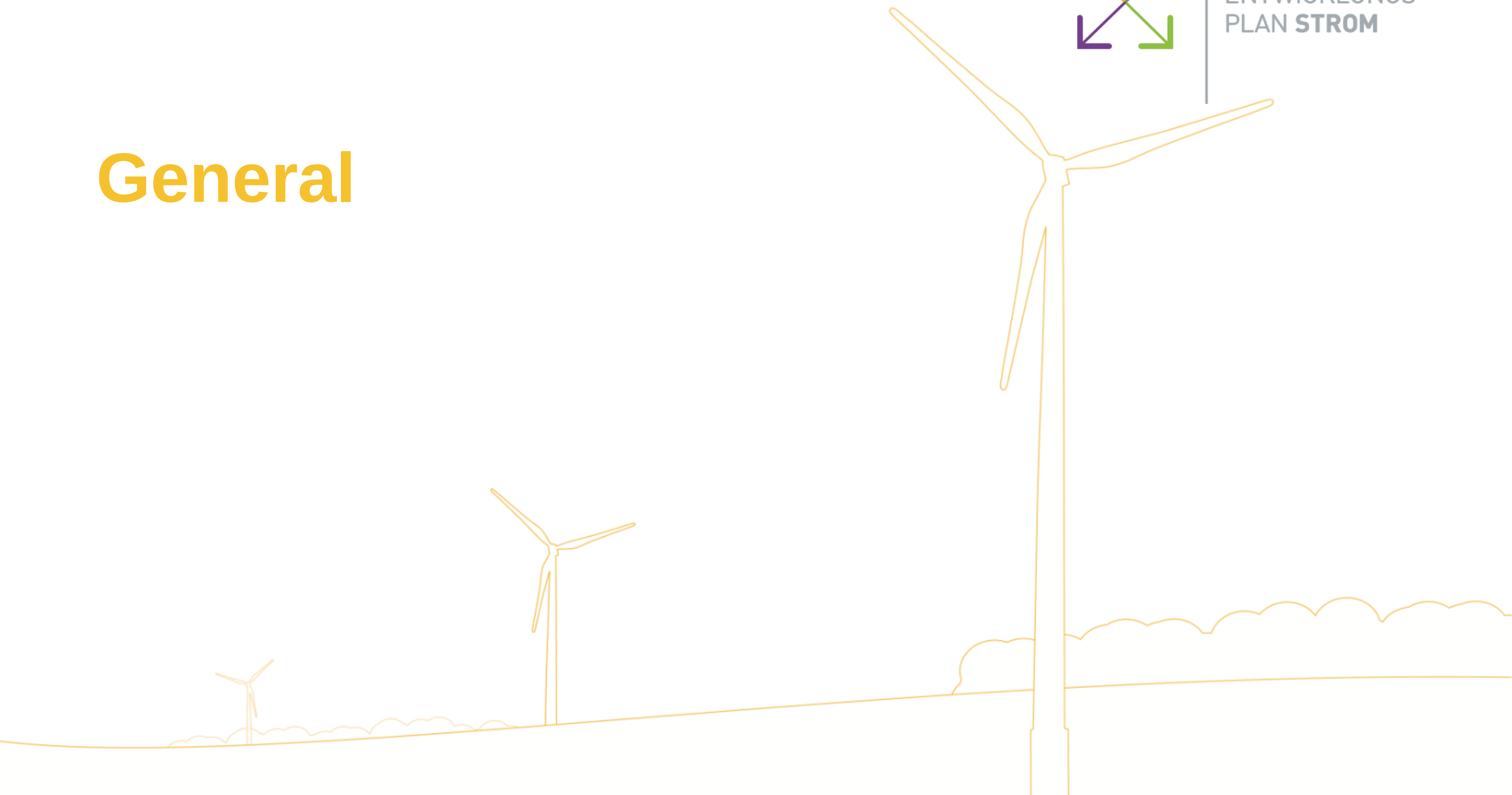
Grid Development Plan 2030 (2019), second draft

General



Grid Development Plan 2030 (2019)

The Grid Development Plan ...

NETZ
ENTWICKLUNGS
PLAN **STROM**

… is the grid development plan for the **onshore transmission grid**.

… constitutes a plan for the **offshore grid connections** together with the FEP and area development plans of the relevant states.

... takes into account the **integration of renewable energy sources** and the **development of the European energy market**.

... describes measures that satisfy both **legal requirements** and the **underlying scenario framework from the Federal Network Agency**.

... highlights **transmission requirements between start and end points** (two grid nodes) – but **does not show specific corridors or routes**.

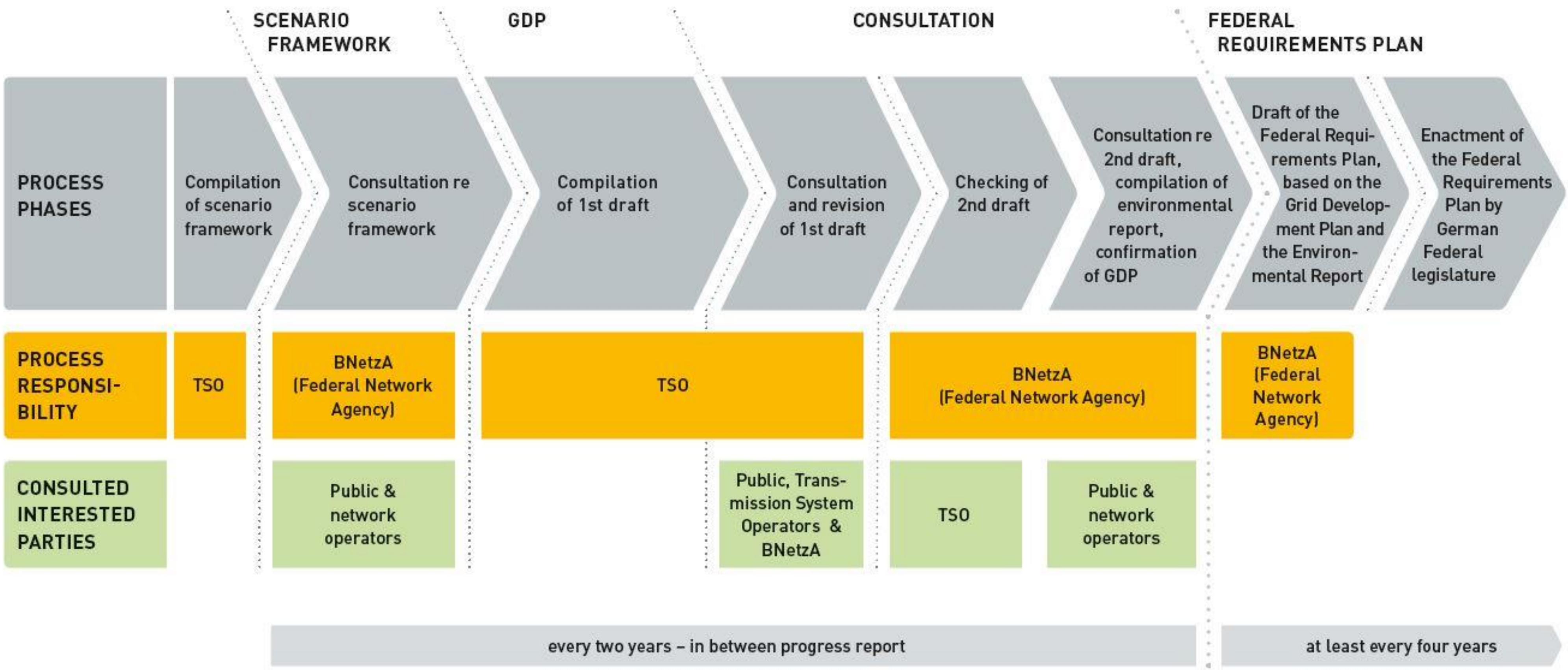
... indicates measures with priority placed on optimisation over grid development, and expansion **(NOVA).**

... shows the expansion of the **380 kV alternating current grid** as well as **high voltage direct current (HVDC) connections** are needed to meet north-south transmission requirements.

... **does not show any potential power station sites** or preferred locations for renewable energy.

Grid Development Plan 2030 (2019)

The GDP process



Grid Development Plan 2030 (2019)

Timeline – Where we stand

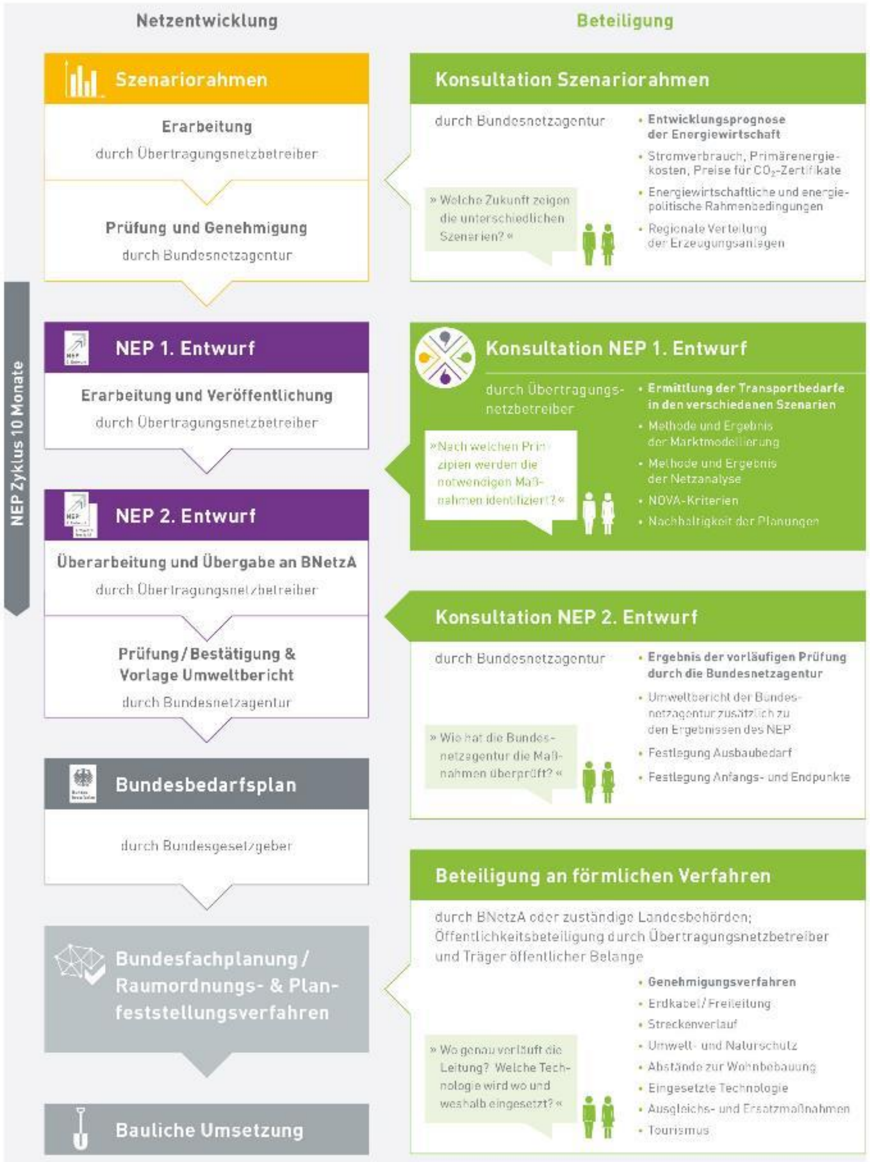
NETZ ENTWICKLUNGS PLAN STROM

GDP and O-GDP 2030 (2017)

- 22.12.2017 – Approval of the GDP 2030 (2017)
- 22.12.2017 – Approval of the O-GDP 2030 (2017)

GDP 2030 (2019)

- 30.1.2018 – Submission of the Draft Scenario Framework by the TSOs
- 15.6.2018 – Approval of the Scenario Framework by the Federal Network Agency (BNetzA)
- 4.2.2019 – Publication of the first draft of the GDP 2030 (2019) by the TSOs
- 4.2. – 4.3.2019 – Public consultation period for the first draft
- 15.4.2019 – Publication of second draft by the TSOs and handover to the BNetzA
- subsequent review and second public consultation by the BNetzA
- End of 2019: approval by the BNetzA (target deadline of the German Energy Industry Act)



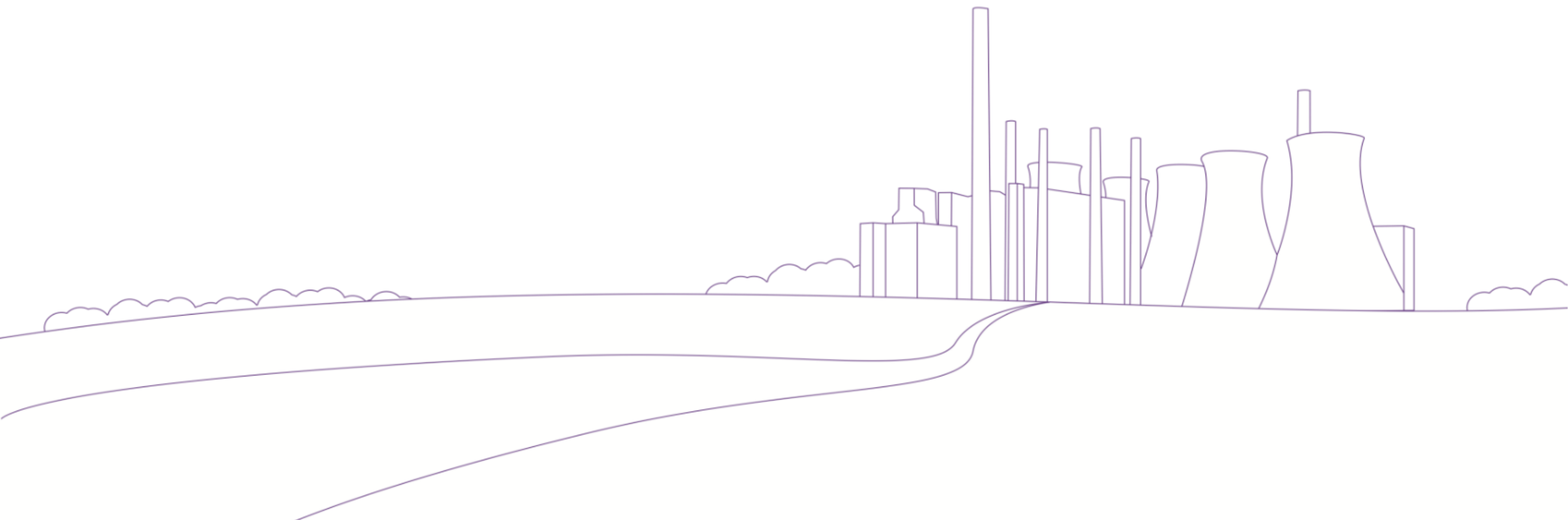
NETZ ENTWICKLUNGS PLAN STROM

Grid Development Plan 2030 (2019)

Overview of the consultation process

NETZ ENTWICKLUNGS PLAN STROM

Consultation of the first draft GDP 2030 (2019)



Consultation first draft GDP 2030 (2019)

Overview

- The first draft of the GDP 2030 (2019) was published by the TSOs on **4.2.2019** with a public consultation period from **4.2. to 4.3.2019**.
- In total **906 statements** were submitted during this period.
- **763 statements** were submitted by **individuals**.
  143 statements were submitted by **institutions.**
- All **electronically submitted statements**, are published at https://www.netzentwicklungsplan.de/de/konsultation-zum-nep-2030-2019/stellungnahmen-nep-2030-2019 (**764 statements**) if the authors approved the publication.
- An individual confirmation or answer to each statement is not given.

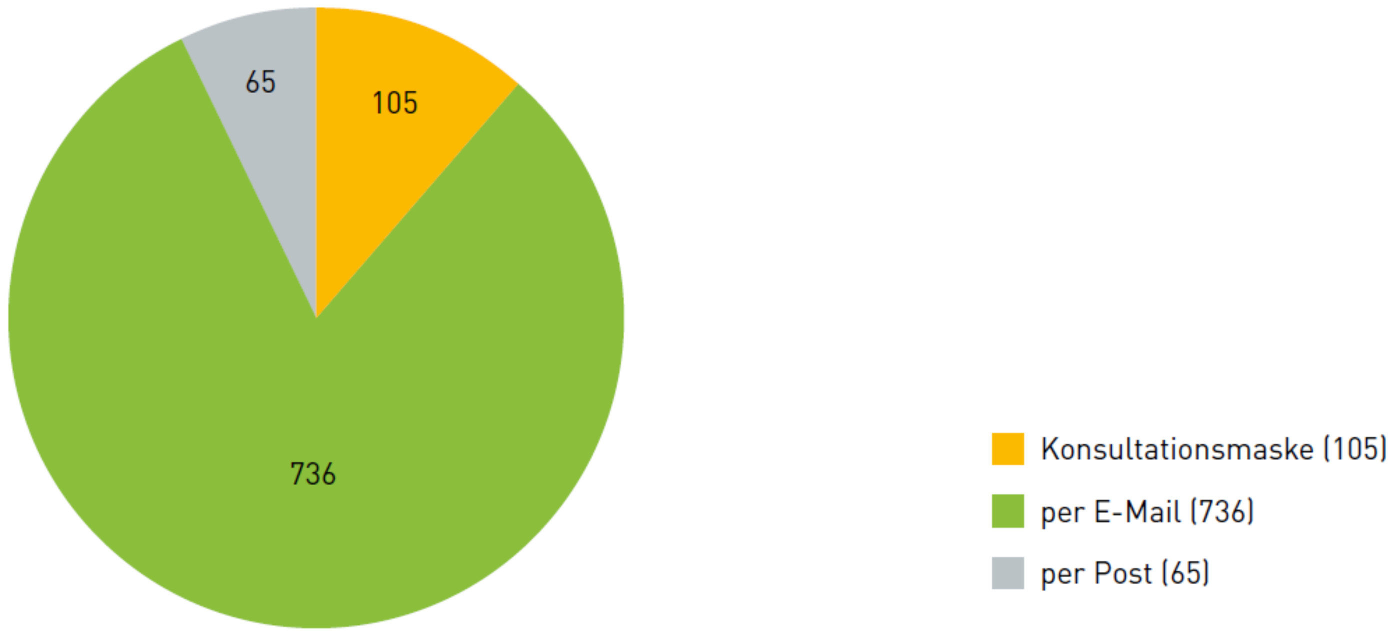
Consultation first draft GDP 2030 (2019)

Incorporation of consultation statements

- The TSOs considered the contents of the submitted statements and revised the first draft of the GDP 2030 (2019) on this basis.
- Each chapter of the second draft contains a **box with a summary** of the main aspects of the consultation concerning it as well as the changes to the chapter.
- Changes to the first draft of GDP are marked ***in italics***.
- The consultation statements are further discussed in a separate **consultation chapter (chapter 7)**

Consultation first draft GDP 2030 (2019)

Statements by channel of submission



Quelle: Übertragungsnetzbetreiber

Consultation first draft GDP 2030 (2019)

Statements by type of stakeholder

Absender	Anzahl der Stellungnahmen
Privatpersonen	763
Kommunen	69
Bürgerinitiativen	22
Bund / Länder	15
Energieunternehmen	12
Verbände	11
Umwelt- / Naturschutzverbände	7
Sonstige	4
Unternehmen	2
Wissenschaft und Forschung	1

Quelle: Übertragungsnetzbetreiber

Compared to the GDP 2030 (2017) with 2133 statements, the number of consultation submissions for the GDP 2030 (2019) **declined by 57%.**

The decline in the number of statements concerns all stakeholder-groups.

The number of serial-letters also decreased significantly.

Consultation first draft GDP 2030 (2019)

Main topics

NETZ ENTWICKLUNGS PLAN **STROM**

- **Basic questions and doubts** about the **assumptions** of the **scenarios,** for example compatibility with the goals of the **Paris Agreement**, the recommendations of the **Commission for Growth, Structural Change and Employment** concerning the exit from coal-fired energy production.
- The results of the **market simulation** and the resulting **requirements for grid expansion** including **the consideration of innovative technologies.**
- Regional concerns, in particular:
  - between Mecklar and Bergrheinfeld/West (P43/P43mod)
  - between Altenfeld and Grafenrheinfeld (P44/P44mod)
  - between Raitersaich, Ludersheim und Altheim (P53)

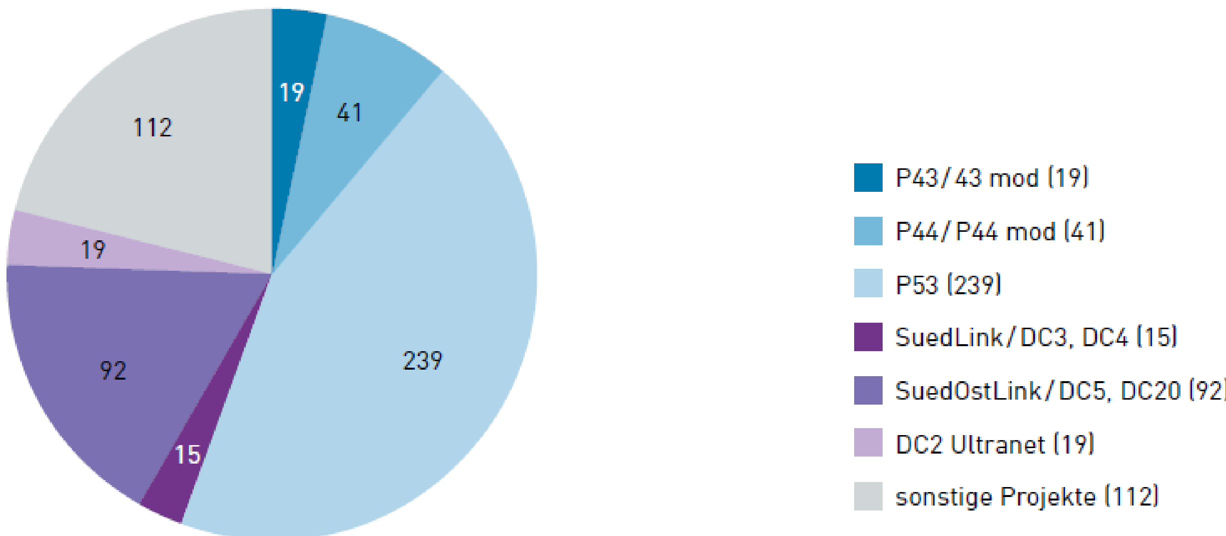
  as well as the three large HVDC-connections
  - from North Rhine Westphalia to Baden-Württemberg (DC2)
  - from Schleswig-Holstein to Bavaria and Baden-Württemberg (DC3/DC4)
  - From Saxony-Anhalt to Bavaria (DC5 with DC20)

Consultation first draft GDP 2030 (2019)

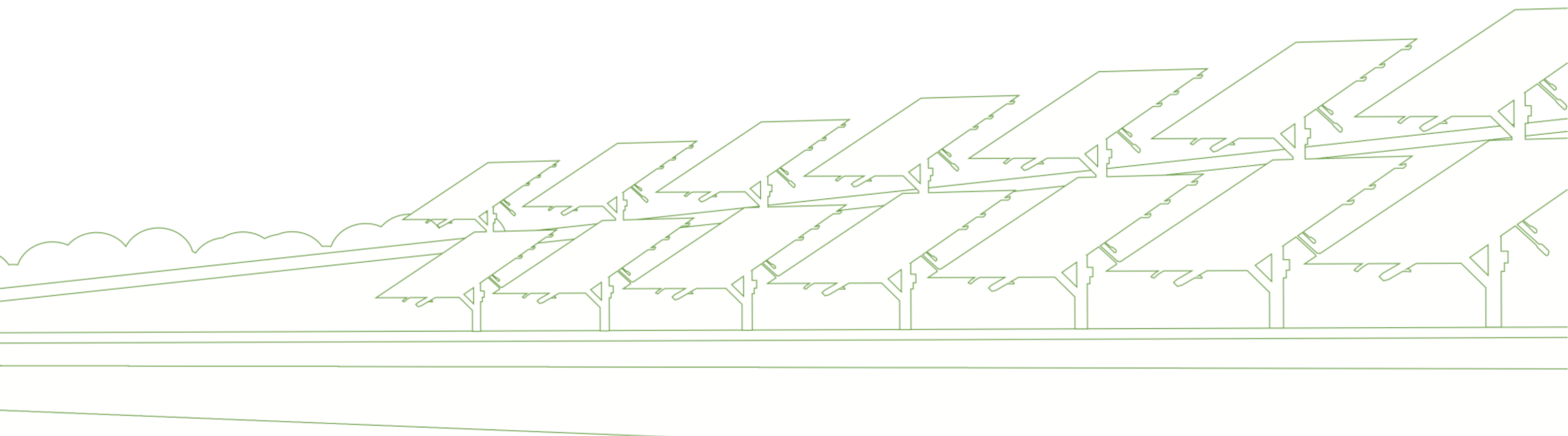
Statements on specific projects

The majority of statements by individuals concern **specific projects**.

The focus of the majority of statements on a few projects lead to **680 statements** concerning projects in the control area of TenneT, almost **75%** of all statements submitted. From those statements, the majority was from **Bavaria**.



