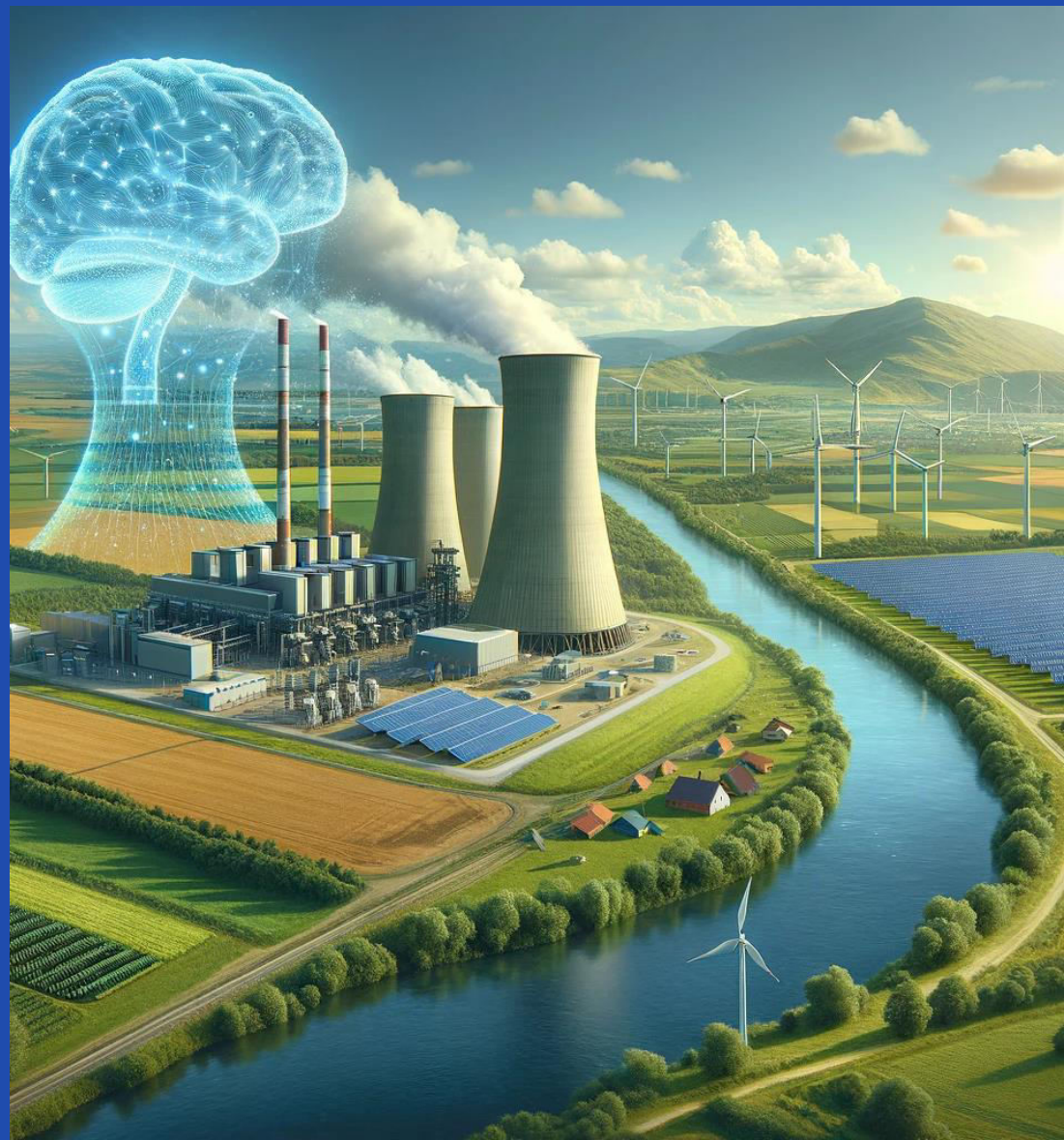
The Role of AI in Transforming the Power Sector: German Experiences



