3.4.10 GERMANY

Sector overview

Existing network

- As of September 2023, Germany's transmission grid comprised an estimated xxx circuit km of transmission lines and xxx MVA of transformer capacity. The transmission network consists mainly of 220 kV and 380 kV AC lines besides several DC lines connecting the offshore renewable capacity and with the transmission systems of neighbouring countries.
- Germany has several electricity interconnections with Austria, Belgium, Denmark, the Czech Republic, Switzerland, France, Luxembourg, the Netherlands, Poland and Sweden.

TSO

- Germany has four grid owners and operators—Amprion GmbH, TenneT TSO GmbH, 50Hertz Transmission, and TransnetBW GmbH.
- Of the total line length, around 36% is owned by TenneT, 28% by Amprion, 28% by 50Hertz, and 8% by TransnetBW.
- In November 2023, German energy company, Energie Baden-Wurttemberg AG (EnBW) concluded the sale of a minority stake in its subsidiary TransnetBW. The Germany federal government has taken over a 24.95 per cent stake in TransnetBW, through Germany's development bank, Kreditanstalt für Wiederaufbau (KfW).
- The German government also plans to buy the German division of of Dutch grid operator TenneT.
- Germany's electricity market is regulated by Federal Network Agency (Bundesnetzagentur/BNetzA), which was set up in 2005.

Investment drivers

- The key drivers for the grid development measures include new DC projects (to increase the north-south as well as the east-west transport capacity), the strong expansion of renewable energy in the north, the dismantling of conventional power plants, the interconnected energy exchange with foreign countries, and the increasing loads in the course of achieving climate neutrality in all sectors.
- The country has revised its OSW targets to 30 GW, 40 GW and 70 GW by 2030, 2035 and 2040 and the new revised targets can only be met with OSW infrastructure expansion, proper grid systems, defined routes and transmission lines.

Expected investment

- The planned investment in the German grid during 2024–33 is at least EURxxx billion, based on the planned expenditure for various TSOs.
- Substantial offshore grid investments have been planned by TenneT TSO, 50Hertz and Amprion.
- As per the second draft of the Network Development Plan (NDP) or Netzentwicklungsplan 2037/2045, released by the TSOs in June 2023, investments in the grid are expected to be above EURxxx billion during the period up to 2037.

Historical capital expenditure trends

Investment trends

- Between 2013 and 2023, the annual investment in the electricity transmission network in Germany increased from EURxxx million to EURxxx million in 2023 (half-yearly data for 2 TSOs and 9 month data for one TSO). The increase is mainly driven by the development of offshore wind links and cross-border interconnections.
- TenneT invested around EURxxx billion for the development of its grid assets between 2013-23.
- Amprion invested around EURxxx billion during the same period. This was followed by an investment of EURxxx billion by 50Hertz.

Investment focus

- In recent years, network development to integrate the growing renewable energy-based capacity in line with the country's energy policy has been one of the key focus areas of investment.
- The development of connection lines for offshore wind farms in Germany has attracted a significant part of total investments in the country's transmission grid.
- The transmission operators have also invested in the renovation and strengthening of the existing system.

Key projects commissioned

- Some of the recently commissioned projects include:
  - 900 MW DolWin6 HVDC offshore grid connection system,
  - Installation of an offshore substation for the Gode Wind 3 OWF.
  - 247 MW Arcadis Ost 1 wind farm grid connection system
  - 380 kV Uckermark Line
  - New reactive power compensation system or static synchronous compensators (STATCOM) at the Gersteinwerk switching substation in Werne.