Scenario Framework



Grid Development Plan 2030 (2019)

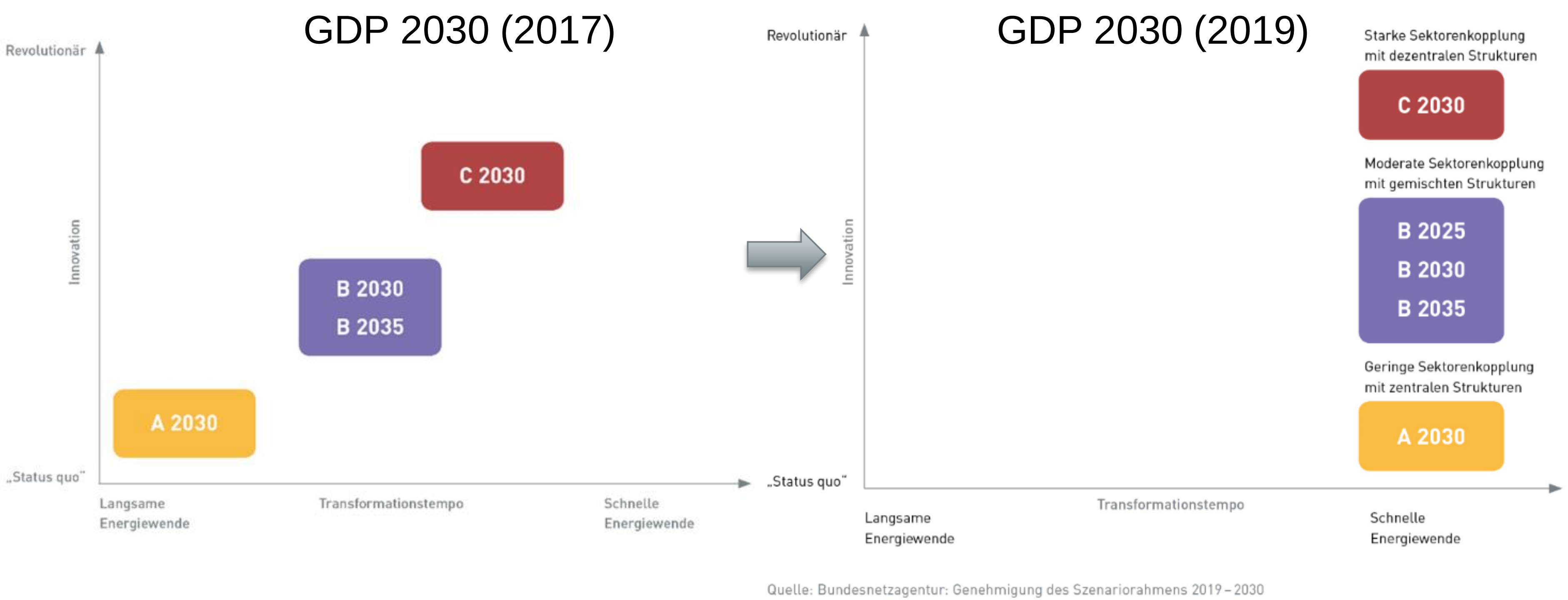
Key elements of the approved Scenario Framework

NETZ ENTWICKLUNGS PLAN **STROM**

- Takes into account the expansion target for renewables from the coalition agreement from March 2018 of **65% renewables by 2030**
- Takes into account **flow based market coupling** as well as minimal **transfer capacities for interconnectors** in line with European planning procedures
- **Cost benefit analyses** for additional interconnectors
- Explicit CO_2 limits for power-generation in all scenarios in line with the **federal climate protection plan 2050** and coordinated with the UBA
- **Peak capping** of max. 3% of the total annual amount of onshore wind energy and solar in all scenarios as **planning instrument**
- Ambitious assumptions for **sector coupling** (E-mobility, heat pumps), **flexibility** (PtX, DSM) and **storage** (central and decentral) – increasing from scenario A to C → **Grid Development Plan in line with the current discussion**
- Calculation of **five scenarios**:
    - Short-term scenario B2025: Ad-hoc-measures / Redispatch prevention
    - Target-scenarios A 2030, B 2030, C 2030
    - Long-term scenario B 2035: sustainability check for the identified measures

Grid Development Plan 2030 (2019)

Classifying the scenarios



→ The scenarios no longer differ in the overall speed of transformation, but only in the assumed innovations (sector-coupling, flexibility, and storage) as well as the share of the different renewable technologies.

Grid Development Plan 2030 (2019)

Conventional generation capacities

NETZ ENTWICKLUNGS PLAN STROM

Installiert (GW)	Referenz 2017	B 2025	A 2030	B 2030	C 2030	B 2035
Kernenergie	9,5	0,0	0,0	0,0	0,0	0,0
Braunkohle	21,2	9,4	9,4	9,3	9,0	9,0
Steinkohle	25,0	13,5	13,5	9,8	8,1	8,1
Erdgas	29,6	32,5	32,8	35,2	33,4	36,9
Öl	4,4	1,3	1,3	1,2	0,9	0,9
Pumpspeicher	9,5	11,6	11,6	11,6	11,6	11,8
sonstige konv. Erzeugung*[1]	4,3	4,1	4,1	4,1	4,1	4,1
Kapazitätsreserve	0,0	2,0	2,0	2,0	2,0	2,0
Summe konv. Erzeugung*[2]	**103,5**	**74,4**	**74,7**	**73,2**	**69,1**	**72,8**

Grid Development Plan 2030 (2019)

Renewable generation capacities

NETZ
ENTWICKLUNGS
PLAN STROM

Installiert (GW)	Referenz 2017	B 2025	A 2030	B 2030	C 2030	B 2035
Wind onshore	50,5	70,5	74,3	81,5	85,5	90,8
Wind offshore	5,4	10,8	20,0	17,0	17,0	23,2
Photovoltaik	42,4	73,3	72,9	91,3	104,5	97,4
Biomasse	7,6	7,3	6,0	6,0	6,0	4,6
Wasserkraft*3	5,6	5,6	5,6	5,6	5,6	5,6
sonstige reg. Erzeugung*4	1,3	1,3	1,3	1,3	1,3	1,3
Summe reg. Erzeugung	**112,8**	**168,8**	**180,1**	**202,7**	**219,9**	**222,9**

Grid Development Plan 2030 (2019)

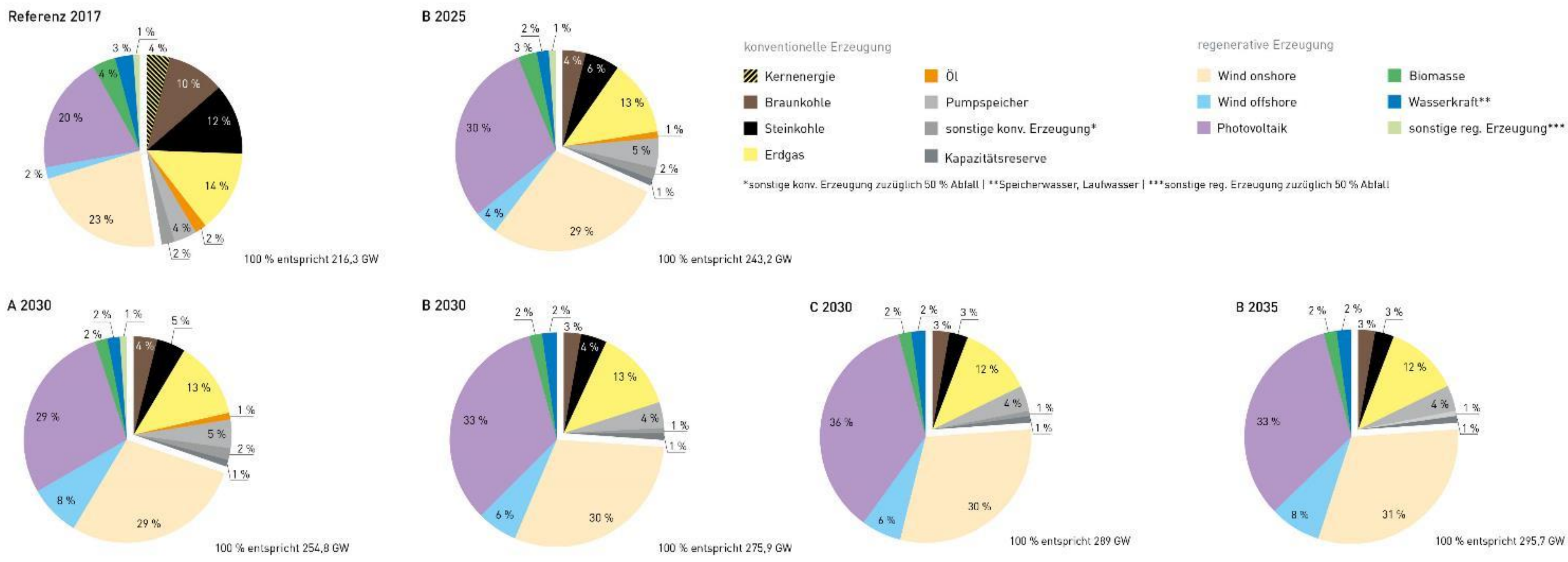
Overview of all scenarios

NETZ ENTWICKLUNGS PLAN STROM

	A 2030	B 2030	C 2030	B 2035
Conventional power stations	74.7 GW (22.9 GW Coal)	73.2 GW (19.1 GW coal)	69.1 GW (17.1 GW coal)	72.8 GW (17.1 GW coal)
Installed capcities of Renewable energy	**180 GW (+40 GW)** **20 GW Offshore** 74 GW Onshore 73 GW PV	**203 GW (+50 GW)** 17 GW Offshore 82 GW Onshore 91 GW PV	**220 GW (+50 GW)** 17 GW Offshore 86 GW Onshore **105 GW PV**	**223 GW** 23,2 GW Offshore 91 GW Onshore 97 GW PV
Net energy consumption	512 TWh	544 TWh	**577 TWh**	549 TWh
Peak-capping (wind and solar)	yes	yes	yes	yes
Sector-Coupling	moderate	high	**Very high**	high
Amount of **flexibility options** and **storage**	moderate	high	**Very high**	high
Collective power plant **emission limit**	184 Mio. t CO_2	184 Mio. t CO_2	184 Mio. t CO_2	127 Mio. t CO_2

Grid Development Plan 2030 (2019)

Overview of the distribution of installed capacity per energy source in the four scenarios of the GDP 2030



Grid Development Plan 2030 (2019)

Results of renewable peak capping

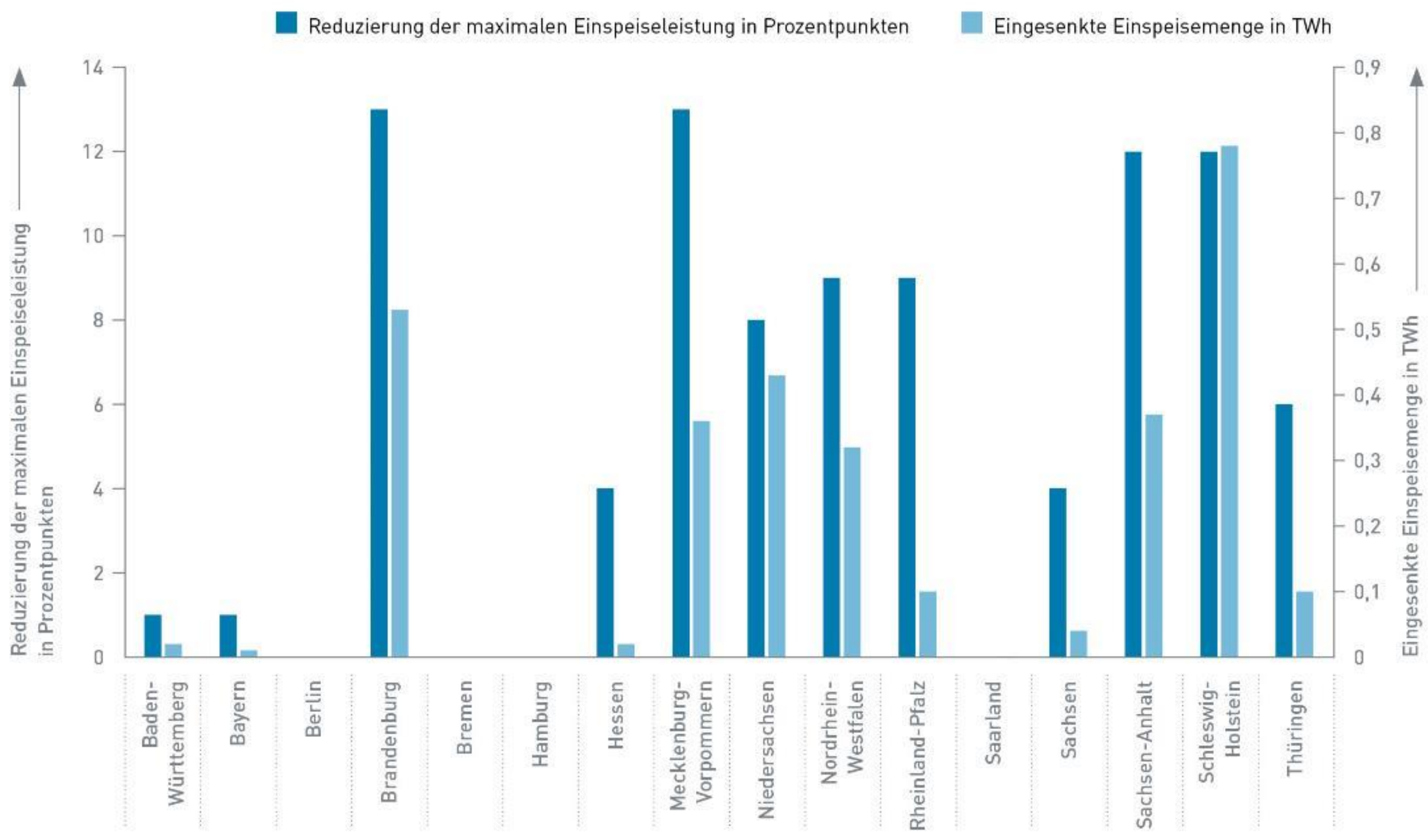
NETZ ENTWICKLUNGS PLAN STROM

Szenario	Eingesenkte Einspeisemenge Onshore-Windenergie (TWh)	Eingesenkte Einspeisemenge Photovoltaik (TWh)
B 2025	2,6	0,8
A 2030	2,8	0,8
B 2030	3,1	1,0
C 2030	3,2	1,1
B 2035	3,4	1,0

Capped amounts of onshore wind and PV

Grid Development Plan 2030 (2019)

Peak capping of onshore wind energy by state

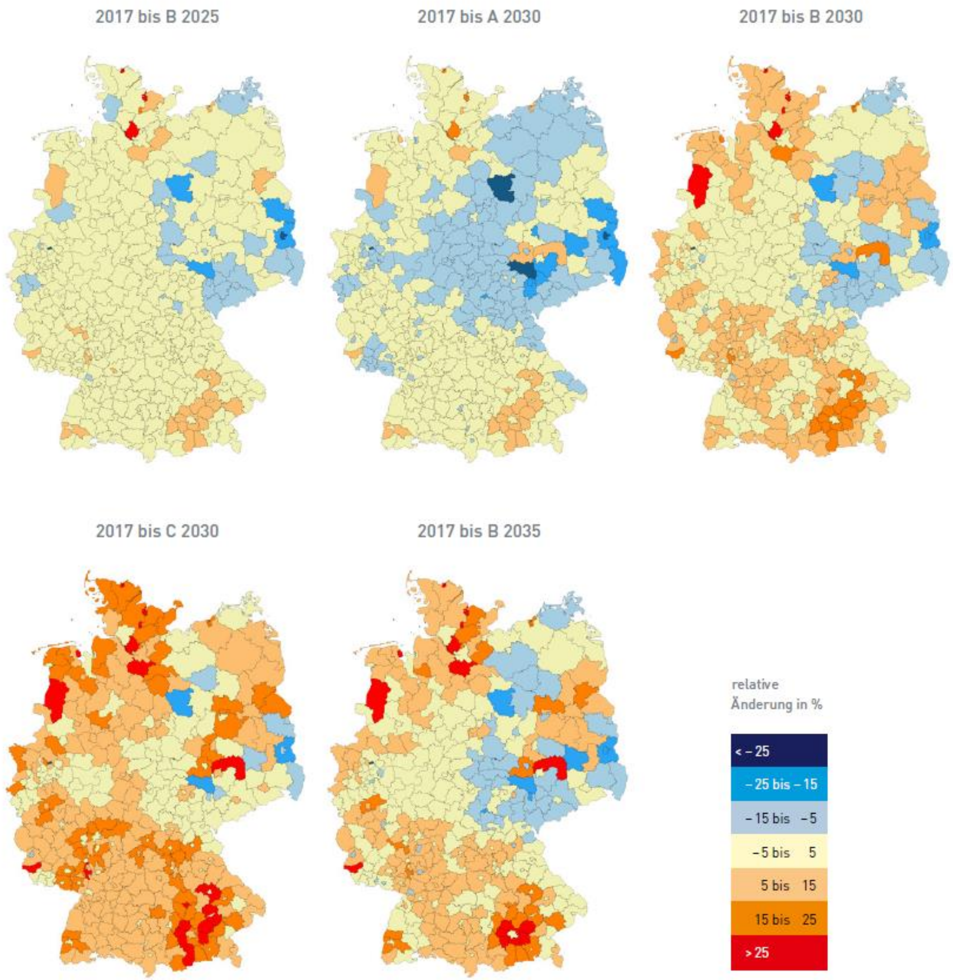


Quelle: Übertragungsnetzbetreiber

Grid Development Plan 2030 (2019)

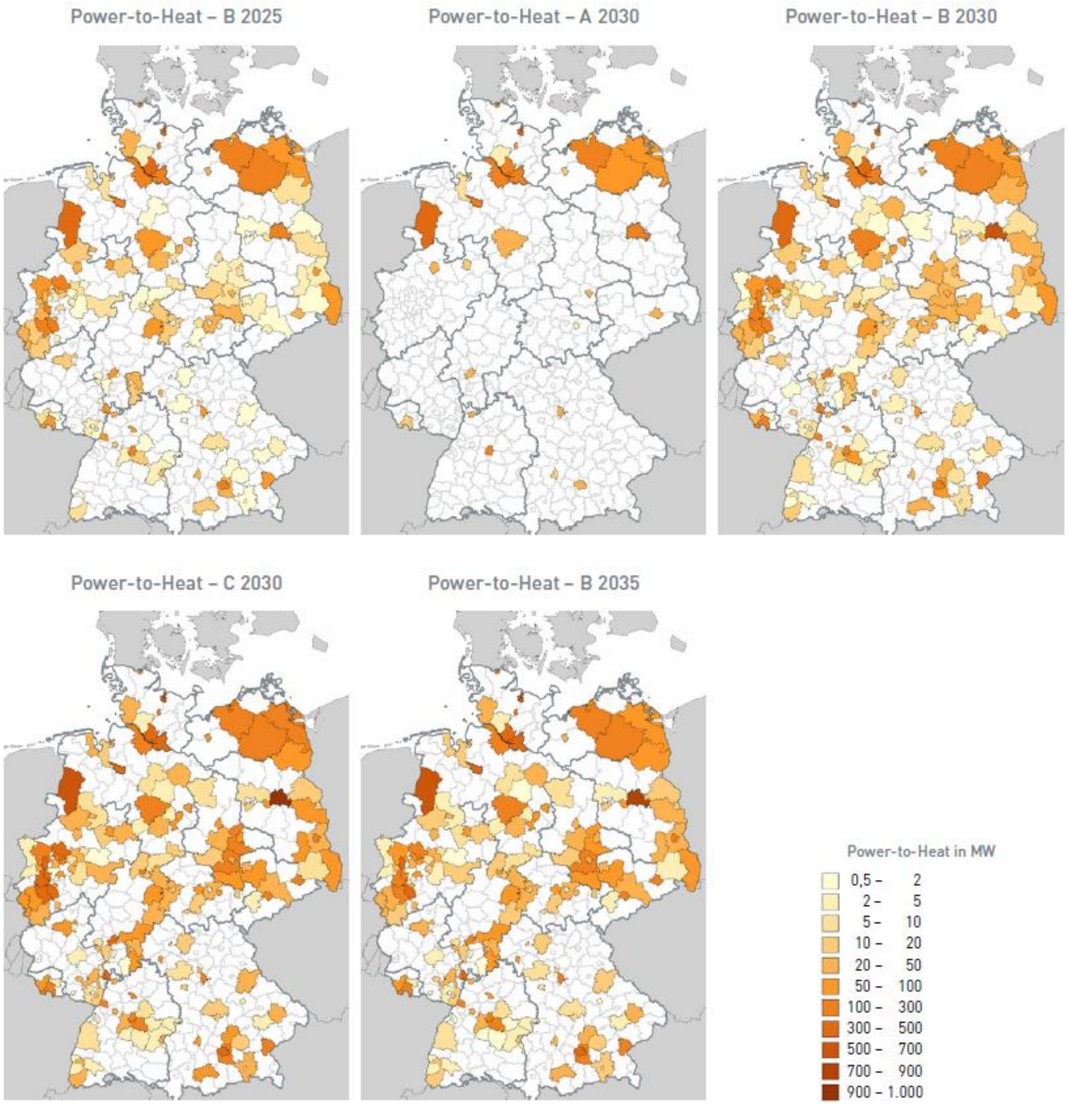
Change of electricity demand by municipality including sector-coupling and PtG/PtH

- **Increasing demand** in urban regions and neighboring conurbations
- **Decreasing demand** in most municipalities in eastern Germany and rural regions.
- **Main factors** determining regional demand are **population** as well as **E-mobility**, **heat pumps** and **PtG- and PtH-facilities**.



NETZ ENTWICKLUNGS PLAN STROM

Regional use of flexibility-options: Power-to-heat facilities



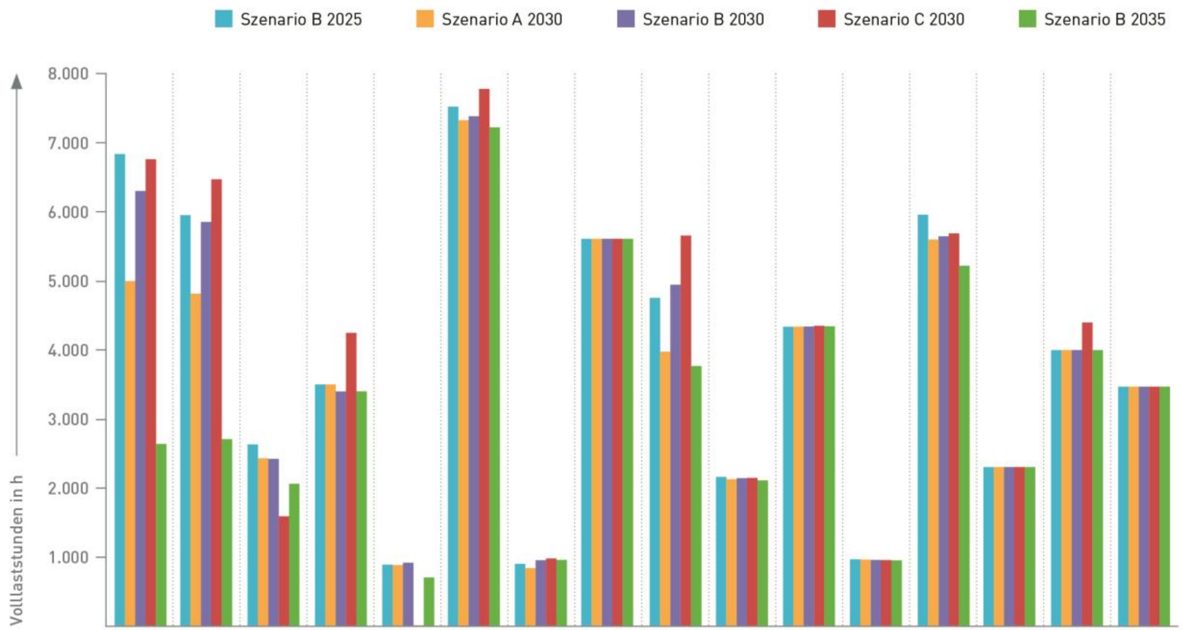
Quelle: Übertragungsnetzbetreiber

Assumed regional distribution of power-to-heat facilities in Germany

Grid Development Plan 2030 (2019)

Full load hours by scenario

Abbildung 46: Vergleich der Volllaststunden je Szenario des NEP 2030 (2019)



	Braun-kohle	Stein-kohle	Erdgas	Kuppel-gas	Öl	Abfall	Pump-speicher	KWK <10 MW	sonstige Konven-tionelle	Wind onshore	Wind offshore	Photo-voltaik	Bio-masse	Speicher-wasser	Lauf-wasser	sonstige EE
B 2025	6.827	5.942	2.624	3.491	883	7.513	894	5.600	4.743	2.154	4.327	960	5.948	2.294	3.989	3.460
A 2030	4.987	4.806	2.421	3.491	876	7.316	833	5.600	3.964	2.119	4.326	956	5.589	2.294	3.989	3.460
B 2030	6.292	5.842	2.414	3.389	910	7.372	947	5.600	4.934	2.133	4.328	950	5.634	2.294	3.989	3.460
C 2030	6.751	6.461	1.582	4.239	3	7.769	973	5.600	5.646	2.139	4.340	949	5.678	2.294	4.388	3.460
B 2035	2.630	2.699	2.054	3.391	697	7.211	950	5.600	3.758	2.102	4.333	944	5.210	2.294	3.989	3.460

Quelle: Übertragungsnetzbetreiber

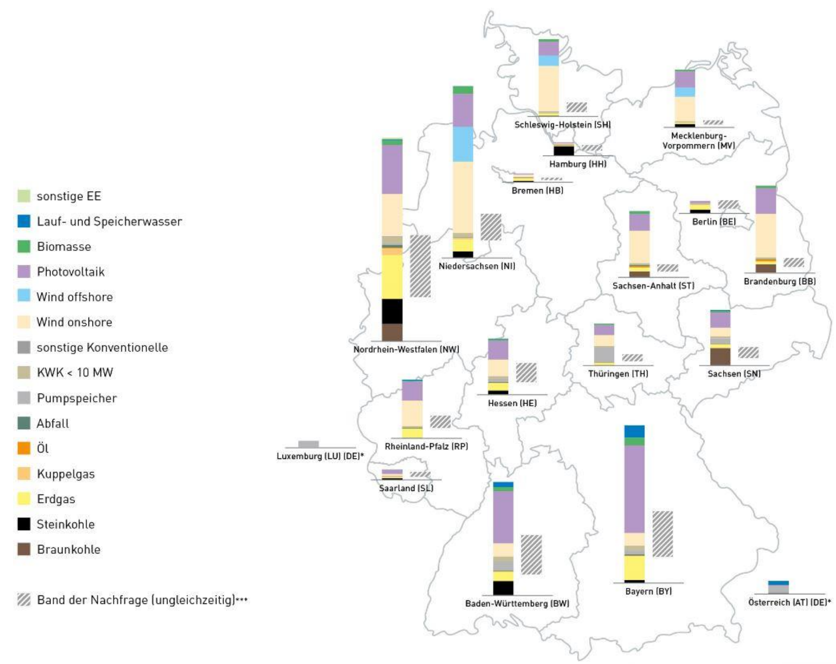
Grid Development Plan 2030 (2019)

Installed capacity by state

Scenario B 2025

B 2025 (in GW)	Braun-kohle	Stein-kohle	Erdgas	Kuppel-gas	Öl	Abfall	Pump-speicher	KWK < 10 MW	sonstige Konven-tionelle	Wind onshore	Wind offshore	Photo-voltaik	Bio-masse	Lauf- und Speicher-wasser	sonstige EE	Band der Nachfrage	zusätzliche Verbraucher DSM	PtG	PtH
BW	0,0	2,8	1,9	0,0	0,1	0,1	1,9	1,0	0,0	2,6	0,0	10,4	0,8	1,0	0,0	4,1 – 11,9	0,3	0,0	0,5
BY	0,0	0,5	4,9	0,0	0,0	0,2	0,8	0,9	0,0	2,6	0,0	17,5	1,5	2,4	0,1	5,1 – 14,2	0,4	0,0	0,5
BE	0,0	0,7	1,0	0,0	0,0	0,0	0,0	0,2	0,0	0,0	0,0	0,5	0,0	0,0	0,0	0,9 – 2,5	0,1	0,0	0,2
BB	1,6	0,0	0,5	0,1	0,3	0,1	0,0	0,3	0,0	8,7	0,0	5,1	0,5	0,0	0,0	1,1 – 2,9	0,1	0,0	0,1
HB	0,0	0,1	0,5	0,2	0,0	0,1	0,0	0,1	0,0	0,5	0,0	0,2	0,0	0,0	0,0	0,3 – 0,8	0,0	0,0	0,2
HH	0,0	1,8	0,2	0,0	0,0	0,0	0,0	0,2	0,0	0,1	0,0	0,2	0,1	0,0	0,0	0,9 – 2,0	0,1	0,0	0,2
HE	0,0	0,7	1,6	0,0	0,0	0,1	0,6	0,5	0,0	3,3	0,0	3,8	0,3	0,1	0,0	2,4 – 6,2	0,2	0,0	0,1
MV	0,0	0,5	0,3	0,0	0,0	0,0	0,0	0,2	0,0	5,0	1,8	3,2	0,3	0,0	0,0	0,5 – 1,3	0,0	0,0	0,4
NI	0,0	1,2	2,4	0,3	0,0	0,1	0,2	0,7	0,0	14,3	6,9	6,6	1,4	0,1	0,0	3,4 – 8,7	0,4	0,1	0,8
NW	3,3	5,0	8,8	1,3	0,2	0,5	0,3	1,3	0,2	8,4	0,0	9,8	0,9	0,2	0,4	8,7 – 21,1	0,8	0,1	1,3
RP	0,0	0,0	1,8	0,0	0,0	0,1	0,0	0,3	0,0	5,2	0,0	3,8	0,2	0,2	0,0	2,0 – 4,4	0,2	0,0	0,1
SL	0,0	0,3	0,2	0,1	0,0	0,0	0,0	0,1	0,0	0,4	0,0	0,9	0,0	0,0	0,1	0,5 – 1,5	0,1	0,0	0,1
SN	3,4	0,0	0,8	0,0	0,0	0,0	1,1	0,4	0,0	1,8	0,0	3,1	0,3	0,1	0,0	1,4 – 3,6	0,1	0,0	0,1
ST	1,0	0,0	0,8	0,0	0,2	0,2	0,1	0,3	0,0	6,4	0,0	3,4	0,5	0,0	0,0	1,0 – 2,5	0,1	0,1	0,1
SH	0,0	0,1	0,5	0,0	0,0	0,0	0,1	0,3	0,1	9,0	2,1	2,8	0,5	0,0	0,0	0,9 – 2,7	0,1	0,0	1,0
TH	0,0	0,0	0,5	0,0	0,0	0,0	3,0	0,3	0,0	2,2	0,0	2,0	0,3	0,0	0,0	0,8 – 2,2	0,1	0,0	0,1
AT (DE)*	0,0	0,0	0,0	0,0	0,0	0,0	1,6	0,0	0,0	0,0	0,0	0,0	0,0	0,8	0,0	0,0 – 0,0	0,0	0,0	0,0
LU (DE)*	0,0	0,0	0,0	0,0	0,0	0,0	1,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0 – 0,0	0,0	0,0	0,0
Summe**	**9,4**	**13,5**	**26,5**	**2,0**	**0,9**	**1,7**	**11,0**	**6,8**	**0,4**	**70,5**	**10,8**	**73,3**	**7,6**	**5,1**	**0,6**	**34,4 – 88,2**	**3,0**	**0,5**	**5,8**

* Erzeugungsanlagen im Ausland mit Einspeisung in das deutsche Übertragungsnetz
** Bei der Aufsummierung der Einzelwerte können sich Rundungsabweichungen ergeben.
*** Das Band der Nachfrage umfasst den klassischen Stromverbrauch sowie Wärmepumpen, Elektromobilität und VNB-Verluste ohne Einsatz von DSM, Power-to-Gas / -Heat.

