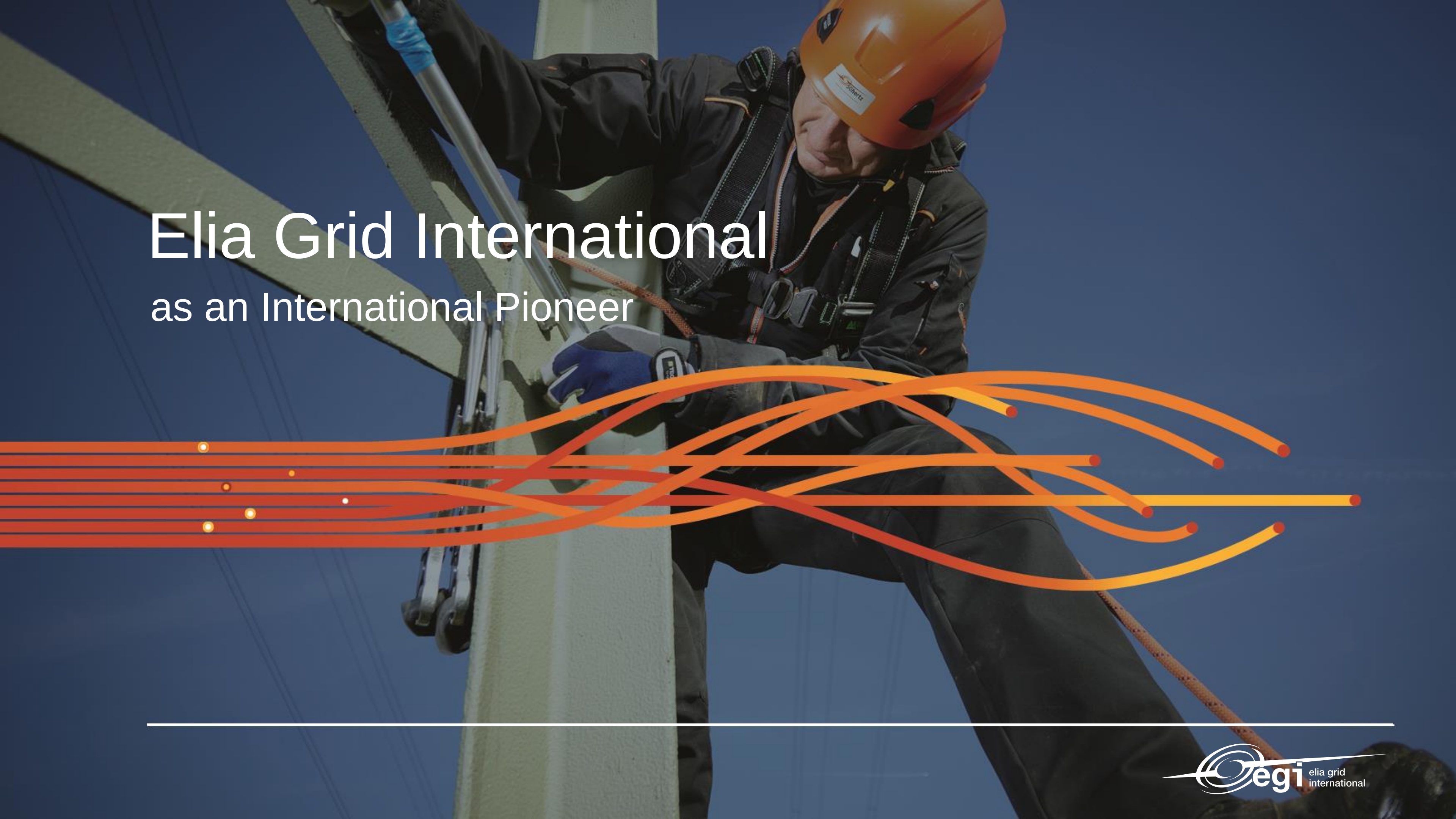
Elia Grid International

as an International Pioneer



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

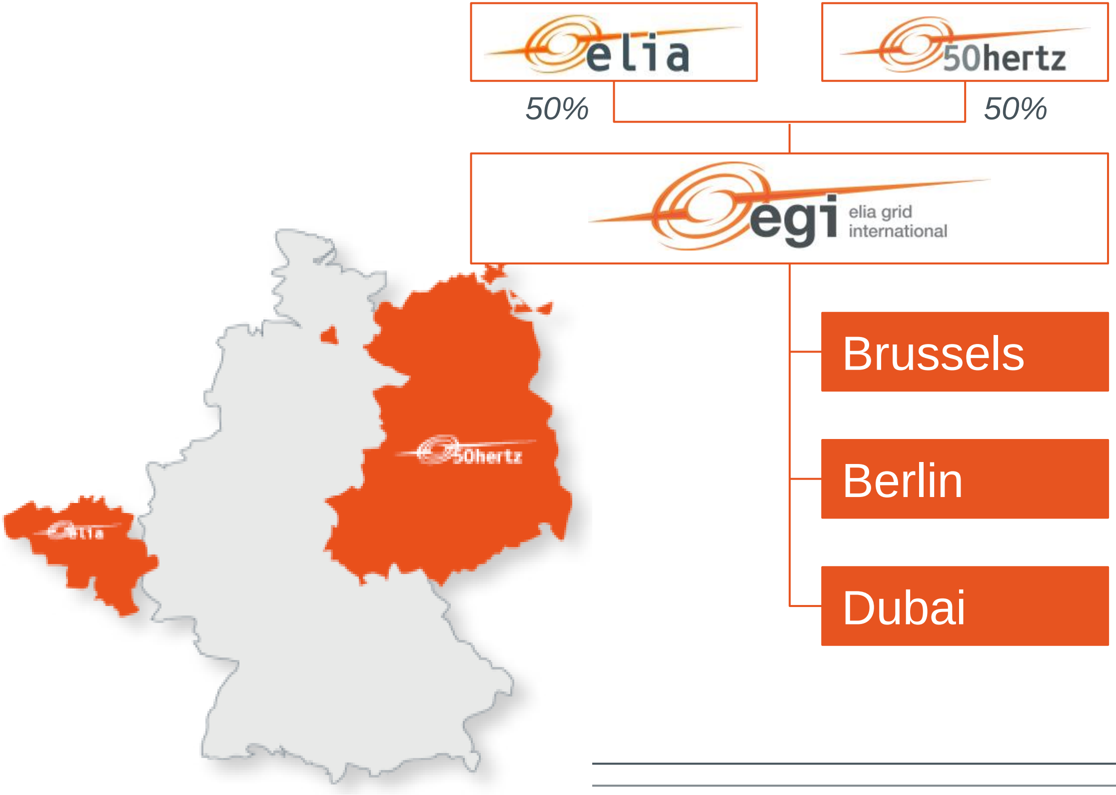
2007～2008年　南米でボランティア

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*

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Elia Grid International: providing assistance in adapting to change

Cross-border and TSO/DSO coordination

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50% penetration of variable renewables

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International and industry experts

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

- **Asset Management**
- **Strategical & Organisational advisory**
- **System operations & grid development**
- **Market development and regulatory framework**

Example services

- how to optimise with uncertainty from cross-border operation, renewables and unbundled market
- how to reorganise with unbundling from vertically integrated utility to TSO/ISO
- how to secure and optimise with uncertainty from cross-border operation, renewables and unbundled market
- pros and cons of (past and future) European / German development compared to other markets

German Balancing Mechanisms

Overview of presentation

1. Need for balancing due to changing power mix
2. Mechanisms for balancing in Germany
    - Short-term markets
    - Imbalance settlements
    - Balancing reserves
3. Performance of the balancing mechanisms
4. GCC and IGCC

Need for balancing due to changing power mix: German policy goals of Energiewende

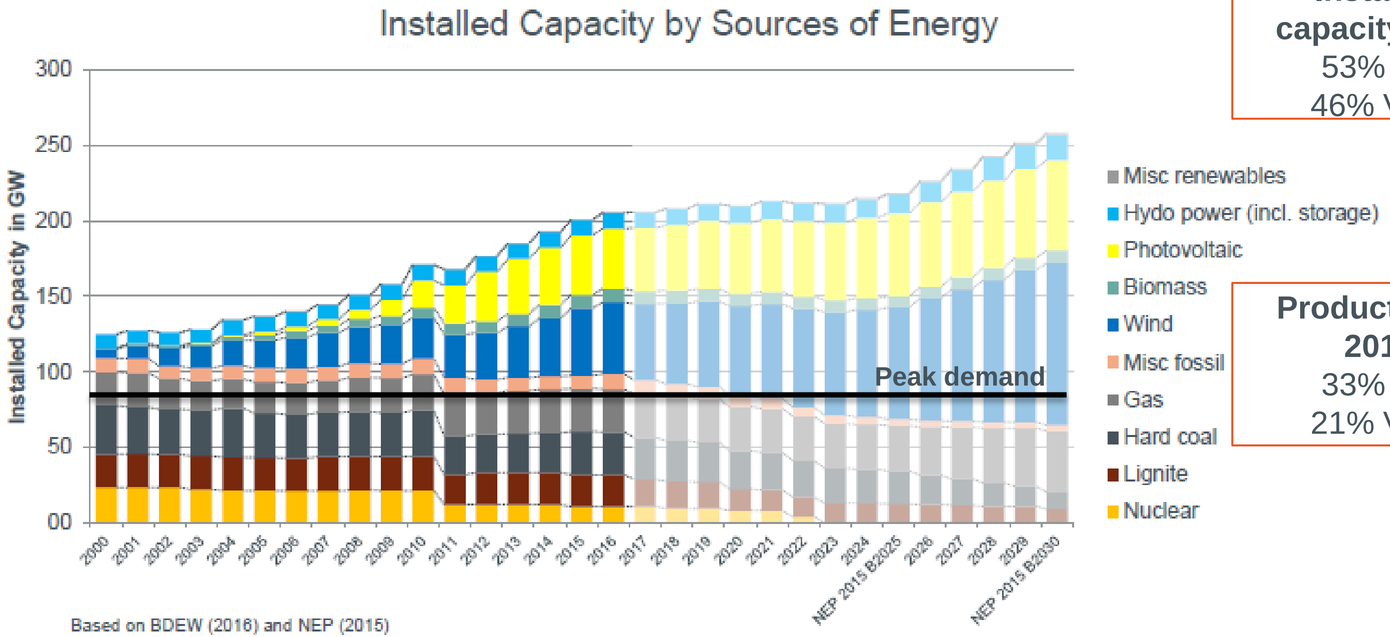
What are the core elements of German „Energiewende“?

