


Global grid

Elia grid

Impact of renewable energies

Global grid

Energy future

ULg 06/11/2019 Jean-Jacques Lambin

Contents

Le Groupe Elia

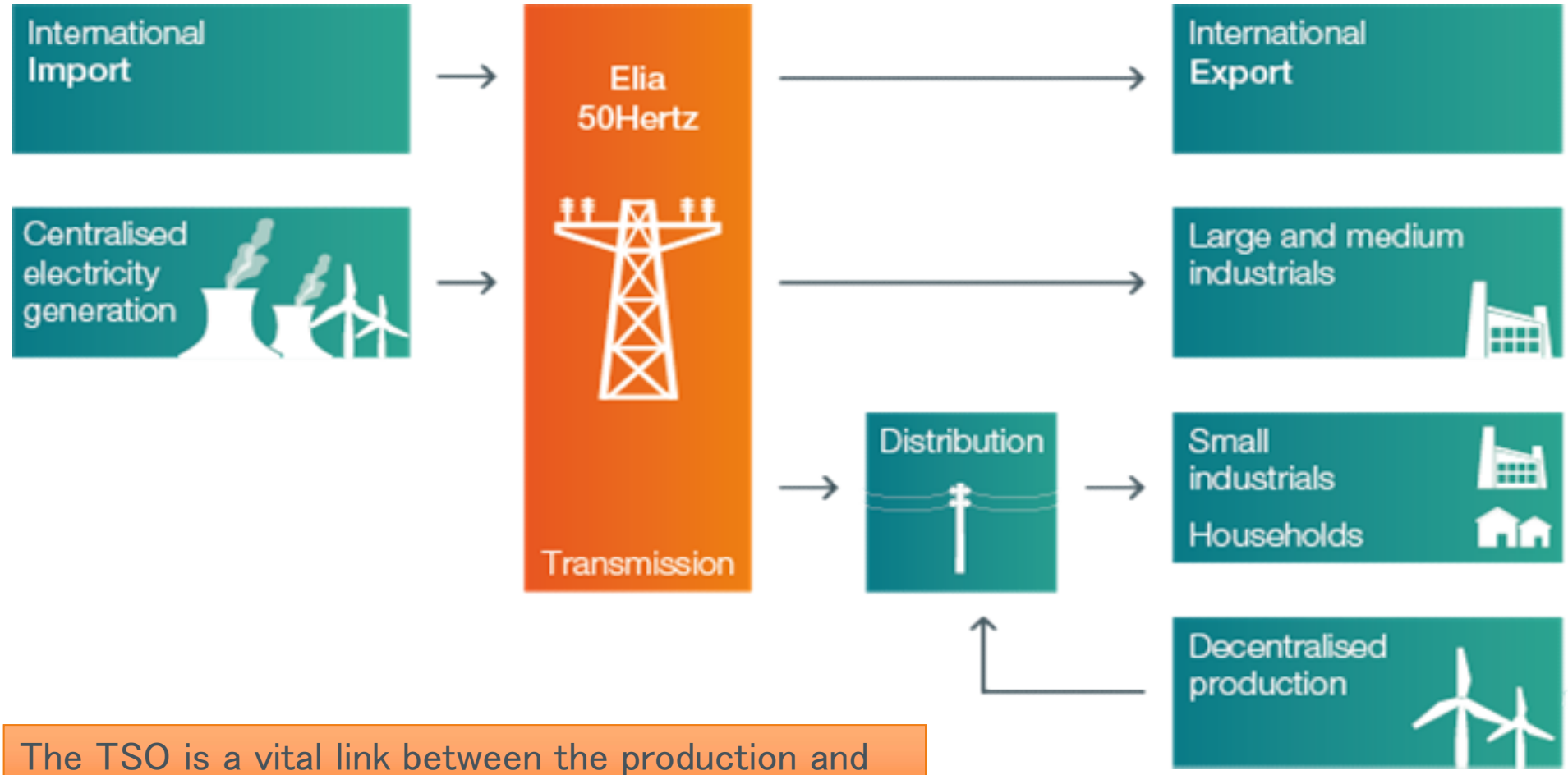
Le groupe Elia, une position unique au coeur de l'Europe

Le groupe Elia s'articule autour de 2 gestionnaires de réseau de transport haute tension (GRT),

Elia en Belgique,

50Hertz en Allemagne

Role of ELIA



The TSO is a vital link between the production and the industrial or private consumers

Elia in some numbers

800

high voltage substations

30.000 - 380.000

22.000

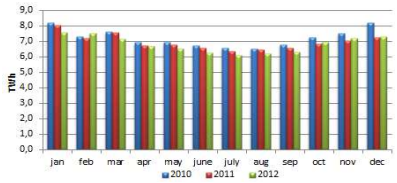
pylons

5.560

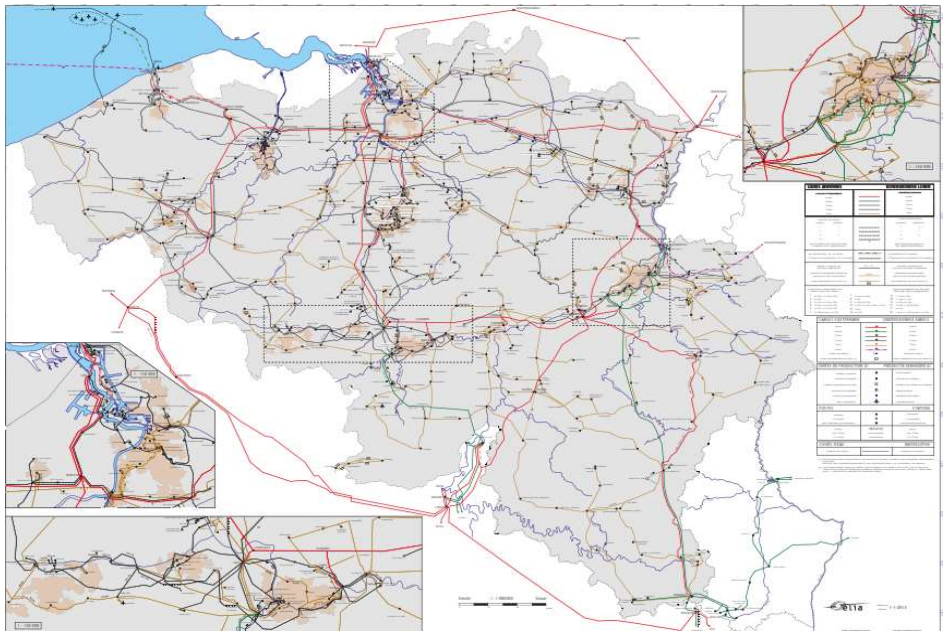
km overhead lines

2.800

km underground cables



81,7 TWh



Elia is de Belgian Transmission System Operator (30 kV - 380 kV) managing over 8.400 km lines and underground cables.

Short-term/Medium-term planning

Permanent monitoring of all equipment

Any component, even the largest (1,000 MW power plant, international line), can be tripped

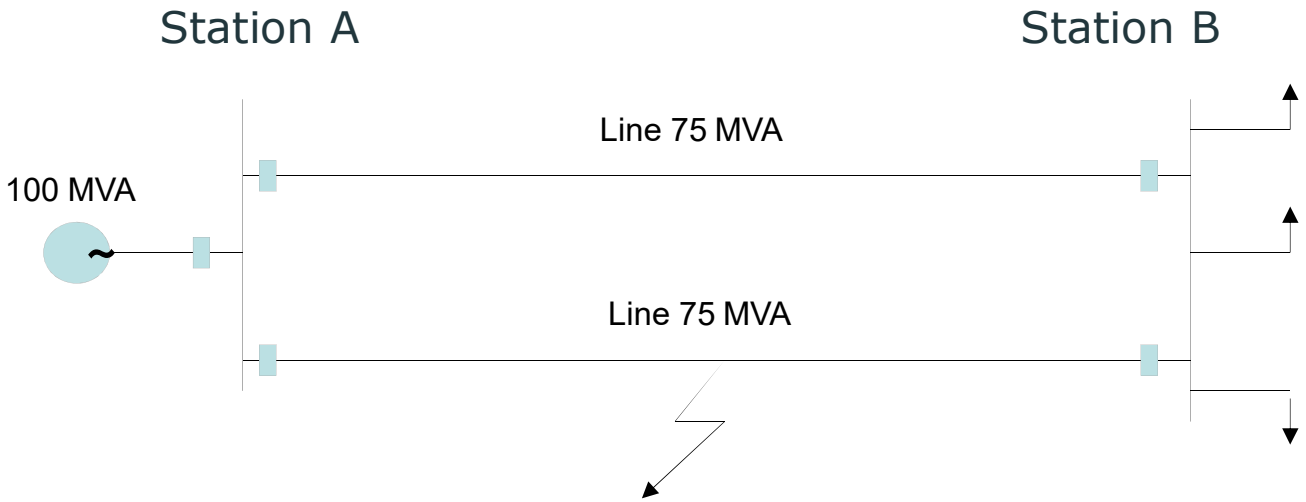
- *Always check that the N-1 is covered. If NOK, look for a solution as quickly as possible.*

The more stressed the base case (N), the more critical the N-1 case

Importance of short-term and medium-term planning

N-1 concept

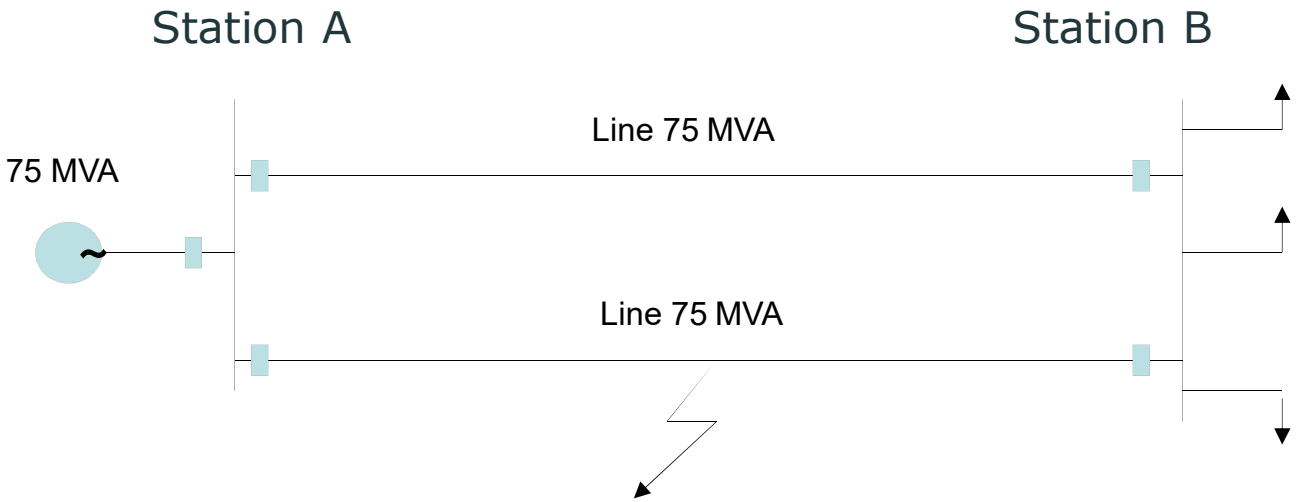
Example 1



N-1 **NOK**

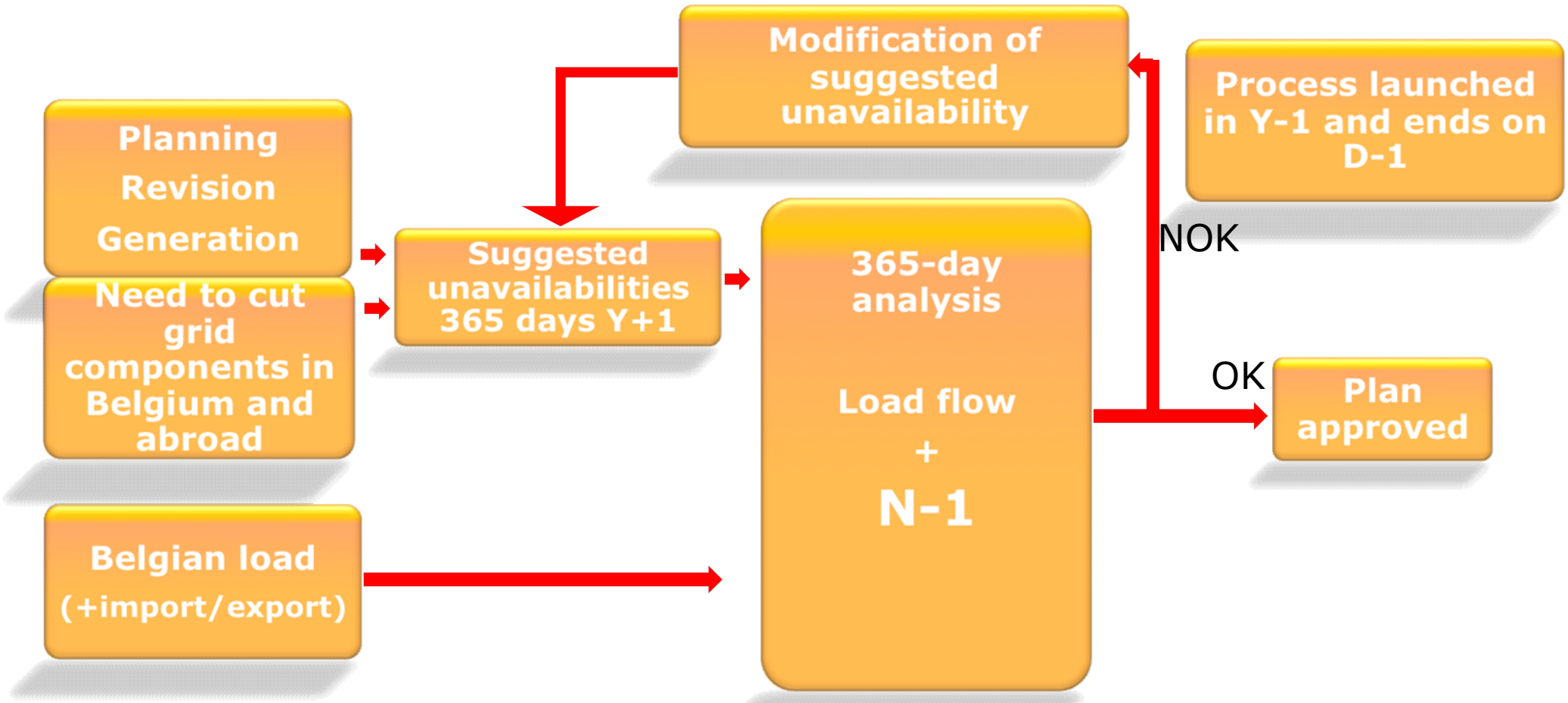
N-1 concept

Example 2



N-1 **OK**

Iterative planning process

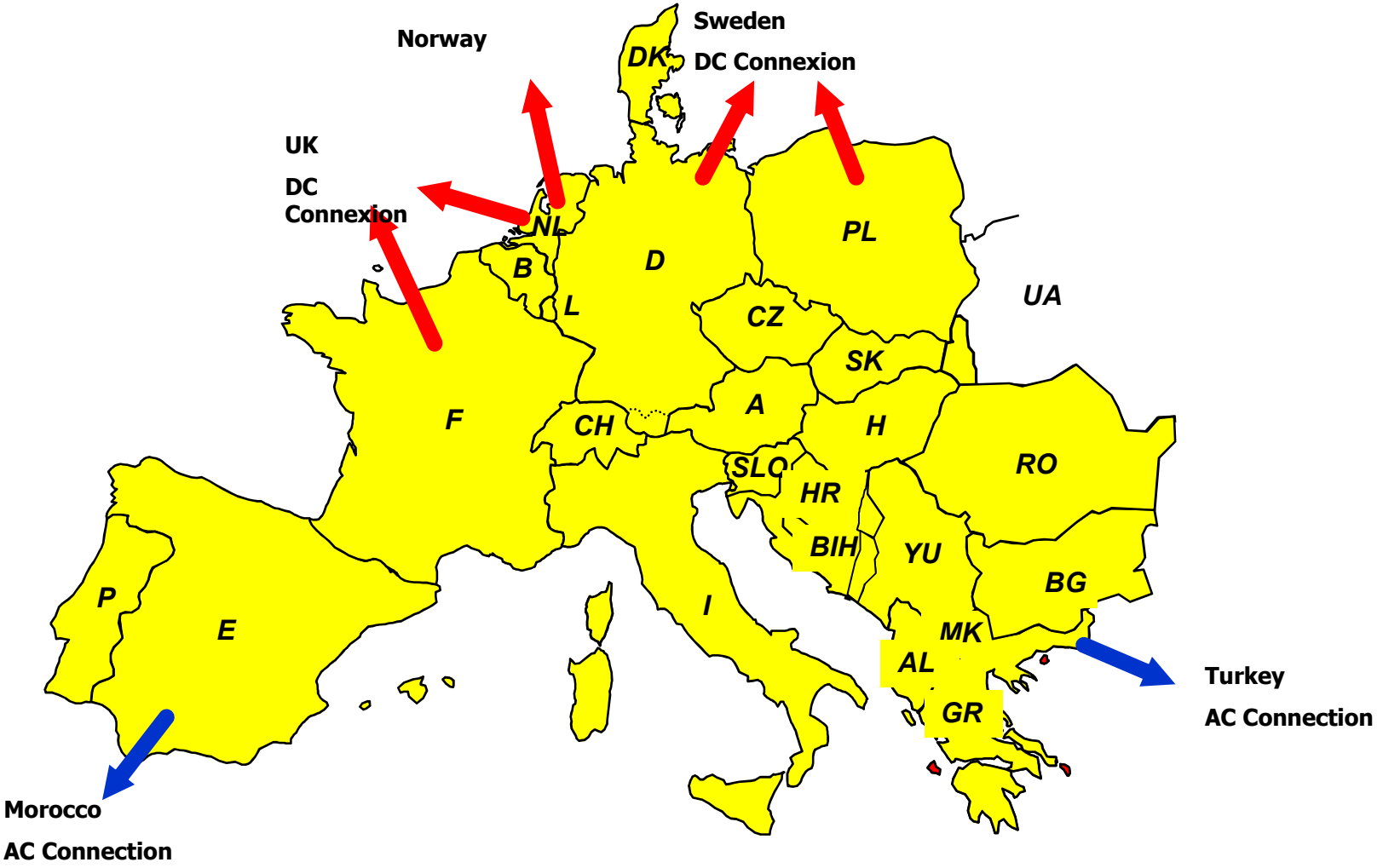


Schedule

The process is iterative and each day is analysed at least seven times.