Historical capital expenditure growth

Figure 1: Growth in Germany's capital expenditure on transmission network (EUR million)

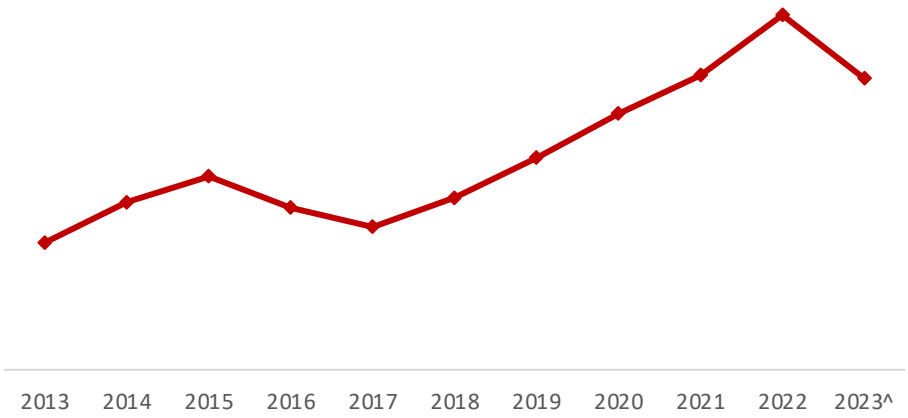

Figure 2: Germany's capital expenditure on transmission network by utility in 2023* (%)

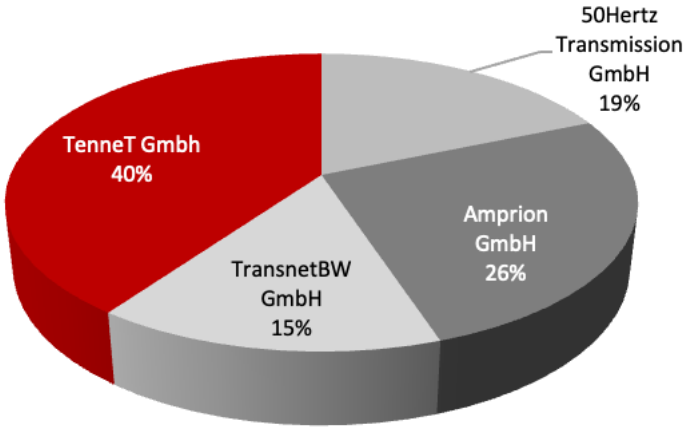

Table 1: Germany's capital expenditure on transmission network for 2013–23 (EUR million)

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
50Hertz Transmission GmbH	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Amprion GmbH	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
TransnetBW GmbH	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
TenneT Gmbh	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Total capital expenditure	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx

Note: *For 9 months ending September 2023; E: Half-yearly figures (January-June 2023);^The data for 2023 include both 9 month and half yearly figures for 3 TSO's. For TransnetBW, investment figures pertain to the EnBW group's Grids segment which includes electricity and gas distribution as well. One of the Polish subsidiaries was restructured at the beginning of 2023 in order to comply with the Polish energy industry regulations. The grid business at this company was previously reported in the "Smart Infrastructure for Customers" segment but will be part of the "System Critical Infrastructure" segment from the 2023 financial year onwards. The figures for the previous year have been restated.
Source: Amprion; TenneT; 50 Hertz; TransnetBW Gmbh ;Global Transmission Research

Future capital investment (1/2)

Expected investment

- Between 2024 and 2037, Germany is expected to invest over EURxxx billion for the expansion of its grid. Of this, under Scenario B and C EURxxx billion would be invested in the offshore grid network and for Scenario A 2037, the investment in offshore grid expansion stands at EURxxx billion. EURxxx billion (including interconnection) will be for the onshore grid under all the three scenarios as stated in the second draft of NDP 2037 by the TSOs.
- Compared to the first draft of the NDP 2037/2045 (2023), the investment costs in the second draft of the NDP have increased by EURxxx billion. The drastic increase in investment costs compared to the previous NDP is caused by the change in the scope of projects and measures as well as the adjustment of standard and project costs.
- The four TSOs have individually also announced investment plans for the next few years.
  - TenneT plans to invest around EURxxx billion during 2024–32 on onshore and offshore grids
  - Amprion has planned an investment of EURxxx billion during the 2024-27 period. It has been assumed that a similar investment would be made in the following four years as well.
  - 50Hertz has announced to invest EURxxx billion during 2024–28. It is expected that similar levels of investments will be required in the subsequent 5-year period.
  - TransnetBW plans to invest EURxxx billion up to 2035.