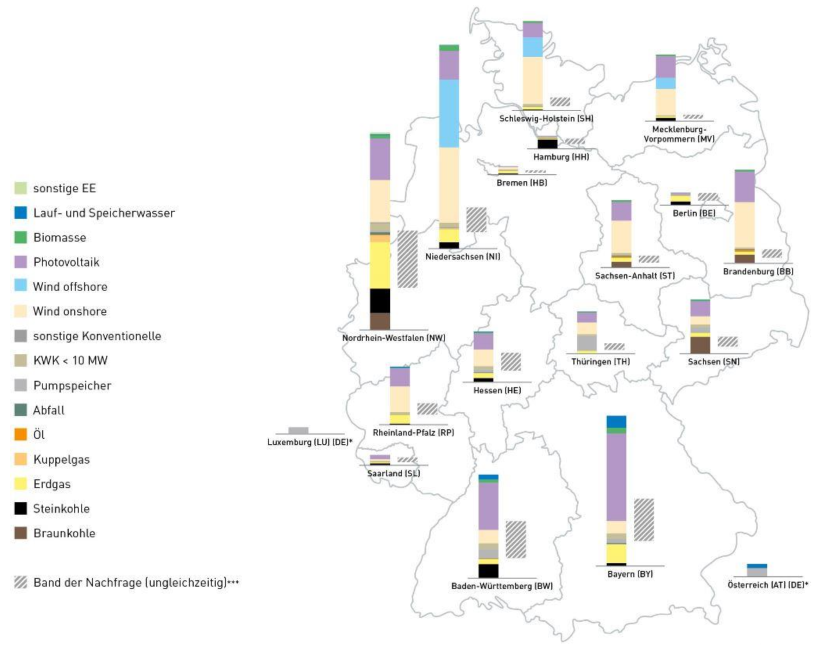


Grid Development Plan 2030 (2019)

Installed capacity by state

Scenario A 2030

A 2030 (in GW)	Braun-kohle	Stein-kohle	Erdgas	Kuppel-gas	Öl	Abfall	Pump-speicher	KWK < 10 MW	sonstige Konven-tionelle	Wind onshore	Wind offshore	Photo-voltaik	Bio-masse	Lauf- und Speicher-wasser	sonstige EE	Band der Nachfrage	zusätzliche Verbraucher		
																	DSM	PtG	PtH
BW	0,0	2,8	1,0	0,0	0,1	0,1	1,9	1,1	0,0	2,8	0,0	9,6	0,7	1,0	0,0	4,0 – 11,5	0,2	0,0	0,2
BY	0,0	0,5	3,9	0,0	0,0	0,2	0,8	1,1	0,0	2,6	0,0	17,9	1,2	2,4	0,1	5,0 – 13,6	0,3	0,1	0,1
BE	0,0	0,7	1,1	0,0	0,0	0,0	0,0	0,2	0,0	0,0	0,0	0,4	0,0	0,0	0,0	0,8 – 2,4	0,0	0,0	0,1
BB	1,6	0,0	0,6	0,1	0,3	0,1	0,0	0,4	0,0	9,3	0,0	6,3	0,4	0,0	0,0	1,1 – 2,7	0,1	0,1	0,0
HB	0,0	0,1	0,5	0,2	0,0	0,1	0,0	0,1	0,0	0,5	0,0	0,2	0,0	0,0	0,0	0,3 – 0,8	0,0	0,0	0,2
HH	0,0	1,8	0,2	0,0	0,0	0,0	0,0	0,3	0,0	0,1	0,0	0,2	0,0	0,0	0,0	0,9 – 2,0	0,1	0,0	0,2
HE	0,0	0,7	1,0	0,0	0,0	0,1	0,6	0,6	0,0	3,4	0,0	3,3	0,2	0,1	0,0	2,3 – 5,9	0,1	0,0	0,0
MV	0,0	0,5	0,3	0,0	0,0	0,0	0,0	0,2	0,0	5,4	2,2	4,5	0,3	0,0	0,0	0,4 – 1,2	0,0	0,0	0,3
NI	0,0	1,2	2,6	0,3	0,0	0,1	0,2	0,8	0,0	15,4	13,8	5,9	1,1	0,1	0,0	3,3 – 8,3	0,2	0,2	0,5
NW	3,3	5,0	9,5	1,3	0,2	0,5	0,3	1,5	0,2	8,6	0,0	8,5	0,7	0,2	0,4	8,5 – 20,2	0,6	0,3	0,0
RP	0,0	0,0	1,9	0,0	0,0	0,1	0,0	0,4	0,0	5,3	0,0	3,7	0,1	0,2	0,0	1,9 – 4,2	0,1	0,1	0,0
SL	0,0	0,3	0,2	0,1	0,0	0,0	0,0	0,1	0,0	0,4	0,0	0,8	0,0	0,0	0,1	0,5 – 1,5	0,0	0,0	0,0
SN	3,4	0,0	0,8	0,0	0,0	0,0	1,1	0,5	0,0	1,8	0,0	3,1	0,3	0,1	0,0	1,4 – 3,4	0,1	0,1	0,0
ST	1,0	0,0	0,8	0,0	0,2	0,2	0,1	0,4	0,0	6,6	0,0	3,8	0,4	0,0	0,0	1,0 – 2,3	0,1	0,1	0,0
SH	0,0	0,1	0,6	0,0	0,0	0,0	0,1	0,3	0,1	9,6	4,0	2,9	0,4	0,0	0,0	0,8 – 2,6	0,1	0,1	0,7
TH	0,0	0,0	0,5	0,0	0,0	0,0	3,0	0,3	0,0	2,4	0,0	2,0	0,2	0,0	0,0	0,7 – 2,0	0,0	0,0	0,0
AT (DE)*	0,0	0,0	0,0	0,0	0,0	0,0	1,6	0,0	0,0	0,0	0,0	0,0	0,0	0,8	0,0	0,0 – 0,0	0,0	0,0	0,0
LU (DE)*	0,0	0,0	0,0	0,0	0,0	0,0	1,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0 – 0,0	0,0	0,0	0,0
Summe**	**9,4**	**13,5**	**25,5**	**2,0**	**0,9**	**1,7**	**11,0**	**8,3**	**0,4**	**74,3**	**20,0**	**72,9**	**6,0**	**5,1**	**0,6**	**33,5 – 84,4**	**2,0**	**1,0**	**2,5**



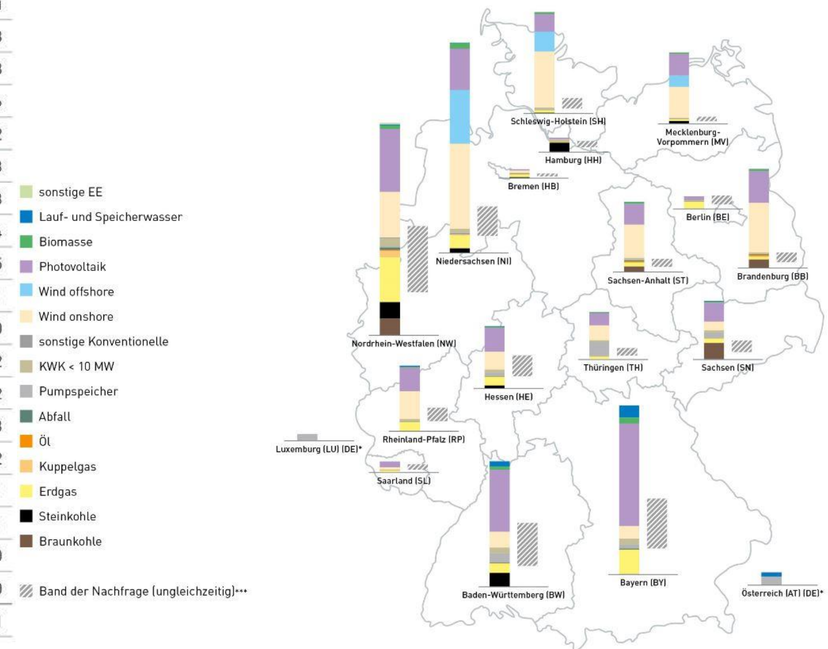
* Erzeugungsanlagen im Ausland mit Einspeisung in das deutsche Übertragungsnetz
** Bei der Aufsummierung der Einzelwerte können sich Rundungsabweichungen ergeben.
*** Das Band der Nachfrage umfasst den klassischen Stromverbrauch sowie Wärmepumpen, Elektromobilität und VNB-Verluste ohne Einsatz von DSM, Power-to-Gas / -Heat.

Grid Development Plan 2030 (2019)

Installed capacity by state

Scenario B 2030

B 2030 (in GW)	Braun-kohle	Stein-kohle	Erdgas	Kuppel-gas	Öl	Abfall	Pump-speicher	KWK < 10 MW	sonstige Konven-tionelle	Wind onshore	Wind offshore	Photo-voltaik	Bio-masse	Lauf- und Speicher-wasser	sonstige EE	Band der Nachfrage	zusätzliche Verbraucher		
																	DSM	PtG	PtH
BW	0,0	2,7	1,9	0,0	0,1	0,1	1,9	1,1	0,0	3,2	0,0	12,5	0,7	1,0	0,0	4,1 – 12,8	0,4	0,0	0,8
BY	0,0	0,0	4,9	0,0	0,0	0,2	0,8	1,1	0,0	2,6	0,0	20,7	1,2	2,4	0,1	5,2 – 15,2	0,5	0,1	0,8
BE	0,0	0,0	1,4	0,0	0,0	0,0	0,0	0,2	0,0	0,0	0,0	0,7	0,0	0,0	0,0	0,9 – 2,6	0,1	0,0	0,6
BB	1,6	0,0	0,5	0,1	0,3	0,1	0,0	0,4	0,0	10,0	0,0	6,5	0,4	0,0	0,0	1,1 – 3,0	0,1	0,1	0,2
HB	0,0	0,1	0,5	0,2	0,0	0,1	0,0	0,1	0,0	0,5	0,0	0,3	0,0	0,0	0,0	0,3 – 0,8	0,0	0,0	0,3
HH	0,0	1,8	0,2	0,0	0,0	0,0	0,0	0,3	0,0	0,1	0,0	0,4	0,0	0,0	0,0	0,9 – 2,1	0,1	0,0	0,3
HE	0,0	0,5	1,8	0,0	0,0	0,1	0,6	0,6	0,0	3,6	0,0	4,9	0,2	0,1	0,0	2,4 – 6,6	0,2	0,0	0,4
MV	0,0	0,5	0,3	0,0	0,0	0,0	0,0	0,2	0,0	6,3	2,3	4,4	0,3	0,0	0,0	0,5 – 1,4	0,0	0,1	0,5
NI	0,0	0,9	2,6	0,3	0,0	0,1	0,2	0,8	0,0	17,1	10,8	8,4	1,1	0,1	0,0	3,4 – 9,3	0,5	0,3	1,1
NW	3,3	3,3	9,0	1,3	0,2	0,5	0,3	1,5	0,2	9,2	0,0	12,7	0,7	0,2	0,4	8,6 – 22,0	1,1	0,6	2,0
RP	0,0	0,0	1,8	0,0	0,0	0,1	0,0	0,4	0,0	5,7	0,0	4,8	0,1	0,2	0,0	2,0 – 4,7	0,2	0,1	0,2
SL	0,0	0,0	0,3	0,1	0,0	0,0	0,0	0,1	0,0	0,4	0,0	1,1	0,0	0,0	0,1	0,5 – 1,6	0,1	0,0	0,2
SN	3,3	0,0	0,9	0,0	0,0	0,0	1,1	0,5	0,0	1,8	0,0	3,8	0,3	0,1	0,0	1,4 – 3,7	0,1	0,1	0,3
ST	1,0	0,0	0,8	0,0	0,2	0,2	0,1	0,4	0,0	6,7	0,0	4,2	0,4	0,0	0,0	1,0 – 2,6	0,1	0,2	0,2
SH	0,0	0,0	0,5	0,0	0,0	0,0	0,1	0,3	0,1	11,3	4,0	3,6	0,4	0,0	0,0	0,9 – 3,0	0,1	0,1	1,1
TH	0,0	0,0	0,5	0,0	0,0	0,0	3,0	0,3	0,0	3,0	0,0	2,5	0,2	0,0	0,0	0,7 – 2,2	0,1	0,0	0,1
AT (DE)*	0,0	0,0	0,0	0,0	0,0	0,0	1,6	0,0	0,0	0,0	0,0	0,0	0,0	0,8	0,0	0,0 – 0,0	0,0	0,0	0,0
LU (DE)*	0,0	0,0	0,0	0,0	0,0	0,0	1,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0 – 0,0	0,0	0,0	0,0
Summe**	**9,3**	**9,8**	**27,8**	**2,0**	**0,9**	**1,7**	**11,0**	**8,3**	**0,3**	**81,5**	**17,0**	**91,3**	**6,0**	**5,1**	**0,6**	**34,2 – 93,2**	**4,0**	**2,0**	**9,1**



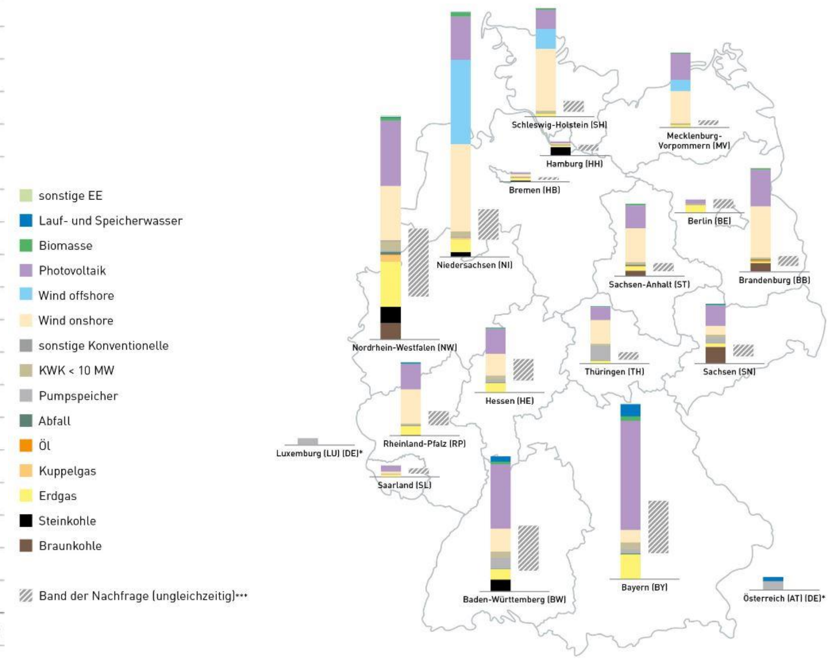
* Erzeugungsanlagen im Ausland mit Einspeisung in das deutsche Übertragungsnetz
** Bei der Aufsummierung der Einzelwerte können sich Rundungsabweichungen ergeben.
*** Das Band der Nachfrage umfasst den klassischen Stromverbrauch sowie Wärmepumpen, Elektromobilität und VNB-Verluste ohne Einsatz von DSM, Power-to-Gas / -Heat.

Grid Development Plan 2030 (2019)

Installed capacity by state

Scenario B 2035

B 2035 (in GW)	Braun-kohle	Stein-kohle	Erdgas	Kuppel-gas	Öl	Abfall	Pump-speicher	KWK < 10 MW	sonstige Konven-tionelle	Wind onshore	Wind offshore	Photo-voltaik	Bio-masse	Lauf- und Speicher-wasser	sonstige EE	Band der Nachfrage	zusätzliche Verbraucher DSM	zusätzliche Verbraucher PtG	zusätzliche Verbraucher PtH
BW	0,0	2,3	2,1	0,0	0,0	0,1	2,1	1,3	0,0	4,6	0,0	13,0	0,5	1,0	0,0	4,1 – 13,1	0,6	0,0	1,1
BY	0,0	0,0	4,9	0,0	0,0	0,2	0,8	1,3	0,0	2,6	0,0	22,0	0,9	2,4	0,1	5,2 – 15,6	0,7	0,2	1,2
BE	0,0	0,0	1,4	0,0	0,0	0,0	0,0	0,3	0,0	0,0	0,0	0,8	0,0	0,0	0,0	0,8 – 2,6	0,1	0,0	0,8
BB	1,6	0,0	0,3	0,1	0,3	0,1	0,0	0,4	0,0	10,3	0,0	7,4	0,3	0,0	0,0	1,1 – 3,1	0,2	0,2	0,4
HB	0,0	0,1	0,5	0,2	0,0	0,1	0,0	0,1	0,0	0,5	0,0	0,3	0,0	0,0	0,0	0,3 – 0,8	0,1	0,0	0,3
HH	0,0	1,6	0,3	0,0	0,0	0,0	0,0	0,3	0,0	0,1	0,0	0,4	0,0	0,0	0,0	0,9 – 2,1	0,2	0,1	0,4
HE	0,0	0,0	1,8	0,0	0,0	0,1	0,6	0,7	0,0	4,4	0,0	5,1	0,2	0,1	0,0	2,4 – 6,7	0,3	0,0	0,6
MV	0,0	0,0	0,4	0,0	0,0	0,0	0,0	0,3	0,0	6,5	2,2	5,3	0,2	0,0	0,0	0,4 – 1,3	0,0	0,1	0,6
NI	0,0	0,9	2,6	0,3	0,0	0,1	0,2	1,0	0,0	17,6	17,0	8,7	0,9	0,1	0,0	3,4 – 9,5	0,6	0,5	1,3
NW	3,2	3,3	9,1	1,3	0,1	0,5	0,3	1,8	0,2	11,0	0,0	13,1	0,5	0,2	0,4	8,6 – 22,2	1,4	0,9	2,8
RP	0,0	0,0	1,8	0,0	0,0	0,1	0,0	0,4	0,0	6,9	0,0	5,1	0,1	0,2	0,0	2,0 – 4,8	0,3	0,2	0,4
SL	0,0	0,0	0,3	0,1	0,0	0,0	0,0	0,1	0,0	0,4	0,0	1,2	0,0	0,0	0,1	0,5 – 1,6	0,1	0,0	0,2
SN	3,3	0,0	0,7	0,0	0,0	0,0	1,1	0,6	0,0	1,8	0,0	4,1	0,2	0,1	0,0	1,4 – 3,7	0,2	0,2	0,5
ST	1,0	0,0	0,9	0,0	0,1	0,2	0,1	0,5	0,0	6,8	0,0	4,6	0,3	0,0	0,0	0,9 – 2,5	0,2	0,4	0,5
SH	0,0	0,0	0,5	0,0	0,0	0,0	0,1	0,4	0,1	12,5	4,0	3,9	0,3	0,0	0,0	0,9 – 3,1	0,2	0,2	1,3
TH	0,0	0,0	0,5	0,0	0,0	0,0	3,0	0,4	0,0	4,8	0,0	2,6	0,2	0,0	0,0	0,7 – 2,2	0,1	0,0	0,2
AT (DE)*	0,0	0,0	0,0	0,0	0,0	0,0	1,6	0,0	0,0	0,0	0,0	0,0	0,0	0,8	0,0	0,0 – 0,0	0,0	0,0	0,0
LU (DE)*	0,0	0,0	0,0	0,0	0,0	0,0	1,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0 – 0,0	0,0	0,0	0,0
Summe**	**9,0**	**8,1**	**28,0**	**2,0**	**0,5**	**1,7**	**11,3**	**9,8**	**0,3**	**90,8**	**23,2**	**97,4**	**4,6**	**5,1**	**0,6**	**33,9 – 94,8**	**5,0**	**3,0**	**12,6**



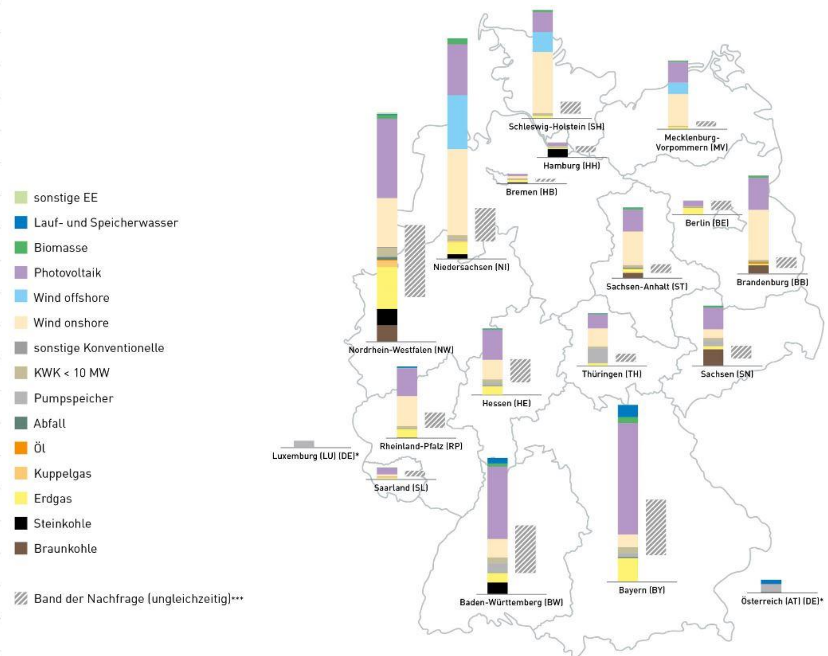
* Erzeugungsanlagen im Ausland mit Einspeisung in das deutsche Übertragungsnetz
** Bei der Aufsummierung der Einzelwerte können sich Rundungsabweichungen ergeben.
*** Das Band der Nachfrage umfasst den klassischen Stromverbrauch sowie Wärmepumpen, Elektromobilität und VNB-Verluste ohne Einsatz von DSM, Power-to-Gas / -Heat.

