

SECTOR COUPLING SYSTEM DESIGN TOWARDS CARBON NEUTRALITY AND MARKET CHALLENGES – A GERMAN PERSPECTIVE

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System Development
National and European Grid Planning Processes
AMPRION GMBH

NATIONAL NETWORK DEVELOPMENT PLAN (NDP) LEGISLATIVE FRAMEWORK

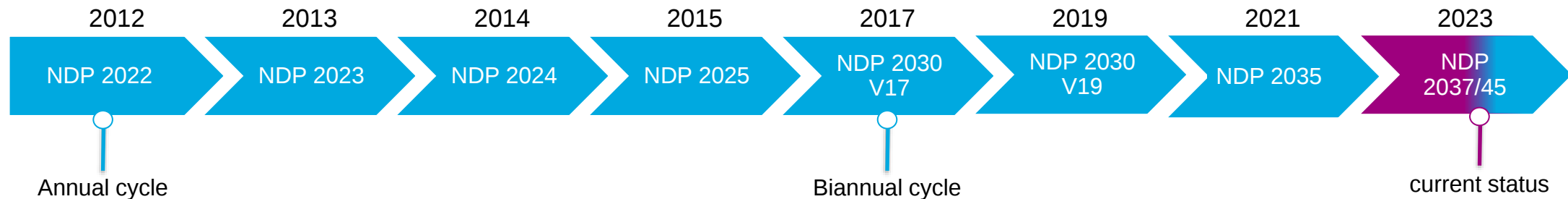
NATIONAL NETWORK DEVELOPMENT PLAN

LEGALLY MANDATED PROCESS SINCE 2012



The Energy Industry Act (§12b I 2 EnWG) requires German Transmission System Operators (TSOs)* to deliver a joint network development plan (NDP) bi-annually.

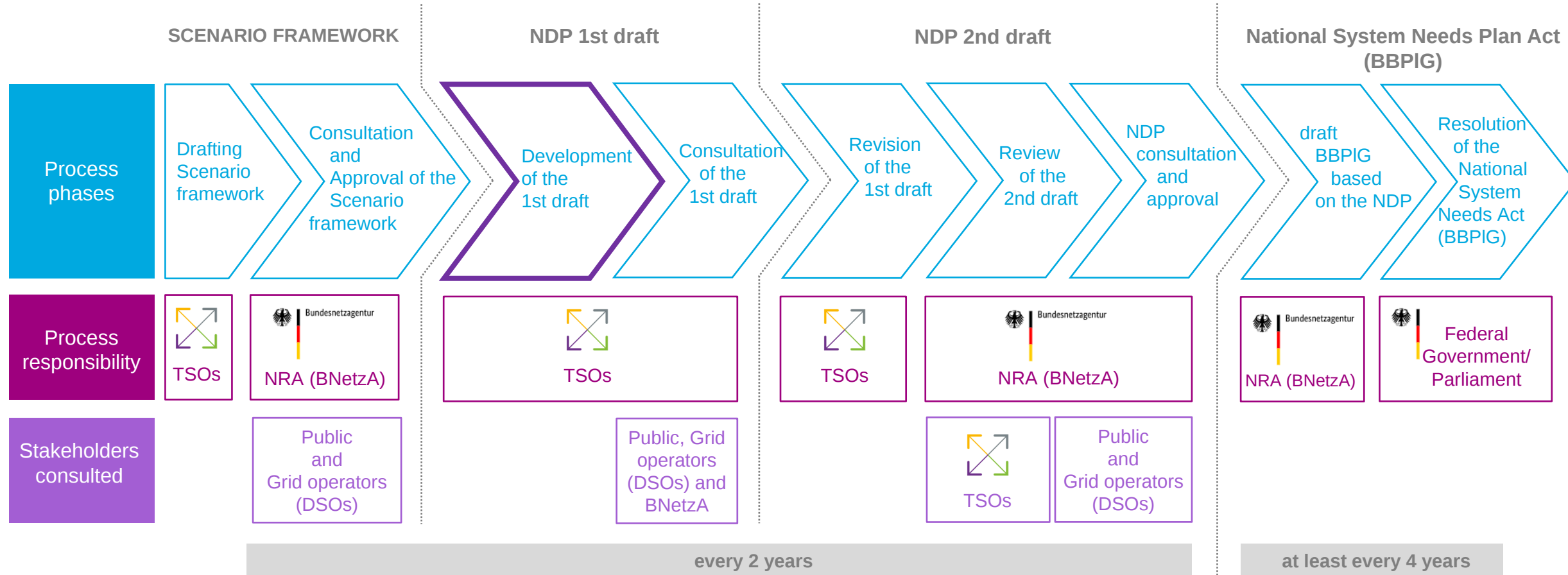
The aim is to identify the need for network expansion and to infer reinforcement and expansion measures, which are then reviewed and approved by the National Regulatory Agency (NRA): Bundesnetzagentur (BNetzA).



