
Elia Grid International
as an International Pioneer
egi
elia grid
international

自己紹介

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中学校まで日本の公立の学校

高校・大学はオーストラリア　電気工学と言語（日本語、スペイン語、中国語）専攻

2003～2006年　Australian Energy Market Operator

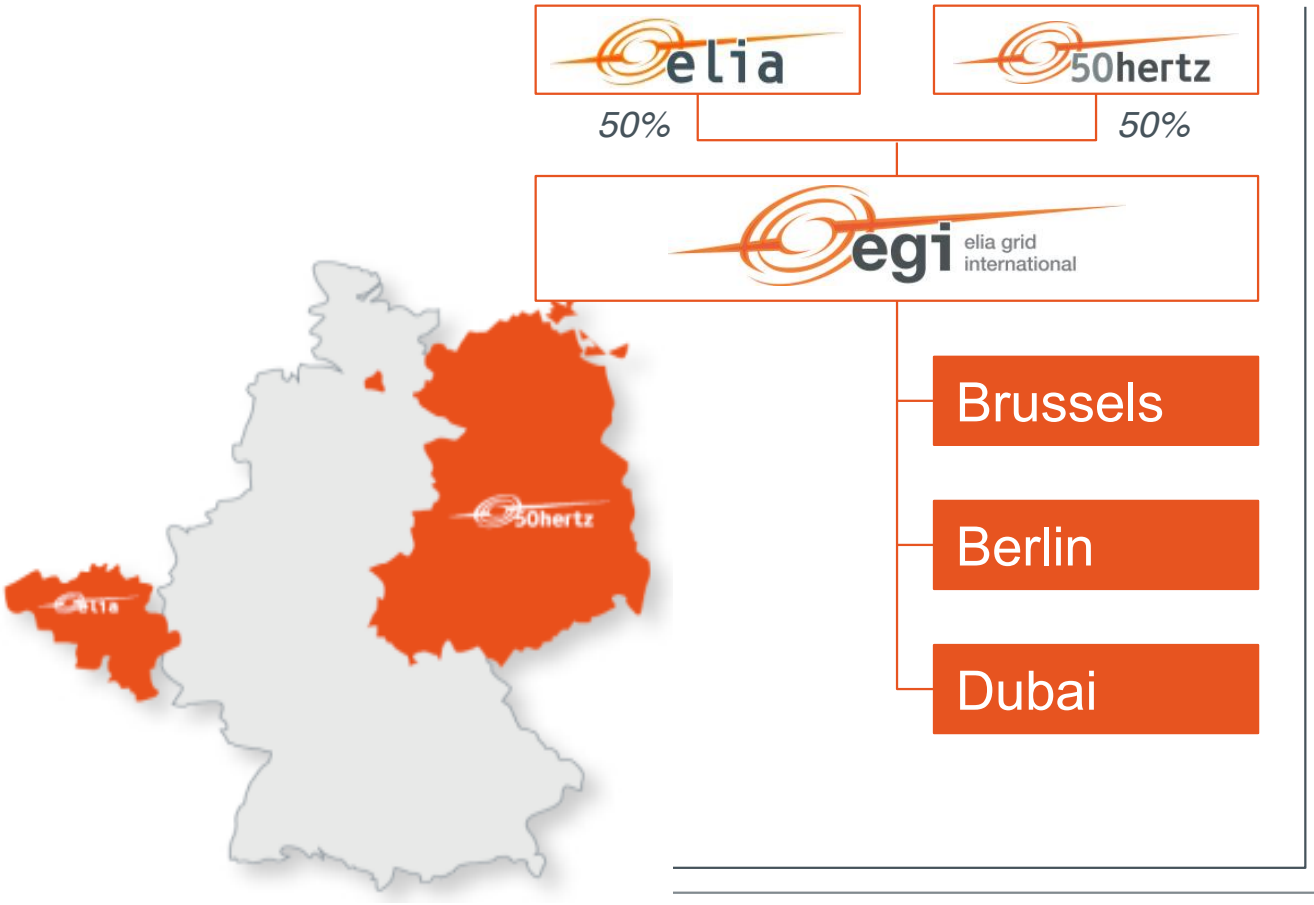
2007～2008年　南米でボランティア

2008～2017年　ヨーロッパ・ドイツで　System Integration of Renewables　に関連した仕事

- Energynautics: Thomas Ackermann
- Ecofys
- Elia Grid International（現在所属）

2017年～　　日本で活動をひろめることが是非できれば！

Elia Grid International: Backed by two major grid operators



EGI offers **consultancy and engineering services** based on experiences from TSOs in Europe:

- Advisory services / Consultancy assignments
- Insights into up-to-date developments in European market
- Workshops

Elia Grid International: international and industry experts working with external partnerships

Cross-border and TSO/DSO coordination

elia — 50%

50hertz — 50%

50% penetration of variable renewables

egi elia grid international

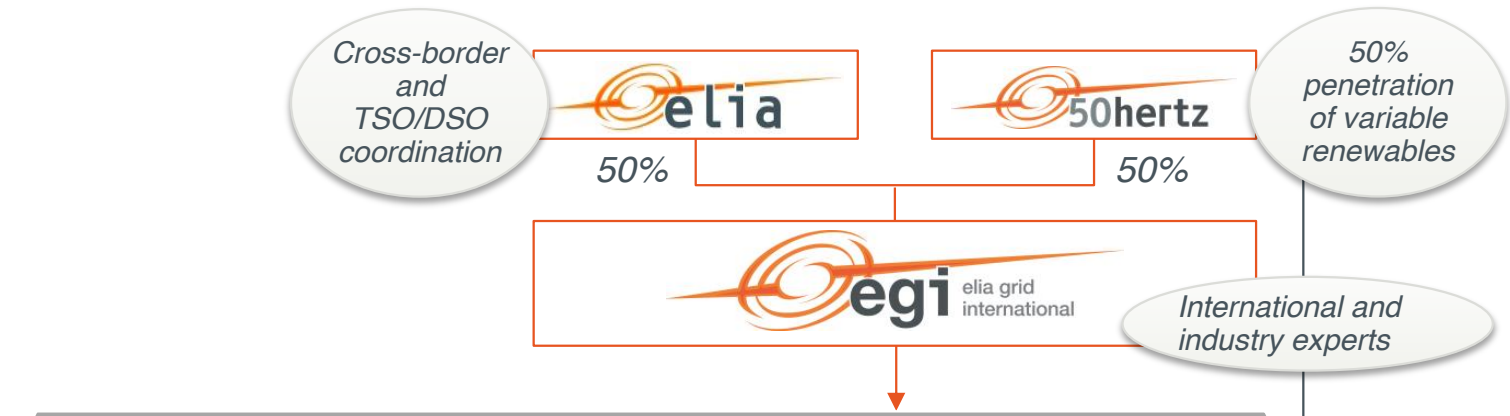
International and industry experts

- *SMA*
- *Younicos*
- *Ecofys*
- *Australia / Italy etc…*

Partnerships

- *Fraunhofer*
- *Poyry*
- *Eridge*

Elia Grid International: providing assistance in adapting to change



Key Driver of Change: Energy Transition
Market Reform & Renewable Energy Integration

- **Asset Management** — how to optimise with uncertainty from cross-border operation, renewables and unbundled market
- **Strategical & Organisational advisory** — how to reorganise with unbundling from vertically integrated utility to TSO/ISO
- **System operations & grid development** — how to secure and optimise with uncertainty from cross-border operation, renewables and unbundled market
- **Market development and regulatory framework** — pros and cons of (past and future) European / German development compared to other markets

German grid planning methodology to integrate high shares of renewables

Experience from 50Hertz

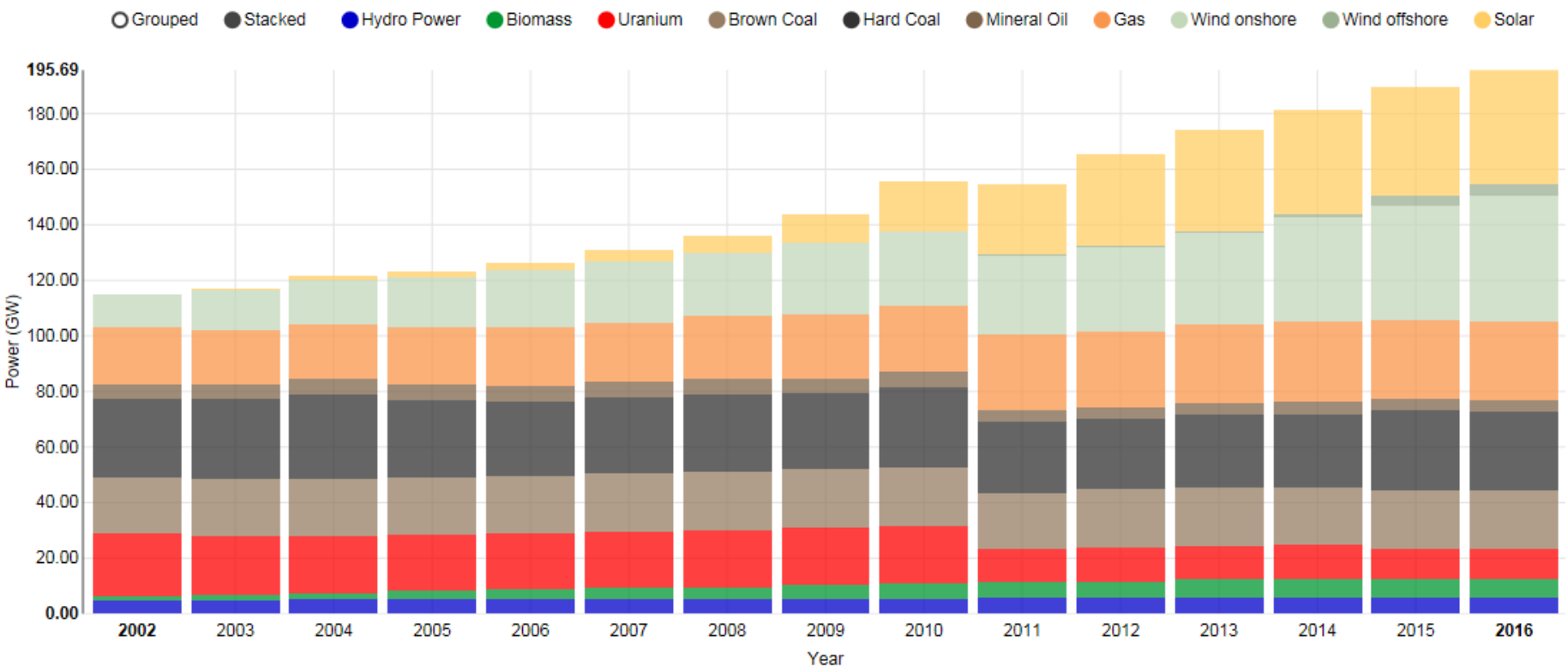
Overview of presentation

1. German renewables development overtakes the grid
2. Grid development identified as key measure to achieve German policy goals of *Energiewende*
3. Costs are increasing and NIMBY delays development
4. Consideration of optimisation principles in grid development plans
5. Question to the audience: what would be important to consider and what is the best way to integrate them in our methods?

German renewables development overtakes the grid:
Renewables in Germany enjoy favourable conditions for investment

- Guaranteed connection
- Priority connection
- Guaranteed feed-in by Feed-in Tariff
- Priority feed-in
- Subject to curtailment for grid congestion -> compensated
- Shallow connection charges

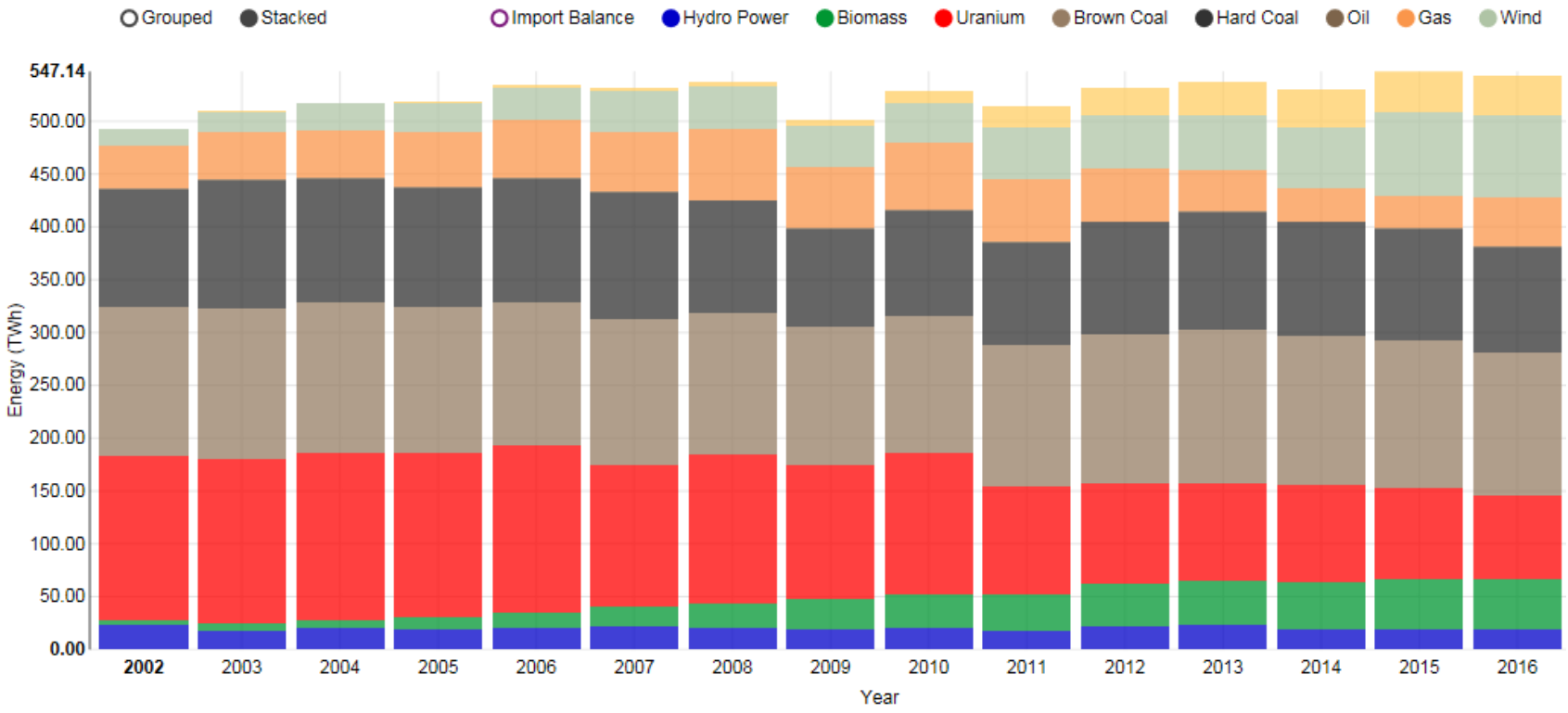
German renewables development overtakes the grid: Development of power generation capacity



Datasource: AGEE, BMWi, Bundesnetzagentur
Last update: 02 Feb 2017 23:13

https://www.energy-charts.de

German renewables development overtakes the grid: Development of power production



Net generation of power plants for public power supply.
Datasource: 50 Hertz, Amprion, Tennet, TransnetBW, Destatis, EEX
Last update: 07 Apr 2017 04:12

https://www.energy-charts.de

Renewables share of yearly electricity production in percentage: 50Hertz is leading development

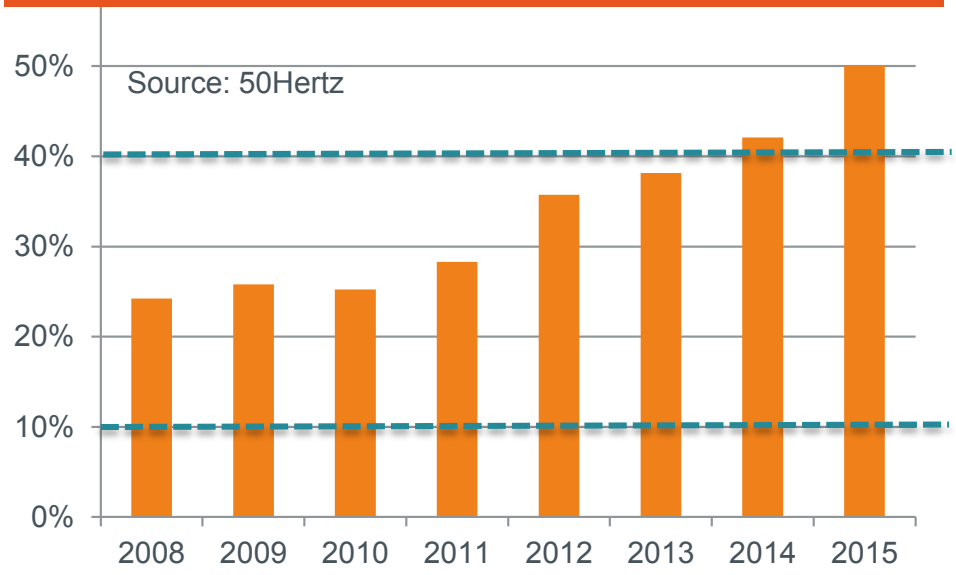
GERMANY

https://www.energy-charts.de

Net generation of power plants for public power supply.
Datasource: 50 Hertz, Amprion, Tennet, TransnetBW, Destatis, EEX
Last update: 02 Apr 2017 09:12

Germany reached 10% penetration in 2004, and 32% in 2016.

