Evolution of Transmission Systems as Precondition for Decarbonisation of Electricity Supply

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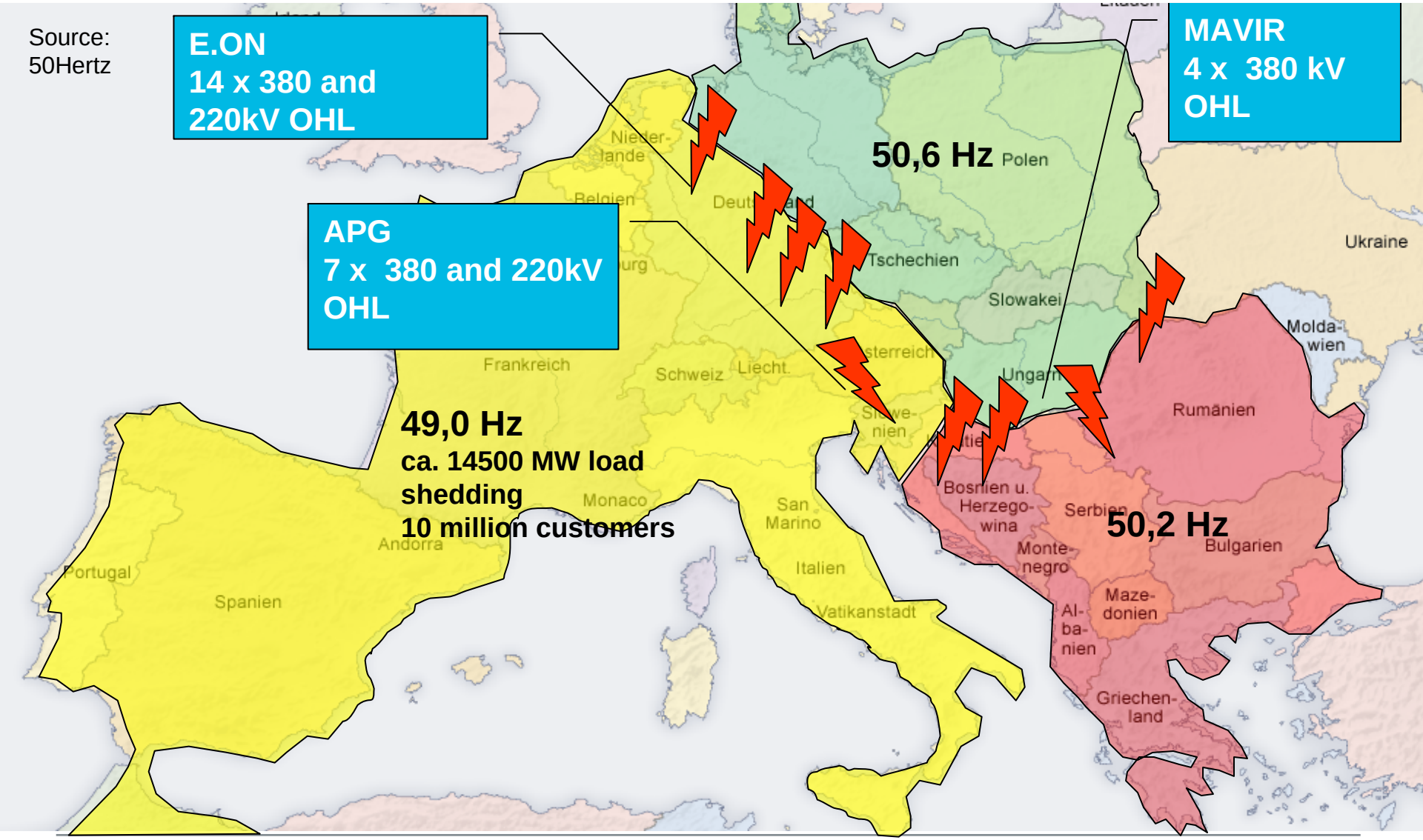
International Conference Elements of a Greenhouse Gas Neutral Society
Berlin, 10th October 2013

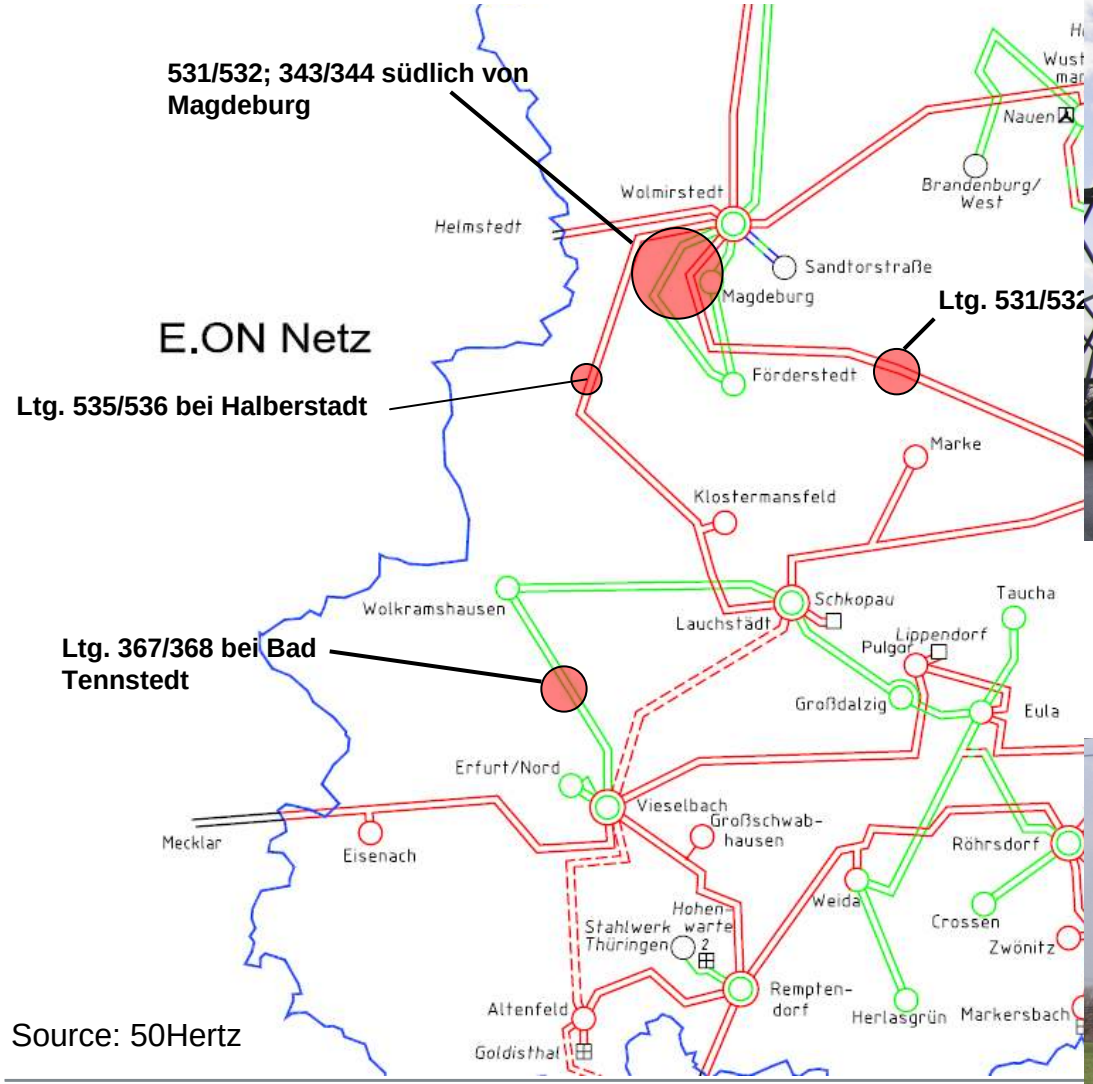
Brief overview on GridLab

Large-scale disturbance on 04th November 2006



Squall line „Kyrill“, 18th January 2007

Outage of 5 transmission (double-system) overhead lines (380 and 220 kV)



Source: 50Hertz

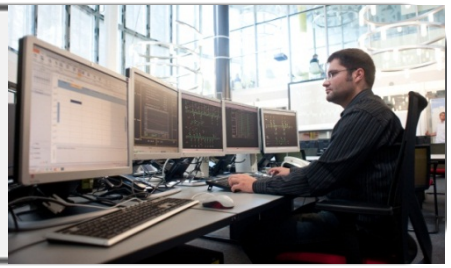
… GridLab establishment as consequence

- **2008:** 50Hertz (TSO for Eastern part of Germany) and the BTU Cottbus started the development of a training center for the dispatching personnel of electricity grid operators with the goal on as real as possible training atmosphere
- **2008-2010:** Development phase with focus on improvement of abilities of dispatching staff of 50Hertz and connected DSOs, and also to assure sufficient recruiting potential for the grid operators
- **December 2010:** Spin-off; foundation of GridLab GmbH in order to provide GridLab services to the overall market for trainings, studies, seminars …
- **March 2011:** Start of operation with own personnel
- **2013:** GridLab now official associated intitute of the Brandenburg Technical Univ.

GridLab portfolio at a glance

Dispatcher Trainings

- Training system for vertical trainings (TSO & DSOs)
- Training system for horizontal trainings (inter-TSO)
- Mobile system for application in customer's locations
- Artificial control area & city grid for virtual trainings



Studies

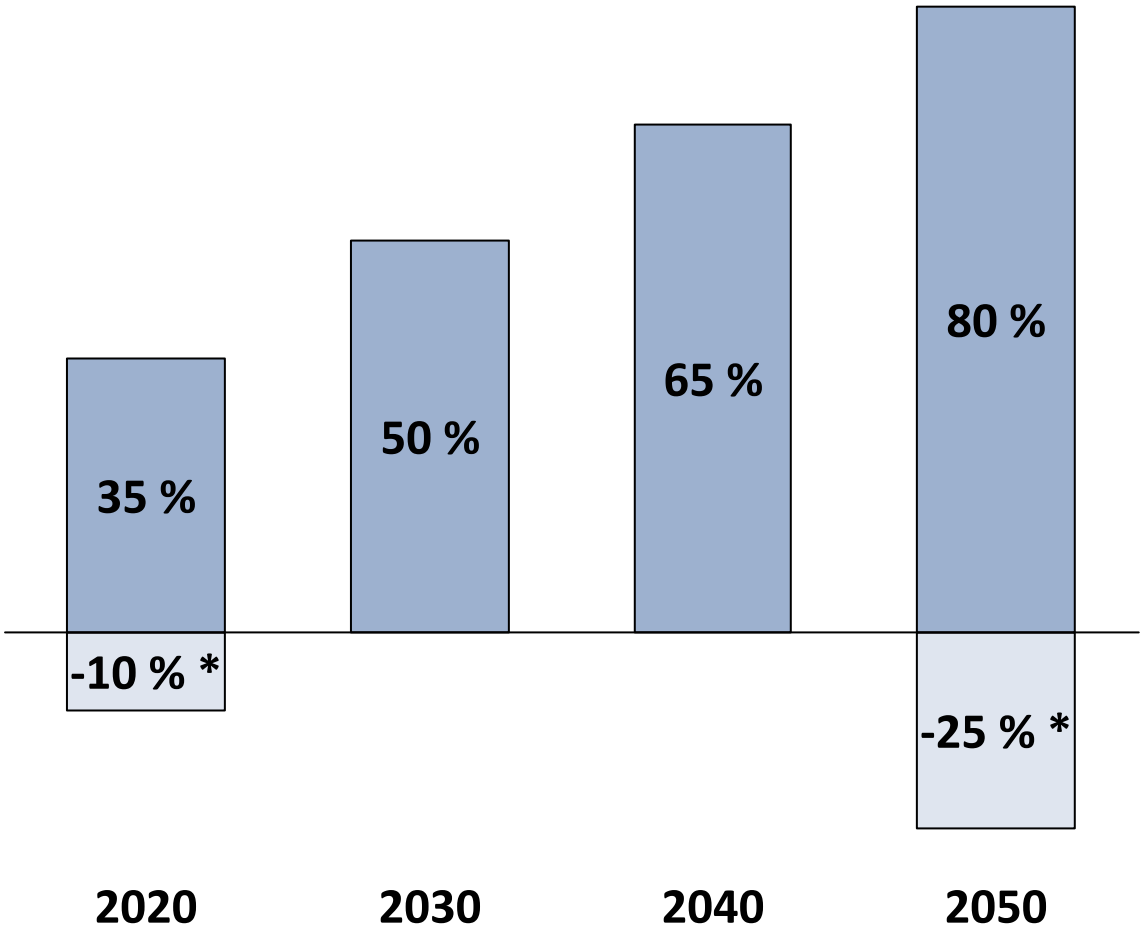
- System operation, ancillary services, network planning
- Renewable energy sources integration
- Storage integration, e.g. hydro, power-to-gas/heat
- Consultancy, workshops, expert interviews

Seminars

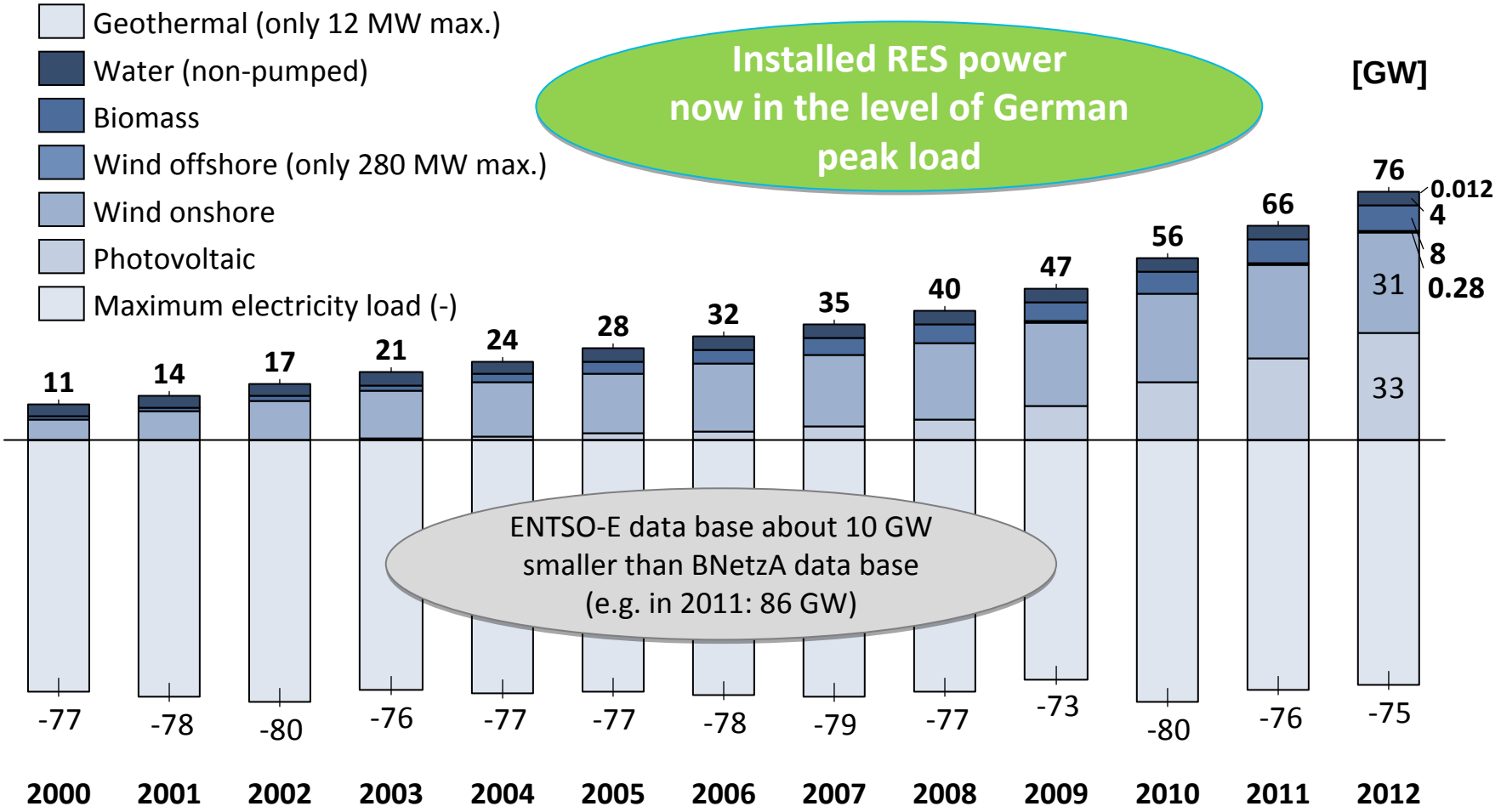
- Switching authorization courses 110/380 kV
- Electrically instructed persons
- Basics of energy supply
- Technical Assessment Center, crises management