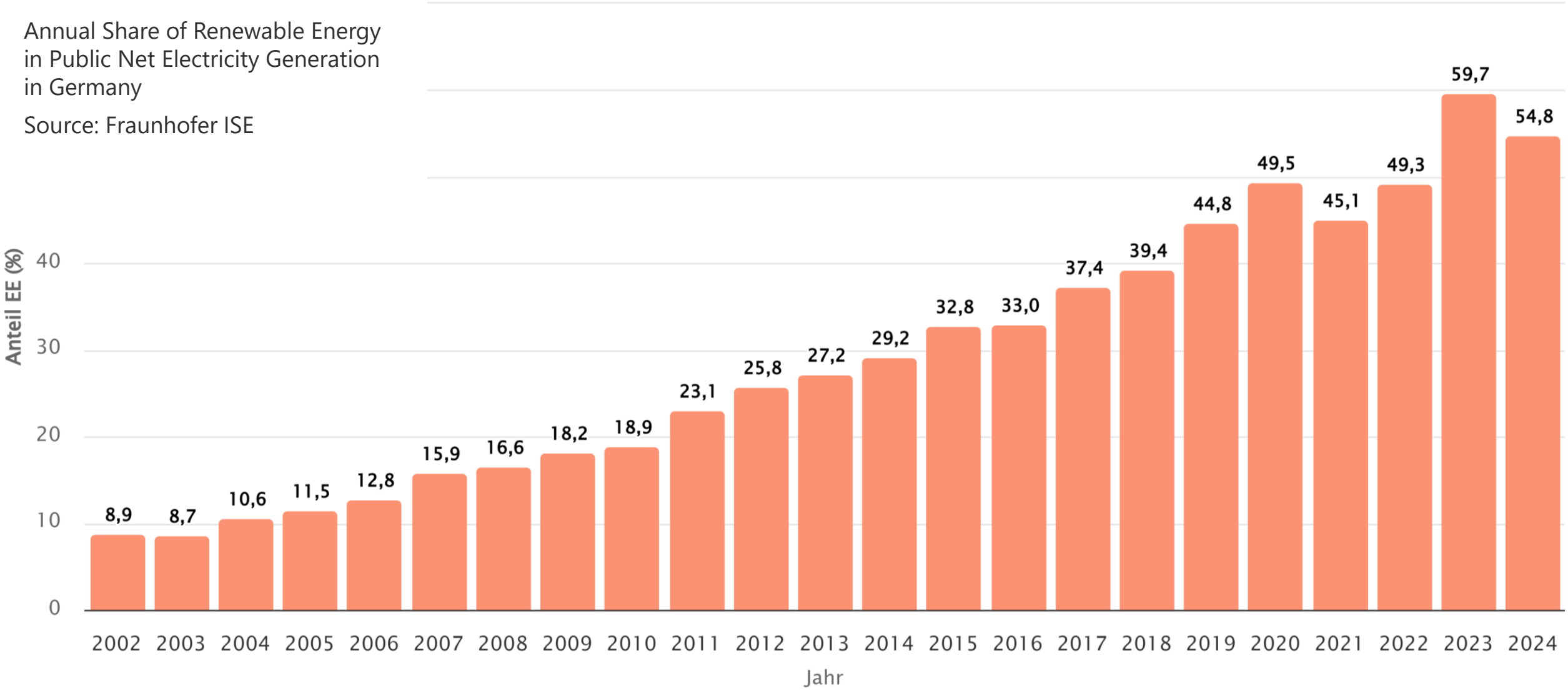
Dr. Peter Deeskow

January 2024, Delhi

Germany has reached nearly 60% of renewable share in Generation in 2023

Annual Share of Renewable Energy in Public Net Electricity Generation in Germany

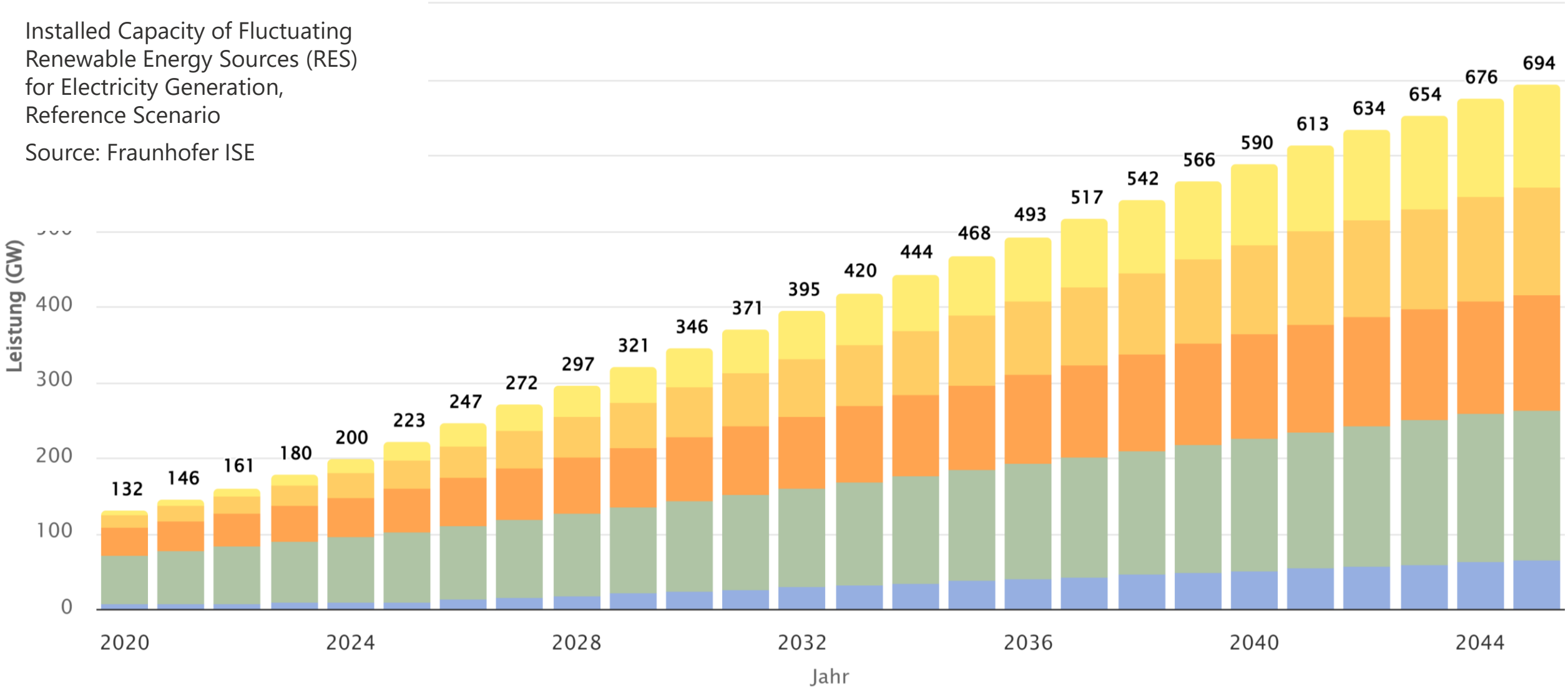
Source: Fraunhofer ISE



The installed capacity of renewable generation in Germany is expected to more than triple in the next 20 years.

Installed Capacity of Fluctuating Renewable Energy Sources (RES) for Electricity Generation, Reference Scenario

