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Martin Tackenberg, Siemens Energy Management | Regensburg, March 7, 2016

Trends and Innovations in the Energy Sector

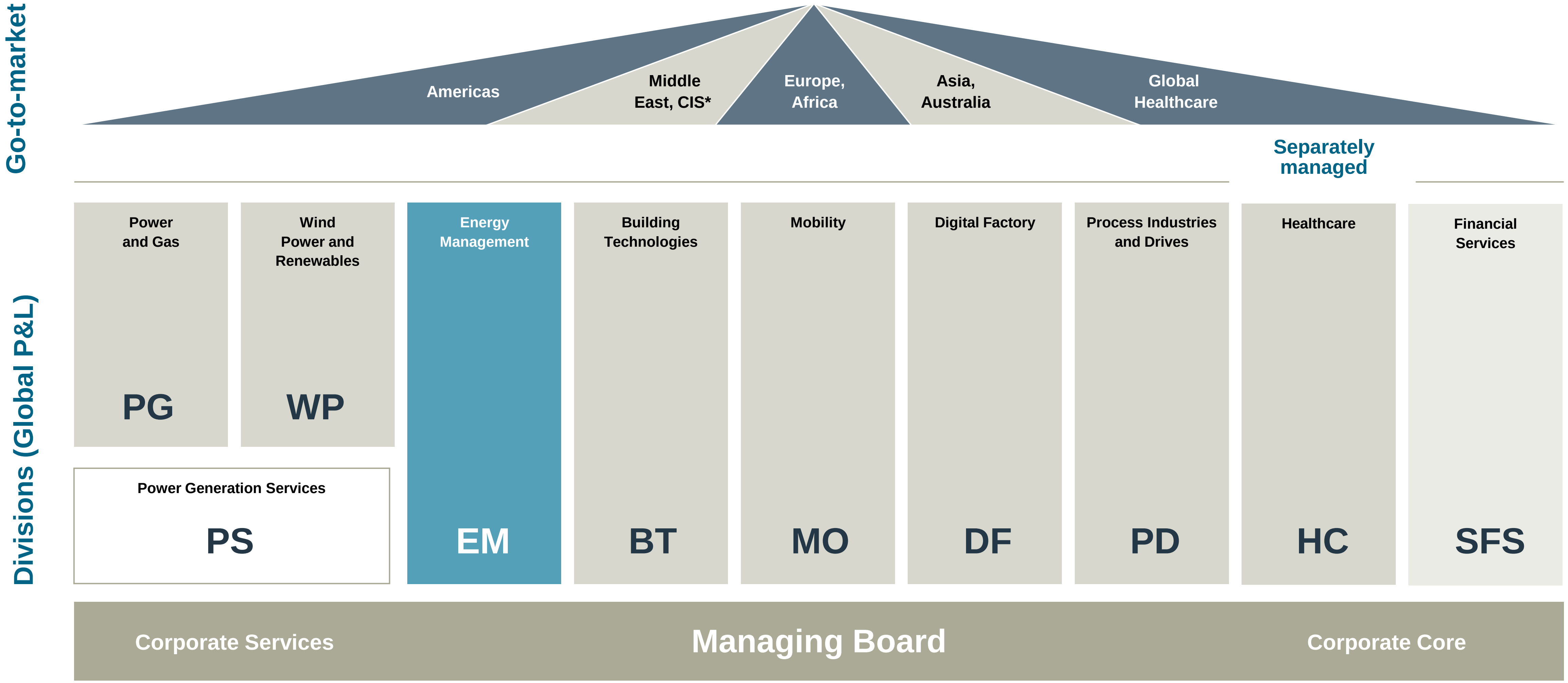
Agenda

Fact & Figures SIEMENS

Global Trends

Our Answers

Flat and market driven organization along the value chain will capture growth opportunities



* Commonwealth of Independent States

Siemens at a glance in FY14

€78.4bn Orders

€4.1bn R&D spending

343,000 Employees in more than **200** Countries

€71.9bn Revenue

Energy Management at a glance
We are where our customers are

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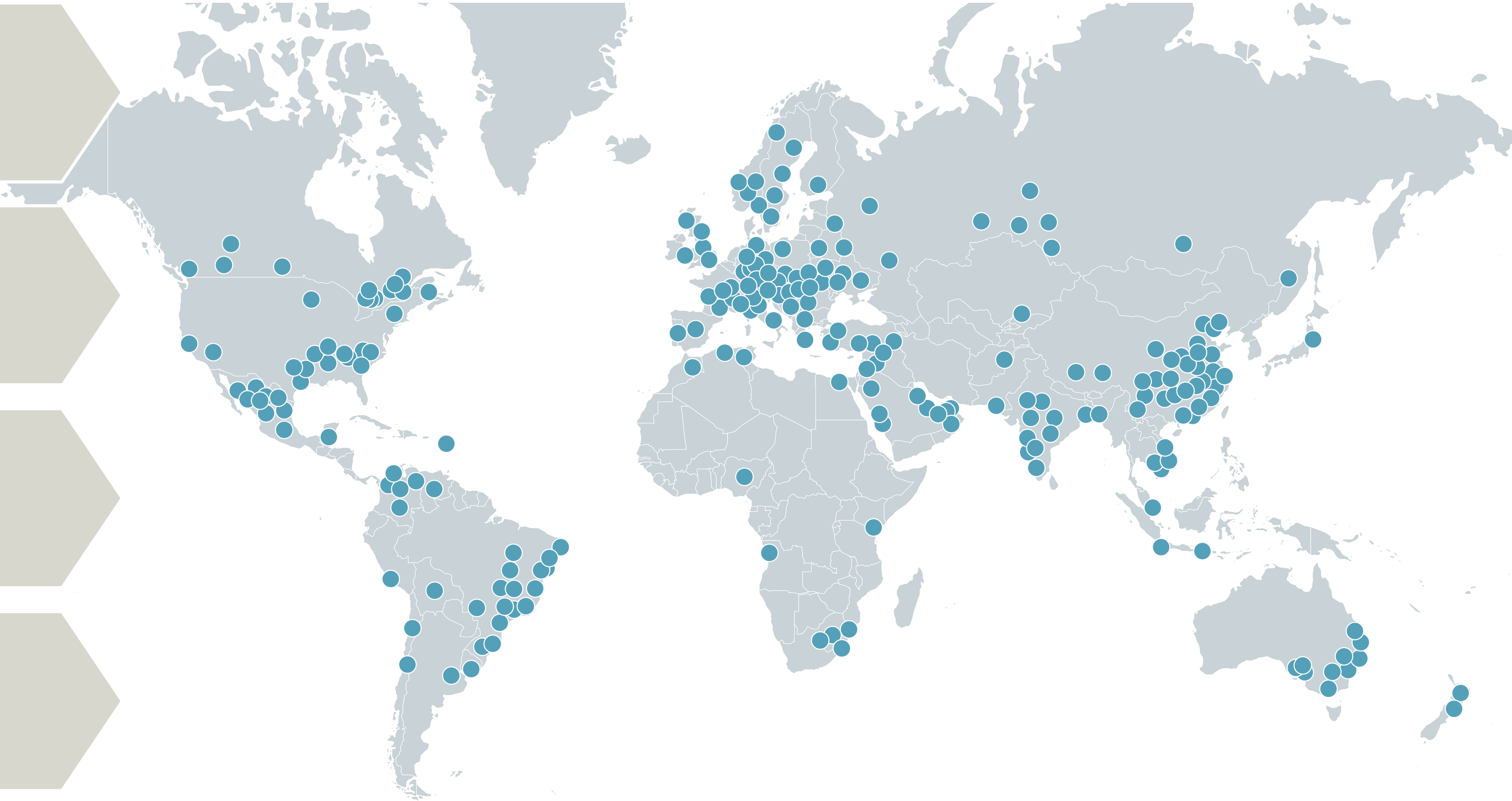
~ €11 bn
Revenue

~ €350 m
Investment in R&D

~ 53,000
Employees

~ 100
Production locations



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The Energy Management Business Units

High Voltage Products

- Circuit breakers
- Disconnectors and earthing switches
- Hybrid switchgear
- Instrument transformers
- Surge arresters
- Coils
- Bushings
- Gas-insulated switchgears(GIS systems)

Transformers

- Power transformers
- Distribution transformers
- Special purpose transformers
- Traction transformers
- Phase shifter transformers
- Transformer lifecycle management (TLM™)
- Transformer components

Transmission Solutions

- High-voltage direct-current transmission (HVDC)
- Reactive power compensation / FACTS
- Turnkey grid access solutions
- Solutions for gas- and air-insulated switchgear (GIS, AIS)
- Gas-insulated lines (GIL)

Medium Voltage & Systems

- Air- and gas-insulated medium-voltage switchgear
- Low-voltage switchgear and busbar-trunking systems
- Generator switchgear
- Storage & grid coupling
- Power supply solutions, E-houses
- Subsea prod. & systems

Low Voltage & Products

- Low-voltage protection, switching, measuring, and monitoring devices
- Low-voltage distribution boards/systems
- Medium-voltage vacuum circuit breakers, contactors, and interrupters

Digital Grid

- Consulting
- Grid automation & control centers
- Grid applications
- Communication devices
- Sensors
- Meter data management
- Data analytics
- Software solutions
- Integration services
- Asset services

Content

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Global Trends

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Siemens Vision 2020 – leading position in Electrification, Automation, Digitalization