The German Energy Turnaround today and tomorrow

Electricity targets of official German energy concept 2020

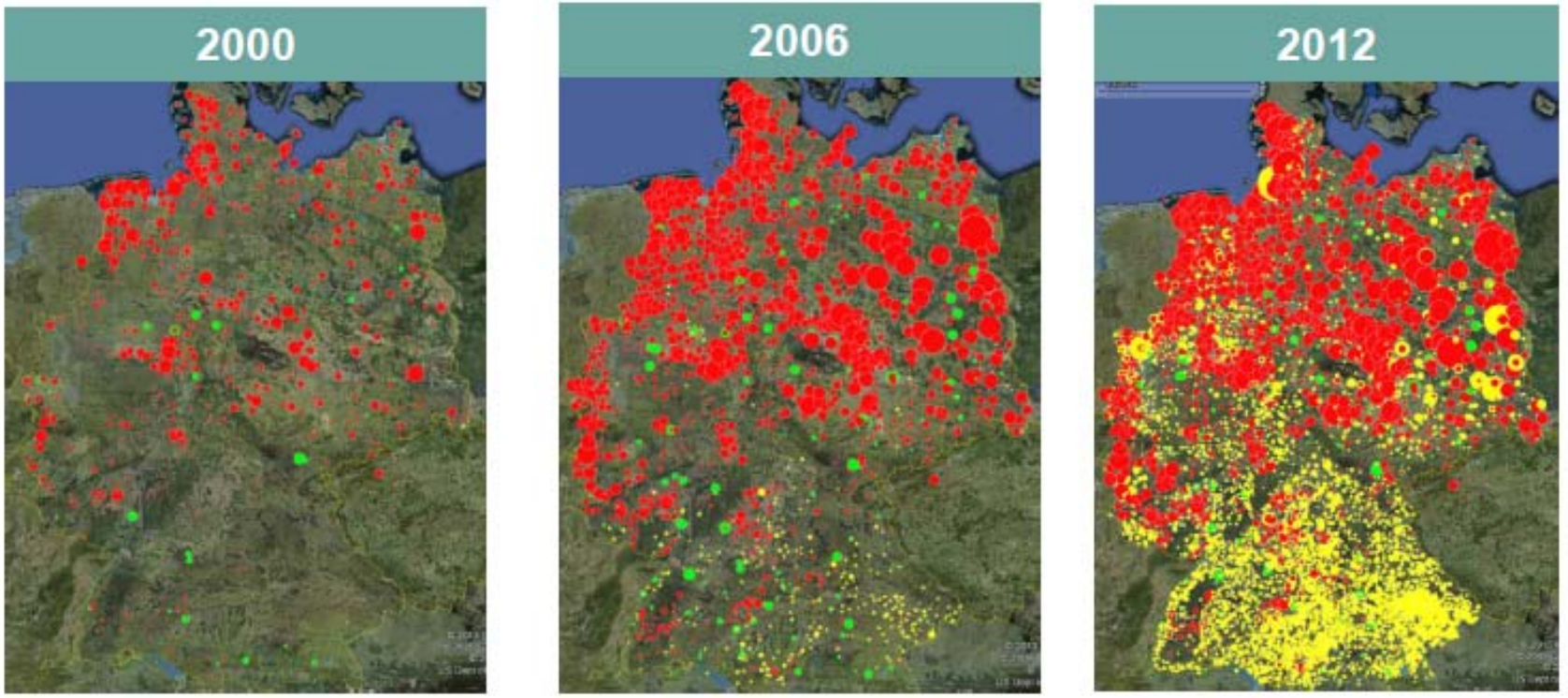


Status quo: Installed RES power vs. German peak load



Source: GridLab; data: Federal Ministry of Environment, “Erneuerbare Energien 2013”, February 2013; UCTE/ENTSO-E, “System Adequacy Retrospect” reports; 2000-2012

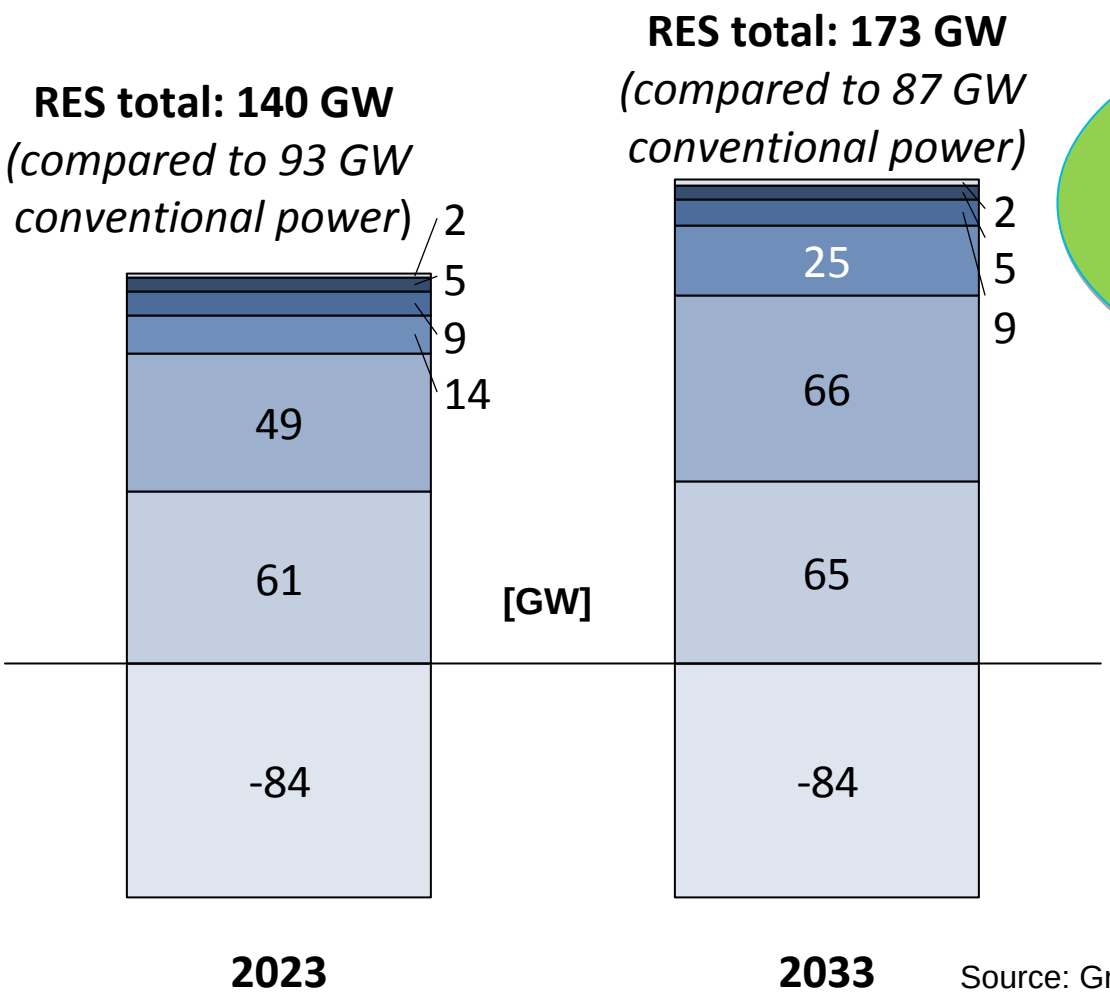
Geographical RES spread in Germany



Source: 50Hertz, Amprion, Tennet, Transnet BW, Google Earth

Outlook: Installed RES power in Germany

Acc. to German Network Development Plan for 2023/33 (main scenario)

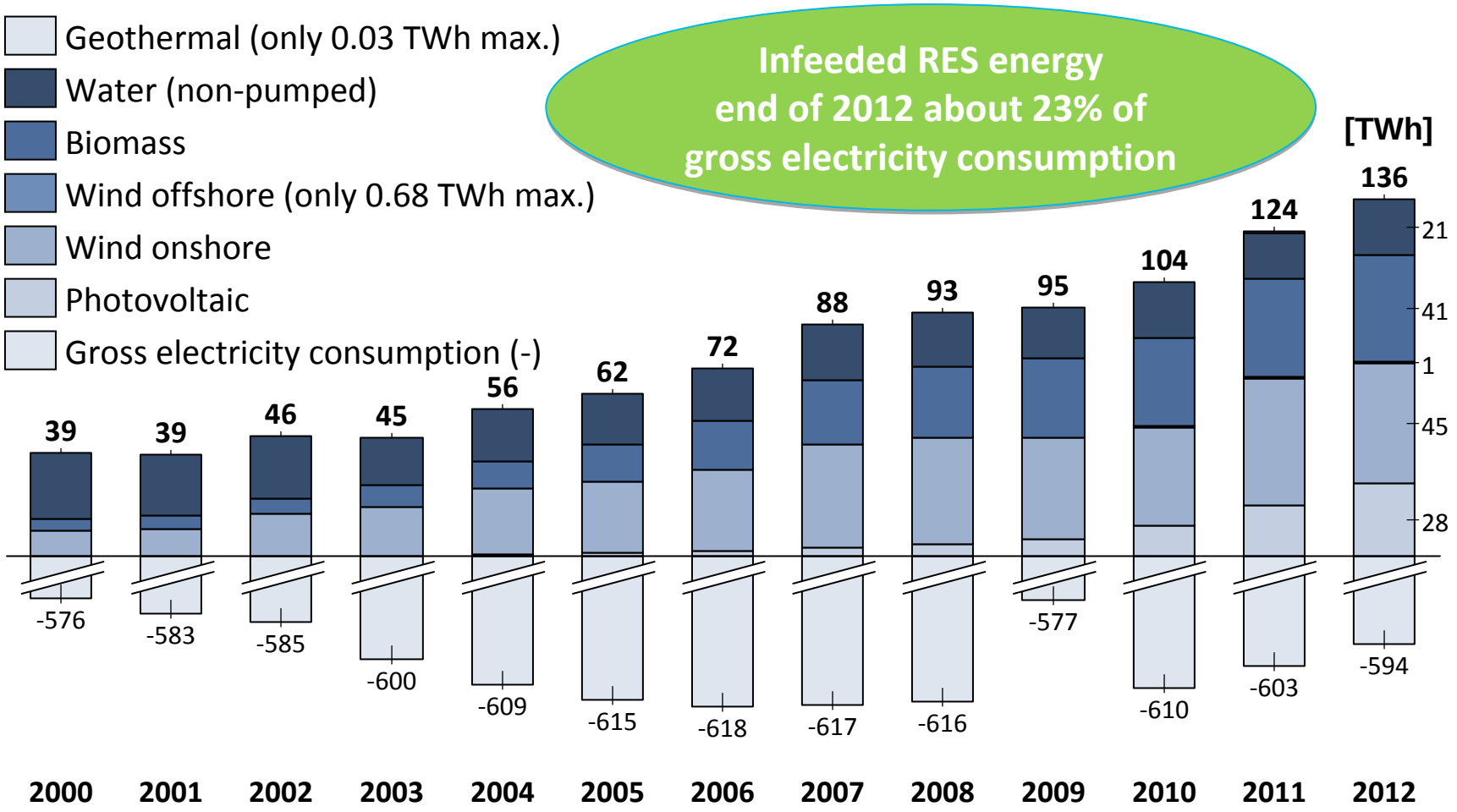


Installed RES power significantly exceeds German peak load, remaining conventional power in the level of German peak load

- Other RES
- Water (non-pumped)
- Biomass
- Wind offshore
- Wind onshore
- Photovoltaic
- Maximum electricity load (-)

Source: GridLab; data: 4 German TSOs, German Network Development Plan (official second draft as of July 2013)

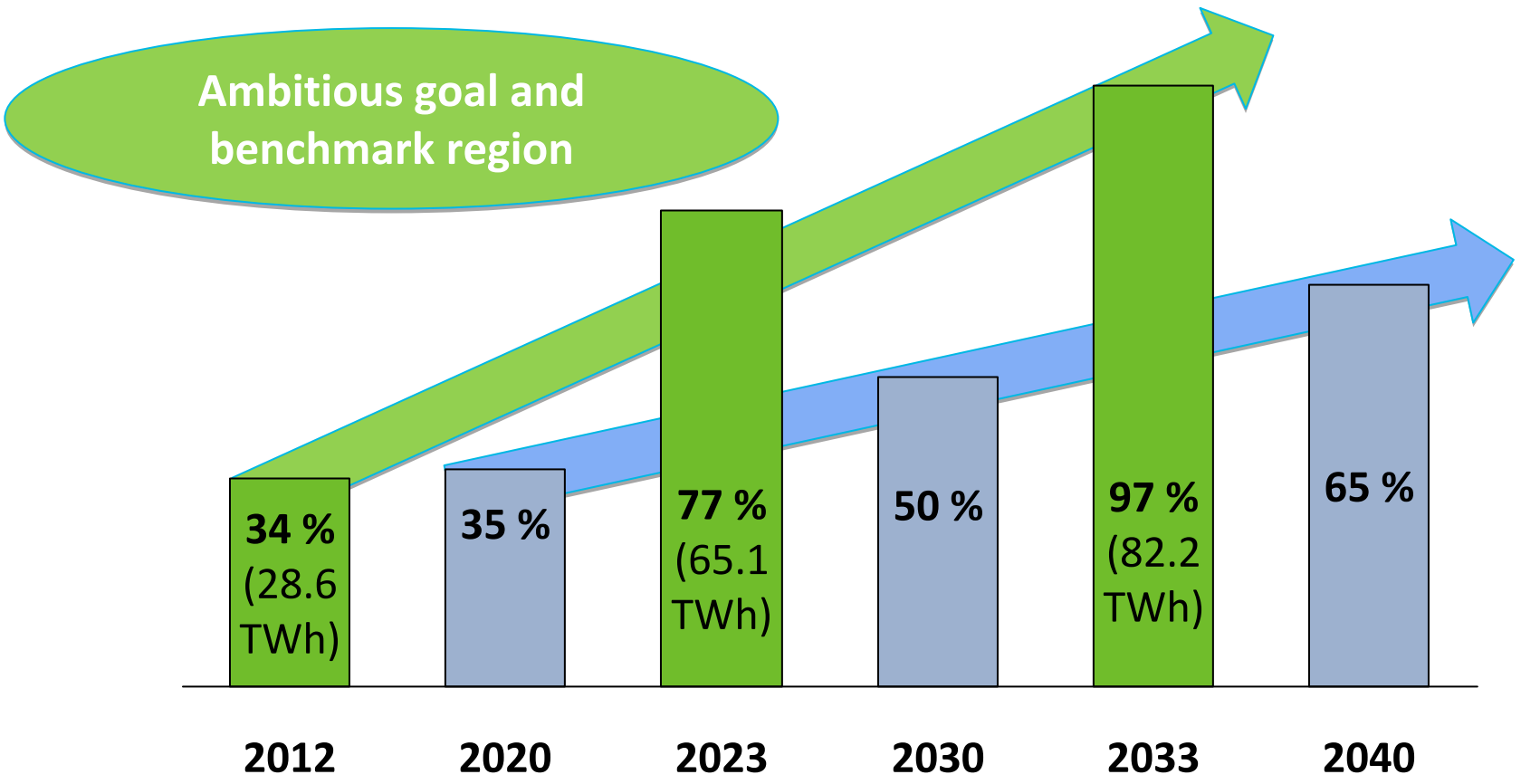
Status quo: RES infeed vs. electricity consumption in Germany