Future capital investment (2/2)

Investment drivers

- Due to the increasing electrification of the building, transport and industrial sectors, the total gross power consumption is expected to increase from about xxx TWh in the previous plan (NDP 2035) to xxx TWh in NDP 2037 (2023 version). A total addition of xxx GW and xxx GW capacity is envisaged by 2037 and by 2045, respectively. The maximum addition is expected in the wind segment, with an onshore wind addition of 102-106 GW and an offshore wind capacity addition of 43-51 GW by 2037.
- The new revised targets can only be met with OSW infrastructure expansion, proper grid systems, defined routes and transmission lines
- To integrate this ever-increasing offshore wind generation, the TSOs have determined offshore grid connection systems in the North Sea and Baltic Sea with a length of about xxx km and a transmission capacity of about 36 GW in Scenario A 2037, as well as a length of about xxx km with a transmission capacity of about 44 GW in Scenarios B 2037 and C 2037. Even after 2037, eight more systems with a transmission capacity of 16 GW will be connected.
- Compared to the project portfolio proposed in NDP 2035 (2021), the present NDP 2037/2045 (2023) identifies new onshore projects with a route length of xxx km and an additional investment of EURxxx billion. This is particularly attributable to the designation of five additional HVDC projects, which are necessary to secure the transmission of upcoming generation and are not yet included in the current Bundesbedarfsplangesetz (BBPIG).

Key projects

- **Interconnections:** Hansa PowerBridge (300-km 300-kV Hurva (Sweden)-Güstrow (Germany) HVDC link); 280 km, 400 kV Niebüll (Germany)–Endrup (Denmark) underground cable link; 380 kV line from Altheim in Bavaria, Germany to St. Peter am Hart in Upper Austria; 380 kV Muhlbach (France)–Eichstetten (Germany) line; and 380 kV Krajnik(Poland)–Vierraden (Germany). GerPol Power Bridge II (Germany–Poland Interconnector)
- **Onshore HVDC connections:** ±525 kV HVDC Corridor C Transmission Project (SuedLink); ±525 kV Corridor A Transmission Project (Ultranet); ±525 kV HVDC Corridor D Project (SuedOstLink)
- **Offshore connections**
- **North Sea:** Cluster BorWin4 (NOR-6-3)–Hanekenfahr Wind Farm Interconnection Project; Cluster BorWin5 (NOR–7–1)–Cloppenburg Ost; Cluster BorWin6 (NOR–7–2)–Buttel; Cluster DolWin4 (NOR–3–2)–Hanekenfahr; Cluster DolWin5 (NOR–1–1)–Emden East; Cluster DolWin6 (NOR–3–3)–Emden East; LanWin3 (NOR–11–1)–Heide-West Transmission Line; LanWin 1 (NOR–12–1)–Unterweser Transmission Line; Balwin1 (NOR–9–1)-Wehrendorf Transmission Line; BalWin3 (NOR-9-2) with Wilhelmshaven grid connection point; BalWin2 (NOR-10-1)-Westerkappeln grid connection; LanWin5 (NOR-13-1)-NordWest hub (Westerstede, Wiefelstede, Rastede, Ovelgönne area); LanWin4 (NOR-11-2)-Wilhelmshaven2; LanWin2 (NOR-12-2)-Heide area; BalWin4 (NOR-9-3)-Unterweser
- **Baltic Sea:** Ostwind 1 - OWF Cluster 1 Baltic Sea Westlich Adlergrund (OST-1-3) (Wikinger/Arkona-Becken Südost); Ostwind 2 - OWF Cluster 2 Baltic Sea Arkonasee [OST-2-1(AC grid connection system OWF Arcadis Ost 1), OST 2-2 (AC grid connection system OWF Baltic Eagle), Ost 2-3 (AC grid connection system OWF Baltic Eagle)];