The closer day D, the more accurate the data and hypotheses.

Day Ahead Congestion Forecast: 25 countries



Italy, black-out on 28 September 2003

The N-1 rule was not respected

Import/export capacities
Market coupling

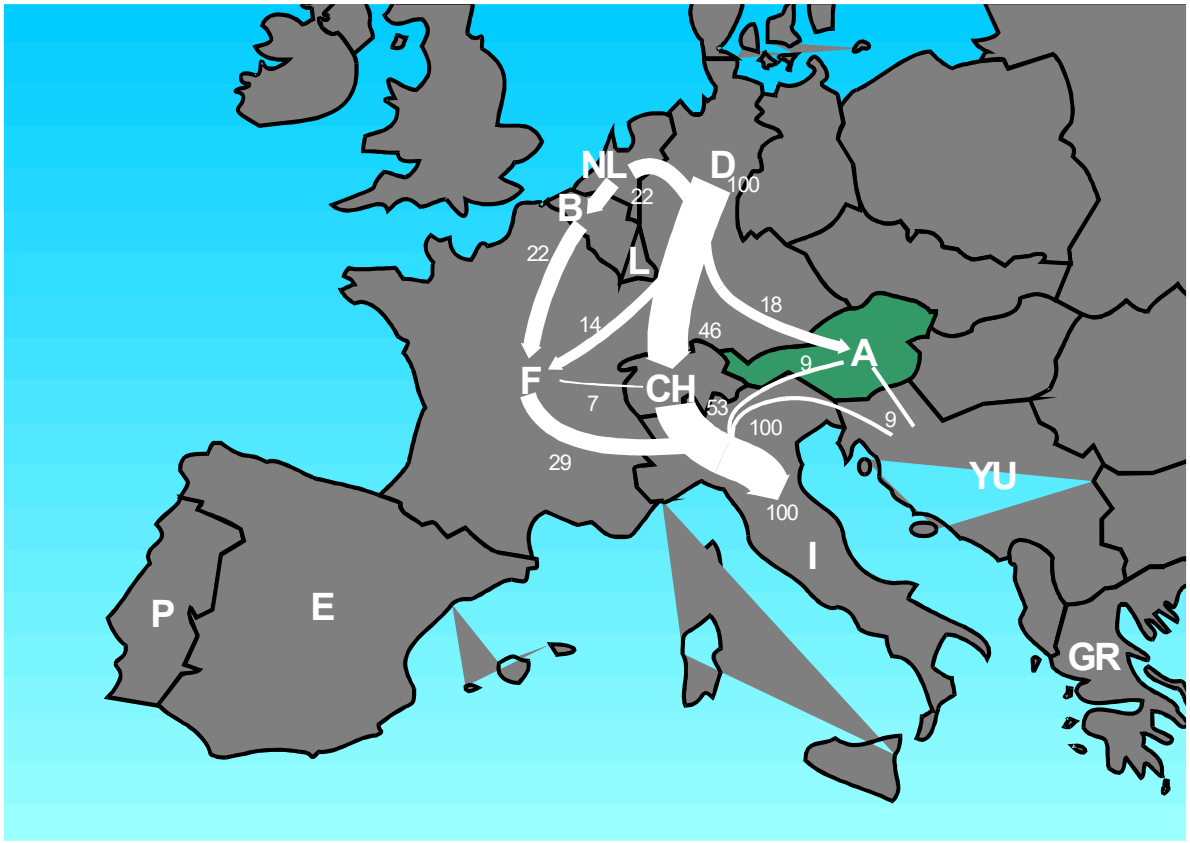
Import/export capacities

Import/export generates Loop flows

Potential import/export capacities

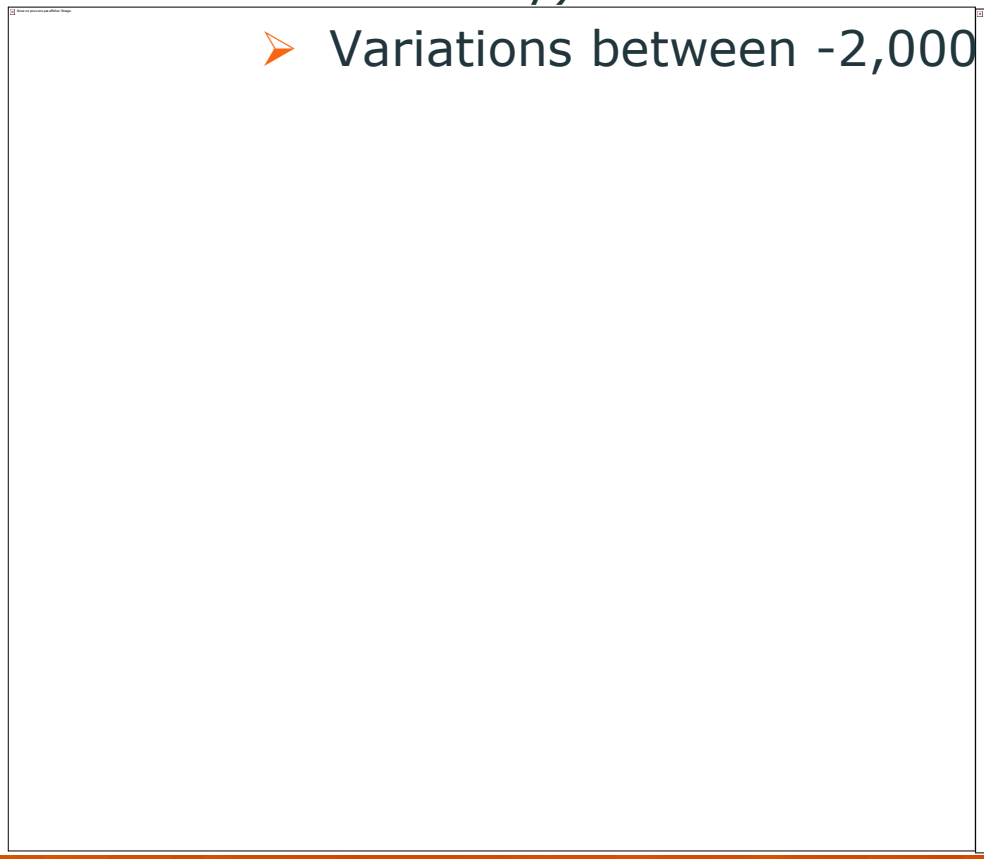
Problem of loop flows

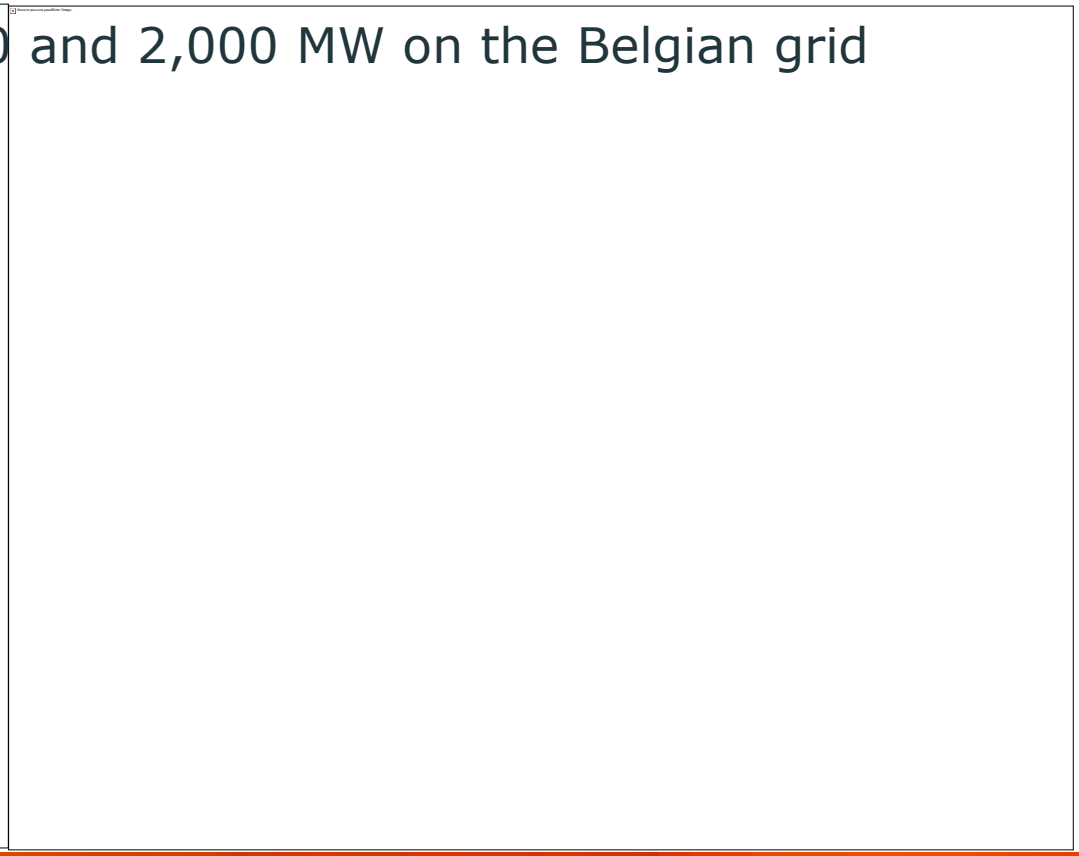
Controlling loop flows
Electricity follows the laws of physics:
path of least resistance



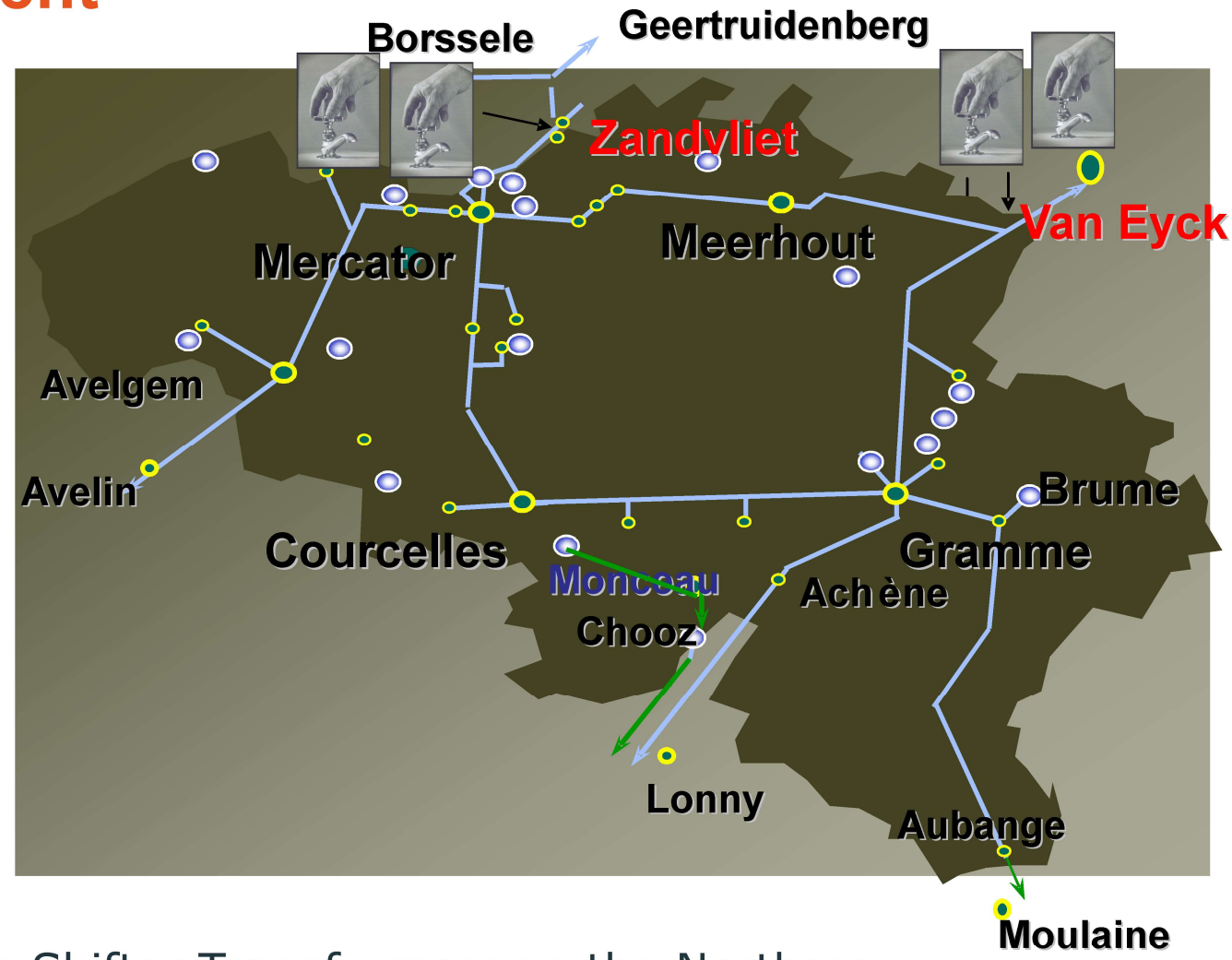
Impacts of wind power on the Elia grid

- Unscheduled flows:
  - Caused by wind farms located in neighbouring countries (north of Germany)
  - Variations between -2,000 and 2,000 MW on the Belgian grid





Flow management



Installation of Phase Shifter Transformers on the Northern border for managing increasing Loop flows

Coreso: centralised coordination between TSOs

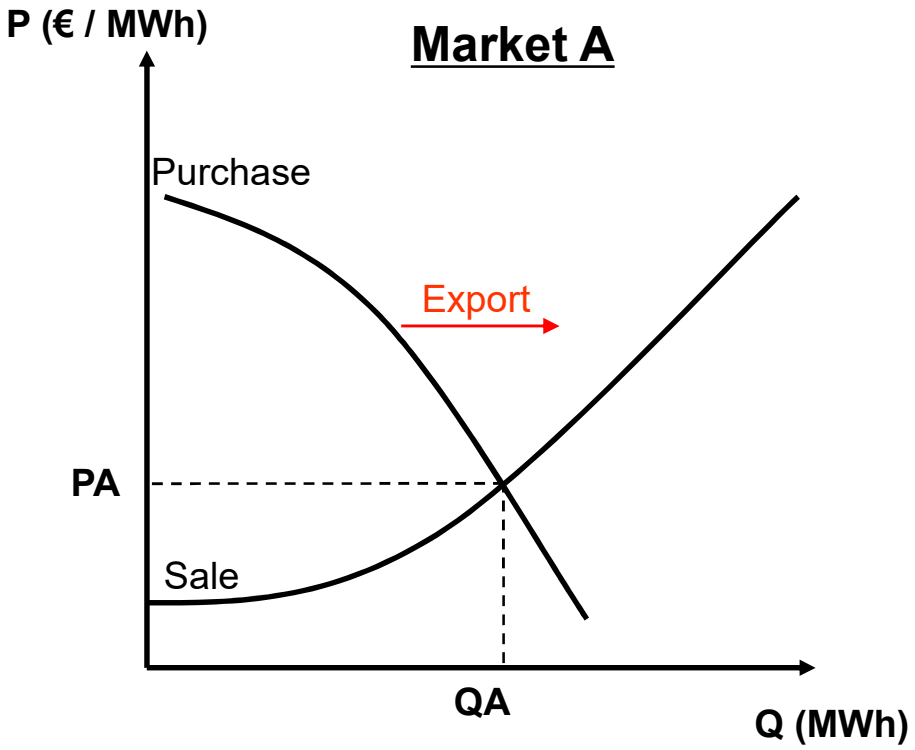
- The first Regional Technical Coordination Service Centre
- Independent company (SA) with its own employees
- Created December 2008 in Brussels
- Operational since 16 February 7d/7 (afternoon shift)
- Round-the-clock operations since 29 June 2009
- Employs 25 engineers (18 are on shift)