Source: GridLab; data: Federal Min. of Environment, “Entwicklung der erneuerbaren Energien in Deutschland im Jahr 2012”, 02/2013

Outlook: RES infeed share

Contribution of Eastern part of Germany to German Energy Turnaround

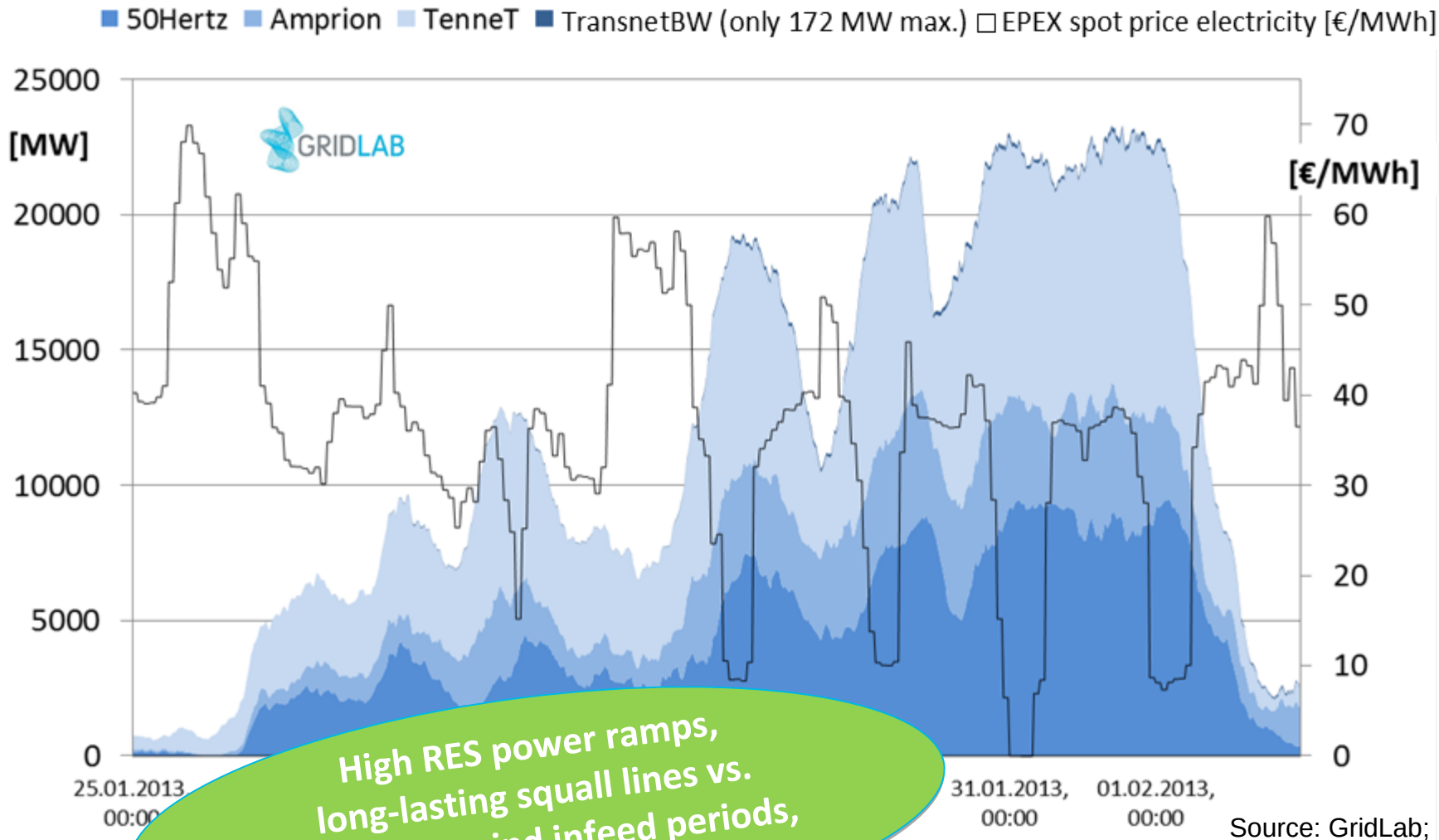


Share of RES energy in Germany (acc. to German Energy Concept 2020)

RES infeed compared to electricity consumption in East Germany (status quo, NDP 2023/33)

Status quo: Wind infeed in Germany

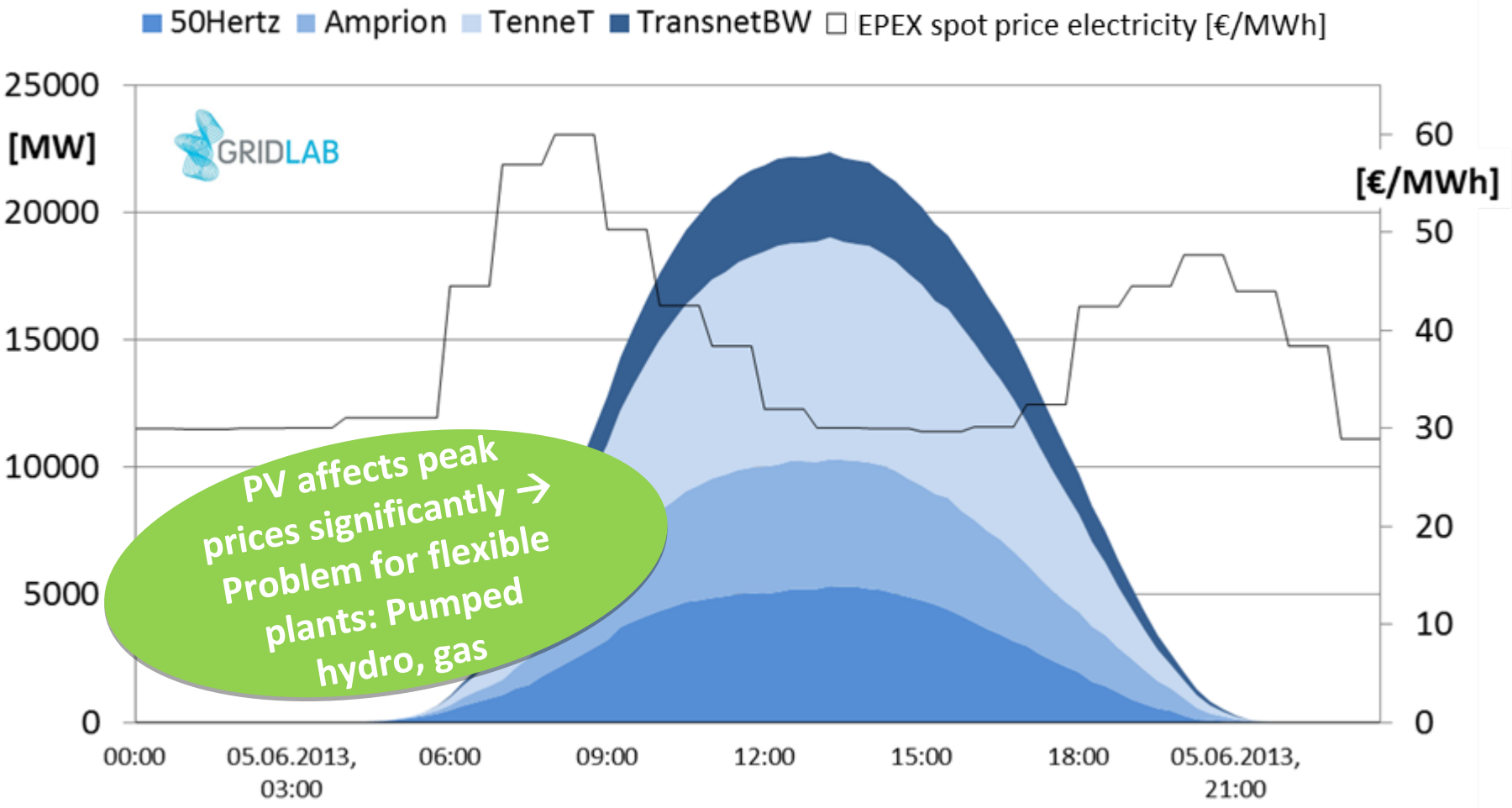
Squall line end of January 2013



Source: GridLab; data: www.transparency.eex.com; www.eex.com

Status quo: PV infeed in Germany

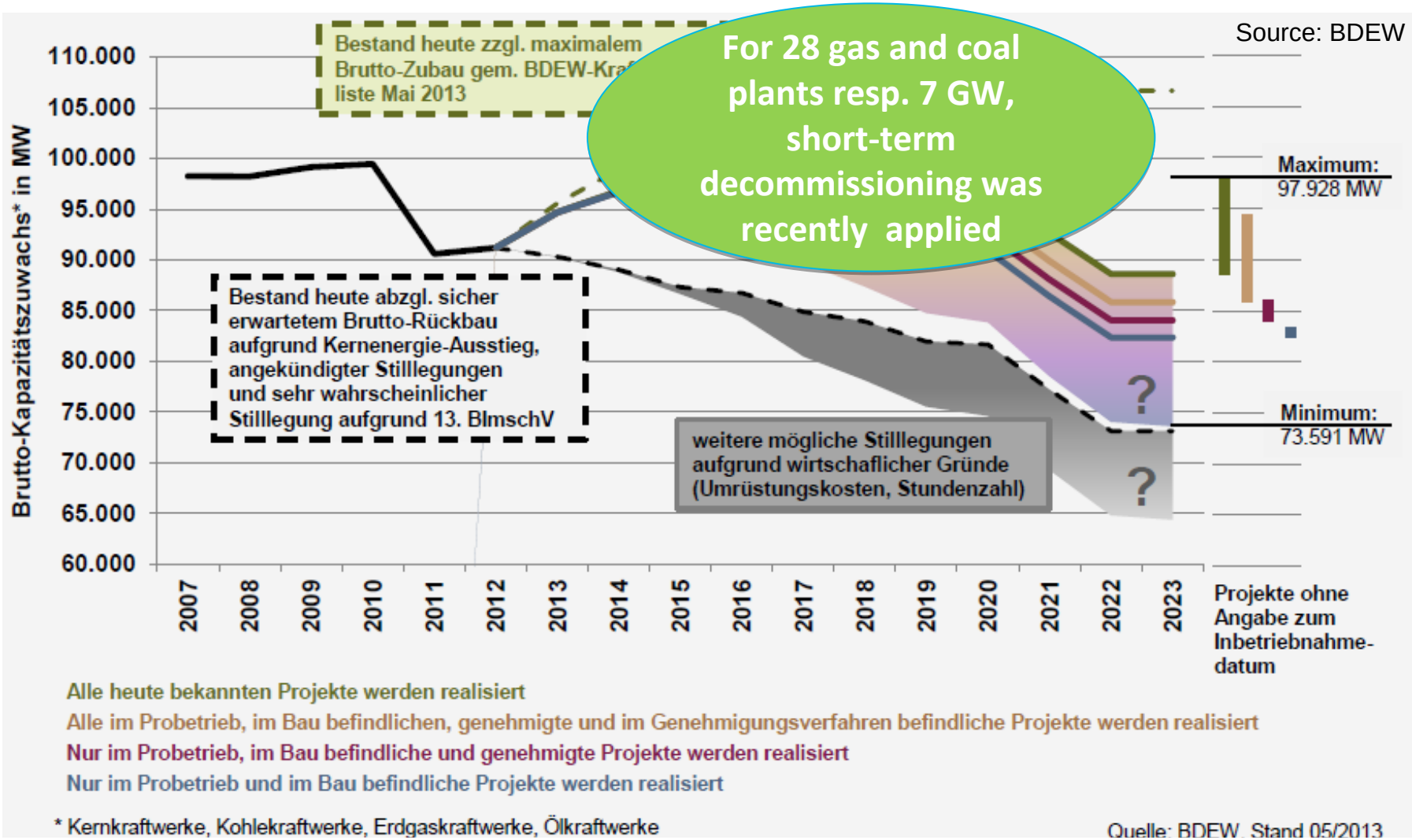
PV infeed 5th June 2013



Source: GridLab; data: www.transparency.eex.com; www.eex.com

Impact on installed conventional power

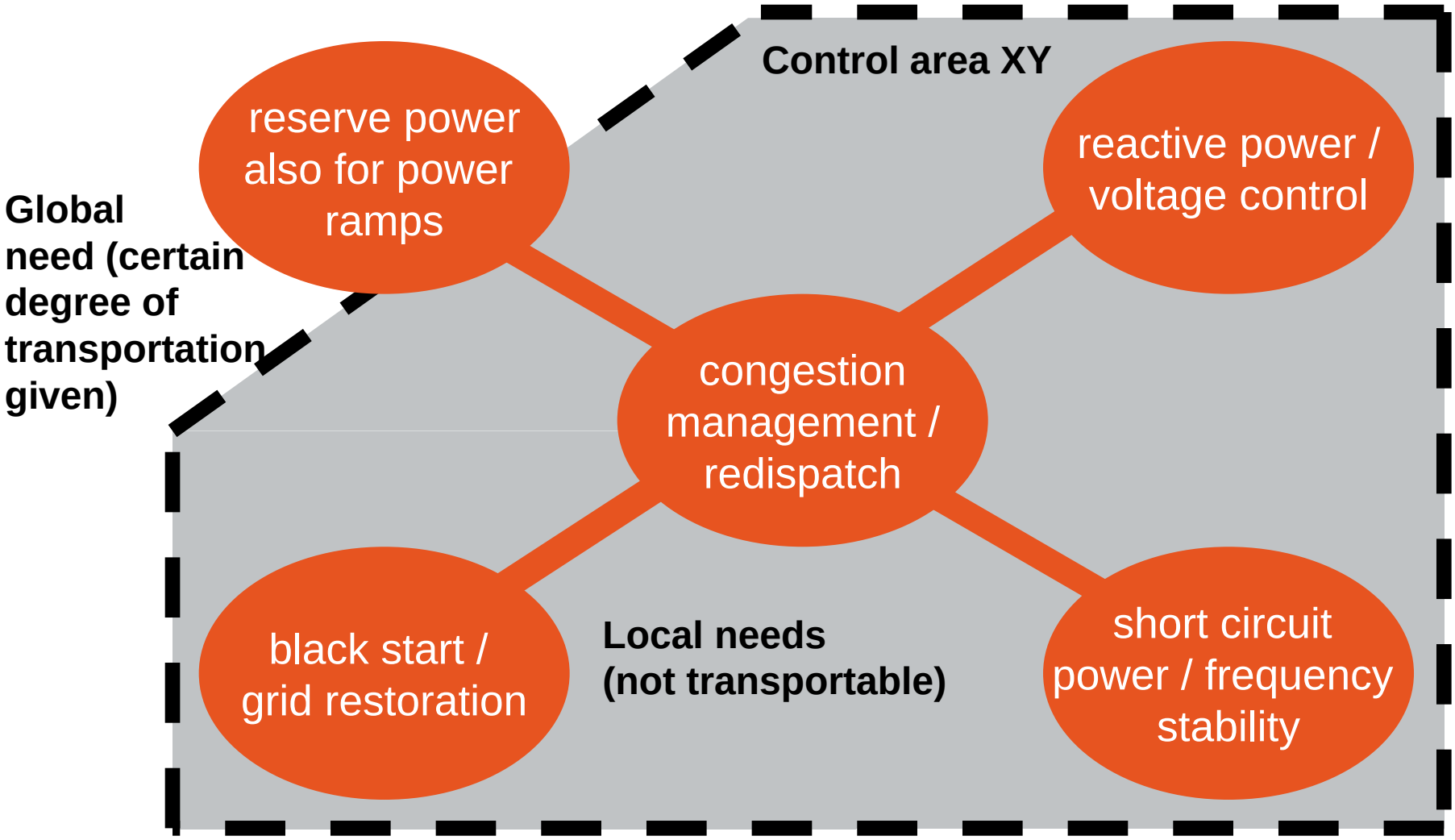
Caused by nuclear phase-out, decreasing peak prices & price spread, …