Global trends

Digital transformation
Networked world of complex and heterogeneous systems

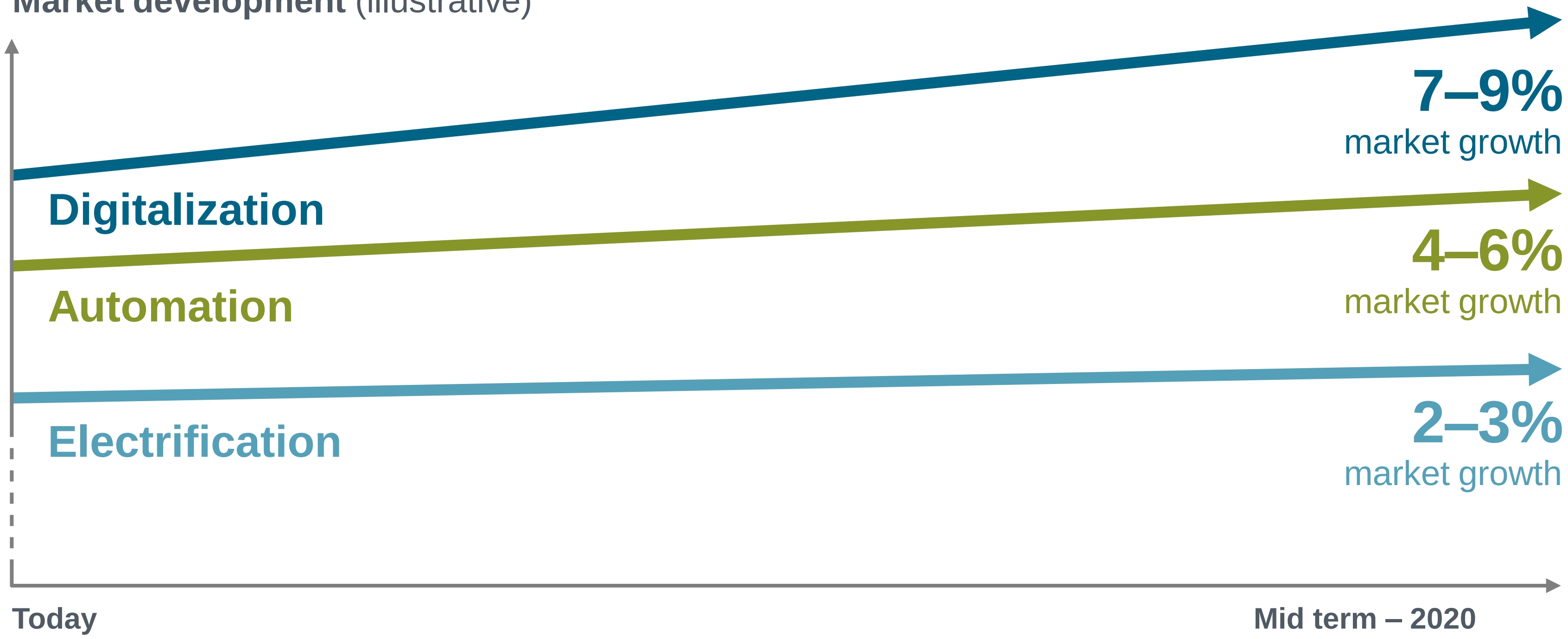
Globalization
Global competition driving productivity and localization

Urbanization
Infrastructure investment needs of urban agglomerations

Demographic change
Decentralized demand of a growing and aging population

Climate change
Higher resource efficiency in an all-electric world

Market development (illustrative)



Power Generation → **Power transmission, distribution, and smart grid** → **Efficient energy application** | **Imaging and in-vitro diagnostics**

Digitalization changes everything


From record store ...

… to streaming

Spotify®


From bookstore ...

… to e-book


Steve Jobs: The Exclusive Biography (English Edition)
amazon

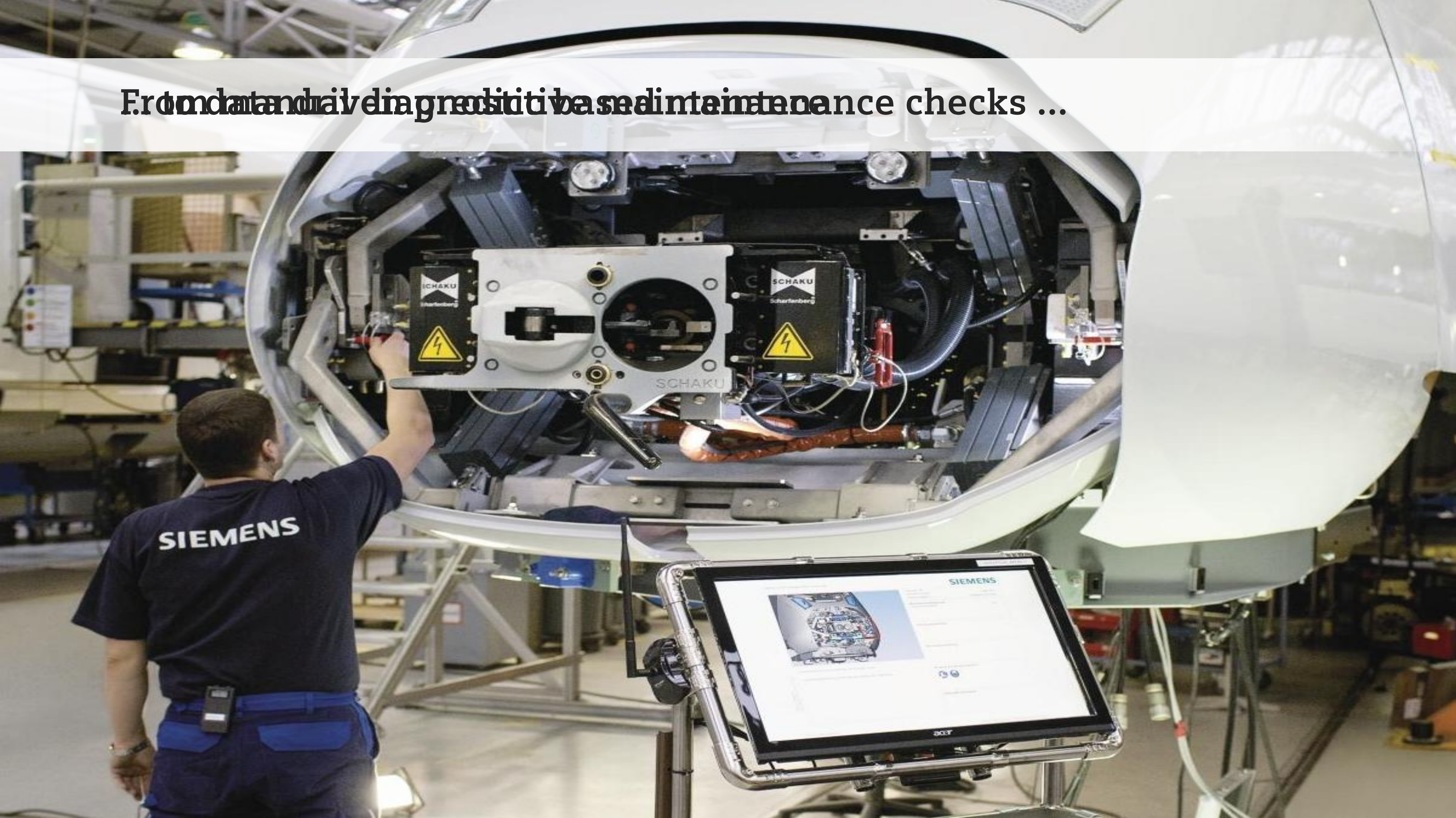

From taxi …


… to ride sharing
UBER

From manual diagnostic based maintenance checks …

From data driven predictive maintenance

... to manual diagnostic based maintenance checks ...



Will this disruption stop in front of our business markets?

From centralized power plants …

From centralized power plants

... to decentralized & fluctuating power generation

Energy Systems are changing fast

German Energiewende:
Complexity is managed with increasing smartness throughout the grid

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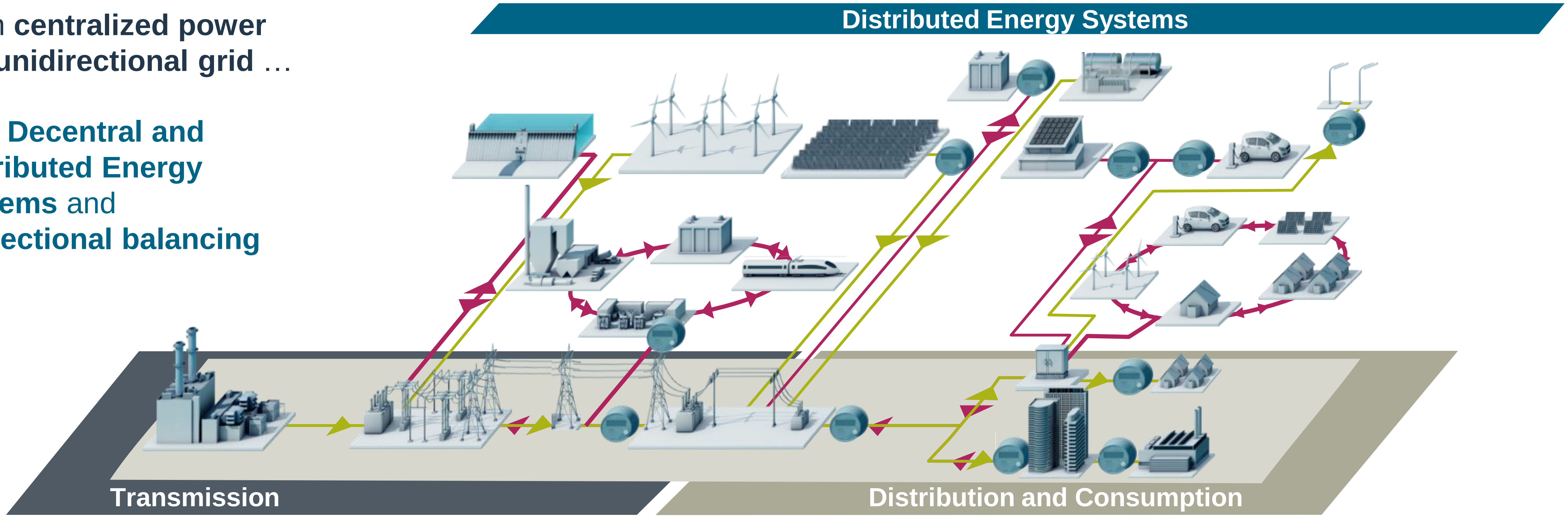
From **centralized power** and **unidirectional grid** …

… to **Decentral and Distributed Energy Systems** and **bidirectional balancing**



1 Changing generation mix higher volatility drives invest in stability / availability	**2 Generation capacity** additions generation capacity increase requires new connections	**3 Distance from source to load** natural resources and demand centers to be linked	**4 Decentralization (public/private)** small / distributed units drive invest in distr. automation/ IT	**5 Refurbishment/ upgrades** installed base is enhanced to cope with new challenges

Energiewende 2.0 –
Worldwide challenges to the energy systems of the future

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Energiewende 2.0

<10%
Traditional mix
- Fossil (coal, gas, oil)
- Nuclear
- Renewables (mainly hydro)

Focus on:
- Efficiency
- Lifecycle cost reduction
- Availability/reliability/security

Past

… 20+%
System integration
- Fossil (coal, gas, oil)
- Renewables (wind, PV, hydro)

- Decreasing spot market prices
- Subsidized economy
- Increasing re-dispatch

Today

40+%
Market integration
- Capacity markets, etc.