Grid Development Plan 2030 (2019)

Installed capacity by state

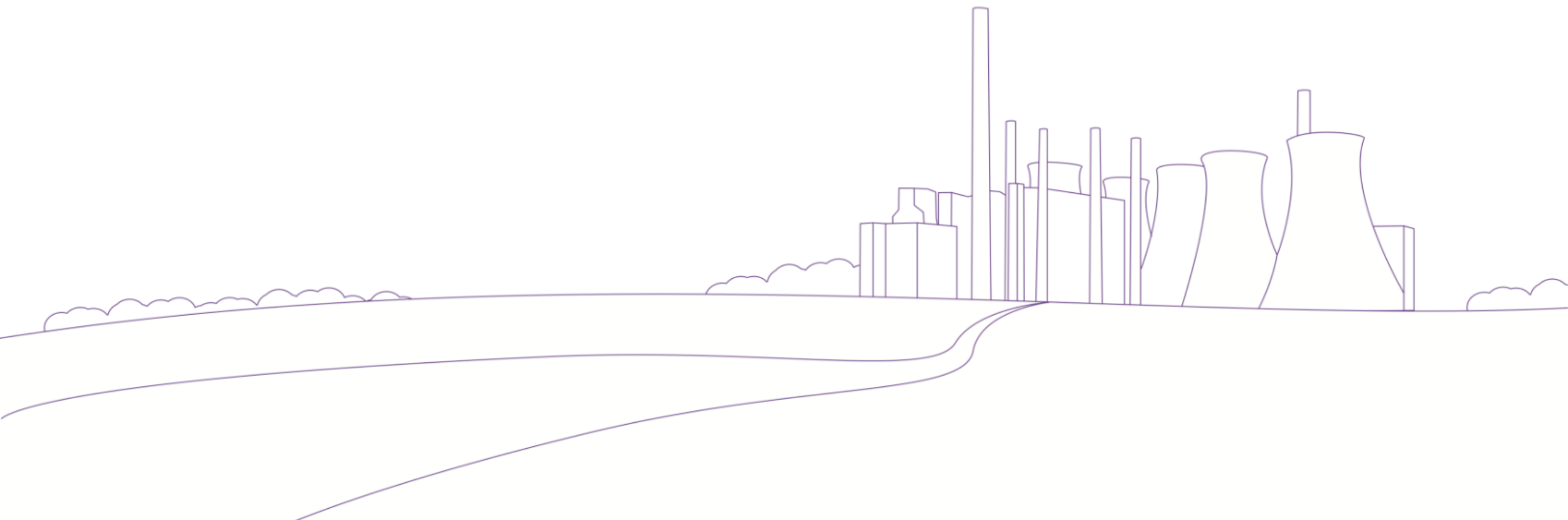
Scenario C 2030

C 2030 (in GW)	Braun-kohle	Stein-kohle	Erdgas	Kuppel-gas	Öl	Abfall	Pump-speicher	KWK < 10 MW	sonstige Konven-tionelle	Wind onshore	Wind offshore	Photo-voltaik	Bio-masse	Lauf- und Speicher-wasser	sonstige EE	Band der Nachfrage	zusätzliche Verbraucher		
																	DSM	PtG	PtH
BW	0,0	2,3	1,9	0,0	0,0	0,1	1,9	1,1	0,0	3,7	0,0	14,6	0,7	1,0	0,0	4,2 – 13,8	0,7	0,0	1,5
BY	0,0	0,0	4,7	0,0	0,0	0,2	0,8	1,1	0,0	2,6	0,0	22,4	1,2	2,4	0,1	5,3 – 16,4	0,8	0,2	1,6
BE	0,0	0,0	1,3	0,0	0,0	0,0	0,0	0,2	0,0	0,0	0,0	1,1	0,0	0,0	0,0	0,9 – 2,7	0,1	0,0	1,0
BB	1,6	0,0	0,2	0,1	0,3	0,1	0,0	0,4	0,0	10,1	0,0	6,5	0,4	0,0	0,0	1,1 – 3,3	0,2	0,2	0,5
HB	0,0	0,1	0,5	0,2	0,0	0,1	0,0	0,1	0,0	0,5	0,0	0,4	0,0	0,0	0,0	0,3 – 0,9	0,1	0,0	0,3
HH	0,0	1,6	0,3	0,0	0,0	0,0	0,0	0,3	0,0	0,1	0,0	0,6	0,0	0,0	0,0	0,9 – 2,2	0,2	0,1	0,5
HE	0,0	0,0	1,7	0,0	0,0	0,1	0,6	0,6	0,0	3,9	0,0	6,0	0,2	0,1	0,0	2,5 – 7,1	0,4	0,0	0,8
MV	0,0	0,0	0,4	0,0	0,0	0,0	0,0	0,2	0,0	6,4	2,2	4,2	0,3	0,0	0,0	0,5 – 1,5	0,0	0,1	0,7
NI	0,0	0,9	2,4	0,3	0,0	0,1	0,2	0,8	0,0	17,3	10,8	10,2	1,1	0,1	0,0	3,5 – 10,1	0,7	0,5	1,6
NW	3,2	3,3	8,4	1,3	0,1	0,5	0,3	1,5	0,2	9,8	0,0	16,0	0,7	0,2	0,4	8,9 – 23,3	1,7	0,9	3,9
RP	0,0	0,0	1,7	0,0	0,0	0,1	0,0	0,4	0,0	6,1	0,0	5,6	0,1	0,2	0,0	2,0 – 5,1	0,4	0,2	0,5
SL	0,0	0,0	0,3	0,1	0,0	0,0	0,0	0,1	0,0	0,4	0,0	1,3	0,0	0,0	0,1	0,5 – 1,6	0,1	0,0	0,3
SN	3,3	0,0	0,6	0,0	0,0	0,0	1,1	0,5	0,0	1,8	0,0	4,4	0,3	0,1	0,0	1,4 – 4,0	0,2	0,2	0,6
ST	1,0	0,0	0,8	0,0	0,1	0,2	0,1	0,4	0,0	6,7	0,0	4,4	0,4	0,0	0,0	1,0 – 2,7	0,2	0,4	0,6
SH	0,0	0,0	0,5	0,0	0,0	0,0	0,1	0,3	0,1	12,3	4,0	4,0	0,4	0,0	0,0	0,9 – 3,3	0,2	0,2	1,4
TH	0,0	0,0	0,5	0,0	0,0	0,0	3,0	0,3	0,0	3,7	0,0	2,8	0,2	0,0	0,0	0,7 – 2,4	0,1	0,0	0,3
AT (DE)*	0,0	0,0	0,0	0,0	0,0	0,0	1,6	0,0	0,0	0,0	0,0	0,0	0,0	0,8	0,0	0,0 – 0,0	0,0	0,0	0,0
LU (DE)*	0,0	0,0	0,0	0,0	0,0	0,0	1,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0 – 0,0	0,0	0,0	0,0
Summe**	**9,0**	**8,1**	**26,0**	**2,0**	**0,5**	**1,7**	**11,0**	**8,3**	**0,3**	**85,5**	**17,0**	**104,5**	**6,0**	**5,1**	**0,6**	**35,1 – 100,2**	**6,0**	**3,0**	**16,1**



* Erzeugungsanlagen im Ausland mit Einspeisung in das deutsche Übertragungsnetz
** Bei der Aufsummierung der Einzelwerte können sich Rundungsabweichungen ergeben.
*** Das Band der Nachfrage umfasst den klassischen Stromverbrauch sowie Wärmepumpen, Elektromobilität und VNB-Verluste ohne Einsatz von DSM, Power-to-Gas / -Heat.

Exit from coal fired power-generation



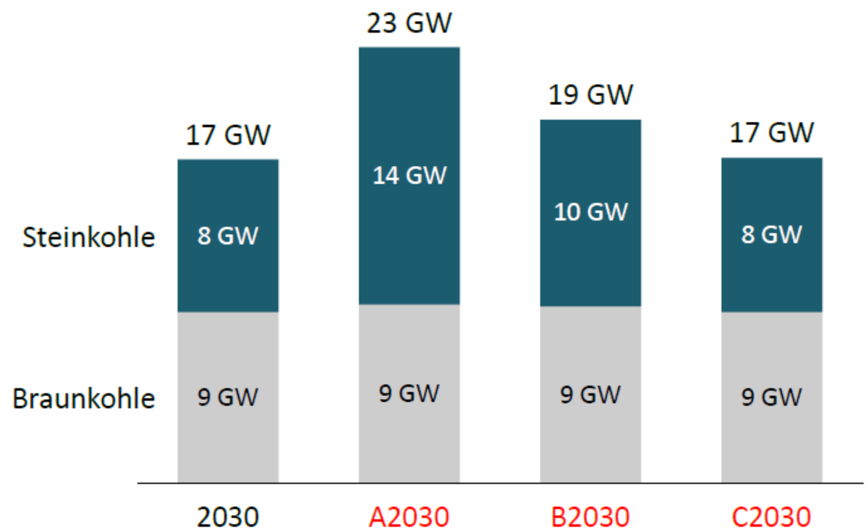
Grid Development Plan 2030 (2019)

Results of the commission on growth and structural change (WSB-commission) and assumed capacities in the GDP 2030 (2019)

NETZ ENTWICKLUNGS PLAN STROM

- **Recommendations of the WSB-commission on capacities of coal-fired power plants**:
  - **17 GW capacity of coal in 2030**
    (8 GW hard coal , 9 GW lignite)
  - **0-<17 GW in 2035**

- **Capacities in the GDP scenarios**
  - **A 2030: 22,9 GW**
    (13,5 GW hard coal 9,4 GW lignite)
  - **B 2030: 19,1 GW**
    (9,8 GW hard coal 9,3 GW lignite)
  - **C 2030: 17,1 GW**
    (8,1 GW hard coal, 9,0 GW lignite)
  - **B 2035: 17,1 GW**
    (8,1 GW hard coal, 9,0 GW lignite)



Rounded numbers

→ **Conclusion:**
- Capacities in **B 2030** almost compatible with recommendations by WSB-commission
- Capacities in **C 2030** almost identical to recommendations by WSB-commission
- Capacities in **B 2035** are at the upper bound of recommended bandwidth.
- The sensitivity calculation in the second draft „**B 2035 – Exit from coal**“ confirms the sustainability of grid measures even in the case of 0 GW coal.

Grid Development Plan 2030 (2019)

Sensitivity calculation „B 2035 – Exit from coal“

- The sensitivity calculation „B 2035 – Exit from coal“ was conducted to make sure that all grid measures identified for 2030 and 2035 are necessary in the case of a complete exit from coal-fired power generation.
- The calculation is based on scenario B 2035. Analogously to the GDP, reductions in coal generation by cogenerating plants were substituted by gas based innovative cogeneration facilities (+1.1 GW).

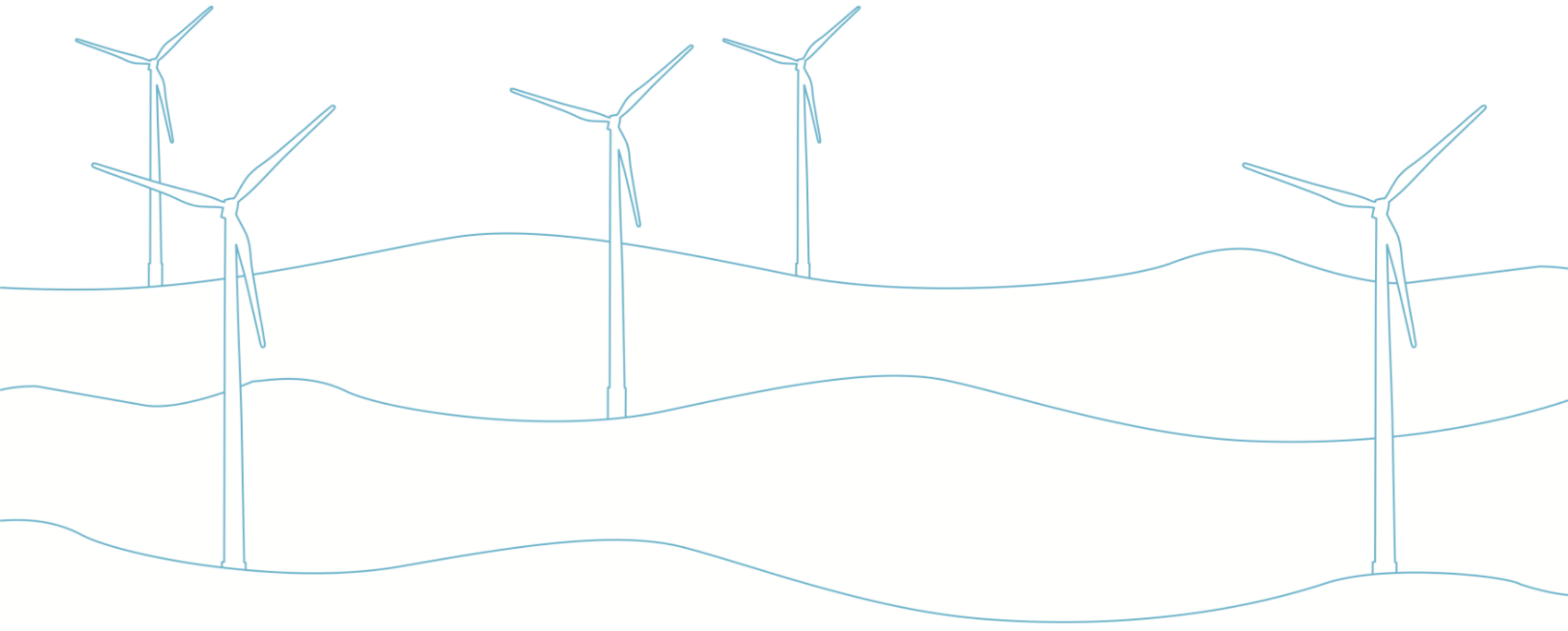
Results of the market-simulation:

- Net exports decline in comparison to B 2035 from 35.9 to 19 TWh: Less exports to southern and western Europe, more imports from northern and eastern Europe.
- + 24 TWh additional generation from gas power plants
- Dumped Energy declines from 6.1 to 4.4 TWh → better integration of renewables
- CO_2-limit is reached without additional CO_2-pricing (96.1 instead of 127 mio. t)

Results of the grid-analysis:

- Grid measures identified in B 2035 are necessary even without power generation from coal → identified measures are robust
- Redispatch with the measures of B 2035 increases from 2.6 to 3.3 TWh

Offshore Grid Development



Grid Development Plan 2030 (2019)

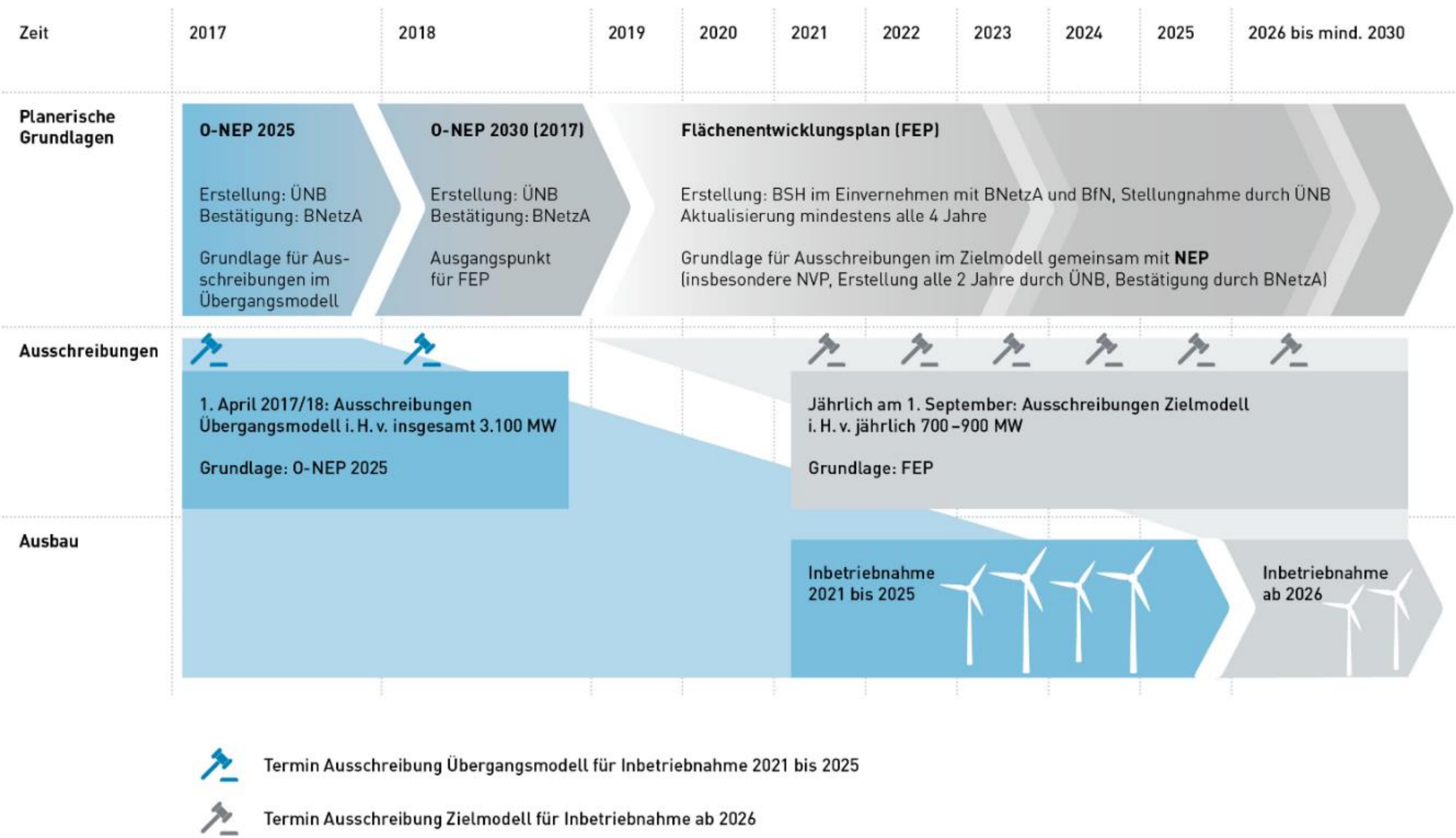
Determining the expansion requirements of the offshore-grid

- The determinations previously laid down in the **O-GDP** have, due to a change in the law, partly been moved to **GDP** and partly to the Area Development Plan (Flächenentwicklungsplan (**FEP**)), compiled by the Bundesamt für Seeschifffahrt und Hydrographie (BSH).
- The GDP and FEP are a coordinated planning tool and together form the basis for the regional planning of the coastal states.
- The current Scenario Framework differs from the current draft of the FEP as well as from the EEG in expecting an expansion of offshore wind up to **17 GW** in Scenario **B 2030 and C 2030**, and of **20 GW** in Scenario **A 2030** as well as **23.2 GW** in Scenario **B 2035**. This expansion happens almost exclusively in the North Sea.

Gebiet	B 2030 / C 2030	A 2030	B 2035
Nordsee	14,8 GW	17,8 GW	21,0 GW
Ostsee	2,2 GW	2,2 GW	2,2 GW
Gesamt	**17,0 GW**	**20,0 GW**	**23,2 GW**

Grid Development Plan 2030 (2019)

From the O-GDP to the FEP



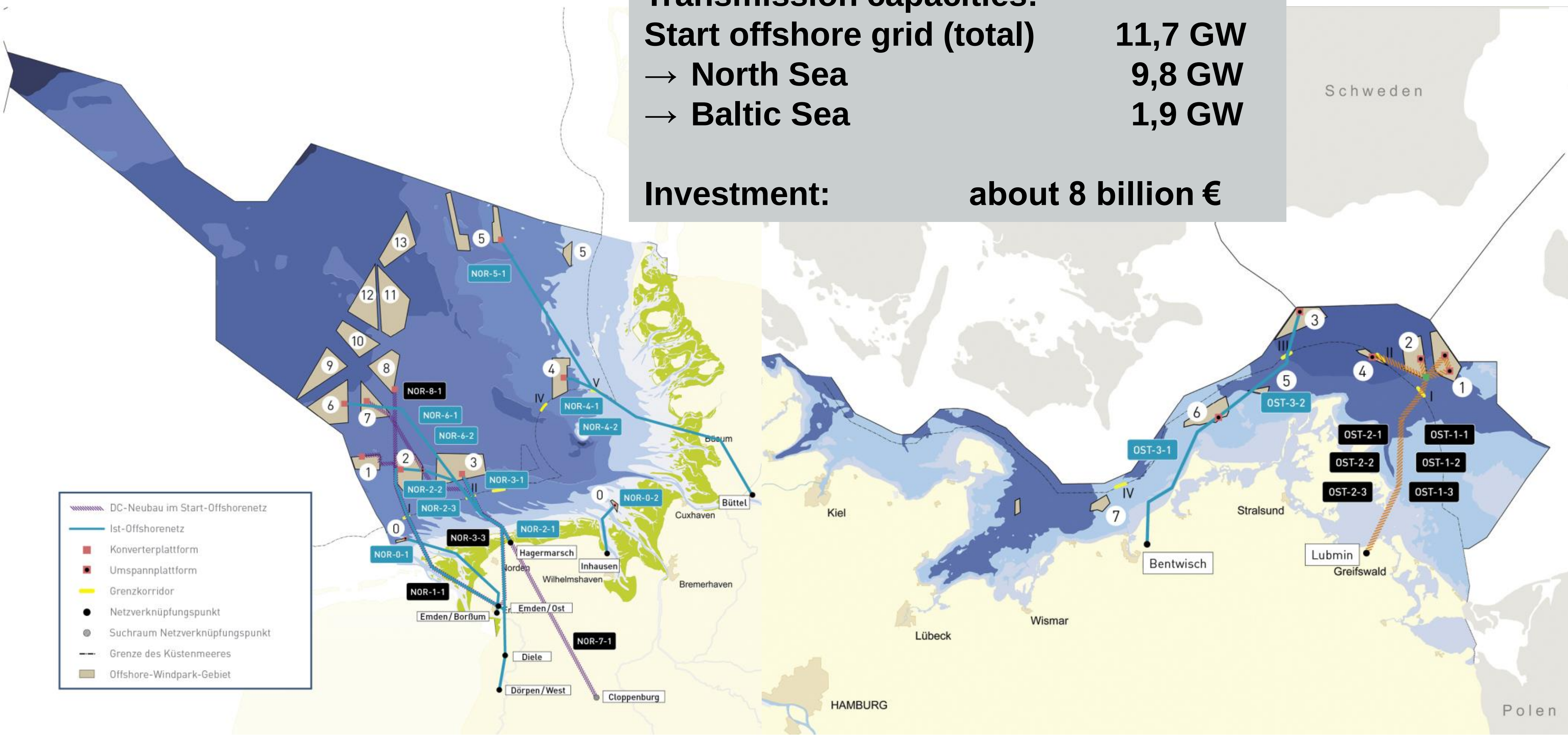
Grid Development Plan 2030 (2019)

Start offshore grid North Sea and Baltic Sea

NETZ ENTWICKLUNGS PLAN STROM

Transmission capacities:

Start offshore grid (total)	**11,7 GW**
→ North Sea	**9,8 GW**
→ Baltic Sea	**1,9 GW**
Investment:	**about 8 billion €**



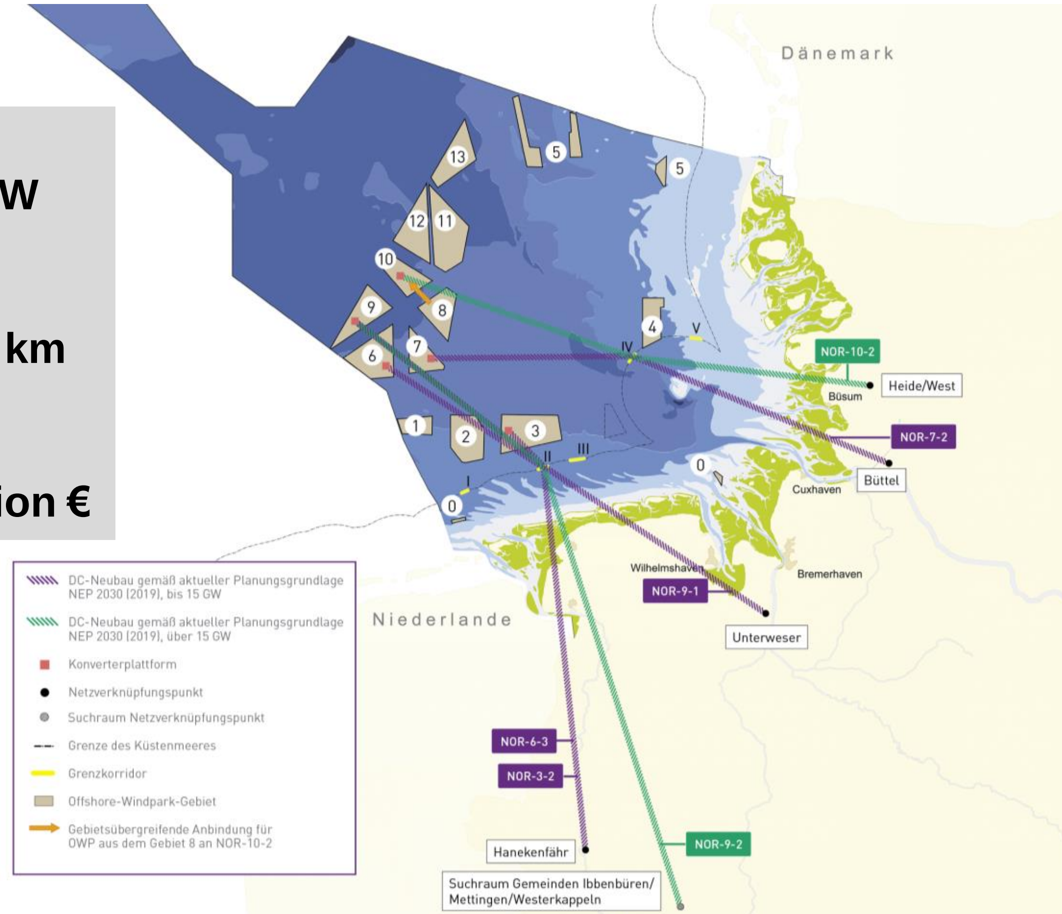
Grid Development Plan 2030 (2019)

Offshore expansion grid North Sea

Scenarios B 2030 and C 2030

NETZ
ENTWICKLUNGS
PLAN **STROM**

Transmission capacity: **expansion grid (North Sea)**	**5,8 GW**
Total length of the **expansion grid (North Sea)**	**1.756 km**
Approximated investment costs **expansion grid (North Sea)**	**9 billion €**



Grid Development Plan 2030 (2019)

Offshore expansion grid North Sea
Scenarios B 2030 and C 2030

NETZ ENTWICKLUNGS PLAN STROM

Projekt	Bezeichnung der Maßnahme	Netzverknüpfungs-punkt	Beginn der Umsetzung	Geplante Fertigstellung
NOR-3-2	HGÜ-Verbindung NOR-3-2 (DolWin4)	Hanekenfähr	2023	2028
NOR-6-3	HGÜ-Verbindung NOR-6-3 (BorWin4)	Hanekenfähr	2024	2029
NOR-7-2	HGÜ-Verbindung NOR-7-2 (BorWin6)	Büttel	2022	2027
NOR-9-1	HGÜ-Verbindung NOR-9-1 (BalWin1)	Unterweser	2024	2029
NOR-9-2	HGÜ-Verbindung NOR-9-2 (BalWin2)	Suchraum Gemeinden Ibbenbüren / Mettingen / Westerkappeln	nach 2025	nach 2030
NOR-10-2	HGÜ-Verbindung NOR-10-2 (BalWin3)	Heide / West	2025	2030

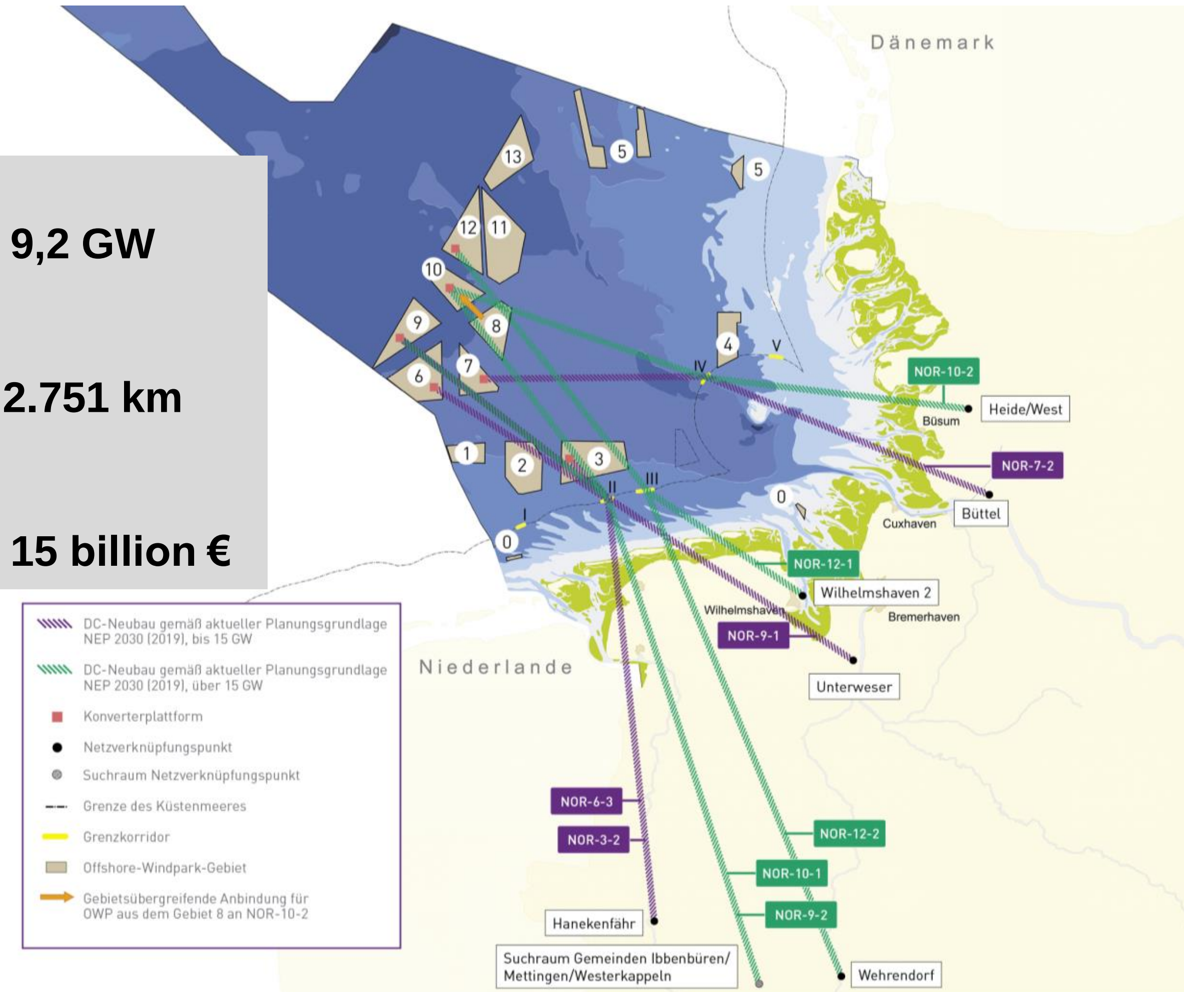
Grid Development Plan 2030 (2019)

