Adapting Power Grid Planning for the Integration of Low Carbon Technologies

A Conceptual Roadmap

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The ongoing energy system transition, driven by the expansion of renewable energy sources and the electrification of sectors such as mobility and heating, dramatically raise loading of electricity grids. Due to these developments, the need for network reinforcement in low voltage grids dramatically rises, which may be mitigated by optimized planning and operation.

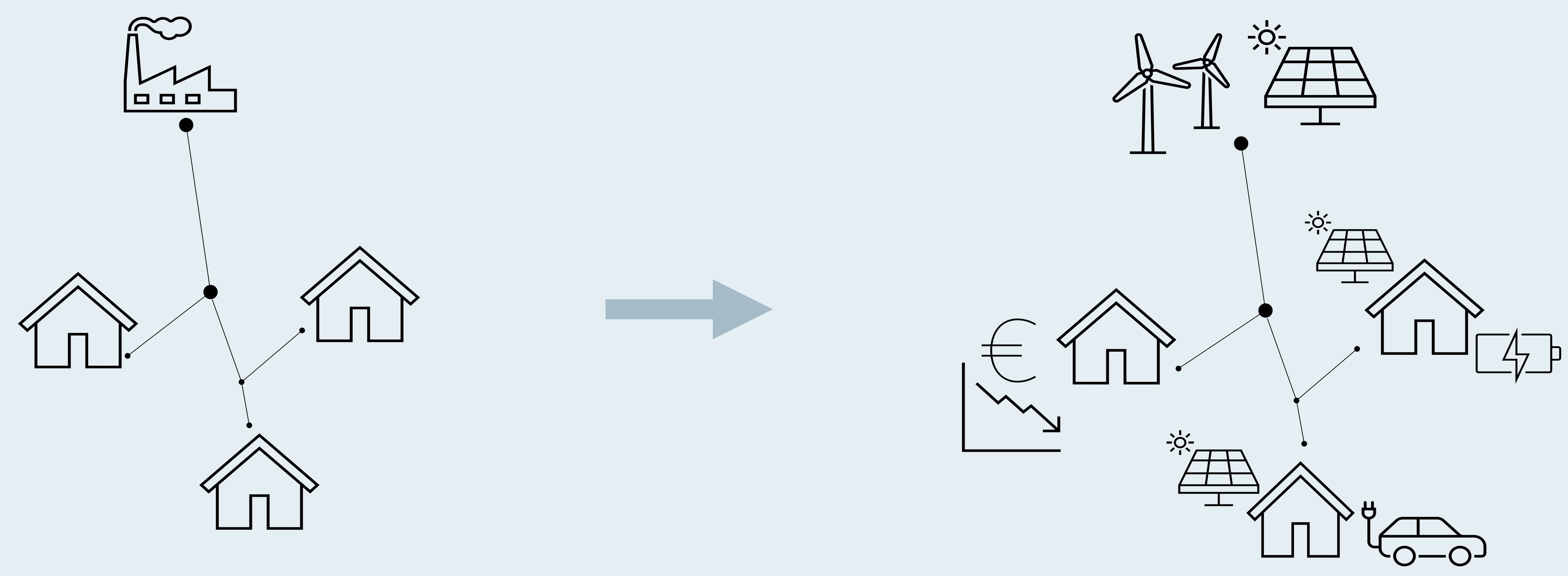
Current Grid Planning principles

- Low voltage grids were built for households and small businesses
- Planning is based on worst-case scenarios
- Planning inflexible demand and generation

New Possibilities for Grid Operation

- Flexible loads (e.g. scheduled charging of electric vehicles, heat pumps)
- Smart Metering (time series datasets)
- Dynamic grid tariffs and direct control by DSOs (e.g. §14a EnWG)

Transformation of the Power System and the Need to Adapt Grid Planning and Operation



- Increased electricity demand (electric vehicles, heat pumps, …)
- Decentralized generation from photovoltaics and wind turbines
- Weather-dependent generation and consumption (sun, wind, temperature, …)
- Emergence of prosumers (costumers who both produce and consume electricity)
- Bidirectional power flows in distribution grids
- Price-sensitive electricity consumption

- **These developments would require a large-scale grid expansion with investment needs of about 150 billion € in Germany with the current approach in grid planning.** [2]
- **Adapting grid planning to the new requirements is essential and can reduce investment needs by about 50 billion €.** [2]

Time Series-based Grid Planning

- Planning based on time series data instead of worst-case scenarios
- Synthetic load profiles are generated to simulate demand patterns
- Smart-meter datasets are used to improve and verify synthetic load profiles if available
- Demand response to incentives or operational signals (§14a EnWG) are modelled
- Flexibilities are considered

