IMPACT OF WIND AND SOLAR ON TRANSMISSION UPGRADE NEEDS

Integration of substantial wind and solar capacity typically requires transmission system investments to: (1) access the best resource locations and (2) smooth the variability of renewable generation over larger areas. The transmission reinforcement projects serve several purposes at the same time. They can enhance energy markets, improve security of supply and enable integration of both new electricity generation and loads. Solar power plants that are connected to the transmission grid share much of the same transmission requirements as wind. Smaller solar installations (distributed, rooftop solar) are impacting the distribution grid.

How much new transmission investment is needed for wind and solar?

Any new power plant usually requires a new line to connect it to the existing power grid, with smaller power plants connecting to a lower voltage distribution grid and larger ones to a higher voltage transmission grid. If high-resource areas are far from demand centres, wind power typically requires more transmission compared to conventional power plants (Figure 1). The development of offshore wind further increases the need for transmission (Figure 2). In decarbonised, weather-dependent power systems, transmission is essential to connect distant electricity sources and demand centres and to harvest differences in weather patterns.

Recent studies estimate a doubling or even tripling of the transmission system to support the clean energy transition. Several factors contribute to the growing need for significant transmission investments, for example, a systemic underinvestment in transmission infrastructure in the past, expansion of the grid to high-resource areas, and increasing demand because of electrification.

Expanding the transmission system is a lengthy process. Long distance or inter-regional transmission expansion has been particularly difficult to build due to siting issues, permitting constraints, cost allocation disputes and lack of incentive (regulated rate of return).

In addition to power plants connected to the transmission grid, large amounts of distributed power plants may also increase transmission system upgrade needs.

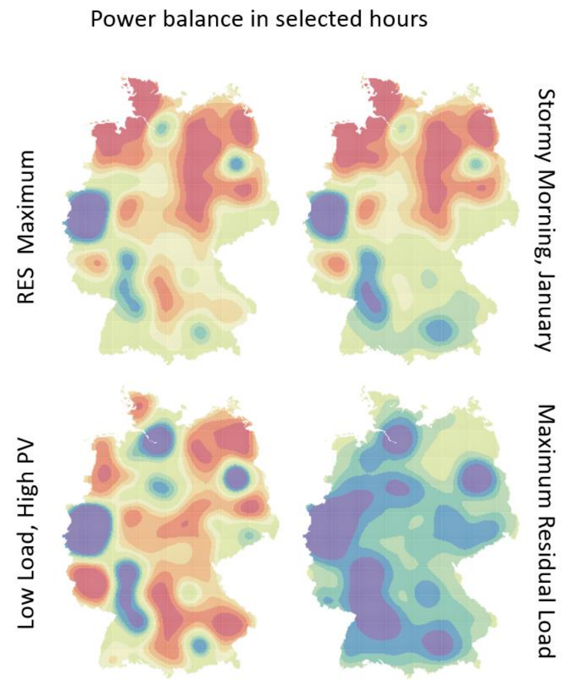

Figure 1. *In Germany, wind power is increasing more rapidly in the north, where it is creating power surplus situations (power balance in red). The consumption is mostly in the south, where some conventional power plants are planned to be retired. This situation will increase the power deficit (power balance in blue/purple) and will require upgrading the north-south transmission. Strategically planning transmission expansion can help access lower cost wind and solar resources and connect those lower cost resources to demand centres. (Source: German TSOs).*

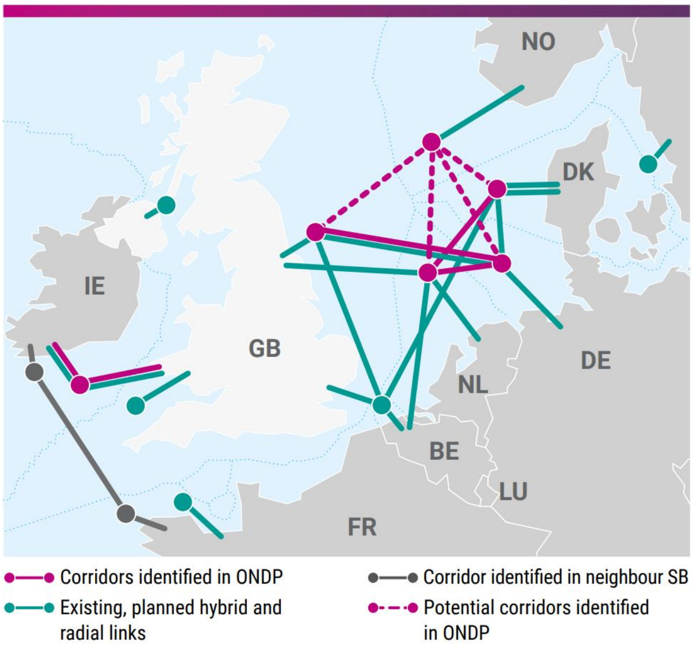

Figure 2. *Transmission corridors identified in the Northern Seas Sea Basin (SB) by 2050 in the Offshore Network Development Plan (ONDP). (Source: ENTSO-E TYNDP 2024, Sea-Basin ONDP Report, Northern Seas Offshore Grids).*

