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Smart Energy 2013

Intelligente Lösungen für die Stadt der Zukunft

Dr. Rainer M. Speh, IC ST TI

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Agenda

- Introduction – We are in the “urban millennium”
- Why we need a new energy system and what is the objective
- The basic concept – simple and robust but different
- Implementation on the lowest level – residential houses
- New way of dispatching – low-voltage & medium-voltage grids
- How to manage urban areas and high load districts
- Summary - Your takeaway from this presentation

We are in the "urban millennium"

Population

- 2009: 50% of the world's population lives in cities
- 2030: urban population will grow from 3.5 billion to 4.7 billion

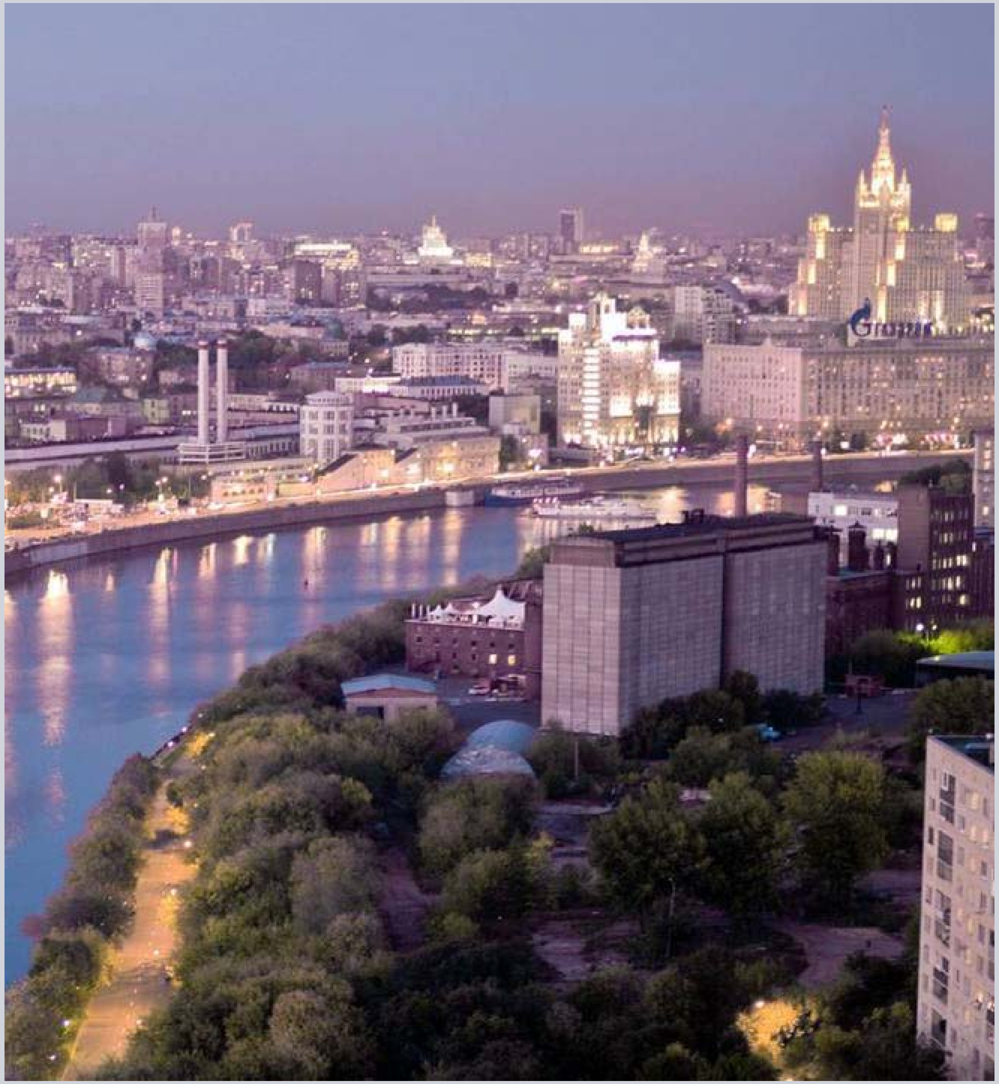
Economy

- ~50% of global GDP is produced in 600 cities
- By 2025, 40% of global GDP growth will be generated by middleweight cities in emerging markets

Environment

Cities stand for

- Two-thirds of the world's energy
- 60% of its drinking water
- Up to 70% of its CO_2 emissions



Basic needs of a city
Success determines competitiveness


Efficient transportation of people and goods


Reliable and efficient supply of energy


Low emissions, water usage and waste

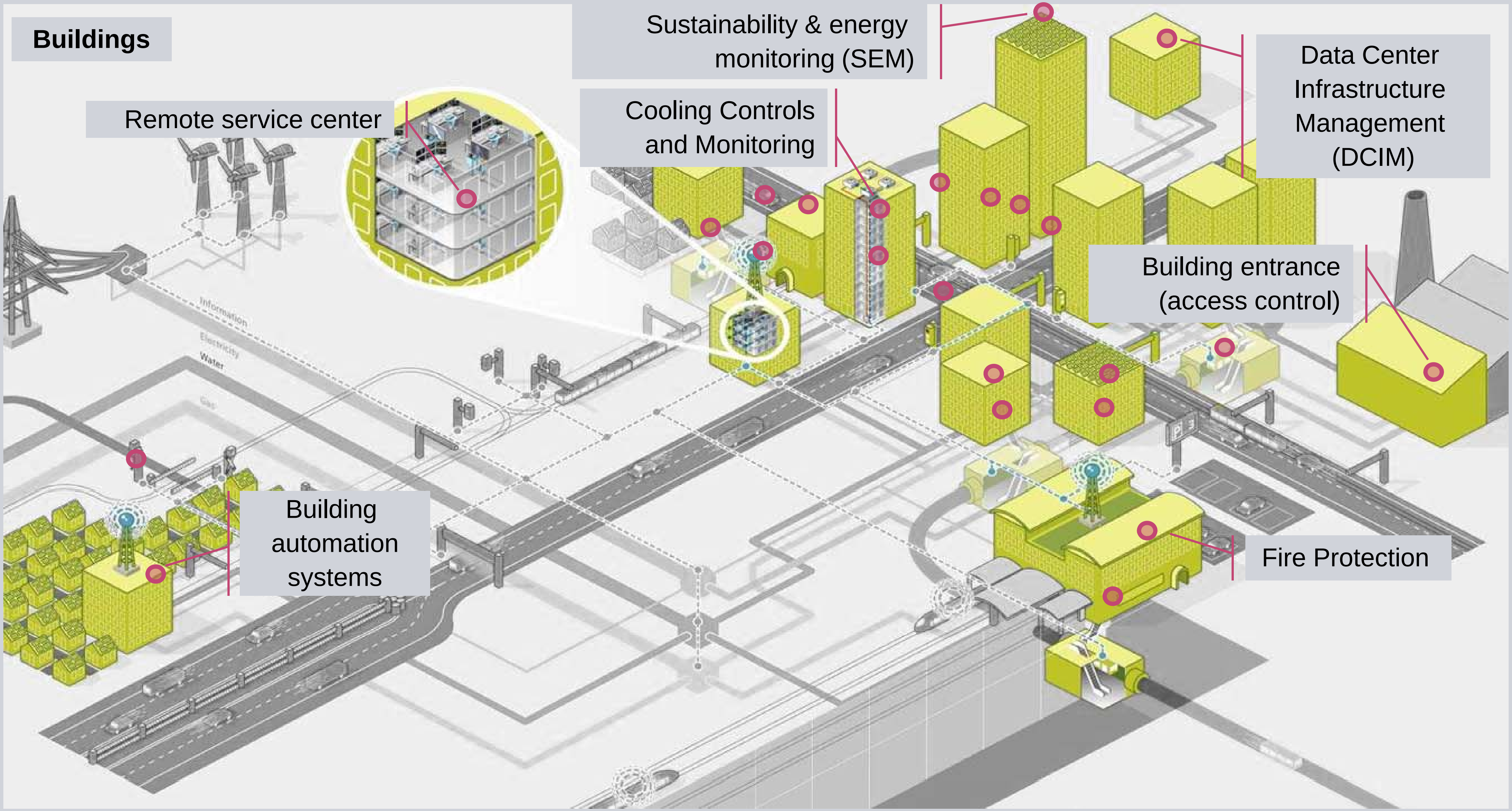

Comfort, life quality and security

Being competitive!

