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JÜLICH FORSCHUNGSZENTRUM

IEA Committee on Energy Research and Technology

Workshop of Experts´Group on R&D Priority –Setting and Evaluation

Long term electricity storage - PtG Convergence of electricity and gas grids

Berlin, October 22th, 2014 | Peter Markewitz

Institute of Energy and Climate Research, Systems Analysis and Technology Evaluation (IEK-STE)

Outline

- Introduction
- **Long term electricity storage**
  - *Power to Gas (PtG) Technology*
  - *Conclusions of existing studies*
- **Project KonStGas – Convergence of electricity and gas grids**

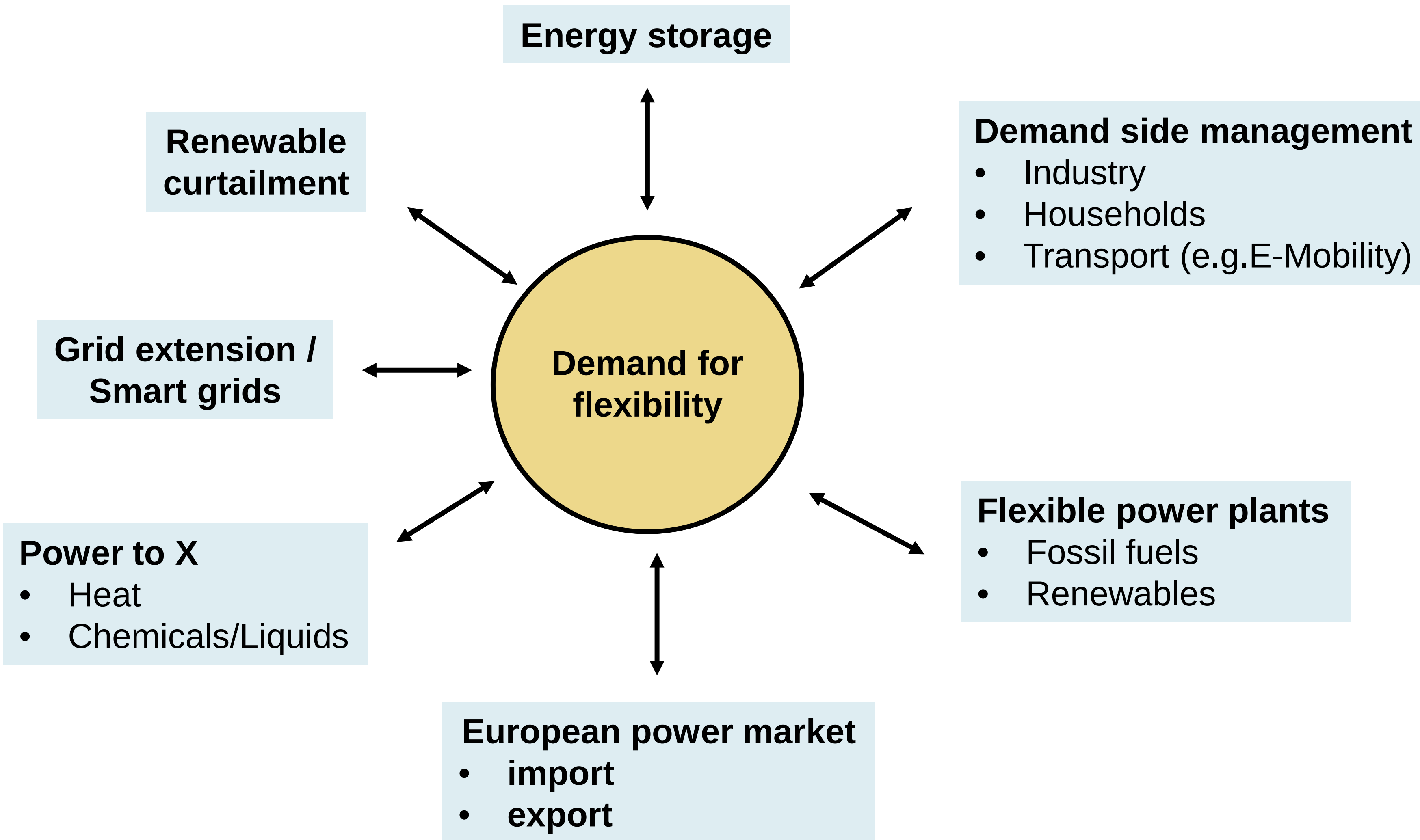
Transformation of the electricty system

Today: ~ 42% of the national CO_2 emissions → energy sector

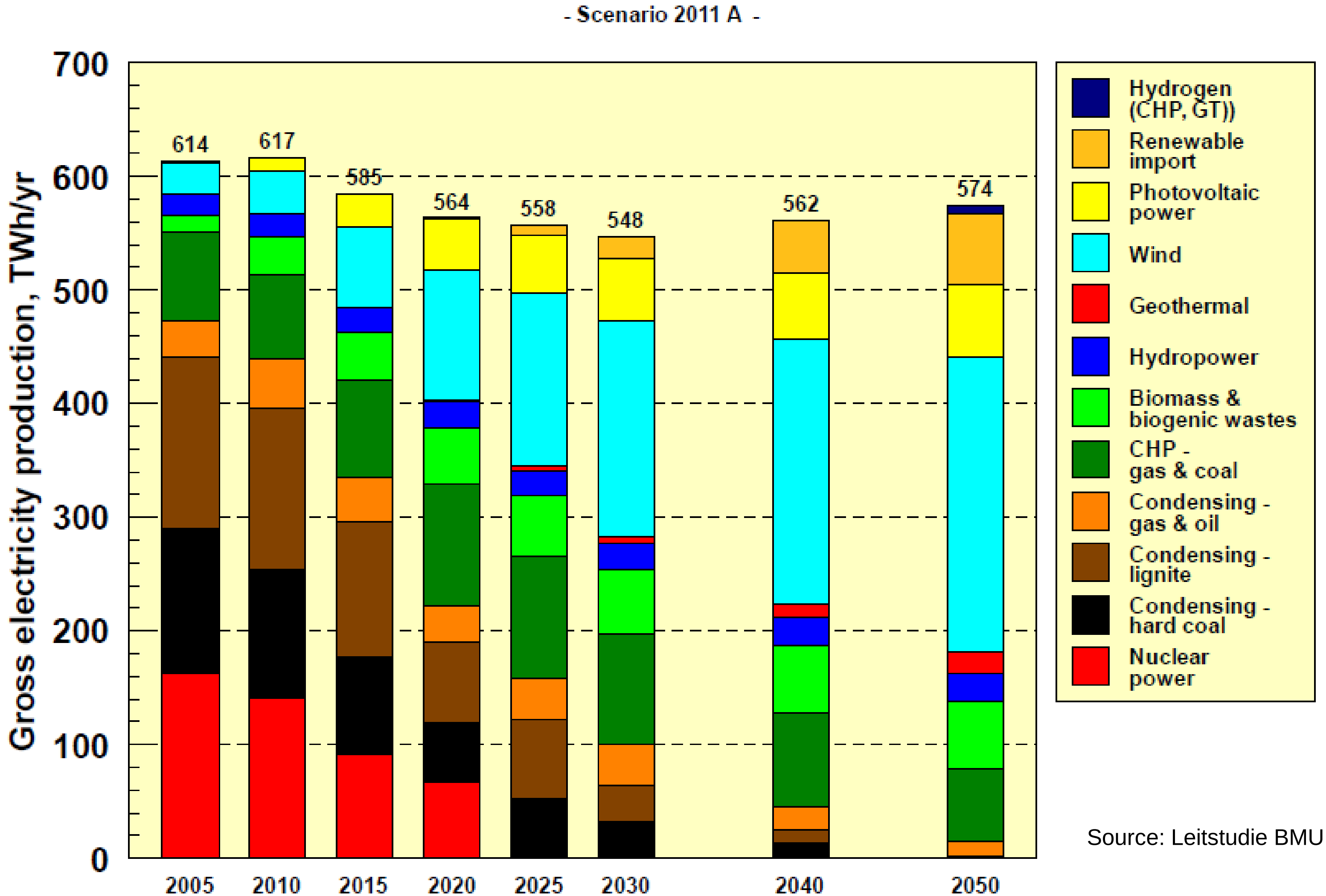
Transformation of the electricity system requires the integration of fluctuating renewable energies
(National energy concept: 2020: 35%, 2030: 50% …. 2050: 80%)

- ➡ Change from a demand oriented system to a more and more supply oriented system
- ➡ Increasing demand for flexibility and control energy supply