50Hertz

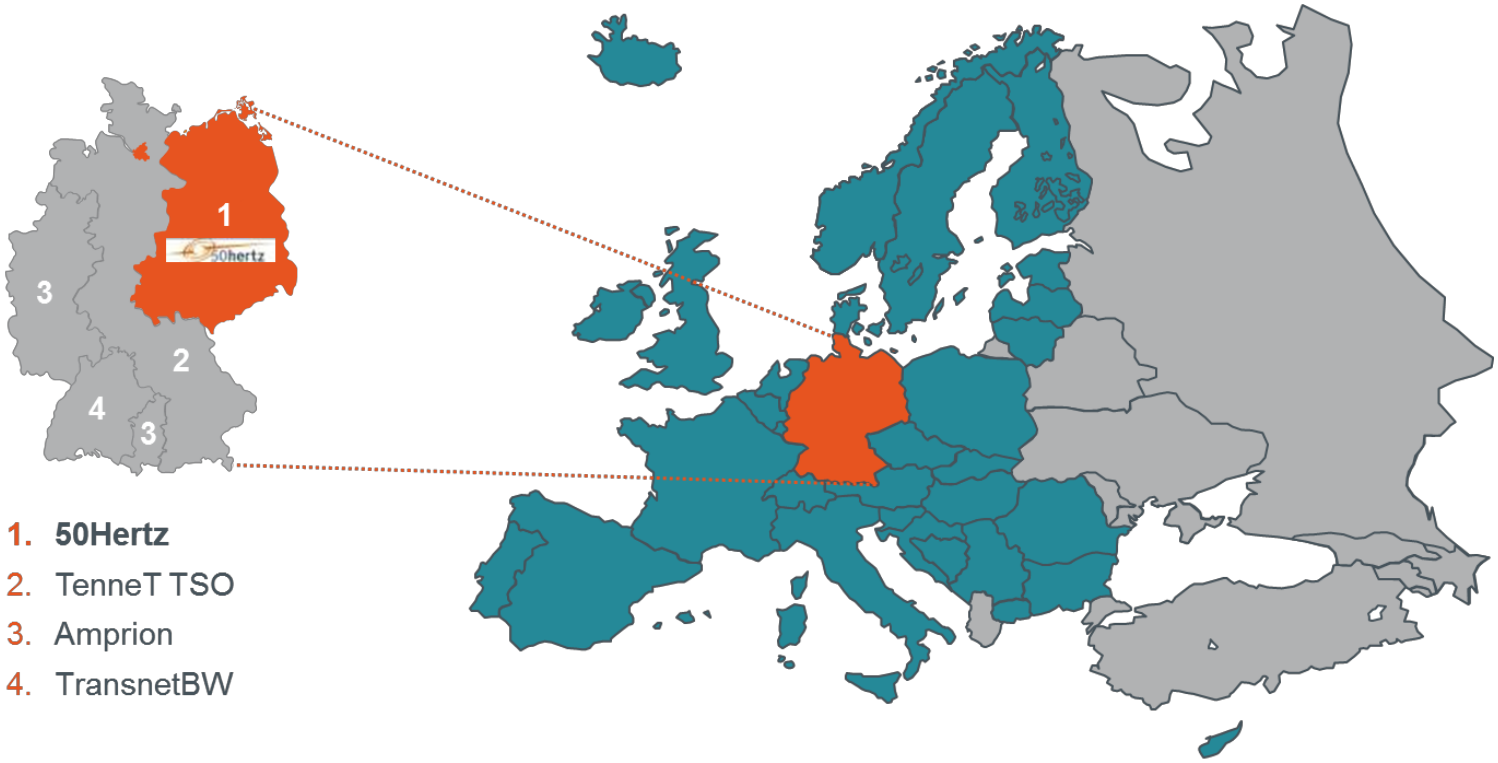


50Hertz reached 10% penetration prior to 2008, and close to 50% in 2015.

The Transmission System Operator 50Hertz
30% of German Grid, 20% of German Population

- Ensures the electricity supply to about **18 million** people in Germany

- Responsible for the operation, maintenance and construction of „electricity highways“ (220 kV and 380 kV)



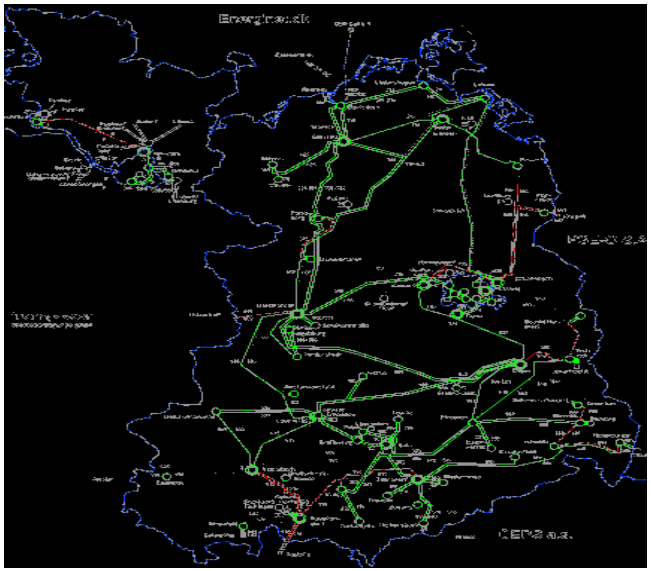
1. **50Hertz**
2. TenneT TSO
3. Amprion
4. TransnetBW

Source: 50Hertz

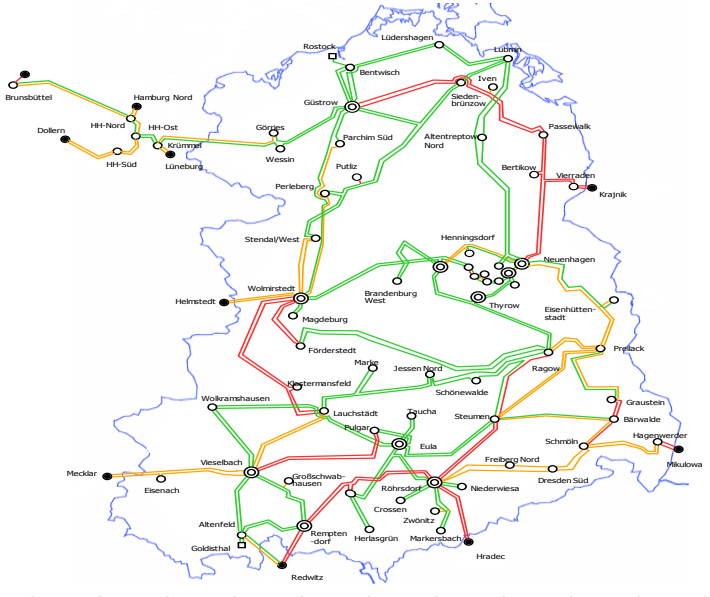
German renewables development overtakes the grid: Example from 50Hertz area

Asynchronous line load > 5h/a

2009



2016



Grid load increases dramatically due to the changing generation infrastructure

Load ≤ 50% *50% < Load < 70%* *Load ≥ 70%* *No values*

Source: 50Hertz

Grid development identified as key measure to achieve German policy goals of Energiewende

What are the core elements of German „Energiewende“?

Policy-driven structural changes in the German energy system:

Phase out of nuclear energy production by 2022

Dynamic Renewables development (EEG 2.0)
Targets: 40-45% share of total electricity consumption until 2025, 80% until 2050

Greenhouse gas reduction: Future of coal-fired generation in question
Target: 40% CO_2 reduction by 2020, 80-95% by 2050

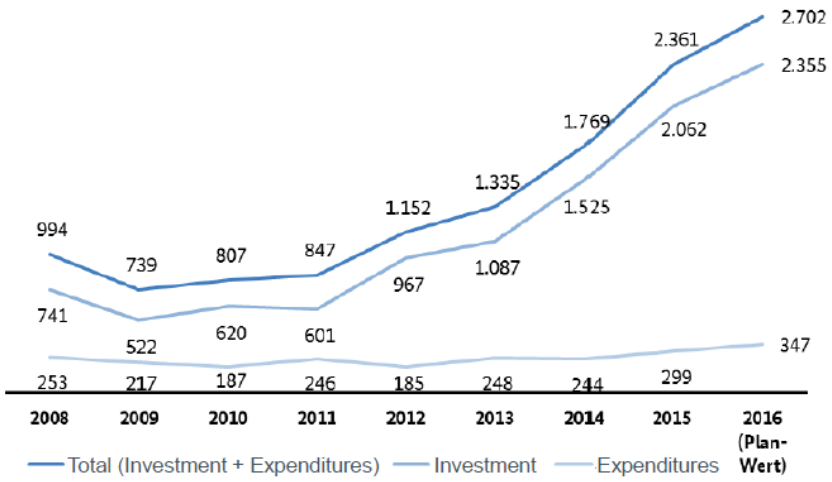
Energy efficiency: 50% increase of electricity efficiency by 2050

Grid extension to transport renewableenergy to the big industrial centres in Southern Germany

Source: 50Hertz

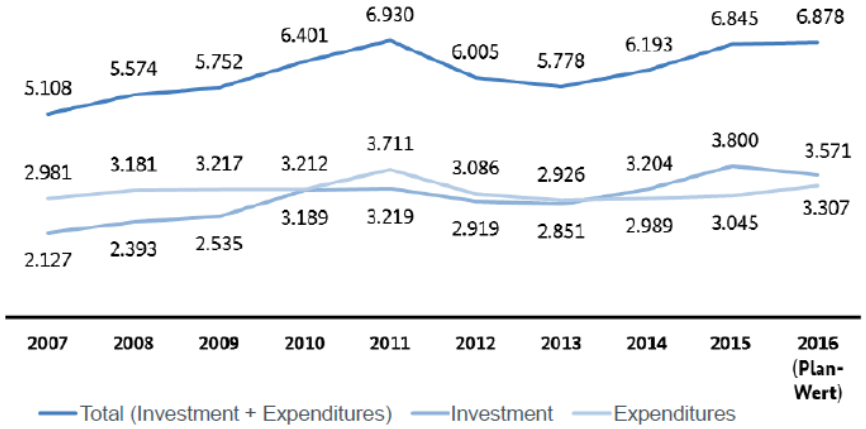
Costs are increasing:
Investment volumes in German grids

Investment for grid infrastructure TSOs in Mil. €



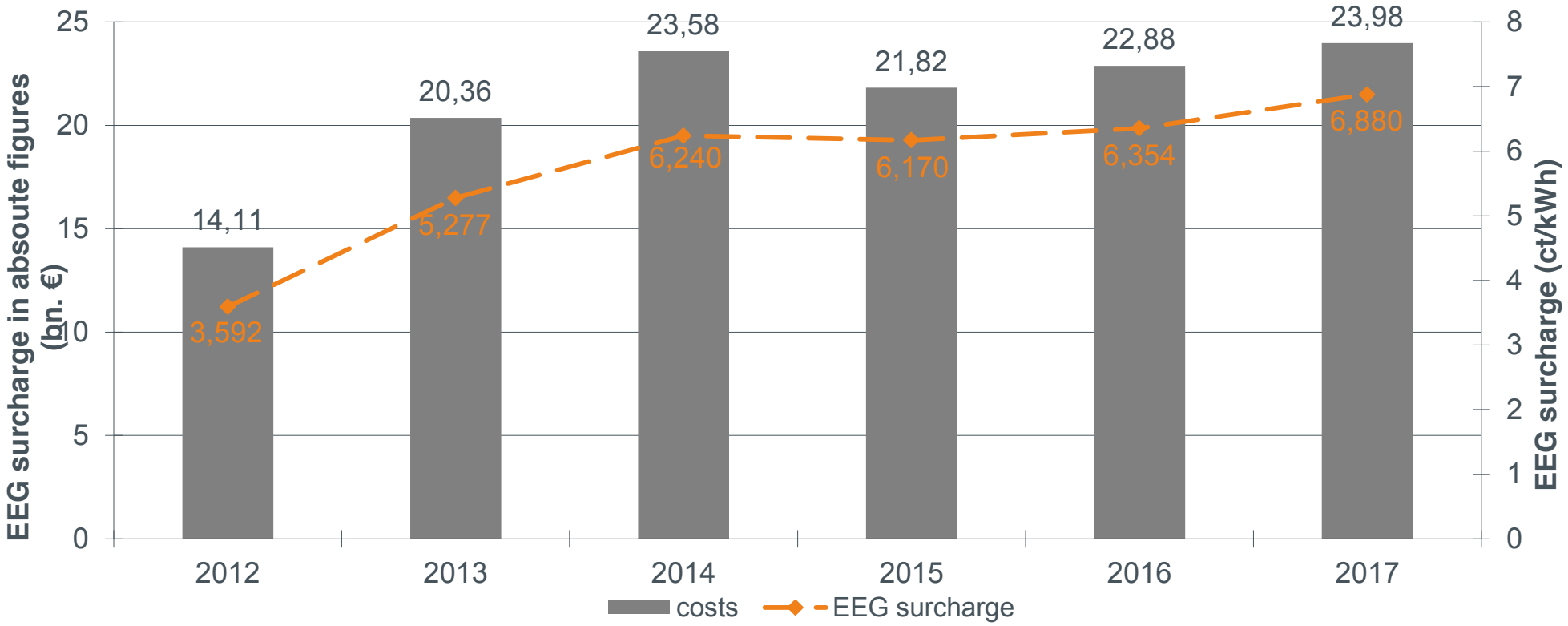
Source: Bundesnetzagentur, Monitoringreport 2016

Investment for grid infrastructure DSOs in Mil. €



Source: Bundesnetzagentur, Monitoringreport 2016

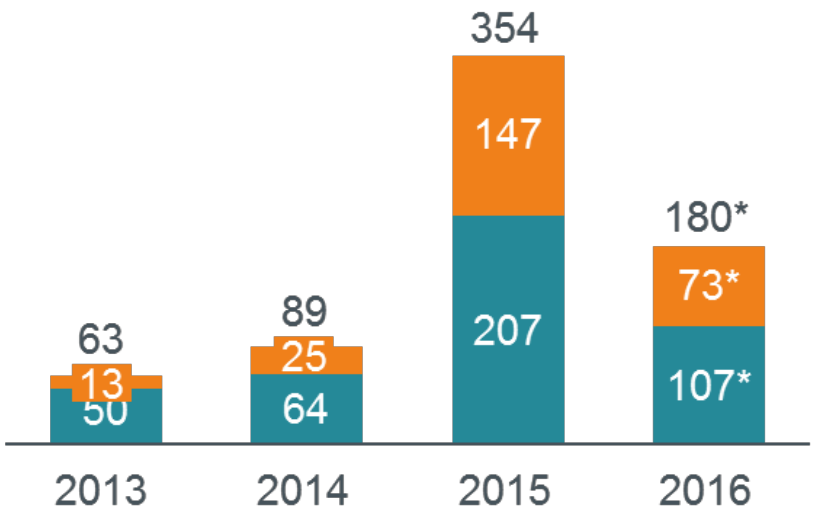
Costs are increasing: FIT costs in Germany
Development of the EEG surcharge from 2012 to 2017