* 50Hertz Transmission GmbH 
Amprion GmbH 
TenneT TSO GmbH 
TransnetBW GmbH 

NATIONAL NETWORK DEVELOPMENT PLAN (NDP)

NUMEROUS CONSULTATIONS



THE KEY DRIVERS FOR CARBON-NEUTRALITY IN 2045

- Sector Coupling
- Flexibilities

THE POWER SUPPLY SYSTEM UNDER TRANSFORMATION

Power Supply System 2022

Net Electricity Demand 2021:
~ 550 TWh



Installed RES
Capacity:
140 GW

Installed
Conventional
Capacity:
78 GW

North-to-South
Transport:
25 GW

Maintaining
Security of Supply



Reinforcing and
Extending Grid
Infrastructure



Developing the
Regulatory Framework
further



Financing
Investments



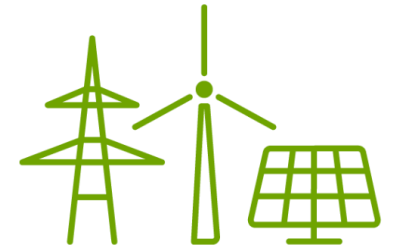
Carbon-neutral Power Supply System 2045

Net Electricity Demand: ~1,100 TWh

Installed RES Capacity:
> 680 GW

Electrolyser
Capacity:
55-80 GW

Small-Scale Battery
Storage Capacity:
~ 100 GW



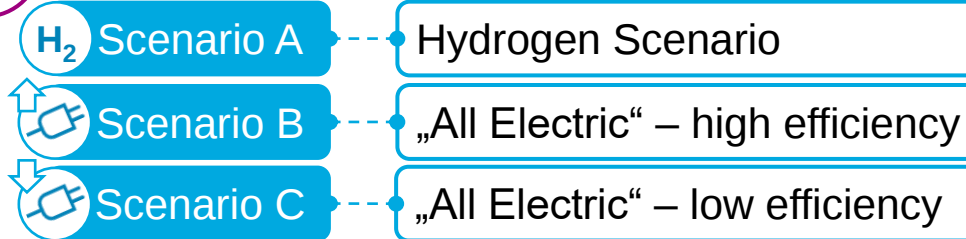
North-to-South
Transport:
> 80 GW

Utility-Scale Battery
Storage Capacity:
43-55 GW

SCENARIO FRAMEWORK SETS OUT THREE DEVELOPMENT PATHS TO ACHIEVE CARBON NEUTRALITY IN 2045

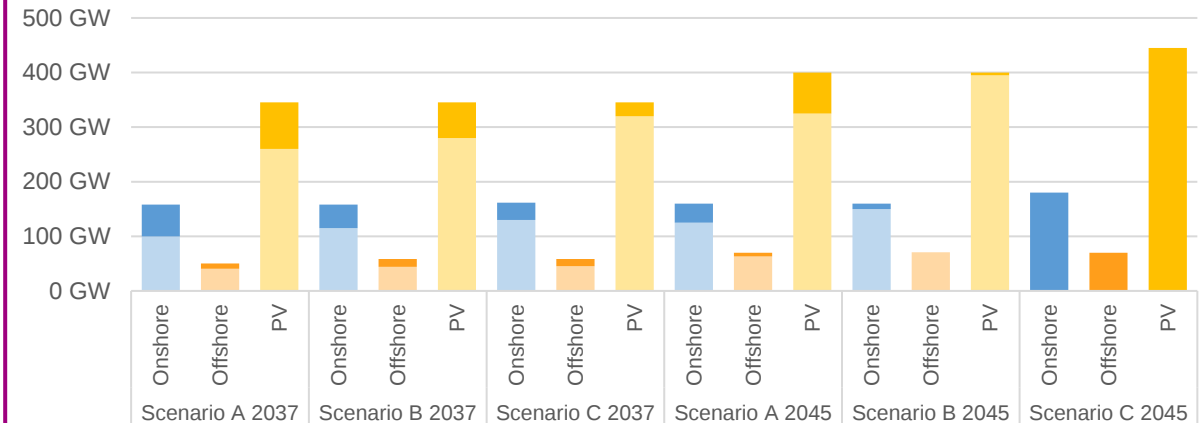


Development paths for 2037 and 2045

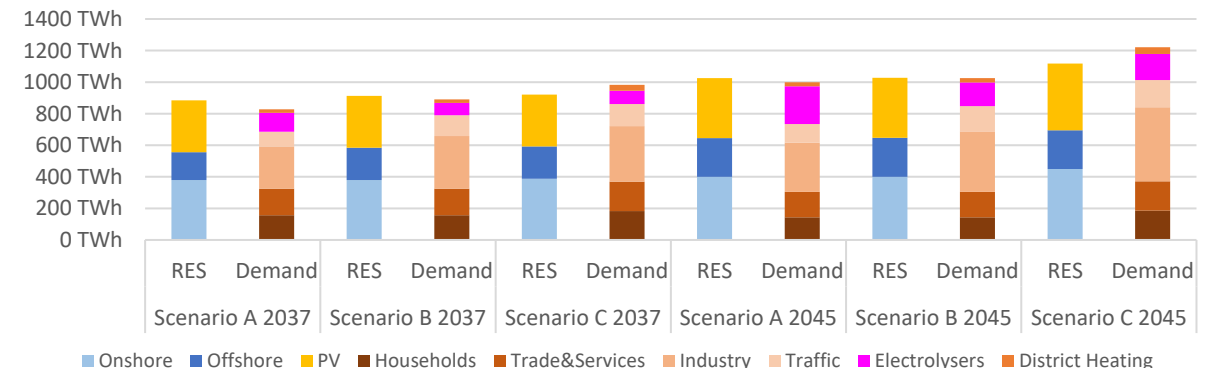


- Assumption of a high degree of energy self-sufficiency
 - Import ratio for hydrogen only 50%
 - Increase in net consumption up to 1200 TWh
- National targets for renewable energy sources (RES) are taken into account
 - RES share of net electricity demand at about 100%
 - Full RES market integration
- Market-oriented operation of new technologies (heat pumps, electric mobility, battery storage, ...) with flexibility of up to 100%.
- Scenario assumptions for other European countries are consistent with ENTSO-E planning products (considered 1.5 °C target)

