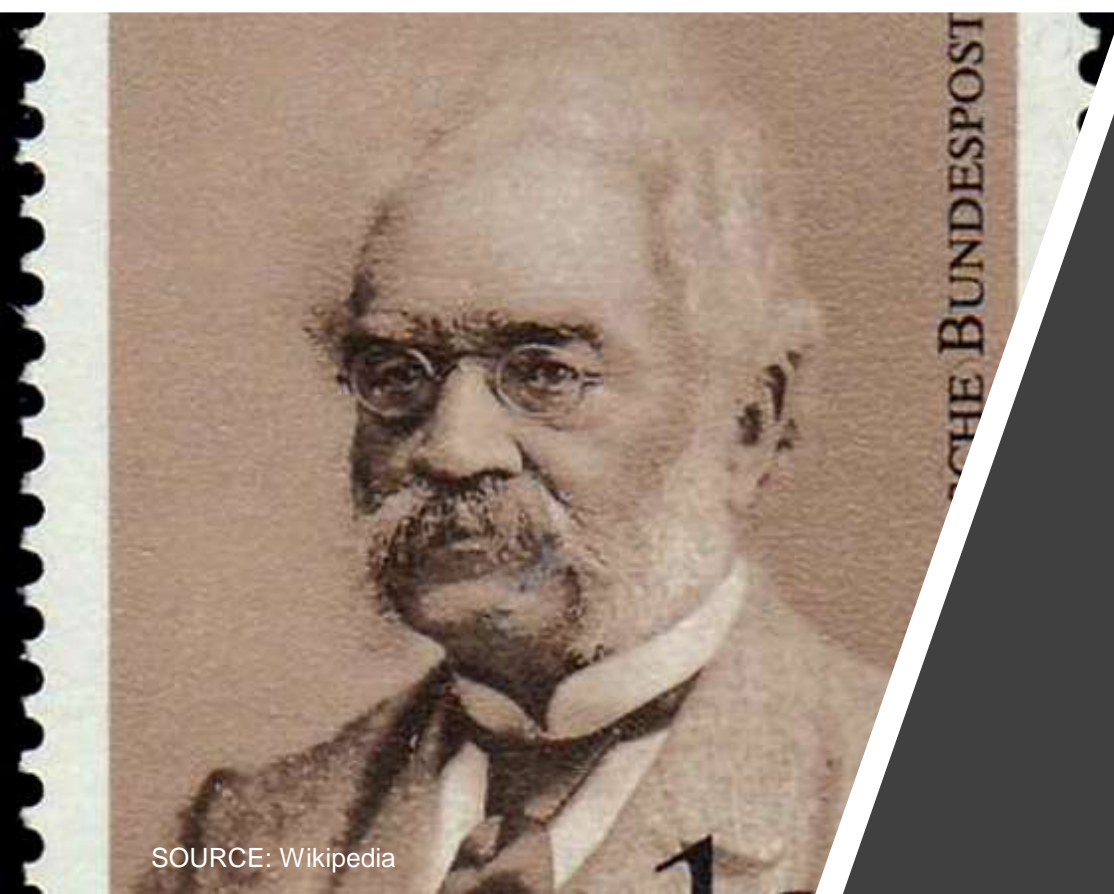
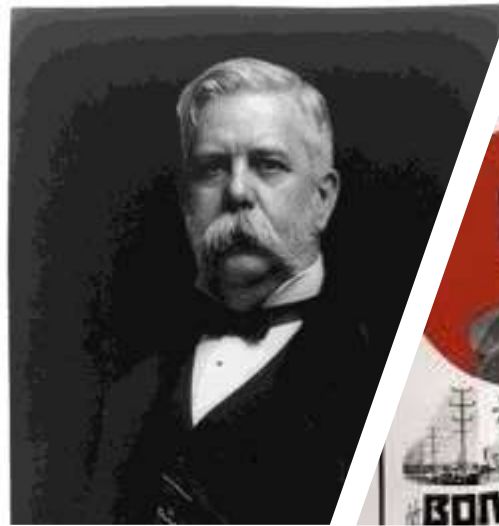
# Electricity for all

Dr. Matti Supponen

Kyiv, December 2019



Ossi Siipponen -08



Westinghouse, Lenin  
Tesla, Edison,  
Siemens



Miguel and Matti

## Menu

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- Basics of the electricity system
- Roles of different players
- How the electricity market works
- Network codes
- Grid investments
- End customers
- Flexibility
- Generation investments and capacity mechanisms
- Future topics

## Voltage = U

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- Mobile phone charger
- Car battery
- Electricity socket
- Medium voltage
- High speed train
- High voltage

= 5V

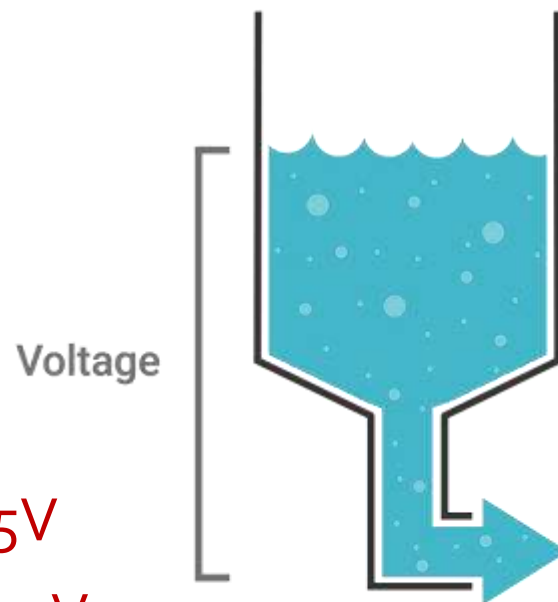
= 12V

~ 230V

~ 10-20kV

~ 25kV

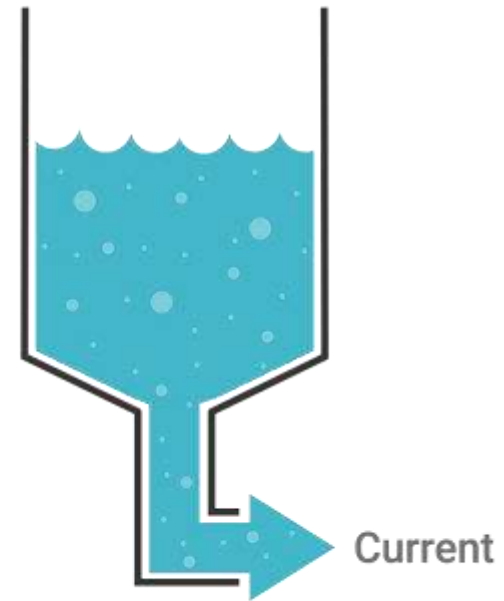
~ 110 – 700kV



## Current = I

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- Mobile phone charger = 1A
- Car battery = 300A
- Electricity socket ~ 16A
- Medium voltage ~ 500A
- High speed train ~ 300A
- High voltage ~ 100 – 2000A



## Power = $U \cdot I$

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- Mobile phone charger = 5W
- Car battery = 3kW
- Flat iron ~ 4kW
- Rue de Mot 24 ~ 300kW
- High speed train ~ 8MW
- Arc furnace ~ 50MW
- Berlin ~ 2000MW





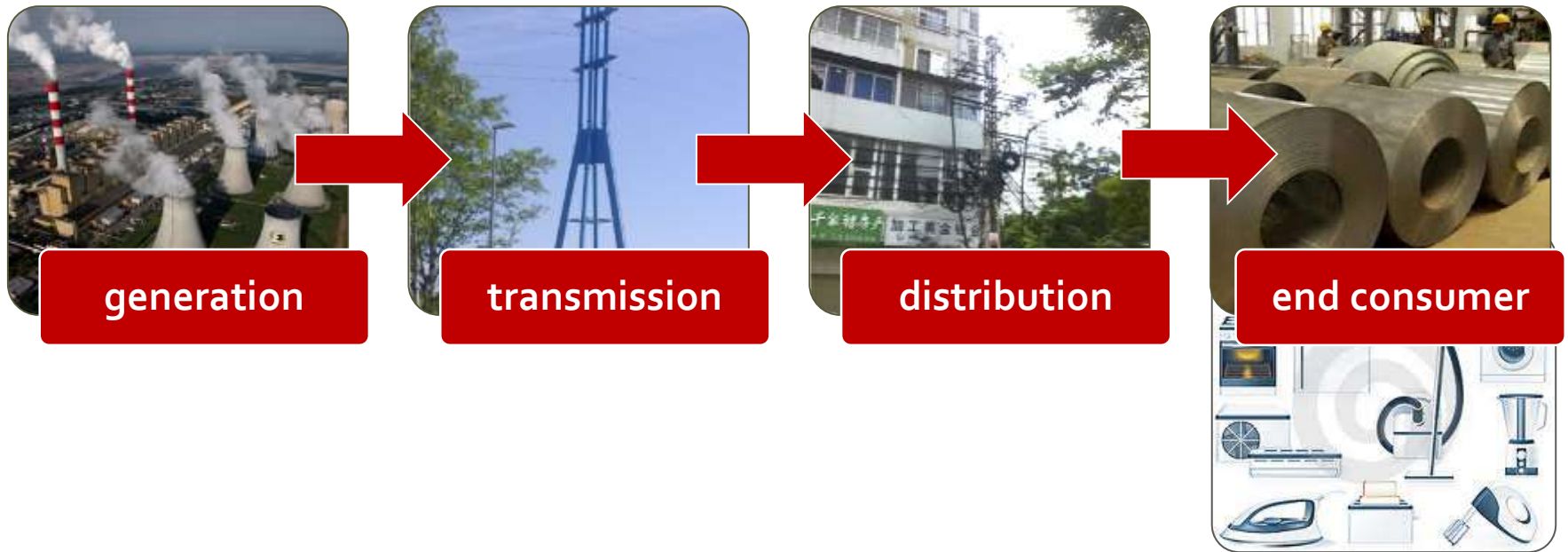
$$\text{Energy} = P * t$$

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- Mobile phone charger ~ 1kWh
- Car battery ~ 10kWh
- Flat iron ~ 100kWh
- High speed train ~ 10GWh
- Arc furnace ~ 200GWh
- Windmill ~ 10GWh
- Comb. cycle gas turbine ~ 2TWh
- Berlin ~ 14TWh

# Physical value chain for electricity

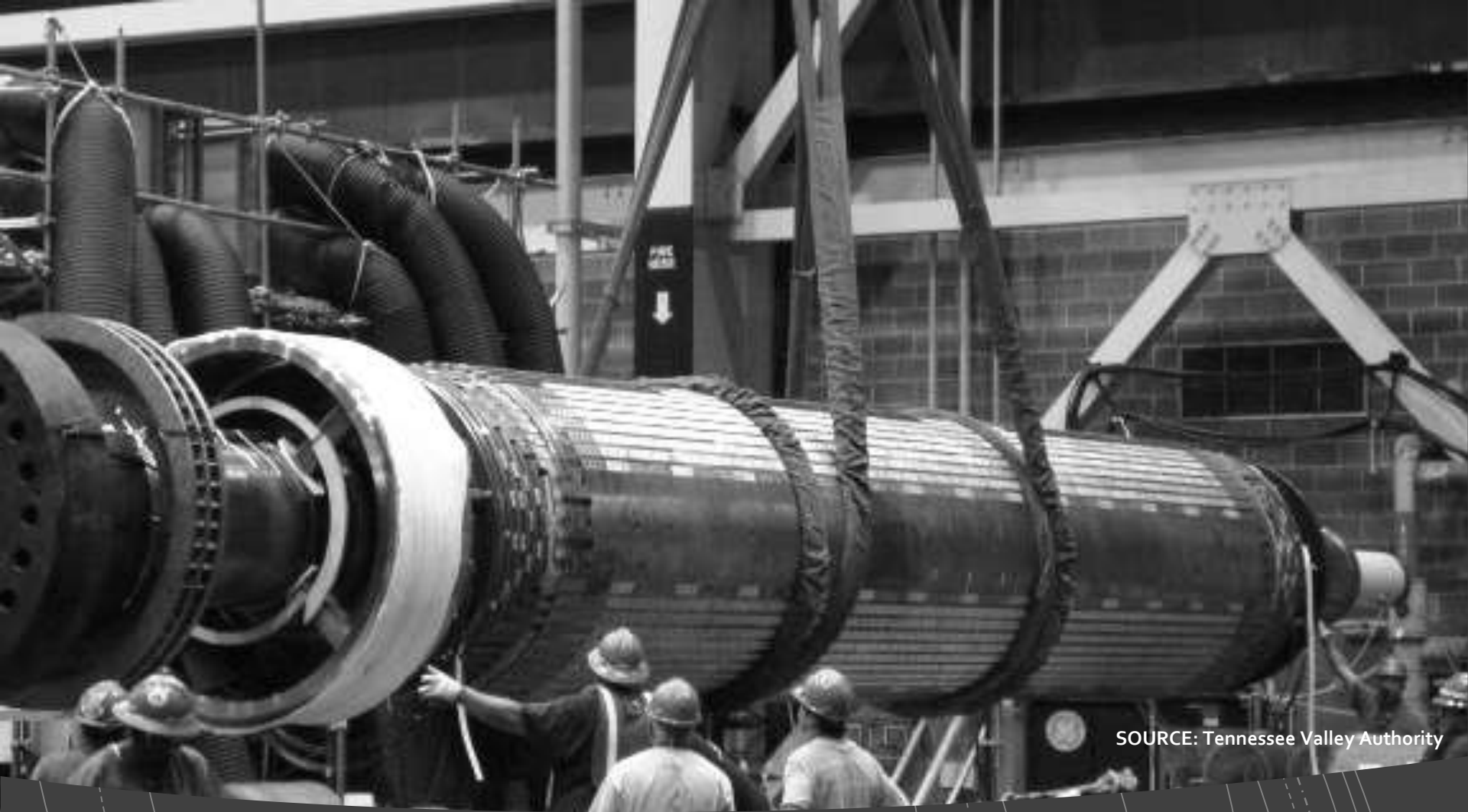
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© George Campbell 1993

# Generator

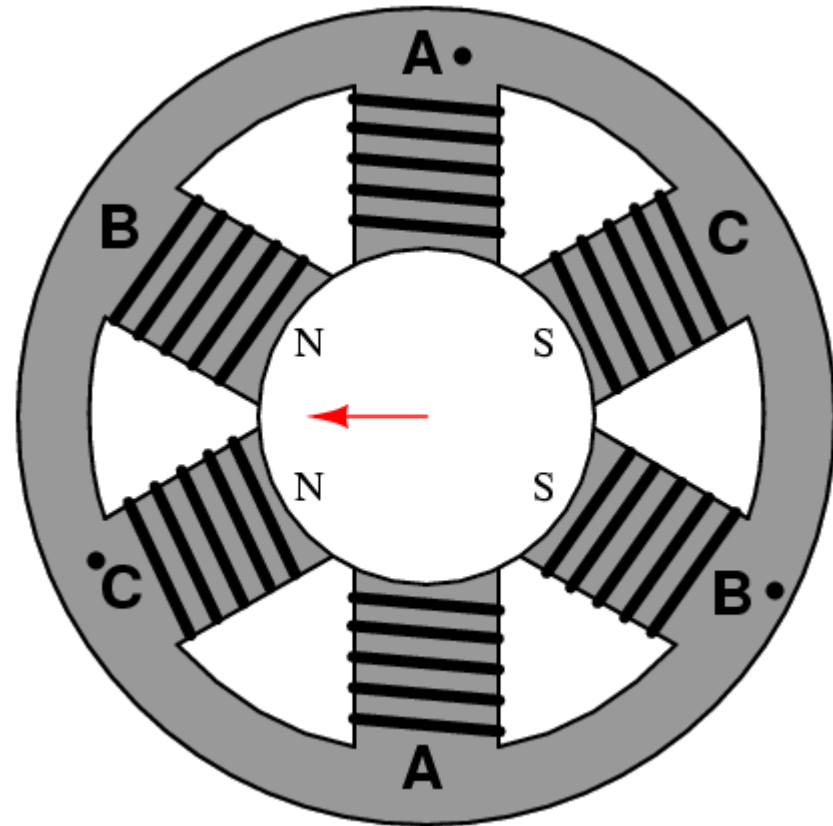


SOURCE: Tennessee Valley Authority

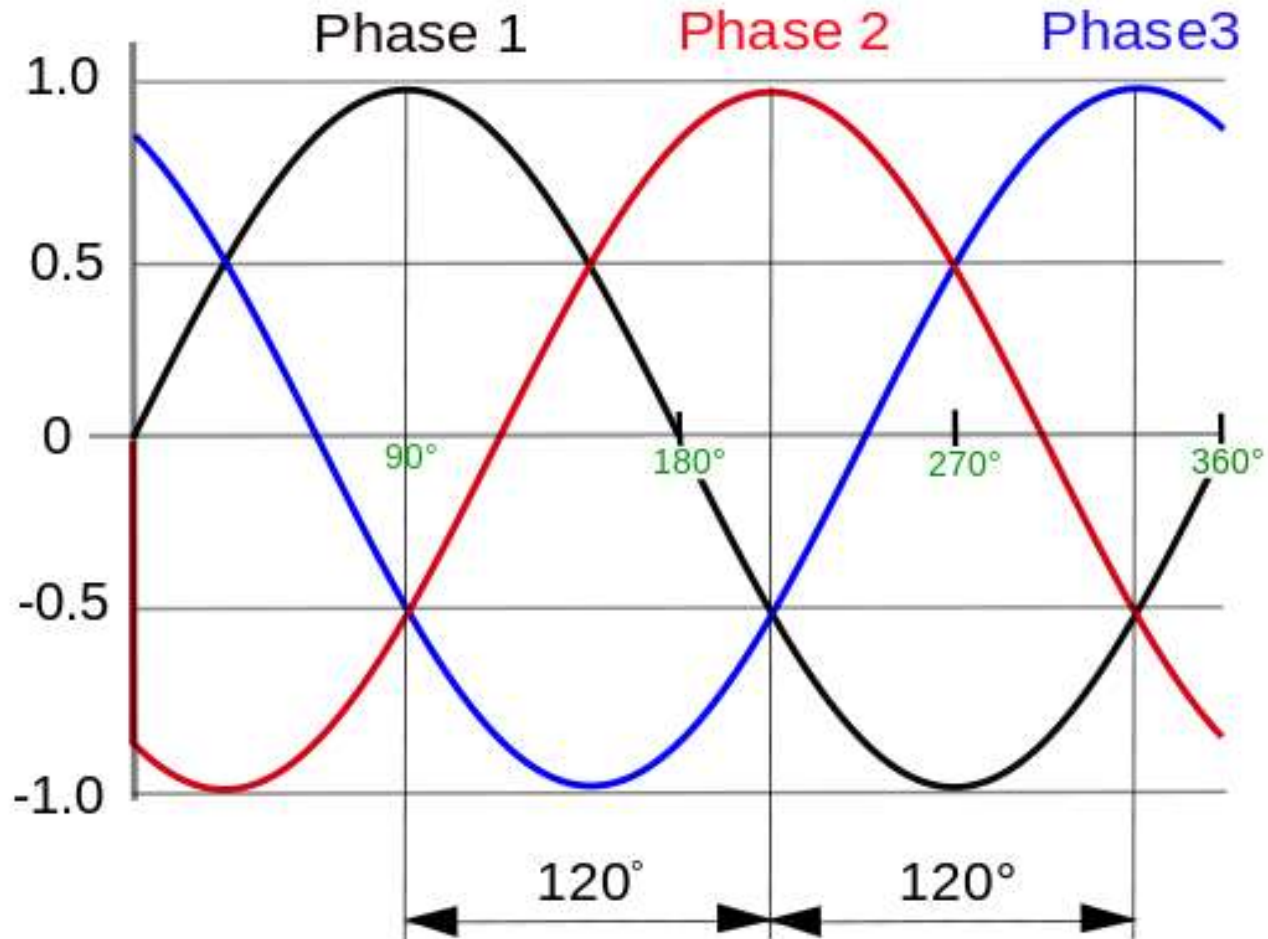
# Rotor

# Electric motor

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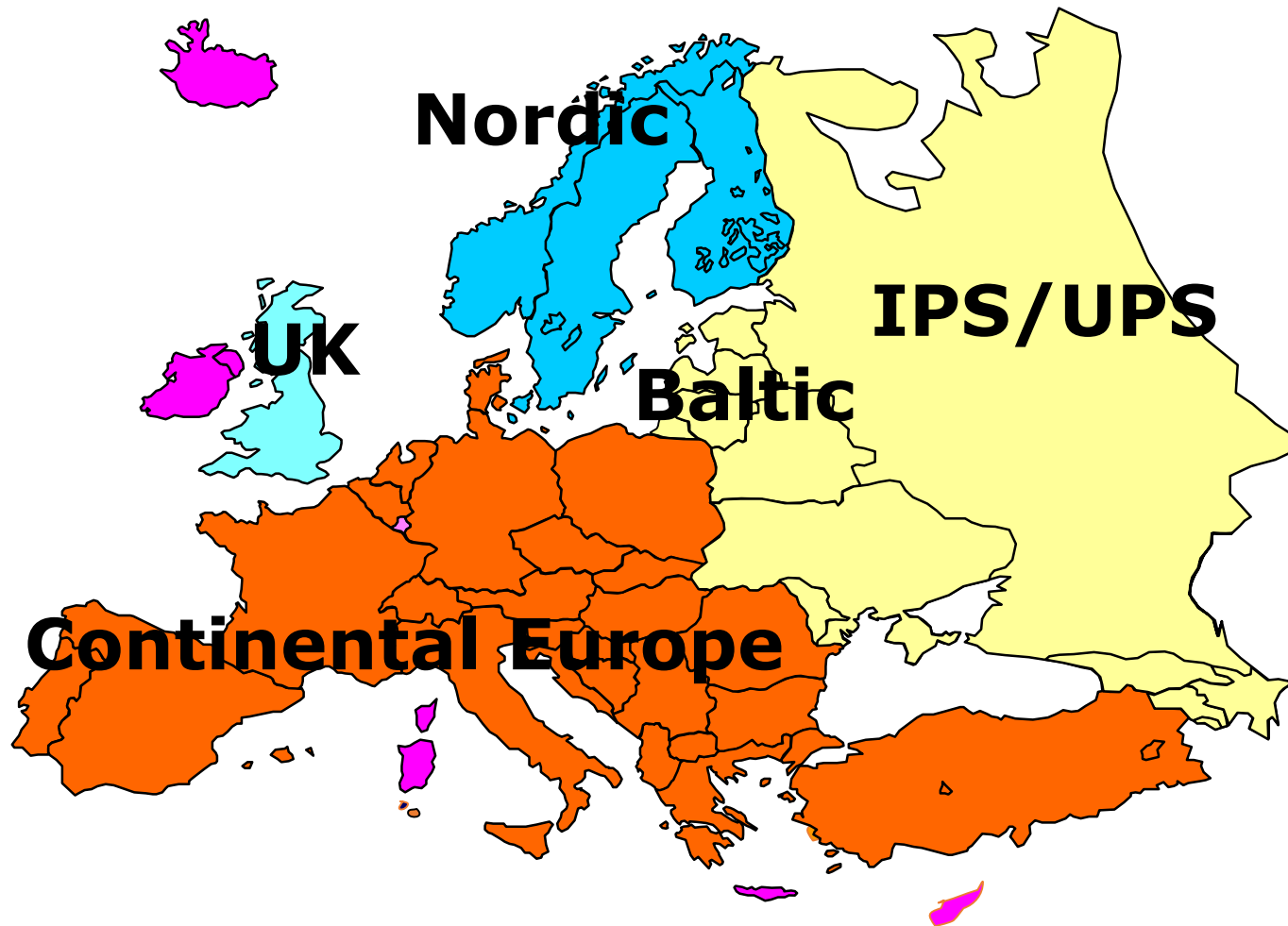


## 3 phase alternating current



## Synchronous zones in Europe

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## Synchronous zones in China

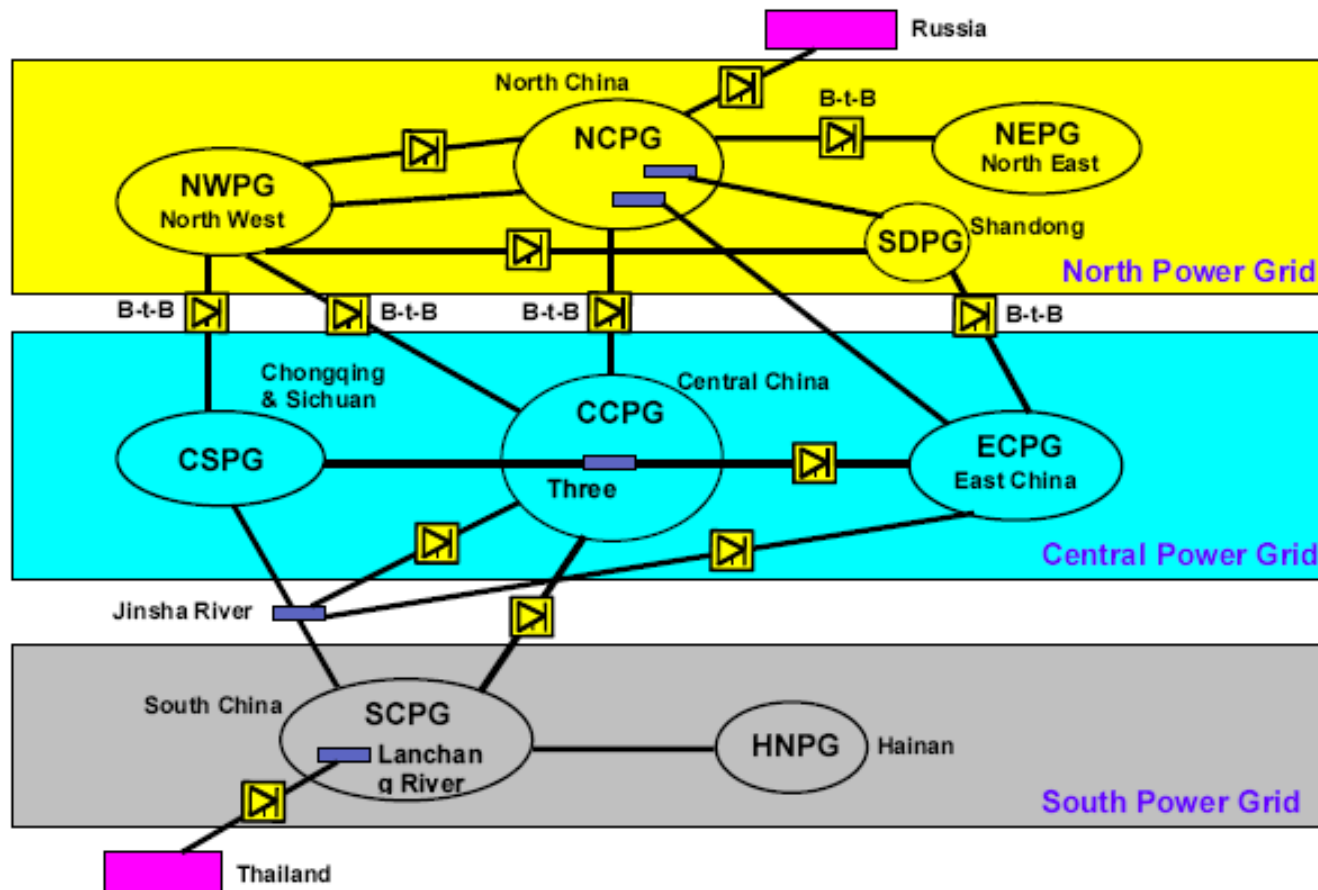
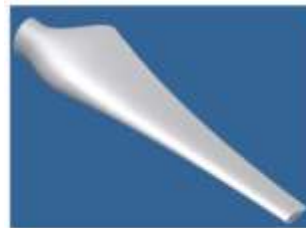