Flexibility technology portfolio



Electricity production in Germany

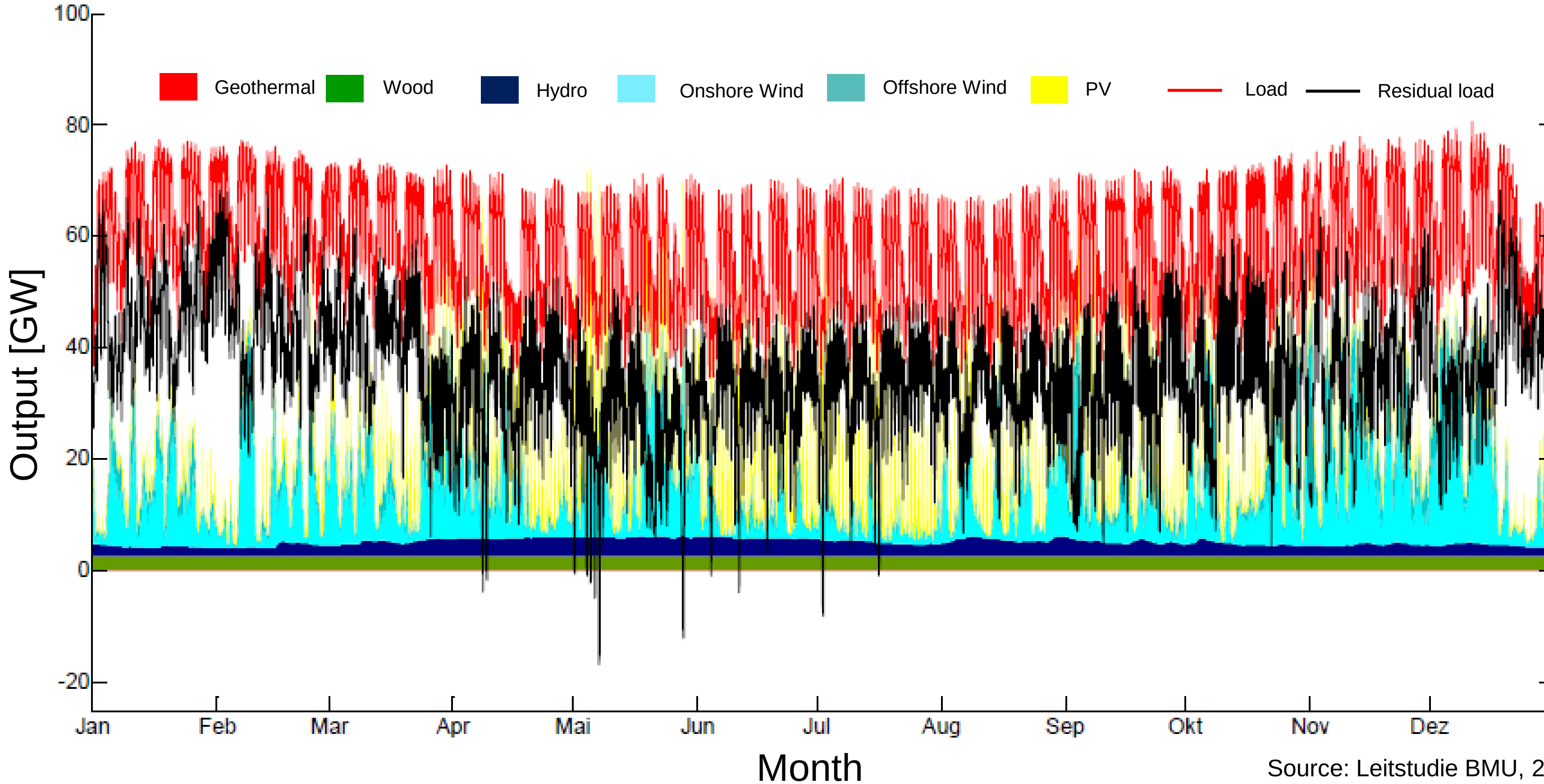


Source: Leitstudie BMU, 2012

Share of RE: **17 %** **41 % (231 TWh)** **85 % (488 TWh)**

Actual value 2013: 25,4 % (152 TWh)

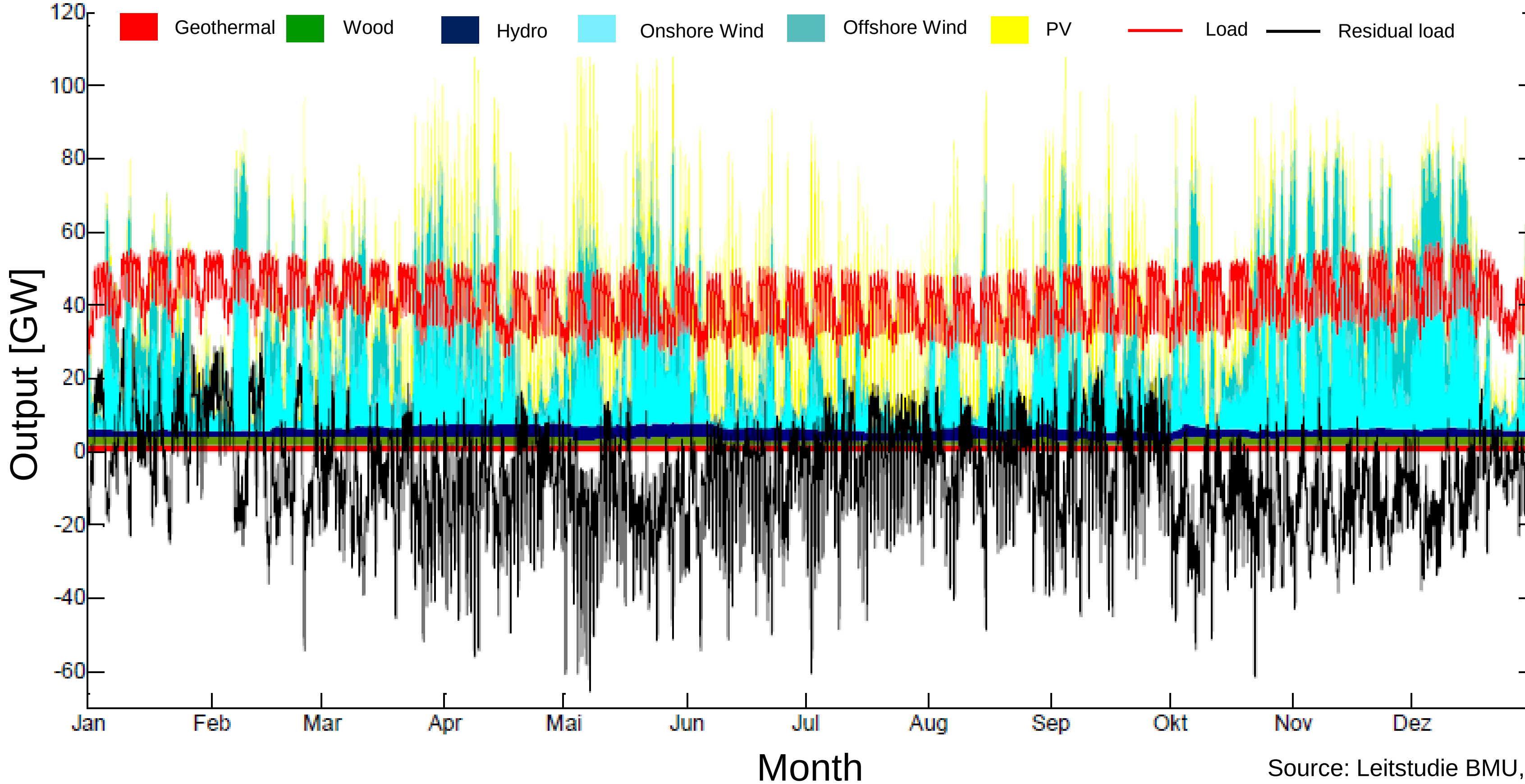
Simulation for the year 2020 (41 % RE)



Source: Leitstudie BMU, 2012

- Only a limited number of days with excess renewable energy (production > load)
- Flexibility can be provided by conventional power plants, biomass, demand side management and renewable electricity curtailment