Installed RES capacities (draft + approval)



RES generation and net electricity demand



UP TO 80(!) GW ELECTROLYSERS IN NDP 2037/45

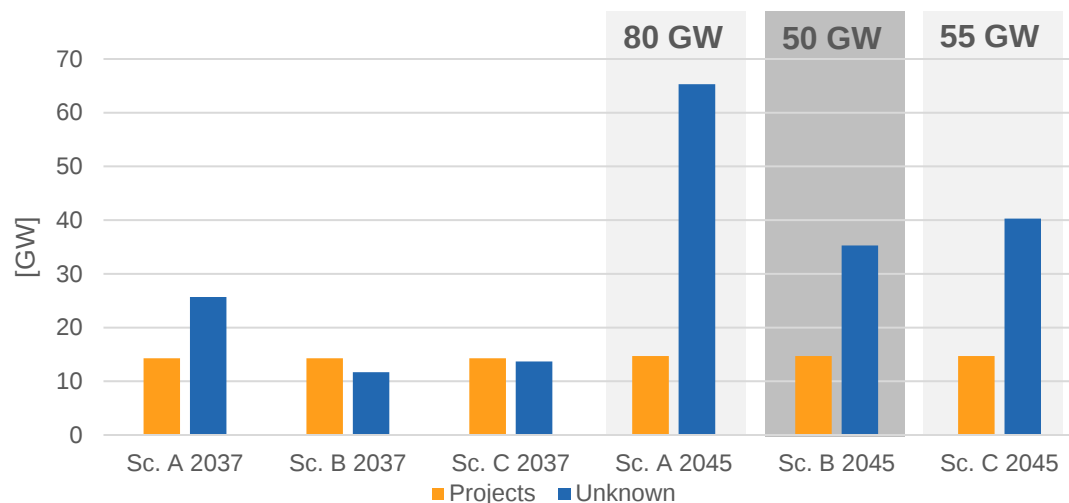
15 GW PROJECTS – 65 GW MAX. LEFT TO ALLOCATE



Production of emission-free hydrogen is one pillar to reach carbon-neutral energy system in 2045

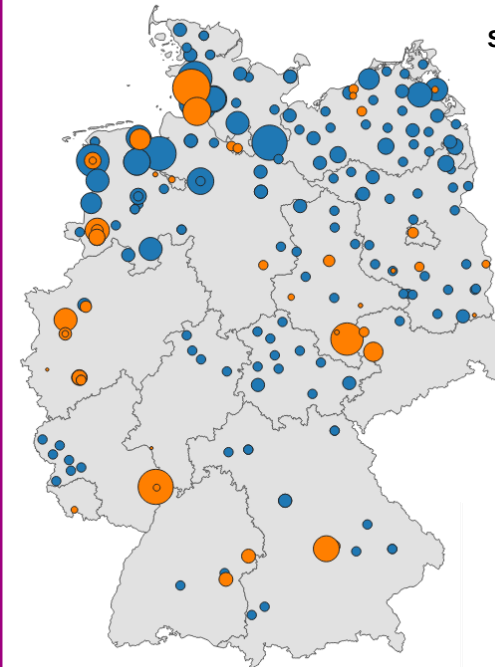
- Projects for up to 15 GW installed capacity already known from industrial partners
- Remaining “gap” to reach scenario target capacity is allocated in a grid-supportive manner
- Power-to-gas production is modelled fully market-oriented

Installed Electrolyser Capacity in NDP 2037/45

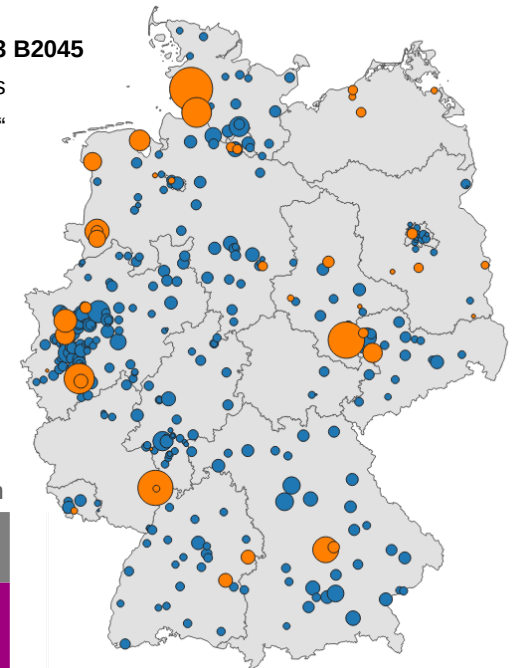


Allocation Methodologies for Electrolysers

Based on residual RES surplus
(methodology applied in NDP 2037/45)

