On behalf of

Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

of the Federal Republic of Germany

Experiences and Lessons Learnt from Germany

Deep Dive Workshop
Scaling Up Clean Energy: Early Actions to Facilitate Integration of Variable Renewable Energy into Existing Power Systems

Christoph Menke (Prof. Dr.- Ing.)

Joint Graduate School of Energy & Environment, KMUTT, Bangkok, Thailand

Trier University of Applied Sciences, Germany

Senior Energy Policy Advisor GIZ, South East Asia

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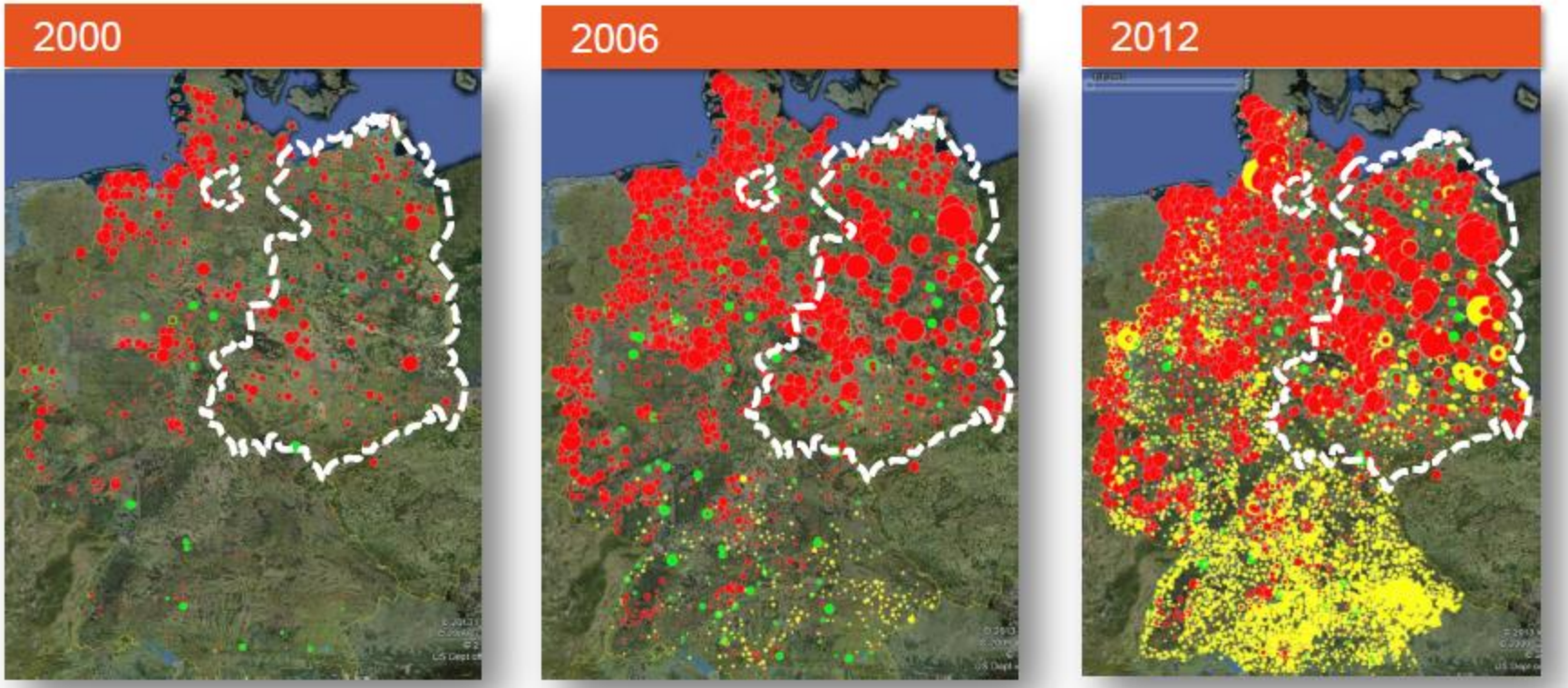
Development of RES in Germany



- wind
- photovoltaics
- biomass

Area proportional to installed capacity

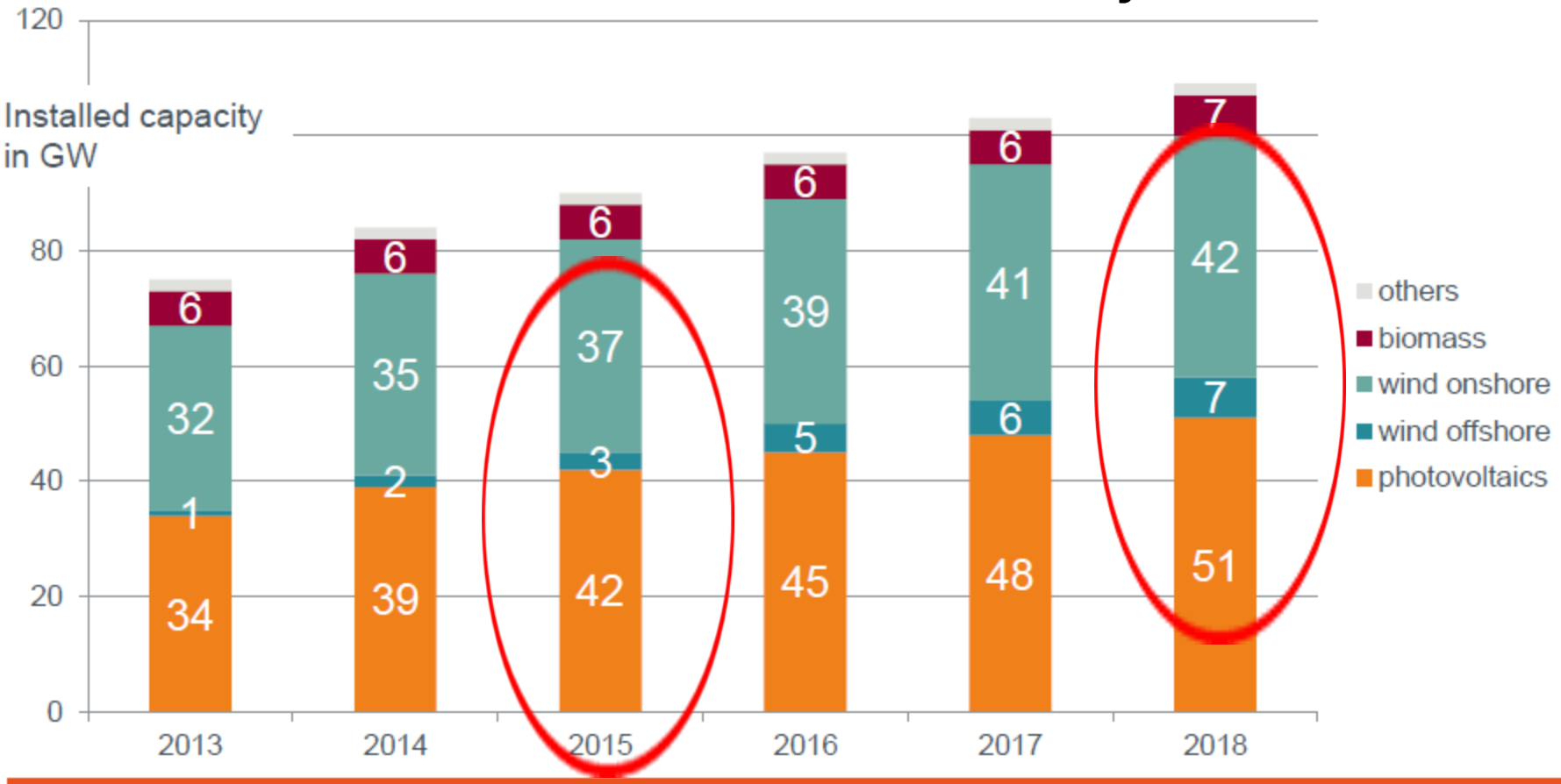
Source: 50HertzT, TenneT, Amprion, TransnetBW, Google Earth