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 renewable energy to the big industrial centres in Southern Germany

Source: 50Hertz

Need for balancing due to changing power mix



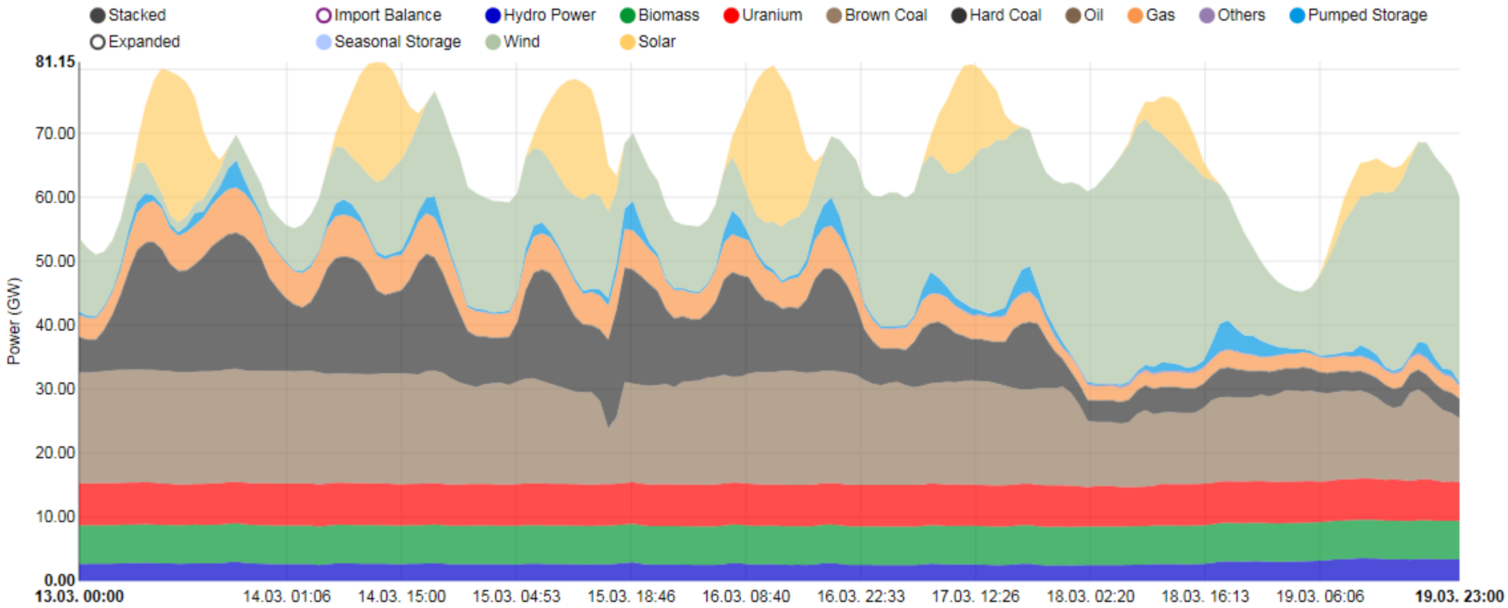
Based on BDEW (2016) and NEP (2015)

Installed capacity 2016
53% RE
46% VRE

Production in 2016
33% RE
21% VRE

- 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

Changing power mix: example production in Germany in week 11 2017



In March, Germany posted yet another wind power record, with production peaking at 38.5 GW on March 18, just topping the of 38 GW on February 22.

https://www.energy-charts.de

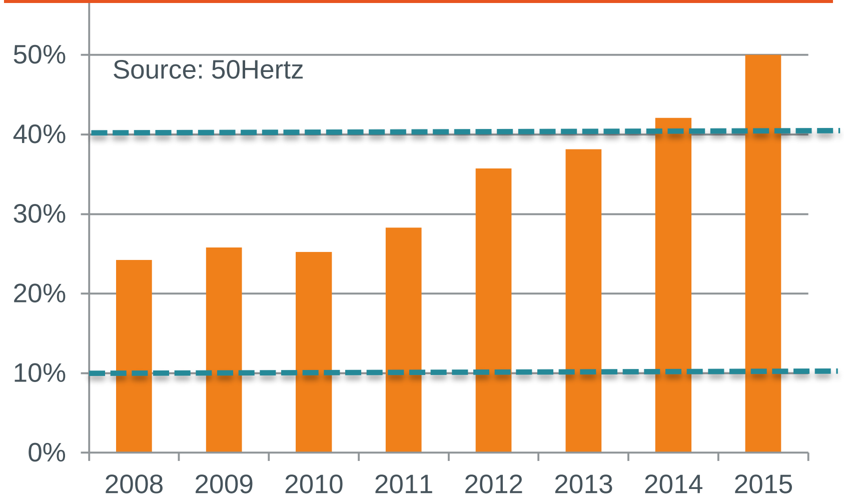
Renewables share of yearly electricity production in percentage: 50Hertz is leading development

GERMANY

https://www.energy-charts.de

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

50Hertz

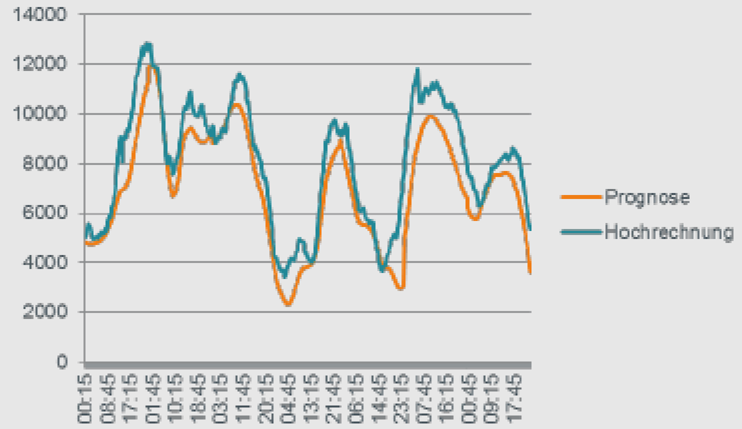


50Hertz reached 10% penetration prior to 2008, and close to 50% in 2015.

Volatile RES feed-in – Wind Energy in 50Hertz

Wind feed-in data at 50Hertz in 2015	
Maximum feed-in	12.832 MW
Minimum feed-in	9 MW
Strongest feed-in increase within a ¼ hour slot	1.192 MW
Strongest feed-in drop within a ¼ hour slot	-1.395 MW
Strongest feed-in difference min. and max. in one calendar day	10.277 MW

Wind energy feed-in (21.12.2015 – 27.12.2015)



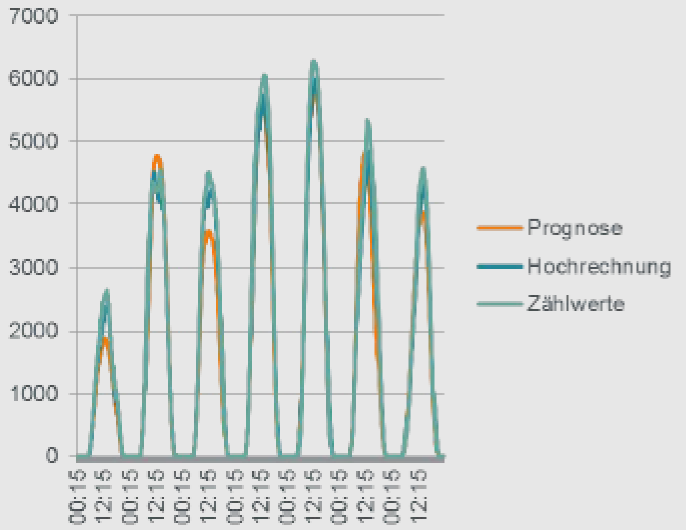
Exact forecasts and an extremely flexible and a fast-reacting control system are essential to compensate fluctuations.

Source: 50Hertz

Volatile RES feed-in – Solar PV in 50Hertz

PV feed-in data 50Hertz area 2015	
Maximum feed-in	5.995 MW
Minimum feed-in	0 MW
Strongest feed-in increase within a ¼ hour slot	1.061 MW
Strongest feed-in drop within a ¼ hour slot	-709 MW
Strongest feed-in difference min. and max. in one calendar day	5.995 MW

PV feed-in (01.06.2015 – 07.06.2015)

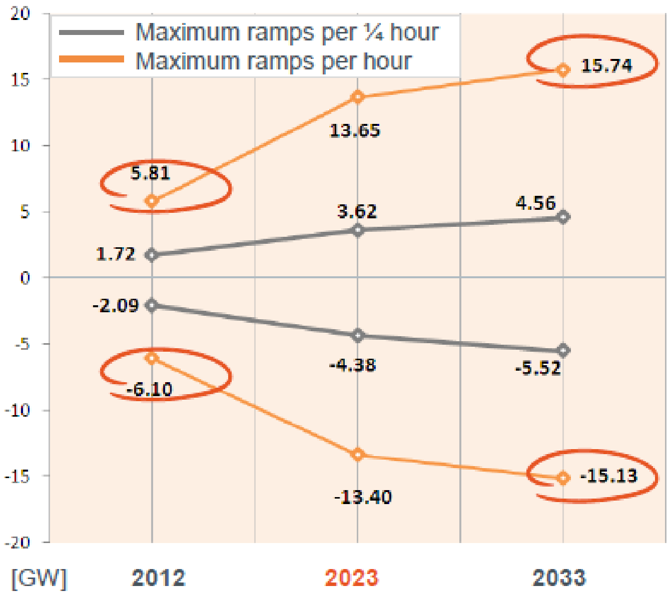


Exact forecasts and an extremely flexible and quickly reacting control system are essential to compensate fluctuations.

Source: 50Hertz

Power ramps caused by RES already amount to > 5 GW/h and are expected to increase to max. ~15 GW/h in 2023

Maximum power ramps caused by wind and PV



Source: 50Hertz

Consequences for the energy system

- Very **high volatility** of RES feed-in
- Extremely **steep RES power ramps** (>1,000 MW in 15 min in 2012)
- Only **limited feed-in stabilisation** via geographical distribution of RES facilities
- **Flexible**, non-volatile **power plants required**
- High requirements on **RES forecasts**, **controllability of RES** generation facilities and **system operations**

Need for balancing due to changing power mix

- **Stochastic imbalances**: unplanned outages (plants and lines) and forecast errors (load and VRE)
- In Europe, primary reserve is not impacted by variable renewables
- Main driver for the need of balancing is **forecast error of demand**
- Increase of variable renewables increases **supply-side forecast errors**, and **residual load ramps** which are higher than traditional load ramps
- DE studies find that need for secondary and tertiary reserves increase with increasing variable renewables (VRE)
    - reserves requirement will increase by 4-6% of the additional installed capacity of VRE
    - improvements in forecast errors in the range of 30-60% will decrease the requirement by (2-4%)
- If imbalance prices are high, operational decisions (forecast quality, portfolio managements) will be made in a way that forecast errors and outage rates will be reduced.
- **Deterministic imbalances**: deviations between the discrete schedules and continuous physical deliverables (schedule leaps)
- Schedule leaps cause significant deterministic imbalances (up to 1500 MW based on 2011 data).

Variable renewables impact on reserves requirement

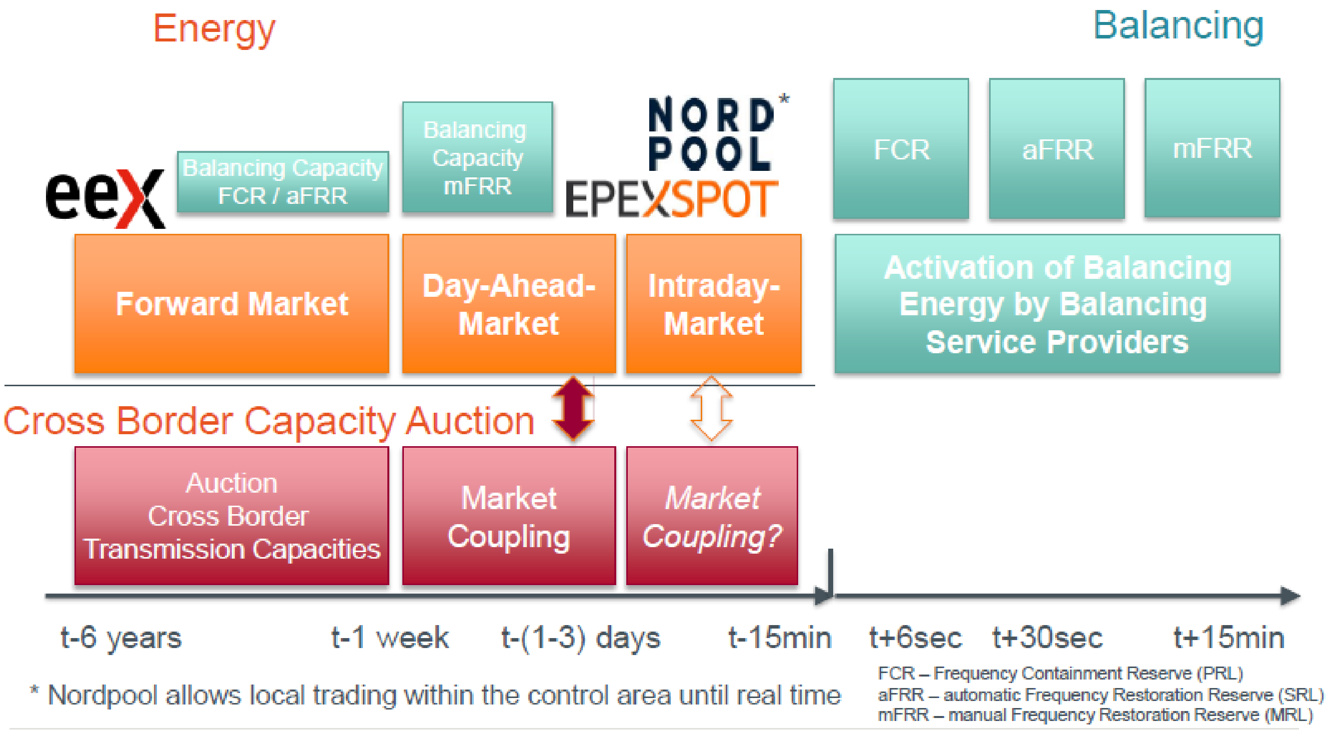
- **HOWEVER**: in DE, while VRE capacity has increased from 27 -> 78 GW since 2008, reserve requirement has reduced by 15% . Also reserves did not increase either in DK, ES & PT. Possible reasons for this:
  - Improvement of wind and solar forecasts
  - Improvement of load forecasts
  - Reduced frequency of plant outages
  - TSOs reduced security margins
  - TSO cooperation in reserve sizing
  - Improved intra-day market liquidity, allowing better portfolio management