Fig.1 Conceptual Overview of China National Grid Interconnection by 2015

SOURCE: Cigre papers, ABB



# Wind generator



*How does a wind turbine work?*

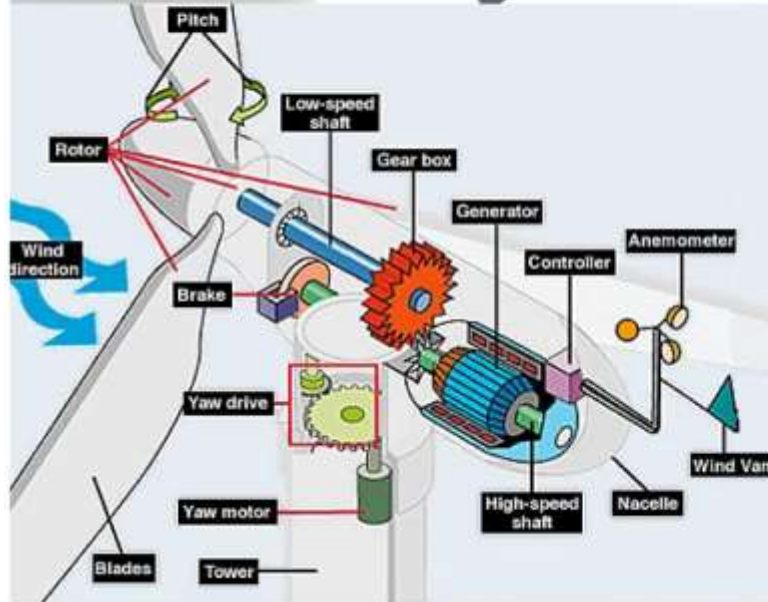
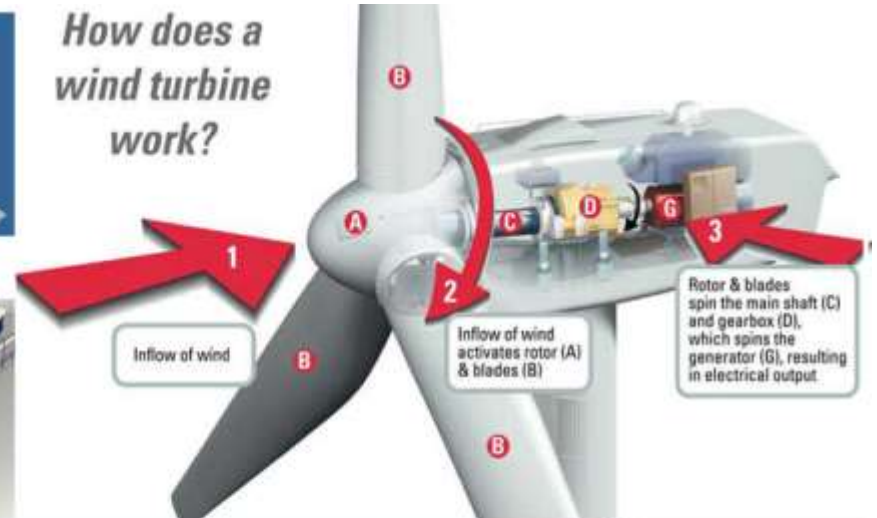


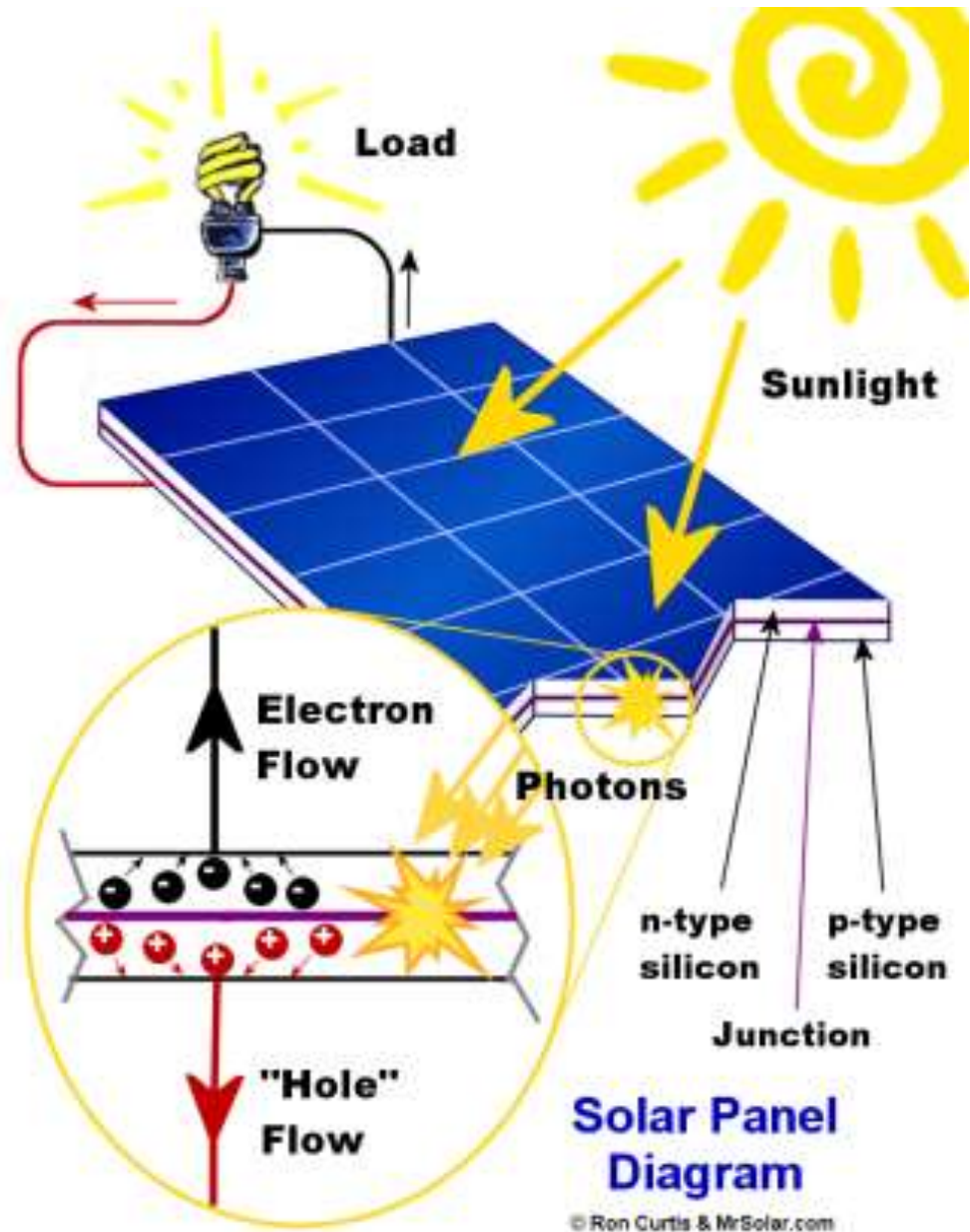
Figure 2 – Generalized Gearbox Schematic [11]  
Typical asynchronous generator, Danish wind turbines, 1959



- 1. Generator shaft
- 2. Pulling bearings
- 3. Rotor
- 4. Rotor aluminium bar
- 5. Rotor aluminium slip
- 6. Stator
- 7. Coil
- 8. Stator poles
- 9. Cool fan
- 10. Ventilator
- 11. Connection box

# Solar panel

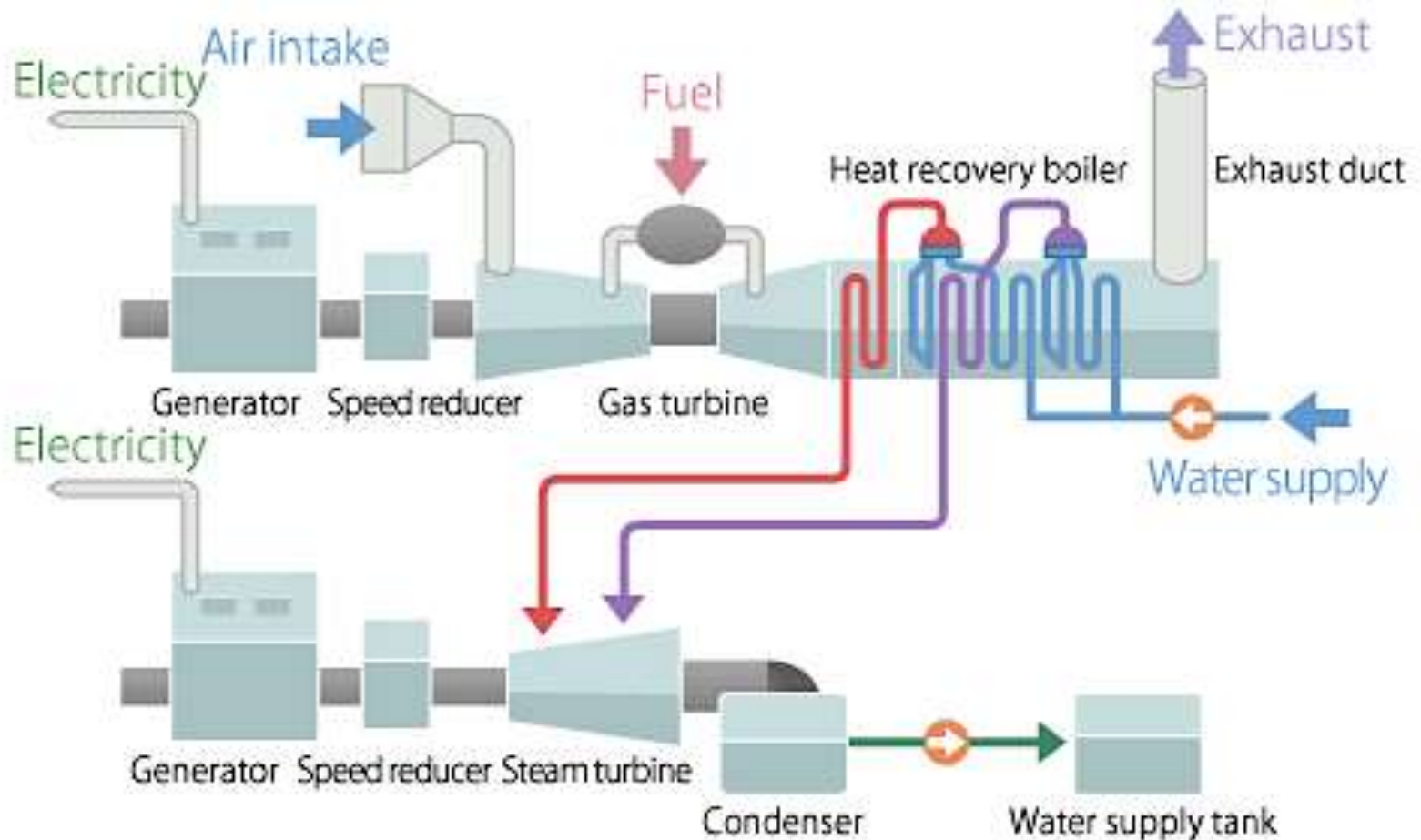
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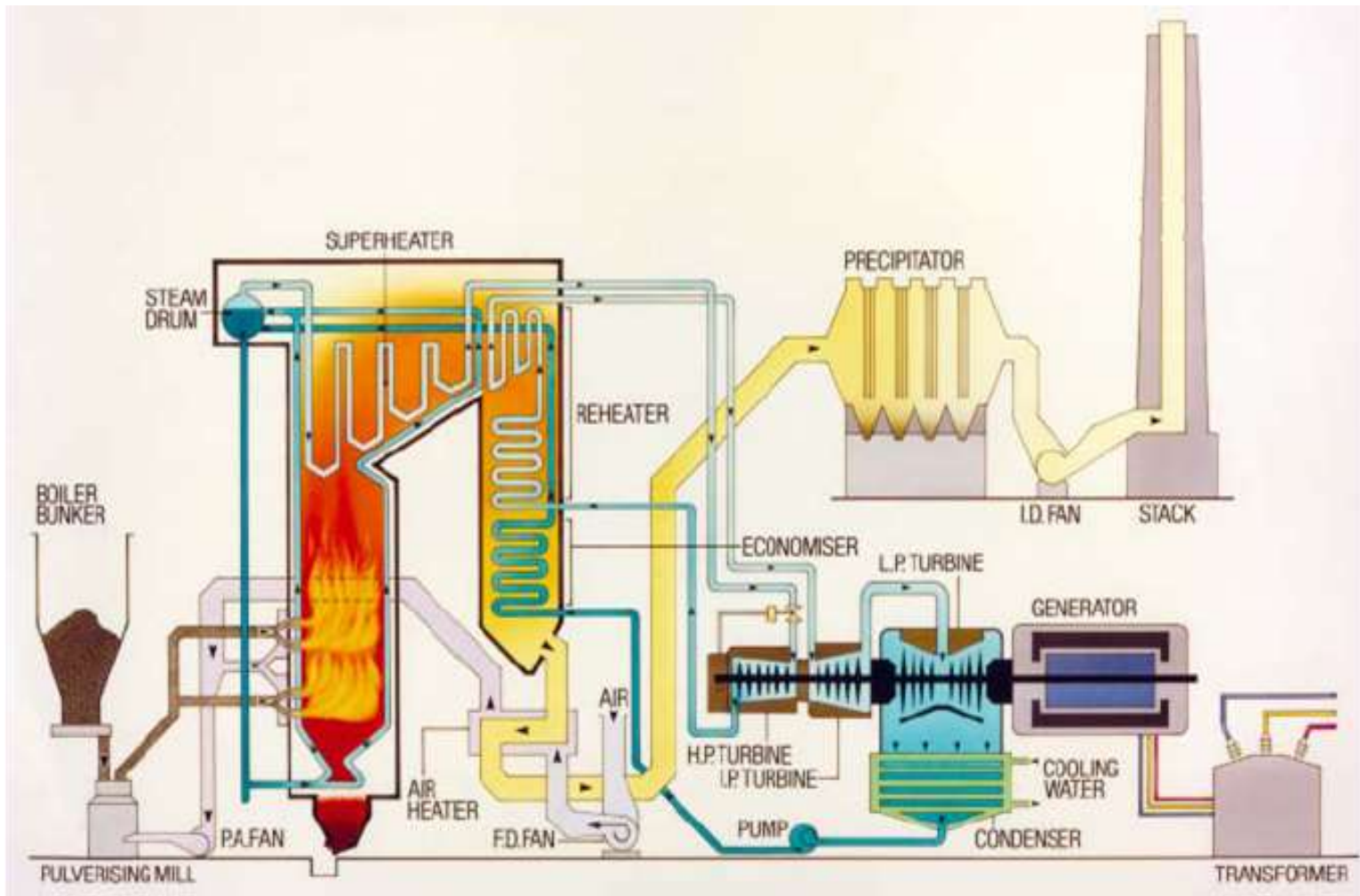


Hydro  
power  
plant

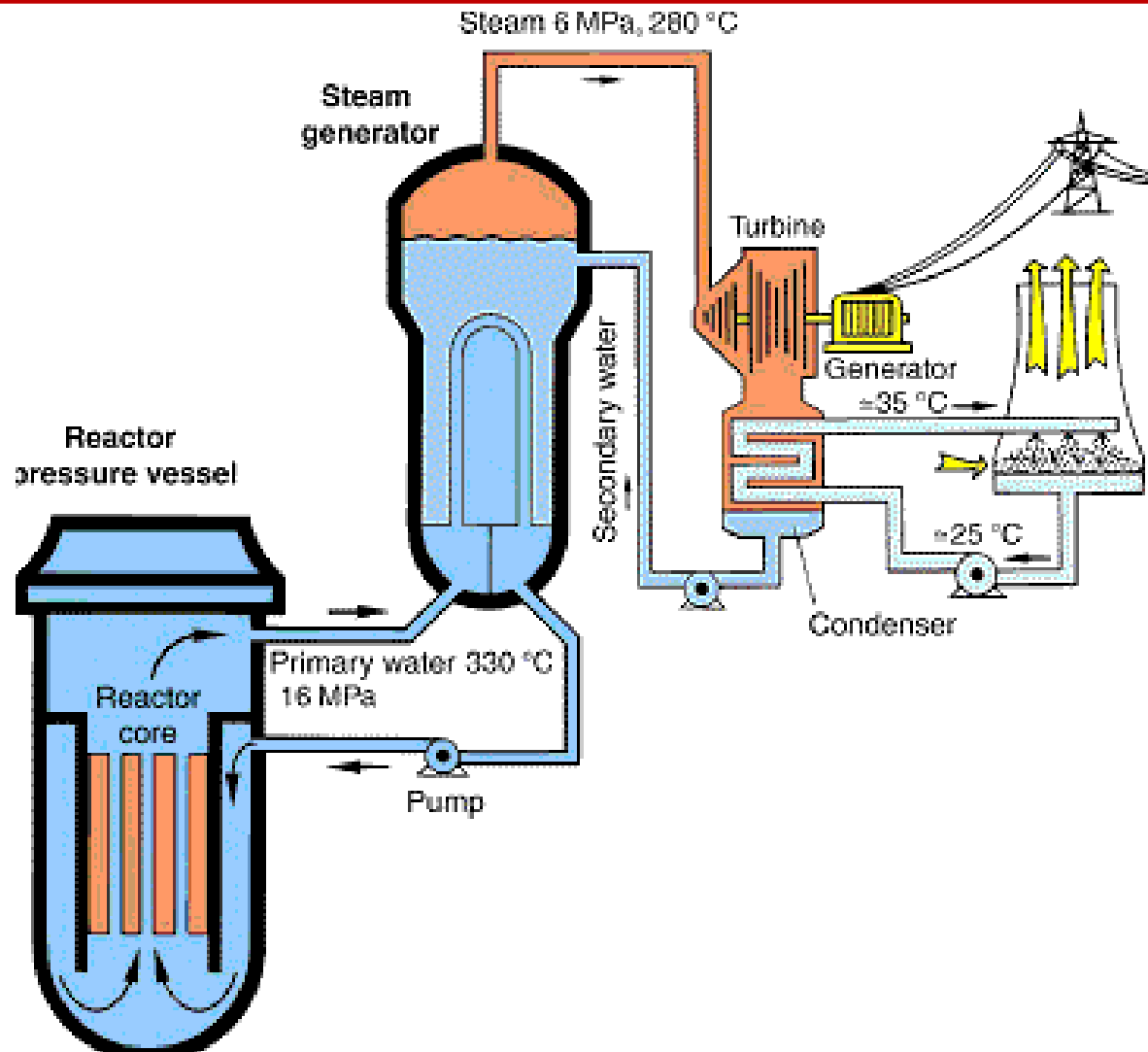
## Combined cycle gas turbine



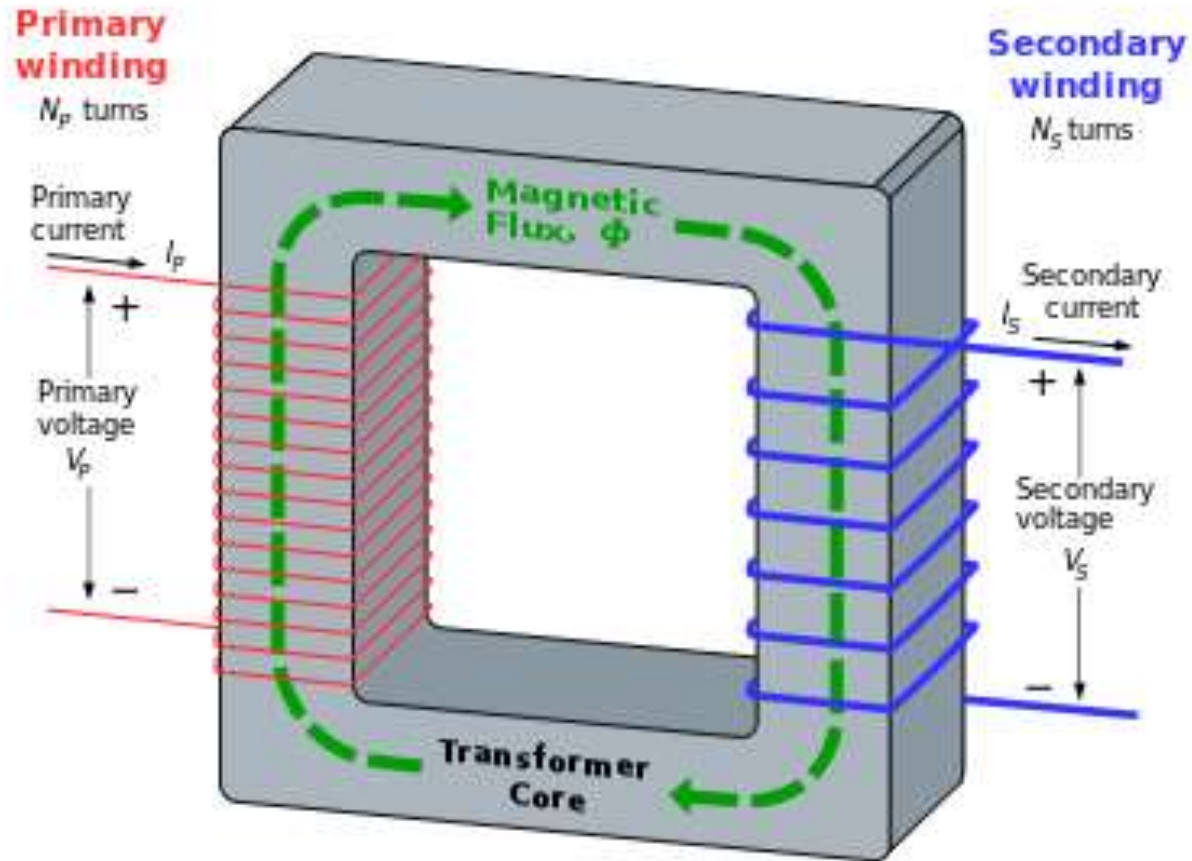
# Coal power station



# Nuclear power station



# Transformer





# Step-up transformer



# Substation

A photograph of a mountainous landscape under a clear blue sky. Several overhead power lines stretch across the frame from the top left towards the right. The lines are supported by a tower on the left. The foreground and middle ground are filled with dense green trees, and a rocky mountain peak is visible on the right side. The text "Overhead line" is centered in the image in a large, white, sans-serif font.

# Overhead line



# Substation

A detailed cross-section of an undersea cable. At the top is a central copper conductor, surrounded by a black insulating layer. Below this is a thick, dark brown layer, followed by a black layer, a textured brown layer, a dark grey layer, a silver layer, a dark grey layer, a layer with a diagonal ribbed pattern, a dark grey layer, and finally a bottom layer with a diagonal ribbed pattern. The entire cable is set against a blue background.

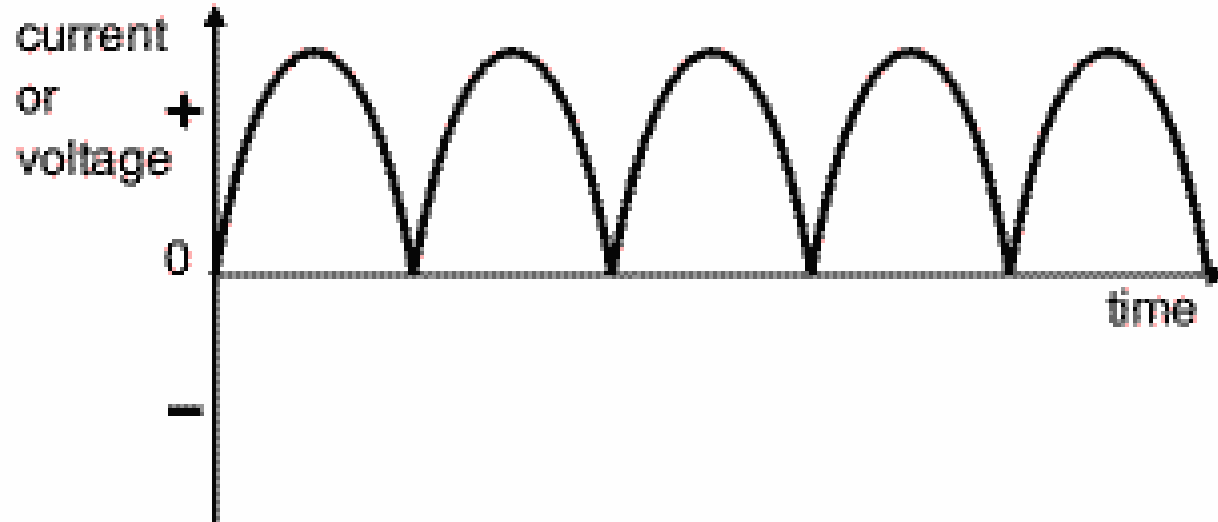
# Undersea cable

A photograph showing the interior of a tunnel. The tunnel walls are lined with numerous large, white, flexible cables that curve along the length of the passage. In the center, a white maintenance vehicle with red and white diagonal stripes is visible. A worker wearing a yellow hard hat is seated inside the vehicle, looking forward. The vehicle has a small red light and a logo on its front. In the upper left corner, a sign reads "VL 7 5120 m". The overall lighting is dim, with some overhead lights visible.

# 380kV cable in Berlin

## Converter - easy part

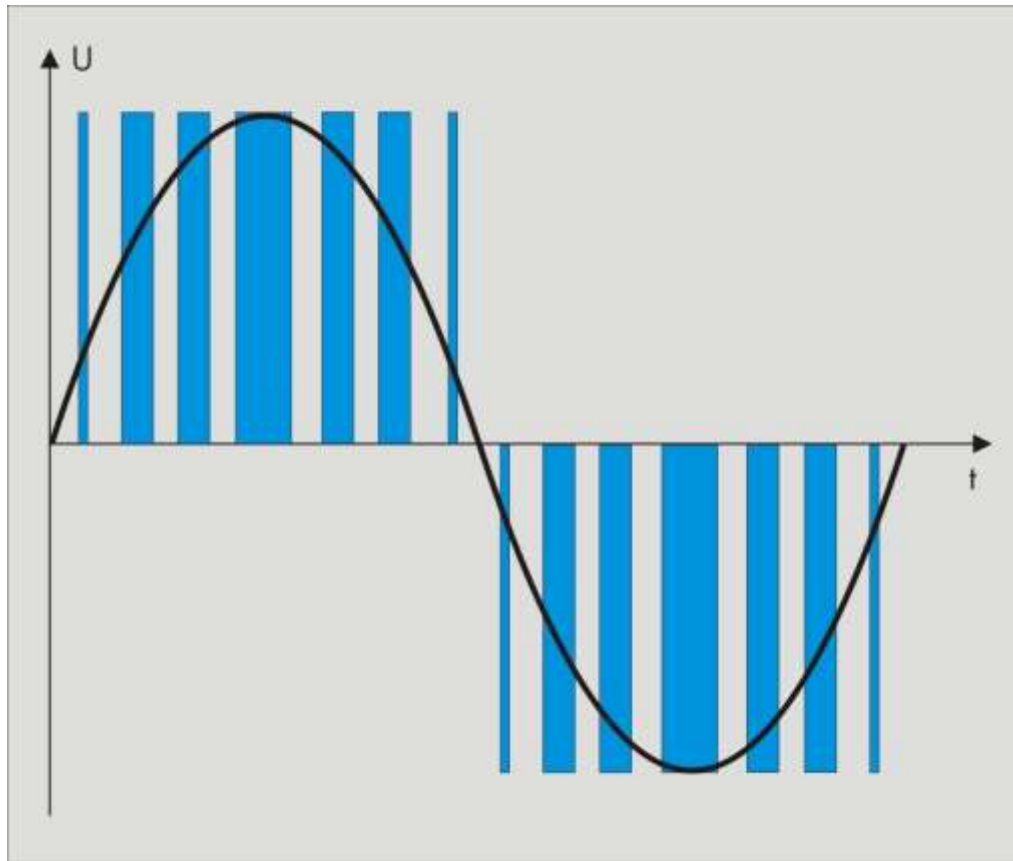
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**DC Variable**

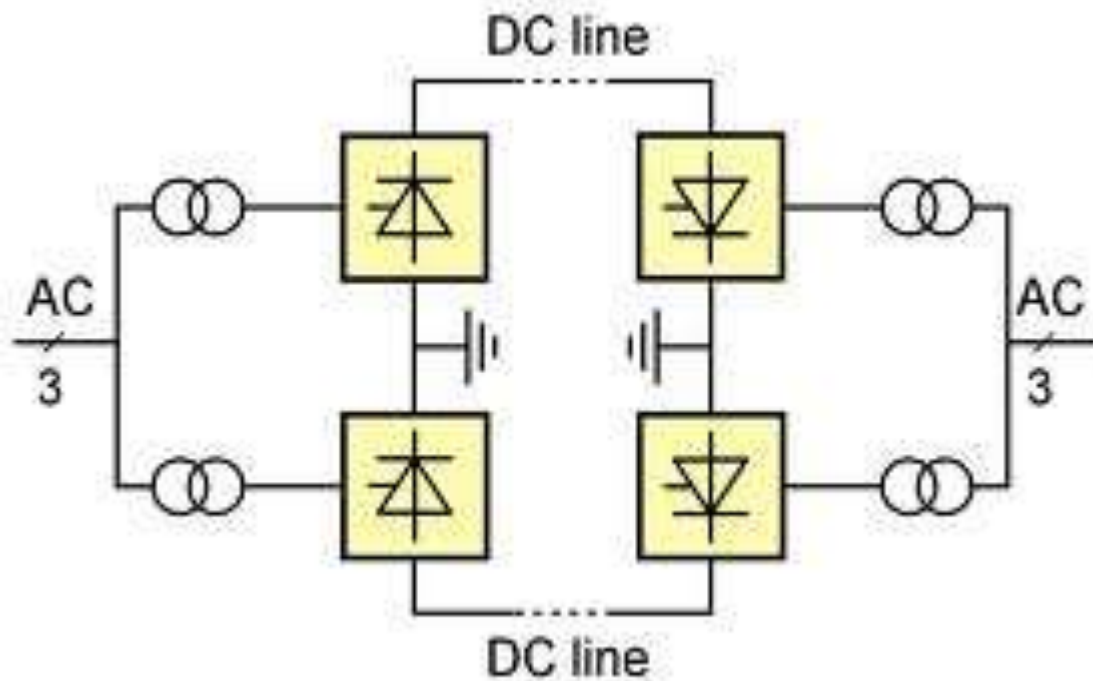
## Converter - difficult part

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## Converter - done

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## Converter - built

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## Back-to-back

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A photograph of a back-to-back substation in Etzenricht, Germany. The image shows a large lattice tower structure with multiple cross-arms, supporting high-voltage power lines. The substation is situated in a field of tall grass. In the background, there are some industrial buildings and a line of trees. The sky is overcast with grey clouds. The text 'Back-to-back station Etzenricht' is overlaid in white on the image.