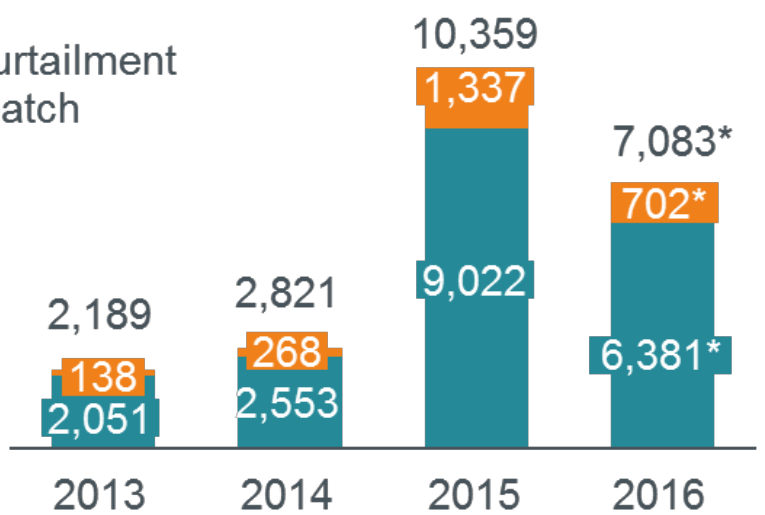
Source: 50Hertz

Costs are increasing:
Interventions to avoid overload of lines

Redispatch and RES curtailment costs in m. €



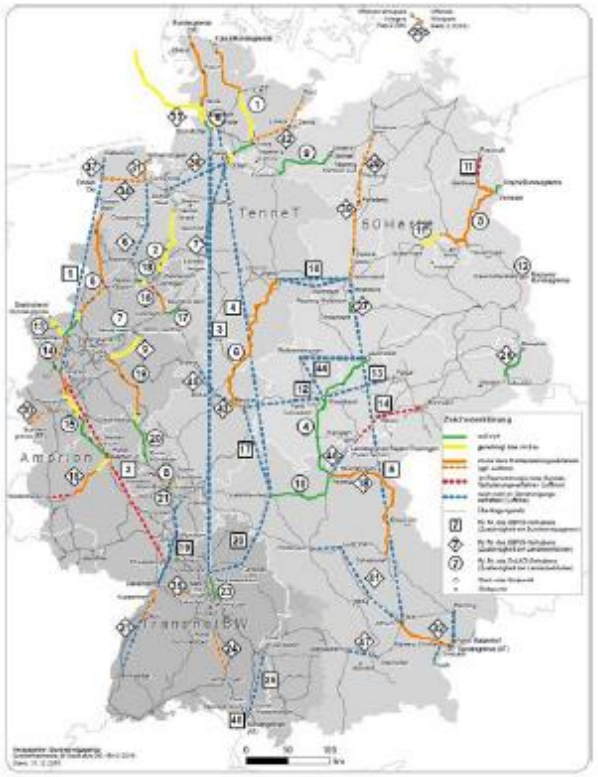
Redispatch and RES curtailment amounts in GWh



Source: 50Hertz; As of 2016/12/31 (preliminary figures – final figures will be available on 2017/08/31)

In 2016 the costs for redispatch and RES curtailment decreased significantly with respect to the previous year.

NIMBY delays development:
Status grid extension Germany Q1 2016



Energy Line Extension Act from 2009:

36 %

50Hertz	264 km of 436 km (rd. 61 %)
Amprion	204 km of 713 km (rd. 29 %)
TenneT	162 km of 643 km (rd. 25 %)
TransnetBW	25 km of 25 km (100 %)

Federal Grid Requirement Plan Act from 2014 (only AC extensions):

4 %

50Hertz	59 km of 781 km (rd. 8 %)
Amprion	38 km of 185 km (rd. 21 %)
TenneT	14 km of 1667 km (< 1 %)
TransnetBW	0 km of 330 km (0 %)

Source: 50Hertz

Consideration of optimisation principles in grid development plans

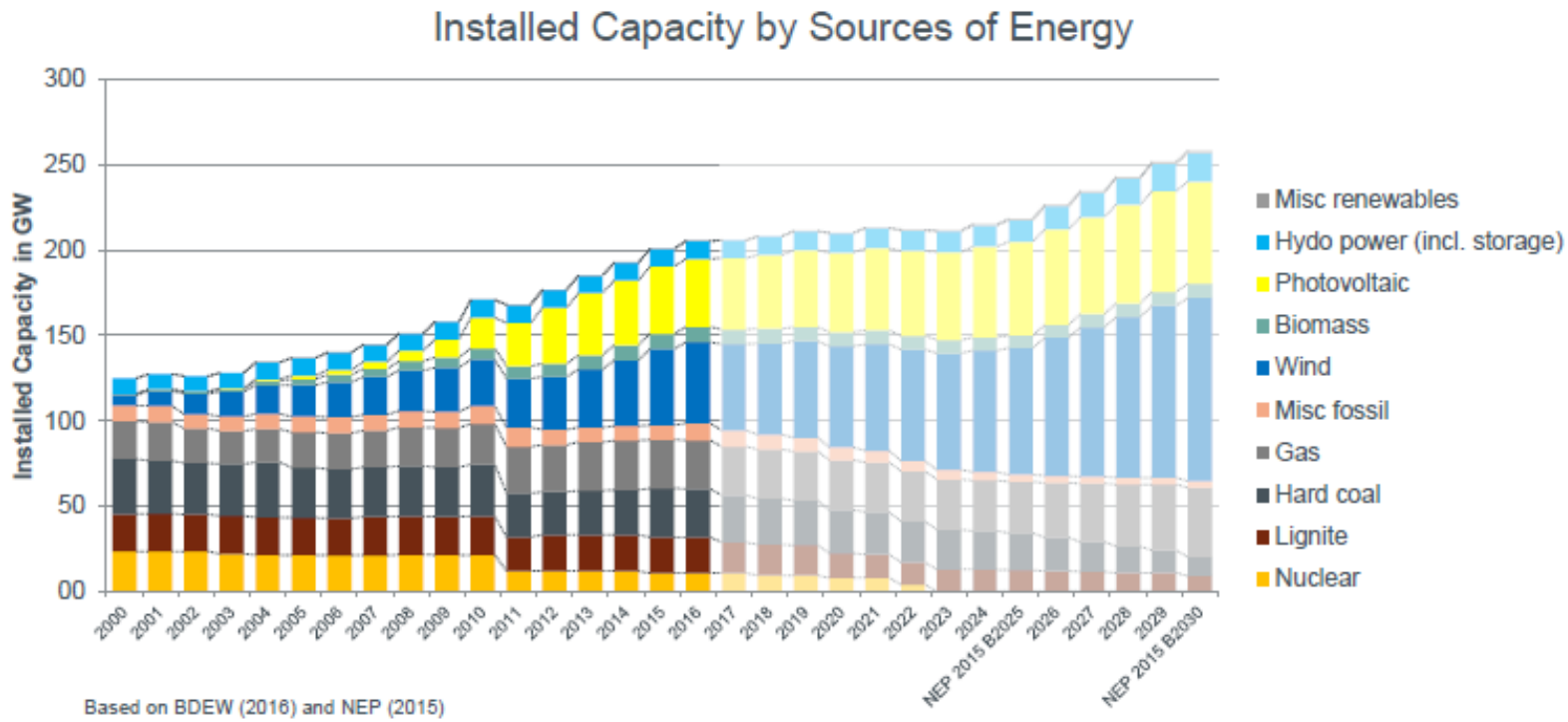
Present

1. NOVA
2. FLM
3. Spitzenkappung
4. DSM
5. PST
6. HVDC
7. European integration (NTC + coordination with TYNDP)

Future

1. NOIVA?
2. FLM
3. Spitzenkappung – couple with demand
4. DSM – couple with congestions
5. PST – more realistic limits and intertemporal
6. HVDC – control capability
7. European integration – flow based

Outlook of German power mix

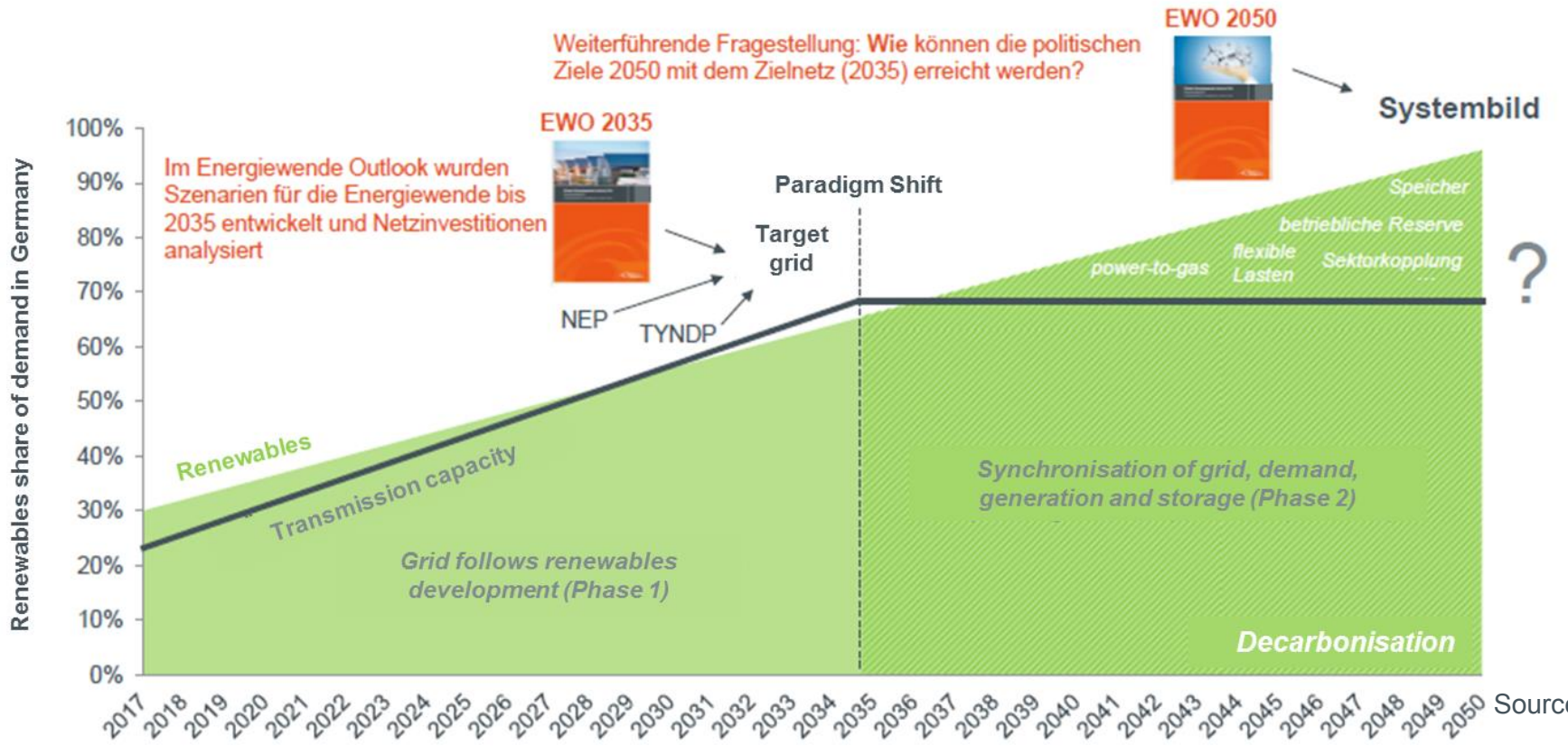


Based on BDEW (2016) and NEP (2015)

- Complete nuclear shutdown until 2023. Fast expansion of installed wind power capacity between 2025 and 2030 after commissioning of new HVDC lines.
- Reduction of conventional capacity by more than 30% until 2030

European, German and 50Hertz grid plans are synchronised to ensure grid will catch up to renewables

Strong coordination to ensure German renewables can be exported and to get support to build national projec



Source: 50Hertz

Question to the audience: what would be important to consider and what is the best way to integrate them in our methods?

Approach to Strategic Grid Development and Market Modelling

Scenario Building

- Basic data: Power plants, RE, Consumption in Germany and EU (…)
- LT renewables outlook
- Setting the basic scenario framework within the NEP-process / Consultation
- Adoption of scenarios for special purposes

Market Modelling

- Setup of Data
- Modelling of different scenarios
- Crosscheck of the Modelling Output
- Interfacing with the Grid Modell
- …

Network Analysis

- Network analysis: Load flow calculations (around the year runs, special situations)
- Contingency Analysis
- short circuit calculations, stability calculations, etc.
- Redispatch
- …

Consideration of optimisation principles at each step

Scenario building, long-term perspective

- Distribution of renewables
- Consumption development – quantity and distribution
- Align with neighbours

Market simulation

- DSM
- Spitzenkappug – Curtailment of renewables
- European integration

Network analysis

- NOVA
- FLM
- PST
- HVDC

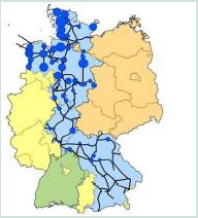
Distribution of renewables (in Germany, quantity is “fixed”)

Rough regionalisation at the state level

- Installed capacity at present (status quo)
- RE developments trends in different regions
- RE targets of the federal and state governments
- Resource potential analysis
- Repowering of existing power plants
- Connection requests and status in the distribution grid (data from DSOs)

Detail regionalisation on post code level

- Installed capacity at present (status quo)
- Repowering of existing power plants
- Country-wide development plans and preferential/suitability/reservation areas
- Resource potential analysis
- Analysis of eligible and excluded areas
- Potential yield and profit analysis of different sites
- Stochastic Model



Assignment of installed services on node level

- Knowledge of electrical connections in lower voltage networks -> evaluation network topology

