Content

- Introduction to KIT
- German Energy Turnaround (‘Deutsche Energiewende’)
- Research into Storage, Efficiency, Renewables, Fission / Fusion
- Europe Energy Perspectives

Germany: Land of Traditions, Land of Progress, Land of Ideas!

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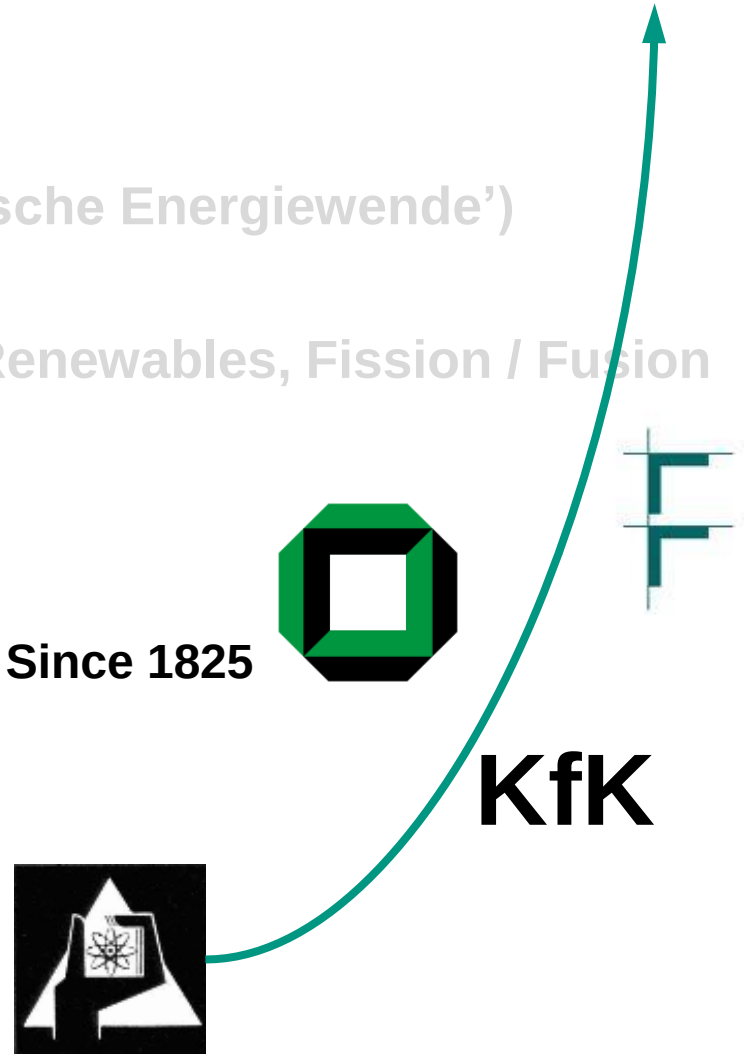


KIT – One Institution, Two Missions

- **Mission of a *state university* with research and teaching**

- **Mission of a *national research institution* of the Helmholtz Association with program oriented provident research**

KIT in Figures

Employees

8,980

23,836

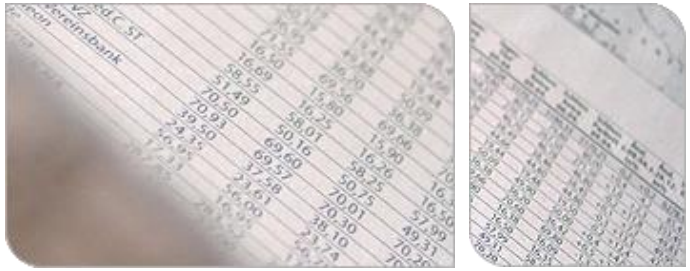
Students

373

Professors

784

Annual Budget in Million Euros



KIT is Research, Higher Education and Innovation

Research

From fundamental questions to specific applications in energy, environment, future technologies and society

Higher Education

Research oriented teaching in a stimulating environment for the elites of tomorrow

Innovation

New products, processes and services to shape the future of our society

Strategic Orientation: Main Research Fields

Energy

Environment

Future Technologies

Fundamental Questions

Society and Technology

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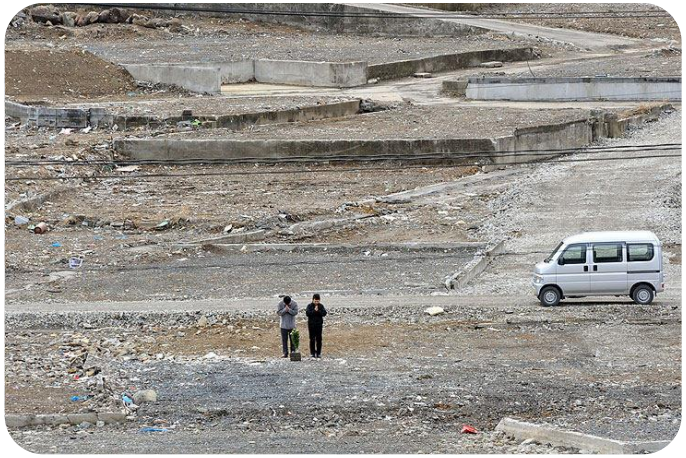
Quelle:
http://http://www.bundesregierung.de/Webs/Breg/DE/Energiekonzept/energiekonzept.html

Three Events dated March 11, 2011: Earthquake, Tsunami, Severe Accident in four NPPs

- 15.800 casualties, more than 3.000 people missing
- 15.000 buildings distroyed
- 340.000 people had to leave their homes
- 87.000 people fled due to releases of radioactivity
- 53.000 existing container houses today



Quelle Fotos: http://www.stern.de/panorama/japan-am-jahrestag-der-tsunami-katastrophe-ein-land-haelt-inne-1798333

11.3.2011: Fukushima → The German Reaction

Block 4 Block 3 Block 2 Block 1

www.n-tv.de – ap, dpa

- **Immediate shutdown of older NPPs in Germany**
- **Performance of stress tests in Germany and Europe**
- **‚Ethic Commission' in Germany, nominated by Chancellor A. Merkel**
- **Phase-out of nuclear power in Germany until 2022**

Development of Renewable Energies for Electricity Production in Connection with Decisions on the European and German Level

”The revolution must start now!“

CONCLUSIONS ON ENERGY
EUROPEAN COUNCIL 4 February 2011

“Within the framework of the necessary reductions in industrialized countries as a group, EU has committed to reduce its greenhouse gas emissions to 80 to 95 % below the level of 1990 until 2050… Decarbonization is possible and may be cheaper as current political concepts in the long term.”

INFORMATION OF TEH COMMISSION
“Energy roadmap 2050“ , December 15, 2011

EU targets for electricity from renewable energies: 19% → 34% → 60%...97%
2010 → 2020 → 2050

“The Way towards Energy of the Future“

Government declaration, June 9, 2011

“Renewable energies are to become the central pillar of future energy supply …
If we take this way towards the energy of the future,
opportunities will be much bigger than the risks.“

Federal objectives for electricity from renewable energies: 17% → 35% → 80%
2010 → 2020 → 2050

Source: PK ZSW mit UM Untersteller 09.01.2012

Germany's New Energy Policy

Die Bundesregierung

Karlsruhe Institute of Technology

Germany will develop to one of the most energy-efficient and environmentally friendly economies worldwide.

- Restructuring of the energy system required to allow the transition to a new energy era ('Energiewende').

- Introduction of a long-term Energy Concept (September 2010).
  - 80% cut of green-house gas emissions by 2050 compared to 1990.
  - Renewables to supply the bulk of German energy in the future.
  - 50% reduction of primary energy consumption by 2050.
  - Final energy consumption in the transport sector to be reduced by 40% in 2050 compared to 2005.
  - 2.1% annual increase in energy productivity relative to final energy consumption.

- Adoption of a comprehensive legislative package, known as Energy Package (Summer 2011).

Germany's New Energy Policy

Die Bundesregierung

Karlsruhe Institute of Technology

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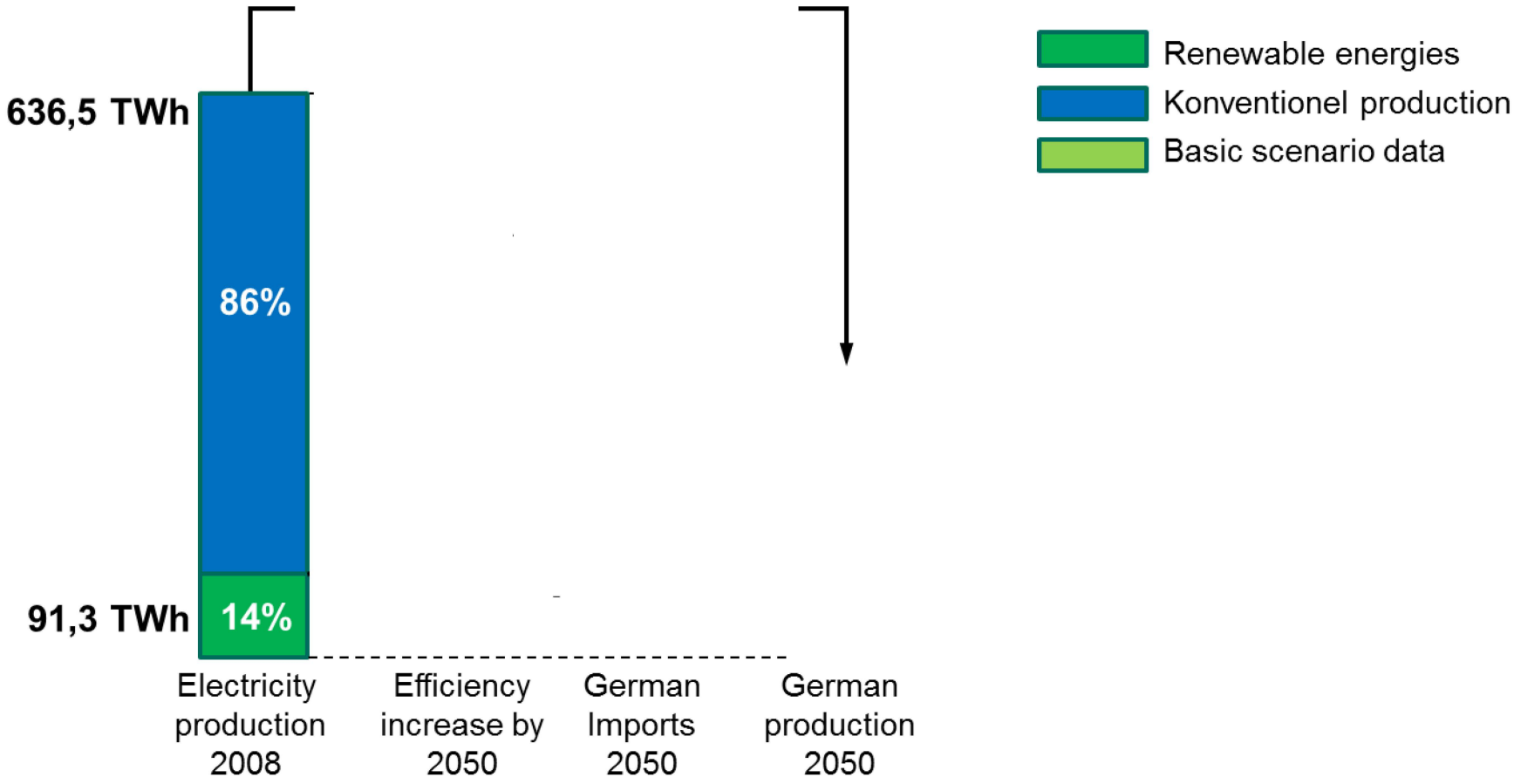
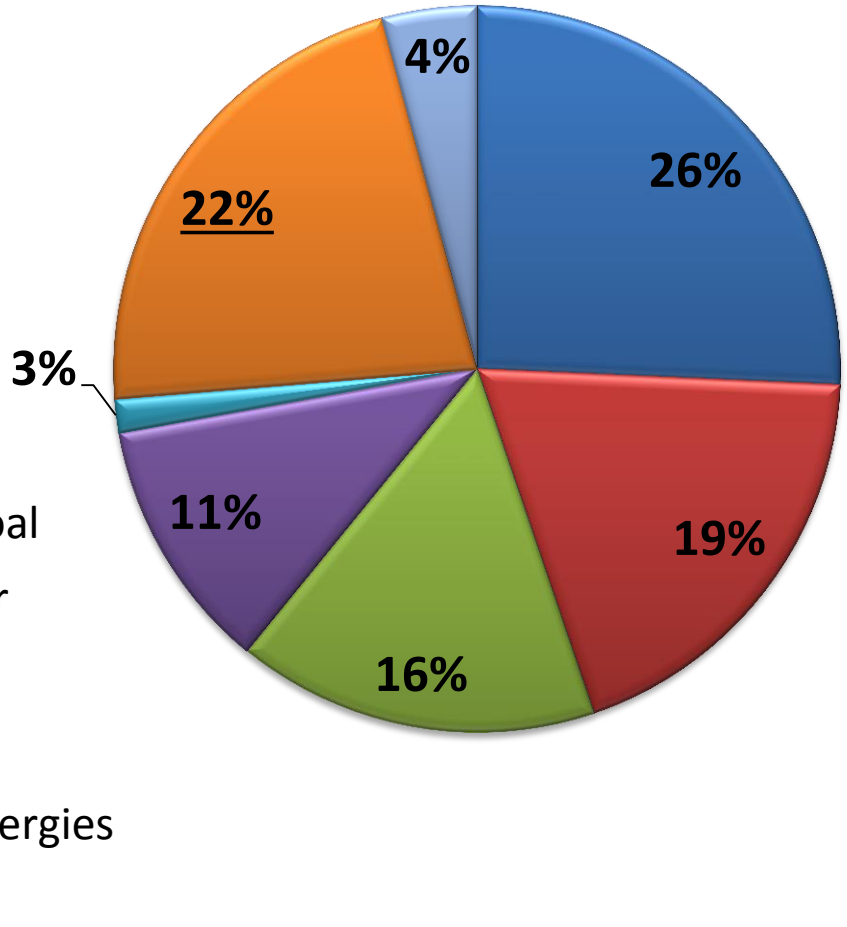
- Adoption of a comprehensive legislative package, known as Energy Package (Summer 2011).
  - Act to restructure the Legal Framework for the Promotion of Electricity Generation from Renewable Energy Sources (EEG).
  - Act on Measures to Accelerate the Expansion of the Electricity Grid (NABEG).
  - Act to Restructure Provisions of the Energy Industry Act (EnWGAndG)
  - Act Amending the Act to Establish a Special Energy and Climate Fund (EKFG-ÄndG)
  - Fourth Ordinance amending the Ordinance on the Award of Public-sector Contracts
  - 13th Act to Amend the Atomic Energy Act (AtomG)
  - Act Strengthening Climate-Friendly Measures in Towns and Municipalities

Energy Concept of German Government 2010
(Basic Scenario)



Electricity Generation in Germany 2012

- **Renewable Energies: 22%**
  - **Wind 7,4%**
  - **Biomass 5,8%**
  - **Hydro 3,4%**
  - **Solar 4,5%**
  - **Municipal Waste 0,8%**



Source: AG Energiebilanzen, 14.2.2013

New Energy for Germany (10/2011) www.bundesregierung.de (1/2)

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- Support of **biomass technologies**.