Mechanisms for balancing: stakeholder roles and responsibilities

- **Balancing responsible parties (BRPs)**: market entities (utilities, sales companies, industrial consumers) that balance portfolio of generators and/or loads. Each physical connection point is associated with one BRP. Quarter-hourly[1] schedules are submitted one day ahead (but can be adjusted one hour ahead of delivery). Deviations from these schedules are penalized.
- **TSO**: activate balancing power in balance area if the sum of BRP imbalances is non-zero.
  1. Determine capacity of reserves required *ex ante*
  2. Acquire capacity and determine price (capacity and/or energy) *ex ante*
  3. Activate balancing power and determine imbalance price (energy) in *real-time*
  4. Allocate costs (via imbalance price and/or grid fees) *ex post*
- **Suppliers of balancing power**: generators and consumers that meet prequalification criteria. Remunerated with capacity payment (EUR/MW per hour) and energy payment (EUR/MWh)

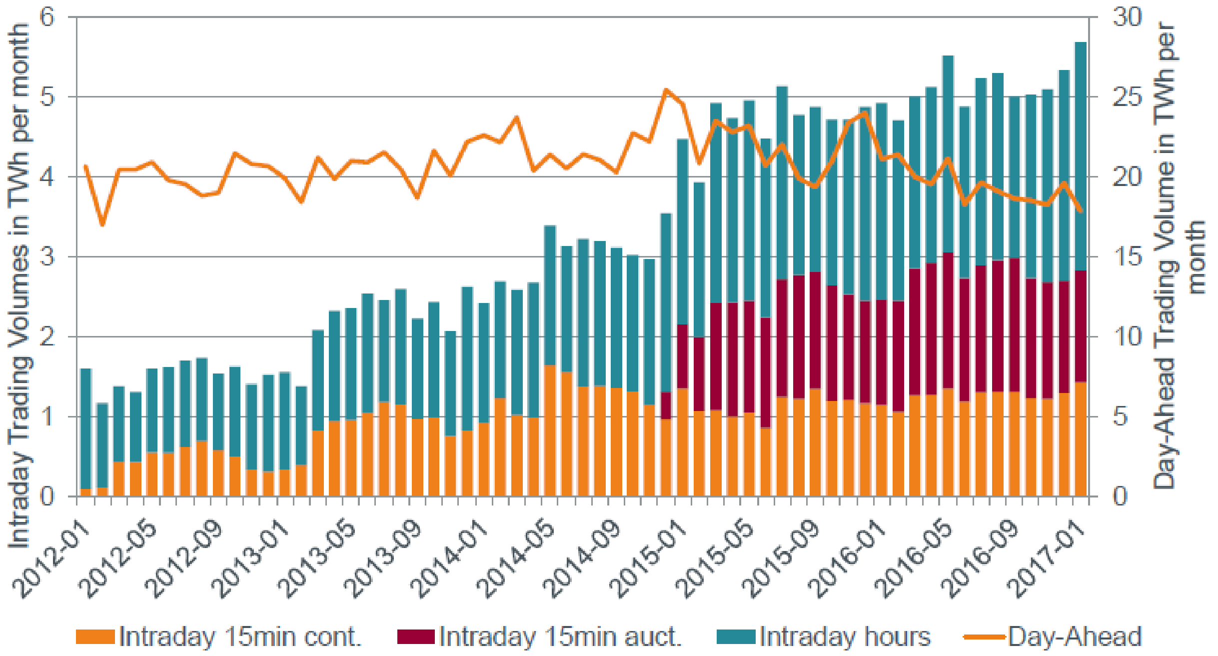
1: half-hourly in France

Mechanisms for balancing: market setup in Germany



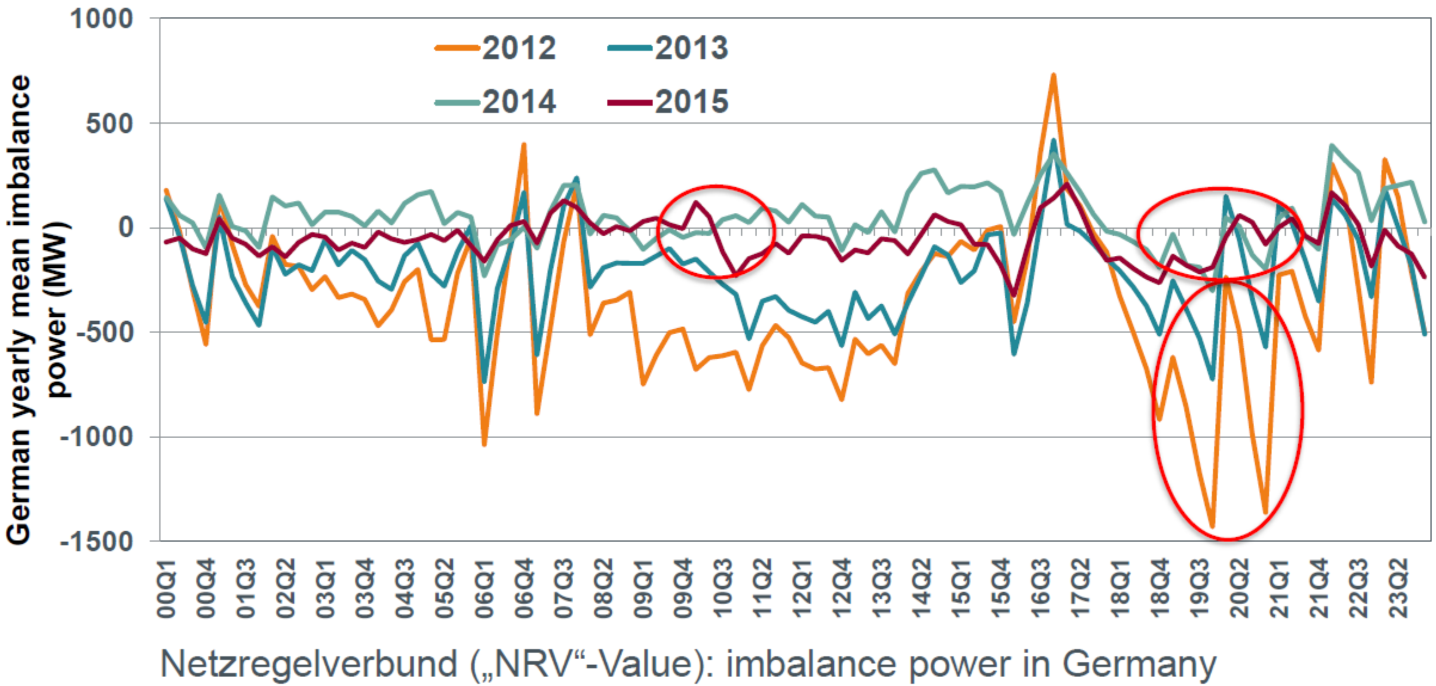
Source: 50Hertz

Performance of the balancing mechanisms: Electricity trading volumes - short term markets



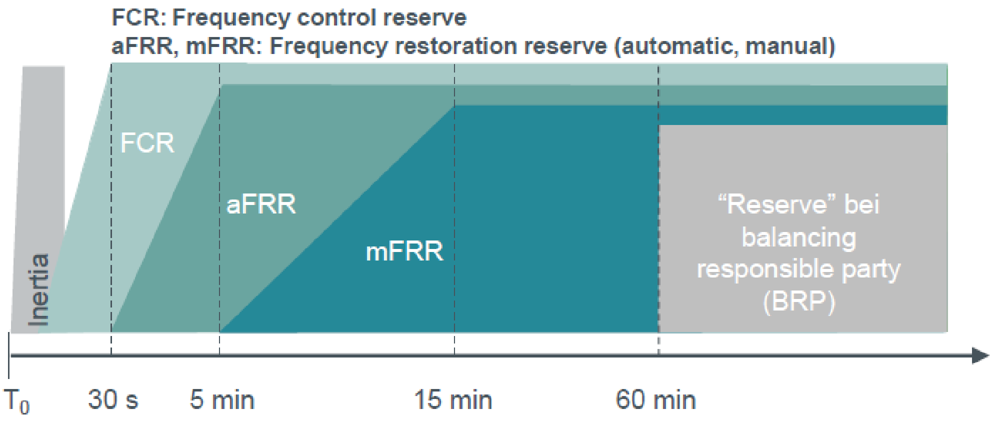
Source: 50Hertz

Performance of the balancing mechanisms: imbalance power



Source: 50Hertz

Mechanisms for balancing: categories of balancing reserves



FCR – Frequency control reserve, local control, capacity price only

aFRR – permanently activated control, capacity and energy price

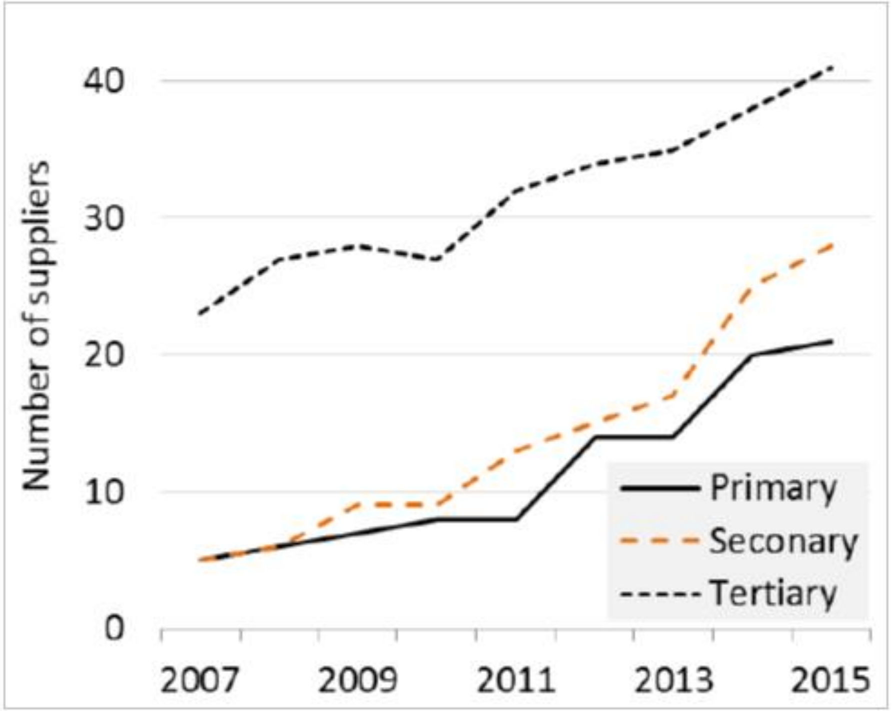
mFRR – activated only in case of large imbalances, capacity and energy price