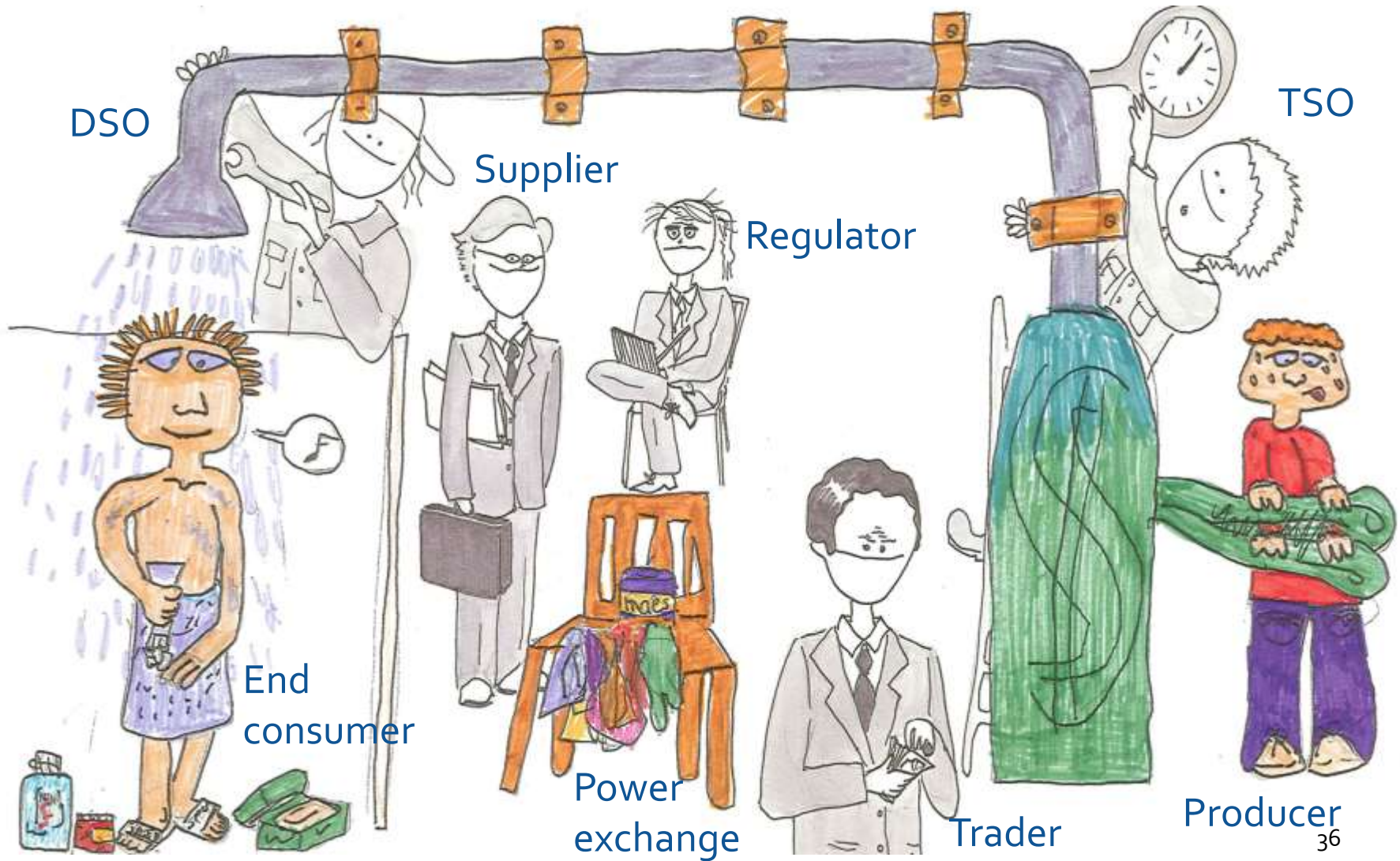
# Back-to-back station Etzenricht

## Good old times

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## New roles



## Regulator's life is not always easy

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Art

## Power market

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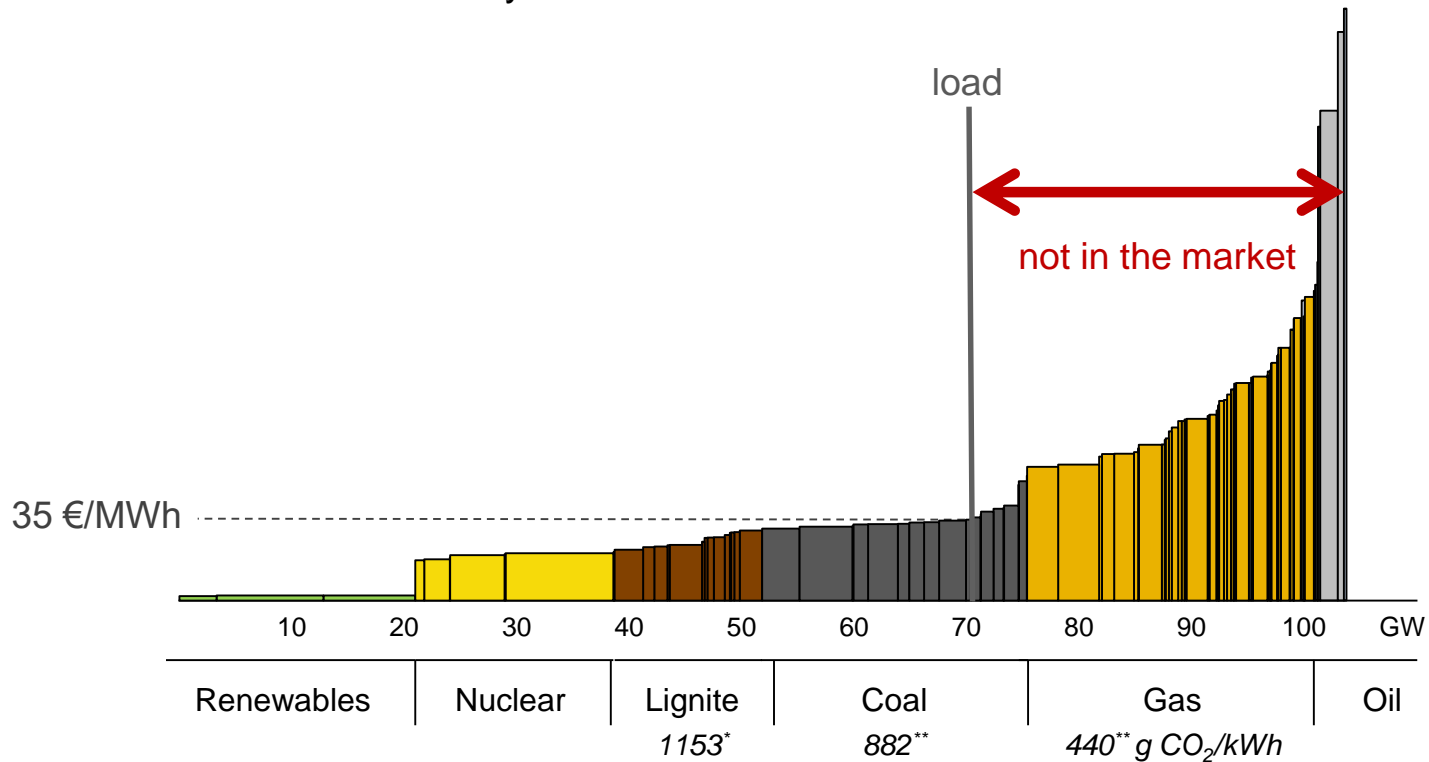
## Power market





# Coal power in duty, gas power stations not in the money

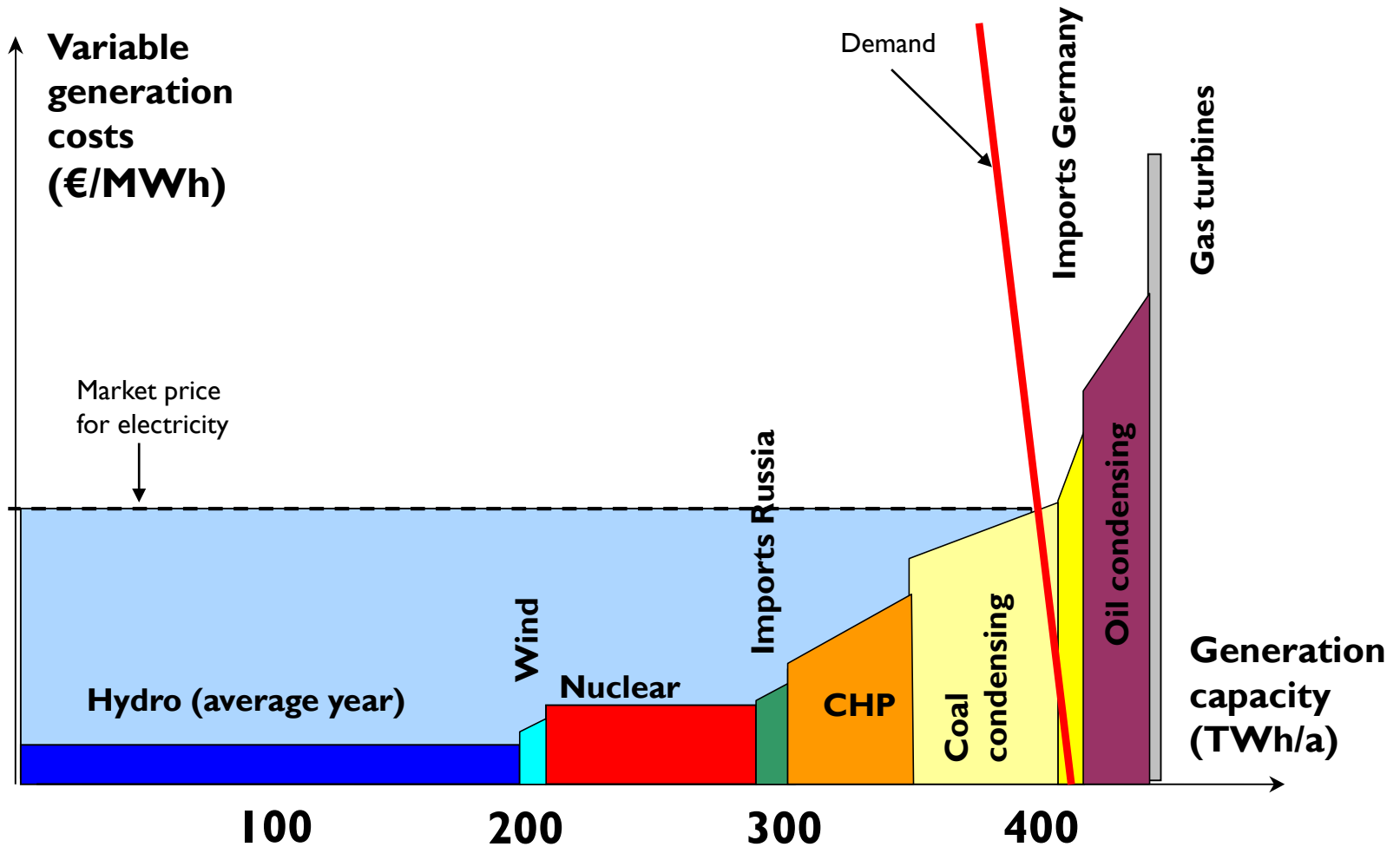
Merit Order Austria/Germany 2014



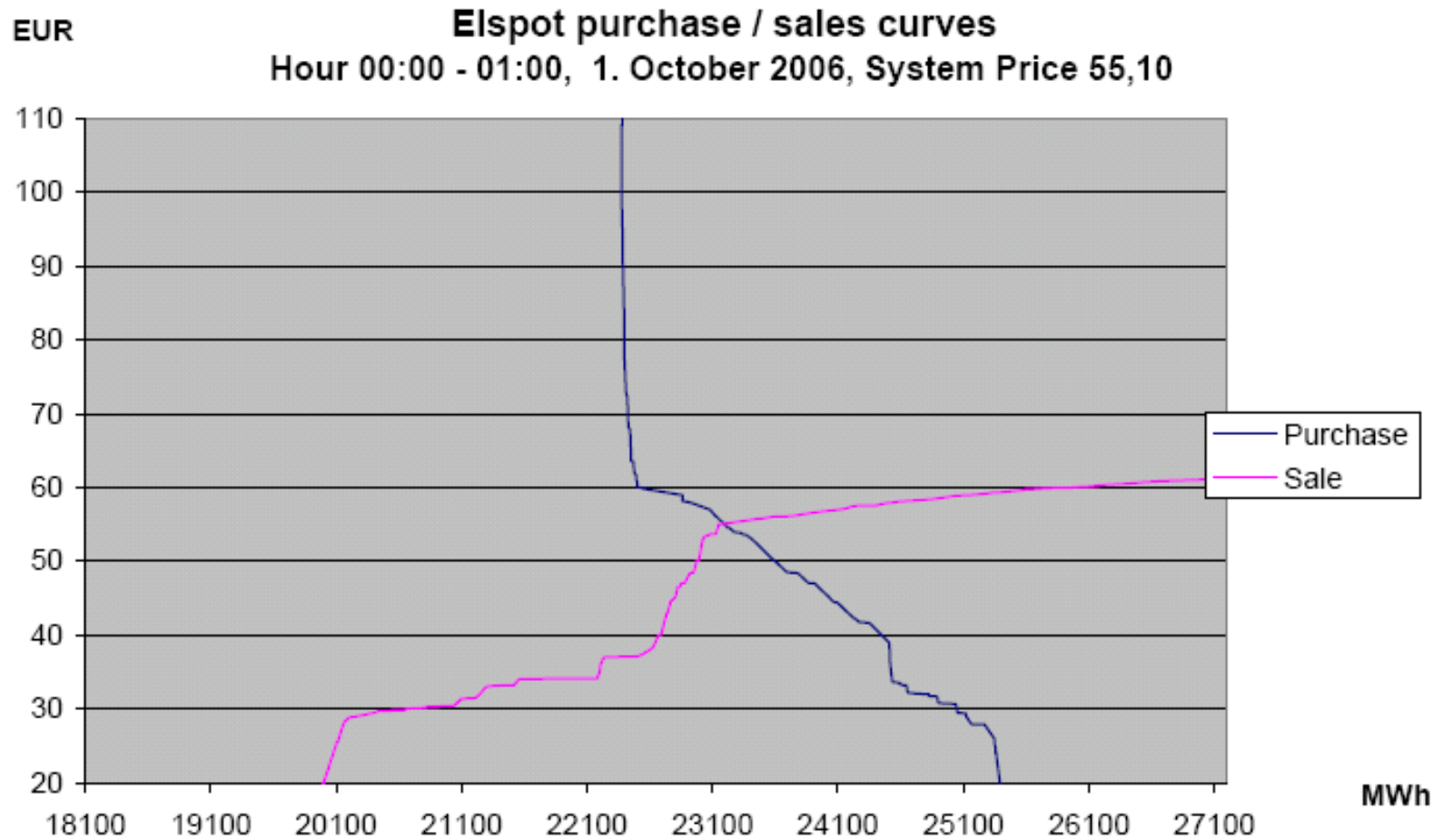
\* [www.co2-emissionen-vergleich.de](http://www.co2-emissionen-vergleich.de)

\*\* E-Control-Referenzwerte

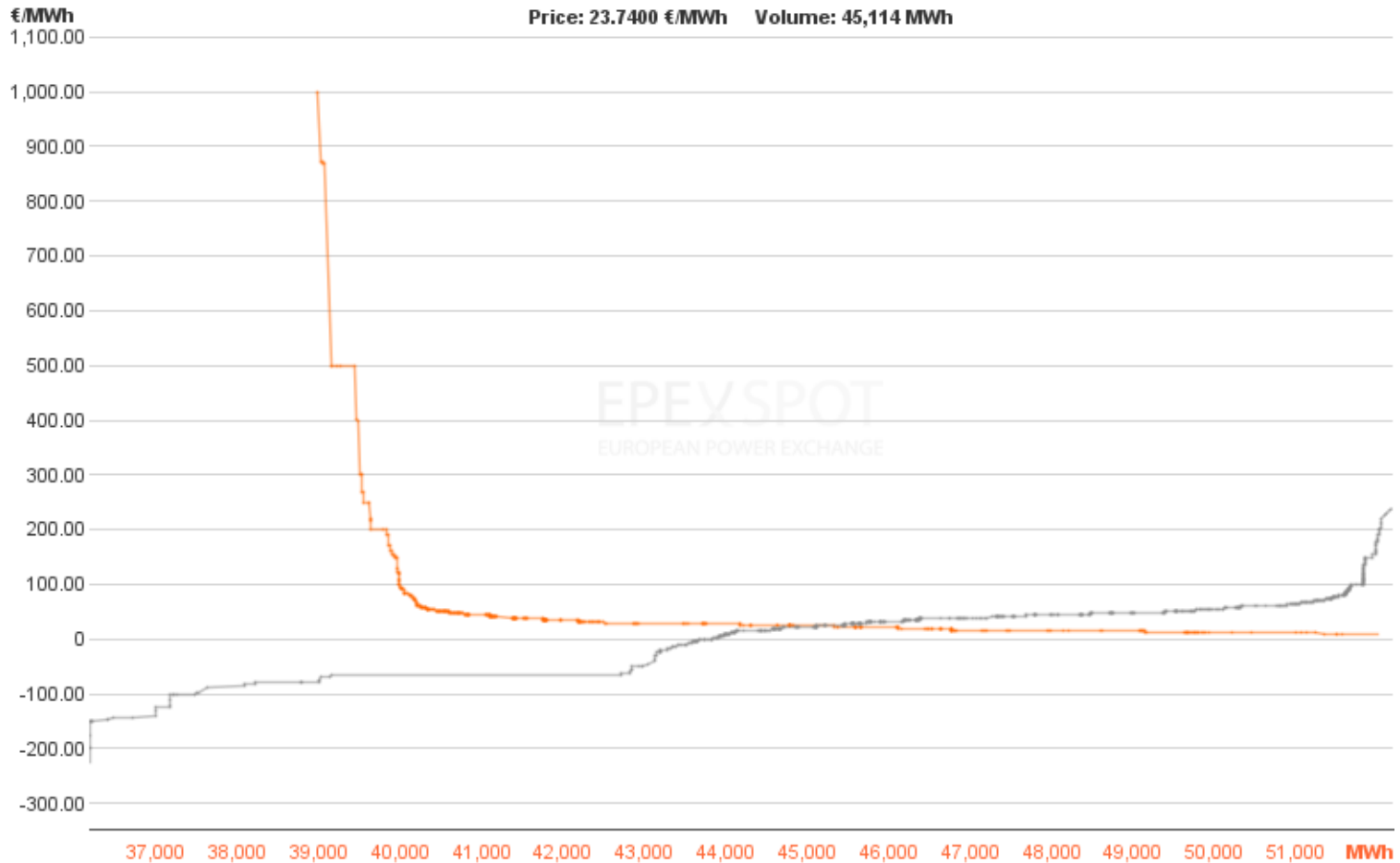
# Nordic electricity market without EU ETS



## Nord pool spot



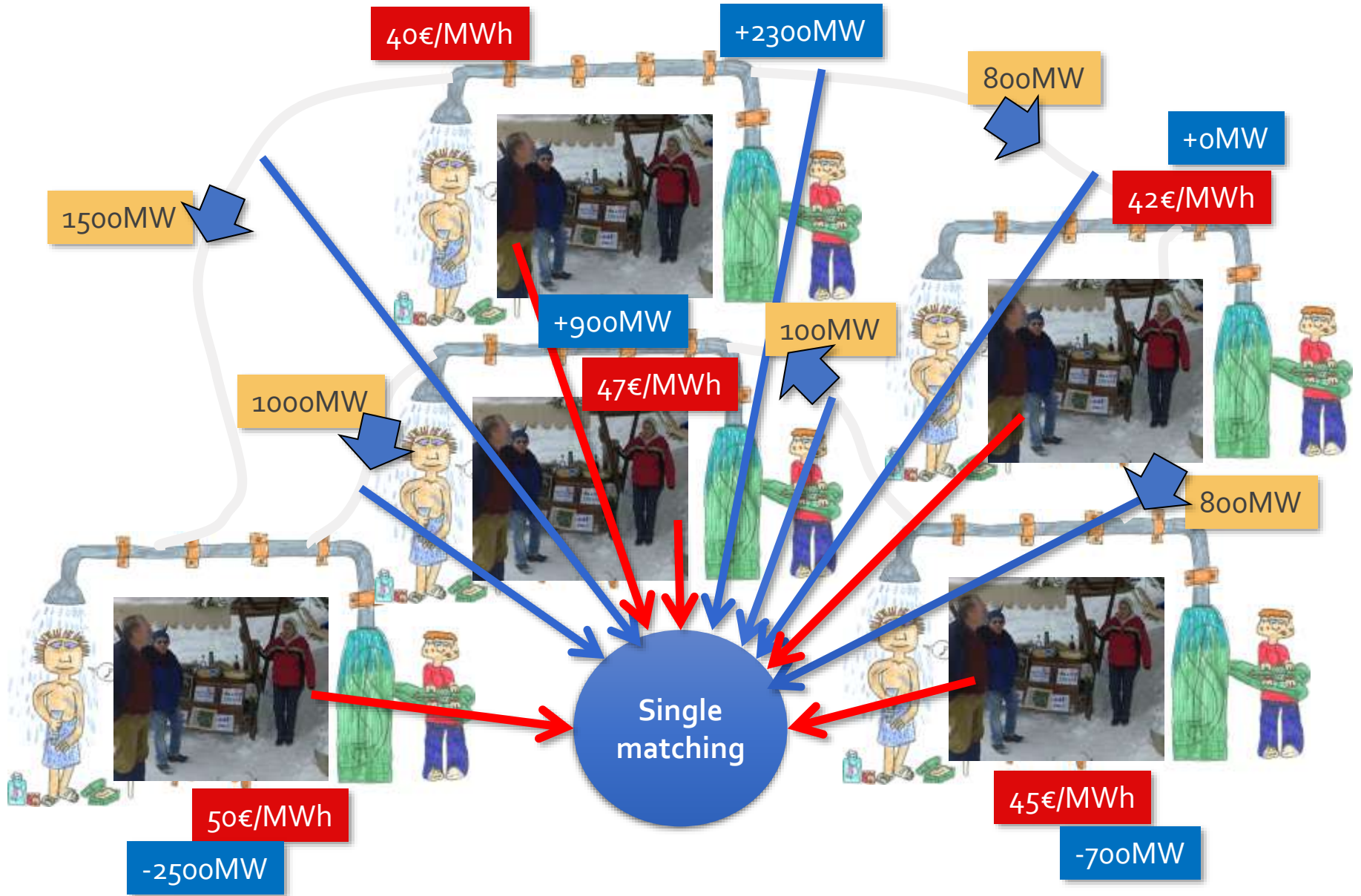
## EPEX Germany/Austria



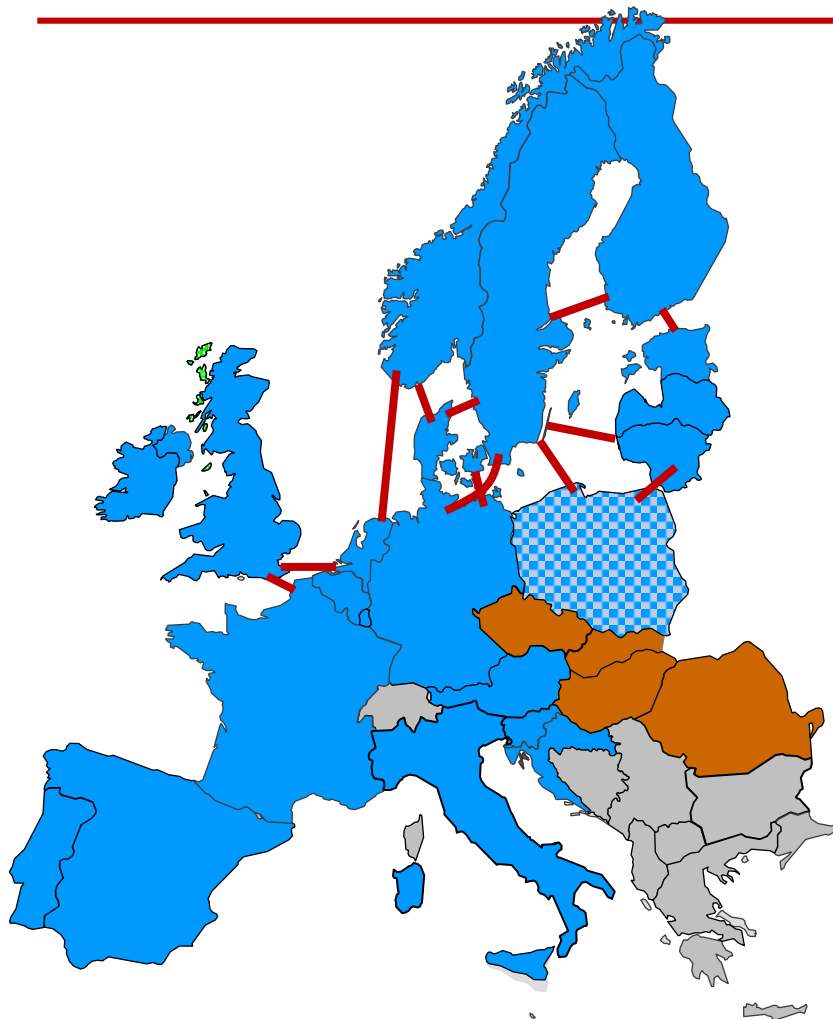
Price for 13.1.2015 hour 11-12


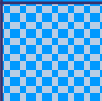



# Market coupling



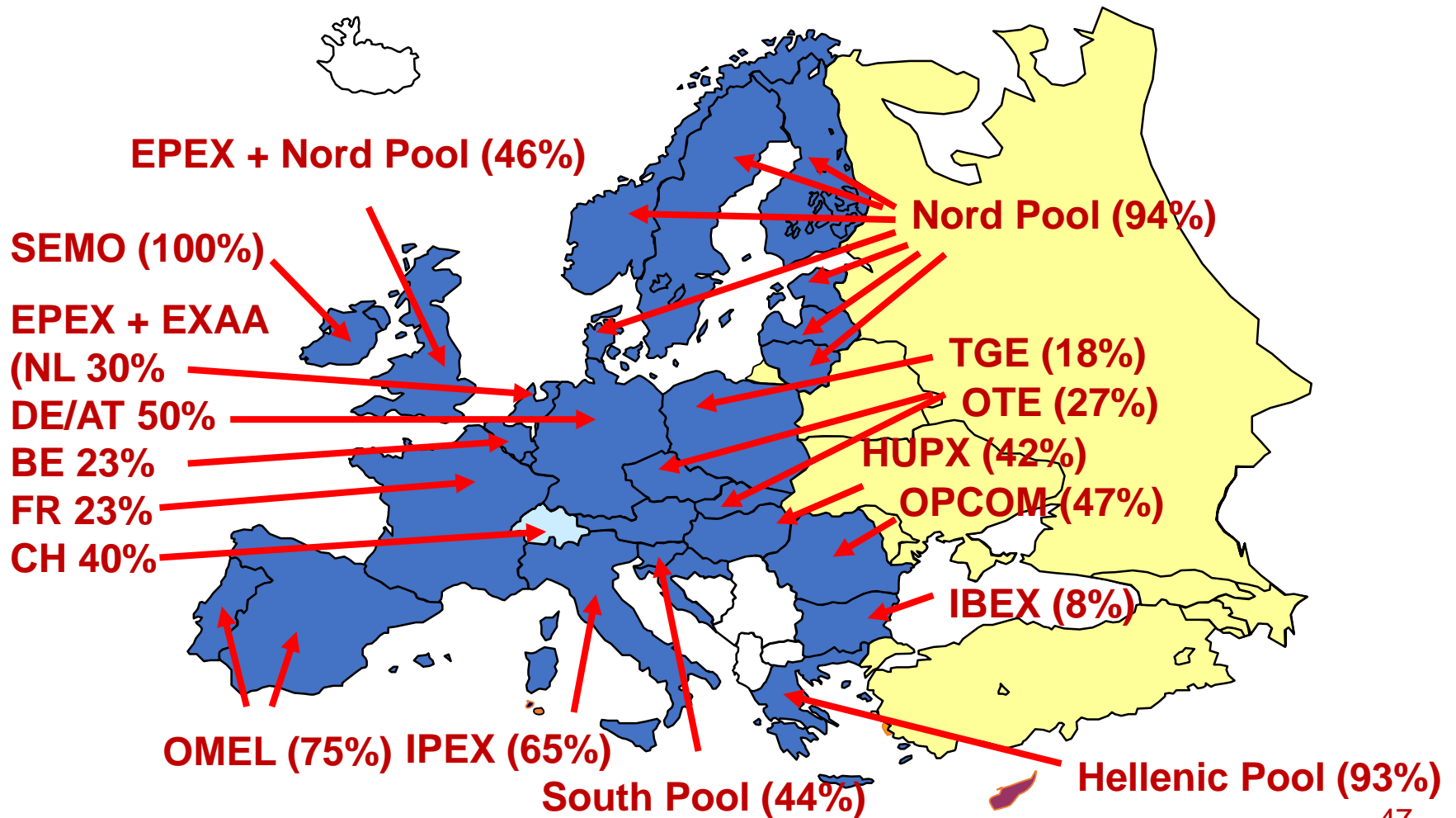
## Day-ahead market coupling status in December 2019



