Technical and Operational Innovations for the Congestion Management of the German Transmission Grid

Name: **Prof. Dr.-Ing. Albert Moser, 26th MEM Congress, 27. October 2021**

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Agenda

- German Energy Transition
- German Grid Development Plan
- Congestion Management in Germany
- Study on SSSC
- Outlook

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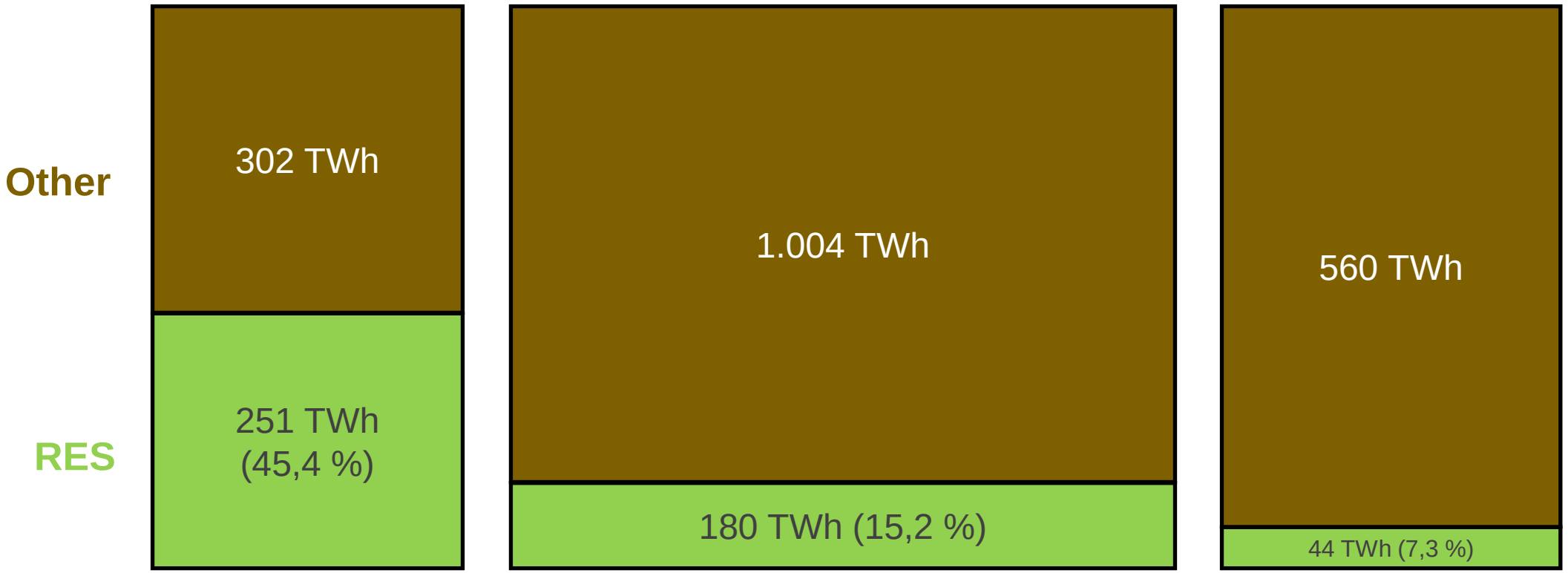
German Energy Transition – 2020 Achievements



Source: AGEE-Stat

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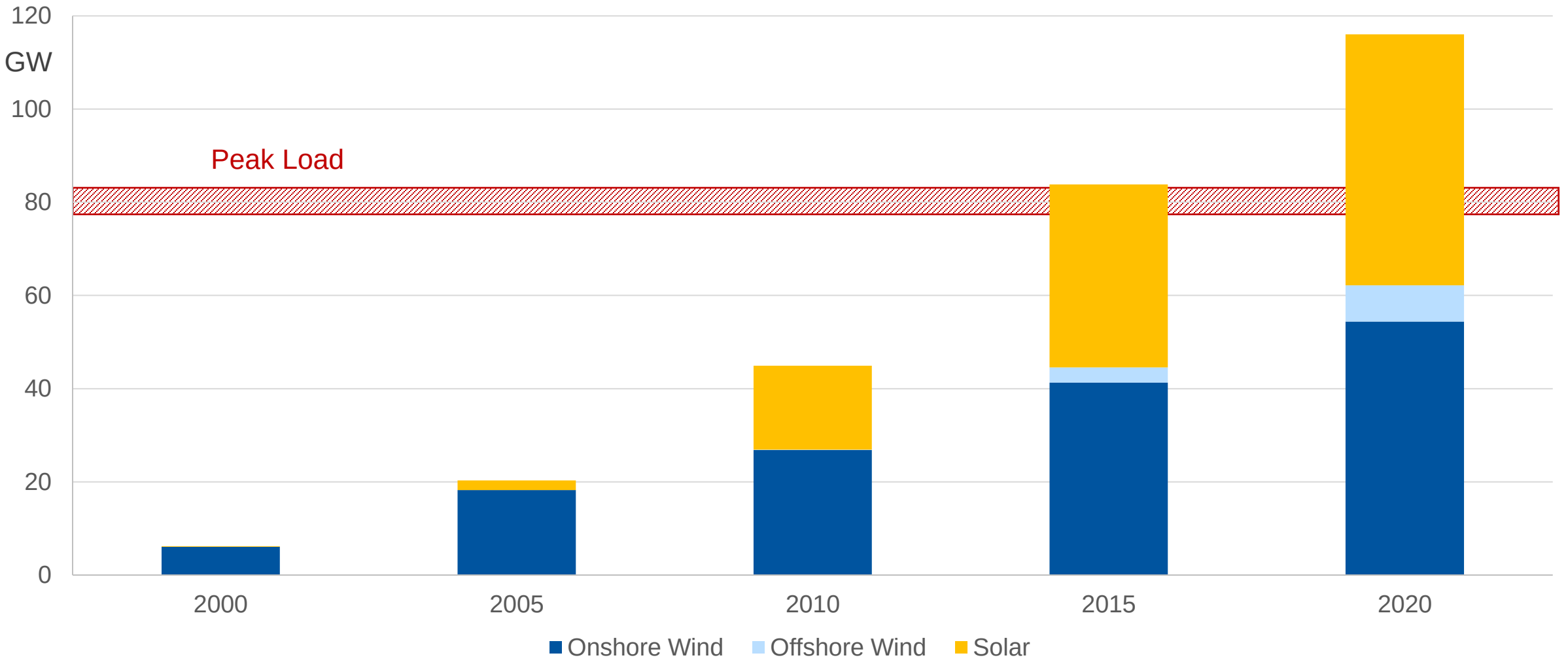
German Energy Transition – Development of RES Capacity