Source:
http://de.wikipedia.org/wiki/Liste_der_Offshore-Windparks

New Energy for Germany (10/2011) www.bundesregierung.de (2/2)

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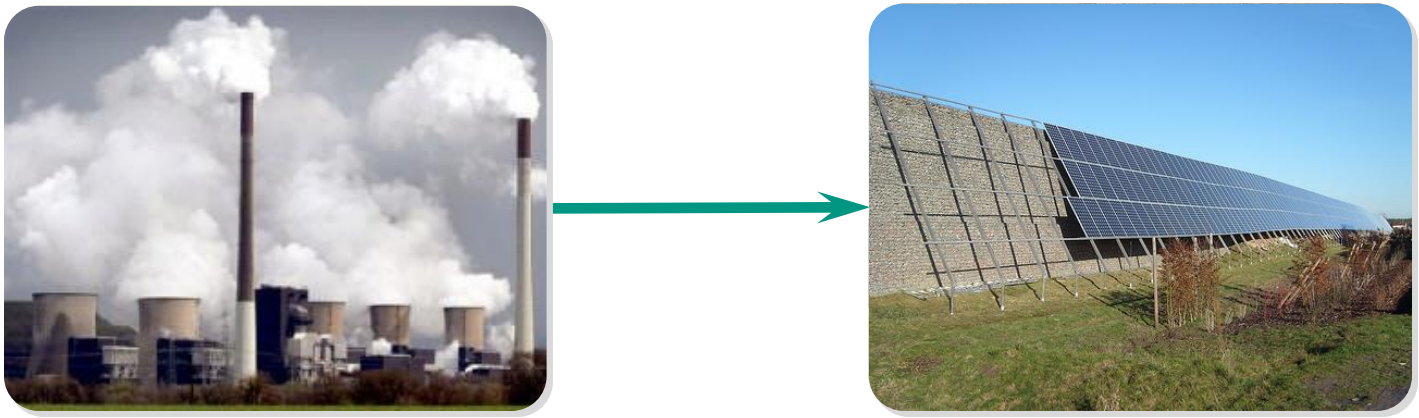
  Public hearing of citizens who are concerned due to new power lines.
- **Energetic renovation and modernisation of buildings**:

  Increase of programme funds for CO_2-efficient buildings.

Source: http://hallo.news352.lu/edito-77382-rieseninvest-in-die-stromautobahn.html

Fundamental New Challenges to Our Energy System

- From point to area
- From central to decentralised
- From direct consumption to storage; i.e. consumer attitude follows energy offers
- Consumer actively controls and provides energy services



Source Fotos: http://www.solar-energie-boden.de and http://www.sonnenfluesterer.de

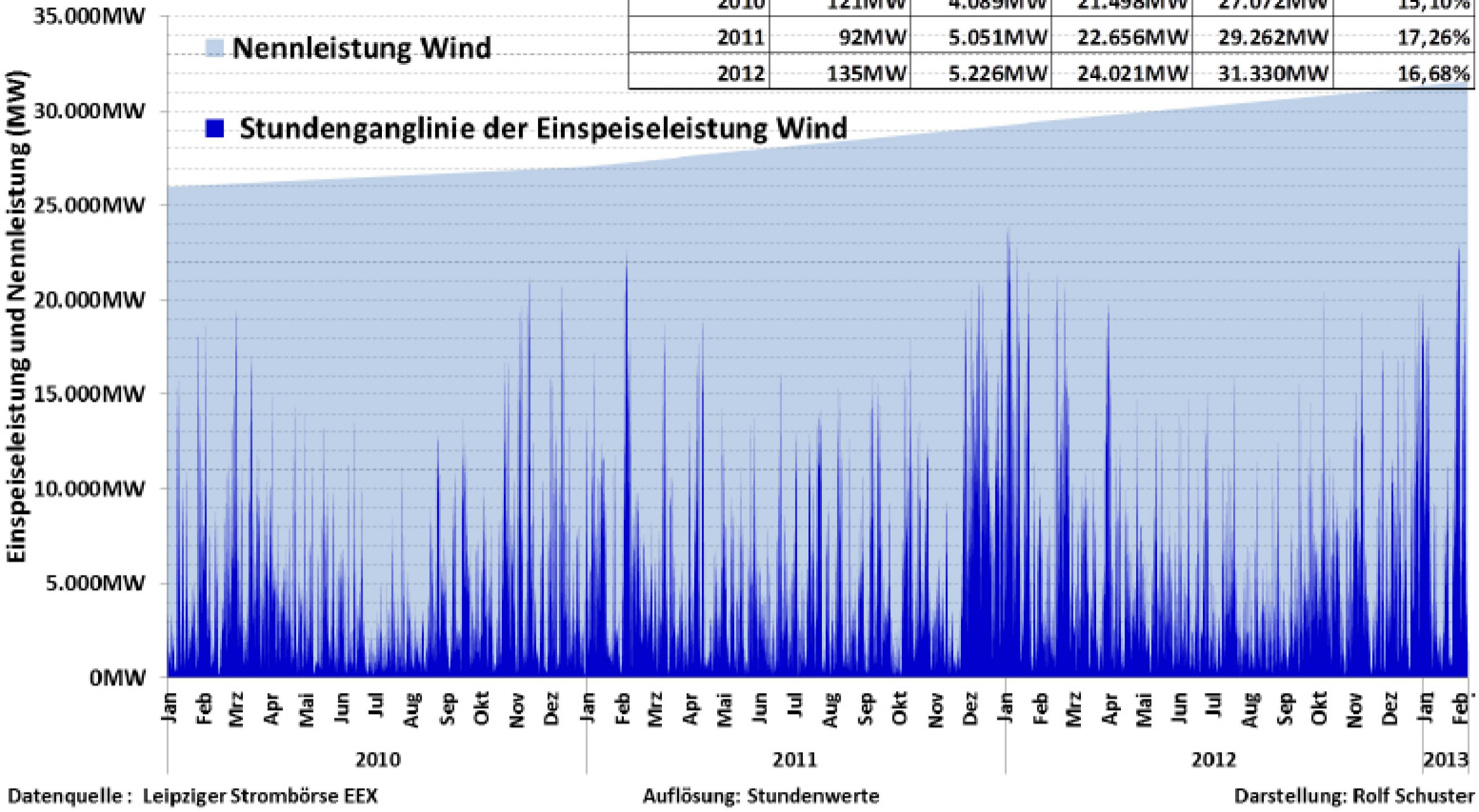
Selected Electricity Data for Germany (2011)

- **Annual peak load electricity: 80 GW**
- **Installed electricity capacity: 160 GW**
- **Reliably available capacity: 93 GW**
- **Thereof based on renewable energies: 12 GW**

- **Annual full load hours:**
  - **Nuclear energy 7,330 hours**
  - **Lignite 6,600 hours**
  - **Biomass 6,400 hours**
  - **Wind 1,380 hours**
  - **Photovoltaics 900 hours**

Source Fotos: http://d1.stern.de/bilder/stern_5/wirtschaft/2011/KW41/energiesparen/erneuerbare_fitwidth_489.jpg
http://www.enbw.com/unternehmen/konzern/energieerzeugung/kernenergie/standorte.html

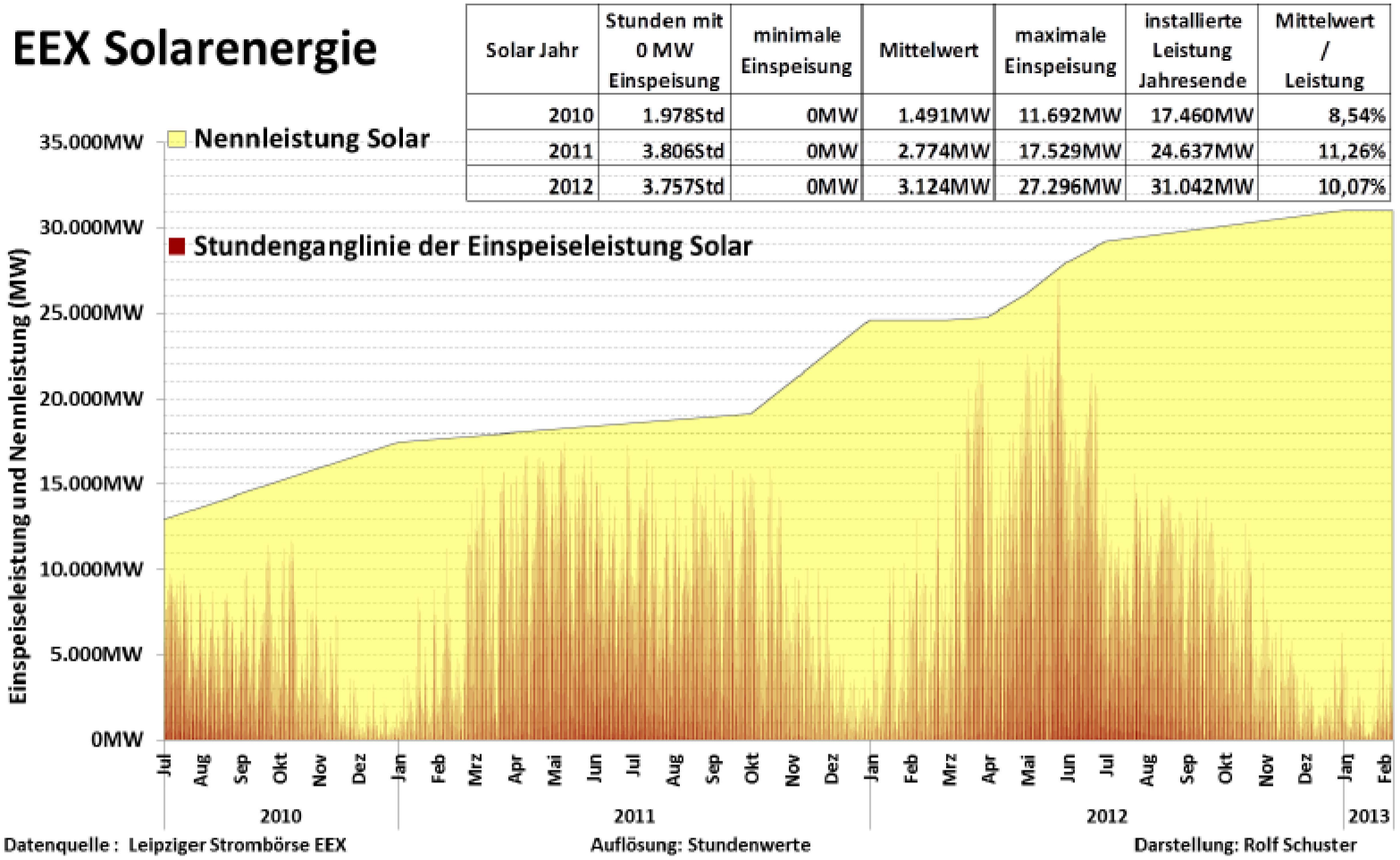
EEX: Wind Energy in Germany (01/2010-02/2013)



Windjahr	minimale Einspeisung	Mittelwert	maximale Einspeisung	installierte Leistung Jahresende	Mittelwert / Leistung
2010	121MW	4.089MW	21.498MW	27.072MW	15,10%
2011	92MW	5.051MW	22.656MW	29.262MW	17,26%
2012	135MW	5.226MW	24.021MW	31.330MW	16,68%

Quelle: Leipzig Electricity Stock Exchange EEX; Karl Linnenfelser

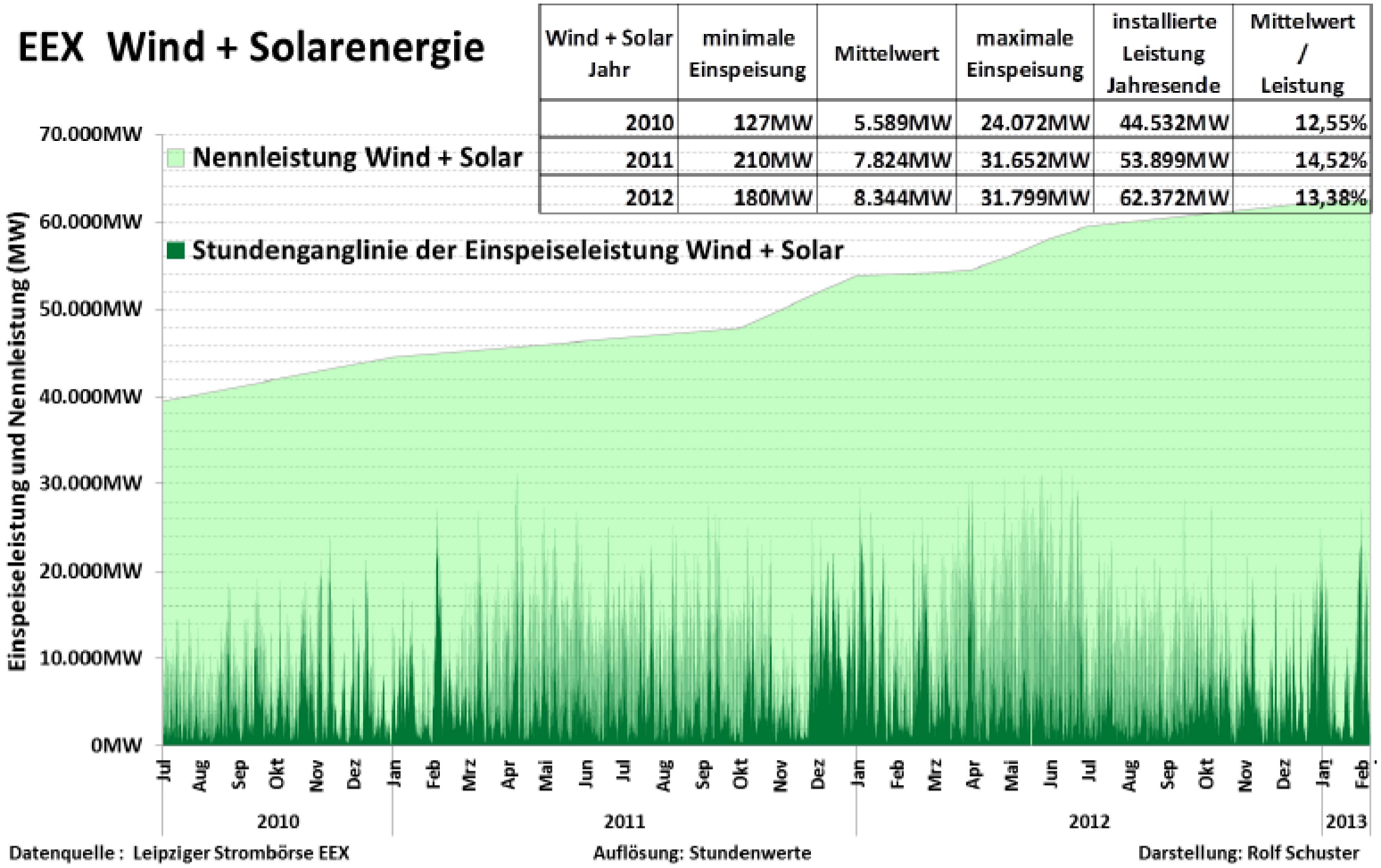
EEX: PV Energy in Germany (01/2010-02/2013)



Solar Jahr	Stunden mit 0 MW Einspeisung	minimale Einspeisung	Mittelwert	maximale Einspeisung	installierte Leistung Jahresende	Mittelwert / Leistung
2010	1.978Std	0MW	1.491MW	11.692MW	17.460MW	8,54%
2011	3.806Std	0MW	2.774MW	17.529MW	24.637MW	11,26%
2012	3.757Std	0MW	3.124MW	27.296MW	31.042MW	10,07%

Quelle: Leipzig Electricity Stock Exchange EEX; Karl Linnenfelser

EEX: Wind & PV Energy in Germany (01/2010-02/2013)