REGIONAL DAY AHEAD IMPLICIT AUCTIONS		
	<b>North West Europe (NWE)</b>	Price coupling
	<b>Poland</b>	Poland coupled within NWE through SwePol- and LitPol -link
	<b>Czech – Slovak – Hungary-Romania</b>	Price coupling

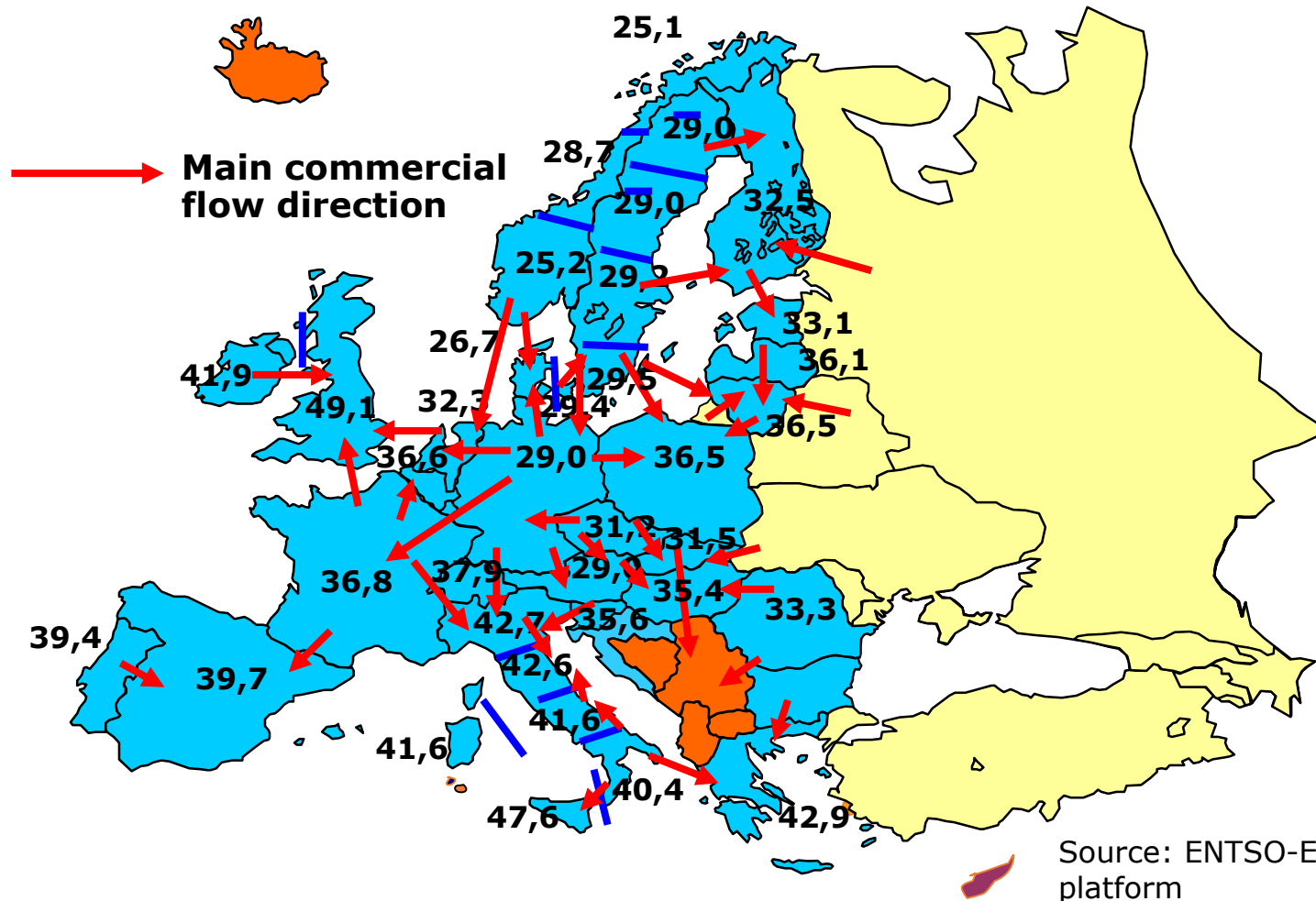
Source: APX, updated by Matti Supponen

## Share of day-ahead spot trading of consumption in 2016

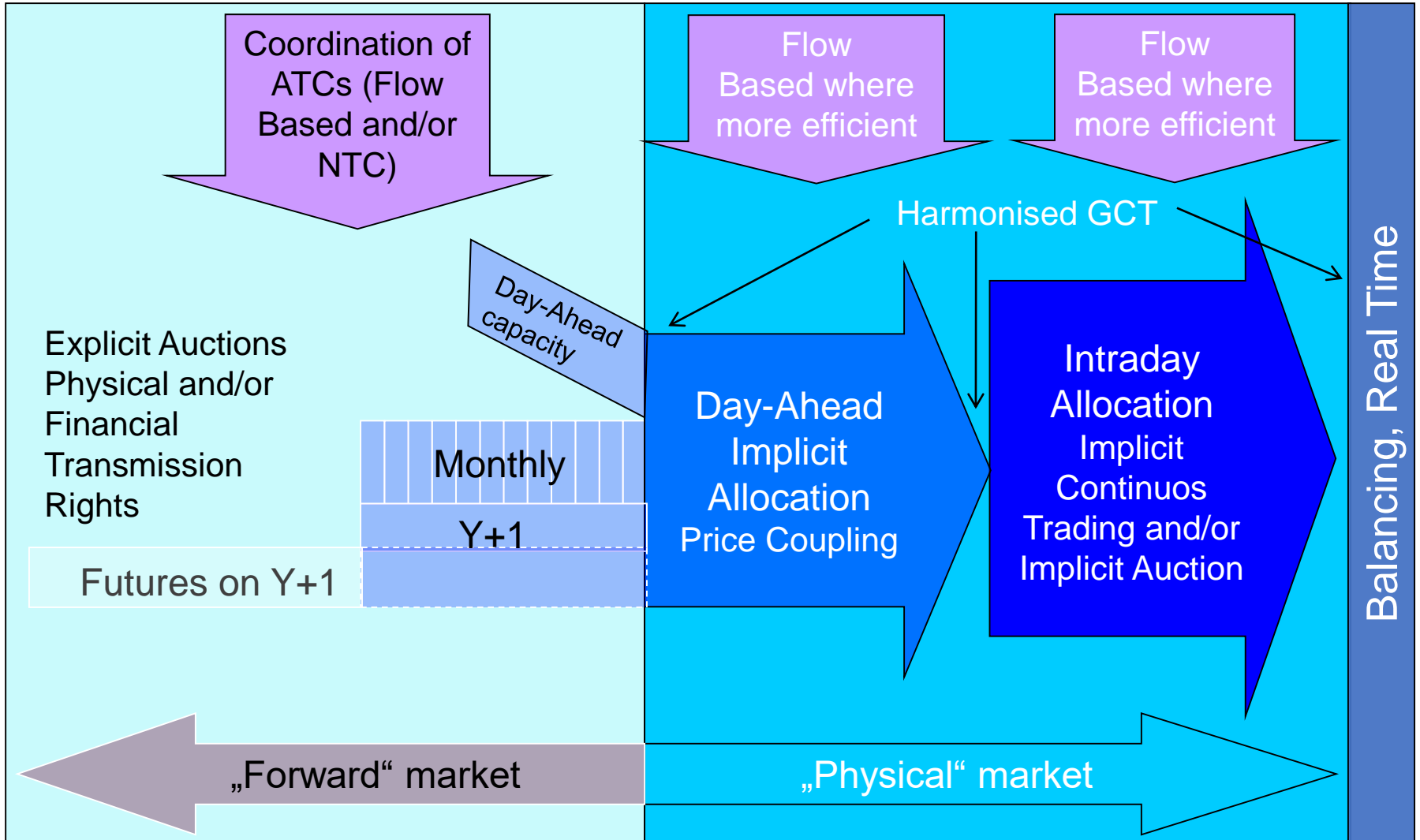




# Average spot prices (€) and electricity cross-border trade in Europe (2016)



# Target Model



**Delivery Areas to be launched at first go-live**

50Hertz Transmission
Amprion
Austria
Denmark West
Denmark East
Estonia
Elia System Operator
Finland
Lithuania
Latvia
Netherlands
Norway 1-5
Portugal Delivery Area
France
Sweden 1-4
Spain Delivery Area
TransnetBW
TenneT TSO

**Virtual areas:**

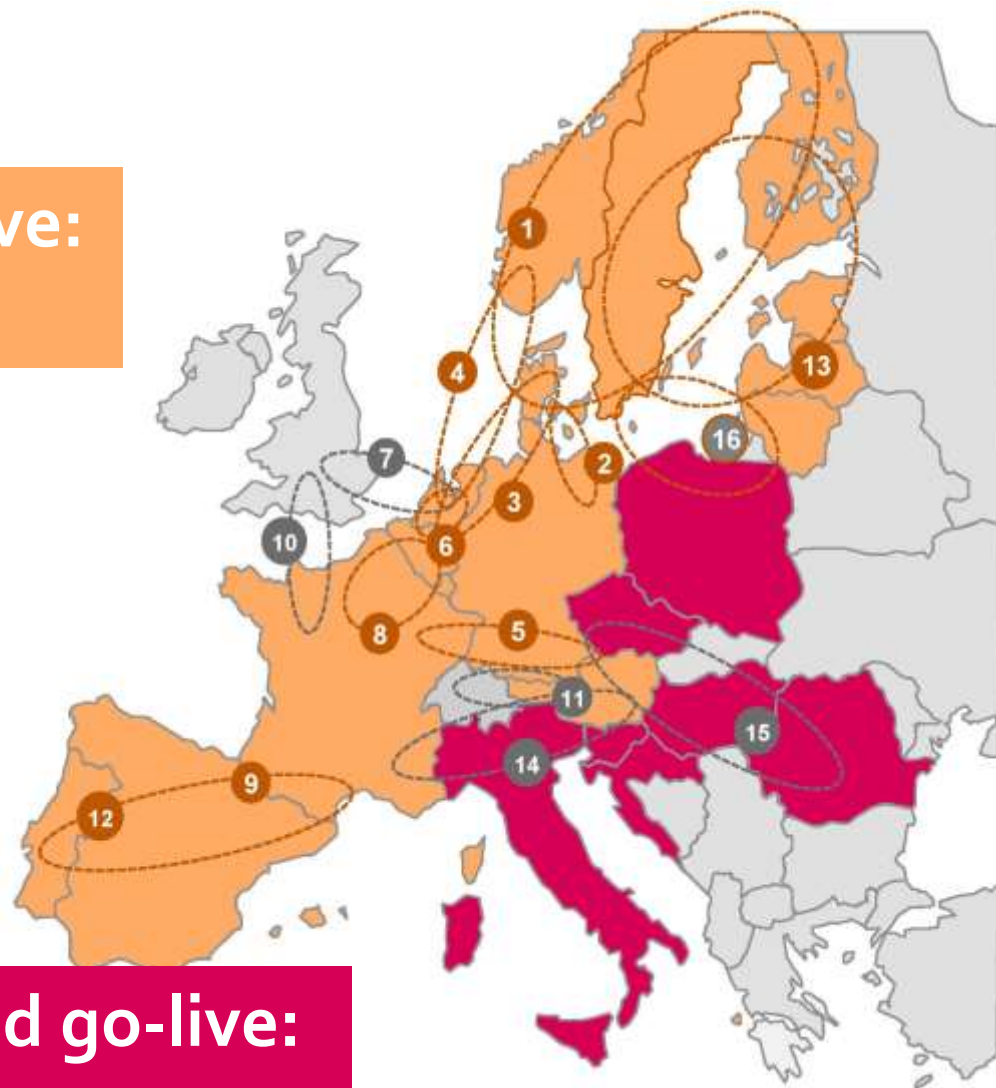
Finland-Russia
Morocco Virtual Delivery Area

**First go-live:  
June 2018**

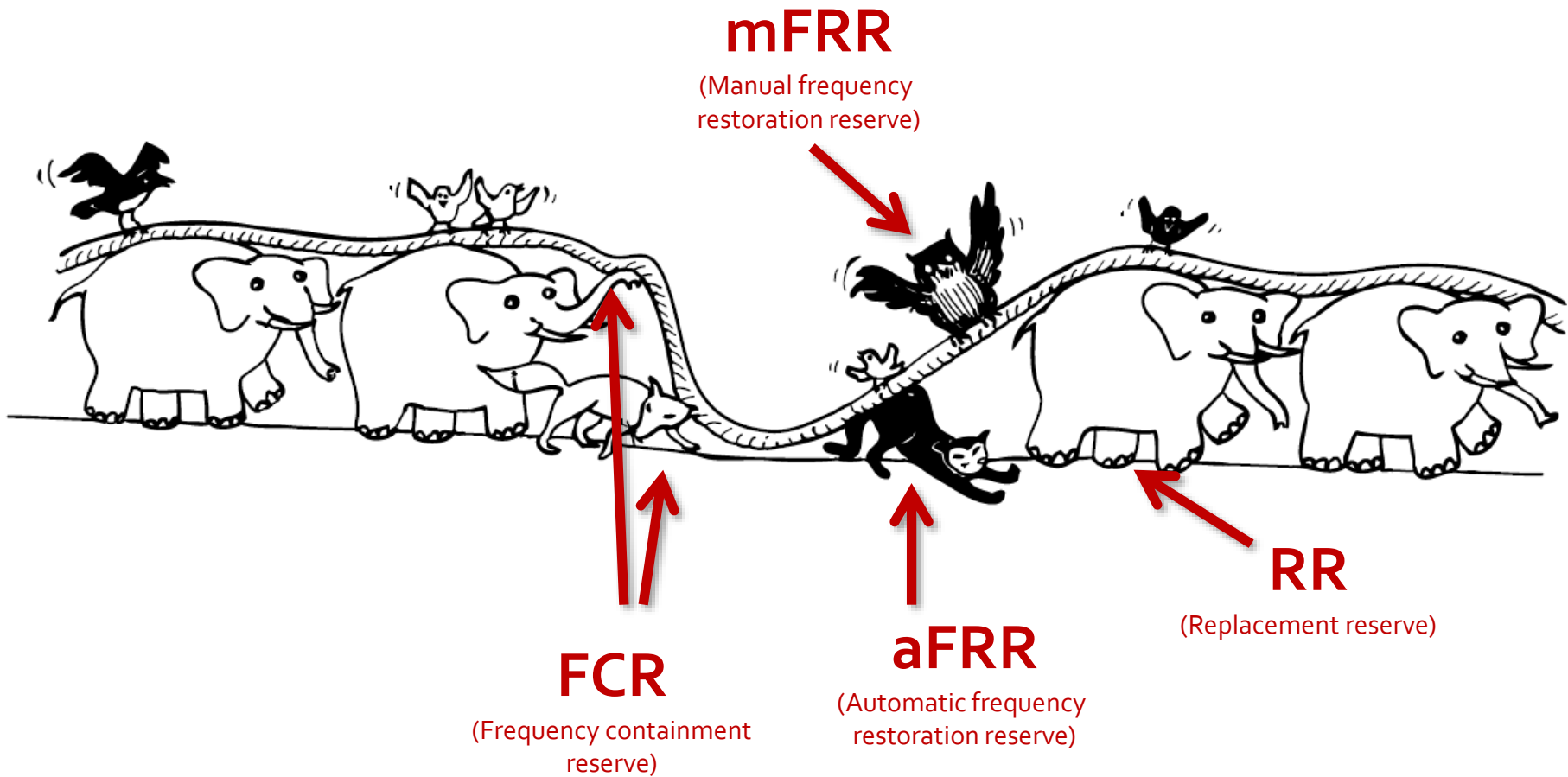
**Delivery Areas to be launched at second go-live**

Croatia
Czech Republic
Hungary
Italy (NORD, CNOR, CSUD, SUD, SARD, SICI, ROSN, FOGN, BRNN, PRGP, COAC, CODC, MALTA)
Poland (PL)
Polish Virtual Area (PLA)
Romania
Slovenia

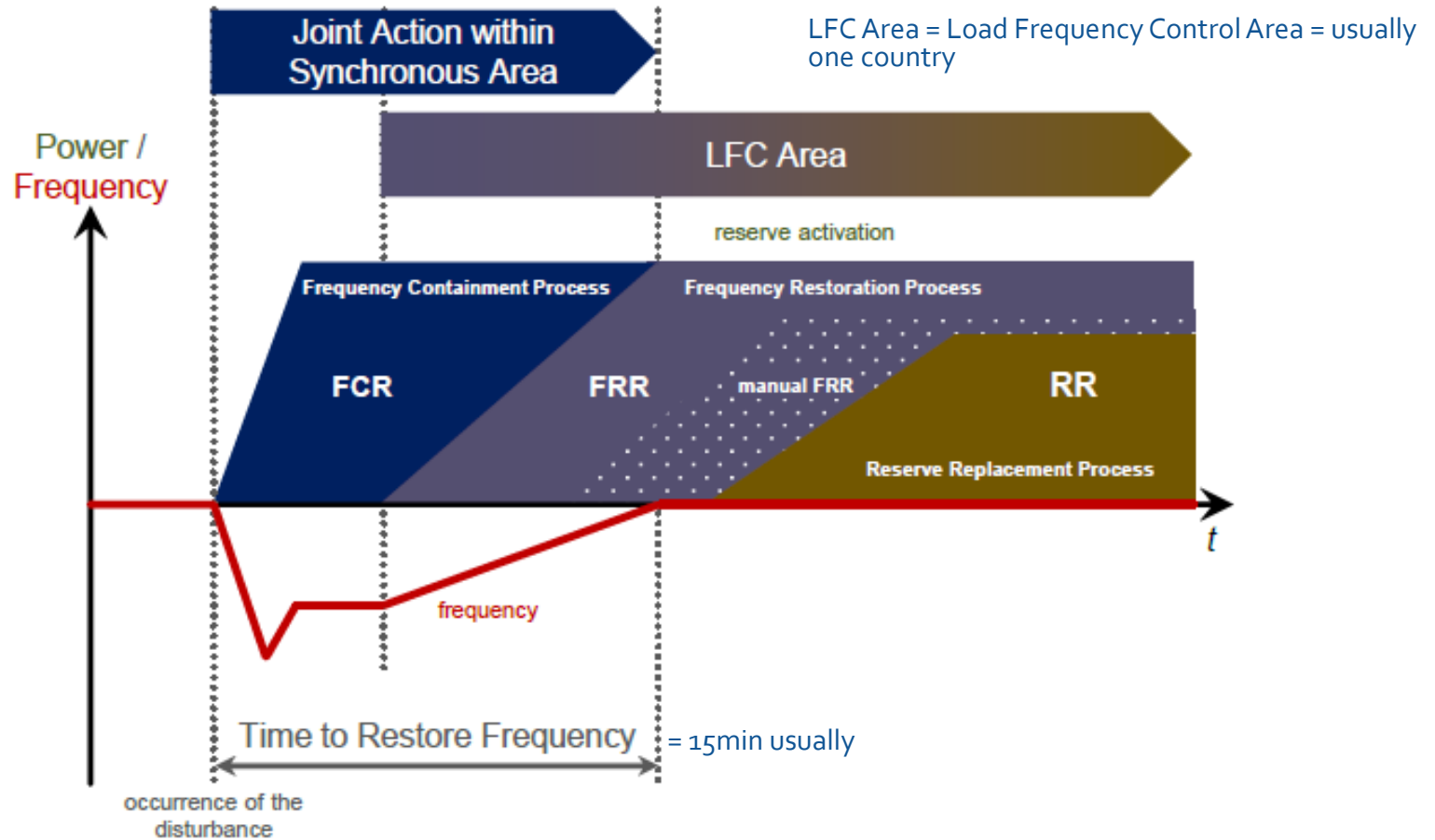
**Second go-live:  
Autumn 2019**



# Balancing



# Balancing

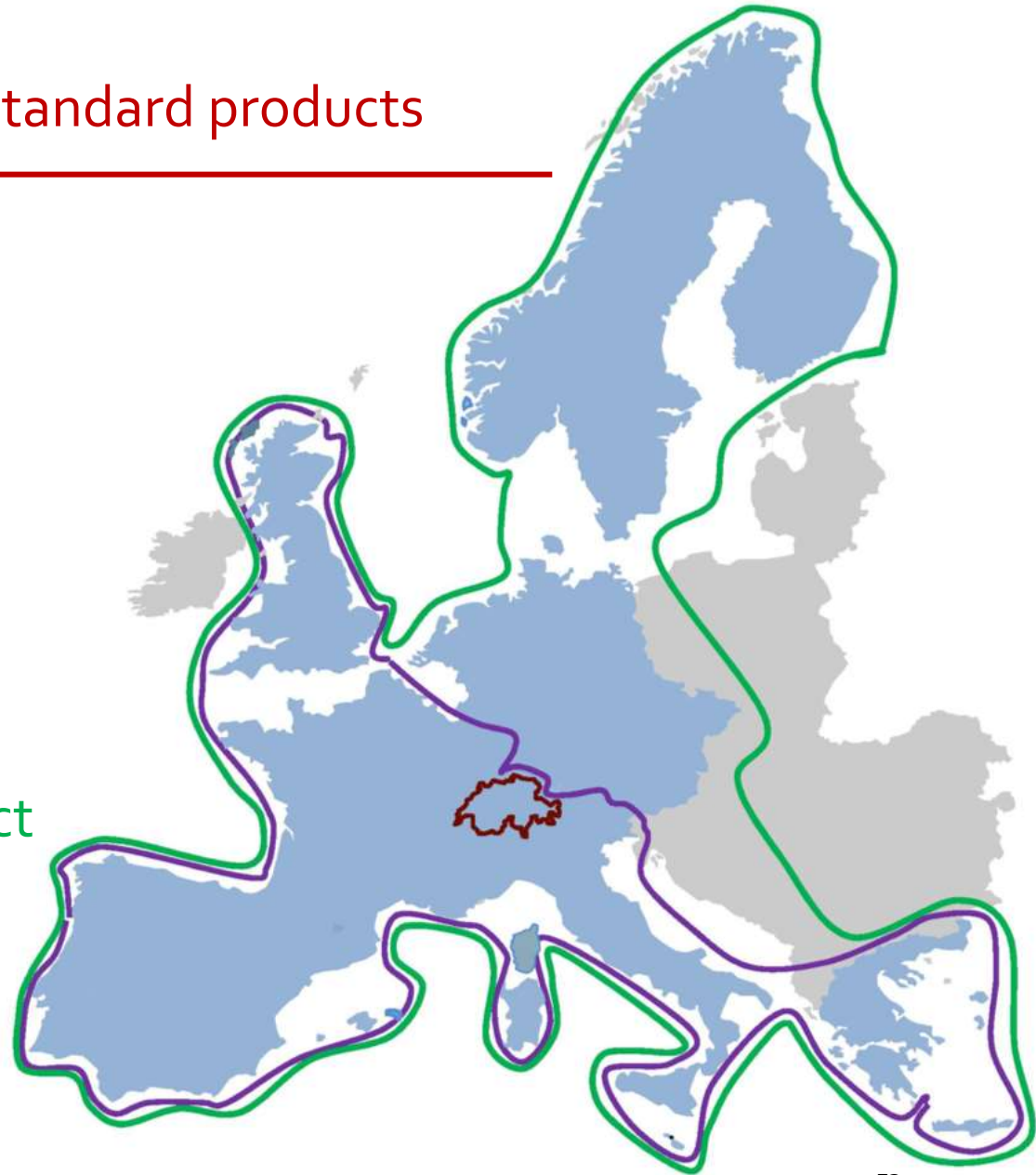


Source: ENTSO-E

## European platforms for standard products

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- RR market – **2019**  
Project Terre
- mFRR market – **2021**  
Project MARI
- aFRR market – **2022**  
ENTSO-E aFRR project