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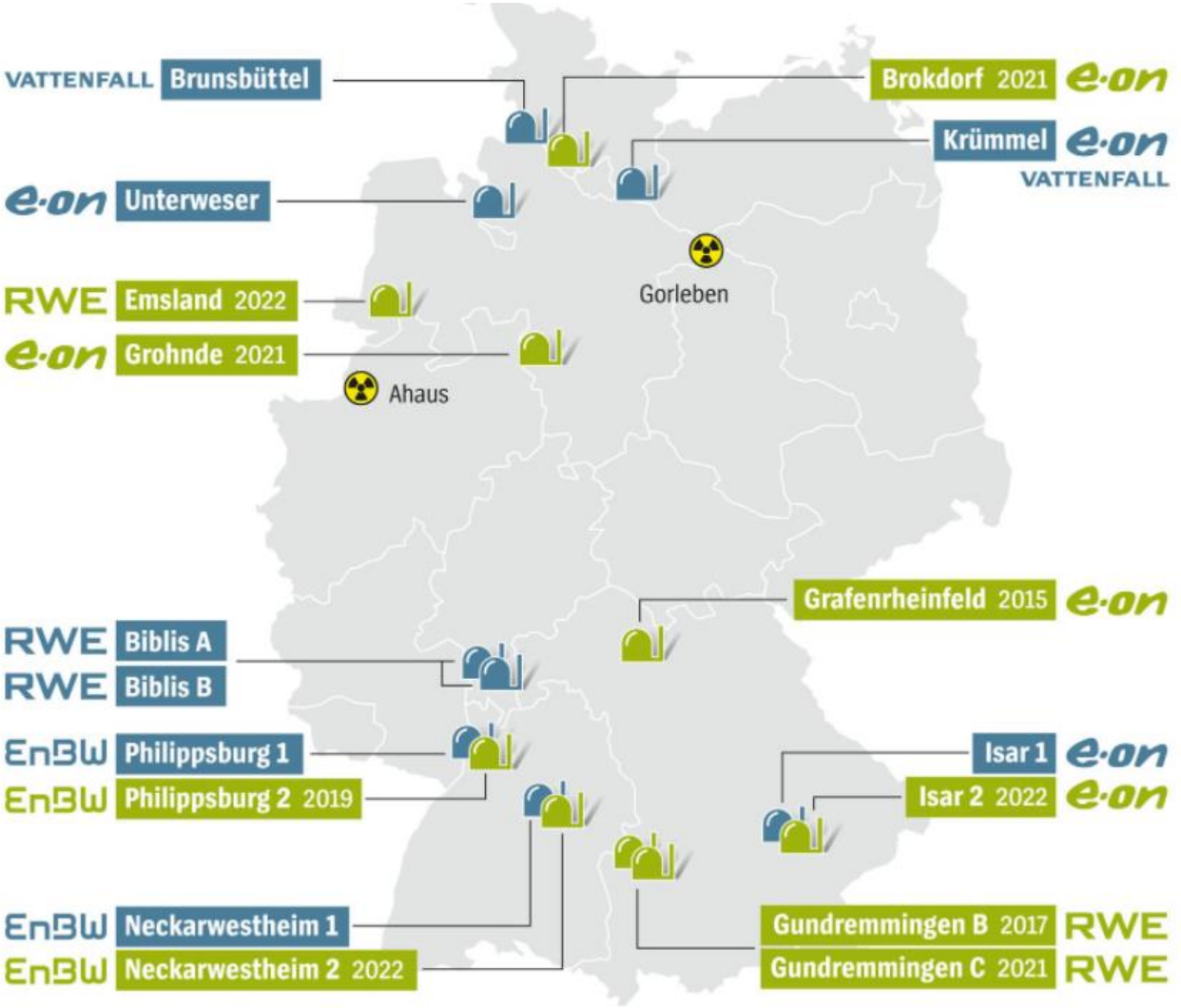
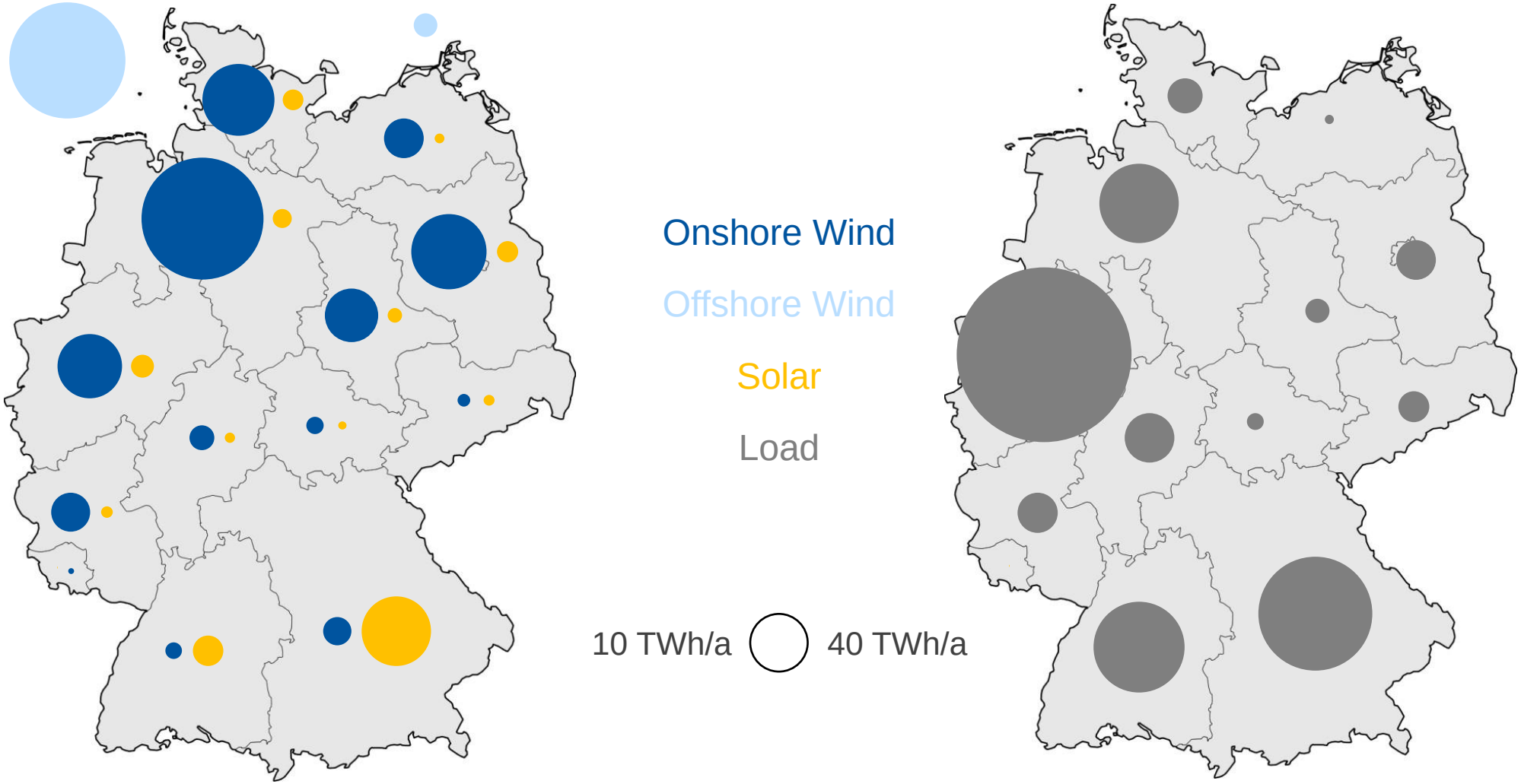
German Energy Transition – Nuclear Phase-Out