Forecasted RES capacity in Germany

Trend-Scenario to determine the RES-surcharge in 2014

Source: r2b

Total Load in Germany around 80 GW



Wind and photovoltaics remain dominant players in RES development.

Gross Electricity Production in Germany 2015 in TWh: 30% from Renewables!

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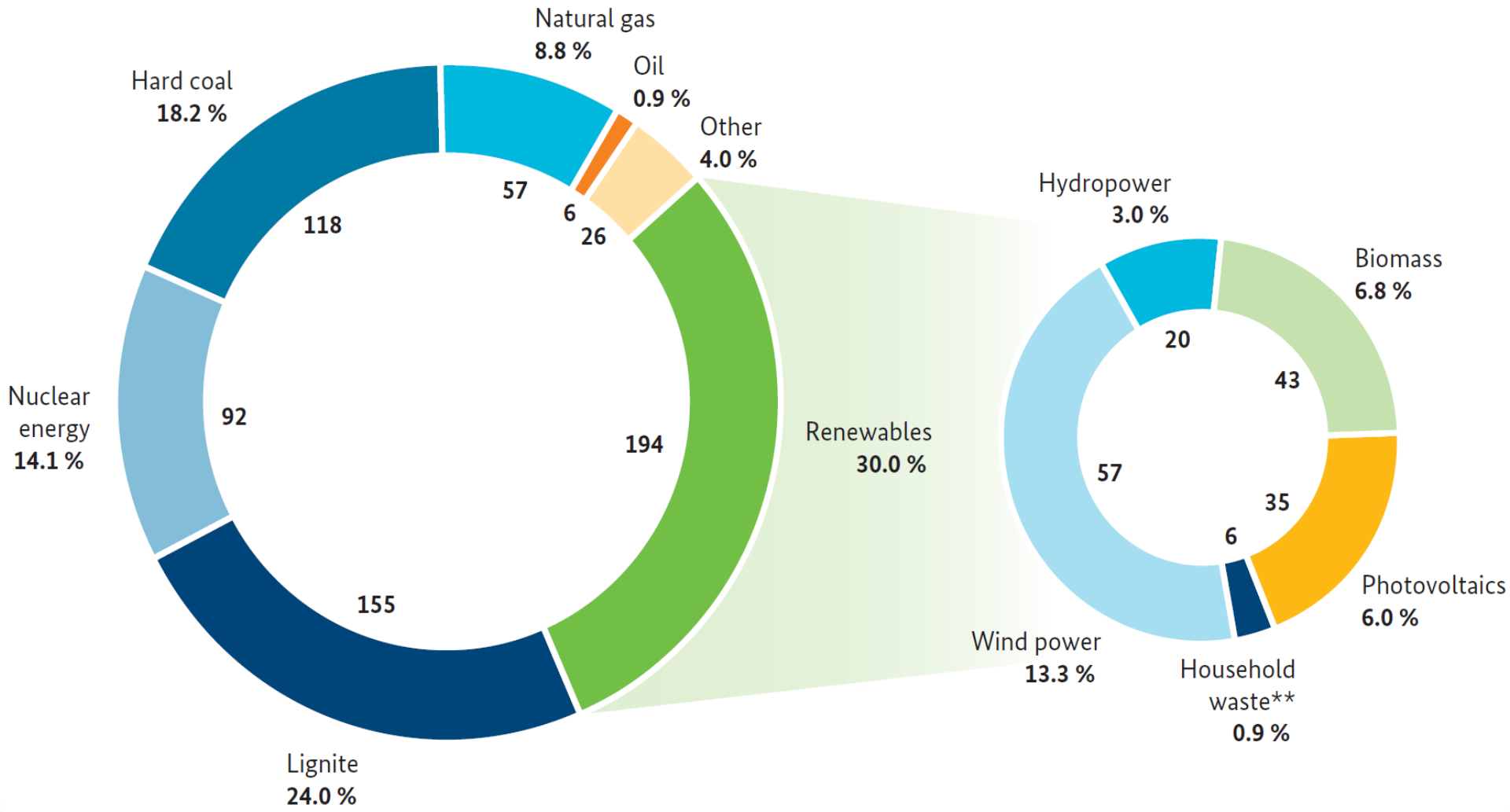