## European electricity rules

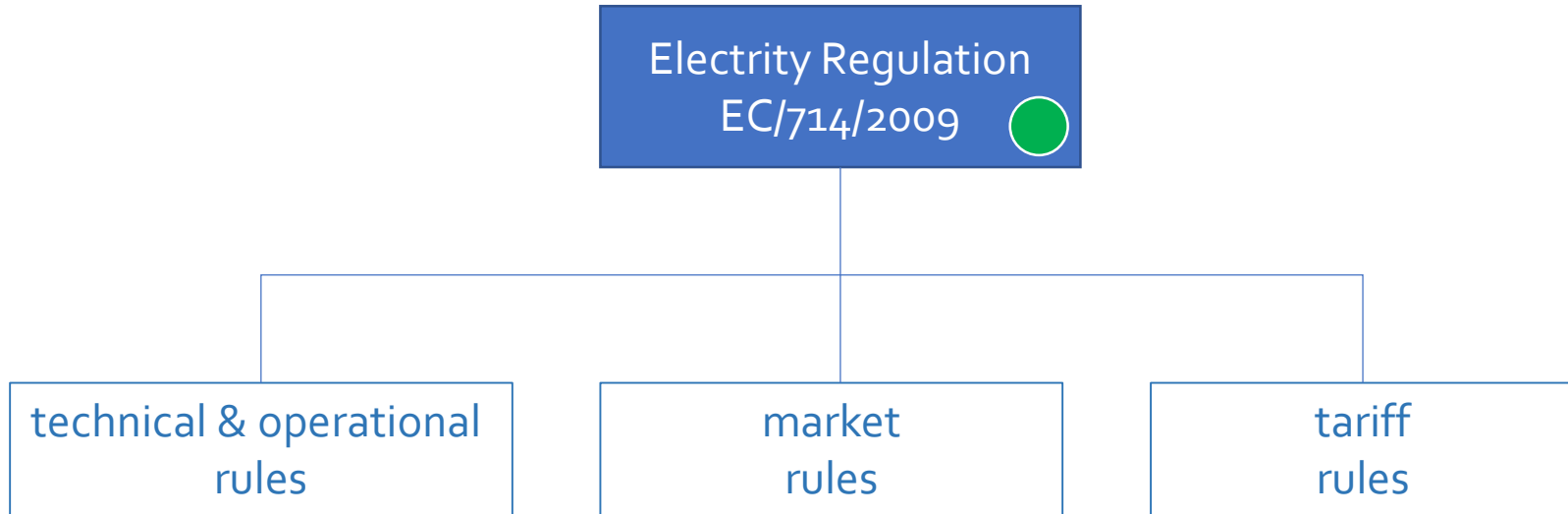
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-  = Finalised
-  = In preparation
-  = Scheduled

## European electricity rules

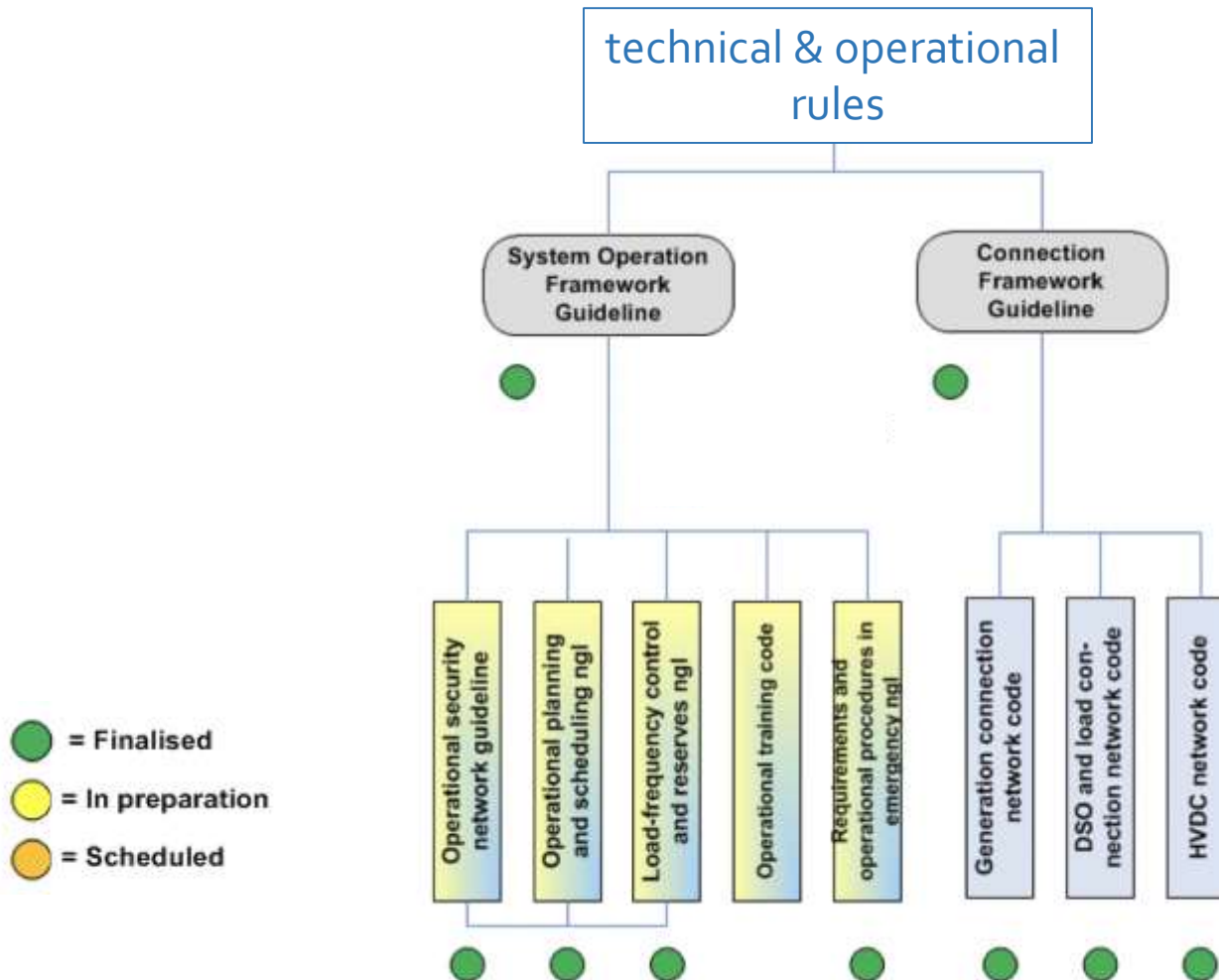
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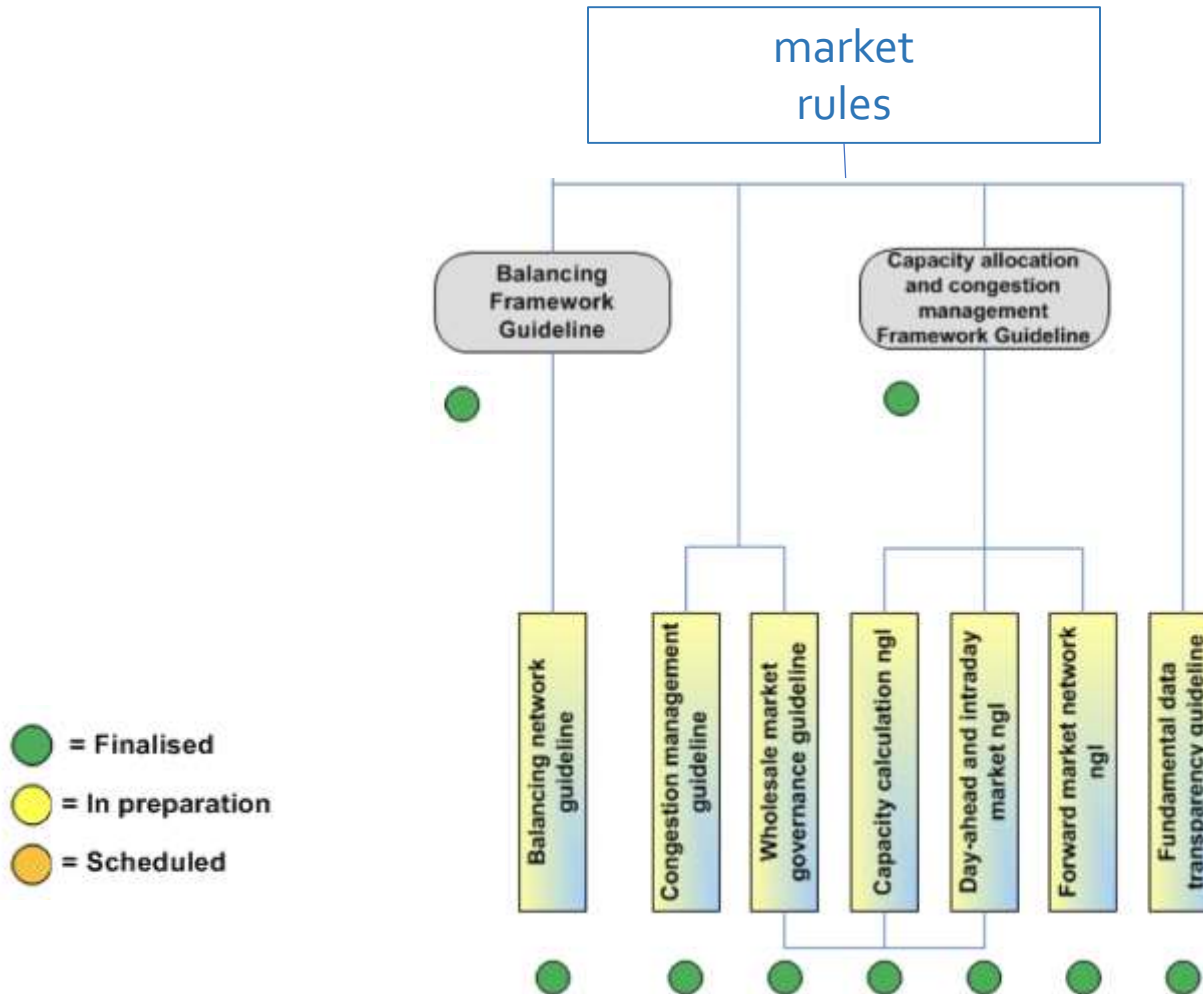
- = Finalised
- = In preparation
- = Scheduled



# European electricity rules

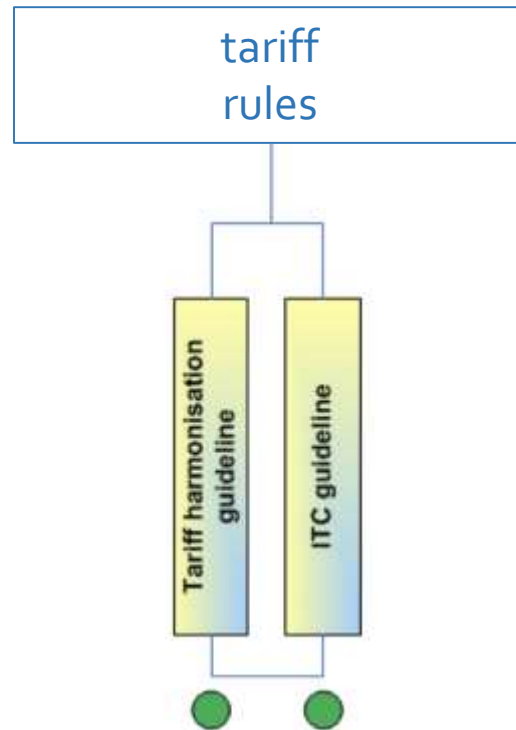





# European electricity rules



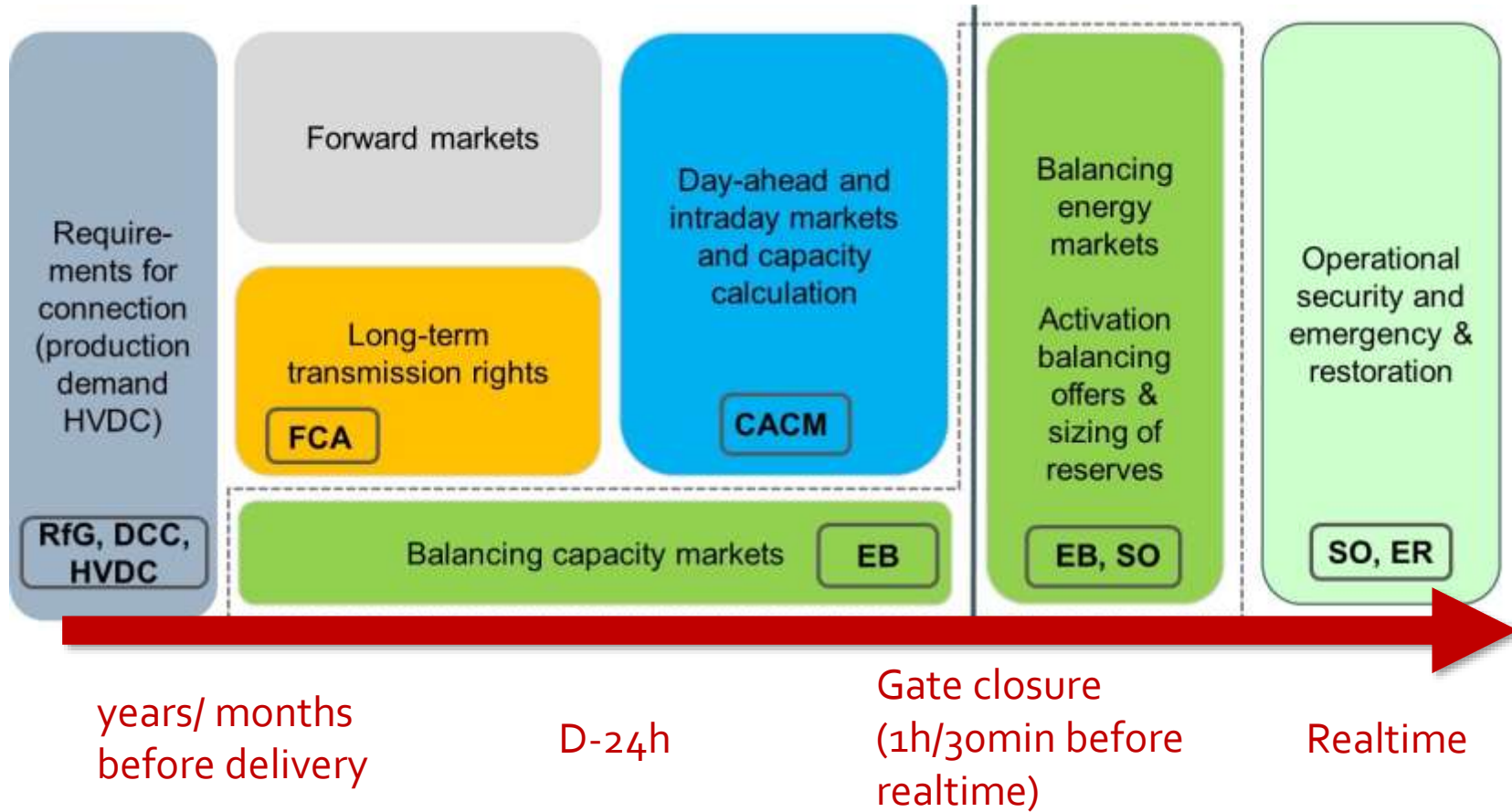
# European electricity rules

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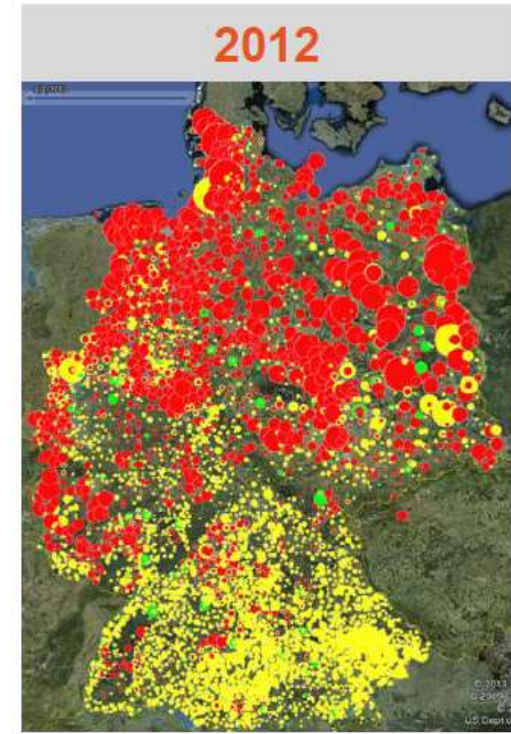
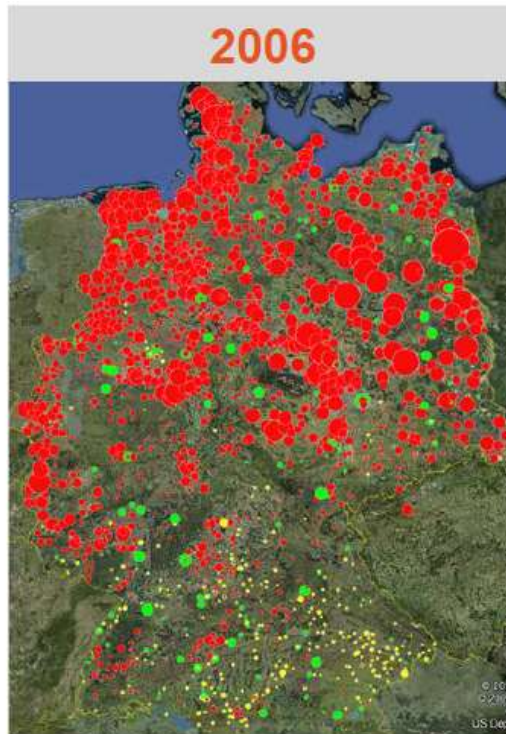
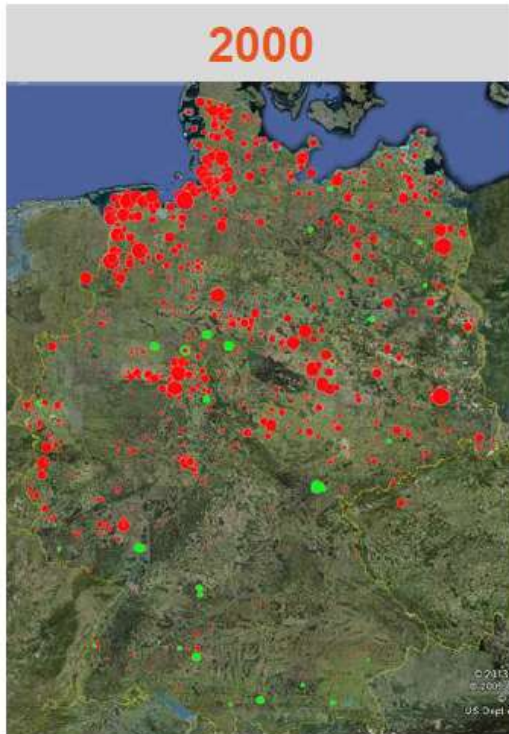
-  = Finalised
-  = In preparation
-  = Scheduled

## Network codes





## Extension of Renewables in Germany



- Wind
- Photovoltaik
- Biomass

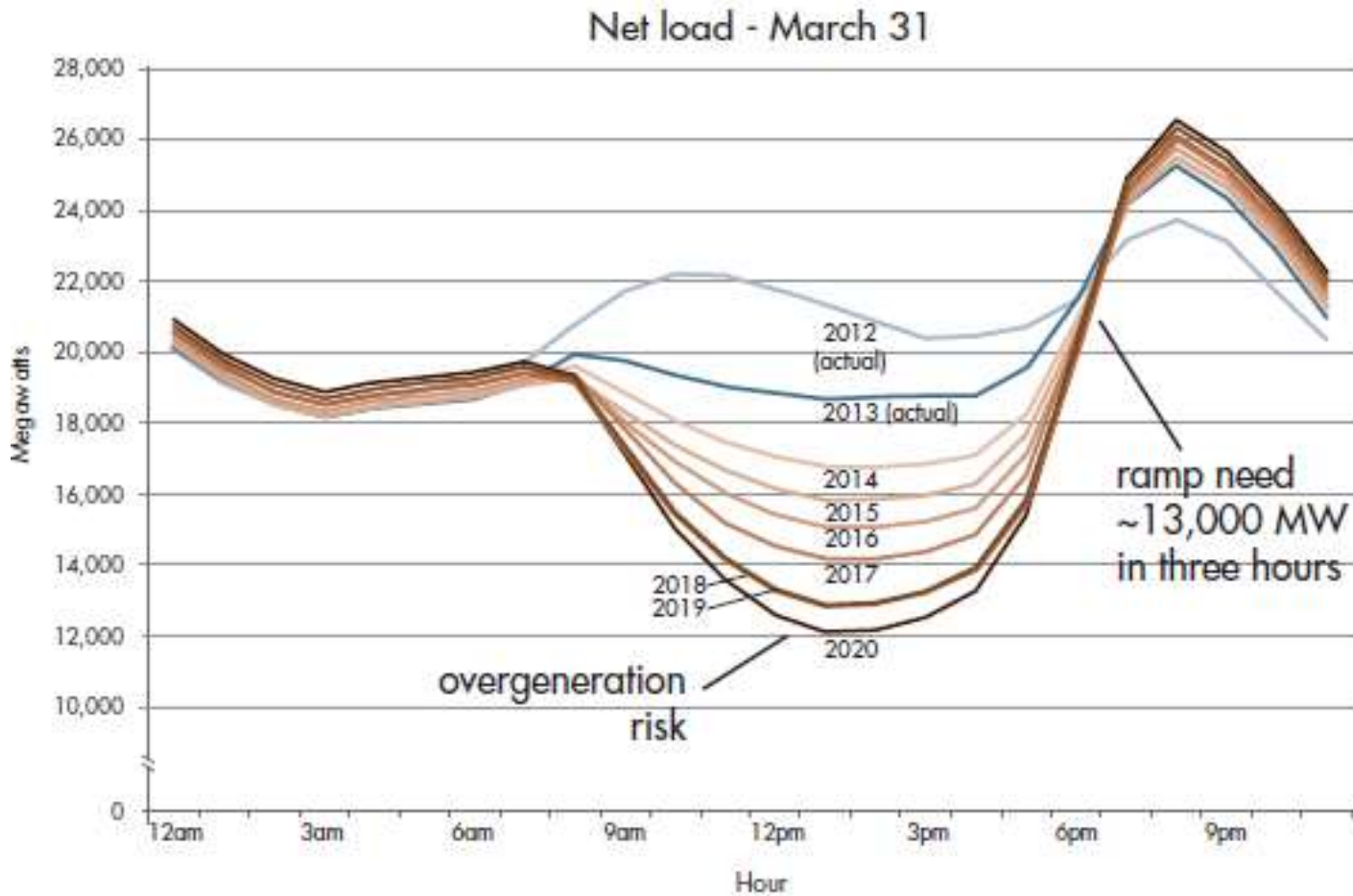
Source: 50HertzT, TenneT,  
Amprion, TransnetBW, Google  
Earth

Source: Boris Schucht, 50 Hertz

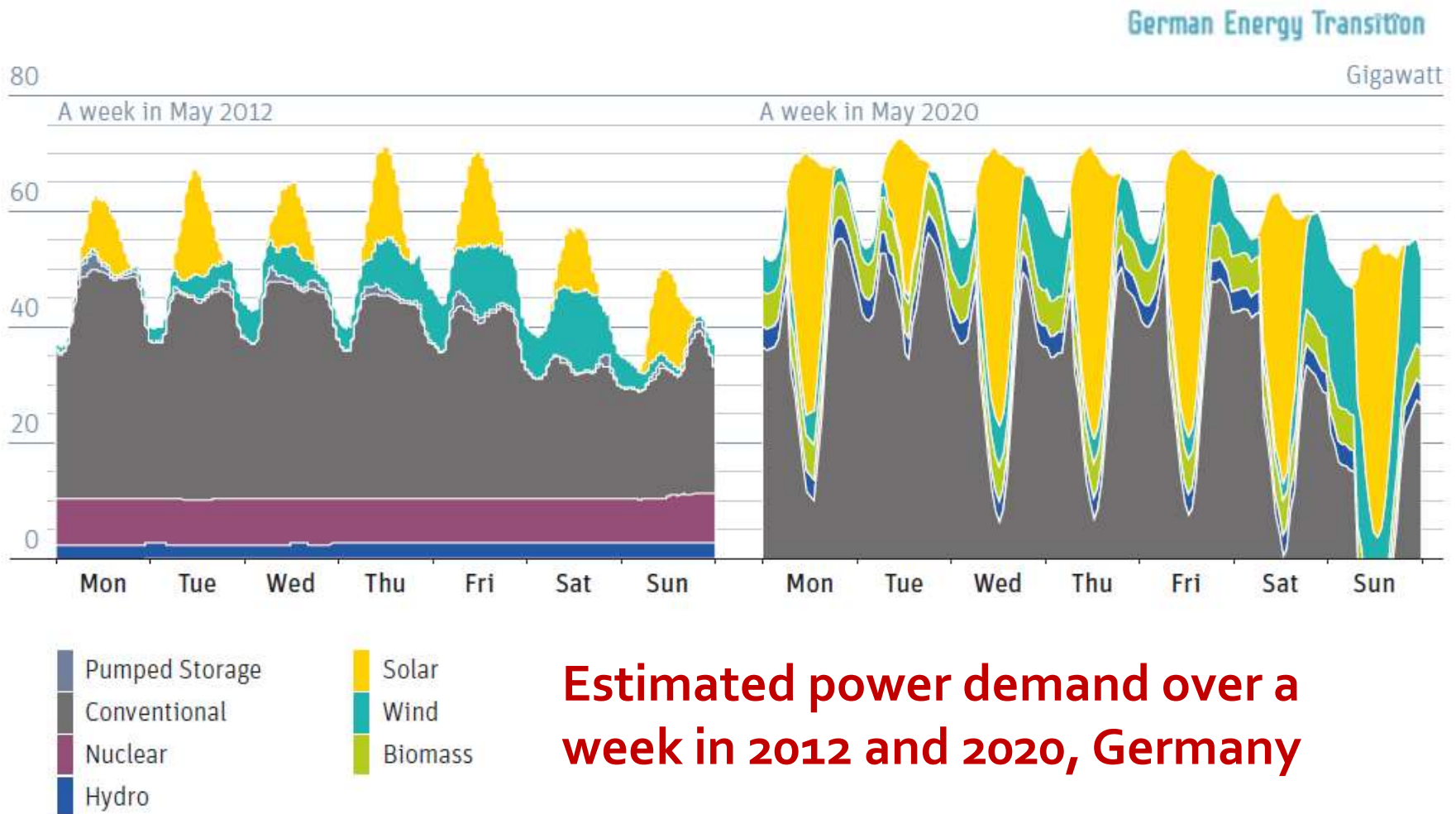
### August 2013:

- Number of units: ~ 1,3 Mio.
- Power > 72 GW
- Energy (2012) ~ 135 TWh

# Duck curve

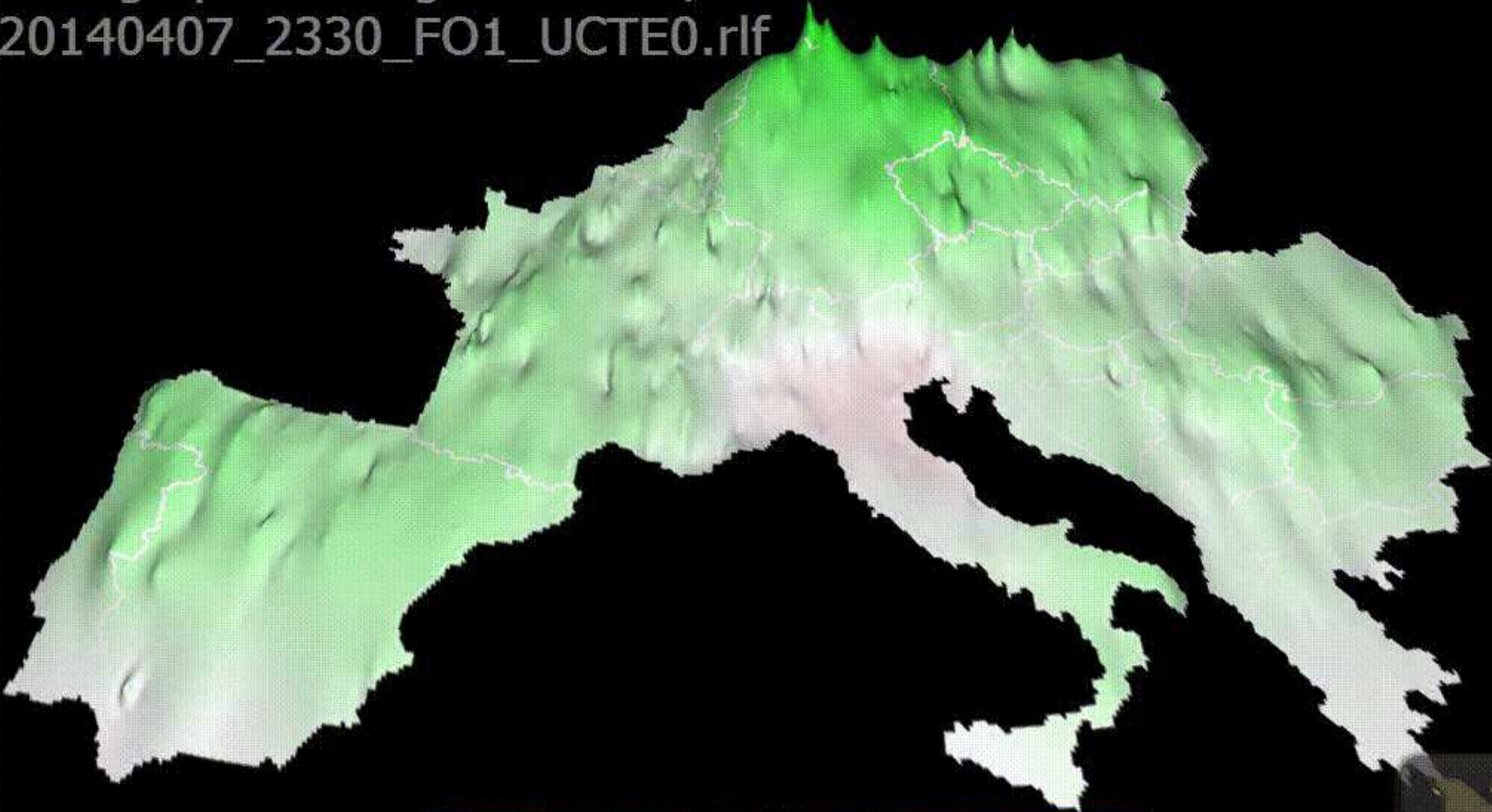


## Renewables need flexible backup, not baseload



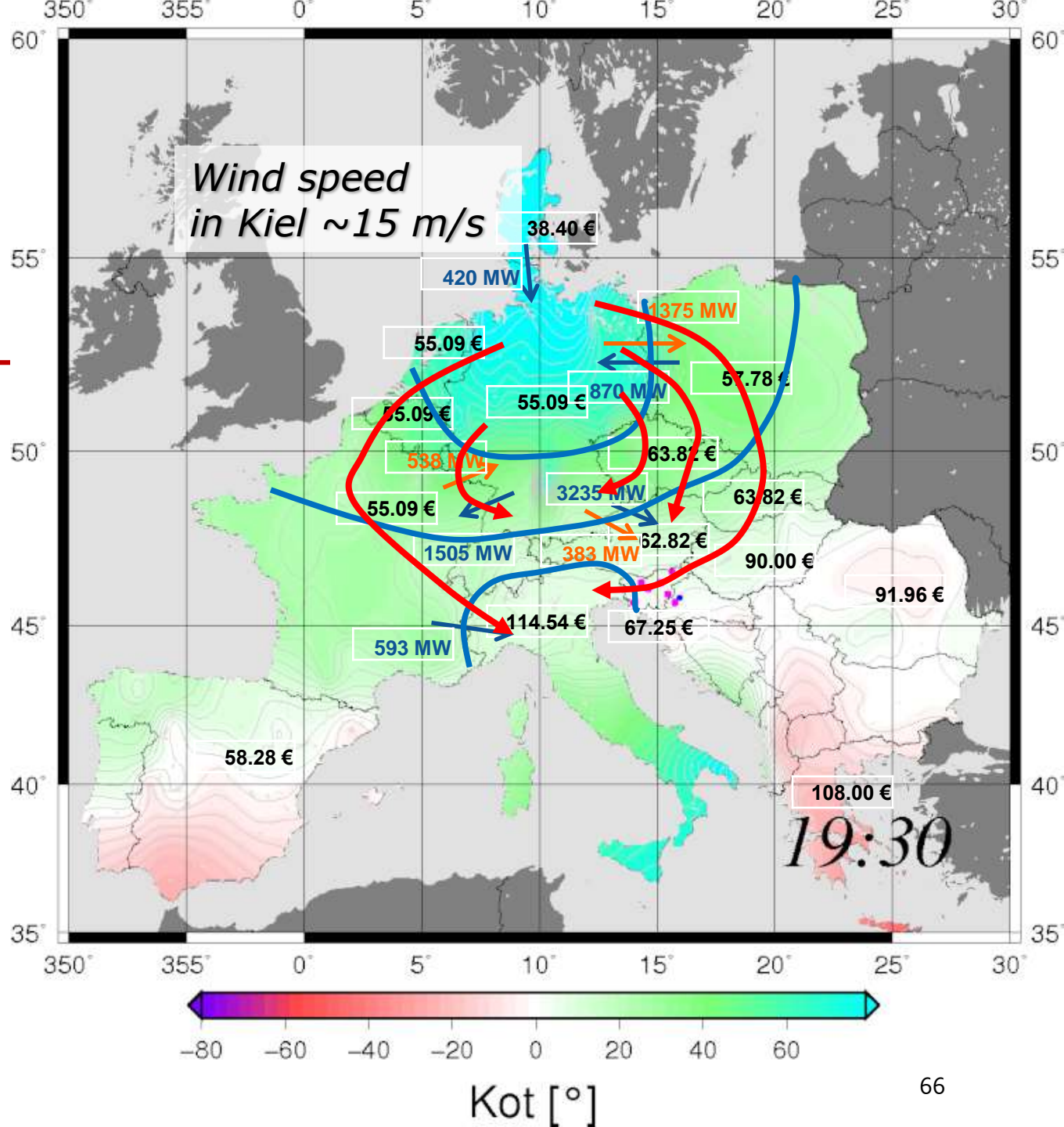


Voltage phase angles 400 kV, UCTE  
20140407\_2330\_FO1\_UCTE0.rlf

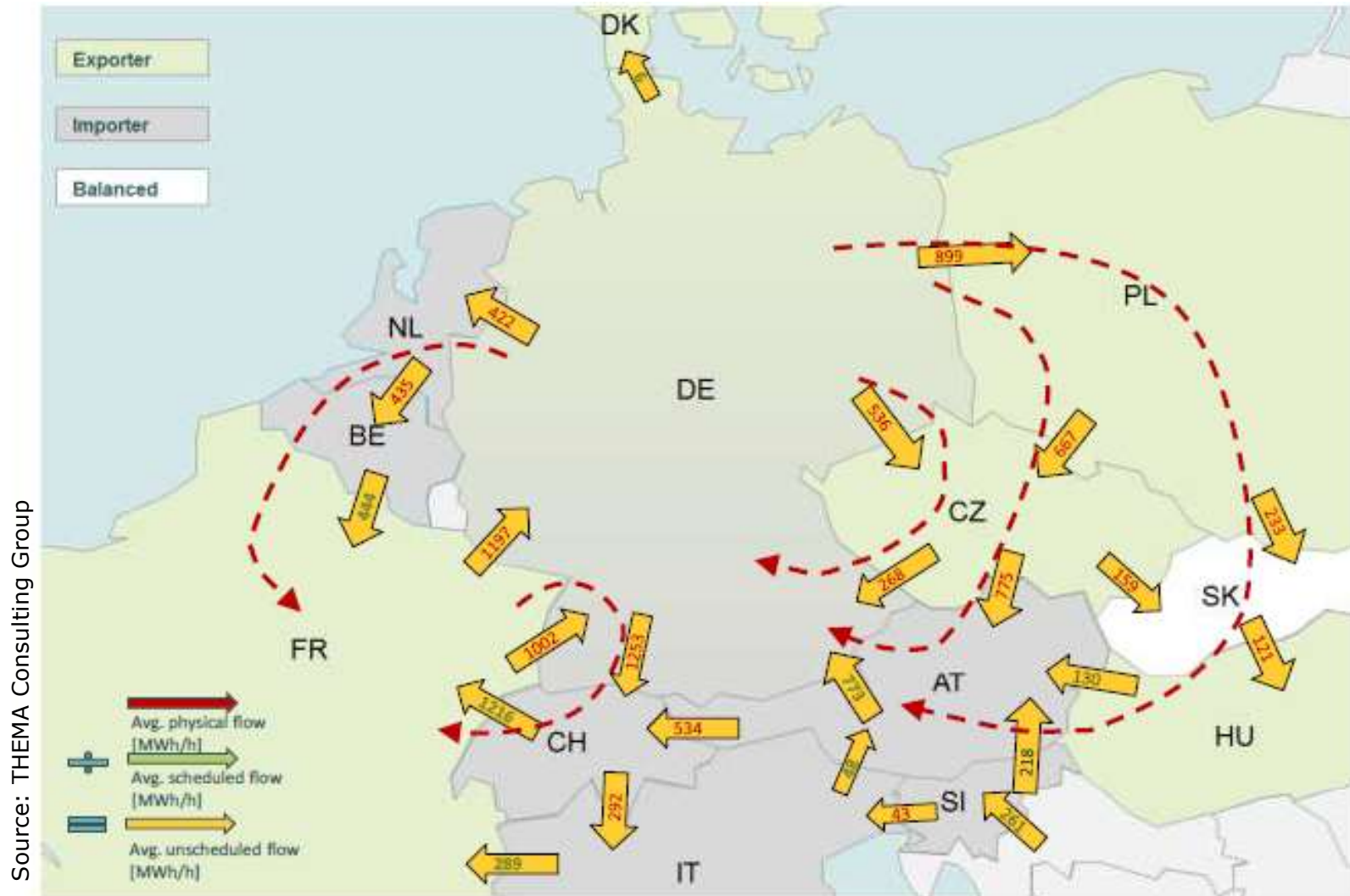


# Prices & flows

8.12.2011

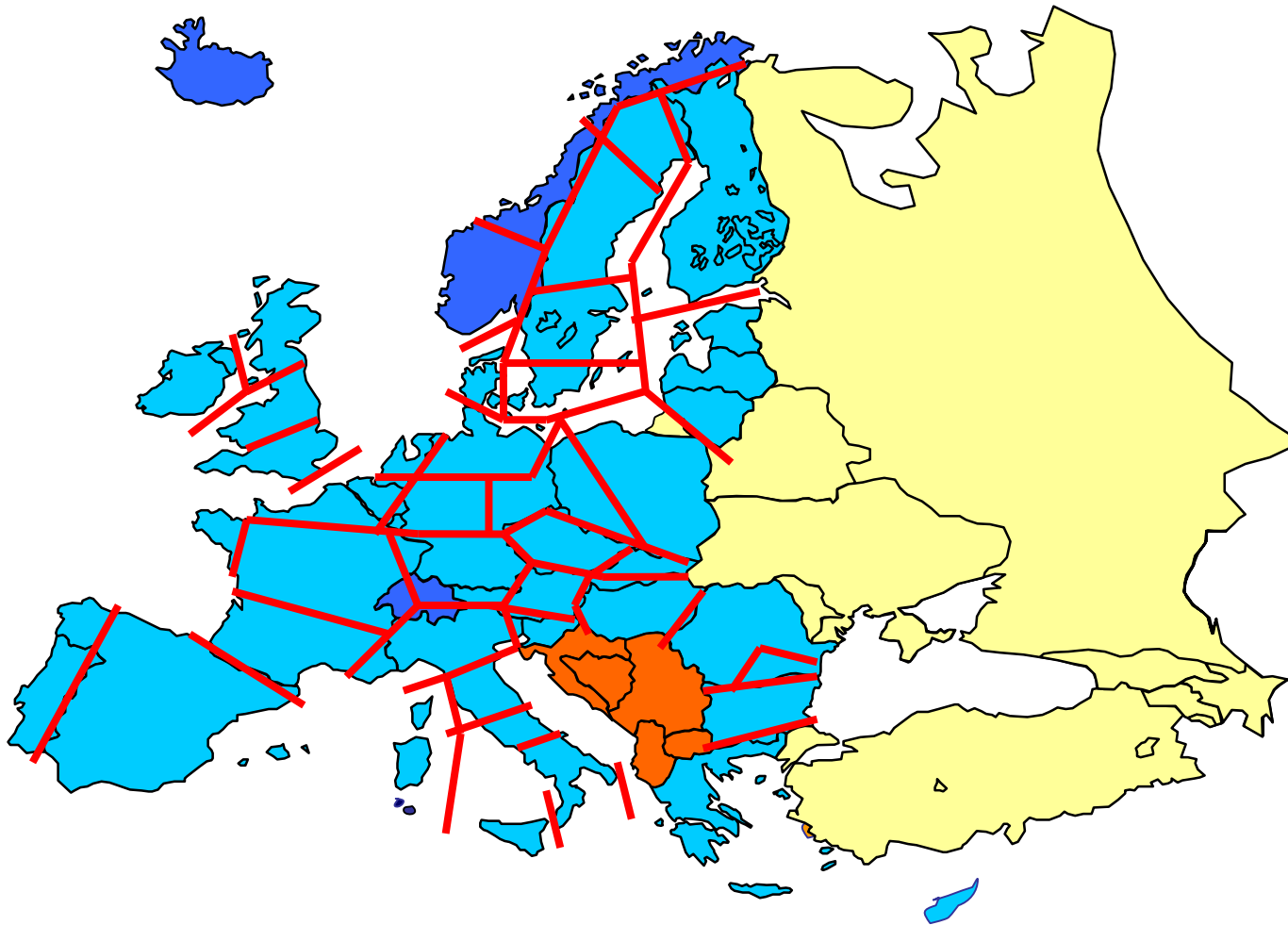


## Average unscheduled flows (2011, 2012, in MWh/h)



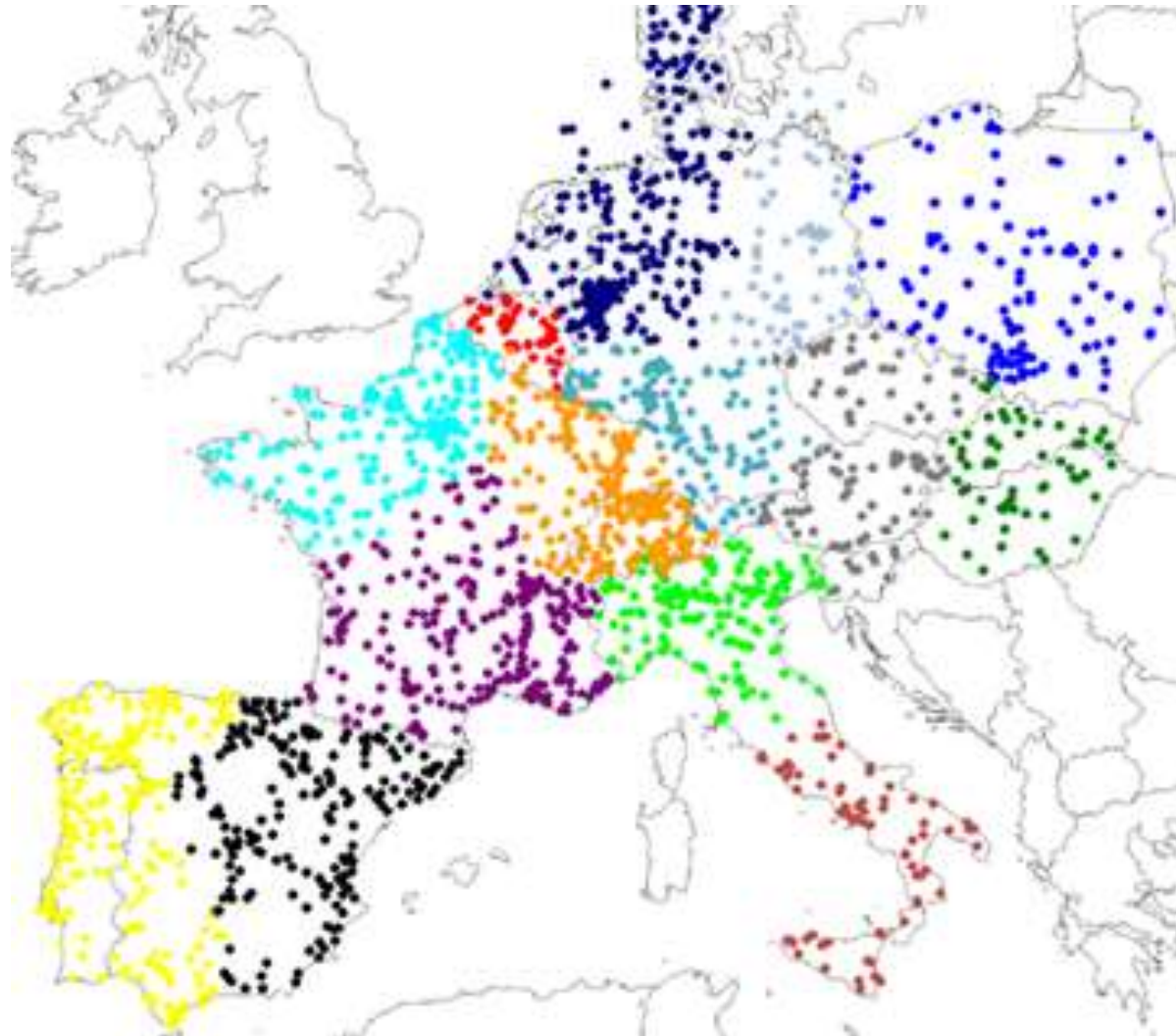
## Matti's proposal for electricity spot-market price zones in Europe

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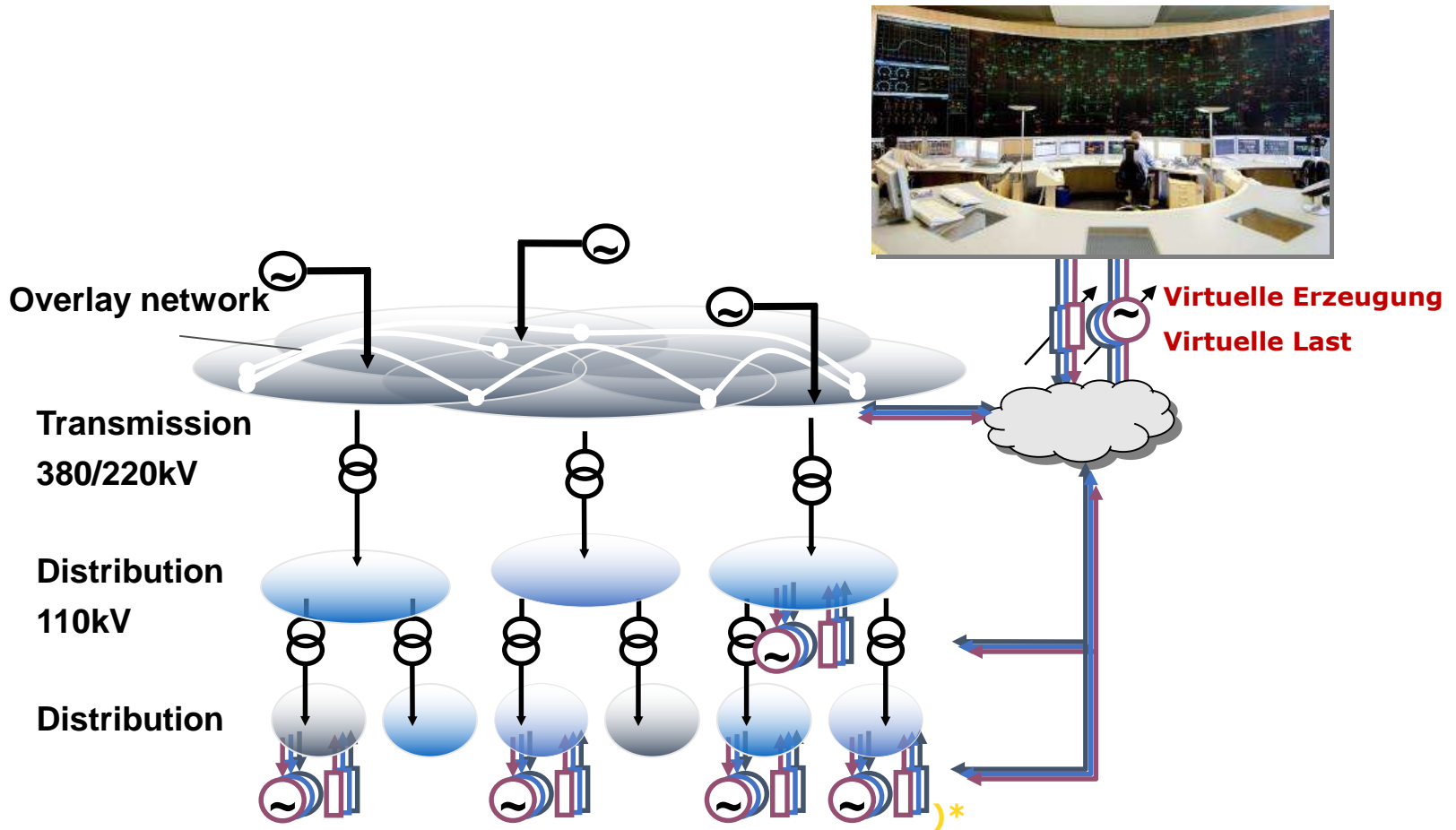


## Or is nodal pricing better?

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# Overlay network?



# Strom- autobahnen

— Gleichstrom-Neubauten    — bereits im Bau, genehmigt oder im Genehmigungsverfahren  
— Wechselstrom-Neubauten



## Link between wholesale and retail

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# Smart homes ... the future is now!

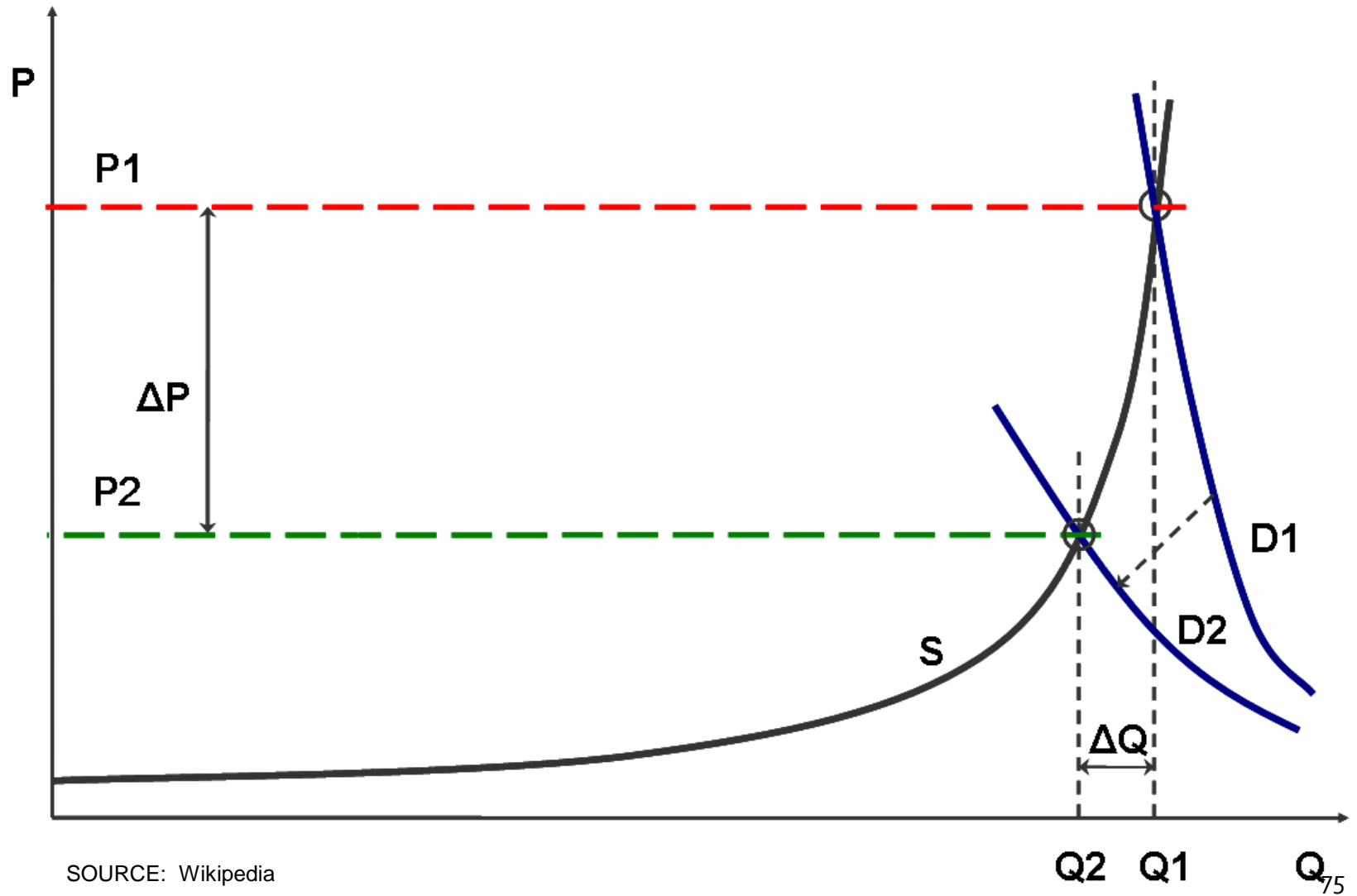


## Smart meters and grids

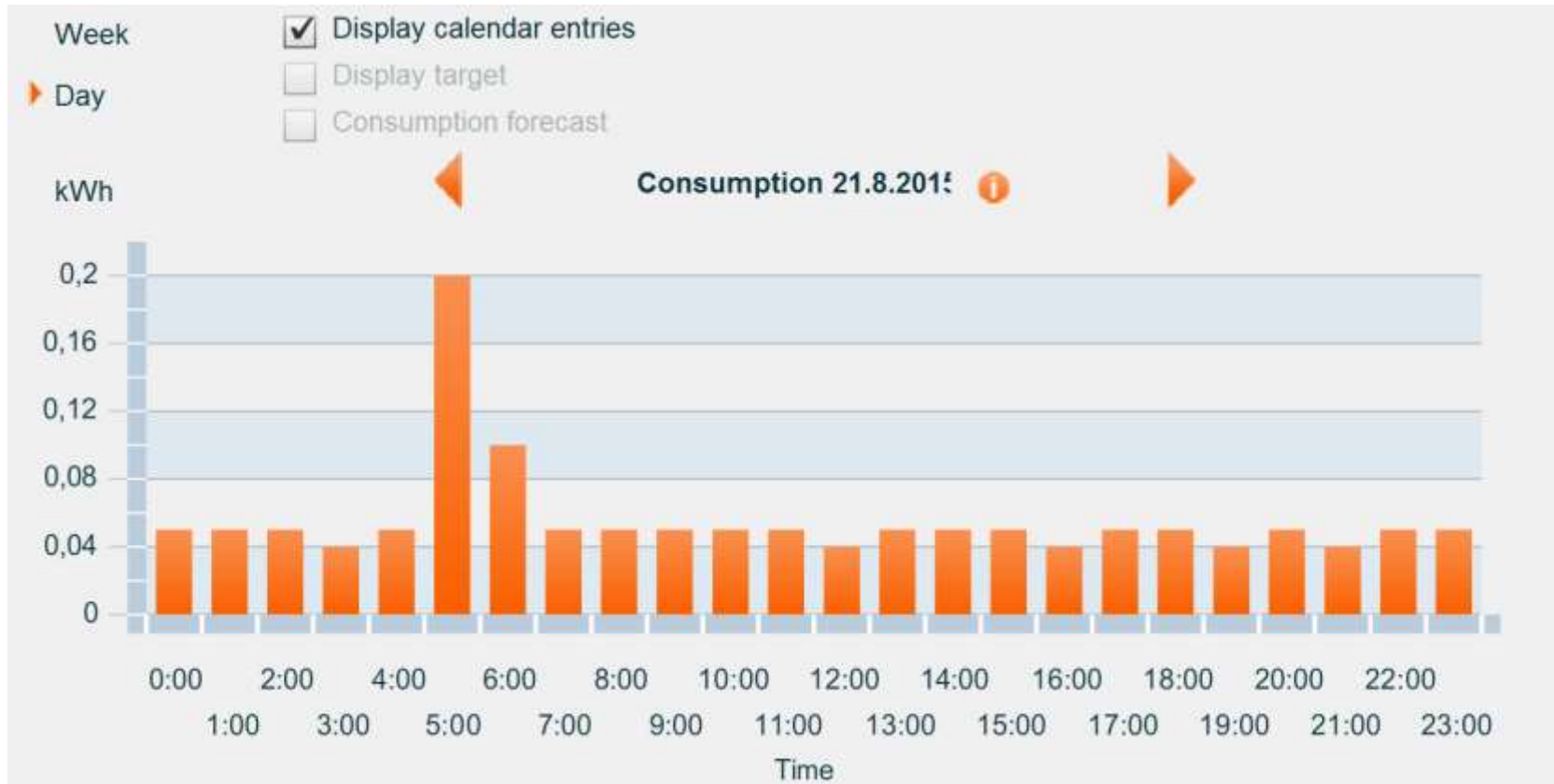
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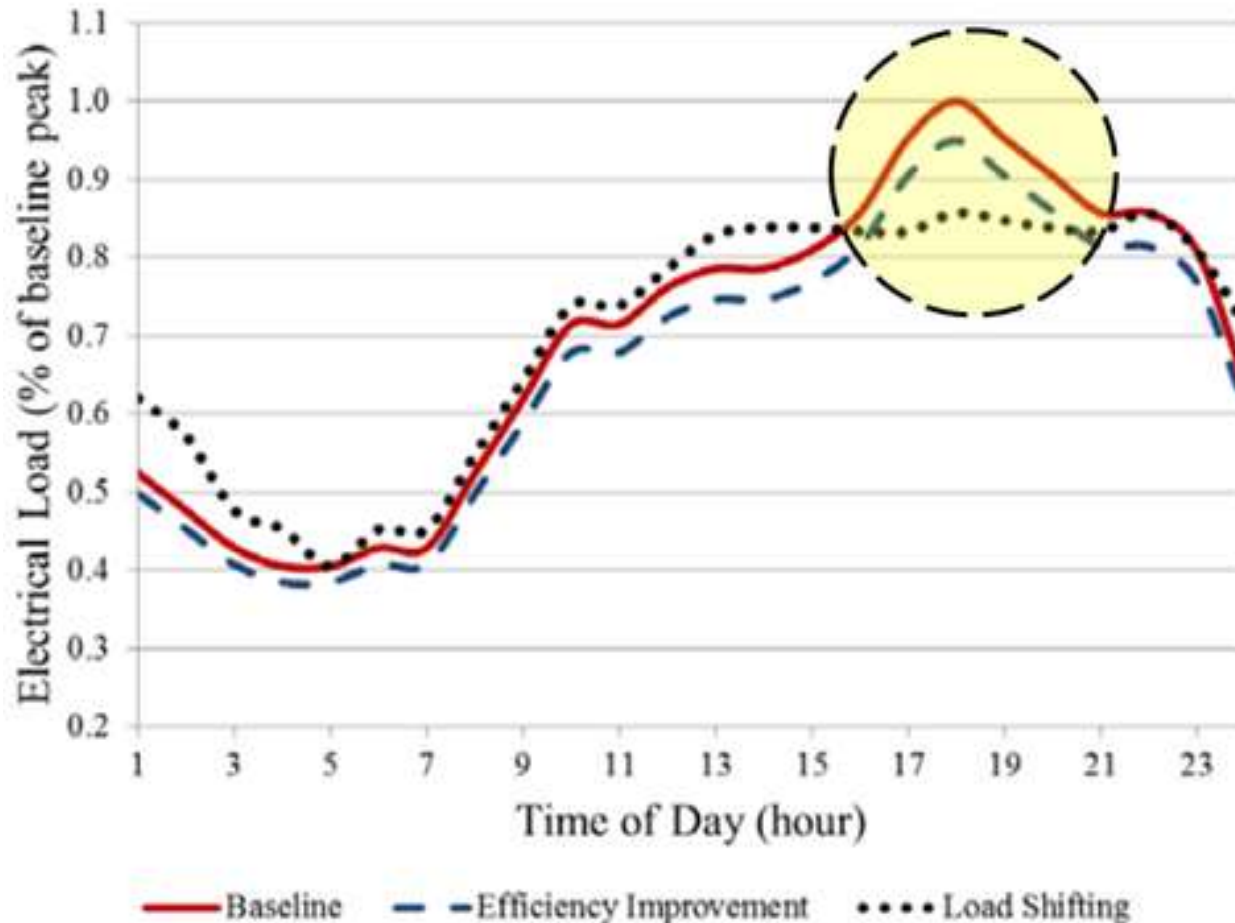
## Influence of demand response on the price