Source: 50Hertz

Mechanisms for balancing: categories of balancing reserves

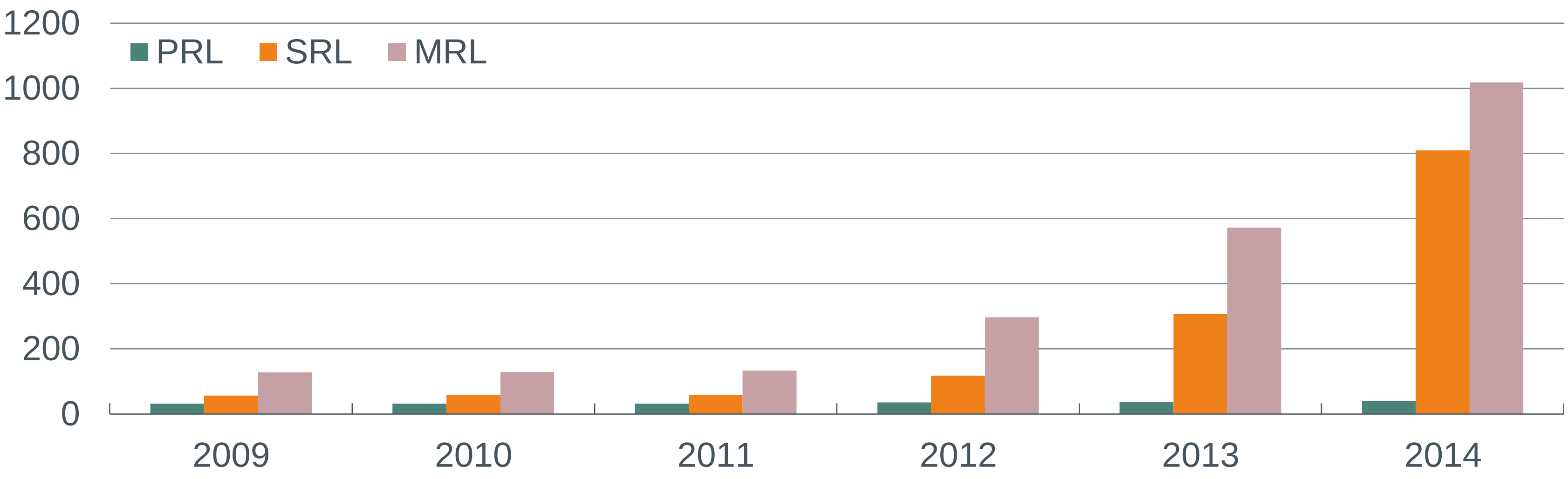
	Primary Control	Secondary Control	Tertiary Control (Minute Reserve)
Response time	30 secs, direct (continuous)	15 min or less, direct	15 min, direct or scheduled
System	UCTE	UCTE and BA	UCTE and BA
Target variable	Frequency	ACE and frequency	Current and expected level of SC activation
Activation	Based on local frequency measurement	Centralized (TSO); IT signal (AGC)	Centralized (TSO); phone / IT signal
Suppliers (typical)	Synchronized generators (large consumers)	Synchronized generators, stand-by hydro plants, large consumers	Synchronized and fast-starting stand-by generators, large consumers
Reserved capacity	3000 MW in UCTE (600 MW in DE)	Determine by TSO (2000 MW in DE)	Determined by TSO (2500 MW in DE)
Sizing method	common European deterministic-static approach	TSO decides DE static-probablistic	TSO decides DE static-probablistic
State-of-art suppliers in market	5 MW batteries in DE 30 MW Aluminium electrolysis	10 MW CHP (DR) in DE	Demand blocks in BE 60 MW wind farms in DE

Performance of the balancing reserves market: number of suppliers



Source: Lion Hirth, neon neue energieökonomik

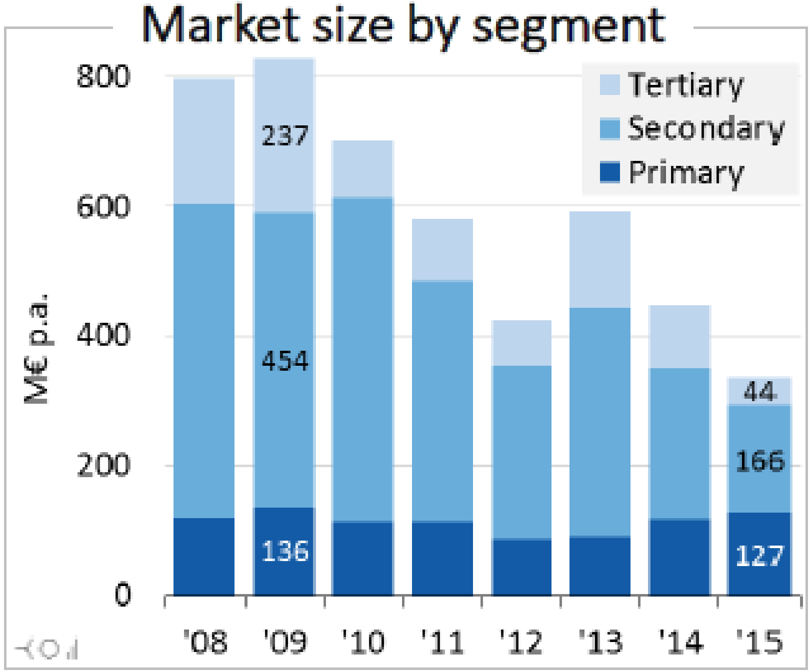
Enhancement of Balancing Power: prequalified balancing power service providers in 50Hertz region



事前審査済みのSRL(Secondary Reserve)とMRL(Tertiary reserve)数が大幅に増加

Source: 50Hertz

Performance of the balancing reserves market: market size

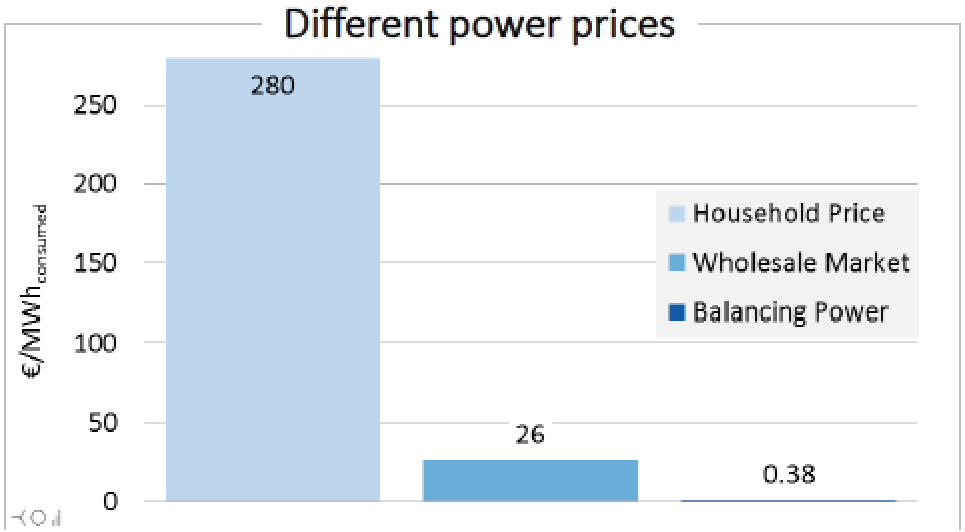


Neon analysis. Based on data from Bundesnetzagentur, Regelleistung.net, TSO websites. Power (capacity) payments only.

- In 2015, the market for balancing power contracted further. Revenues totalled €340m, 60% less than in 2009 and 25% less than in 2014.
- The markets for secondary and tertiary balancing (minute reserve) continue to decline. Primary balancing remains stable.
- Since 2009, revenue has declined by 60% in secondary balancing –and by 80% in tertiary.

Source: Lion Hirth, neon neue energieökonomik

Side note: comparison of market size

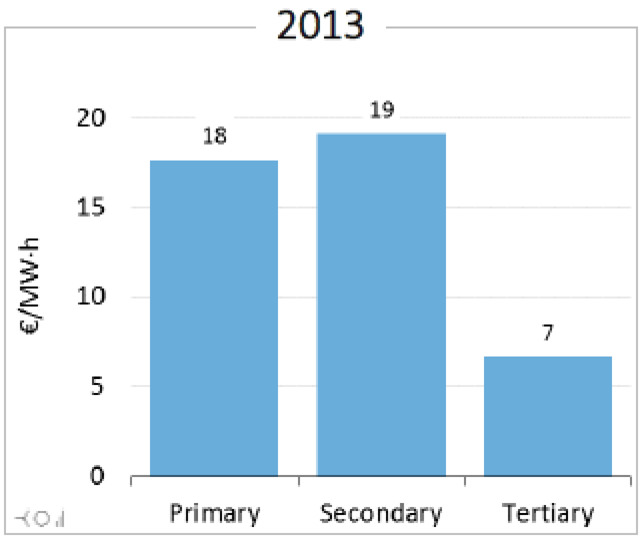


Neon analysis. Based on data from Bundesnetzagentur, Regelleistung.net, TSO websites. Power (capacity) payments only.

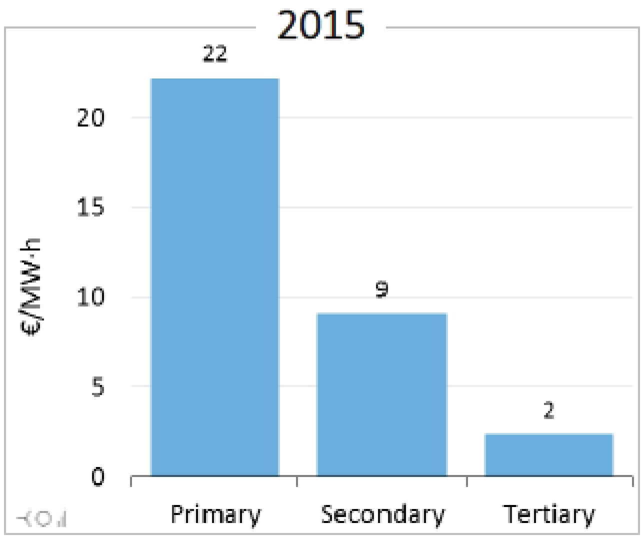
The retail electricity price for households is about €280 per MWh. Of this, €0.38 (0.1%) pays for holding balancing reserves.

Source: Lion Hirth, neon neue energieökonomik

Performance of the balancing reserves market: prices in different market segments



Neon analysis. Based on data from Bundesnetzagentur, Regelleistung.net, TSO websites. Power (capacity) payments only.



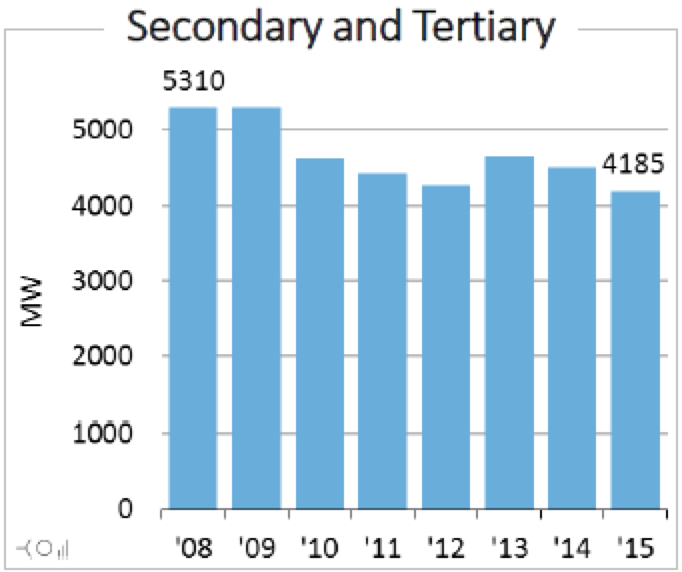
Neon analysis. Based on data from Bundesnetzagentur, Regelleistung.net, TSO websites. Power (capacity) payments only.

Two years ago, secondary balancing was more expensive than primary.