- Increase in Power2Heat and CHP
- Demand-side management
- Increase in storage solutions
- HVDC/AC overlay

60+%
Regional self-sustaining systems
- Topological power plants

- Increase in “autonomous” grids
- HVDC overlay and meshed AC/DC systems
- Power2Chem/CO_2toValue
- System stability

Mid-term

80+%
Decoupled generation and consumption
- All energy sources working together

- Complete integration of decentralized power generation
- Storage systems/Power2X
- Return to gas power plants?

Long-term

We are addressing all key elements of energy systems….

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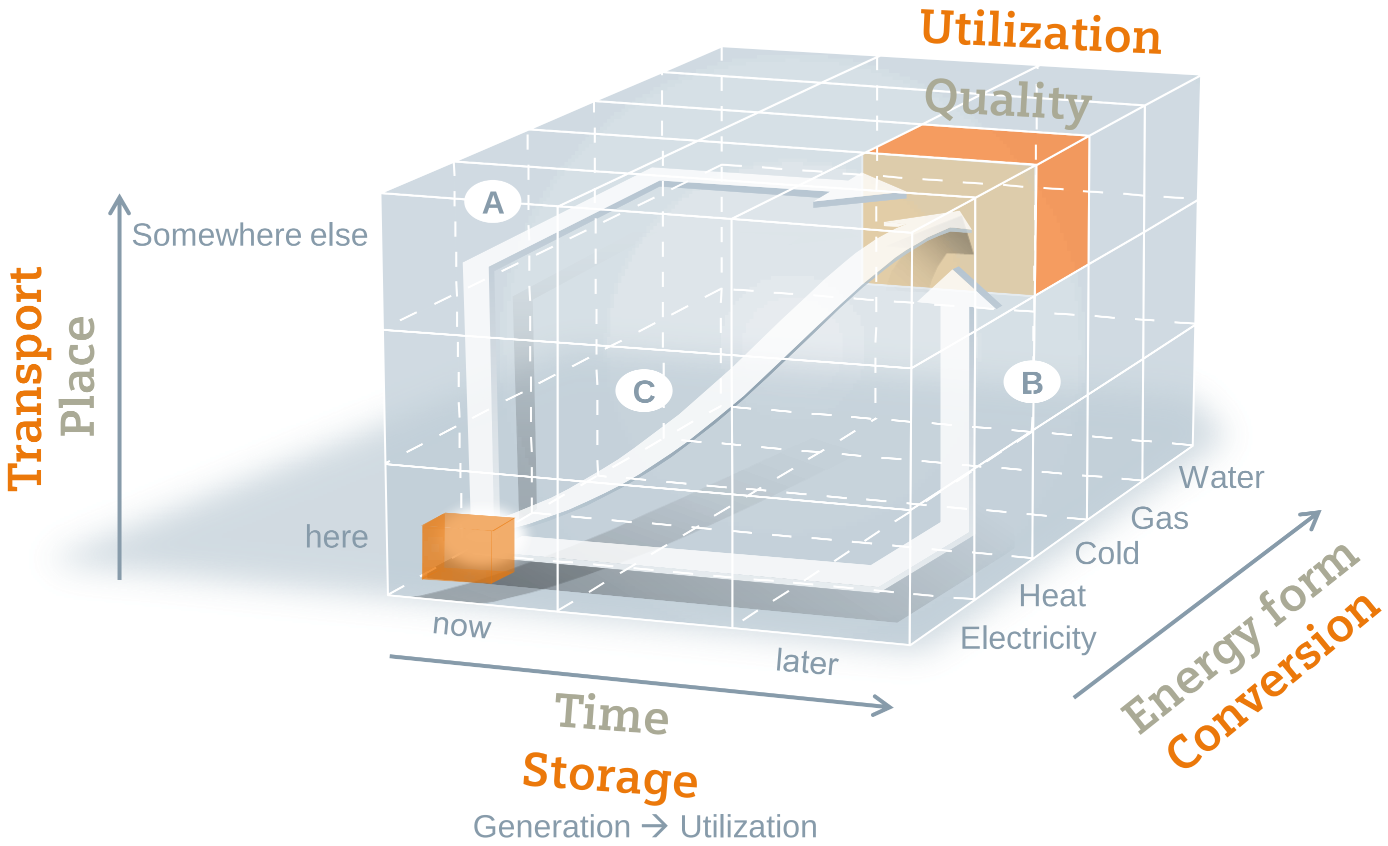
The core question of the optimal pathway from source to utilization is Energy at the *right Place*, on the *right Time*, in the *required Form* and *Quality*

... Conversion

... Transport

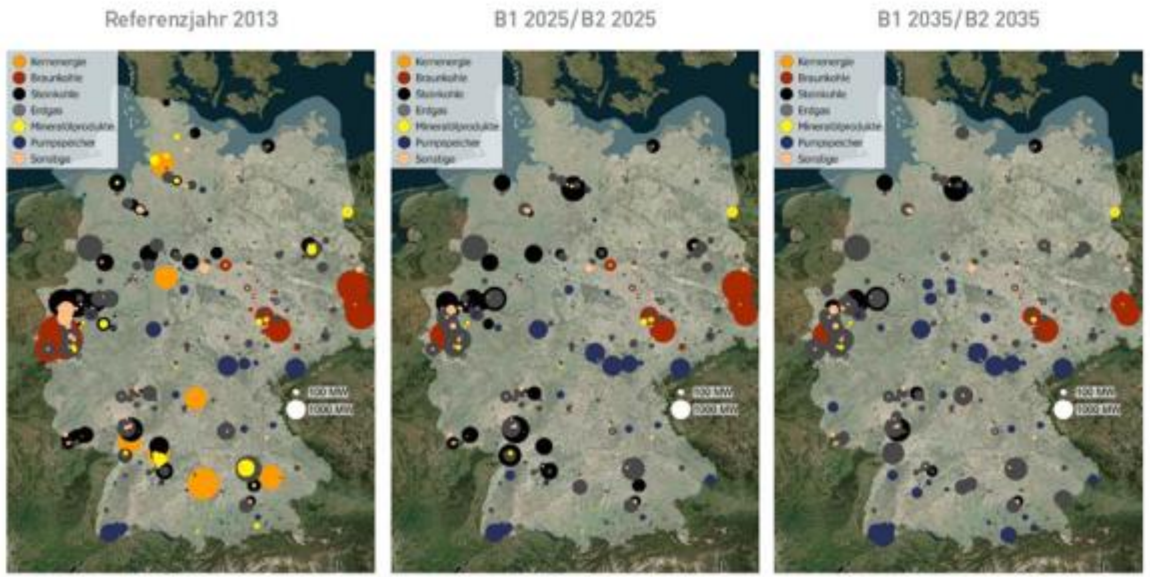
... Storage

... Utilization



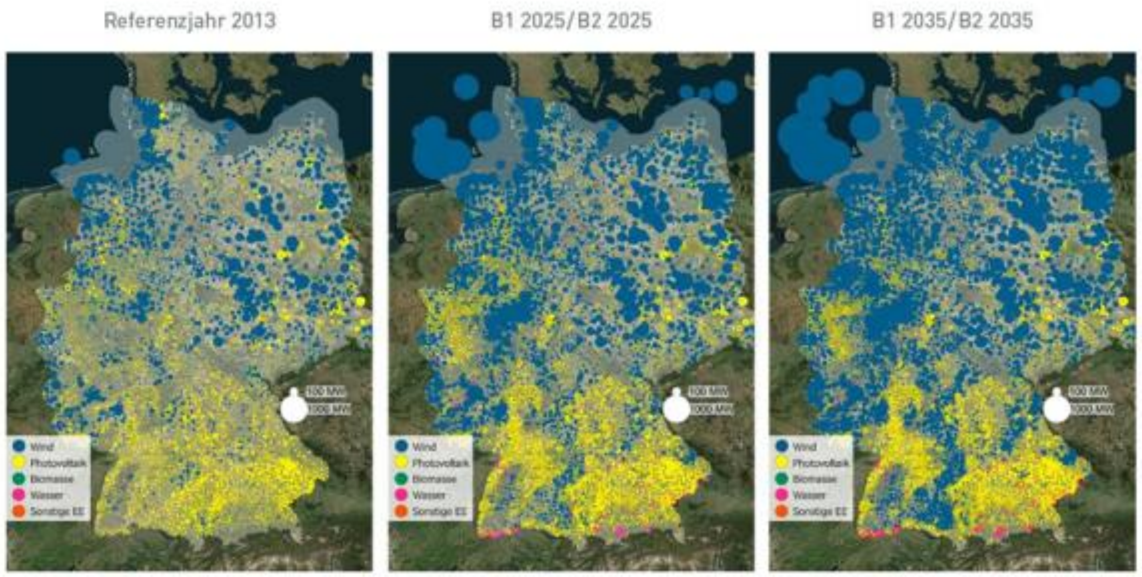
Expected development of the German Energy Mix (2013 – 2025 – 2035)

Decrease of dispatchable (conventional) Power Generation



- Kernenergie
- Braunkohle
- Steinkohle
- Erdgas
- Mineralölprodukte
- Pumpspeicher
- Sonstige

Increase of variable Power Generation (Wind, PV)



- Wind
- Photovoltaik
- Biomasse
- Wasser
- Sonstige EE

Source: TransnetBW

Energiewende 2.0 –
Future energy systems: Decoupling of generation and consumption

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Past
Production follows consumption