Offshore expansion grid North Sea

Scenario A 2030

NETZ ENTWICKLUNGS PLAN **STROM**

Transmission capacity: expansion grid (North Sea)	**9,2 GW**
Total length of the expansion grid (North Sea)	**2.751 km**
Approximated investment costs expansion grid (North Sea)	**15 billion €**



Grid Development Plan 2030 (2019)

Offshore expansion grid North Sea

Scenario A 2030

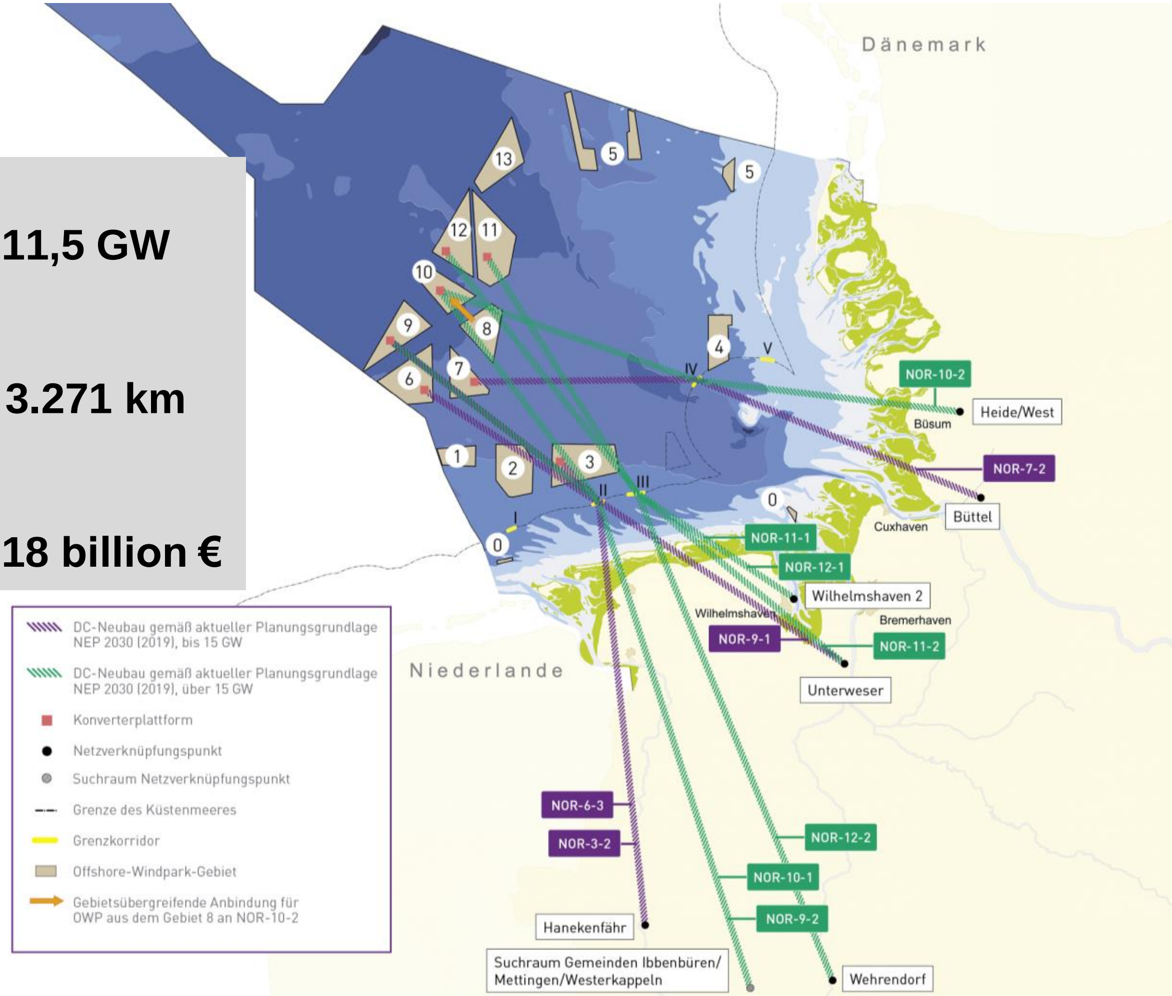
Projekt	Bezeichnung der Maßnahme	Netzverknüpfungs-punkt	Beginn der Umsetzung	Geplante Fertigstellung
NOR-3-2	HGÜ-Verbindung NOR-3-2 (DolWin4)	Hanekenfähr	2023	2028
NOR-6-3	HGÜ-Verbindung NOR-6-3 (BorWin4)	Hanekenfähr	2024	2029
NOR-7-2	HGÜ-Verbindung NOR-7-2 (BorWin6)	Büttel	2022	2027
NOR-9-1	HGÜ-Verbindung NOR-9-1 (BalWin1)	Unterweser	2023	2028
NOR-9-2	HGÜ-Verbindung NOR-9-2 (BalWin2)	Suchraum Gemeinden Ibbenbüren / Mettingen / Westerkappeln	nach 2025	nach 2030
NOR-10-1	HGÜ-Verbindung NOR-10-1 (BalWin4)	Suchraum Gemeinden Ibbenbüren / Mettingen / Westerkappeln	nach 2025	nach 2030
NOR-10-2	HGÜ-Verbindung NOR-10-2 (BalWin3)	Heide / West	2024	2029
NOR-12-1	HGÜ-Verbindung NOR-12-1 (LanWin1)	Wilhelmshaven 2	2025	2030
NOR-12-2	HGÜ-Verbindung NOR-12-2 (LanWin2)	Wehrendorf	nach 2025	nach 2030

Grid Development Plan 2030 (2019)

Offshore expansion grid North Sea

Scenario B 2035

Transmission capacity: expansion grid (North Sea)	**11,5 GW**
Total length of the expansion grid (North Sea)	**3.271 km**
Approximated investment costs expansion grid (North Sea)	**18 billion €**



Grid Development Plan 2030 (2019)

Offshore expansion grid North Sea

Scenario B 2035

NETZ ENTWICKLUNGS PLAN STROM

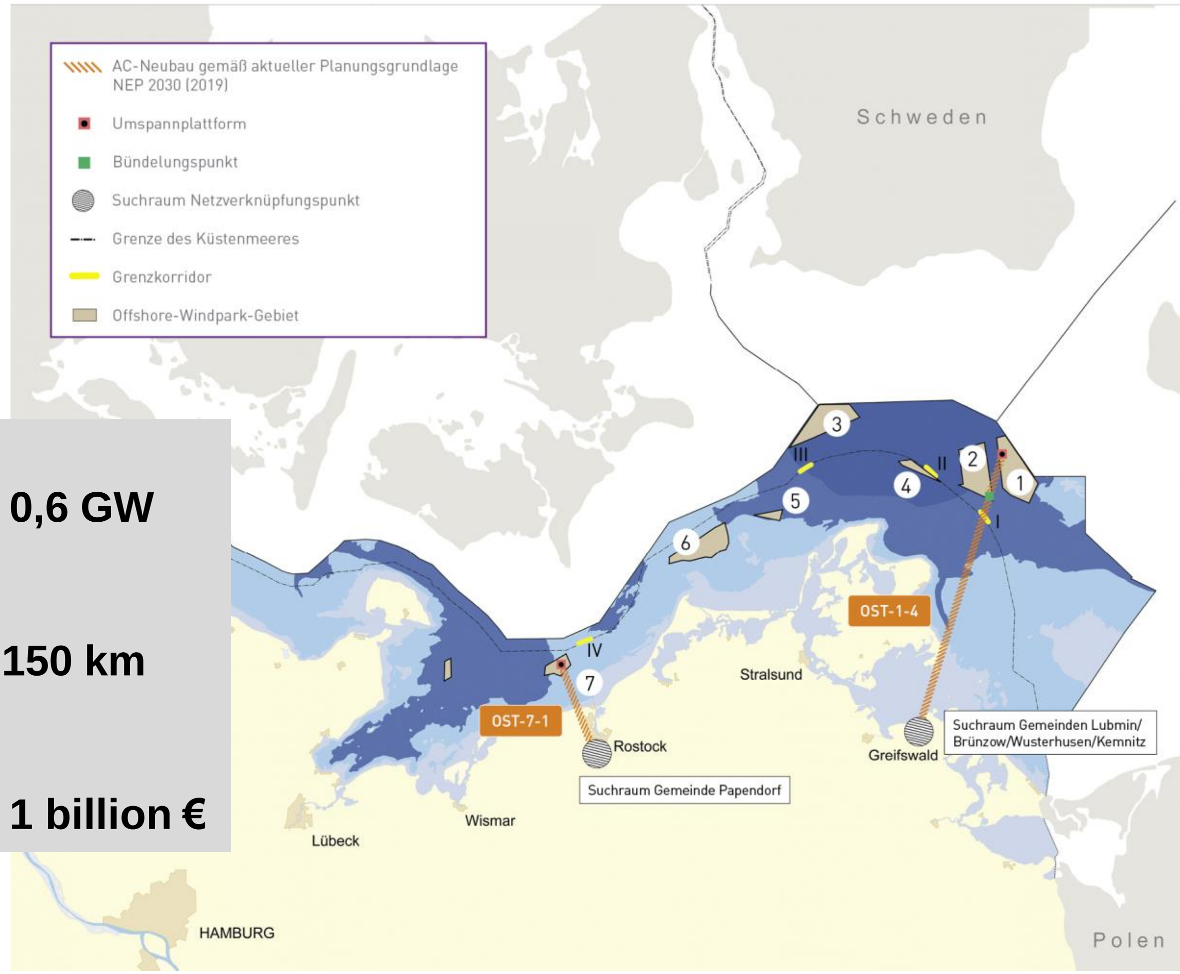
Projekt	Bezeichnung der Maßnahme	Netzverknüpfungs-punkt	Beginn der Umsetzung	Geplante Fertigstellung
NOR-3-2	HGÜ-Verbindung NOR-3-2 (DolWin4)	Hanekenfähr	2023	2028
NOR-6-3	HGÜ-Verbindung NOR-6-3 (BorWin4)	Hanekenfähr	2024	2029
NOR-7-2	HGÜ-Verbindung NOR-7-2 (BorWin6)	Büttel	2022	2027
NOR-9-1	HGÜ-Verbindung NOR-9-1 (BalWin1)	Unterweser	2024	2029
NOR-9-2	HGÜ-Verbindung NOR-9-2 (BalWin2)	Suchraum Gemeinden Ibbenbüren / Mettingen / Westerkappeln	nach 2025	nach 2030
NOR-10-1	HGÜ-Verbindung NOR-10-1 (BalWin4)	Suchraum Gemeinden Ibbenbüren / Mettingen / Westerkappeln	nach 2025	nach 2030
NOR-10-2	HGÜ-Verbindung NOR-10-2 (BalWin3)	Heide / West	2025	2030
NOR-11-1	HGÜ-Verbindung NOR-11-1 (LanWin3)	Wilhelmshaven 2	2029	2034
NOR-11-2	HGÜ-Verbindung NOR-11-2 (LanWin4)	Unterweser	2030	2035
NOR-12-1	HGÜ-Verbindung NOR-12-1 (LanWin1)	Wilhelmshaven 2	2027	2032
NOR-12-2	HGÜ-Verbindung NOR-12-2 (LanWin2)	Wehrendorf	nach 2025	nach 2030

Grid Development Plan 2030 (2019)

Offshore expansion grid Baltic Sea

Scenarios A 2030, B 2030, C 2030 und B 2035

NETZ ENTWICKLUNGS PLAN STROM



Transmission capacity: expansion grid (Baltic Sea)	**0,6 GW**
Total length of the expansion grid (Baltic Sea)	**150 km**
Approximated investment costs expansion grid (Baltic Sea)	**1 billion €**

Grid Development Plan 2030 (2019)

Offshore expansion grid Baltic Sea

Scenarios A 2030, B 2030, C 2030 und B 2035

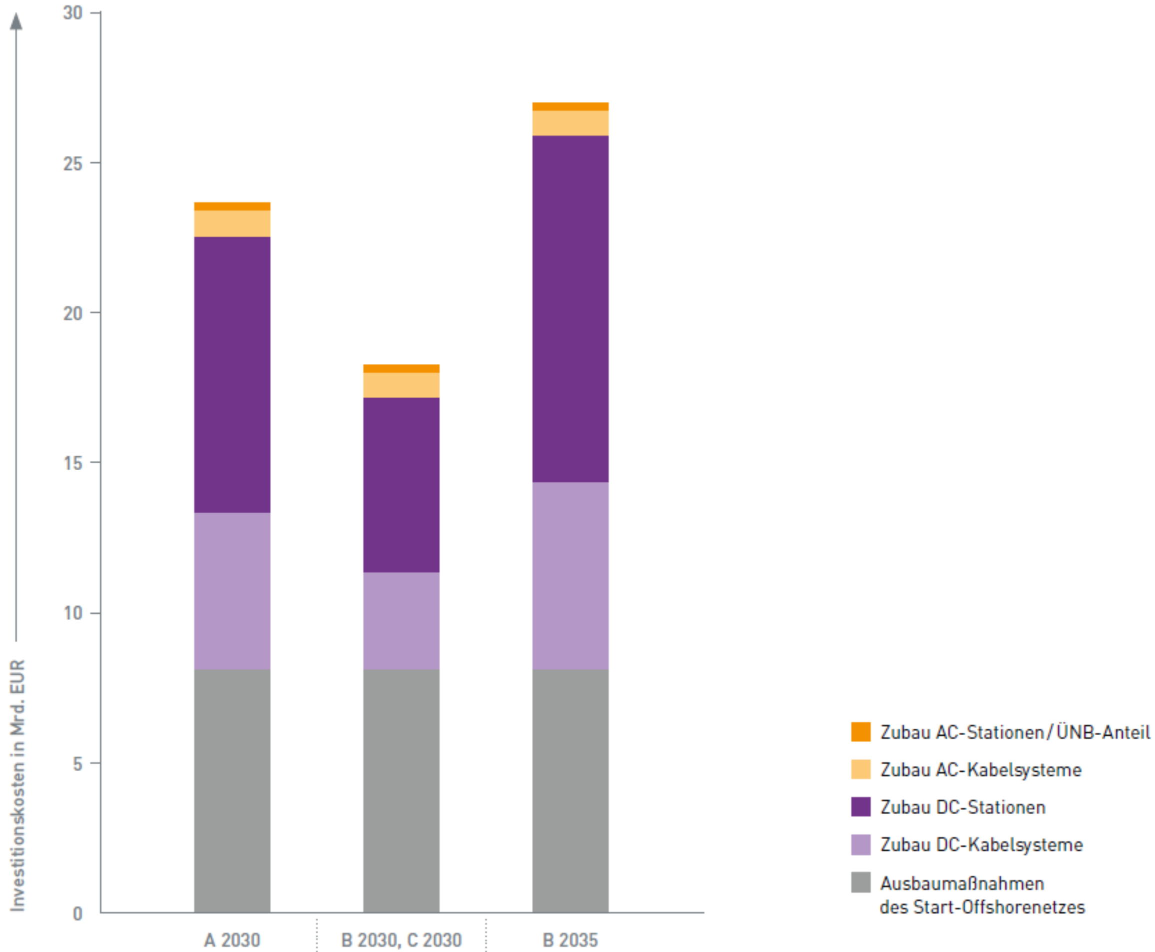
NETZ ENTWICKLUNGS PLAN STROM

Projekt	Bezeichnung der Maßnahme	Netzverknüpfungs-punkt	Beginn der Umsetzung	Geplante Fertigstellung
OST-1-4	AC-Verbindung OST-1-4	Suchraum Gemeinden Lubmin / Brünzow / Wusterhusen / Kemnitz	2023	2026
OST-7-1	AC-Verbindung OST-7-1 (nördlich Warnemünde)	Suchraum Gemeinde Papendorf	2026	2029

Grid Development Plan 2030 (2019)

Approximated investment costs offshore grid

Abbildung 32: Schätzung des Investitionsvolumens in Abhängigkeit der Szenarien des NEP 2030 (2019)



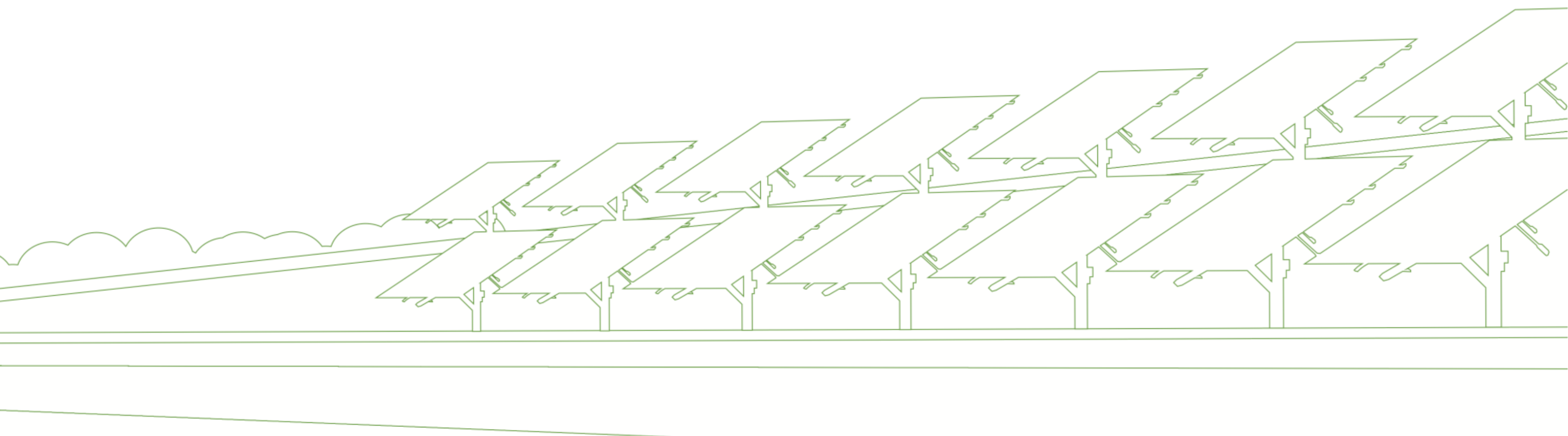
Grid Development Plan 2030 (2019)

Sensitivity calculation for the Baltic Sea

- In a **sensitivity calculation** 50Hertz evaluated the impact of an increase of 1 GW offshore generation in the territorial waters of the Baltic Sea in easily accessible areas.
- The results show that an increased feed-in from offshore wind in the Baltic Sea compared to the current Scenario Framework **does not necessitate further onshore grid measures** beyond the measures already identified.
- This implies **additional flexibility** in the political goals for power generation from offshore wind in a bandwidth of **17 to 20 GW**.

NETZ
ENTWICKLUNGS
PLAN **STROM**

Results of the market simulation



Grid Development Plan 2030 (2019)

Results of the market simulation (I)

- The market simulation of the GDP 2030 (2019) reflects the **ongoing transformation of the energy sector** towards the integration of renewable energy.
- **Wind (on- and offshore) is the energy source with the highest share of overall power generation** in all scenarios. With 55% in 2025 up to 70% in 2035, Germany exhibits a large share of renewable generation compared to its European neighbours.
- The goal of **65% renewable energy of gross electricity consumption** as formulated in the **coalition agreement** is reached in **all scenarios for 2030** – and even slightly exceeded (67%-68%). In Scenario B 2035 the share of renewables as fraction of gross electricity consumption increases to 73.7 %.
- Increased **flexibility from cogeneration facilities** and demand side flexibility support the integration of fluctuating renewables. However, it can be expected that generation from renewables will be capped more frequently as a result of market outcomes, because it cannot be integrated.
- In the **scenarios with the target year 2030** the amount of **Dumped Energy** (= generation without corresponding demand) increases significantly compared to the GDP 2030 (2017), but remains low overall (2 - 4.5 TWh) in comparison to the total power generation from renewables.

Grid Development Plan 2030 (2019)

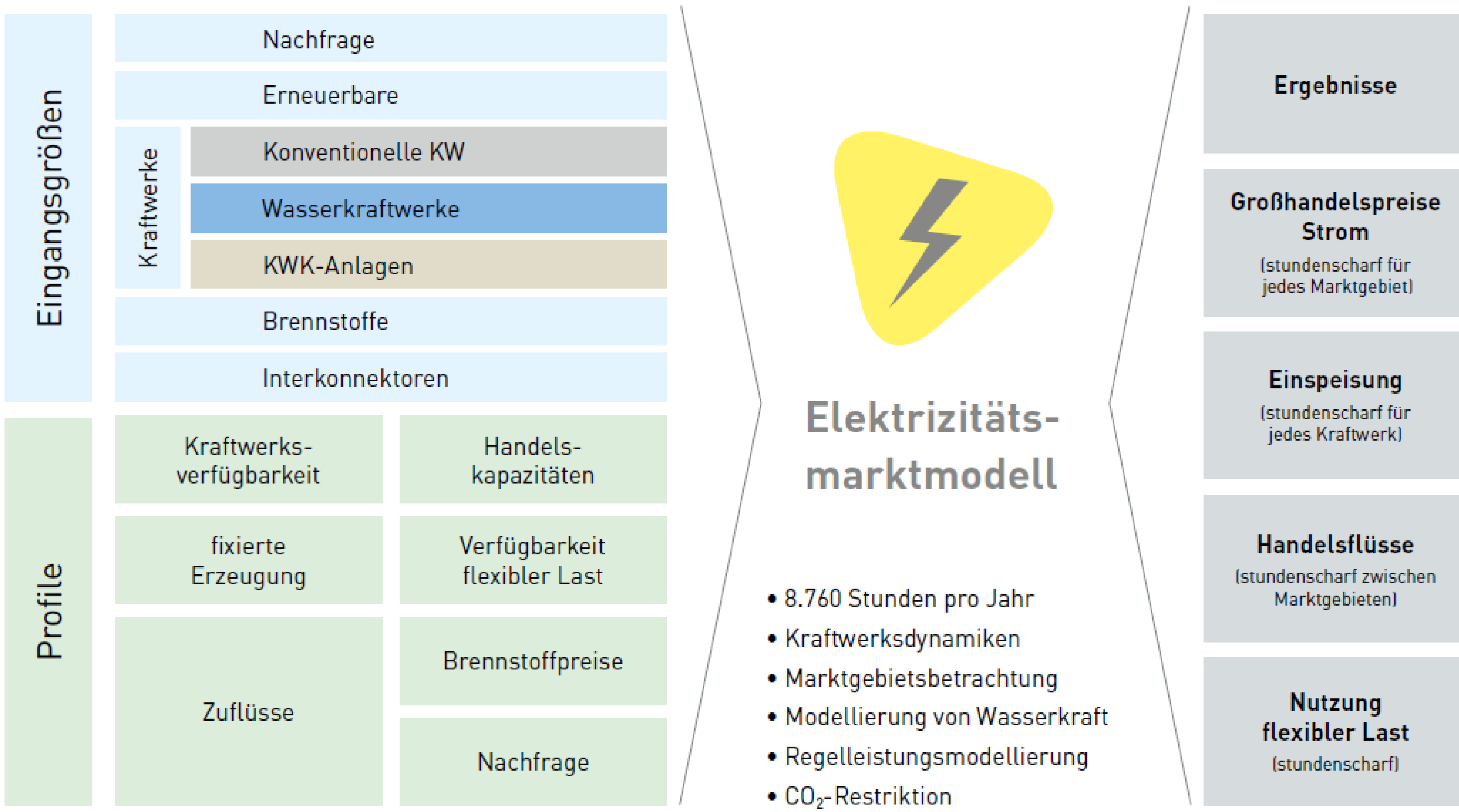
Results of the market simulation (II)

NETZ ENTWICKLUNGS PLAN **STROM**

- **Full-load hours of thermal power generation technologies significantly differ between the scenarios for all energy sources**. The reasons for the differences are among others the full flexibilization of thermal power generation in scenario C 2030 as well as additional CO_2 prices in the scenarios A 2030 and B 2035. The full-lead hours of lignite power plants are significantly below those of the GDP 2030 (2017) in all scenarios.
- **An additional CO_2 price** in Germany for reaching the limits set in the Scenario Framework is necessary **only in scenario A 2030 (+10 €/t CO_2) and B 2035 (+28 €/t CO_2)**. In all other scenarios the limit for emissions is reached without additions to the European CO_2 price.
- **In all scenarios a strong inner-German difference in power generation can be observed.** While power generation, mostly from renewables, in Northern and Eastern Germany is almost twice as high as local demand, Southern and Western Germany exhibit a generation deficit. Between a quarter and half of yearly demand must be imported from other Federal States or other countries.