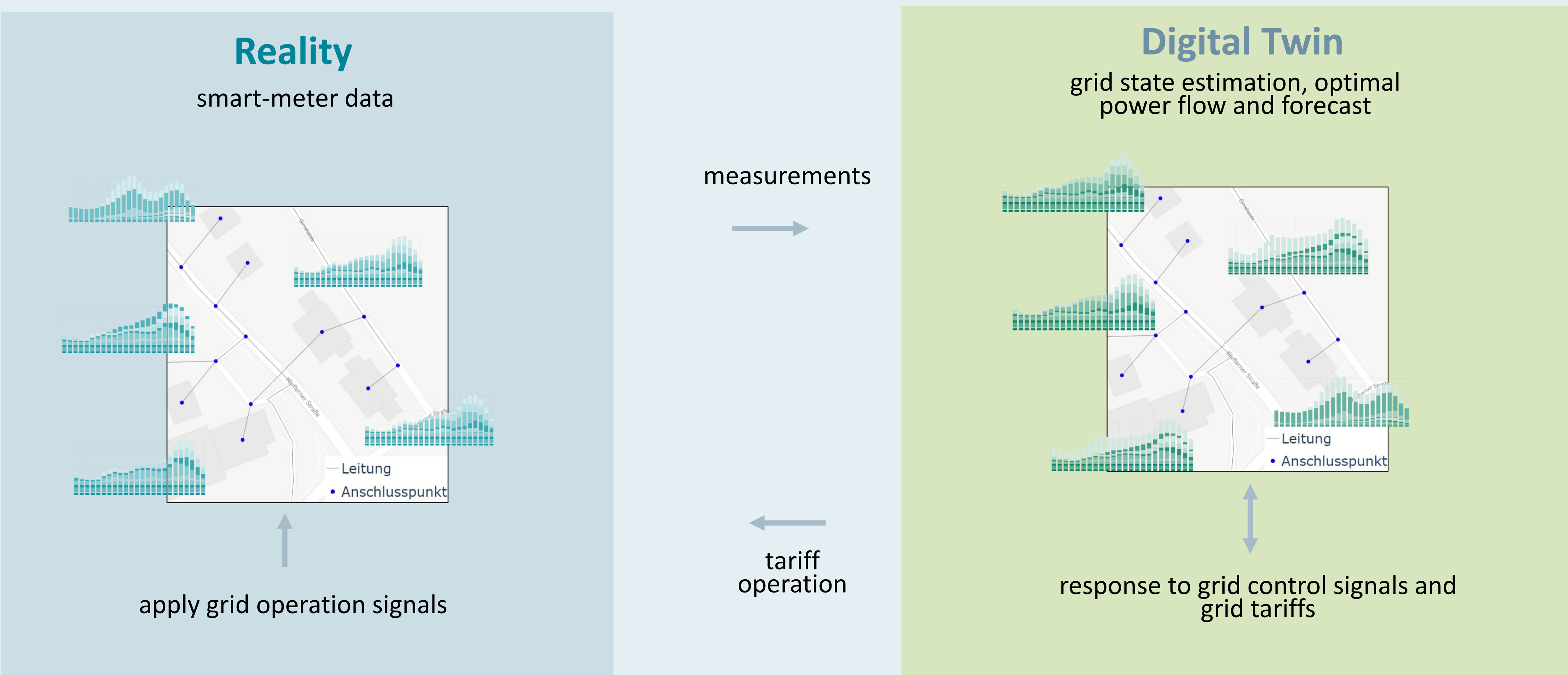
Reduce grid reinforcement by:

- Improved accuracy of estimated grid status
- Operational improvements for optimized power consumption (e.g. flexibility utilization, grid tariff designs, …)
- Reduce peak load in worst-case scenarios by modelling effects of grid tariffs and grid control operations

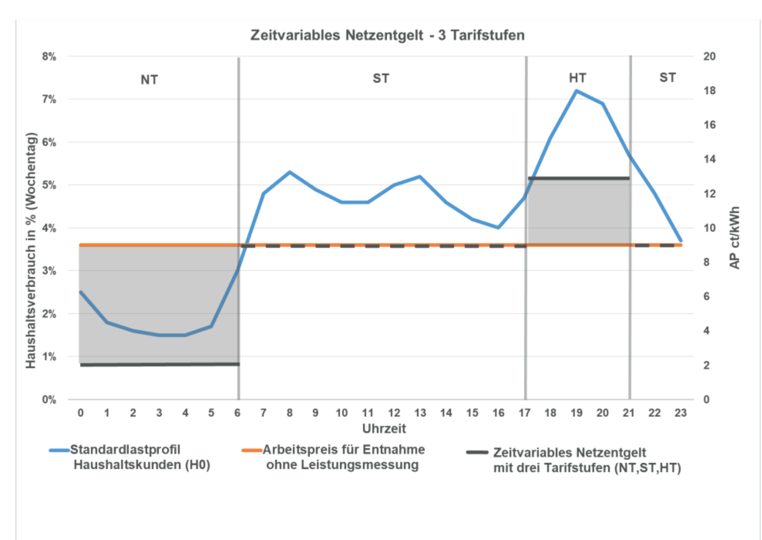
Time Variable Grid Tariffs to Reduce Peak Load

- Dynamic or static time variable grid tariffs incentivize demand behavior that reduces grid loading
- Time-of-Use tariff introduced in Germany in April 2025 - effects on grid need to be studied
- Other grid tariff designs need to be investigated

Digital Twin for Data-Driven Grid Planning



3-tier Time-of-Use Grid Tariff[1]



Vision

- **Grid planning becomes more flexible and efficient**
- **Costumers adapt demand to grid load**
- **Support secure integration of low carbon technologies**

1 BNetzA, BK8-22/010-A
2 Bründlinger, Thomas, et al. "dena-Leitstudie Integrierte Energiewende." Impulse für die Gestaltung des Energiesystems bis 2050 (2018): 510.

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