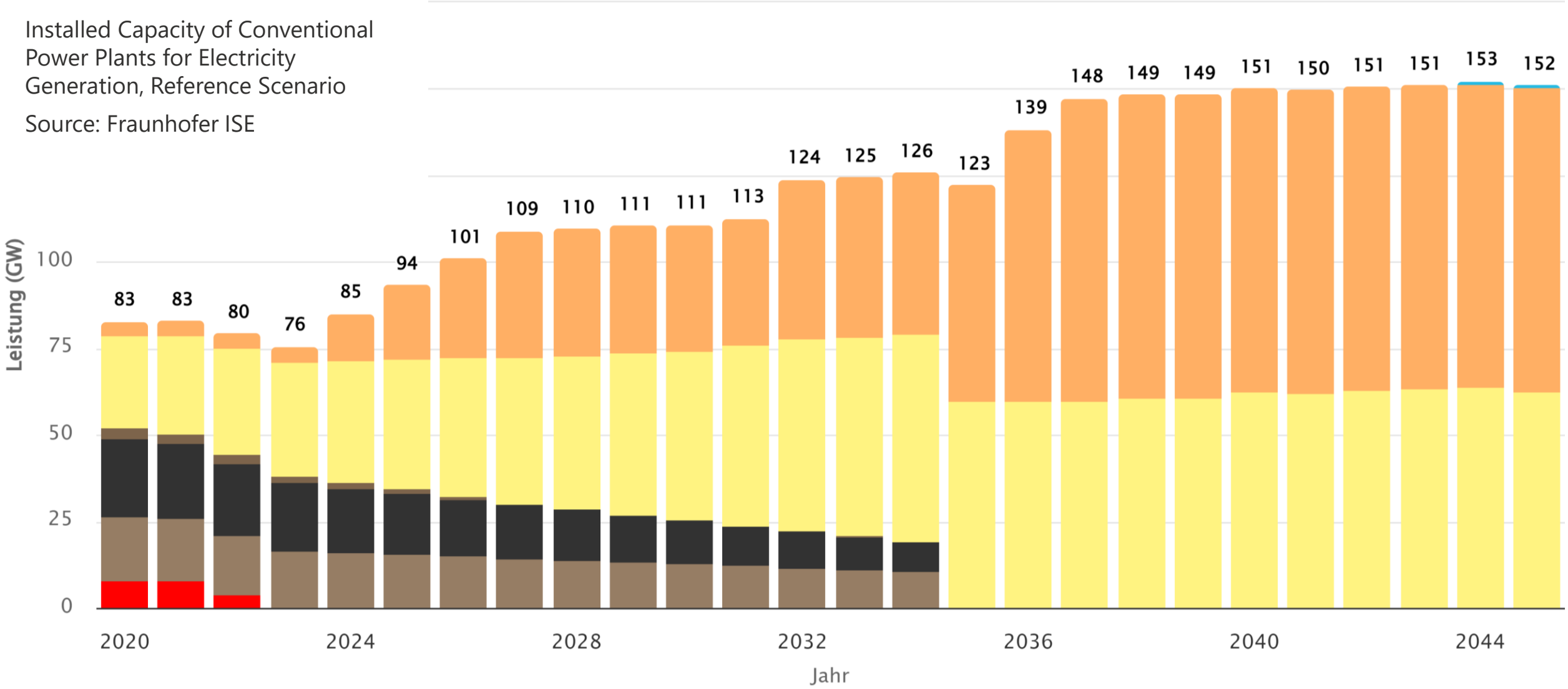
Source: Fraunhofer ISE



The installed capacity of conventional generation in Germany is expected to nearly double the next 20 years.

Installed Capacity of Conventional Power Plants for Electricity Generation, Reference Scenario

Source: Fraunhofer ISE



A number of challenges are arising from having many conventional and a hugh number of renewable generation units

Streamling Operation and Maintenance

- Monitoring and Diagnosis of decentralized generation
- Supporting Remote Operation
- Enabling dynamic maintenance scheduling
- Optimizing Asset Utilization
- Increasing Operational Flexiblity of large units

Ensuring Grid Stability and Reliability

- Integrating fluctuating renewables and storage devices
- Balancing demand and supply
- Handling increased complexity with advanced control and optimization

Improving Operational Excellence

- Handling Hugh Data Flows of operational data, maintenance records etc.
- Collecting insights from numerous small-scale decentralized facilities to enable cross-learning
- Creating centralized knowledge bases and training modules

AI can help to tackle these challenges: Example Use Cases

Predicting Equipment Failures & Reducing Downtime

Assisting Asset Management with automated Root Cause Analyis

Supporting complex control tasks

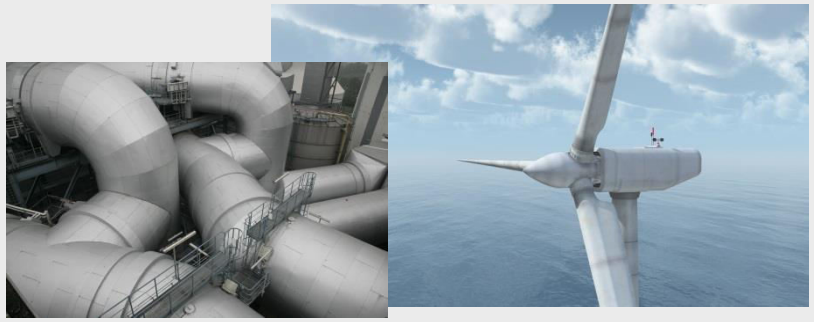
Supporting Integration of Renewables by improved forecasting

Enabling Smart Grid Management for Improved Reliability & Automated Demand Response

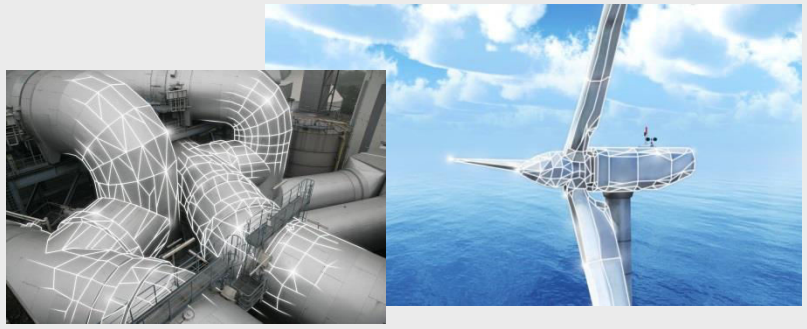
Enabling Automation of Processes in Asset Management and Plant Operation