Grid Development Plan 2030 (2019)

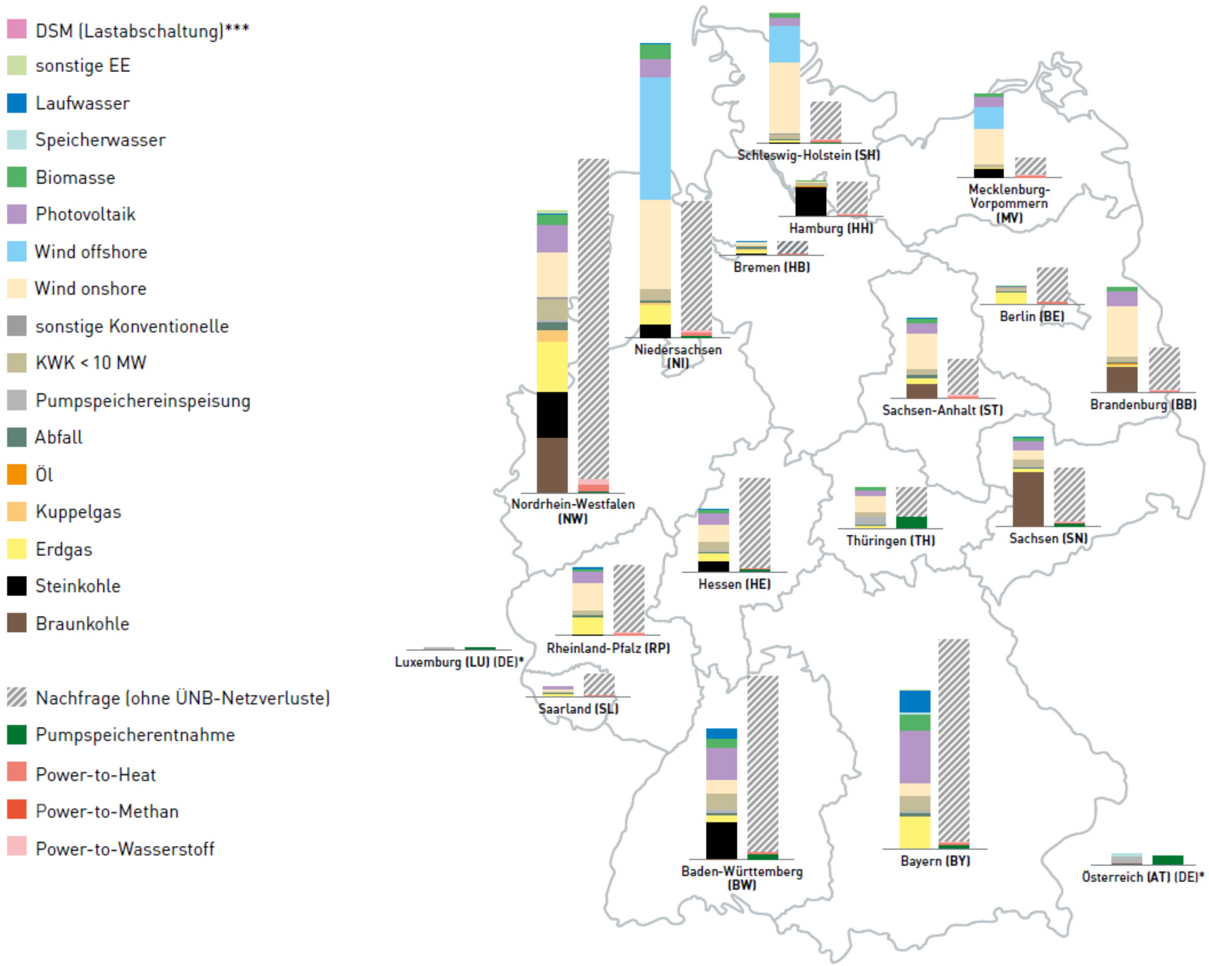
Overview of the market model of the electricity market



Quelle: Pöyry Management Consulting / Übertragungsnetzbetreiber

Grid Development Plan 2030 (2019)

Energy balance B 2030: North/South Divide



Generation surplus in Northern Germany:

Power generation in Northern and Eastern German states is almost double the local demand.

Generation deficit in Southern Germany:

Between a quarter and half of energy demand in Southern States is satisfied by imports from other states or countries.

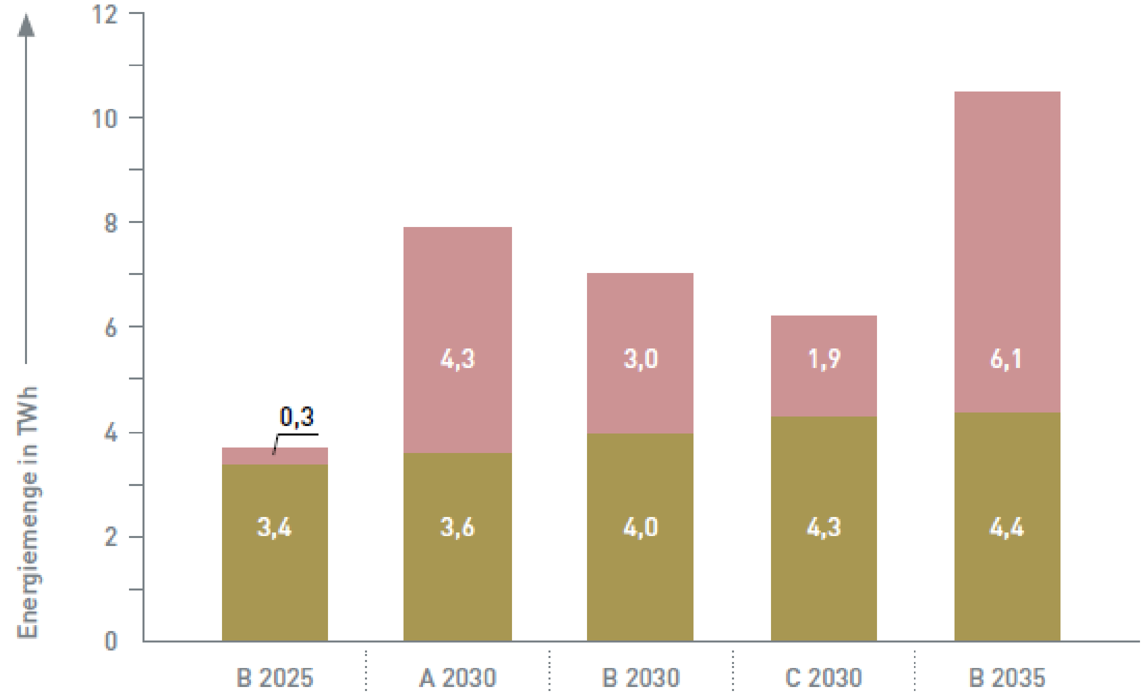
The overall trend is the same in all scenarios, only values differ slightly

Grid Development Plan 2030 (2019)

Peak capping and Dumped Energy

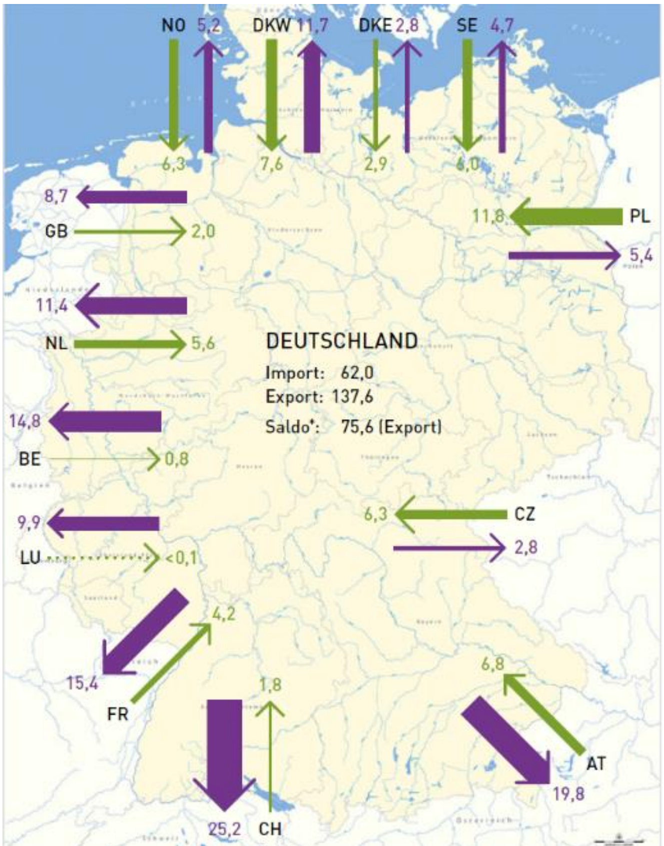
- Significant amounts of Dumped Energy (generation surplus from renewables without corresponding demand) for the first time
- Overall amount is still low compared to overall generation from renewables
- The sum of peak capping and Dumped Energy amounts to just 1.5 - 2.2% of total generation from renewables in 2030 and 2.4 % in 2035

Theoretically this implies a potential for local use of surplus energy (e.g. by PtX)

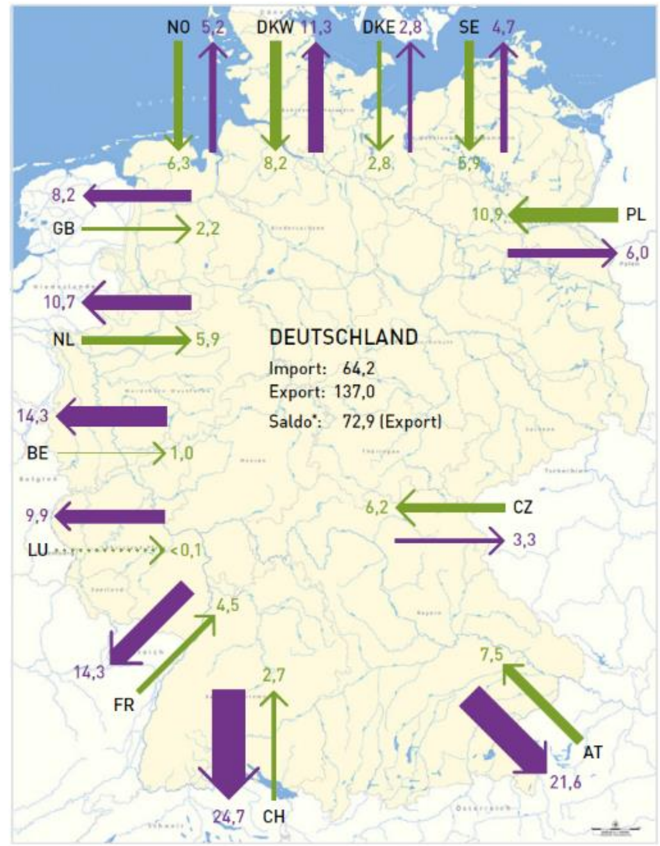


Grid Development Plan 2030 (2019)

Trade: Net power exporter in A 2030 and B 2030



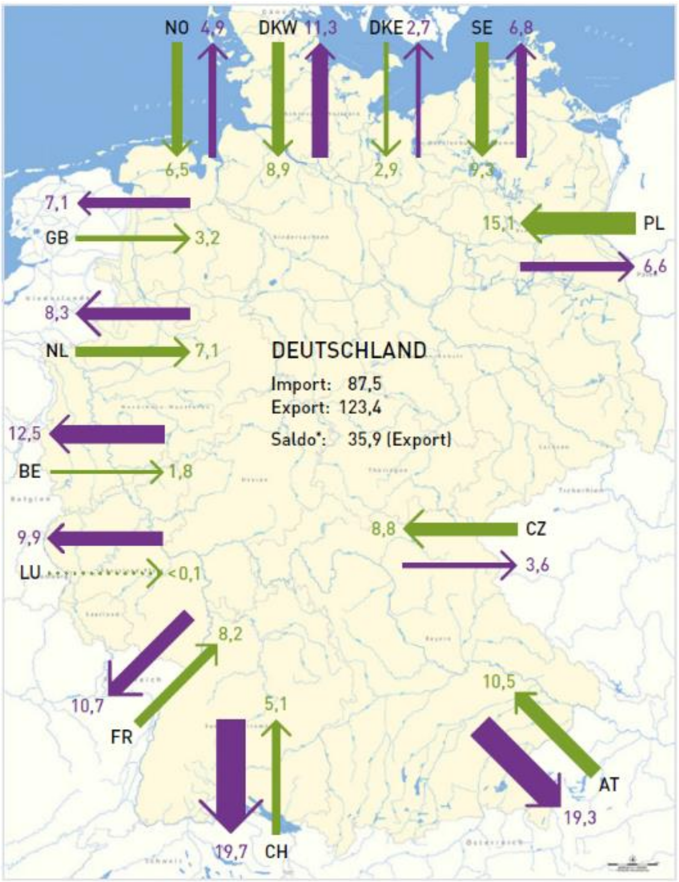
A 2030



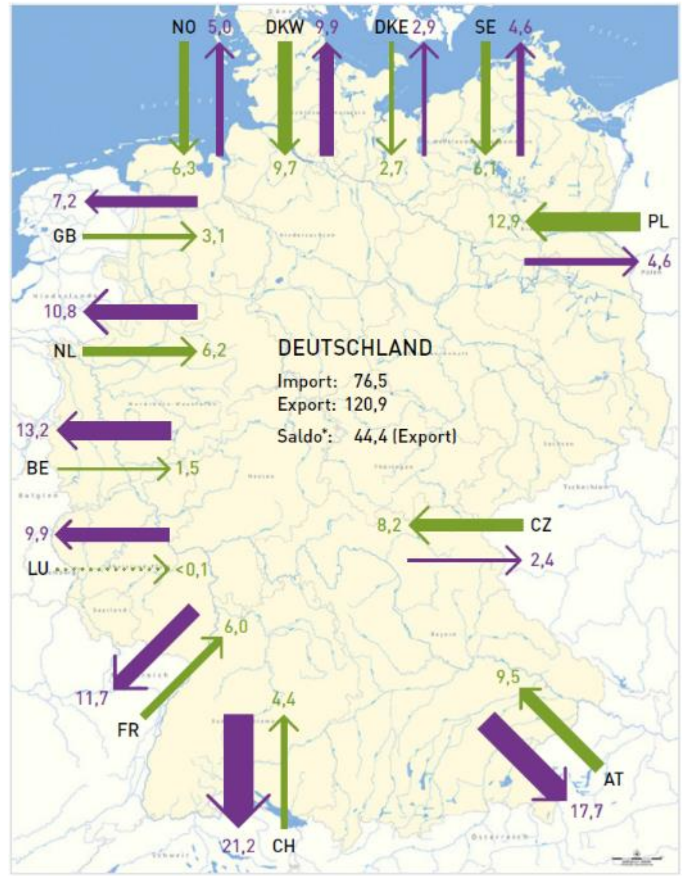
B 2030

Grid Development Plan 2030 (2019)

Trade: Net export significantly higher in C 2030 compared to B 2035



B 2035

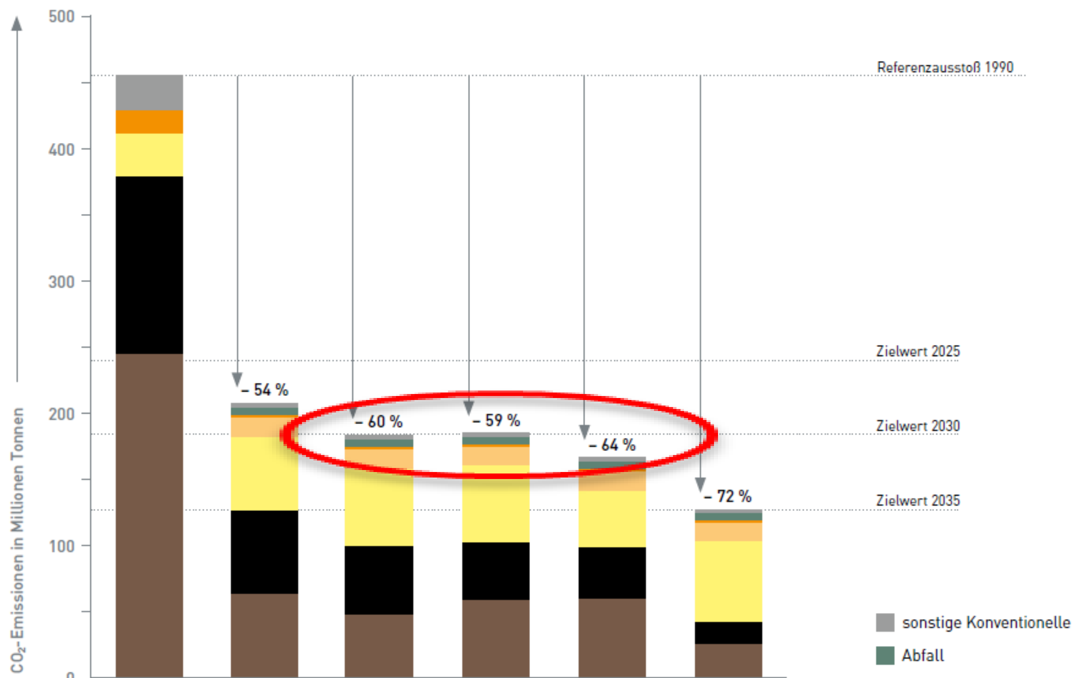


C 2030

Grid Development Plan 2030 (2019)

Power plant use and CO_2-emissions: Additional CO_2 price only in A 2030 and B 2035

Abbildung 47: CO_2-Emissionen in der Stromerzeugung in Deutschland in den Szenarien des NEP 2030 (2019)

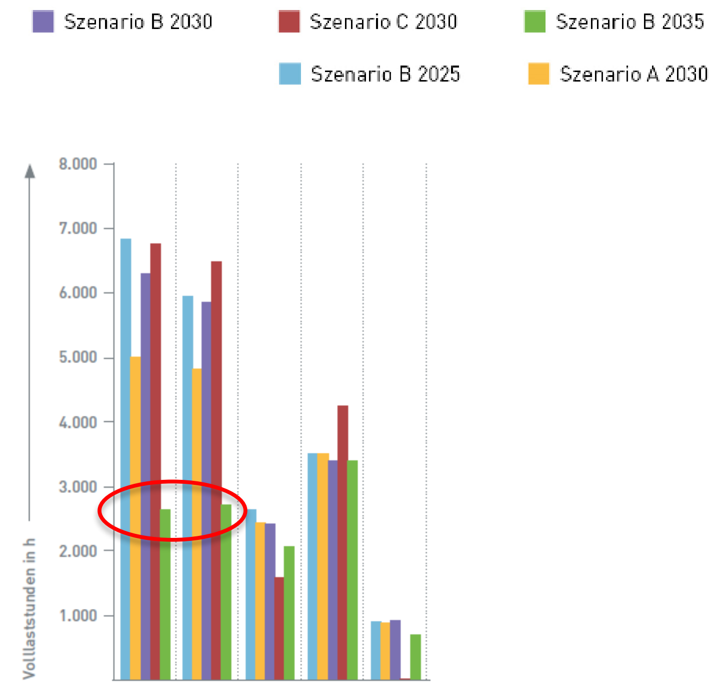


CO_2-Emissionen in Mio. t	Referenz 1990	B 2025	A 2030	B 2030	C 2030	B 2035
Summe pro Szenario	455	207	183	184	166	127

+ 10 €/t

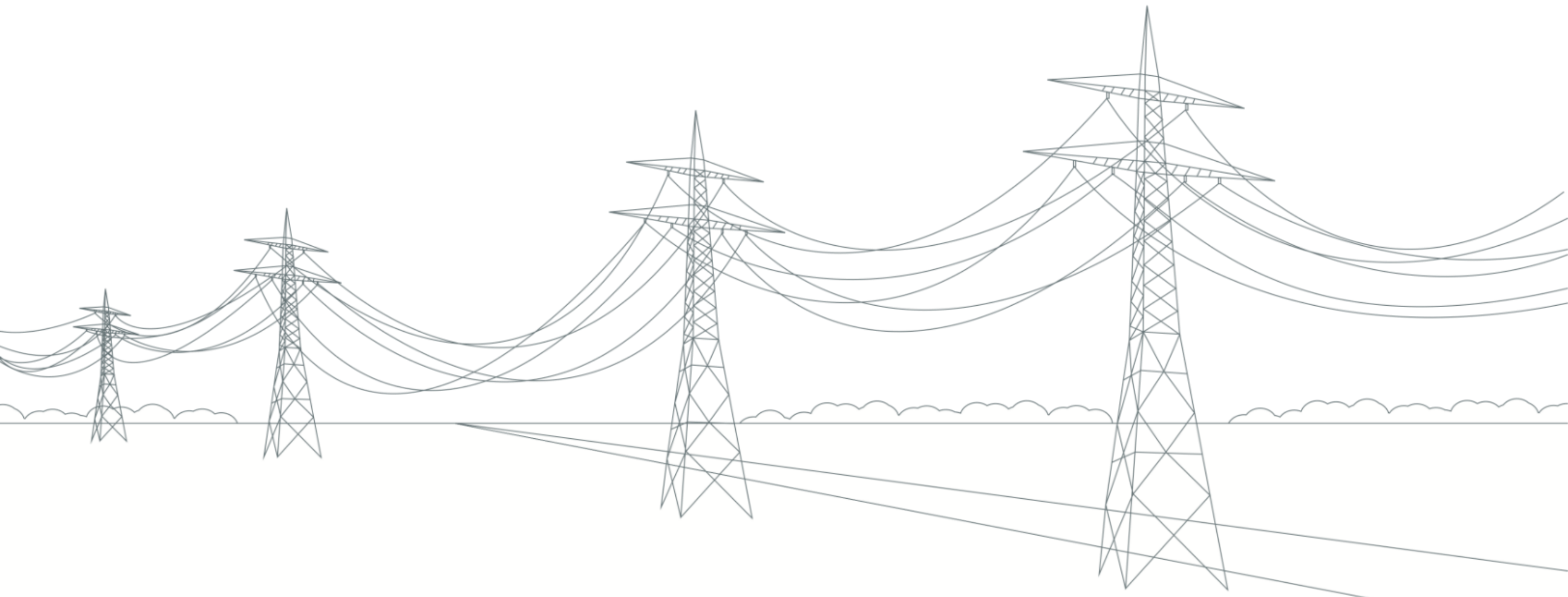
+28 €/t

Quelle: Übertragungsnetzbetreiber



	Braun-kohle	Stein-kohle	Erdgas	Kuppel-gas	Öl
B 2025	6.827	5.942	2.624	3.491	883
A 2030	4.987	4.806	2.421	3.491	876
B 2030	6.292	5.842	2.414	3.389	910
C 2030	6.751	6.461	1.582	4.239	3
B 2035	2.630	2.699	2.054	3.391	697

Results of the grid analyses



Grid Development Plan 2030 (2019)

Key results of the grid analyses (I)

- Due to the new definition of the starting grid (measures become part of the starting grid at the beginning of the plan approval procedures instead of at the end), **the starting grid grew by about one third compared to the GDP 2030 (2017)**.
- Apart from the ad-hoc measures already approved by the Federal Network Agency (BNetzA) after the GDP 2030 (2017), **further redispatch-lowering measures were identified**. Additionally, the use of grid booster pilots was analysed.
- Further phase-shifting transformers were included in the target grids for 2030 and 2035 to optimise power flows in the AC grid and to thereby **reduce the need for grid development and expansion**.

Grid Development Plan 2030 (2019)

Key results of the grid analyses (II)

NETZ ENTWICKLUNGS PLAN STROM

- For the first time, the TSOs implicitly **accounted for the potential of future innovative technologies** (for example modern system controls, grid booster). To account for this potential, bottlenecks in the scenarios for 2030 and 2035 were not fully eliminated with grid enhancement and grid expansion measures.
- In addition to 4 TWh of peak capping, a **redispatch volume of 1.1 TWh in A 2030, 1.9 TWh in B 2030, and 2.6 TWh in C 2030 and B 2035** remain in the proposed grids.
- To integrate 65 % of renewables into the energy system the TSOs continue their approach of **optimising and developing the existing AC grid, adding devices to steer the power-flow, as well as new DC connections** to handle the north-south electricity transport needs.

Grid Development Plan 2030 (2019)

Key results of the grid analyses (III)

NETZ ENTWICKLUNGS PLAN **STROM**

- Due to the assumed innovations of the grid and markets, **the development and expansion needs of the GDP 2030 (2019) remain constant compared to the GDP 2030 (2017).**
- The overall length of identified connections in scenario B 2030 (2019), including additional DC connections, are **slightly below those identified in Scenario B 2030 (2017)**, where the focus was exclusively on expanding the AC grid.
- **All measures of the Federal Requirements Plan** (Bundesbedarfsplan) as well as the additional measures confirmed by the BNetzA in the NEP 2030 (2017) **are necessary** in all scenarios for 2030 as well as 2035.
- The **necessity of these measures**, which are needed for an adequate grid in the face of rising transport needs, **is once more confirmed in the GDP 2030 (2019).**

Grid Development Plan 2030 (2019)

Key results of the grid analyses (short)

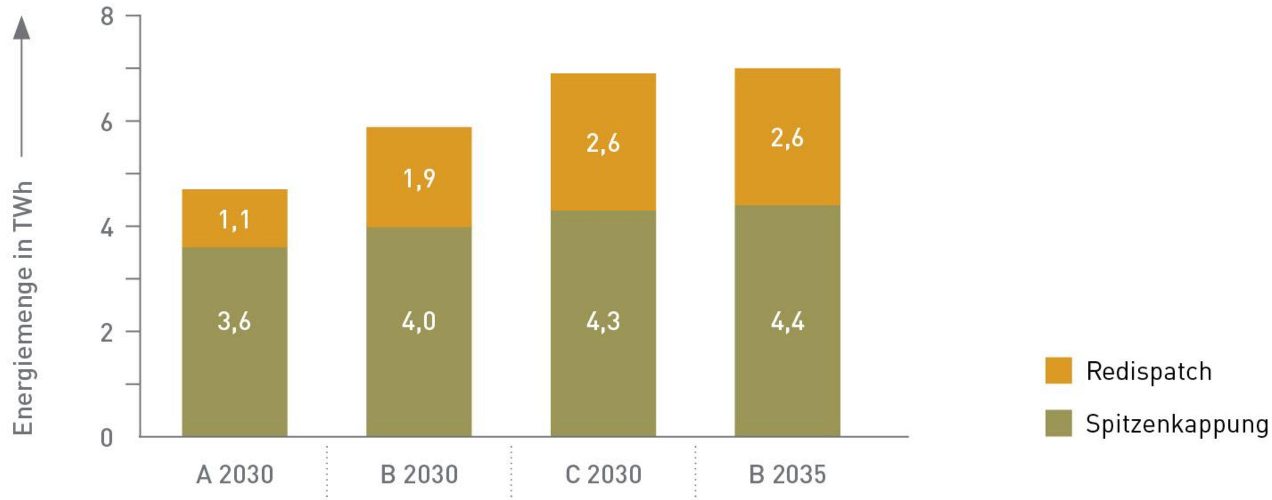
NETZ
ENTWICKLUNGS
PLAN **STROM**

- **All measures of the Federal Requirements Plan** (Bundesbedarfsplan) **as well as the additional measures confirmed by the BNetzA in the NEP 2030 (2017) are necessary** in all scenarios for 2030 as well as 2035. They are not sufficient, however, for an adequate grid.
- For the first time, the TSOs implicitly **accounted for the potential of future innovative technologies** (for example modern system controls, grid booster). To account for this potential, bottlenecks in the scenarios for 2030 and 2035 were not fully eliminated with grid enhancement and grid expansion measures.
- In addition to 4 TWh of peak capping, a **redispatch volume of 1.1 TWh in A 2030, 1.9 TWh in B 2030, and 2.6 TWh in C 2030 and B 2035** remain in the proposed grids.
- Due to the assumed innovations of the grid and markets, **the development and expansion needs of the GDP 2030 (2019) remain constant compared to the GDP 2030 (2017),** even though transport needs are higher due to more renewables in the system.

