Low Carbon Ukraine

Policy advice on low-carbon policies for Ukraine

Supported by:

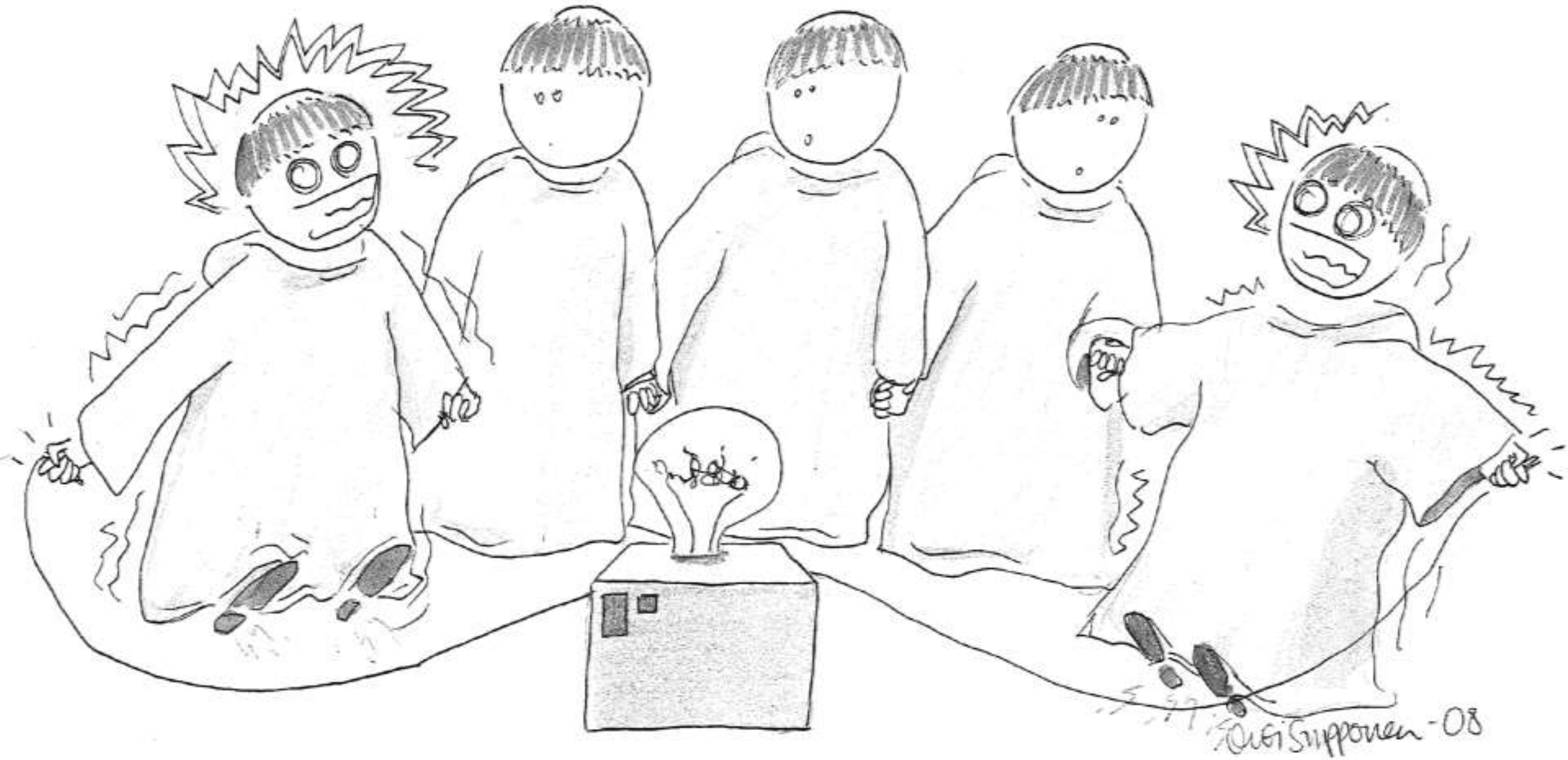
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

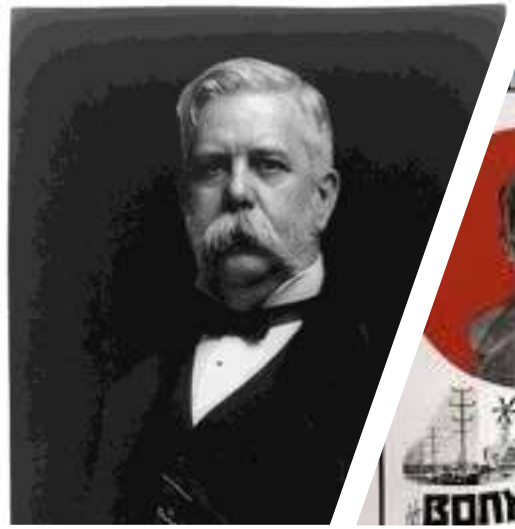
based on a decision of the German Bundestag

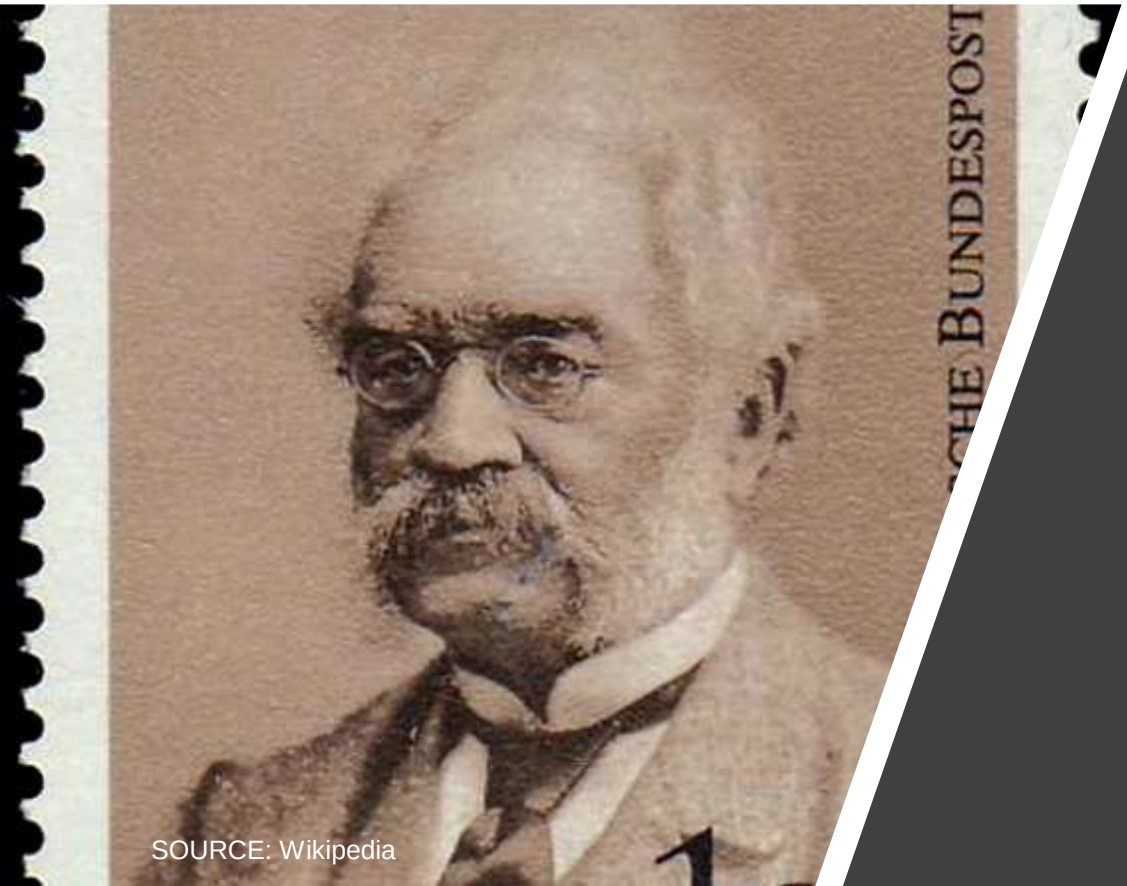
Electricity for all

Dr. Matti Supponen

Kyiv, December 2019


Outi Sipponen -08





SOURCE: Wikipedia

Westinghouse, Lenin Tesla, Edison, Siemens

Miguel and Matti

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Menu

- 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

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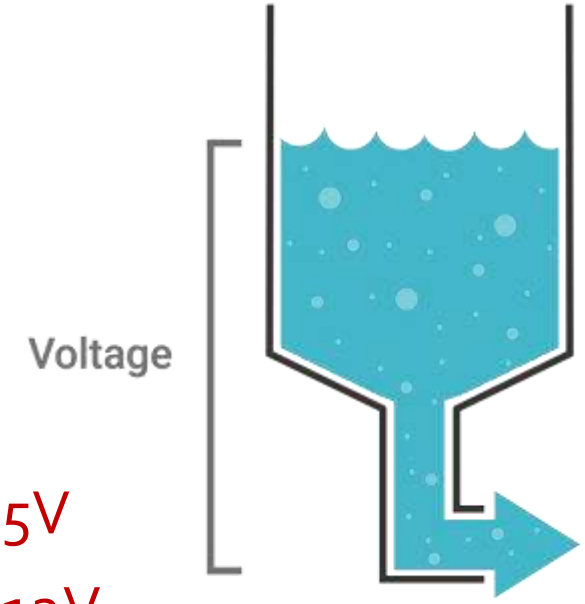
Voltage = U



- Mobile phone charger = 5V
- Car battery = 12V
- Electricity socket ~ 230V
- Medium voltage ~ 10-20kV
- High speed train ~ 25kV
- High voltage ~ 110 – 700kV

picture source: blog.aurosolar.com

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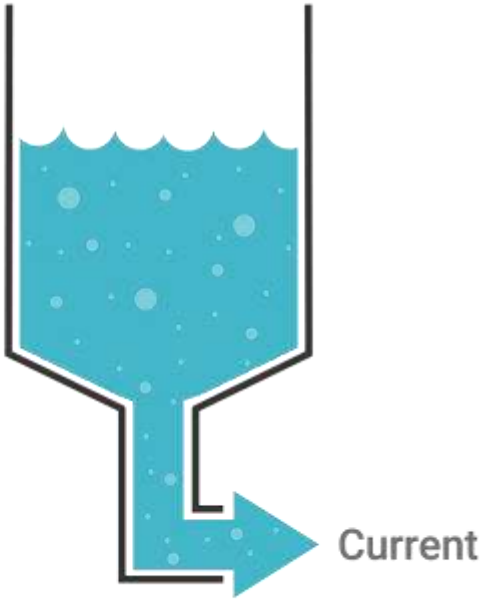
Current = I



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

picture source: blog.aurosolar.com

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Power = U* I

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

Energy = P*t

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

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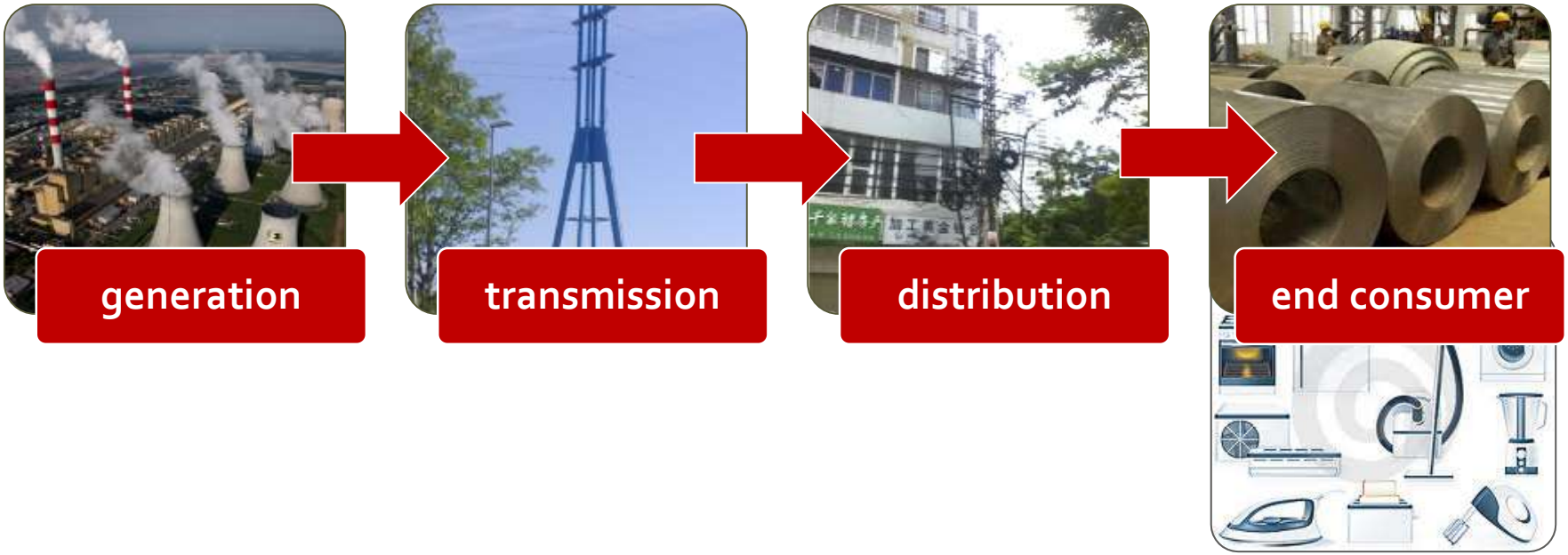
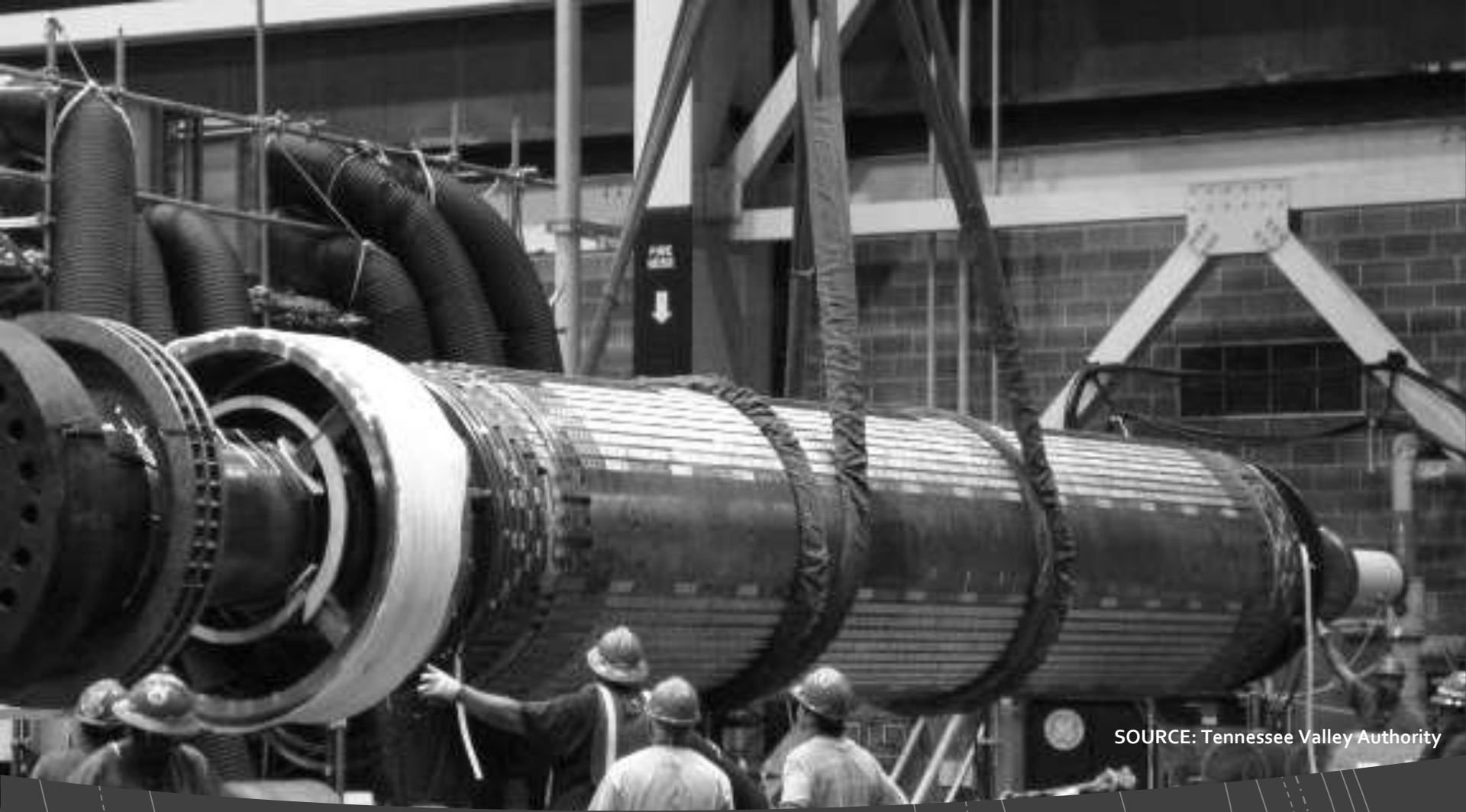
Physical value chain for electricity



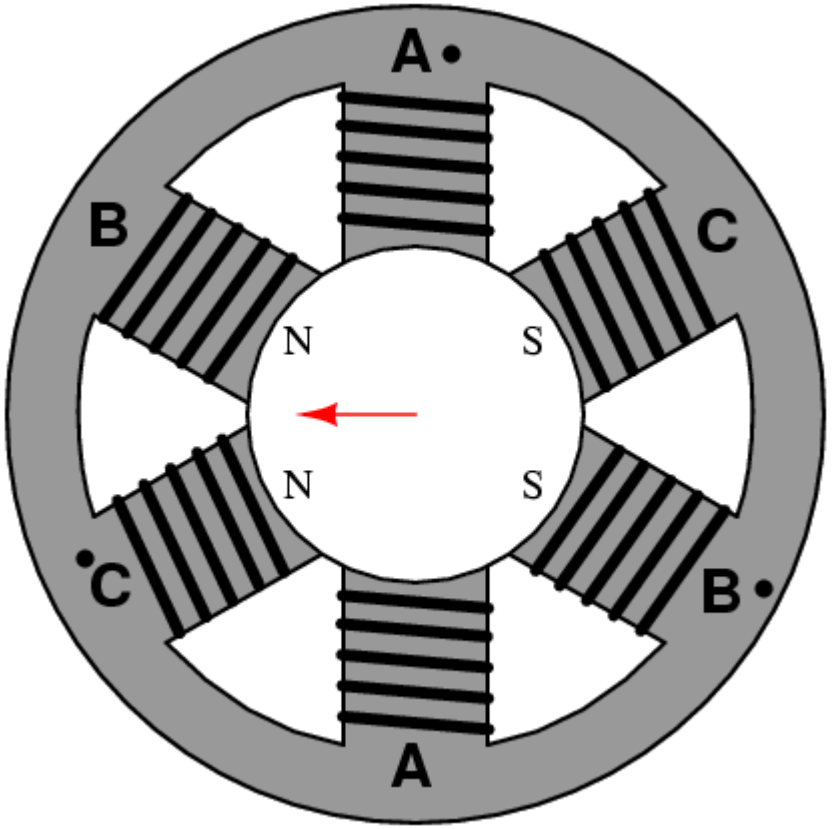
Generator



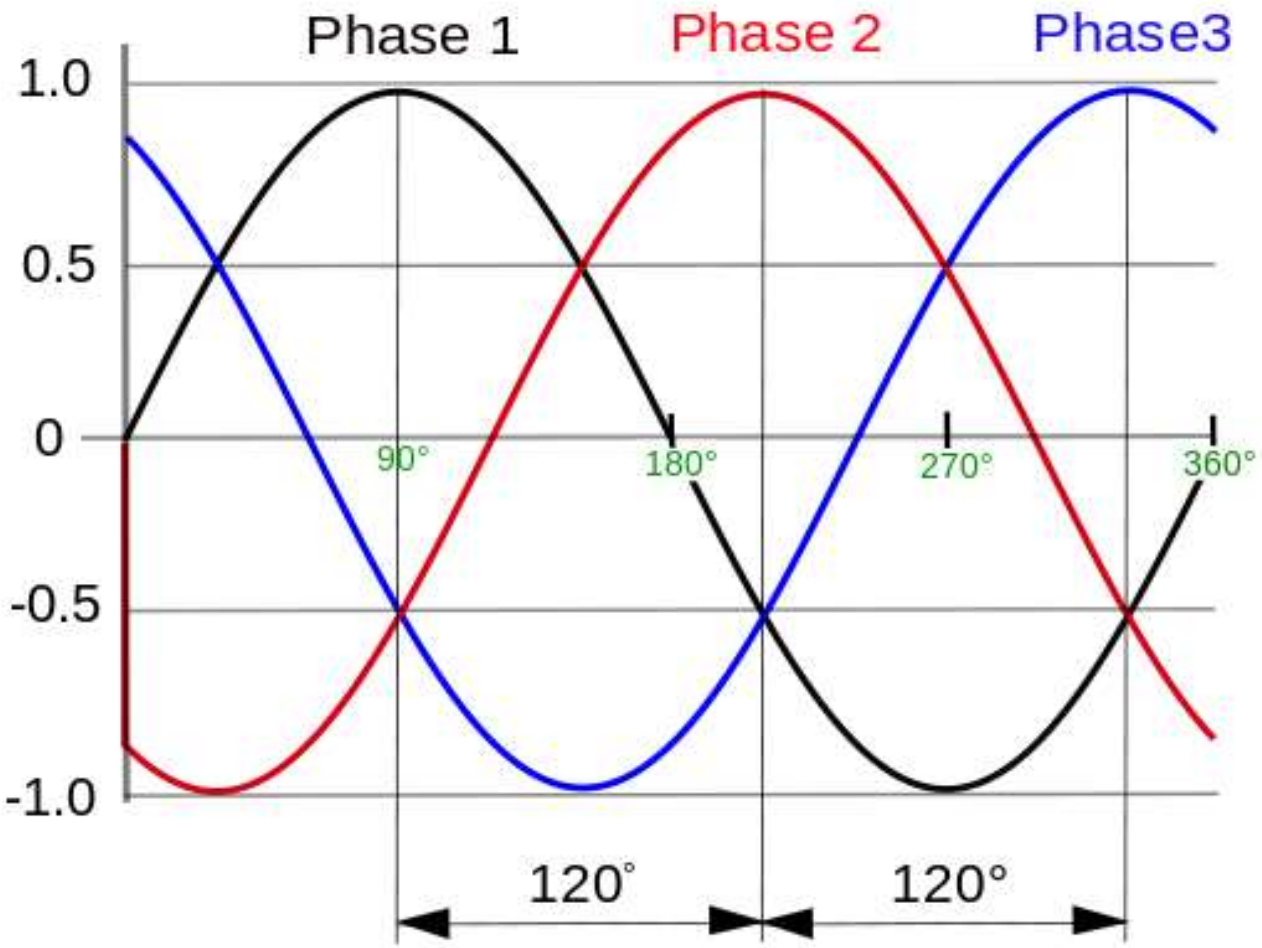
SOURCE: Tennessee Valley Authority

Rotor

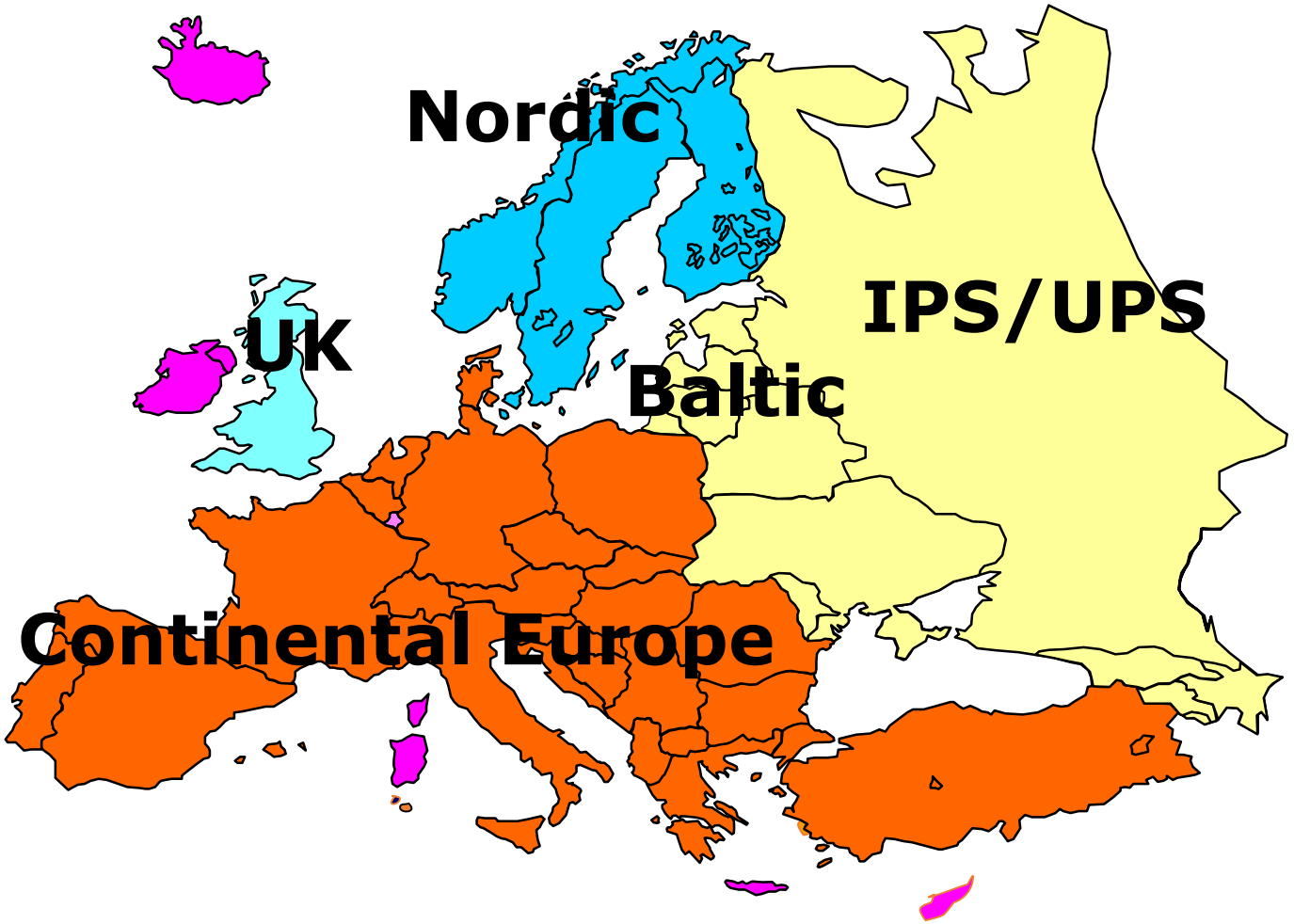
Electric motor



3 phase alternating current



Synchronous zones in Europe



Synchronous zones in China

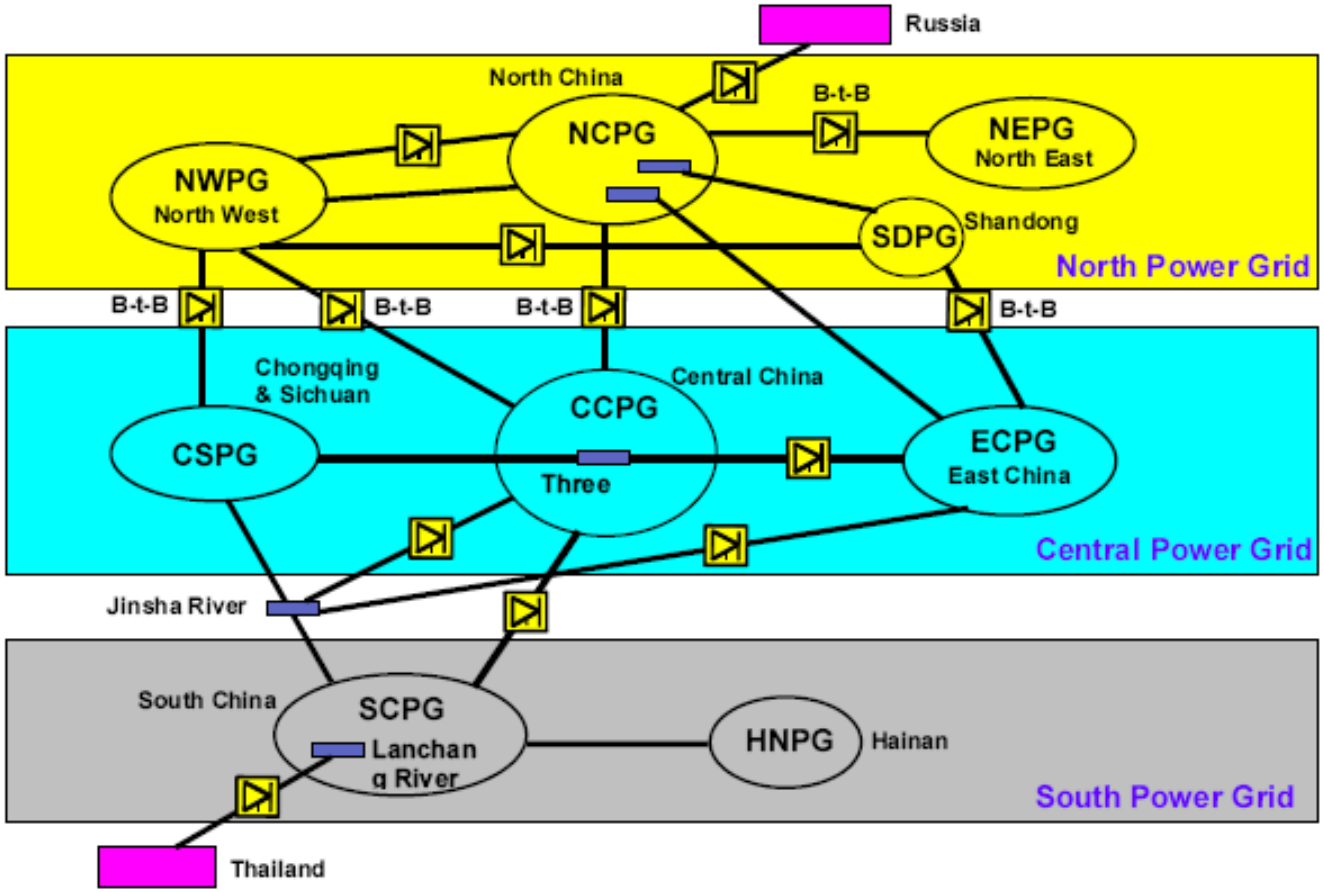


Fig.1 Conceptual Overview of China National Grid Interconnection by 2015

SOURCE: Cigre papers, ABB

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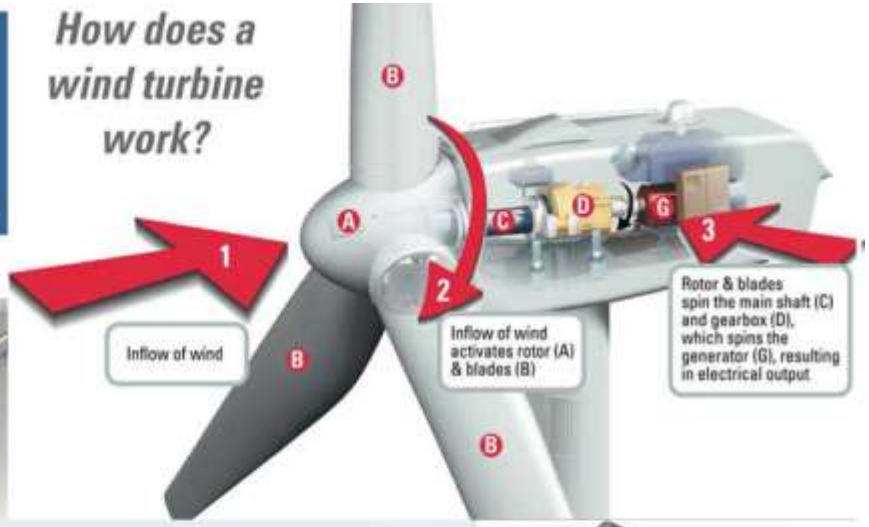
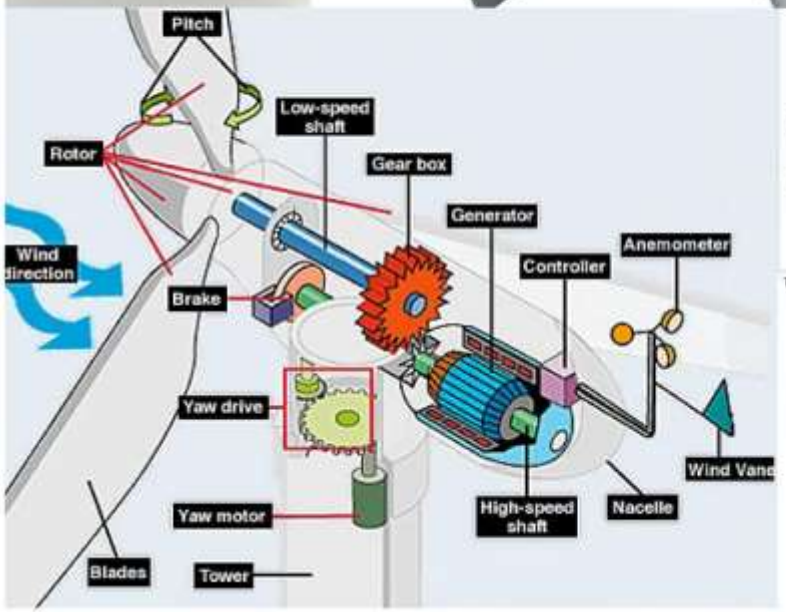
Wind generator