Decommissioned 2011

Source: Der Spiegel

German Energy Transition – Distribution of RES and Load



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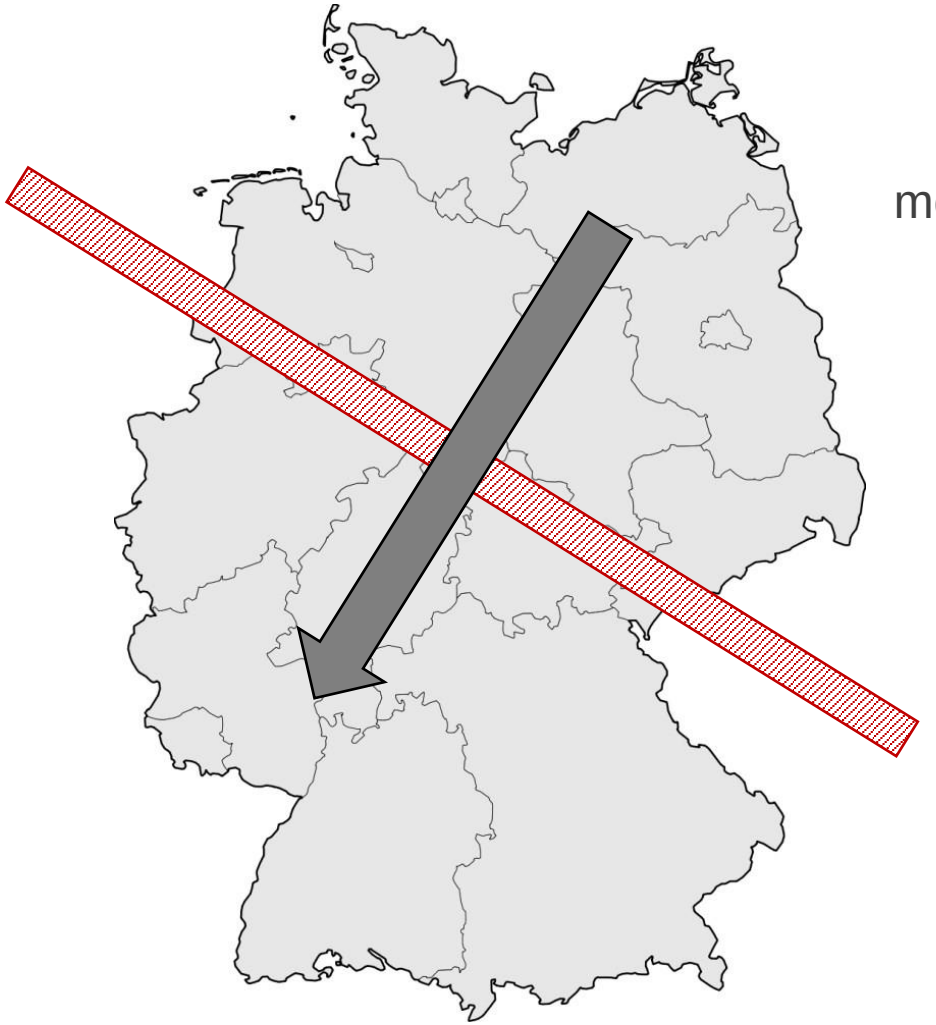
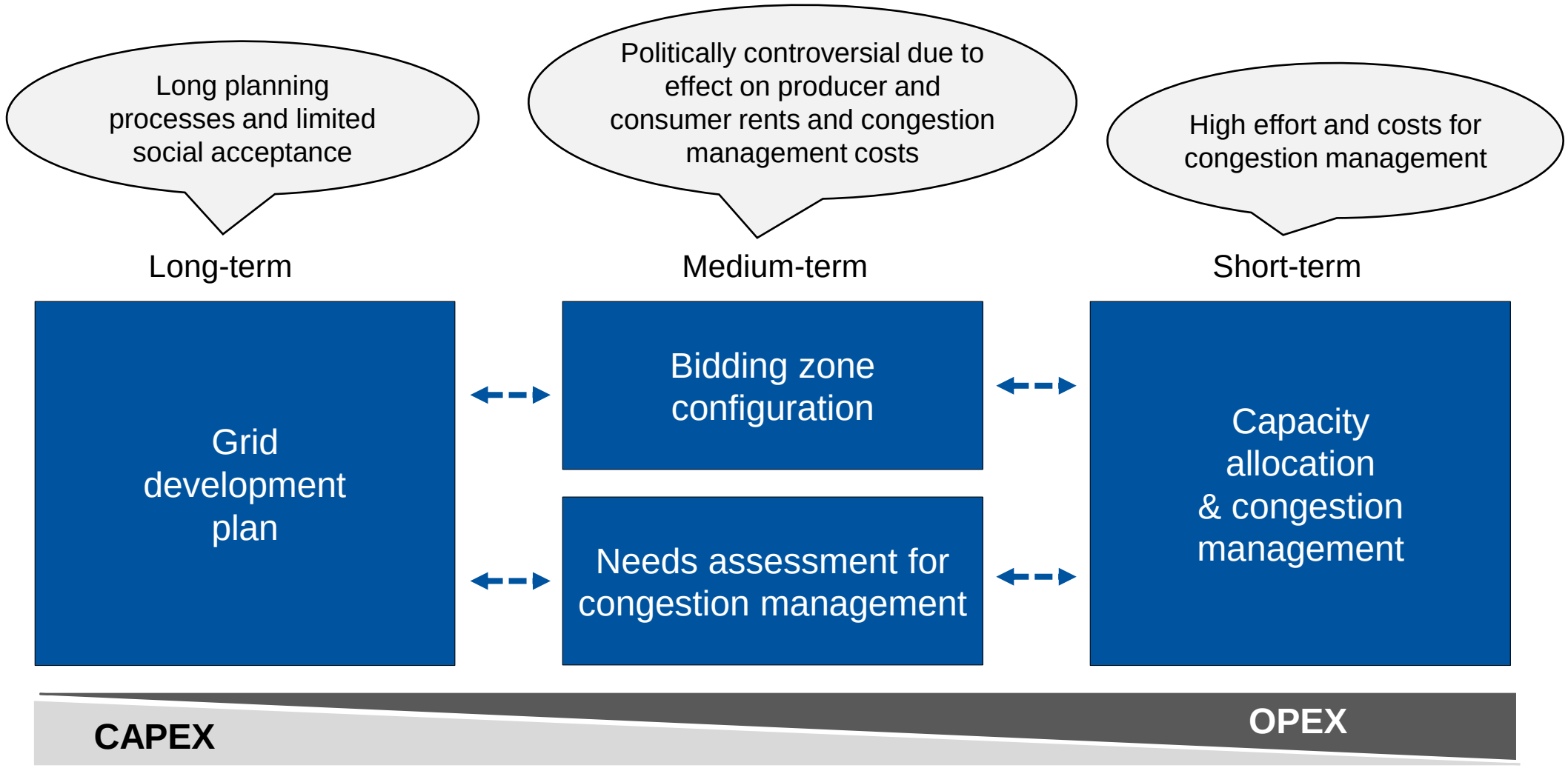
German Energy Transition – Increasing Transmission Requirements from North to South



more RES

more Load

German Energy Transition – Regulatory Framework for Transmission Capacities



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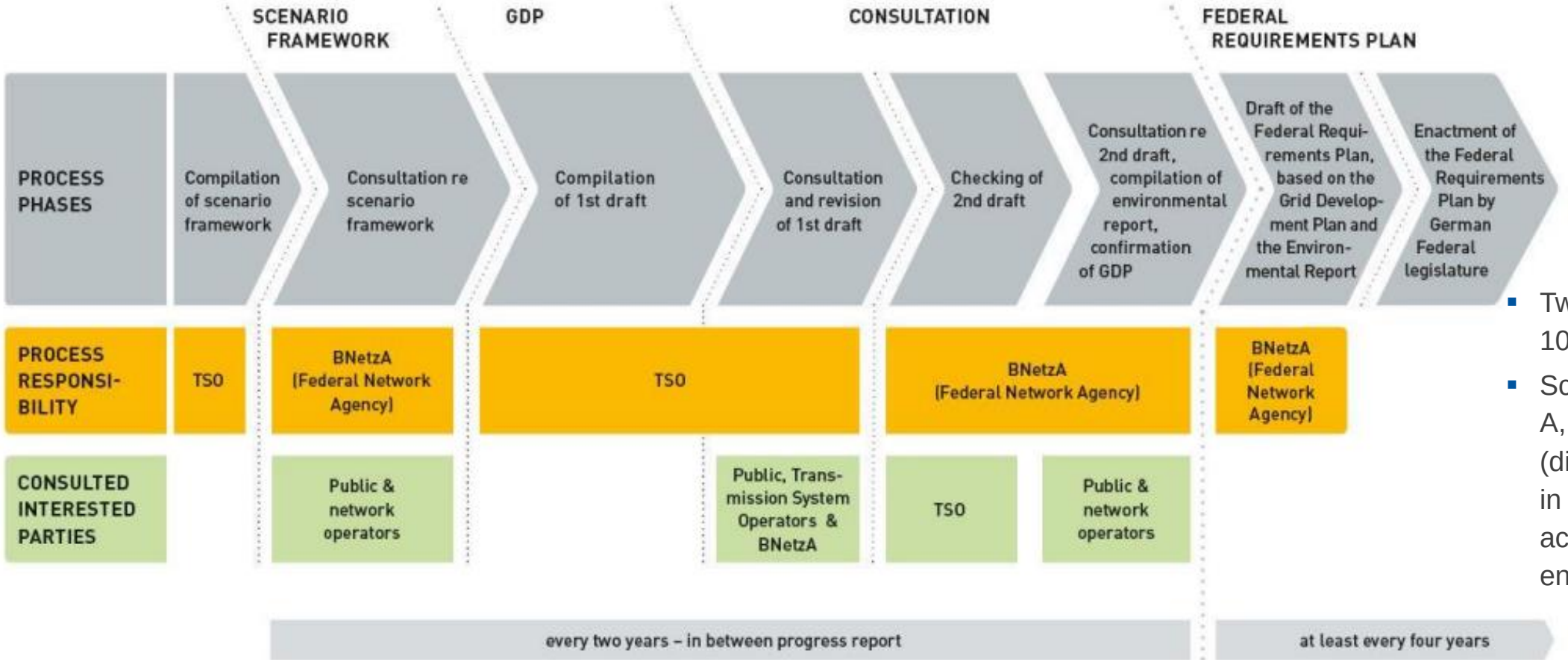
German Grid Development Plan – Process Overview



- Two time horizon: 10 & 15 years
- Scenarios: A, B and C (different advances in energy transition according national energy policy)

Source: German TSOs

German Grid Development Plan – Scenario Framework for 2035 (Generation)

Scenario	2019	2035 – A	2035 – B	2035 – C	2040 - A
Conventional generation capacity	100,1 GW	61,2 GW	57,7 GW	62,0 GW	57,4 GW
Wind onshore	53,4 GW	81,5 GW	86,8 GW	90,9 GW	88,8 GW
Wind offshore	7,5 GW	28,0 GW	30,0 GW	34,0 GW	40,0 GW
Solar	49,0 GW	110,2 GW	117,8 GW	120,1 GW	125,8 GW
Other RES	14,4 GW	13,7 GW	14,4 GW	15,6 GW	15,1 GW

German Grid Development Plan – Scenario Framework for 2035 (Consumption)

Scenario	2019	2035 – A	2035 – B	2035 – C	2040 - A
Heat pumps (housholds)	1,0 Mio.	3,0 Mio.	5,0 Mio.	7,0 Mio.	6,5 Mio.
Power-to-heat (industry)	0,8 GW	4,0 GW	6,0 GW	8,0 GW	7,0 GW
Power-to-gas	< 0,1 GW	3,5 GW	5,5 GW	8,5 GW	10,5 GW
Batteries (home)	0,6 GW	11,0 GW	14,1 GW	16,8 GW	14,9 GW
Batteries (large-scale)	0,4 GW	3,6 GW	3,8 GW	3,8 GW	3,8 GW
Net electricity consumption	524,3 TWh/a	603,4 TWh/a	621,5 TWh/a	651,5 TWh/a	653,2 TWh/a