Renewables development in Germany

2015

Represents 100 MW

2025*

Represents 100 MW

Wind

Soalar PV

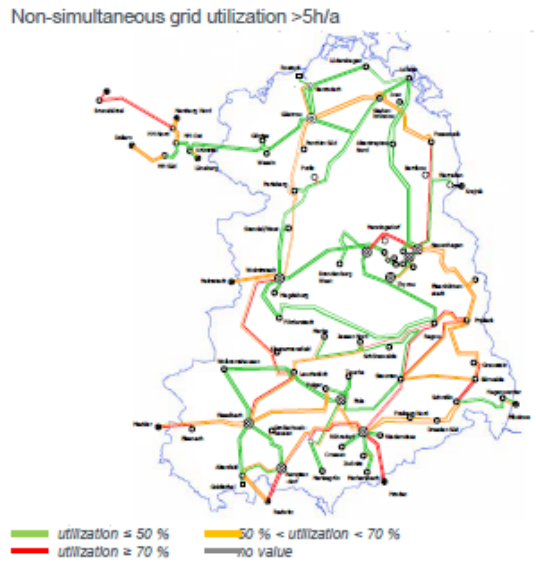
Biomass

Source: 50Hertz

*) Scenario B of NEP2025

Congestions and Grid Extension Area

Grid utilization at 50Hertz 2015*



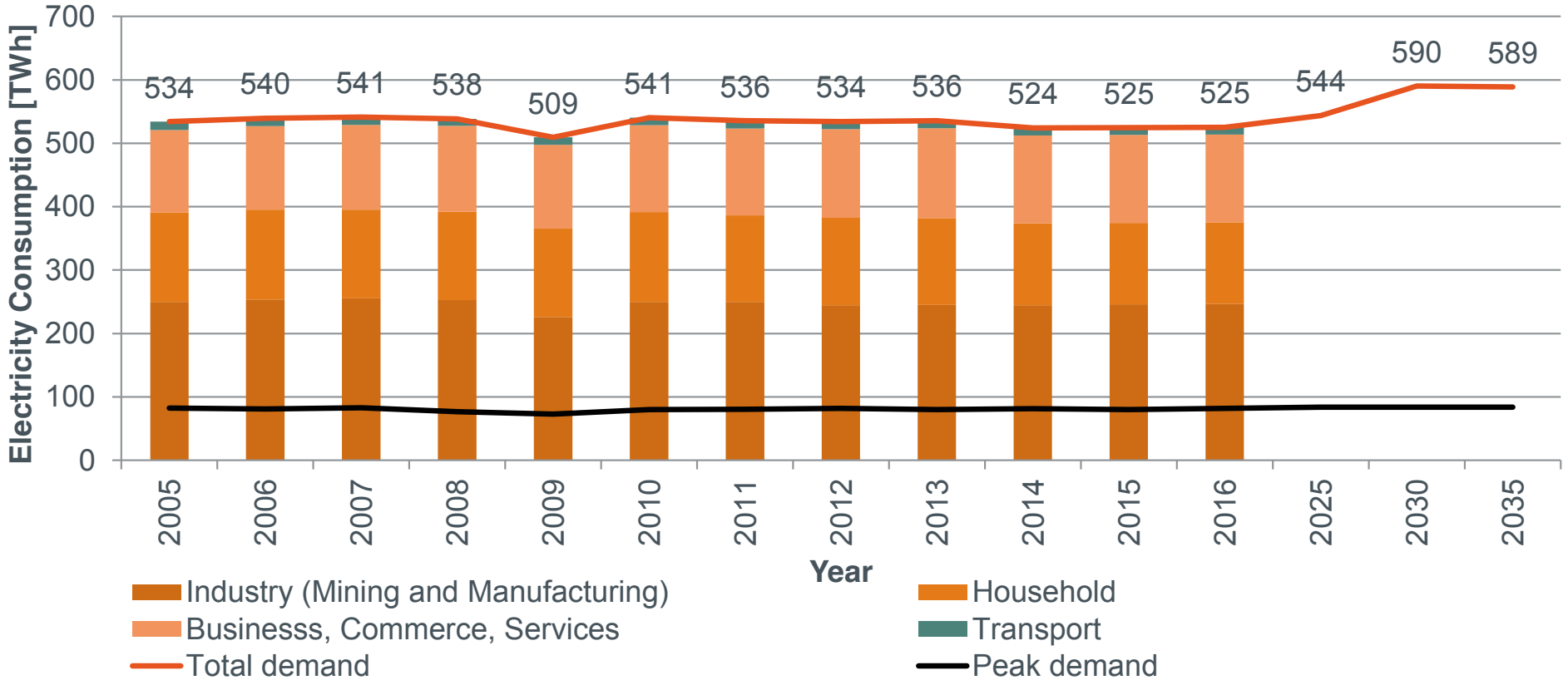
"Grid Extension Area" until 2019

- Aim of the Grid Extension Area: Synchronisation of grid extension and RES installation by limiting RES installations in North of Germany.

*After taking the interconnector Krajnik (Poland) – Vierraden (Germany) out of operation

Source: 50Hertz

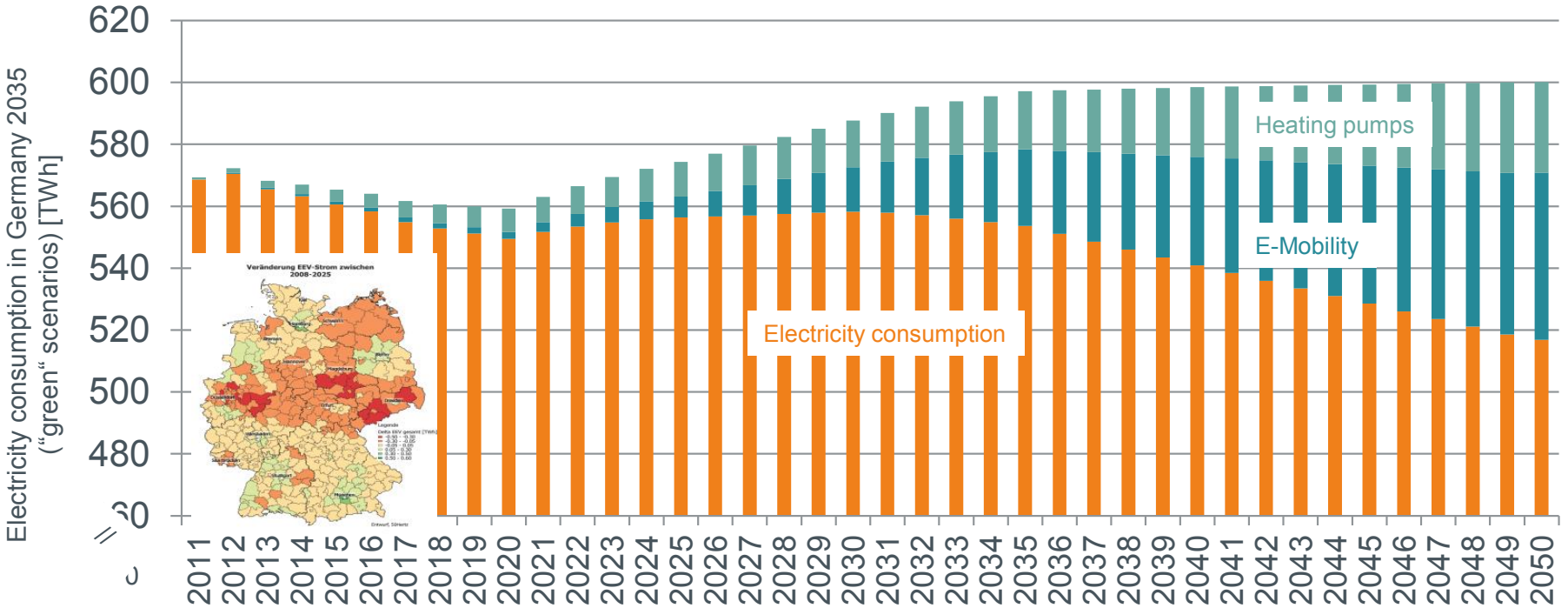
Consumption development – quantity and distribution
Demand outlook in the German Grid Development Plan



Source: 50Hertz

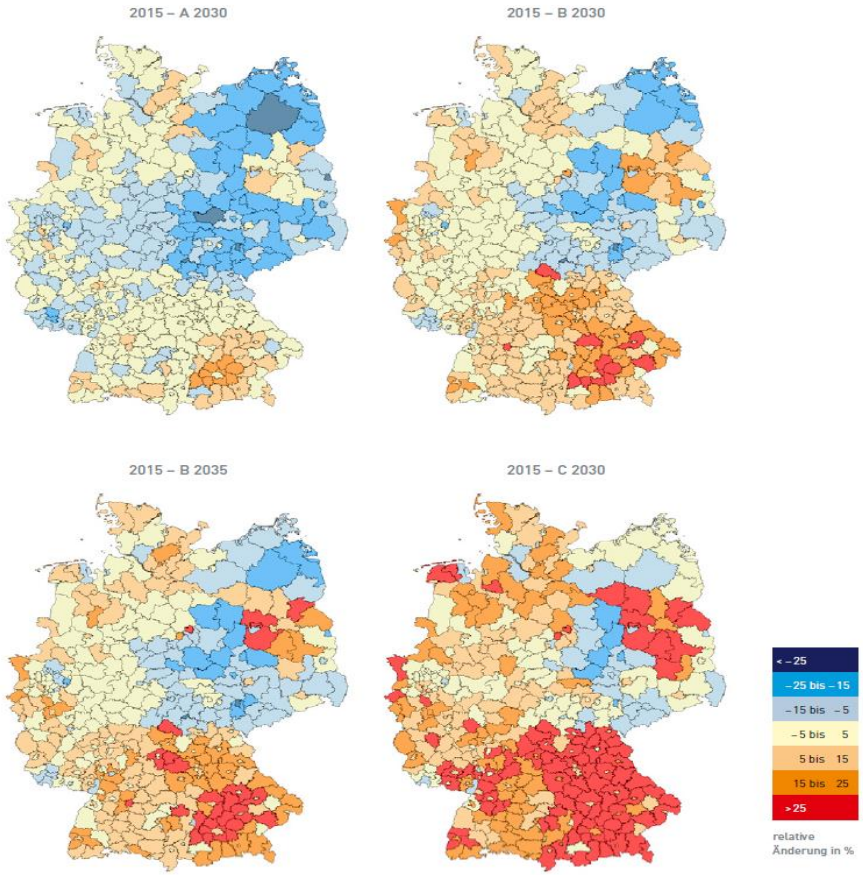
Consumption development – quantity and distribution
Through the electrification of the heat and transportation sectors, electricity consumption will rise in the long-term

- Electricity consumption increases despite improvements in efficiency due to the increase in heating pumps and the increased use of electric cars.



Source: 50Hertz

Consumption development – quantity and distribution
Growth of Load assumed for German Grid Development Plan



For different Scenarios many different assumptions and input parameters need to be derived. e.g the growth of the network load.

Top Left: Conservative Scenario

A lot of conventional thermal Power plants stay in place. Conservative assumptions for Renewables

Top Right/Bottom Left: Transformational Scenarios

Middle Course between Conservative and innovative Scenario for two time horizons (2030/35)

Bottom Right: Innovative Scenario

A lot of renewable generation. Increased consumption.

Source: German Grid Development Plan

Consideration of optimisation principles in grid development plans: Scenarios, long-term perspective

- Align with neighbouring countries (without EU, will Energiewende succeed?)
  - Conventional power plants (phase-out of nuclear and coal)
  - Renewables (EU targets)
  - Market integration (physical and market exchange capacity)
  - Interdependency = vulnerability? How to strike balance between robust and efficient?

Consideration of optimisation principles at each step

Scenario building, long-term perspective

- Distribution of renewables
- Consumption development – quantity and distribution
- Align with neighbours

Market simulation

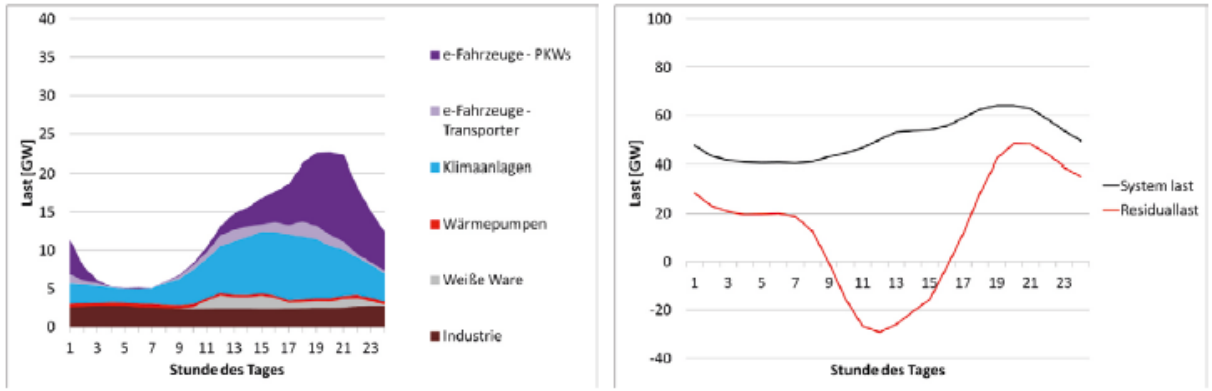
- DSM
- Spitzenkappug – Curtailment of renewables
- European integration