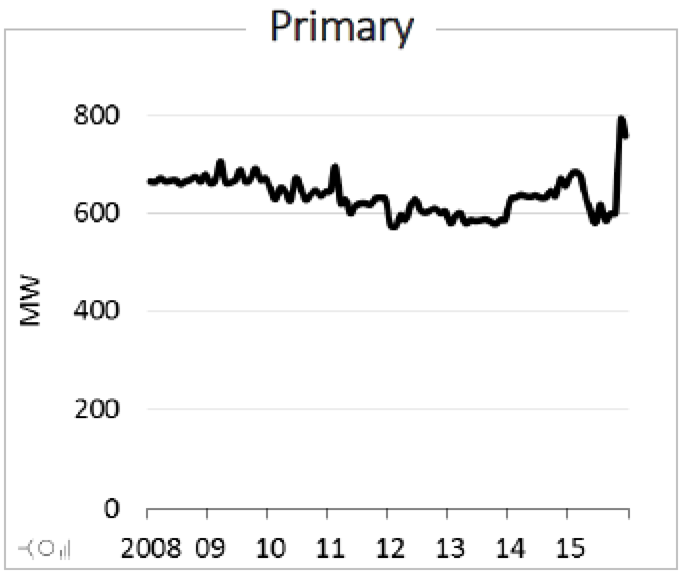
In 2015, primary balancing was by far the priciest product.

Source: Lion Hirth, neon neue energieökonomik

Performance of the balancing reserves market: procured volume



Neon analysis. Based on data from Bundesnetzagentur, Regelleistung.net, TSO websites. Power (capacity) payments only.



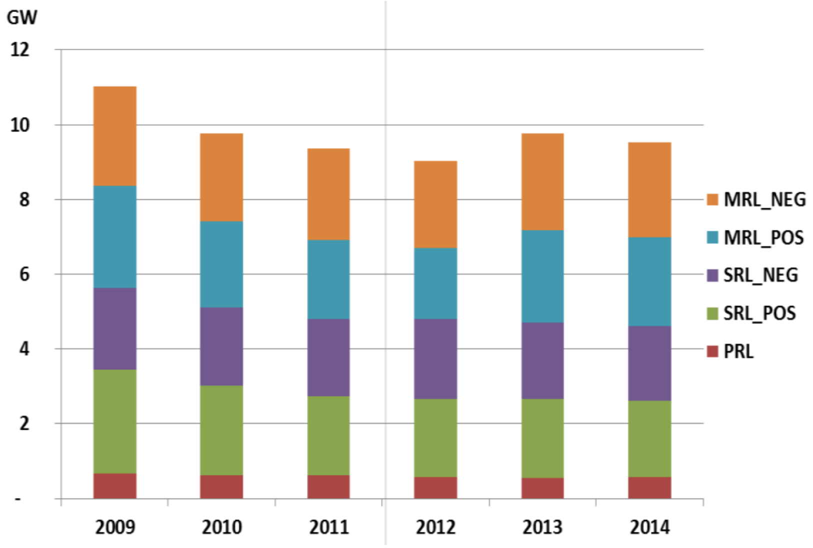
Neon analysis. Based on data from Bundesnetzagentur, Regelleistung.net, TSO websites. Power (capacity) payments only.

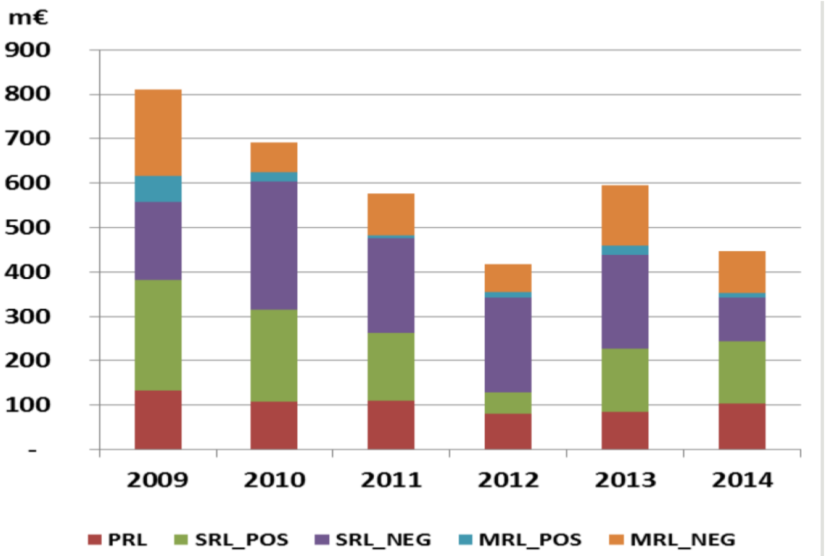
The requirement for secondary and tertiary balancing, determined by the TSOs, declined further.

Primary reserve is set commonly by European TSOs. (Includes 25 MW for CH and 35 MW for NL.)

Source: Lion Hirth, neon neue energieökonomik

Performance of the balancing reserves market: procured volume and procurement cost



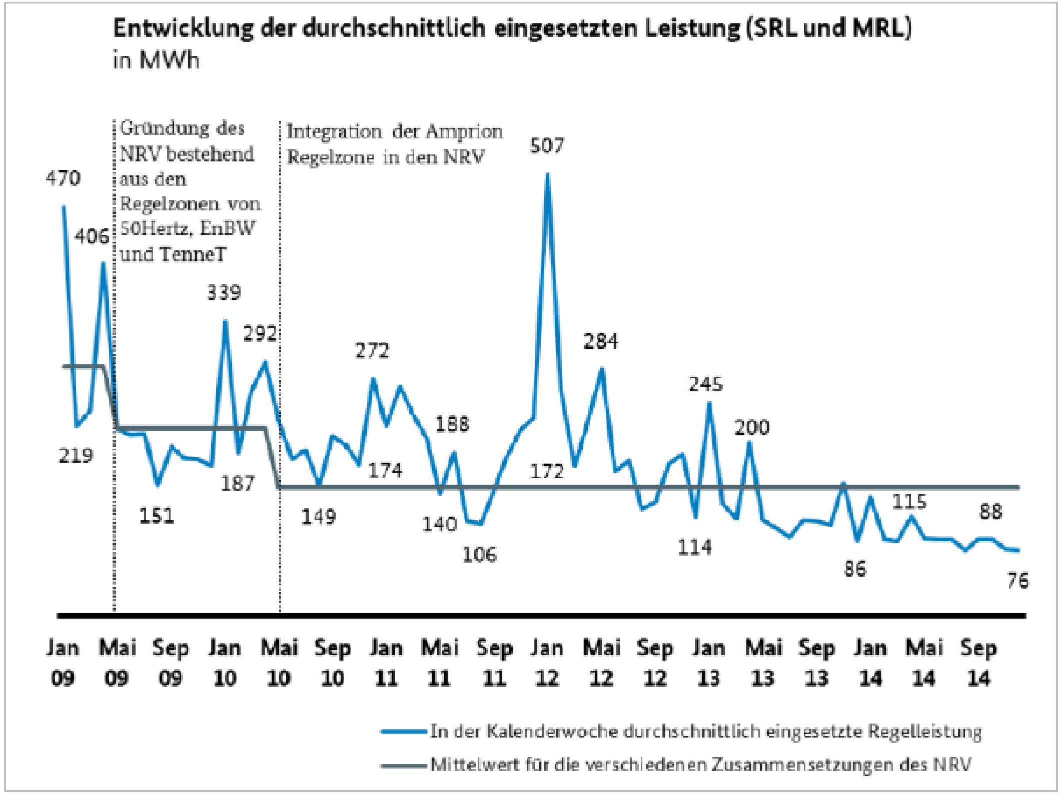


Since 2008, installed wind and solar capacity tripled. At the same time, SRL requirement decreased by 20%

After the Introduction of the GCC in 2010, costs went down almost 50%

Source: 50Hertz

Performance of the balancing reserves market: activated volume



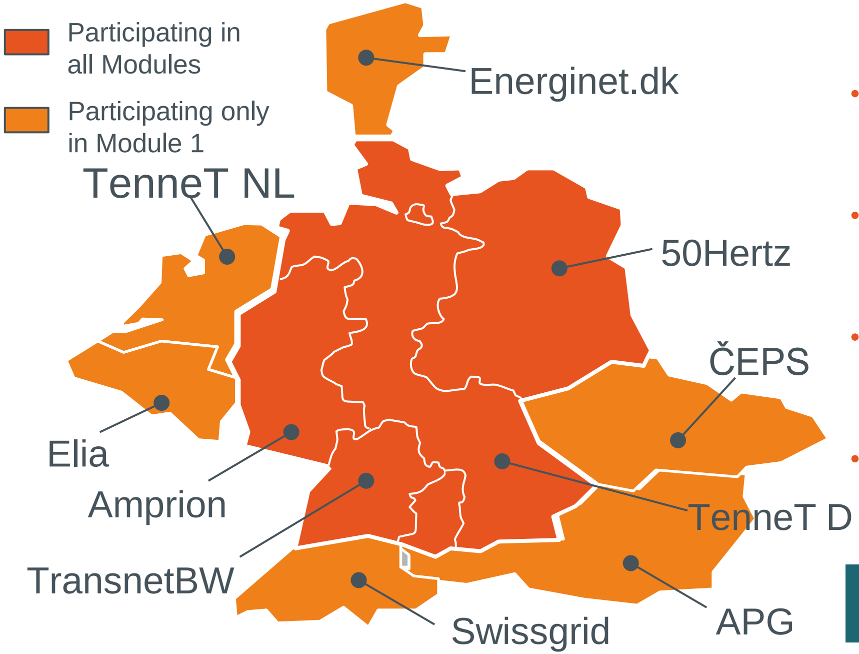
Source: BNetzA Monitoringbericht 2015

European harmonisation of balancing power

- TOP-DOWN: European Union aims to harmonize and integrate European balancing systems and markets
  - NC: FCR (Frequency Control and Reserves)
  - NC: EB (Electricity Balancing)
- BOTTOM-UP: TSO cooperation initiatives in four stages:
  i. Imbalance netting
  ii. Common reserve sizing
  iii. Common reserve procurement
  iv. Common reserve dispatch/activation

  - **GCC:** covers all stages
  - **IGCC:** focuses on secondary reserve, and imbalance netting (sizing is done individually). Includes DK, NL, CH, BE, CZ, AT, FR TSOs.
  - Other: common procurement of primary reserve by bilateral cooperation of CH, FR, DE, AT TSOs.

Grid Control Cooperation (GCC) and International Grid Control Cooperation (IGCC)



Grid control cooperation (GCC) functioning in four modules

- **Module 1:** Avoid activation of secondary control power in the opposite direction
  → reduction of secondary control energy
- **Module 2:** Joint dimensioning and mutual support with secondary control power among participating TSOs
  → reduction of secondary control power
- **Module 3:** Joint activation procedures: Activation signal will be provided by that TSO where the generator is connected
  → one common market area
- **Module 4:** Common Merit Order List or common control energy prices
  → further cost optimization

Technical solution via connection of load-frequency controllers.

