Chemical storage of excess electricity - Interdisciplinary collaboration at TUM

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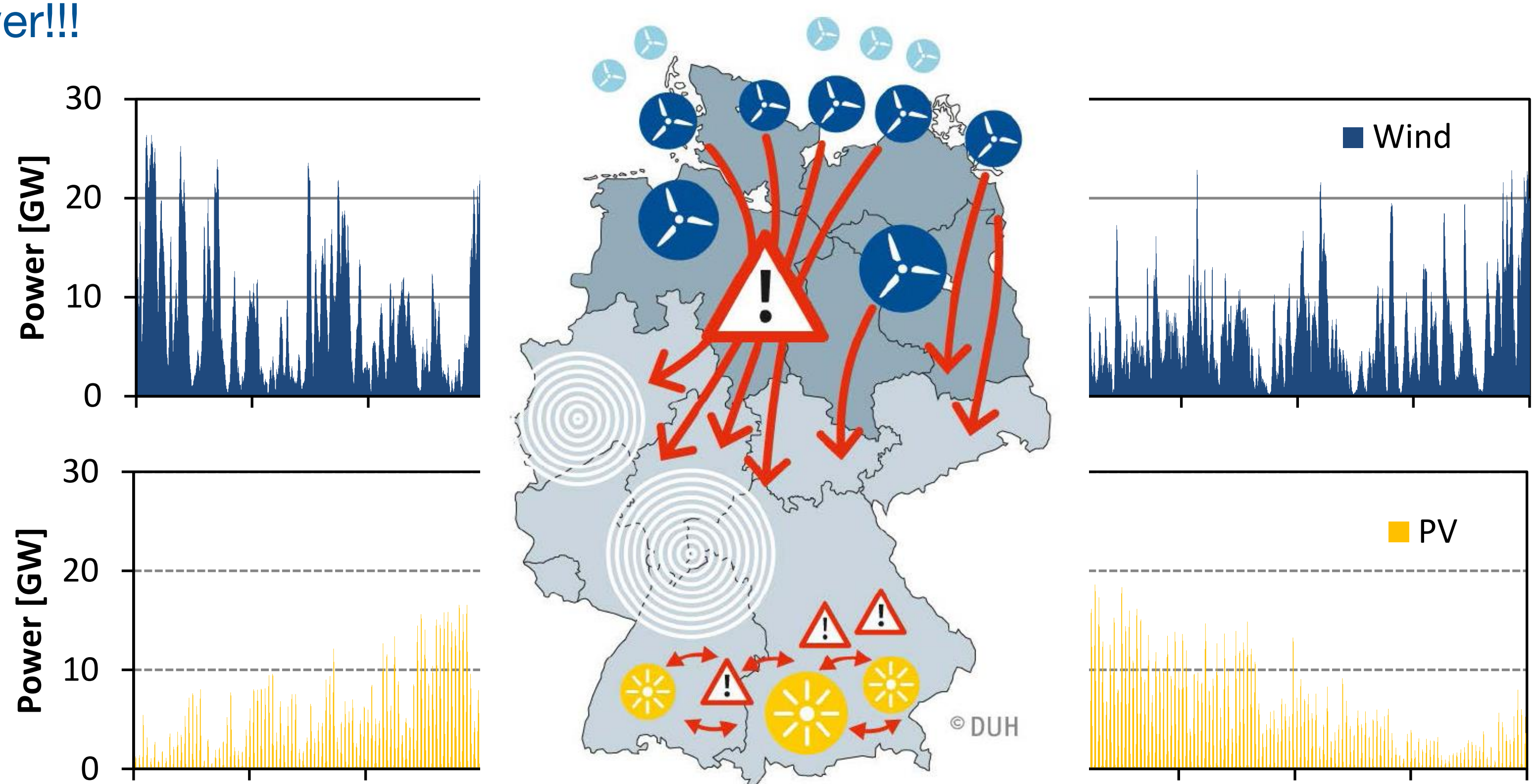
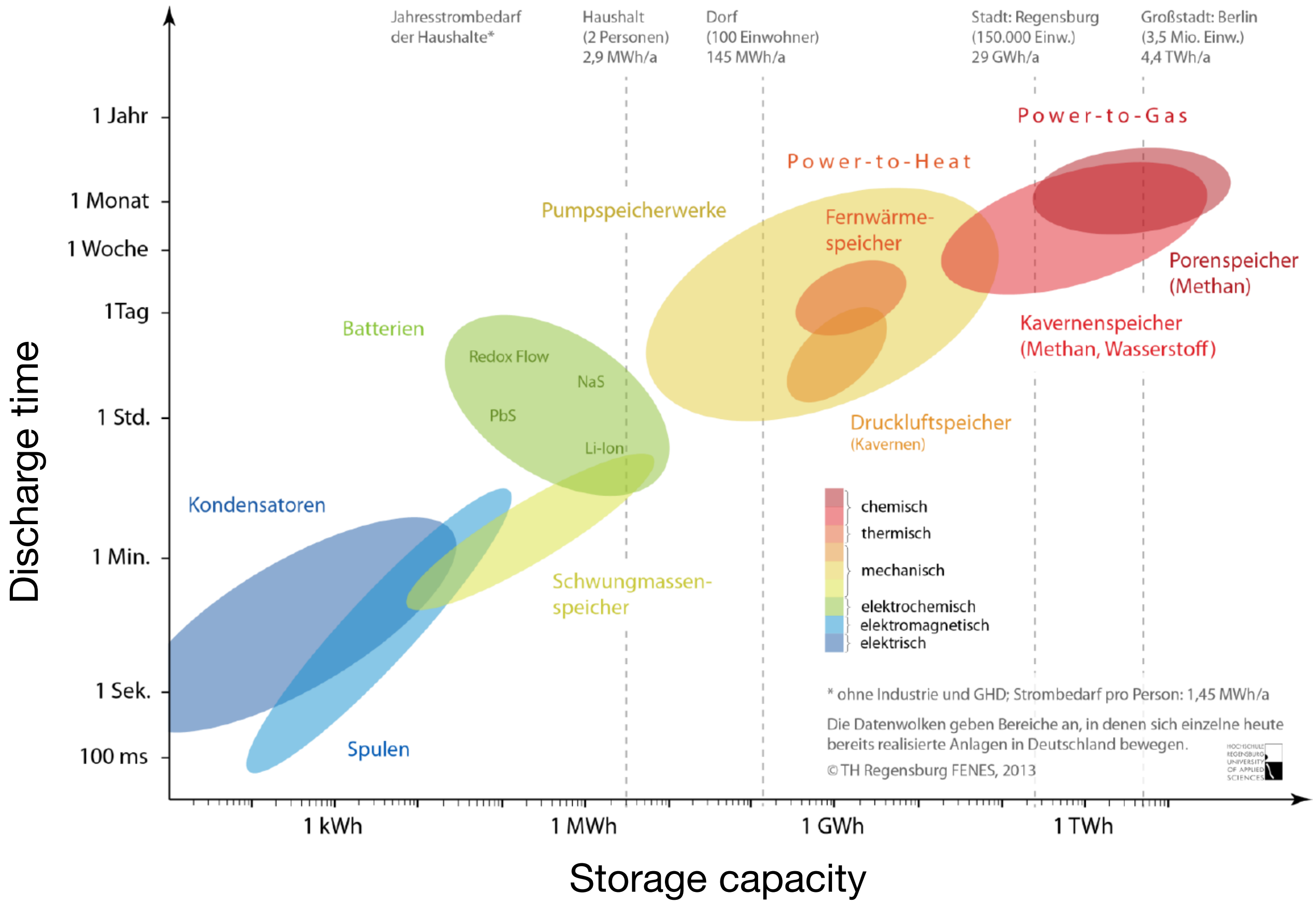
Motivation for Power-to-Gas / Power-to-X