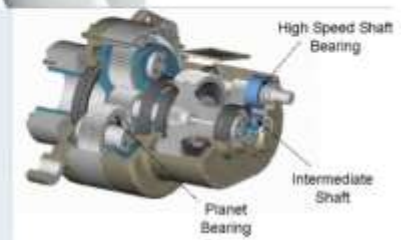
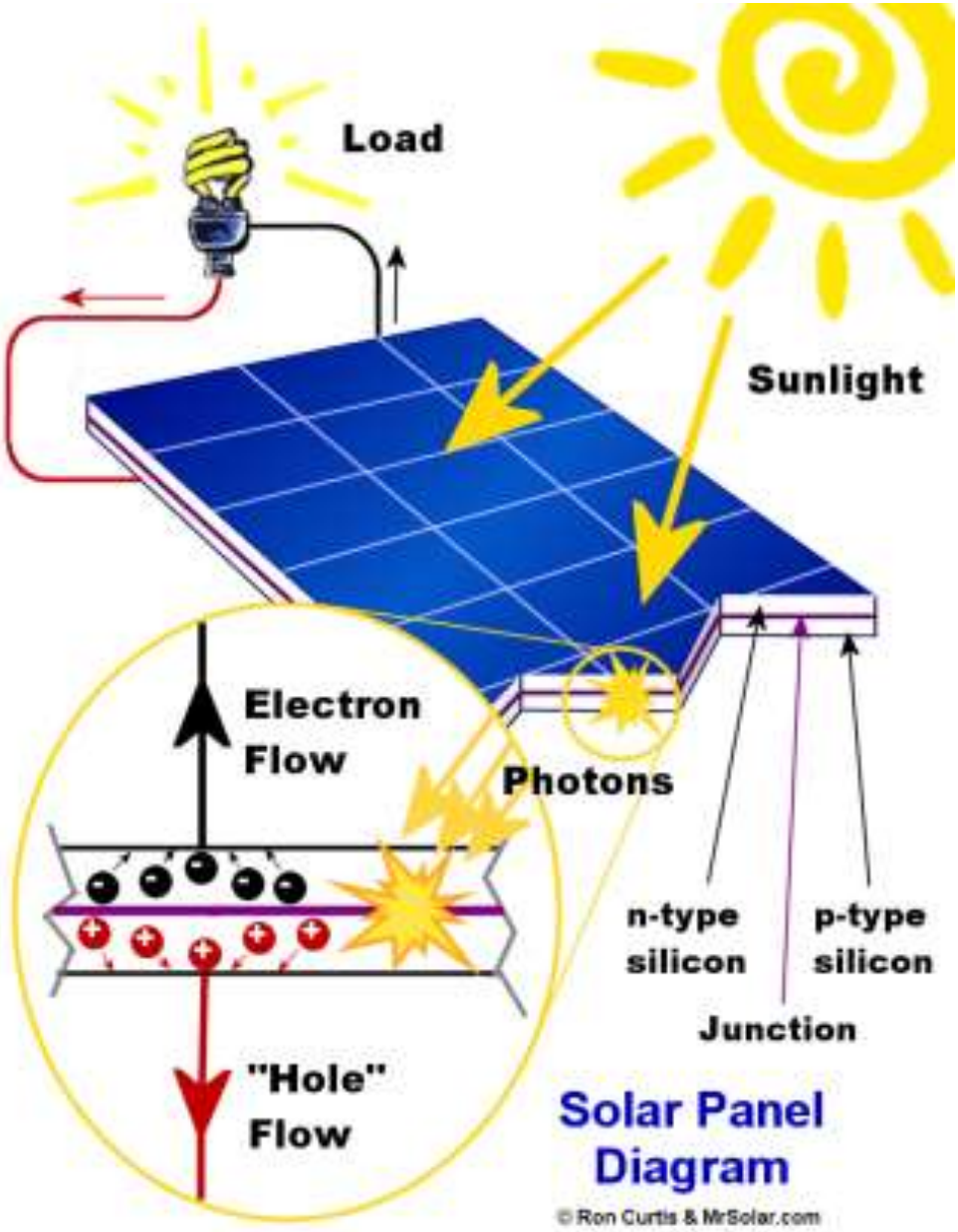


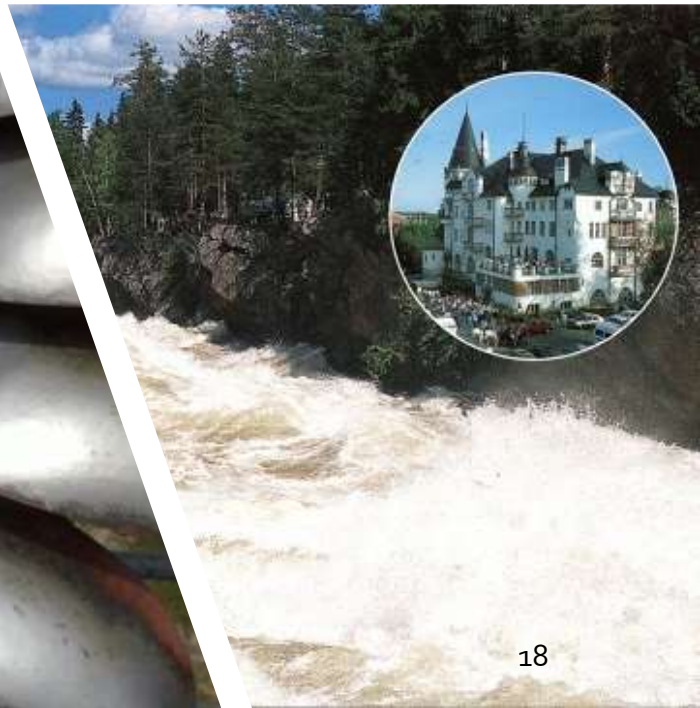
Figure 2 – Generalized Gearbox Schematic [11]

Typical asynchronous generator, Danish wind turbines, 1999

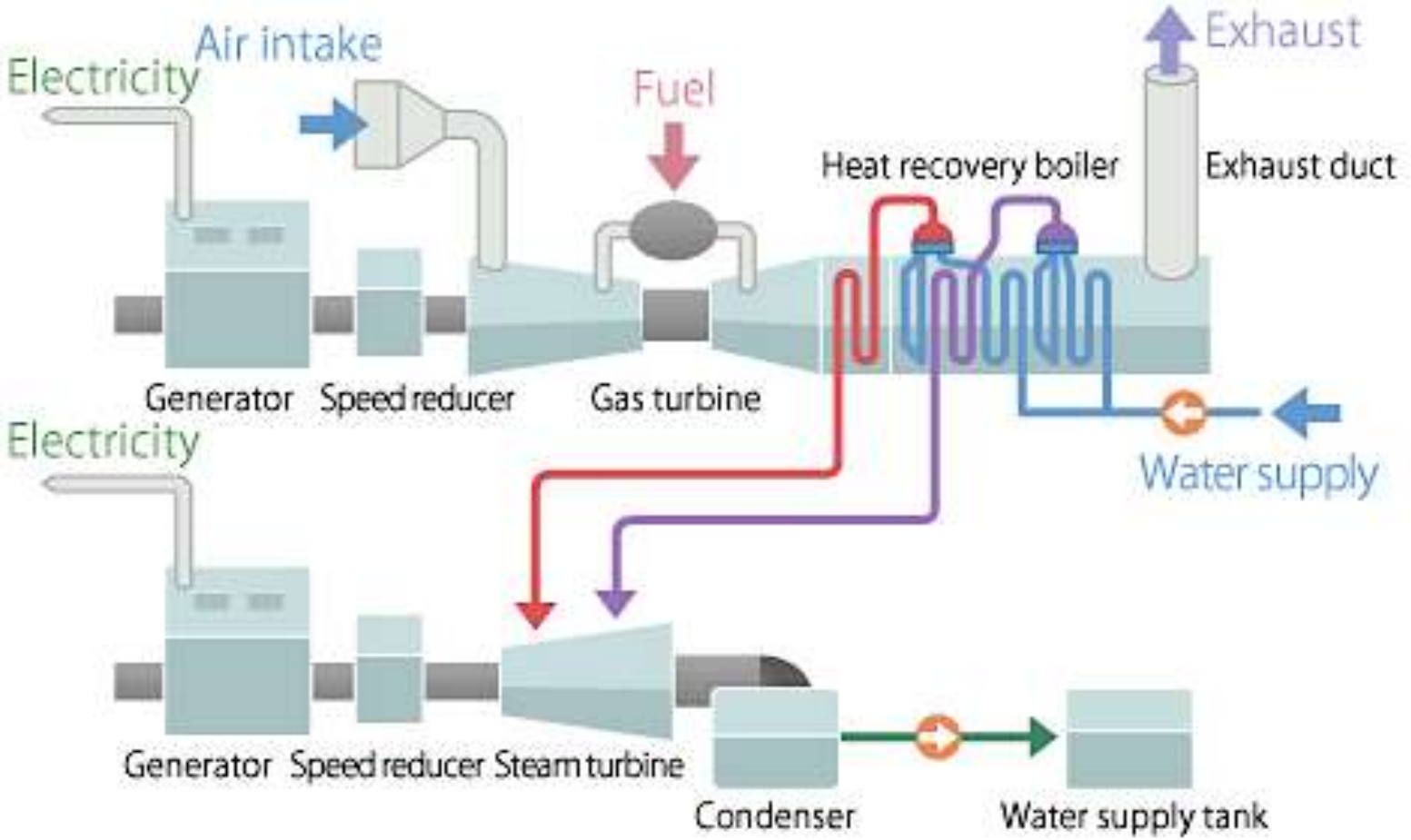
Solar panel


Load
Sunlight
Electron
Flow
Photons
n-type
silicon
p-type
silicon
Junction
"Hole"
Flow
Solar Panel
Diagram
© Ron Curtis & MrSolar.com