Requirements are drastically changing from closed island solutions/ single products to cross-linked intelligent infrastructure solutions

Infrastructure & Cities Sector

The power house for automation of infrastructure



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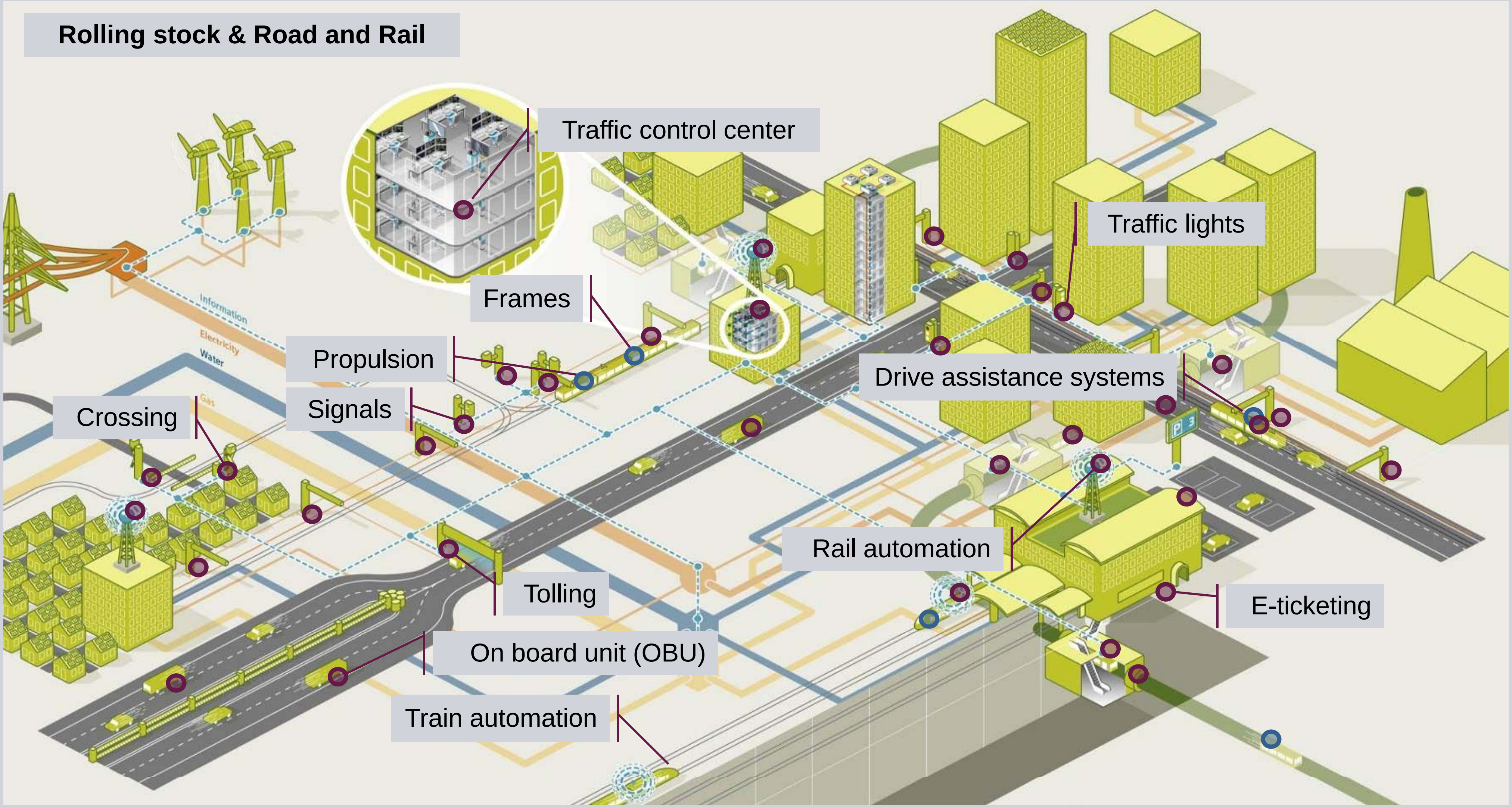

Infrastructure & Cities Sector
The power house for automation of infrastructure

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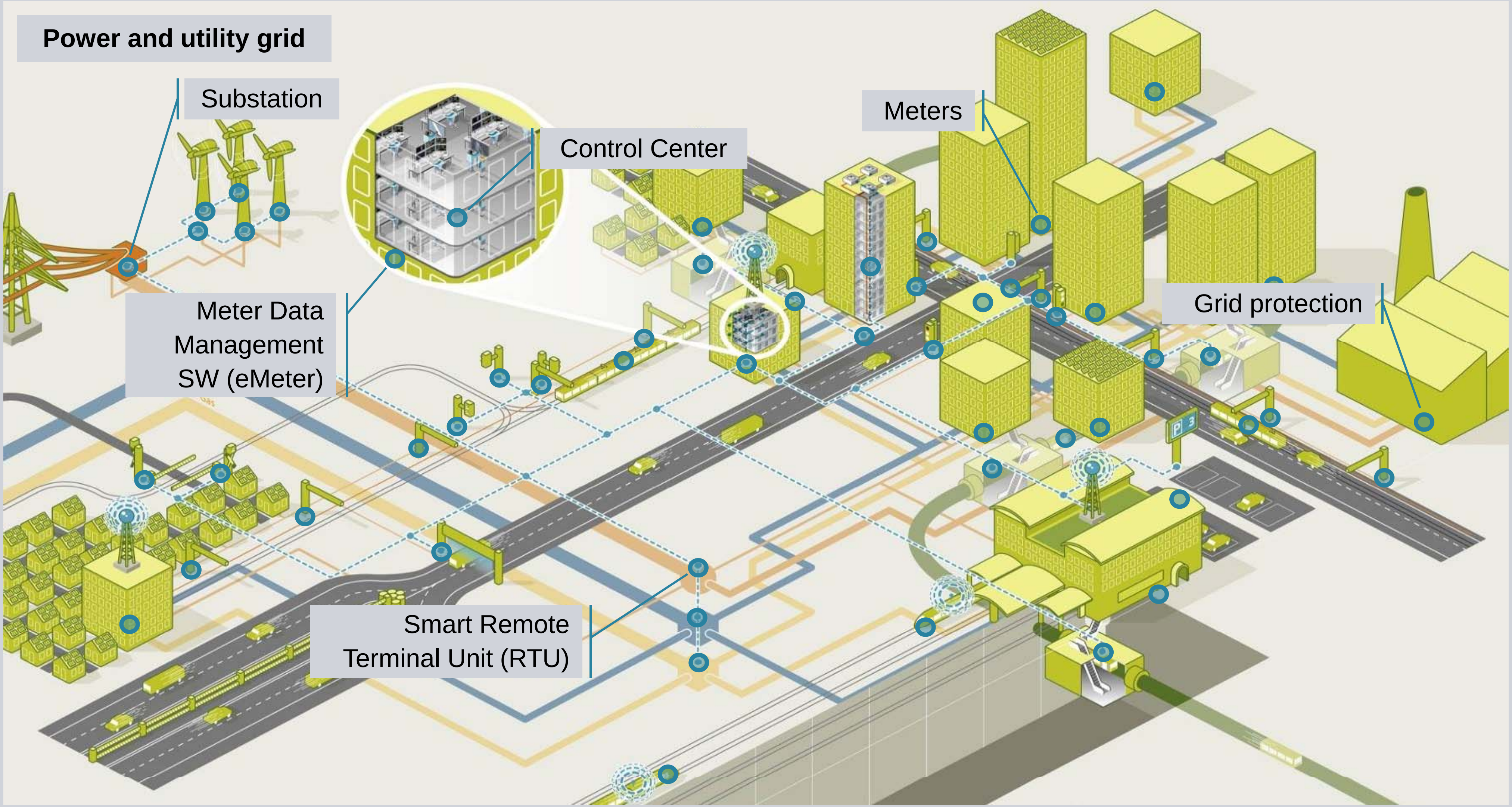