Expected capital investment by type

Table 5: Germany's planned capital expenditure on transmission network for 2023–37 (EUR billion)

Category	A/B/C 2037	A/B/C2045
Offshore	Scenario B and C=xxx; Scenario A=xxx	xxx
Onshore	All scenarios-xxx	xxx
Total	**xxx**	**xxx**

Category (Onshore network)	A/B/C 2037
AC Zubaunetz (Extension network)*	xxx
AC Startnetz (Start network)	xxx
DC Zubaunetz (Extension network)	xxx
DC Startnetz (Start network)	xxx
Total	**xxx**

Note: Start network includes connection systems which are in operation or are commissioned or that develop a wind farm which has been awarded a contract. *Including systems for reactive power compensation; Investment figures for onshore and offshore grid development is based on the cost estimates given in the second draft NDP 2037 (2023 Version)
Source: Draft NDP 2037; Global Transmission Research

- The NDP 2037/2045 (2023) identified an additional need for 20 new offshore grid connection systems with a route length of approximately xxx km and an investment volume of EURxxx billion based on the offshore grid connection systems confirmed in the NDP 2035 (2021).
- Onshore network investment in the scenario up to 2045 is expected to remain the same at EURxxx billion while offshore grid investment is estimated at EURxxx billion.
- Investment for onshore connections includes EURxxx billion on the AC Start network and EURxxx billion on the DC Start network. For the Extension network (Zubaunetz) up to 2037, a total of EURxxx million is earmarked.

Key programmes and initiatives (1/2)

Table 3: Germany's key programmes and initiatives

Name	Scope of work	Planned completion
North Sea Wind Power Hub (NSWPH)	German TSO TenneT is championing and leading the visionary NSWPH, which envisages the creation of an artificial island in the middle of large offshore wind capacity zones and building a large electricity system in the North Sea based on the hub and spoke principle. For this, TenneT has collaborated with Denmark's TSO Energinet.dk, gas infrastructure company Gasunie and the Port of Rotterdam. The project is included in the fourth list of European Projects of Common Interest (PCI). This project is the first building block of the hub-and-spoke concept connecting up to 12 GW future offshore wind parks to the systems of Germany, Denmark and the Netherlands. An integral part of the NSWPH is to assess the perspectives of coupling large-scale wind power production with the gas system through power-to-gas (PtG) technology. The project partners have indicated that the giant 12GW hub could be built in the early 2030s.	Early 2030s
Digitising the power grid	TenneT plans to scale up its pilot schemes for digitising the power grid. It is pursuing a digital venture, involving the connection of car batteries to provide extra power to help balance the country's grid. For a mobile sensoring pilot, TenneT has collaborated with Volkswagen to investigate how weather data obtained from vehicle sensors can be used to improve solar energy prognosis and minimise errors. It analysed the sensor data using big data methods and imported it into feed-in forecasts to investigate if the spatial distribution of sensors can achieve a considerable improvement in the forecast quality.	NA
Long-term collaborations	In August 2023, TenneT signed multi-year corporate framework agreements with eight partners for the supply and installation 110 kV, 150 kV, 220 kV and 380 kV onshore, high voltage alternating current (HVAC) connections in Germany. As per TenneT, forming these long-term collaborations will encourage smart ways of working and fast deliveries. It would also help the contractors to focus on innovation, and to adjust their production processes and machinery accordingly, which would in turn reflect in improved materials and design optimisation. Additionally, TenneT also foresees increased opportunities to develop longer cables in one piece (depending on the voltage level), of up to xxx metres. In May 2023, TenneT TenneT, has awarded the cooperation agreement for xxx km of high voltage direct current (HVDC) cable systems to NKT A/S, Nexans, and a consortium of Jan De Nul Group, LS Cable & System, and Denys. The cable systems will link offshore wind farms (OWFs) in the Dutch and German North Sea. The EUR6 billion agreement covers at least ten ±525 kV HVDC cable systems. This includes six German 2 GW offshore grid connection systems with delivery through 2031, one German onshore project NordOstLink to be operational in 2032, and plans for future projects.	NA