AI is used to support Predictive Maintenance by detecting anomalies

Act on right moment, reduce additional costs of unplanned outages and increase overall planned availability through predictive maintenance

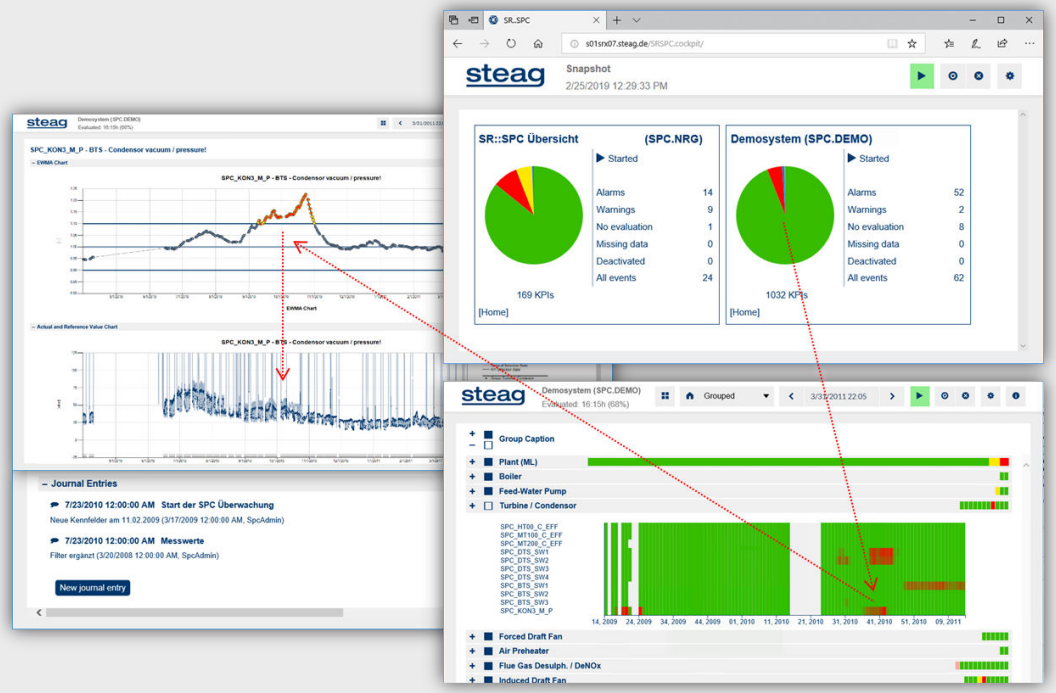


Current sensor-based data



Digital replica / digital twin

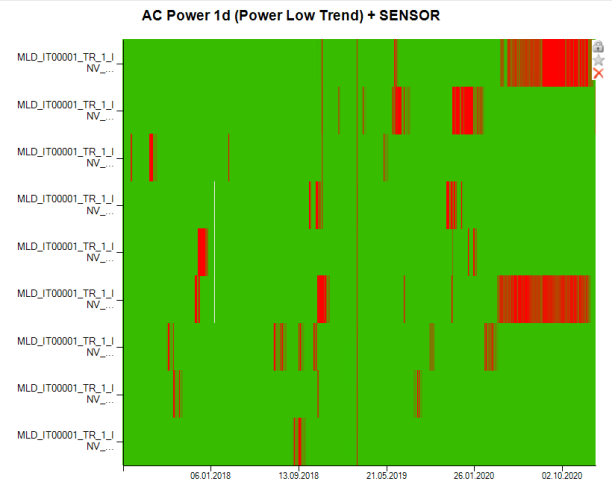
Compare

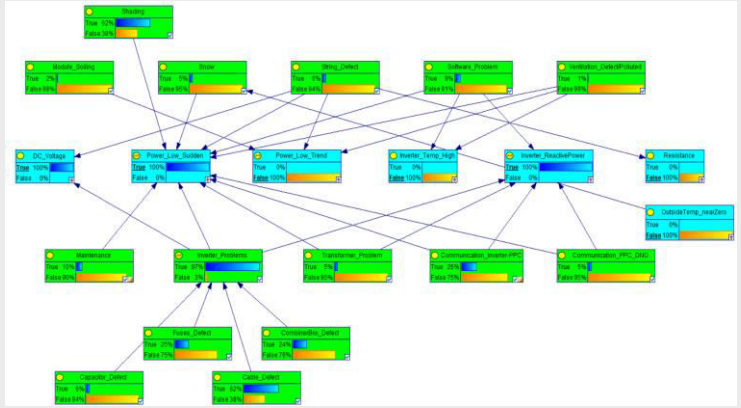


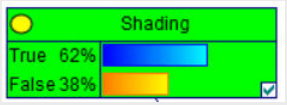
... anomaly detection
... early stage information
... avoid false alarms