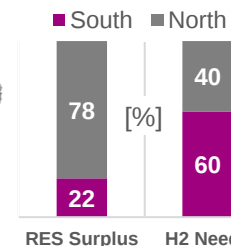


Based on H2-Needs



Scenario NDP23 B2045

Projects
„Offsite“

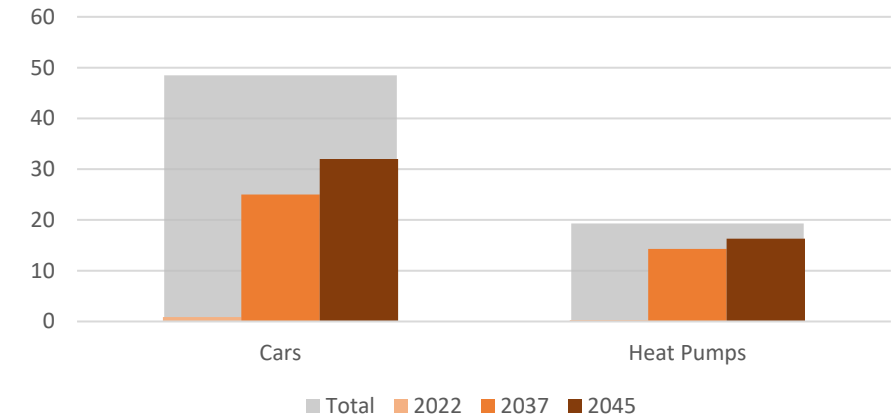


➔ Both allocations methodologies are extreme in regards to the respective characteristics, the actual allocation will most likely lie in between

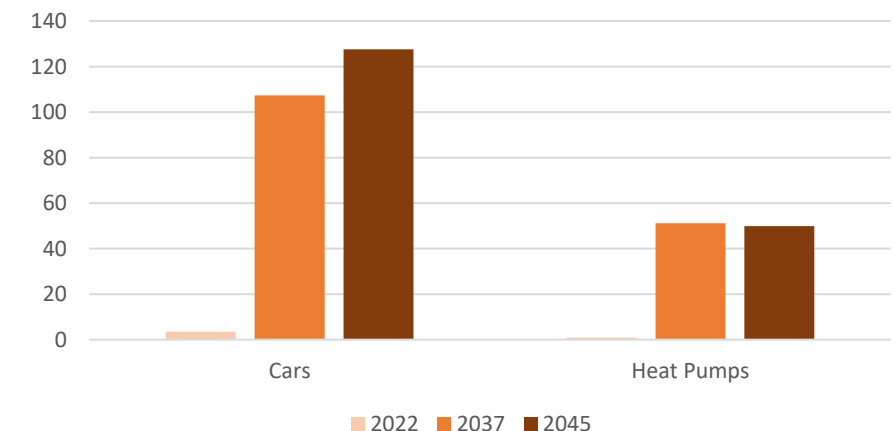
DECENTRALIZED FLEXIBILITY THOROUGH ELECTRIC VEHICLES AND HEAT-PUMPS

- Efforts to decarbonize households mainly focused on electrification
 - Share of electric cars increases up to 67% in 2045 (2% today)
 - Share of residential houses with Heat Pumps increases up to 85% in 2045 (1% today)
- These new electric loads provide a significant potential of flexibility
 - Loading of electric cars can be optimized, based on assumed mobility-patterns
 - Heating can be shifted within a two-hour range to react on electricity prices
 - Up to 100% of these units can be considered as market-oriented

Scenarios B/C: Deployed Units [in Million]