Grid Development Plan 2030 (2019)

Redispatch and peak capping: room for innovation

Spitzenkappung und verbleibender Redispatch mit den Zielnetzen 2030 und 2035

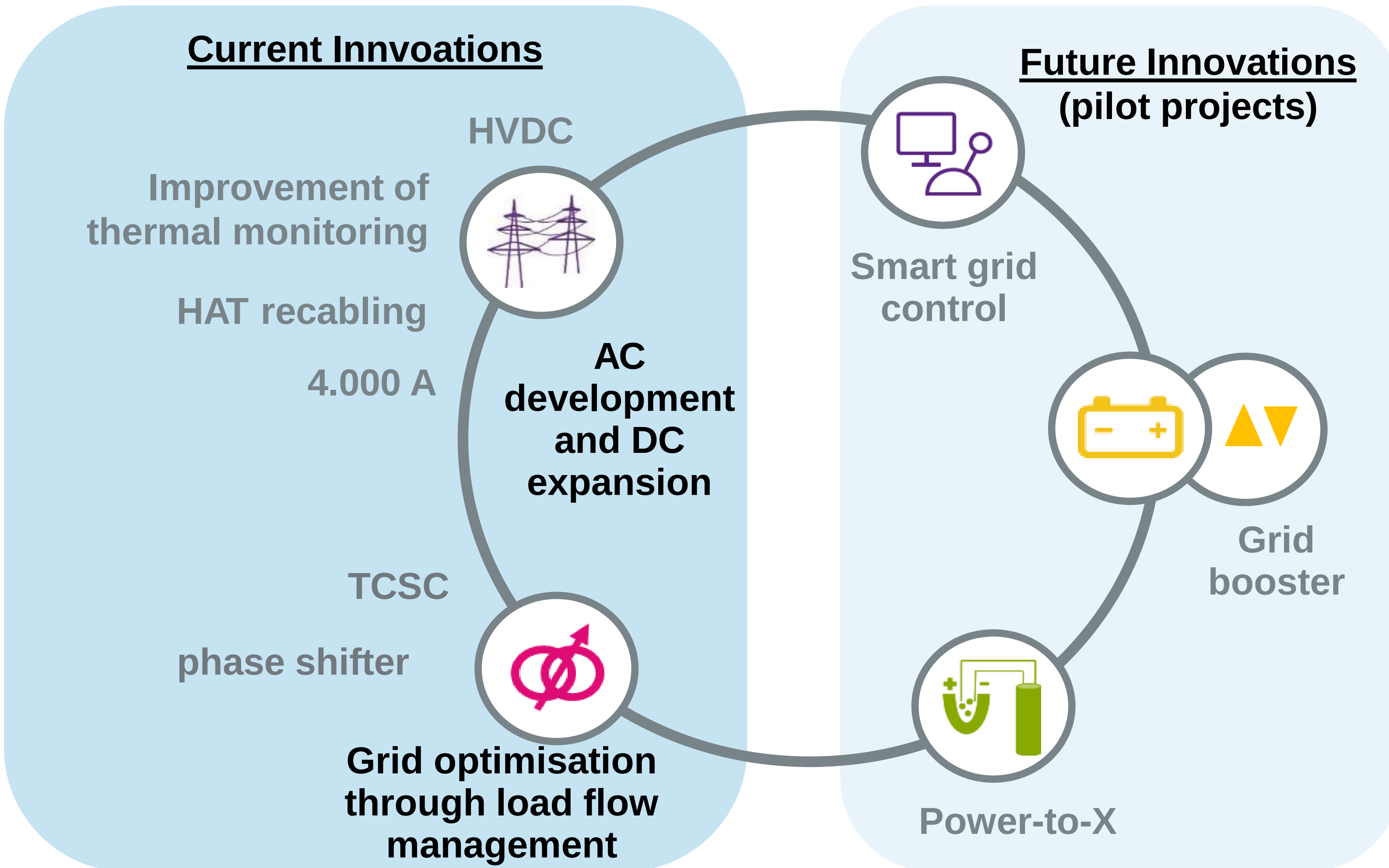


Quelle: Übertragungsnetzbetreiber

Grid Development Plan 2030 (2019)

TSO’s factor in diverse innovations to minimize grid-development and expansion needs

NETZ ENTWICKLUNGS PLAN STROM



Starting grid GDP 2030 (2019)

New definition of starting grid:

- Up to now: current grid, EnLAG measures and measures with planning permission as well as measures currently being built.
- New: Additional measures for which the plan approval procedure started.

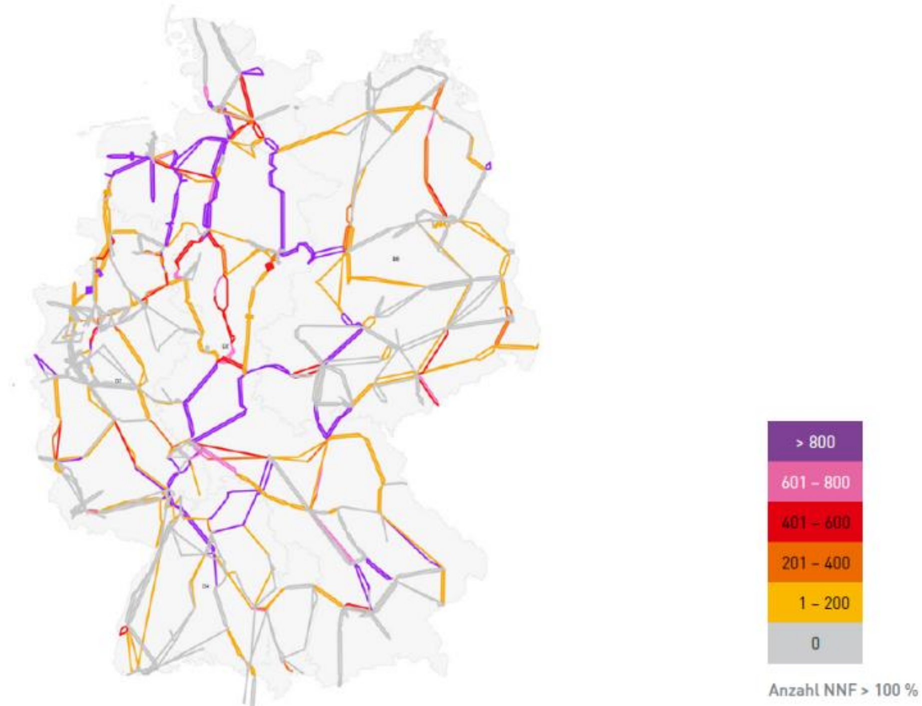
Total amount: 2,630 km
about 700 km more than in the GDP 2030 (2017)

Existing AC lines with new OHL conductors	130 km
New AC lines in existing routes	1,650 km
New AC lines in new routes	600 km
New DC lines:	250 km
Estimated investments:	EUR 12,5 billion

Grid Development Plan 2030 (2019)

Overload in the starting grid including interconnectors

Maximum load per circuit in the case of failure of one grid element.
So called „(n-1) –case“.



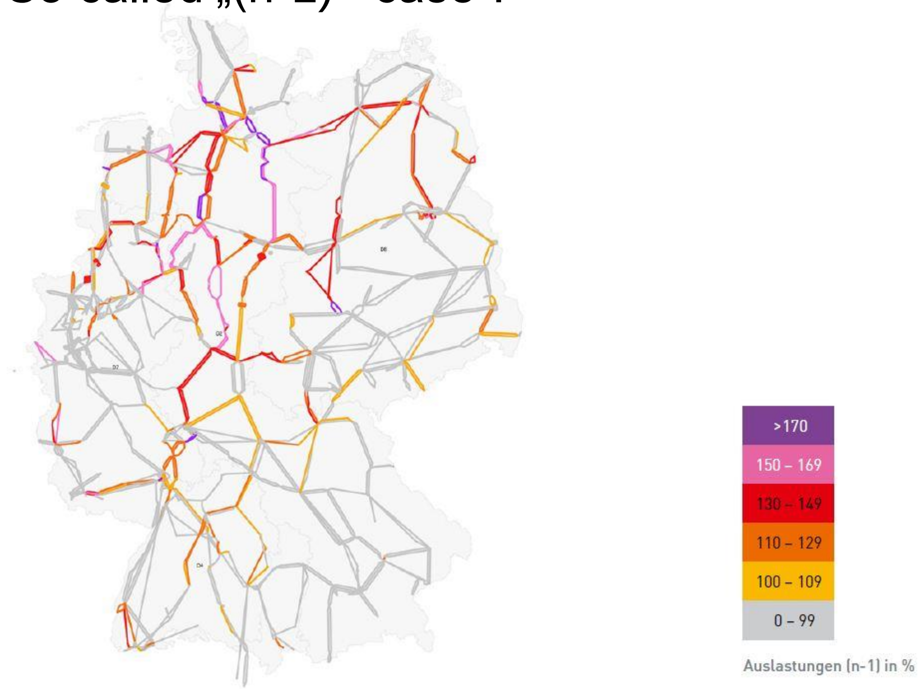
Maximum utilisation of line capacity:
More than 300% on some lines

Frequency of overloading:
Over 1000 hours on some lines

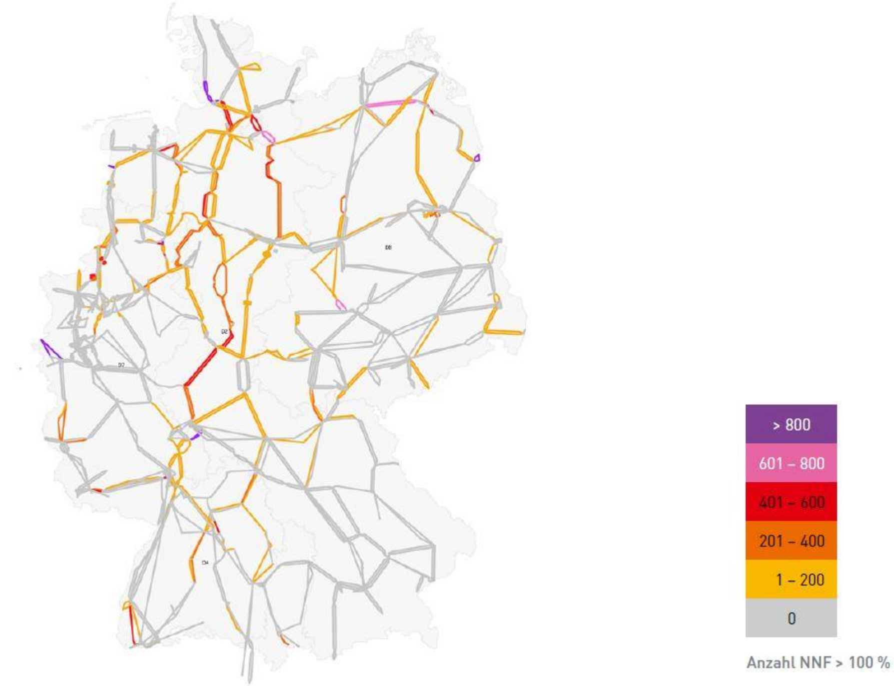
Grid Development Plan 2030 (2019)

Overload in the confirmed grid from the Federal Requirements Plan including interconnectors

Maximum load per circuit in the case of failure of one grid element.
So called „(n-1) –case“:



Quelle: Übertragungsnetzbetreiber



Quelle: Übertragungsnetzbetreiber

Maximum utilisation of line capacity:
More than 200% on some lines

Frequency of overloading:
Over 1000 hours on some lines

NETZ
ENTWICKLUNGS
PLAN **STROM**

Scenario B 2025

Confirmation of facilities for grid optimization and avoidance of redispatch:

- Confirmed ad hoc measures from GDP 2030 (2017) – 9 measures, including one power line (P310)
- Further phase shifters from GDP 2030 (2019) – 4 measures, one per control area.
- Grid booster pilots (purple)

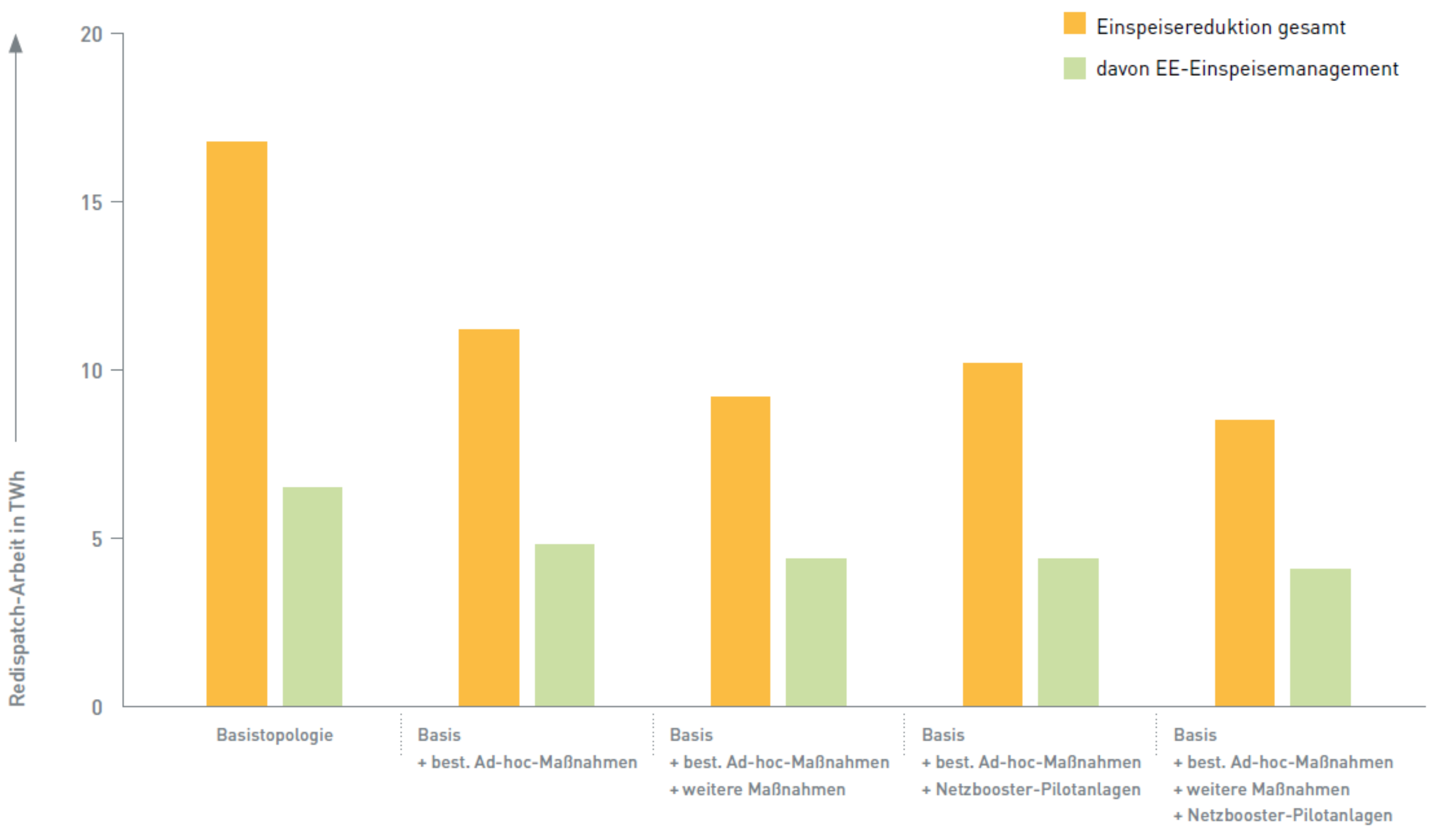
Depicted on the map as well:

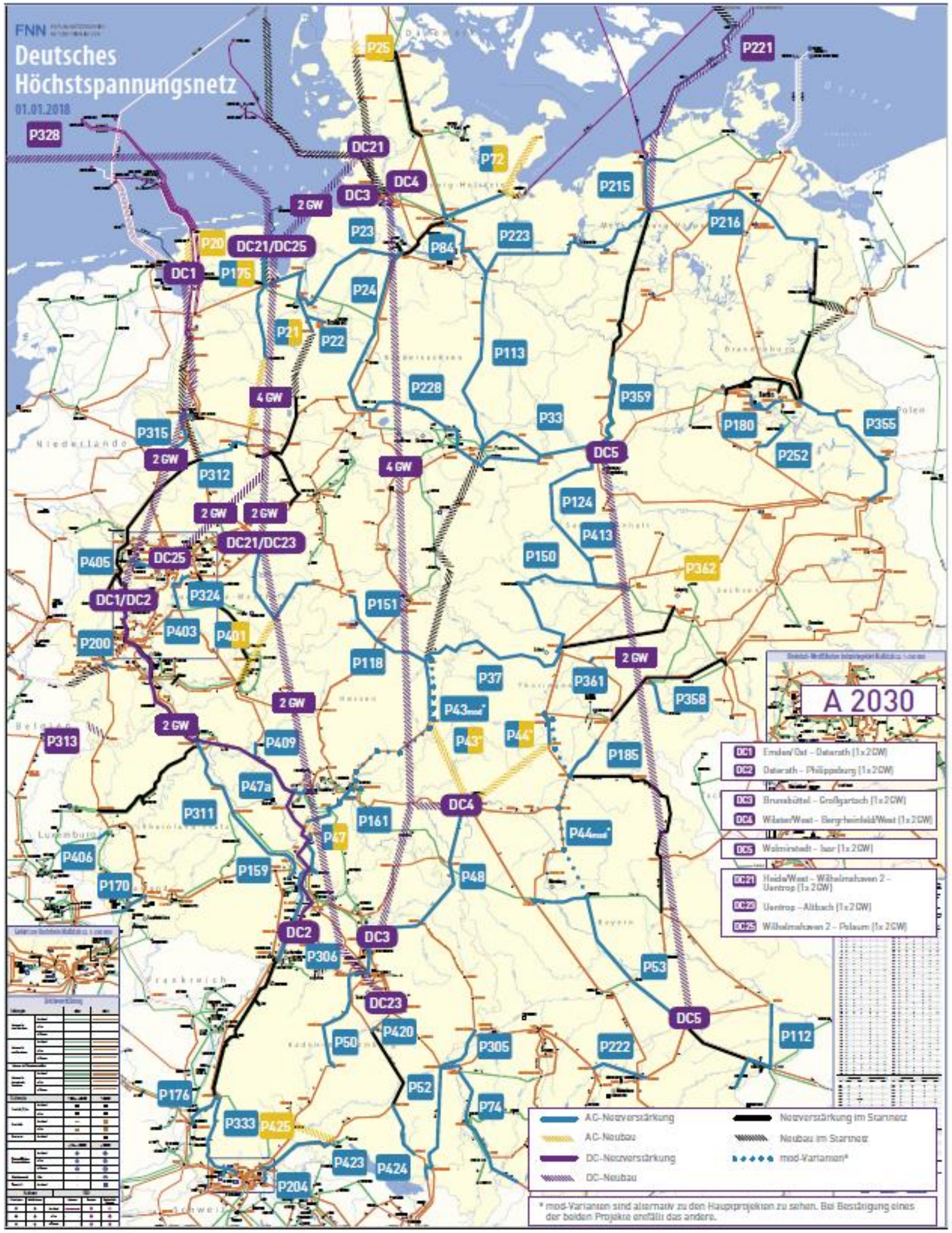
- Further facilities for load flow management from the 2030 and 2035 scenarios (grey)

Grid Development Plan 2030 (2019)

Scenario B 2025: Ad hoc measures significantly decrease redispatch volume

Abbildung 58: Redispatch-Bewertung der untersuchten Netztopologien im Szenario B 2025

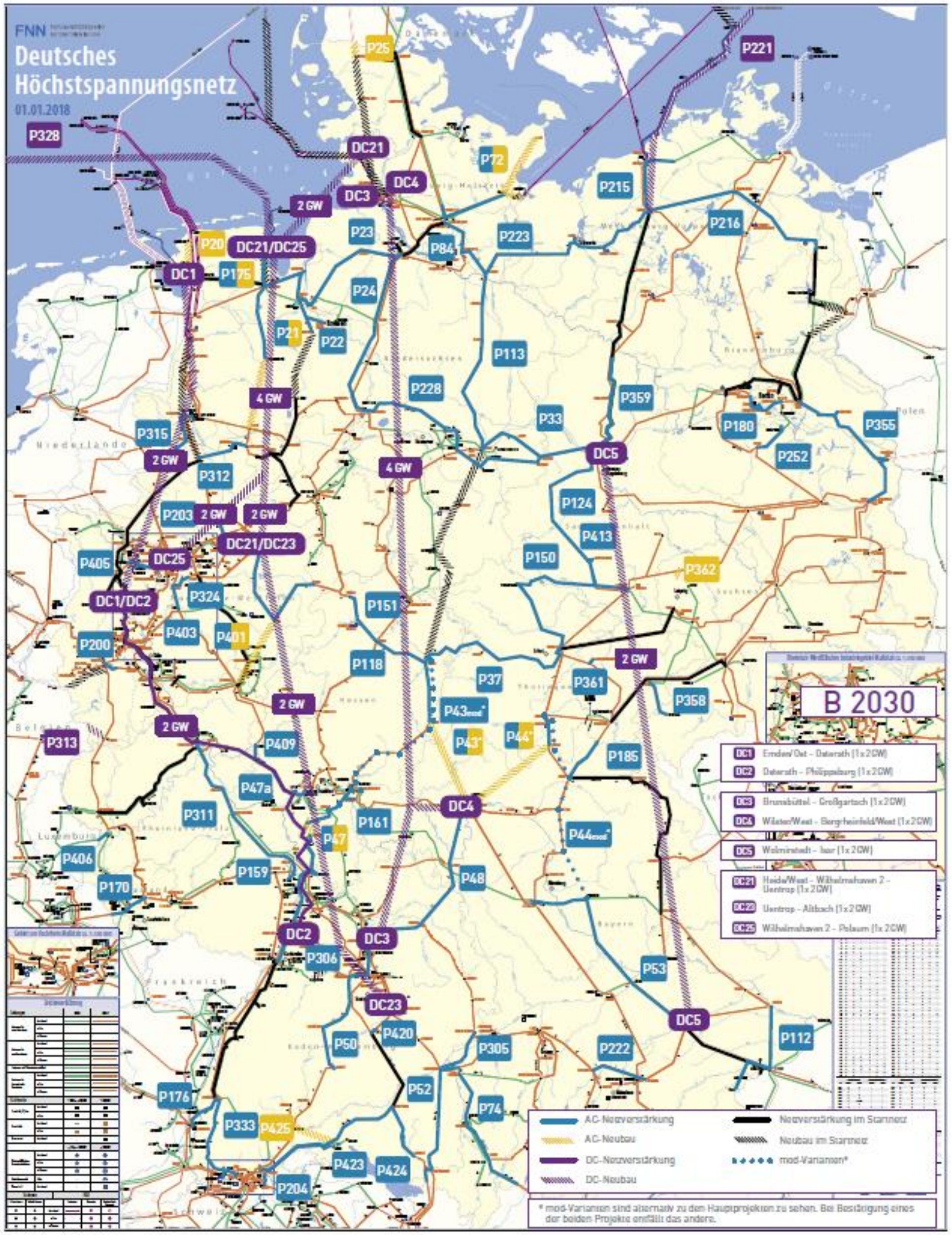




NETZ
ENTWICKLUNGS
PLAN **STROM**

Scenario A 2030 incl. starting grid

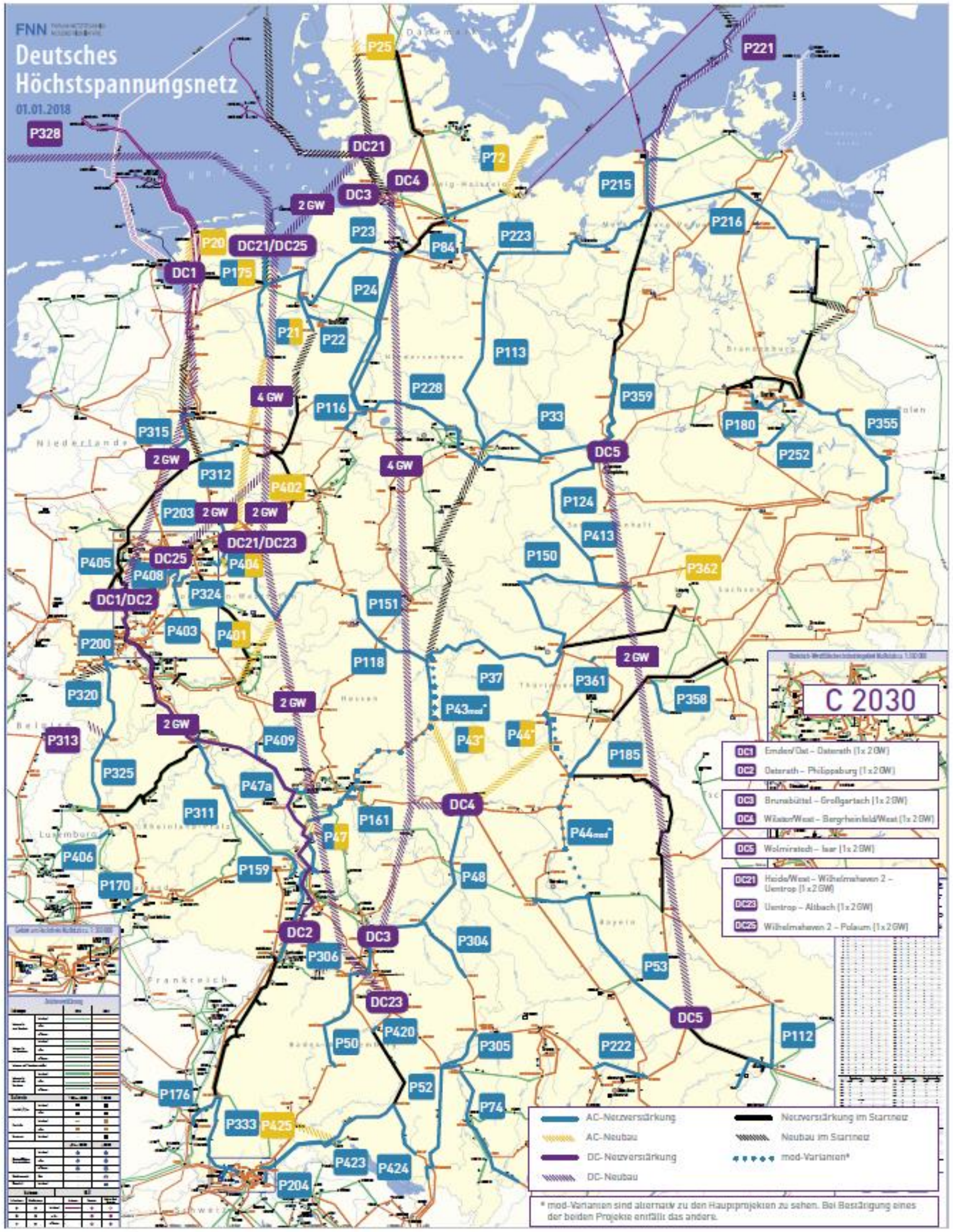
Expansion of DC connections in Germany	3,780 km
• Transport capacity	12 GW
• Interconnectors to BEL, DNK, NOR, GBR und SWE	520 km
Expansion of AC grid	1,030 km
DC/AC grid enhancement	6,670 km
• Thereof new OHL on existing pylons	2,280 km
Estimated investments if all DC lines (except DC2) are built as underground cables	EUR 61 billion