To follow-up with decarbonization of electricity supply, ancillary services must be ensured and more flexibility tools must be made available

Operational challenges of RES integration

Ancillary services must be ensured along the decarbonization pathway



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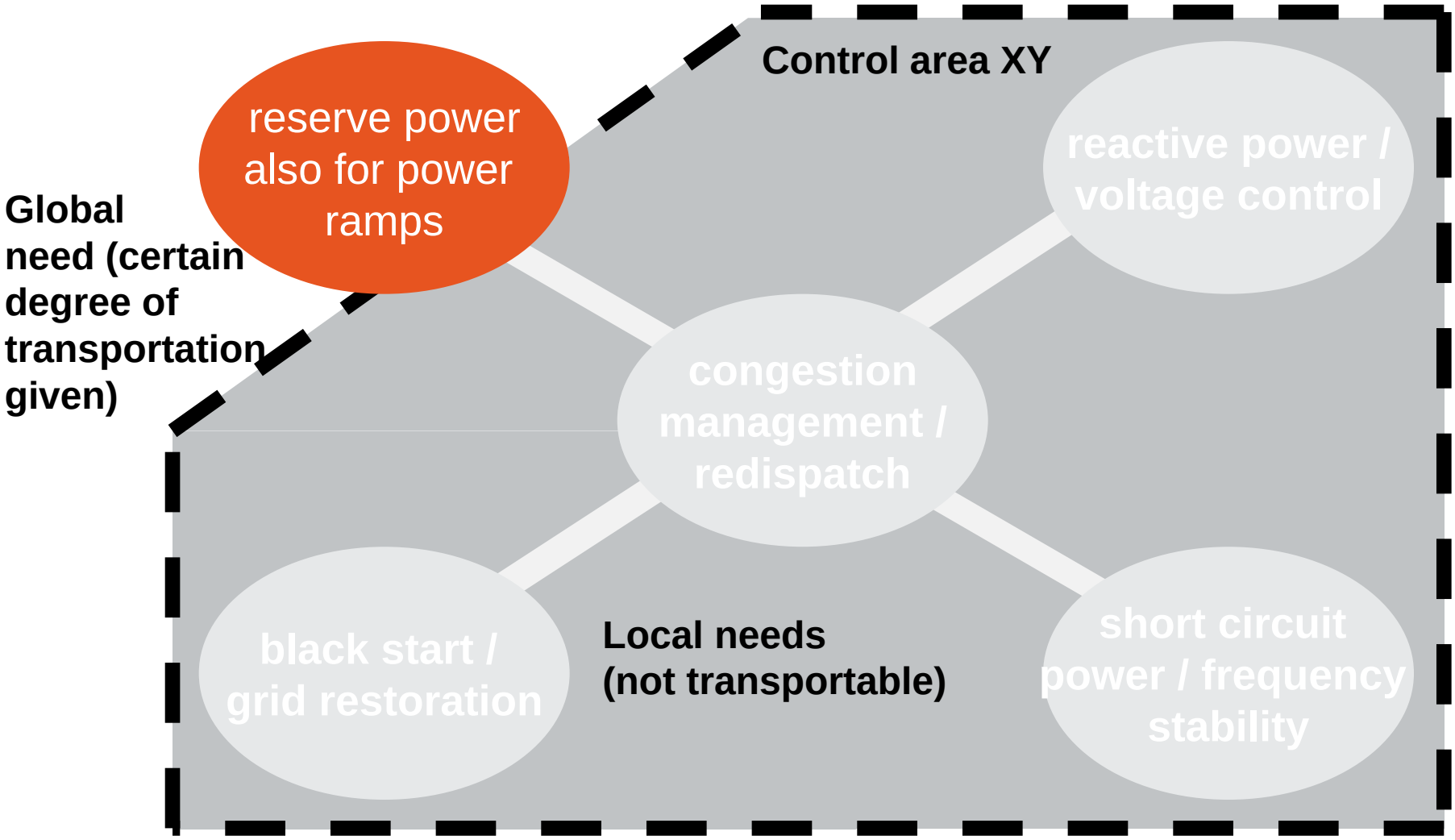
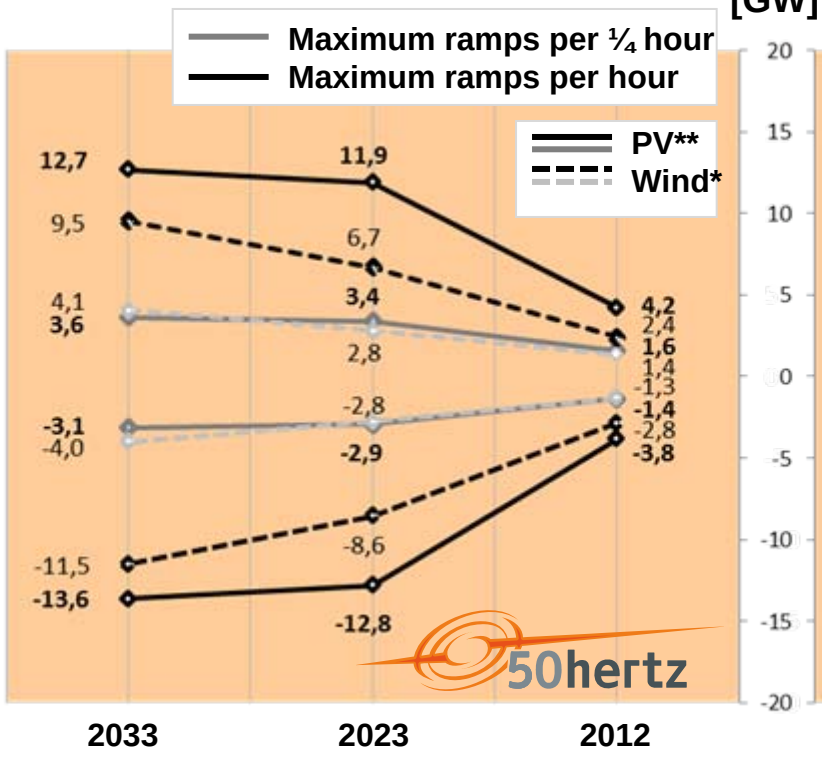


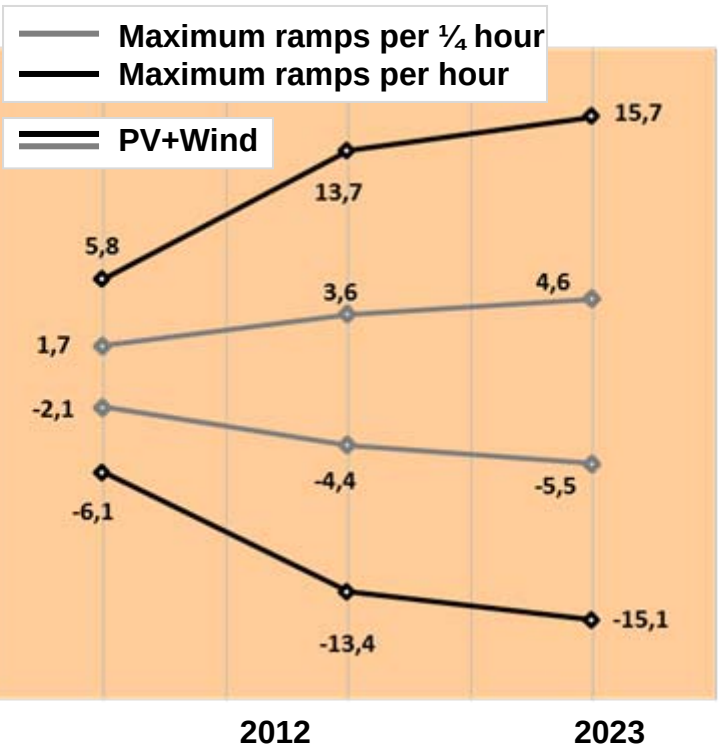
Power ramps caused by German RES

Today & tomorrow (based on German Network Development Plan 2023/33)

Maximum power ramps caused by German wind power* respectively PV power**



Maximum power ramps caused by German wind power* and PV power**



Source: 50Hertz

* Installed German wind power, average for 2011 was 27,61 GW (*source: "Stammdatenbank" of the four TSO's*)

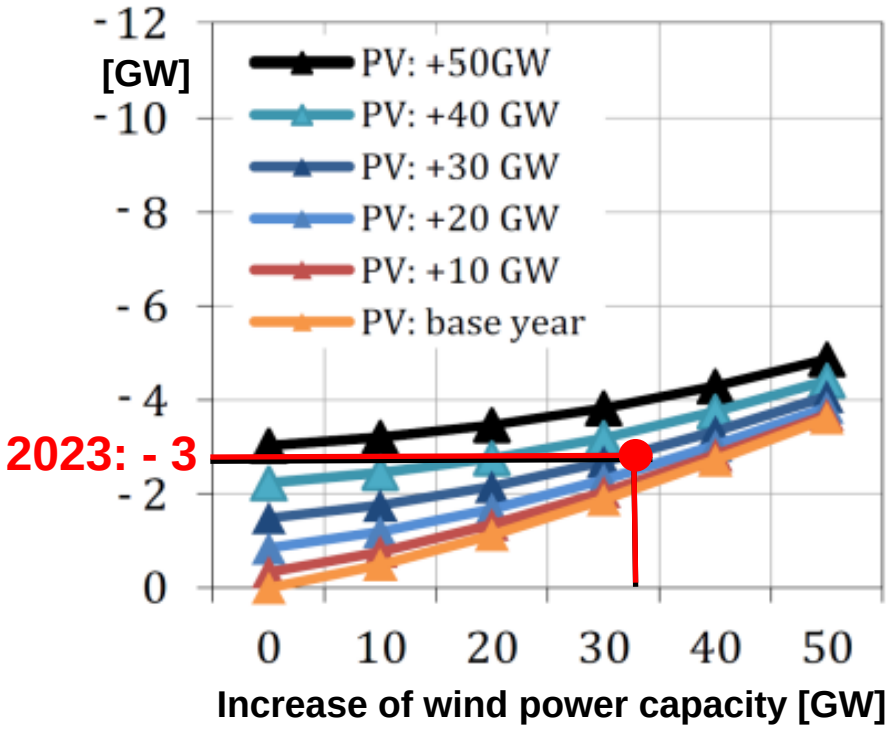
** Installed German PV power, average for 2011 was 17,08 GW (*source: IWES "Windenergiereport Deutschland 2011")*
In 2022 and 2032 the data of the installed power as well as the 1 hour ramps can be found in "Leitszenario (B)" of the NEP (*source: plan for the development of the German transmission grid: "Netzentwicklungsplan 2012").* The ¼ hour ramps for the years 2022 and 2032 are extrapolated by using the maximal ramps per ¼ hour of 2011 *(source: feed-in data of the four German TSO's).*

Development of reserve power need

Forecast of Leipzig University put in context with German NDP for 2023

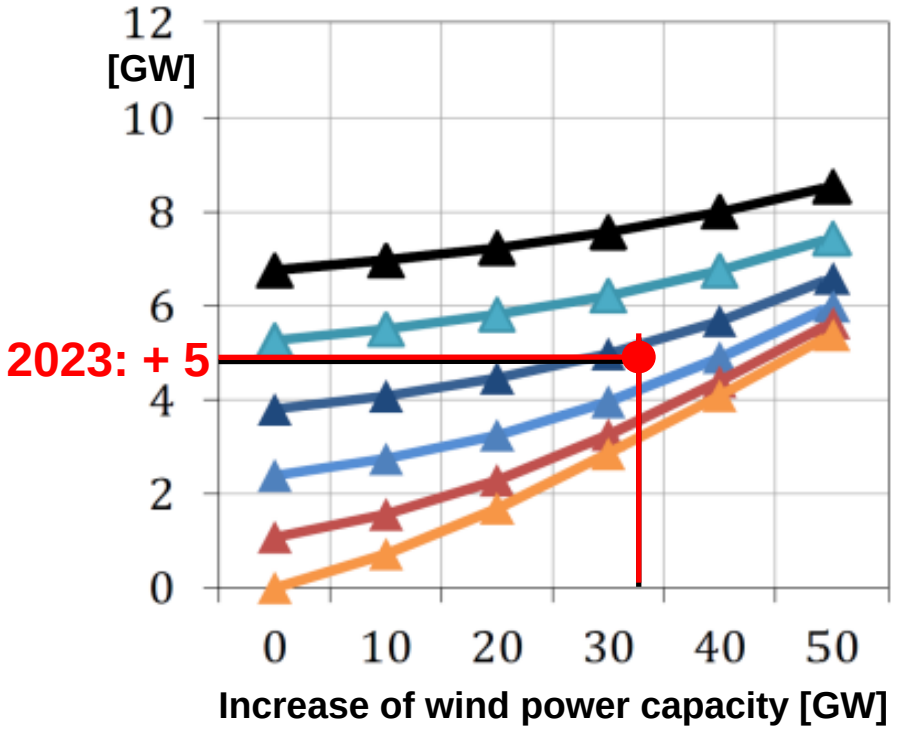
Additional <u>negative</u> reserve power

(- 3 GW as add-on to 2012 value (ca. - 5,1 GW))



Additional <u>positive</u> reserve power

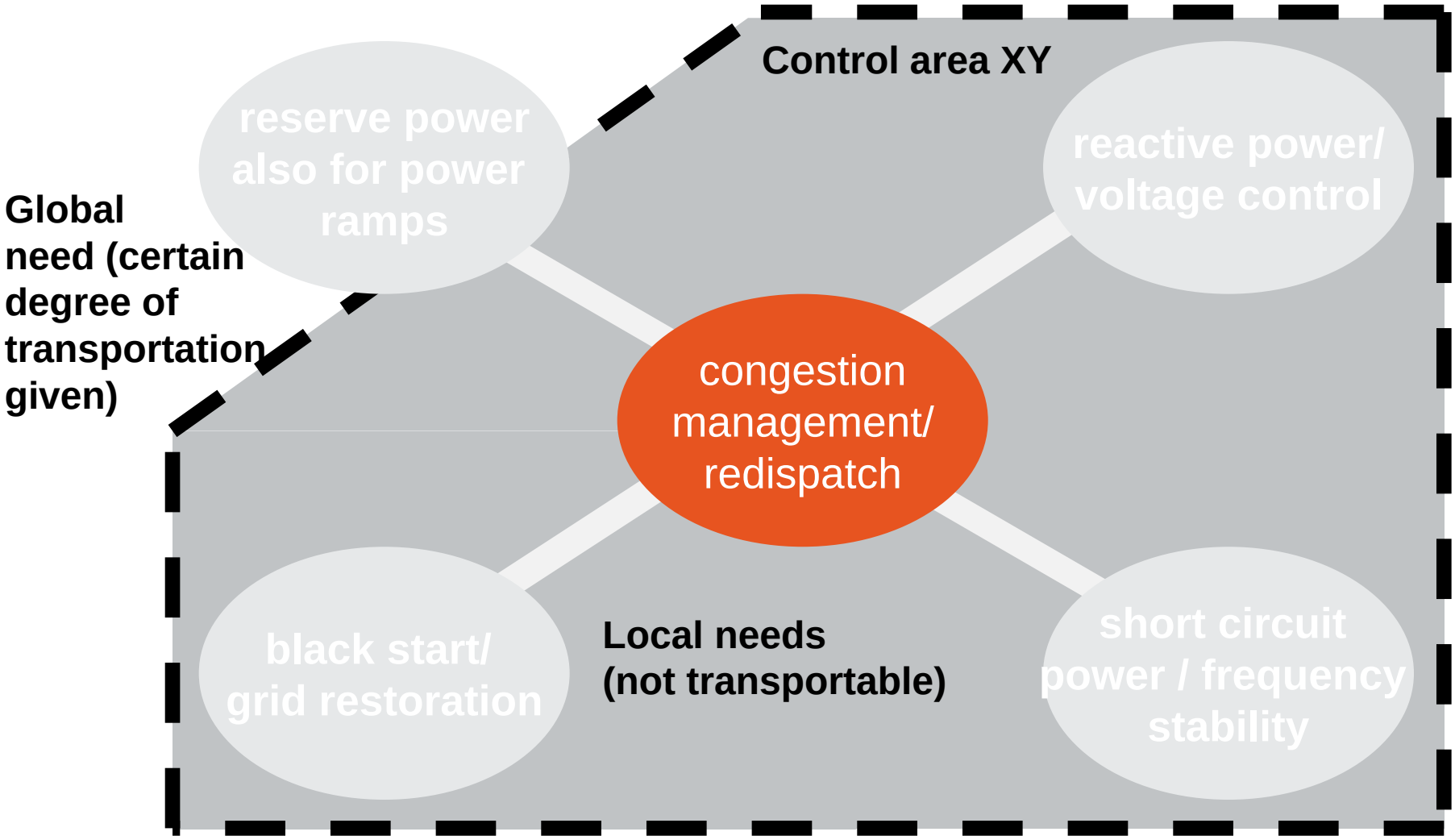
(+ 5 GW as add-on to 2012 value (ca. + 4.4 GW))



