Die Digitalisierung des Energiesystems

Niedersächsische Energietage, Hannover, 7. 11. 2017
Michael Weinhold, CTO Siemens Energy Management

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Agenda

1	Trends
2	Energiespeicher und Sektorkopplung
3	Innovationsfelder der Digitalisierung
4	Ausblick

The Energy Revolution: Big Picture

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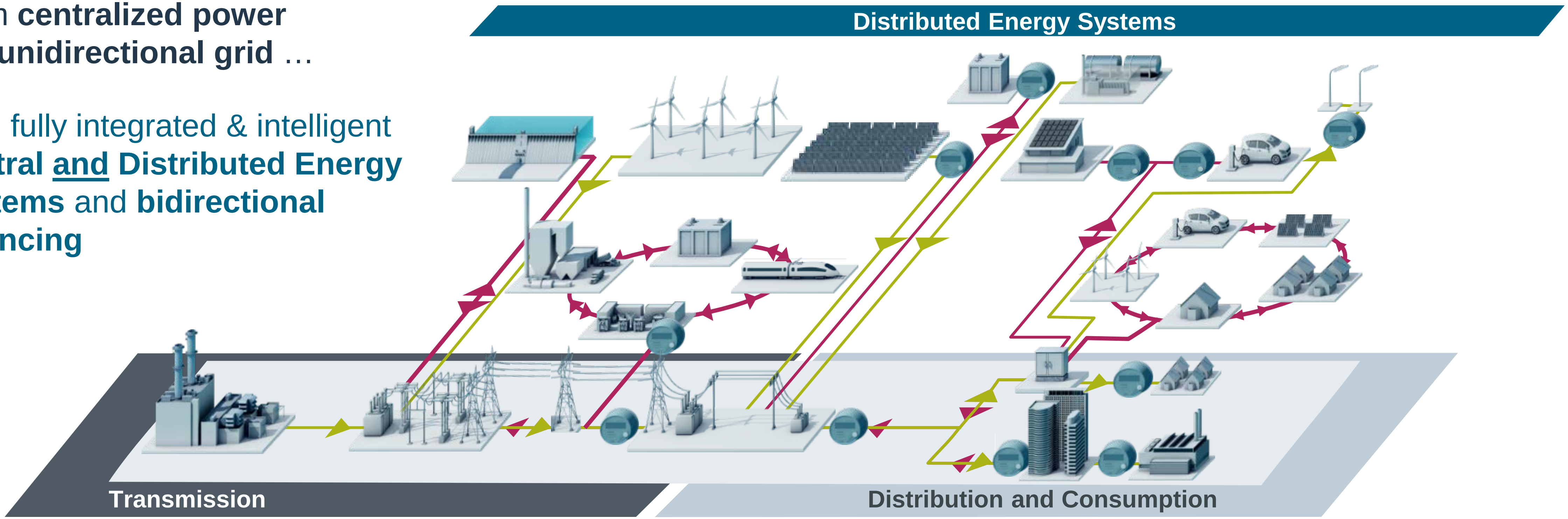
From **centralized power and unidirectional grid** …

… to fully integrated & intelligent **Central and Distributed Energy Systems** and **bidirectional balancing**



1 Changing generation mix	**2** Generation capacity additions	**3** Distance from source to load	**4** Decentralization (public/private)	**5** Refurbishment/ upgrades

Storyline of the global Energy Transitions: Electricity is key to reach sustainable Energy Systems!

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Political Targets:
1. De-carbonization
2. Sustainability
3. Energy Efficiency
4. Resiliency

+

Breakthrough Technologies (Performance & Cost):
1. Wind- and PV Power Gen.
2. Energy Storage (Li-Ion)
3. Digitalization

1. Large-scale Renewable integration into the electricity system (Wind, PV, Hydro)
2. Distributed Energy Systems to maximize:
   1. Energy System efficiency
   2. Local Renewable integration
   3. Resiliency
3. Electrification of Consumption e. g. Heat Pump, E-Car

Changing System Operation (“Physics & Acceptance”)

Consumer-centric Energy World („Physics & Psychology“)

Global on-shore wind potential

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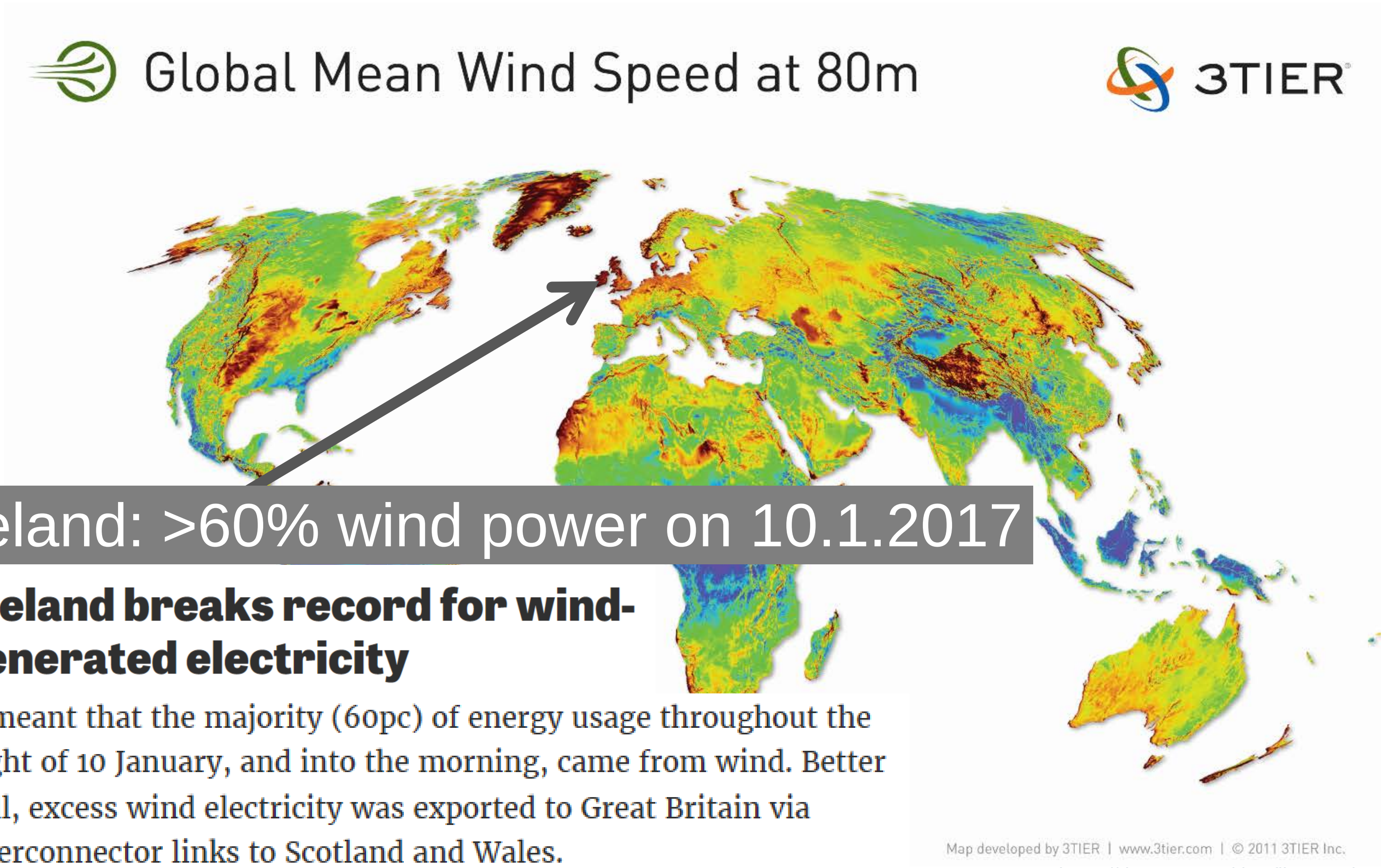

Ireland: >60% wind power on 10.1.2017

Ireland breaks record for wind-generated electricity

It meant that the majority (60pc) of energy usage throughout the night of 10 January, and into the morning, came from wind. Better still, excess wind electricity was exported to Great Britain via interconnector links to Scotland and Wales.

https://dupontconsulting.files.wordpress.com/2012/01/3tier_5km_global_wind_speed.jpg
https://www.siliconrepublic.com/innovation/irish-wind-energy-record

Global solar energy yield

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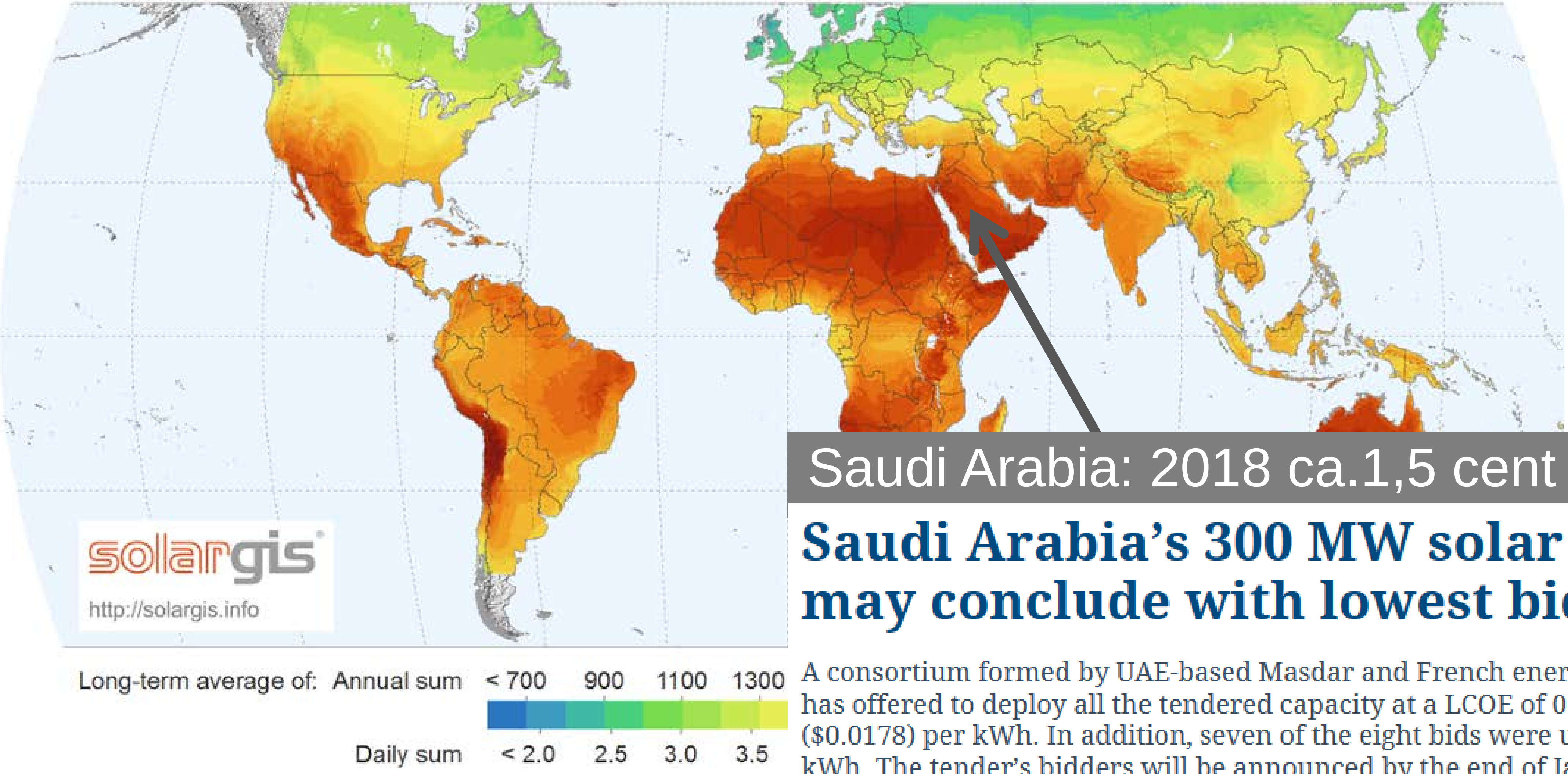


Saudi Arabia: 2018 ca.1,5 cent €/kWh

Saudi Arabia's 300 MW solar tender may conclude with lowest bid ever

A consortium formed by UAE-based Masdar and French energy giant EDF has offered to deploy all the tendered capacity at a LCOE of 0.06697 SAR ($0.0178) per kWh. In addition, seven of the eight bids were under $0.03 per kWh. The tender's bidders will be announced by the end of January 2018.