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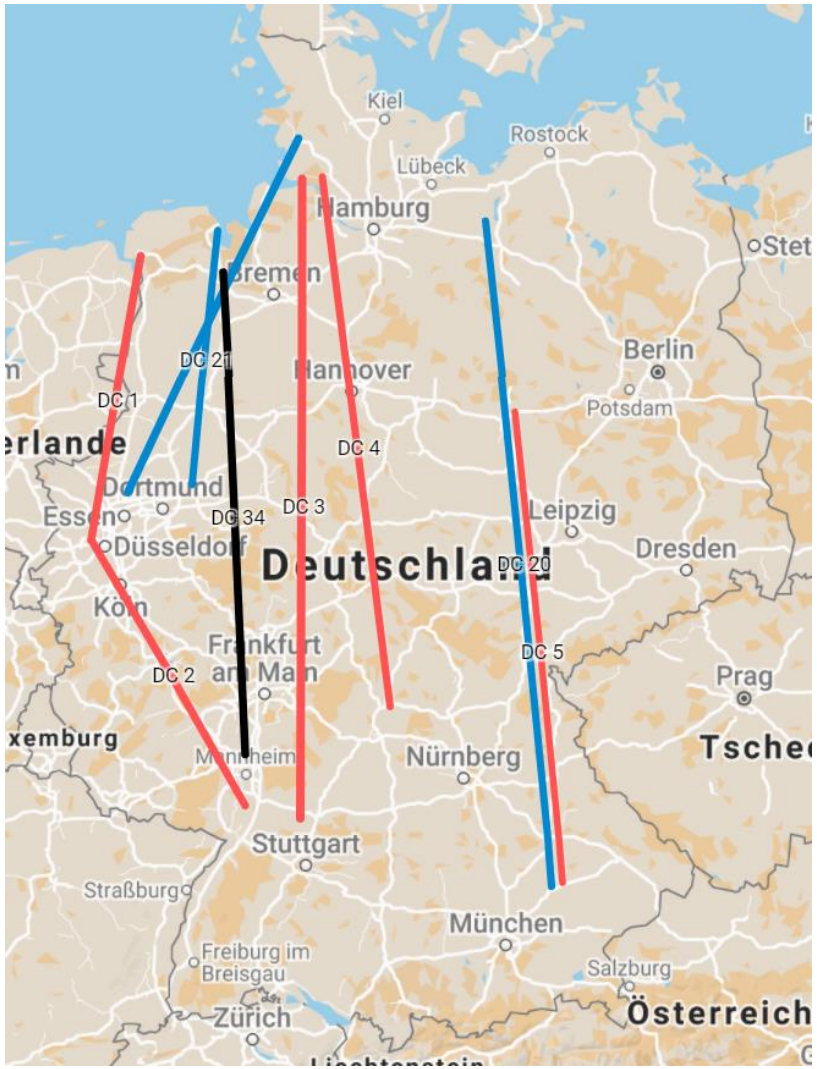
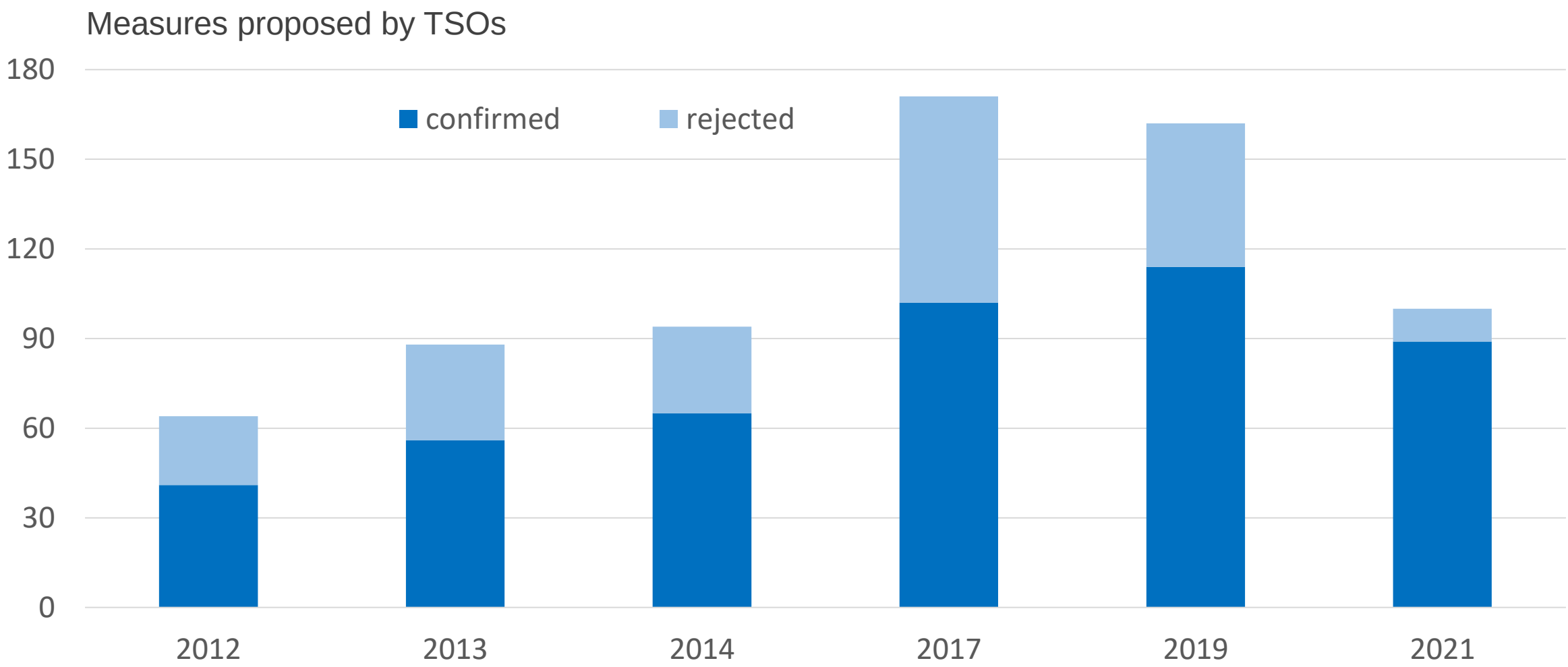
German Grid Development Plan – HVDC Lines

- 8 HVDC lines serve as backbone for grid extension
  - 2 GW transmission capacity each
  - 4 planned for 2022 (red)
  - 3 planned for 2030 (blue)
  - 1 planned for 2035 (black)
- Current status of German grid development plan
  - New lines (AC): 450 km
  - New lines (DC): 1.950 km
  - Upgraded lines (AC): 3.400 km
  - + lines already at least in planning approval procedure (AC, DC): ca. 5.000 km