Network analysis

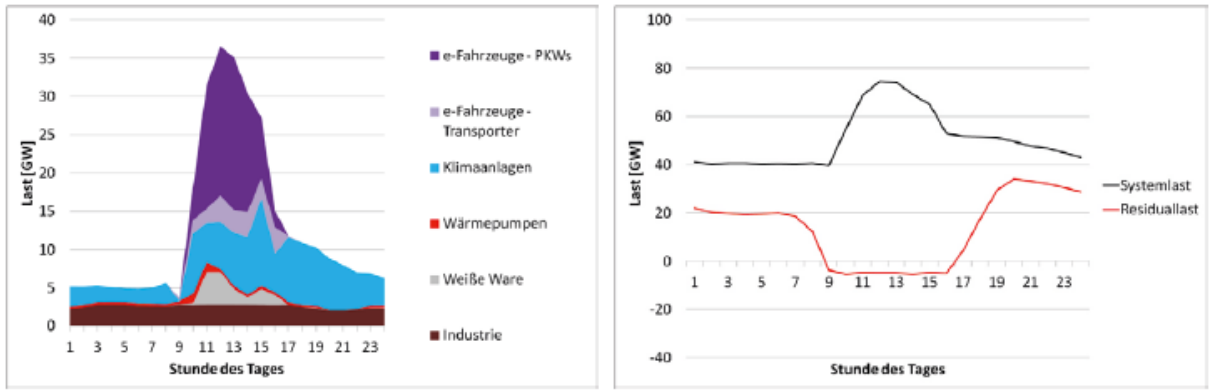
- NOVA
- FLM
- PST
- HVDC

DSM

Situation without DSM

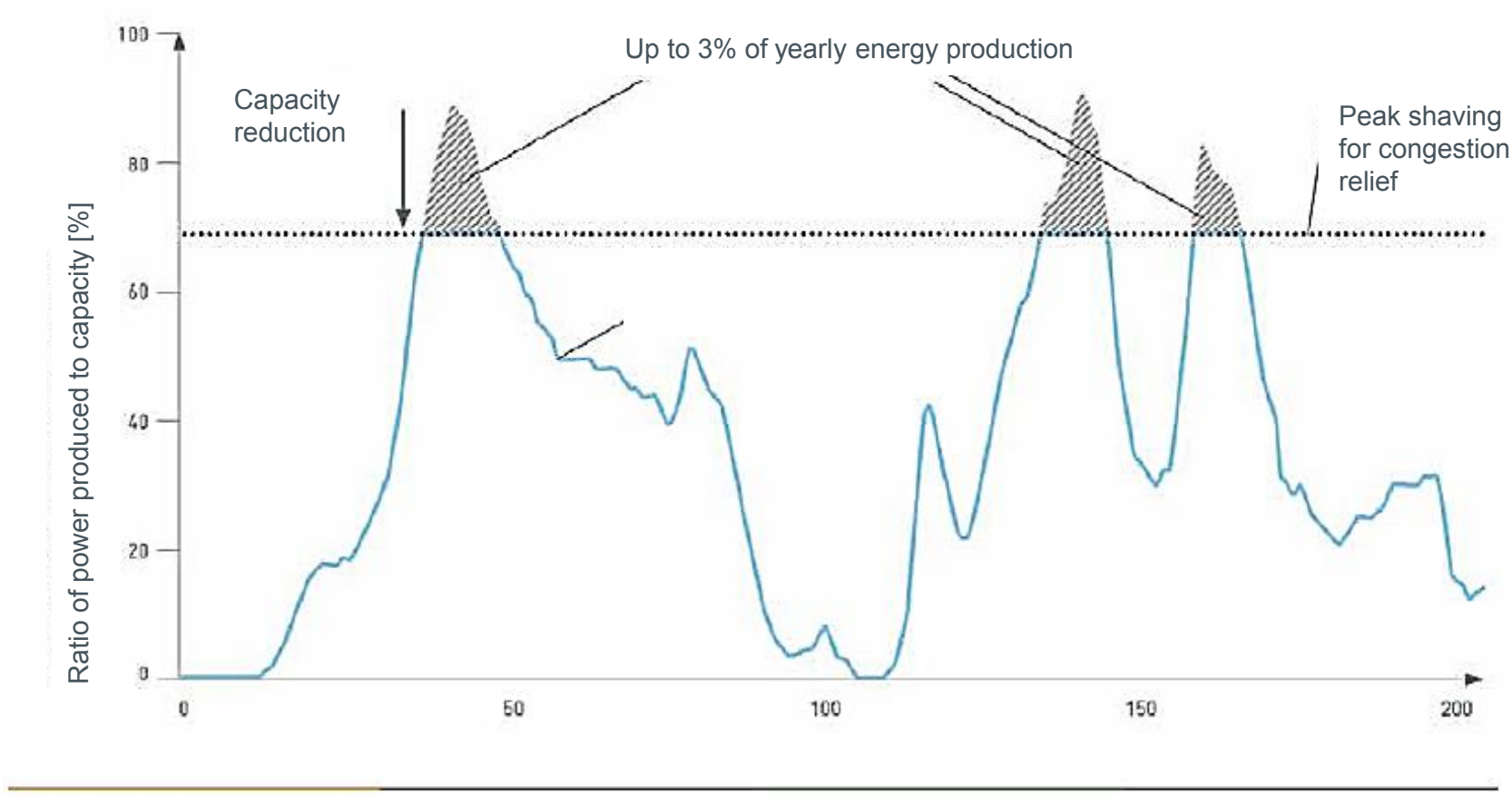


Situation with DSM



Source: Fraunhofer ISI

Spitzenkappug – Curtailment of renewables

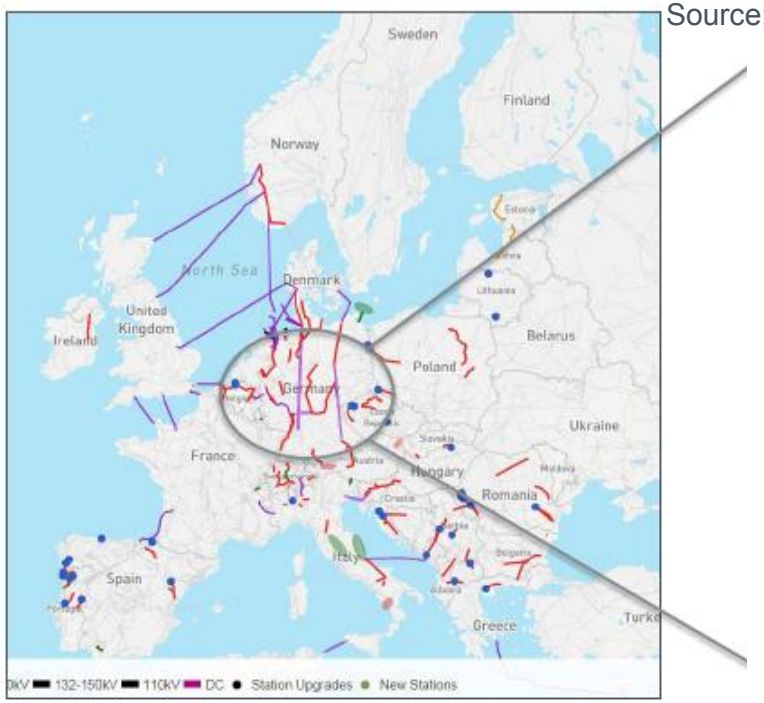


Source: German Grid Development Plan

European integration: pan-European projects

Develop grid infrastructure to cater for renewables power flows and to deliver flexibility: **projects for European integration**

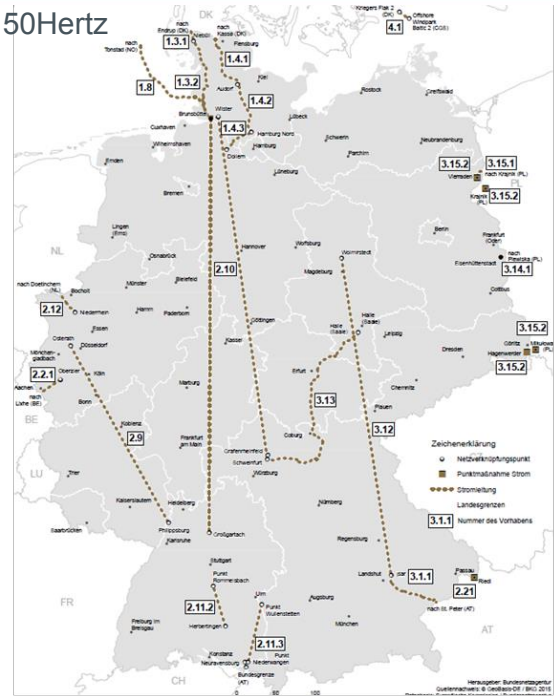
2016 - 10 years EU Grid Development Plan



Expected investment needs: approx. **150 bn. €**

Projects of Common Interest

Source: 50Hertz



© BNetzA PCI map, 4th quarter 2016

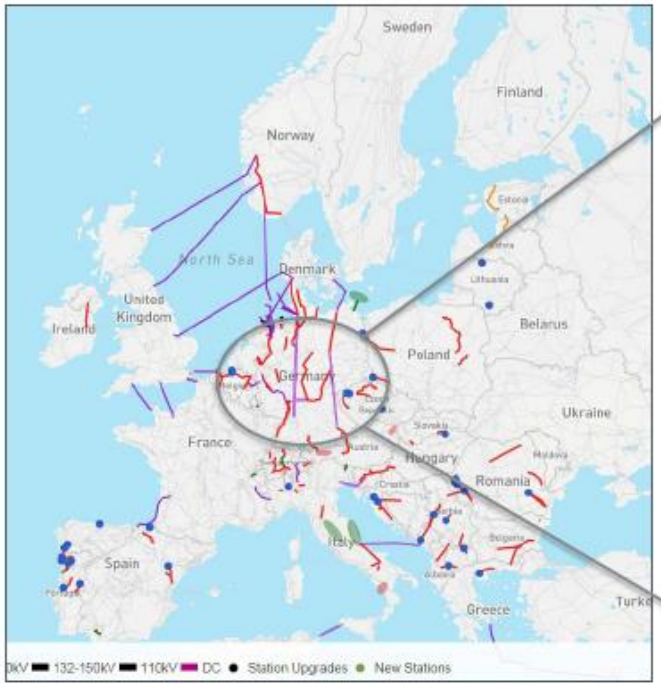
European

- Ten Year Network Development Plan (ENTSO-E)
- Projects of Common Interest (EC)

European integration: pan-European projects

Develop grid infrastructure to cater for power flow changes and to deliver flexibility: **coordination of European and national plans**

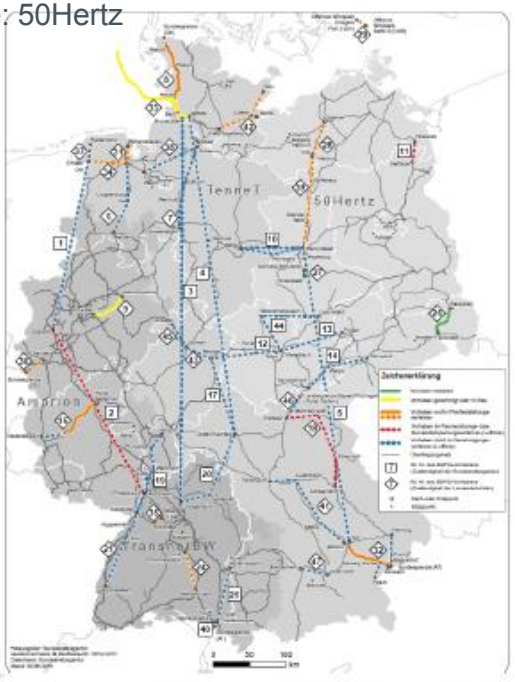
2016 - 10 years EU Grid Development Plan



Expected investment needs: approx. **150 bn. €**

German Federal Requirement Plan 2016

Source: 50Hertz



Expected investment needs: approx. **50 bn. €**

Coordinated planning of

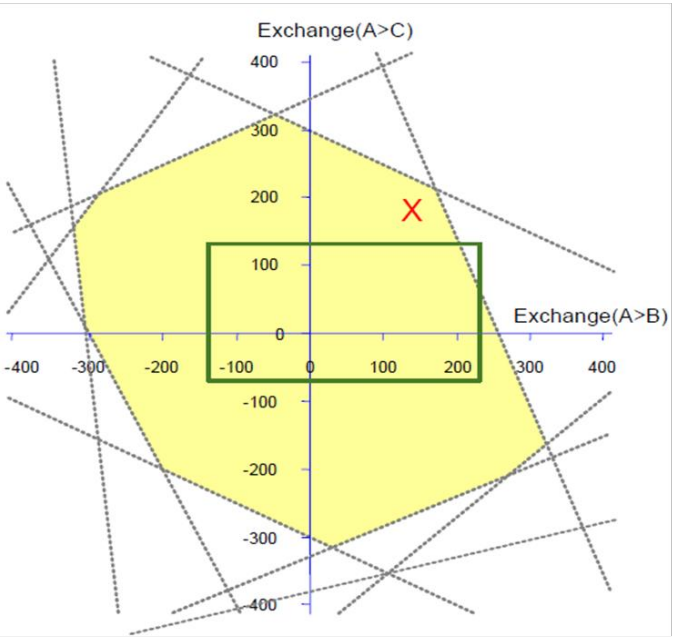
European

- TYNDP (ENTSO-E)
- PCI (EC)

German

- NEP (German TSO + BNetzA)
- EnLAG: 2009 (German Govt)
- BBP: 2013-2015 (German Govt)

European integration: cross border capacity



Green:	NTC Limits
Dashed Lines:	FB Contingencies Determined by the RAMs of the CBCOs
X:	Result of the Market Coupling
Yellow Area:	Area of Security of Supply (SoS)

- Within an electrical network power flows always flows from a source to a sink.
- In electrical AC-grids the power flow is determined by the laws of physics, i.e. impedances of the lines, voltages, reactive power flows
- Within the highly meshed European grids, this can lead to congestions, due to trading of energy

A FB Approach is a methodology which describes the network in order to take into account the impacts of cross-border exchanges on network security constraints when optimising the market flows.

Thus maximum capacity for trading between regions can be free, ensuring n-1 security in each region and optimising the social welfare.

Consideration of optimisation principles at each step

Scenario building, long-term perspective

- Distribution of renewables
- Consumption development – quantity and distribution
- Align with neighbours

Market simulation

- DSM
- Spitzenkappug – Curtailment of renewables
- European integration

Network analysis

- NOVA
- FLM
- PST
- HVDC

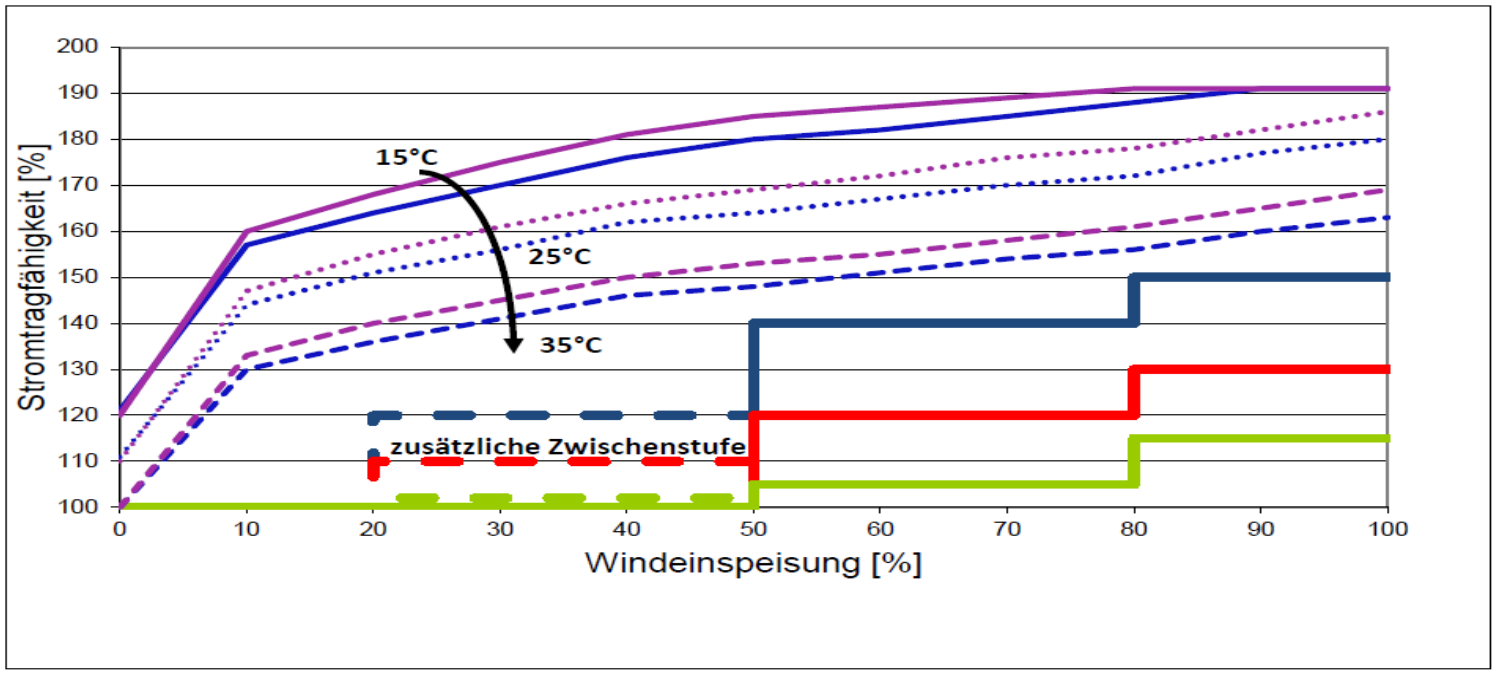
NOVA principle is applied in Network analysis / selection of measurements

380/220-kV-Transmission-**NETWORK**

OPTIMISATION	**R**EINFORCEMENT	**E**XPANSION
control of load flow (e.g. using Phaseshifters)	Upgrade of voltage (220 → 380 kV)	New 380 kV lines and substations
Temperature dependent operation of HV lines (Dynamic Line Rating)	HTLS conductors (high temperature, low sag)	Overlay (perspective)

Source: 50Hertz

FLM - Freileitungsmonitoring: Dynamic Line Rating
Consideration of DLR in planning