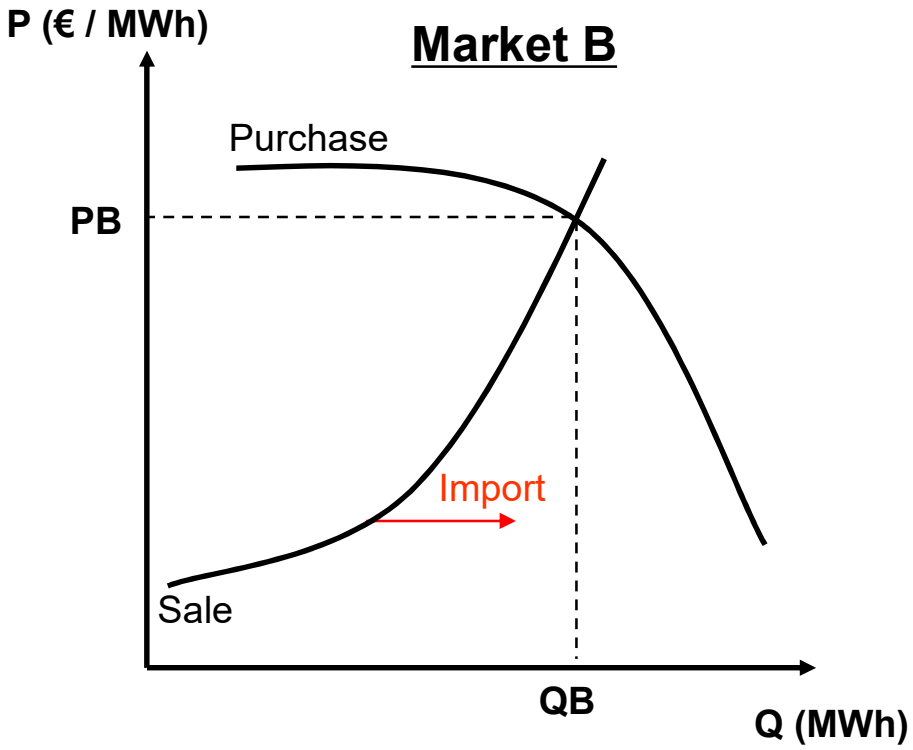
Impact of import/export capacities on the markets

Market Coupling

Market Coupling

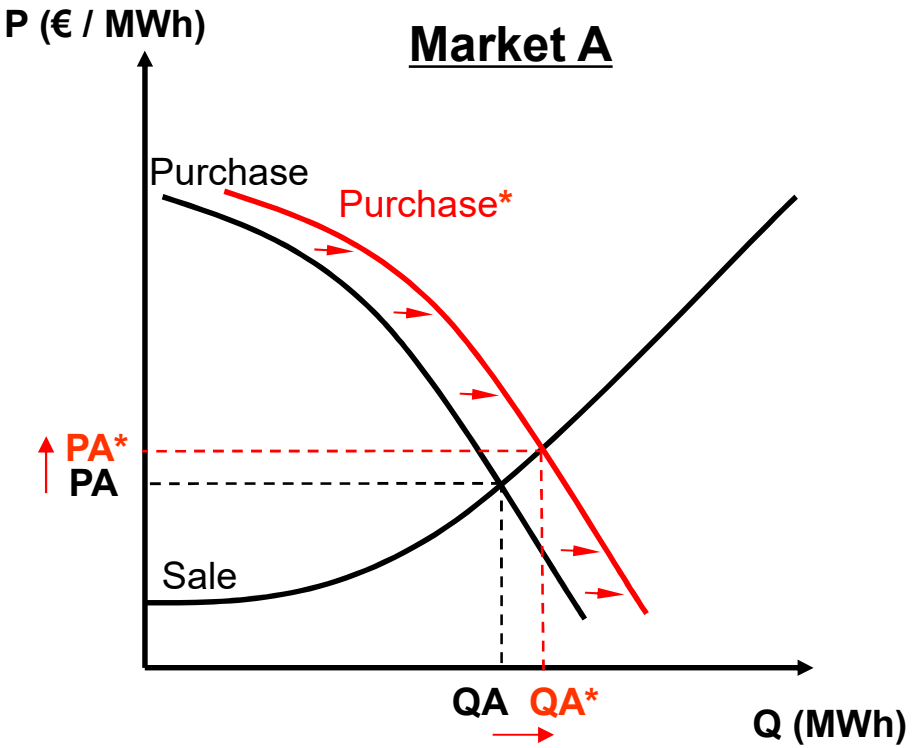
Market Coupling (basic concept)

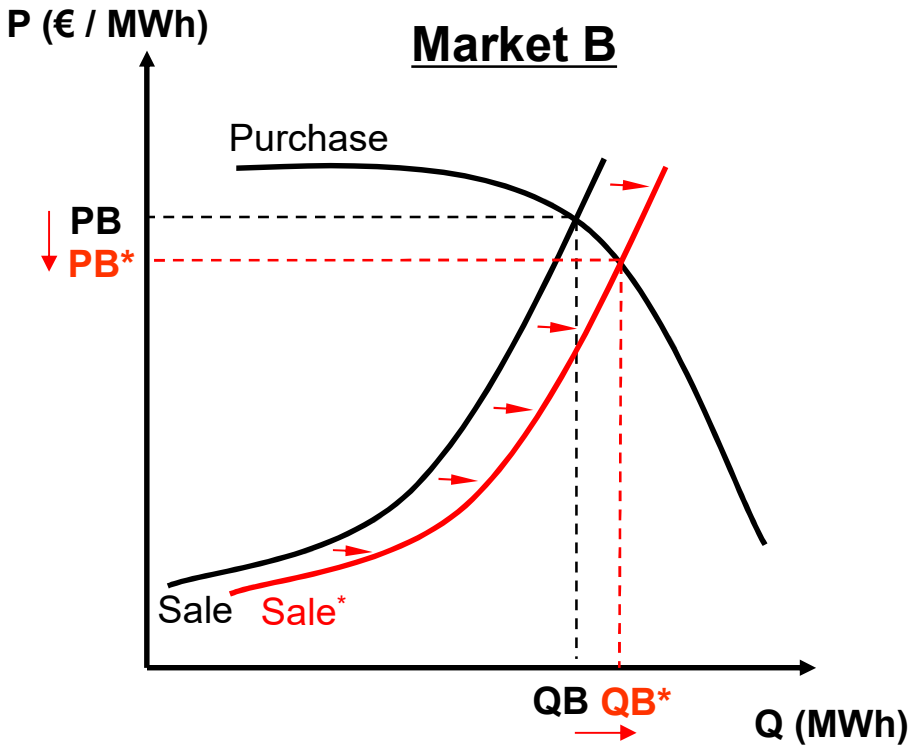




- **Isolated price Market A < isolated Price Market B**
- **Market A can export to market B (purchase- and sale curve shift)**

Market Coupling (basic concept)





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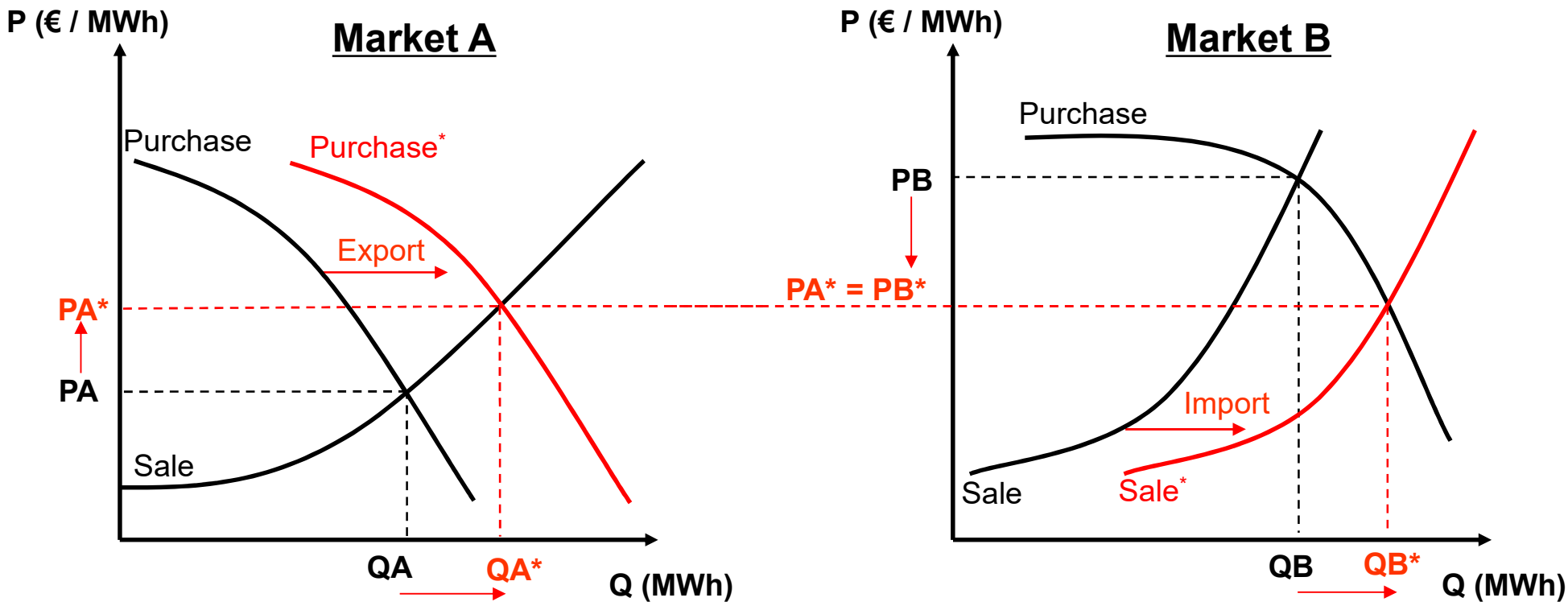
Market Coupling (basic concept)



- **Isolated price Market A < isolated Price Market B**
- **Market A can export to market B (purchase- and sale curve shift)**
- **Prices market A and B converge till price market A = price market B**

Impact of renewable energies on grid management

20-20-20 targets

Resources available in Belgium

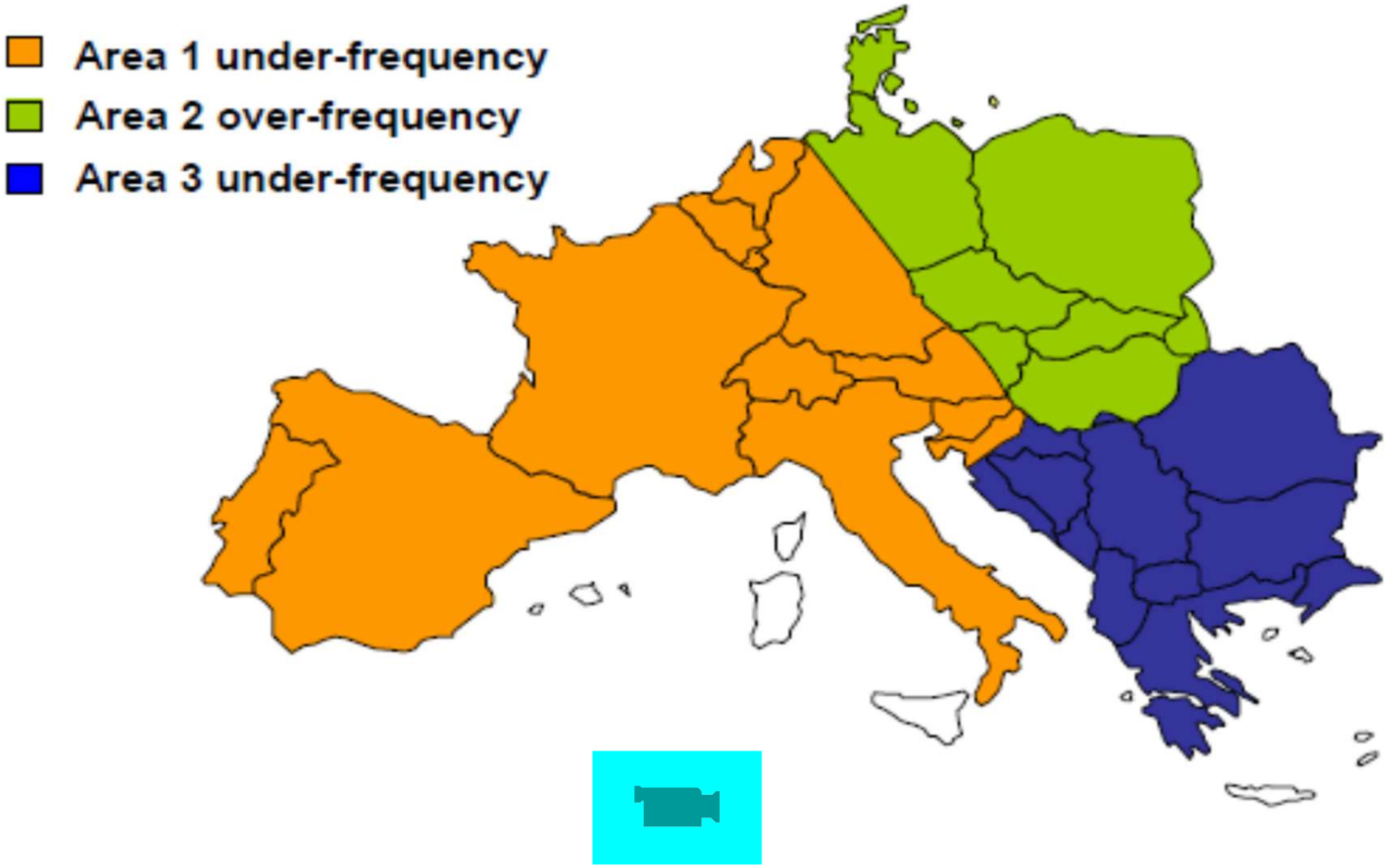
- 1) Major offshore/onshore wind farms
- 2) Decentralised generation
  - Small wind farms/individual wind turbines
  - Photovoltaics
  - Industrial/individual cogeneration units (Stirling)
  - Biomass
  - Small hydraulic units

Considerable decentralised generation potential

Germany, incident on 4 Novembre 2006

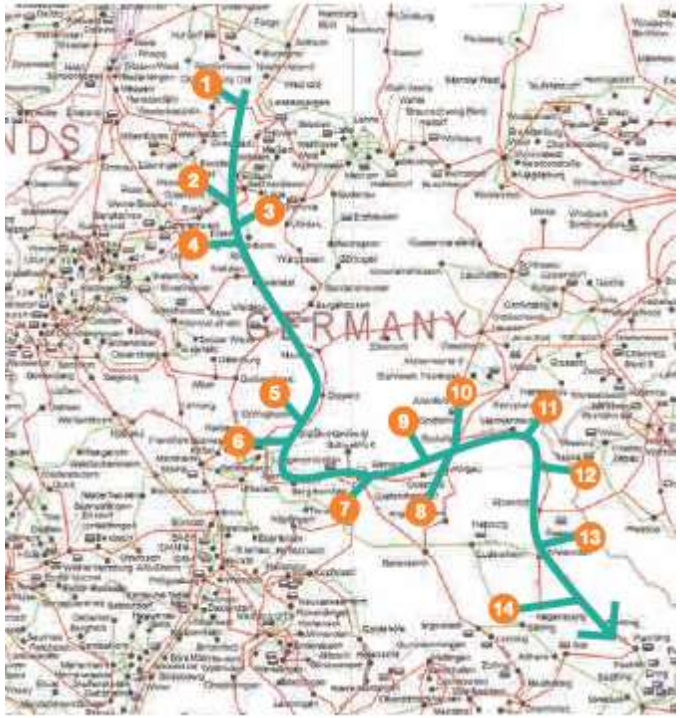
Le Norwegian Pearl

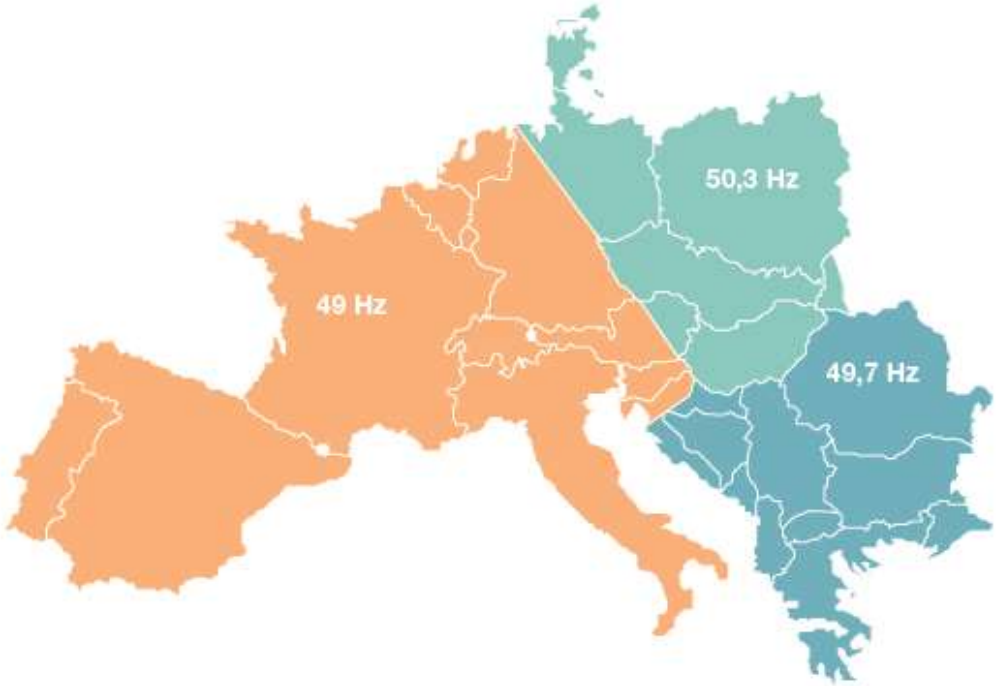
Incident on 4 November 2006



Incident on 4 November 2006

Europe is divided into 3 electric zones





Impact of decentralised generation on Elia's activities

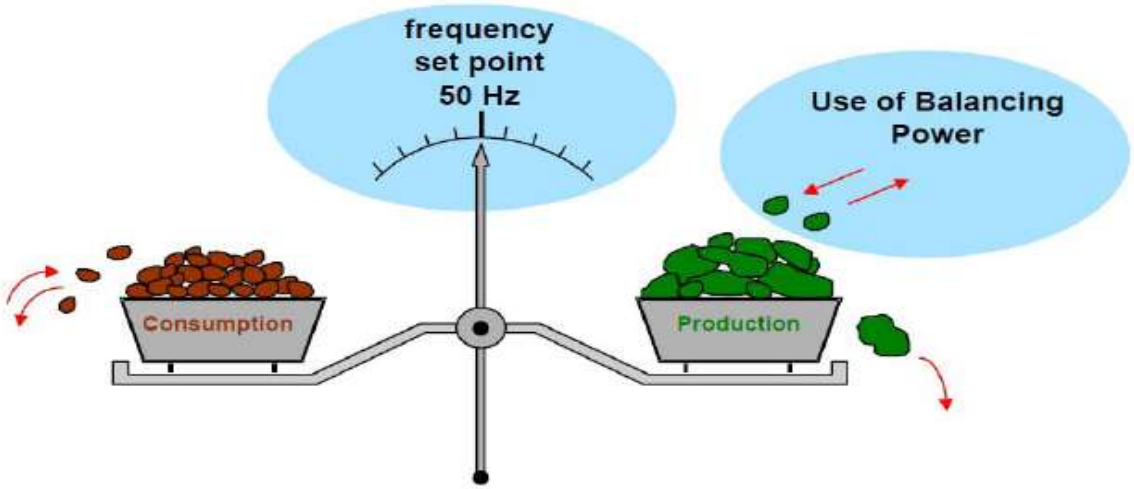
- Although decentralised generation units are connected to DSOs' grids, as the volume of these units is growing significantly, it affects the overall management of the electricity grid in Belgium.