German Grid Development Plan – Approval Practice of Federal Network Agency



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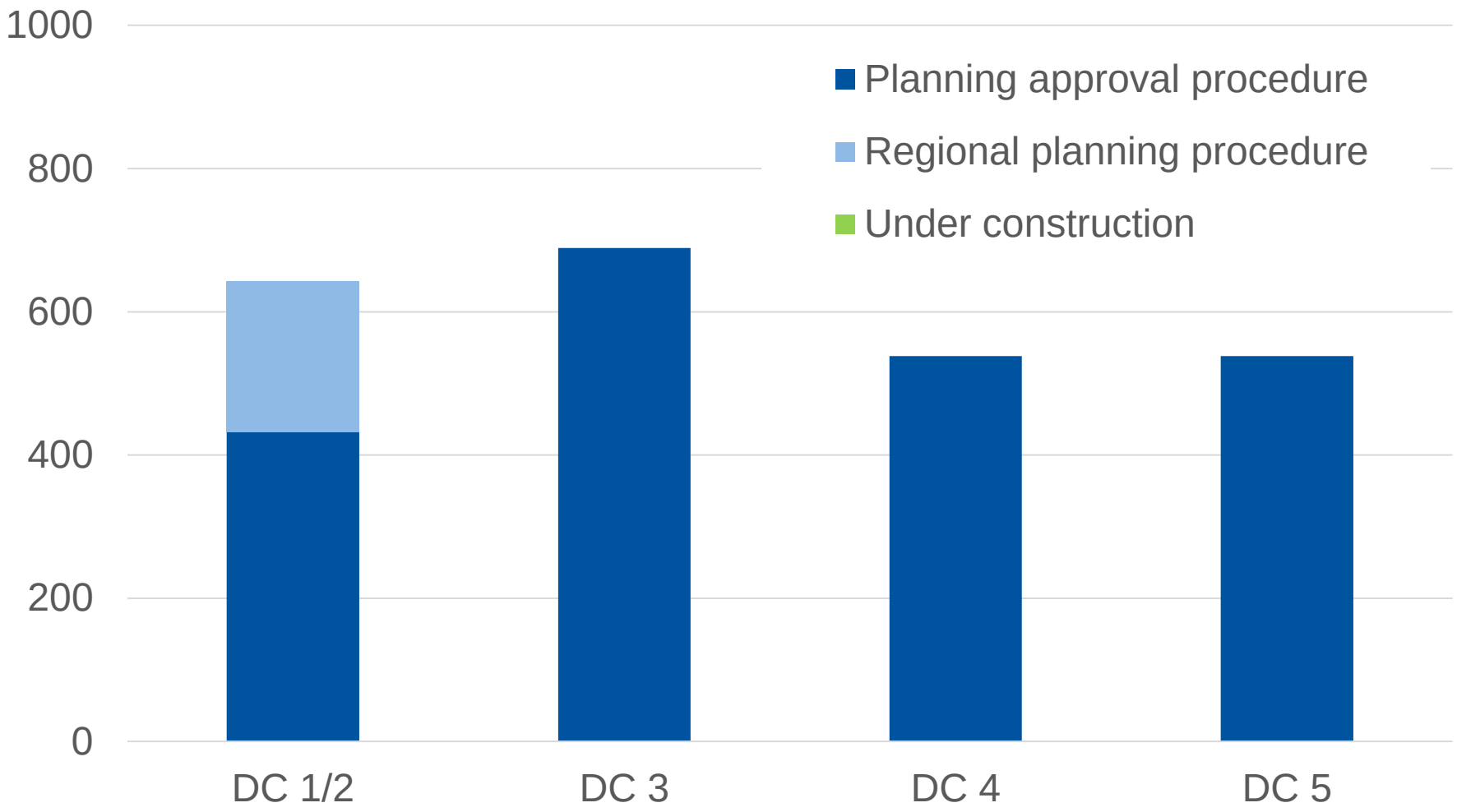
German Grid Development Plan – Implementation Delays



Delays for HVDC lines

- DC 1: 2022 → 2025
- DC 2: 2022 → 2024
- DC 3: 2022 → 2026
- DC 4: 2022 → 2026
- DC 5: 2022 → 2025

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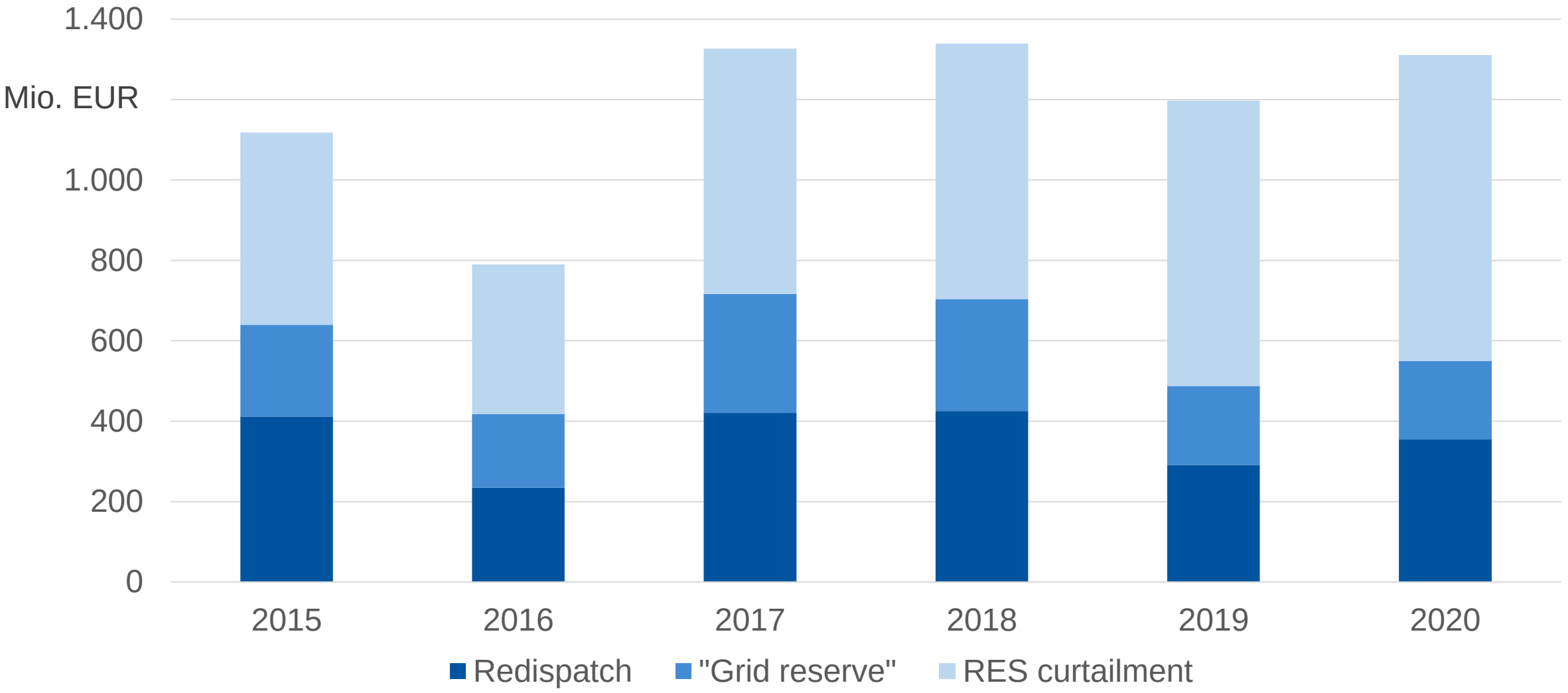
Congestion Management in Germany – High Costs



Congestion Management in Germany – Overview

Remedial actions already used or planned for congestion management

- „Grid reserve“: Power plants outside the market, for redispatch purpose only
- Dynamic line rating
- Redispatch 2.0: Integration of RES into redispatch
- Phase shifting transformers (PST): load flow control
- Thyristor-controlled series capacitor (TCSC): load flow control
- „Special network equipment“: New power plants, for the purpose of curative remedial actions only
- „Grid booster“: Large-scale battery storage, for the purpose of curative remedial actions only

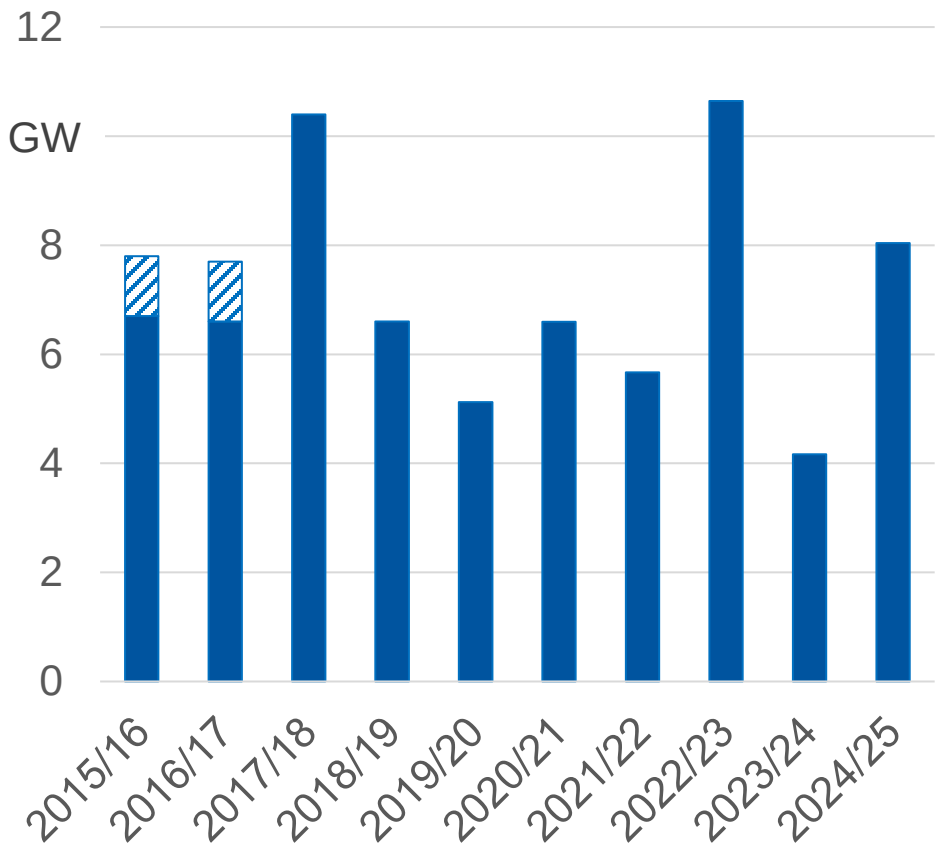
Possible other options

- Static synchronous series compensator (SSSC): load flow control
- Unified power flow controller (UPFC): load flow control
- Curative redispatch