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Important Boundary Conditions
The political framework in Germany

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The new Energy Age is known in Germany as Energy Transition or in German as **"Energiewende"**

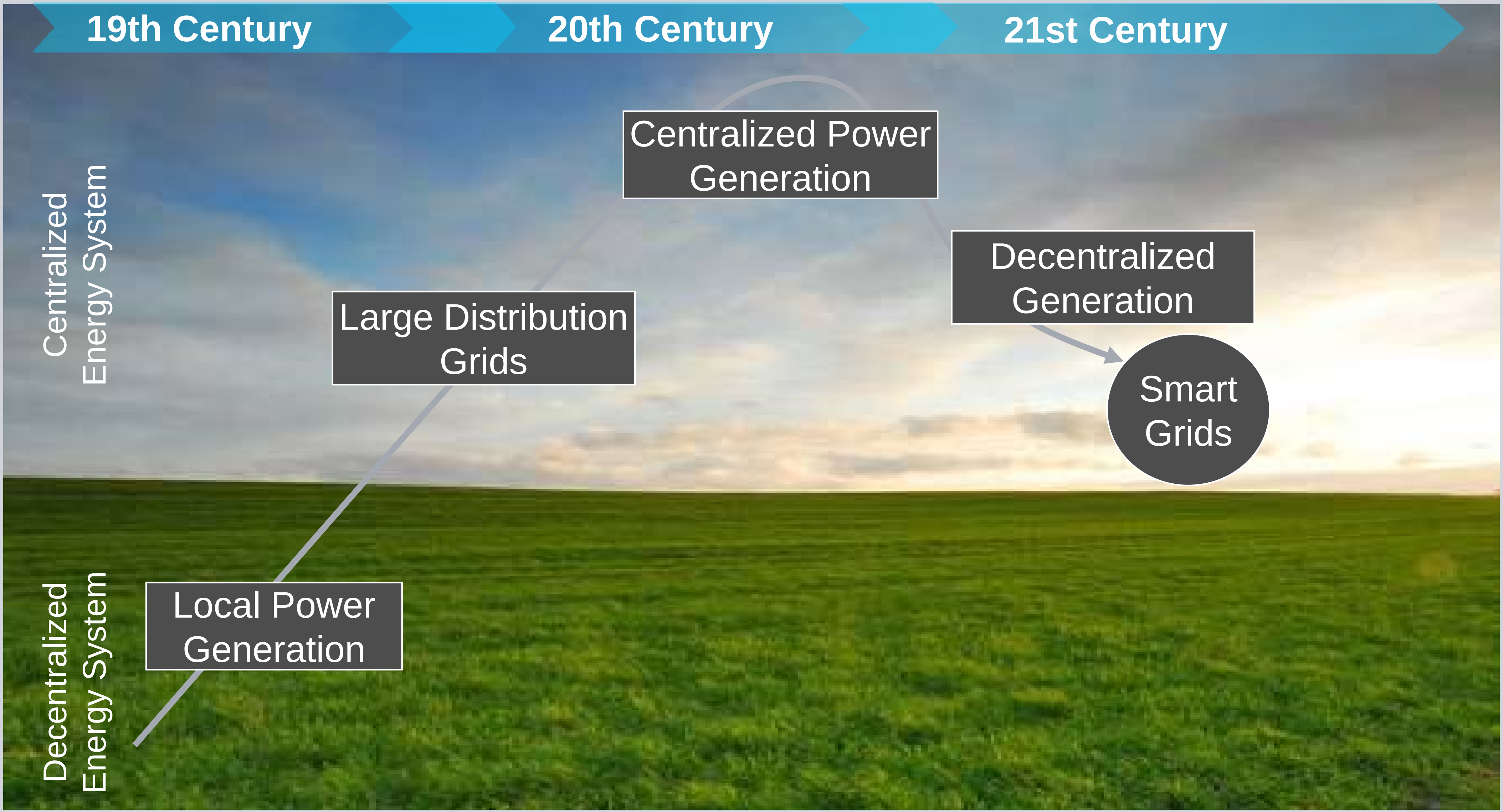
Energy transition is the transition to a sustainable economy by the means of **renewable energy, energy efficiency and sustainable development**. The final goal is the abolishment of nuclear, coal and other non renewable energy sources.

In detail, the **Goals for 2050** are as follows:
- reduction of greenhouses gases compared to 1990 by **80 - 95%**
- reduction of primary energy consumption compared to 2008 by **50%**
- reduction of electrical energy consumption compared to 2008 by **25%**
- share of renewable energy on total energy consumption = **60%**
- share of renewable energy resources for electricity = **80%**

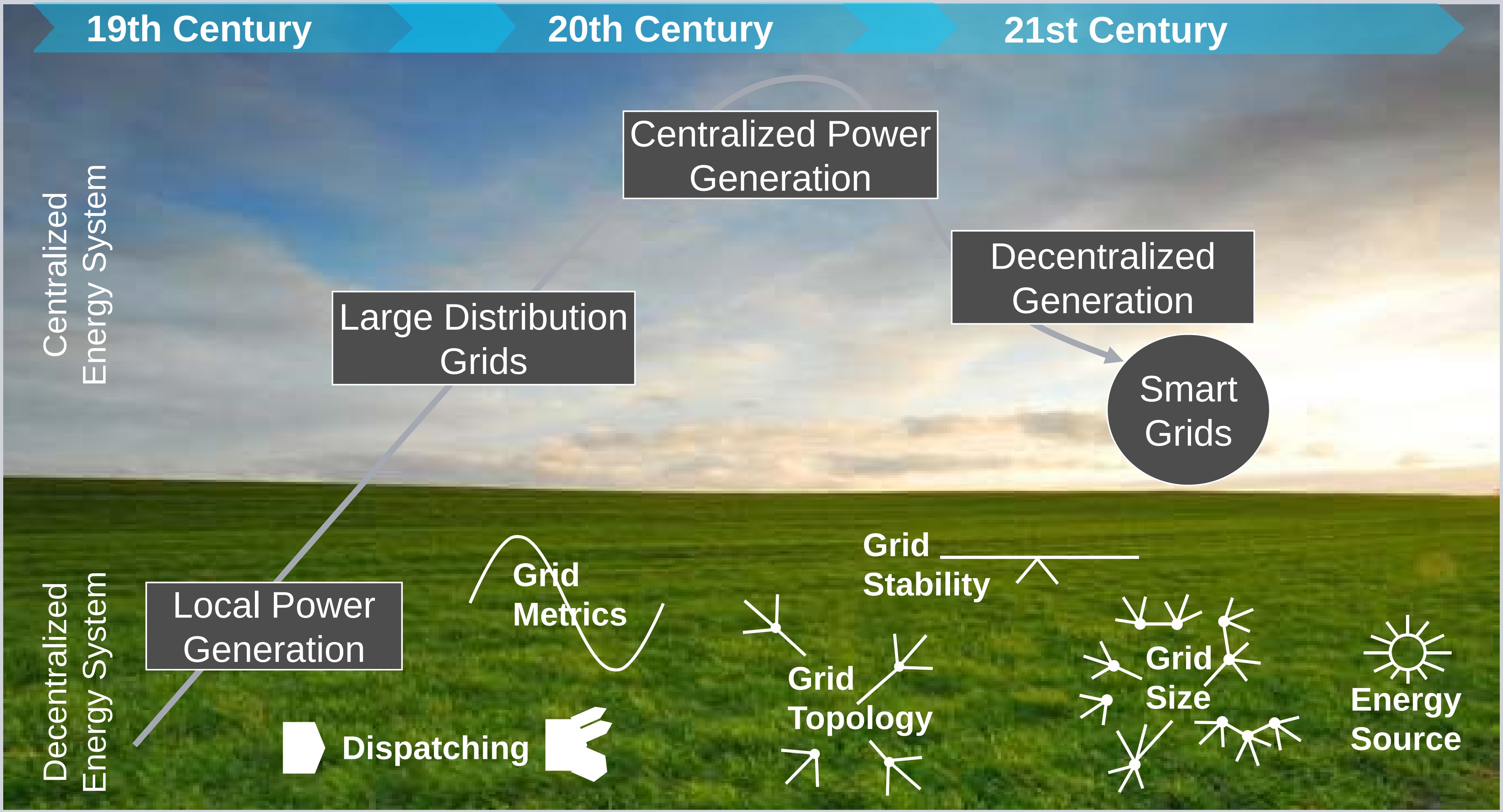
Source: Energiekonzept der Bundesregierung Sep 28, 2010