GCC – full harmonized German market

IGCC – cooperation of TSOs to avoid activation of aFRR

Source: 50Hertz

Introduction of the (I)GCC

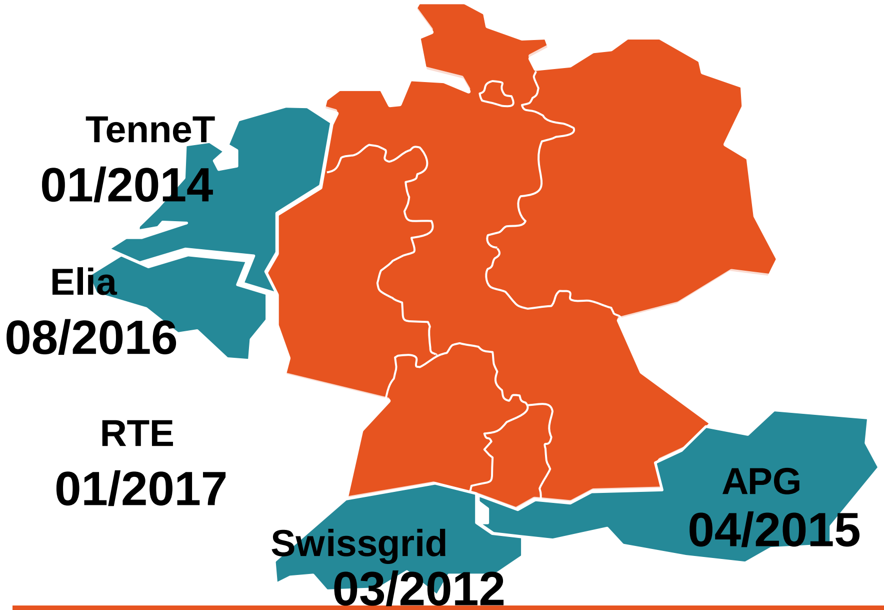
GCC as an initiative from German TSOs

- No legal obligation from the Regulator or Government to introduce the GCC
- Cost saving potential seen
- Potential for a reduction of secondary control power seen
- Eases the integration of renewables by freeing control reserves

Introduction of the IGCC

- An independent effort of European TSOs triggered by Germany
- Benefits of the GCC seen by other European TSOs
- Easy adoption to other (non-German) control areas (Module 1)
- The more participants (German and non-German) the more potential for cost savings, however the technical implementation might get more complex

Primary reserve cooperation

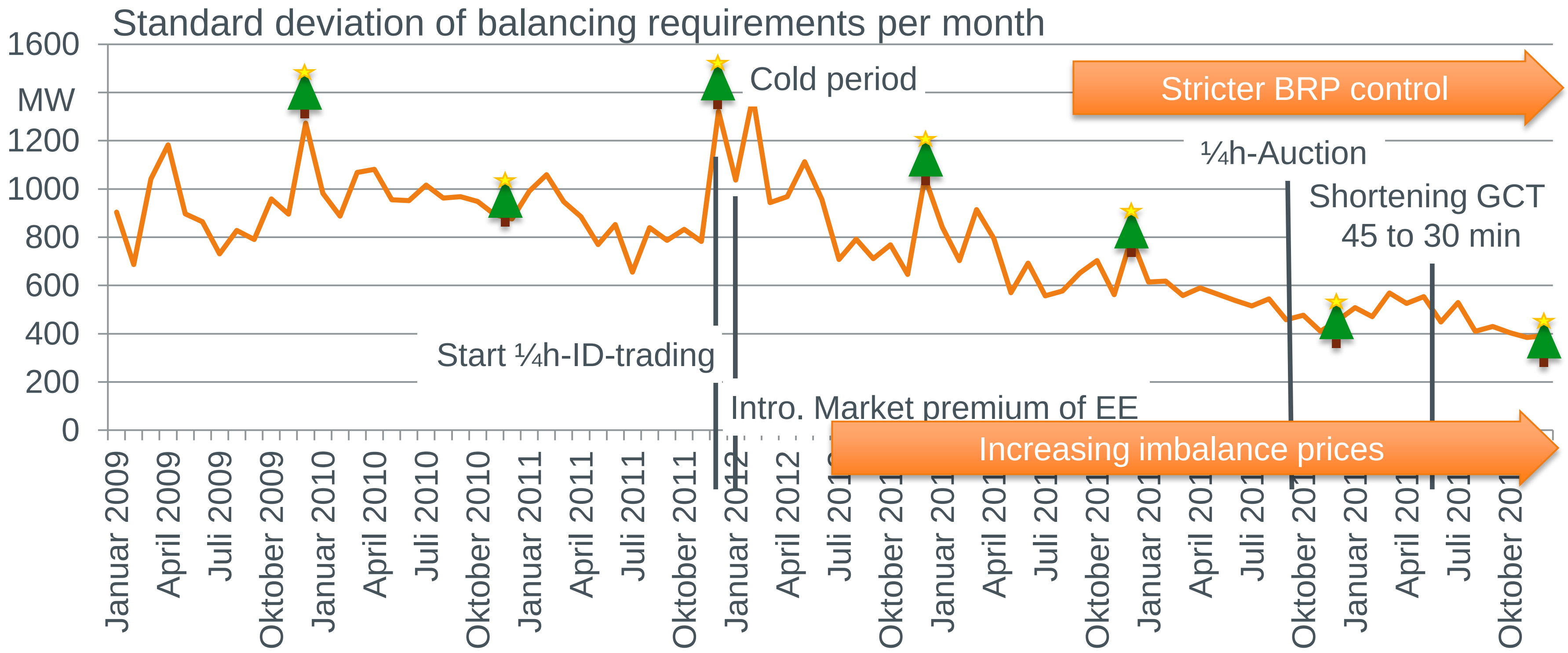


- Common procurement of primary reserves for Austria, Switzerland, Germany, Netherlands, Belgium and France
- Currently in discussion with Denmark to broaden cooperation

Common procurement of primary reserve and imbalance netting are the "low hanging fruits" of international balancing power cooperation

Source: 50Hertz

Development of balancing requirements in Germany



Source: 50Hertz

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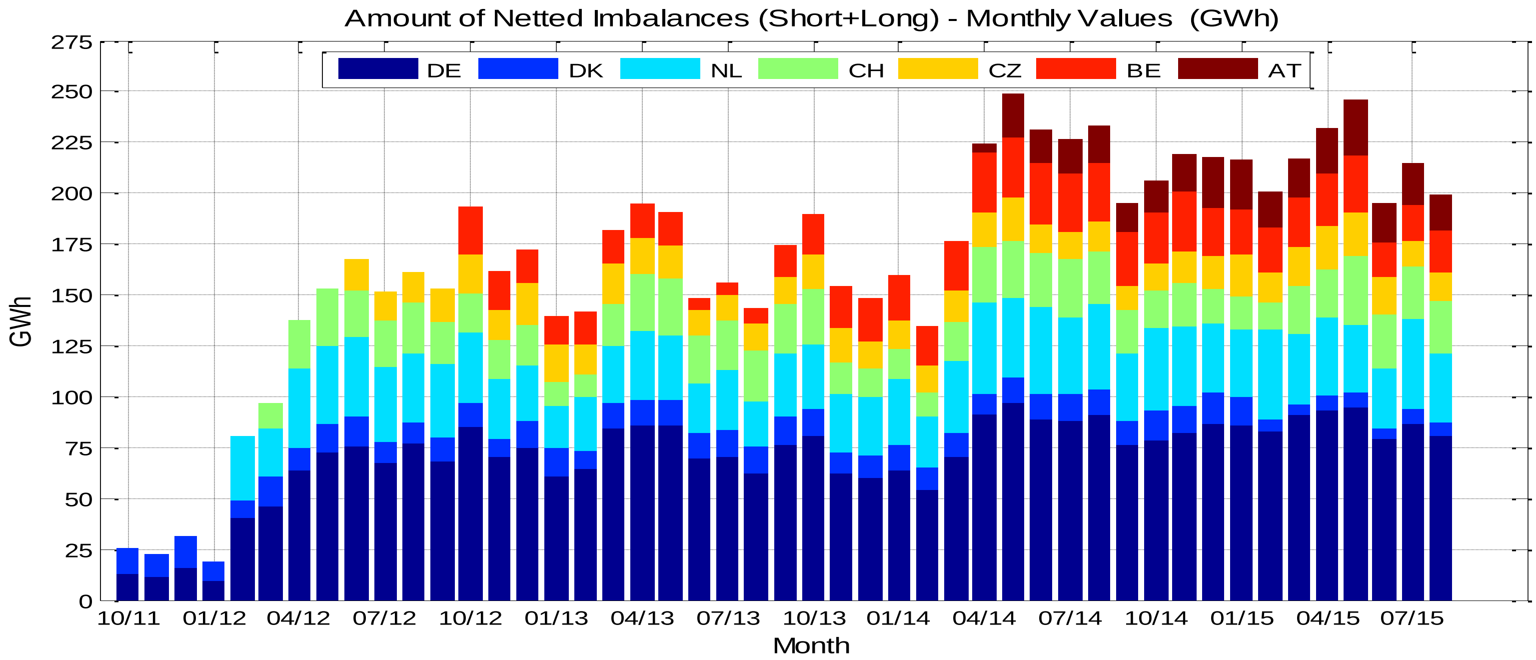
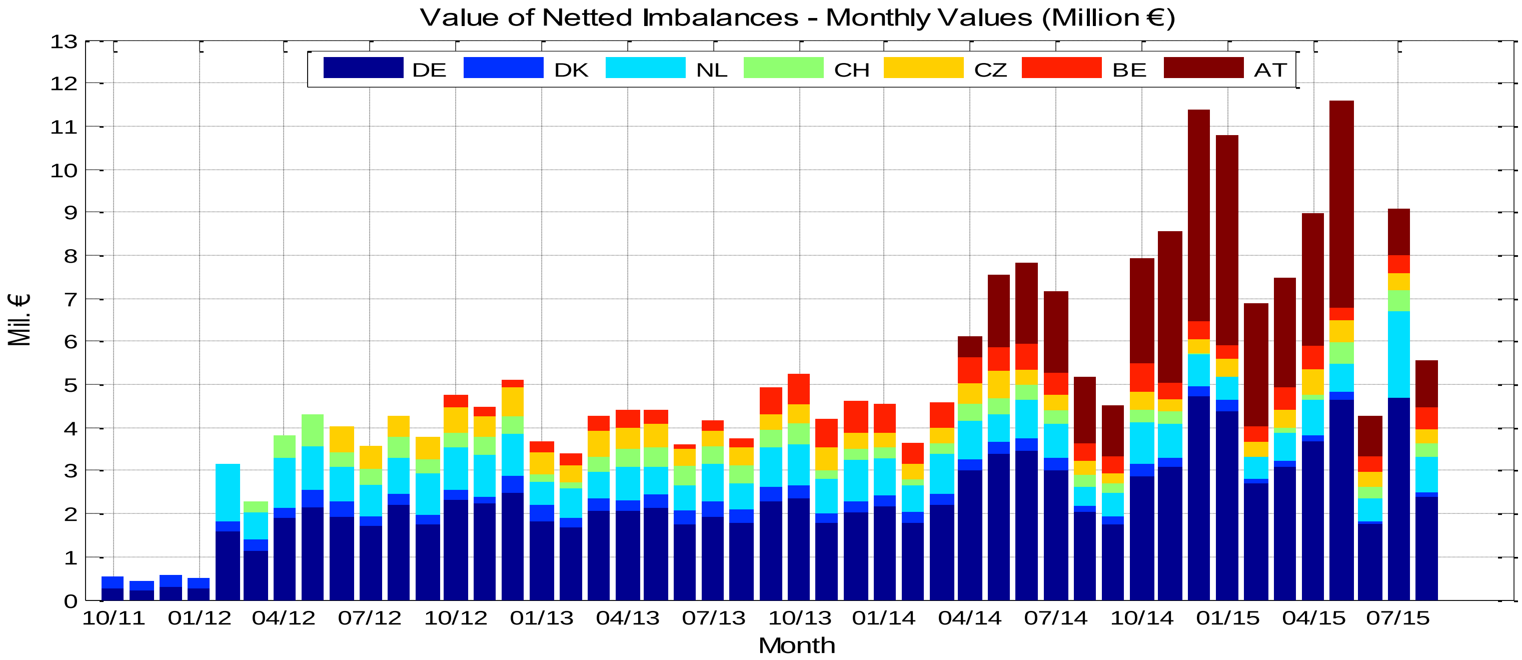
Monthly Volumes of Netted Imbanlances



From October 2011 to October 2015 (Source 50Hertz)

Monthly Values of Netted Imbanlances



From October 2011 to October 2015 (Source 50Hertz)

Barriers for VRE (and DR) provision of (negative) balancing power

- Some implementation issues may persist, but larger obstacle is:
- Design of balancing markets constitutes a prohibitive entry barrier. Options to remove barrier are:
  - Adjust balancing power auction design
    - PC and SC auctions in DE require provision for a full-week. Weather forecasts in this horizon are much too uncertain to provide *firm* reserves.
    - E.g., daily auction with contract duration of one hour (like day-ahead spot)
  - Introduce a second energy auction
    - Generators are rewarded only with energy payments for provision of balancing services (DK, NL)
  - Conditional bids: joint bids on spot and balancing power markets, e.g., offering balancing services only in those hours where plants are dispatched.
  - Pay-as-bid could be replaced with uniform (marginal) pricing
  - Foster passive balancing