Congestion Management in Germany – “Grid Reserve”

- Prohibition of decommissioning for system-relevant power plants
- Transfer into “grid reserve”
- Additionally, contracts with foreign power plants, e.g. in Austria, as part of “grid reserve”
- Use as remedial action for congestion management
- Financing via network fees

„Grid Reserve“



„Grid Reserve“ in 2021/22

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Congestion Management in Germany – Redispatch 2.0

Merit order for remedial actions at redispatch 1.0

1. Grid related measures (topology changes, PST, …)
2. Redispatch of conventional power plants (> 10 MW)
3. Activation of „grid reserve“
4. Curtailment for RES (> 100 kW)

Merit order of remedial actions at redispatch 2.0

1. Grid related measures (topology changes, PST, …)
2. Redispatch of conventional power plants and RES (> 100 kW)
3. Activation of „grid reserve“

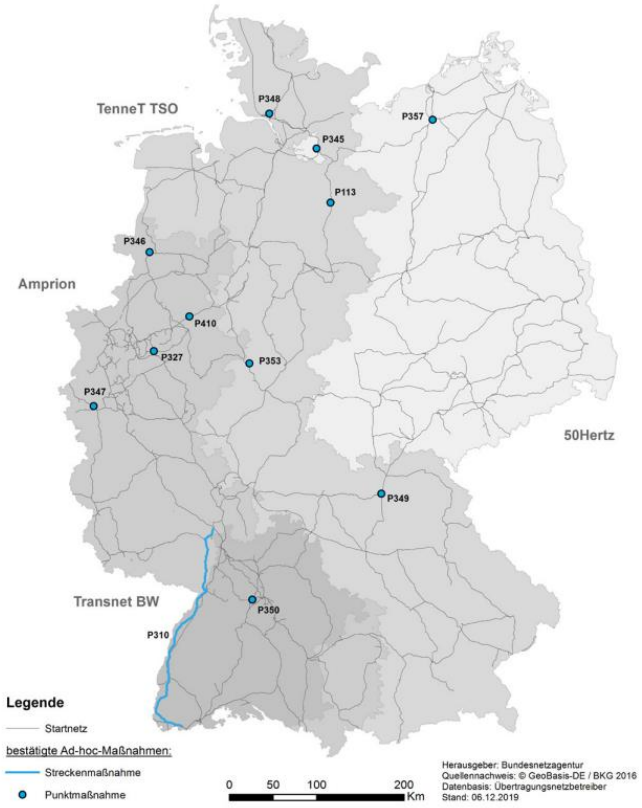
Major changes

- Former curtailment of RES is now integrated into redispatch procedure for conventional power plants.
- DSOs also included in redispatch process.
- TSOs and DSOs demanding redispatch are in charge of balancing.
- Priority feed-in of RES cancelled, instead minimum factors specify how much better the curtailment of RES must generally work compared to the curtailment of conventional generation
- Central IT platform (connect+) for data exchange between TSOs, DSOs, power plants, RES and BRP

Congestion Management in Germany – Future Load Flow Control

- Load flow control devices as ad-hoc measures
  - 7 phase shifting transformers in grid development plan 2017
  - 1 thyristor-controlled series capacitor in grid development plan 2017
  - 3 phase shifting transformers in grid development plan 2019
- Fast load flow control devices for curative remedial actions
  - 4 „Special network equipment“ with a total capacity of 1.2 GW
  - 3 “Grid booster” with a capacity of 0,45 GW in grid development plan 2019

“PST & TCSC”



“Grid Booster” &
“Special Network Equipment”

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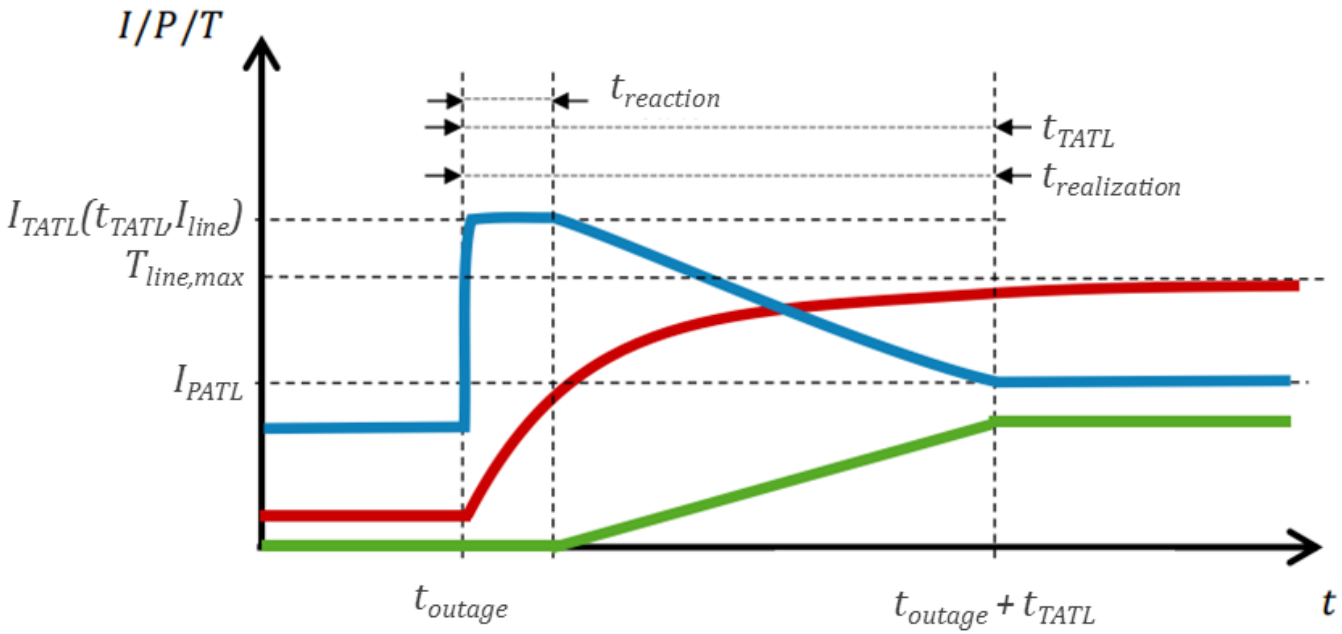
Congestion Management in Germany – Curative Remedial Actions

- Up to now, (n-1) security has been considered as preventive remedial actions within congestion management.
- Application of curative remedial actions to reduce redispatch volumes
  - Only in the event of an actual outage, fast activation ($t_{reaction}$) of curative remedial actions is taken
  - Utilization of thermal reserves of overhead lines
    (TATL, temporary admissible transmission loading, vs. PATL, permanent admissible transmission loading)



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Study on SSC – Introduction

Objective of the Study

- Modelling of SSSC to determine advantages of SSSC as power flow control in German grid operation

Simulation Framework

- Market and grid model parameterization for future scenarios
- Accurate modelling of SSSC for the integration in an OPF

Sensitivity Analysis

- Analyze impact of different locations of SSSC in a scenario with delayed grid expansion

Advantages of SSSC

- Flexibilities regarding
  - **short installation times** (Possibility of geographical shifting if necessary)
  - **modularity** of SSSC
- Small **space requirements**
- **Redundancy** in line with (n-1)-criterion given by adding one module

➔ **Use of market and grid simulations to determine the advantages of SSSC as power flow control in German grid operation as well as effects on redispatch and curtailment volumes**

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Study on SSC – Introduction

Scenario Overview

- Decision for the year 2023 as a stressed year for grid security: Nuclear phase-out, HVDC lines not commissioned, planned Ad-Hoc measures

** Network Development Plan

	Reference	Reference - 4 SSSC	Grid Delay	Grid Delay - 4 SSSC	Grid Delay - Locational	Grid Delay - Locational 20%
Year	2023*					
Market	Generation Power Plants: Germany: **BNetzA** list, Remaining: interpolated **MAF 2017** values RES Infeed: Meteorological year 2017 based on **Merra-2** and **ENTSO-E Factsheet 2017** data Combined Heat and Power (CHP) infeed: Must-run restrictions based on 2017's temperatures + **Eurostat** Net Transfer Capacities (NTCs): **ENTSO-E transparency platform** data + ENTSO-E and Nord Pool data Demand: Assumed to be constant to the values of 2017 but within range of MAF values					
Grid Status	NDP** 2017 with known delay		Only BBPlG/ EnLAG measures			
SSSC integration	No	Yes, same locations and dimensioning as PST in NDP 2019	No	Yes, same locations and dimensioning as PST in NDP 2019	New Locations based on grid congestions	Grid Delay Locational Scenario with voltage injection capability increased by 20%