Source: BMWI 2016

Renewables need flexible backup, not baseload

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

Source: Volker Quaschning, HTW Berlin

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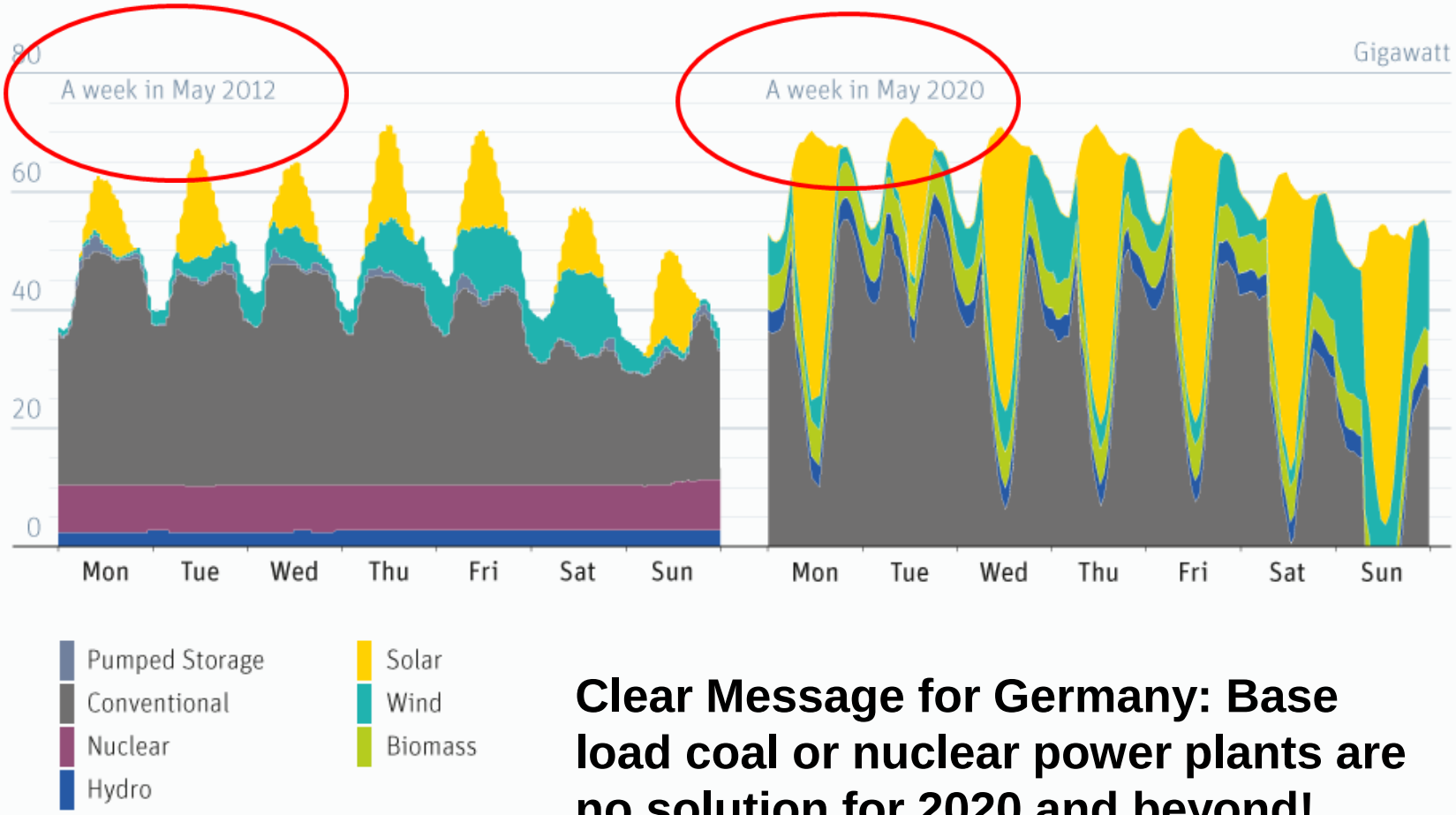


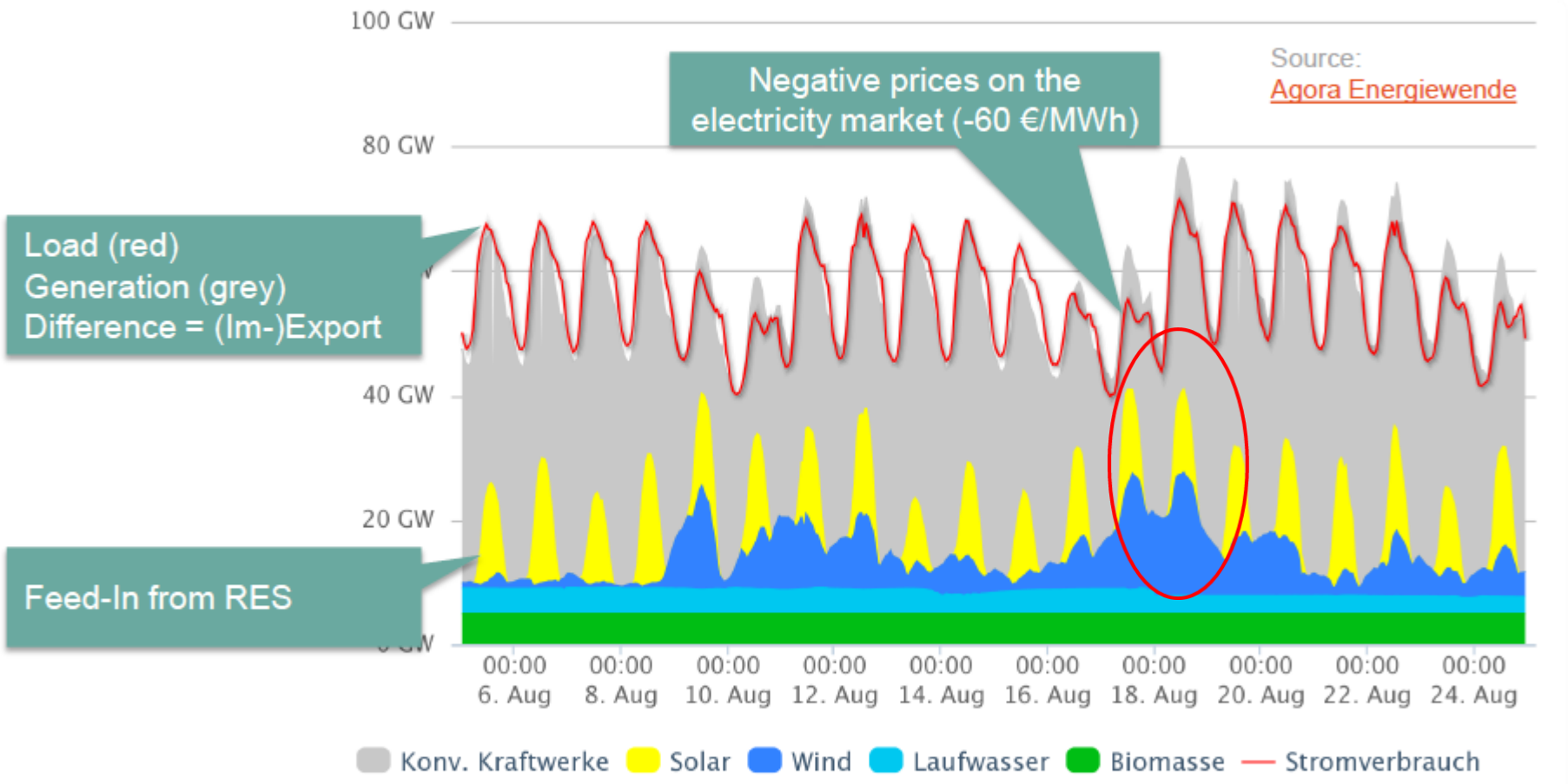
Clear Message for Germany: Base load coal or nuclear power plants are no solution for 2020 and beyond!