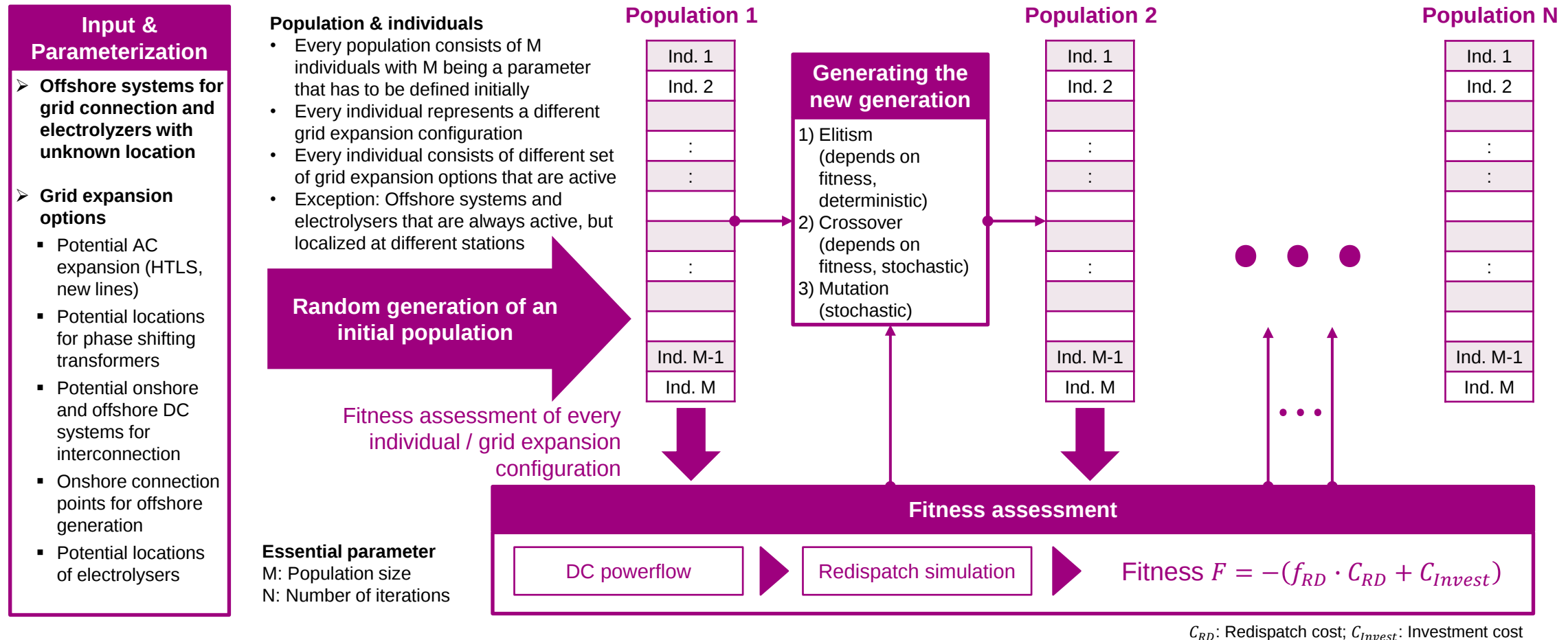


Scenarios B/C: Potential of Flexibility [GW]



NDP 2037/45 – A SELECTION OF RESULTS

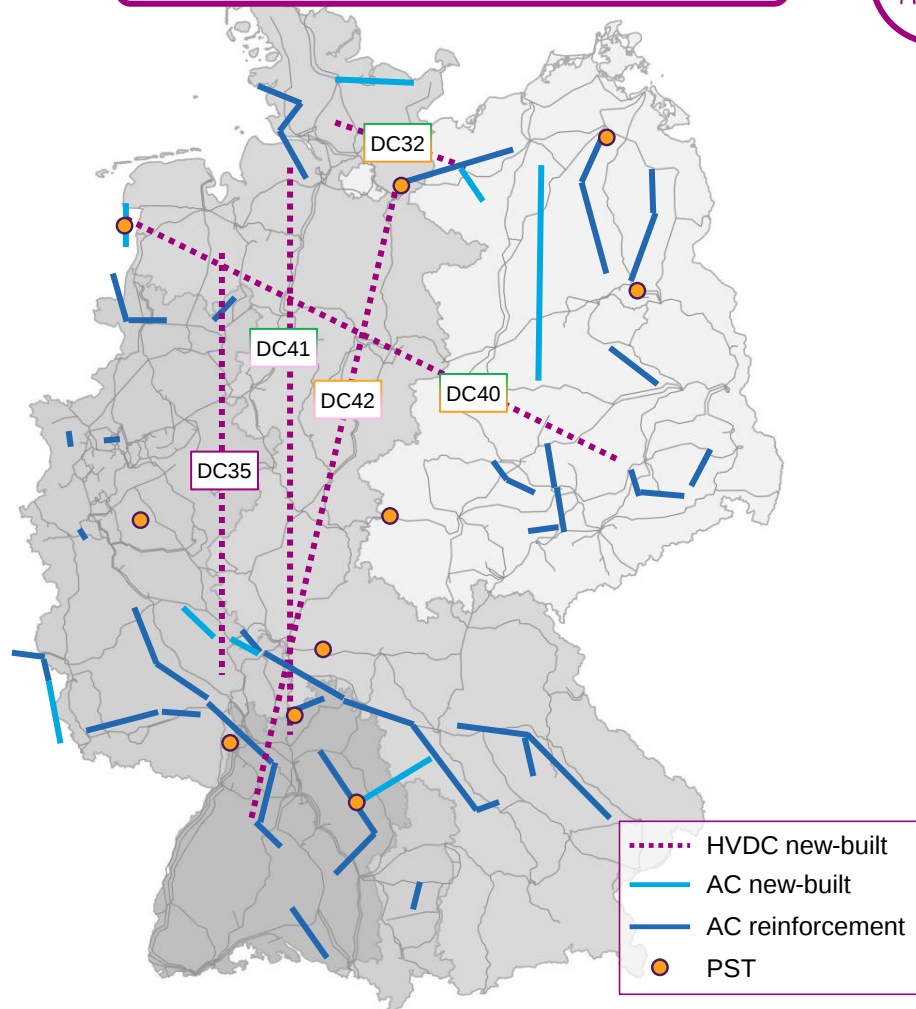
METAHEURISTIC OPTIMISATION OF EXPANSION OPTIONS BASED ON GENETIC ALGORITHM



ONSHORE GRID FOR CARBON-NEUTRALITY

TRANSMISSION SYSTEM GROWS BY MORE THAN 40%

New onshore projects in NDP 2023



- The German TSOs have developed a carbon-neutral energy system in Germany for the first time
- The **target onshore transmission grid** is needed **by 2037** already
- After 2037 additional RES generation is integrated predominantly by
 - power-to-hydrogen sector coupling
 - exploitation of demand-side flexibilities
- Newly identified HVDC-expansion:
 - five new-built HVDC transmission projects (approx. **2,600 km**)
- Newly identified AC-expansion:
 - approx. **1,300 km** new-built AC transmission line projects
 - approx. **3,200 km** AC transmission line reinforcement projects
- Together with projects identified in previous NDPs the **total onshore transmission system expansion** amounts to **> 15,000 km** (35,000 km → > 50,000 km)