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Study on SSC – Introduction

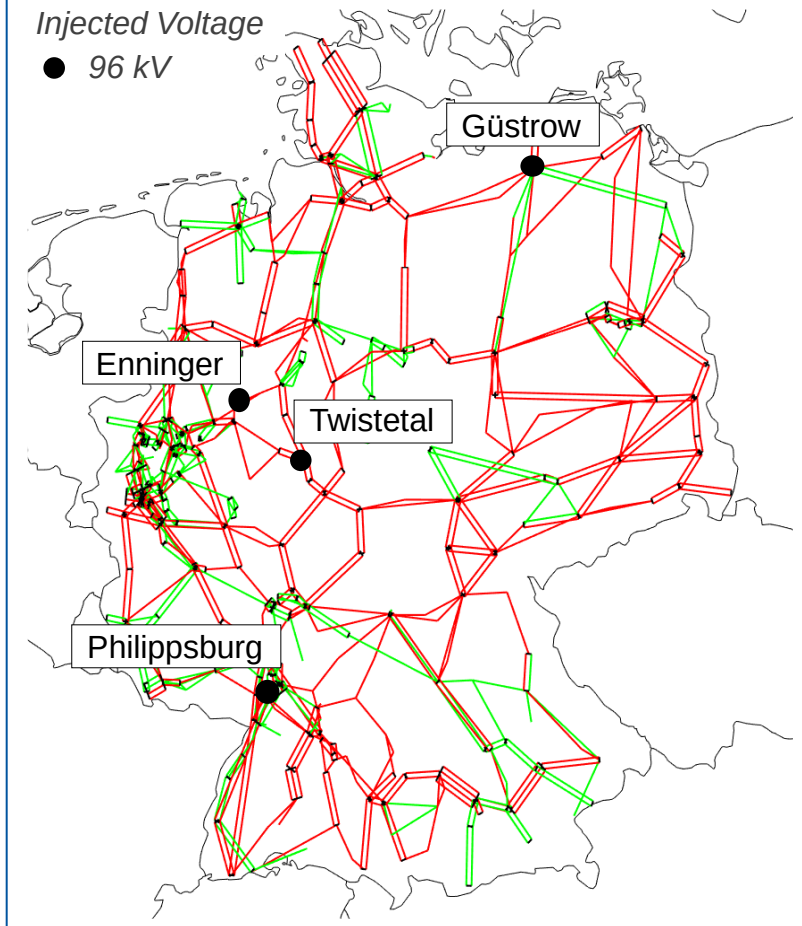
SSSC Parameterization

- Parameters of PST equivalents*
  - Line voltage: 400 kV
  - Line rating: 2750 MVA
  - Degrees of control**: 24°
  - Injected voltage per phase at line rating ~ 96 kV
- Resulting SSSC parameters depend on final deployment configuration and model type

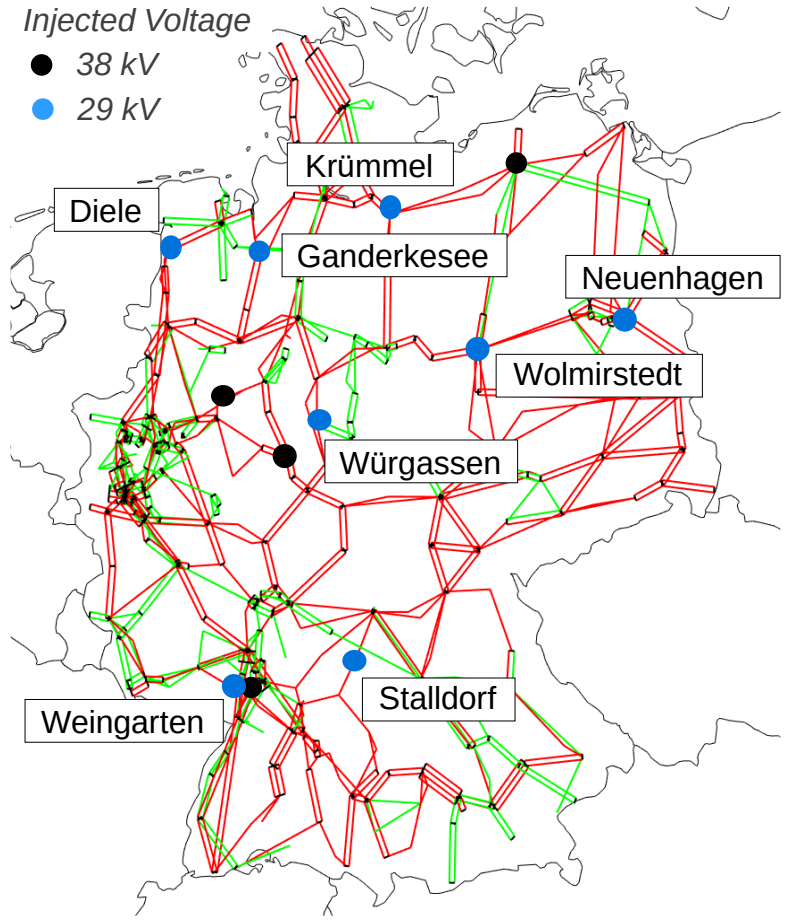
* Dependent on the required rating, PST have to be arranged in parallel

** Based on standard size of PST in Germany

Locations of SSSC - 4 SSSC



Locations of SSSC - Locational



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Study on SSC – Investigation Framework

Toolchain

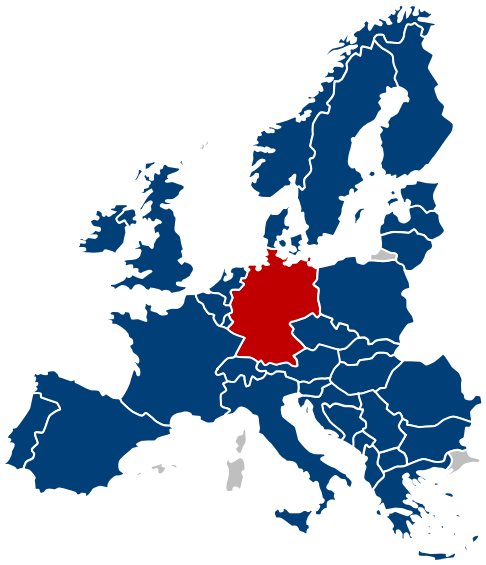
Market Parameters

Grid Parameters

Other Input Parameters

Scenario and Scope

Market Simulation
Grid Simulation



European Market Simulation

Results Market Simulation
Hourly infeed of generation

German Grid Simulation

Results Grid Simulation
Congestion, redispatch, RES curtailment

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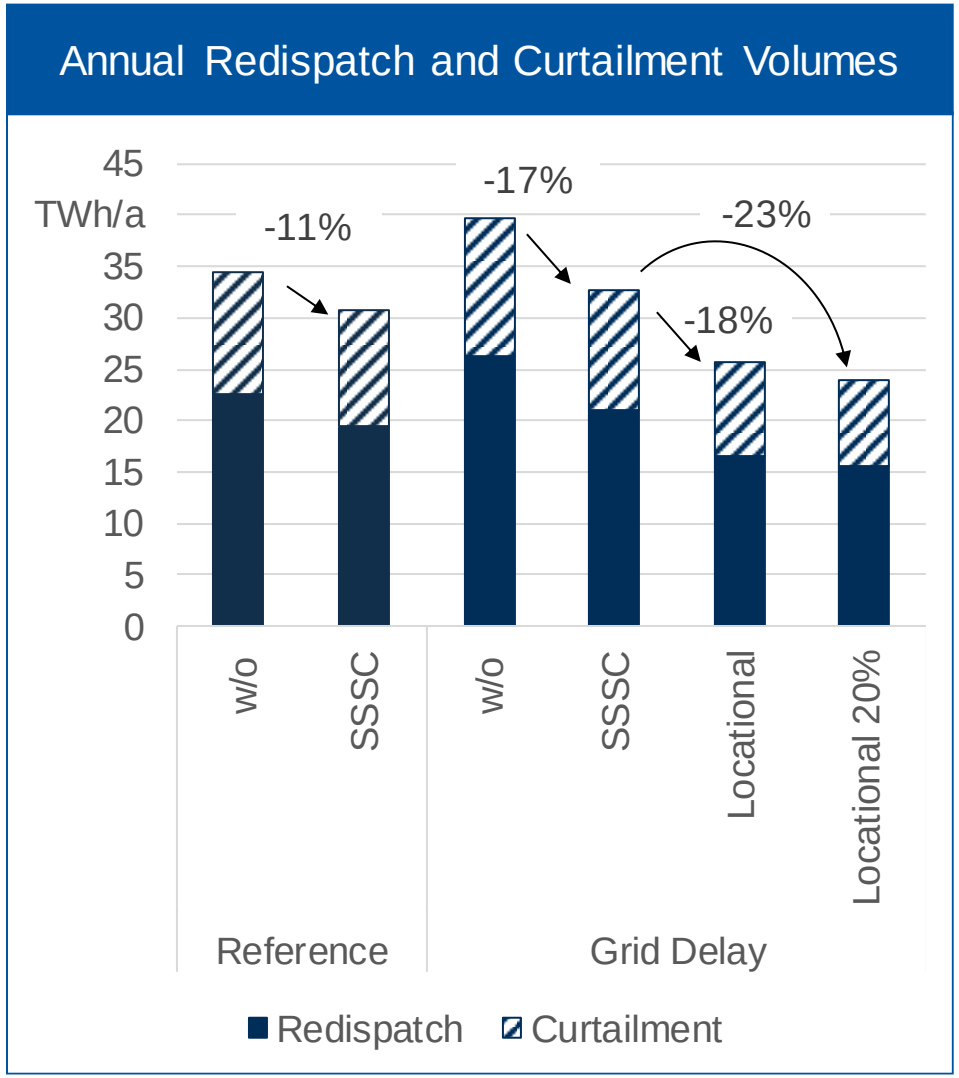
Study on SSC – Key Results