To shape the future needs knowledge about history -

How did we get to the current system structure?



. . . and what will be changed in the future



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Two basic design and operating principles for distributed control systems

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The optimal structure of an automation system is achieved,
when the structure of the monitored process is fully replicated.

Any information should be processed in the automation layer,
in which it is possible for the first time.

Source: Leit- und Schutztechnik in der Elektrischen Energietechnik
ESEM, TU Kaiserslautern, 2011, 2012, 2013

Source: thebureauinvestigates.com

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A basic thought about the new Energy System

- Everybody agrees on a more **decentralized structure** of the new Energy System in terms of building blocks like generation resources, storage facilities and smart meter.
- But if operating principles are discussed, many people still think **more centralized** like huge numbers of loads being influenced by demand-side-management systems.

To operate the new Energy System in a centralized manner might be wrong

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Today's Mantras for Electrical Grid Design and Control

- Precise 50/60Hz frequency for grid control and timing
- Strict AC voltage band level for grid control and for the consumers
- Importance of power quality in the grid, e.g. harmonics, flicker, etc.
- Non-use of DC on a broader scale
- Reliability depends on grid availability
- Grid stability based on inertia provided by centralized power plants in a meshed grid

The new Paradigm
A different Way of Dispatching

**Balance
Power Generation
and Consumption
on the possible lowest
voltage level *)**

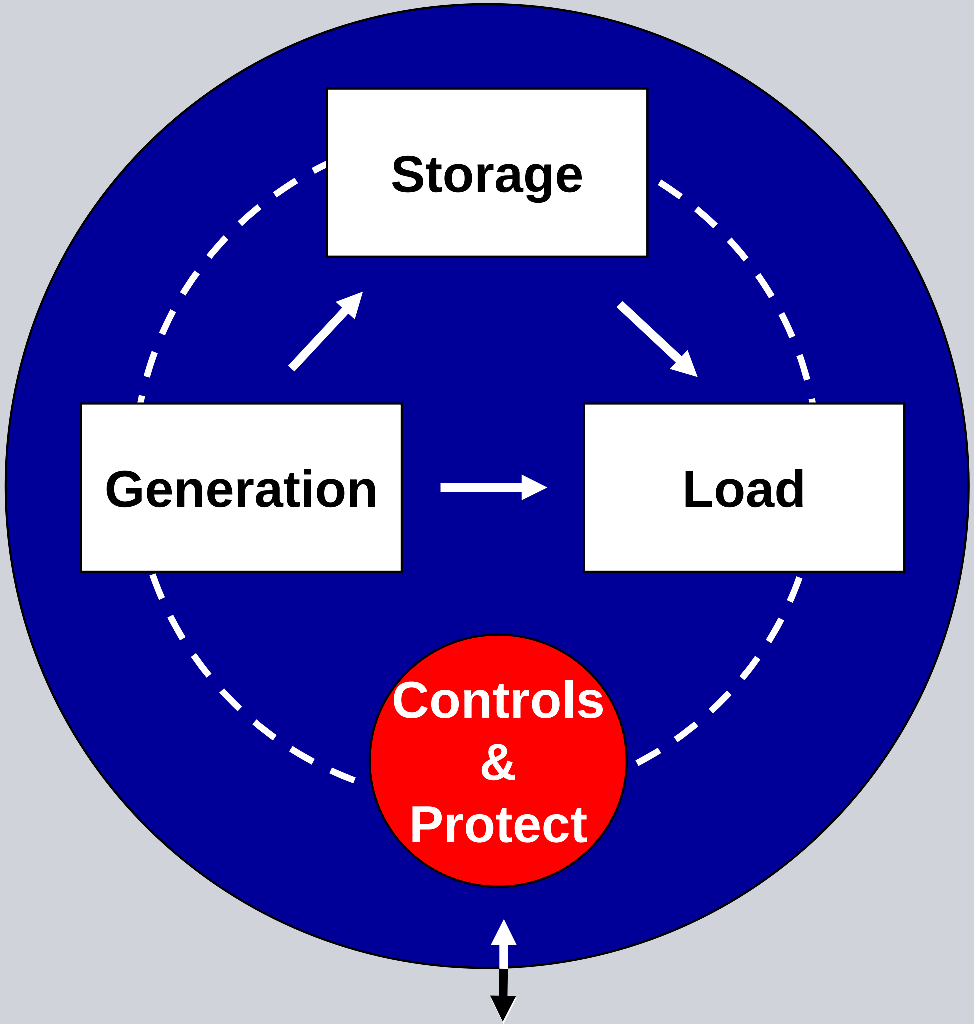
*) this approach is also known as the micro grid principle but used here in a different context

Thus, fulfilling the requirements of the second principle

The basic Design Principle

A cellular structure on all levels according to the first principle

- The shown cellular concepts is used on all levels
- Each cell can comprise generation resources, storage capabilities and loads
- But also cells comprising a single component like generation or storage are possible
- From outside, the whole cell is handled like a single entity
- For dispatching purposes only one figure will be provided to the dispatcher, i.e. the residual power in the next dispatching period
- As this figure comes with a sign, a generation as well as a load behavior is possible



$$P = f(t_{n+1})$$

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Enabling Technologies
Photovoltaics


Source: RMS

- efficiency of PV modules up to 24%; CPV modules up to 40%
- production: 700 – 1100 kWh / kWp & a
- space requirement: 8-9 m² / kWp
- total asset cost: 1000 – 1900 € / kWp
- installed capacity by end 2012: 34 GW

all figures except efficiency are related to Germany as of 2012

Source: re.jrc.ec.europa.eu/pvgis

Enabling Technologies

Small-scale and medium-scale storage

Source: APC

- Storage capabilities will be key to manage the new energy system
- Keeping the cellular structure in mind, the smallest cell would be a private home
- Depending on the storage utilization a small 30 -50 kWh device or a medium 500 kWh device would be feasible

Necessary Improvements

- As batteries are a feasible solution for small storage facilities only, a new technology has to be developed

- Electrical power consumption of a family of four in Germany is ~ 4000 kWh per year
- To bridge a gap of some days, the small storage facility would be used
- To become energy autarkic, i.e. to bridge the winter time, the medium storage has to be considered

Enabling Technologies
H_2 Infrastructure


Source: EERE

- Utilize small-scale electrolyzers to produce H_2 decentralized
- Either store H_2 locally or feed-in into a local H_2 infrastructure
- H_2 being used for fuel-cell based cars or local power generation facilities
- Ensure availability of pipe work in new residential or urban areas

Necessary Improvements

- Commercial available Unitized Reversible Fuel Fells (URFC) including a storage capability as replacement for batteries


Source: Siemens AG

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Is there really a need to run an AC network at home?