AI helps to identify possible root cause Analysis from detected anomalies

Detect Anomalies → Use Anomalies as Evidence in a Bayesian Network → Posterior Probabilities of Possible Causes P(Cause | Effect)

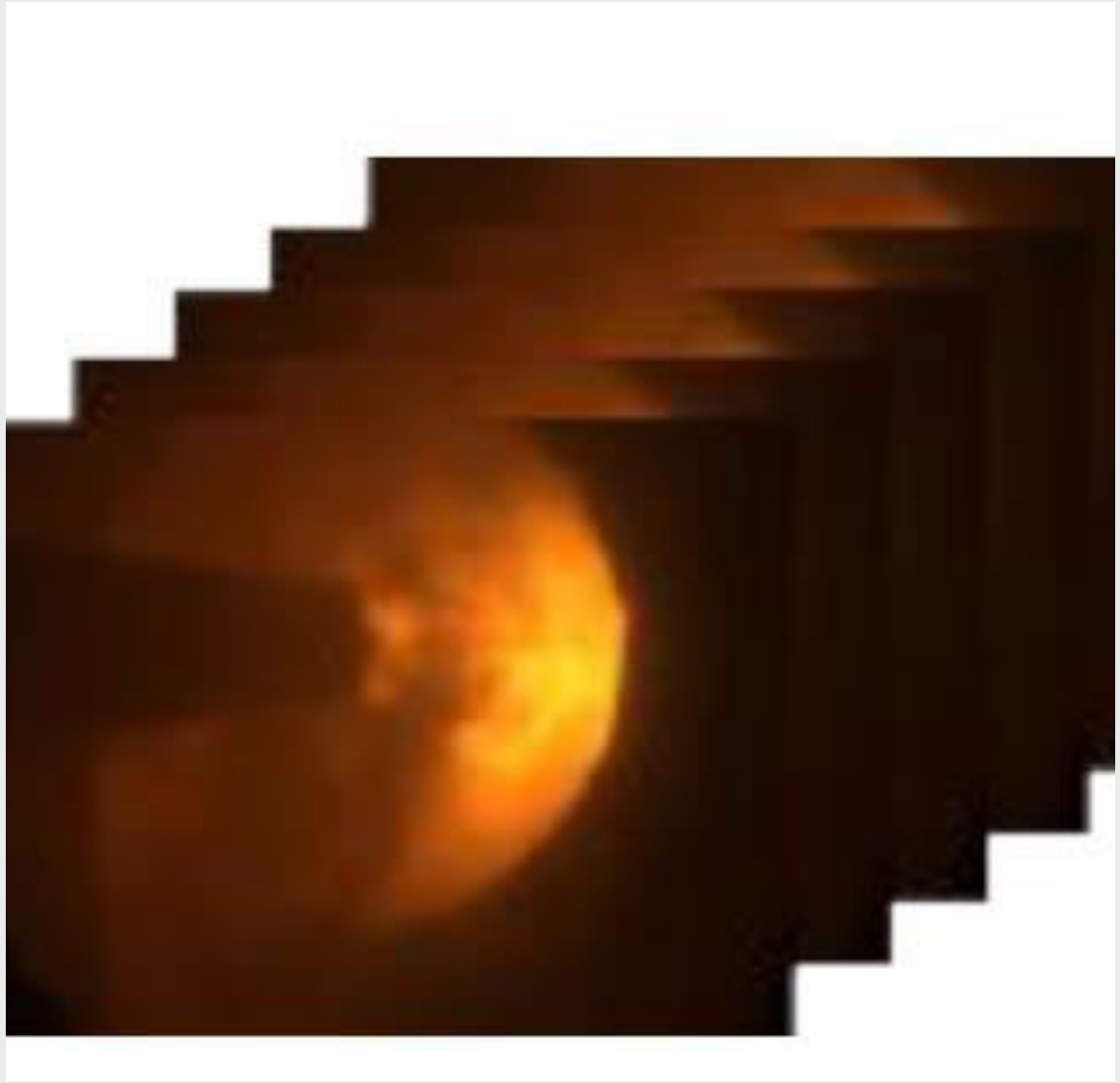






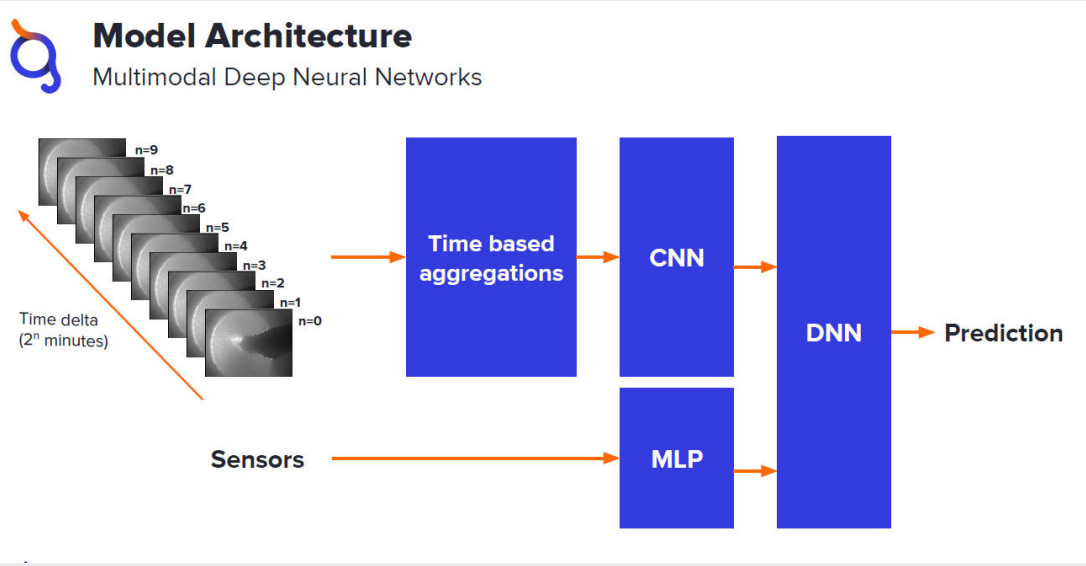
Source: Deeskow et al., EPRI AI Summit 2022

AI is used for Combustion Optimization