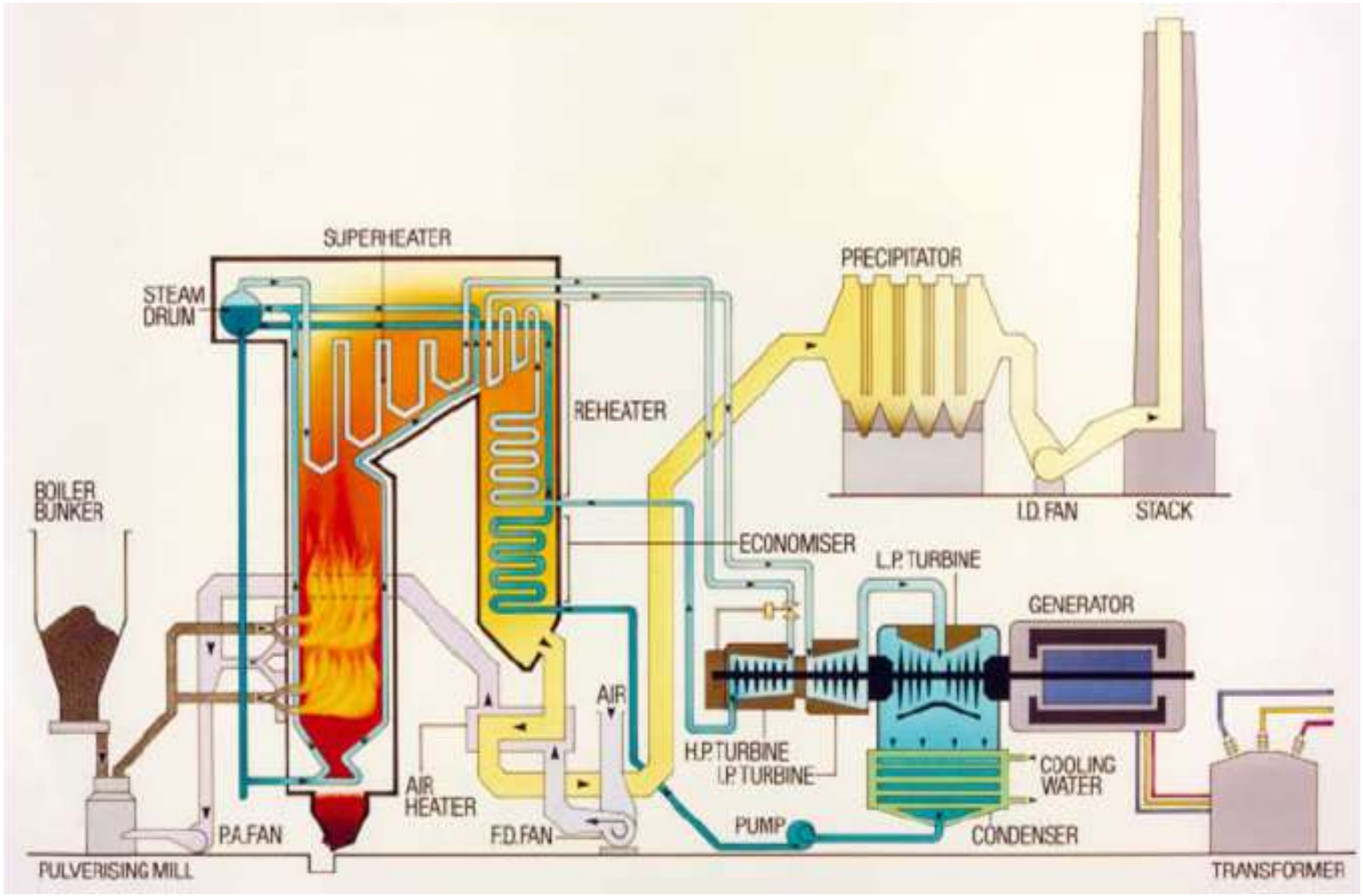
Hydro power plant



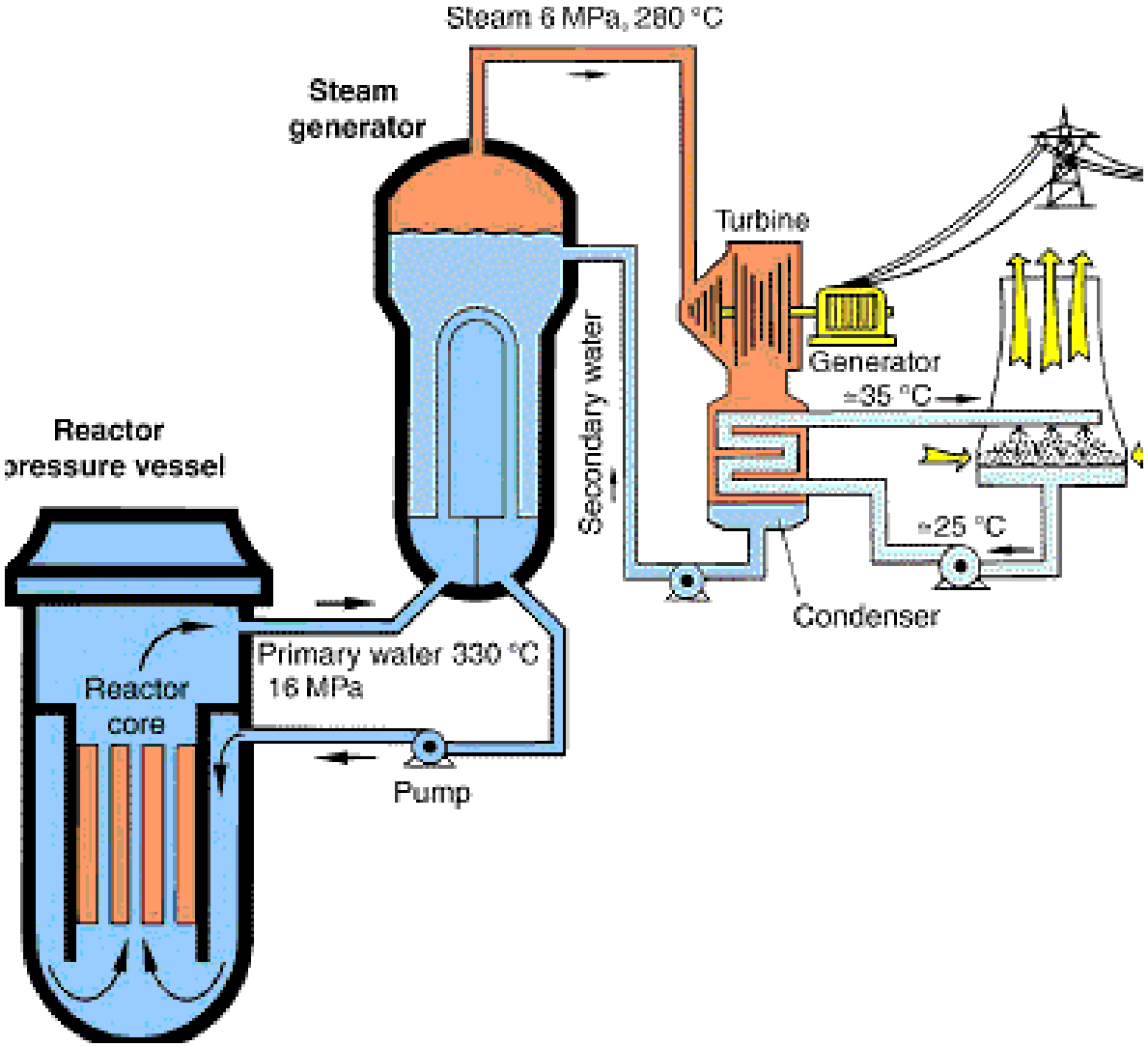
Combined cycle gas turbine



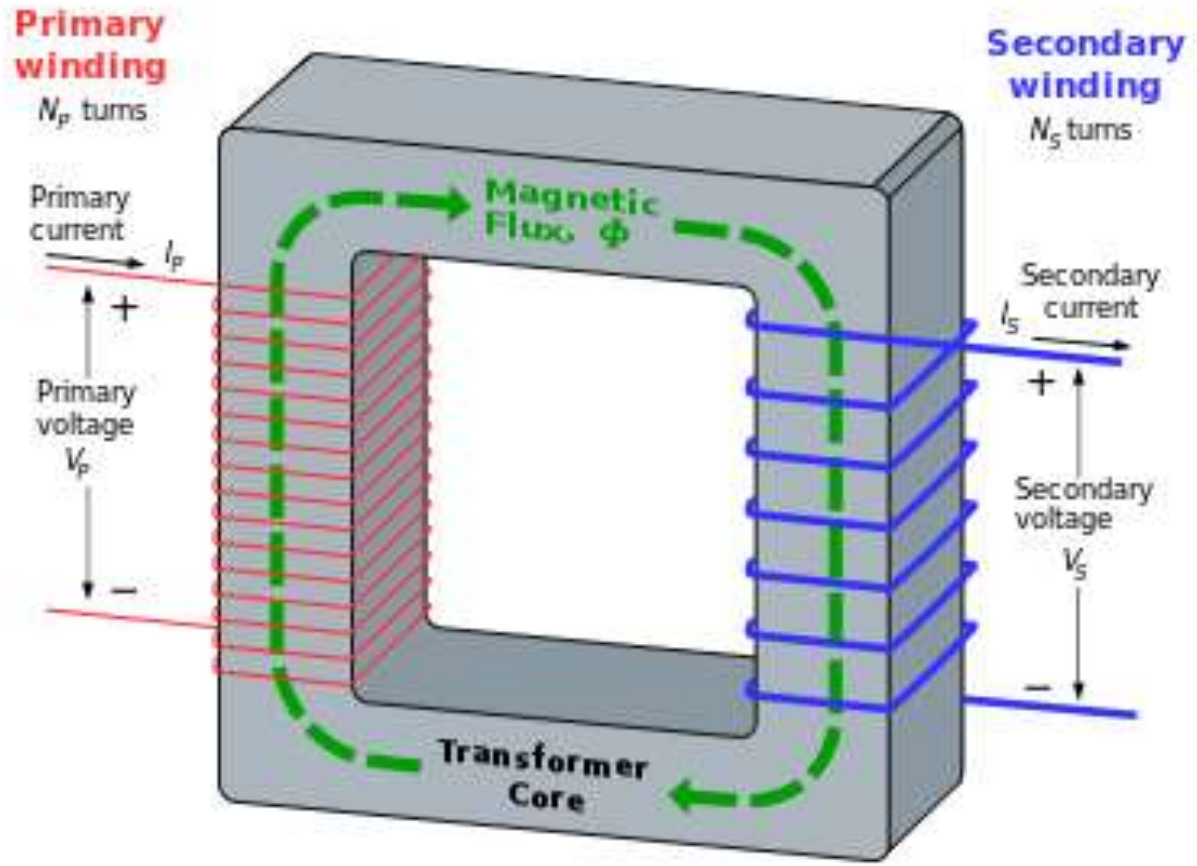
Coal power station



Nuclear power station



Transformer




Step-up transformer
(C) George Campbell

Substation

SOURCE: Statnett

Praha Sever SOURCE: Eltodo

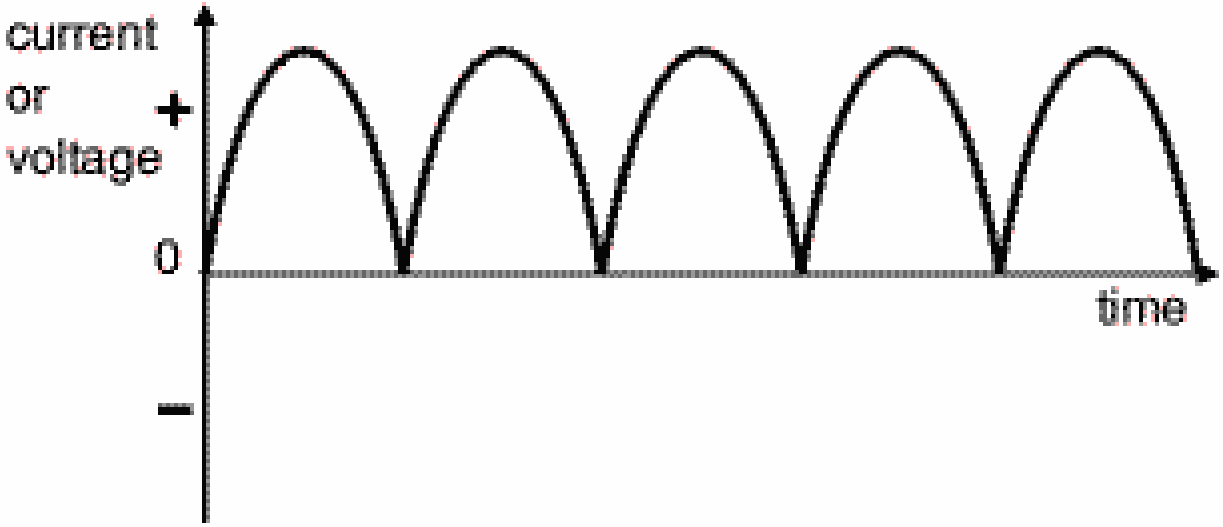
Undersea cable

Praha Sever SOURCE: Eltodo

380kV cable in Berlin

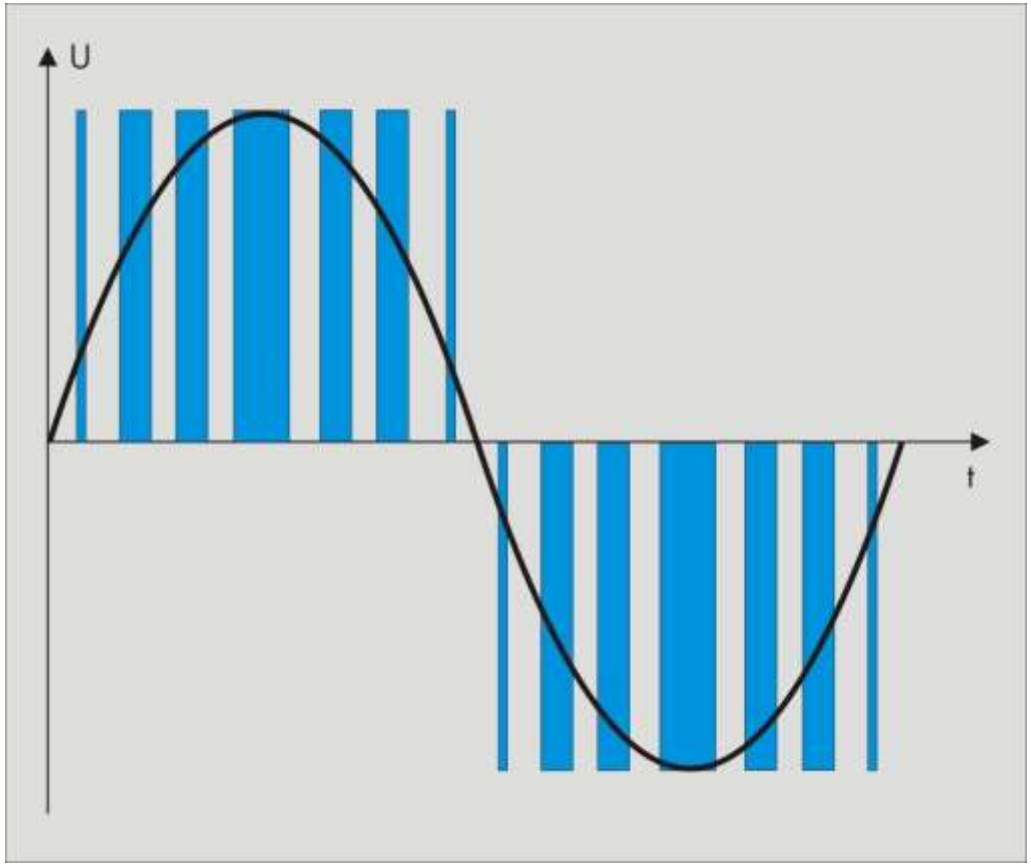
Source: Wikipedia

Converter - easy part

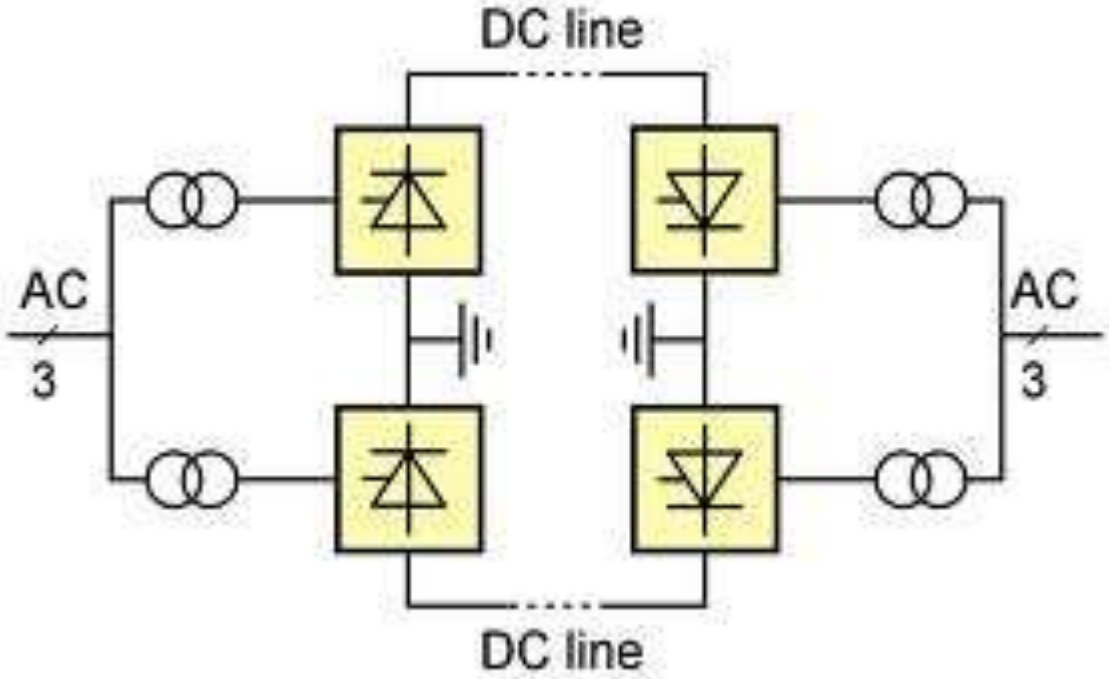


DC Variable

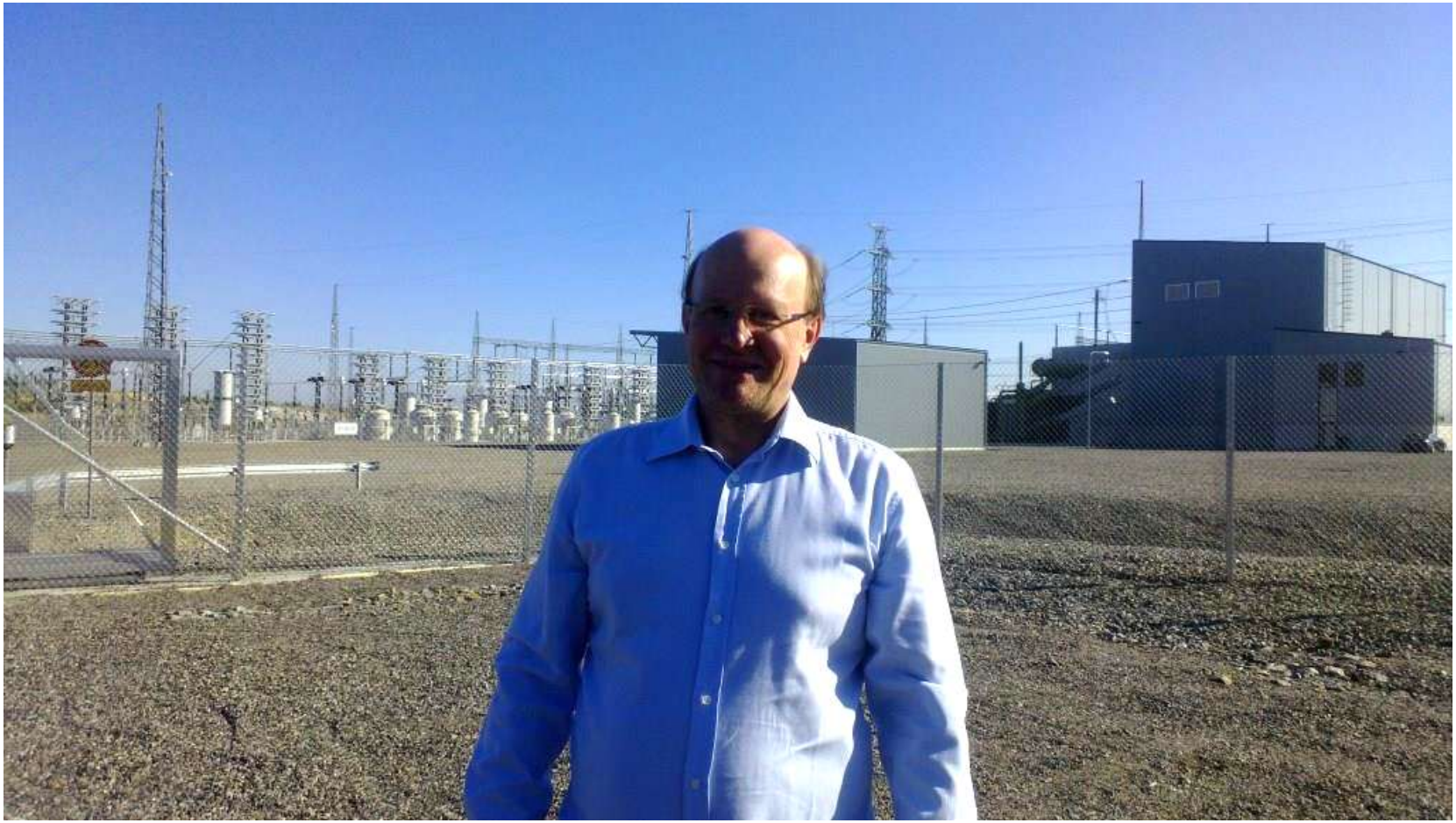
Converter - difficult part



Converter - done



Converter - built



Back-to-back

Back-to-back station Etzenricht

SOURCE: Wikimedia

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Good old times

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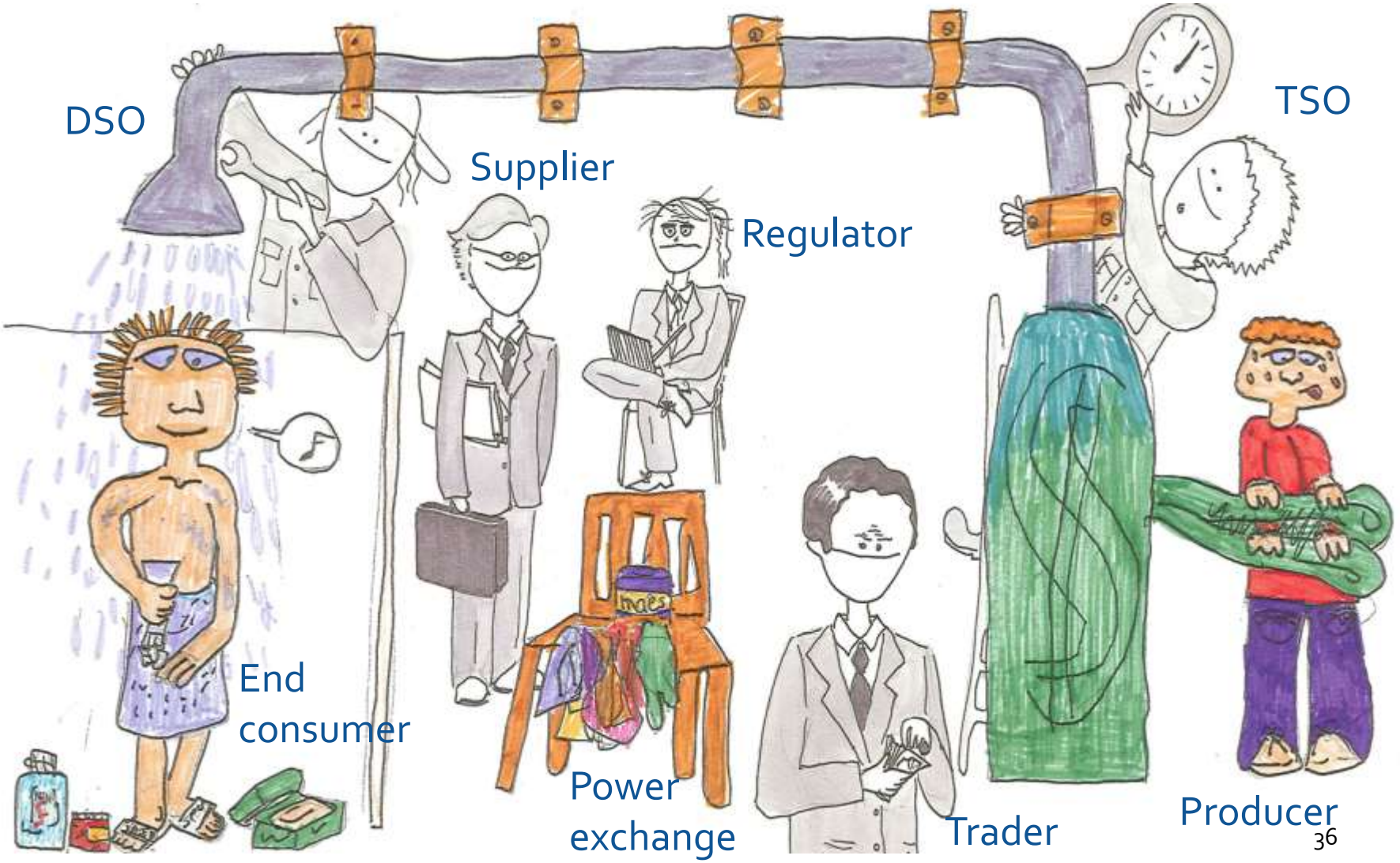
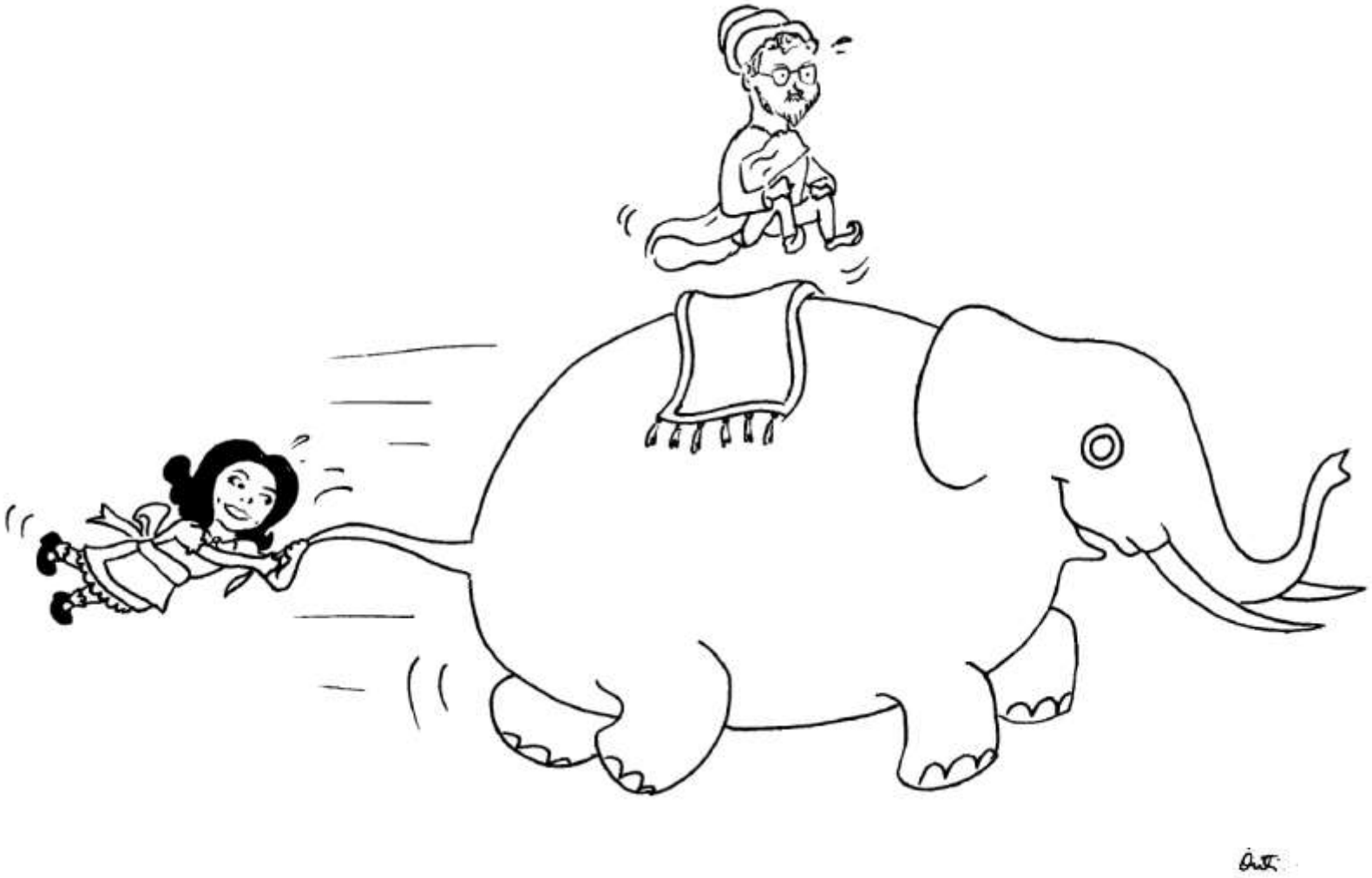
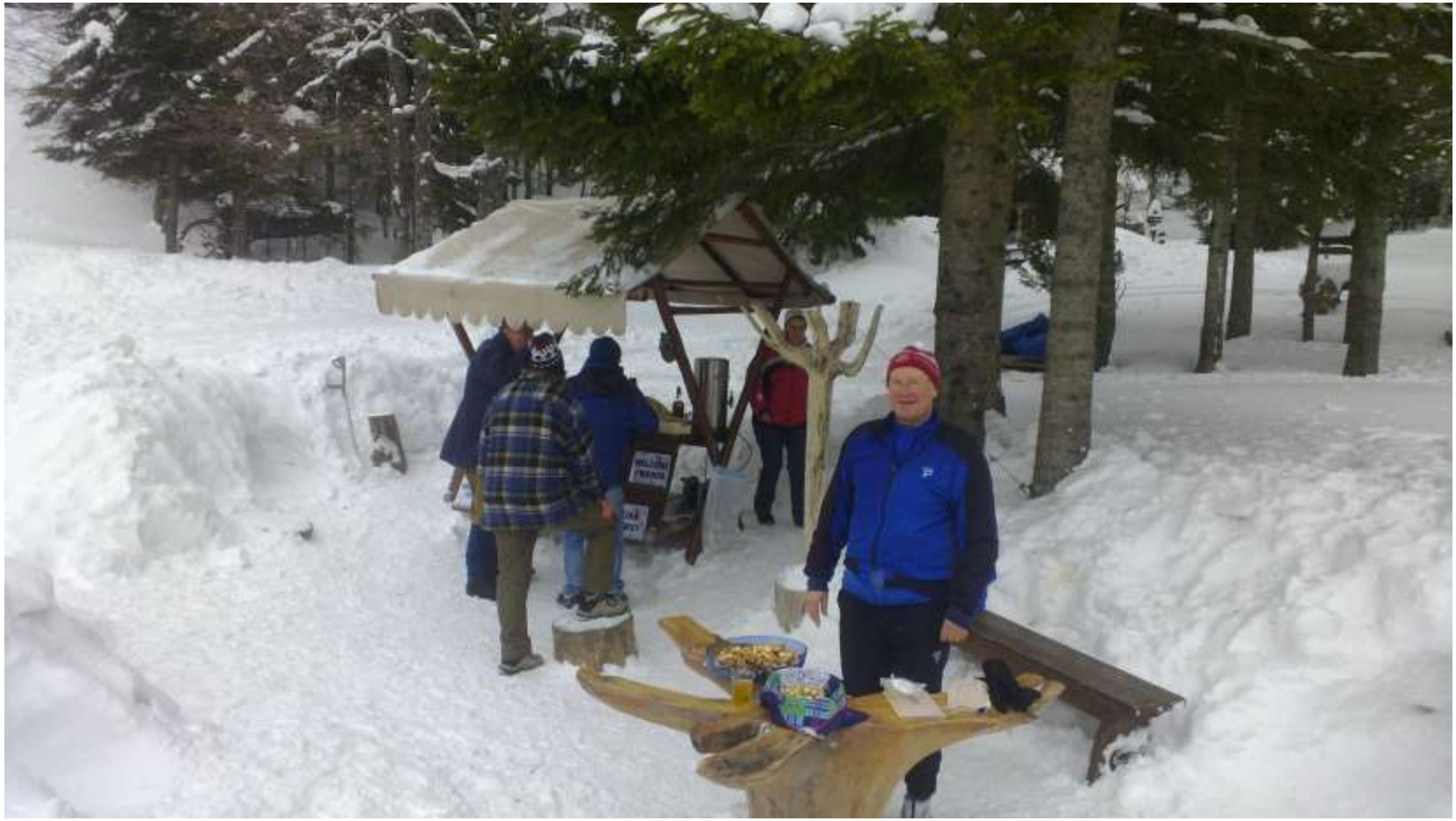
New roles



Regulator's life is not always easy



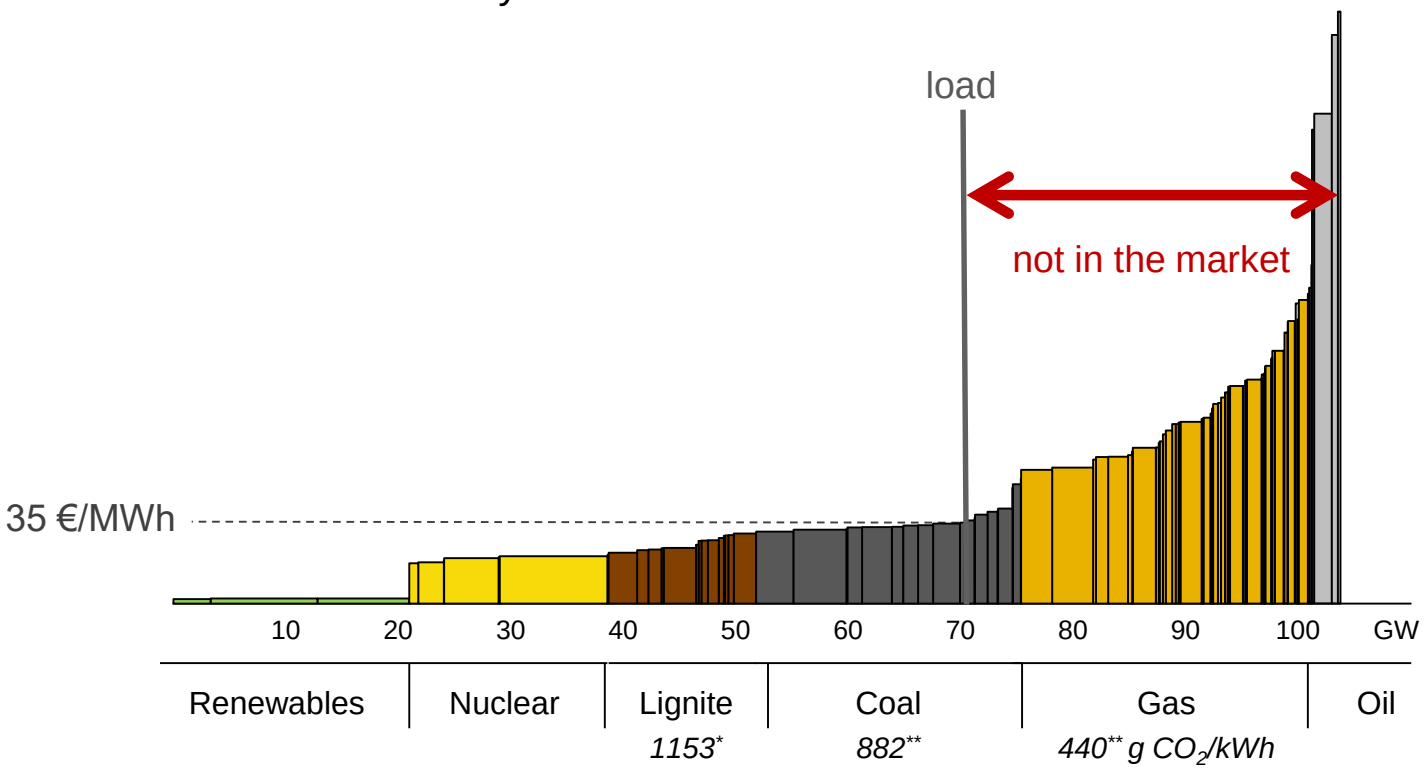
Power market



Power market

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

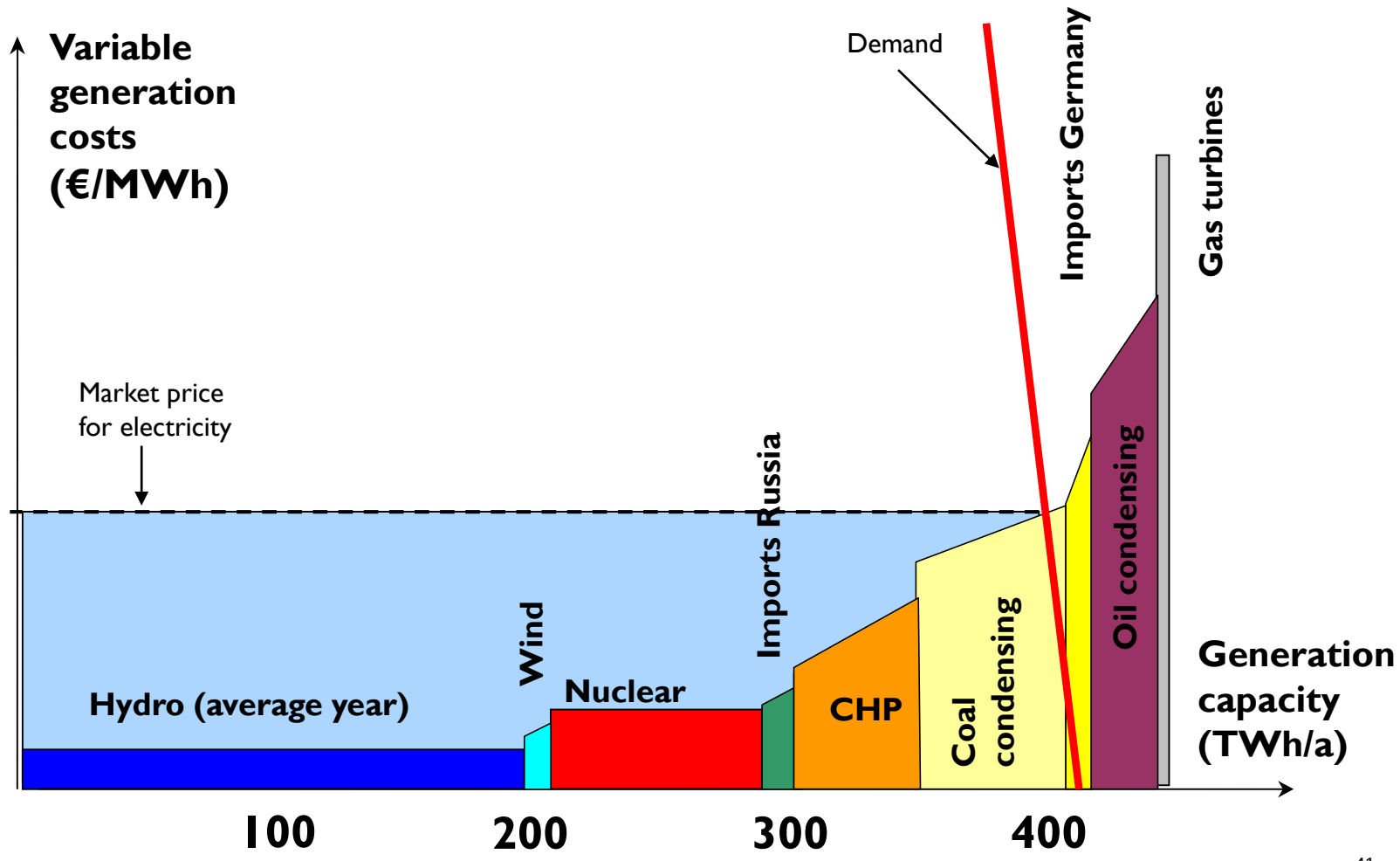
Merit Order Austria/Germany 2014



* www.co2-emissionen-vergleich.de

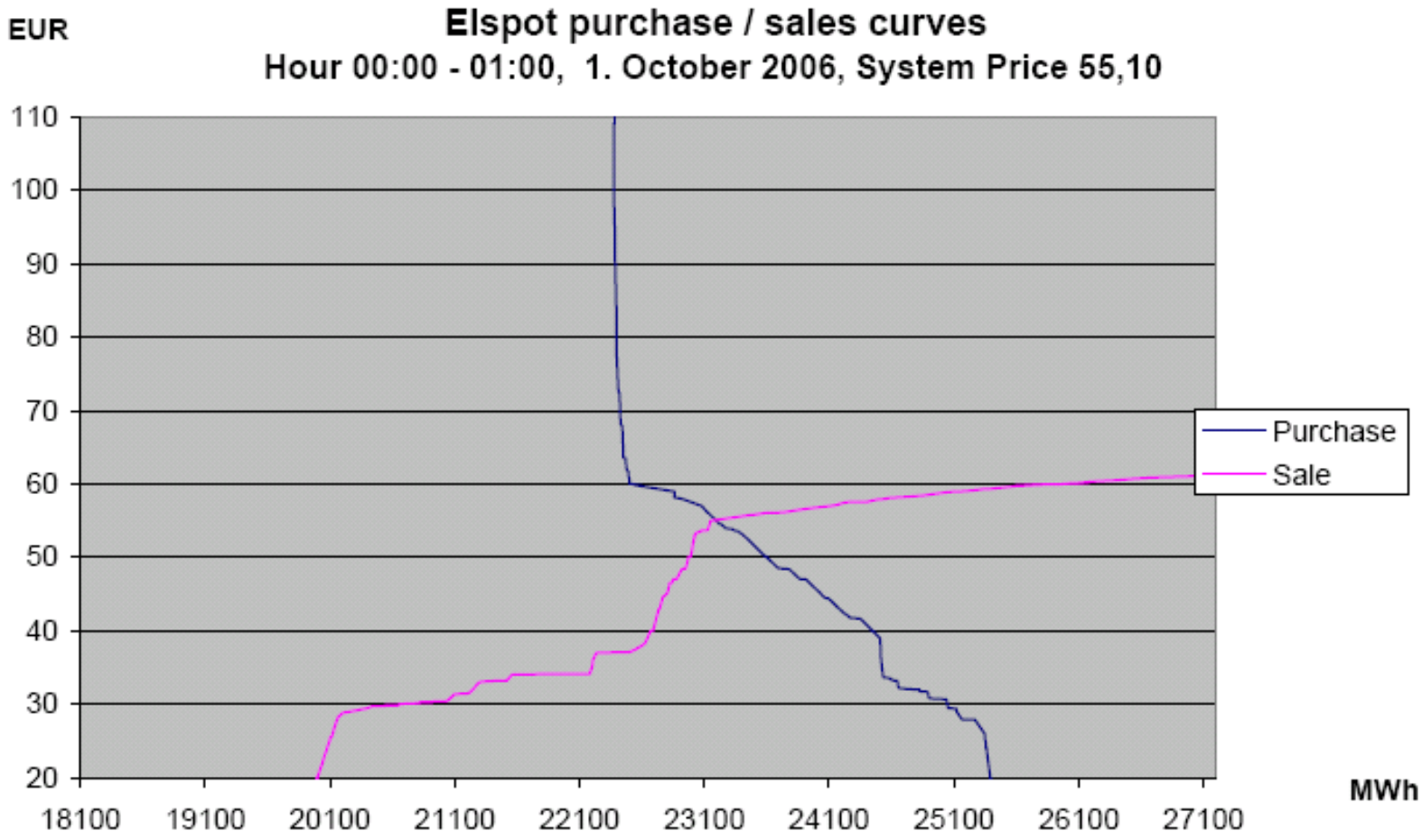
** E-Control-Referenzwerte

Nordic electricity market without EU ETS



SOURCE: Federation of Finnish Technology industries

Nord pool spot



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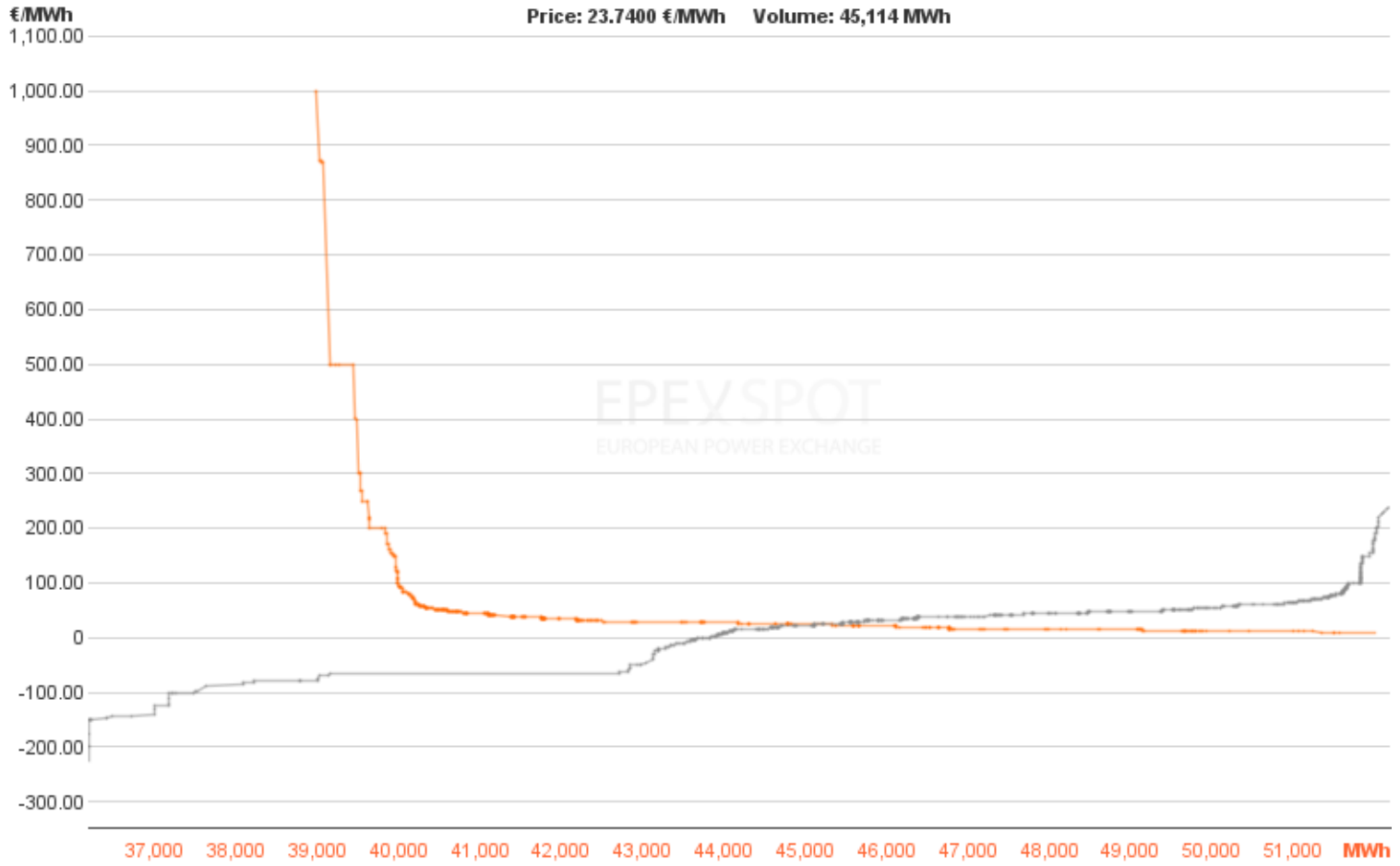
EPEX Germany/Austria