Further reading

Hirth, Lion & Inka Ziegenhagen (2015): "Balancing power and variable renewables: Three links", *Renewable & Sustainable Energy Reviews* 50, 1035-1051. http://dx.doi.org/10.1016/j.rser.2015.04.180

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Hirth, Lion & Inka Ziegenhagen (2013): "Wind, Sonne, und Regelleistung", Energiewirtschaftliche Tagesfragen 10/2013. www.et-energie-online.de/AktuellesHeft/Inhalt/tabid/69/Year/2013/Month/10/NewsModule/416/201310.aspx

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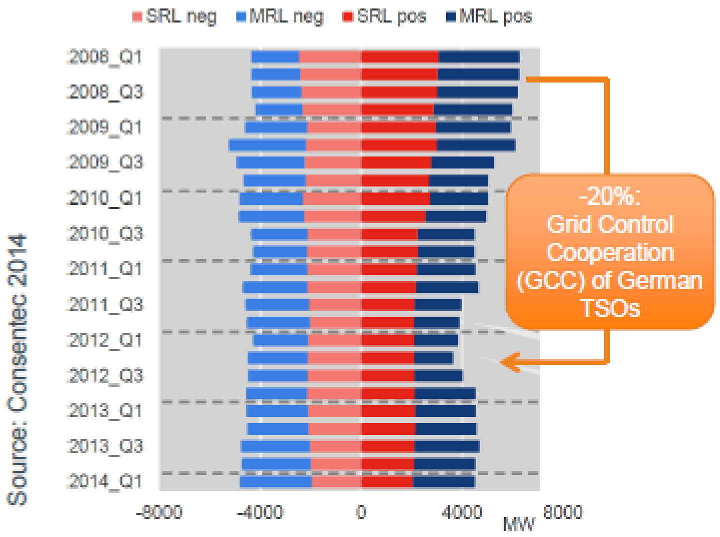
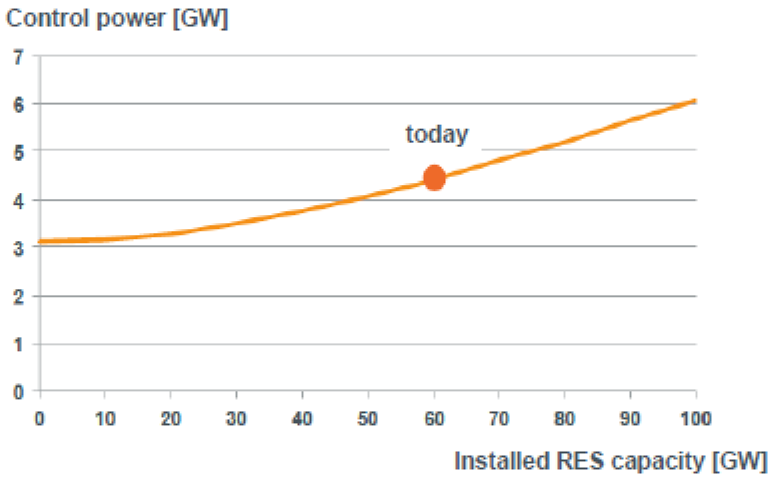




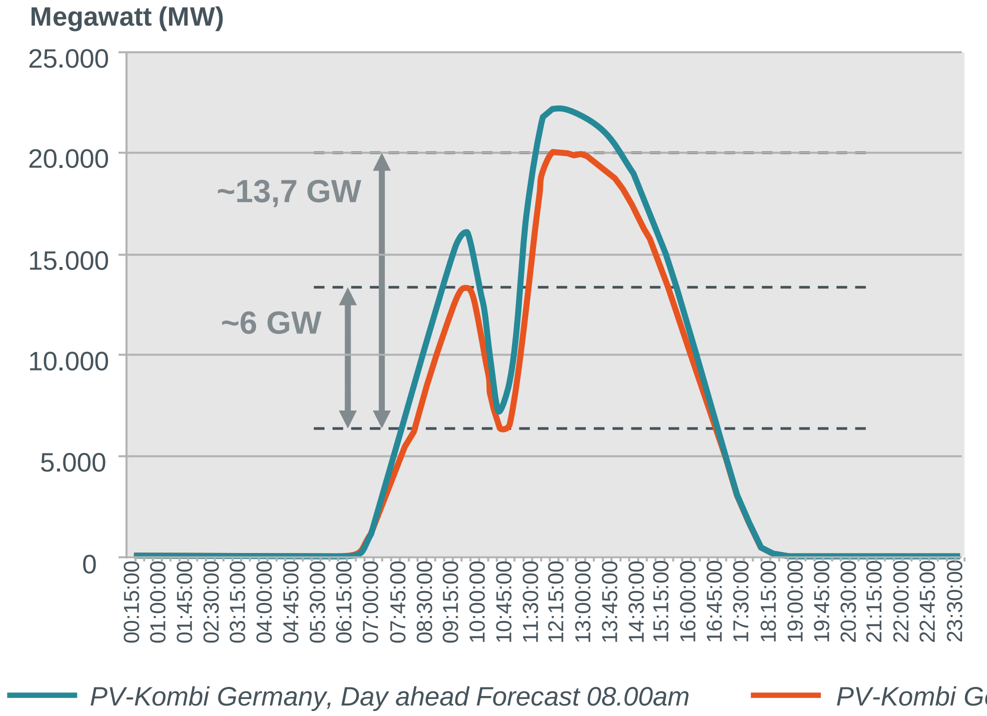
Less control power need in the recent years

- Grid Control Cooperation (GCC) of German TSOs
- IGCC: Cooperation of European TSOs
- Stronger incentives for balancing groups

More control power need expected for the years to come

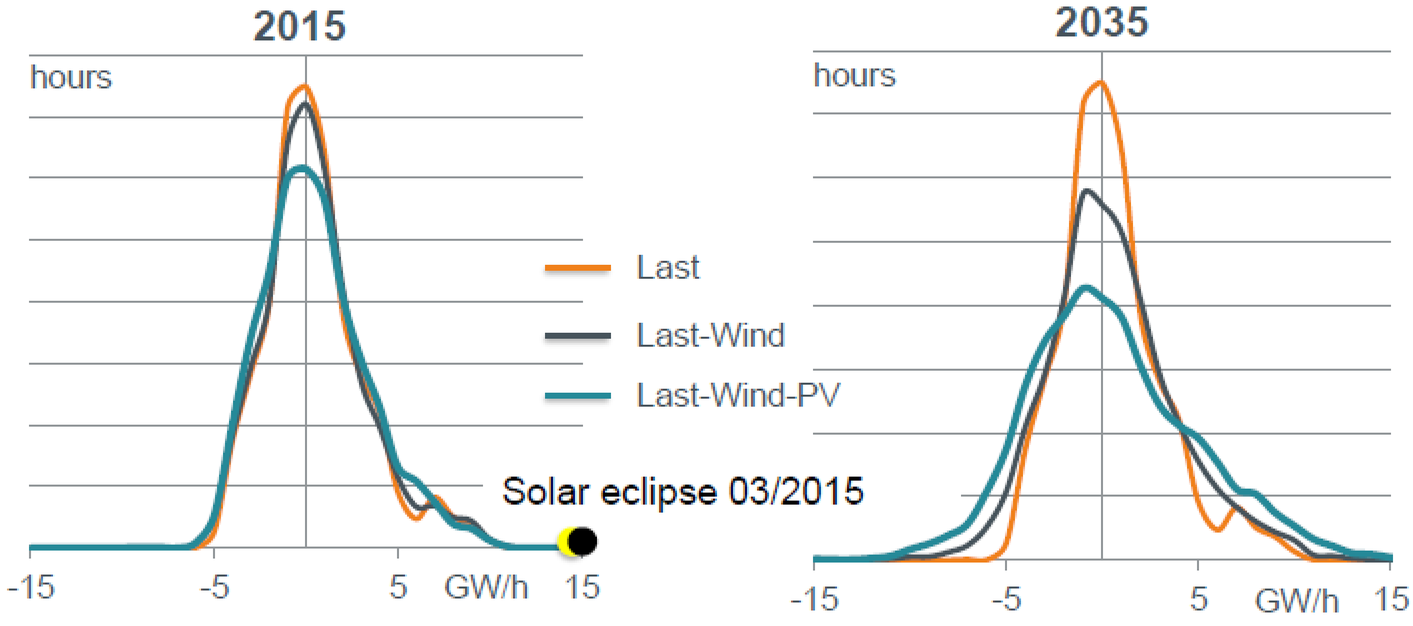
- Growing installed RES capacity:
  - Forecast errors of PV and wind energy
  - ~ 30-70 MW more control power per GW of installed RES capacity needed

Performance of the balancing mechanisms: Solar eclipse 2015: A successful trial-run for the future's electricity system



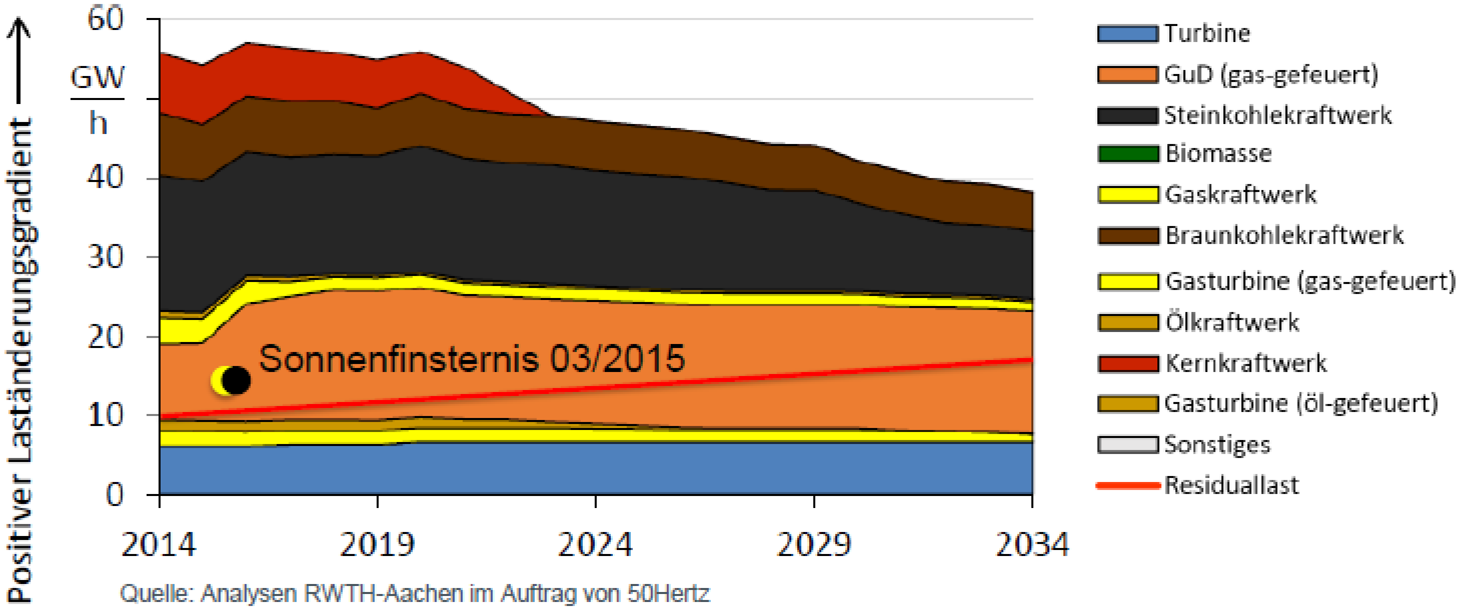
Conclusions

- The market mechanisms that were developed and introduced over the last years work well
- TSOs were able to grant high system stability by adapting additional measures
- A highly flexible control system as adopted in this exceptional situation will be required on a daily basis in the future



- Gradients are currently determined by load; in the future volatile RES will determine gradients
- Solar eclipse in 2015 was a preview of daily situation in 2035