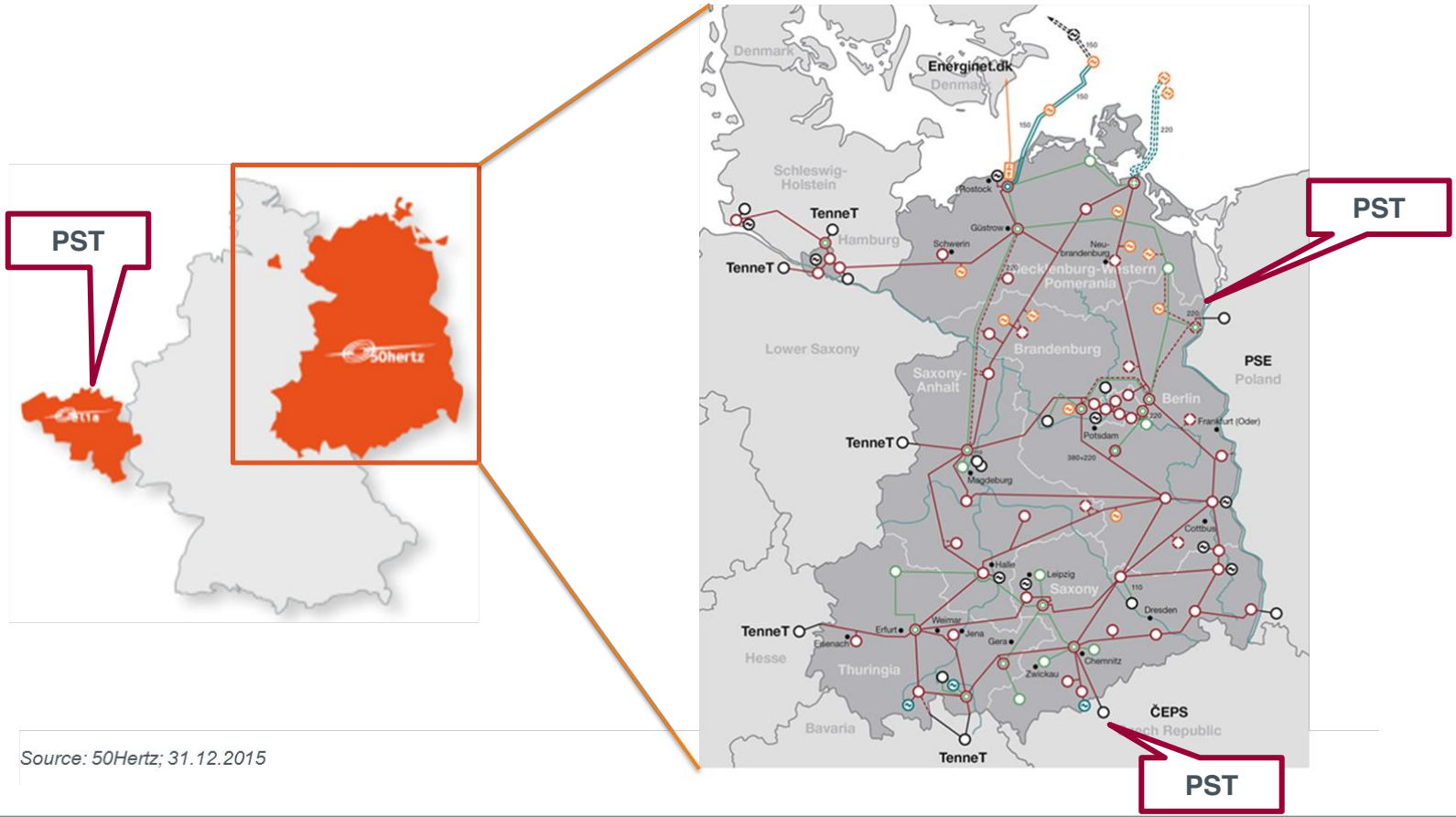


FLM-Stufung für Norddeutschland
FLM-Stufung für Mitteldeutschland
FLM-Stufung für Süddeutschland

Potenzial für FLM-Monitoring für den Seiltyp Al/St 564/72
Potenzial für FLM-Monitoring für den Seiltyp Al/St 230/30

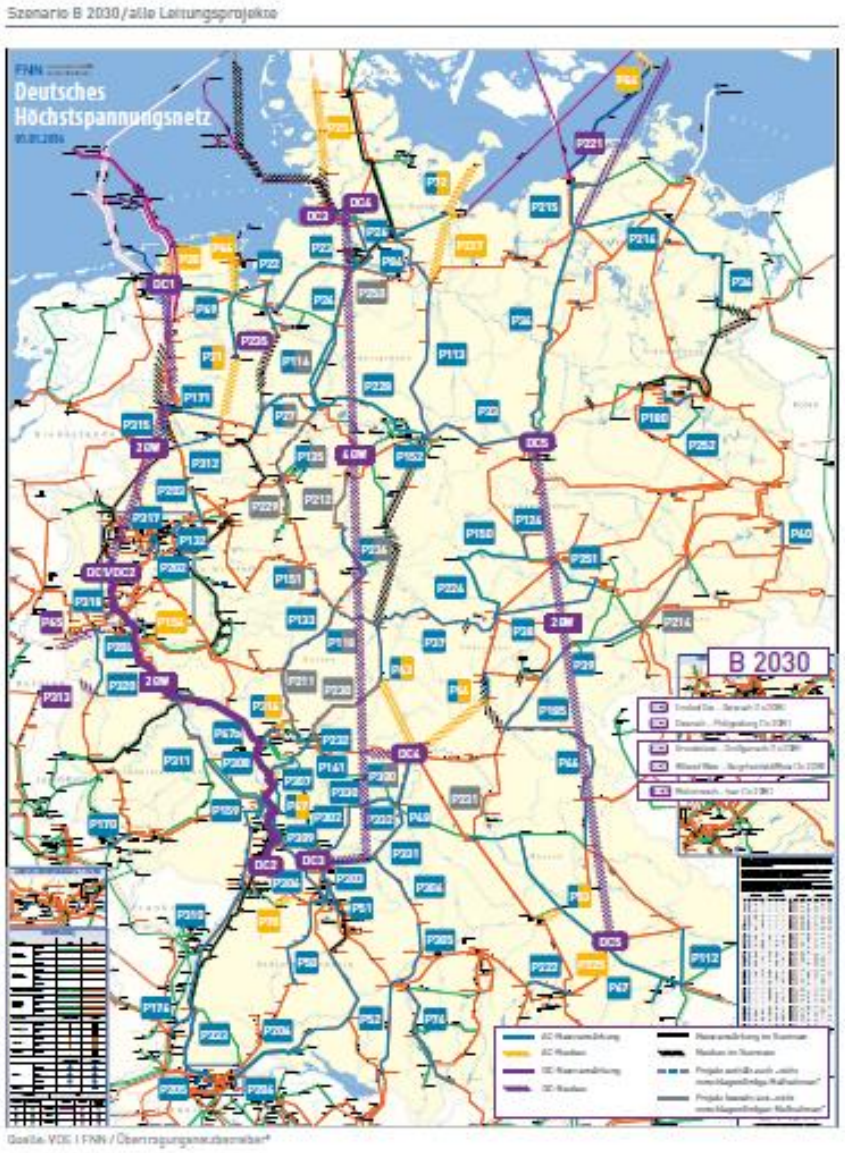
Source: German Grid Development Plan

PST – Phase Shifting Transformers



Source: 50Hertz; 31.12.2015

HVDC – High Voltage Direct Current lines: Planned projects and control strategy



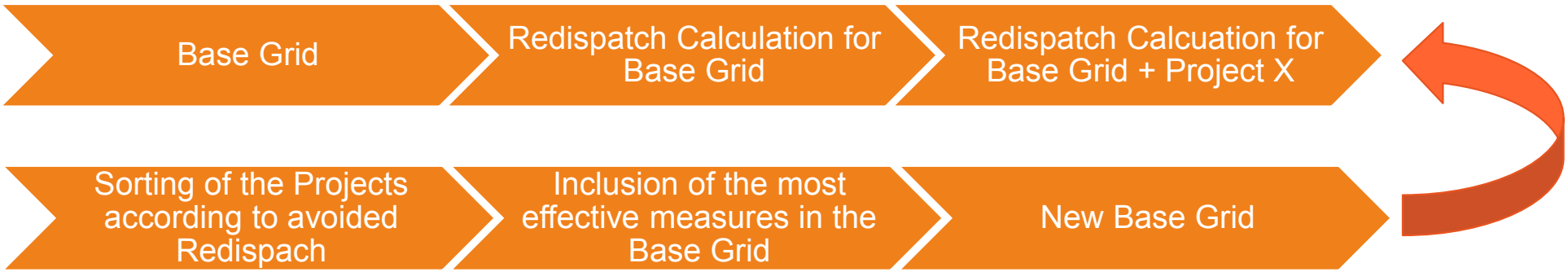
Source: German Grid Development Plan

Analysis Criteria Applied in the GDP (1/2)

- **Contingency Analysis based on year round simulations:**
  - Ability of the project to redu

$$Score = \sum_{i=1}^{\substack{Anzahl\\Zweige}} \sum_{j=1}^{\substack{Anzahl\\Ausfallelemente}} \sum_{t=1}^{8760} \left[(\alpha_{i,j,t})_{(m-1)} - (\alpha_{i,j,t})_{(m)}\right],$$
$$\forall (\alpha_{i,j,t})_{(m-1)} > 100\% \wedge (\alpha_{i,j,t})_{(m)} \leq 100\%$$

- **Avoided Redispatch (in year round simulations)**



Analysis Criteria Applied in the GDP (2/2)

- **Avoided Curtailment of renewables (Renewables Integration)**
  - This can be derived out out of the Redispatch simulations described above.
  - The avoided curtailment is on indicator for additional Renewables integration.

- **Robustness**
  - How Effective is the Project in different Scenarios?
  - Robustness of past Scenarios in previous NEPs is also considered.

- **NORE Criteria**
  A. Equipping an existing line with new Conductors
  B. Build a new transmission line within an existing Corridor
  C. Build a new transmission line using a new Corridor

For each project and each Criteria a KPI is derived: A-> Best / B-> med. effect / C-> low effect

Discussion points

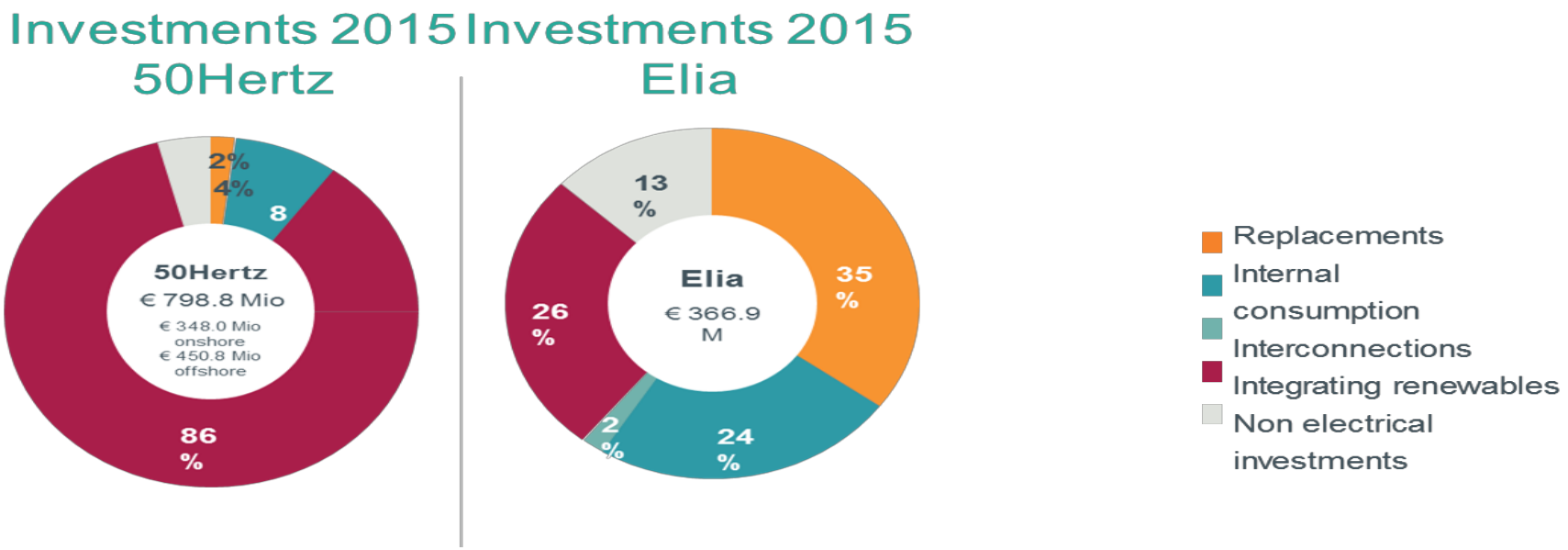
- Uncoordinated grid vs. generation
- Should we compare in grid planning the cost of new assets <-> cost of operational measures?
- Congestion-free grid means security is provided by generators -> Consideration of grid reserve
- Sensitivity of scenarios/assumptions on grid “hot-spots”

Benefits of dynamic line rating for safe and efficient increase of grid capacity (experience from Elia Transmission)

Overview of presentation

1. Characteristics of Belgian grid:
    - Aging assets
    - Highly impacted by large neighbours
    - Limited generation
    - High import country
    - Geographically concentrated wind
2. Dynamic Line Rating: basic principles
3. Demonstrated benefits for Belgian grid

Characteristics of Belgian grid: aging assets

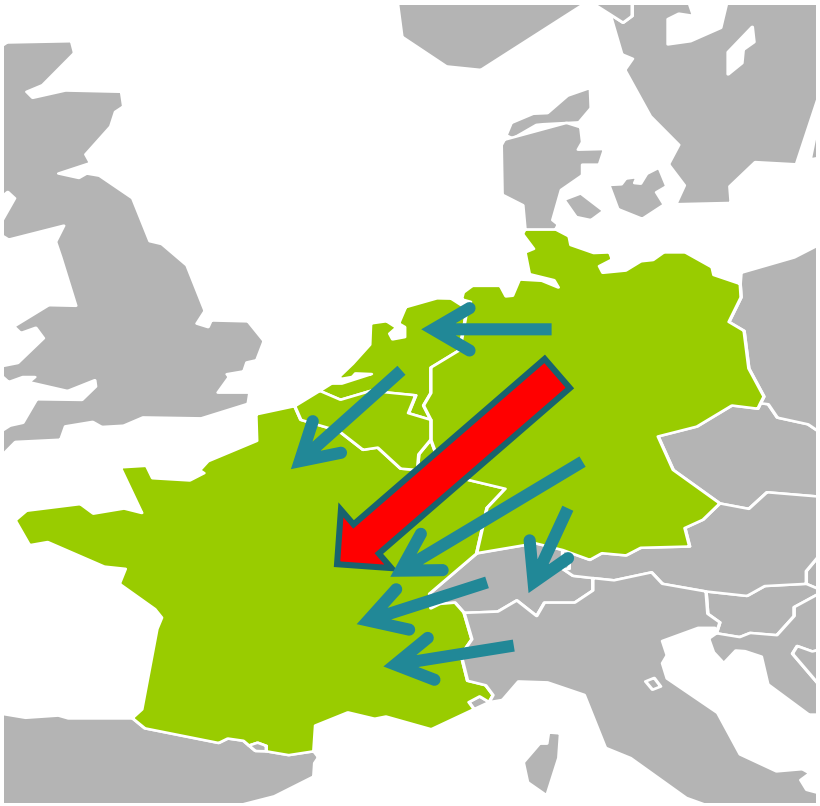


In Belgium, Elia is investing circa 2.3 billion EUR over the next decade. Investments are mainly driven by replacements and the internal consumption.