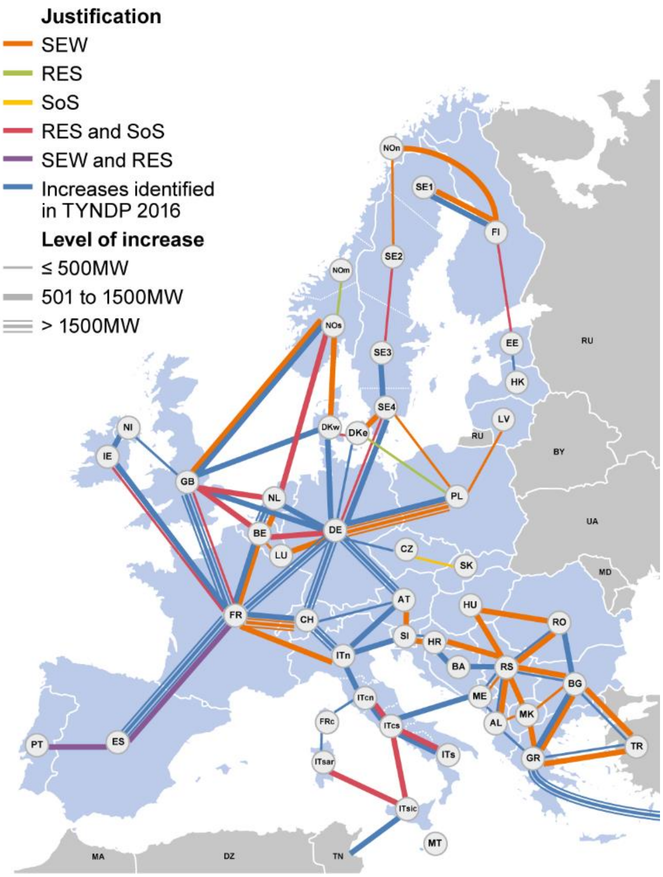

Figure 3. *European-wide analyses on grid reinforcement needs. The green lines indicate the routes where the justification for building is mainly due to renewables. SEW: socio-economic welfare, RES: renewable energy sources, SoS: security of supply. (Source: ENTSO-E TYNDP 2018, scenario Global Climate Action for year 2040).*

Are there other options besides building more transmission lines?

New wind and solar power plants will change power flow patterns in the existing power grid, affecting power flow direction, line losses, power quality and stability, as well as location, magnitude and frequency of congestion. In addition to transmission upgrades, solutions include storage, grid forming technologies, using more of the existing line capacity (dynamic line rating), and investing in devices like Flexible Alternating Current Transmission Systems (FACTS). Increasing capacity through re-conductoring existing corridors is also an option.

Do transmission upgrades increase or decrease the cost of wind and solar?

The magnitude of transmission upgrade investments depends on the distance, the type of transmission expansion (AC or DC), and the strength of the existing grid. The improvements to the transmission grid benefit the whole power system, making it difficult to determine appropriate cost allocation. Figure 3 provides an example of how multiple factors can justify the need for reinforcement.

Latest trends of large offshore wind build-out have started discussion on cost sharing options between benefitting countries or regions.

Overall, transmission is only a small fraction of the total energy price for consumers.

Associated publications

- Holttinen, H. et al. (2021). **Design and operation of energy systems with large amounts of variable generation**. Final summary report, IEA WIND TCP Task 25. https://doi.org/10.32040/2242-122X.2021.T396
- ESIG (2024). **Interregional Transmission for Resilience: Using Regional Diversity to Prioritize Additional Interregional Transmission**. https://www.esig.energy/interregional-transmission-for-resilience
- ENTSO-E (2024). **Ten Year Network Development Plan (TYNDP)**. https://tyndp.entsoe.eu/

More information

This Fact Sheet draws from the work of IEA Wind TCP Task 25, a research collaboration among 17 countries. The vision in the start of this network was to provide information to facilitate the highest economically feasible wind energy share within electricity power systems worldwide. IEA Wind TCP Task 25 has since broadened its focus to analyze and further develop the methodology to assess the impact of wind and solar power on power and energy systems.

See our website at

https://iea-wind.org/task25/

See also other fact sheets

Impacts of Wind and Solar Power on Power System Stability
Balancing Power Systems with Large Shares of Wind and Solar Energy
Wind and Solar Integration Issues