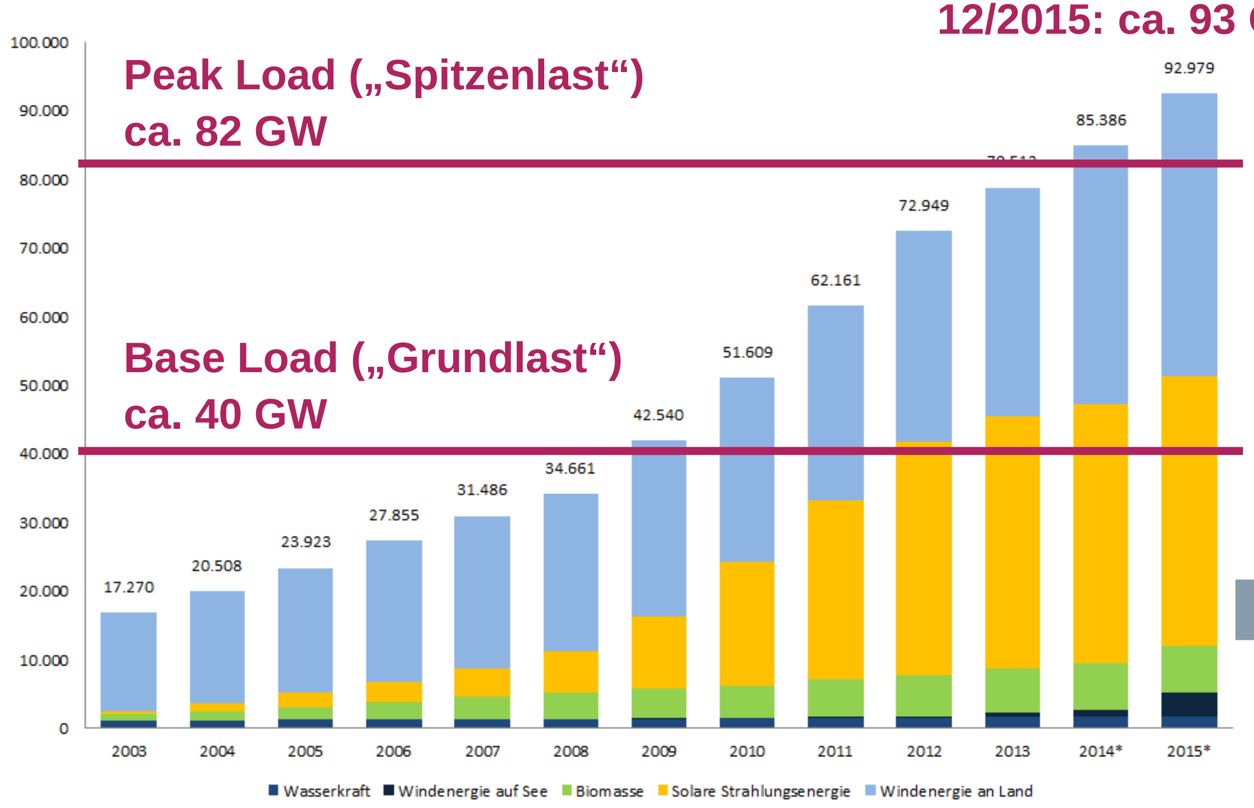
https://en.wikipedia.org/wiki/Photovoltaic_system#/media/File:SolarGIS-Solar-map-World-map-en.png
https://www.pv-magazine.com/2017/10/04/saudi-arabias-300-mw-solar-tender-may-conclude-with-lowest-bid-ever/

Germany: more renewable generation capacity than peak load

10/2017: ca. 109 GW

Entwicklung der installierten Leistung zur Stromerzeugung aus Erneuerbaren Energien 2003 - 2015
in MW

12/2015: ca. 93 GW



More installed Wind- and PV-capacity than Peak Load

>65GW of Wind and PV-Power Plants connected to LV- and MV-systems

Trend towards an „Electronic Grid“

Resulting Challenges for grid operators:

- Changing system dynamics
- Frequency and Voltage Stability
- Short Circuit Power
- …

Source: http://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/ErneuerbareEnergien/ZahlenDatenInformationen/zahlenunddaten-node.html

CHP “Fortuna” in Germany – new performance and efficiency world record

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Customer
Stadtwerke Düsseldorf
Location
Düsseldorf, Germany
Date
2016

~ 61.5% net efficiency

603,8 MWel electrical output

300 MWth maximum district heating capacity

Challenges

- Profitable operation despite high gas prices (vs. coal)
- High resource efficiency
- Fast start-up for balancing energy

Solution

- The highest efficiency combined heat and power station in Germany with core components from Siemens: SGT5-8000H gas turbine, SST5-5000 steam turbine, generator, I&C system, BENSON® HRSG

Customer benefits

- Electrical efficiency of around 61.5% and a record power generating capacity of 603.8 MW during test run
- Plant can supply around 300 MW of heat for district heating
- Handover to customer 19 days ahead of schedule

ULTRANET, Germany, 2021
World's first VSC HVDC with full-bridge converter

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Customer	Amprion / TransnetBW
Project Name	ULTRANET
Location	Osterath – Philippsburg, Germany
Power Rating	2000 MW, bipolar
Type of Plant	HVDC PLUS in full-bridge topology, 340 km
Voltage Levels	± 380 kV DC, 400 kV AC, 50 Hz
Semiconductors	IGBT

The innovation: Converter using Power Electronic Building Blocks and intelligent control software

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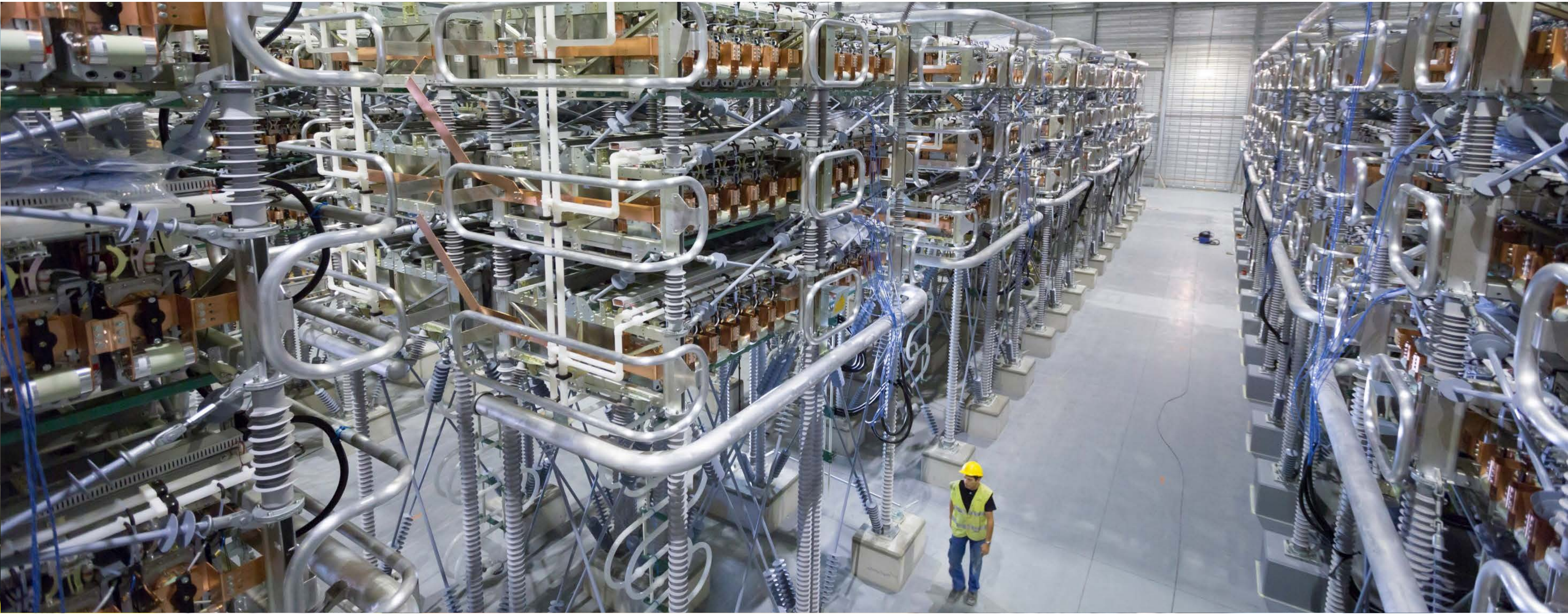

Digitalization drives dramatic change in energy systems

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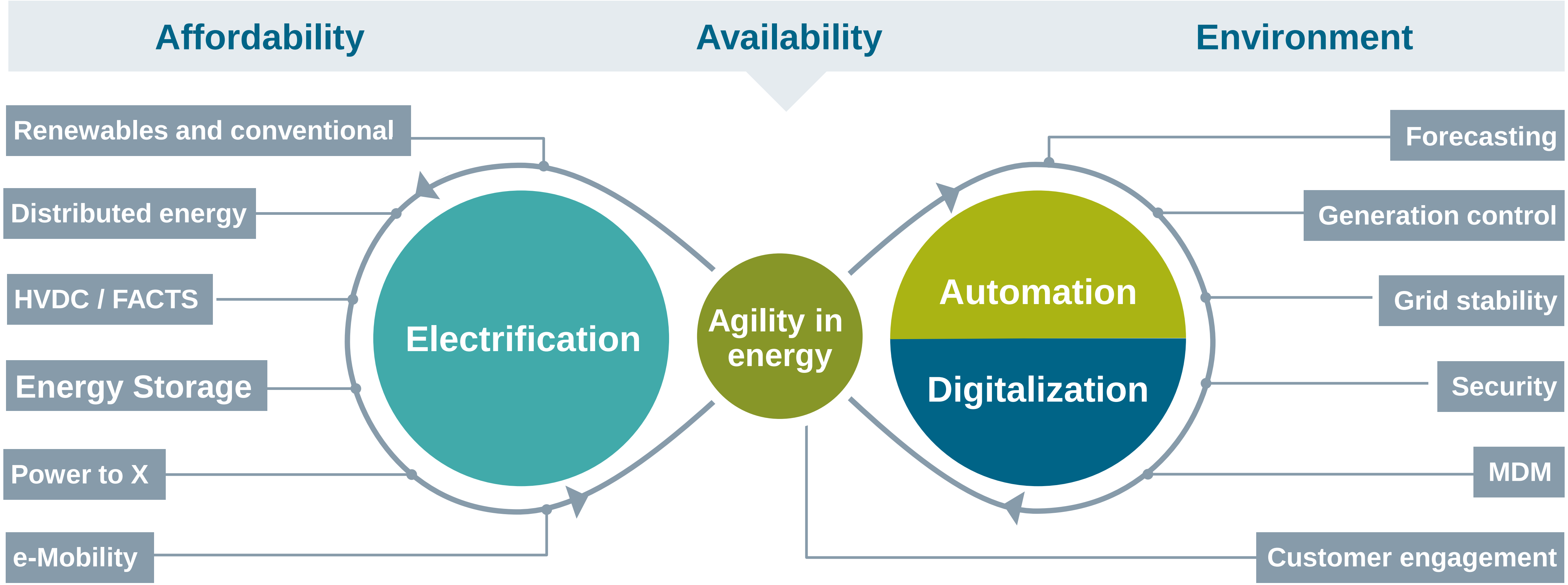