Increasing installation of fluctuating energy sources like wind and solar energy requires technologies and processes for the storage and distribution of power!!!

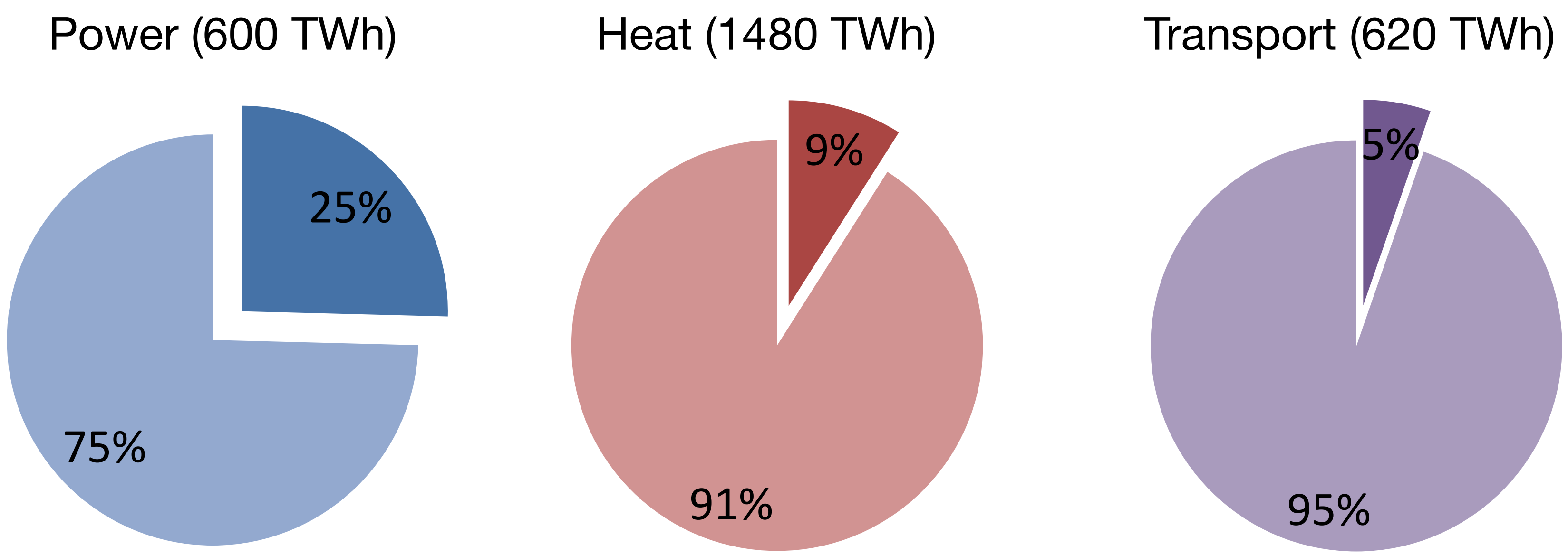


What storage technologies do we have/need?



Status quo of the „Energiewende“

“Energiewende“ not only for the power sector!!!



→ Connecting the sectors by Power-to-X!!!

Source: BMWi (2013)

Seed Funding PtG – Project description

- Title: „Seed Funding PtG“ – Chemical storage of excess electricity
- Project runtime: 12 month
- 5 TUM-Partners: APT, ENS, LES,TEC, TC1 and ZAE
- Main research areas: system analysis, electrolysis, synthesis
- Goals:
  - Enhance visibility of TUM activities and bundle research efforts by the partners
  - Coordination of common approach and initiation of a demonstration project and research platform, respectively
  - Acquisition of potential industry partners

→ Interdisciplinary research team (MW, CH, EI)

Project levels

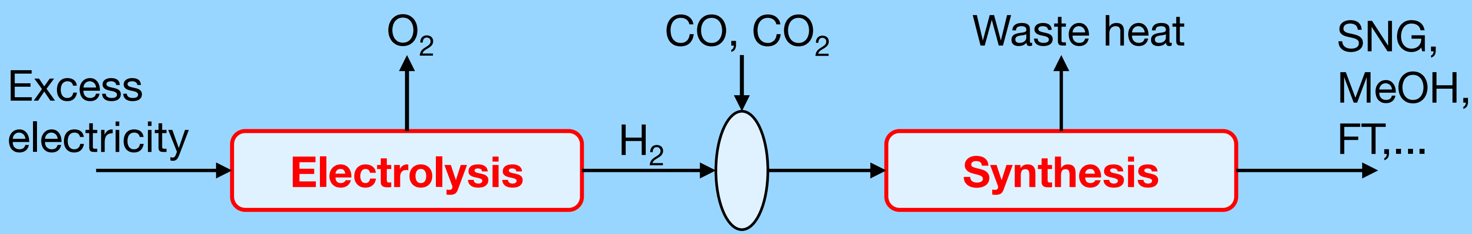
Energy system level

Analysis of chemical storage integration in future energy scenarios

Storage level

Integration of chemical storage in flexible power plant concepts and analysis of synergy effects from integration of material and energy balance

Technology level



- Investigation and optimization of dynamic behavior
- Test of commercial technologies
- Analysis of new electrode materials

- Investigation of innovative reactor concepts
- Analysis of dynamic behavior
- Basic research: Catalysis, reaction kinetics

Project structure

Research on chemical storage of excess electricity

System
(ENS, LES)

- Future energy systems
- Integration of innovative power plant concepts
- Storage concepts

Electrolysis
(TEC, ZAE)

- Dynamic behavior
- Material development
- Process development
- Testing of market-available modules

Synthesis
(LES, TC1, APT)

- Catalysis and reaction kinetics
- Reactor design
- Waste heat utilization and heat integration
- Dynamic behavior

Future technologies and concepts

System – Research needs and work packages

→ Which market shares are possible for PtX?