## Price based demand response



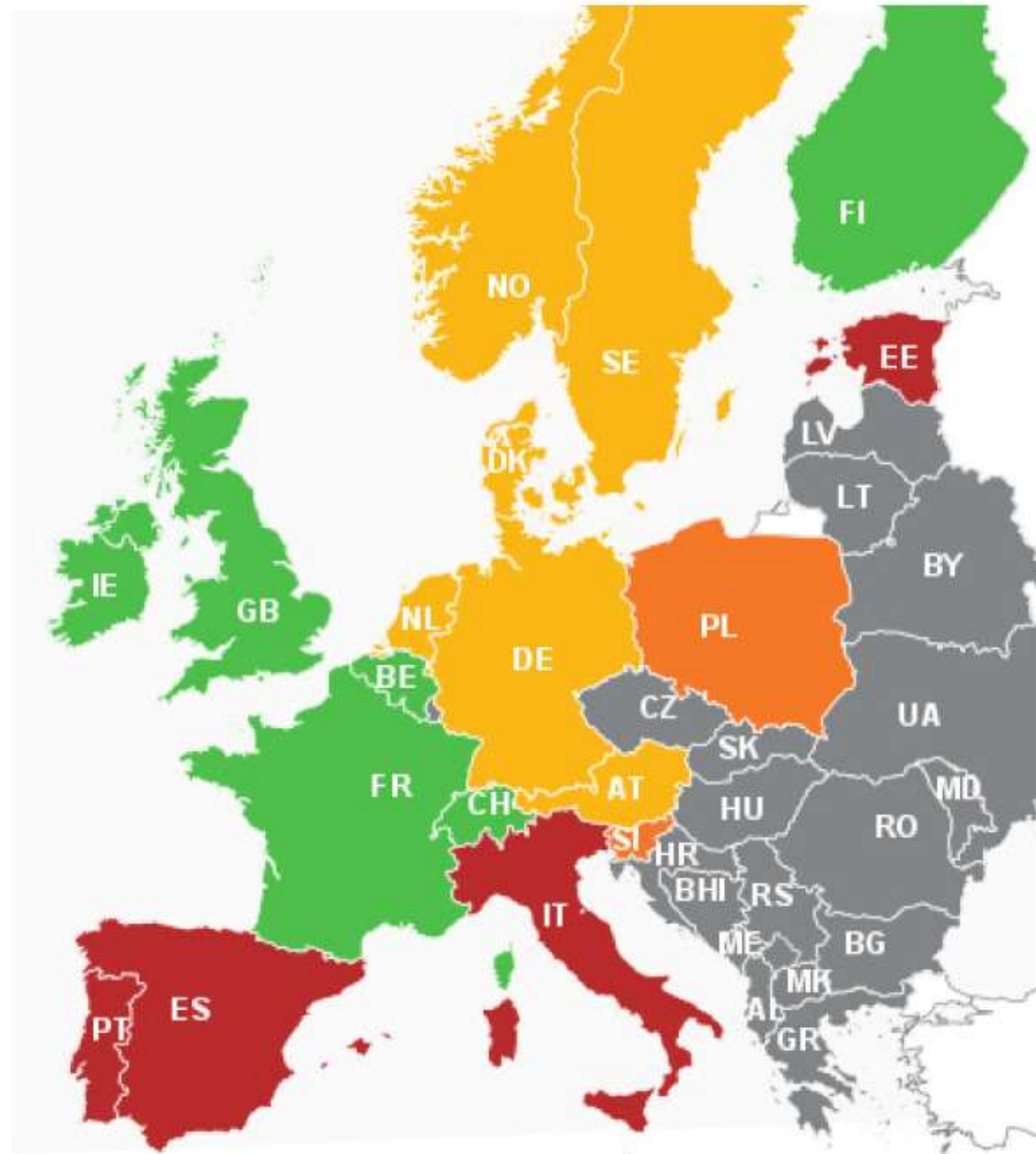
## Load control = incentive based demand response



# Aggregators

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- Commercially active
- Partial opening
- Preliminary development
- Closed
- Not assessed



# Dispatching

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## TSOs' Regional Security Cooperation Initiatives

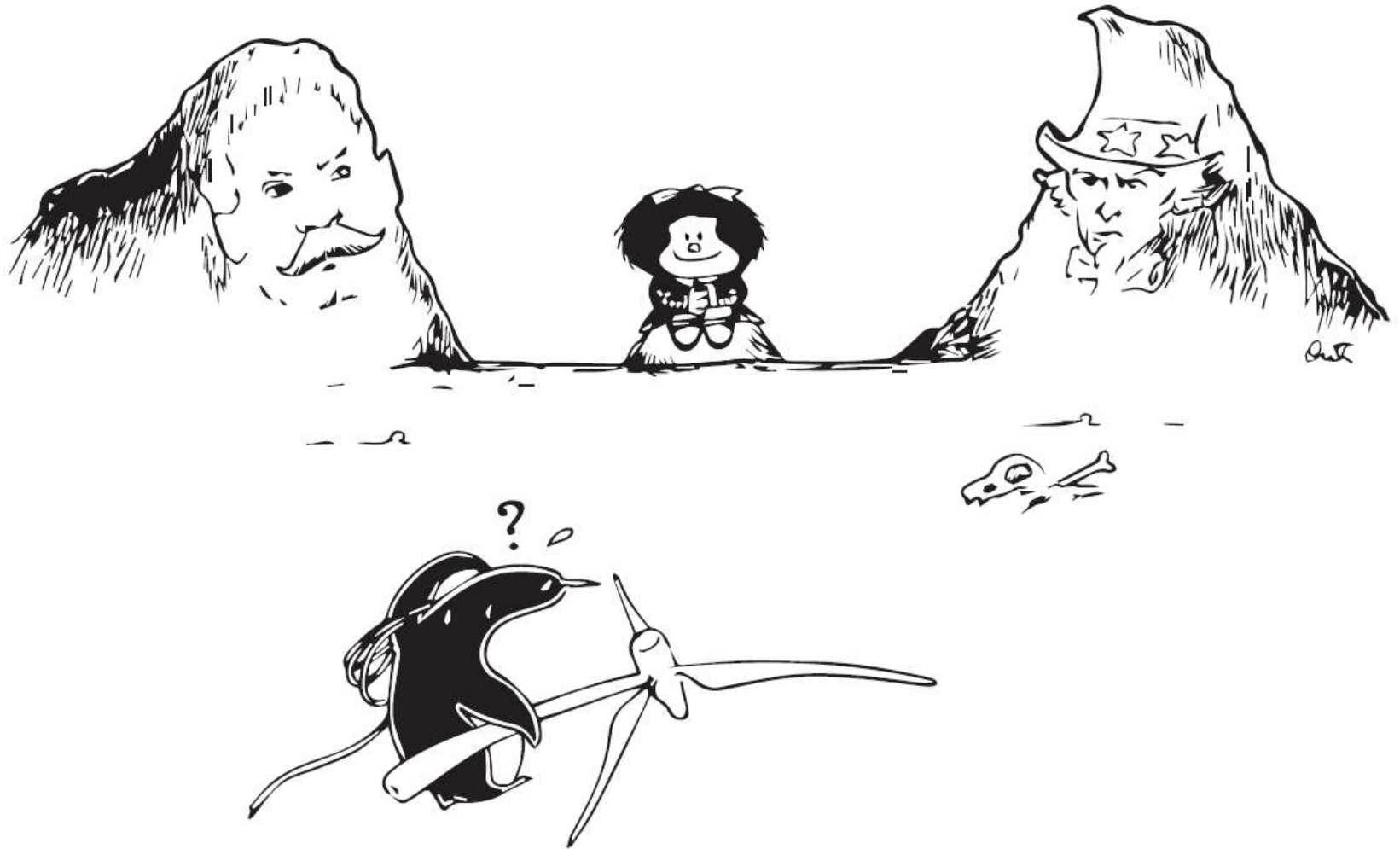


Source: ENTSO-E

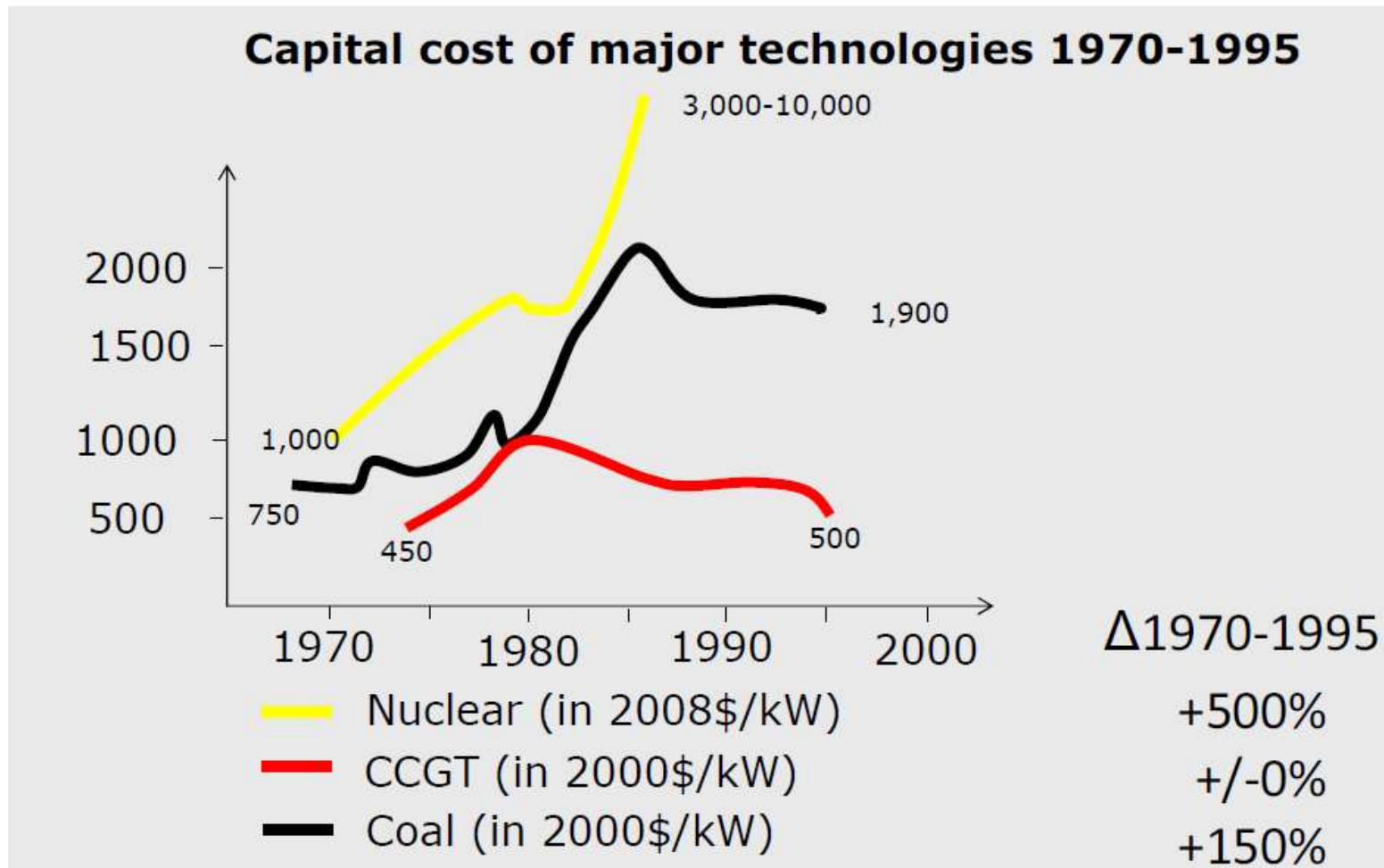


# Investments

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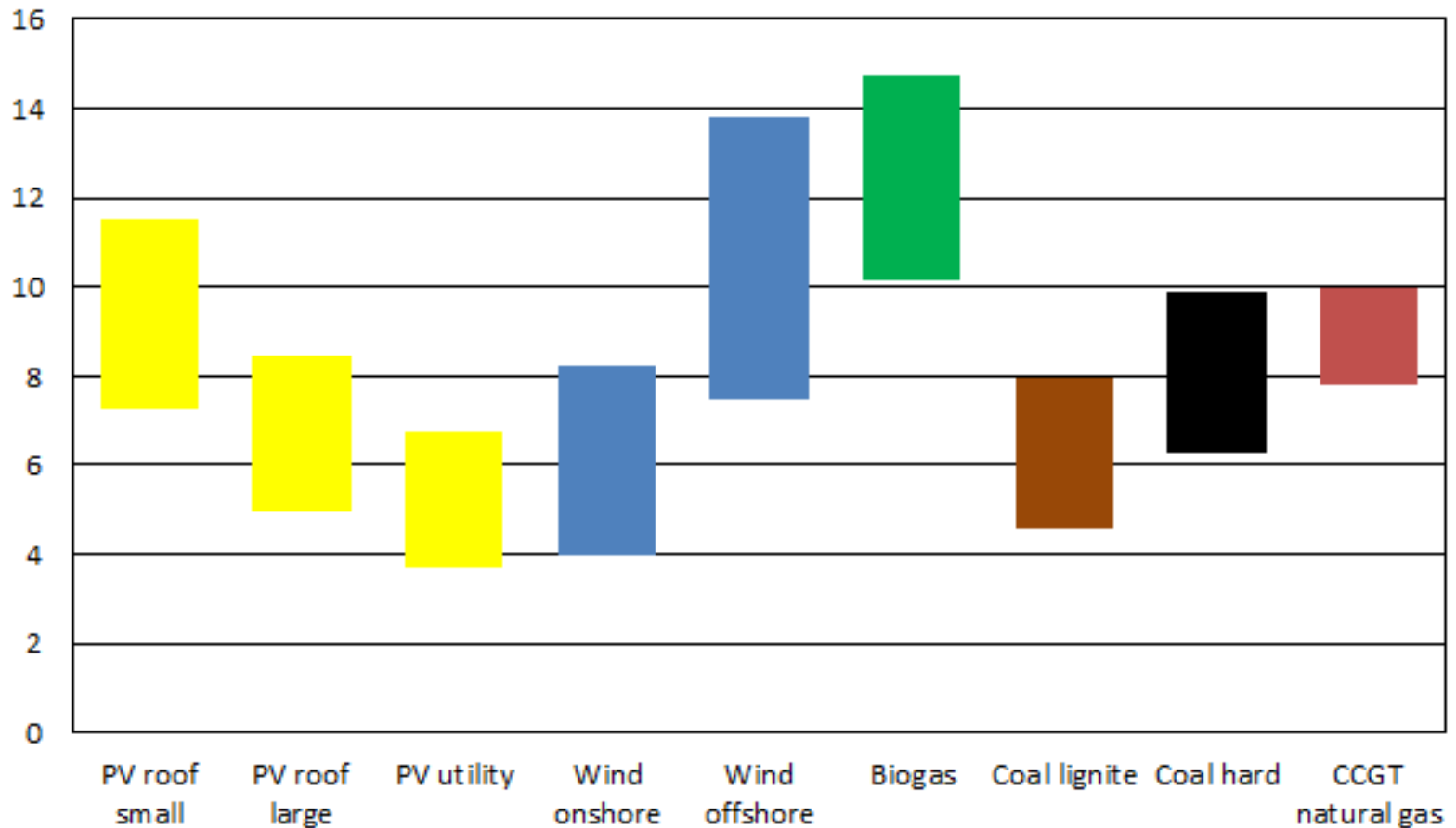
## Capital cost decrease is no physical law



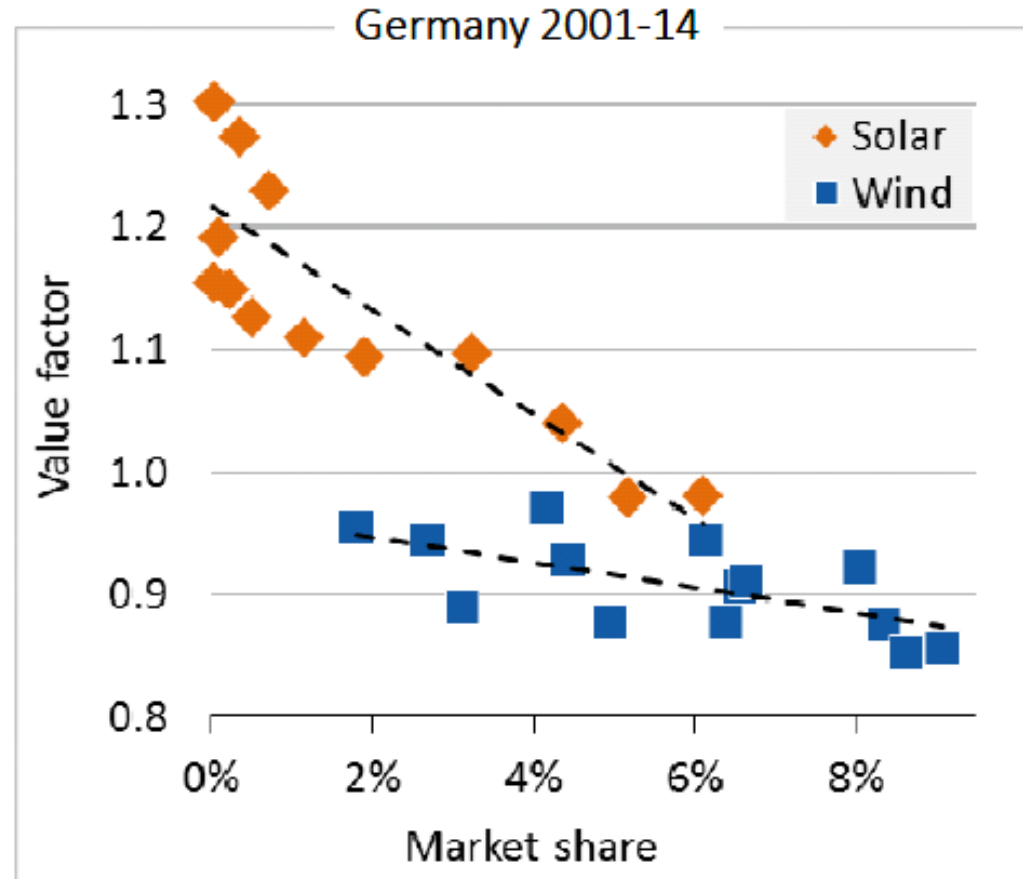
Source: Zachmann, Bruegel

## Levelized cost of electricity in Germany

in EuroCent/kWh, source: Fraunhofer ISE; March 2018



## The wind and solar value drop



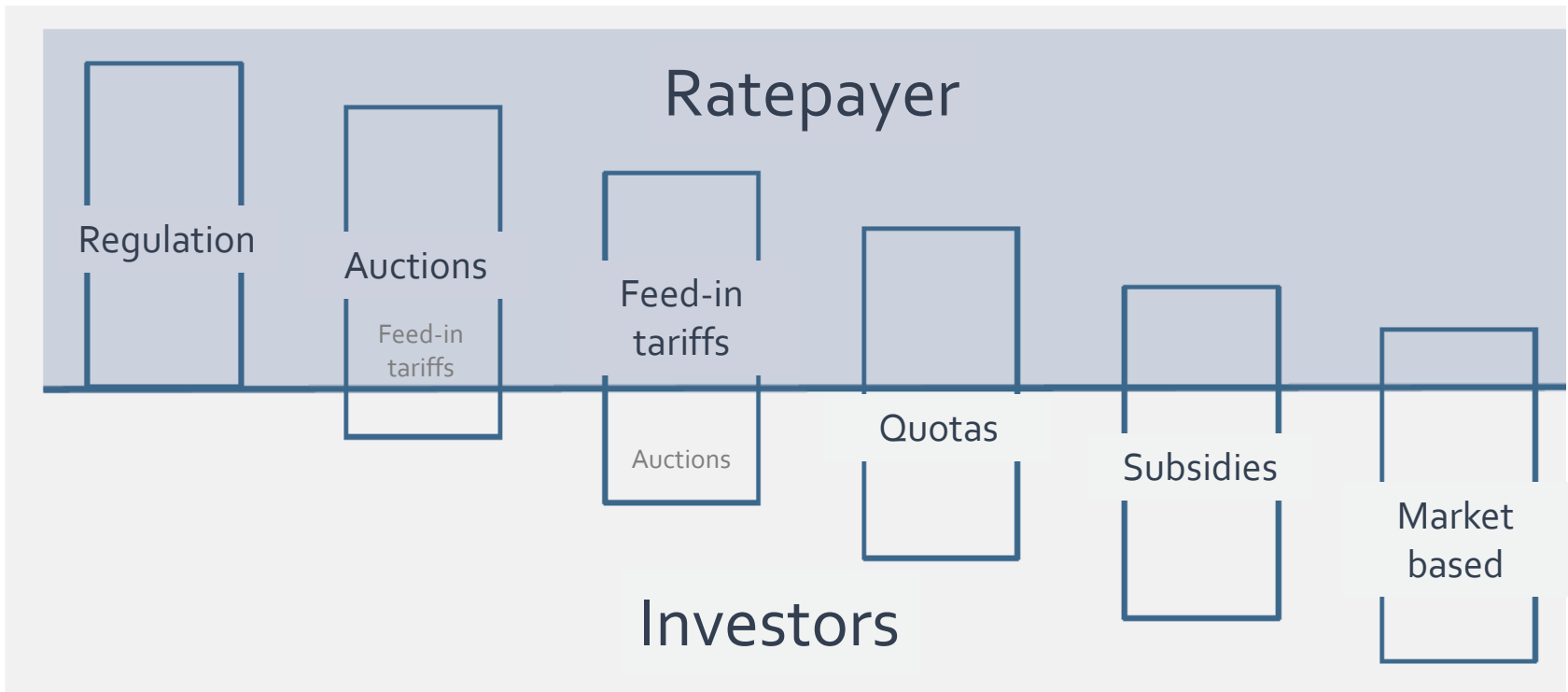
Value Factor =  
Market value /  
base price