Characteristics of Belgian grid: Highly impacted by large neighbours

Market

Physical



Operation & Coordination

- ✓ **Internal congestion control**
- ✓ **Physical border flow control**
- ✓ **Loop flow management**

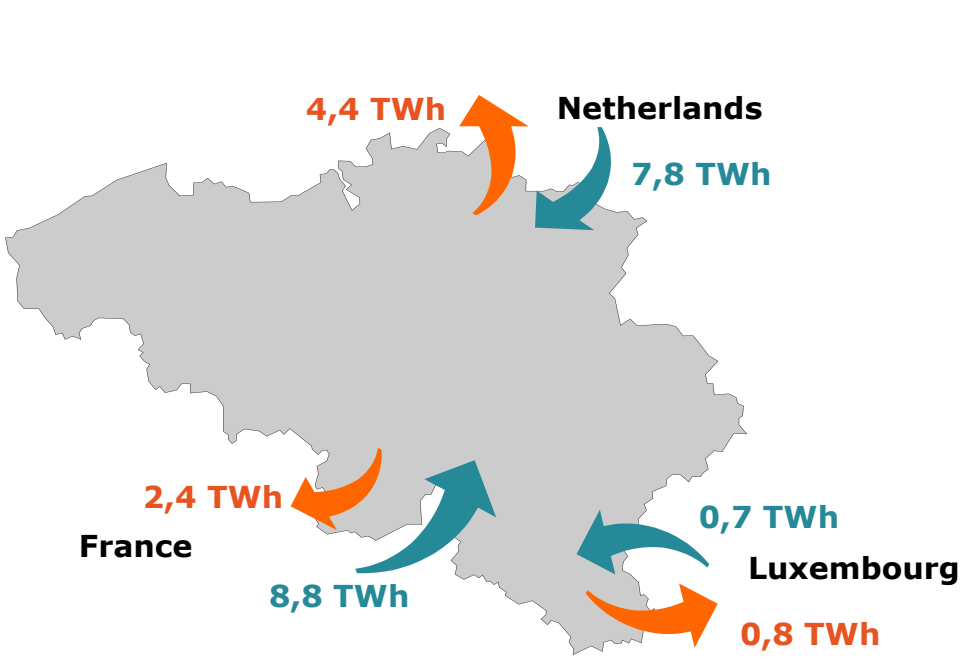
Characteristics of Belgian grid: limited generation

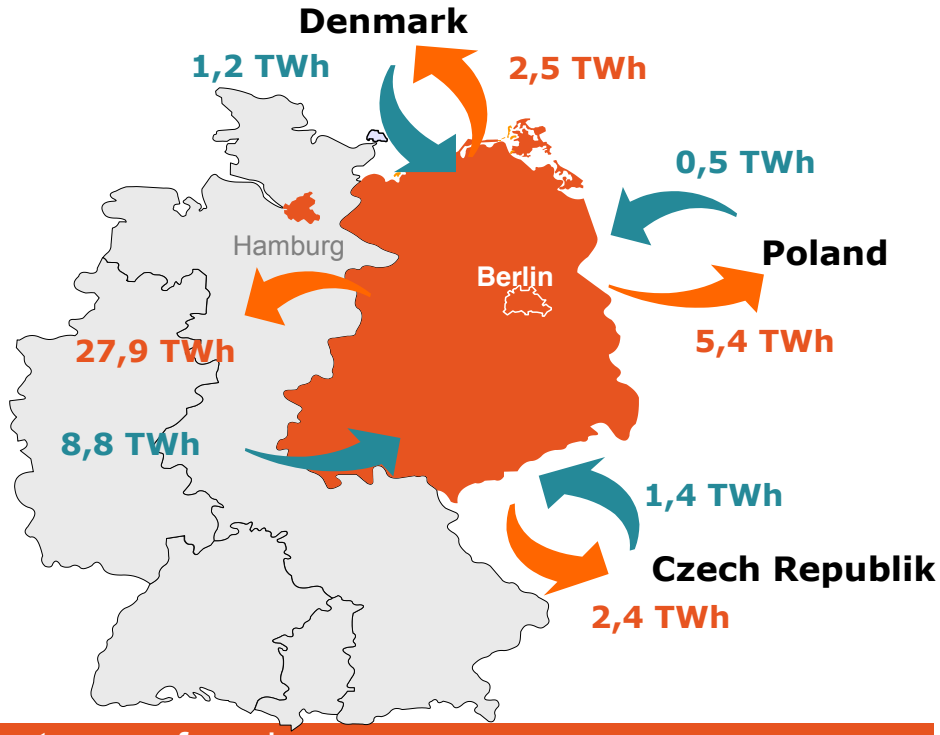
Risk of shortage (scarcity) in Belgium

Unplanned shut down of 3 nuclear power units

- Seven pressurized water reactors operated by Electrabel
- Supplied about half of Belgium's electricity
- All due to be shut down by the end of 2025
- Unexpected lengthy outages in 2014

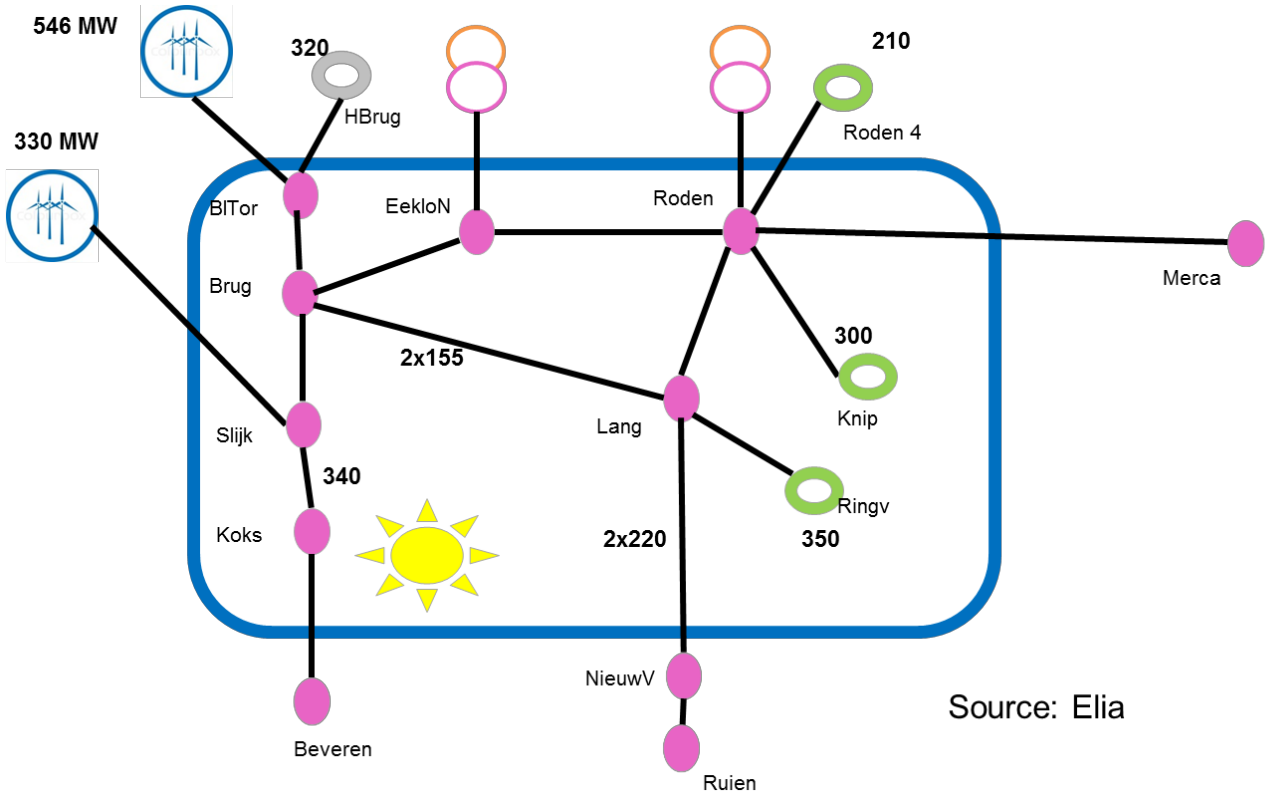
Characteristics of Belgian grid: high import country



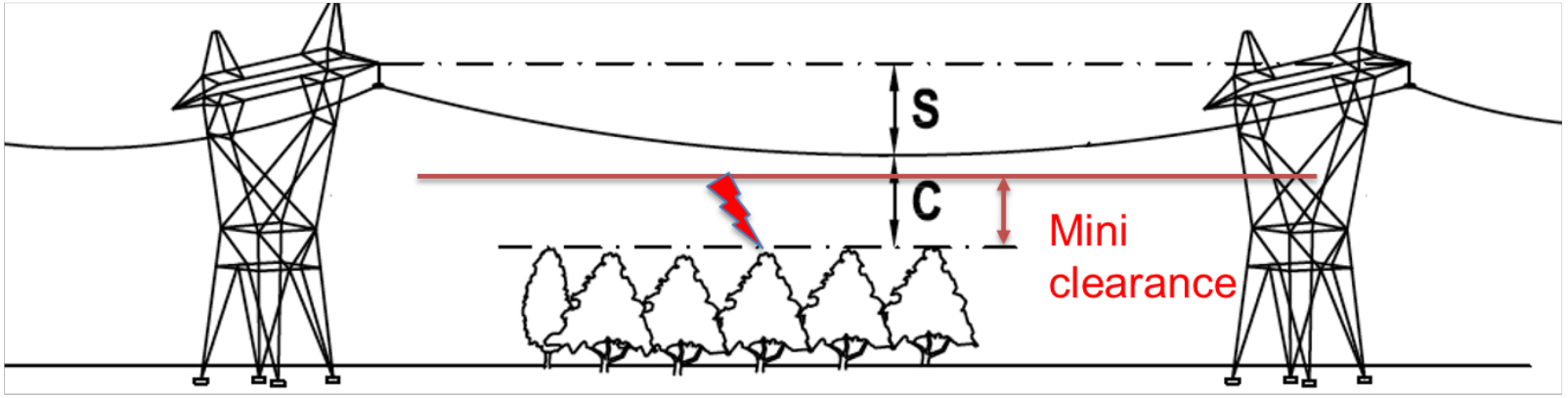


- Significant imports in Belgium due to continued outages of nuclear
- In comparison: increased Renewables share within control zone 50Hertz results in high exports

Characteristics of Belgian grid: geographically concentrated wind and solar PV



Dynamic Line Rating: basic principles

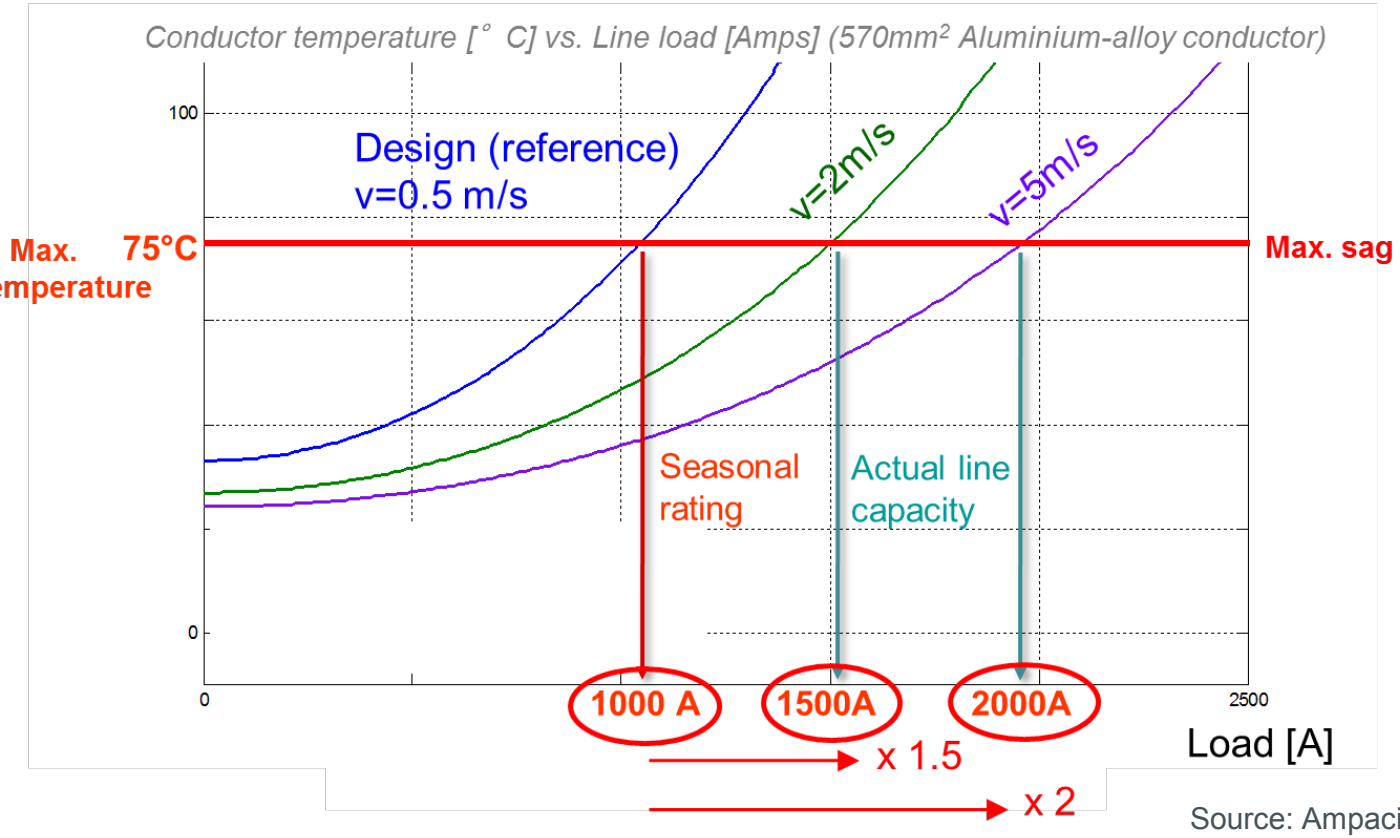


- **Sag** (Clearance) is the ultimate limit to operation of an overhead line
- Besides line current, many external factors can be measured / estimated / compounded: Sag is the **ultimate consequence** of line load
- It is pointless to measure conductor **temperature** (**fluctuating** along the line)
- **Real-time** and **direct** measurement of Sag
- Monitoring of other parameters
- Use of historical data

Source: Ampacimon

Dynamic Line Rating: basic principles

… Wind is the most critical factor (and varies a lot with time and location)



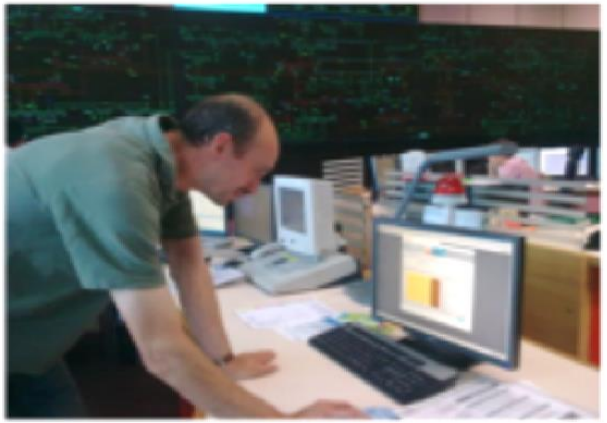
Source: Ampacimon

Real time monitoring of line rating with Ampacimon measurement devices

- Vibration analysis => sag
- Calibration requires data on conductors, topology, sagging, weather