Price for 13.1.2015 hour 11-12

Market coupling

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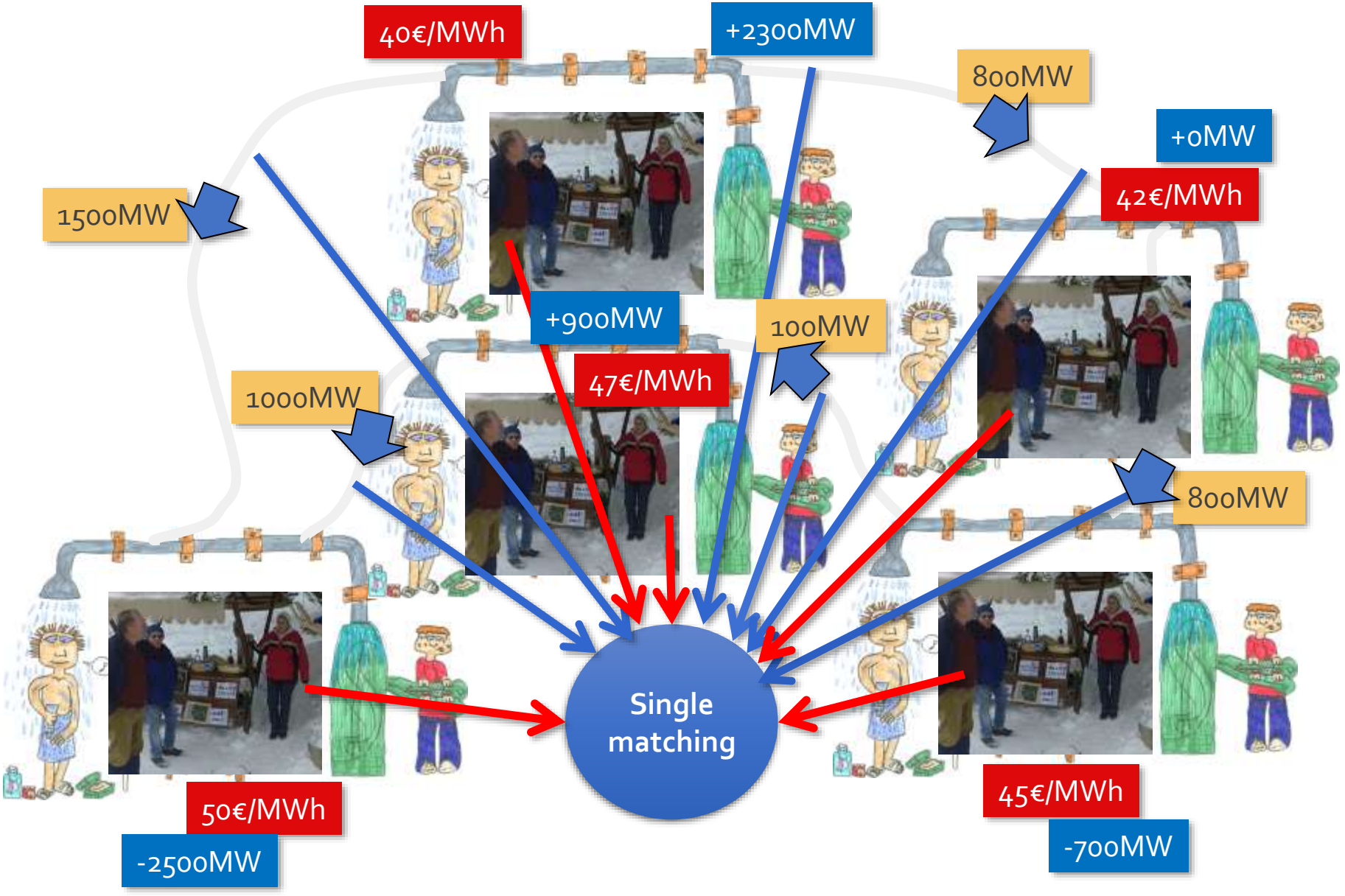
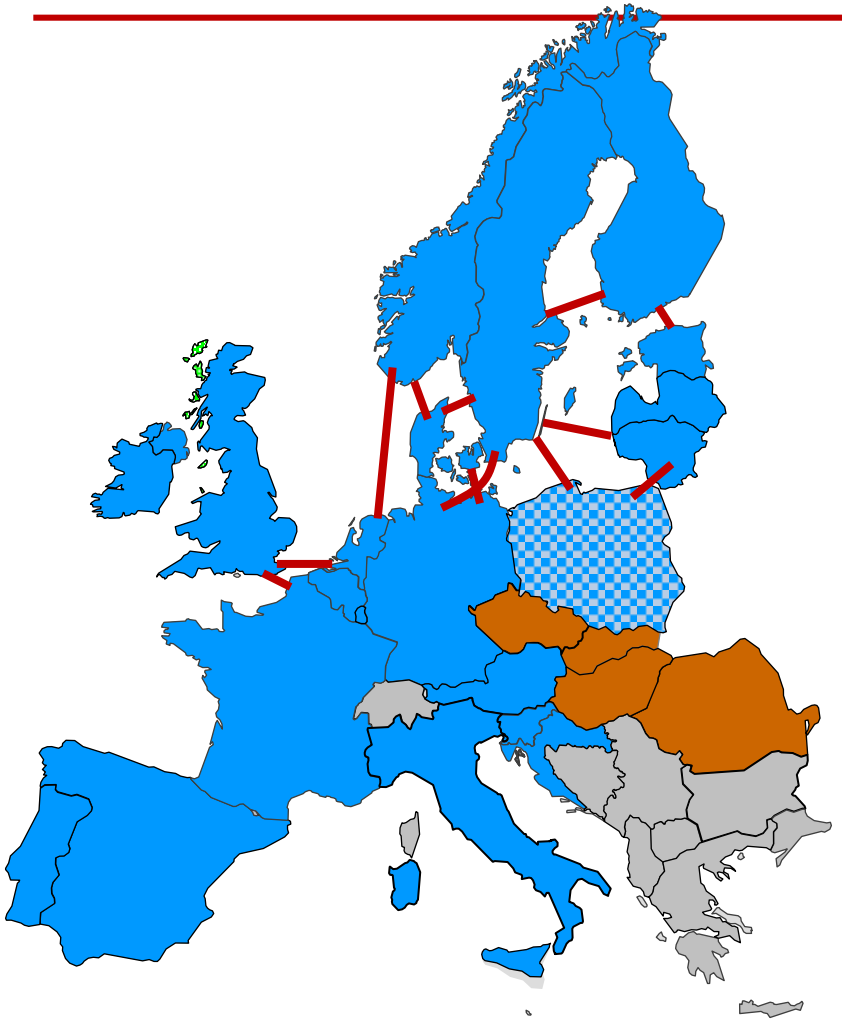


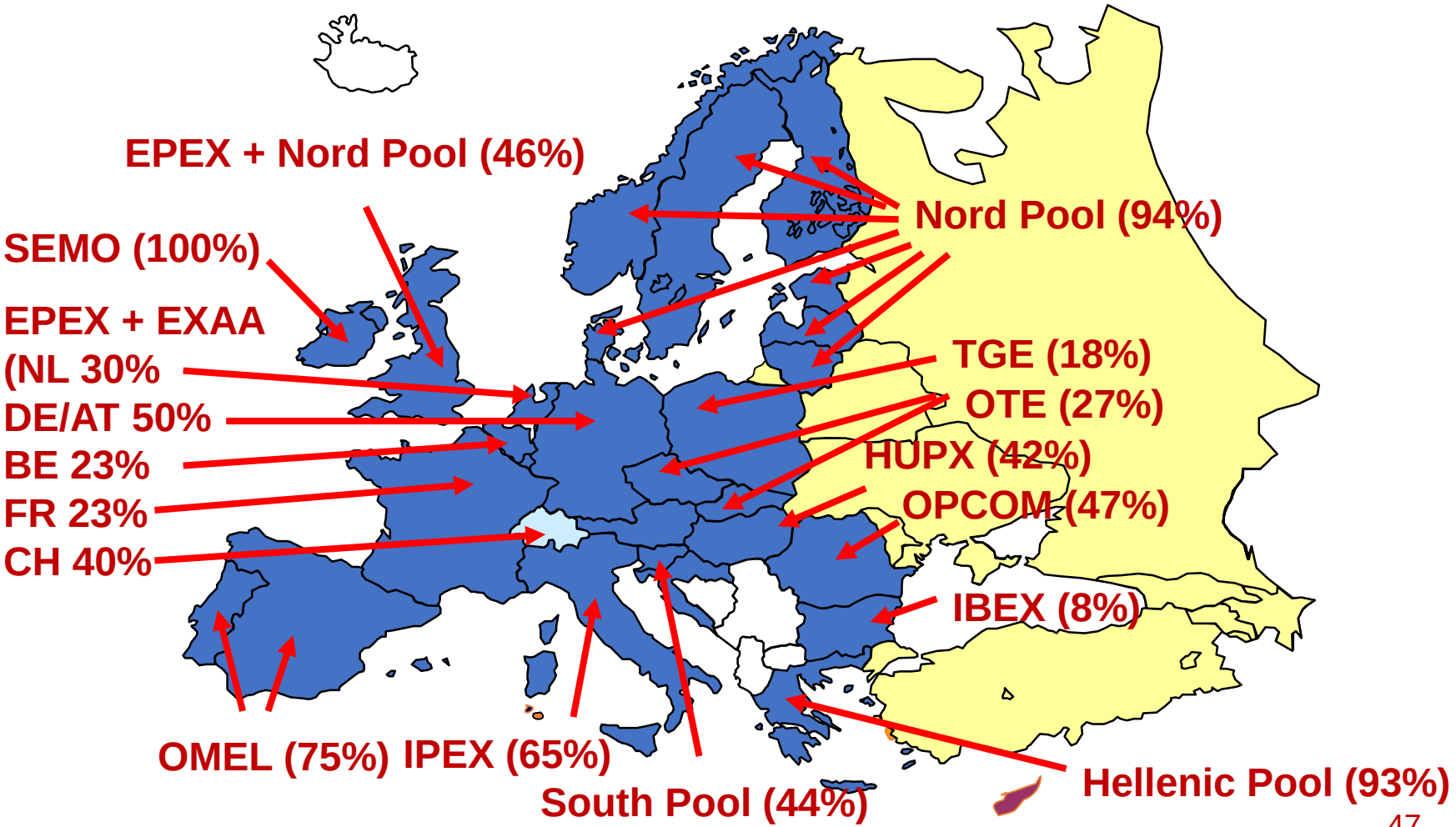
Day-ahead market coupling status in December 2019



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

Source: APX, updated by Matti Supponen

Share of day-ahead spot trading of consumption in 2016



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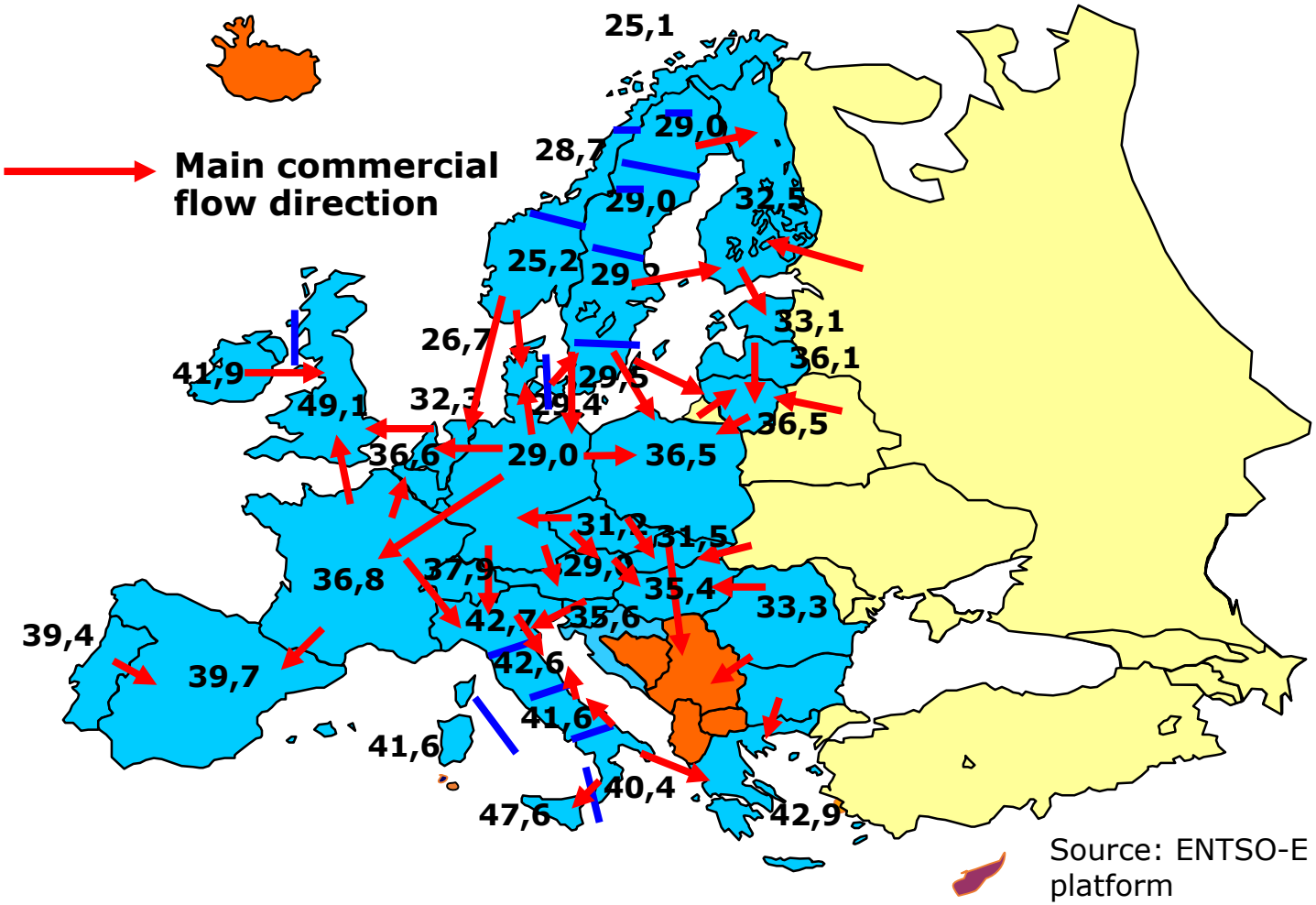
Average spot prices (€) and electricity cross-border trade in Europe (2016)



Source: ENTSO-E Transparency platform

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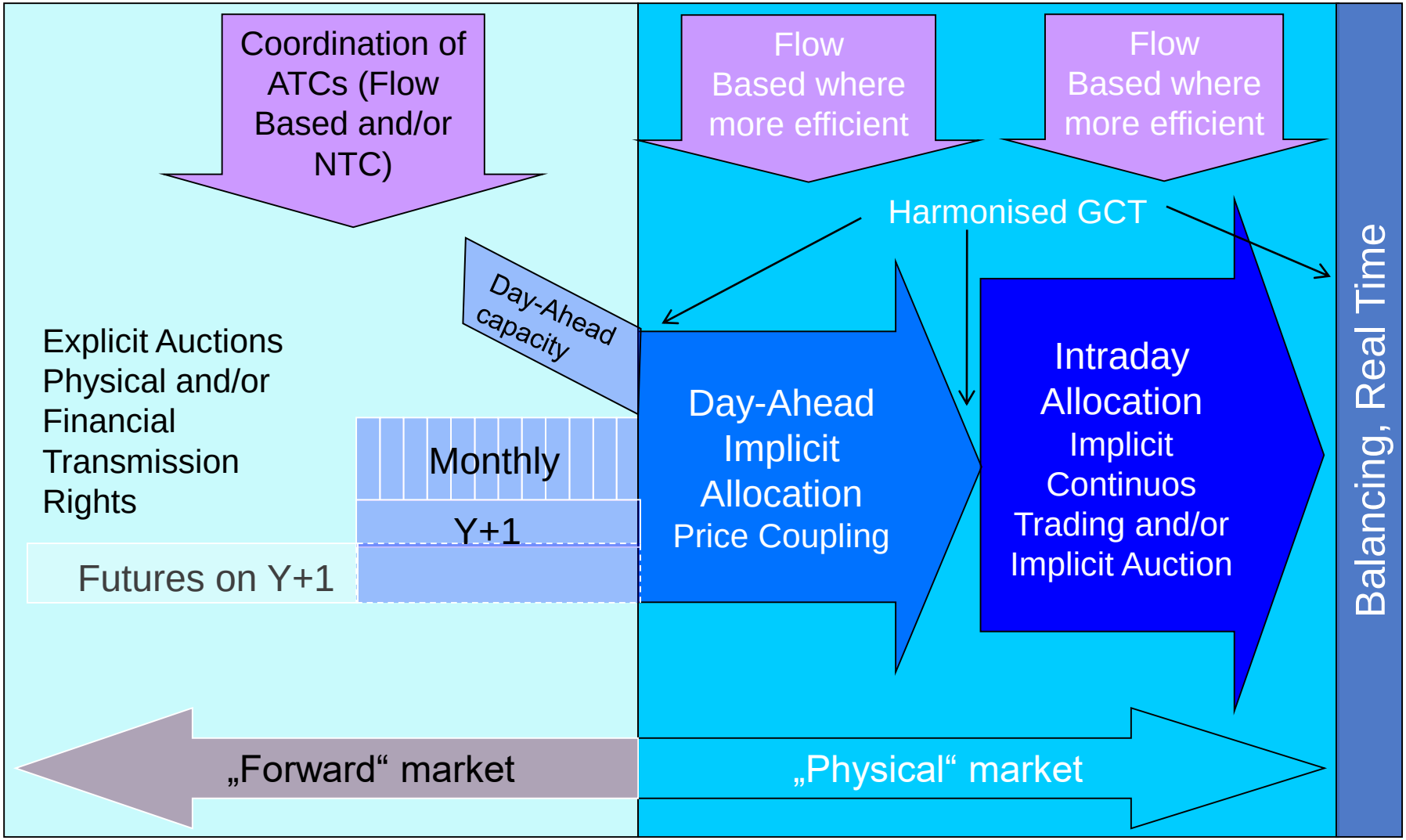
Target Model



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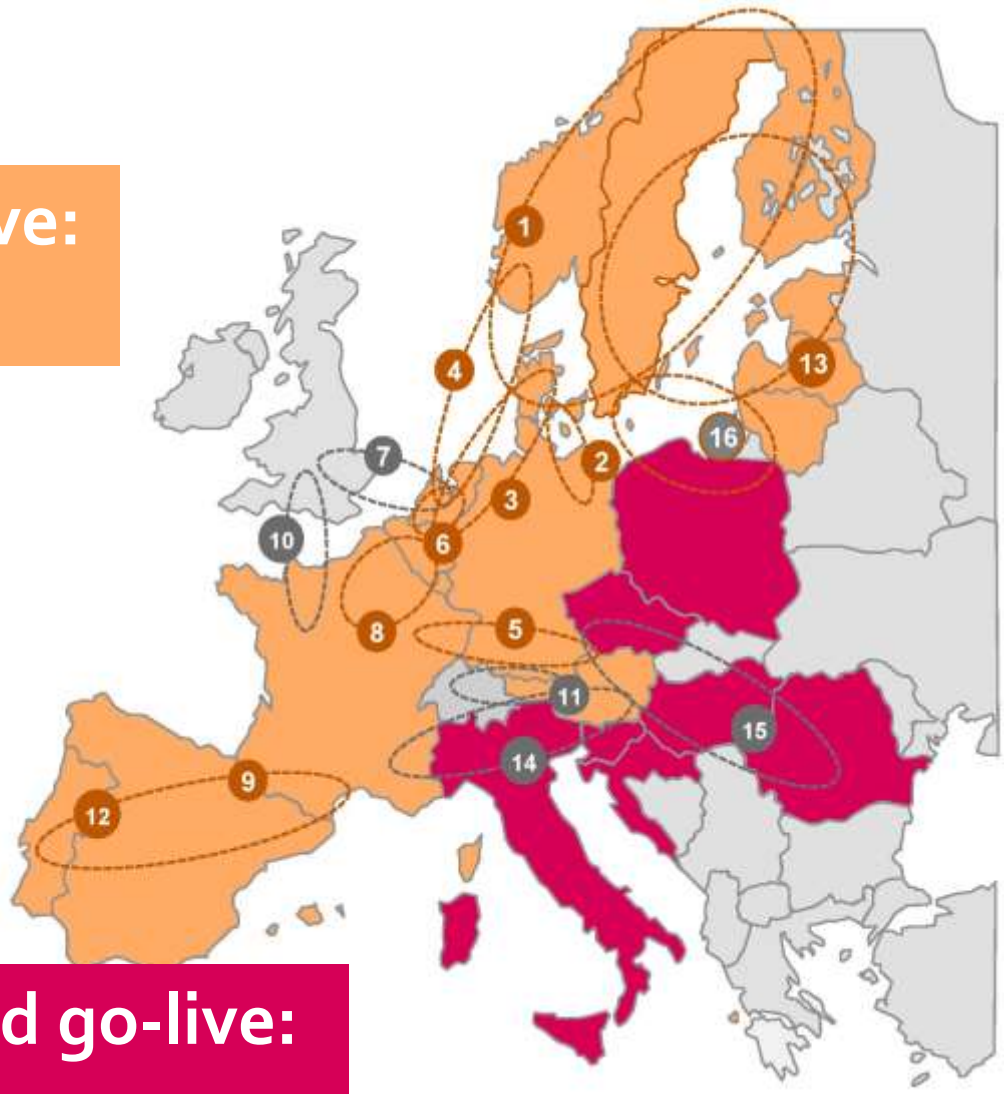
Delivery Areas to be launched at first go-live
50Hertz Transmission
Amprion
Austria
Denmark West
Denmark East
Estonia
Elia System Operator
Finland
Lithuania
Latvia
Netherlands
Norway 1-5
Portugal Delivery Area
France
Sweden 1-4
Spain Delivery Area
TransnetBW
TenneT TSO
Virtual areas:
Finland-Russia
Morocco 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



Source: XBID project

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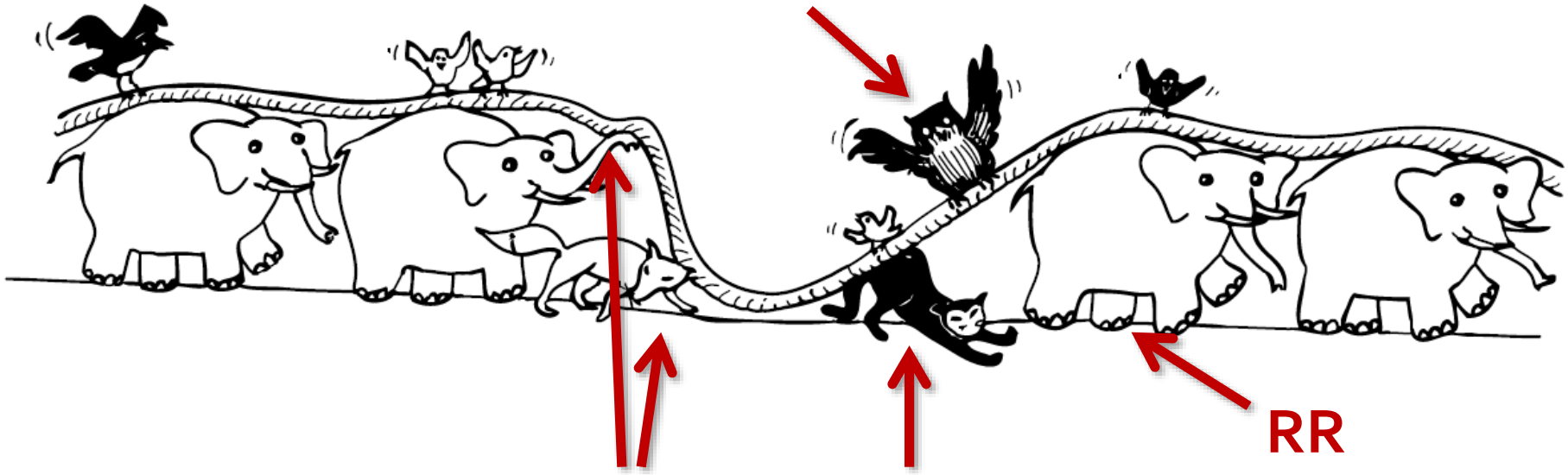
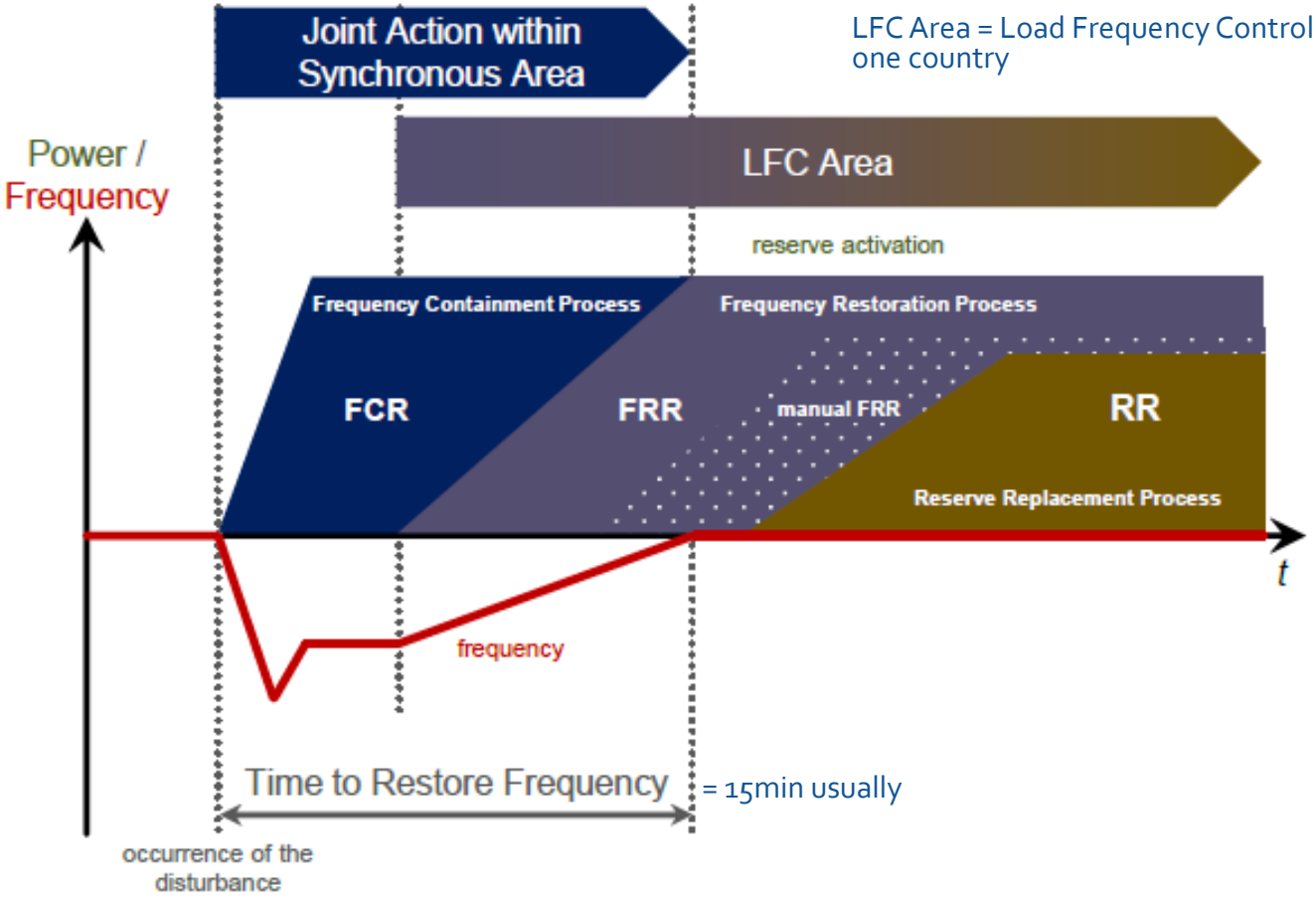
Balancing