HVDC/FACTS = High Voltage Direct Current/Flexible AC Transmission Systems **MDM** = Meter Data Management

IoT Operating Systems to manage Infrastructures example Mindsphere

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Operating System of Infrastructures

Siemens Software and Digital Services

- EnergyIP
- Fault Detection
- Demand Management
- Leak Detection
- Energy Trading/ Blockchain
- eCar Charging
- Railigent
- Storage
- Car Sharing
- Intermodal Traffic Management
- Fleet Management
- Traffic Management
- Your App
- Your App

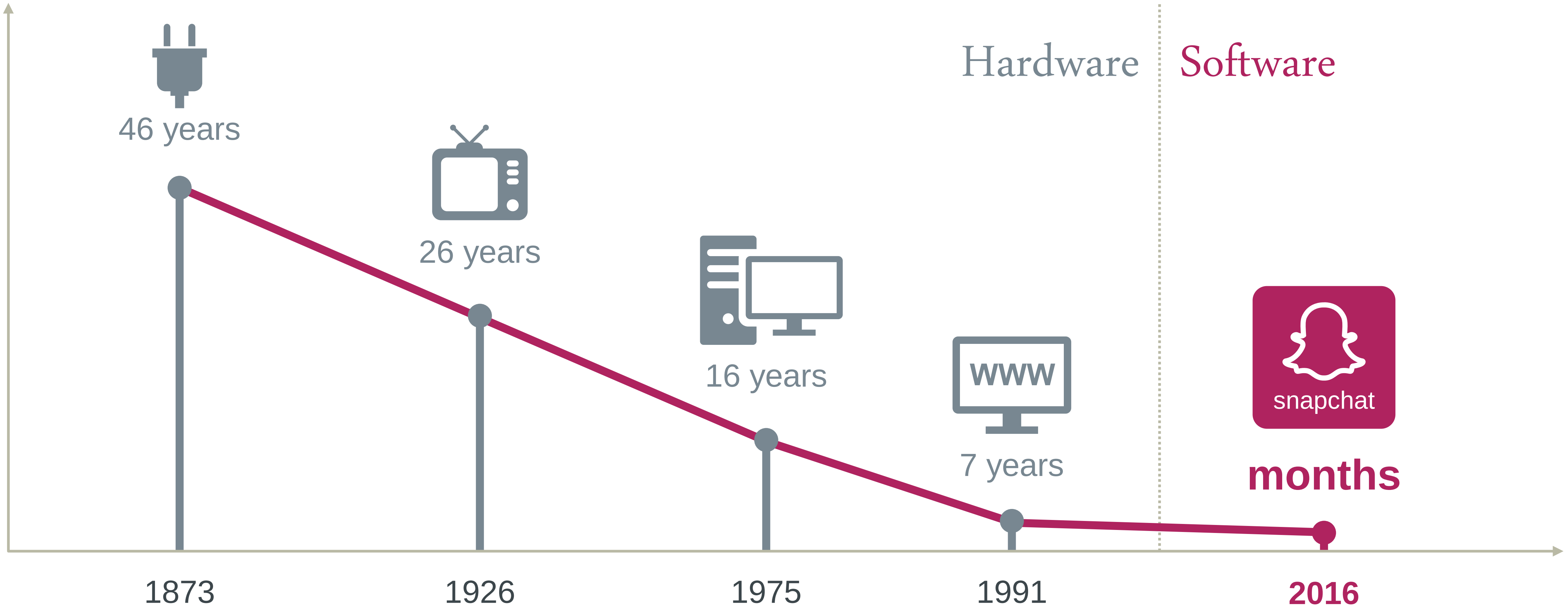
MindSphere – the cloud-based, open IoT operating system

Microgrid and transportation – electric devices

Holistic IT Security Concept

Technology adoption in the U.S.

Time until used by 1/4 of American population



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Increasing electrification in all sectors – Heading towards an "all-electric world"

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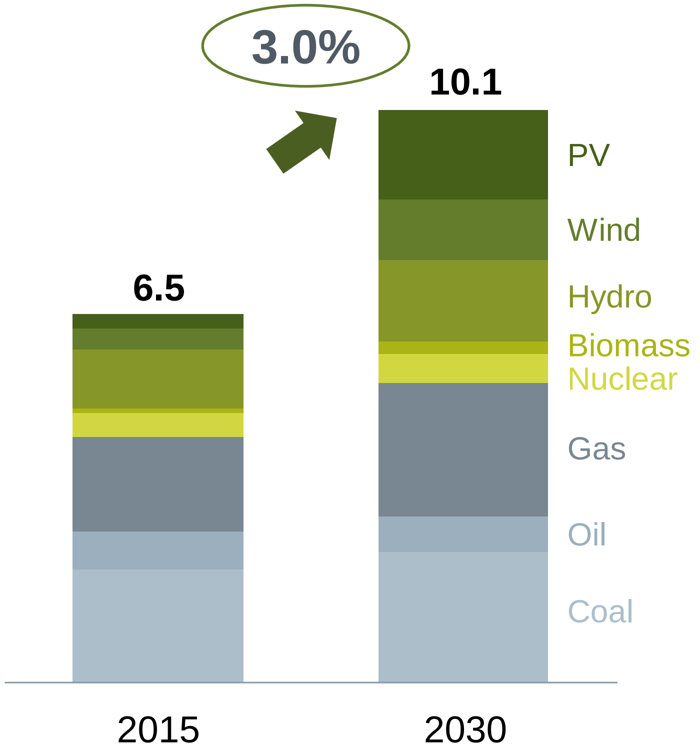
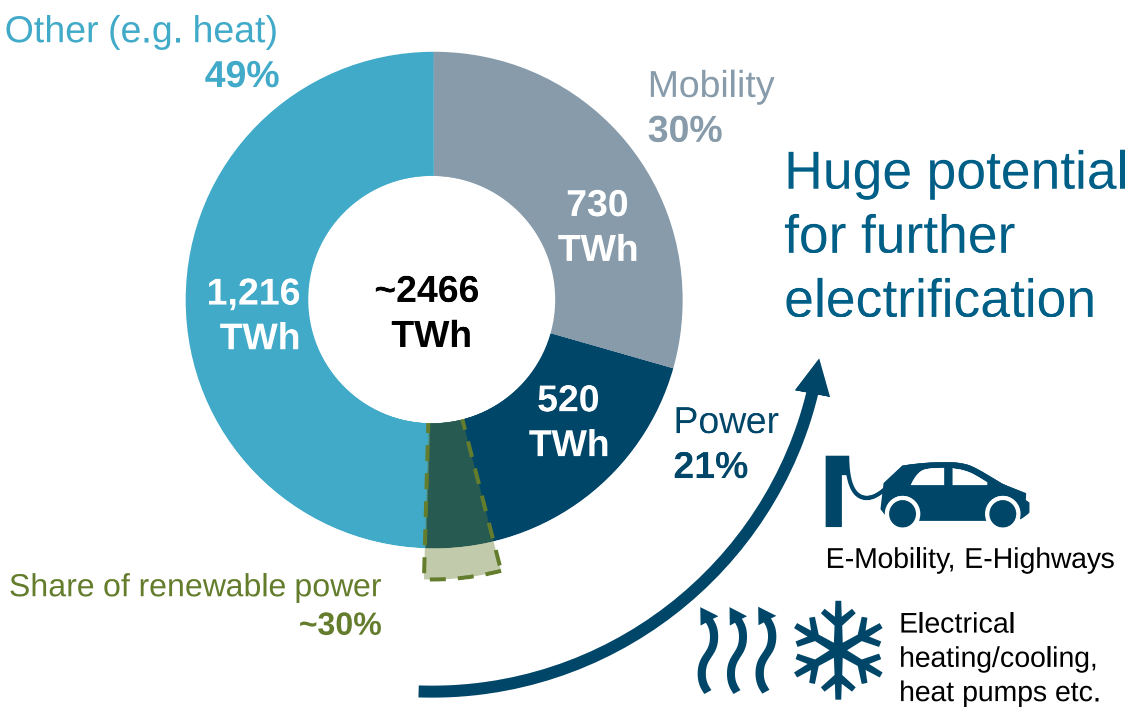
Global power generation capacity in TW



Renewables and distributed power generation grow above average

Final energy consumption in Germany 2015



Huge potential for further electrification

Source: Siemens Energy 2020 Project 2014 – Base Case Scenario ⬭ CAGR 15 – 30e

Source: umweltbundesamt.de/Arbeitsgemeinschaft Energiebilanzen, status 7/16; IHS

Energy storage applications and sector couplings

Application cases by location of storage

Central
Large Utilities

Distributed
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

Heating, Cooling

Power-to-heating and -cooling

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District Heating Storage
N-Ergie AG, Nürnberg

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Hight ca. 70m

Status May 9, 2014

1500 MWh

Thermal Capacity

in operation since 1/2015

Status Jan 6, 2015

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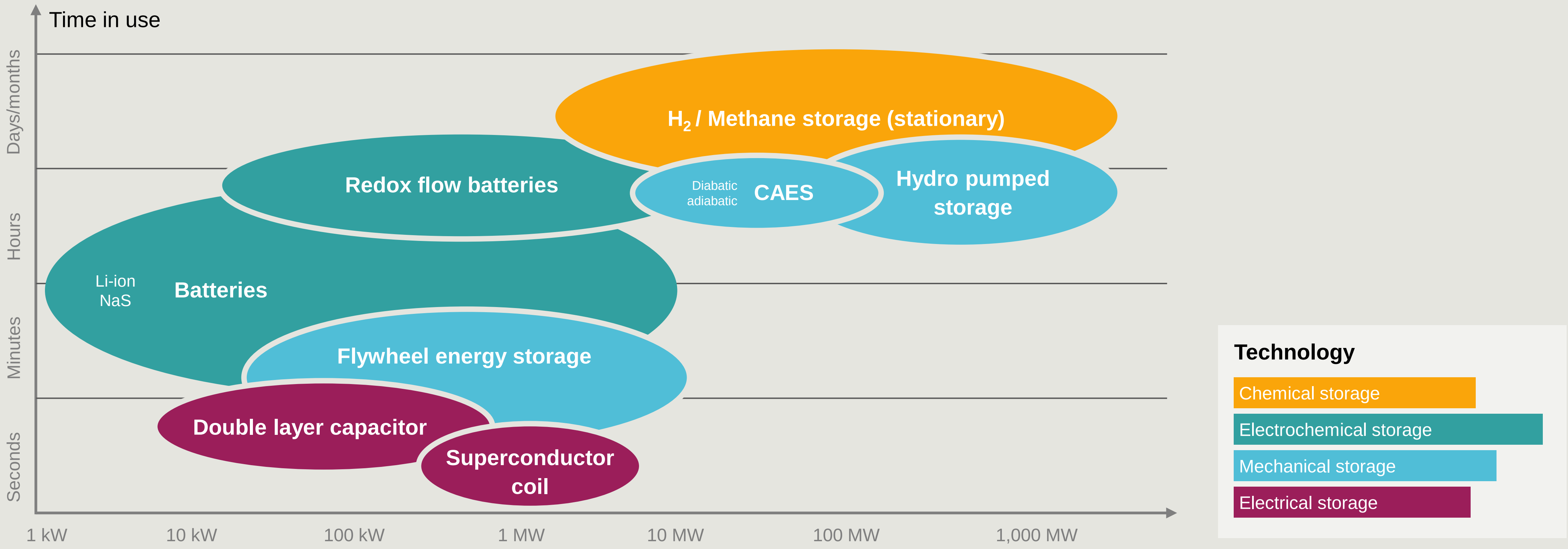
Power-to-power Energy Storage technologies