German Energy Transition energytransition.de

Source: www.energiewende.de, by Heinrich-Böll-Stiftung, 2013

Ensure positive contribution to system balance

Load situation in Germany in August 2014



- Allow for efficient curtailment in times of oversupply
- Incentivice efficient forecasting and marketing of RES to minimize balancing

Power System Flexibility Options: Sequence in Germany

1. Improved Forecast of Wind and PV output!

2. Supply-side flexibility

- Flexible operation of conventional power plants !!!
- Management of vRE infeed

3a. Grid expansion, interconnection

- Grid expansion & upgrade & make grid “intelligent”
- Regional interconnection

3b. Demand-side flexibility

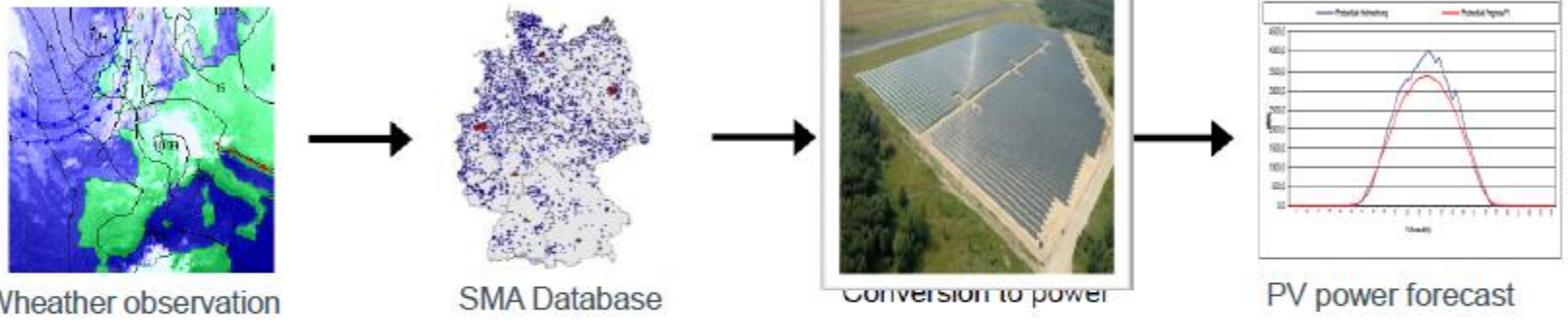
- Demand-side-management

4. Electricity Storage

- Hydro pump storage, batteries, later Power-to-gas or heat, E-mobility)

Solution: Improved solar power forecasting!

Day Ahead Forecast Solar power



- External input of forecast values:
  - solar power forecast 2 suppliers (EnergyMeteoSystems, Meteocontrol)
  - Areas: Germany, 50Hertz, DSO-regions
  - Horizon day-ahead <= 96 hours; horizon short term <= 8 hours
  - 3 daily updates; ¼ hour short term updates
- Combined Forecast with weighted experience by 50Hertz
  - Linear combination of commercially available forecasts

Accuracy of solar forecast has reached 5-7% Root Mean Square Error (RMSE)

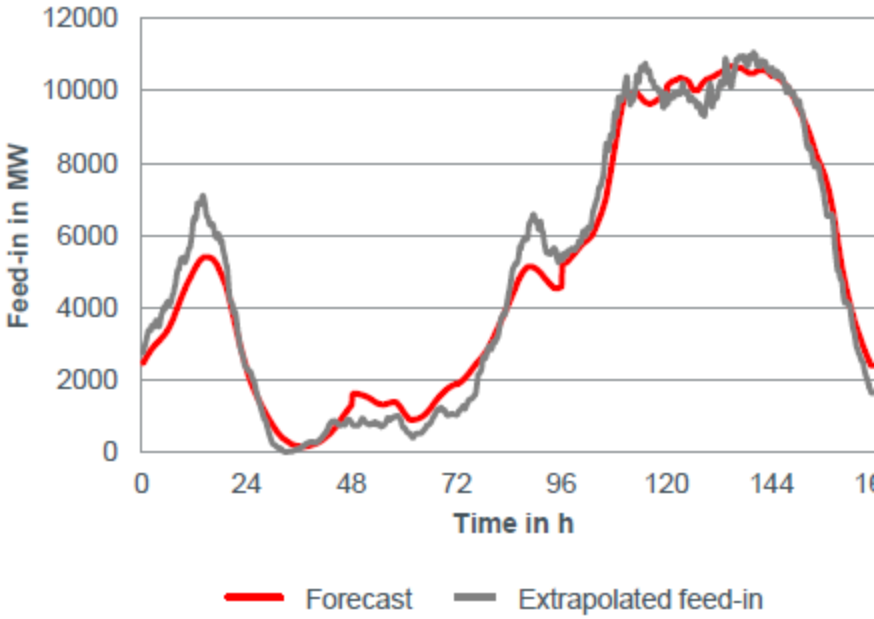
Day ahead forecast

Solution: Improved wind power forecasting!

Fluctuating feed-in of renewable energies – wind energy

Data feed-in of wind energy at 50Hertz (2013)	
Maximum feed-in	11,064 MW
Minimal feed-in	0 MW
Biggest increase within ¼ hour	+1,431 MW
Biggest decrease within ¼ hour	-901 MW
Biggest difference between Min and Max within one day	9,675 MW