Balancing



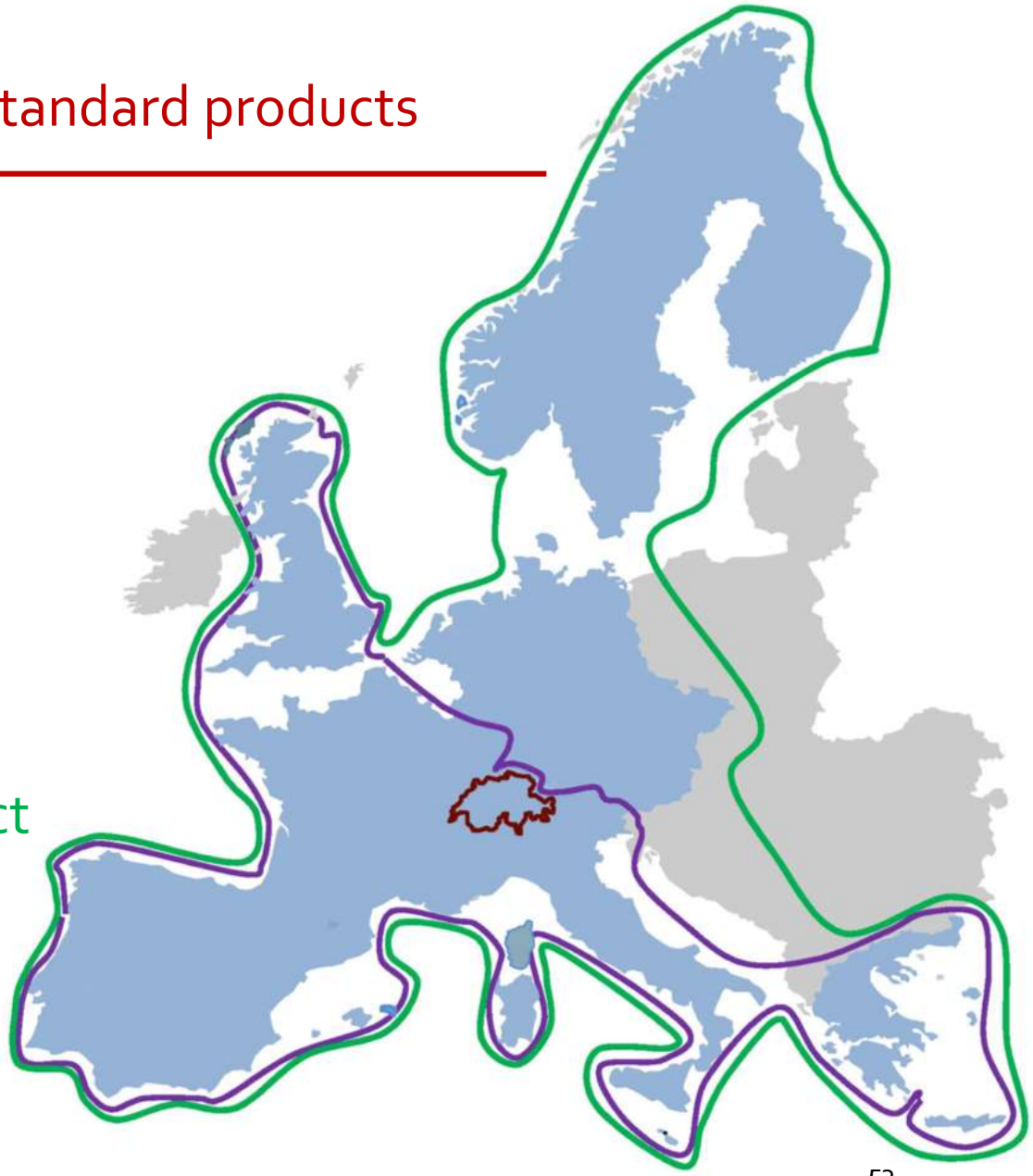
LFC Area = Load Frequency Control Area = usually one country

= 15min usually

Source: ENTSO-E

European platforms for standard products

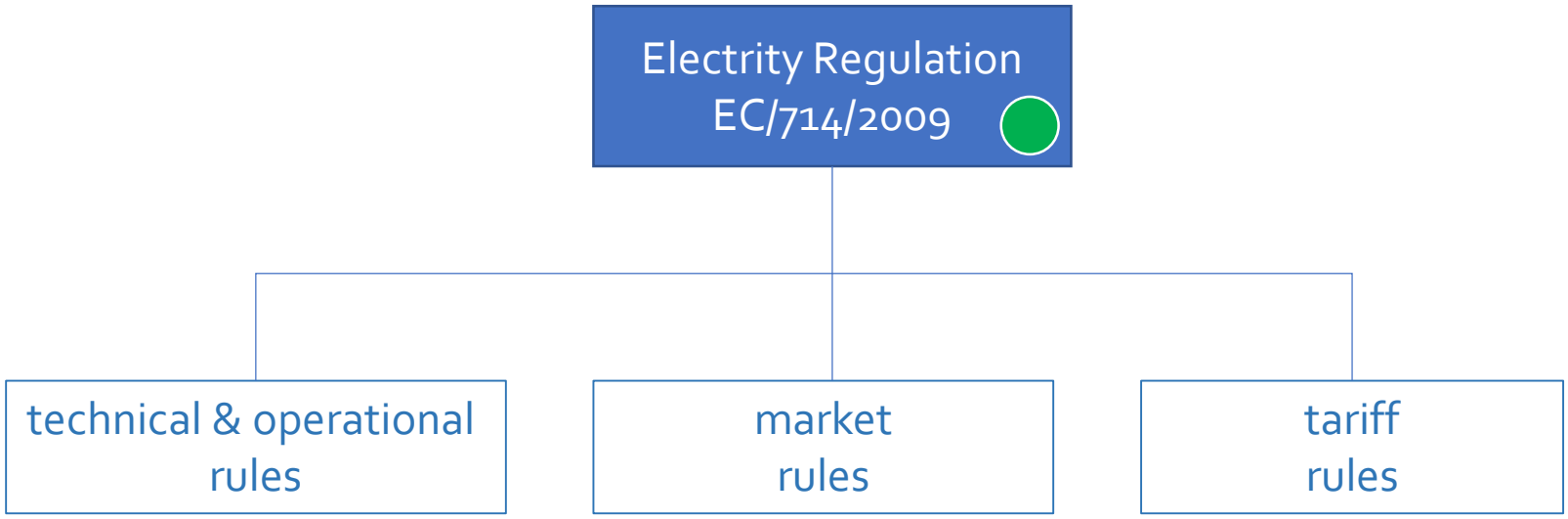
- RR market – **2019**
  Project Terre
- mFRR market – **2021**
  Project MARI
- aFRR market – **2022**
  ENTSO-E aFRR project



European electricity rules

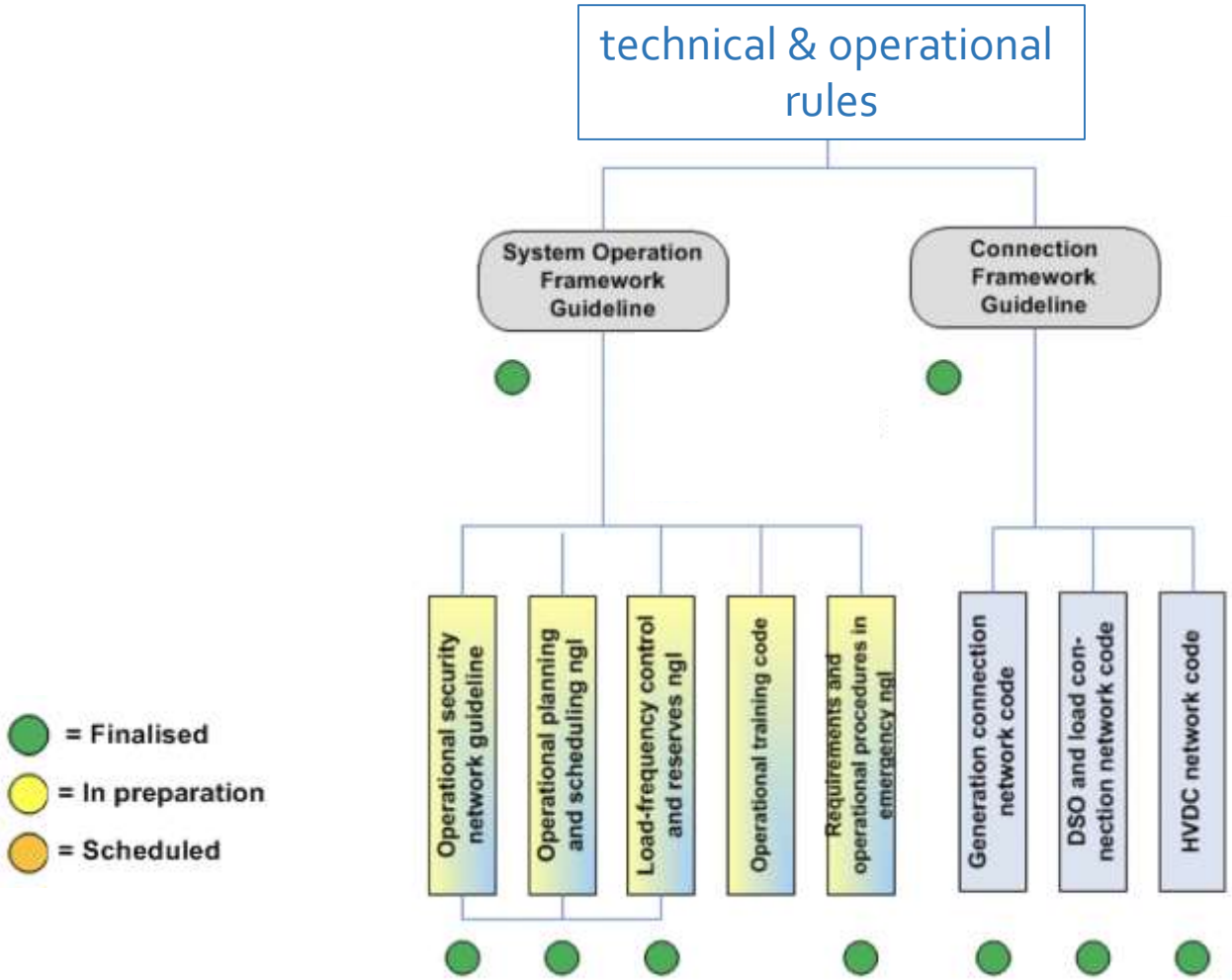
= Finalised
= In preparation
= Scheduled

European electricity rules

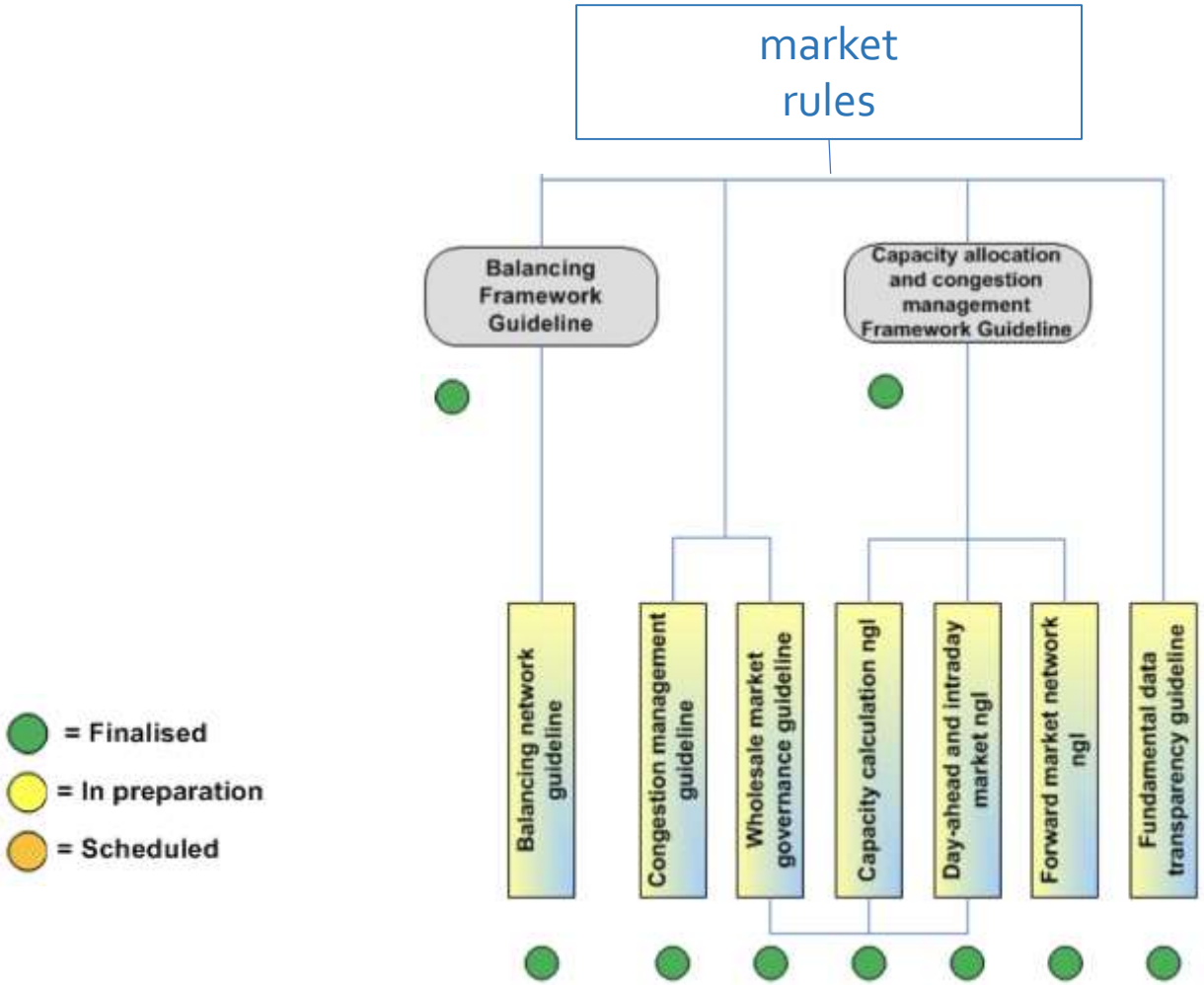


= Finalised
= In preparation
= Scheduled

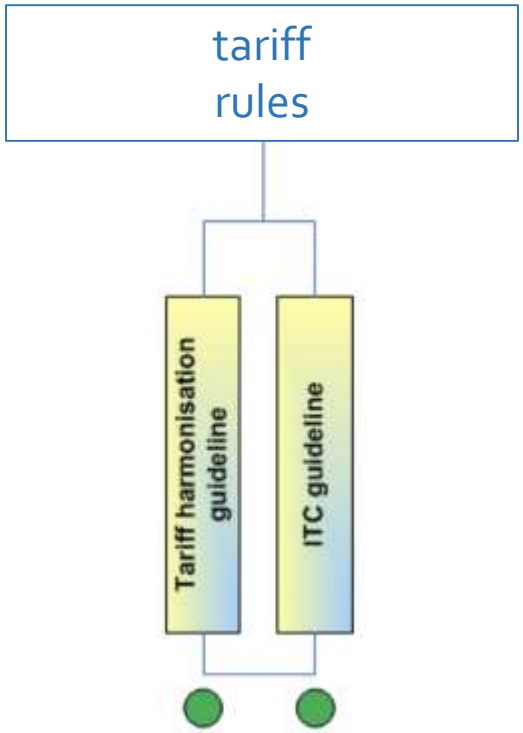
European electricity rules



European electricity rules



European electricity rules

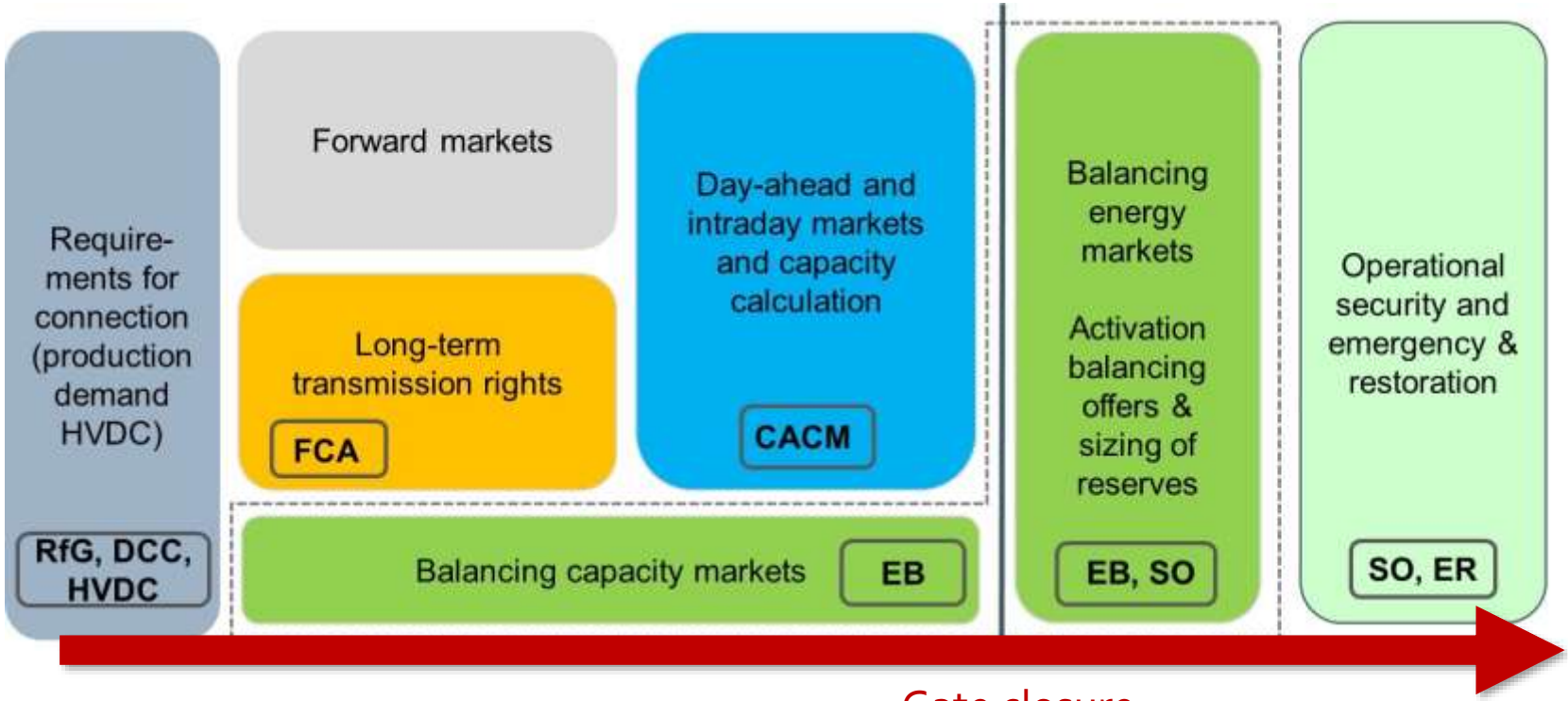


= Finalised

= In preparation

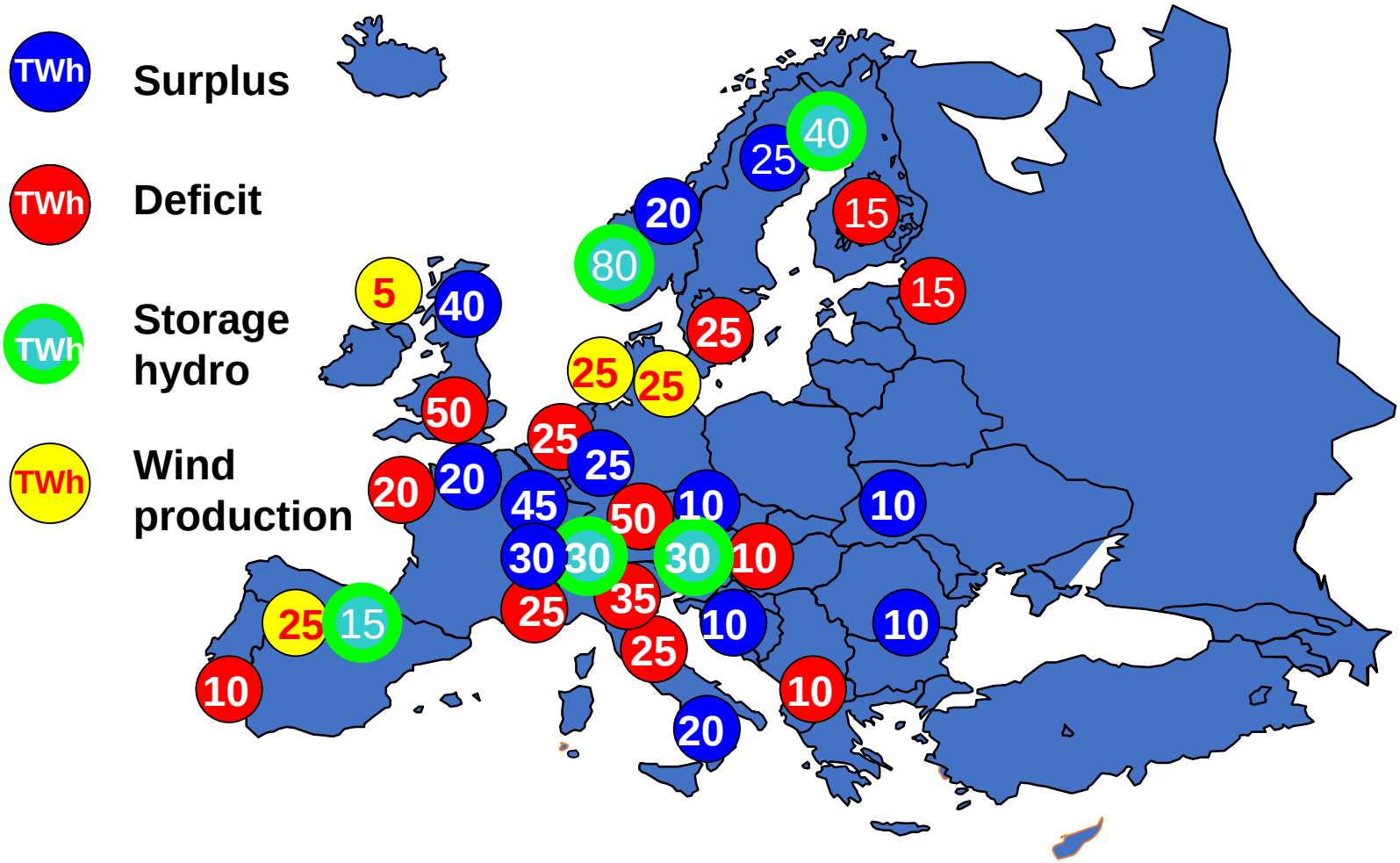
= Scheduled

Network codes

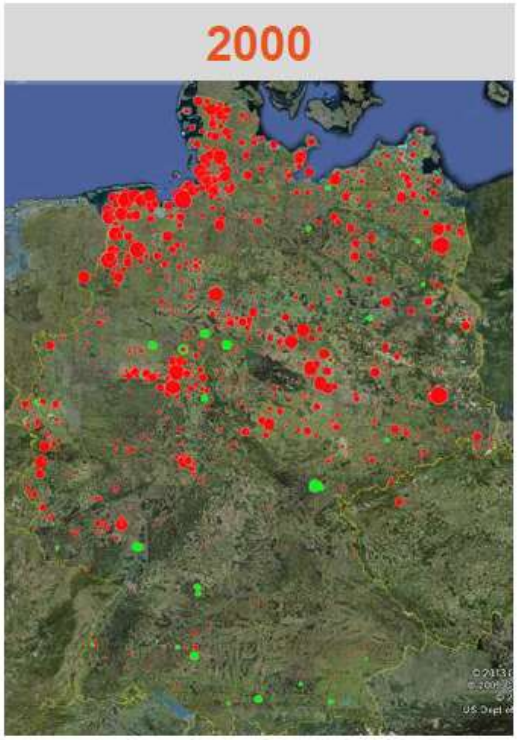


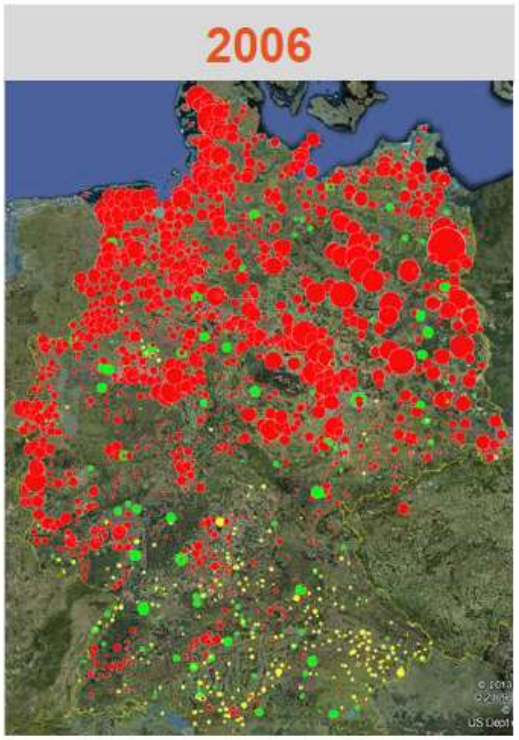
Source: ENTSO-E

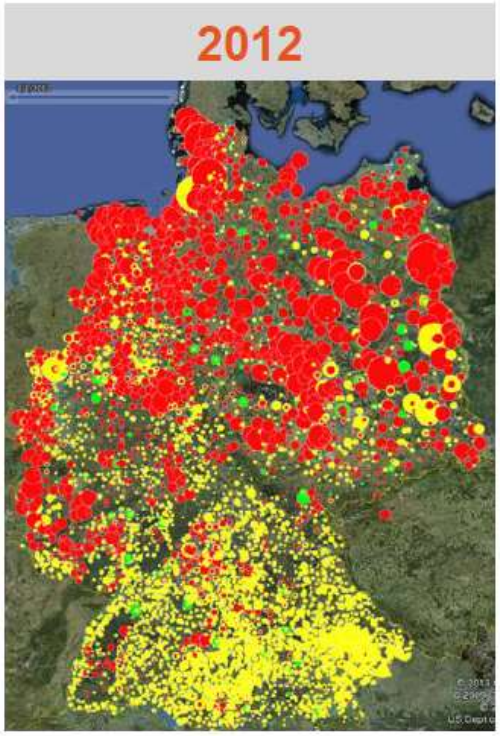
Surplus and deficit areas (2008)