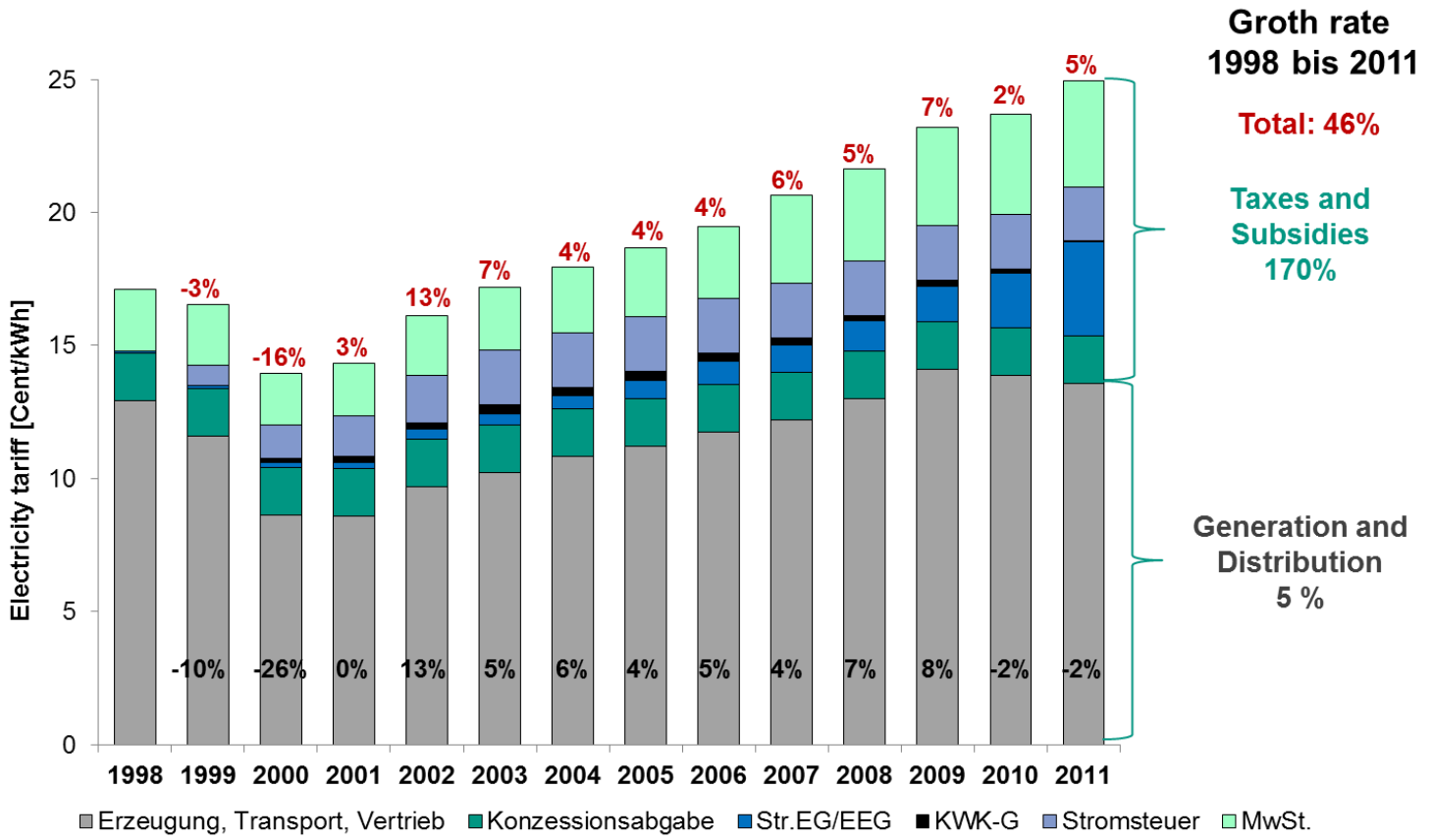


Wind + Solar Jahr	minimale Einspeisung	Mittelwert	maximale Einspeisung	installierte Leistung Jahresende	Mittelwert / Leistung
2010	127MW	5.589MW	24.072MW	44.532MW	12,55%
2011	210MW	7.824MW	31.652MW	53.899MW	14,52%
2012	180MW	8.344MW	31.799MW	62.372MW	13,38%

Quelle: Leipzig Electricity Stock Exchange EEX; Karl Linnenfelser

Electricity Prices for Private Households in Germany

- **Some 20 billion Euro in 2013 to be paid by end-consumers due to EEG Act (Renewable Energies Act).**
- **This is 5.277€Cent per kWh in 2013 (2012: 3.592 €Cent per kWh).**



Quelle: Bundesverband der Energie- und Wasserwirtschaft (BDEW)

Urgent Questions

- **Is the public willing to pay for the ‘Energiewende’?**
- **Is the public willing to change its habits?**

- **What about security of supply?**
- **What about Germany‘s competitiveness?**
- **What about our neighbours?**

- **Can research provide innovative solutions in time?**

http://de.123rf.com/photo_7659991_amsterdam-august-19-2010-crowds-on-the-quay-visit-the-tall-ships-at-sail-2010-in-amsterdam-holland-o.html

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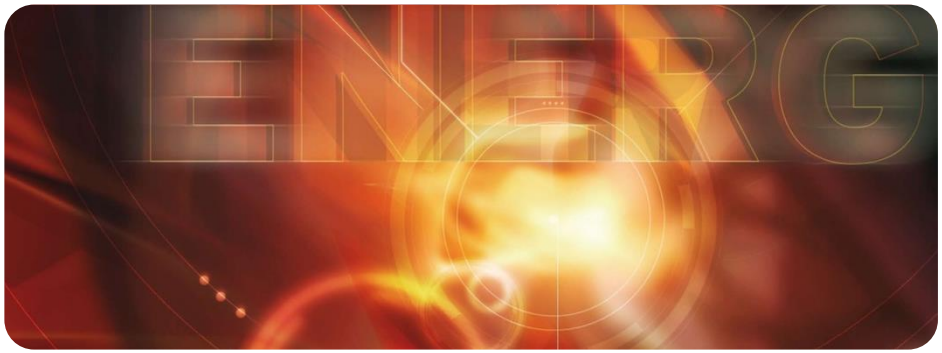
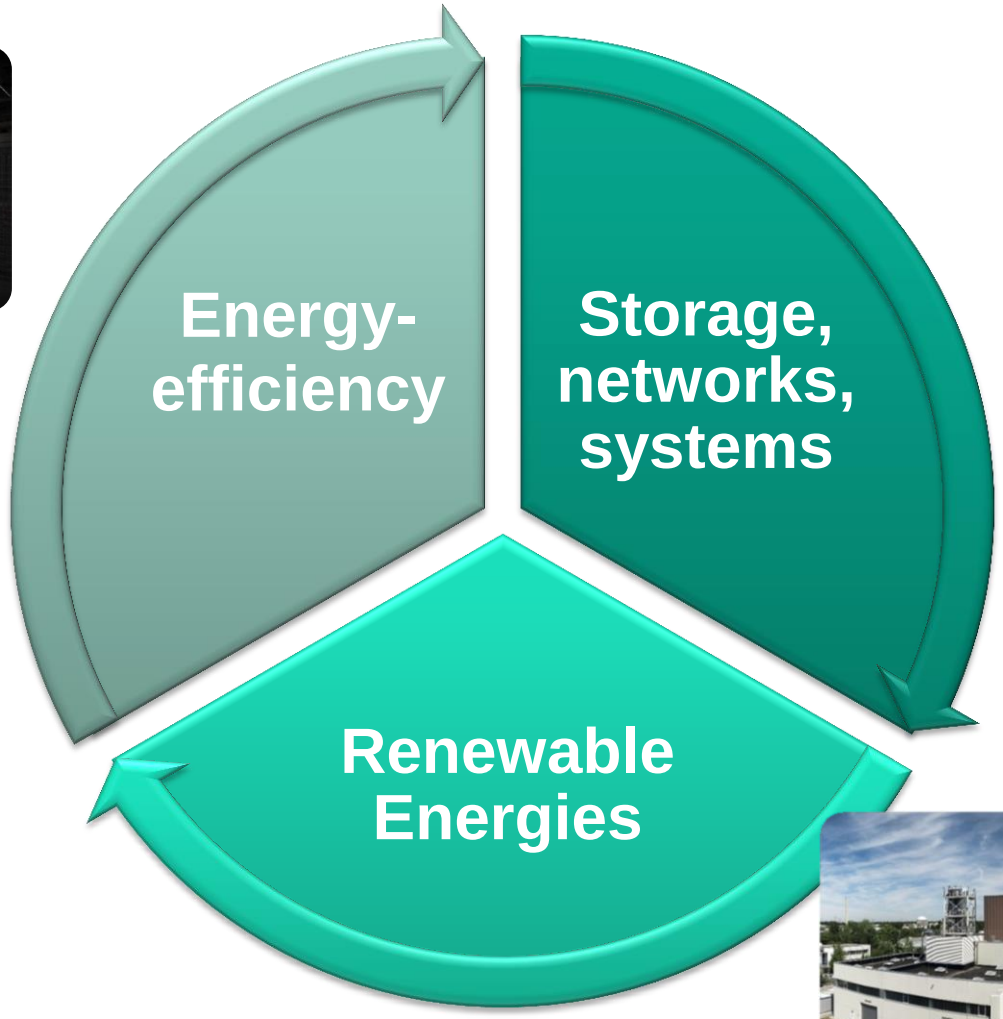


Major Energy Research Topics at KIT Energy Center

Source:
Celitement faciltiy



Source:
Schluchsee plant

Source: bioliq plant

Read more: http://www.energy.kit.edu/

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Source: Getty Images
http://www.spiegel.de/wirtschaft/unternehmen/bild-867202-209317.html

Wind Offshore: Strategy & Portfolio of EnBW

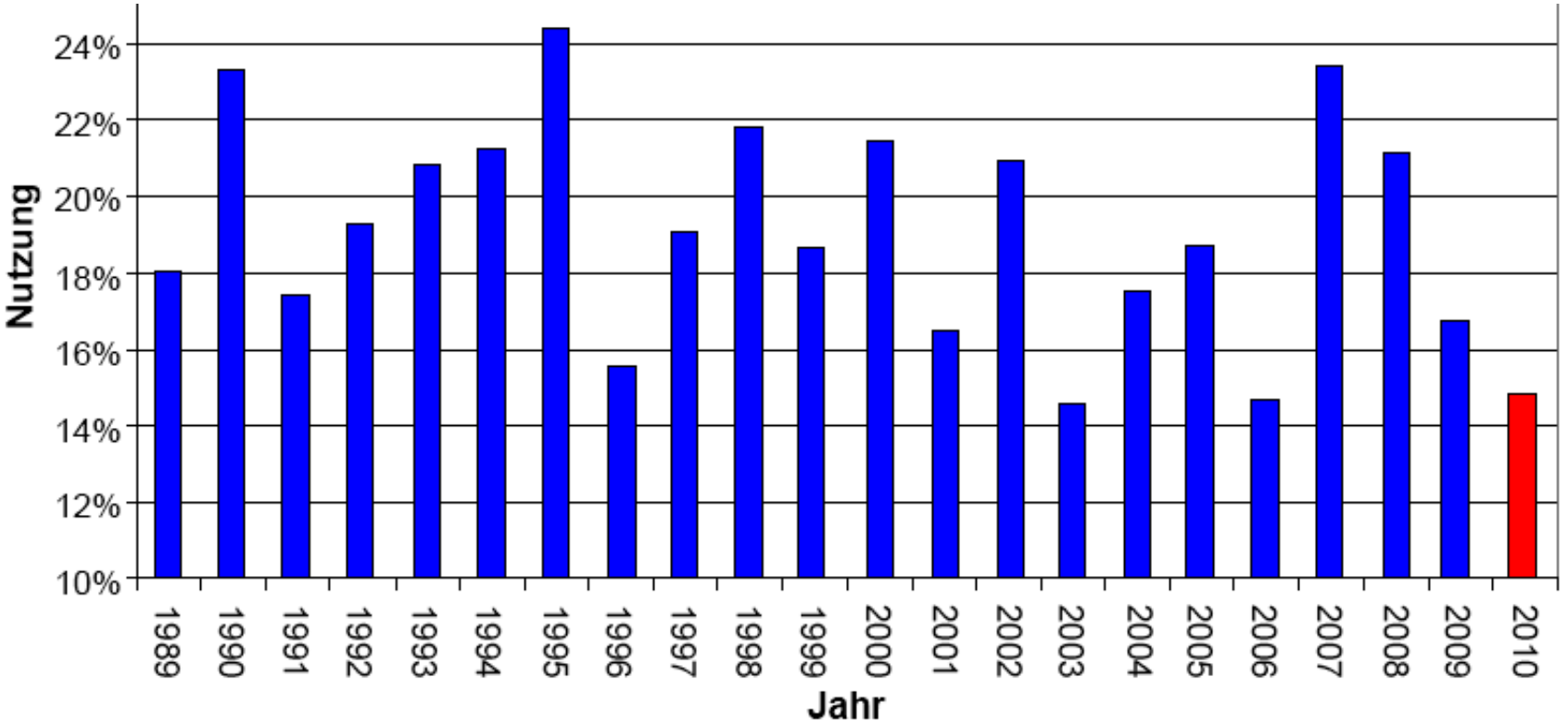
- **Erection of wind farms in North Sea and Baltic Sea.**
- **Stepwise increase of degree of difficulty, i.e.:**
  Water depth, distance from land, turbine size, turbine number.

	EnBW Windpark Baltic 1	EnBW Windpark Baltic 2	EnBW Windpark Hohe See	EnBW Windpark Hohe Dreiht
Distance from land	16 km	32 km	85 km	92 km
Water depth	18 m	30 m	39 m	39 m
Turbine/Park size	2,3 / 48,3 MWel	3,6 / ~288 MWel	5-6 / ~4-500 Mwel	5-6 / ~4-700 MWel
	2010	2013	2014	2016

Source: EnBW November 2011

Average Time Availability of Wind Power in Germany

- Wind generators have a time availability between 15% and 25%.