- Many devices in the residential area run internally on direct current (DC)
- Examples are e.g. TVs, HiFi equipment and computers
- Latest technology in lighting is based on LEDs, thus using internally DC as well
- If hybrid domestic appliances are considered having a cold and a warm water inlet, even dish washers and washing machines could be operated with DC
- Even state-of-the-art cookers are using the induction principle, thus could be powered by DC as well

There are only a few exemptions to run AC devices at home

Residential Approach

Decoupling the Prosumer Nodes from the Low-Voltage Grid

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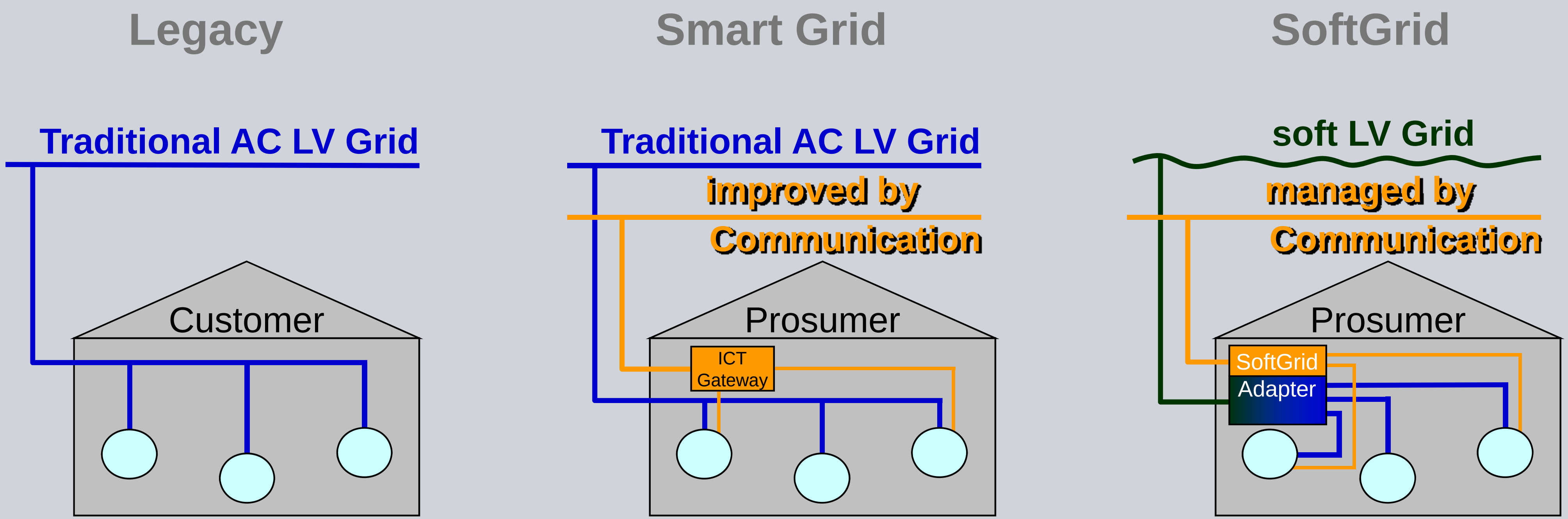

An important step towards a soft low-voltage grid with relaxed grid mantras

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Low-voltage and Medium-voltage Approach
System structure

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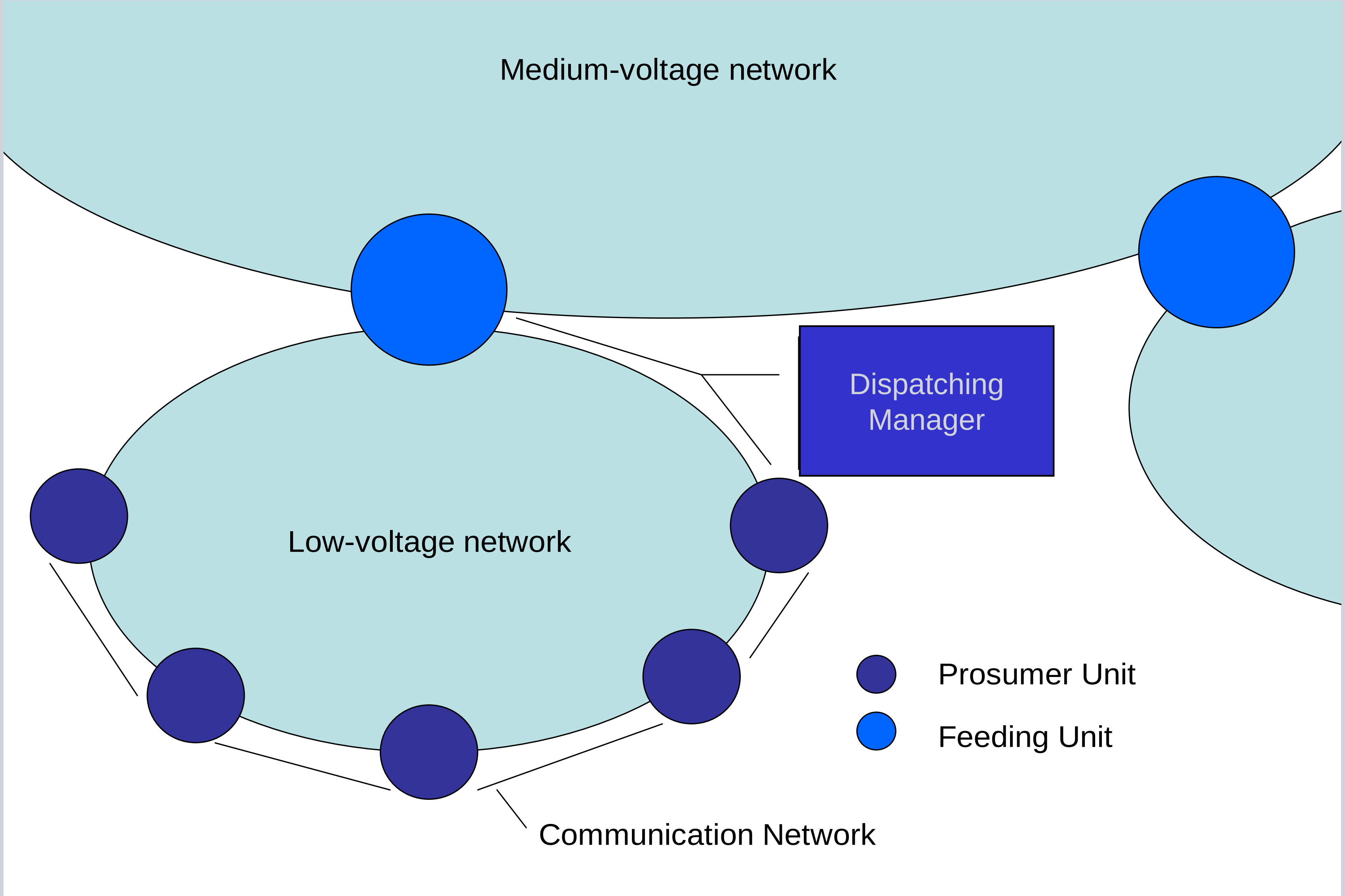