Each dot represents  
one year

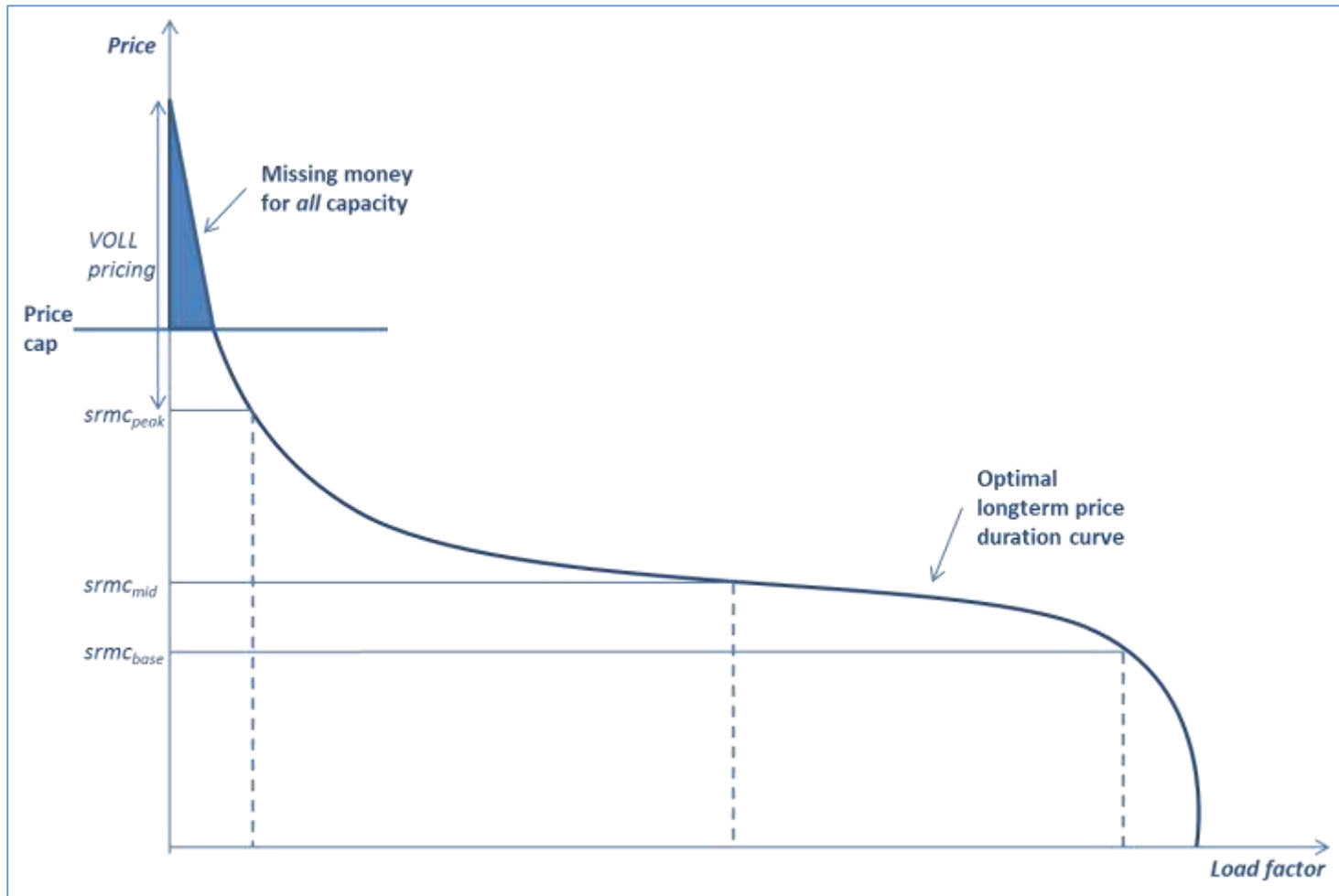



## Who takes the risk?

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# Capacity mechanisms



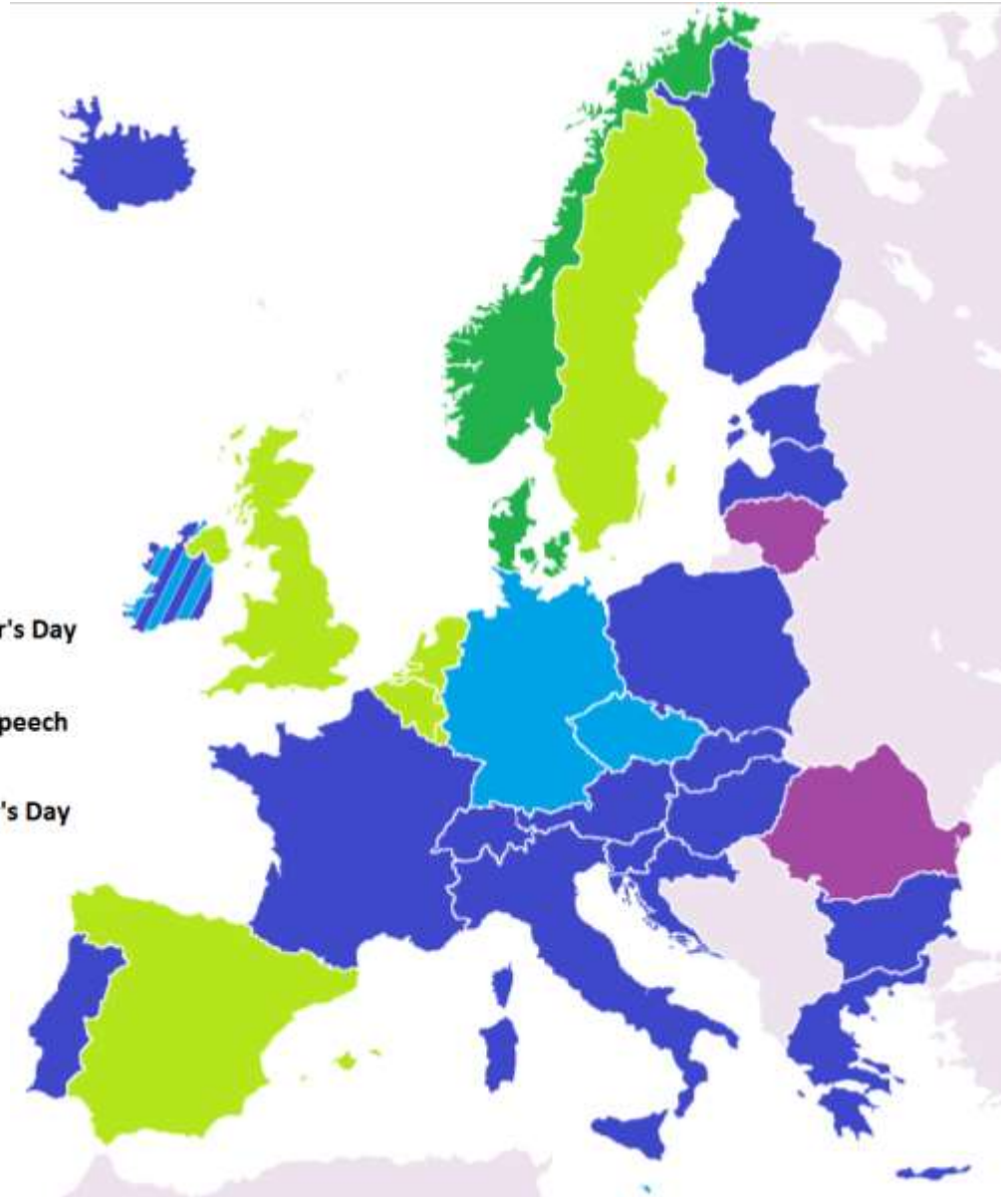
A photograph of a forest floor covered in brown leaves, twigs, and several bright yellow mushrooms. The text "Capacity mechanisms" is overlaid in white, bold font in the center of the image.

# Capacity mechanisms

# Capacity mechanisms

## Christmas and New Year's Addresses by European Heads of States

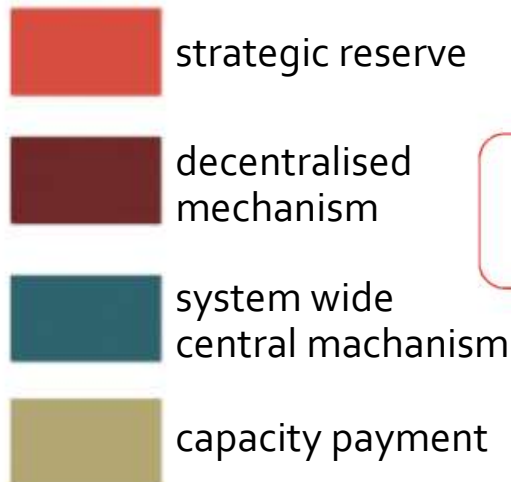
- President delivers speech on New Year's Eve/New Year's Day
- President delivers speech at Christmas
- President delivers combined Christmas & New Year's speech
- Monarch delivers speech at Christmas
- Monarch delivers speech on New Year's Eve/New Year's Day
- No specific speech



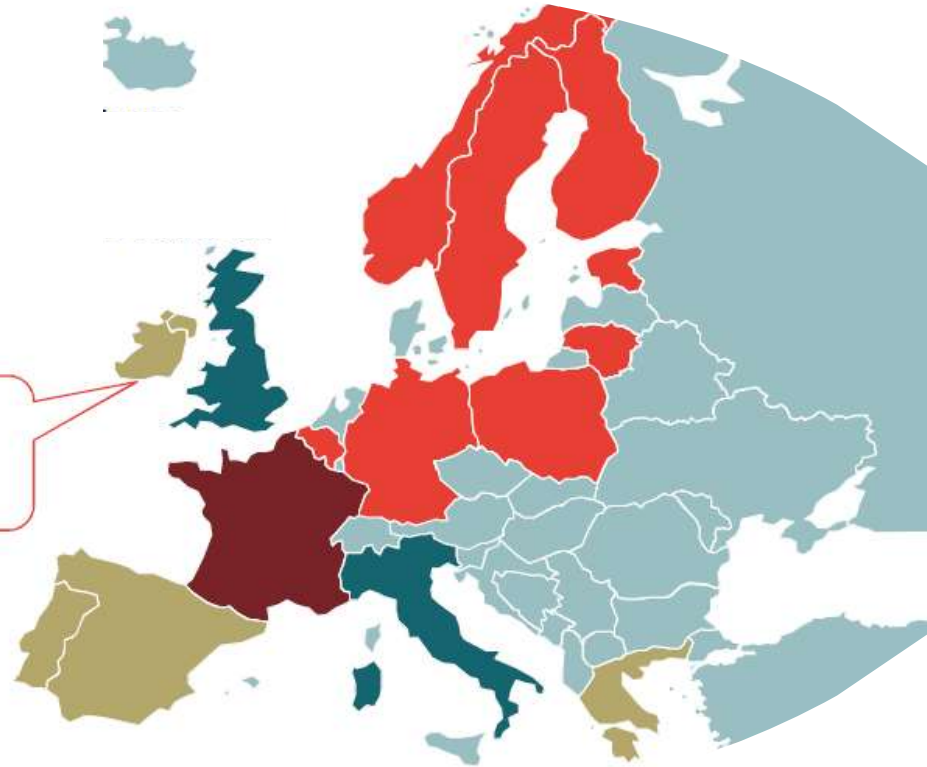


# Who does what (or is planning to)?

... regarding capacity mechanisms



RoI/NI: Considering to move to a system wide central mechanism (reliability options)



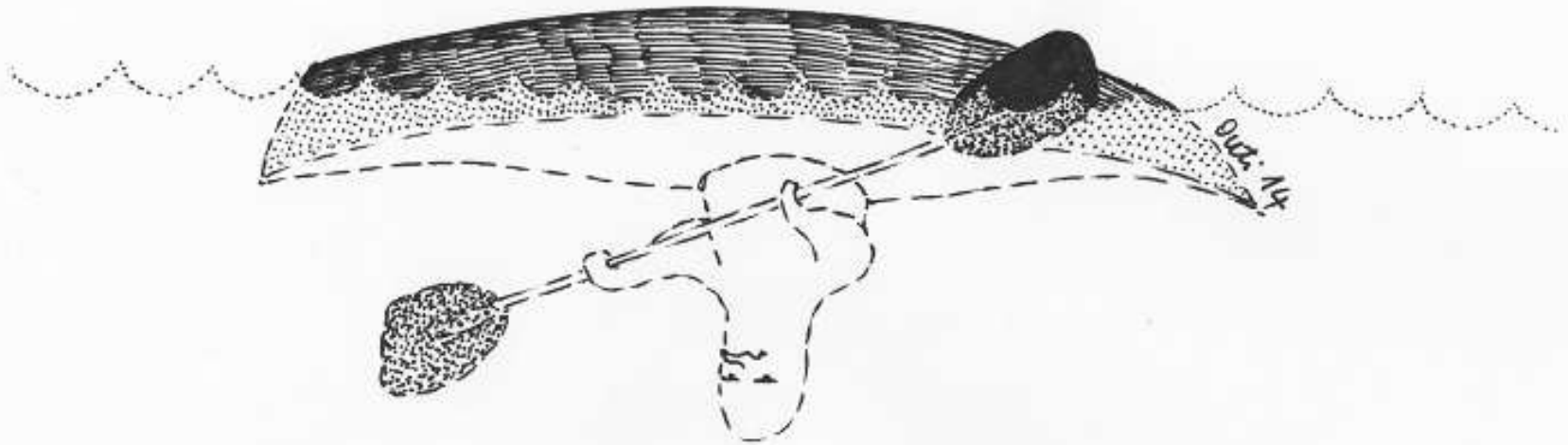
Variation in models reflects the issues and political perceptions

## Capacity payment vs. strategic reserve in Europe

Market	Market design	Per gross electricity generated €/MWh	Committed capacity MW
Ireland	Capacity payment	20	7.000
Greece	Capacity payment	9	11.000
PJM	Capacity market	5.5	136.000
UK	Capacity market	5	49.000
UK	Strategic reserve	4	2.000
Spain	Capacity payment	2.7	25.000
Italy	Capacity payment	0.5	-
Finland	Strategic reserve	0.3	600
Norway	Strategic reserve	0.2	300
Sweden	Strategic reserve	0.1	2.000

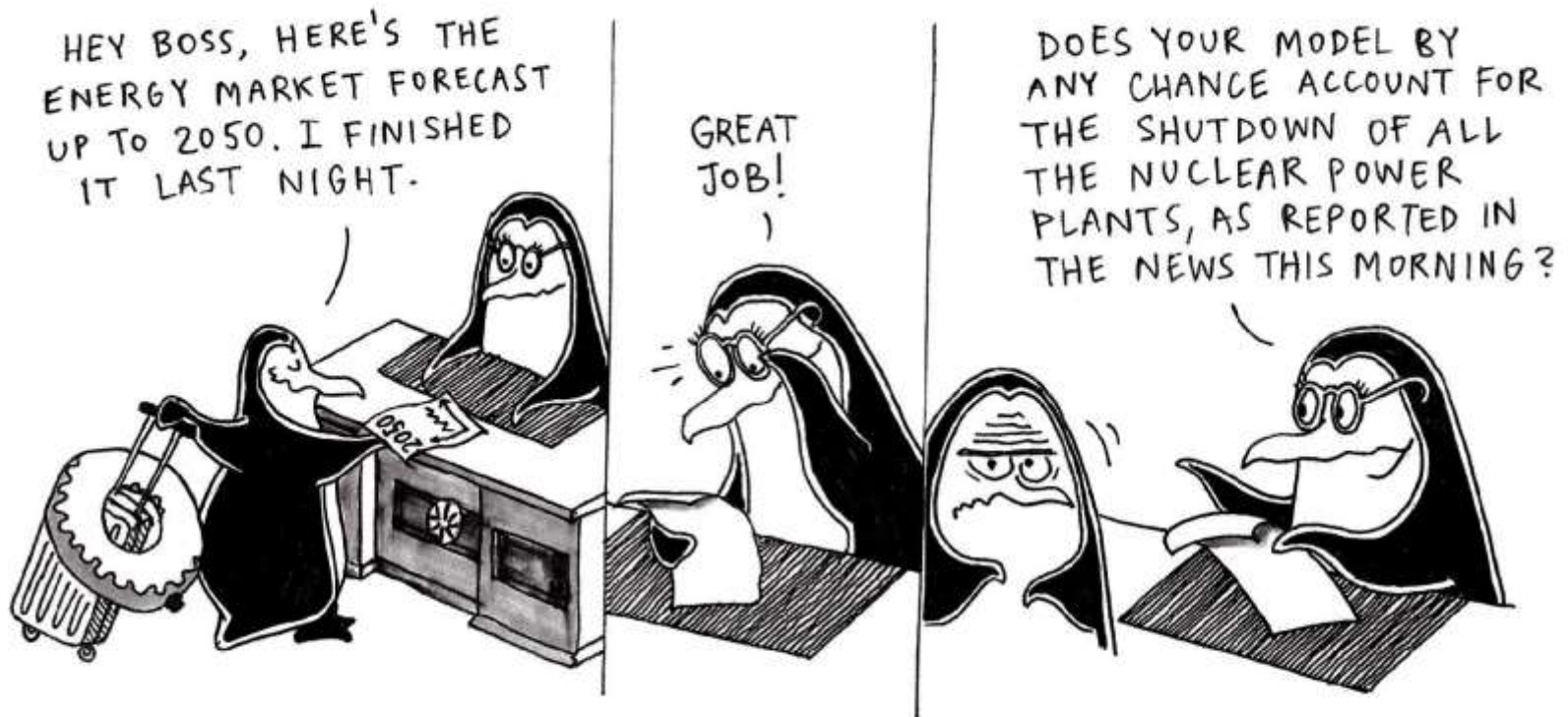
## Reversibility of capacity mechanisms

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## Future is uncertain

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by Outi Supponen

## Future issues regarding electricity markets

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### **Design issues**

- Capacity mechanisms
- New forms of trading (for example peer-to-peer)
- Local markets (including DSO congestion management)
- Role of DSOs vs. TSOs
- Concepts for demand response

## Future issues regarding electricity markets

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### **Digitalisation**

- Cybersecurity, Internet of Things, Big data
- Who will manage data platforms?
- More active control of assets for balancing

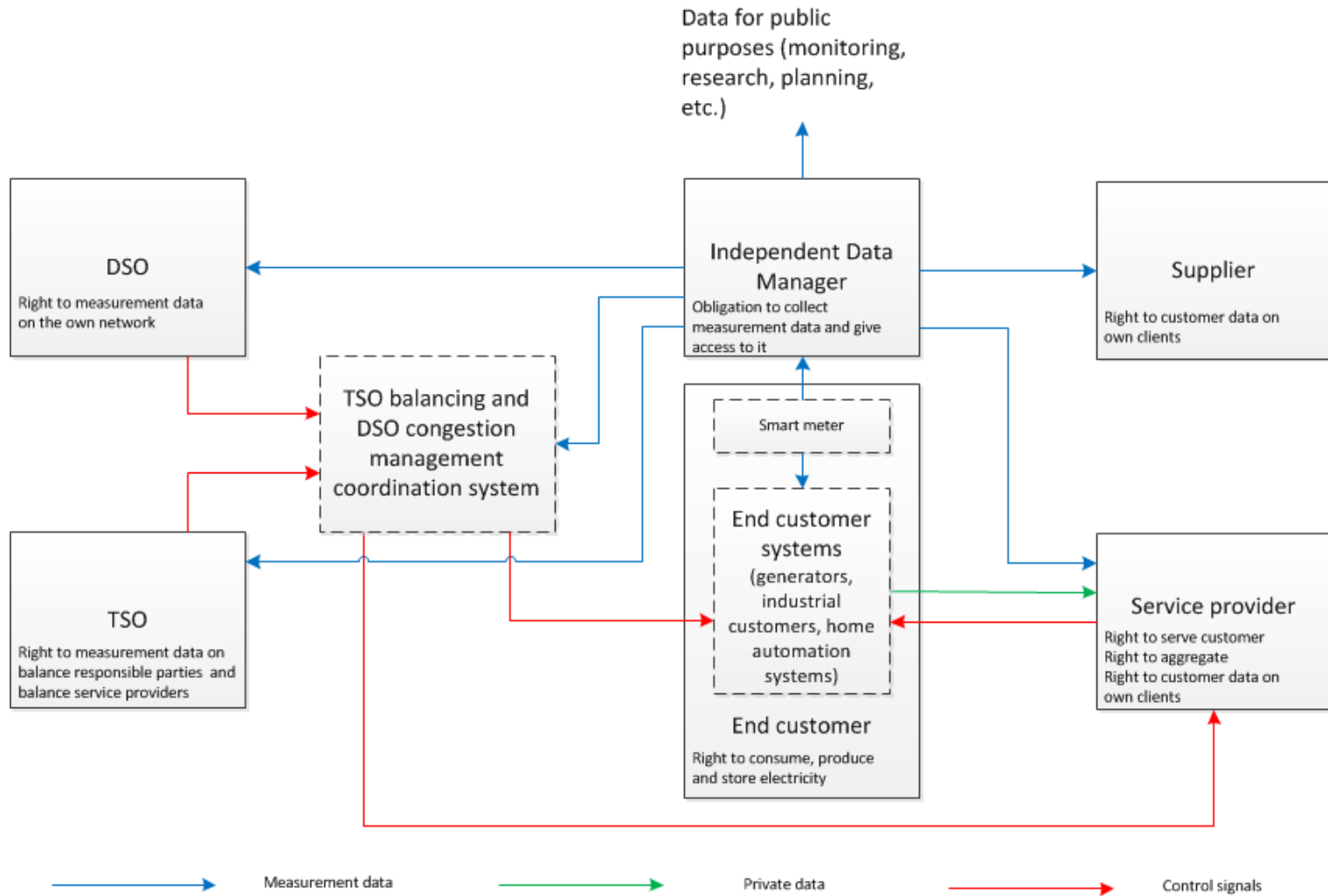
## Future issues regarding electricity markets

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### **Sector coupling**

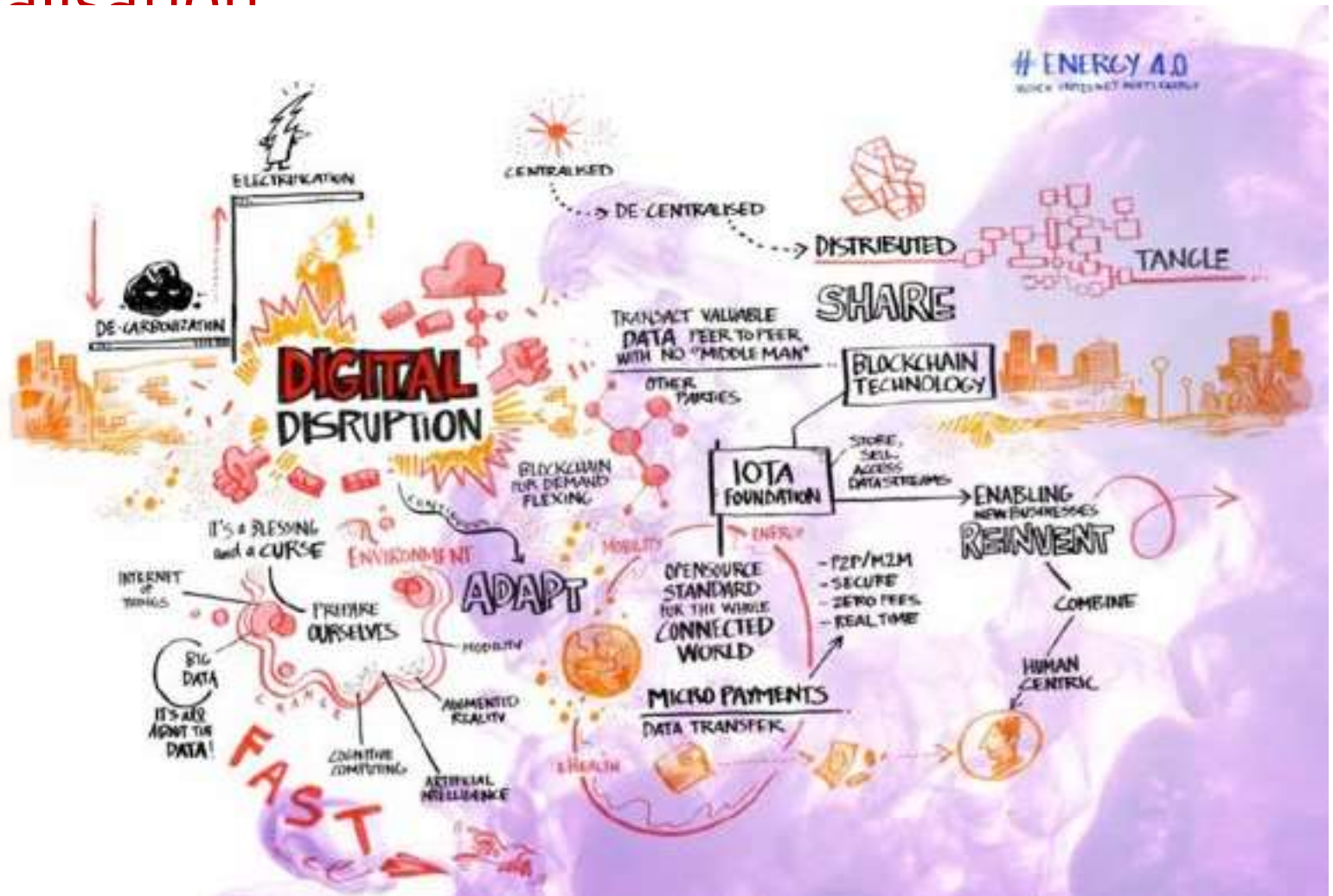
- Power to gas
- Power to liquids
- Interplay between electricity and heat
- electrification of transport
- ...

# New relations between players

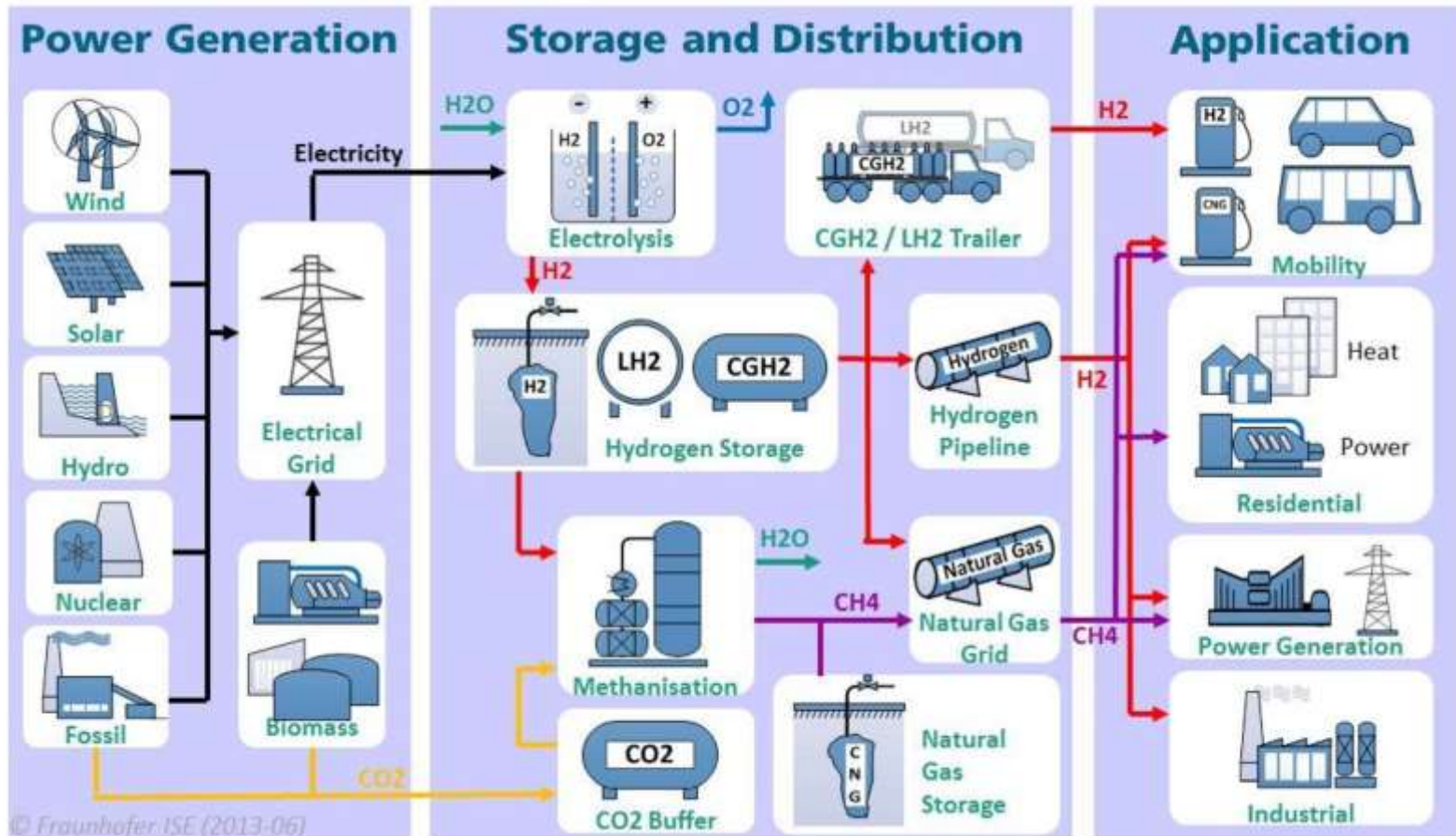




# Digitalisation and



## Sector coupling provides opportunities for flexible storage...



... by integrating a growing share of renewable electricity in carbon-intensive industries

## Regulation vs. market

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Regulation	Regulation/ market	Market
<ul style="list-style-type: none"><li>• Grid tariffs</li><li>• Regulated prices</li><li>• Capacity mechanisms</li><li>• RES targets</li><li>• Subsidies</li><li>• Energy efficiency targets</li><li>• Mandatory ancillary services</li><li>• Priority dispatch</li><li>• Emission standards</li></ul>	<ul style="list-style-type: none"><li>• Emissions trading</li><li>• Trading of green certificates</li><li>• Auctions for generation capacity</li></ul>	<ul style="list-style-type: none"><li>• Competition</li><li>• Free price formation</li><li>• Liquidity</li><li>• Markets for ancillary services</li><li>• Right to self-produce/-consume and store electricity</li><li>• Right to be aggregated</li></ul>



# Low Carbon Ukraine

Policy advice on low-carbon policies for Ukraine

Supported by:



Federal Ministry  
for the Environment, Nature Conservation  
and Nuclear Safety

based on a decision of the German Bundestag



Thank you for your

attention!