Extension of Renewables in Germany







- Wind
- Photovoltaik
- Biomass

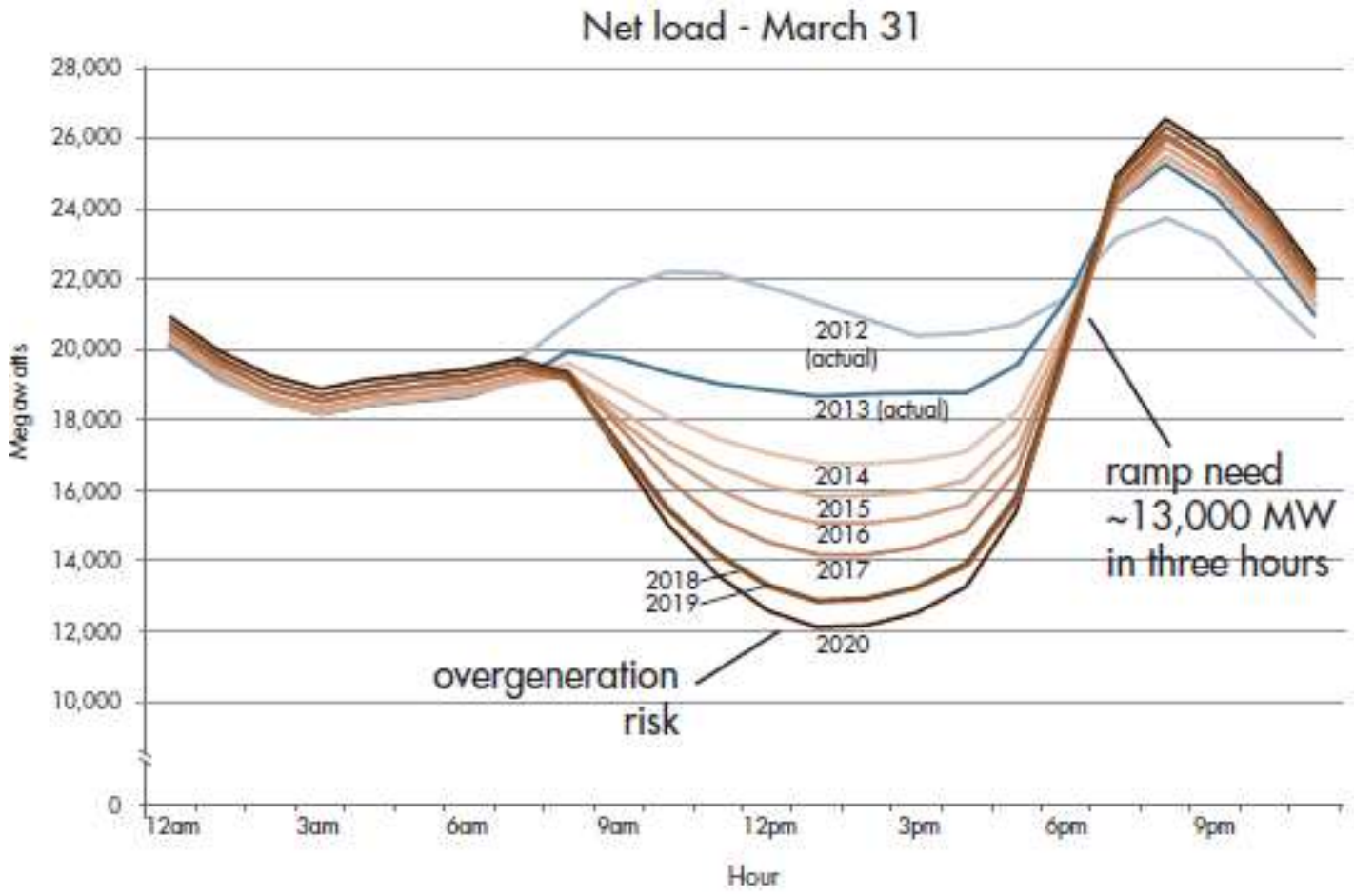
Source: 50HertzT, TenneT, Amprion, TransnetBW, Google Earth

August 2013:

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

Source: Boris Schucht, 5o Hertz

Duck curve



Source: Caiso

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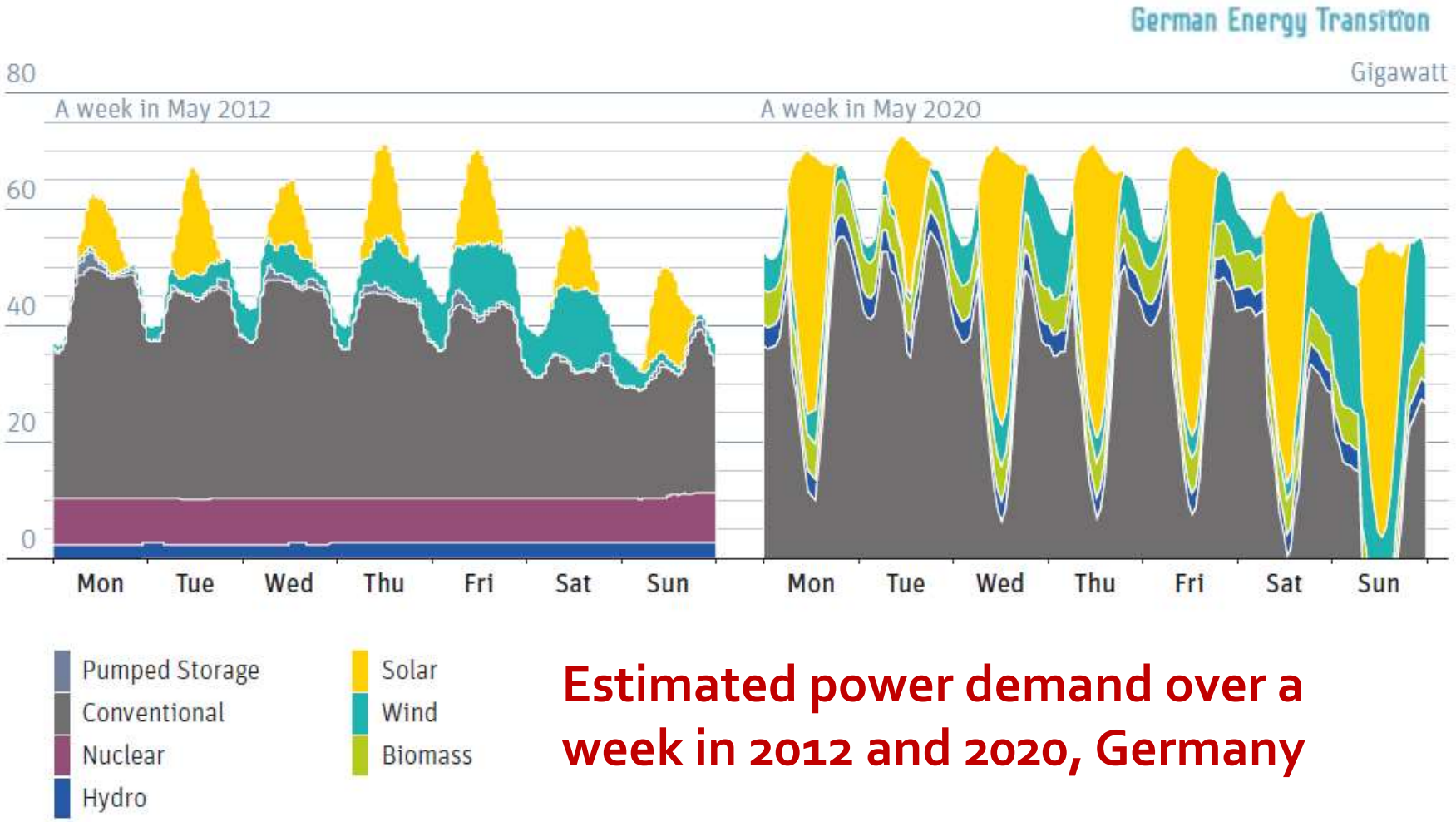
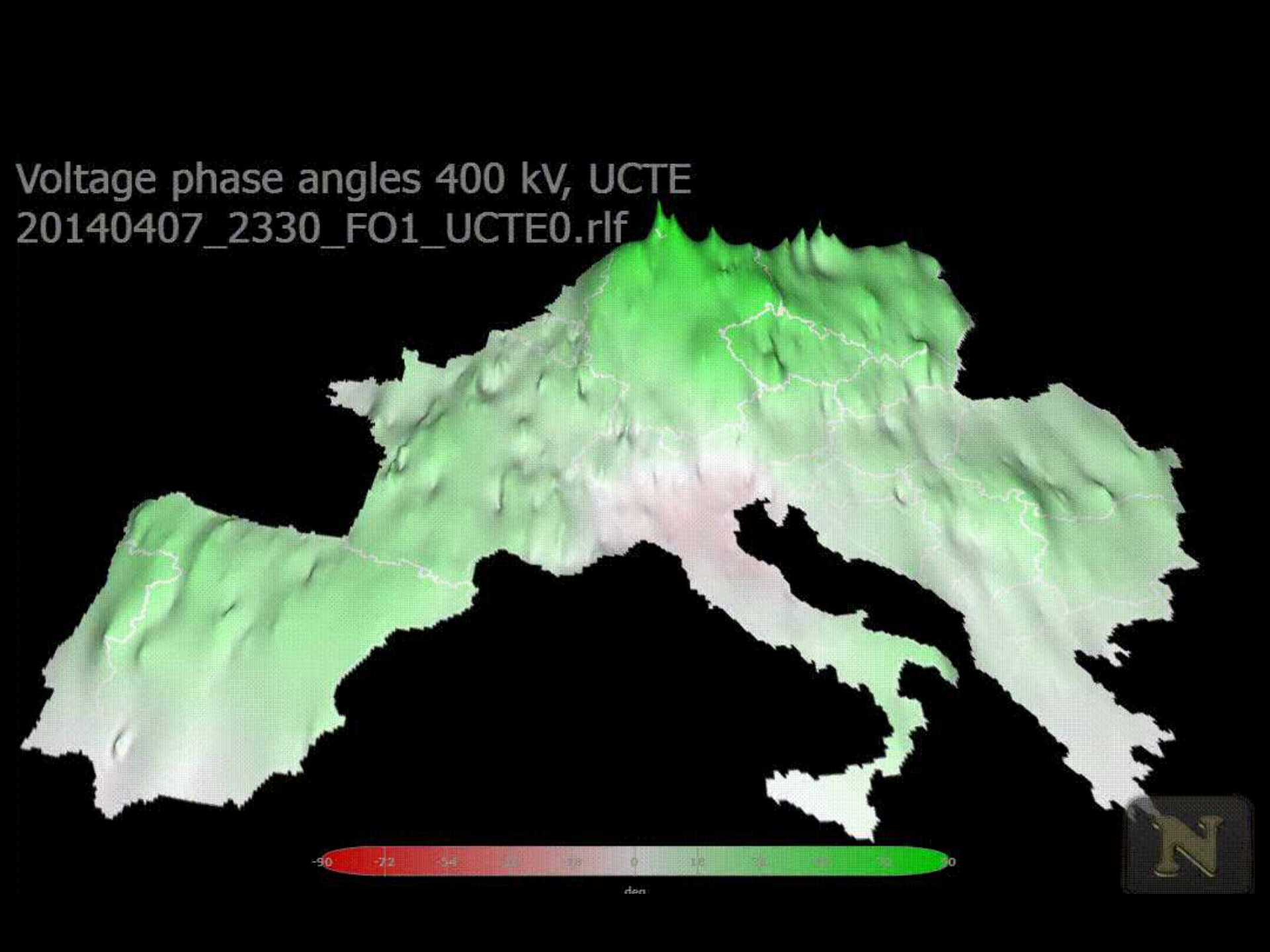
Renewables need flexible backup, not baseload



Estimated power demand over a week in 2012 and 2020, Germany

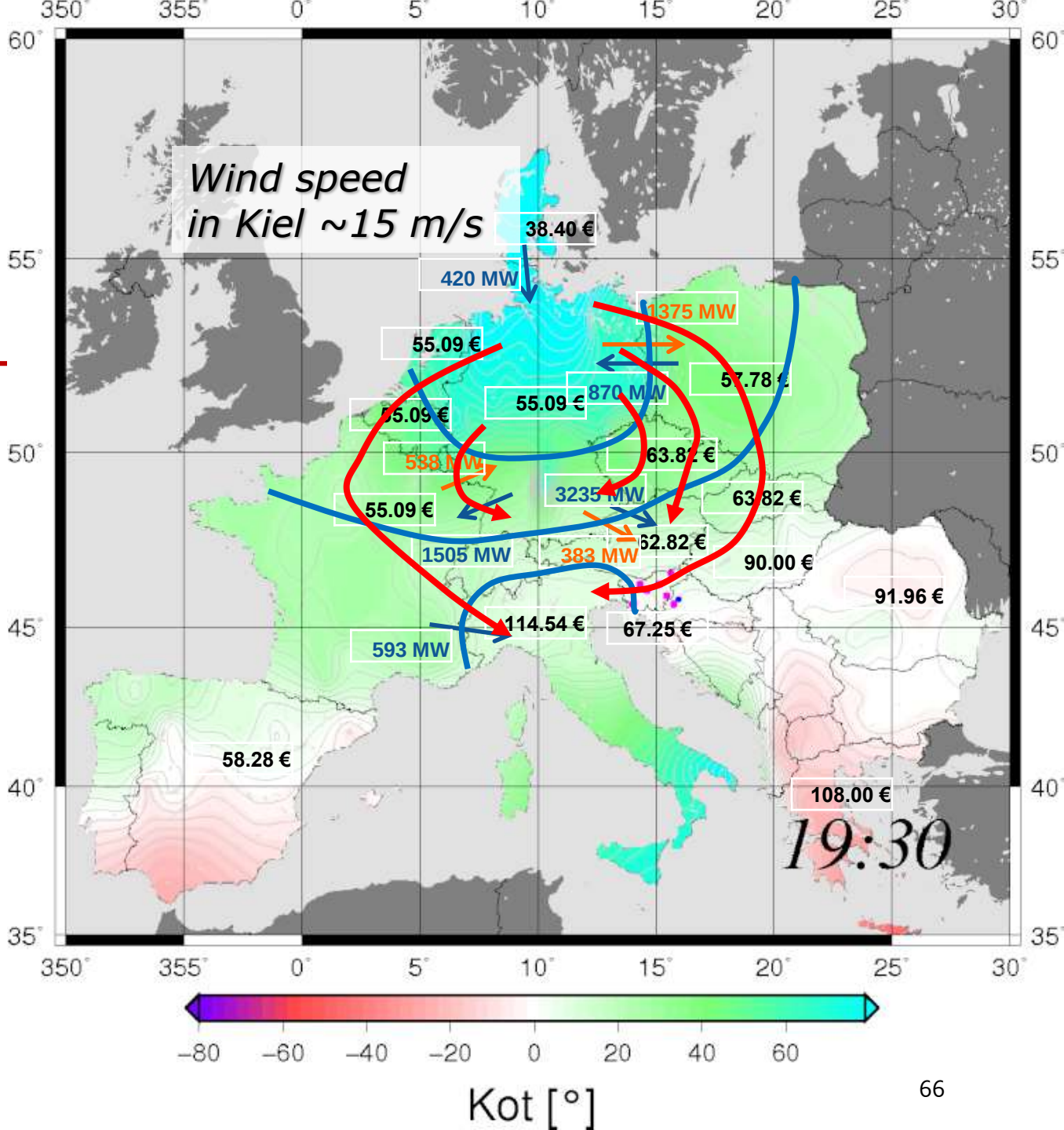
Source: Volker Quaschning, HTW


Voltage phase angles 400 kV, UCTE
20140407_2330_FO1_UCTE0.rlf
-90
-72
-54
0
18
36
54
90
deg

Low Carbon Ukraine

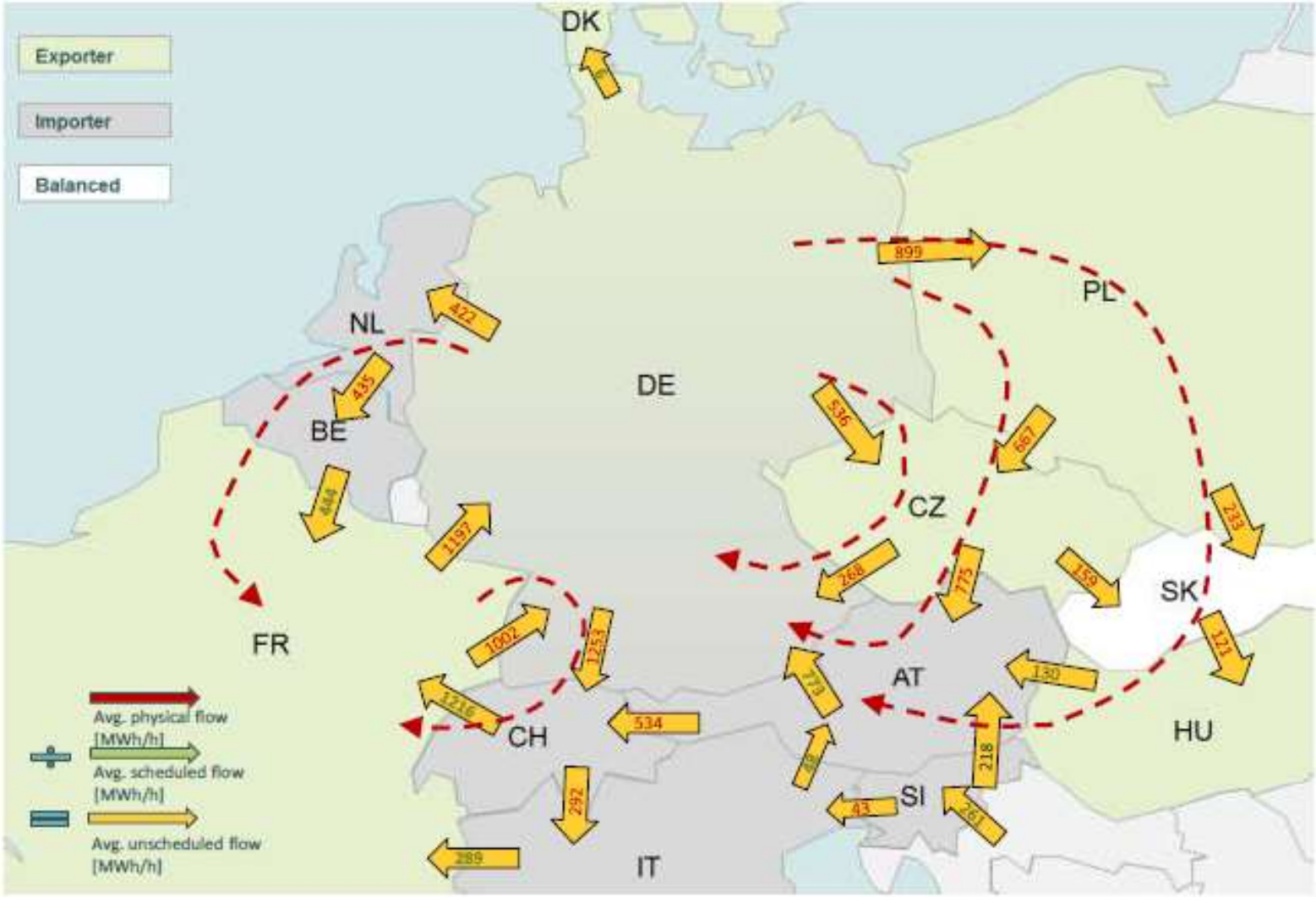
Prices & flows

8.12.2011



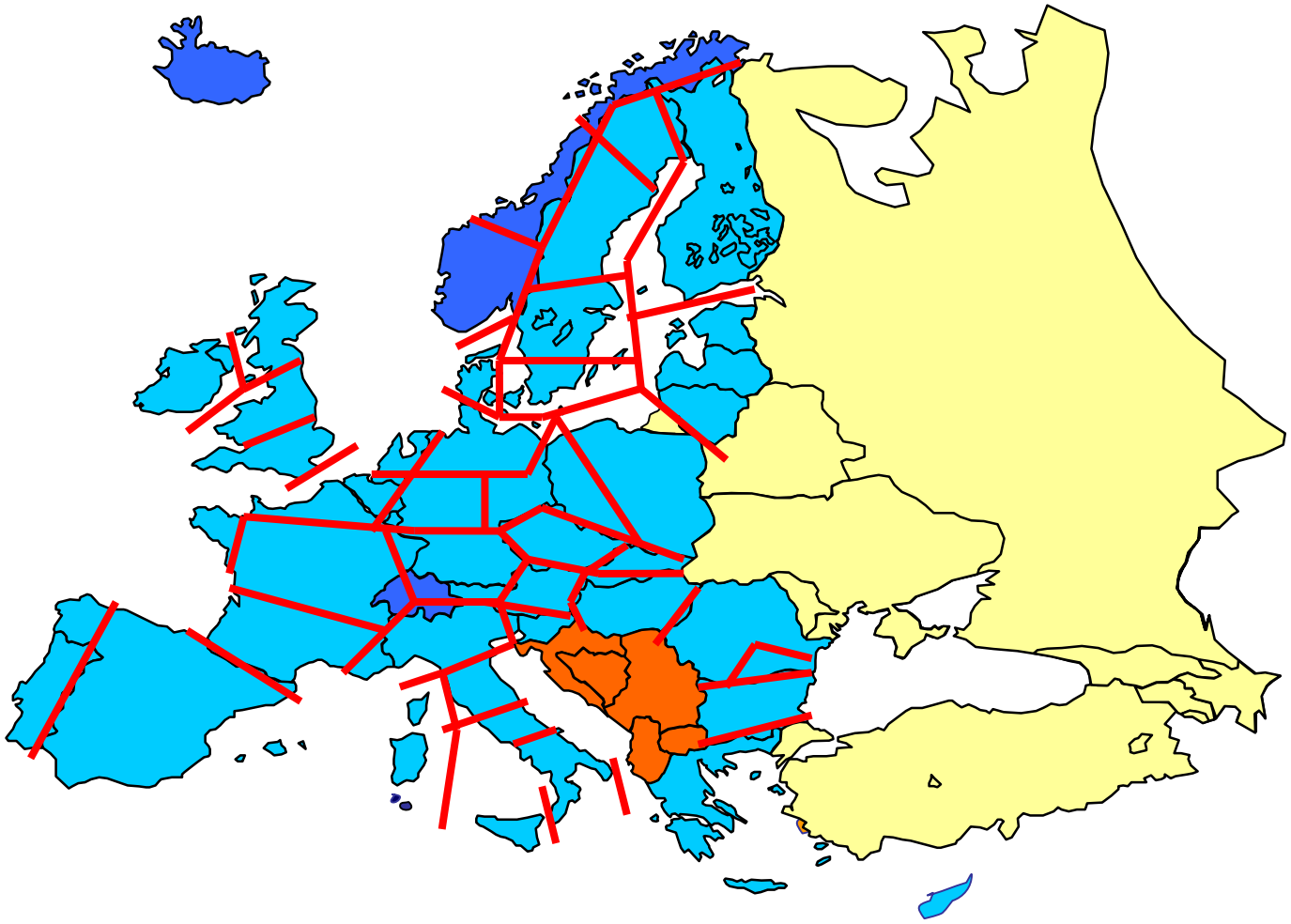
Phase angle map from ELES

Average unschueduled flows (2011, 2012, in MWh/h)

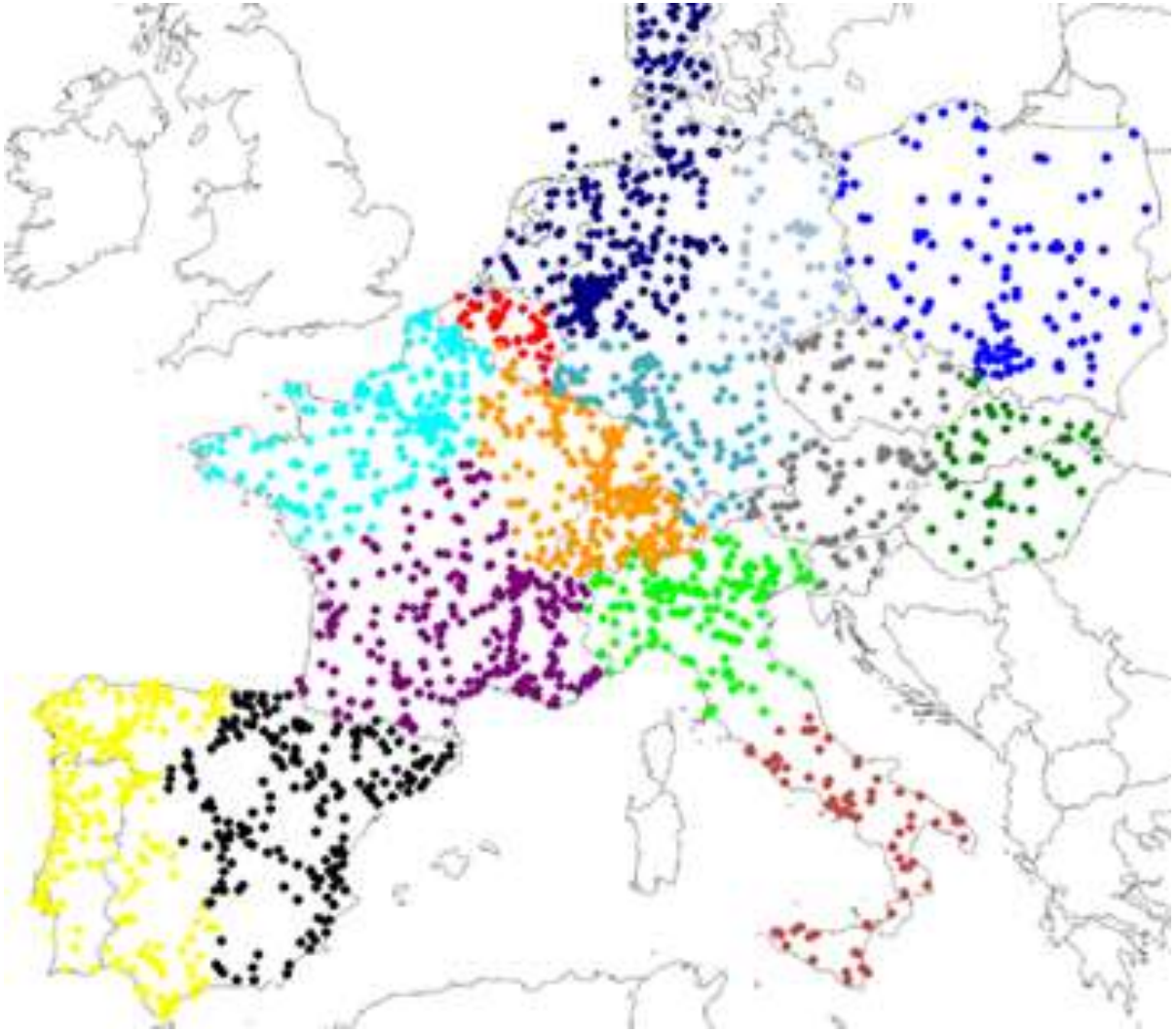


Source: THEMA Consulting Group

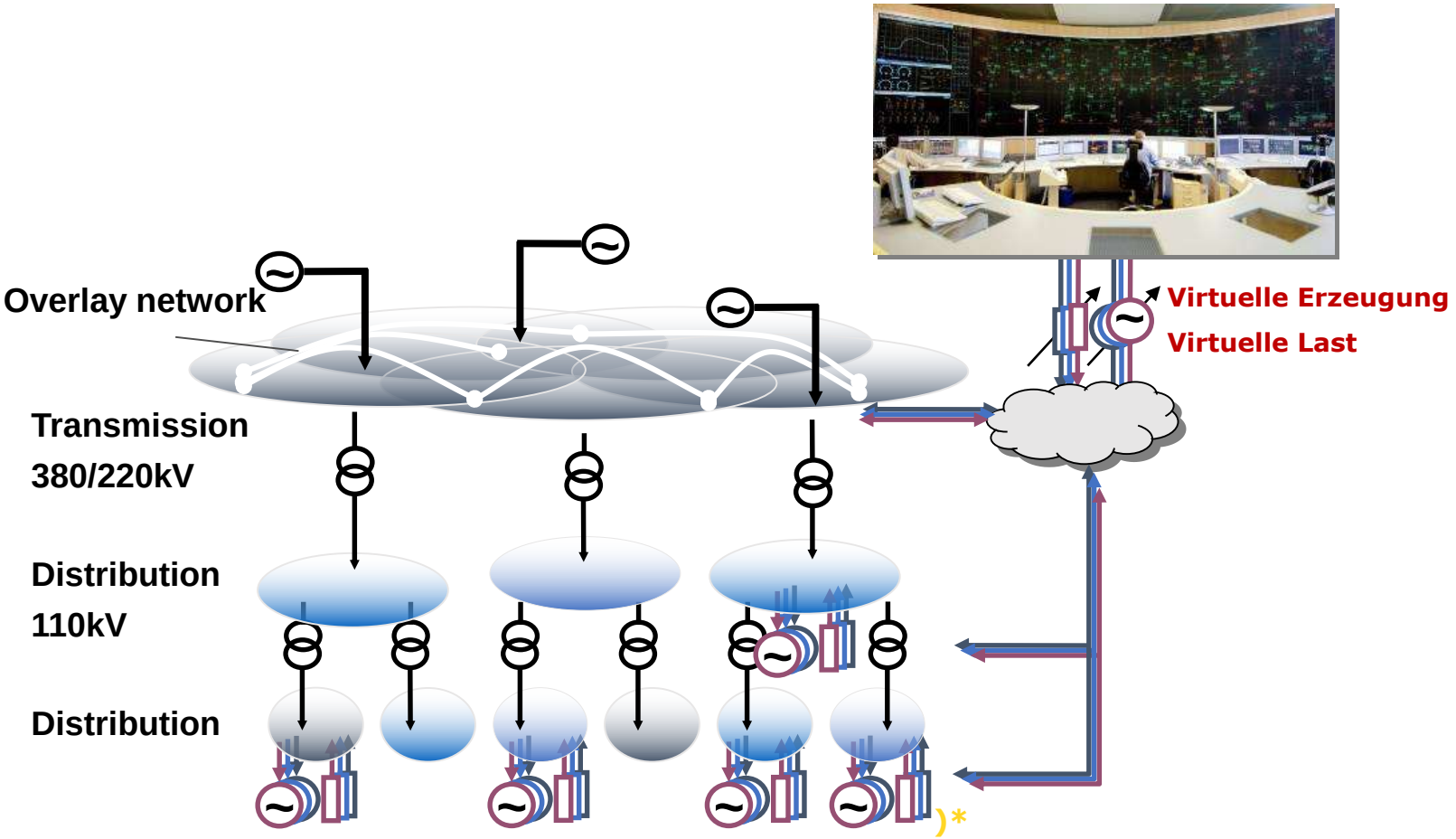
Matti's proposal for electricity spot-market price zones in Europe



Or is nodal pricing better?