Low-voltage and Medium-voltage Approach
Dispatching principle

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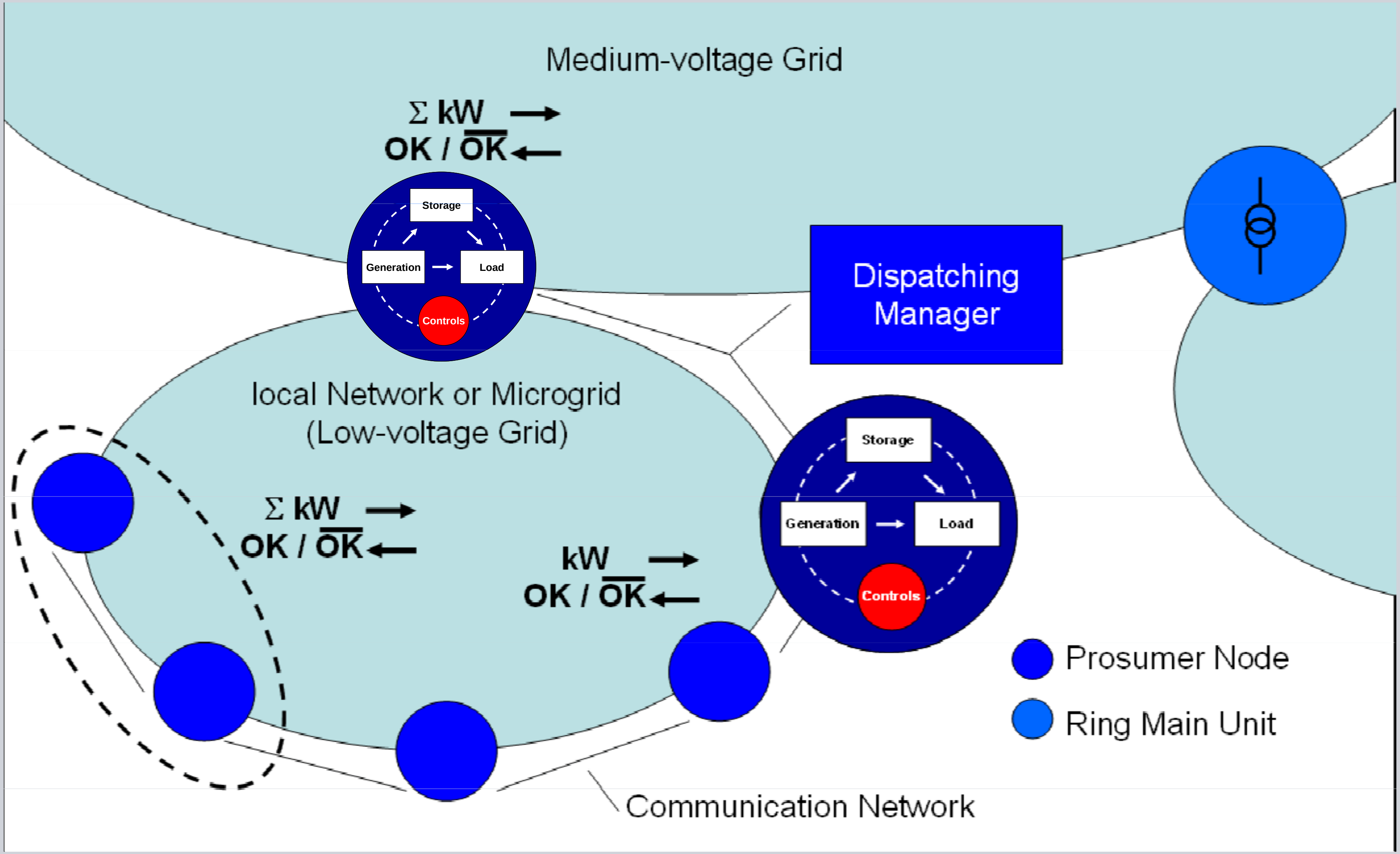

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Why concepts for urban and high-load areas differ

Different Requirements

- Higher density of population
- Less opportunities to install renewable generation resources
- Higher load density
- Mission-critical consumers with
- increased demand on availability

More Choices for Implementation

- Industrial customers with huge potential for load shifting
- eCars commuting daily into the city and acting as moveable batteries
- Many public facilities

What would be the best approach to replace Nuclear Power Plants?

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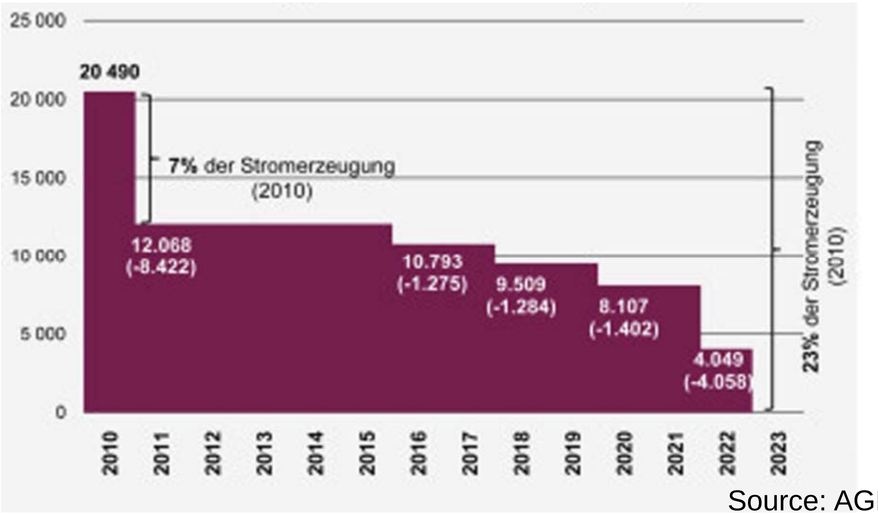

Source: AGEB

Repowering existing locations with latest technologies, e.g. Siemens Gas Turbine SGT-5-8000H as part of a CCPP utilizing **existing equipment** like cooling towers and grid connection as well as generator and transformer

Source: AGEB

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Do we really need major improvements of the electrical Grid?

Source: Übertragungsnetzbetreiber (ÜNB)

- In order to transport the electrical energy produced mainly by off-shore wind parks in the north of Germany to the main load areas, the grid has to be improved by means of High-Voltage Direct-Current (HVDC) links
- But due to the volatile generation characteristics of renewable energy resources, the main problem remains
- Not the improvement by new links, but the availability of storage capabilities is key, the manage the grid of the future

Yes, but the main problem remains unsolved, the problem to store energy

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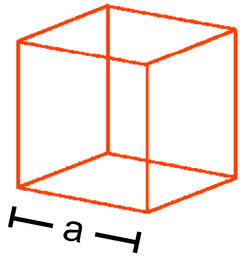
How can we store electrical power on a large scale?