Source: Inka Ziegenhagen, Chair Prof. Bruckner, University of Leipzig, 2013; supplemented by GridLab

Operational challenges of RES integration

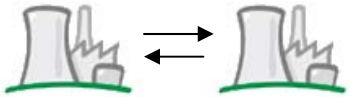
Ancillary services must be ensured along the decarbonization pathway



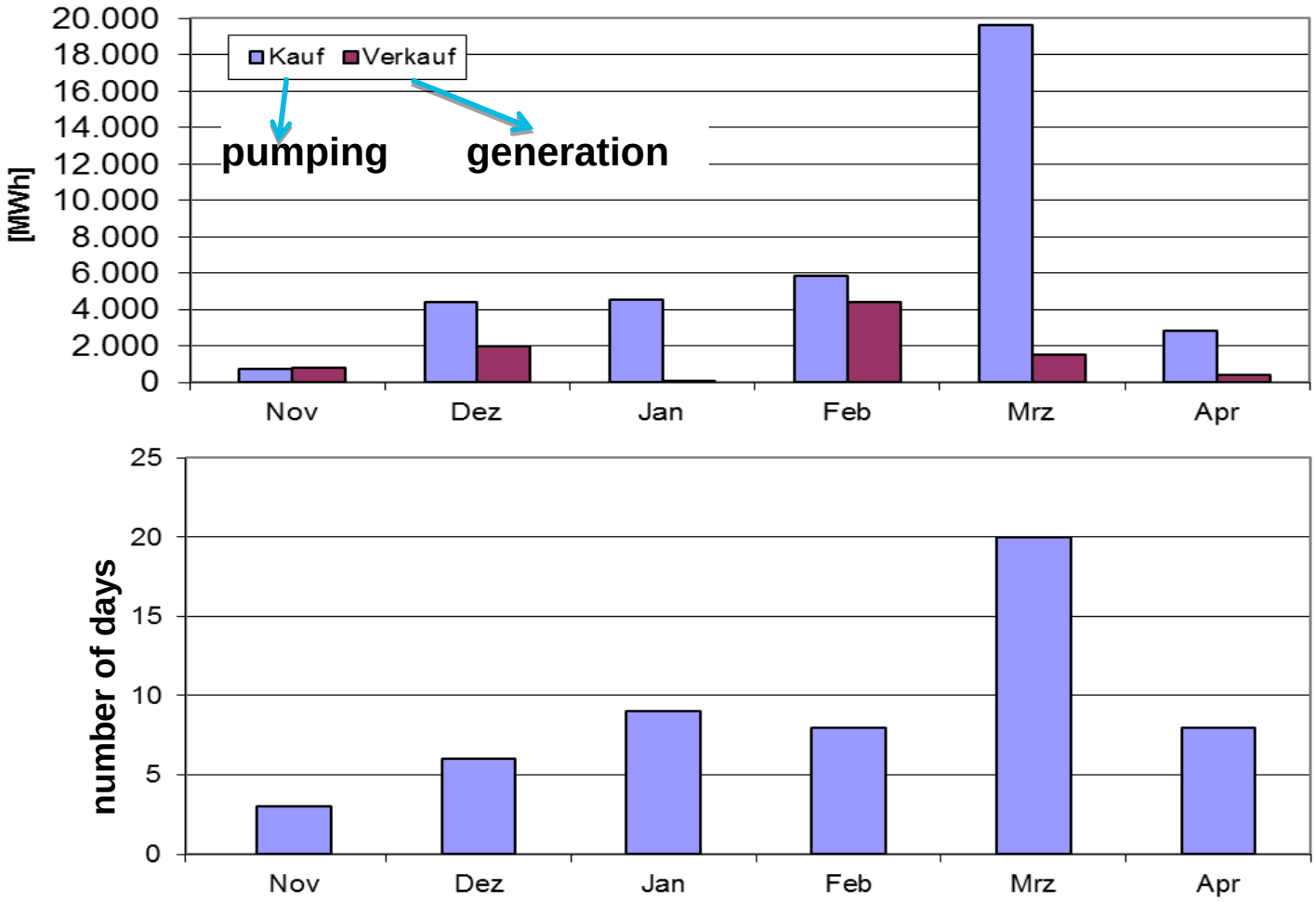
Congestion management acc. Energy Act

Example of unexpected strong squall-line

Source: 50Hertz

Grid related measures	Market related measures	Generation curtailment	
			
Special **switching measures** to reduces the power flows on congested lines	Especially **redipatch measures**: To decrease conventional generation on one side of congested line, and in parallel to increase conventional generation on the other side of congested line in order to reduce the power flow	Once that the conventional generation is reduced to a minimum level still keeping the grid stability, as **local measure** also RES infeed in local areas to be curtailed	As last measure a **global adaptation** of all generations: all RES infeeds in the control area to be curtailed

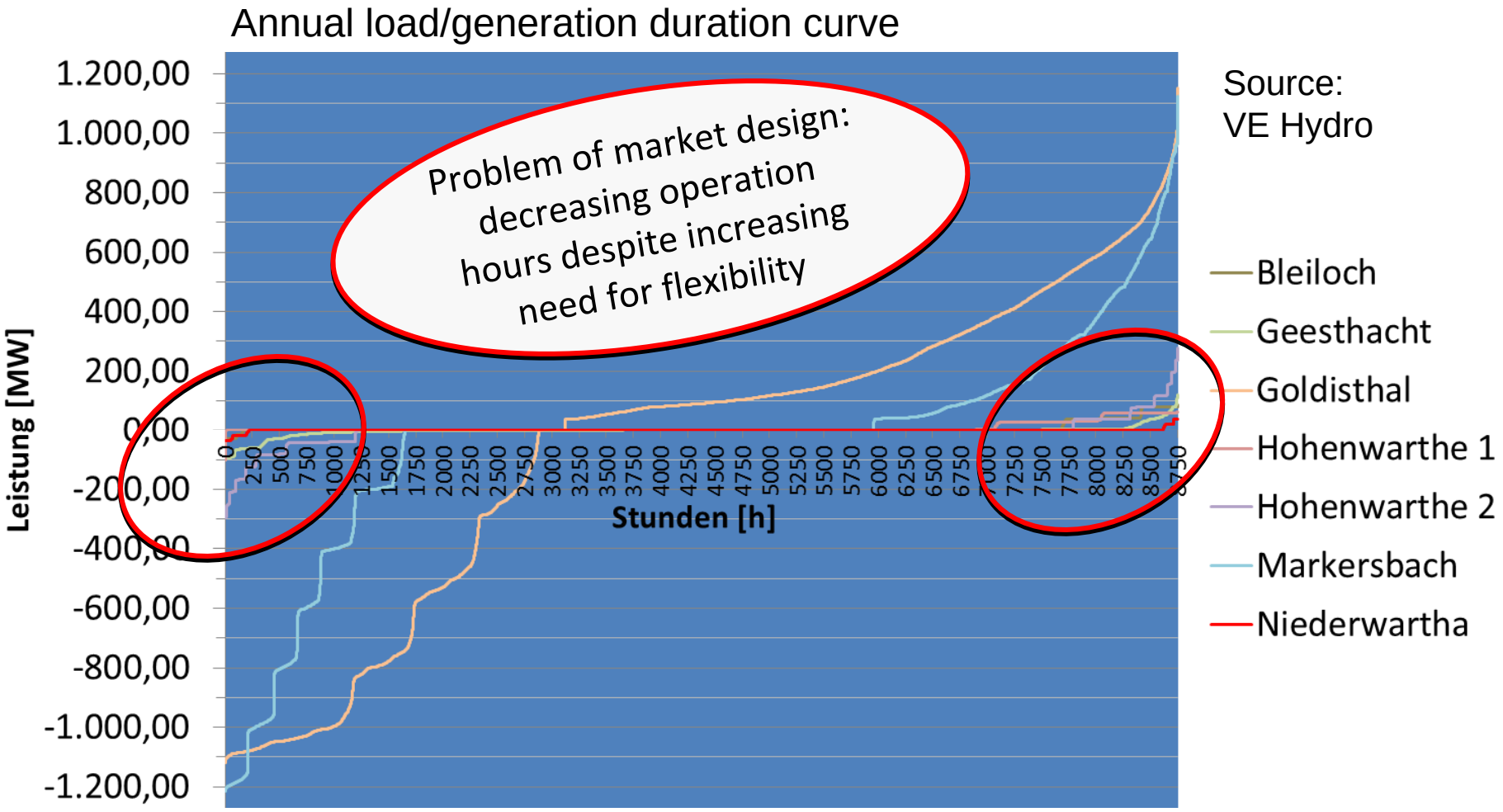
Redispatch application with pumped storage power plants



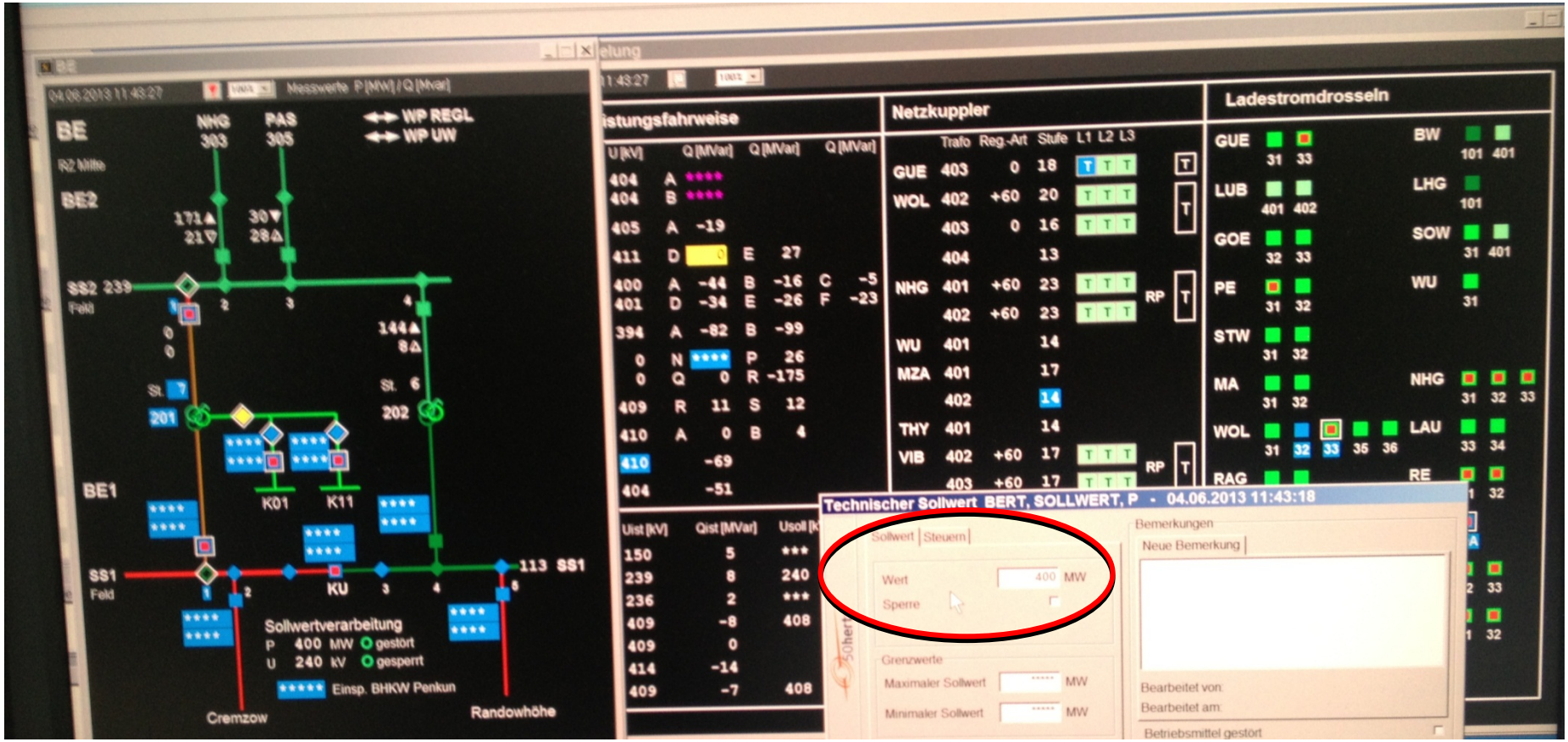
Source:
VE Hydro

Pumped storage operation hours

Example for 50Hertz control area in 2011



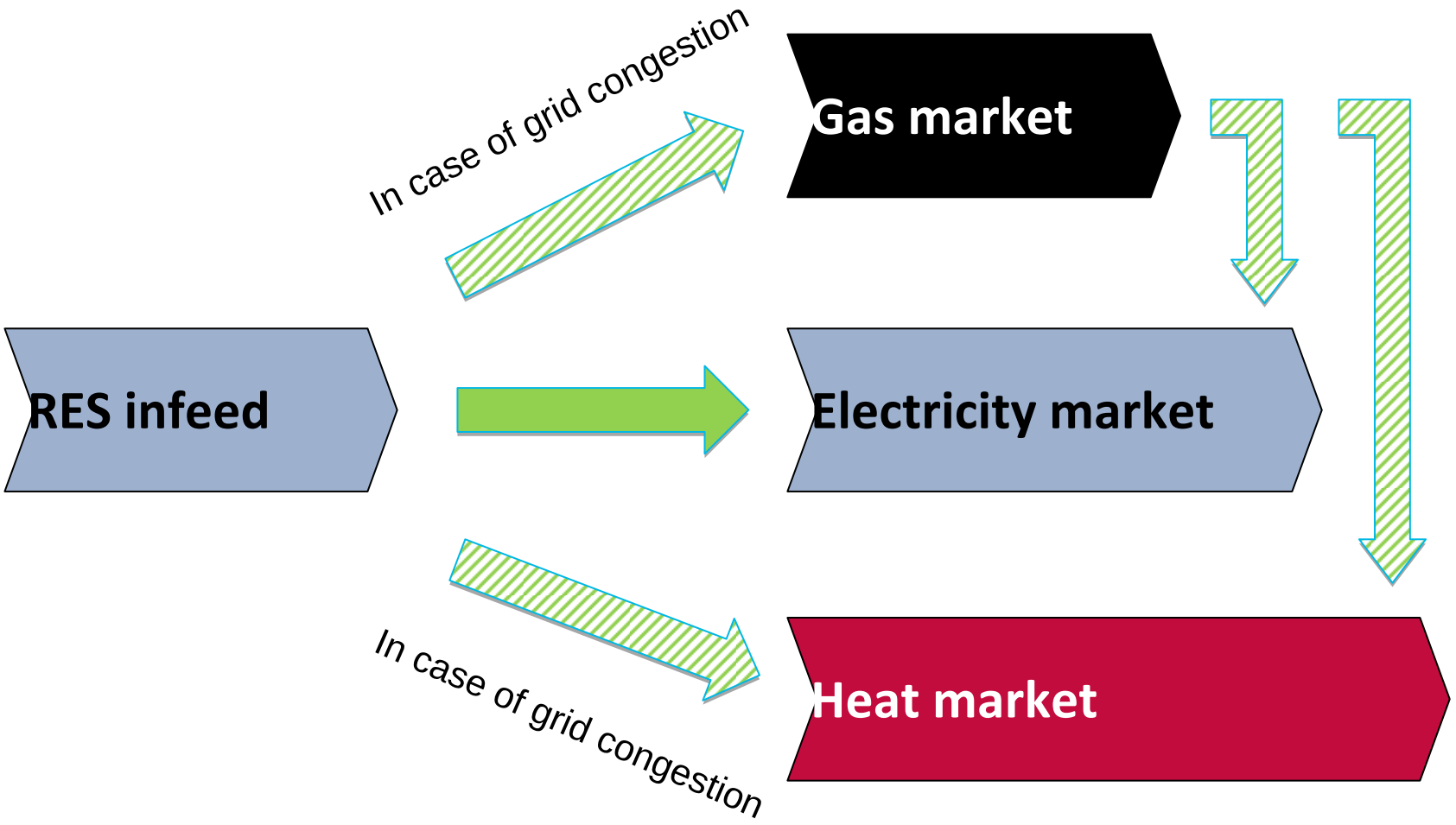
Redispatch application of first wind farms