Hourly Flexibilities of current and future power plant parkt in Germany
Assumption: No new power plants built, technical reasons for existing power plants to quit operation



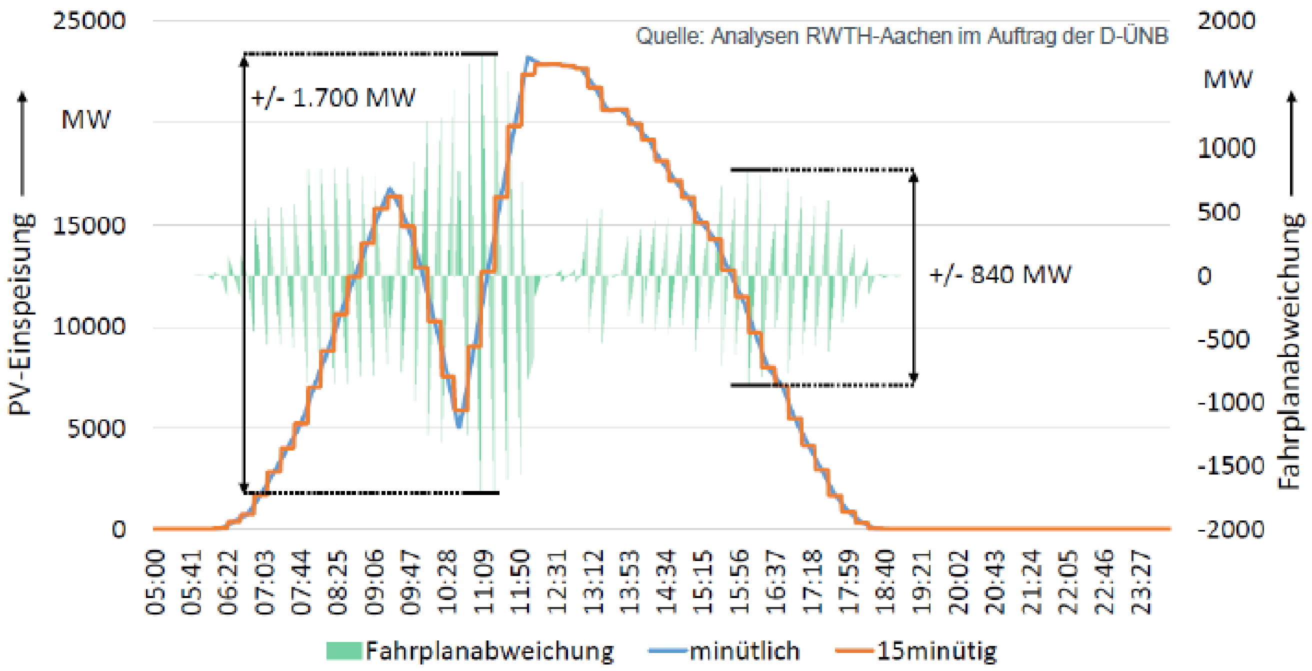
Quelle: Analysen RWTH-Aachen im Auftrag von 50Hertz

- Conventional power plant parkt supplies suffient flexibility
  ➔ no security risk
- But: Potentially high costs for flexibility
  ➔ if the frame is correct, the market will provide efficient solutions

Performance of the balancing mechanisms: imbalance settlement

- **The purpose of balancing power is to respond to unexpected events, but schedule leaps are known to occur every day at the same time. A dedicated approach for this imbalance may be more appropriate.** For example:
  - Mandate smoother transitions between intervals
  - Shorten intervals
  - Introduce a dedicated ramping product
  - Passive balancing (use the imbalance price to incentivize BRPs to voluntarily stabilize the system)

Deterministic imbalance



- Precise schedule and balacning by market parties important
- If market design is not changed, gradients of residual load will lead to increase of needed control power in the long term

Imbalance Settlement
TSO & BSP

Transmission System Operator (TSO)

- Overall a financial neutral position is achieved
  - Costs for activated Balancing Energy are charged to BRP
  - Costs for procured Balancing Capacity are part of grid tariff

Balancing Service Provider (BSP)

- Settlement is done „pay as bid“

- Incentive to be available and to deliver
  - No payments if BSP is not available or cannot deliver
  - Payment is based on metered delivery (aFRR) or requested delivery (mFRR)
  - In case of non-delivery or to often unavailable penalties are possible
    - Worst case: prequalification will be withdrawn

Imbalance Settlement

BRP

Balancing Responsible Parties (BRP)

- Settlement to BRPs is based on activated Balancing Energy
- Germany has an 1-price-system (symmetric price)
  - price for positive or negative imbalances of BRPs (reBAP) is the same
  - Imbalance Settlement Period = 15min
- Additional price components:
  - Benchmark with Intraday price (intraday price is always “better”)
  - If activated Balancing Energy exceeds 80%: +50% but min. 100 €/MWh

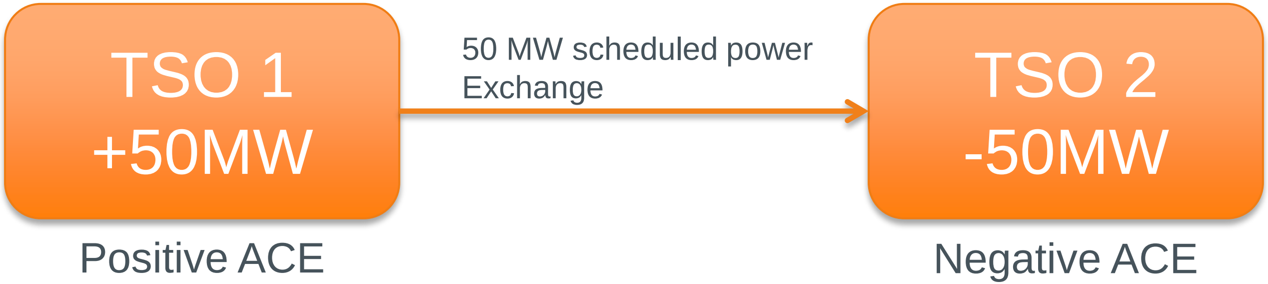
- Incentive to be balanced
  - By contract BRP is forced to be balanced
  - reBAP gives an additional financial incentive

Imbalance settlements

- Determination of imbalance price
  - EUR/MWh deviation from submitted schedule by BRP
  - All costs are born by unbalanced BRPs (same price for under and over supplied BRPs)
  - Since May 2010, there is a common German imbalance price reBAP, set for 15-minute settlement intervals as the **average dispatch cost (net energy payments divided by net balancing energy)**, which is different to the energy price in the balancing market (not the marginal cost of activating balancing reserves, even though this would be most efficient allocation)
  - Prices are published with delay of several months
  - Capacity reserve costs are socialized and not recovered by imbalance settlement
  - In late 2012, BnetzA introduced a punitive mark-up to increase price spread (difference between imbalance price and corresponding day-ahead price). **The imbalance spread is the economic incentive for BRP to follow schedule.** BRPs aggrevating system imbalance pay the spread, while those that correct system imabalance earn the spread.

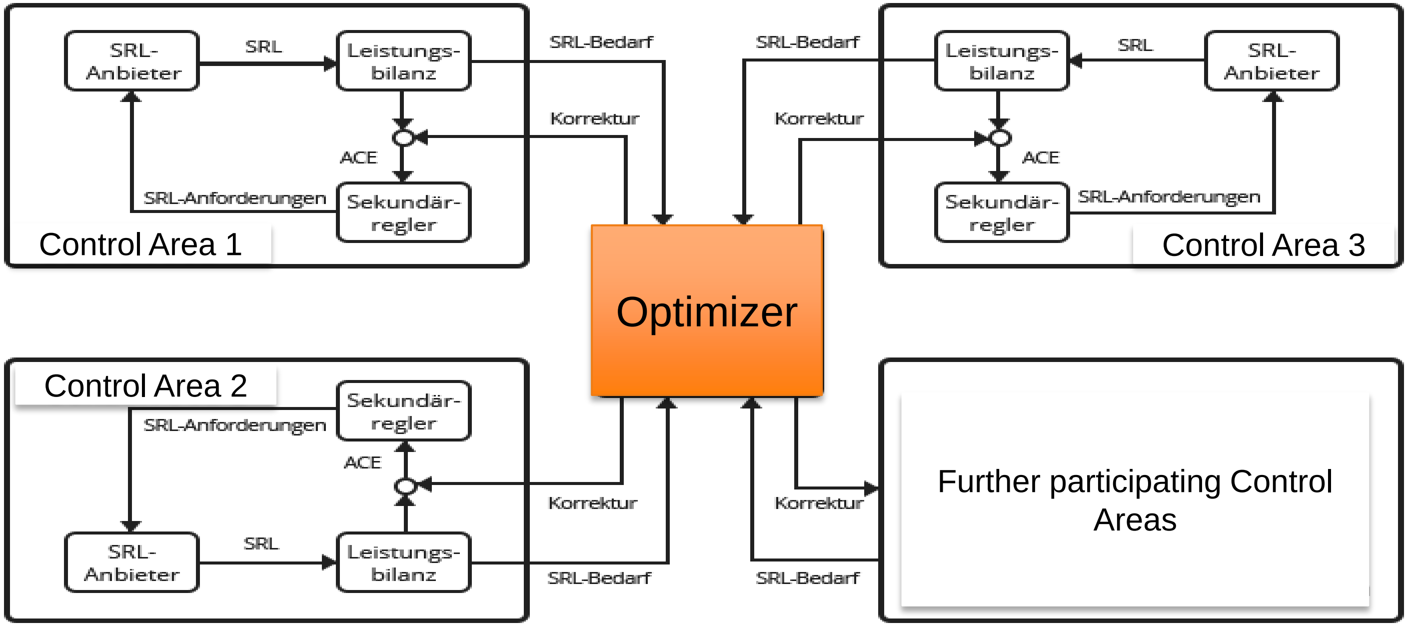
M1: Prevent counteracting control reserve activation

- avoid the activation of reverse control power through controlled and targeted energy exchange between the control areas
- Potential for cost saving in the reduced activatoin of secondary and minute reserve and related costs



- In this example none of the TSOs has to activate control reserves

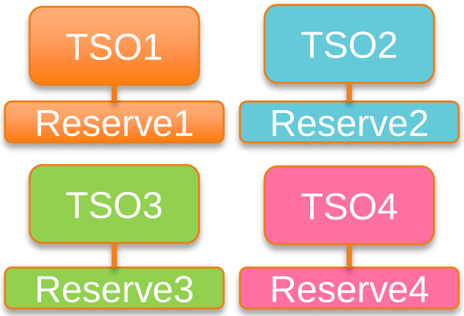
Module 1 in Operatioin



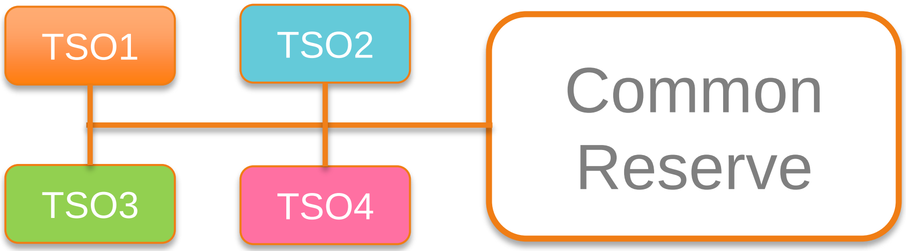
M2: Common dimensioning of control reserve

- Only the 4 German TSO participate in module 2
- A joint dimensioning of control reserve across control areas bears potential for further cost savings
- Access to commonly hold reserves of the 4 TSOs
- Necessity for a common German market

Before



After



M3: Common procurement of secondary control reserve

- Only the 4 German TSO participate in this module
- Allows procurement of secondary control from another control area
- Activates and multiplies competition between the secondary control reserve providers
- Further cost savings on the TSO side

M4: Cost-optimised activation of control reserve

- Only the 4 German TSO participate in this module
- Introduction of the Merit Order Lists
- Automatic activation of reserves according to the Merit order
- The aim of module one is a cost optimsation of the whole secondary control power procurement process