40 GWh – The pumped-hydro storage capacity of Germany

The equivalent edge length “a” for fuel storage



16 m: Diesel

20 m: Methanol

18 m: Ethanol

166 m: Methan, 1 bar

230 m H_2, 1 bar

40 m H_2, 200 bar*

96 m Lead-acid battery

*) w/o container

Only chemical storage allows effective and transportable energy storage

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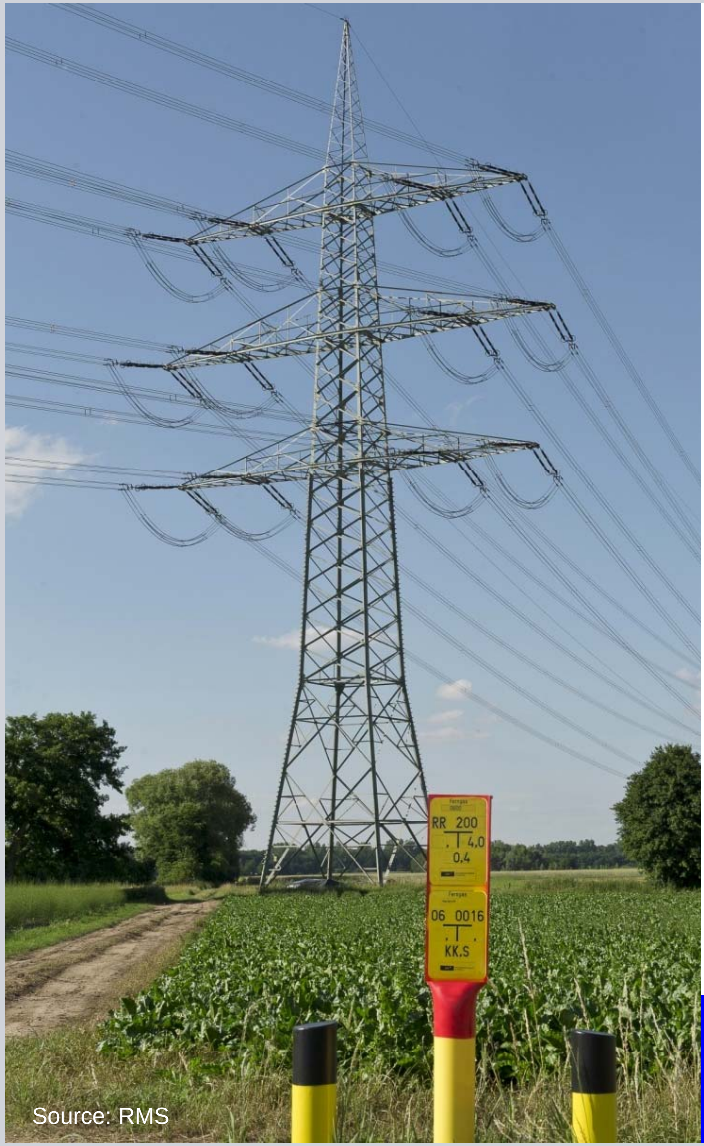
Electricity & Gas
The perfect team of the new Energy Age



Source: RMS

- Power to Gas - an application to produce in a first step hydrogen by means of electrical power generated by renewable resources like Wind or PV

$$2\,H_2O + \text{energy} \rightarrow 4\,H^+ + 4\,e^- + O_2$$

$$4\,H^+ + 4\,e^- \rightarrow 2\,H_2$$

- Hydrogen can be feed-in to a maximum of 5% directly into the gas grid. A limit up to 15% is under discussion

- In a second step, methane could be produced out of hydrogen and CO_2 and feed-in the existing gas network w/o any limitation

$$CO_2 + 3\,H_2 \rightarrow CH_4 + H_2O$$

Total efficiency η >= 50% *)

*) considering a CHP plant

The Gas Grid

The preferred partner for renewable energy resources *)

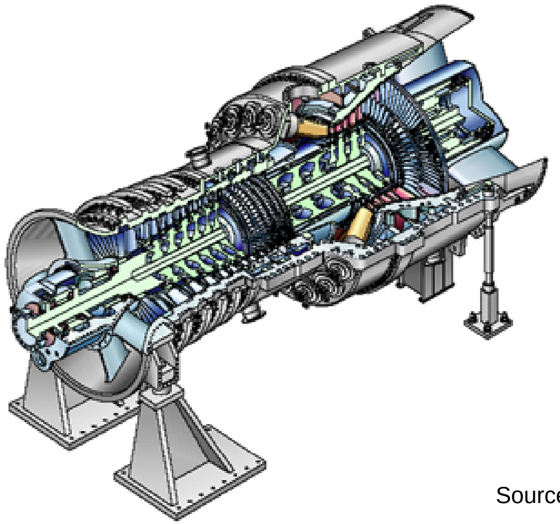
Source: RMS

- Total length of the gas grid: 443.000 km; thereof 141.000 km low-pressure, 181.000 km medium-pressure and 119.000 km high-pressure
- Grand total of yearly transport: ~1000 TWh
- 47 underground storage facilities with a total capacity of > 200 TWh equivalent to >20% of yearly consumption; latest studies claim even more than 500 TWh
- Transport capability of a single transport gas pipeline: ~70 GW_{th} in comparison to a state-of-the-art HVDC link: ~ 4 GW)

*) all figures refer to Germany

The Gas Grid provides huge transport and storage capacities

Siemens SGT5-8000H
The benchmark in efficiency



Source: Siemens AG

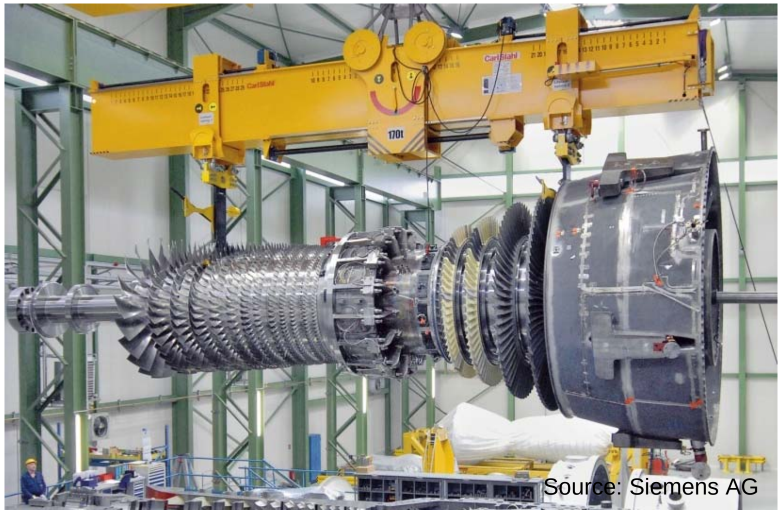
Technical Data

- rated power: 375 MW
- efficiency simple cycle: 40%

- CCPP power: 575 MW
- efficiency combined cycle: 60,75%

Necessary Improvements

Improve the engine running on methane with H_2 content up to 15%



Source: Siemens AG

Electricity & Gas

So why not using the hybrid approach?

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Missing Technologies and necessary Improvements

- Electrolysers on a large scale, i.e. >= 50 MW are not available
- Investigations ongoing on direct feed-in of H_2 into the gas grid; old municipal gas networks comprise up to 50% of H_2
- No methanation on a large scale due to cost reasons; using natural gas is cheaper
- Missing experiences on big combustion turbines running on gas comprising more than 2 weight per cent of H_2