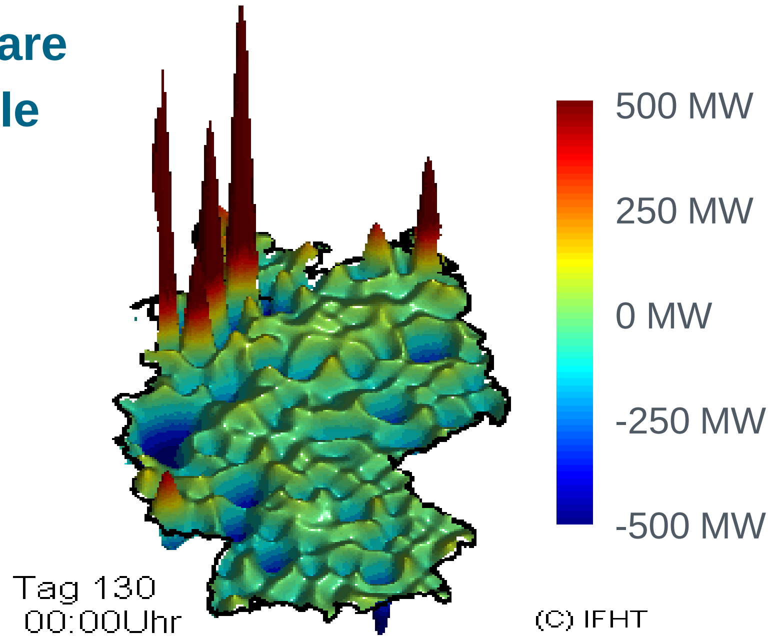
Today
Consumption vs. production

Future
Production decoupled from consumption

- **2035+: Installed capacity** of renewable energy systems: >220 GW
  - Electrical energy produced: 446 TWh
  - Electricity generation is occasionally 2.4 times higher than maximum consumption!
- **Excess energy** in northern states of Germany
  - More than 7,000 MW for over 3,000 hours per year
- **Grid stability** is the highest priority

Reducing uncertainties is a major challenge for research and development!

80% share of renewable energy in 2035+



Renewable Production in Germany Largely Depending on Seasonal Effects

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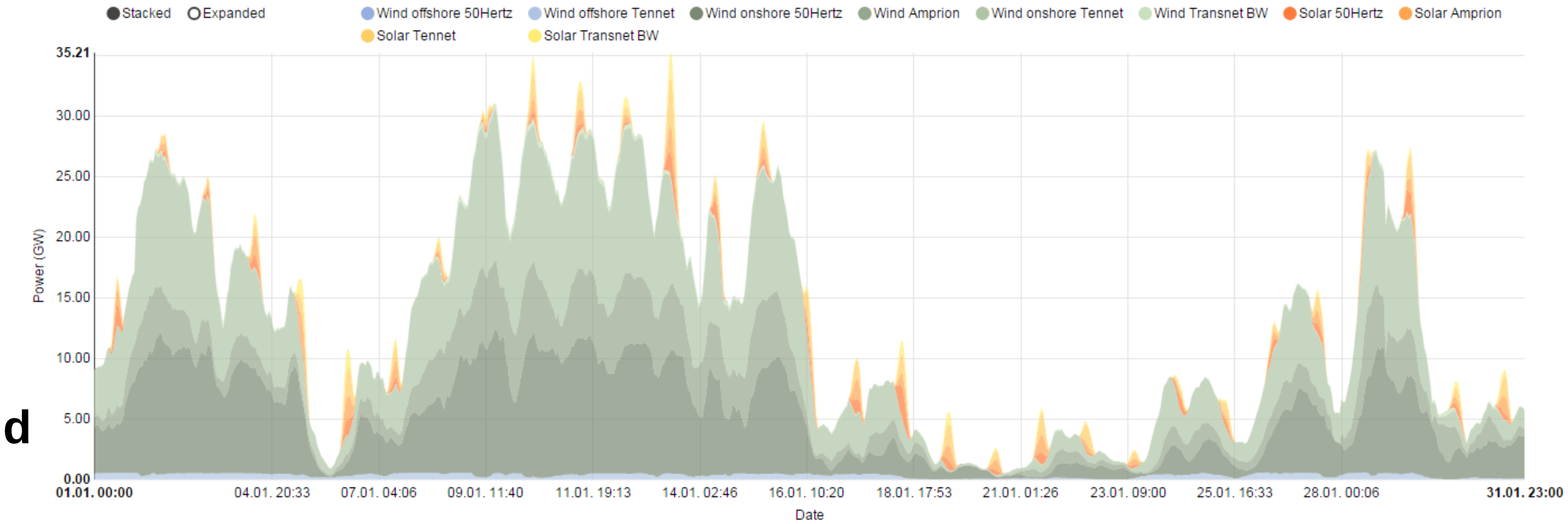
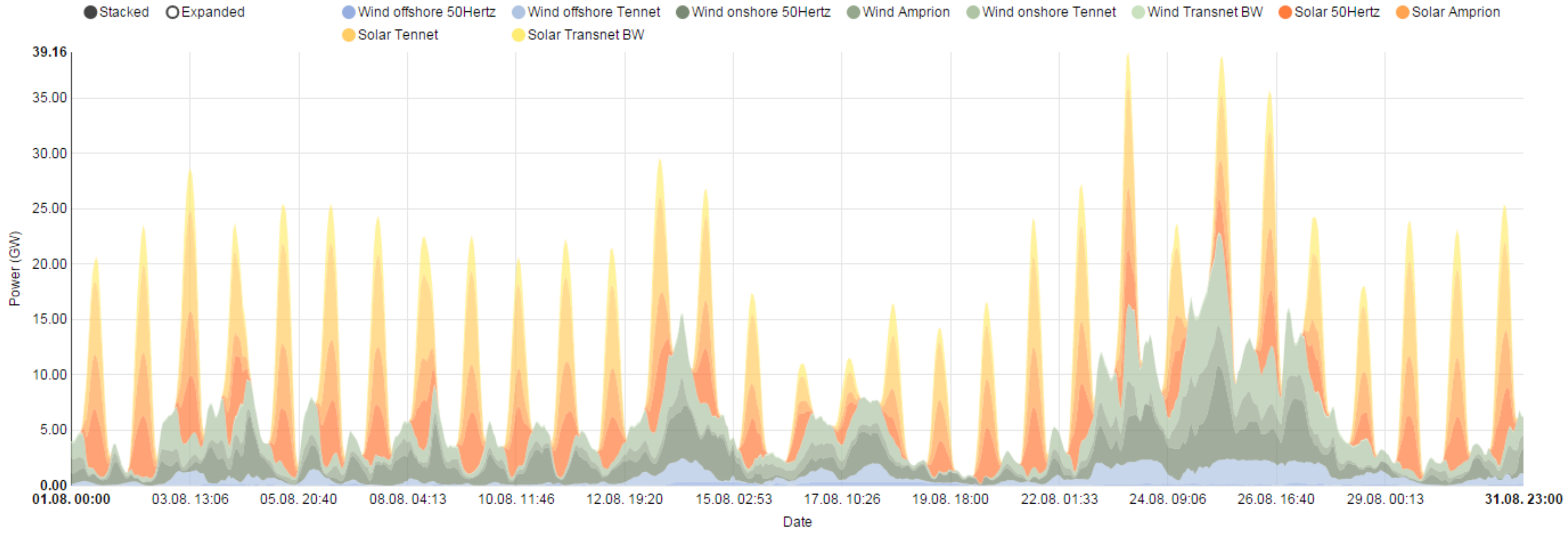
Renewable Production Germany January 2015



Wind

Solar

Renewable Production Germany August 2015



Source: https://www.energy-charts.de/power.htm

Generation mix in 2030: Opportunities, Threats and Uncertainties

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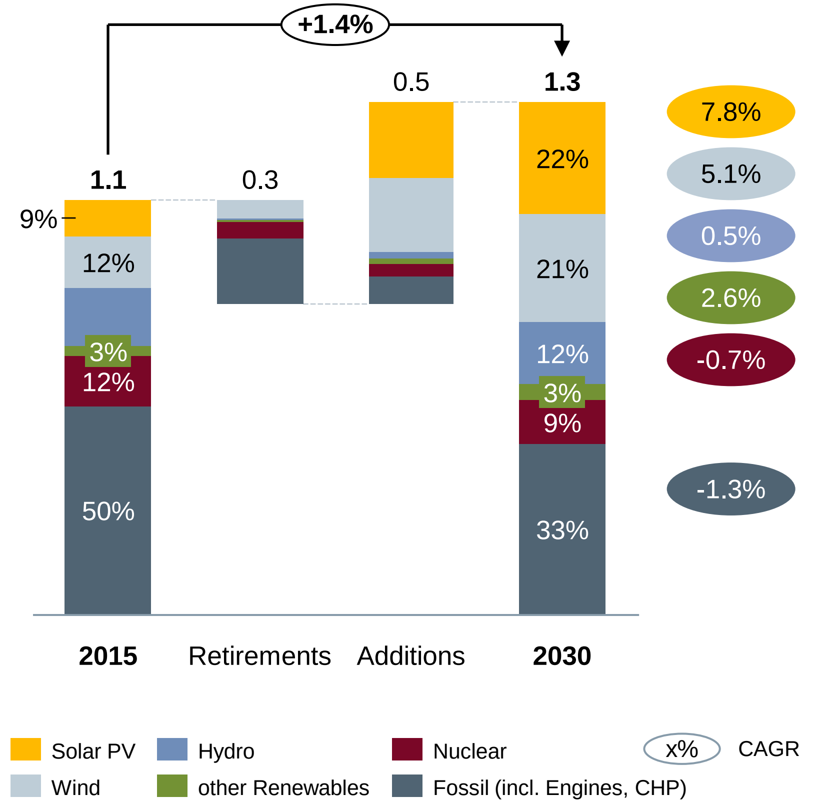
Changing generation mix

EU28 generation capacity until 2030 (TW)



Source: Siemens

Impact on Grid business

- Connections for renewables
- Grid extensions required
- Stability challenges
- Power quality and security
- Automated operation and situational awareness
- New business models, solutions and customers

- New and growing players in the energy market, e.g. Google NEST, Viessmann

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- Regulatory uncertainty and public acceptance
- Disruptive potential from cheap storage

Content

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Increasing role of Power Electronics and Digitalization in all voltage levels master the energy transition