Feed-in wind energy (01/12/2013 – 07/12/201

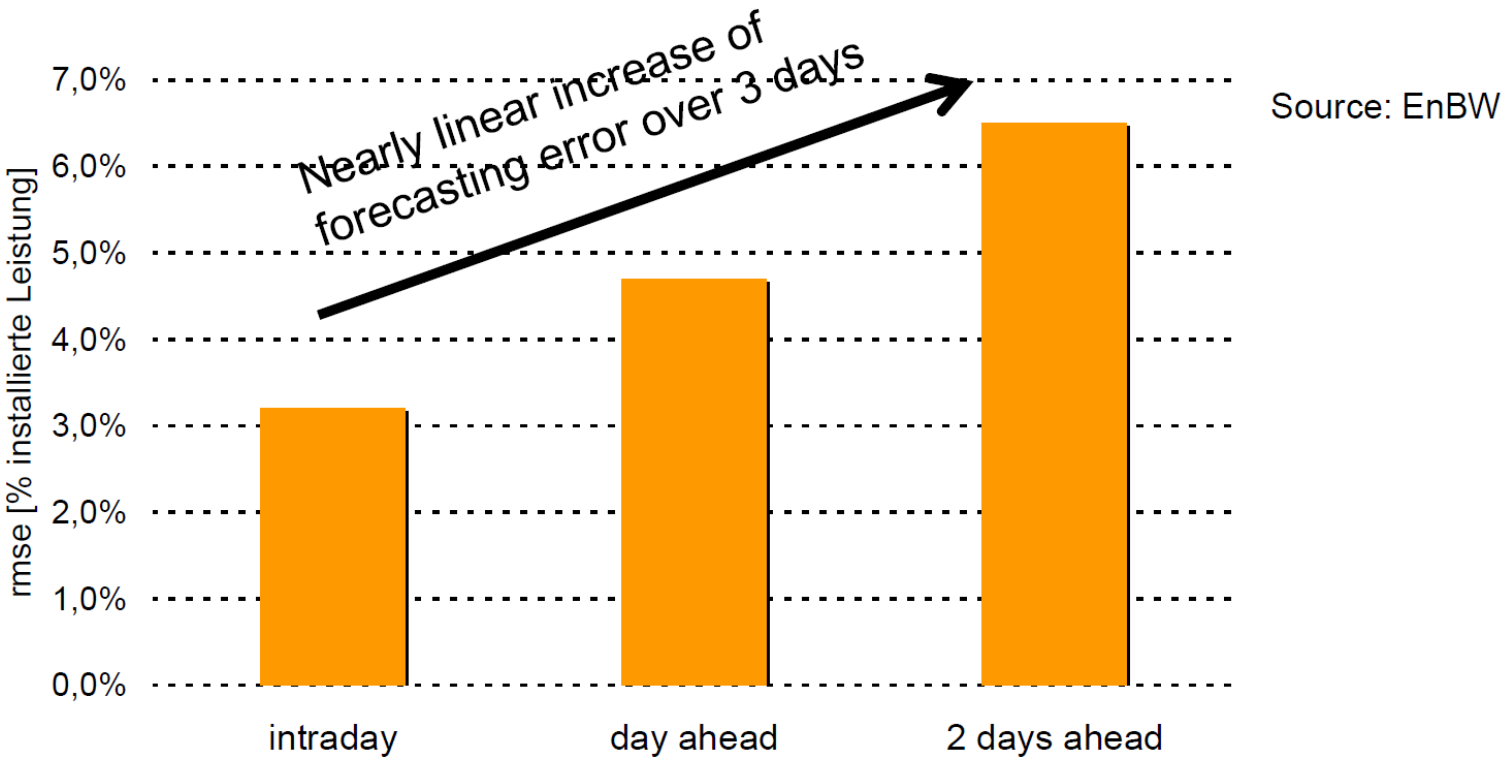


High requirements on forecasts, controlling ability and system operation.

Solution: Improved wind power forecasting!

Evaluation of forecasts

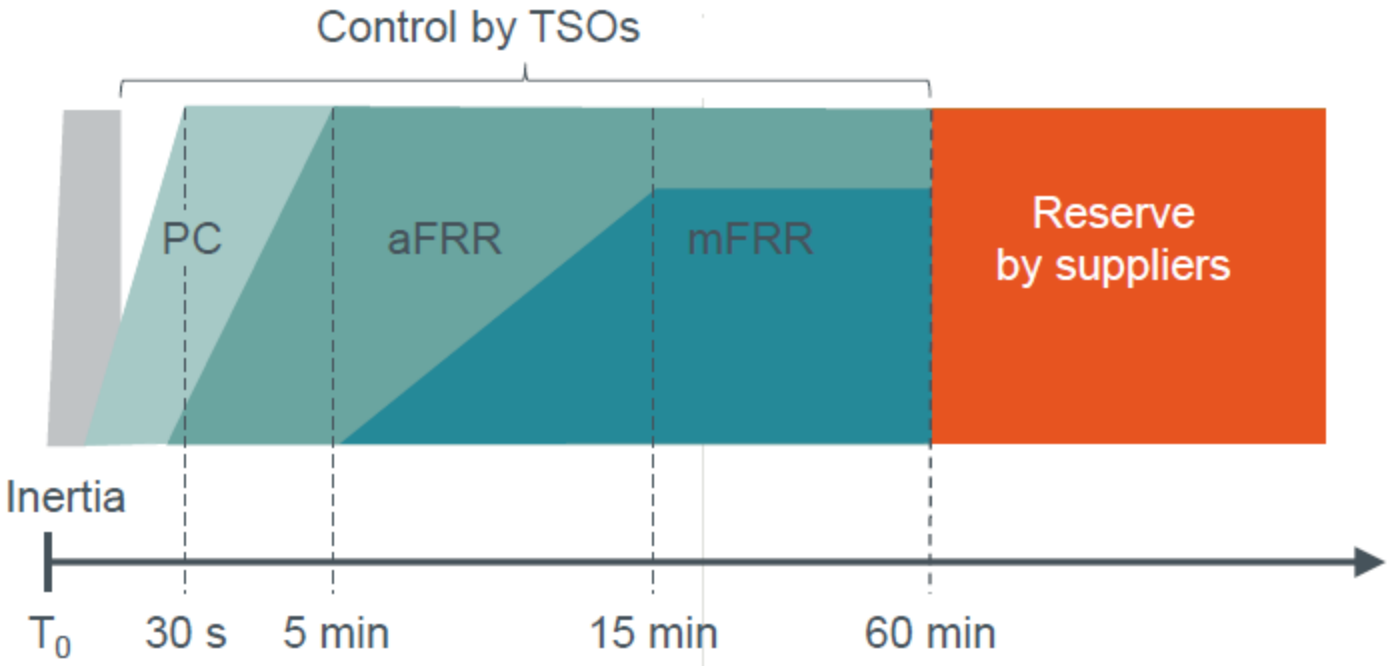
Previento prediction of total aggregate of German wind farms
(January 2005 – July 2006)