Vibration Monitors on Critical Spans

Central Server



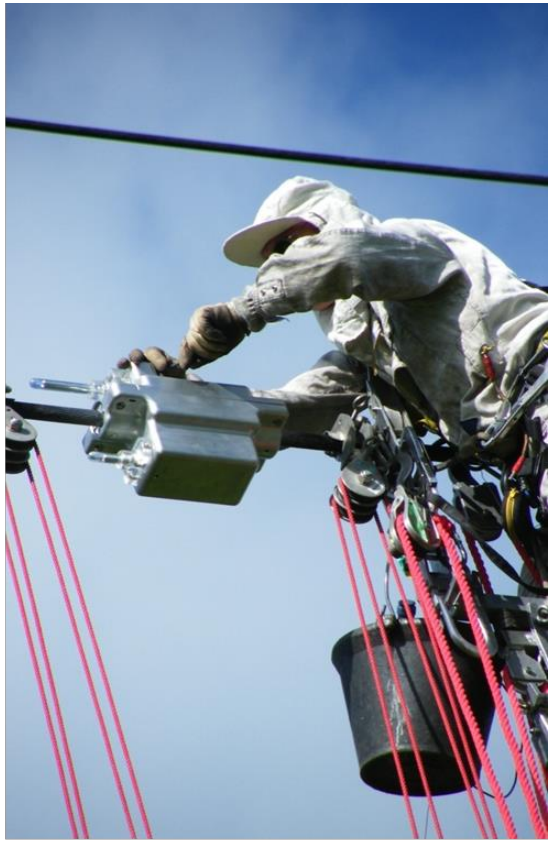
Ampacity Screen at TSO Dispatching

Installation of Amapcimon DLR sensors

Line out of service

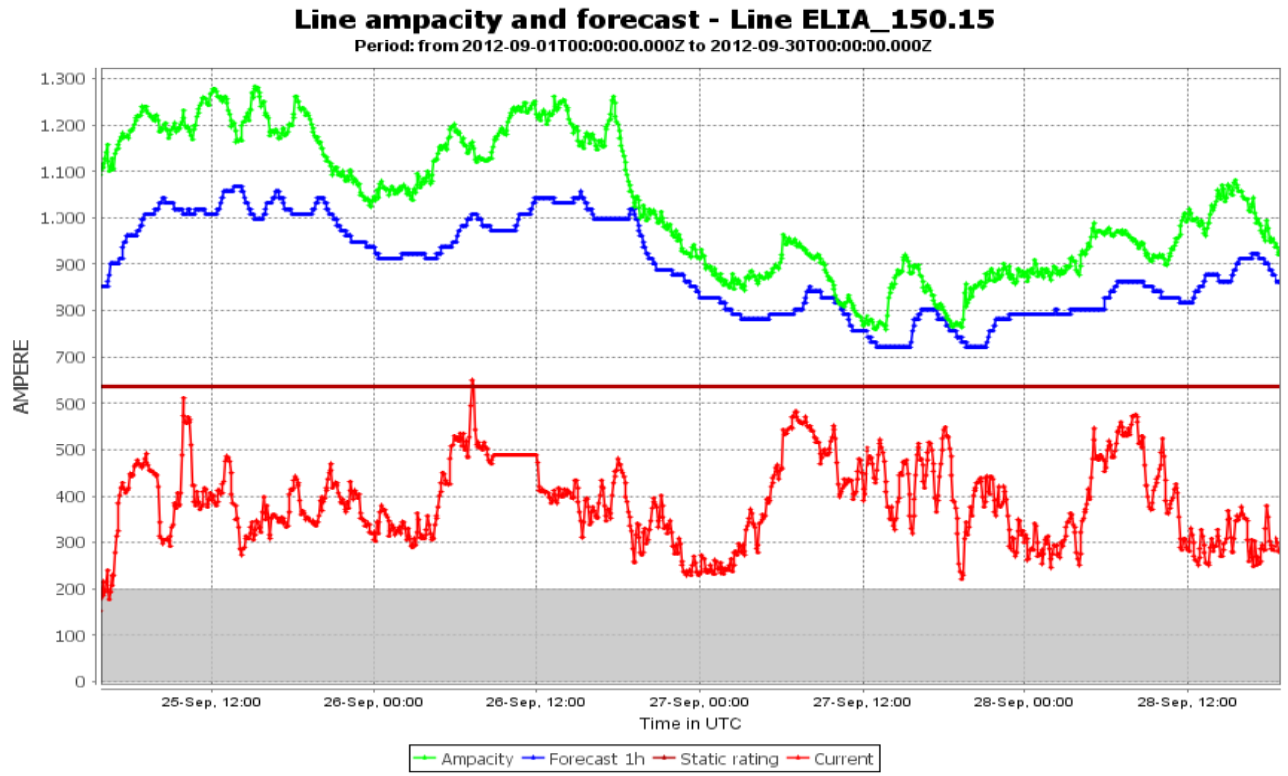
- Simple & quick to install **(typically 30 mn, live or dead line)**
- **Self-powered**
- **No calibration**
- **No maintenance**

Line in service



Source: Ampacimon

DLR capacity 1 hour ahead forecast



In operation : we use the forecast 1h, more stable value.
This value is capped to 130% of the static seasonal rating

Characteristics of Belgian grid: bottlenecks

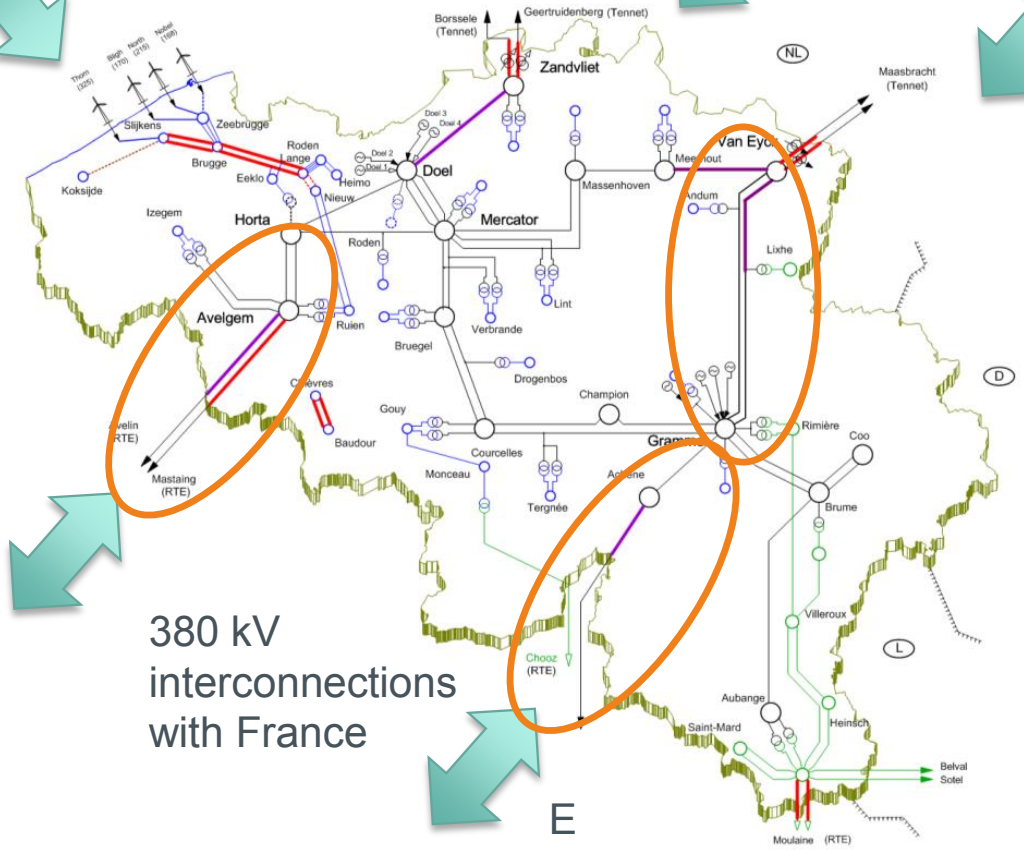
Offshore wind:
875 MW

C

A/B
380 kV
interconnections
with Netherlands

Bottlenecks for import and transit

D



380 kV
interconnections
with France

E

Demonstrated benefits for Belgian grid: DLR on main corridors and wind connections

Offshore wind:
875 MW

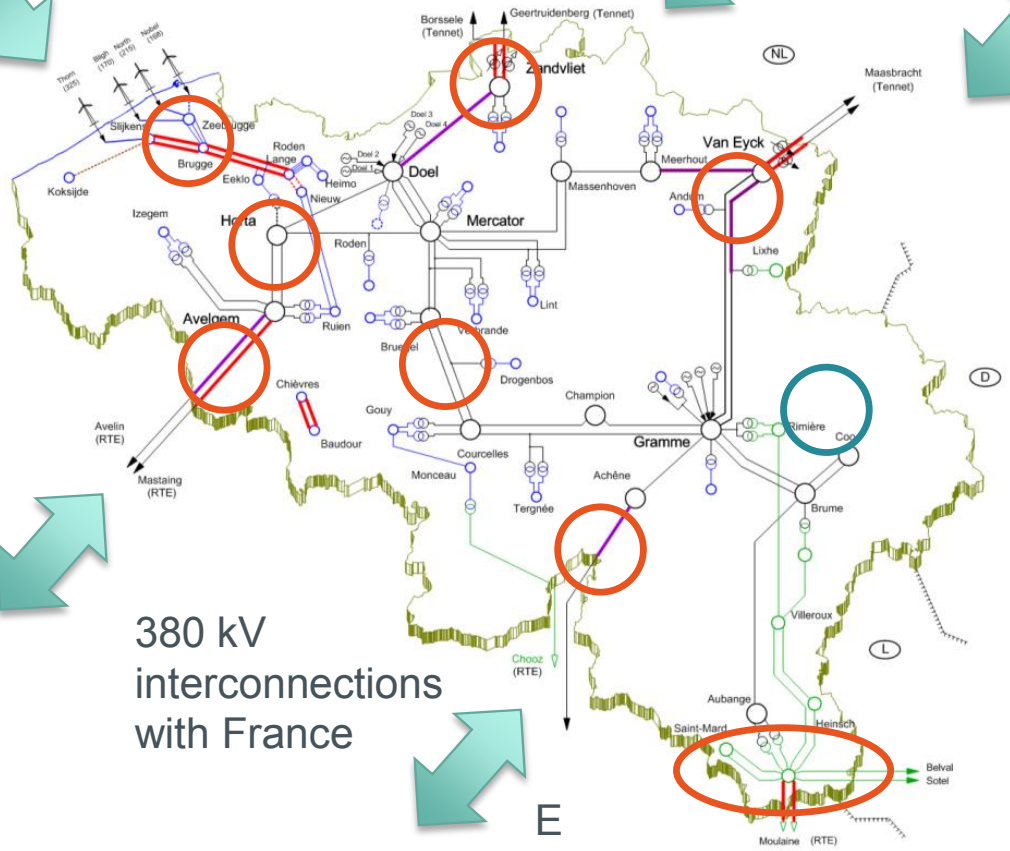
C

A/B
380 kV
interconnections
with Netherlands

D

380 kV
interconnections
with France

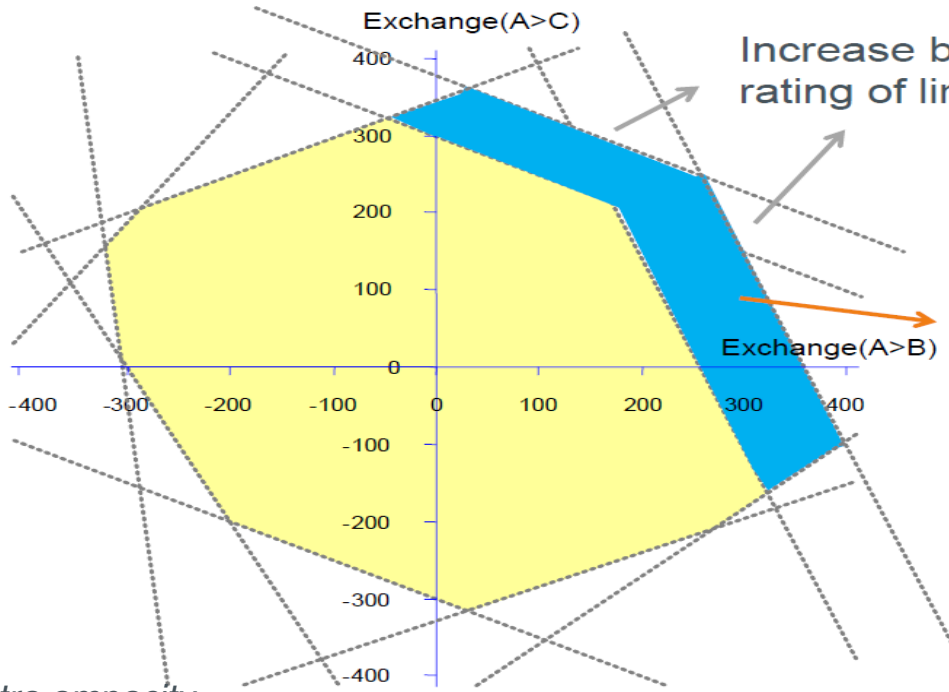
E



Demonstrated benefits for Belgian grid:
Increased security of supply → winter supply risk identified mid 2014

- **August 2014**
  Elia decision to implement DLR on critical Belgian border lines
- **September 2014**
  Principle agreement with neighbouring TSO RTE & Tennet
- **October**
  Agreement with neighbours about opertional limits
- **November**
  Finalize Instalation
- **December**
  DLR opérational

Demonstrated benefits for Belgian grid:
Increased import capacity, access to cheaper energy



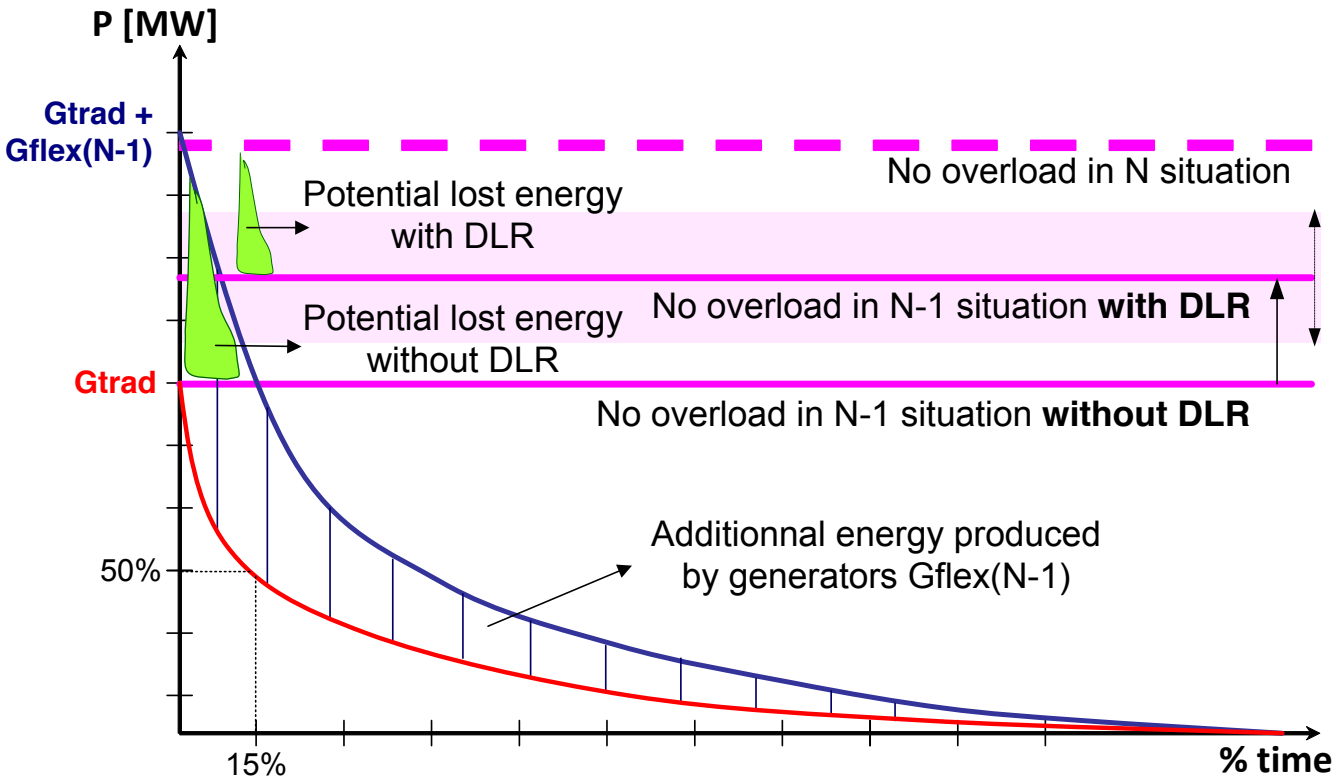
Increase by 3% the rating of limiting lines

Increase by 22% the available volume for the market

Ex:19/2/2015, market limited by Belgian lines. By using the 2-day ahead forecast, less constrain. During only 4 hours, the gain on the CWE welfare has been computed to 247.250 €

→ *Giving a few extra ampacity on critical lines increases significantly the FB domain*

Demonstrated benefits for Belgian grid: Increased wind infeed, less curtailment



Demonstrated benefits for Belgian grid: Optimised asset management

Maximise assets usage

Optimise maintenance schedules

1. Scheduled outage on a 220kV line, due to last several months
   Would require costly re-dispatching plan

   - 1 **adjacent line** equipped with DLR sensors
   - This line carries the extra **load during 3 months, average +40% capacity**
   - System can be re-deployed on other lines

Question to the audience: what is the experience DLR used / considered in Japan for RE integration?

ご清聴ありがとうございました

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