Source: Vahrenholt 2010
Data in 2010 until July

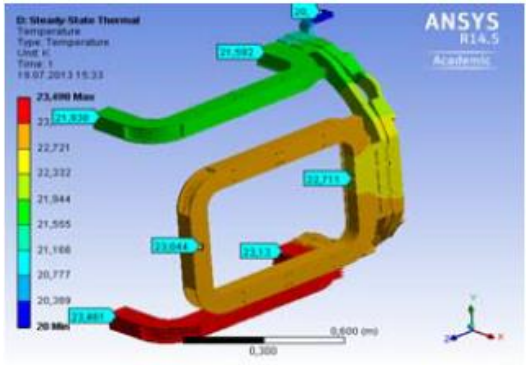
European Research Project: Suprapower

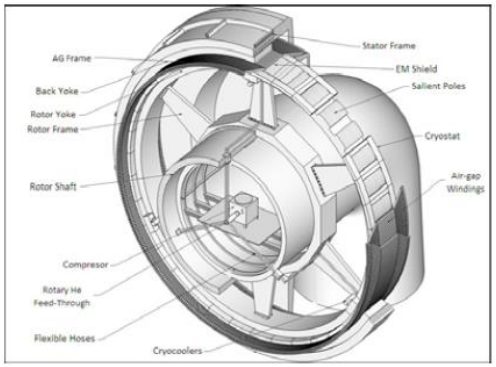
Final Product:

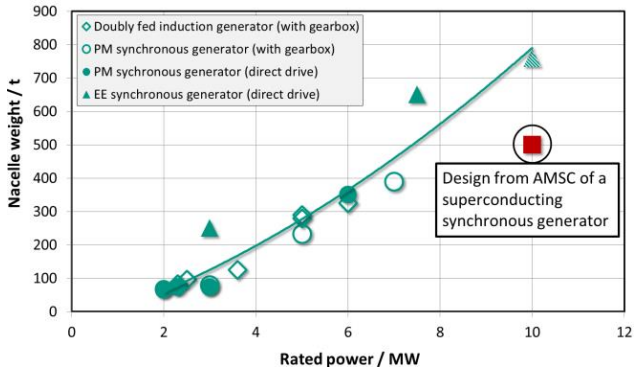
- **Superconducting, reliable, lightweight, and more powerful offshore wind turbine**

Objectives:

- **Reduction of head mass, size and cost (SC-generator)**
- **Reduction of operating, maintenance and transportation cost**
- **Increase reliability and efficiency (direct drive)**
- **Maximization of power conversion**







Source: KIT-ITEP-Neumann

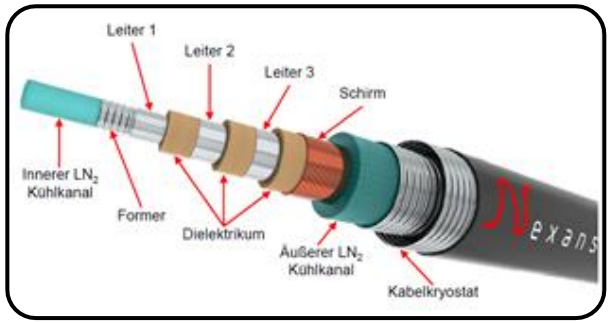
AmpaCity Project: HT Superconducting Cable

Objectives:

- Implementation of a 1 km HTS Power Transmission Line in the urban mid-voltage grid of City of Essen
- Study and layout of an urban SC Mid-Voltage Grid (KIT coordination)
- Test phase of the cable in urban grid > 1 year
- Investigation of cable behavior on a 1:1 model cable (work package KIT)
- Refitting of the model cable with 2nd generation HTS tapes (KIT)
- Development of a universal FEM tool to design/optimize cables (KIT)

Power cable characteristics:

- Designed for 10 kV, 2.3 kA
- Cable lengths 1 km, conductor length 90 km
- Integrated NEXANS HTS Fault Current Limiter
- Superconductor Sumitomo BSCCO-reinforced
- Liquid N2 - cooled



Source: KIT-ITEP-Goldacker

AmpaCity Project: HT Superconducting Cable

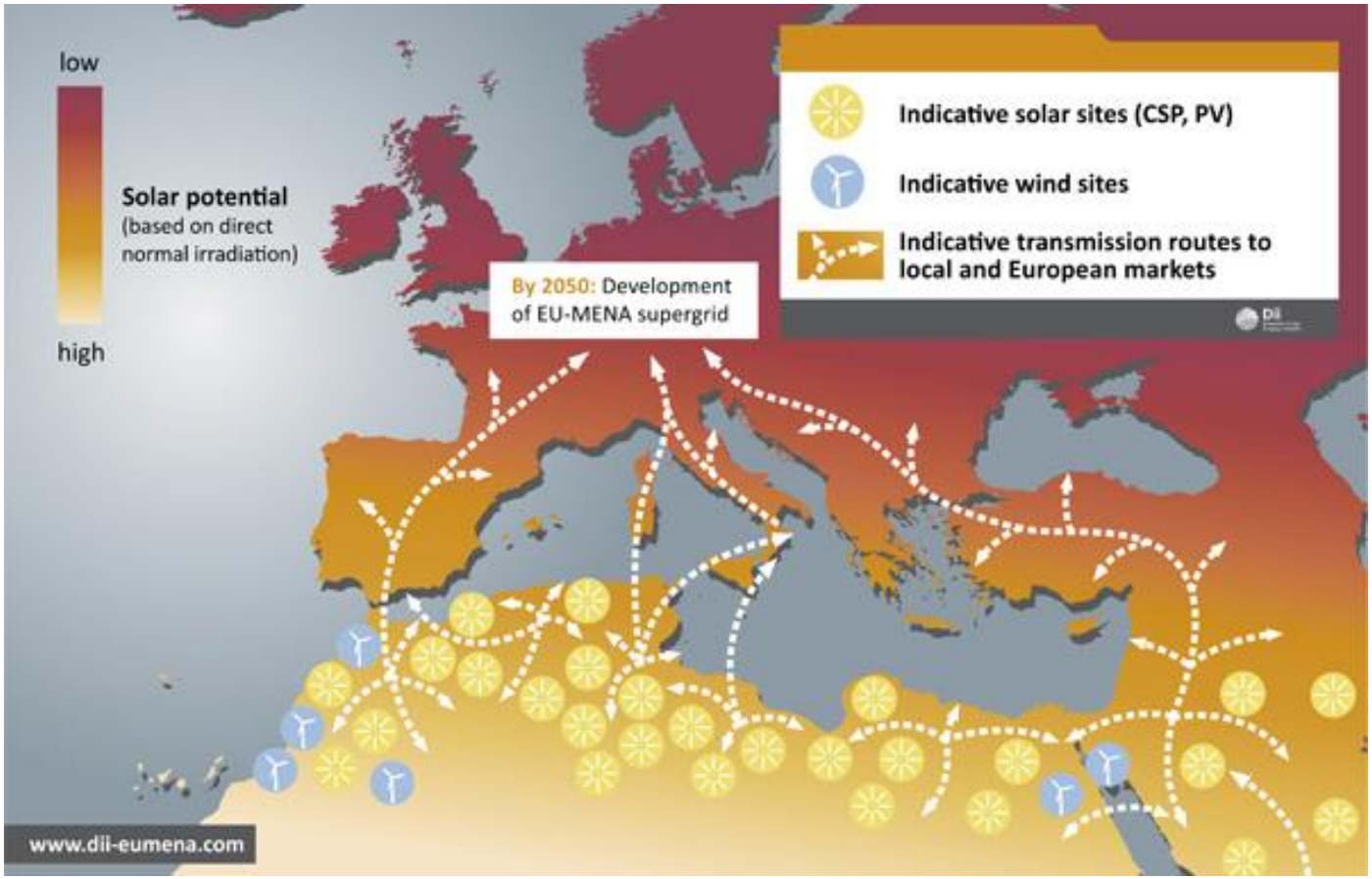
What about another realization at Toronto Lake Shore Drive?

Source: http://commons.wikimedia.org/wiki/File:122_-_Toronto_-_Septembre_2009.jpg

Source: KIT-ITEP-Goldacker

Desertec industrial initiative (Dii)

- **Power from sun and wind in Middle East and North Africa**
- **15% of power could be transported to Europe**



Source: Industrieinitiative Dii, http://www.dii-eumena.com/

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Source: bioliq® Pilot Plant KIT
http://www.kit.edu/visit/pi_2013_12692.php

The Bioliq® Process

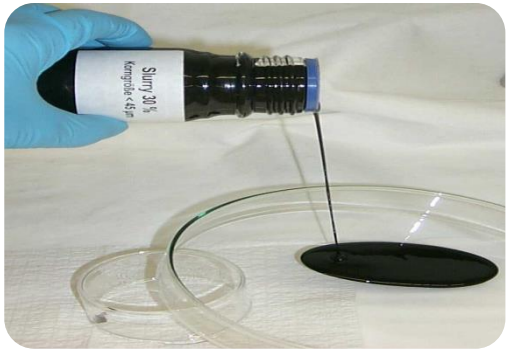
bioliq - pilot plant

- Decentralized energy densification
- Central substantial grafting

Stepwise build-up

biomass conditioning, fast pyrolysis, slurry production
2009/10

gasification
2011/12



gas conditioning, Fuel production
2012/13

Energy density

1,5 GJ/m³ straw

20 GJ/m³ Bioliq® Syncrude

36 GJ/m³ petrol

Bioliq® Pilot Plant at KIT (2011)

Step 1: Fast Pyrolysis, Slurry Production

Step 2: Gasification

Step 3/4: Gas Conditioning, Fuel Production

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  Public hearing of citizens who are concerned due to new power lines.
- **Energetic renovation and modernisation of buildings**:

  Increase of programme funds for CO_2-efficient buildings.

Source: http://www.badische-zeitung.de/suedwest-1/pumpspeicherwerk-atdorf-ueber-die-erste-huerde--38212649.html

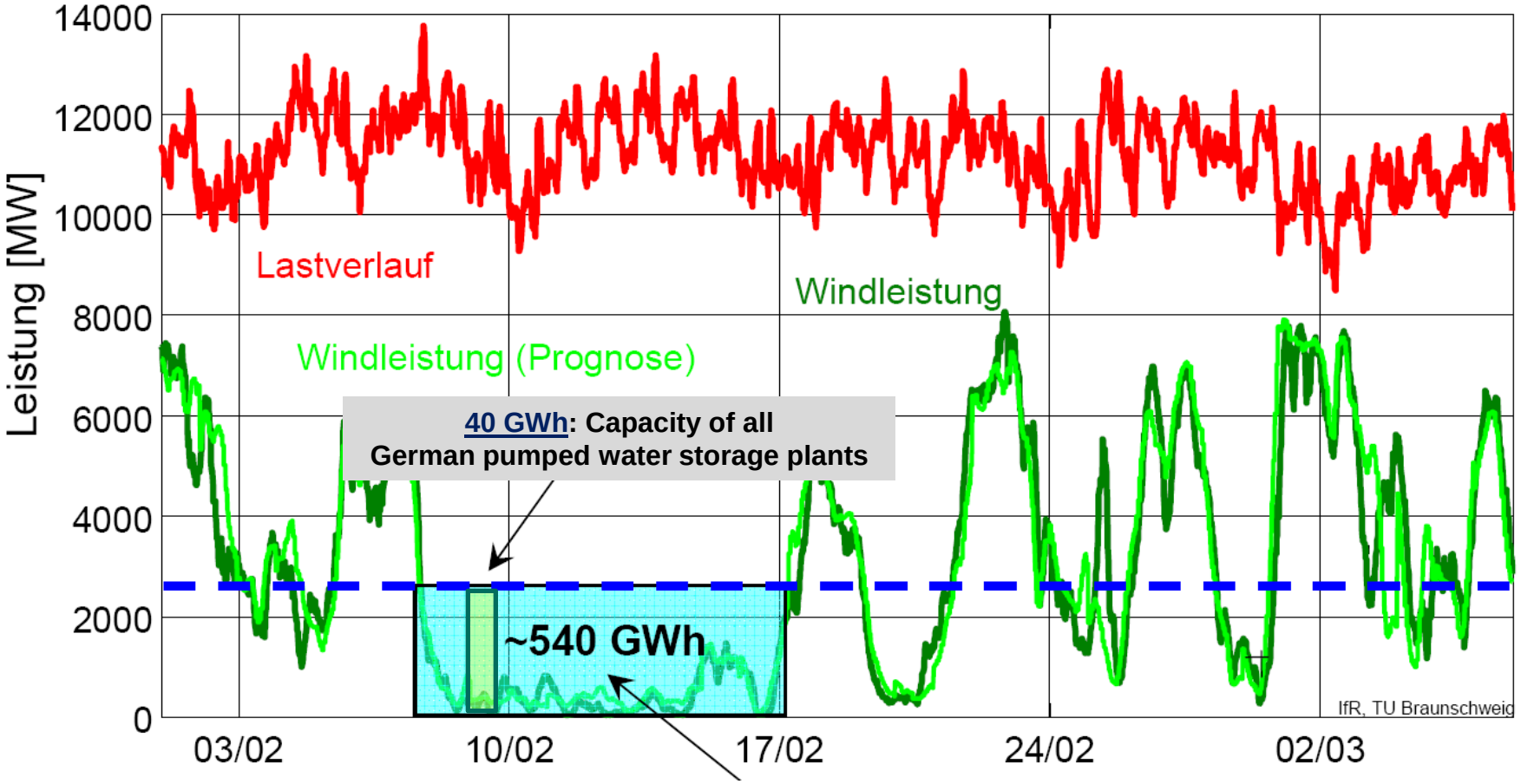
Pump Water Reservoirs

- **Germany: if in 2030 some 30% of the electricity is produced by wind, the required storage capacity is about 3.000 GWh to make up for one week free of wind.**
- **This is about 70 times of today‘s pump water capacity of 40 GWh in Germany.**
- **What about public acceptance?**

Source: Schluchsee Plant Gemeinde Schluchsee. http://schluchsee-wolfsgrund.jugendherberge-bw.de/lage-und-umgebung-fr-sw.html

Wind Energy and Required Storage Capacity

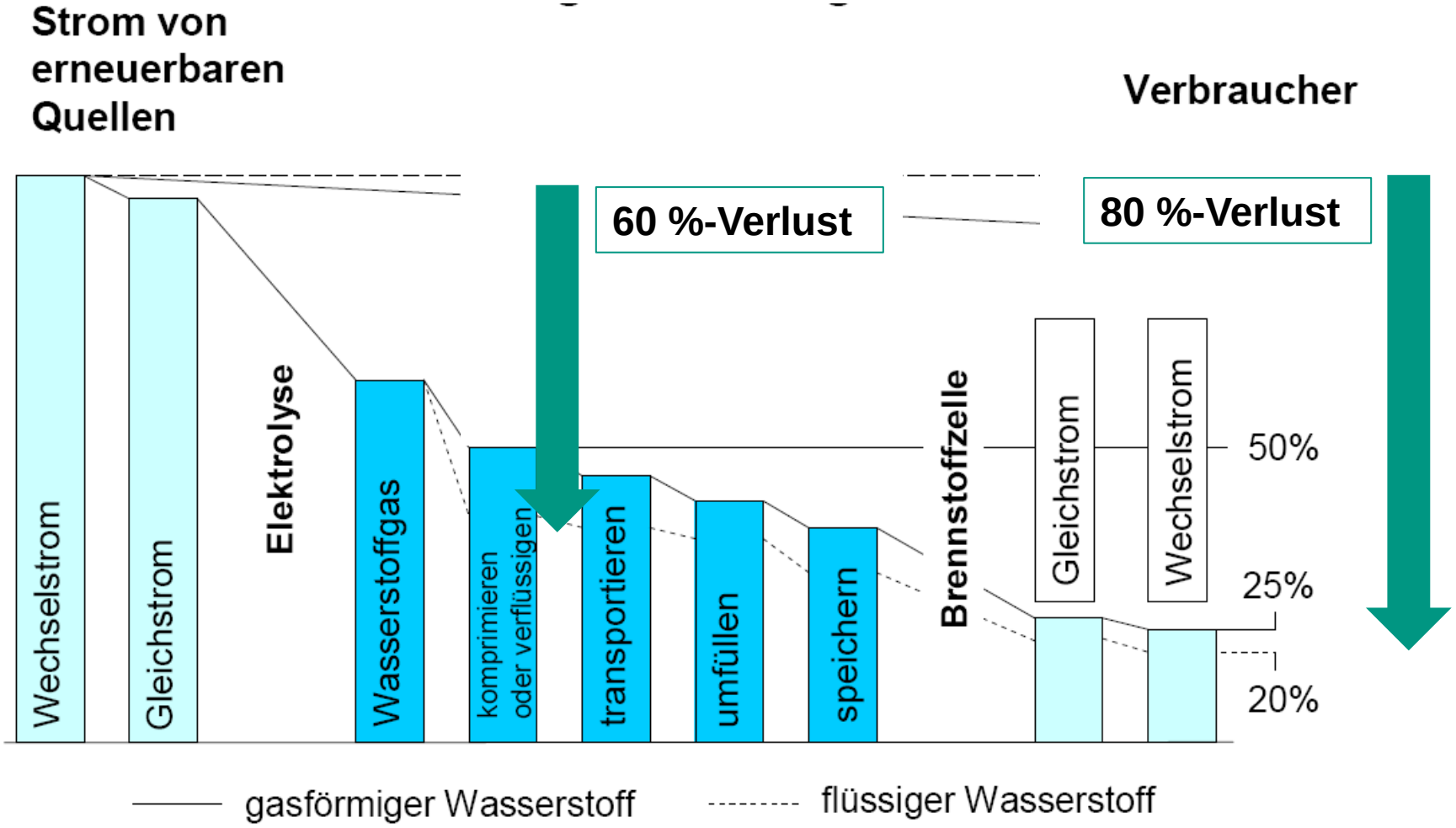
Situation of Transmission Grid Vattenfall Europe February 2008