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1 Changing generation mix

- Interconnectors
- Network Control Systems
- Synthetic Inertia

2 Generation capacity additions

- Transmission Grid Capacity additions
- Intelligent Distribution Grid
- Smart Substation

3 Distance from source to load

- High Voltage DC Systems (HVDC)
- Flexible AC Transmission Systems (FACTS)
- Supergrids

4 Decentralization (public / private)

- Active Network Mgmt., Microgrids, Nanogrids
- Distributed Energy Systems (DES)
- Energy Storage, Electrolyzers, Power-to-X

5 Refurbishment / upgrades

- Equipment with higher voltage ratings
- Cyber Security Solutions
- Resilience

Future challenges for utilities and solution implications

Challenges	Solution	Portfolio
Variable power generation Capacity constraints Frequency and voltage stability challenges Shorter market time intervals	Situational awareness and forecasting	▪ Phasor Measurement Unit ▪ Advanced Control Center
	Fast reacting grid control, adaptive assets	▪ Dynamic Grid Control Center ▪ Digital substation ▪ Adaptive protection
	More interconnector capacity and grid stabilization	▪ HVDC, FACTS ▪ Controllable Transformer ▪ Energy storage
	Market integration of TSO, DSO, generators and retailers	▪ Virtual Power Plant ▪ Dynamic Load Management ▪ Central Information Hub

Future challenges for utilities and Siemens portfolio implications

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Challenges	Solution	Portfolio
Variable power generation Capacity constraints Frequency and voltage stability challenges Shorter market time intervals	**Situational awareness and forecasting**	▪ **Phasor Measurement Unit** ▪ **Advanced Control Center**
	Fast reacting grid control, adaptive assets	▪ **Dynamic Grid Control Center** ▪ **Digital substation** ▪ **Adaptive protection**
	More interconnector capacity and grid stabilization	▪ **HVDC, FACTS** ▪ **Controllable Transformer** ▪ **Energy storage**
	Market integration of TSO, DSO, generators and retailers	▪ **Virtual Power Plant** ▪ **Dynamic Load Management** ▪ **Central Information Hub**

Ensuring stability and security of the system: Advanced control center for PJM Interconnection


PJM ©2012

Control centers

- Large scale energy management system
- Real time market pricing
- Dual-primary control center
- Capability to run the grid independently or as a single virtual control center

Benefits

- Increased security and reliability of the grid
- Practically uninterrupted power supply and grid control

Spectrum Power Active Network Management
Releasing hidden capacity by Active Network Management

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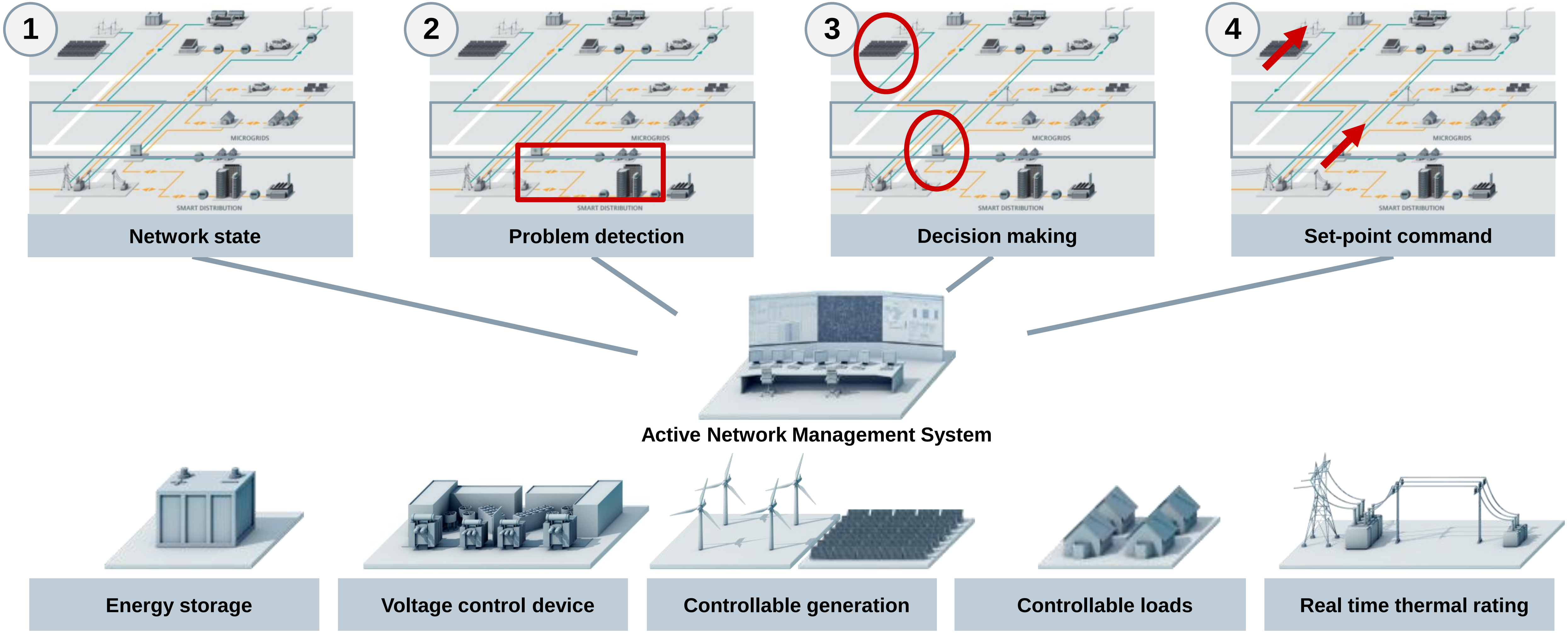

Future challenges for utilities and Siemens portfolio implications

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Challenges	Solution	Portfolio
Variable power generation	Situational awareness and forecasting	▪ Phasor Measurement Unit ▪ Advanced Control Center
Capacity constraints	Fast reacting grid control, adaptive assets	▪ Dynamic Grid Control Center ▪ Digital substation ▪ Adaptive protection
Frequency and voltage stability challenges	More interconnector capacity and grid stabilization	▪ HVDC, FACTS ▪ Controllable Transformer ▪ Energy storage
Shorter market time intervals	Market integration of TSO, DSO, generators and retailers	▪ Virtual Power Plant ▪ Dynamic Load Management ▪ Central Information Hub

Research project
Dynamic Grid Control Center

Gefördert durch:

Bundesministerium für Wirtschaft und Energie

aufgrund eines Beschlusses des Deutschen Bundestages

Otto von Guericke Universität Magdeburg

Technische Universität Ilmenau

Fraunhofer

Ruhr Universität Bochum RUB

TenneT

50hertz

TransnetBW

amprion

Challenge:

- Changing system dynamics
- More power electronics within the grid, less rotating mass

Target:

- Autopilot and Master Power Control operation
- Controllable grid dynamics
- Self healing capabilities

Partnering:

- 3 universities
- 4 TSOs
- 2 scientific institutes

Future challenges for utilities and Siemens portfolio implications

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Challenges	Solution	Portfolio
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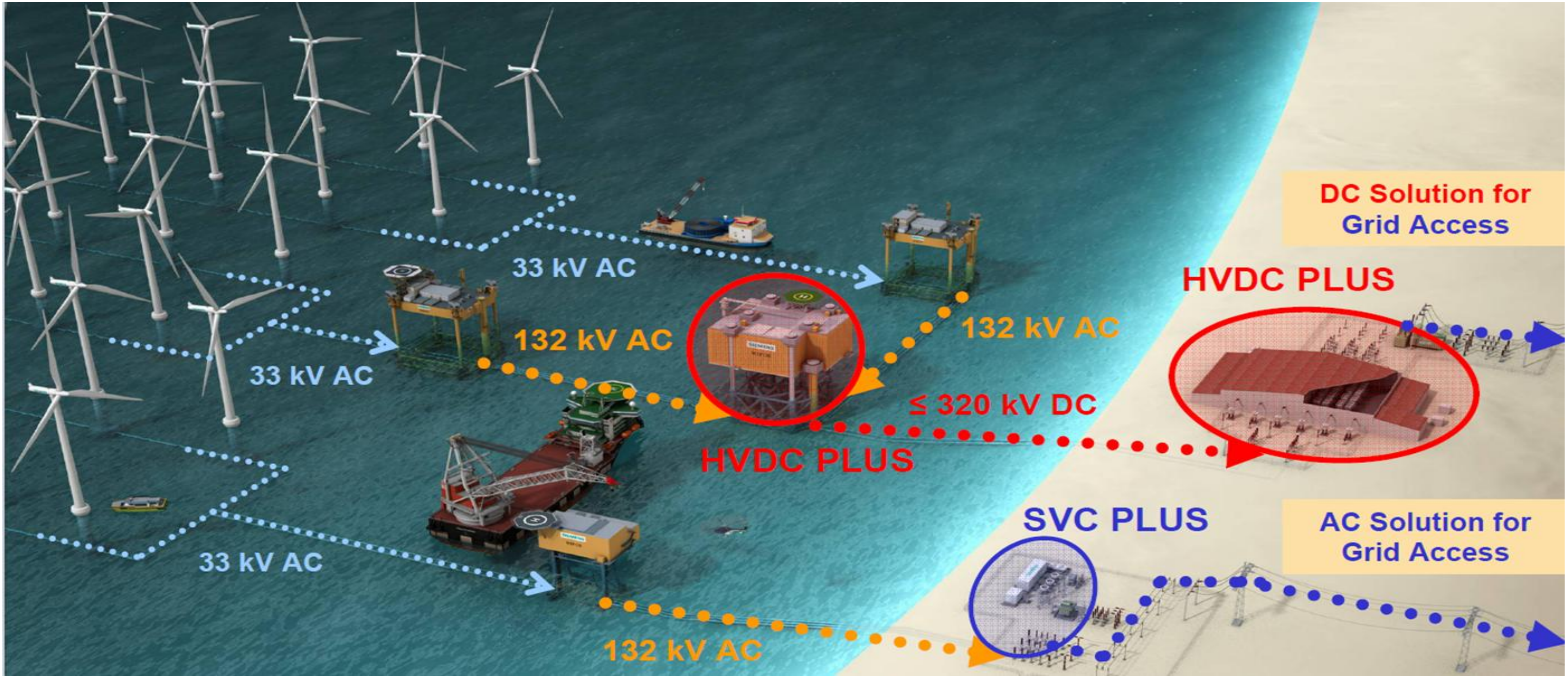
Wind offshore and the grid connection – Strong need for innovations