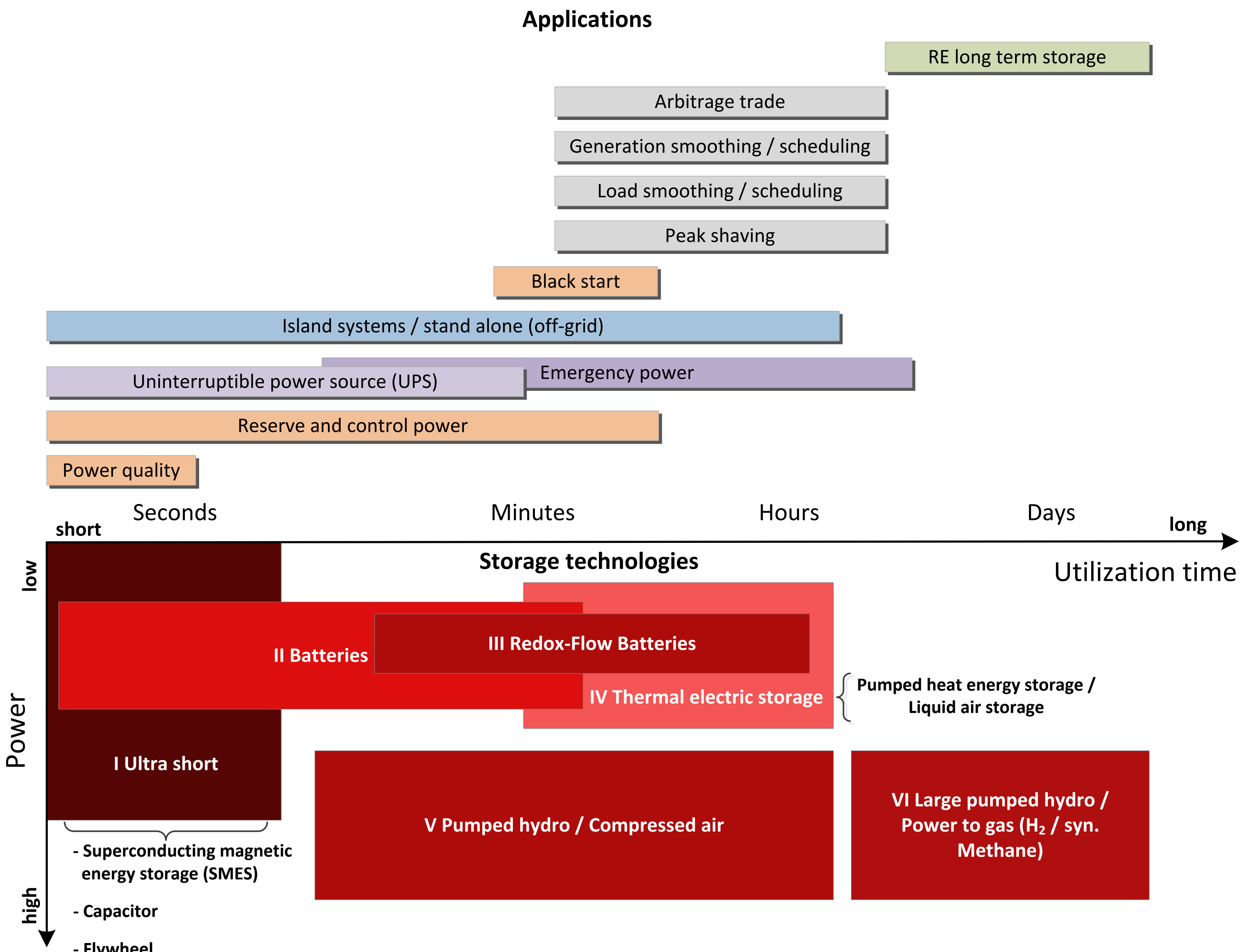
Simulation for the year 2050 (85 % RE)



Source: Leitstudie BMU, 2012

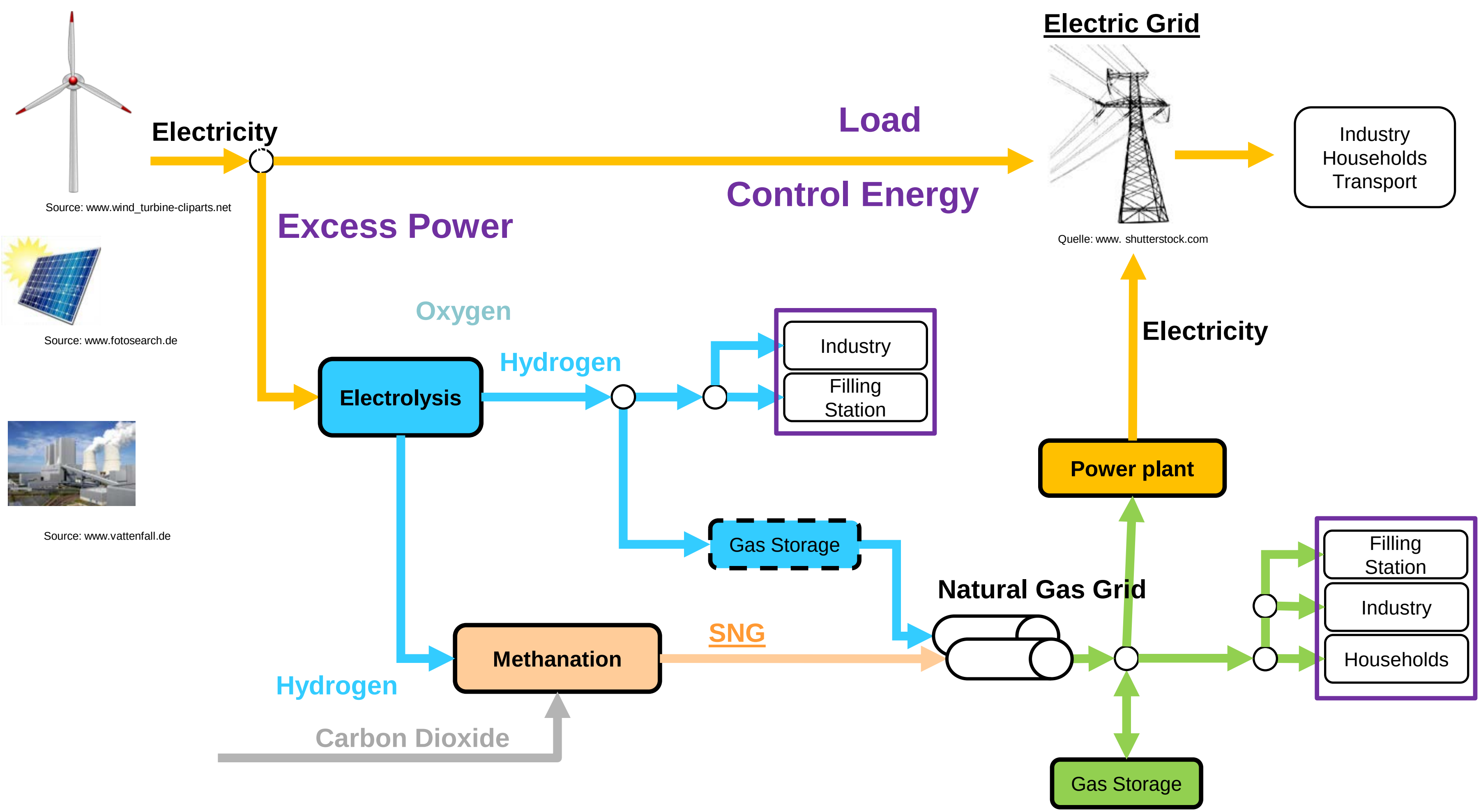
- Numerous days with excess renewable energy (production > load)
- Also longer periods (days to weeks) with low renewable production (load > RE production)
- Flexibility has to be provided by thermal power plants and storages
- Storage might be interesting to reduce renewable curtailment (economics ?!)