Note: NA; not available
Source: Global Transmission Research

Key programmes and initiatives (2/2)

Table 3: Germany's key programmes and initiatives

Name	Scope of work	Completion
Voltage stability pilot project	In June 2023, 50Hertz and ENERTRAG SE, a major operator of renewable energy plants, launched a joint pilot project for the provision of reactive power through renewable energy near Bertikow in Brandenburg, Germany. In the pilot project, ENERTRAG and 50Hertz want to test how reactive power activation works technically in practice and can be contractually designed, including with a view to a future reactive power market. Ground-mounted photovoltaic systems can also provide reactive power via their inverters when there is no sun, for example at night. Other pilot projects have seen reactive power sources in the distribution grid effectively harnessed for the extra-high-voltage grid, such as a Deutsche Bahn converter and the Wendefurth pumped-storage power plant. As it upgrades its substations in the years ahead, 50Hertz will be investing in reactive power compensation systems that contribute either dynamically (static synchronous compensators (STATCOMs)) or statically (mechanically switched capacitors with damping network (MSCDNs) or reactors) to voltage regulation at key points on the grid. 50Hertz has also introduced a new tool to estimate regional reactive power demand in operational planning.	NA
Joint information platform	In September 2023, the four German TSOs adapted their joint information platform 'netztransparenz.de'. From now on, it offers a clear insight into the daily workings of the electricity market, complemented with information about German and European legal situations and future developments.	NA
Netzbooster	The TSOs are implementing the Netzbooster (or grid booster) project to allow for more efficient operation of the existing transmission infrastructure and lower preventive re-dispatch measures. TransnetBW is implementing a 250 MW Netzbooster at Kupferzell (Baden-Württemberg), a major grid hub scheduled to be completed in 2025. TenneT is also deploying a 100 MW/100 MWh grid booster each in Ottenhofen in Bavaria and Audorf in Schleswig-Holstein scheduled for operation this year. Amprion announced a 250 MW decentralised grid booster system, which will be implemented in the area of LEW Verteilnetz (LVN), a regional network operator of the E.ON Group, in Bavarian Swabia by 2026. While the systems are still classed as 'innovation projects', their deployment will provide operators with crucial experience in a new approach to grid management.	2026
InterSTORE	The Interoperable opeN-source Tools to Enable hybRidisation, utiliSation, and moneTisation of stORage flexibility (InterSTORE), is a EU funded research and development (R&D) and innovation programmes which aims to deploy and demonstrate a set of interoperable open-source tools to integrate distributed energy storage (DES) and distributed energy resources (DER). There are six participating countries and Germany is one of them. The Living Lab Energy Campus (LLEC) at Forschungszentrum Jülich (FZJ, "Jülich Research Centre") constitutes a testbed where both innovative hardware and software solutions for district energy systems are tested under close to real conditions, in a scientifically monitored environment incorporating real users.	NA

In January 2024, Eurogrid GmbH, the parent company of 50Hertz secured funds worth EURxxx billion with its third and fourth Green Bond, making it the highest bond amount in the history of the company. The funds from the bonds will be used to finance selected projects on land and at sea that can increase the integration and transportation of additional amounts of renewable electricity. The corporate bonds have a volume of EURxxx million (term five years; pricing 3,598 per cent) and EURxxx million (term ten years; pricing 3,915 per cent). Banco Santander, Mizuho Bank, Rabobank, and UniCredit Bank from the group of Eurogrid core banks on the regulated market in Luxembourg, will issue the bonds. The Green Bond complies with the principles of the International Capital Markets Association (ICMA). The projects financed through this Green Bond are in line with the EU action plan to mitigate climate change and contribute to the 50Hertz strategy "100% by 2032".

Note: NA; not available
Source: Global Transmission Research