- **Specific Optimization Goal**: Enhancing efficiency and reducing emissions in combustion processes with model predictive control
- **Complex Data Environment**: Handling multimodal data from various sensors and systems.
- **Data Labeling and Long-term Analysis**: Challenges in correlating operational changes with outcomes due to delayed effects.

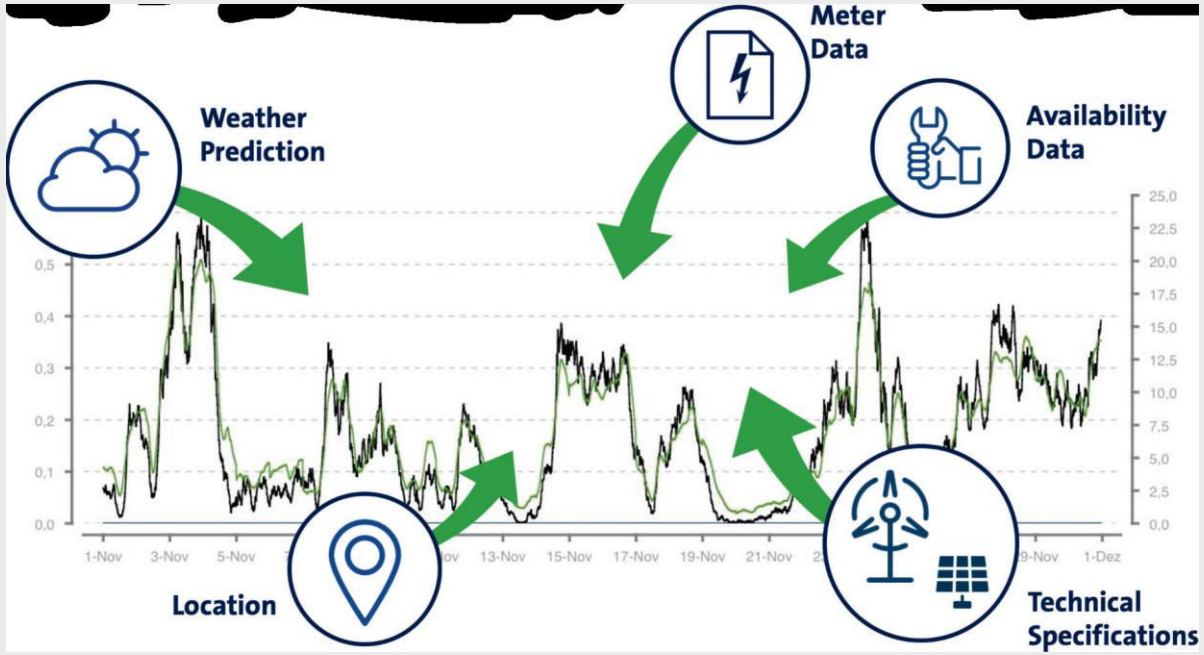
Deep Learning has recently enabled improvements in Combustion Optimization