1. Management of the electricity grid in Belgium

1. Balance between generation ←→ load
2. Management of system services: Prim R, Sec R, Tert R, voltage control
3. Management of flows, import/export, Must Run
4. System security, safeguard plan

Management of the electricity grid

- **Balance between generation ←→ consumption**
- AC electricity is not stored, generation and consumption must always be balanced



* Source: Elia Communication

Management of the electricity grid

- **Available resources: system services**

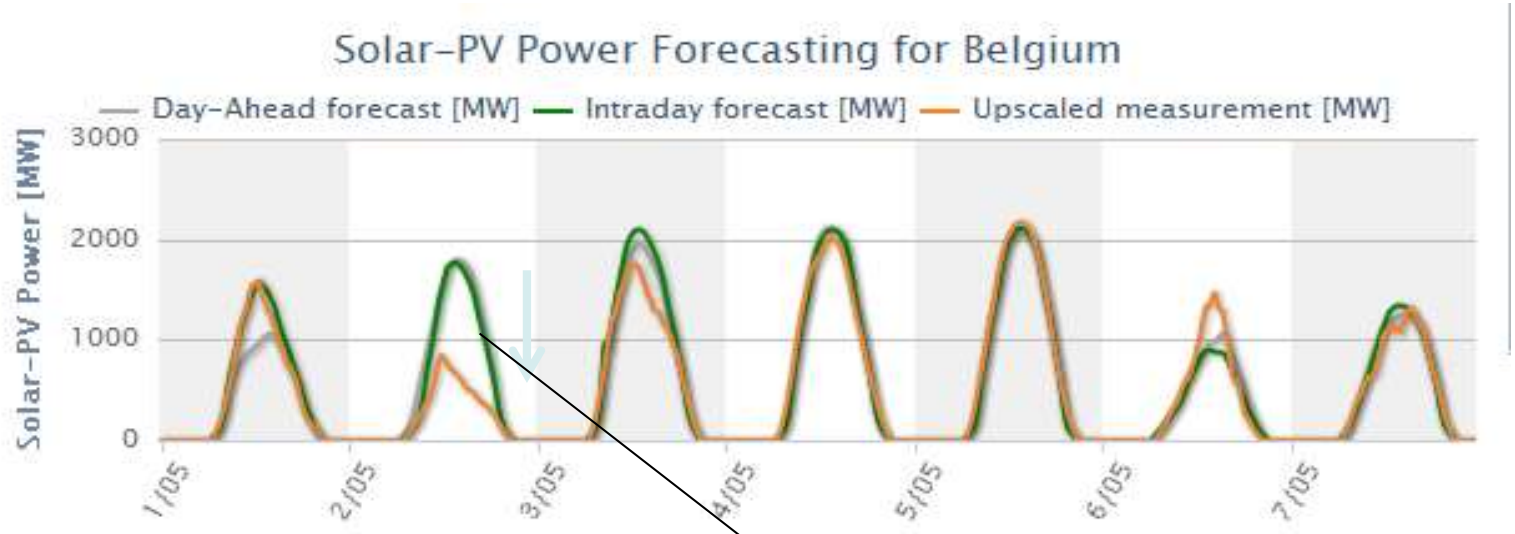
  - **Primary reserve (R1)**: 3000 MW in ENTSO-E. Enough for facing the loss of 2 of the biggest nuclear plants within 15'

    Frequency deviations and involuntary power exchanges on borders occur

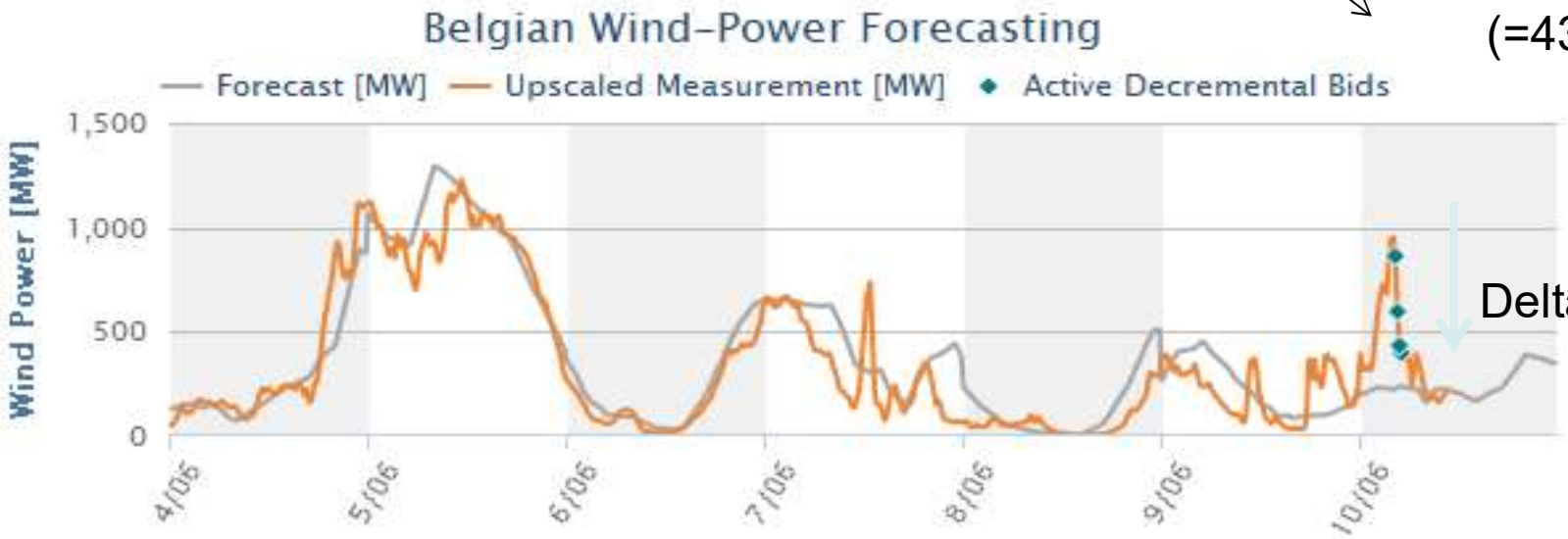
  - **Secondary reserve (automatic)**: Used in order to restore the initial balance between generation and consumption and thus restore frequency and cross border power exchanges.

  - **Tertiary reserve (manuel)**: In case of larger imbalances in the control area.

Impact of forecasting errors

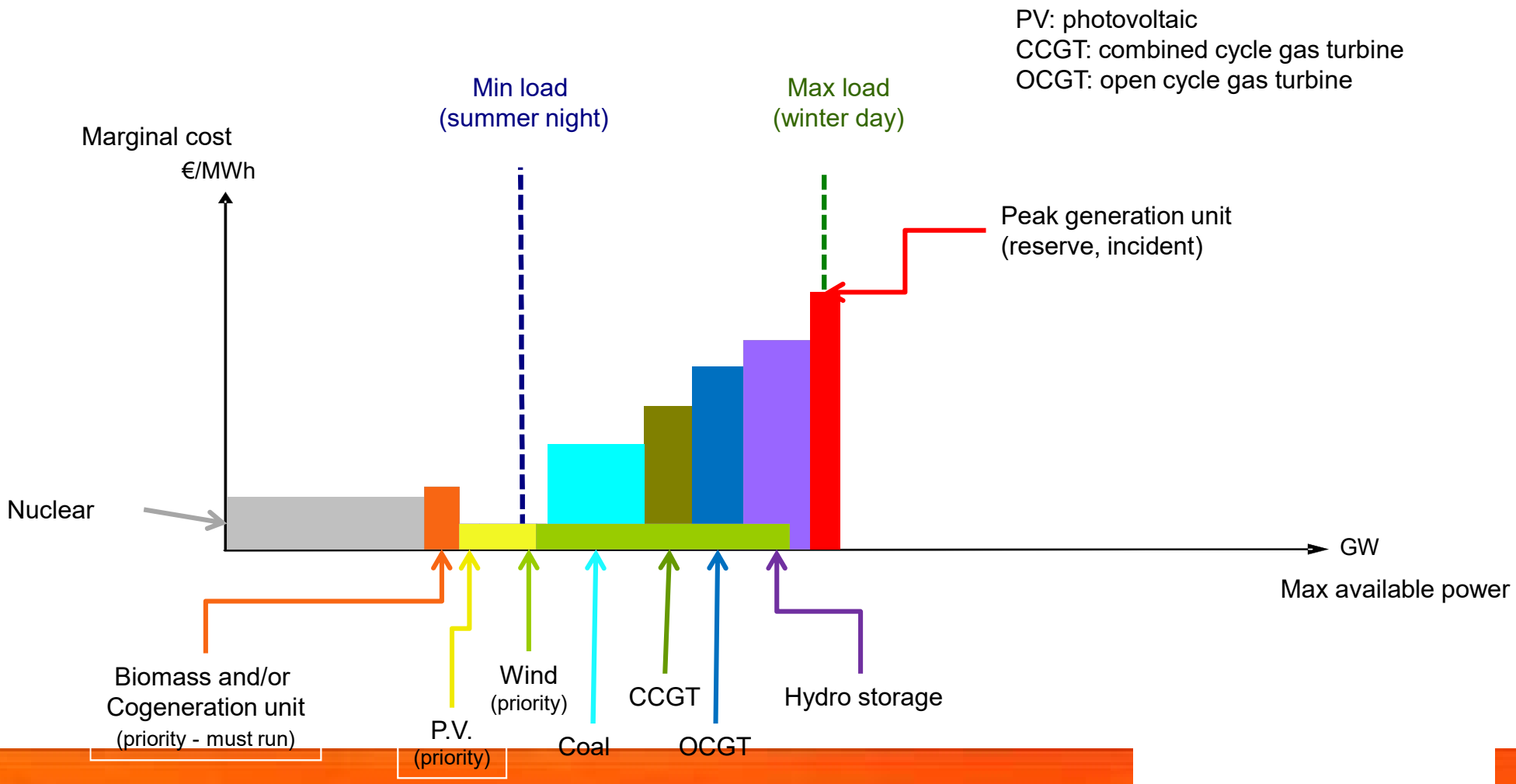


Delta P = 1211W
(=43% of $P_{installed}$)

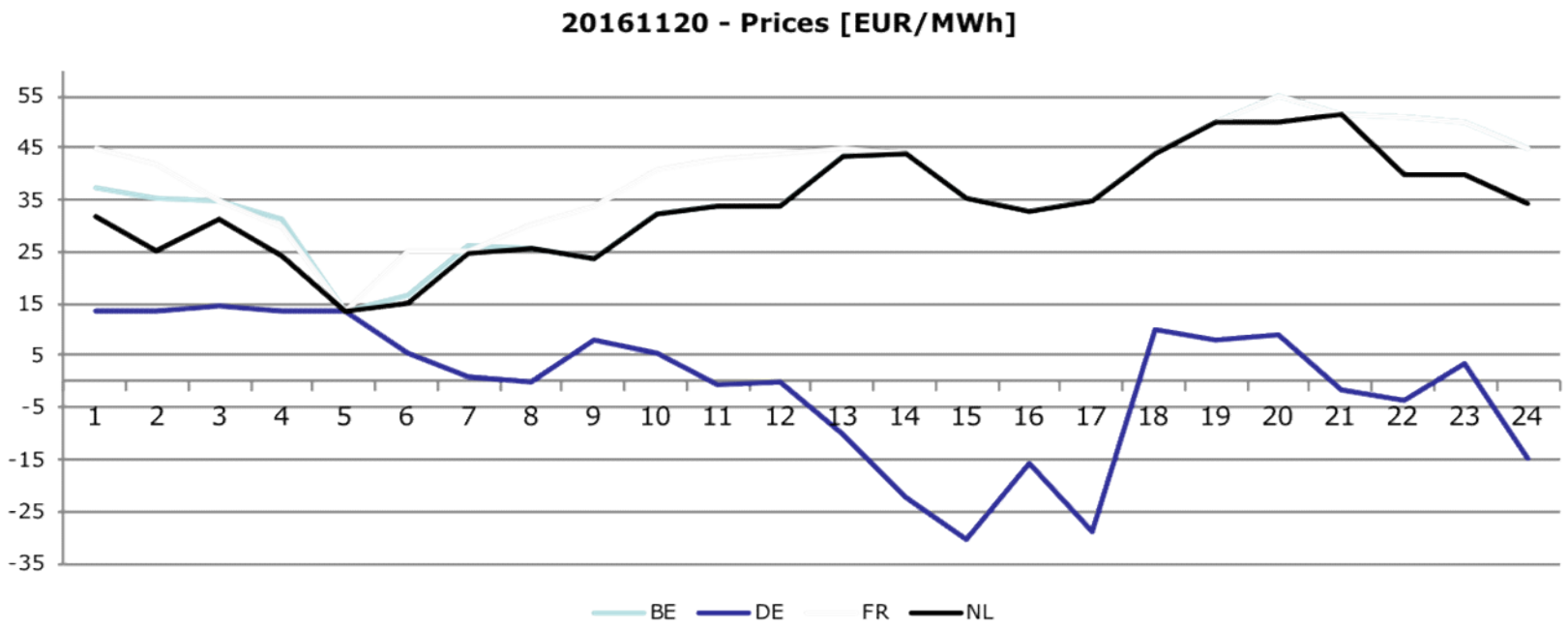


Delta P = 729W
(=41% of $P_{installed}$)