Classification of storage technologies



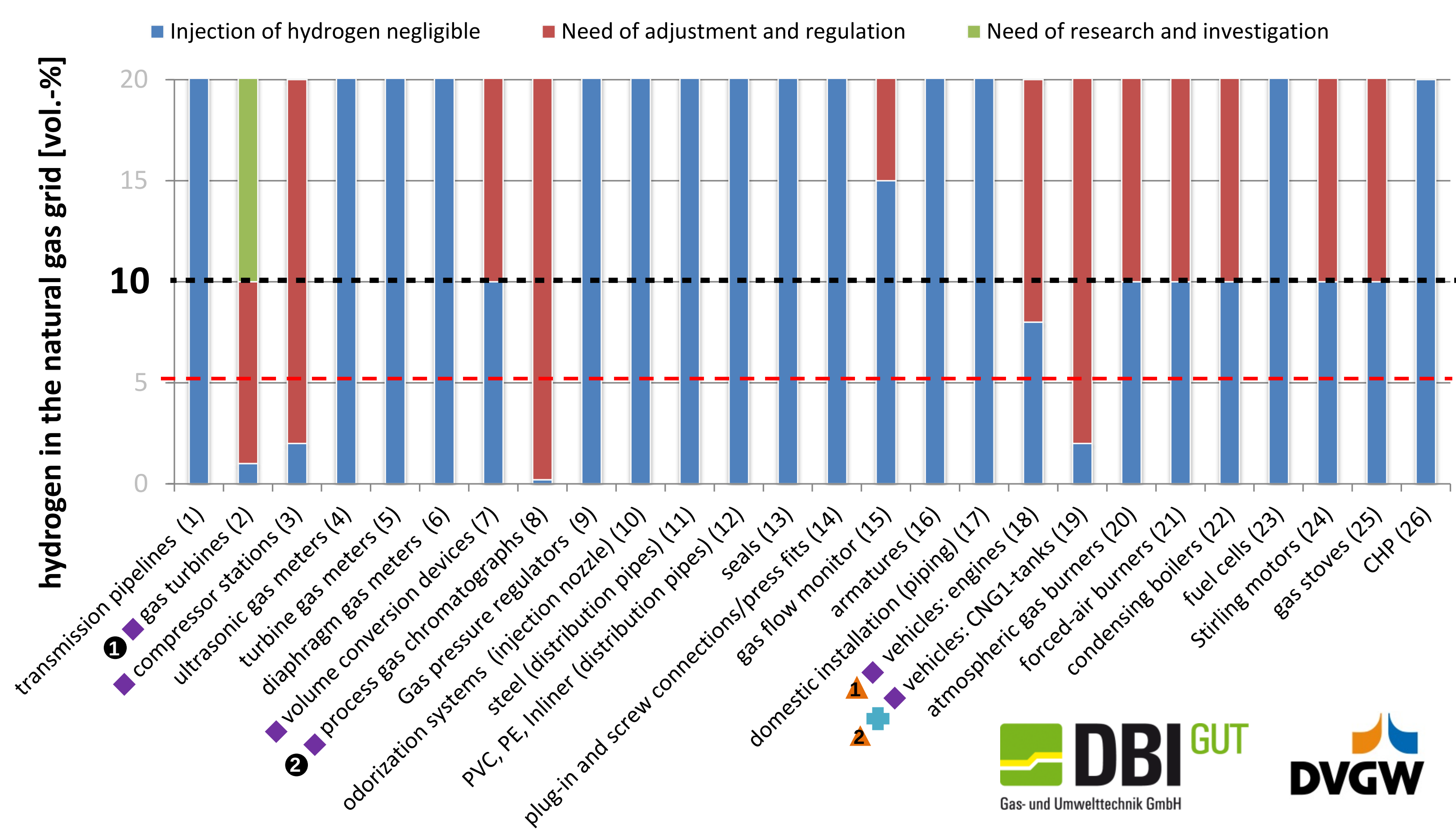
Source: Stenzel et al. 2013

Power to Gas (P2G): Hydrogen or SNG



SNG: Synthetic Natural Gas

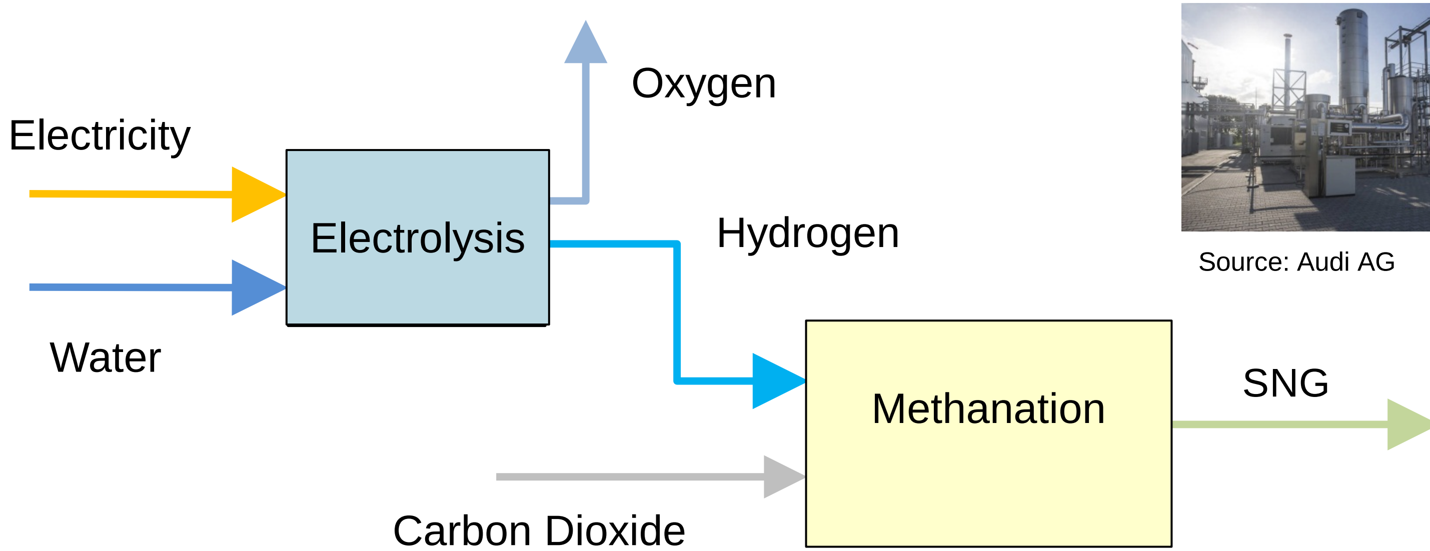
Hydrogen injection into the gas grid
H_2 tolerances - Current state of knowledge



- limit by regulations / standards / manufacturer specifications
- 1 consideration of the the methane number
- 2 max. 2 vol.-% H_2 (DIN 51624)
- limit for sensitive components
- 1 density elements, flame flashback, guarantees / warranties
- 2 H_2 level> 0.2 vol -%: PGC's required with calibratable H2-determination
- DVGW follow-up project / R&D- project for further investigation
- solution for higher H2 admixture available

Source: Müller-Syring et al., 2012

Methanation