NETZ
ENTWICKLUNGS
PLAN **STROM**

Scenario B 2030 incl. starting grid

Expansion of DC connections in Germany	3,780 km
• Transport capacity	12 GW
• Interconnectors to BEL, DNK, NOR, GBR und SWE	520 km
Expansion of AC grid	1,030 km
DC/AC grid enhancement	6,710 km
• Thereof new OHL on existing pylons	2,190 km
Estimated investments if all DC lines (except DC2) are built as underground cables	EUR 61 billion



NETZ
ENTWICKLUNGS
PLAN **STROM**

Scenario C 2030 incl. starting grid

Expansion of DC connections in Germany	3,780 km
• Transport capacity	12 GW
• Interconnectors to BEL, DNK, NOR, GBR und SWE	520 km
Expansion of AC grid	1,130 km
DC/AC grid development	7,180 km
• Thereof new OHL on existing pylons	2,420 km
Estimated investments if all DC lines (except DC2) are built as underground cables	EUR 62.5 billion

Scenario B 2035 incl. starting grid

Expansion of DC connections in Germany	4,080 km
• Transport capacity:	14 GW
• Interconnectors to BEL, DNK, NOR, GBR und SWE	520 km
Expansion of AC grid	1,140 km
DC/AC grid development	7,490 km
• Thereof new OHL on existing pylons	2,110 km
Estimated investments if all DC lines (except DC2) are built as underground cables	EUR 68 billion

Grid Development Plan 2030 (2019)

Need for grid enhancement and expansion in 2030: 4,350 to 4,950 km in addition to FRP (BBP)

Angaben in km	AC-Verstärkung		DC-Verstärkung		AC-Neubau	DC-Neubau	Summe	Measures in addition to FRP (BBP)
	Zu-/ Umbeseilung	Neubau in Bestandstrasse	Zu-/ Umbeseilung	Neubau in Bestandstrasse				
Startnetz	130	1.650	0	0	600	250	**2.630**	
Zubaunetz								
A 2030	*1.850*	*2.700*	*300*	*40*	*430*	*3.530*	***8.740***	
B 2030	*1.760*	*2.830*	300	40	430	3.530	***8.890***	
C 2030	*1.990*	*3.070*	*300*	*40*	*530*	*3.530*	***9.460***	
B 2035	*1.750*	*3.030*	300	580	*550*	3.830	***10.040***	
Start- und Zubaunetz								
A 2030	*1.980*	*4.350*	*300*	*40*	*1.030*	*3.780*	***11.480***	**4,350 km**
B 2030	*1.890*	*4.480*	300	40	1.030	3.780	***11.520***	**4,400 km**
C 2030	*2.120*	*4.720*	*300*	*40*	*1.130*	*3.780*	***12.090***	**4,950 km**
B 2035	*1.880*	*4.680*	300	580	*1.150*	4.080	***12.670***	

Grid Development Plan 2030 (2019)

Estimated investments including full cabling of DC connections and DC interconnectors

NETZ
ENTWICKLUNGS
PLAN **STROM**

Angaben in Mrd. EUR (gerundet)	A 2030	B 2030	C 2030	B 2035
DC-Zubaunetz	28,5	28,5	28,5	33,5
DC-Startnetz	1,5	1,5	1,5	1,5
AC-Zubaunetz*	20,0	20,0	21,5	22,0
AC-Startnetz	11,0	11,0	11,0	11,0
Summe	**61,0**	**61,0**	**62,5**	**68,0**

* inkl. Anlagen zur Blindleistungskompensation

Grid Development Plan 2030 (2019)

Estimated investments onshore:

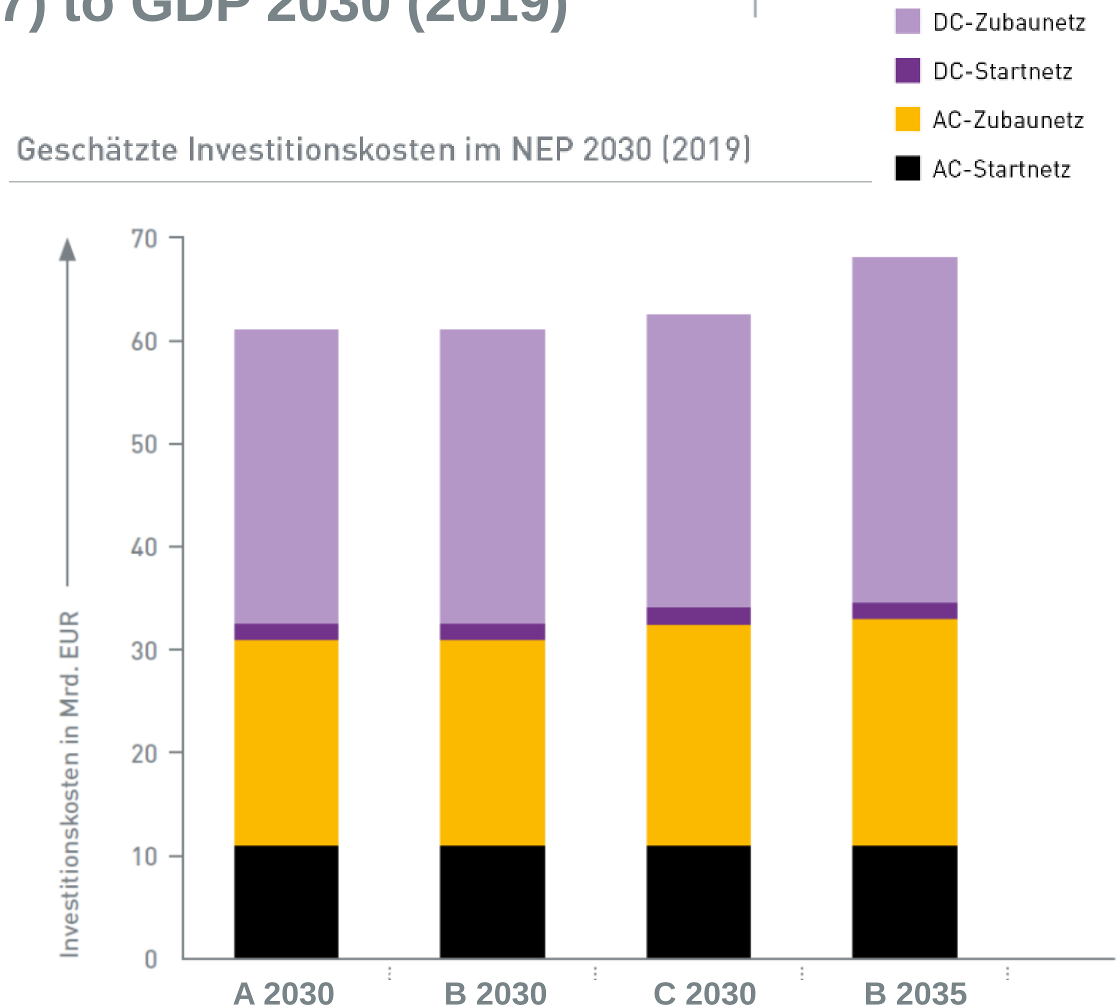
Increase from GDP 2030 (2017) to GDP 2030 (2019)

<u>Three main reasons</u>:

1. Adjustment of standard costs
   - Update of cost base
   - Consideration of TSO experiences
   - Consideration of costs for planning and permission procedures
2. New configuration
   - More DC underground cables instead of AC overhead lines → acceptance
   - Additional ad hoc measures
3. Consideration of additional reactive power facilities

<u>Putting the costs into perspective</u>:

- Investments are made over the years up to 2030/2035
- Projects are depreciated over a period of up to 40 years



Use of underground cables (DC)

NETZ ENTWICKLUNGS PLAN STROM

- In 2016 the legislator introduced the rule that **underground cables have to take precedence** over overhead lines for four of the five **DC projects** of the Federal Requirements Plan (Bundesbedarfsplan). Accordingly, the costs for these DC projects (DC1, and DC3-DC5) as well as the newly identified DC connections (DC20, DC21, DC23, DC25) are calculated for the use of underground cables.
- Generally the **additional costs for underground cables** as compared to overhead lines for both DC and AC cables strongly depend on local factors like soil structure.
- For DC cables the standard costs in the GDP 2030 (2019) were estimated to be 6 million € per km for one connection with 1 x 2 GW and 12 million € per km for 2 x 2 GW.
- This cost estimate takes into account **experiences of the TSOs** with the first AC underground cable pilots as well as HVDC underground cables like offshore connections and undersea cables.

Grid Development Plan 2030 (2019)

Use of underground cables (AC)

- In the GDP **AC lines** are generally assumed to be realized as overhead lines. The costs for partial underground cabling were taken into account only if the projects are defined as **pilot projects for partial underground cabling** according to § 2 EnLAG or § 4 BBPlG. Further details can be found in the project profiles of the relevant projects.
- Generally, the **additional costs for underground cables** as compared to overhead lines for both DC and AC cables strongly depend on local factors like soil structure.
- For **AC projects with partial underground cabling,** the costs for the underground cable sections are estimated at **11.4 million € per km for the 380 kV underground cable**. This includes the necessary cable transition facilities and at the same time assumes higher acceptance.

Grid Development Plan 2030 (2019)

Cost-benefit-analyses for interconnectors

NETZ ENTWICKLUNGS PLAN STROM

- According to the demand by the Federal Network Agency (BNetzA) the TSOs conducted cost benefit analyses (CBA) for the eight additional interconnectors that are not yet in the FRP (BBP) – based on Scenario B 2035.
- The procedure for conducting the CBAs largely followed that of the TYNDP 2018. Further details can be found in chapter 5.4 of the GDP.
- The results of the CBAs can be found in the project profiles in the appendix to the GDP.

Tabelle 24: Übersicht über die ausgewerteten Indikatoren im Rahmen der Kosten-Nutzen-Analyse

Indikator (gemäß ENTSO-E Bezeichnung)	Berechnungsmethode bzw. Ursprung	Einheit
B1. Socio-economic welfare	Marksimulation und Redispatch	€ / Jahr
B2. Variation in CO_2 emissions	Marksimulation und Redispatch	Tonnen / Jahr
B3. RES integration	Marksimulation und Redispatch	MW bzw. MWh / Jahr
B4. Societal well-being as result of RES integration and change in CO_2 emissions	Marksimulation und Redispatch	€ / Jahr
B5. Variation in grid losses	Lastflussberechnung	MWh / Jahr
C1. Capital Expenditure (CAPEX)	ÜNB Info	€
C2. Operational Expenditure (OPEX)	ÜNB Info	€ / Jahr

Grid Development Plan 2030 (2019)

Analysis of the system stability

- Based on Scenario B 2035 the TSOs conducted system stability analyses
- Frequency stability, angle stability (transient stability), and voltage stability were analysed.
- A short version of the analysis can be found in Chapter 5.5 of the GDP, a separate longer version is as a separate document on www.netzentwicklungsplan.de (in German)
- The analysis shows a considerable need for reactive power compensation systems to cover stationary and controllable requirements with a total installed capacity of at least 38.1 to 74.3 Gvar (127 to 248 facilities with 300 MVA each)

Zubaubedarf [Gvar]	TenneT	Transnet BW	Amprion	50Hertz	Deutschland
Stationär spannungshebend	3,0 – 10,4	1,5 – 2,3	1,6 – 8,9	5,1 – 9,4	11,2 – 31,1
Stationär spannungssenkend	0,0 – 2,6	0,3 – 1,4	1,2 – 5,2	2,2 – 6,5	4,3 – 14,8
Regelbar	6,2 – 7,7	1,1 – 1,8	4,2 – 5,8	11,1 – 13,1	22,6 – 28,4
Summe	**9,2 – 20,7**	**2,9 – 5,5**	**7,0 – 19,9**	**18,4 – 29,1**	**38,1 – 74,3**

Grid Development Plan 2030 (2019)

Analysis of the system stability

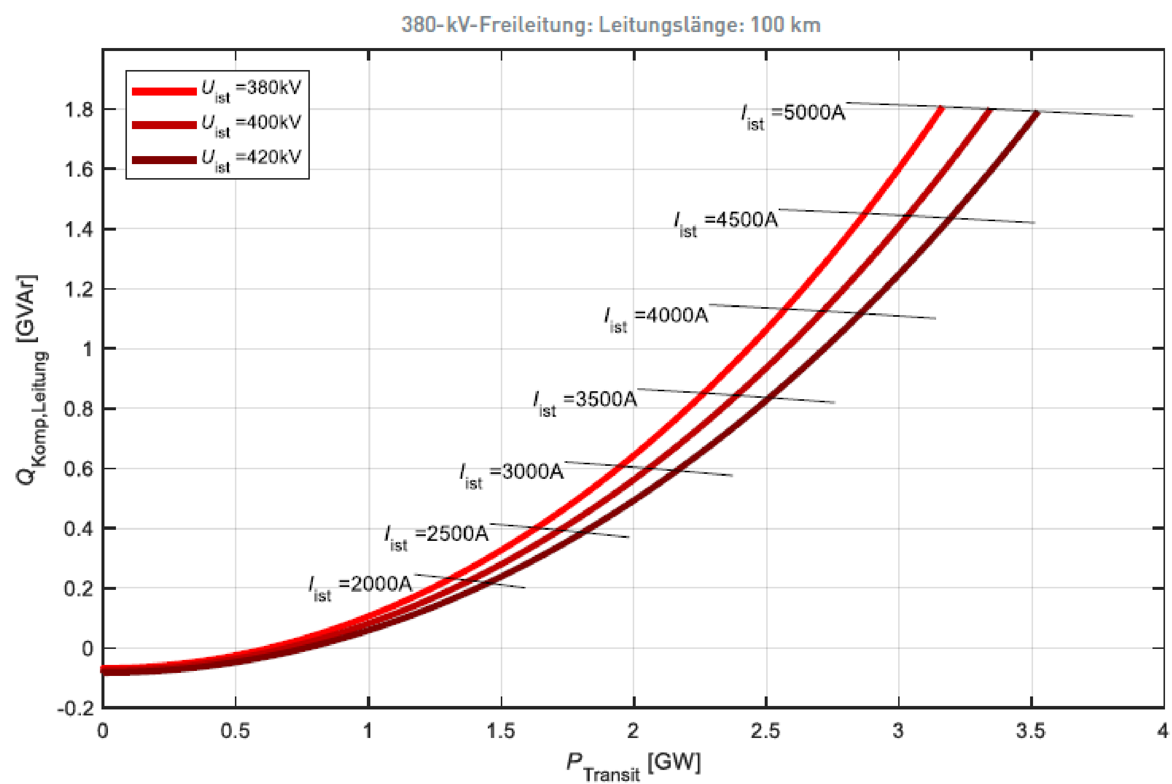
NETZ ENTWICKLUNGS PLAN STROM

Why does the demand for reactive power compensation rise so steeply?

- One reason is the decommission of conventional power plants (thus they cannot provide reactive power any more)
- Second reason is the higher utilization of existing transmission lines – leading to an overproportional increase of reactive power compensation

→ **Side effect of NOVA + innovations**

Abbildung 8: Blindleistungsbedarf einer 100 km langen 380-kV-Freileitung



Grid Development Plan 2030 (2019)

Conclusion (I)

NETZ ENTWICKLUNGS PLAN STROM

Approved Scenario Framework of the Federal Network Agency

- **Challenging framework (65 % renewable, CEP, accounting for climate protection plan, flexible demand-side) means a chance to implement innovations in the market and grid-models.**

Ambitious approach of the TSOs

Use of **grid expansion reducing measures**

Already in market model

(i.e. peak capping)

Supplemented with assumptions about the grid:

Combination of

Proven instruments in line with the planning guidelines
(i.e. NOVA, improved thermal monitoring of overhead lines)

with the use of innovative technologies in grid planning and grid control. (i.e. load flow management, 4000 A, km-optimised combination of AC and DC, no elimination of bottlenecks → leaves room for future developments)

TSOs introduce an ambitious concept and count on the development of all actors of the energy transition

Grid Development Plan 2030 (2019)

Conclusion (II)

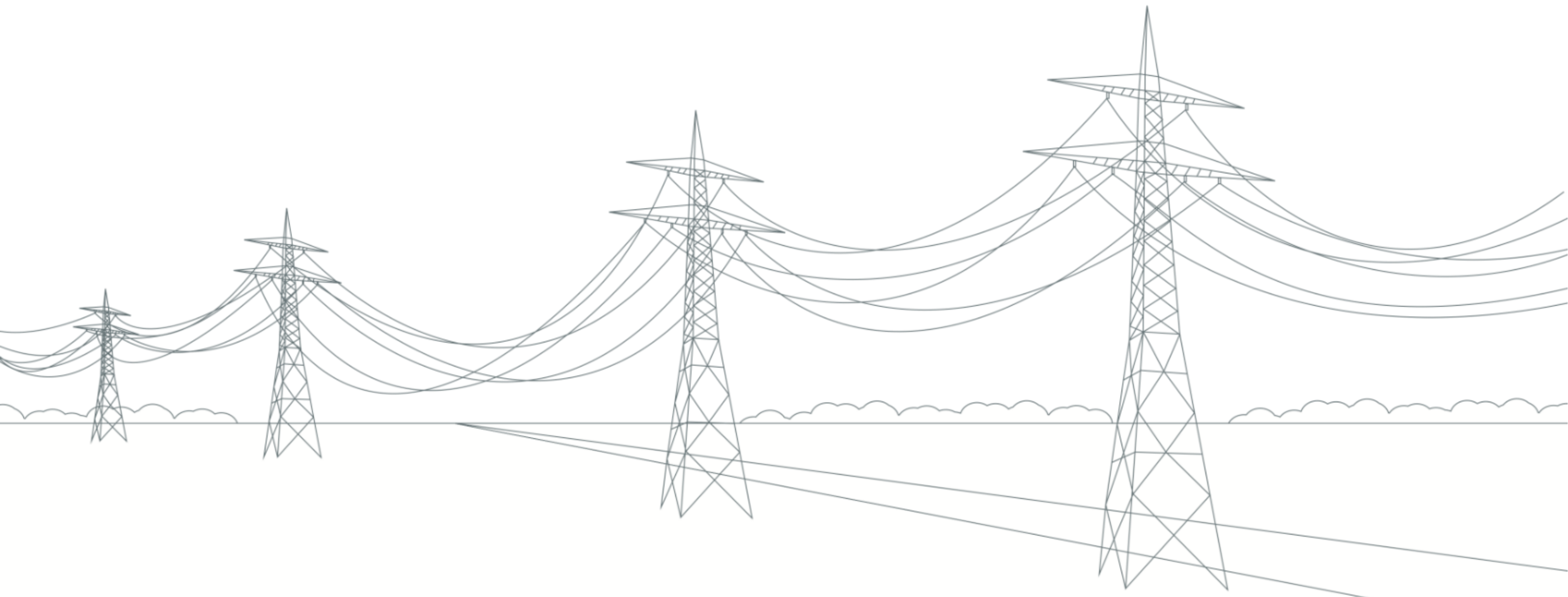
Results of the GDP 2030 (2019):

- Ambitious goals for renewable integration (>65% 2030**) can be integrated with similar amount of line km** as that of the GDP 2030 (2017)
- **Combination of AC and DC** (+ 4 GW HVDC in 2030, + 2 further GW HVDC in 2035) enable the **efficient integration of renewable energy** into the grid, are robust with respect to a further rising share of renewables and are **open to new technological developments**.
- **The development** of market incentives/business models and technological innovations by diverse players of the energy transition is necessary to make the assumptions made by the TSOs a reality.
- The rising **need for reactive power compensation systems** shows: besides the grid enhancement and expansion, controllability and stability of the grid play an increasingly important role.

→ GDP 2030 (2019) is an adequate basis for the Federal Requirements Plan (Bundesbedarfsplan)

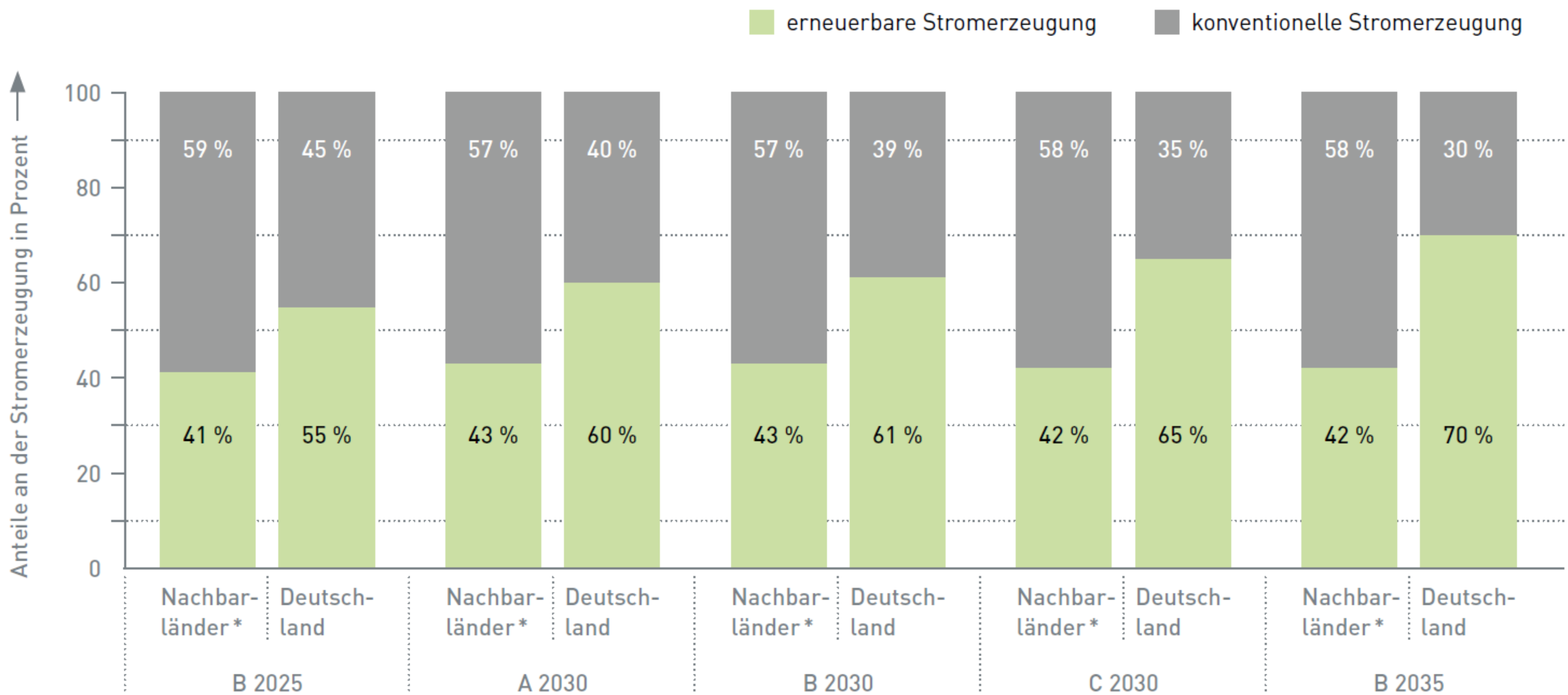
NETZ
ENTWICKLUNGS
PLAN STROM

Backup



Grid Development Plan 2030 (2019)

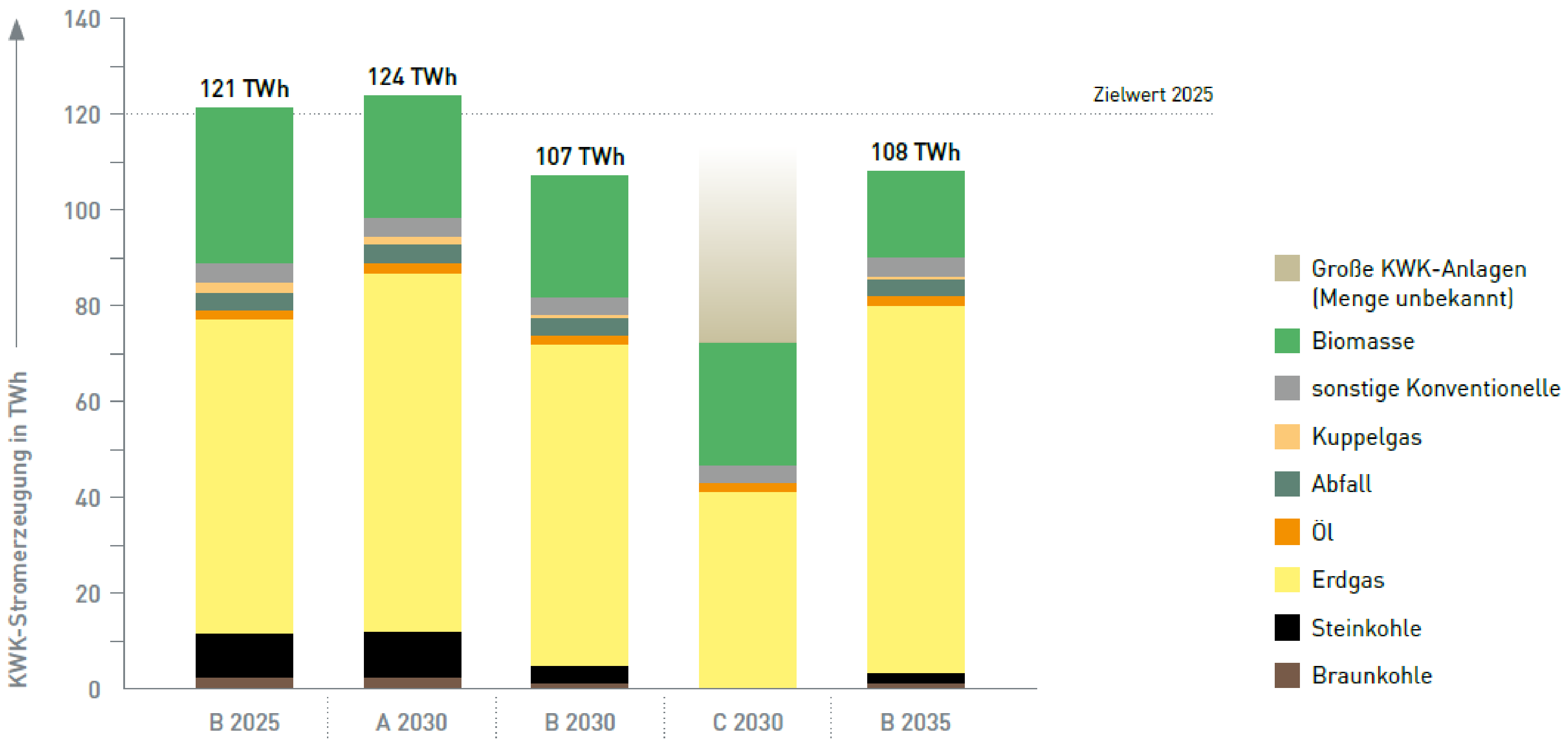
Share of conventional and renewable generation as fraction of overall power generation



*Länder mit gemeinsamer Grenze zu Deutschland

Grid Development Plan 2030 (2019)

Cogeneration by primary energy source GDP 2030



Grid Development Plan 2030 (2019)

Renewable energy as share of gross power consumption

NETZ ENTWICKLUNGS PLAN **STROM**