Source: Study by DNK/WEC “Energie für Deutschland 2011“, Bloomberg – Energy Storage technologies Q2 2011
CAES – Compressed Air Energy Storage

Winning Energy storage technologies (from todays perspective)

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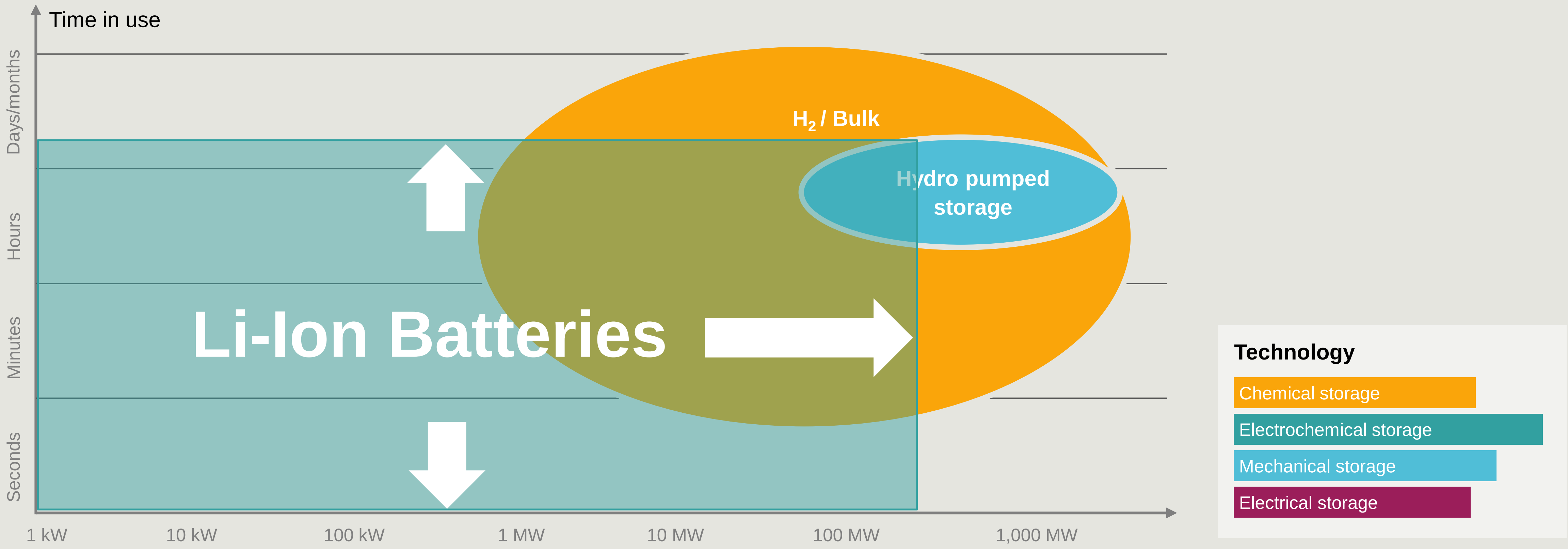

Source: Study by DNK/WEC "Energie für Deutschland 2011", Bloomberg – Energy Storage technologies Q2 2011
CAES – Compressed Air Energy Storage

Energy Storage for very different purposes

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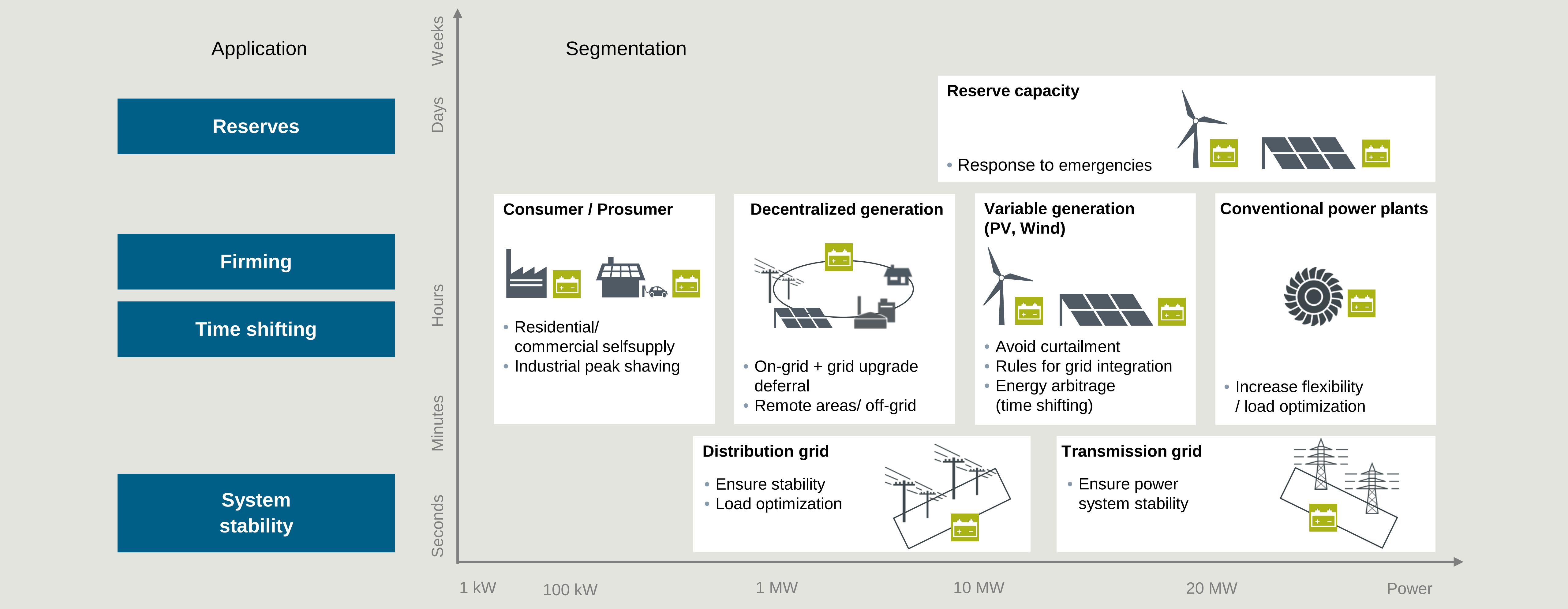

InovCity Évora, Portugal: Energy storage pilot project with EDP

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472 kW/
360 kWh
SIESTORAGE system
MicroGrid Controler

Main applications

Energy backup, voltage regulation, peak shaving, Islanding

Turnkey solution

Electrification of Mobility

Siemens key applications in the process of being "electrified"

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eBus: Sustainable public transportation

- DC charging post, off-board and on-board pantographs
- Flexible, fast-charging system mounted on mast or roof of a bus stop
- Implemented by the Hamburger Hochbahn AG

eFerry: CO_2-free shipping

- World's 1st all-electric car ferry developed with Fjellstrand shipyard (Norway)
- Powered by three battery packs
- 1st ferry (360 passen-gers, 120 vehicles) in operation since 2015

Taxibot: Innovative aircraft towing truck

- Pilot-controlled taxiing without aircraft engines running
- Major fuel savings, emission & noise reduction, foreign object damage
- Certification granted, three Taxibots operating in Frankfurt

eHighway: Electric road freight transport

- Hybrid trucks supplied with electricity from overhead contact lines at up to 90km/h
- Increased system efficiency and energy savings
- Cooperation with Scania, demonstration projects in Sweden and California

eAir: Hybrid electric airliner

- Fuel consumption ~51% of aircraft operating costs
- Electric propulsion: >25% fuel, emission and noise reduction
- Development of hybrid electric airliner in research cooperation with Airbus

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Power-to-heating and -cooling

Pump Storage Capacity of Germany (ca. 40 GWh max) and equivalent chemical energy (fuel) storage

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The 9 biggest Pumped Hydro Plants in Germany:

Goldistahl:
1060 MW, 8,5 GWh

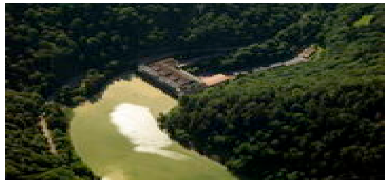
Markersbach:
1050 MW, 4 GWh

Wehr:
992 MW, 6 GWh

Waldeck II:
480 MW, 3,4 GWh

Säckingen:
370 MW, 2 GWh

Hohenwarte II:
320 MW, 2,1 GWh



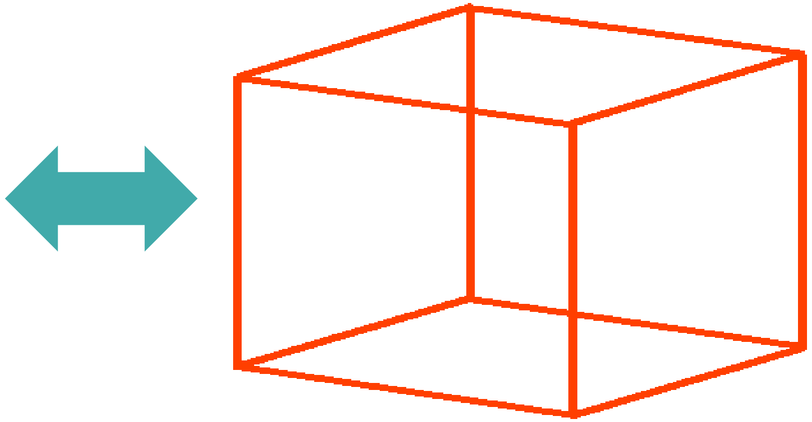
Witznau:
248 MW, 0,63 GWh

Erzhausen:
223 MW, 0,94 GWh

Waldshut:
176 MW, 0,4 GWh

Quelle: UBA- Datenbank, 2011

With respect to stored Energy equivalent cube of:



16 m: Diesel

166 m: (CH_4, 1 bar)

230 m: (H_2, 1 bar)

40 m: (H_2, 200 bar)

Pumped Hydro Storage Capacity of Germany compared to wind-energy in-feed in north-eastern Germany