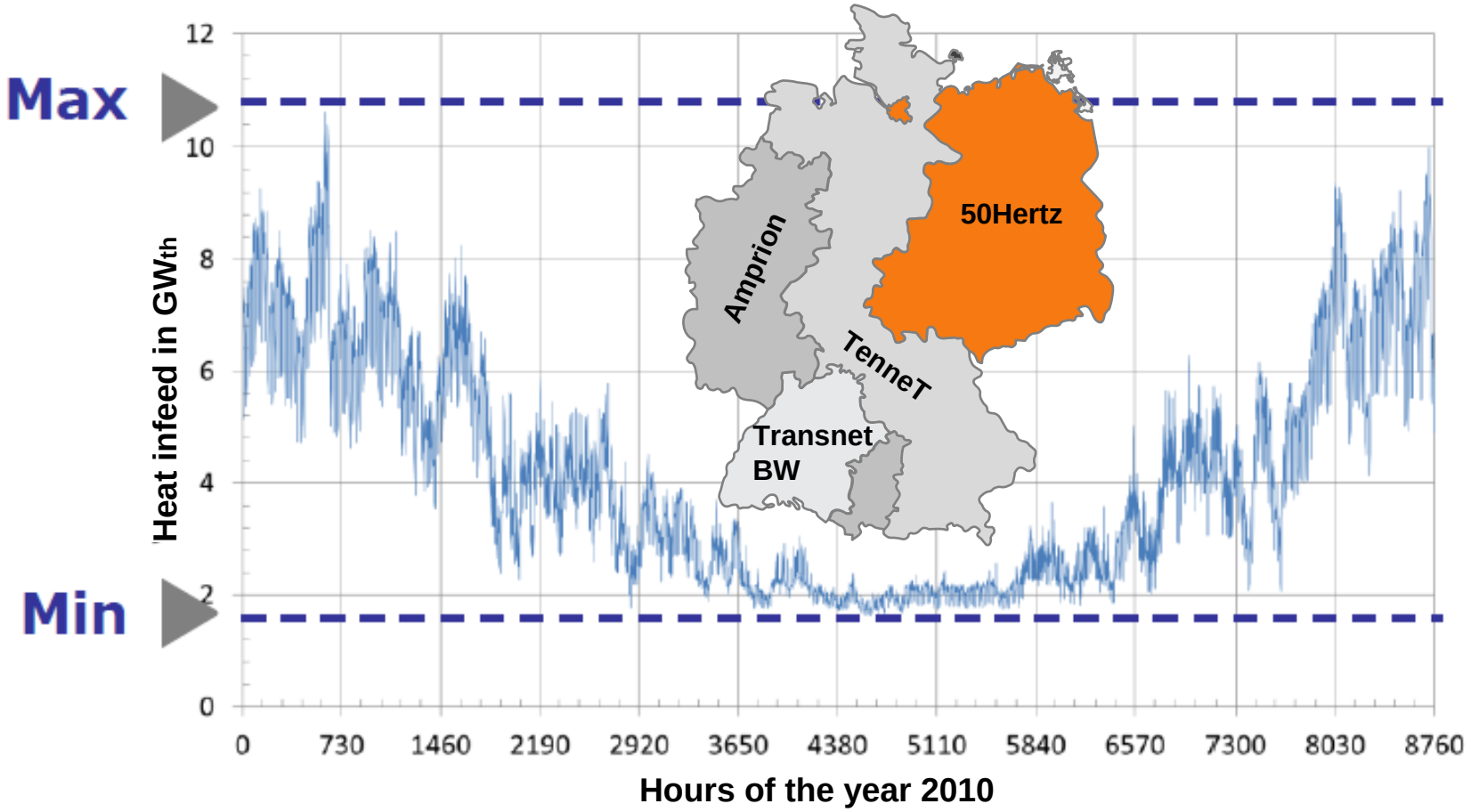
Monitor window of TSO 50Hertz control center for direct adaptation of active power of the windfarm Bertikow also for cross-border redispatch purpose (interconnection to Poland)

New congestion management tools needed

Power-to-heat/gas to bypass wind energy surplus into other energy markets



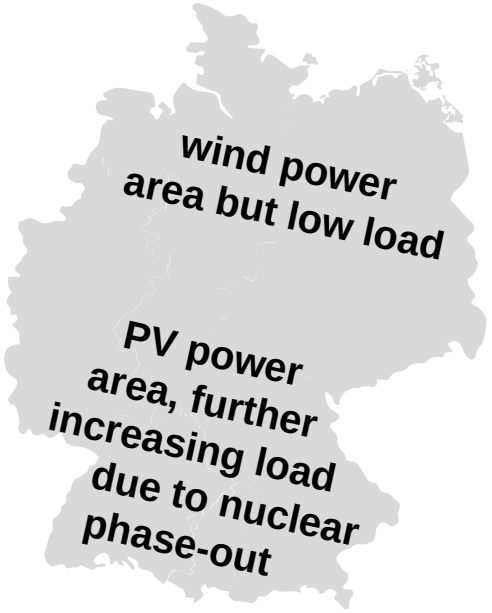
Theoretical power-to-heat-potential of 50Hertz control area of up to 11.8 GW_{el} in maximum



Source: Univ. Leipzig/Prof. Bruckner, 50Hertz

Grid extension as overall measure

German context



22 bn € up to 2023

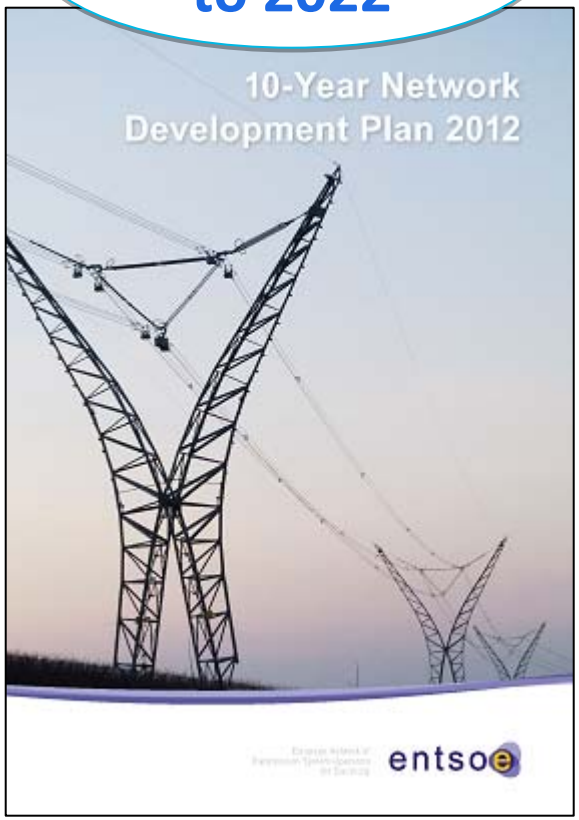
22 bn € up to 2023

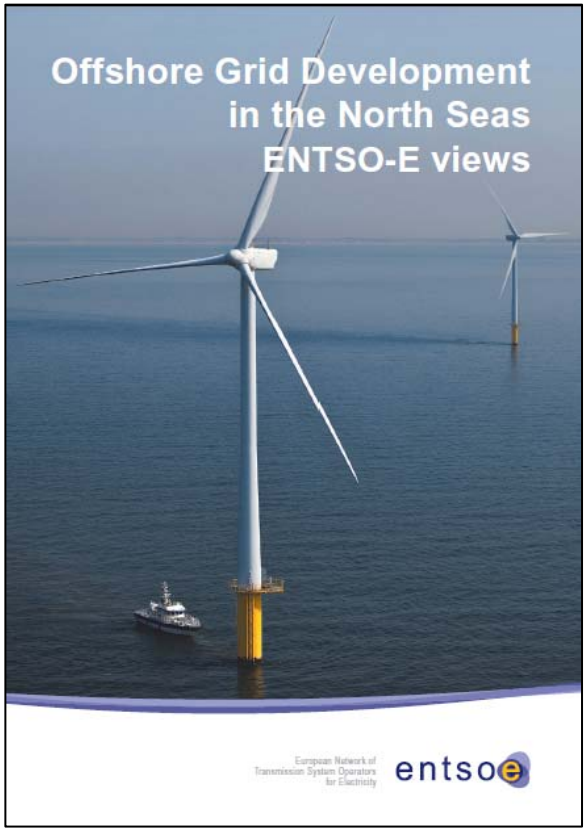
18 bn € up to 2020

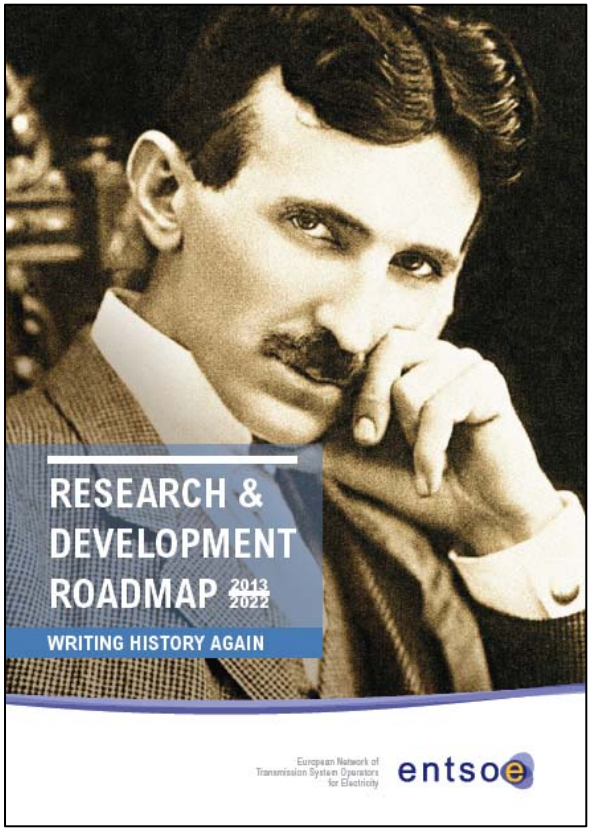
Grid extension as overall measure

European context - 10-Year Network Development Plan of ENTSO-E

104 bn € up to 2022

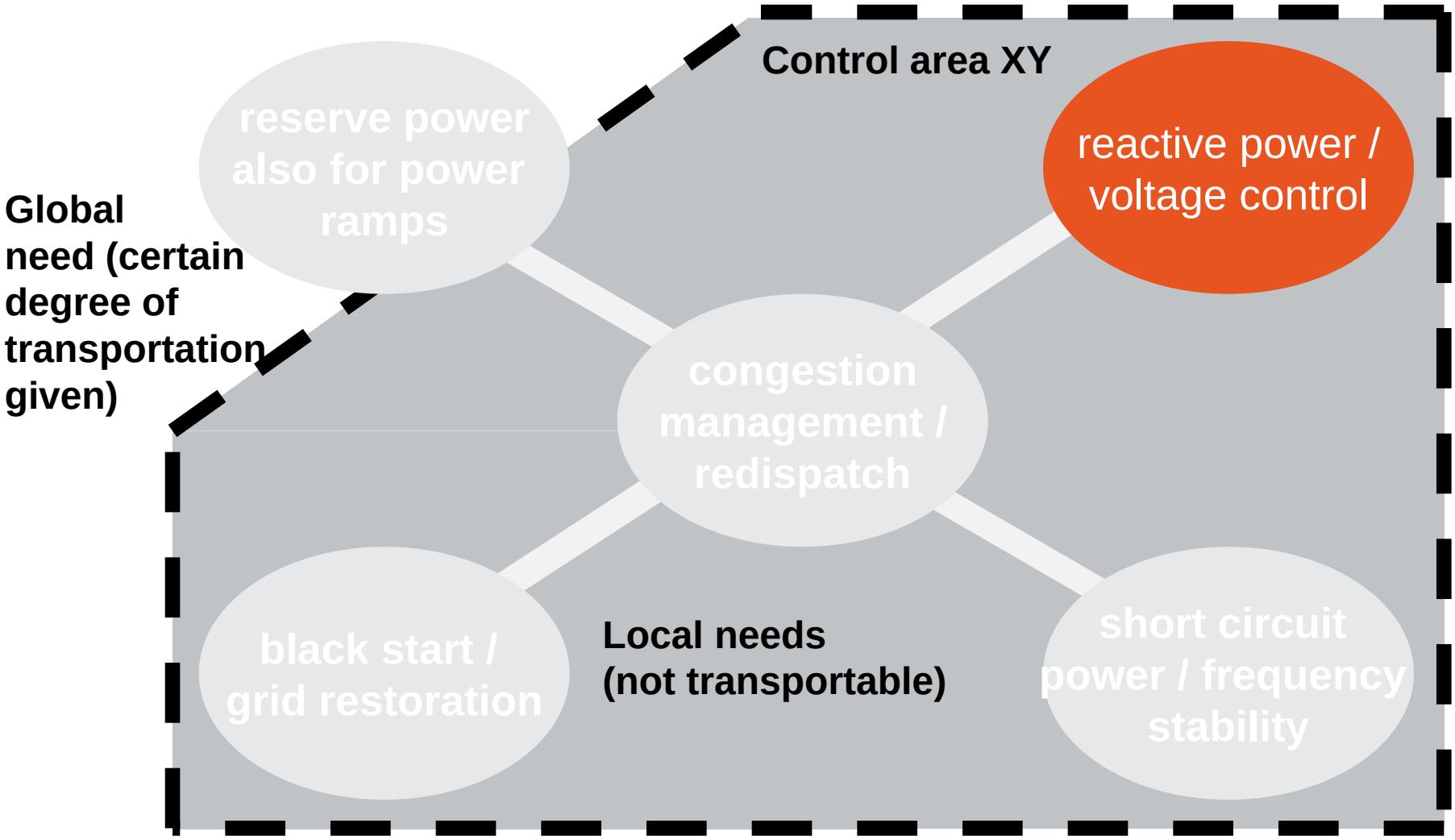






Operational challenges of RES integration

Ancillary services must be ensured along the decarbonization pathway



Aspect reactive power / voltage control

Increasing reactive power needs esp. caused by nuclear phase-out

Out of BNetzA winter report 2012/2013:

Endangered voltage situation in winter 2012/13

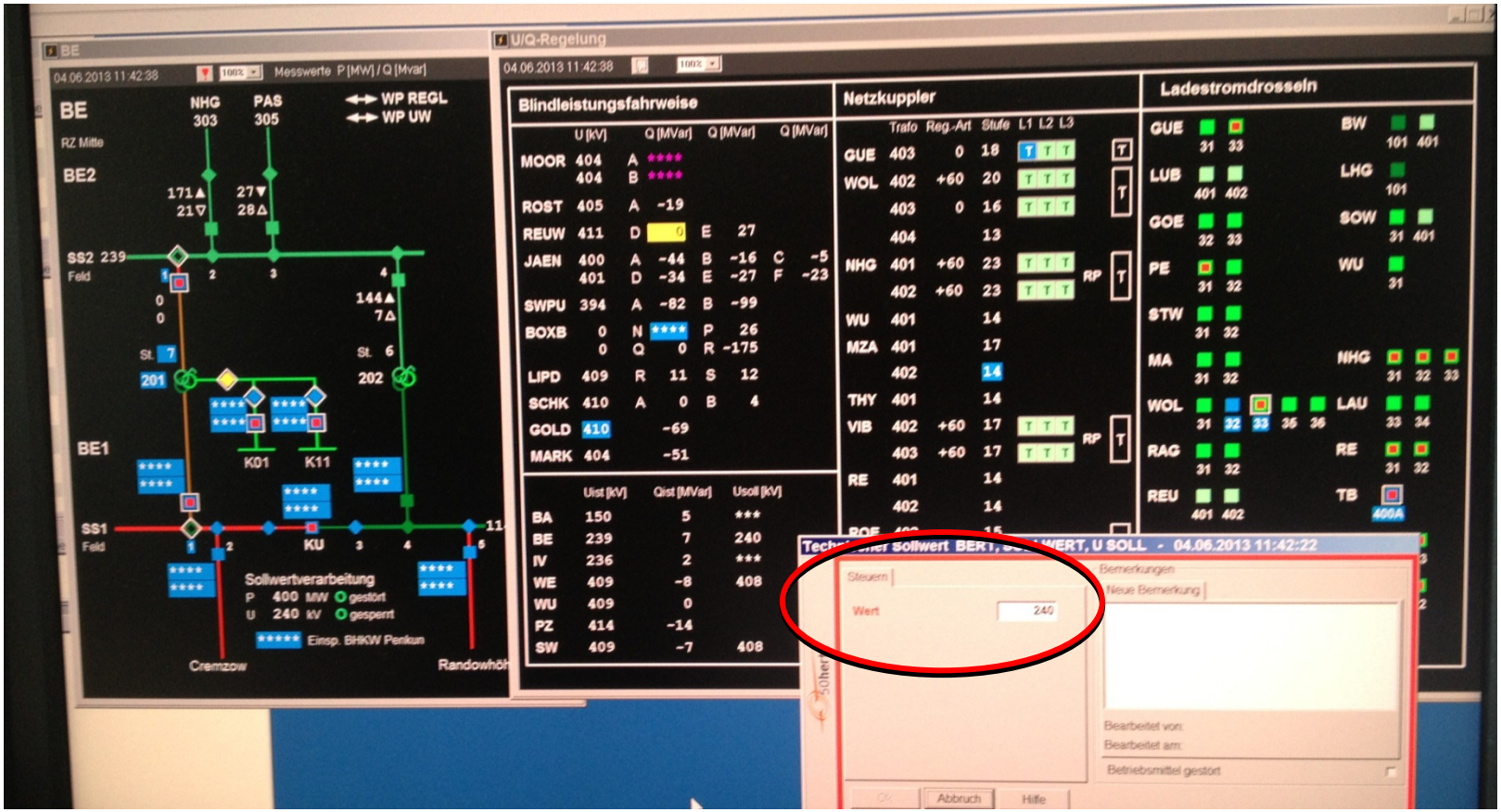
For winter 2012/13, the voltage related related risks cased by phase 1 of nuclear phase-out were assumed to be lower than for the previous winter as following measures were realized:

- Conversion of generator of (phased-out) nuclear power station Bilblis A to rotating phase-shifter
- Commissioning of conventional reactive power compensation devices
- Commissioning of new 380 kV line Hamburg-Schwerin

Nevertheless, esp. from 9th to 10th November 2012 critical voltage situations occured in Tennet TSO control area (area Emden)….

Aspect reactive power / voltage control

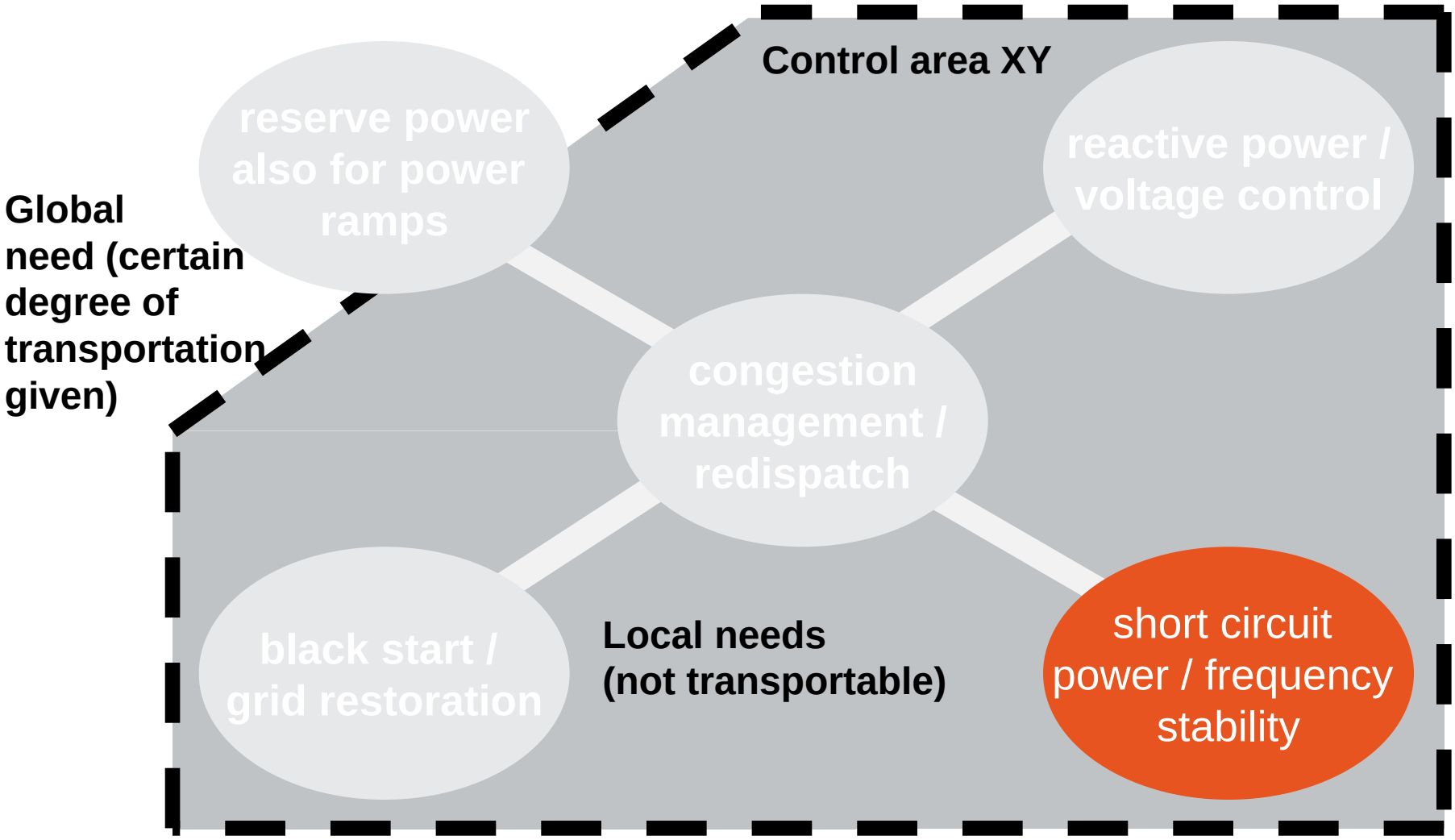
First windfarms already controllable by 50Hertz



Monitor window of TSO 50Hertz control center for direct adaptation of voltage value (indirect adaptation of reactive power) for the connection point of the windfarm Bertikow

Operational challenges of RES integration

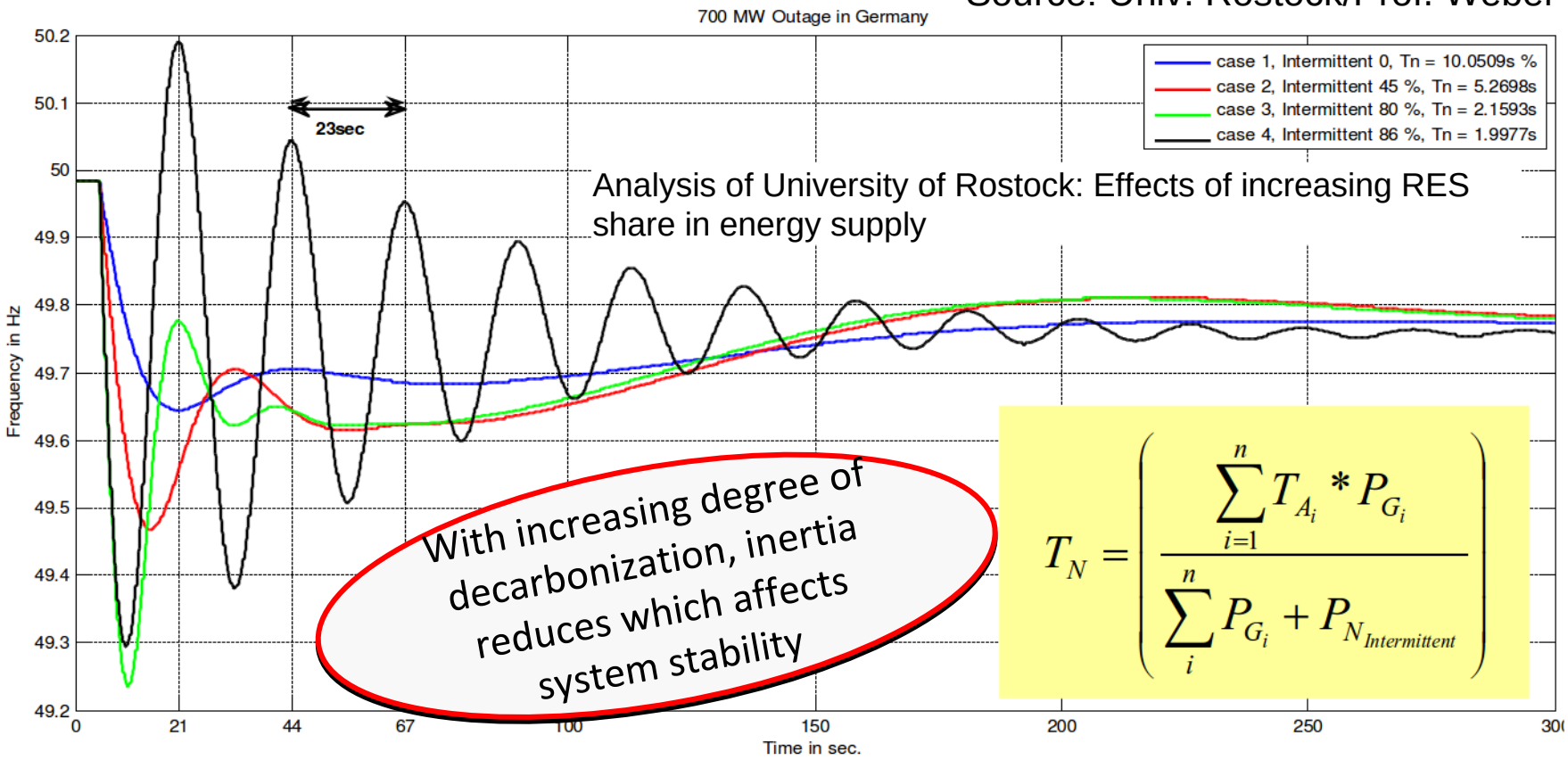
Ancillary services must be ensured along the decarbonization pathway



Aspect Short circuit power / grid stability

Sufficient short circuit power for grid protection schemes as well as inertia for frequency stability required

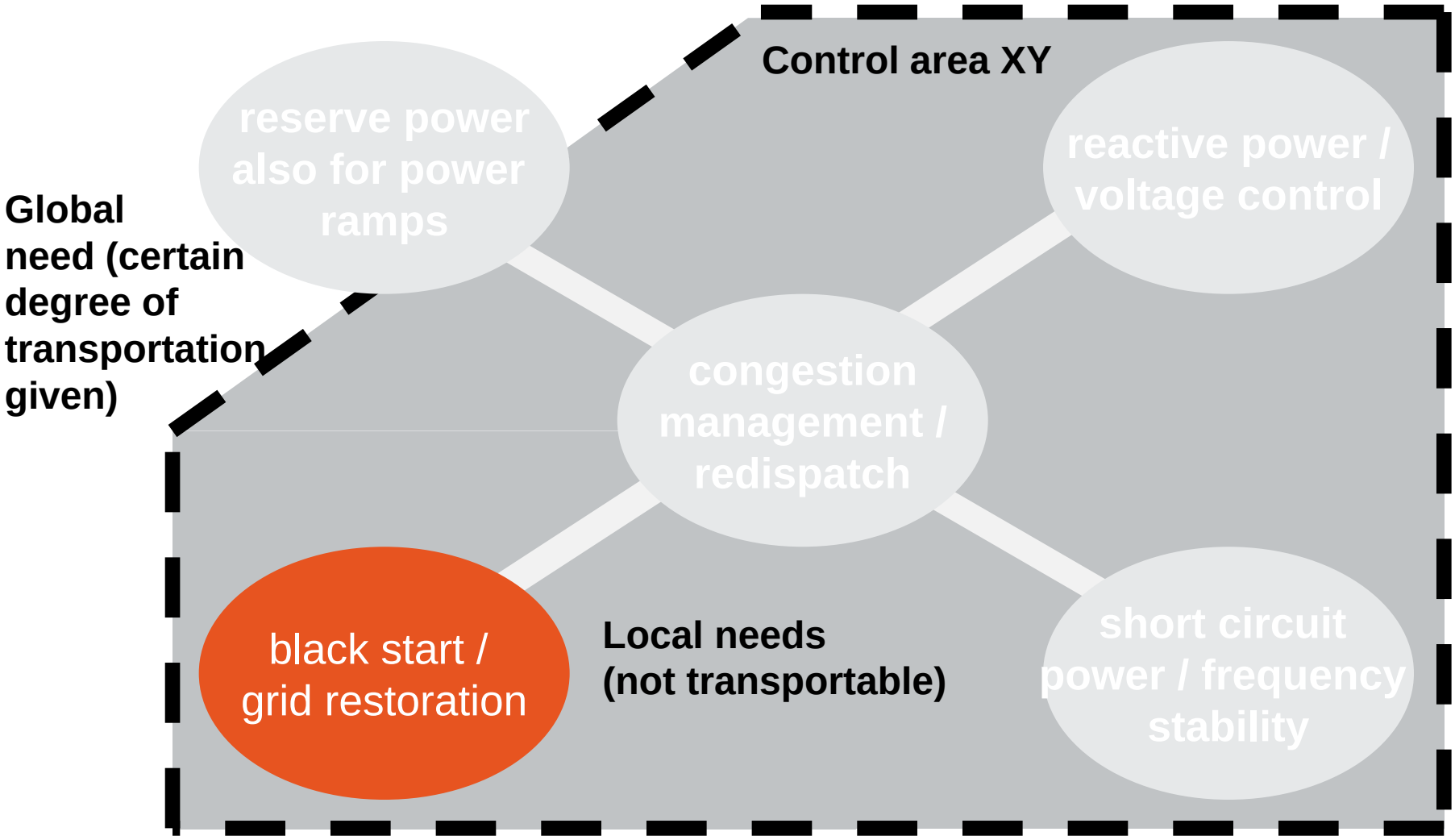
Source: Univ. Rostock/Prof. Weber



Related the grid structures, this analysis is based on simplified (copper plate) model i.e. real stability problems can be expected with lower share of fluctuating RES power.