540 GWh: Required storage capacity to provide continuous, average power supply

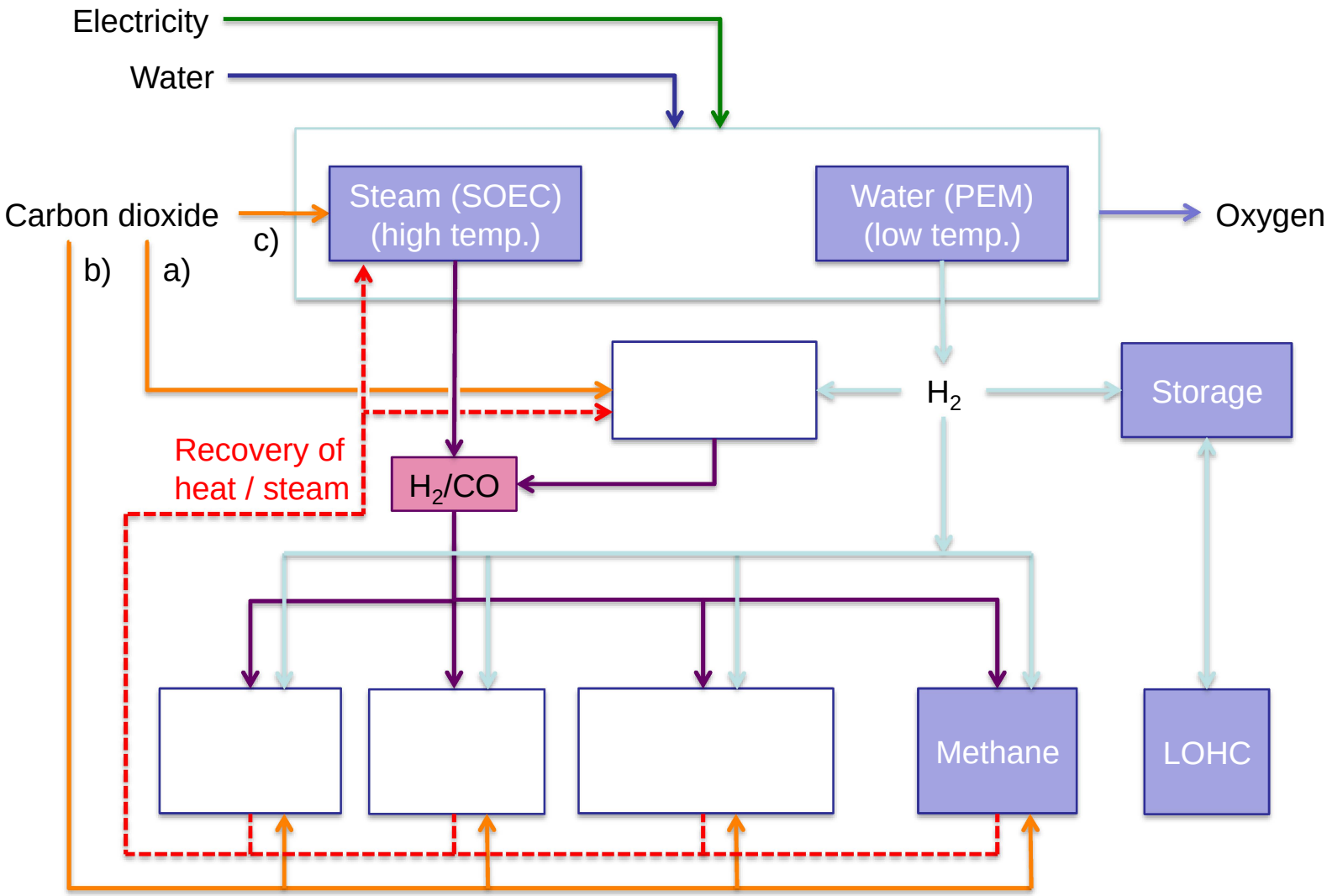
Quelle: IfR, TU Braunschweig, ABB

Hydrogen as Energy Carrier: Process Losses



Quelle: Bossel, European Cell Forum ; Technikfolgenabschätzung Nr. 1, 15 Jg. April 2006

Power-to-Fuels: Cardinal Routes



Source: KIT-IMVT-Dittmeyer

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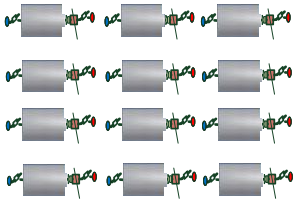
From Fundamentals to Prototypes:
Complete Development up to Battery Level

COMPETENCE E

Karlsruhe Institute of Technology

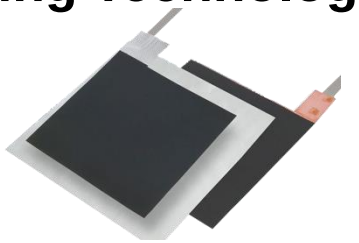
Cell Integration



Cell Assembly

Characterisation

Coating Technology



energy density

power density

costs

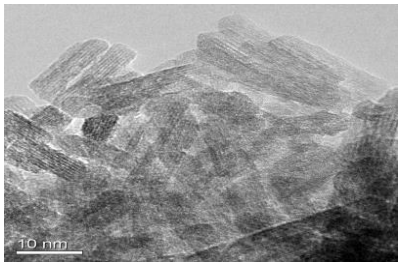
cycle life

reliability

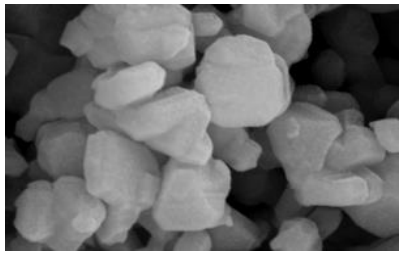
safety

ecology

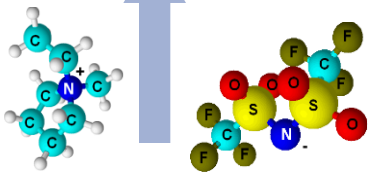
Anode Material



Cathode Material



Electrolyte



System Competence along the Value Chain

Cost-effective product design and production technologies

Material → Cell → Battery → Inverter → E-Motor → Power Train

High-energy Materials

Compact Cell Designs

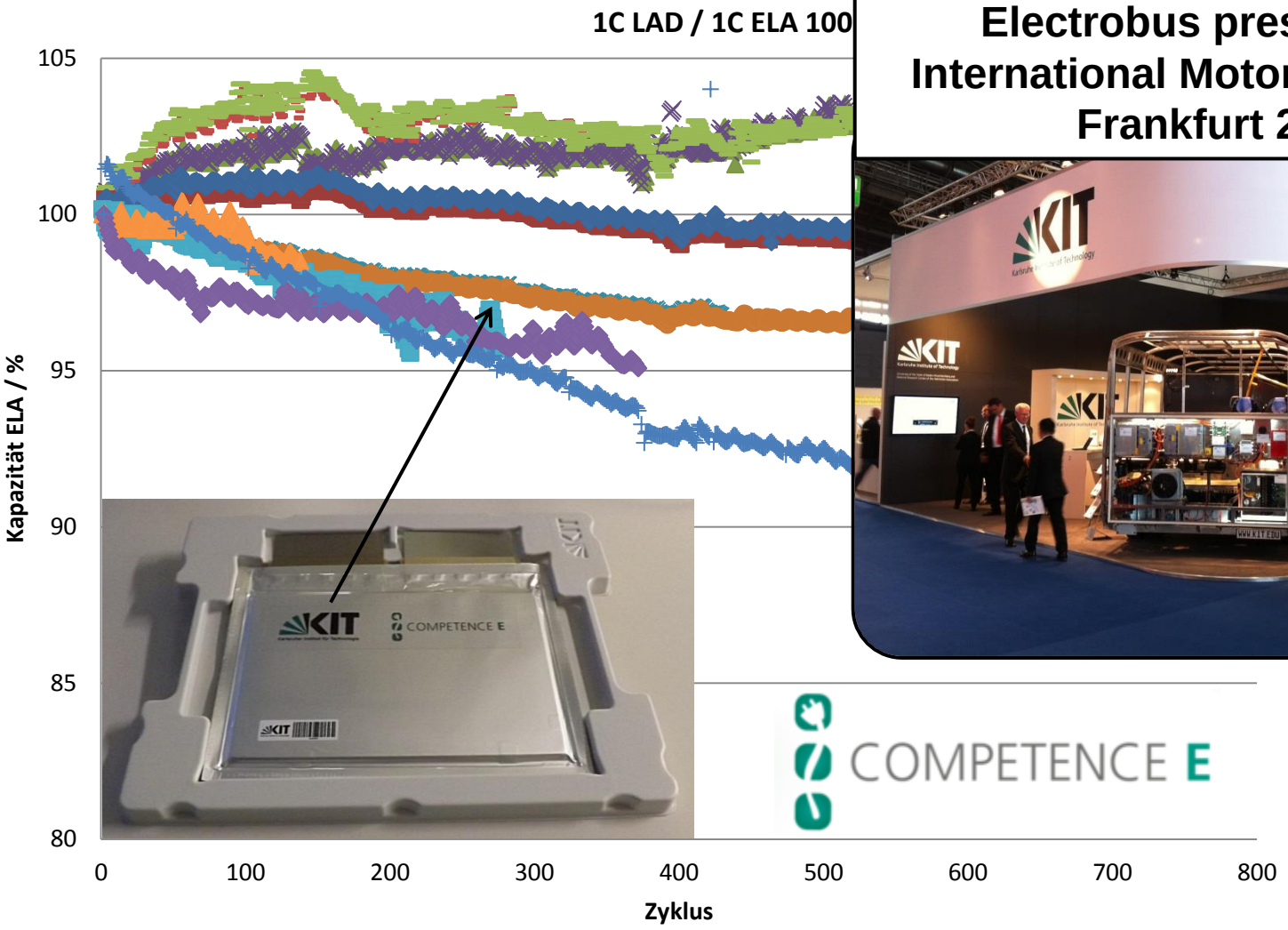
Modular Battery Designs

Optimized Manufacturing Methods

COMPETENCE E

250 €/kWh at 250 Wh/kg
on battery system level in 2018

Cycle Life Performance of KIT 20Ah-Cell Compared to International Benchmark Cells



Electrobus presented at International Motor Show (IAA) Frankfurt 2013

Quelle: Competence E at KIT

Can Full Electric Vehicles Contribute to Store Excess Electricity from Renewable Energies?

- Comparison of storage capacities

Elektroauto	Pumpspeicherkraftwerk
Assumptions: • 1 Mio. FEV (Goal of 2020 in D) as mobile storages in a smart grid • Each having 20 kWh battery storage capacity • 70% availability for storage • 50% free capacity in average	Assumptions: • All German pumped storage water power plants considered • *Atdorf Plant: plus 12.5 GWh*
 Quelle: www.think.no	 
7.000 MWh capacity	**40.000 MWh capacity**

MeRegioMobil: System Integration
User – Energy Sources – Storage Systems

- Intelligent integration of electromobility

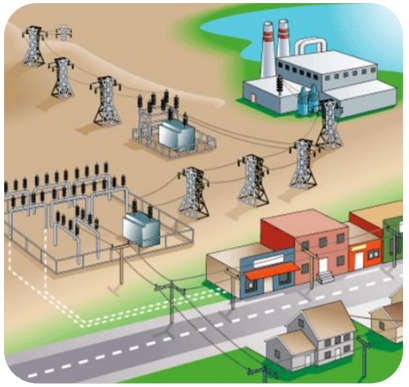
Quelle: KIT-Zentrum Mobilitätssysteme

New Energy for Germany (10/2011) www.bundesregierung.de (2/2)

Germany will develop to one of the most energy-efficient and environmentally friendly economies worldwide.

- To store electricity generated from renewables, there is a need for further **pumped-storage hydropower plants**.
  In parallel, research into **new storage technologies** will be funded.
- Fast enlargement of the **electricity grid** in order to distribute electricity from wind parks and to make up for decentralised production.
  Public hearing of citizens who are concerned due to new power lines.
- **Energetic renovation and modernisation of buildings**:

  Increase of programme funds for CO_2-efficient buildings.



Source: https://uwaterloo.ca/sustainable-energy-policy/sites/ca.sustainable-energy-policy/files/uploads/files/A%20Regional%20Comparison%20of%20Smart%20Grids.pdf

The German Power Grid

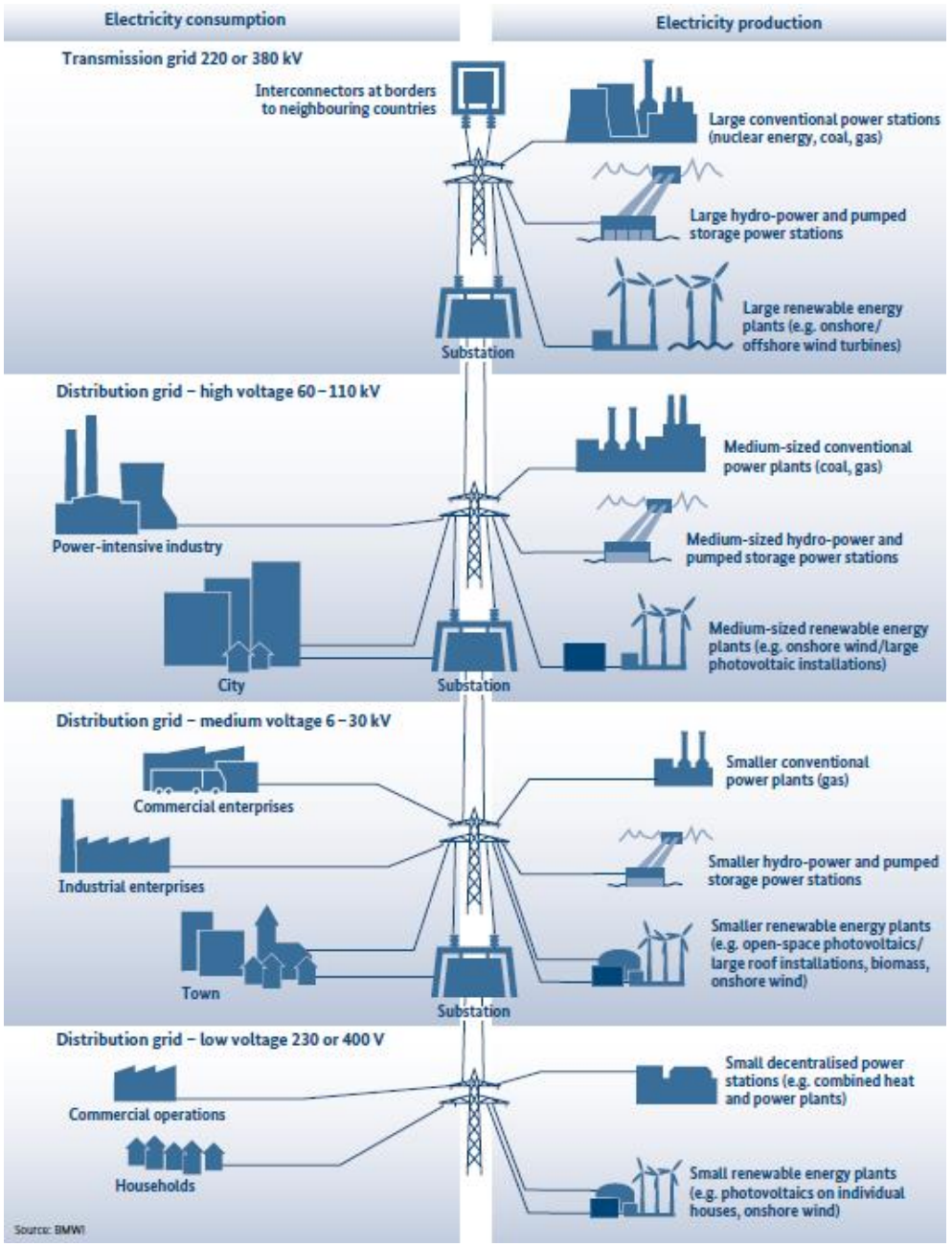
Transmission Grid

- **Extra-high voltage:**
  220kV – 380kV
  35,000 km.