Offshore wind power connection:
Example BorWin2 in the North Sea to supply 800.000 German households

Integrate 800 MW from 100 km offshore distance with highest efficiency

Offshore wind power connection:
Example BorWin2 in the North Sea to supply 800.000 German households

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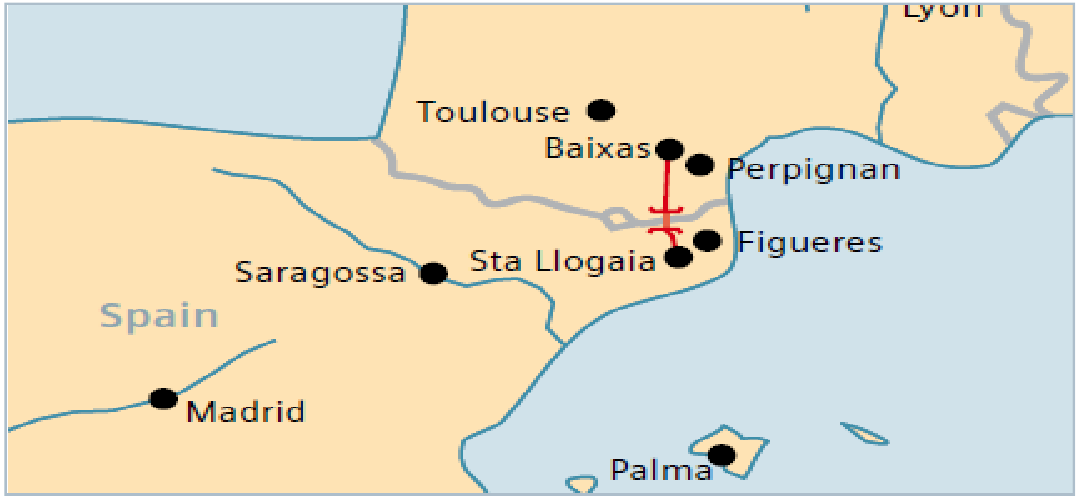
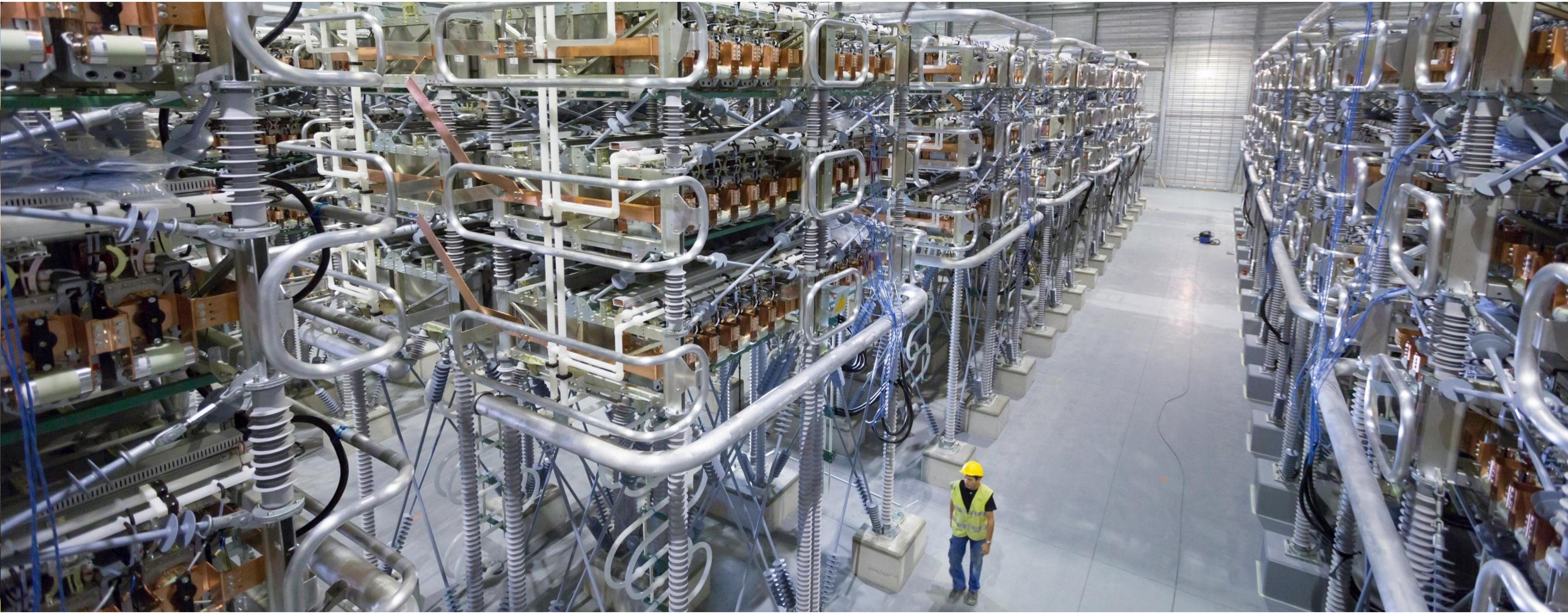
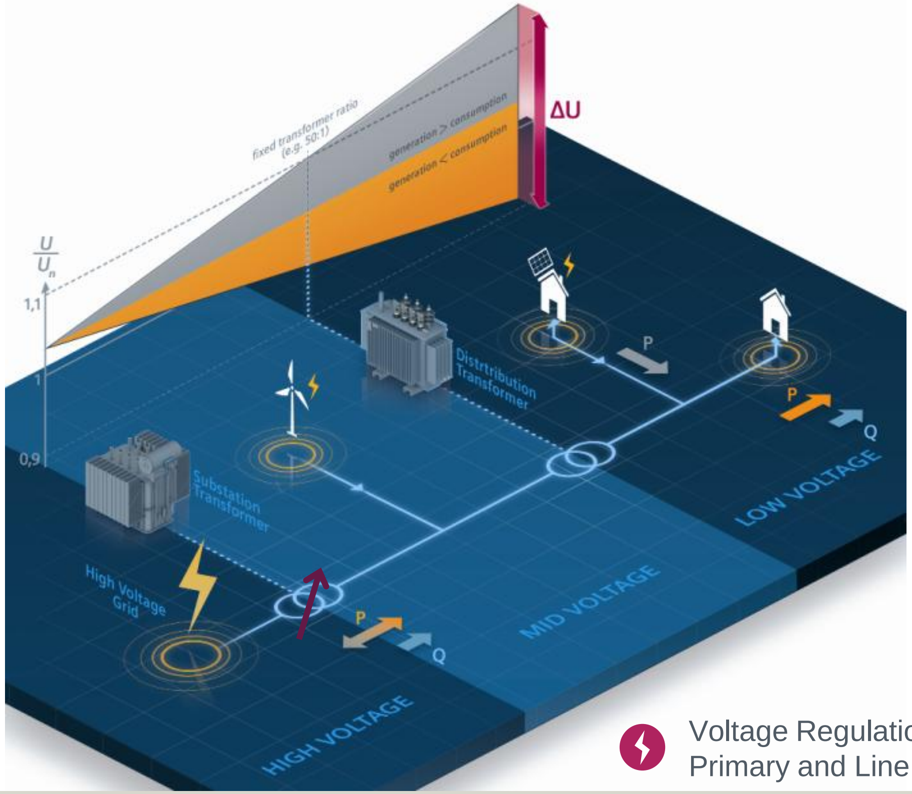
Customer	**INELFE (Rte and REE)**
Project Name	**INELFE**
Location	**Baixas, France to Santa Llogaia, Spain**
Power Rating	**2 x 1000 MW**
Type of Plant	**HVDC PLUS 65 km underground cable**
Voltage Levels	**± 320 kV DC**
	400 kV AC, 50 Hz
Semiconductors	**IGBT**



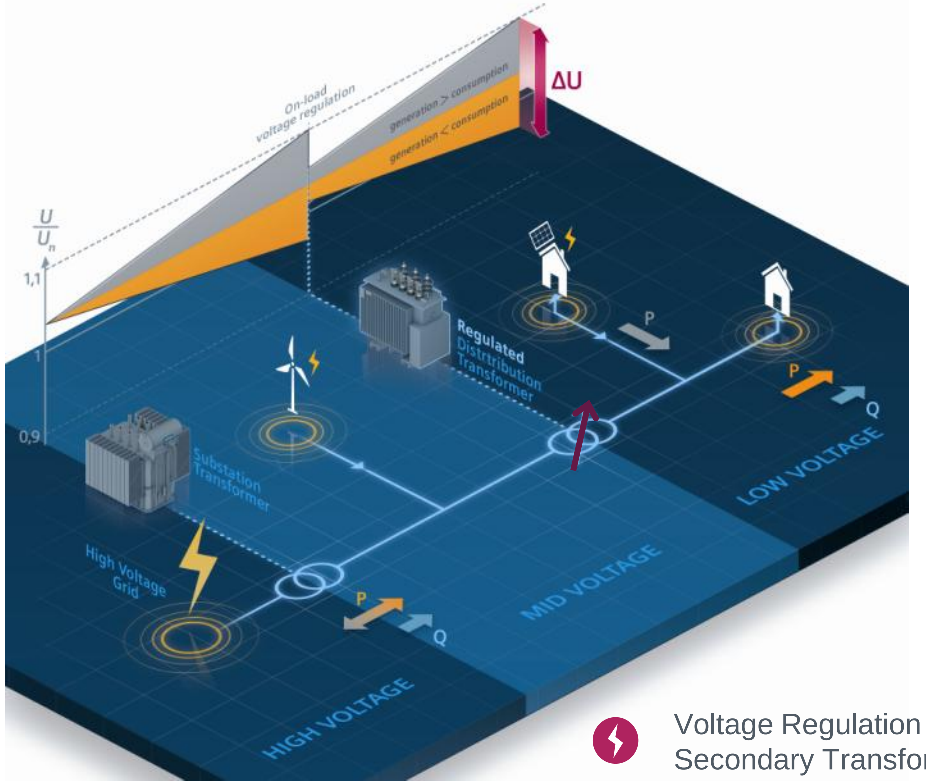
The innovation: Converter using intelligent control software