Overlay network?



Source: Klaus Kleinekorte in VDE DACH 2010 conference

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Strom-autobahnen

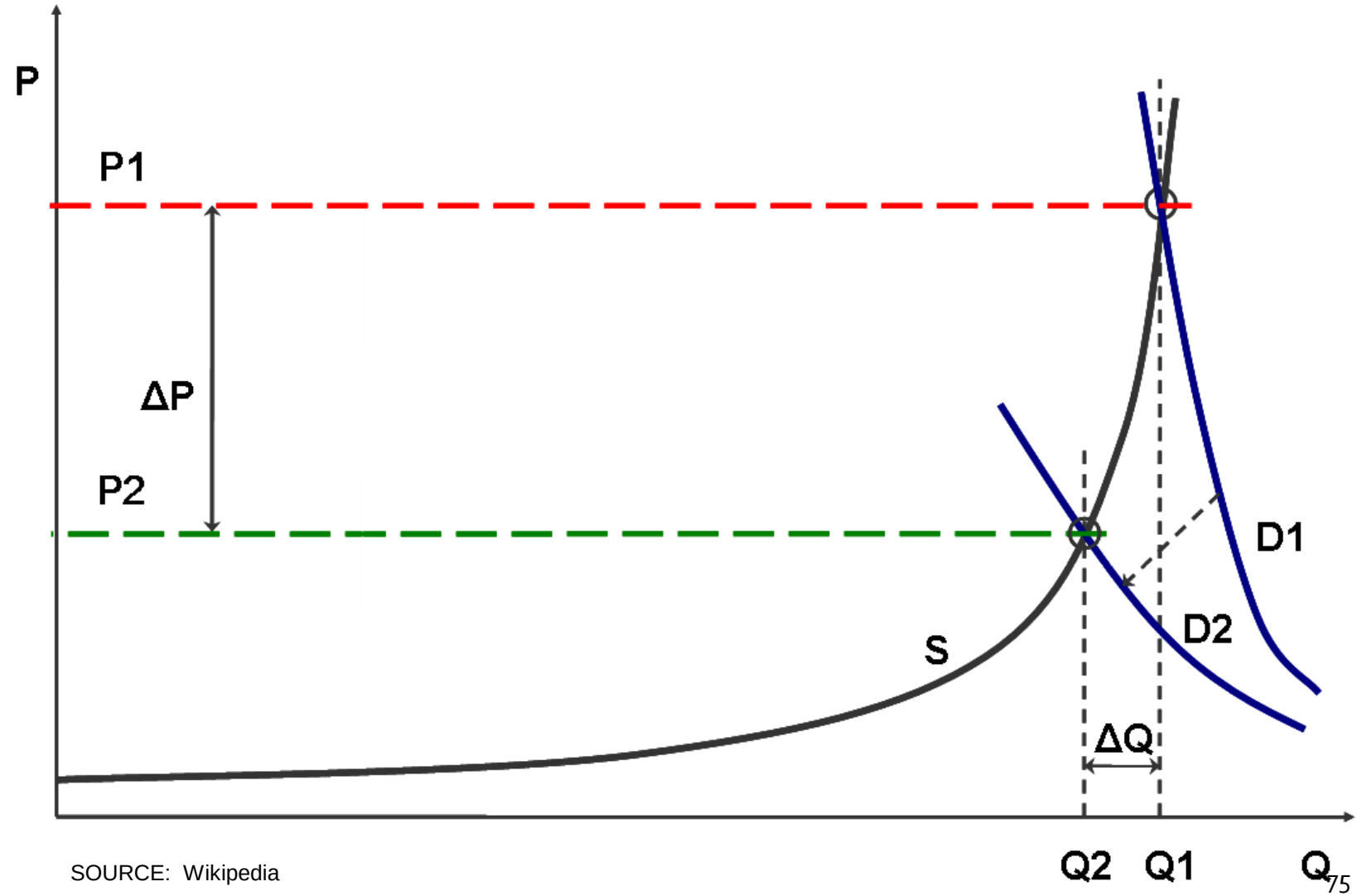
Link between wholesale and retail

Source: FSR encyclopedia

Smart homes … the future is now!

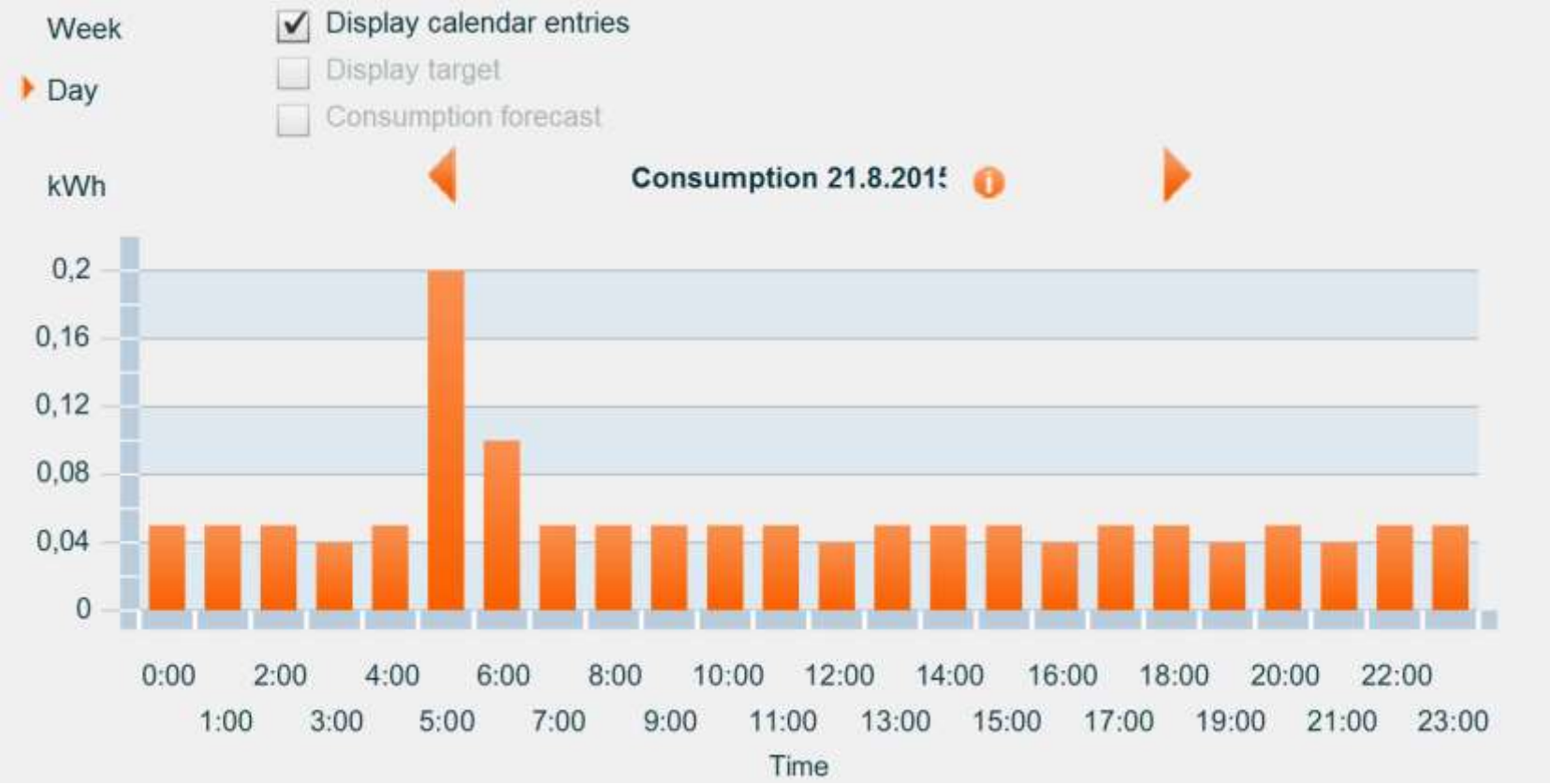
Smart meters and grids

Influence of demand response on the price



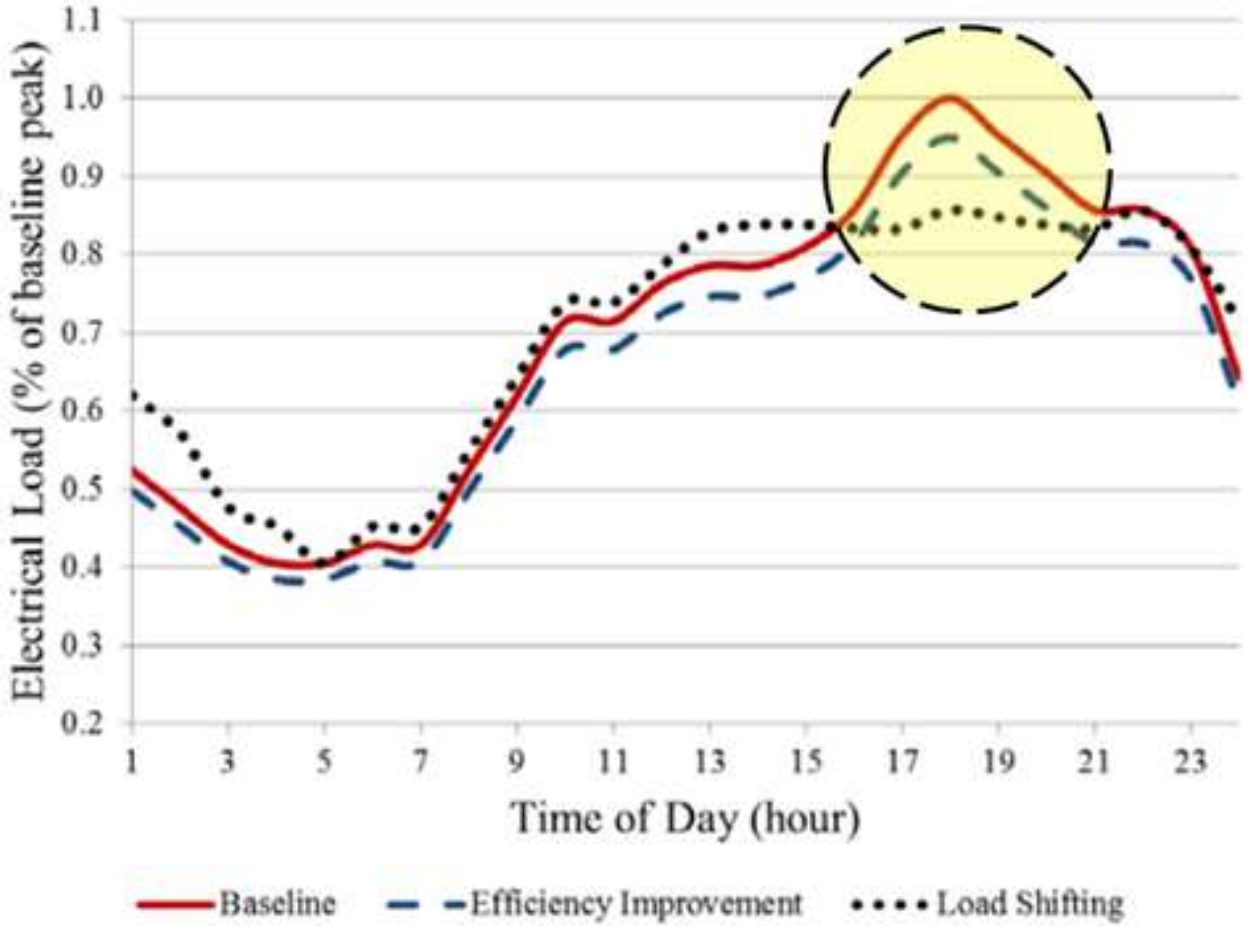
SOURCE: Wikipedia

Price based demand response



Source: Helen Sävel system

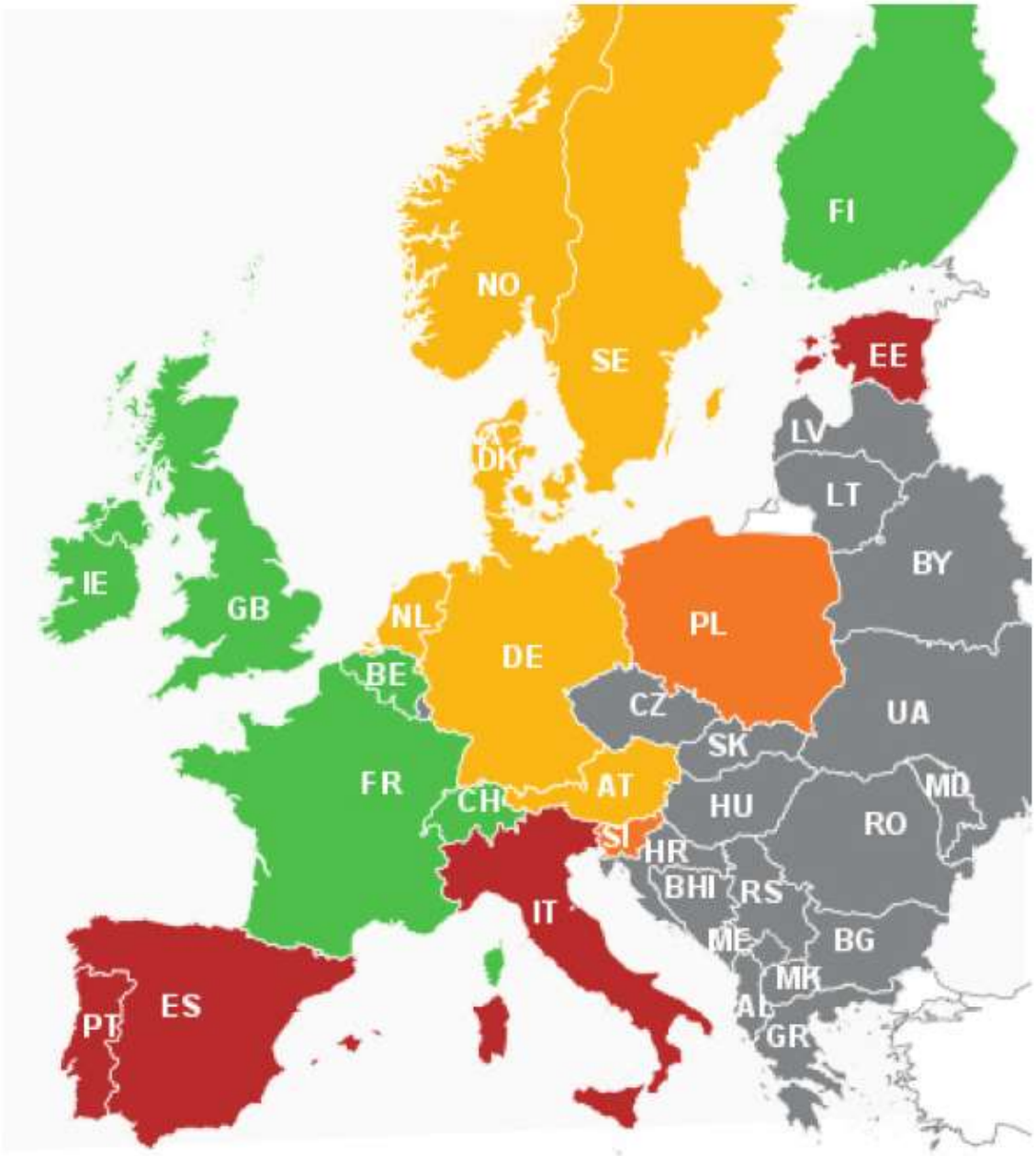
Load control = incentive based demand response



SOURCE: Quora

Aggregators

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



Source: SEDC 2017

Dispatching

TSOs' Regional Security Cooperation Initiatives

- Coreso
- TSC
- TSC + Coreso
- TSC + SSC
- Nordic
- Nordic + TSC
- MIBEL
- MIBEL + Coreso
- SCC
- Baltic – initial stage

Source: ENTSO-E

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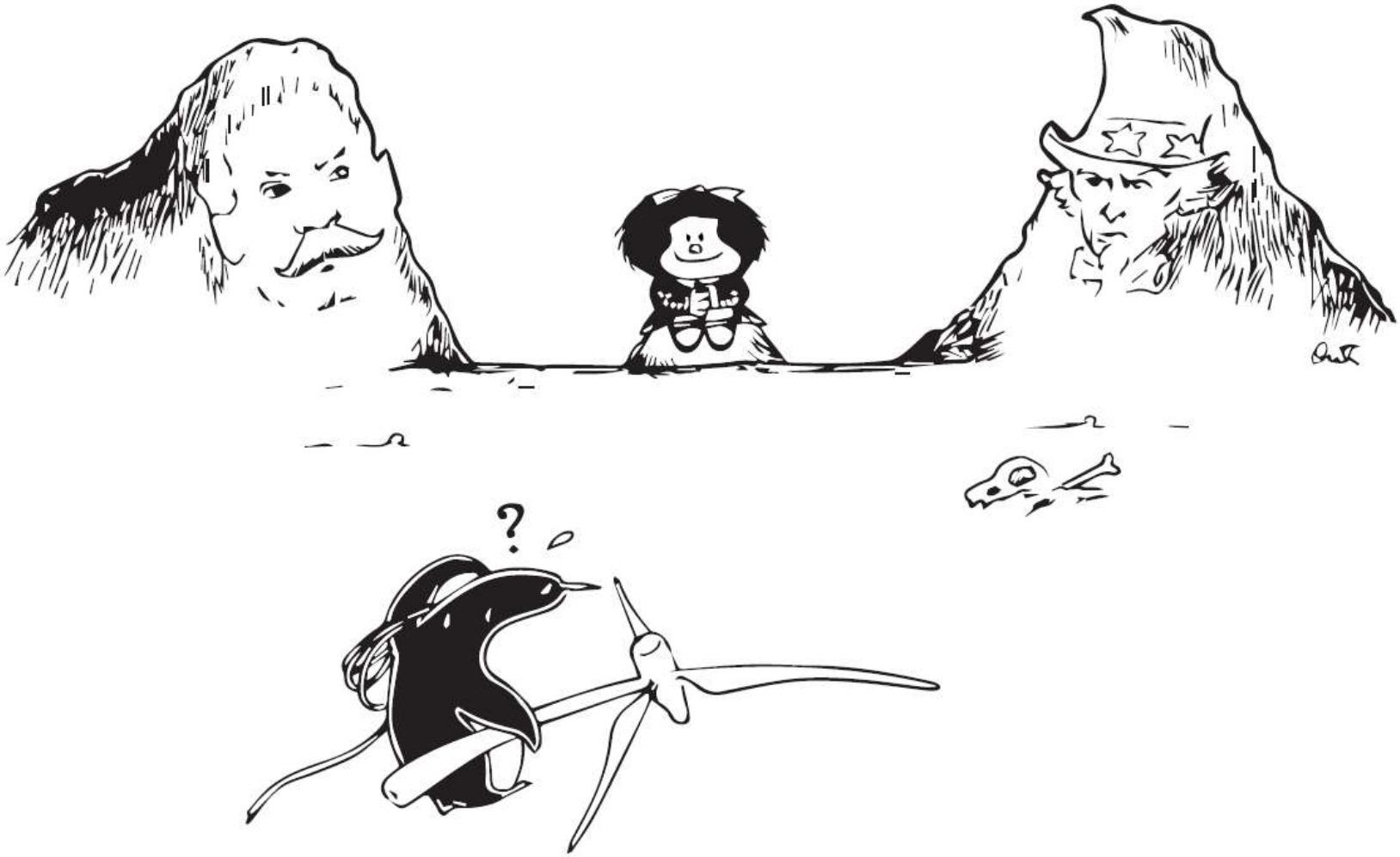
Investments



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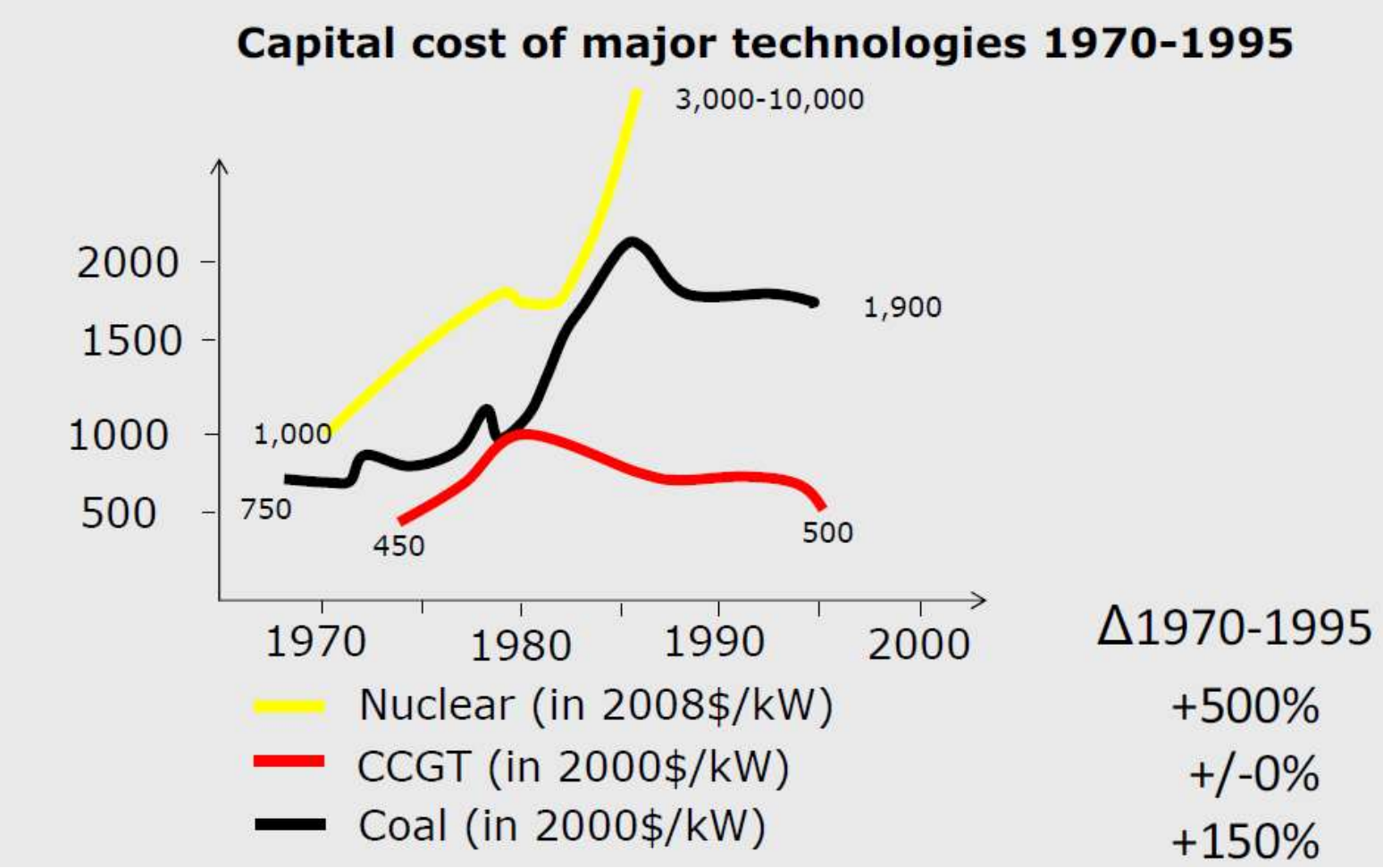
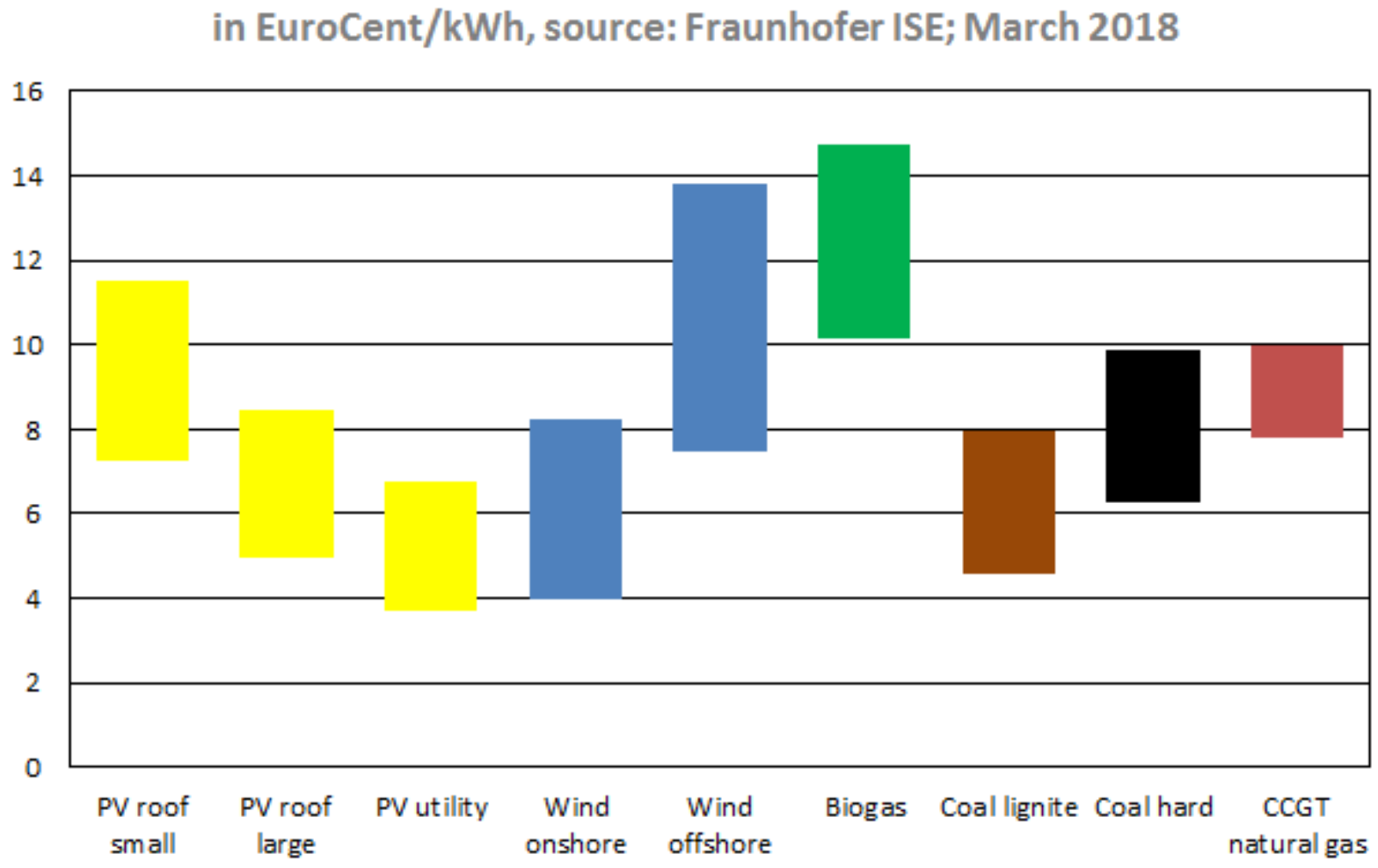
Capital cost decrease is no physical law



Source: Zachmann, Bruegel

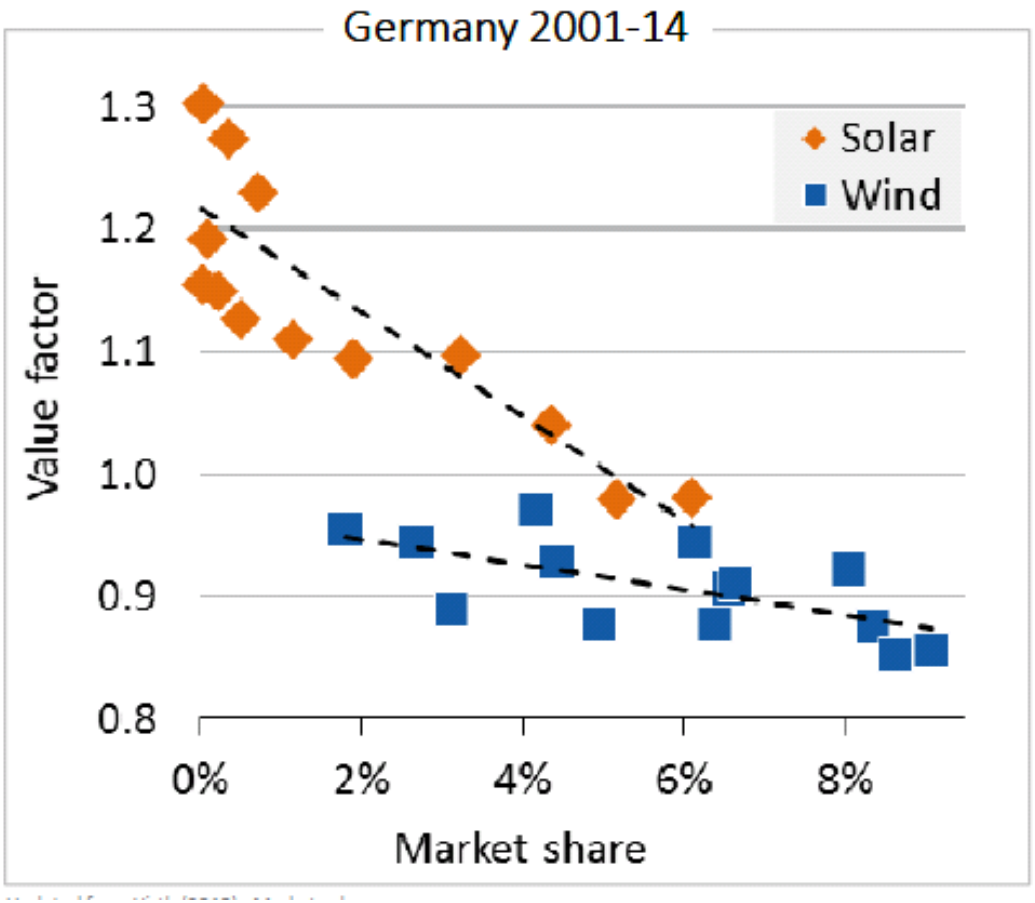
Levelized cost of electricity in Germany



The wind and solar value drop

Value Factor = Market value / base price

Each dot represents one year



?