Operational challenges of RES integration

Ancillary services must be ensured along the decarbonization pathway

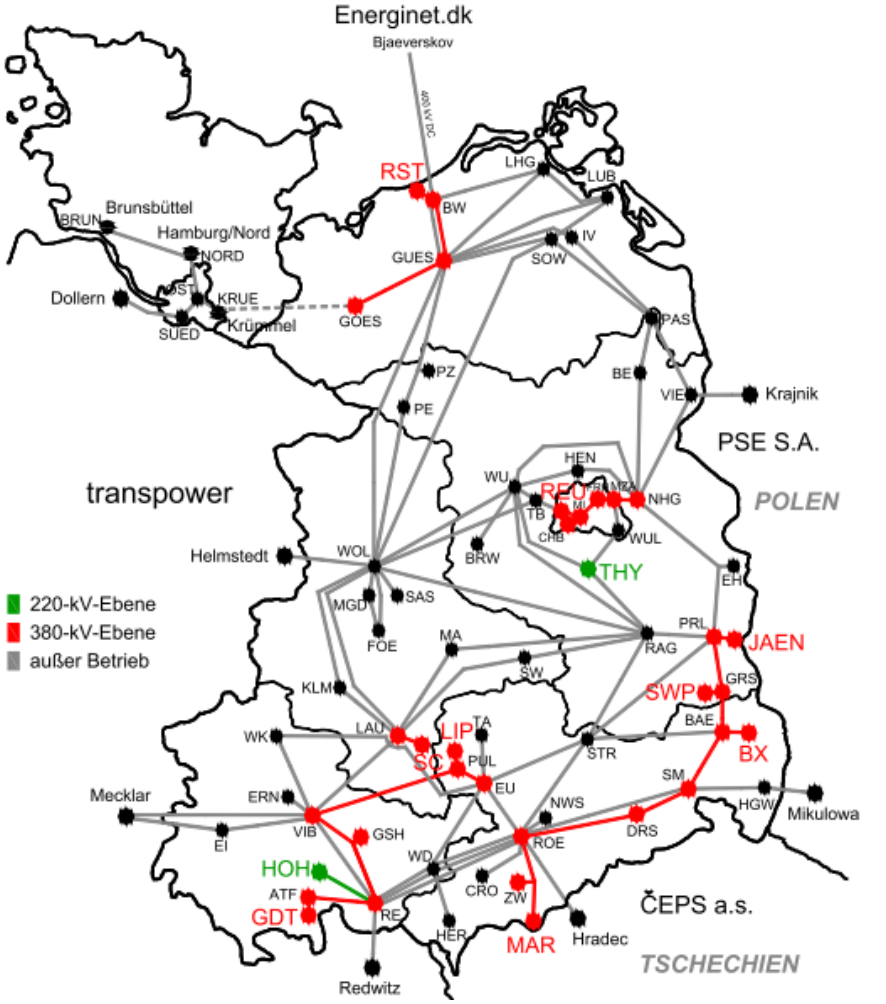


Aspect black start and grid restoration

Extract of 50Hertz grid restoration concept

Netzwiederaufbau ohne Spannungsvorgabe von benachbarten Übertragungsnetzen

1. Teilnetzwiederaufbau ausgehend von thermischen Dampfkraftwerksblöcken im Eigenbedarfsinselbetrieb
   - KW Rostock
   - KW Reuter West
   - KW Jänschwalde
   - KW Schwarze Pumpe
   - KW Boxberg
   - KW Lippendorf
   - KW Schkopau
2. Teilnetzwiederaufbau ausgehend von schwarzstartfähigen Kraftwerken
   - GTKW Thyrow
   - PSW Markersbach
   - PSW Goldisthal
   - PSW Hohenwarte II



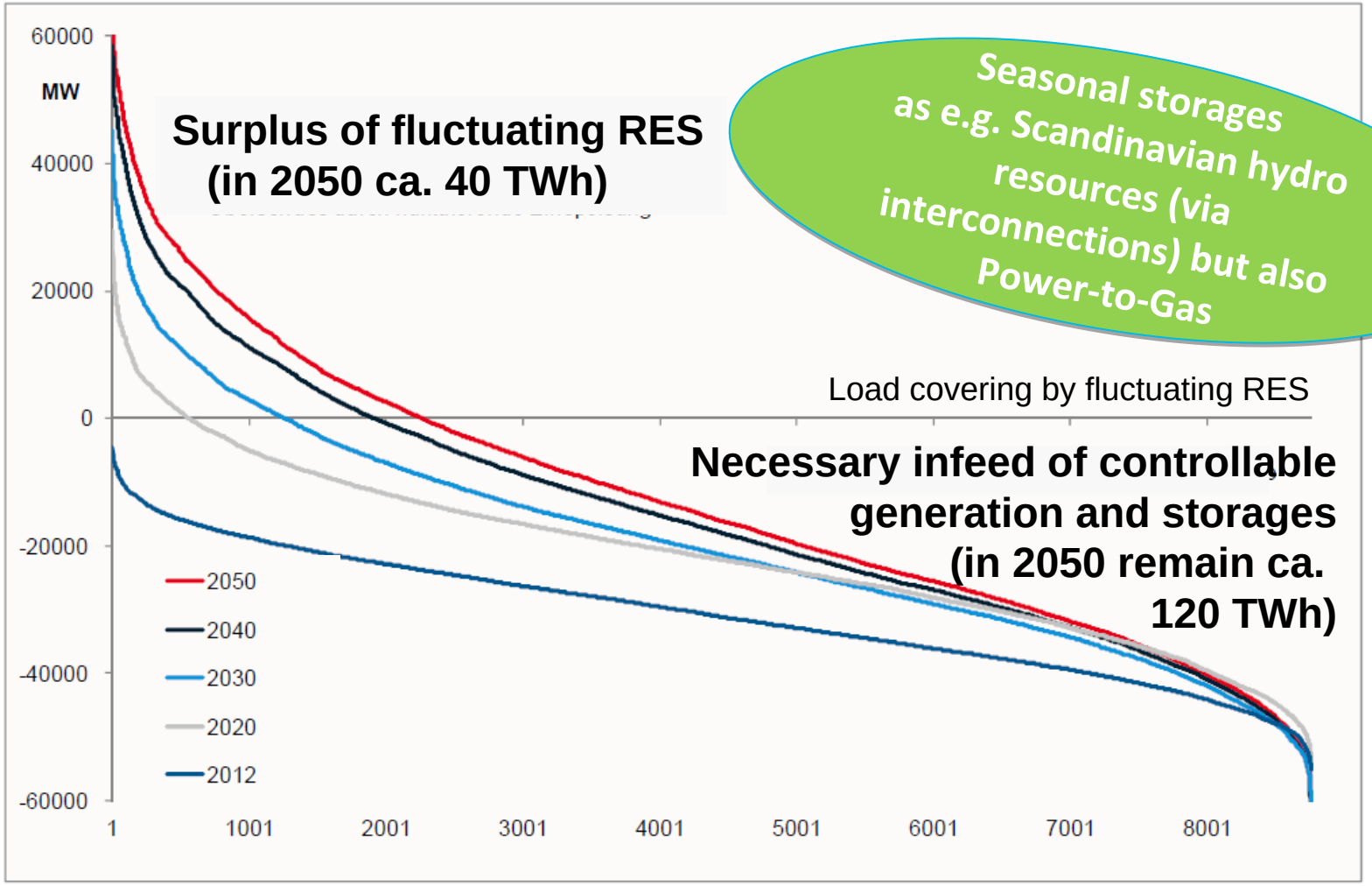
Source: 50Hertz

The German Energy Turnaround the day after tomorrow

Outlook: Yield German fluctuating RES

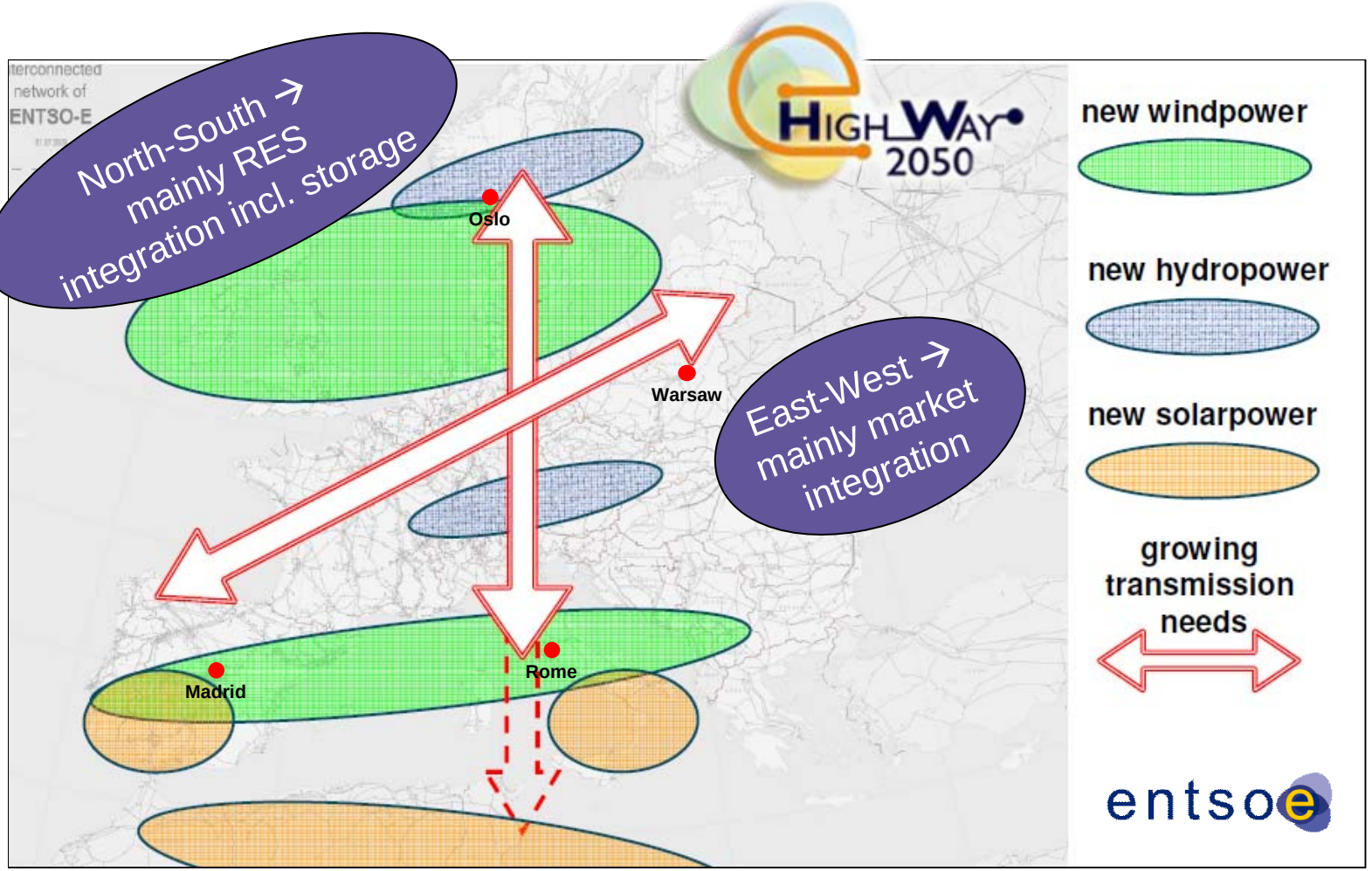
Annual load duration curve

Source: Prognos



Grid extension as overall measure

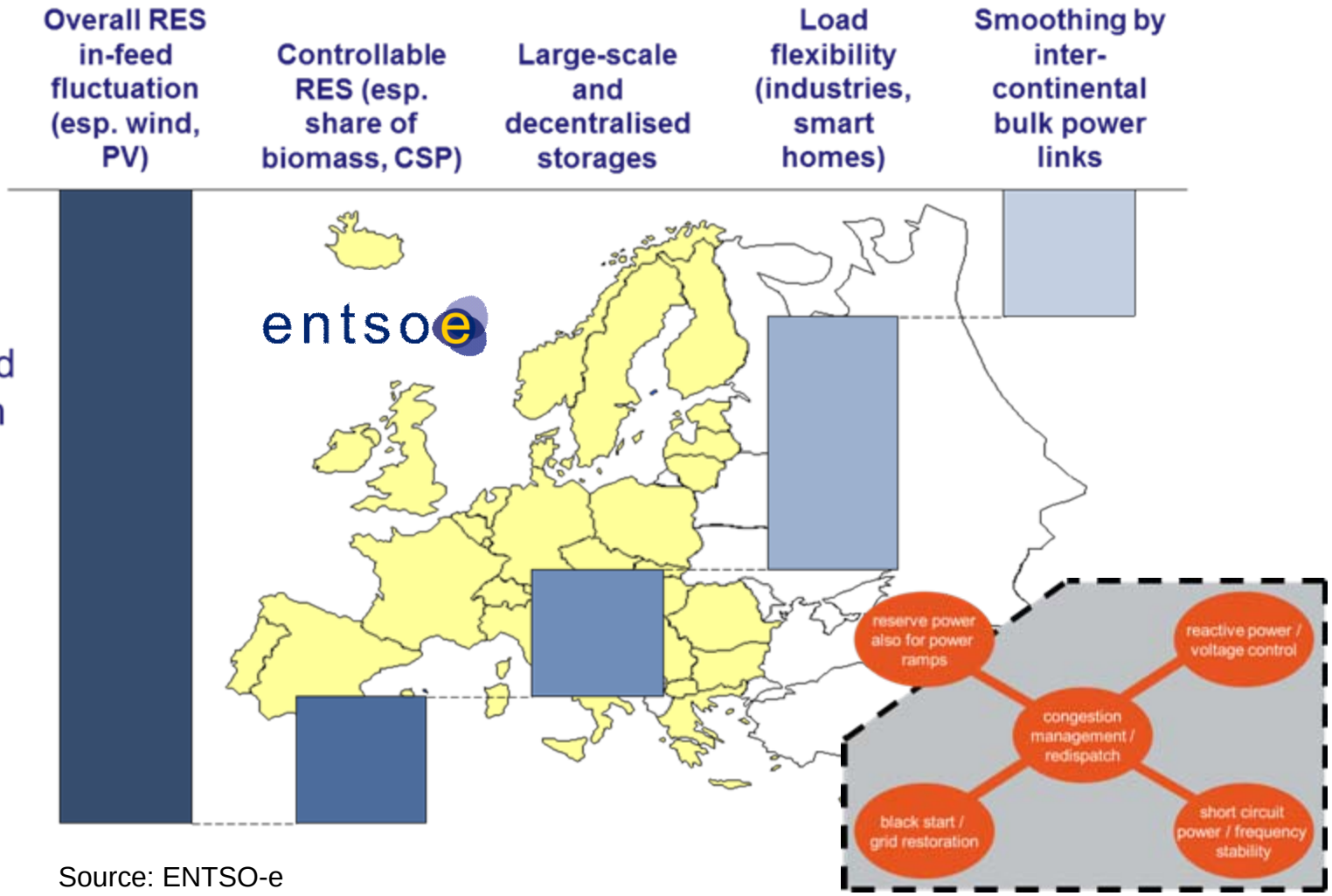
Modular Develop. Plan on pan-Europ. Electricity Highways System 2050



Source: ENTSO-e

There are more dimensions than grid reinforcement/extension …

Example:
Scenario of 100% RES based electricity system for 2050



Source: ENTSO-e

Thank you for attention!

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