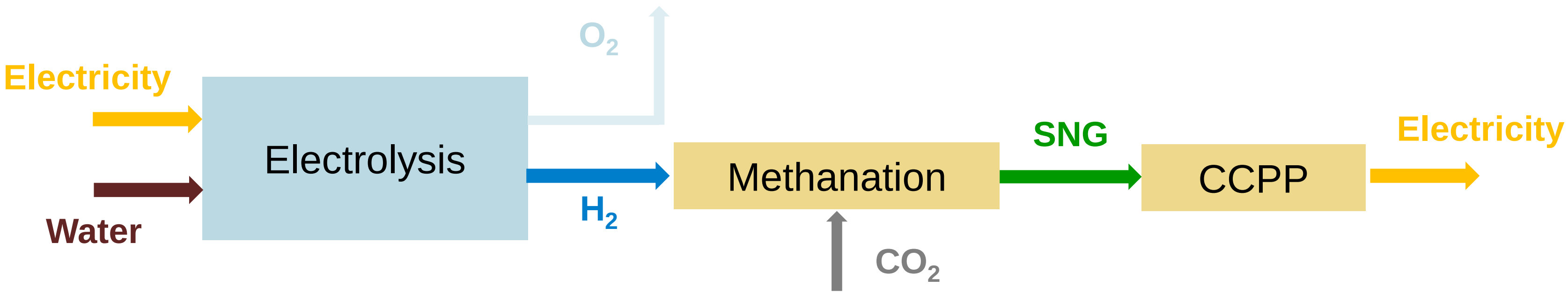


Source: Audi AG

Sabatier [1]- stoichiometric equation 1) French chemist Paul Sabatier 1854-1941	$\mathbf{H_2 + CO_2 \leftrightarrow CO + H_2O}$ **(+41 kJ/mol)** $\mathbf{3H_2 + CO \leftrightarrow CH_4 + H_2O}$ **(- 206 kJ/mol)** $\mathbf{4\ H_2 + CO_2 \leftrightarrow CH_4 + 2\ H_2O}$ **(-165 KJ/mol)** **(200-600°C), 1-100 bar**
Thermodynamic rate fo conversion	$\eta_{Sabatier} = \frac{H_{u,CH_4}}{4 \cdot H_{u,H_2}} =$ **83 %**

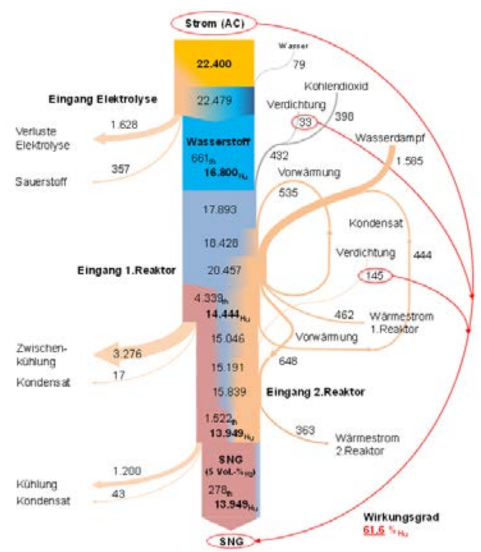
- Idea of SNG production: 1970´s
- Catalysts are necessesary (e.g. Nickel, Ruthenium), today: only catalysts for CO reaction available
- Challenge: Flexibility, Heat transfer → conversion rate

P2G: Efficiency



Today	70%	x	75%	x	60%	=	**32%**

Literature: 28-35%
Maximum value: 45% (Sterner, 2009)