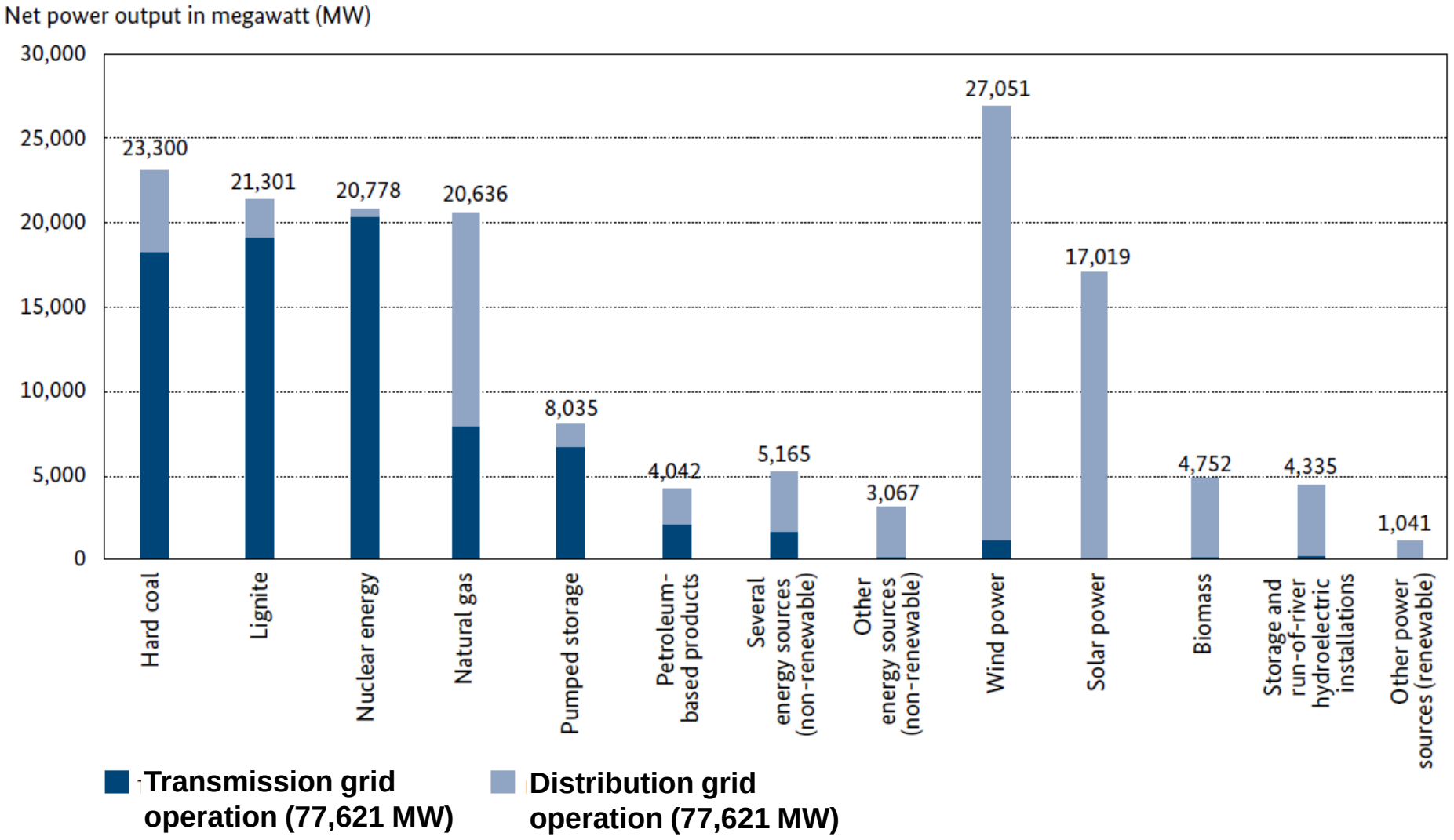
Distribution Grid

- **High voltage:**
  60kV – 110 kV; 80,000 km.
- **Medium voiltage:**
  6kV – 30kV; 500,000 km.
- **Low voltage:**
  230V – 400 V; 1,100,000 km.

- **Today, mainly one-way grid.**



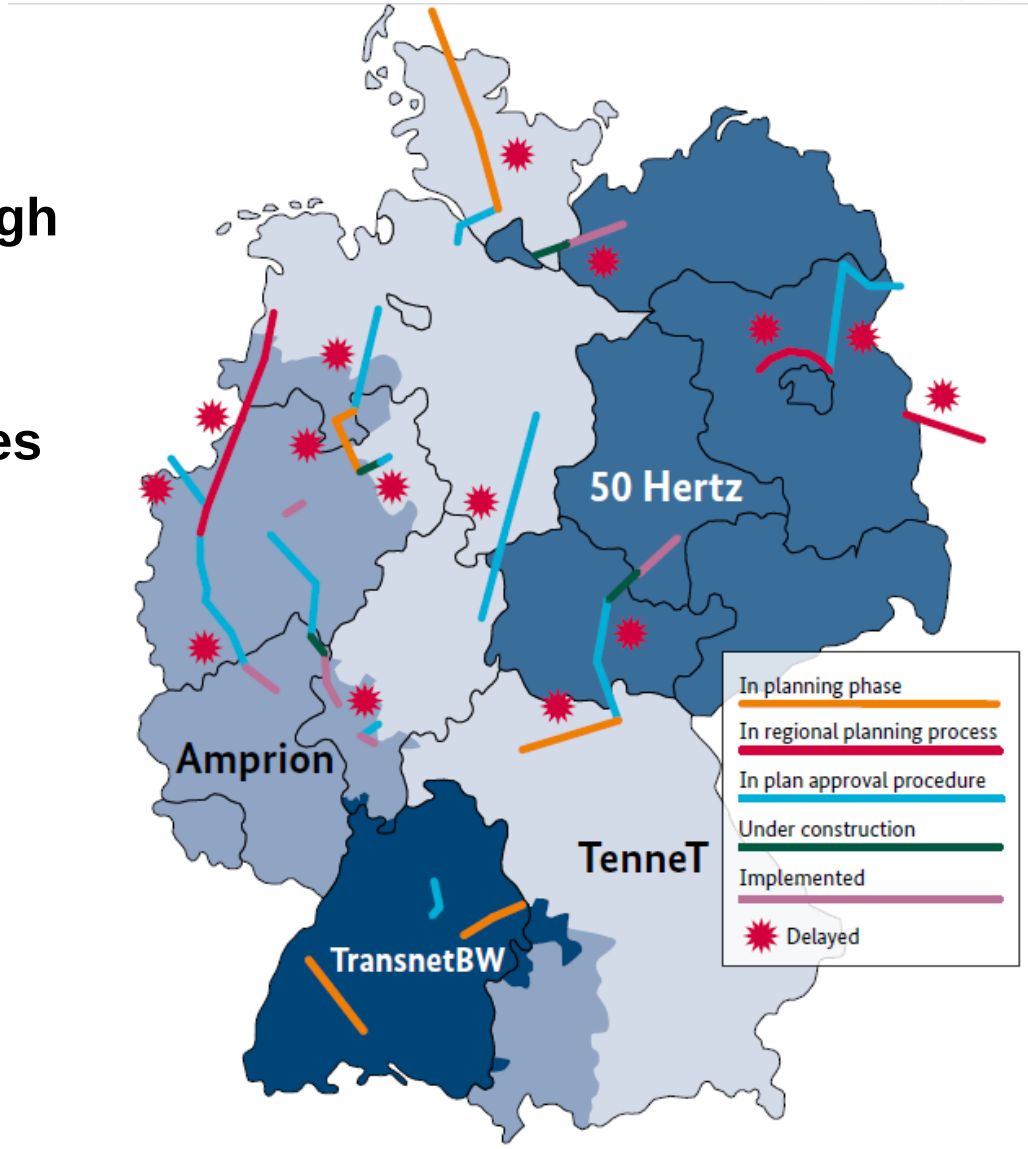
Generation capacity by Energy Source (at 31/12/2010)



Source: Federal Network Agency

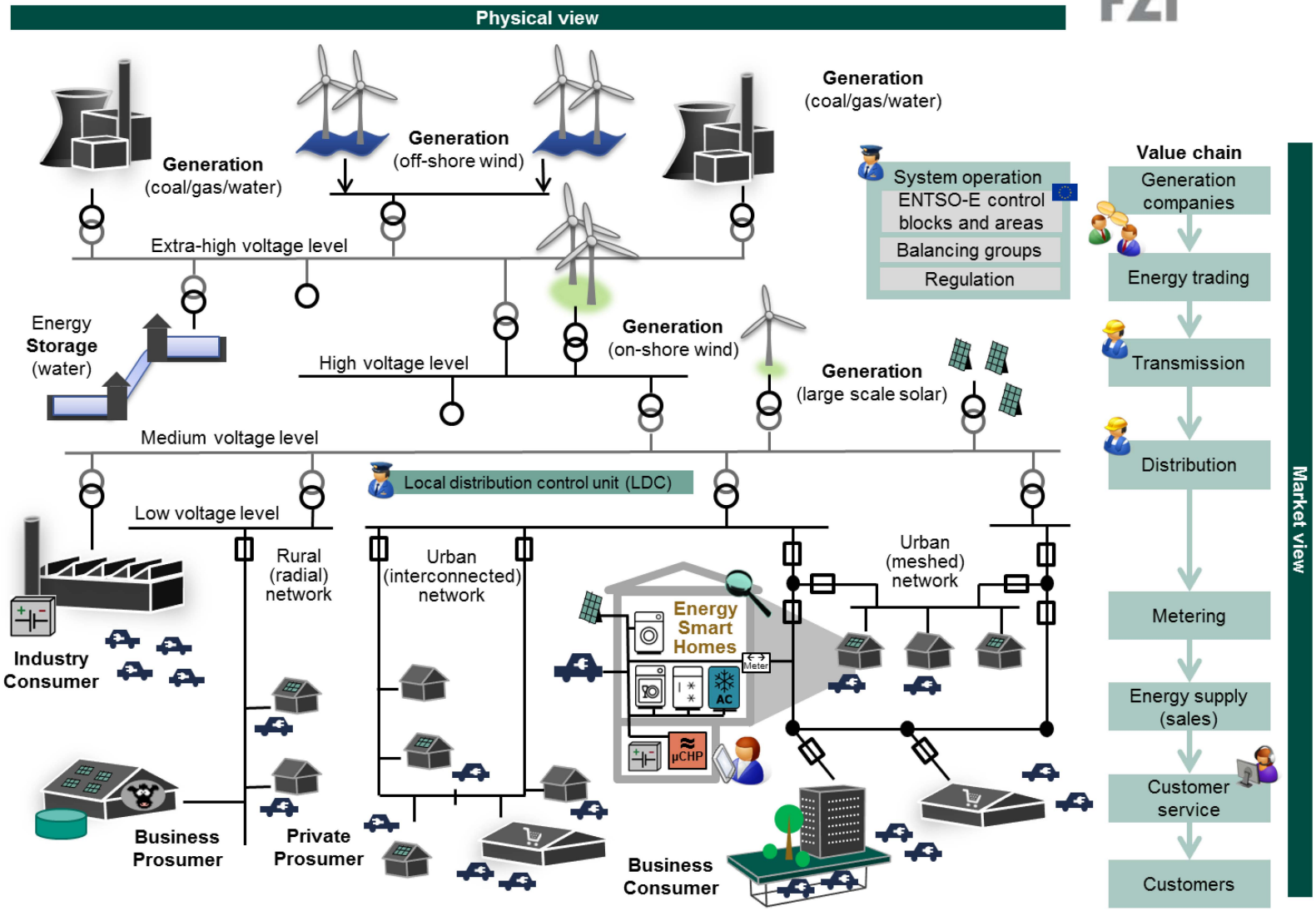
The German Extra-high Voltage Grid
(Status: May 7, 2012)

- **Some 4,500 km of extra-high voltage lines required by 2020.**
- **Wind power almost doubles from 2012 to 2020.**
- **1,900 km are prioritised.**
- **Just over 200 km have yet been built.**



Source: Federal Network Agency

Smart Energy Systems Vision



Source: KIT-AIFB, FZI, Hartmut Schmeck

Shaping Future Energy Systems: Research on Energy Management

Goal:

- Exploit **load flexibility** to provide **virtual storage** by decentralized load management (load shaping, load shifting)
- Provide **ancillary services** for **grid stabilization** (reactive power, operating reserve)

Different Environments:

- **Smart Home**
  - Intelligent household appliances with Smart Grid capabilities
  - Usage of home automation systems for energy management

- **Smart Building / Smart Office**
  - Building energy management (HVAC)
  - Intelligent decentralized power generation

- **Smart Factory**
  - Efficient production processes with optimized usage of renewable energies (Green Production)
  - Offering demand response and reduction of peak loads

Energy Smart Home Lab on KIT Campus

Karlsruher Institut für Technologie

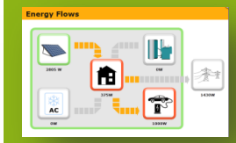
izeus

MeRegio Mobil

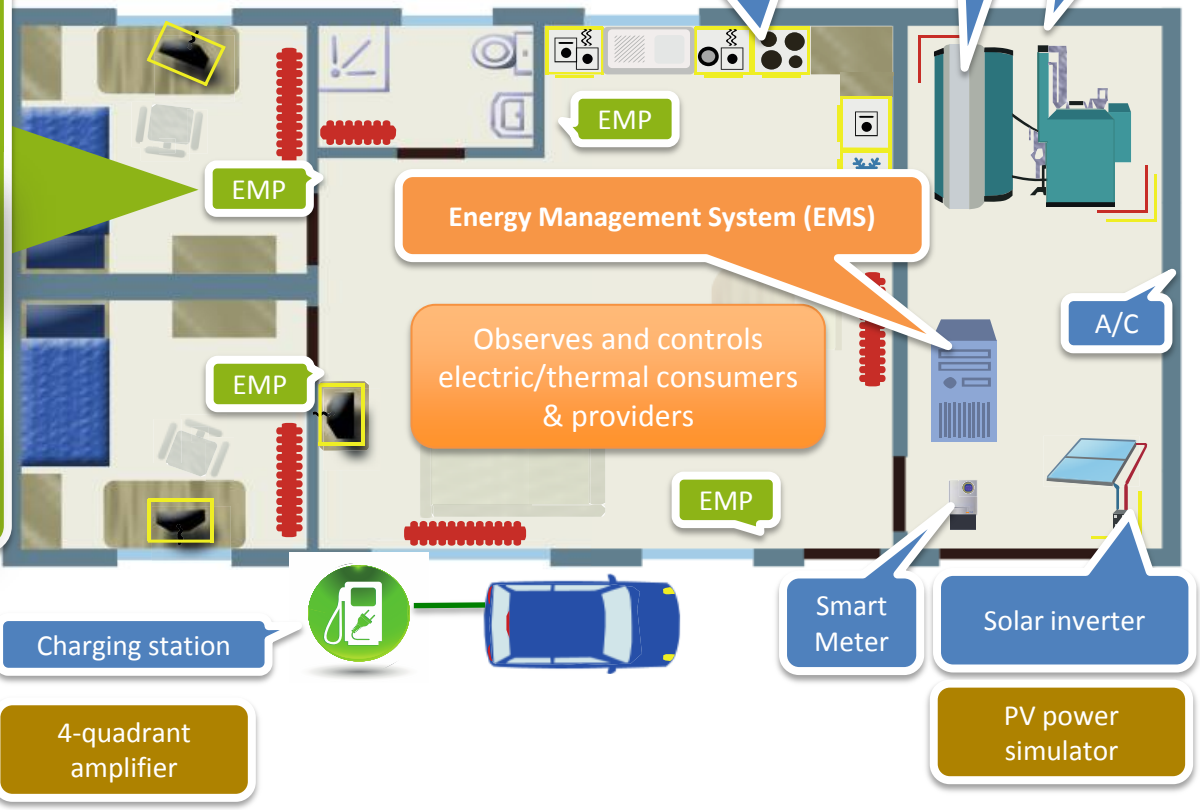
FZI

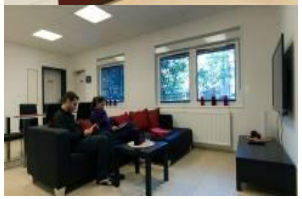
Energy Management Panel (EMP)