Hybrid solutions with Electricity & Gas – an interesting area for engagement

Die VDE/ETG-Studie "Aktive Energieetze" führt den Begriff "Smart Supply" ein

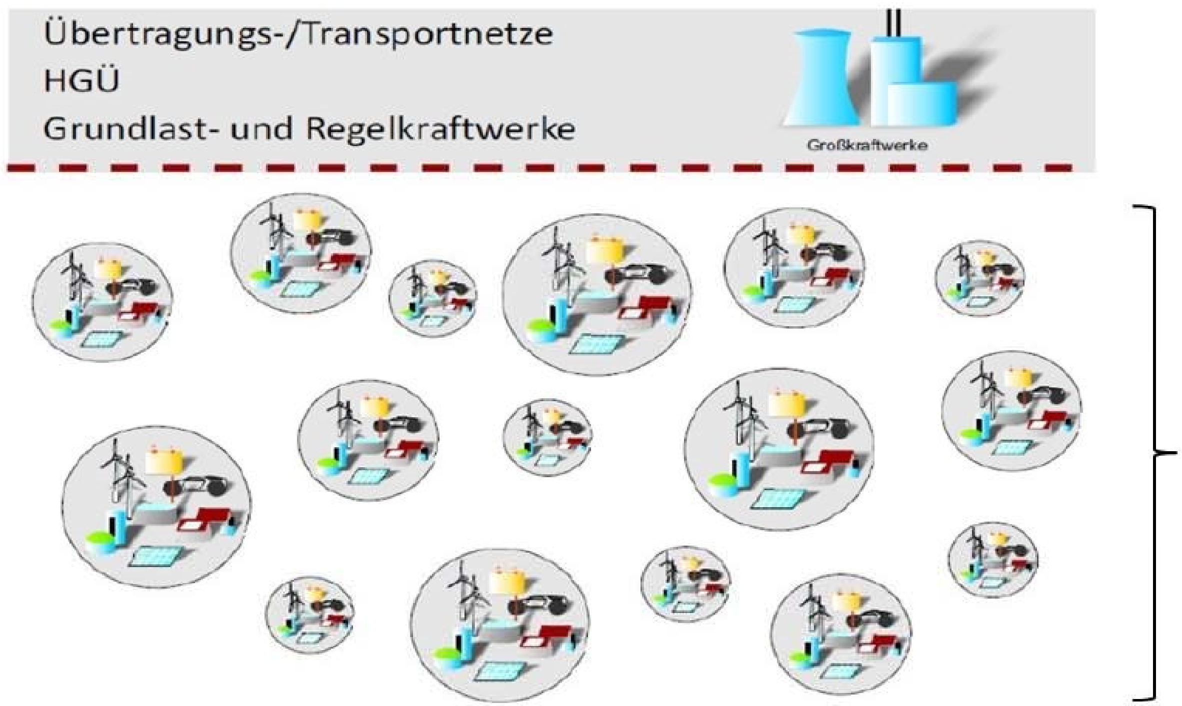
Smart Supply

Funktion	Smart Grid	Smart Market
Netzautomatisierung	Versorgungsqualität durch Regelbarkeit sichern	Diskriminierungsfreier Netzzugang
Energiespeicher	Last-/Spannungsregelung auf Vertragsbasis	Markt für Energie und Systemdienstleistungen
Lastmanagement DSM	Last-/Spannungsregelung auf Vertragsbasis	Markt für Regelreserve
Virtuelles Kraftwerk VKW	Last-/Spannungsregelung auf Vertragsbasis	Ergebnisoptimierung an verschiedenen Märkten
Lastbeeinflussung DSR	Last-/Spannungsregelung Variable Netzentgelte	Dynamische/ Sonder-Tarife Marktintegration Kunden

Smart Supply basiert auf “Zellularer Organisation”

Es wird die Förderung von selbstbilanzierenden und Systemdienstleistungen generierenden Smart - Supply – Zellen empfohlen mit den Zielen:

- Reduzierung der Komplexität der Systemsteuerung
- Paradigmenwechsel in den Bilanzierungsprozessen
- Qualifizierung des Fahrplanmanagements
- Förderung regionaler Märkte.



Regelzone
Netzbetrieb, Vorhaltung und Management Systemdienste

Smart Grid +
Selbstbilanzierung,
Automatisierung,
Systemdienste

Smart Market
Virtuelle Kraftwerke,
Flexibles, optimiertes Agieren auf Märkten,
Marktintegration Kunden

VDE

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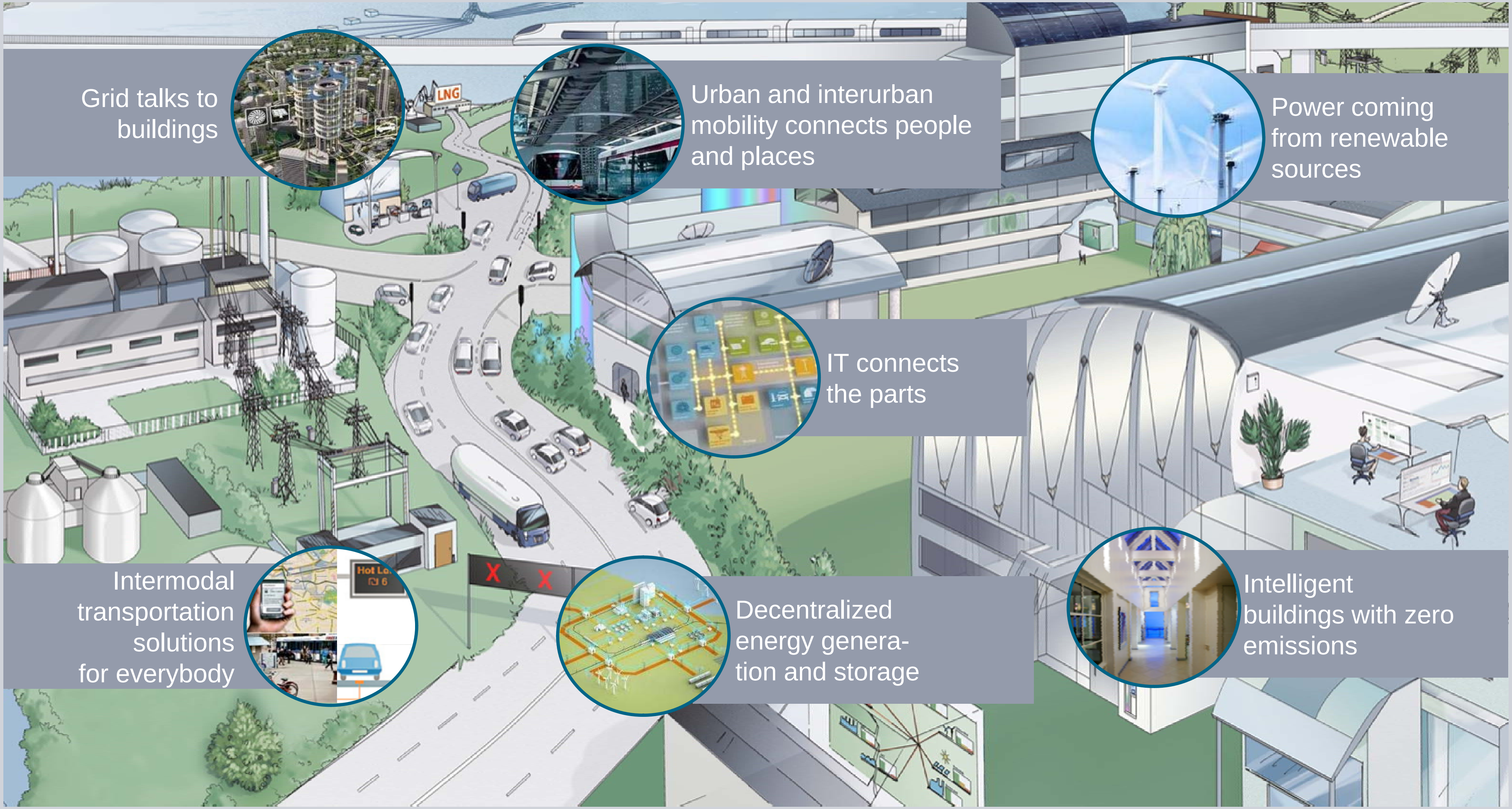
We are working on the city of tomorrow

A picture of the future



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Citizen 3.0

Source: politnetzwerk.de

The Key Success Factor for the City of the Future

Intelligente Lösungen für die Stadt der Zukunft