Source: Lion Hirth NEON

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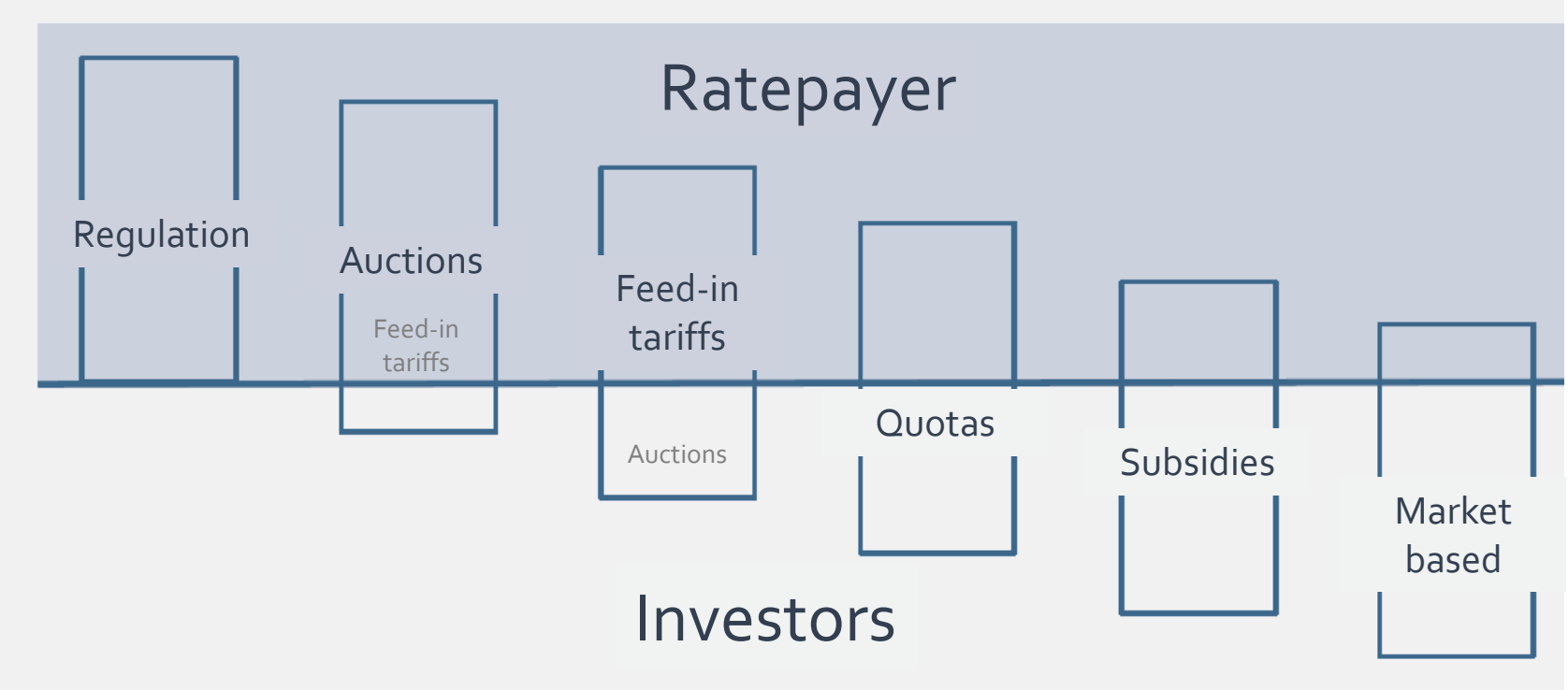
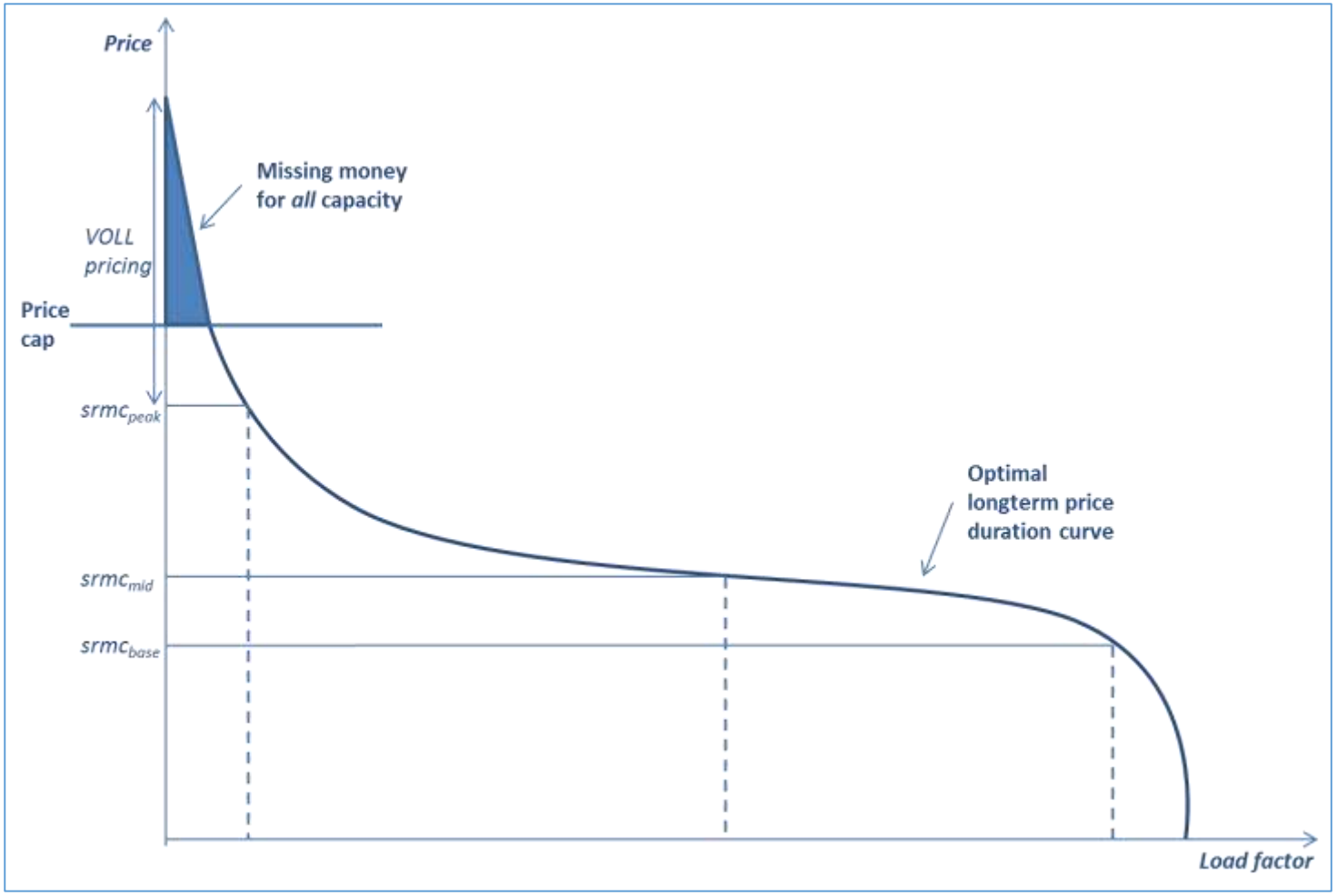
Who takes the risk?



Source: IEA Energy Technology Perspectives 2014
Modified by Matti

Capacity mechanisms



Source: Thema consulting


Capacity
mechanisms

Capacity mechanisms

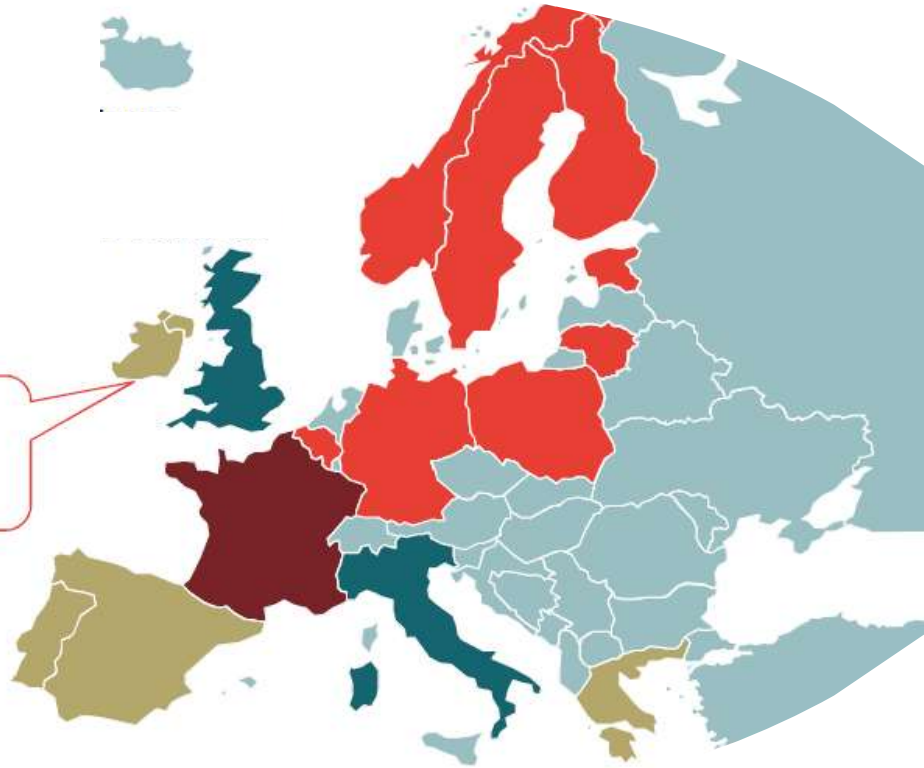
Christmas and New Year's Addresses by European Heads of States

Who does what (or is planning to)?

… regarding capacity mechanisms

- strategic reserve
- decentralised mechanism
- system wide central machanism
- capacity payment

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

SOURCE: Thema consulting

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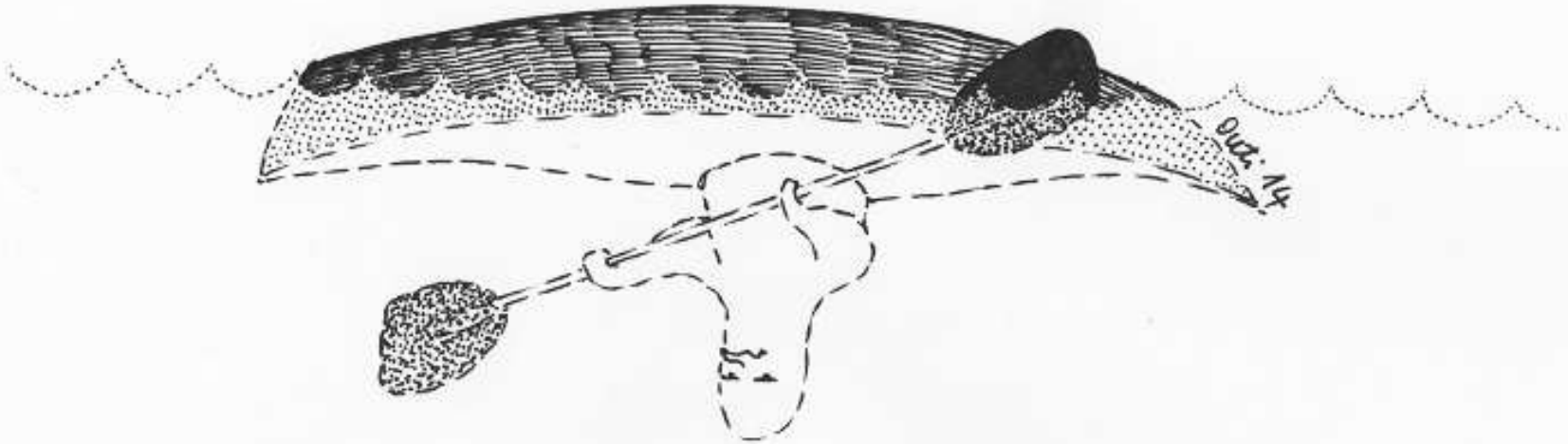
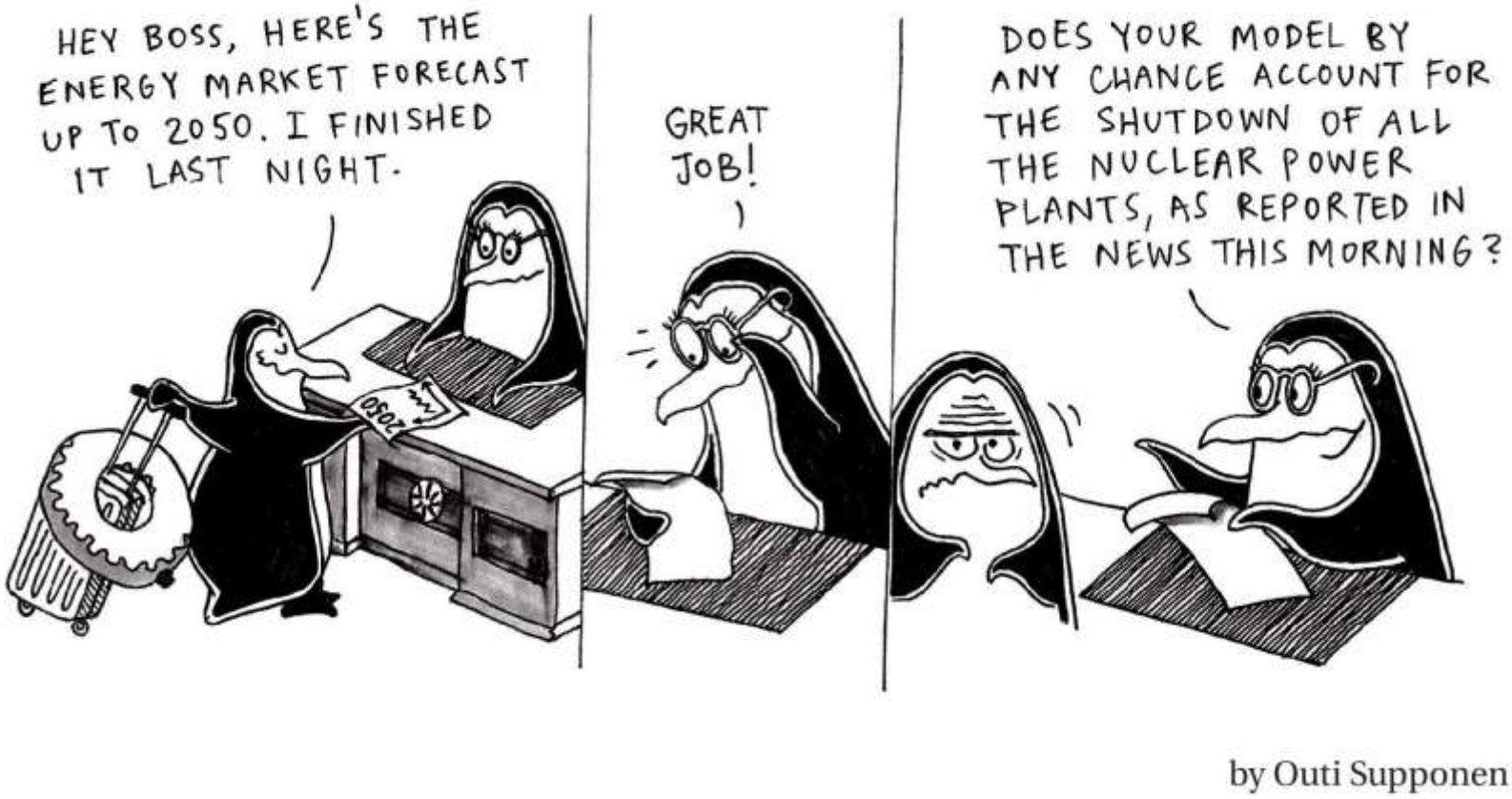
Reversibility of capacity mechanisms



Future is uncertain



Source: PhD thesis of Stefano Moret, EPFL
"Strategic planning under uncertainty"

Future issues regarding electricity markets

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

Digitalisation

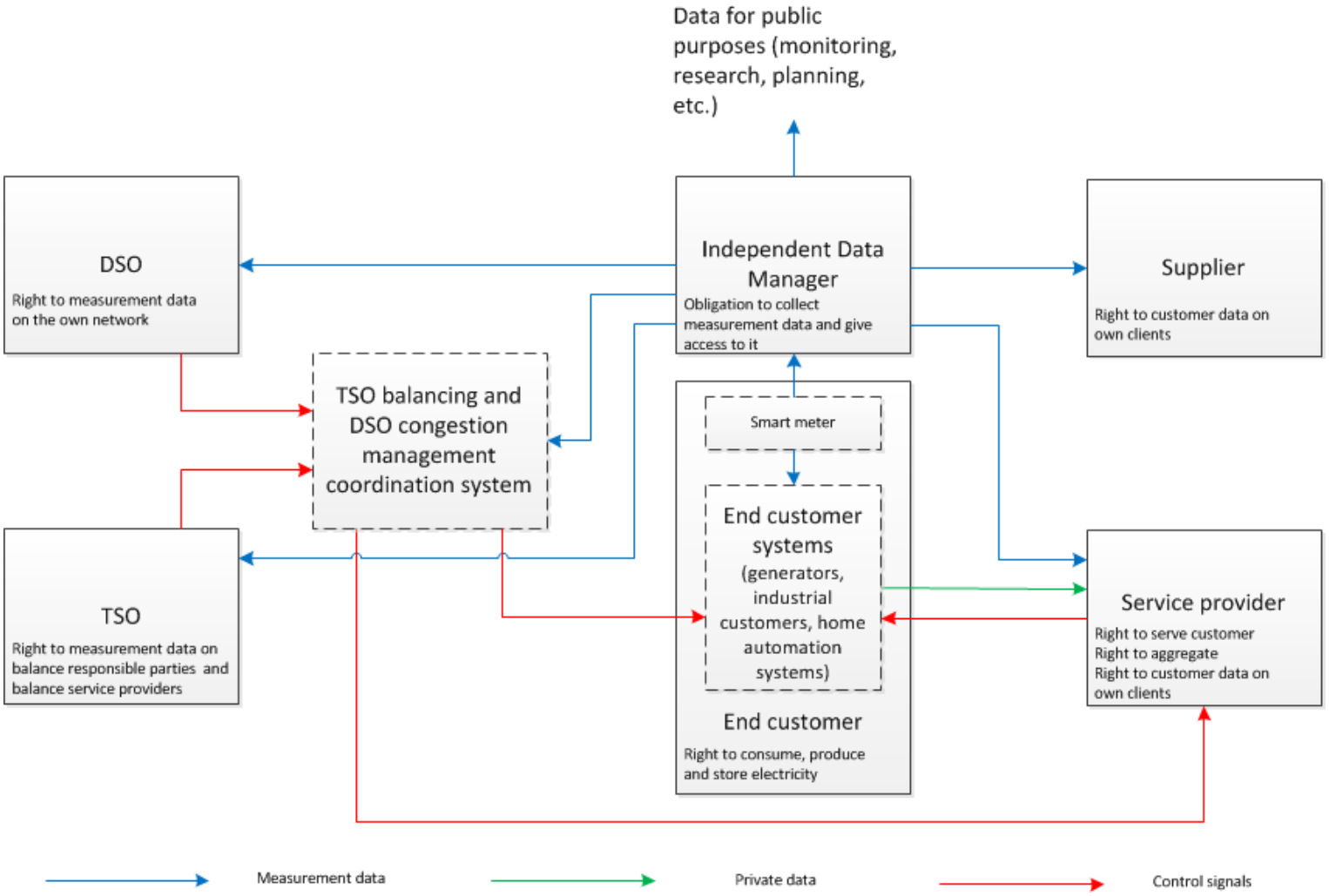
- Cybersecurity, Internet of Things, Big data
- Who will manage data platforms?
- More active control of assets for balancing

Future issues regarding electricity markets

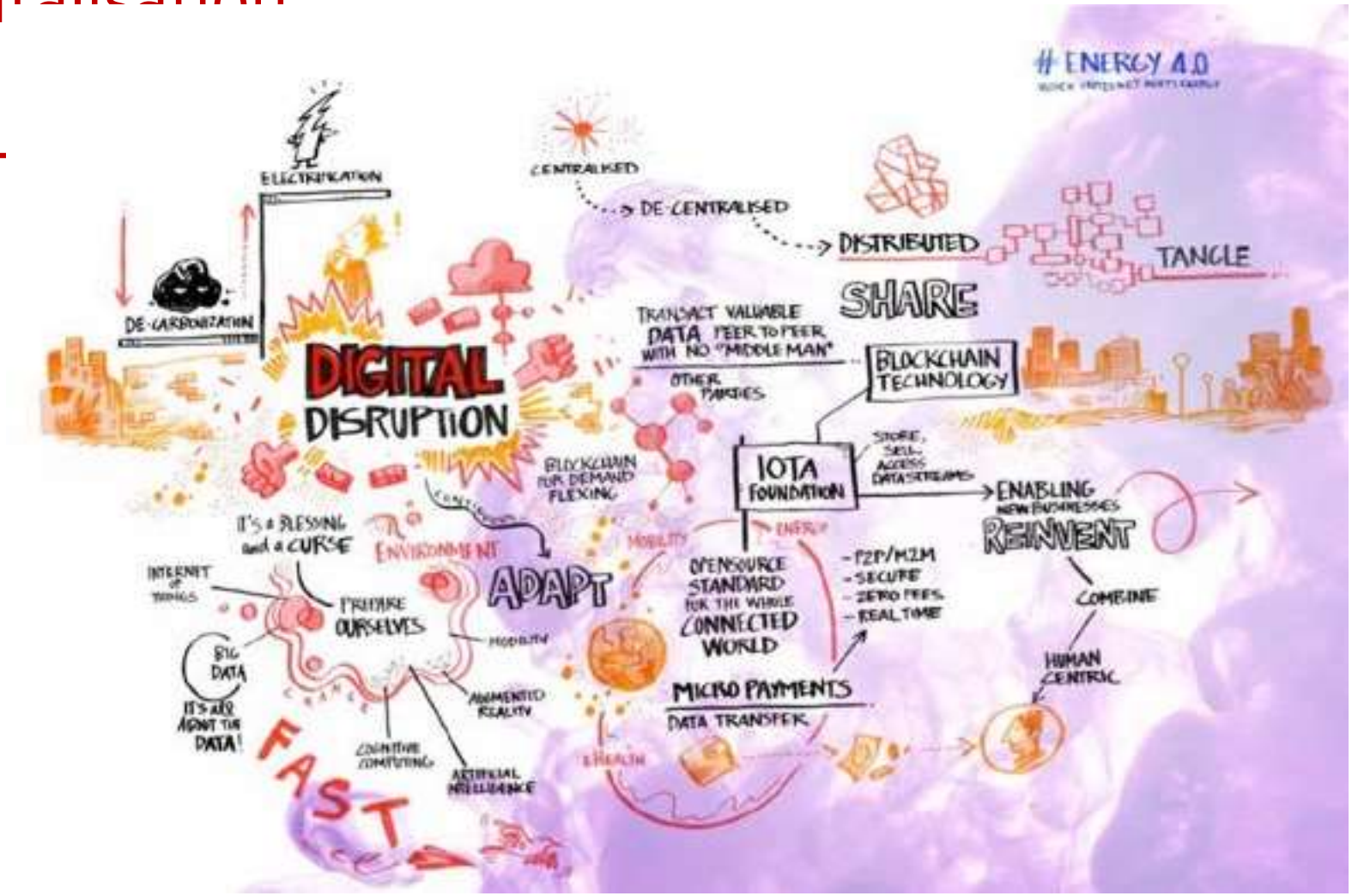
Sector coupling

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

New relations between players

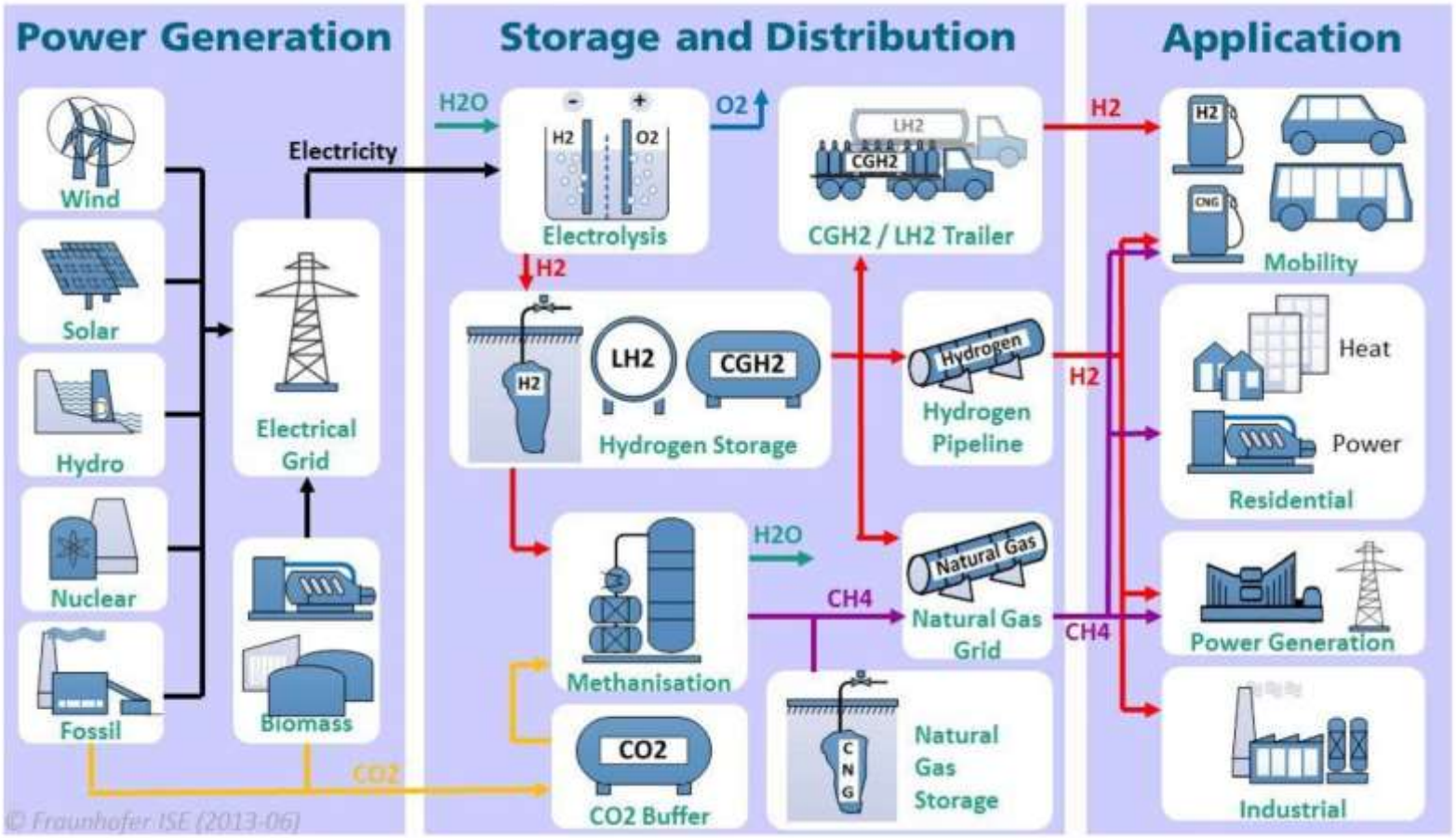


Digitalisation and



Source: Pöyry

Sector coupling provides opportunities for flexible storage…



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

Regulation vs. market

Regualation	Regulation/ market	Market
• Grid tariffs • Regulated prices • Capacity mechanisms • RES targets • Subsidies • Energy efficiency targets • Mandatory ancillary services • Priority dispatch • Emission standards	• Emissions trading • Trading of green certificates • Auctions for generation capacity	• Competition • Free price formation • Liquidity • Markets for ancillary services • Right to self-produce/-consume and store electricity • Right to be aggregated

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!