Visualisation of energy usage



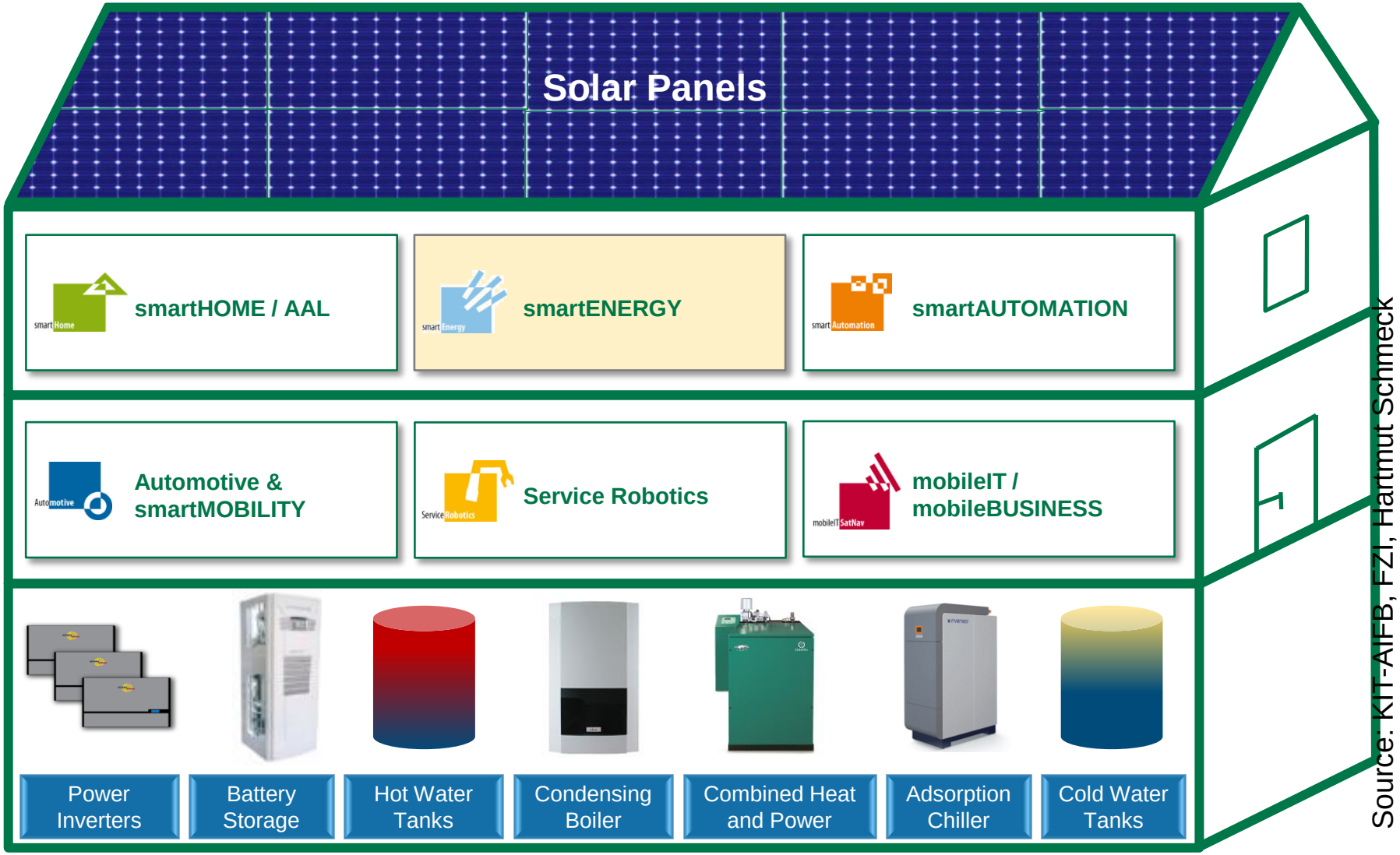
Discover user preferences





Source: KIT-AIFB, FZI, Hartmut Schmeck

FZI House of Living Labs (HoLL)



Source: KIT-AIFB, FZI, Hartmut Schmeck

Nuclear Energy and Safety

- Safety of Nuclear Reactors
- Partitioning & Transmutation
- Nuclear Waste Disposal
- Radiation Protection
- Nuclear Decommissioning Technologies

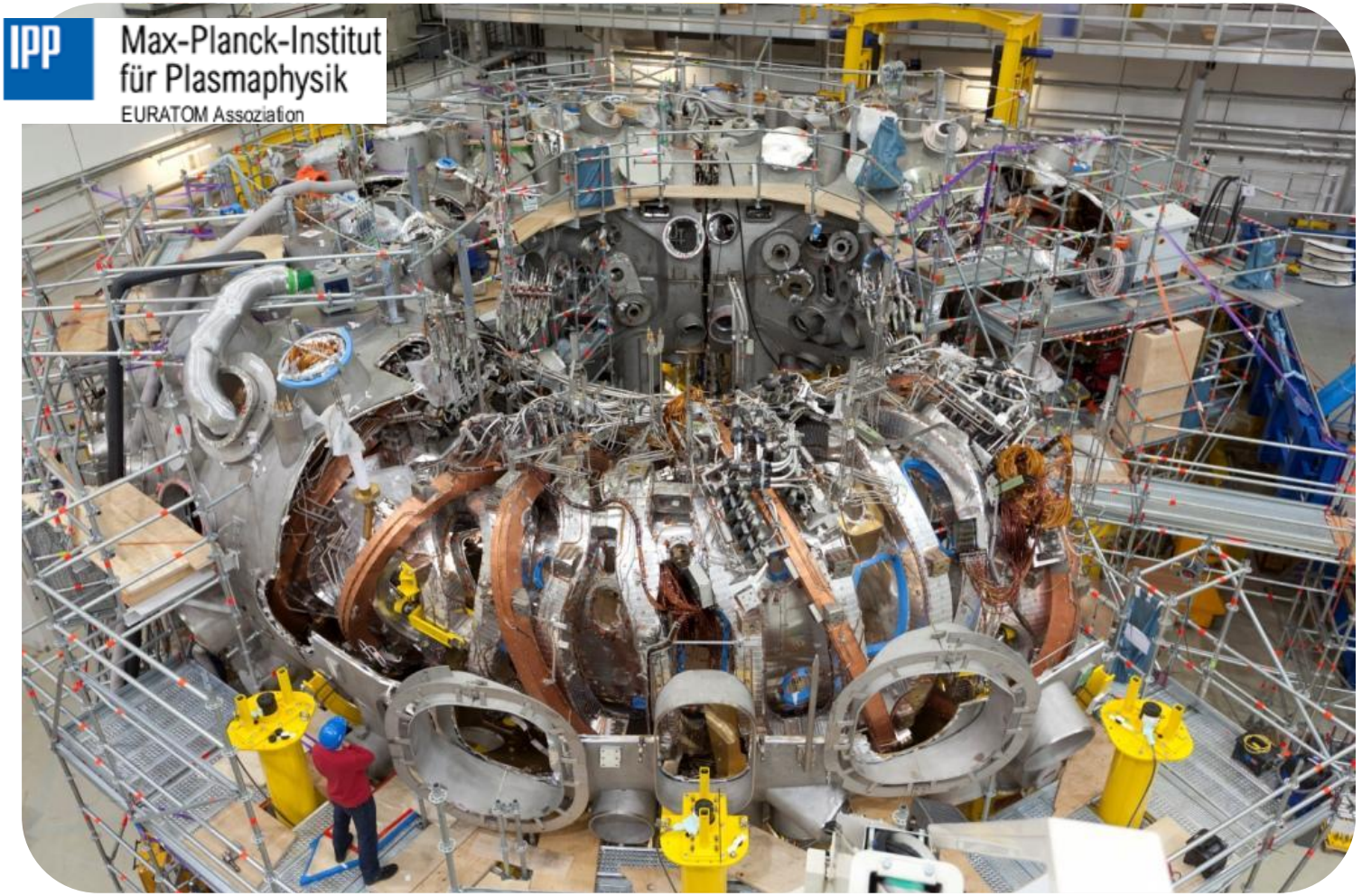
Fusion Technology

- Tritium Technology
- Breeder Blanket
- Structural Materials
- Divertor Technology
- Fusion Magnets
- Gyrotrons
- Fusion Projects:

  ITER, DEMO, IFMIF, W7X

Wendelstein W7X at IPP Greifswald Germany

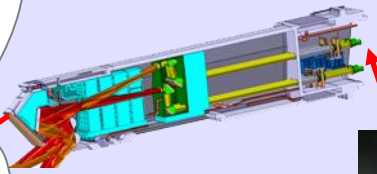
- Bird‘s eye view

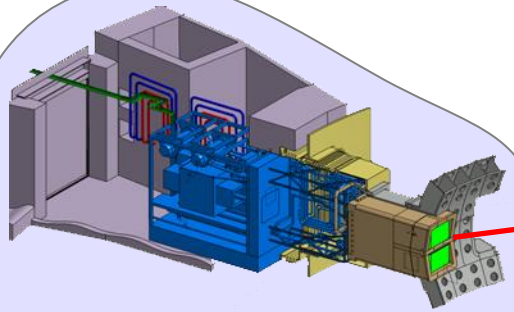


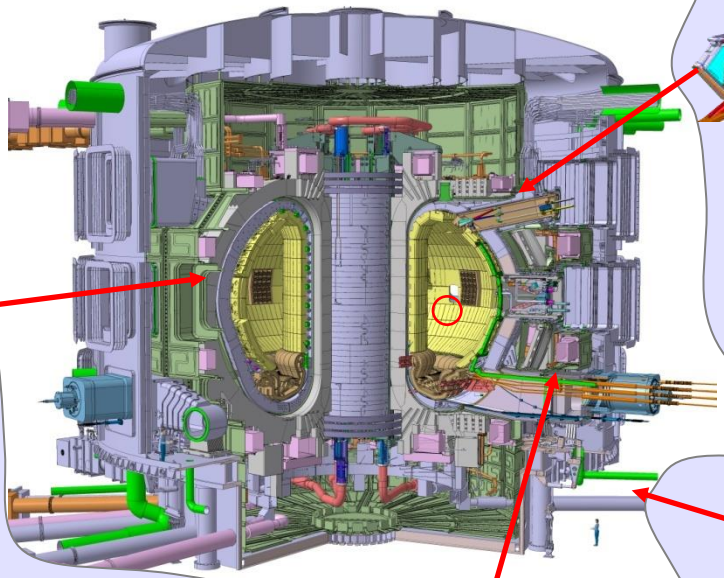
KIT‘s Contributions to ITER

- Safety Research

- Plasma heating & Operation
- Gyrotrons
- ECRH Upper Launcher







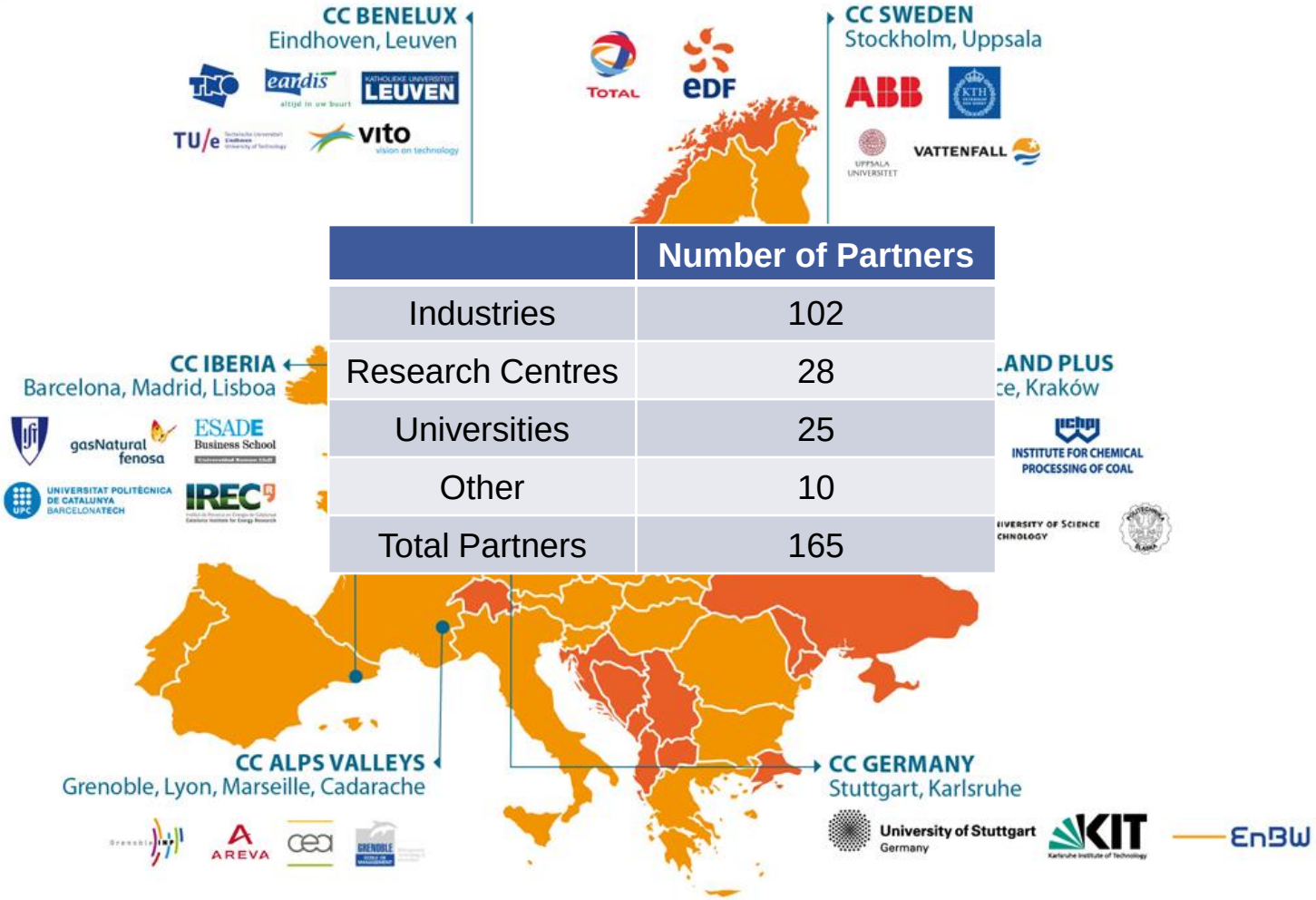
- Test blanket module & systems
- Tritium fuel cycle
- Vacuum systems