Impact on CWE merit order



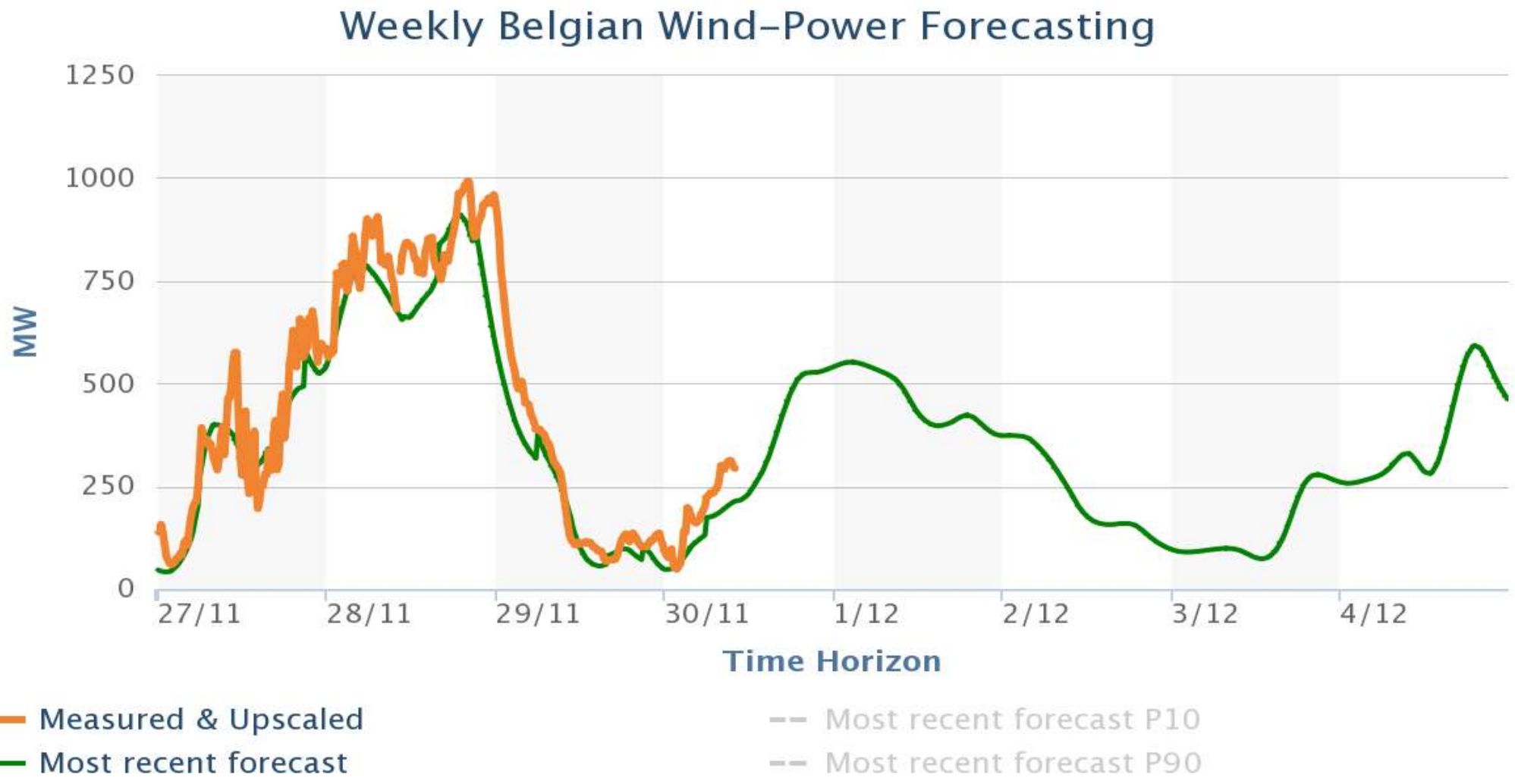
CWE Prices 20/11/2016



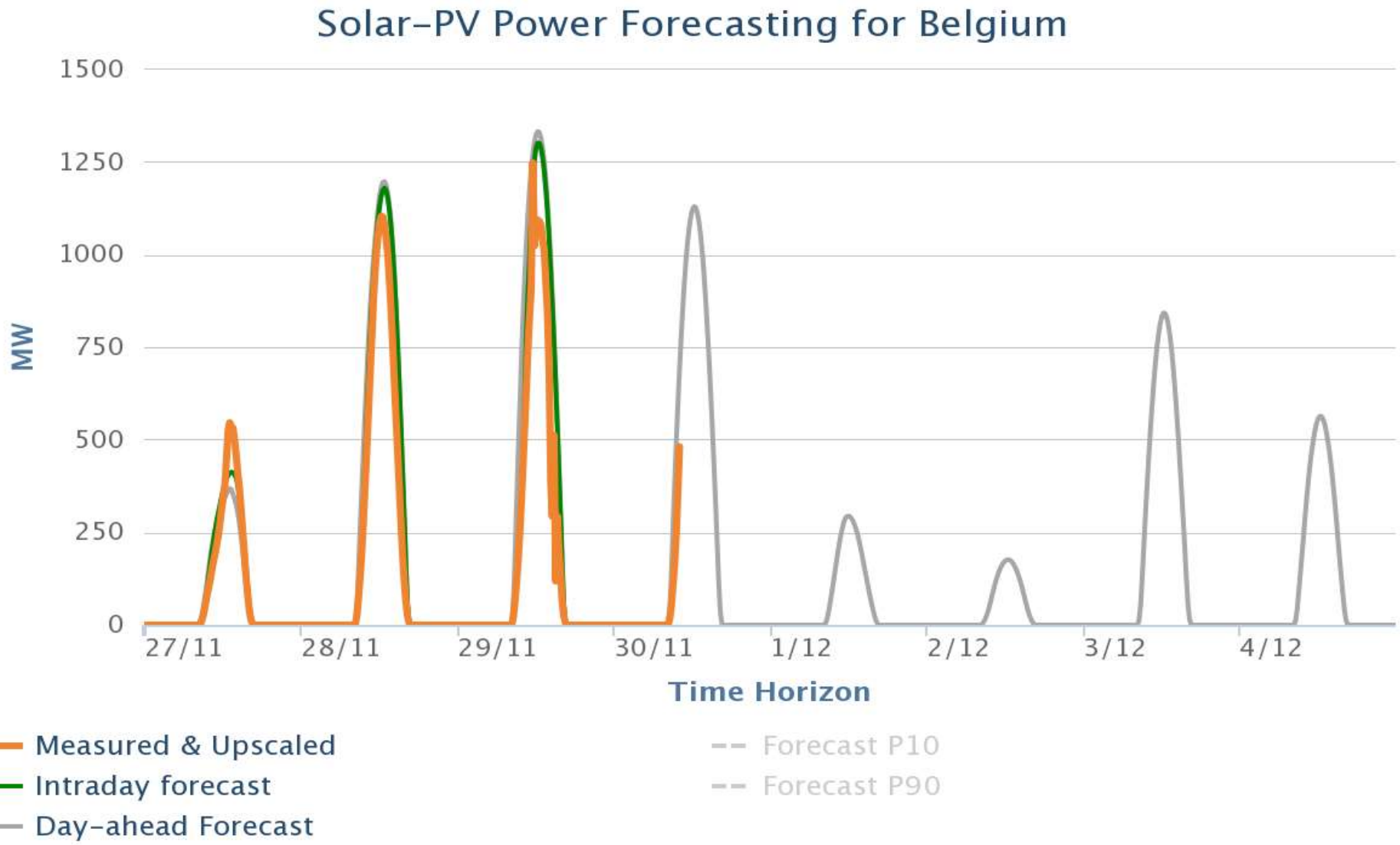
New needs to be taken into account

- **Balance between generation ←→ load**
  - Good overview of decentralised generation units per domain of activity and substation
  - Wind/solar/temperature forecasting tools
  - System service management: takes into account the intermittent nature of renewable energies as regards the volume of reserves
    - ✓ Prim R, Sec R, Tert R

Wind Forecasting



Solar Forecasting



Wind power

Available theoretical power

The available wind power P_{vent} is equal to:

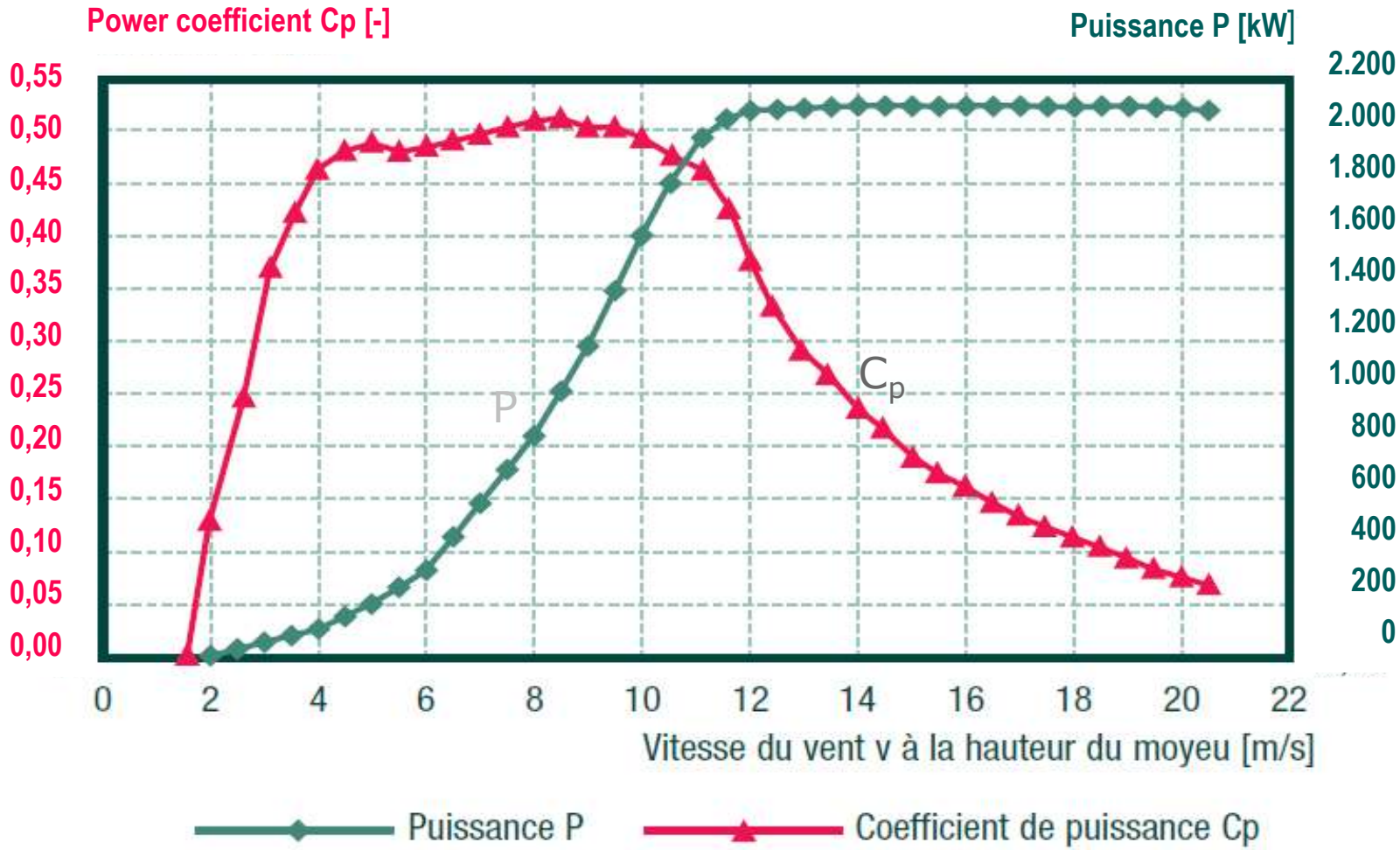
$$P_{vent} = \frac{1}{2} \rho A . v_{vent}^{3} \quad [W]$$

- ρ = Air density
- A = Area swept by the blades
- v_{vent} = Wind speed [m/s]

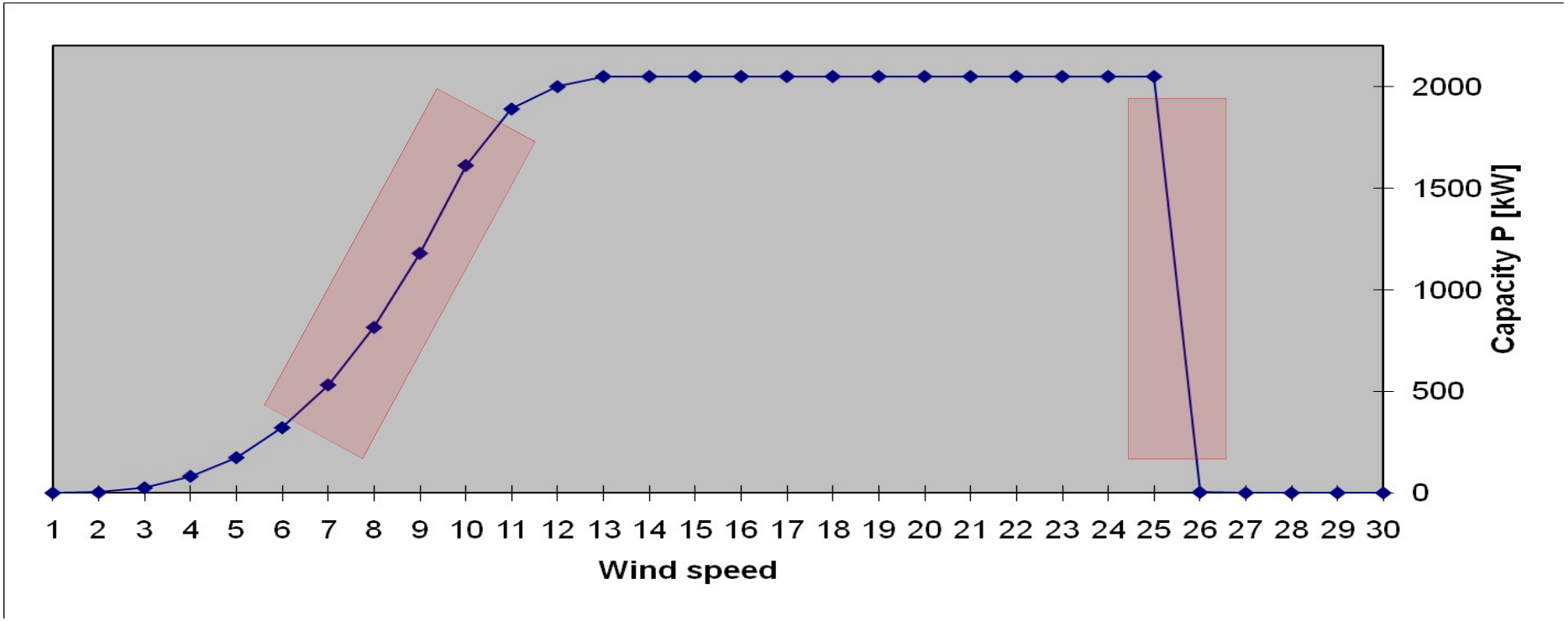
Example :
Wind speed: 10 m/s, Rotor diameter: 82 m

Wind power: 1/2 x 1,225 x 5,281 x 10^3 = 3.235 kW
Captured power by the wind turbine = Wind power x **cp**
Cp : performance coefficiant, theoretical maximum = 0,59

Power curve= f(wind speed)