Area Voltage Control for Voltage Stability
Effects of the different Voltage Control Strategies



Voltage Regulation on MV
Primary and Line Volt. Transformer



Voltage Regulation on LV
Secondary Transformer

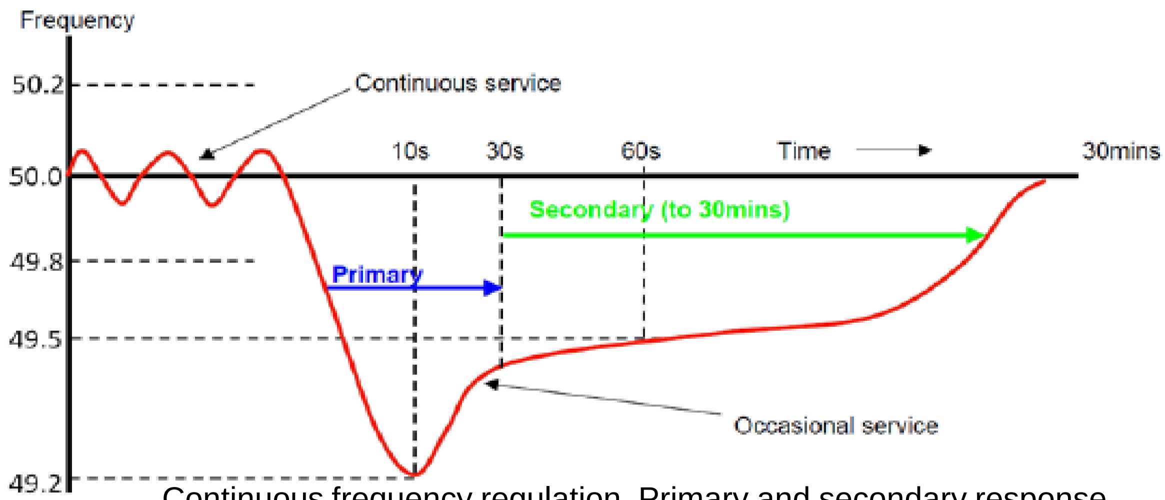
Voltage Control in low voltage grids: “FITformer REG”

Low-voltage load regulation range in three steps

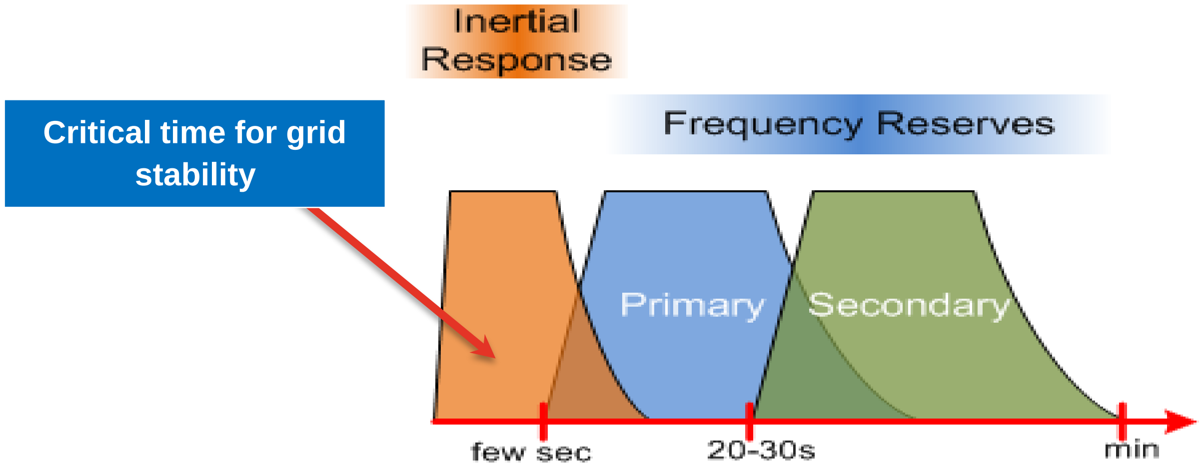
- With well-proven electromechanical switching devices
- Switching under load

Frequency stability

- Frequency behaviour defined based on operational and statutory limits
- Power plants with synchronous generators participate in frequency control
- Two types of mandatory frequency response services
  - Primary (tens of seconds)
  - Secondary (up to minutes)

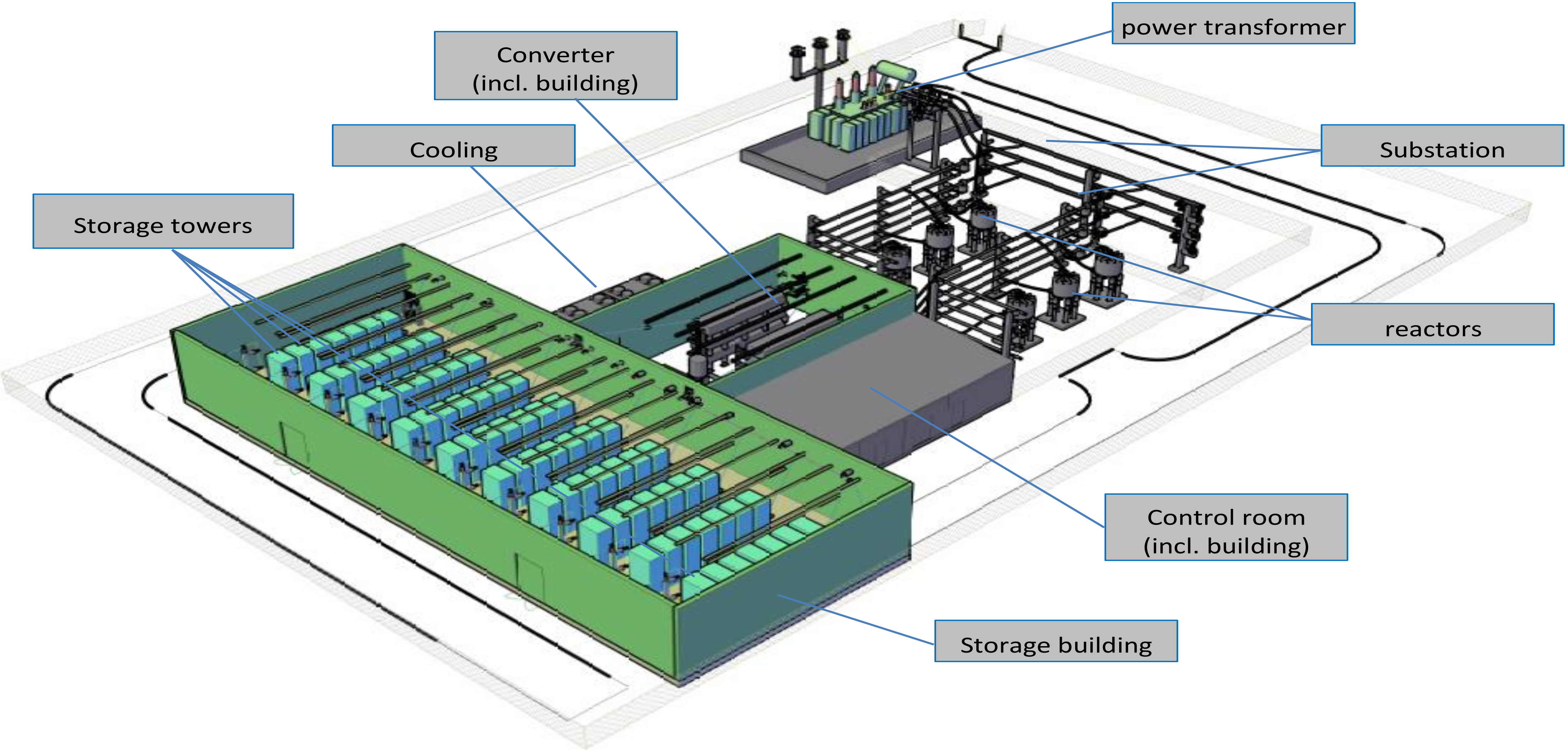


Continuous frequency regulation, Primary and secondary response



Source: Based on GB frequency control

SVC PLUS Frequency Stabilizer
Layout of entire 50 MVA station



Energy storage facilitates the integration of infrastructures and energy carriers

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Application cases by location of storage

Central Large Utilities	**De-central** Small utilities, municipalities, industry – prosumer

Pumped storage

Electricity

Grid balancing and stability

H2 / Chemicals

Electricity

H_2/ Methane (gas grid)

H_2 Fuel for car

Power-to-gas
Power-to-chemicals

Battery

Electricity

Grid stability, self-supply, electro-mobility

Thermal

Heat

Power-to-heat

SIESTORAGE References
here: Network Stabilization and Blackstart applications

SIESTORAGE installation as standard container at the grid of ENEL, Italy

for network stabilization with infeed of power from decentralized, renewable sources

Commissioning in 2012

1MVA/500 kWh

SIESTORAGE installation in existing modernized substation of VEO* Eisenhüttenstadt, Germany

for black start in the steel and rolling mill of Arcelor Mittal GmbH (AMEH)

Commissioned in 2014

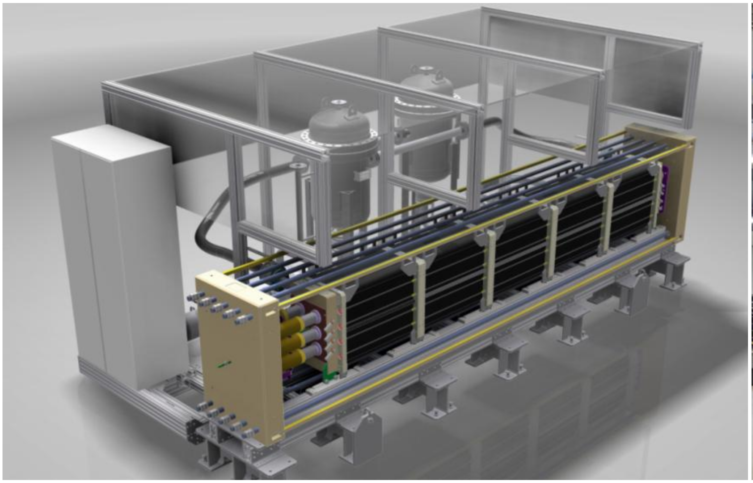
2,8 MVA /720 kWh

One-stop-shop:

- **From planning and installation through to commissioning and services**
- **Possibility of integration into prefabricated standard container or existing building**

* (Vulkan Energiewirtschaft Oderbrücke GmbH)

Energiepark Mainz – Project scope and key facts



- Location: Mainz-Hechtsheim (DE)
- 3 high performance electrolysis systems, peak power of 2 MW el. each (6 MW peak)
- Highly dynamic operation over broad load range (ramp speed 10% per sec.)
- First Electrolyzer delivered mid of march
- Plant commissioning scheduled July 2015

STADTWERKE MAINZ AG · Hochschule RheinMain · Linde · SIEMENS · Gefördert durch Bundesministerium für Wirtschaft und Energie aufgrund eines Beschlusses des Deutschen Bundestages · ENERGIESPEICHER Forschungsinitiative der Bundesregierung

Future challenges for utilities and Siemens portfolio implications

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Virtual Power Plants: RWE, Stadtwerke München and Mark-E

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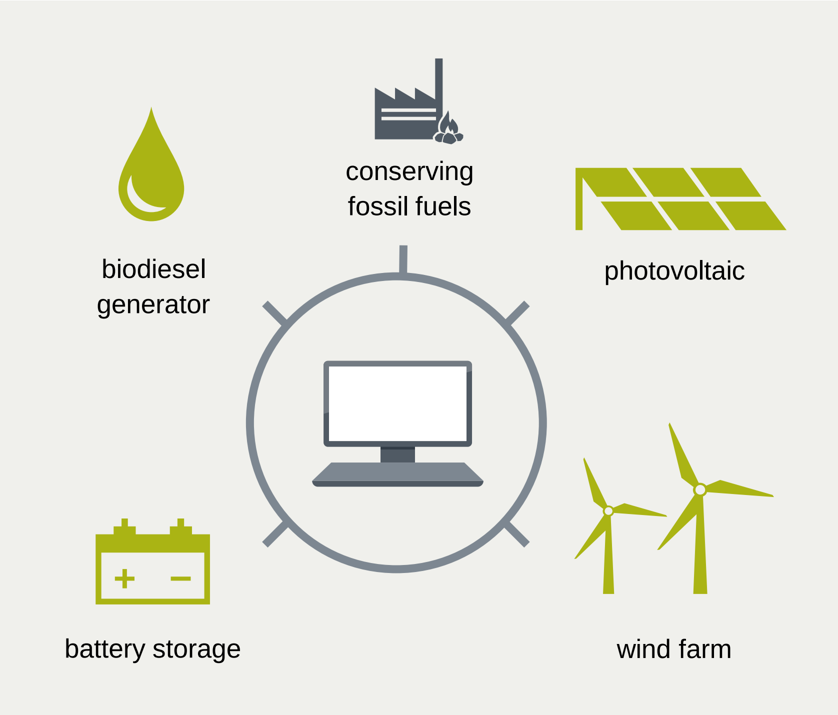
Integration of distributed generation and load flexibility into power markets

Revenue improvement for distributed renewable generation

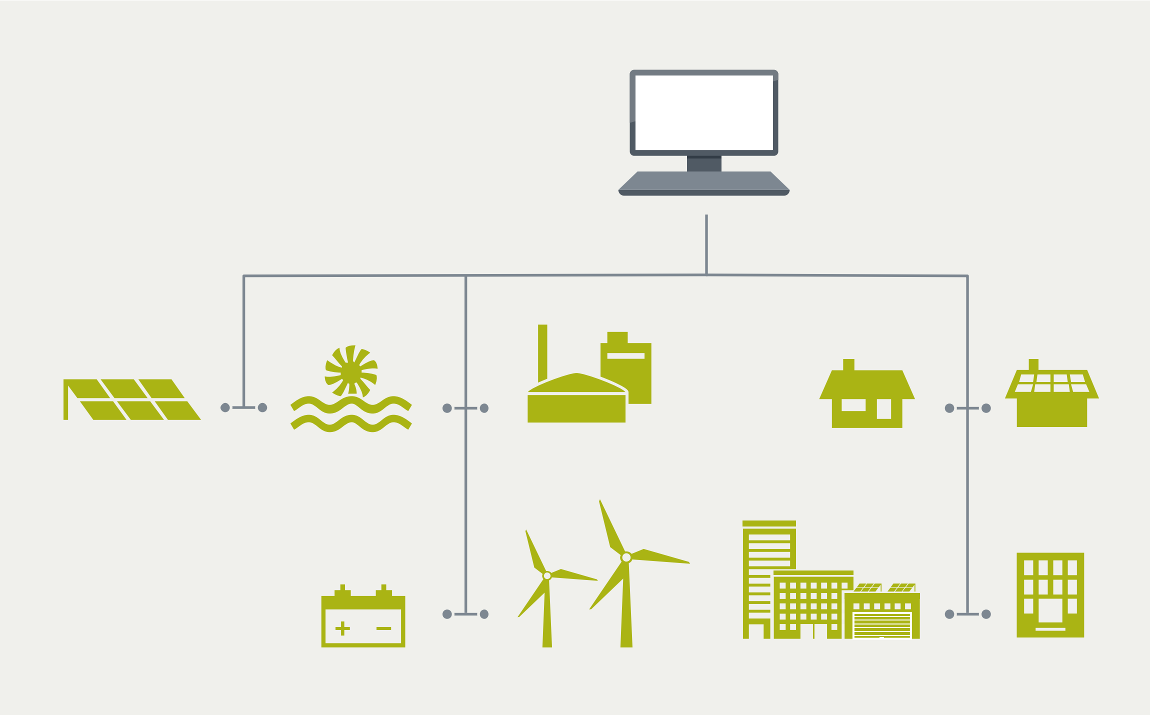
Improved cost efficiency of mixed generation fleet

Renewables can deliver a solid distributed supply and topological power.

Hybrid power plants expand conventional power plants by integrating renewables – and thus conserving fossil fuels.



Microgrid control systems manage distributed consumers and energy producers – and efficiently improve grid stability



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Microgrid
IREN2 research project in Wildpoldsried, Germany

AÜW

AllgäuNetz
Der Leitungsverbund

RWTH AACHEN UNIVERSITY

IDKOM

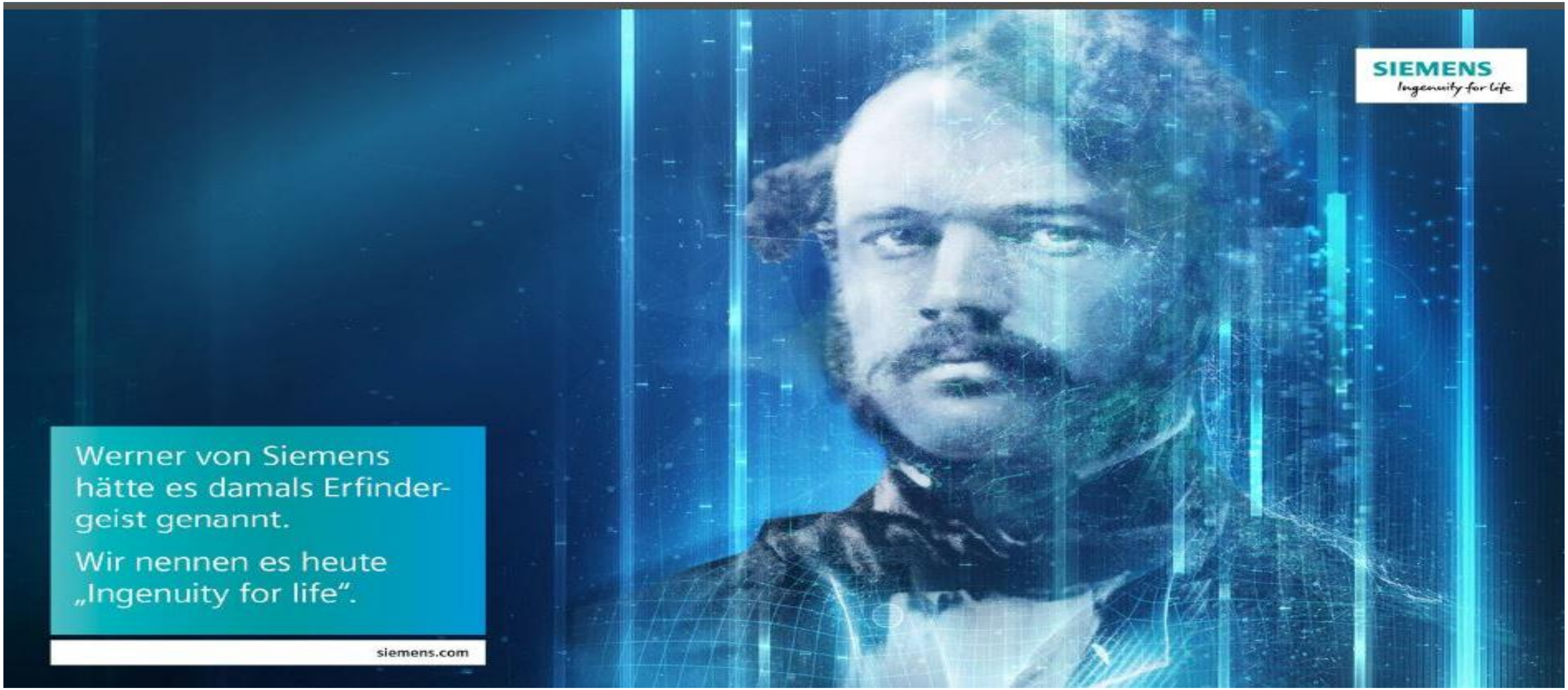
Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

Challenge:
Optimize regional use of local renewable generation

Solution:
Combining micro grid and VPP to form a topological power plant, which can be operated in island mode

Benefits:
- Stable and economically optimized grid operation
- Black start capability
- Profitable use of renewable resources independently of the supply grid
- Ancillary services from the distribution grid

Siemens – Ingenuity for Life



Thank you!

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