- Magnet development from cable to test
- Current leads

Content

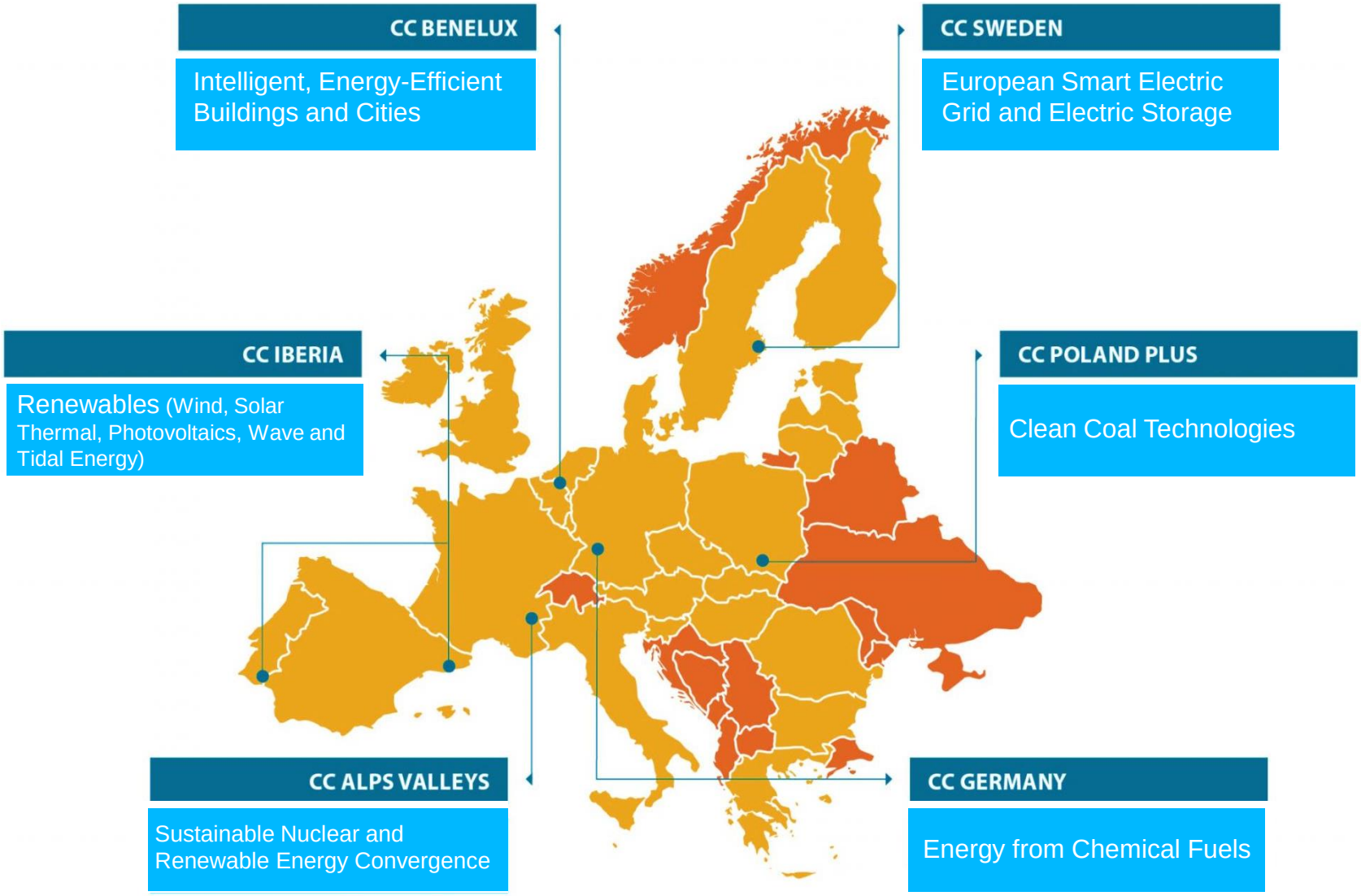
- Introduction to KIT
- German Energy Turnaround (‘Deutsche Energiewende’)
- Research into Storage, Efficiency, Renewables, Fission / Fusion
- **Europe Energy Perspectives**

KIC InnoEnergy – Development of the European Energy System in 2050

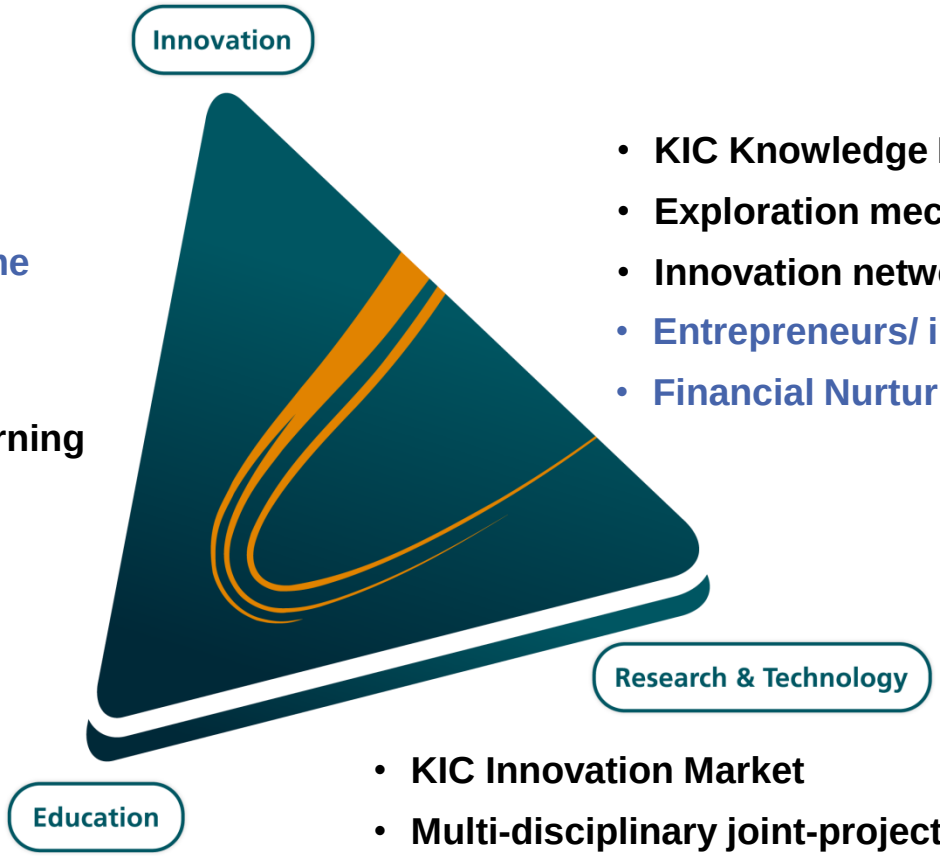


	Number of Partners
Industries	102
Research Centres	28
Universities	25
Other	10
Total Partners	165

KIC InnoEnergy – Partners and Topics



Integration of the knowledge triangle



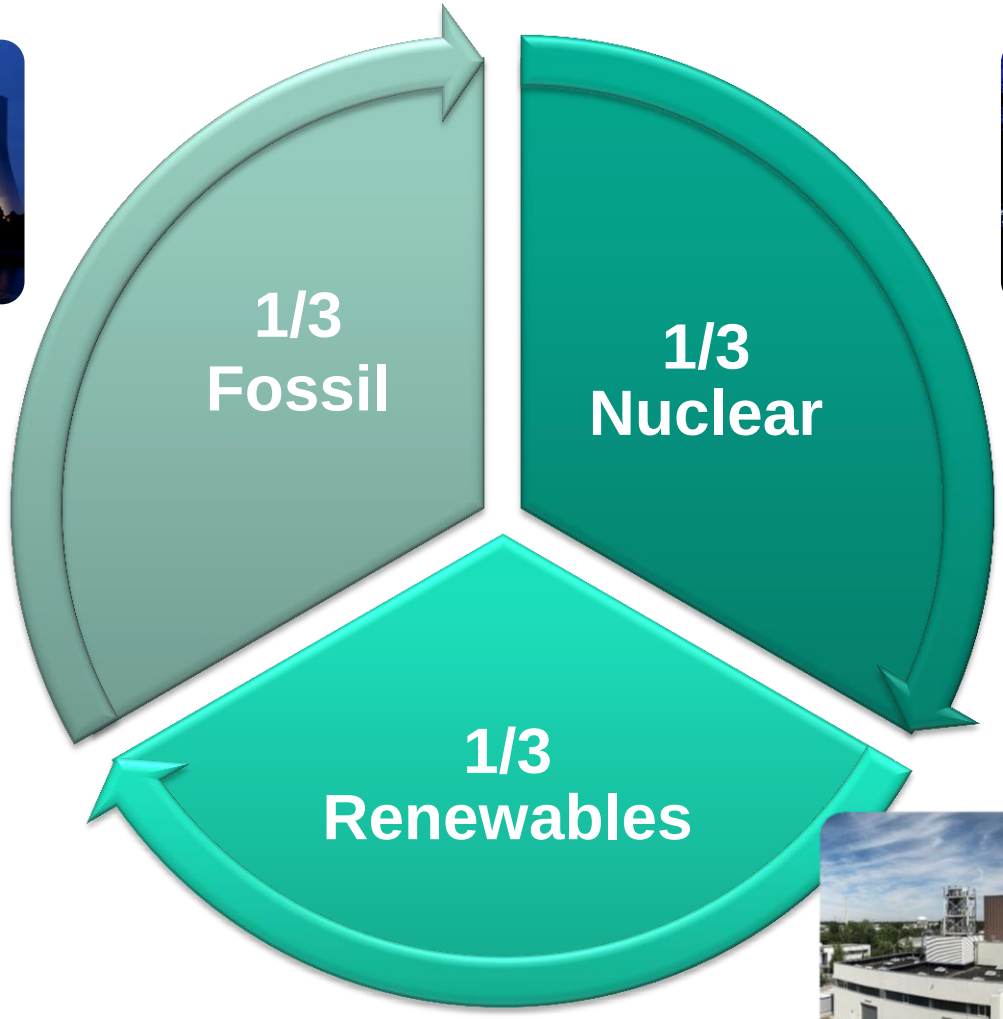
- KIC Mobility Programme
- KIC Explore House
- New curricula
- Culture of life-long-learning

- KIC Knowledge Market
- Exploration mechanisms
- Innovation network research
- Entrepreneurs/ intrapreneurs
- Financial Nurturing

- KIC Innovation Market
- Multi-disciplinary joint-projects
- Open & Cross Innovation
- State-of-the-art IP policy
- Exploitation mechanisms

What is a Reasonable Energy Mix for Europe?

Source:
Duisburg-Walsum



Source: NPP.

Source: bioliq plant

Final remarks.

- The ‘Energiewende’ is a long journey.
- No option is for free, but many (in combination) are feasible.
- The ‘smart’ grid expansion is the foundation for the implementation of renewable energies.
- Local and central power stations are required.
- Public acceptance is a corner stone.
- Research and development is mandatory.
- It is a national / European / global challenge.

- Political decisions cannot bend physics and market laws.

Thank you very much for listening.

Joachim U. Knebel
Karlsruhe Institute of Technology
Chief Science Officer (CSO-4)

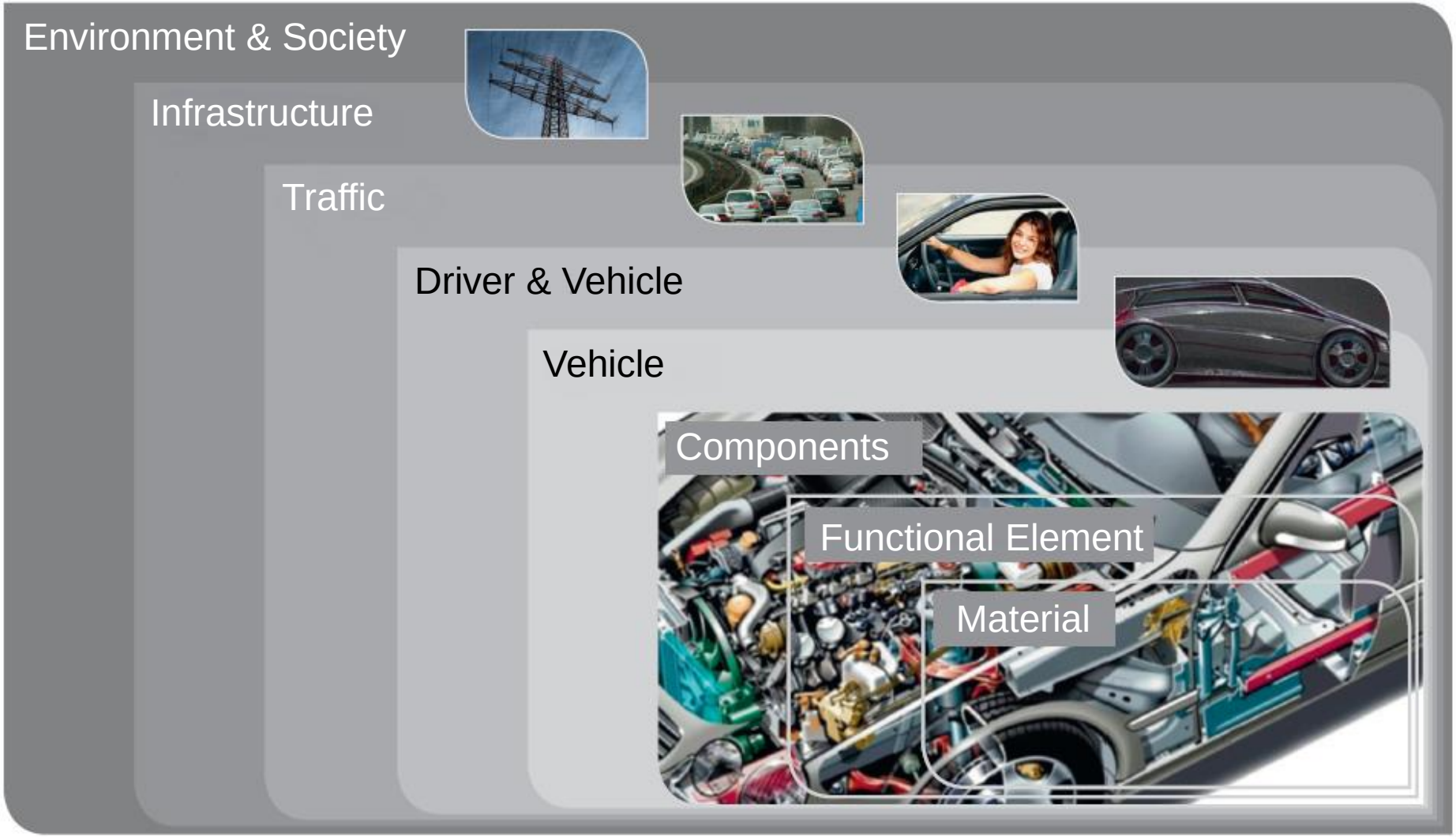
http://www.kit.edu/eps/cso-4/
mailto: joachim.knebel@kit.edu

KIT Center Mobility Systems:
Test Facilities from Lab Scale to Prototypes …

900 Scientists in
40 Institutes (32 CN / 7 CS / FZJ)

… cars, trucks, trains, work machines and more .

Multi Disciplinary Mobility Systems Approach



Research Topics

Karlsruhe Institute of Technology