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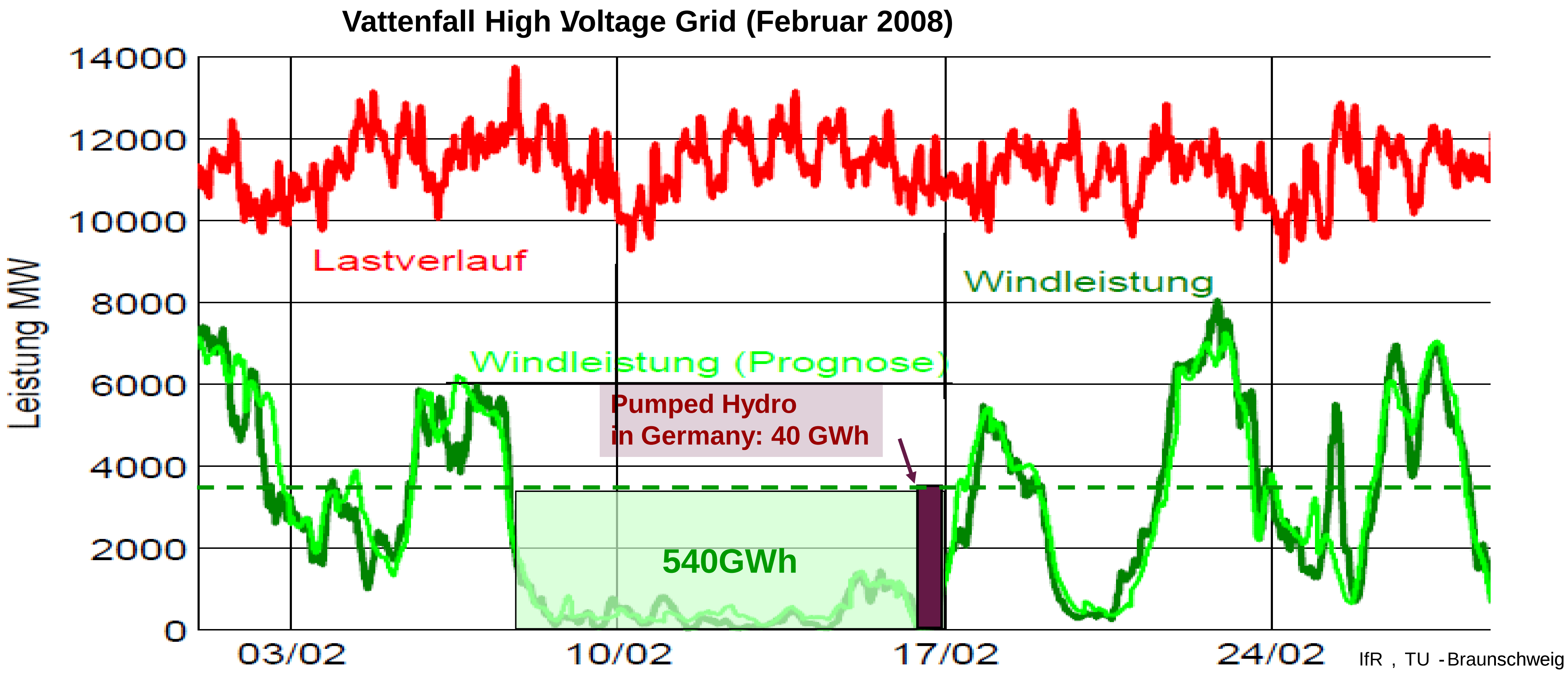

Quelle: VDE

Energy storage applications and sector couplings

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Power-to-heating and -cooling

Power-to-X: H_2O and CO_2 electrolysis form the basis for long-term bulk energy storage, mobility, and manifold chemical processes

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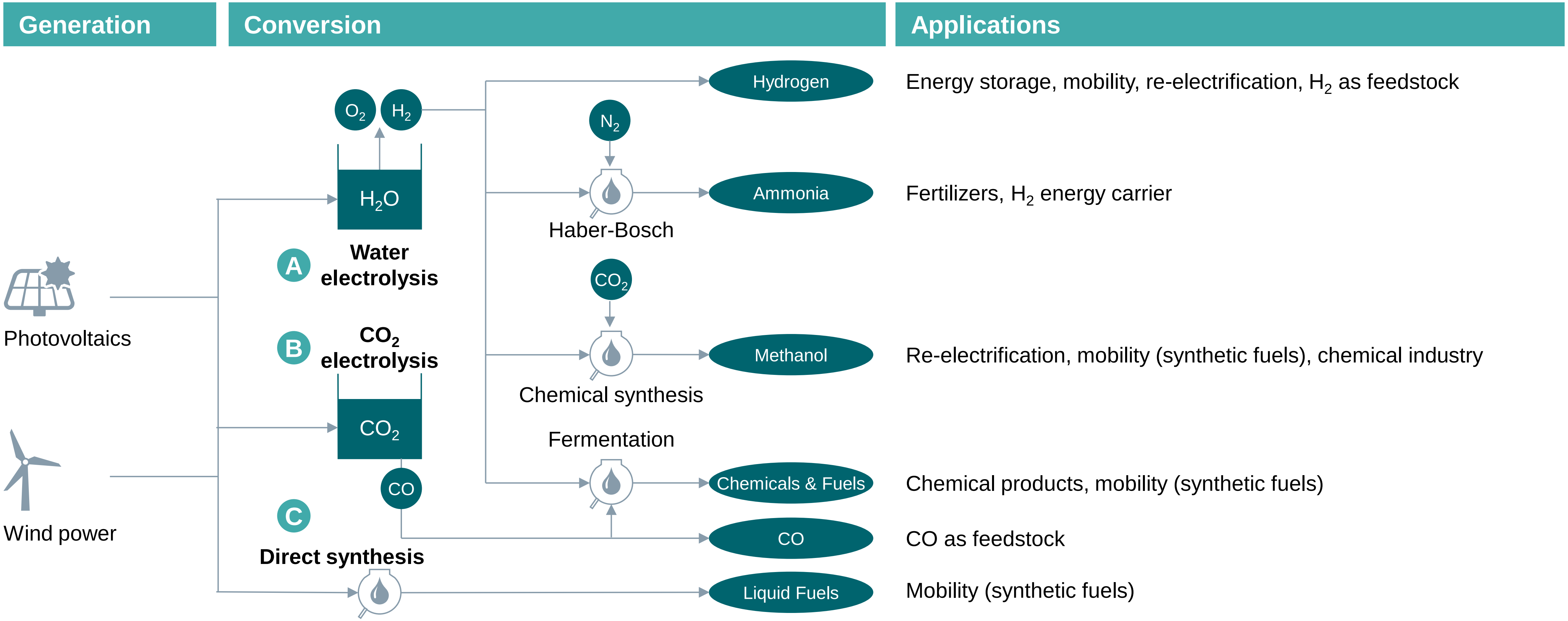
Power-to-X: A Water Electrolysis – B CO2 Electrolysis – C e-Fuels and Ammonia



Source: Siemens AG (simplified)

Energiepark Mainz
Hydrogen-Electrolysis hall

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Key facts

- Three SILYZER 200
- In total about 4 MW DC nominal load and DC 6 MW overload
- High dynamic:
  load changes within sec.
- 35 bar pressure at gas outlet
- Produced were so far up to 500 kg(H_2)/day
  -> Fuel for about 50.000 km in a fuel cell passenger car*

Assumption: Passenger Fuel cell car consumption about 1 kg/100km

Energiepark Mainz
Realization

Agenda

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Challenges

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Energy System Stakeholder challenges

- Complexity and Uncertainty (Technology, Regulation)
- System Dynamics (Stability)
- Vulnerability (Physical and Cyber Attacks)

Competitive advantage through:

- Adaptability, flexibility, speed
- Forecasting accuracy
- Decision Quality

Data Analytics turns data into knowledge

In a digital world, Cyber Security is essential and requires a holistic approach that is more than the sum of its features

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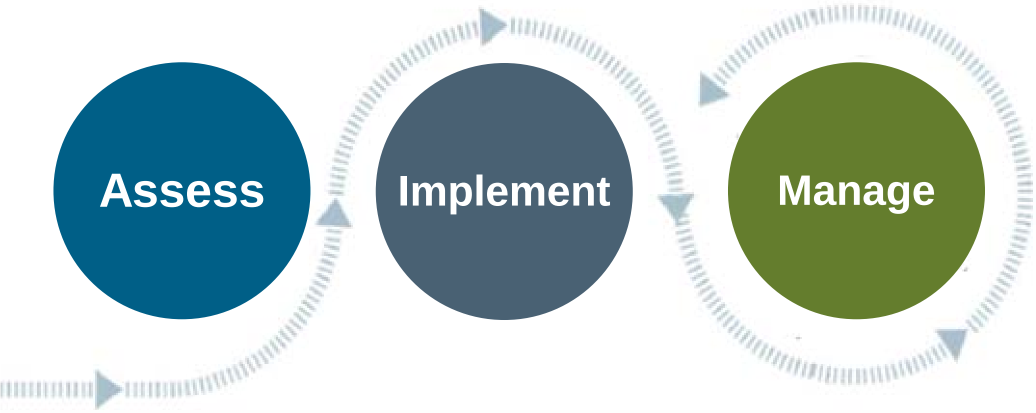
- Monitoring of components
- Threat Intelligence

- Vulnerability Handling
- Incident Handling
- Security Patch Management

- Security & Privacy by Design
- Secure Processes

- Proven protection concepts based on international standards
- Certified processes:
  - ISO/IEC 27001,
  - IEC 62443-2-4

- Support of operational security:
  - Access control
  - Security log and event management



Siemens as a trusted partner helps customer to secure the grid

EE-ISAC: Founding member and board member European Energy – Information Sharing and Analysis Center (www.ee-isac.eu)

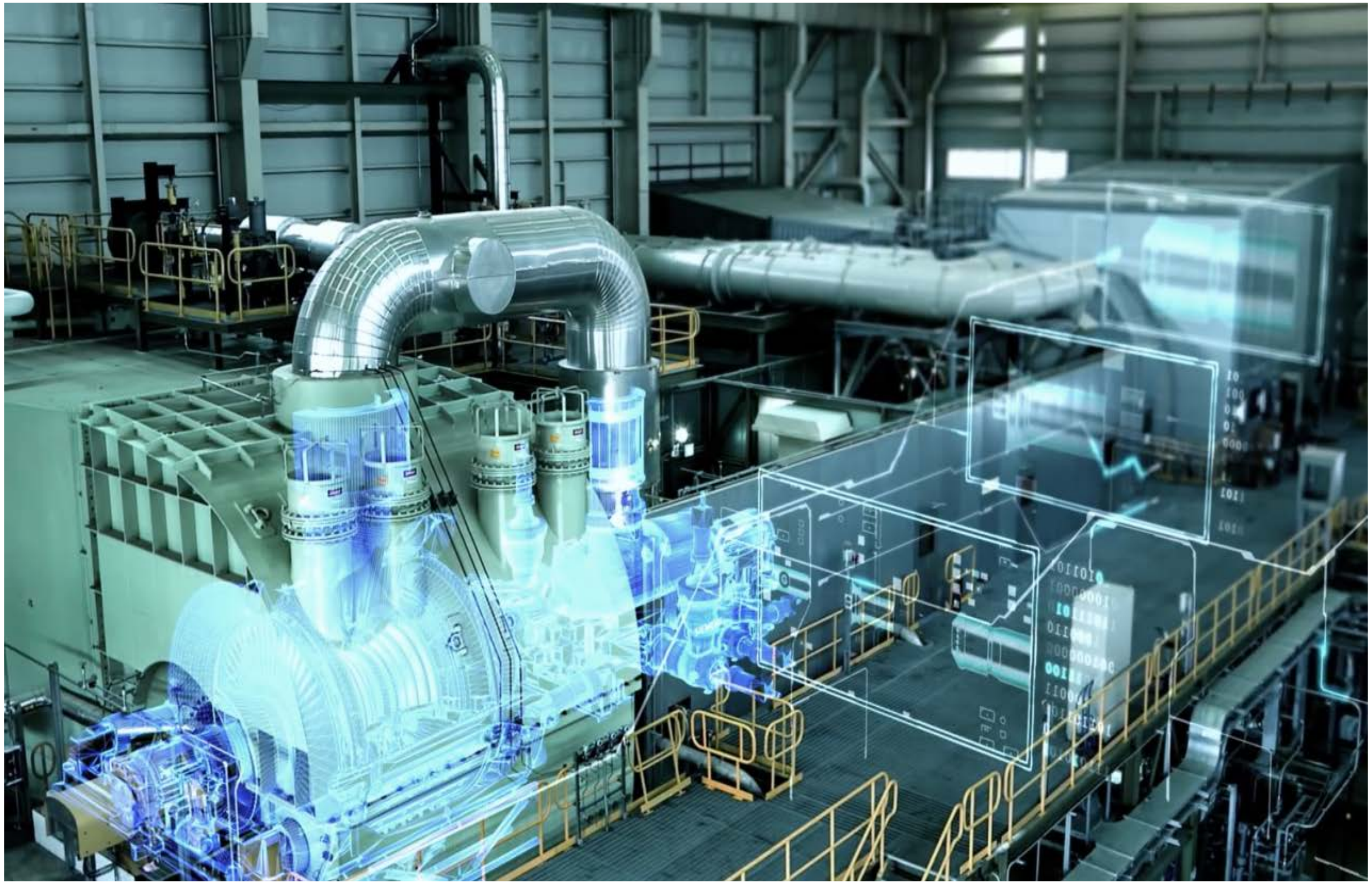
Energy Expert Cyber Security Platform (EECSP) – Guidance for European Commission on policy and regulatory directions