- **Integrated Model Architecture**: Leveraging deep neural networks for effective data synthesis.
- **Self-Supervised Learning Approach:** Utilization of large, unlabeled data sets for model training.
- **Enhanced Prediction Accuracy**: Applying transfer learning and ensemble methods for more precise predictions.
- **Operational Improvements**: Significant reductions in CO2 and coal usage, increased efficiency and improved product quality (e.g. in cement plants)

Source: Volker Stephan, Iqony & Kelvin Fernades, Nilg.ai, 2023

SMEs have developed AI solutions for Forecasting of Renewable Power Supply



Source: enercast GmbH, Accurate Power Generation Forecasts for Variable Renewable Energy Sources
Using enercast e³ Technology, 2020

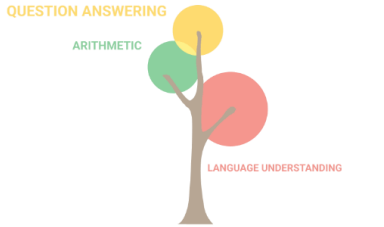
- **AI-Driven Enhancement of Renewables**: Reliable forecast of the power output is key for optimized operation and maintenance of the plant and for the stable integraton into the grid
- **Neural Network Predictions**: trained on widely available weather forecasts and historical turbine data to predict wind power output ahead of actual generation.
- **Optimal Delivery Commitments**: The model recommends how to make optimal hourly delivery commitments to the power grid a full day in advance, enhancing the value of energy sources that can be scheduled.
- **Boost in Wind Energy Value**: Google & Deepmind report 20% increase in the value of their wind energy, compared to scenarios without time-based commitments

AI enables grid optimization

- **Challenge**: Integration of decentralized energy generators and consumers, like solar systems and electric vehicles,
- **Approach**: Measurement data from the grid were analyzed using AI to identify generator and consumer profiles, including external factors like weather and typical consumer load patterns.
- **Methodology**: The project utilized state-of-the-art machine learning methods for detecting large consumers and physical models for solar-induced energy generation.
- **Results**: The AI-based analysis enables automatic evaluation of consumer and generator profiles, aiding grid optimization with a focus on photovoltaic generation and electric vehicle energy demands.

Source: Reasonance GmbH, Netze BW

Large Language Models open up new possibilities for the application of AI.



- LLMS are basicly huge deep learning artificial neural networks that learn word relationsships and meanings from extensive text data.
- LLMS generate new text as an output by predicting likely next words.
- LLMs operate on complex statisitcs and probalilities, meaning they generate the most probable reponses, which are not necessarily correct.
- LLMs developed important skills in creating various text types such as strories, summaries, emails, code and solving tasks like translation, comomn sense reasoning and others

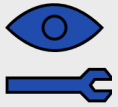
Source: Google

Use Cases of LLM based applications for Asset Management are currently explored

LLMs can be integrated with various digital systems for comprehensive task management, e.g.:

- **Data Retrieval**: Integration with company databases and file shares alllow easy natural language based access to and analysis of drawings, inspection reports, work orders …
- **Automating Workflows**: drafting of emails, generate maintenance reports, preparing of perfomance reports …
- **Decision Support**: LLMs assist in making informed decisions by analyzing vast amounts of textual data such as Maintenace reports, performance data and documentaton. In interacting with other applications they visualize results and propose measures
- **Hands free Operation**: Use speech-to-text applications and LLMs to provide assistance to operators in the field

AI is essential for advancing towards a sustainable and efficient global energy future. The seminar will discuss this in detail.



Detecting Equipment failures: tubeleak detection

AI for load forecasting an generation optimization

Assisting Asset Management with Digital Twins

AI for improving grid operation

AI for (cyber) risk management

AI to support drone based inspection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