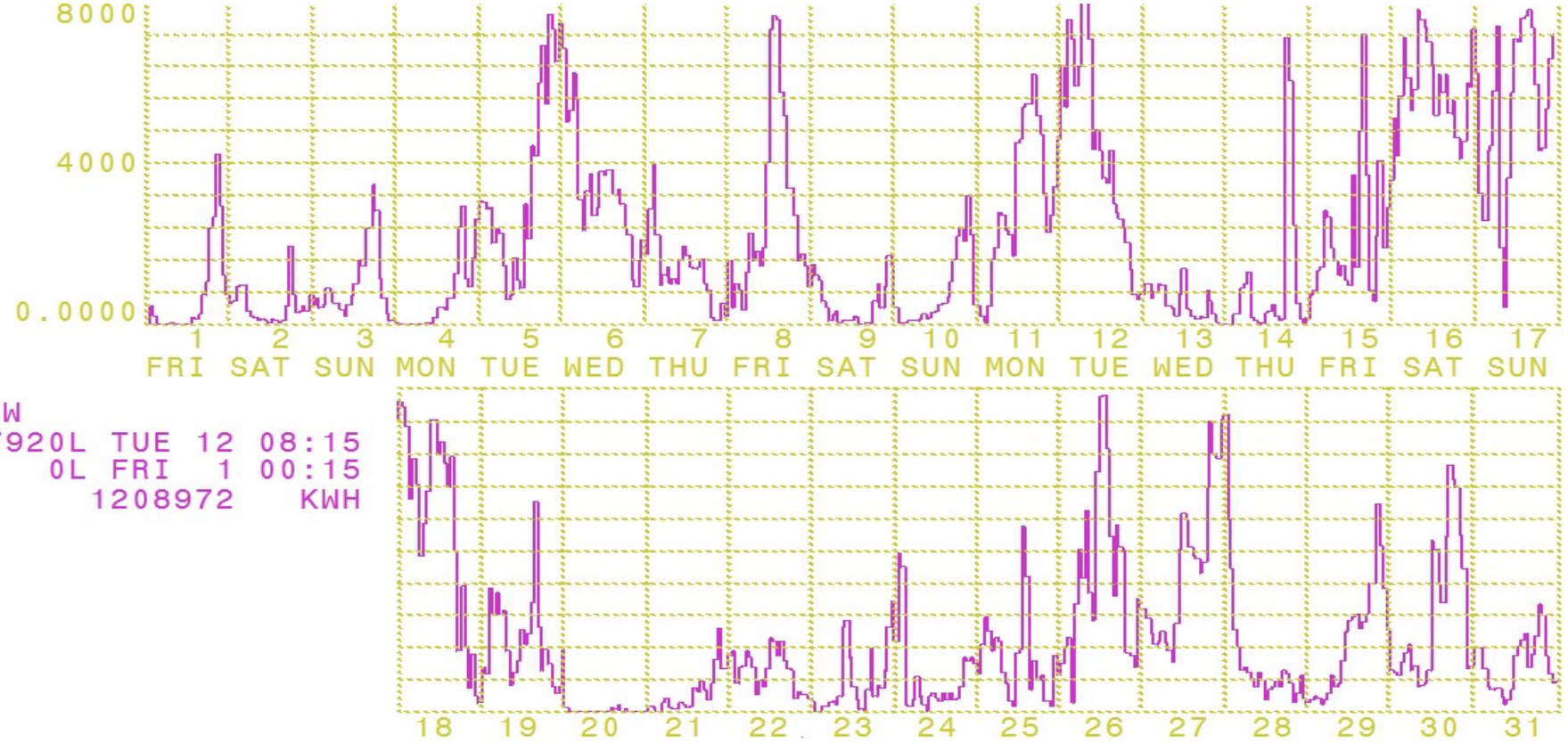


Restrictive areas in wind turbine operation



Onshore farms

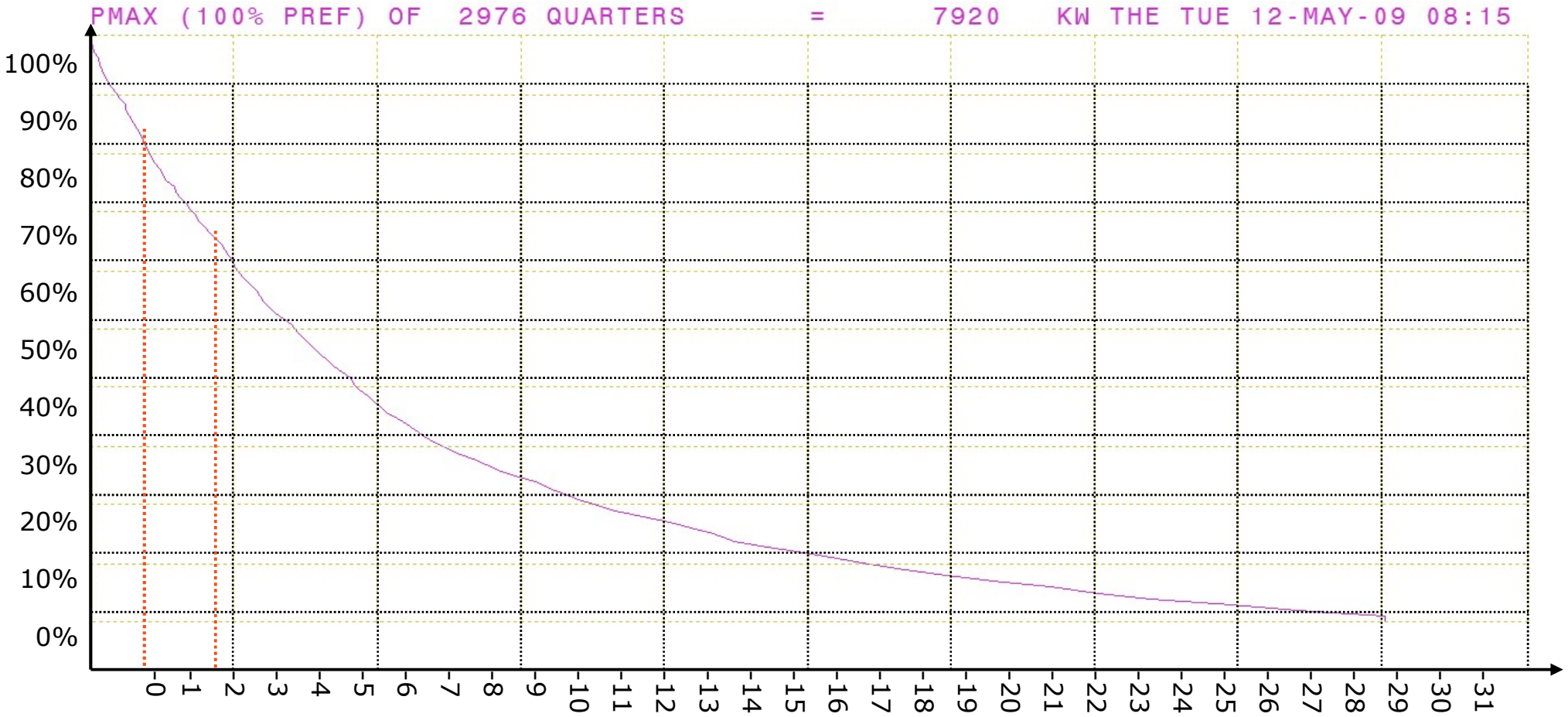
Monthly generation of a farm



UNIT = KW
MAX: 7920L TUE 12 08:15
MIN: 0L FRI 1 00:15
ENERGY= 1208972 KWH

Onshore farm

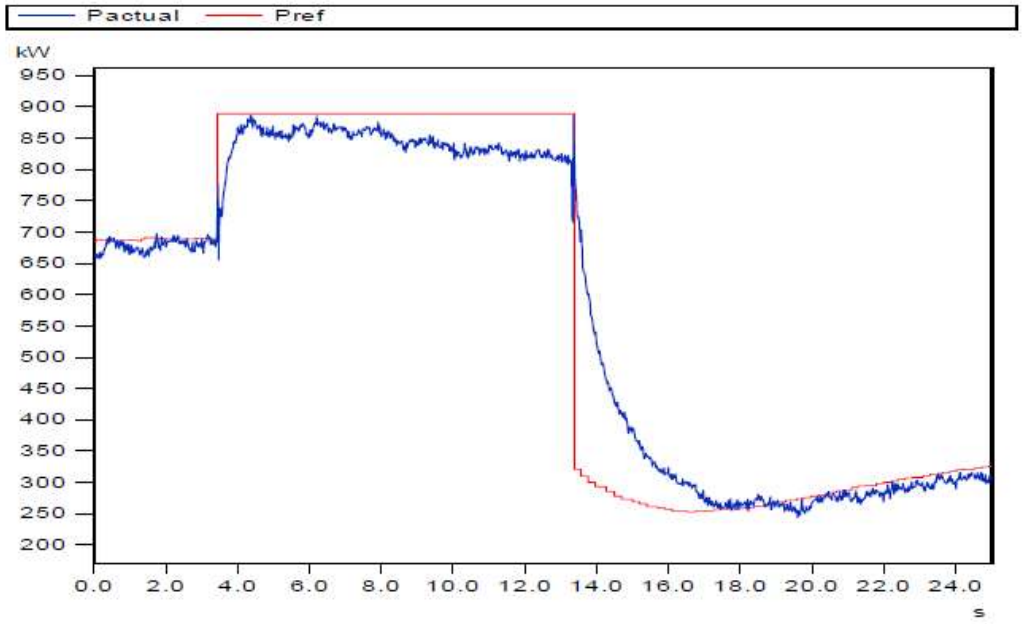
Monthly monotonic curve for the same farm



2. Underfrequency:

Optional active power boost, using the inertia of the rotor.

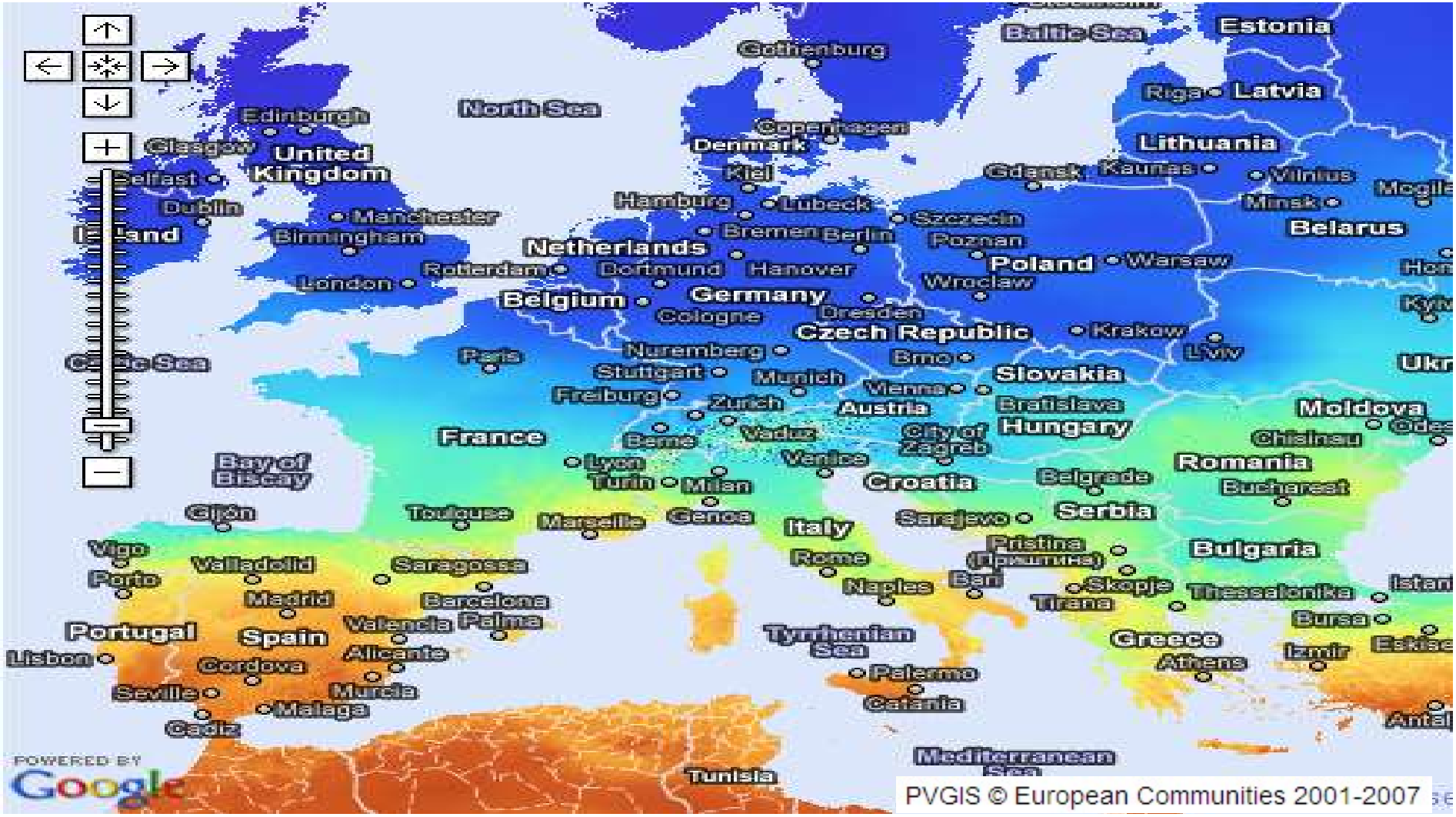
- ✓ $P_{boost} = 10\%P_{rated}$
- ✓ Available as soon as $P_{actual} \geq 4\%P_{rated}$
- ✓ P_{boost} fully available within 800ms
- ✓ Boost for max. 10 seconds
- ✓ Recovery time after boost = 2 x T_{boost}



- **Performance achieved by changing excitation, using rotor inertia.**
- **Activated based on local frequency measurement.**
- **Additional investment in WF necessary.**
- **Cost relevant => Economical value for the power system?**
- **Impact to the max. installable wind power?**

Photovoltaics

Potential in Europe

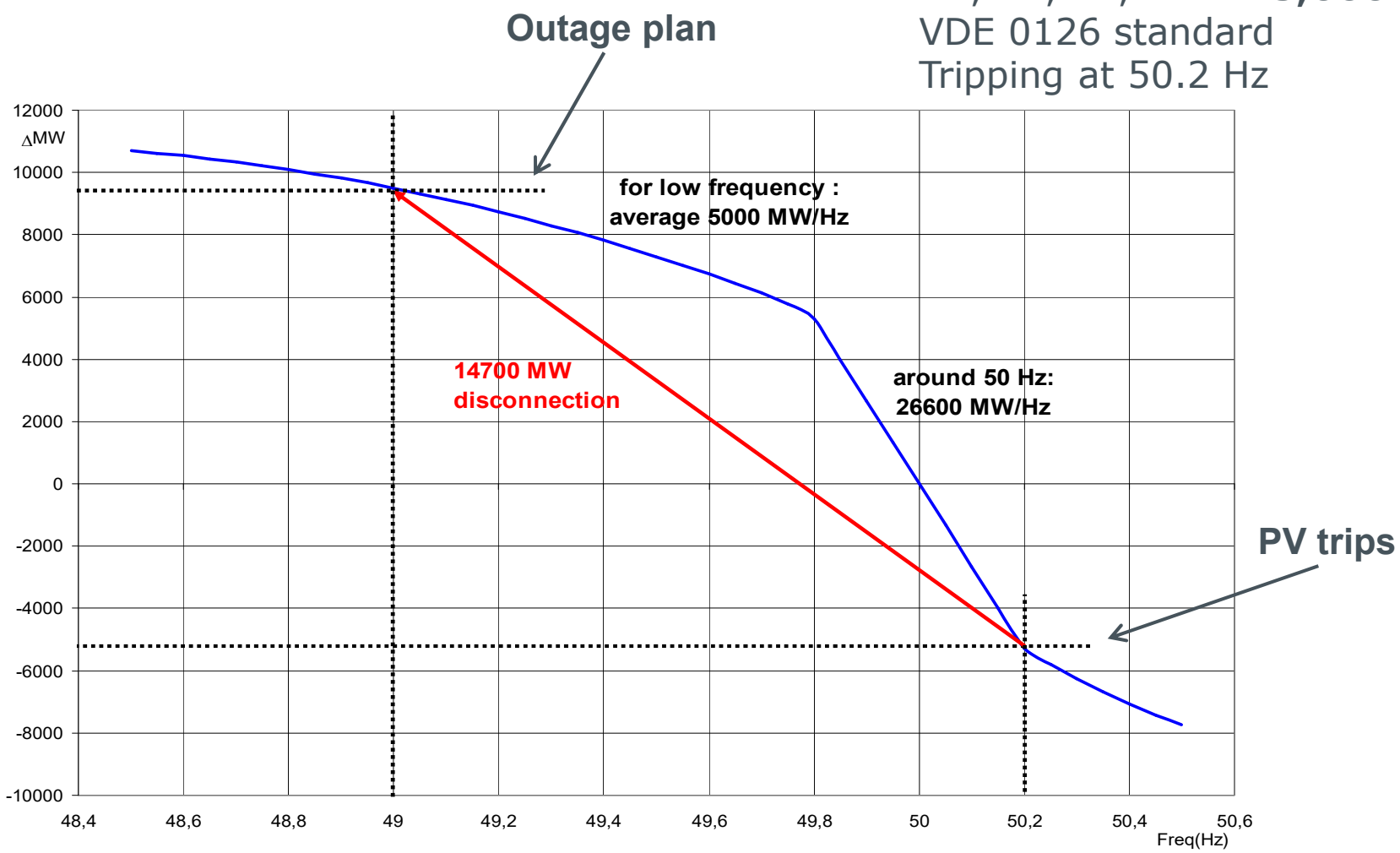


Yearly total of global irradiation on horizontal surface

200 500 800 1100 1400 1700 2000 [kWh/m²]

Risk of disconnection at 50.2 Hz

DE, BE, FR, AT = **15,000 MWp**
VDE 0126 standard
Tripping at 50.2 Hz

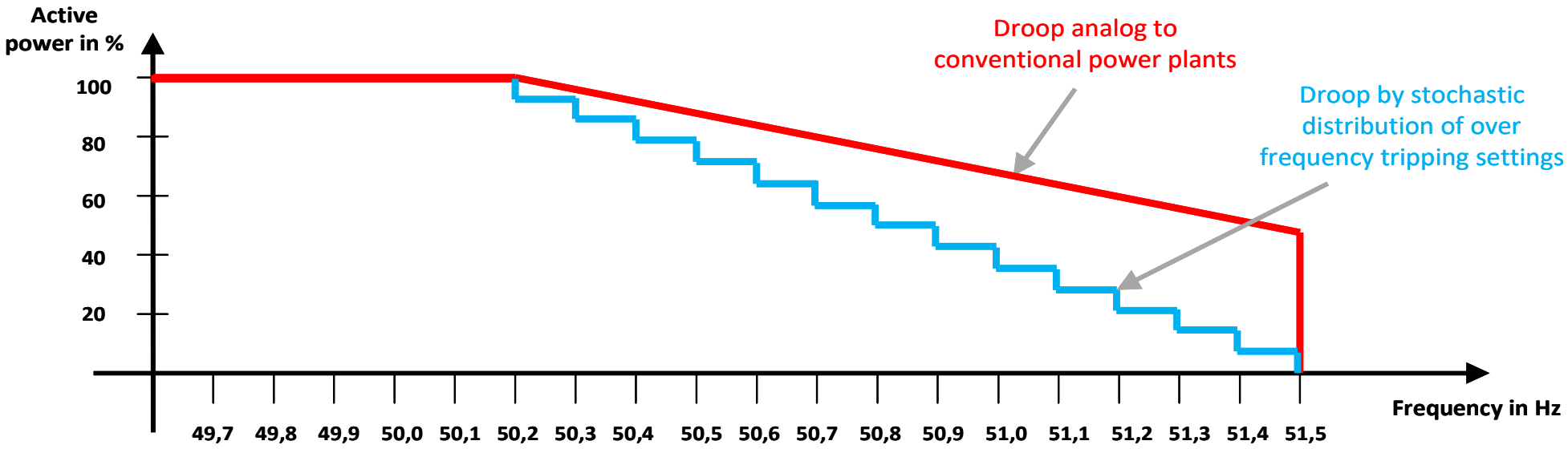


➔ **Risk of increasing uncontrolled frequency fluctuations**

taking into account the f-sensitivity of generation (primary reserve + self-regulation) and load

Modification of the standard: gradual reduction of generation

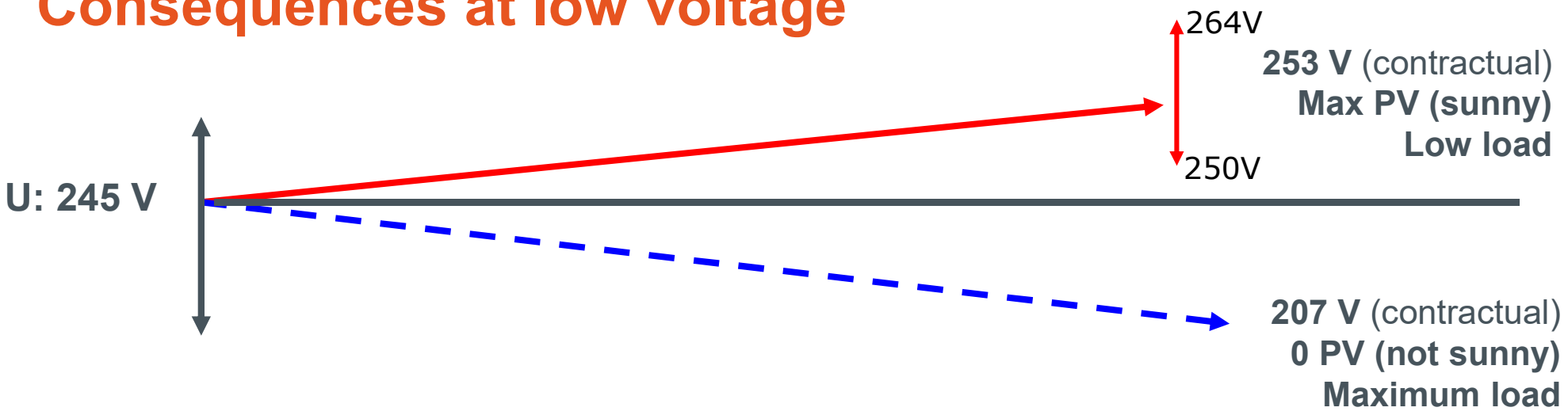
- New units (from 2012 onwards)
  - Gradual reduction of generation
- Existing units
  - Coordinated retrofitting