Smart Grid Task Force EG 2 – Network Codes for TSO and DSO

Active in Standardization

Digital Twins allow us to further push the limits of Technologies and Products

“Digital twin” in Power Generation



Value for the customer

- Optimizing the products already in the design phase by using massively historical data
- Advanced quality assessment and risk optimization
- Better service and maintenance of the product in the field
- Cost savings along the entire value chain

Energy Management requires an open and standard-based end-to-end architecture from field level to applications and services

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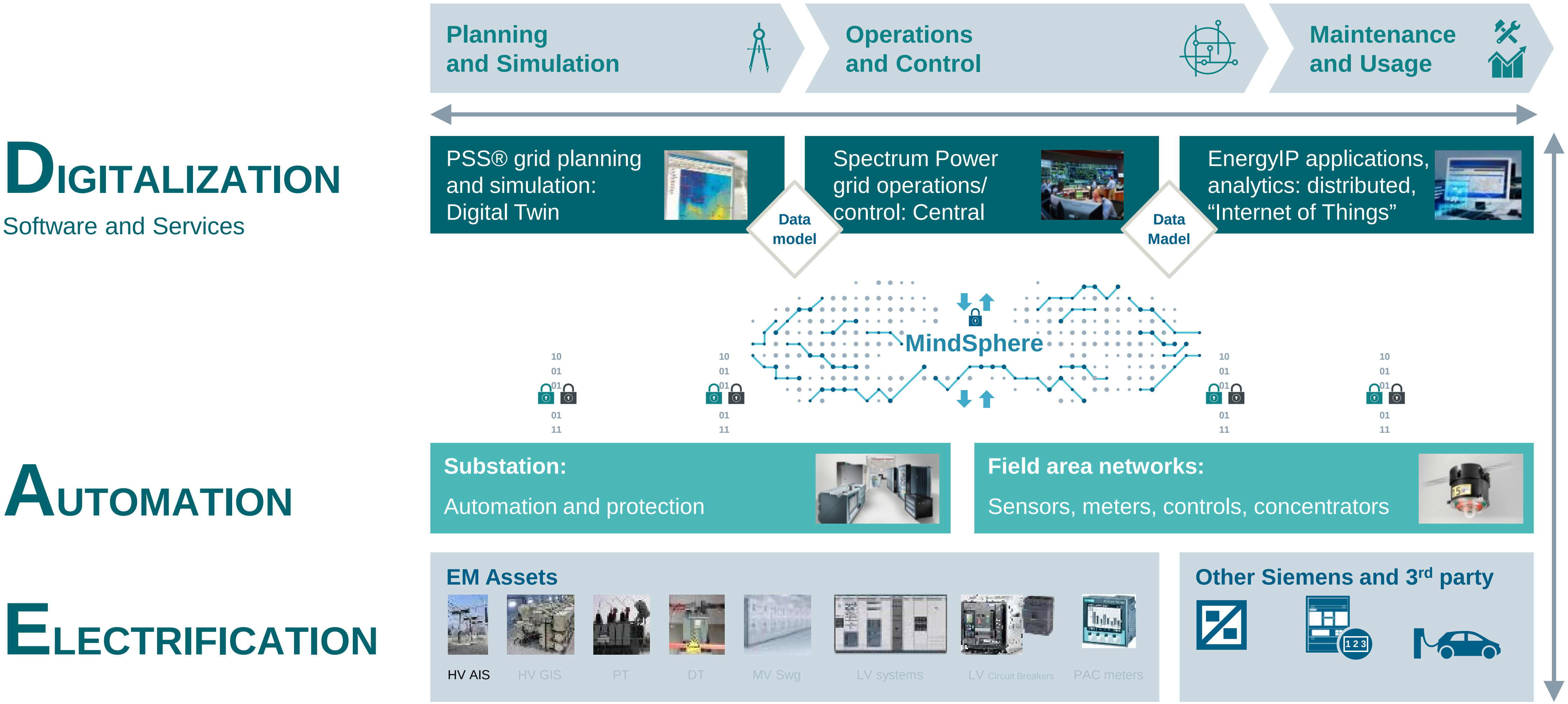

Digital Substation / Scope

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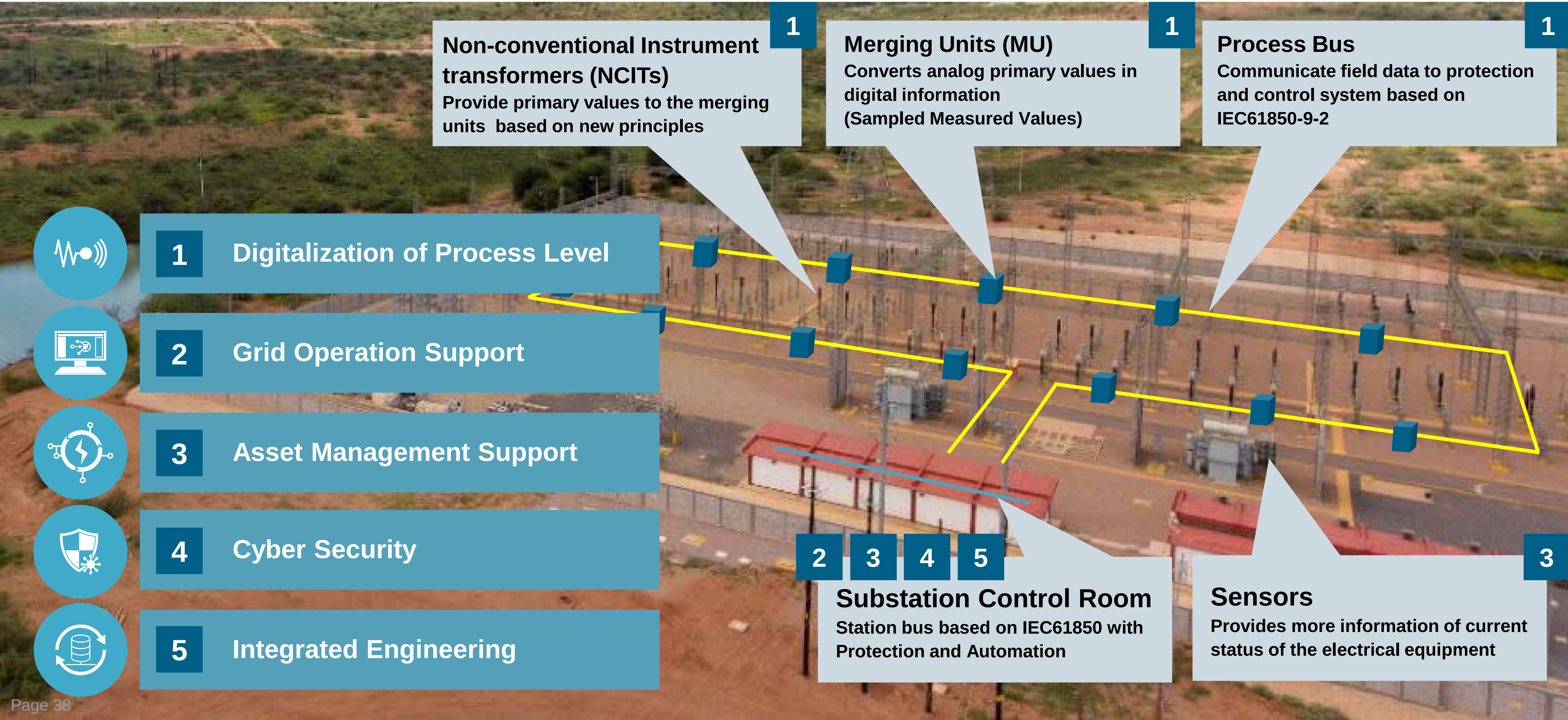
1 Digitalization of Process Level

2 Grid Operation Support

3 Asset Management Support

4 Cyber Security

5 Integrated Engineering



Microgrid
IREN2 research project in Wildpoldsried, Germany

Solution

Combining micro grid and Virtual Power Plant 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
- Ancillary services from the distribution grid

Island of Ventotene, ENEL, Italy:
SIESTORAGE and SICAM Microgrid Manager
Sustainable and independent microgrid

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10-15%
Oil/CO_2 savings

Off-grid
electrification…
Increased use of renewable energy and optimized fuel engine operation

Grid stabilization

Reference projects demonstrate the broad range of different prosumers in a distributed energy system

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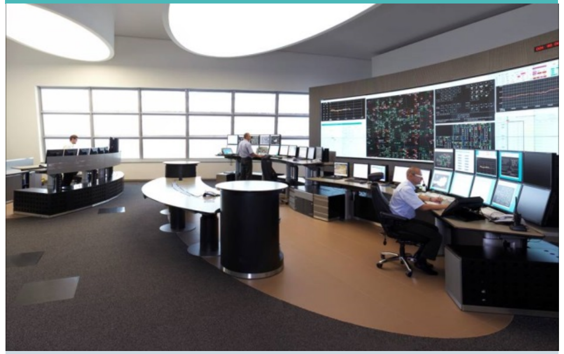
Battery storage system safeguards power supply at VEO

- Black start capability of power plant's gas turbine at any time and without feeding in power from the public grid
- This island network keeps the critical production processes at the steel mill operating

Data analytics decision-making support for GESTAMP



- Real-time monitoring via web portal
- Early detection of machinery failure and inefficient processes
- Customized reports
- Worldwide implementation possible

Turnkey integrated power supply solution for Südzucker

- Drawing power from the high-voltage grid, but also feeding electricity from the on-site power plants into the grid

Intelligent microgrid for Savona University

- Highly energy-efficient conventional and renewable sources are controlled in real-time
- The campus can generate enough electricity and heat to satisfy its needs autonomously

At the front edge of digital innovation:
Elhub: Market transaction management, Statnett, Norway