Source: Dr. M. Lange, energy&meteo systems, 2014

energy&meteo systems

Three control power types exist to keep frequency of 50Hz

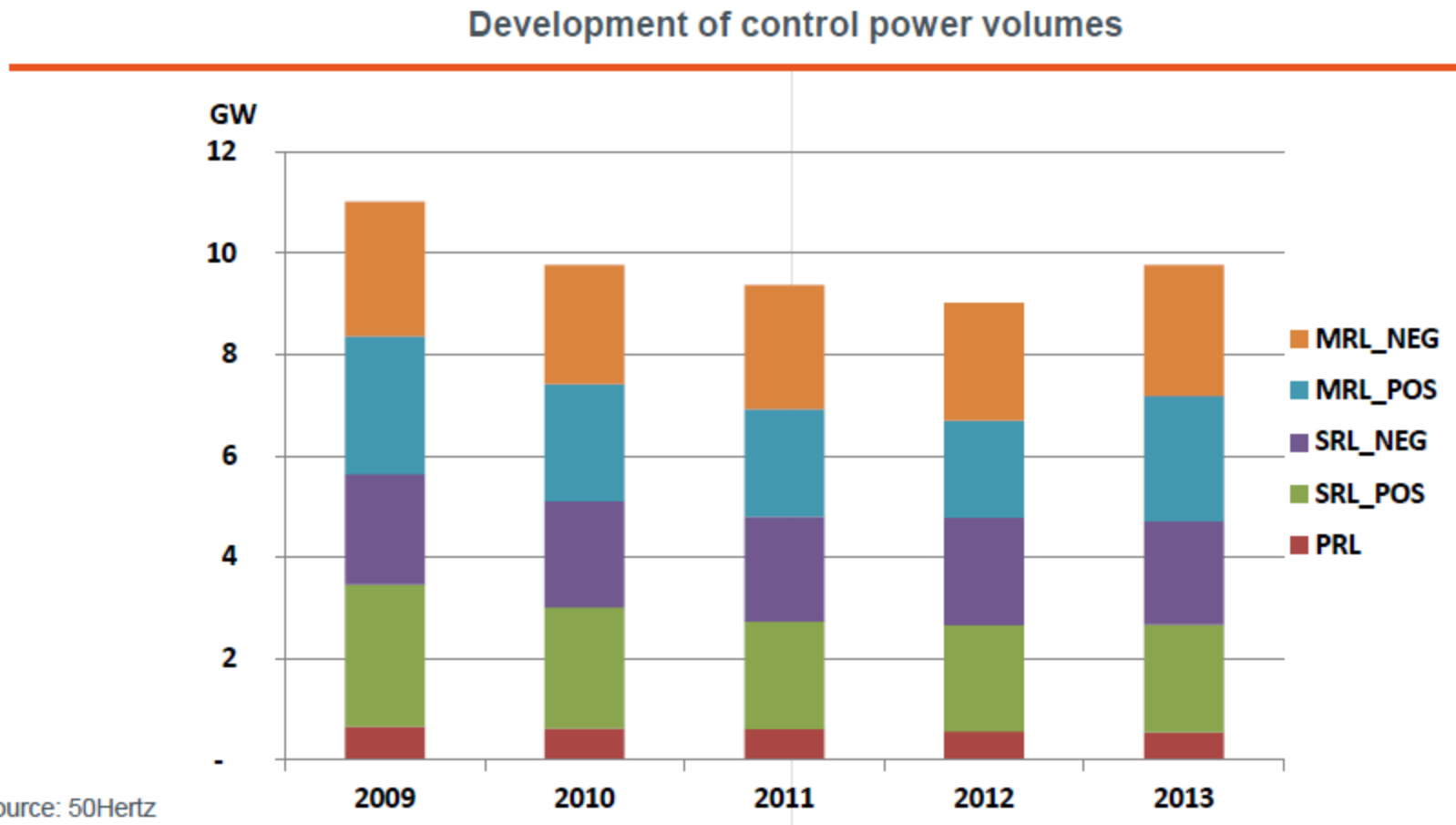


PC: Primary control
aFRR : Automatic Frequency Restoration Reserve = secondary control
mFRR: Manual Frequency Restoration Reserve = tertiary control (minute reserve)

Source: 50Hertz

So far there has been no need for significant changes in control power products, as control power prices have been steadily decreasing in recent years. This might change as the Energiewende is gaining pace.

Despite a slight downward trend in the recent years, control power volumes are expected to increase in the future

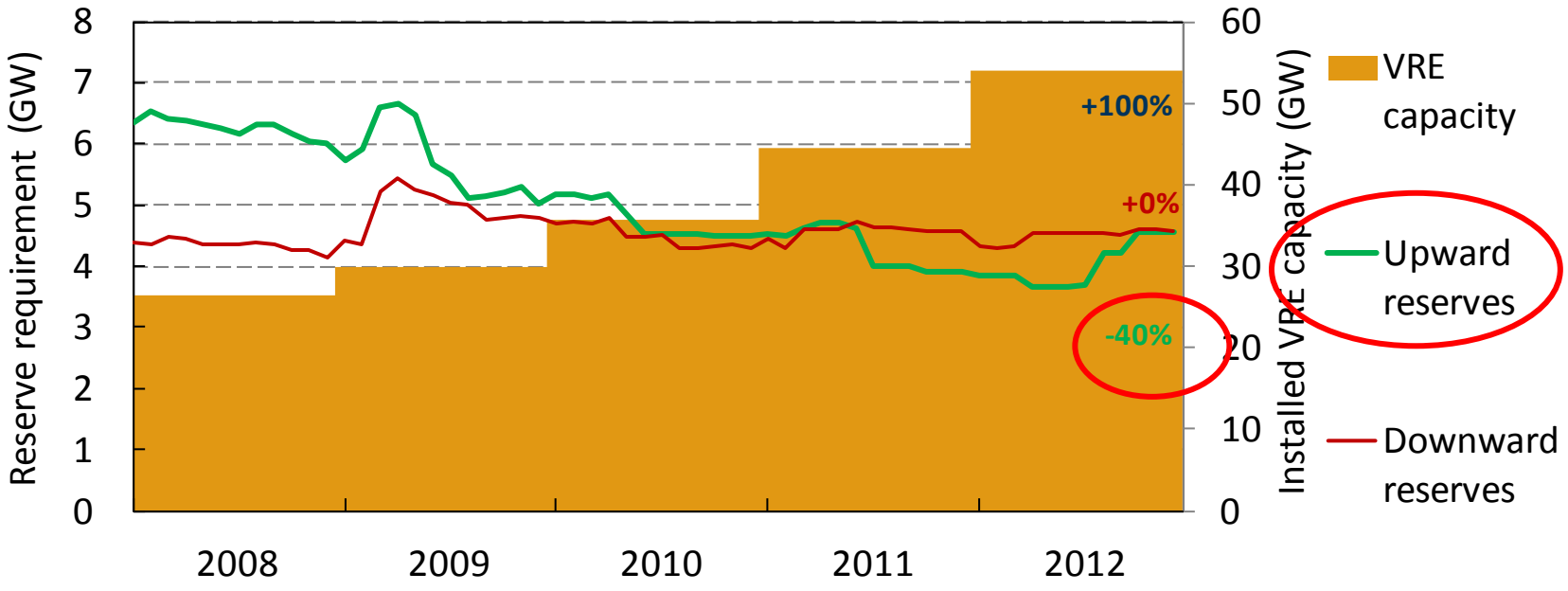


Source: 50Hertz

Grid Control Cooperation (GCC) made it possible to reduce control power volumes in the recent years. Despite GCC we expect an increase of control power in the future as RES share will continue to rise.

Solution: Co-operation with neighbours to reduce reserve power

Required frequency restoration reserves in Germany



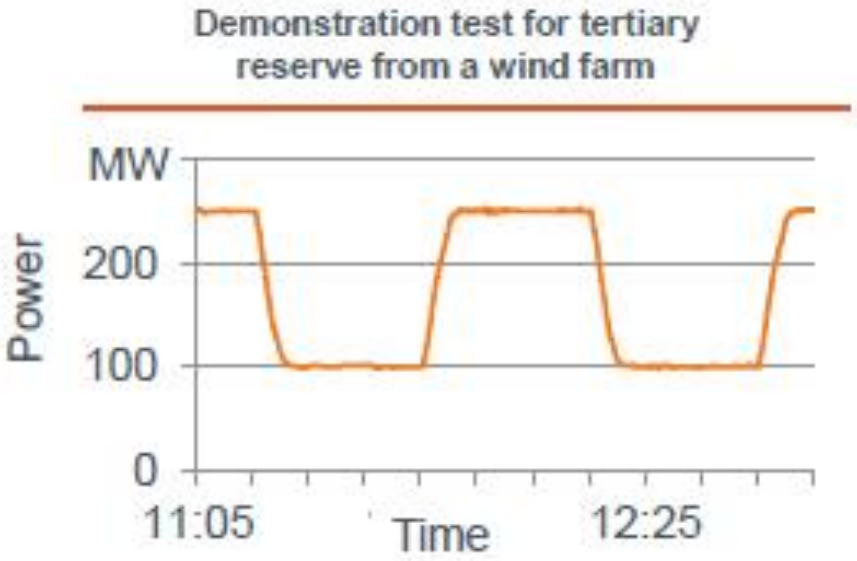
- Germany has four balancing areas (historic reasons)
- Reserve sharing mechanism across four areas
- Reduced requirements despite rapid increase of vRE

Source: OECD/IEA 2014

Solution: Wind power as system balancing power!