Production costs of SNG

Today: ~18 €cts/KWh[1)] $_{SNG}$

Mid term: ~13 €cts/KWh $_{SNG}$

Long term: ~10 €cts/kWh $_{SNG}$

Price for natural gas: 2.2 €cts/kWh

1) Electricity price: 3 €cts/kWh

P2G: Hydrogen vs. Methanation

	Advantages	Disadvantages
H_2 feed into the natural gas grid	• Use of the existing natural gas infrastructure	• Limited H_2 share (limited H_2 tolerance of CNG vehicles, gas turbines, etc.) • Costs
Methanation	• Unrestricted use of the existing natural gas infrastructure (incl. storage) • Higher energy density • No technical modifications necessary (grid, compressors, end use appliances) • Large storage capacity	• Low overall efficiency due to losses during methanation • CO_2 available ? • Costs • Demonstration of the methanation process • Flexibility

Conclusions of existing studies: Long term storage demand

- **Increasing share of renewables requires higher flexibility on the supply and demand side**

- **40 % RE**
  - No long term storage demand
  - Only limited RE electricity excess (VDE: Negative residual load in 44 h per year)
  - Flexibility provided by conventional power plants

- **80 % RE**
  - Flexibility can be provided by conventional power plants and storages
  - Long term storage becomes more interesting for RE integration and GHG reduction
  - High RE electricity excess
  - For the highest production peaks (sporadic events) RE curtailment is an economic option

- **100 % RE**
  - Very high RE electricity excess (RE excess → H_2 for other applications ?)
  - Long term storages required to provide carbon free flexibility
  - Large storage capacity required (VDE: 3 times higher than in the 80% case)
  - Additional flexibility by renewable curtailment and renewable import

„Integration of fluctuating Renewables with particular focus on electricity and gas grids – Convergence of Electricity and Gas grids "

KonStGas Project

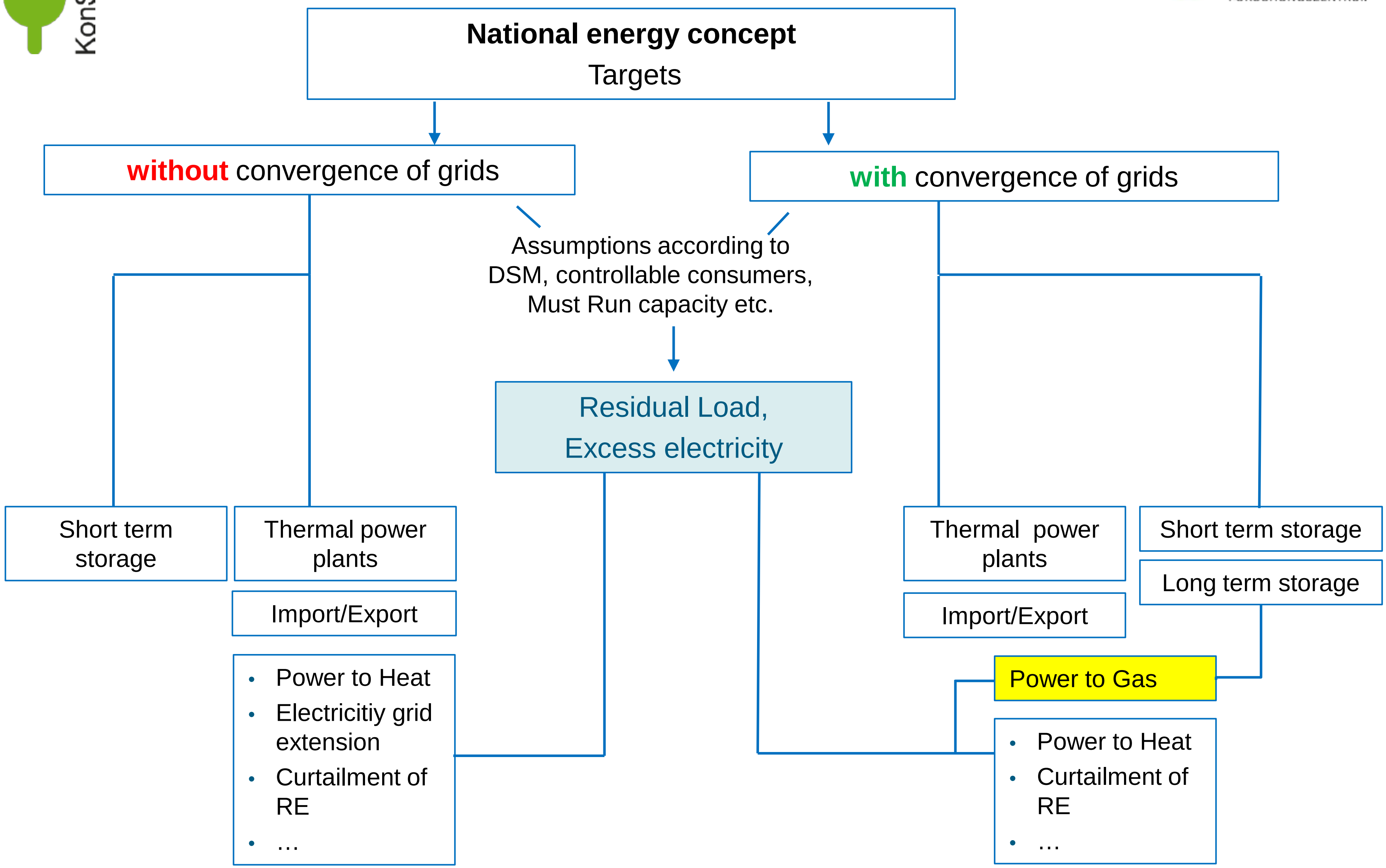
Funded by the Ministry of Economic Affairs and Energy (BMWi)
Förderkennzeichen: 03255761