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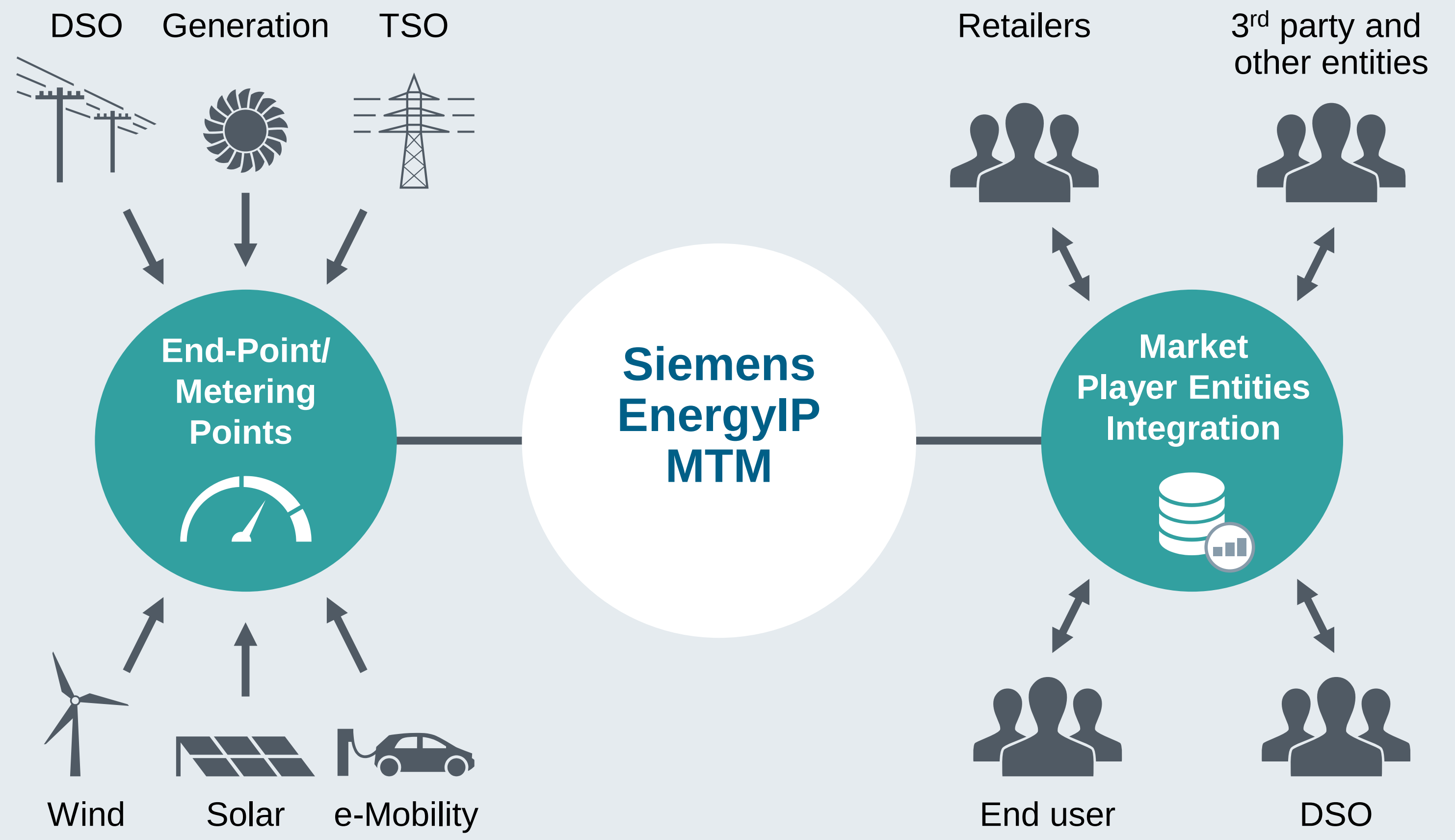
EnergyIP® 8
- Meter Data Management (MDM) application
- Market Transaction Management (MTM)

Benefits
- Peak avoidance
- Distributed optimization
- CO_2 and cost avoidance
- Allocation of grid losses and unaccounted energy



DSO: Distribution System Operators **TSO:** Transmission System Operators **MTM:** Market Transaction Management

Possible advantages of the blockchain technology

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Blockchain

Cost reduction:
(real-time) peer-to-peer transactions with integrated payment / currency

- No separate financial management process necessary any more

Security:
Immutable records &
Trust of source

- No verification costs to prove the origin e.g. of renewable energy, performance validation

New Business Models:
Multi-stakeholder collaboration in different use cases

- (P2P) energy trading (incl. e. g. regulation power), grid charging, nodal pricing, EV-Charging

Optimization:
Data available in one distributed / shared database

- analytics across shared data (e. g. price data, market data, load profiles, grid utilization)

Innovative Microgrid solution using blockchain technology supporting New York's Reforming the Energy Vision (REV) program

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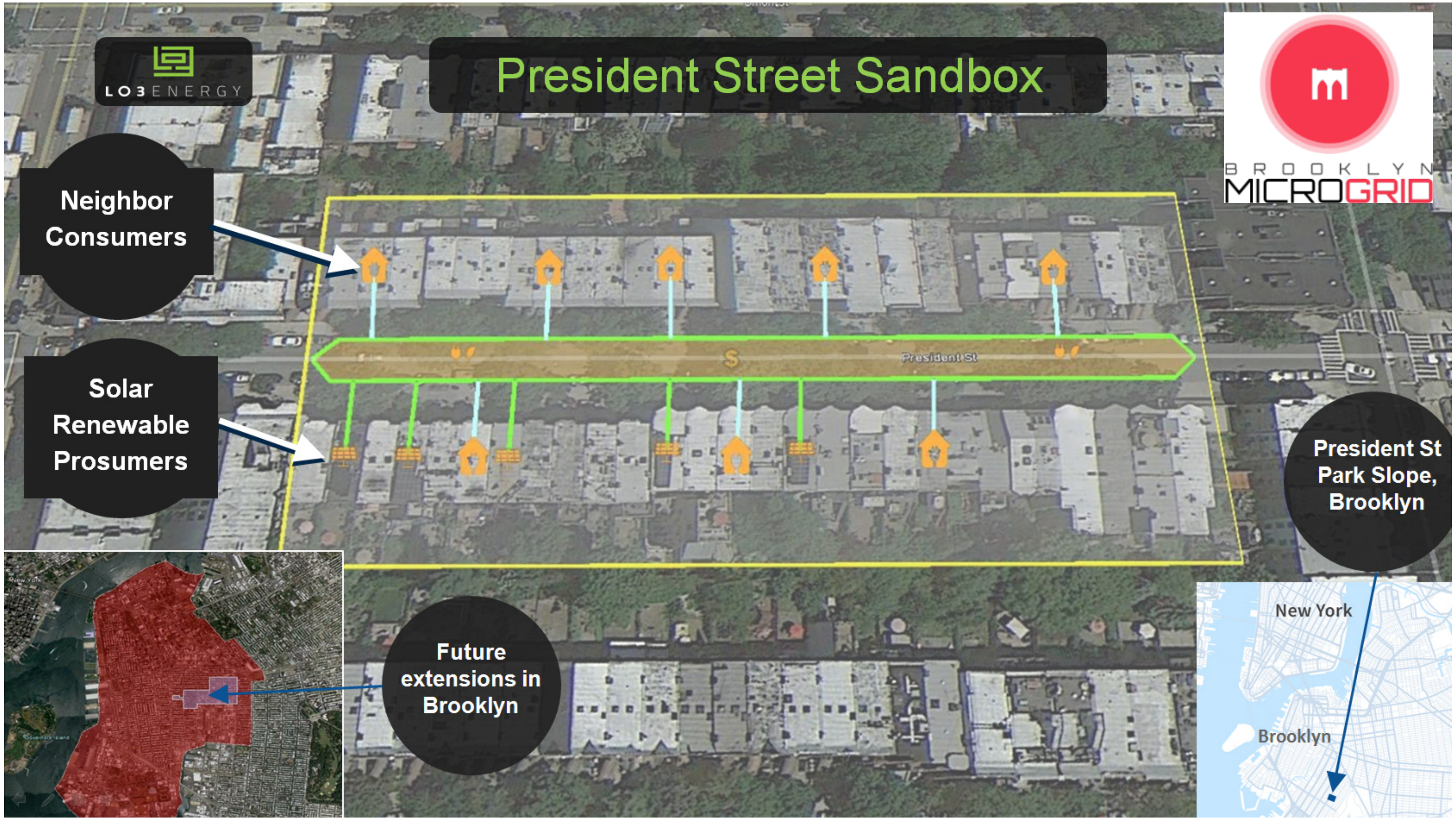

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LO3 ENERGY

TRANSACTIVEGRID

Application of Artificial Intelligence (including Machine Learning)

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	Inform			Act
		Analyze		
	Descriptive Analytics	**Diagnostic** Analytics	**Predictive** Analytics	**Prescriptive** Analytics
	What happened?	Why did it happen?	What will / should happen?	What shall we do?
Business Applications	• Service statistics • Sales reports	• Root cause identification • Fault analysis	• Condition monitoring • Fault prediction	• Power optimization • Load balancing

Data Mining

Machine Learning

Definition and Evolution of AI

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Definition of AI — Creating machines that perform functions that require intelligence when performed by people (Kurzweil, 1990)

Before 2011

1946: Zuse's *Z3*, first programmable electronic computer

1997: IBM Deep Blue defeats world's chess champion Kasparov

2005: Honda's humanoid robot *Asimo* comes to life

2011 – 2016:

2011: Watson wins *Jeopardy!* against most successful contestants

2014: Alexa, Amazon's intelligent assistant debuts

2016: AlphaGo beats Lee Sedol in a Go match

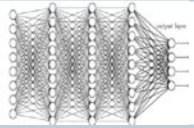
Expected by 2030+

~2020: All-over virtual personal assistants as interface for consumers

202x: Fully autonomously driving cars become market-ready

20xx: Robots may build robot "children" on their own

Major breakthroughs



Algorithmic advances in **deep learning**

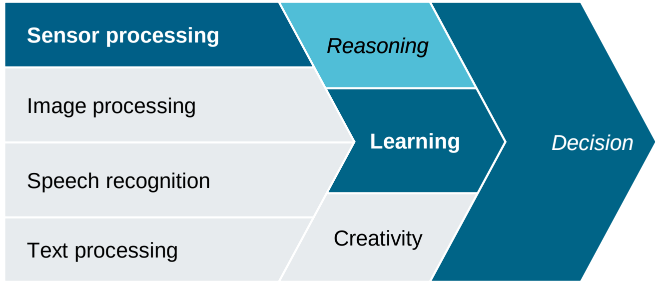
Increasing **computing power**

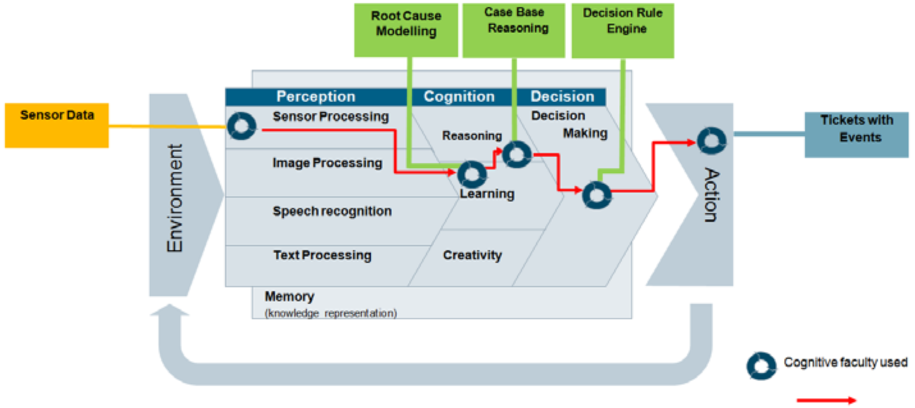
0110110
1011101
0011011
0101010
1100101

Usage of huge **datasets** leverage full potential of AI

Open platforms and data bases

Use Case: Next Generation Root Cause Analysis





High Level View

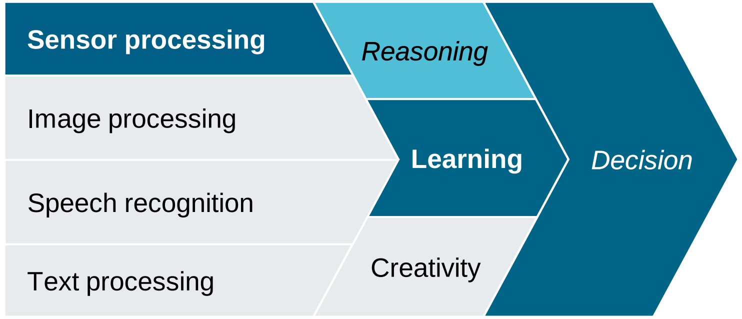
Detailed AI Work Flow

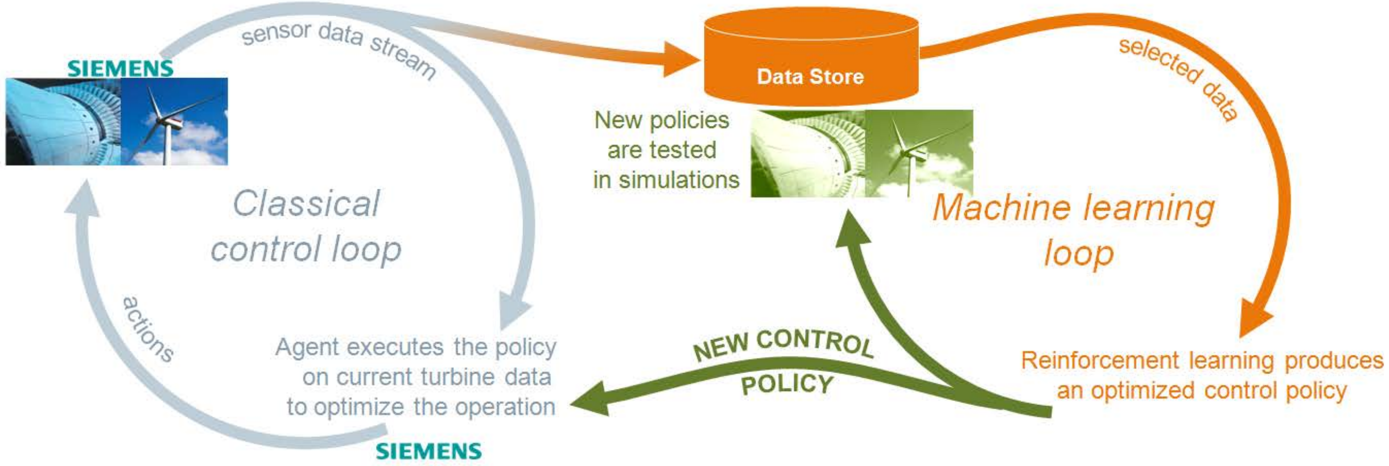
Efficiency & competitiveness

Use Cases in Power Generation:
Gas Turbine Emission Reduction
Wind Turbine Control

Benefit for Gas Turbines: Reduced costs from emissions

Benefit for Wind Turbines: Increased Energy yield





Artificial Intelligence
Deep Learning Example: Online Decision Support for Power Grids

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Growing share of renewable energy and distributed power generation call for enhanced capabilities of intelligent devices.

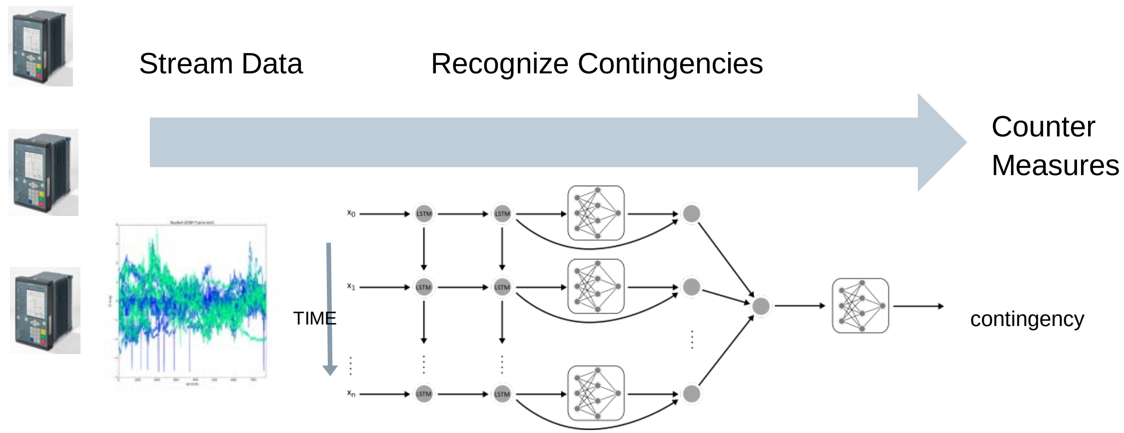
Wide-Area Disturbance Classification

- Wide area monitoring combined with decision support
- Disturbance identification and compensation

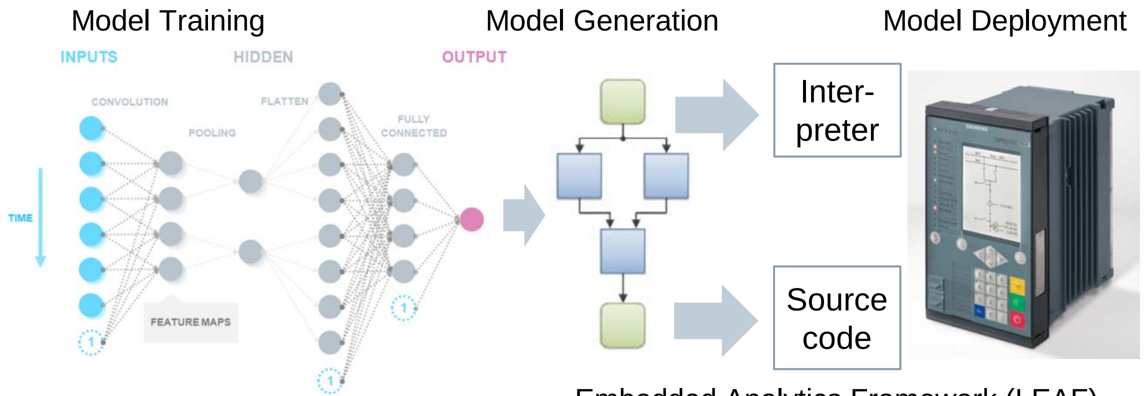
Fault Localization and Classification

- Increase quality of supporting information in case of faults
- Localization of faults even in difficult cases

Operation Center: Disturbance Classification



Infield: Fault location using neural networks



Embedded Analytics Framework (LEAF)

Agenda

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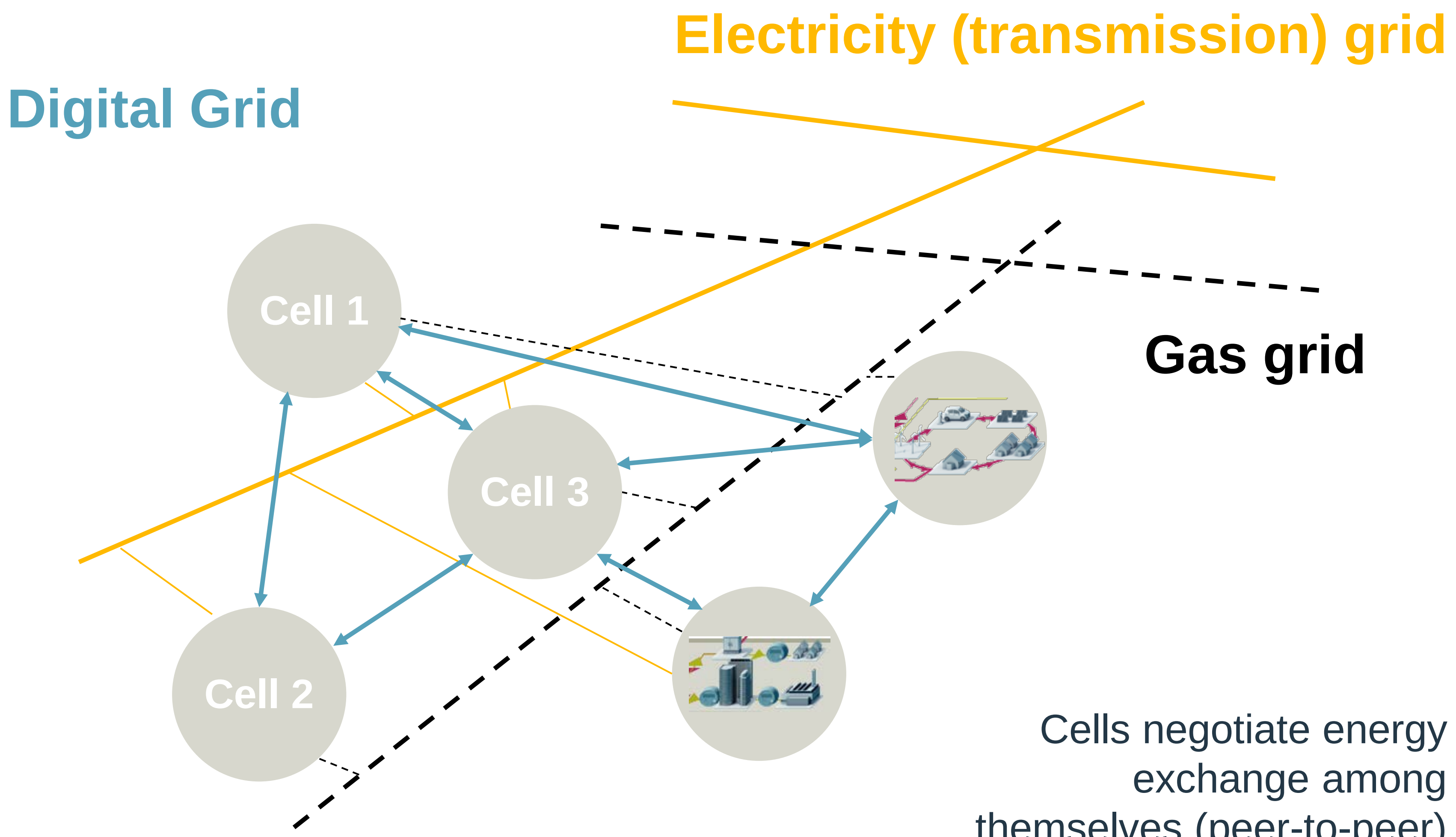
1	Trends
2	Energiespeicher und Sektorkopplung
3	Innovationsfelder der Digitalisierung
4	Ausblick

The three essential grids in context of an energy cell concept



Cells negotiate energy exchange among themselves (peer-to-peer)

Energy cells can be

- Community
- Factory
- Power plant
- Dedicated storage facility

Energy cells contain

- Power generation
- Thermal and gas grids
- Energy storage
- Power-to-X (-value)
- Dynamic load control
- ICT, self-organizing, self-healing intelligence
- Resiliency
- …

Outlook

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1	More Wind- and PV, Electrification, Distributed Energy Systems
2	Sector-couplings and Energy Storage increasingly relevant
3	Digitalization key enabler (simulation, operation, market integration)
4	Emerging Sharing Economy concepts for Prosumers
5	Artificial Intelligence gaining momentum

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Thank you very much!

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