EFFICIENT OFFSHORE-WIND INTEGRATION IS CRUCIAL



North Sea

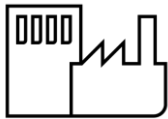
Offshore-wind in 2045

70 GW

installed capacity in Germany

13,300 km

New offshore connection HVDC-lines needed



Connections close to demand centres

reaches from the Rhine-Ruhr region (Düsseldorf, Dortmund, Cologne) to the Rhine-Main region (Frankfurt)

Advantages:

- integration in existing AC-infrastructure
- reduction of generation redispatch
- reduction of AC-power flows and reactive power demand



Interconnection of offshore connections

sea-side DC interconnections

INTERCONNECTION IS A JOINT EUROPEAN INITIATIVE

Advantages:

- redundancy of connections and increased flexibilities
- reduction of onshore grid expansion
- enhanced European market integration



NATIONAL OFFSHORE INTERCONNECTION PROJECTS

NDP 2037/45 IDENTIFIES TWO PROJECTS

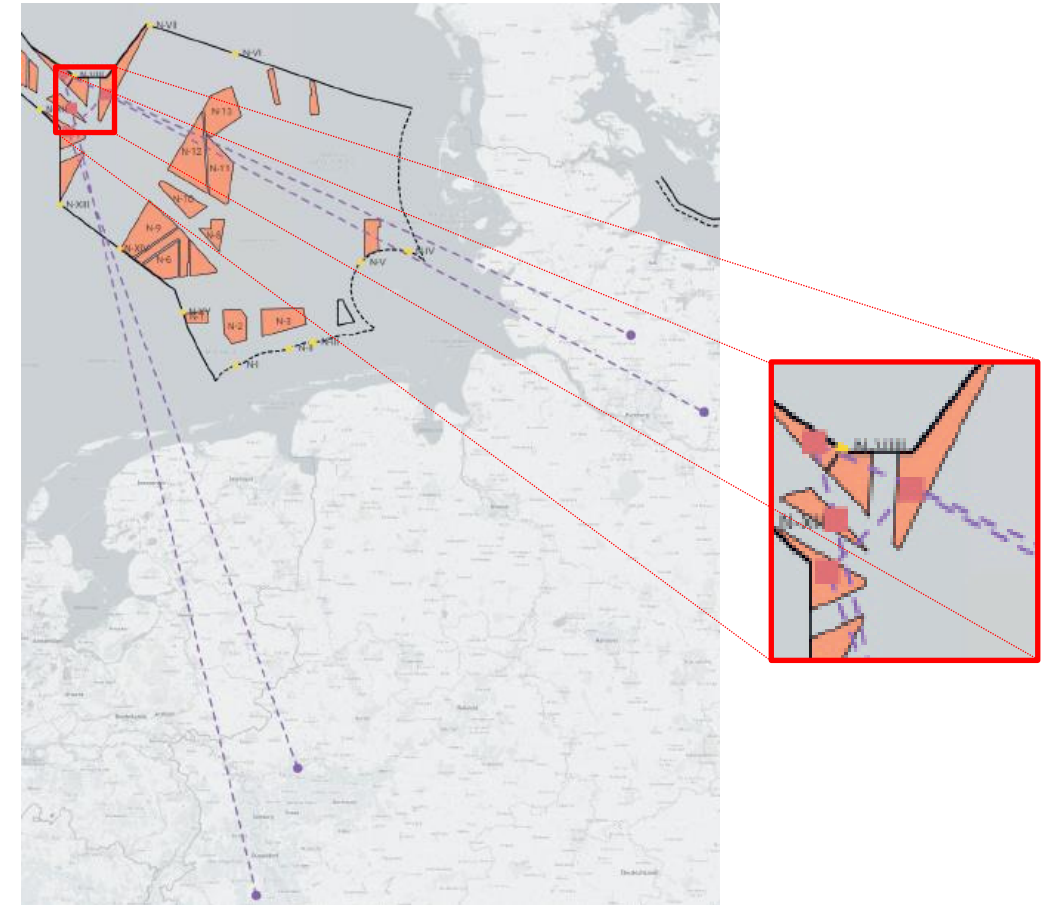
Benefits of national offshore interconnection

- In-depth analysis of national offshore interconnection projects in German NDP 2037/2045
- Results shows positive cost-benefit ratio

Offshore Interconnection Projects	
Length	73 km
CAPEX	1,200 Mio. € (cable: 400 / platform: 800 Mio. €)
Redispatch reduction	98 Mio. € / years → ~ 1,500 Mio. € for 25 years

- Assessment of national offshore interconnection by national regulator until end of 2023
- In case of positive decision: inclusion in national legislation