Start of project: end of 2013
End of project: 2016

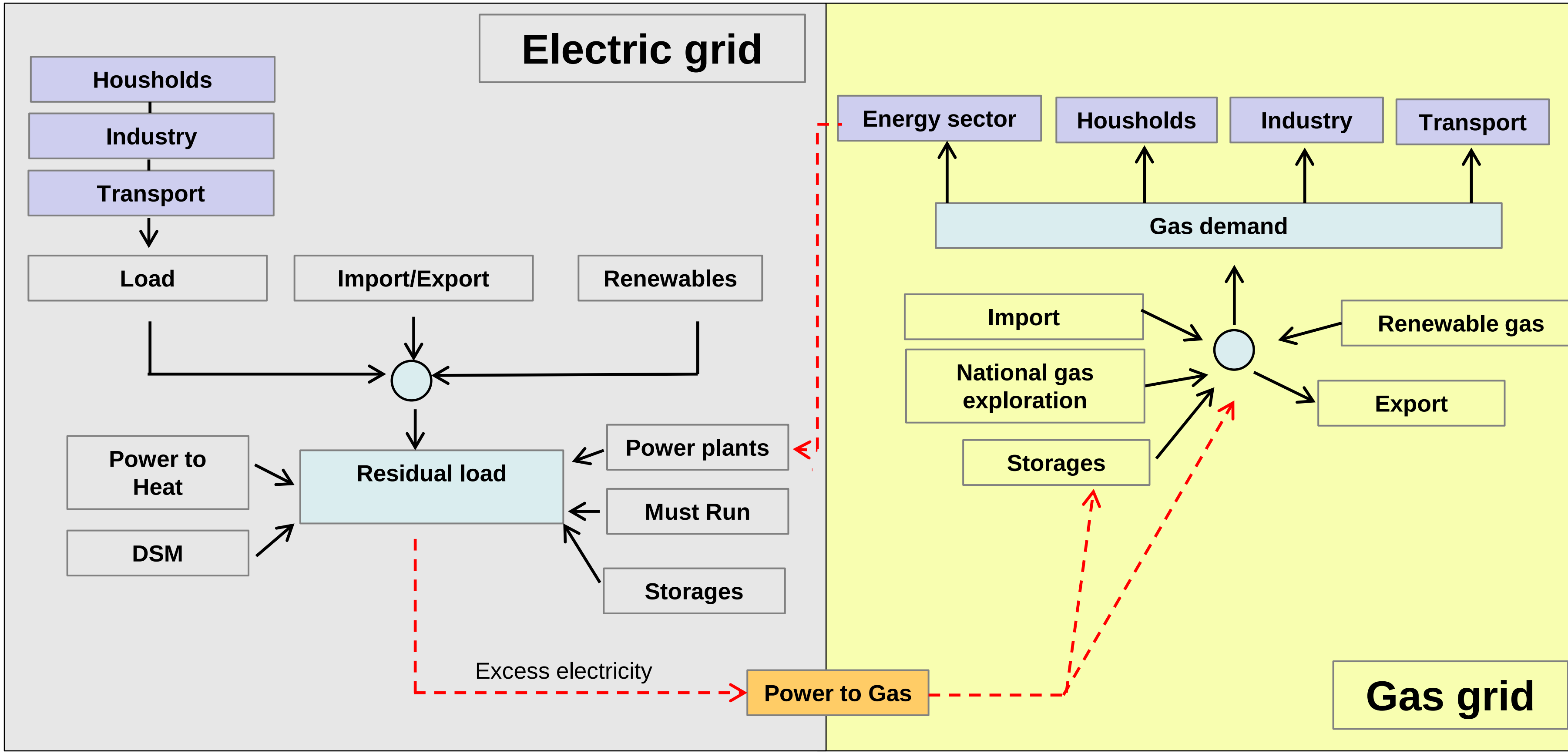
Adressed questions in the KonStGas project

- How large is the surplus electricity production taking into account Must Run capacity, DSM, controllable consumers, export, power to heat etc. ?
- What could be the role of long term storage options (Focus on PtG) ?
- What impacts on gas and electricity grids can be expected if PtG is applied large scale? (e.g. gas composition, grid modifications etc.) ?
- Where are the best sites (gas grid – electricity grid – installed REN capacity) to integrate Renewables?
- When and where do we need a SNG production from PtG ? Are CO_2-sources (e.g. biogas conditioning) available ?
- What are the (macro)economic impacts of different stategies?

Scenario definition



Systems to be simulated by models



Major challenges:

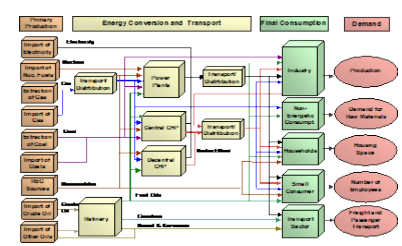
- Regional resolution of electricity and gas demand, electricity production, CO_2-sources etc.
- Temporal resolution of electricity and gas demand, electricity production (load profiles)

Involved institutions

Partners	Tasks
TU Clausthal (ite)	National gas transport grid
DBI Leipzig	National gas distribution grid
TU Dresden (EE^2)	European gas market
KIT Karlsruhe (IIP)	European electricity market
RWTH Aachen (IAEW)	National electricity grid and power plants
FZ Jülich (IEK-STE)	National energy system
Fraunhofer Umsicht RUB Bochum University gwi Essen FZ Jülich (IEK-STE) Wuppertal Institute OTH Regensburg Fraunhofer IWES	Data - technologies, - consumer load profiles, - production profiles of RE - regionalization of demand and production - …
RWE AG, Ontras, 50hertz DVGW	Industry panel

National Gas transport grid
Source: TU Clausthal

European gas transport grid
Source: TU Dresden



National energy system
Source: FZ Jülich (IEK-STE)

PtG Demonstration plants in Germany

18 pilot projects
- 2x CH_4 injection
- 5x H_2 injection
- 8 E-gas for mobility

5 projects in preparation

Source: DVGW, 2014
www.dvgw-innovation.de

Thank you for your attention!

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