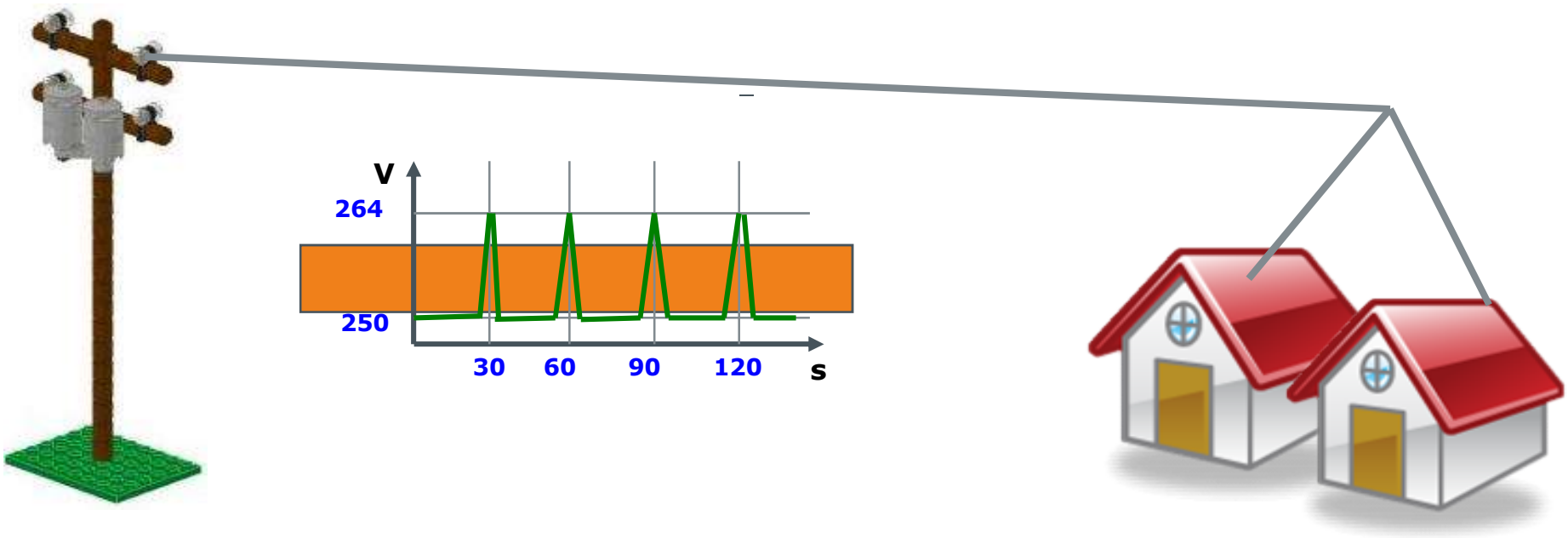


Voltage problems
Standard DIN VDE 0126-1-1

- Maximum instantaneous voltage: **264.5 V** (115%)
- Maximum average voltage over 10 minutes: **253.0 V** (110%)
- Former instantaneous limit: **243.8 V** (106%)
- Reconnection after **30 seconds**

Consequences at low voltage





PV Germany: SMA solution

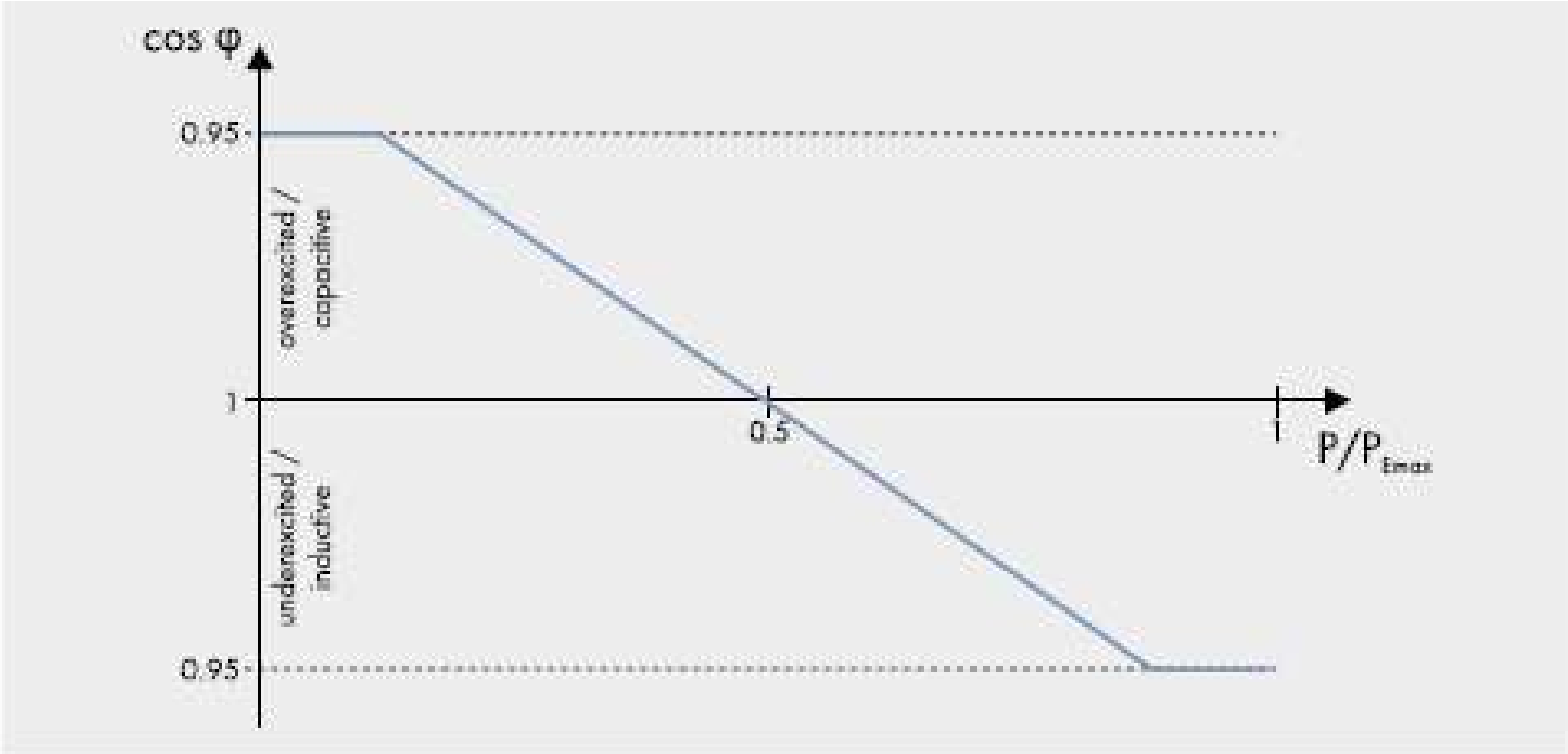
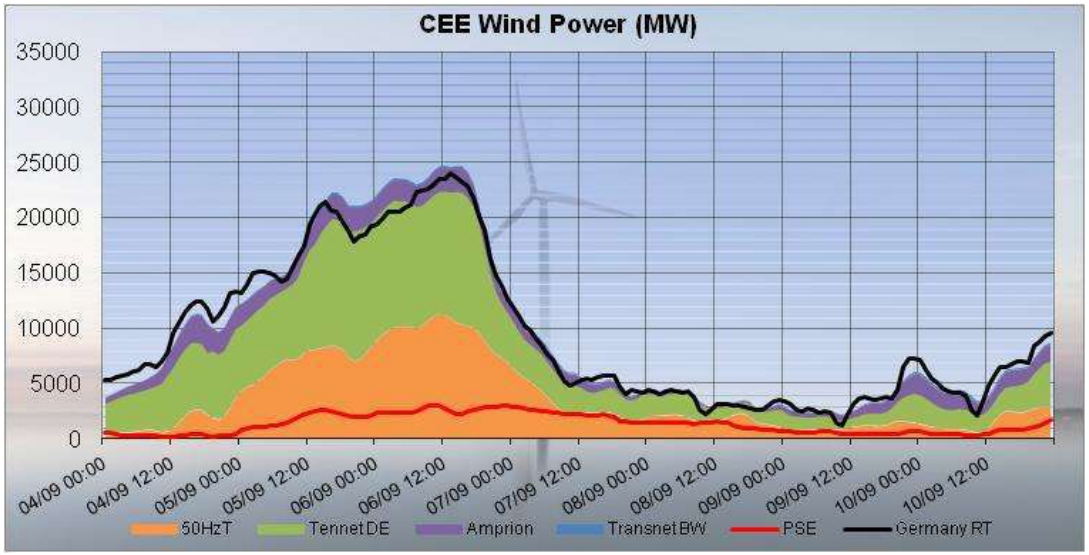


Fig. 4: Among others, the reactive power may be regulated as a function of the supplied active power

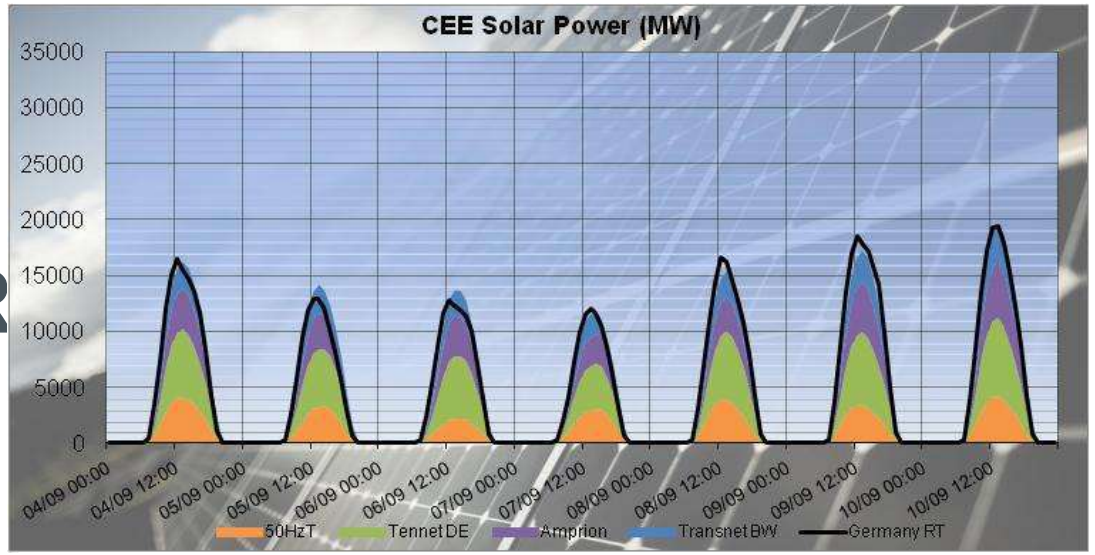
Global Grid

Renewable Energy in Germany

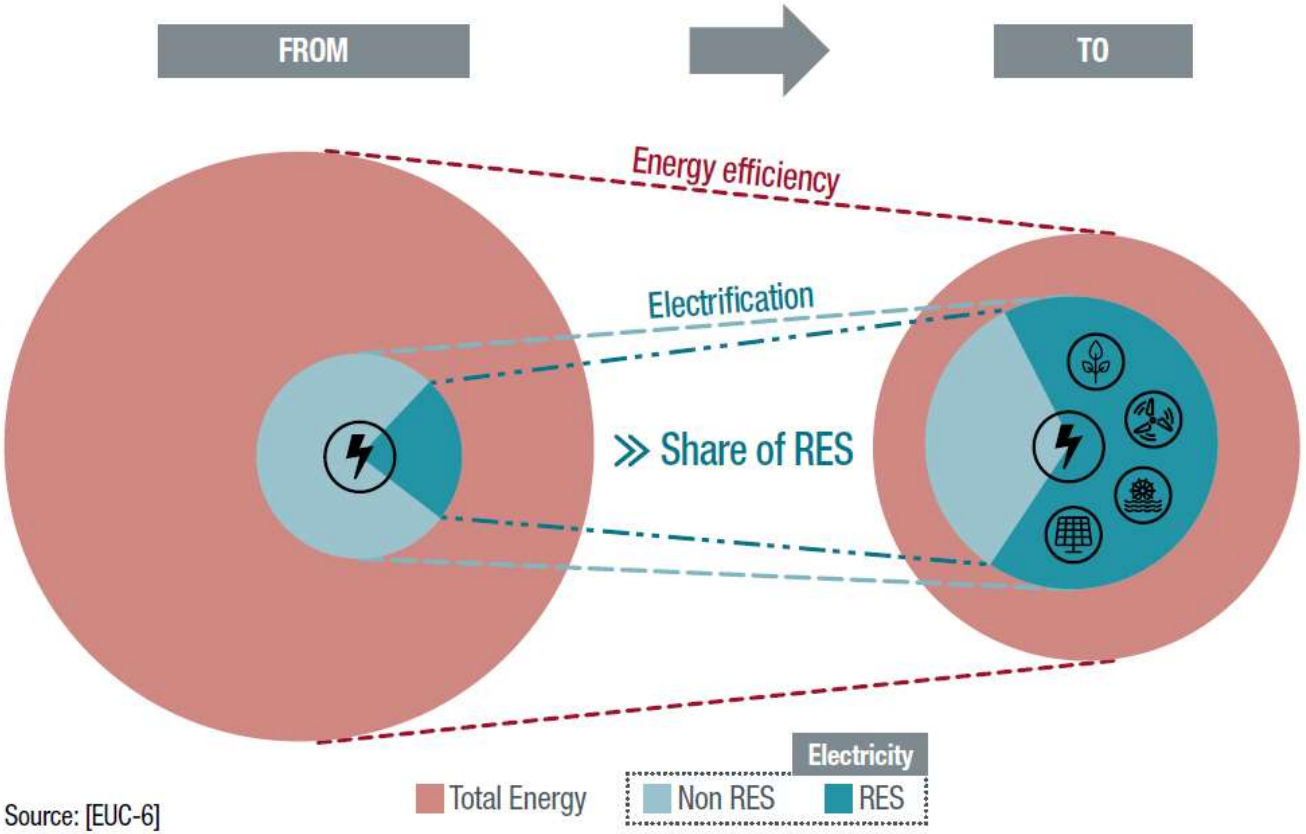
- **WIND**



- **SOLAR**



European Objectives 2040-2050



Source: [EUC-6]

The total energy consumed will be reduced with additional energy efficiency measures

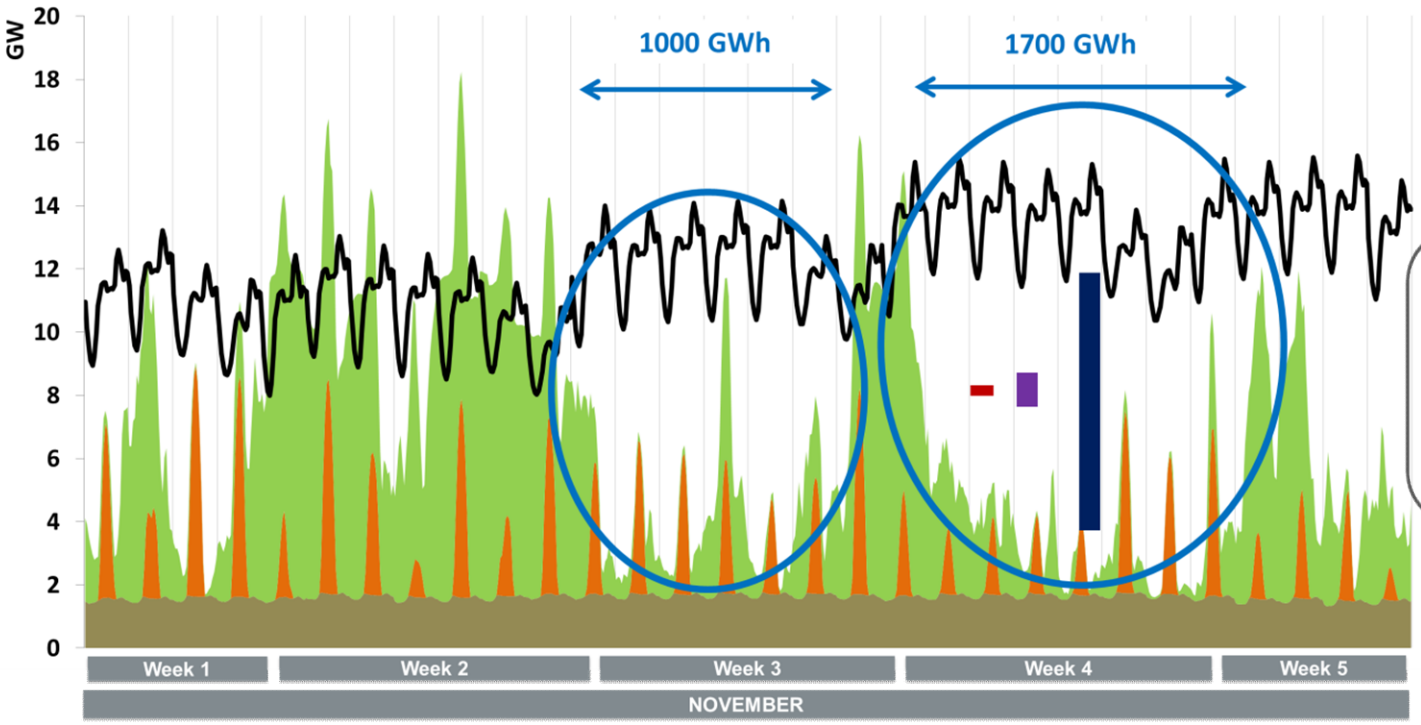
The electricity share in the final energy consumption will increase with additional electrification

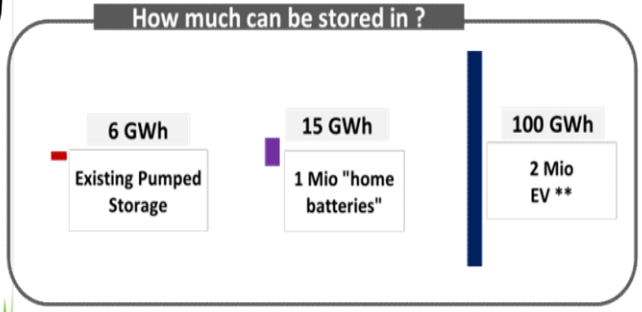
The increase of renewables in the energy mix and particurarly in the electricity sector will increase

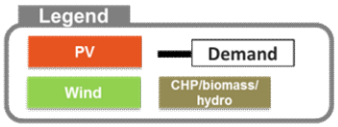
Types of storage and limitations

- Hydraulic : pumped storage
- Lithium ion batteries
- Biomass
- Power to Gas : H2 or CH4
- CAES (crompressed air energy storage)
- Kinetic energy
- Sensitive or latent heat
- Etc.