National Offshore Interconnection Projects



MARKET CHALLENGES FOR A CARBON-NEUTRAL POWER SUPPLY SYSTEM

CHALLENGES OF TRANSFORMATION

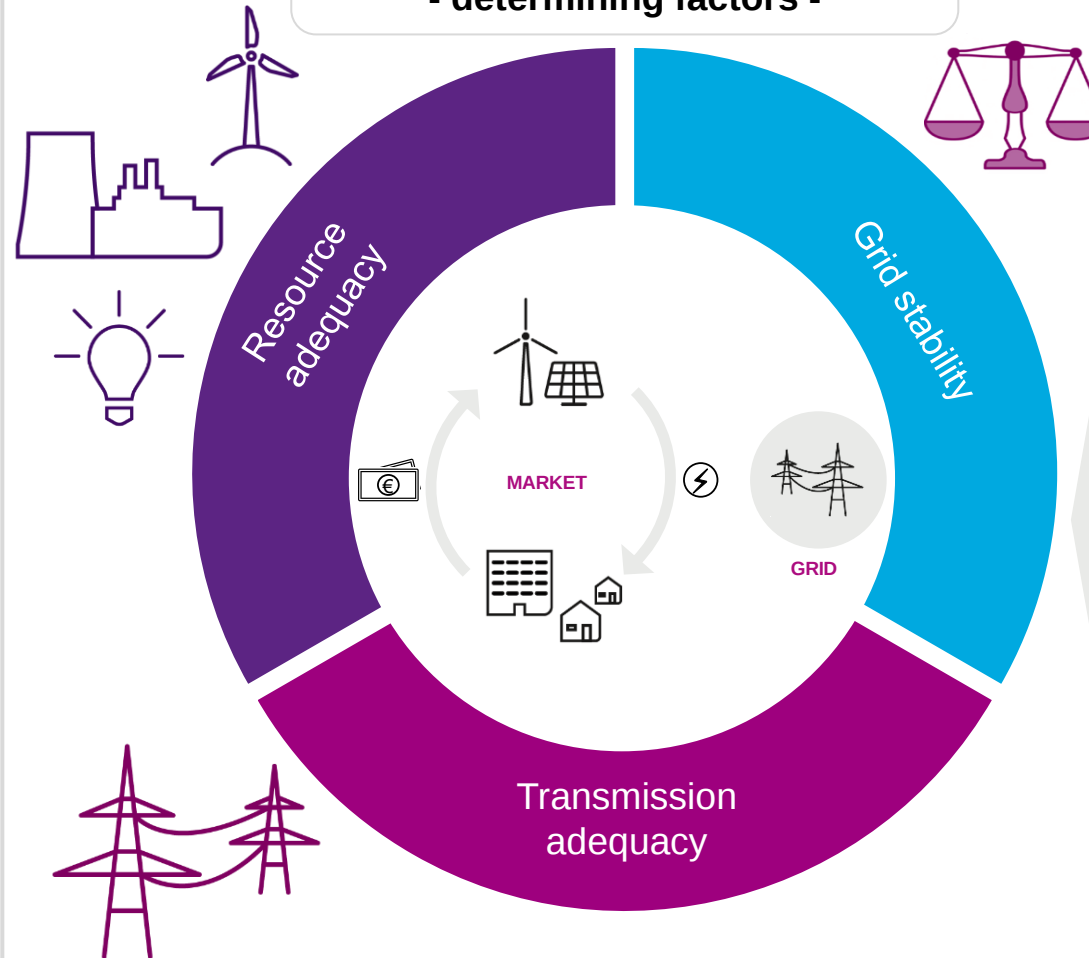
System Security

- challenges -

- Substitution of firm generation capacity by resource-dependent RES generation
- Displacement of synchronous generators by IBRs
- Integration of new equipment
- Increasing power exchanges and higher cross-border capacities
- Higher utilisation of the transmission system
- More volatile and rapidly-changing power flows

Security of Supply

- determining factors -



TSO responsibility

- physical reality -

Transmission of active power

Securing steady-state voltage stability (reactive power)