Ensure positive contribution to system balance

Balancing with wind power



- Wind farms have the technical capability to provide negative balancing energy
- Current challenges are in the calculation method for the reference production „What would have been the production without the request from the TSO?“

Solution: DSR and DSM as secondary control power!

New providers of control power are very welcome: Electric boilers and a steel mill prequalified in the 50Hertz control area

Electric boilers Stadtwerke Schwerin

- Three electric boilers prequalified for **secondary control** (aFRR) provision
- Up to **10 MW** aFRR
- Start of aFRR marketing in December **2013**

Steel mill Hamburg

- Electric furnace 3 of ArcelorMittal Hamburg GmbH prequalified for **tertiary control** provision (mFRR)
- Up to **70 MW** mFRR
- Start of mFRR marketing in **2010**

Sources: Stadtwerke Schwerin, ArcelorMittal Hamburg GmbH

Solution: Batteries for primary control!

New providers of control power are very welcome: Batteries prequalified in the 50Hertz control area

Source: YOUNICOS

Battery Berlin-Adlershof

- **Power:** 1 MW
- **Capacity:** 6.2 MWh
- **Technology:** Lithium-Ion Sodium-Sulphur
- **Commissioning:** 01/2012
- **Usage:** primary control

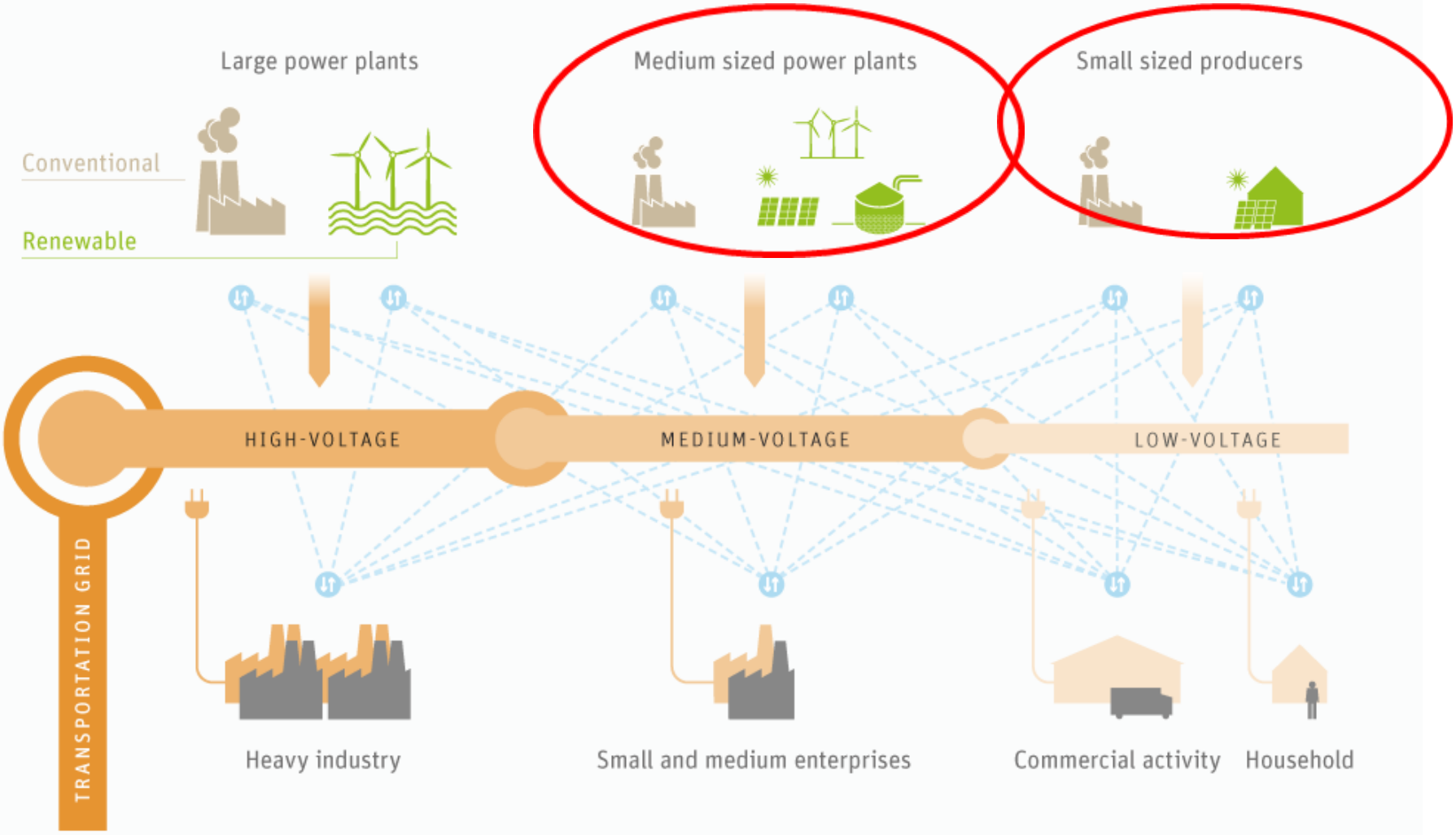
Battery Schwerin

- **Power:** 5 MW
- **Capacity:** 5 MWh
- **Technology:** Lithium-Ion
- **Commissioning:** 09/2014
- **Usage:** primary control