2040, need storage and flexible demand during periods of no wind and no sun



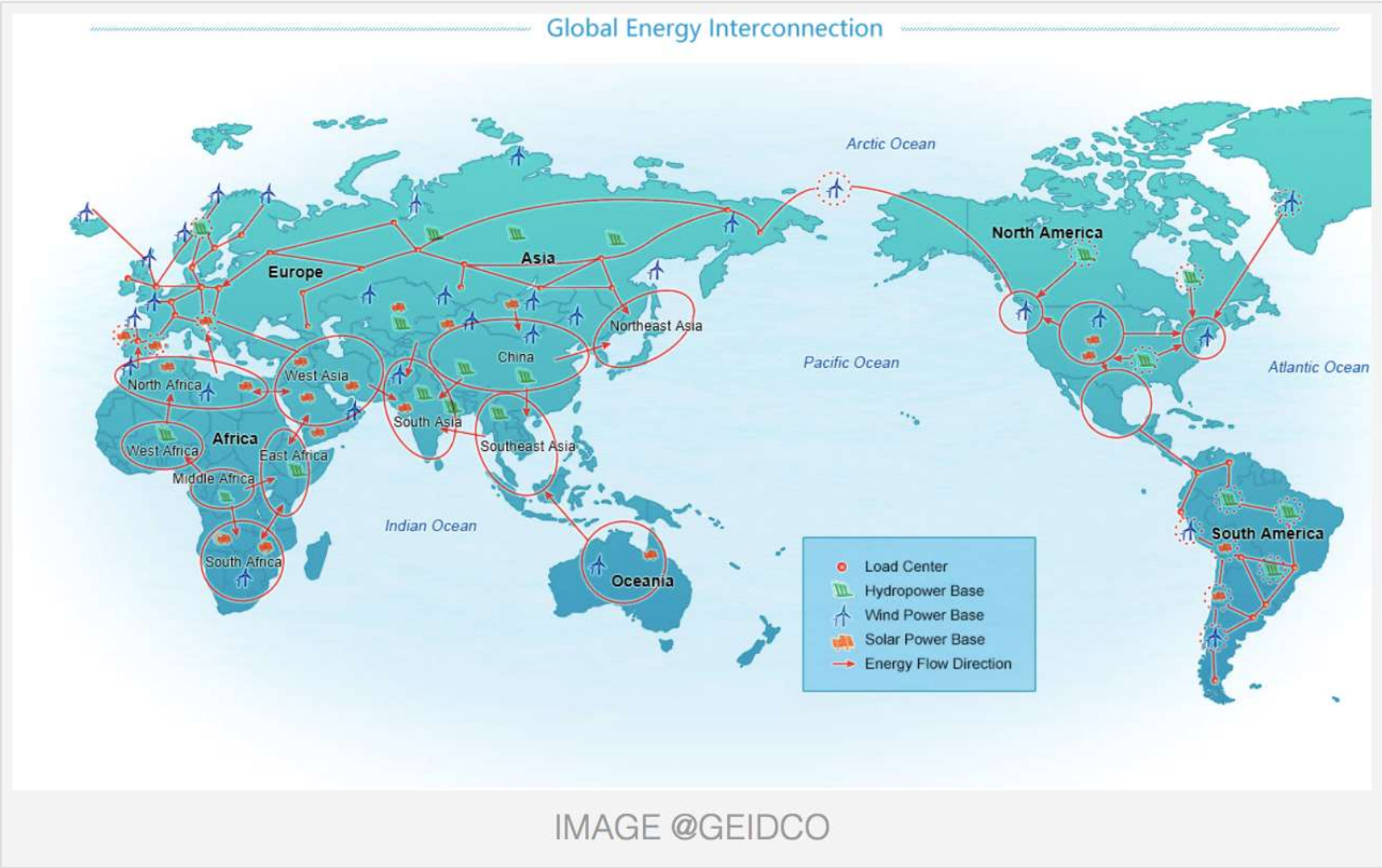




** 18 GW of PV*
11 GW of wind

*** if connected permantly to the grid and batteries of EV only used to store energy to balance the system*

Global Grid


Global Energy Interconnection
Arctic Ocean
North America
Europe
Asia
Northeast Asia
China
Pacific Ocean
Atlantic Ocean
North Africa
West Asia
South Asia
Southeast Asia
Africa
West Africa
East Africa
Middle Africa
South Africa
Indian Ocean
Oceania
South America
Load Center
Hydropower Base
Wind Power Base
Solar Power Base
Energy Flow Direction
IMAGE @GEIDCO

Technical characteristics of the global grid

Need:

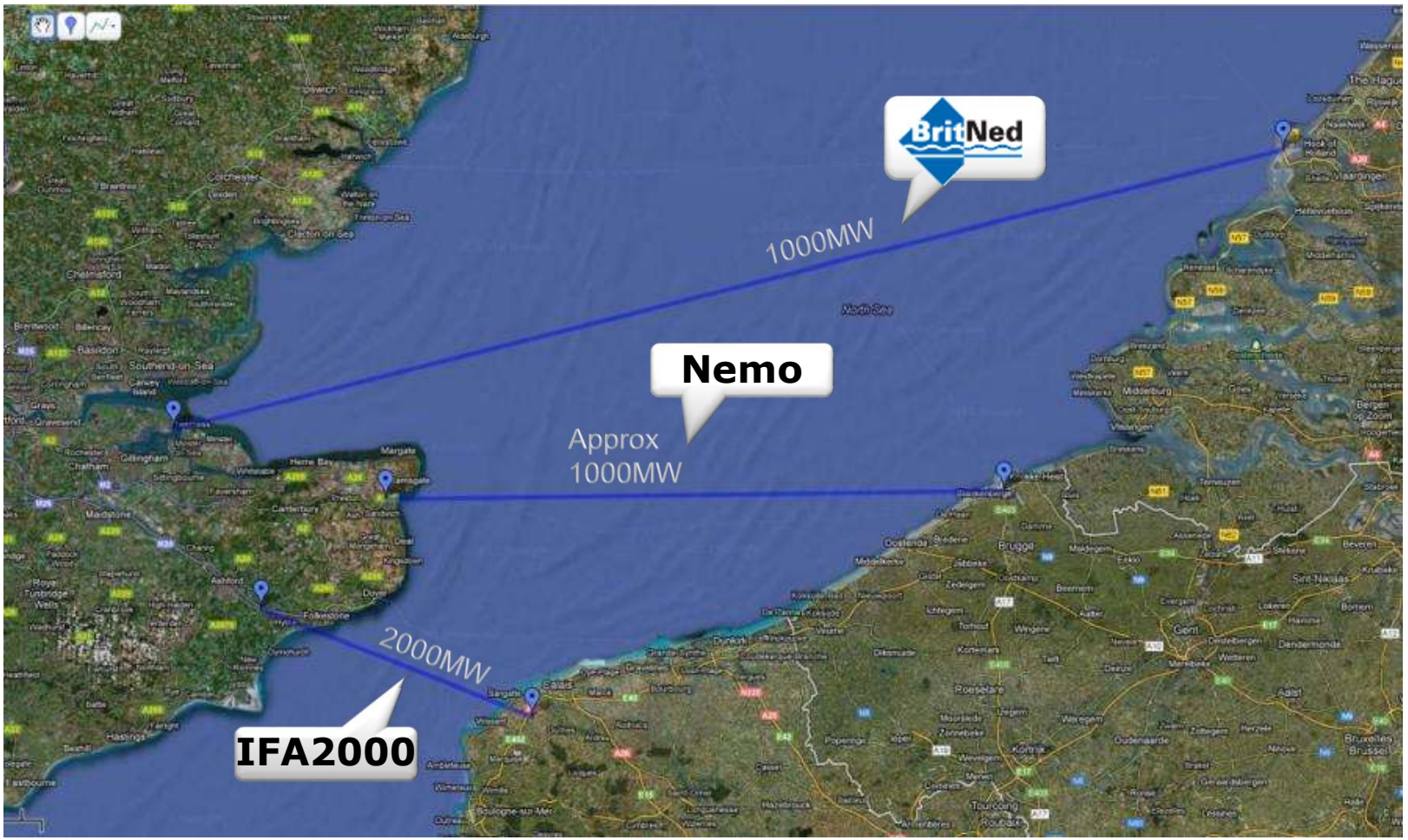
Transport of very large power over long distances

Adapted technology:

Direct curent links

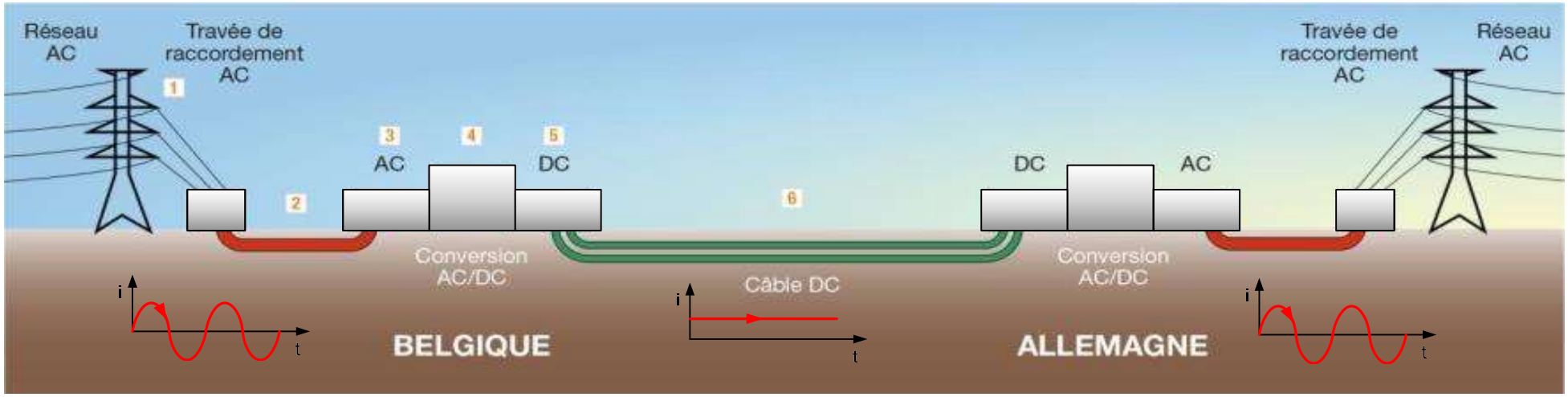
- Low losses
- Easy flow modulation
- Participation in system services

Nemo Link :new electricity interconnector between UK and the continent



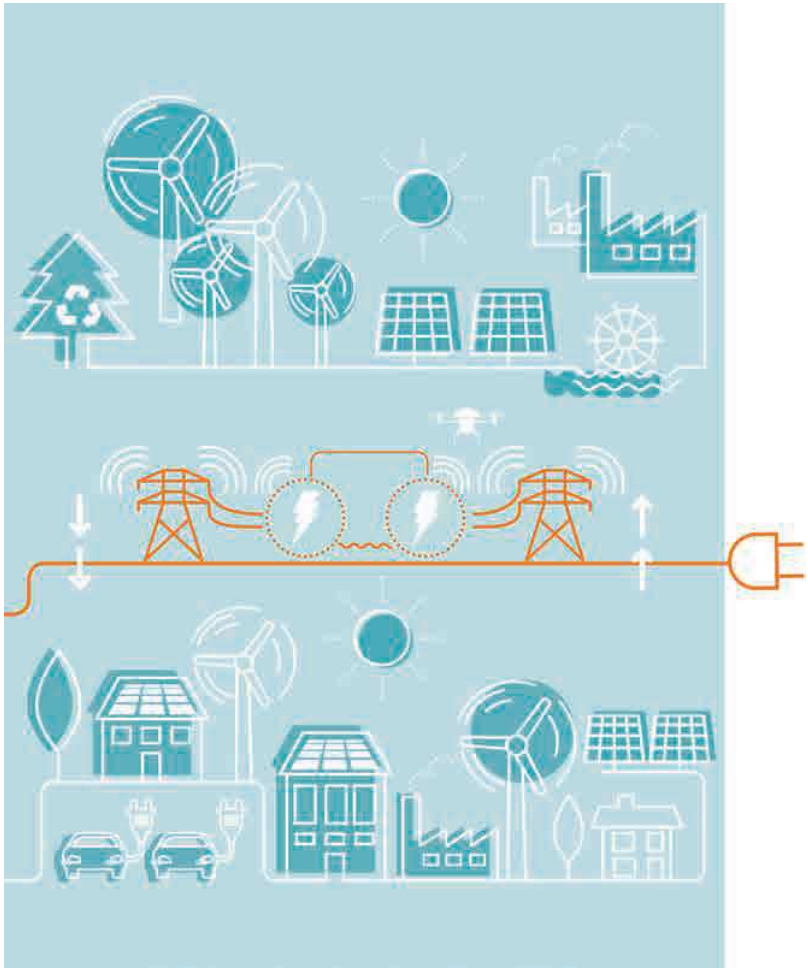
The ALEGrO interconnector

Converter station technology	HVDC VSC multilevel Symmetrical Monopole	
Bi-directional capacity	~ 1000 MW	
Cable technology	HVDC XLPE	
Applied DC voltage	320 kV	
New interconnection	Belgium	Germany
TSO	Elia	Amprion
Region	Liège	Aachen
Converter station location	Visé	Oberzier
Route length	49 km	45 km



Energy future

Energy future



Energy future

Technical problem

- Intermittence of renewable energies
- Variability of renewable energies

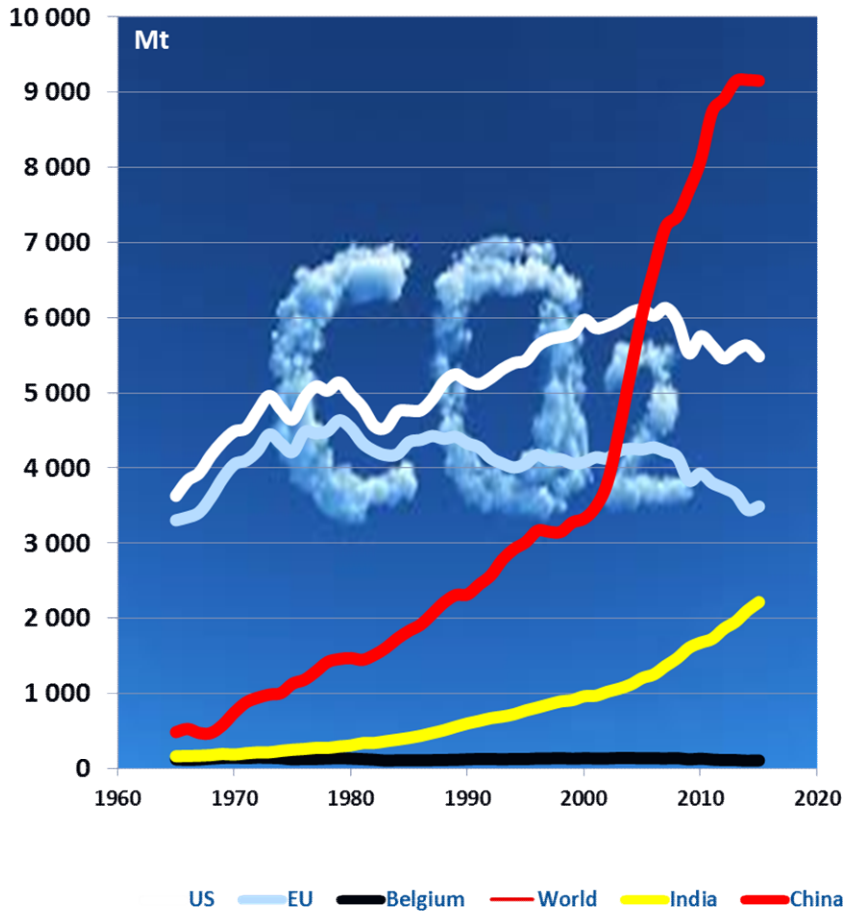
Problems to be solved locally, at European level and with global grid

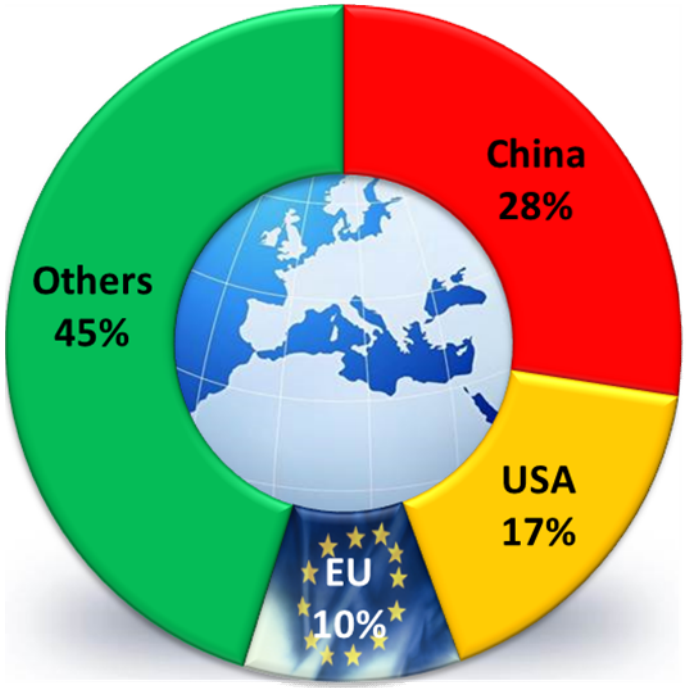
Political issue

- Nuclear shutdown
- Réduction of CO2 emissions

Global problem to solve at planet level

Energy future





Samuele Furfari Data : BP 2016

Many thanks for your attention!

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