Balancing

Securing the provision of grid inertia

Dynamic reactive power control

Securing the provision of short-circuit current

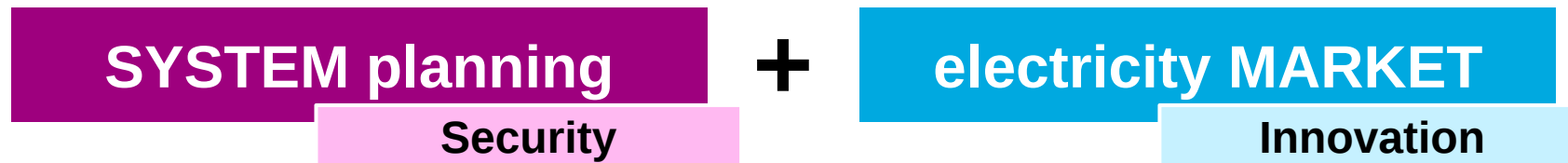
Securing island operation capability

Securing black-start capability

POTENTIAL SOLUTION

A SYSTEM ENGINEERING VIEW ON THE ENERGY SYSTEM

SYSTE(M)ARKET



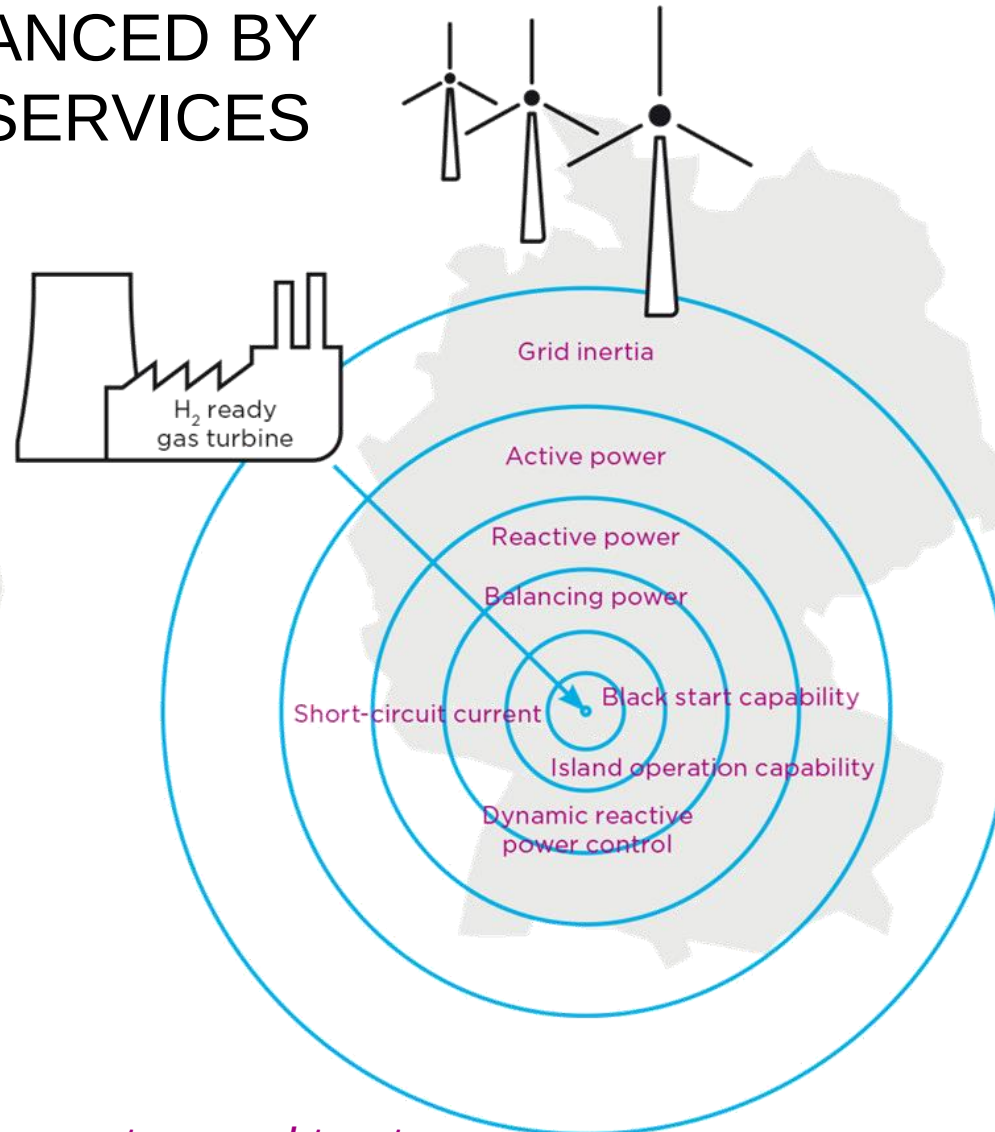
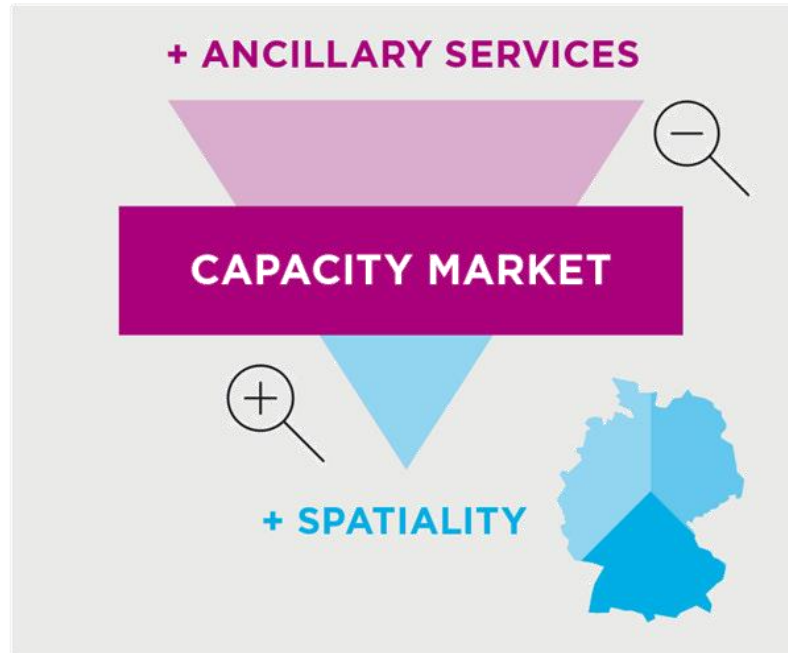
The SYSTE(M)ARKET is designed to ensure resource adequacy and robust system operation in the long term by providing incentives for



This is achieved by the spatially and objectively differentiated long-term remuneration for the provision of the necessary potentials (capacities)

BASIC CONCEPT

A CAPACITY MARKET ENHANCED BY SPATIALITY & ANCILLARY SERVICES



Further information also available at: www.systemmarkt.net

THANK YOU FOR YOUR ATTENTION!

Any questions?