The future power grid will be bidirectional and intelligent

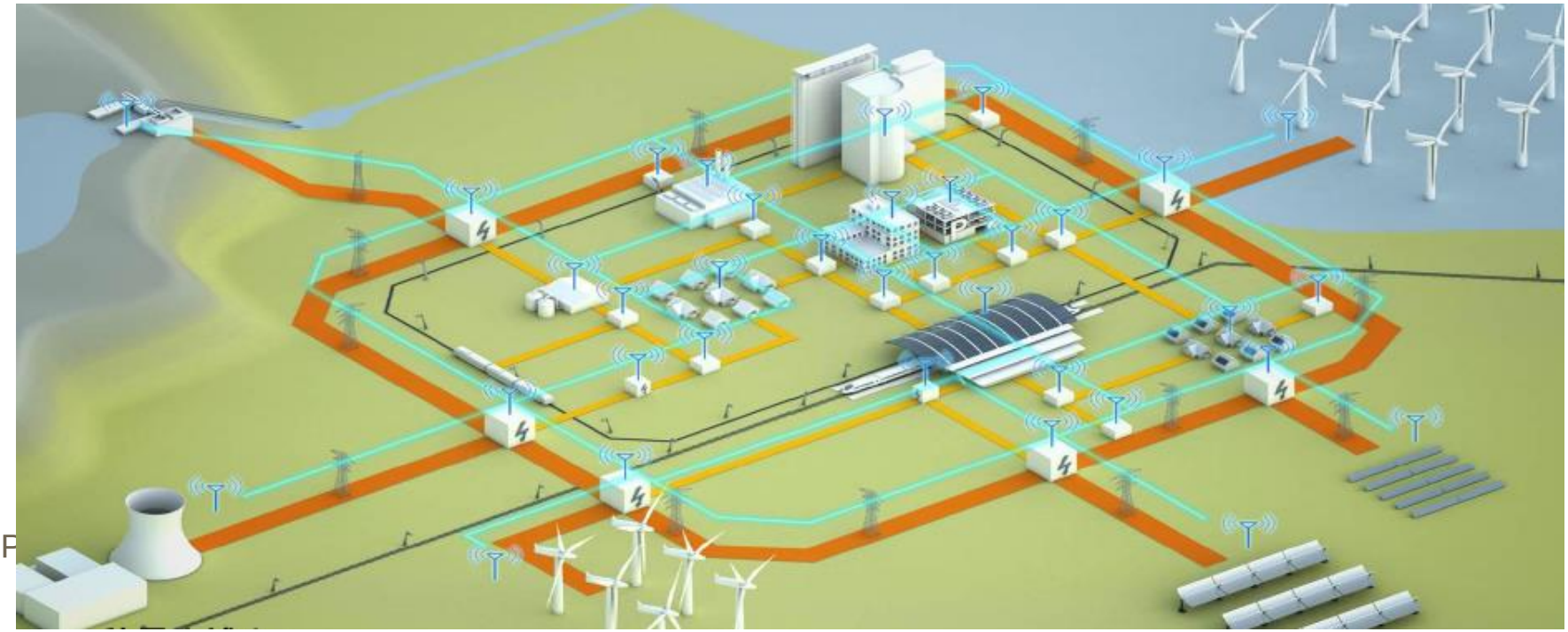
Electricity and information flow in power grid

Source: IFEU



German Energy Transition energytransition.de CC BY SA

Smart Grids have to come in next decade
Each country has to make its pilot tests
To see, what kind of smart grid elements need to be built in and when
There is no blueprint to be copied from other countries.



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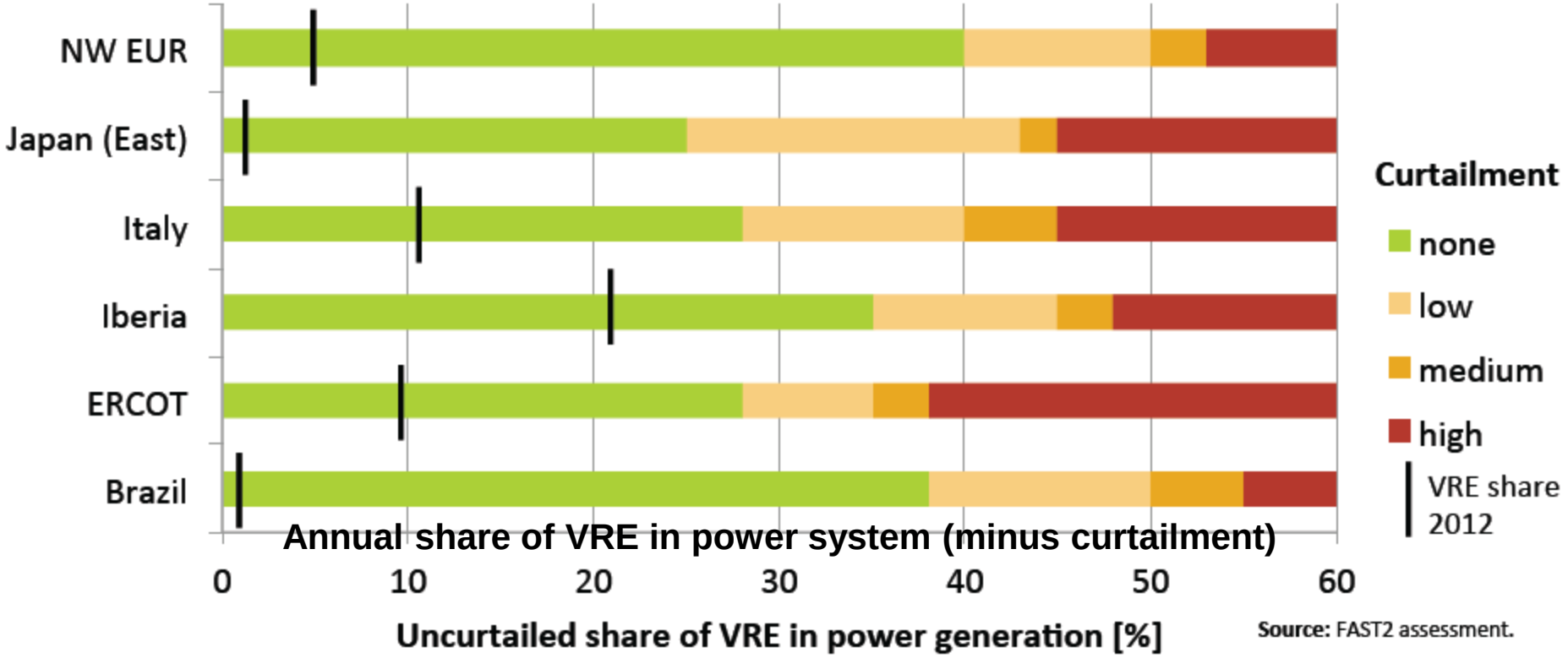
Much higher shares technically feasible



Source: FAST2 assessment.

- **IEA assessment: All power systems can take 25% in annual generation already today.**
- **There is no technical limit on how much variable generation a power system can absorb**
  - But system transformation increased flexibility required for higher shares

Summary of Experiences and Lessons Learnt from Germany

1. **High share of vRE** are no problem to stability and grid in Germany, as the growths **took place over 10 years** so **TSO/DSO could adjust and learn**!

2. **Base load power** is outdated in Germany soon and has **no economic future**, **flexible power plants are required**.

3. The **whole electricity market** must adopt to the higher vRE share, e.g. reserve power market, grid services, forecasting, etc.

4. There are many **tools and options to balance the grid** now tested in Germany since 10 years and are **proven and cost effective.**

5. **Storages** becomes important when vRE reaches more than **around 40%** in a grid.

Recommendations based on German experience:
Early Actions for Asian countries for vRE integration:

1. **Develop** and **improve forecasting for wind** and for **solar (PV) now**!

2. **Start now with learning**, because **TSO/DSO and regulation needs at least 5 years** to adopt to new situation.

3. **Test smart grid** applications in grid, like **storage** at low and medium voltage level; like DSM and load management, etc.

4. **Transform energy market**, so that vRE can be integrated **and** can **offer system services**, like ramping, active power control, inertia, etc.

5. In **near** future technically more than **25% - 30% of energy can come from vRE** if **grid** is **managed right** and **energy market design** is **adequate**. In long term much more is possible.

Thank you for your kind attention!

Prof. Dr.–Ing. Christoph Menke

Trier University of Applied Sciences, Germany

Joint Graduate School of Energy and Environment, Bangkok, Thailand

Senior Consultant for Renewable Energy Policy, GIZ GmbH, Germany

menke@fh-trier.de