Redispatch and Curtailment Volumes

- Modularity and flexibility in positioning given with SSSC may double the benefit regarding redispatch volumes compared to a PST with same capacity *(comparison of Grid Delay 4 SSSC and Locational sensitivity)*

Further aspects to be investigated in future

- Existing interdependencies between the dimensioning of SSSC and **dynamic line rating** must be considered -
  - Reduced redispatch volumes expected
  - but higher loading of SSSC possible
- Introduction of the **Flow-Based** market simulation in accordance with the Clean Energy Package leads to increased redispatch volumes due to the given **minRAM**
- No consideration of other than **German grid congestions** as well as no consideration of **reactive remedial measures**, which possibly result in lower redispatch volumes
- **Positioning of SSSC** relies on study results and expert knowledge; might be even more beneficial with the usage of a positioning heuristic



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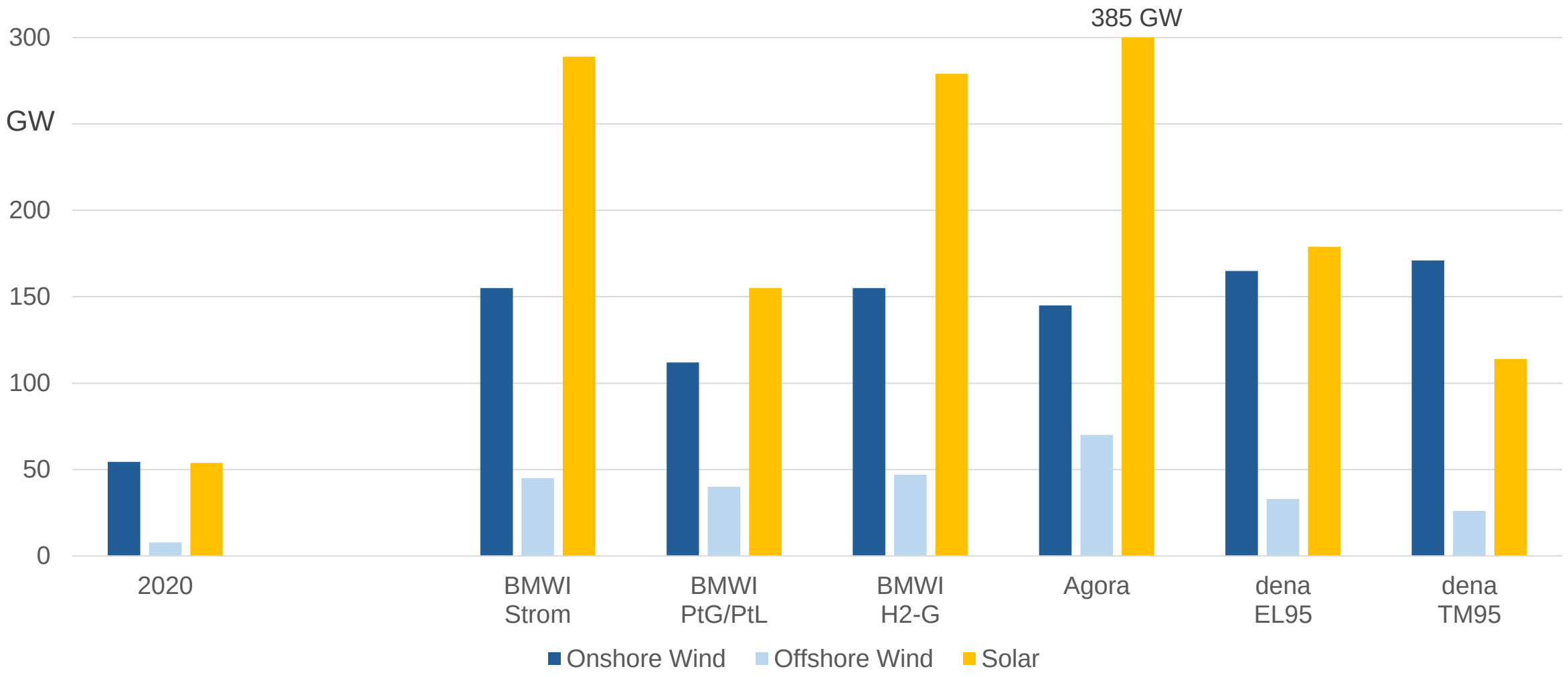
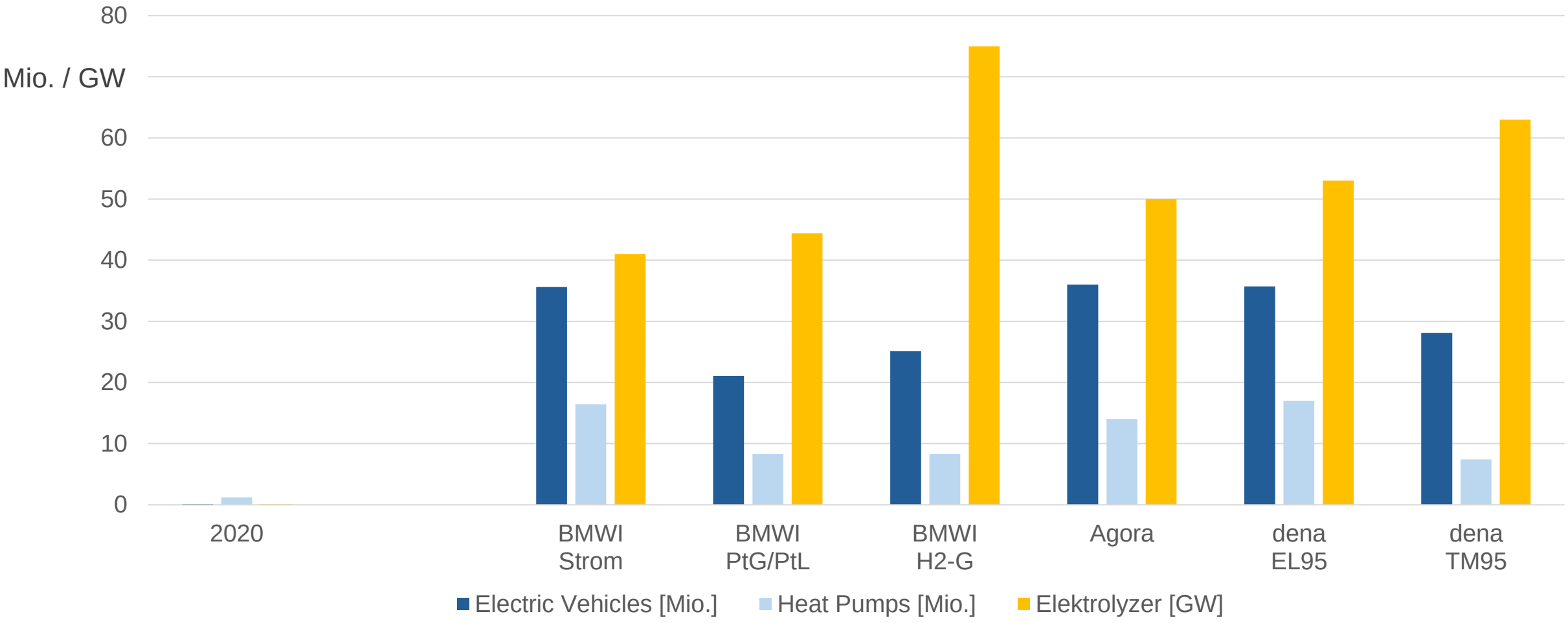
Outlook – Climate-neutral Germany (RES)



Outlook – Climate-neutral Germany (Consumption)



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Thank you for your attention!

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