→ How does that influence the need for additional investments in the power grid

→ What end product(s) might be best suitable to fulfill the need(s)

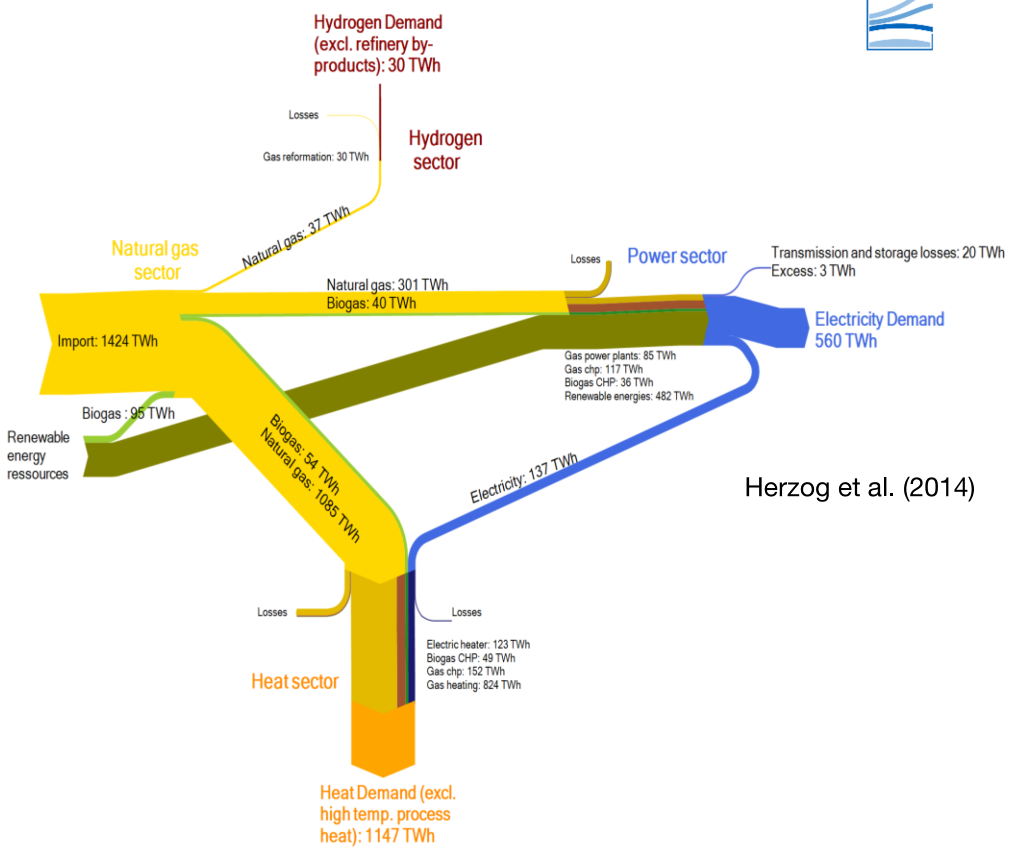
→ Can SNG for example reduce the dependency on fossil natural gas

→ What is economically and what is commercially preferable?

Work packages:

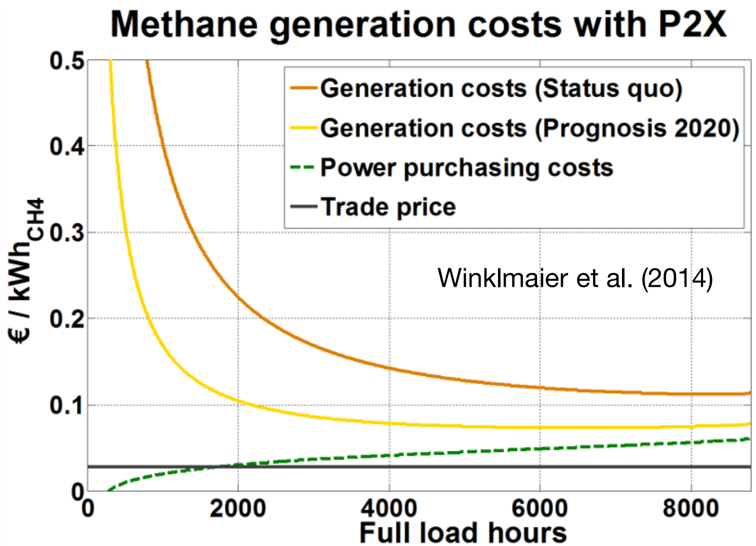
- Analysis of global causal relations of relevant markets and future trends (heat, power and gas)
- Modeling of individual systems (markets) and subsequent coupling of the models
- Evaluation of innovative system integration concepts (IGCC-EPI)
- Evaluation of competitiveness of PtX

System - Investigations



Herzog et al. (2014)

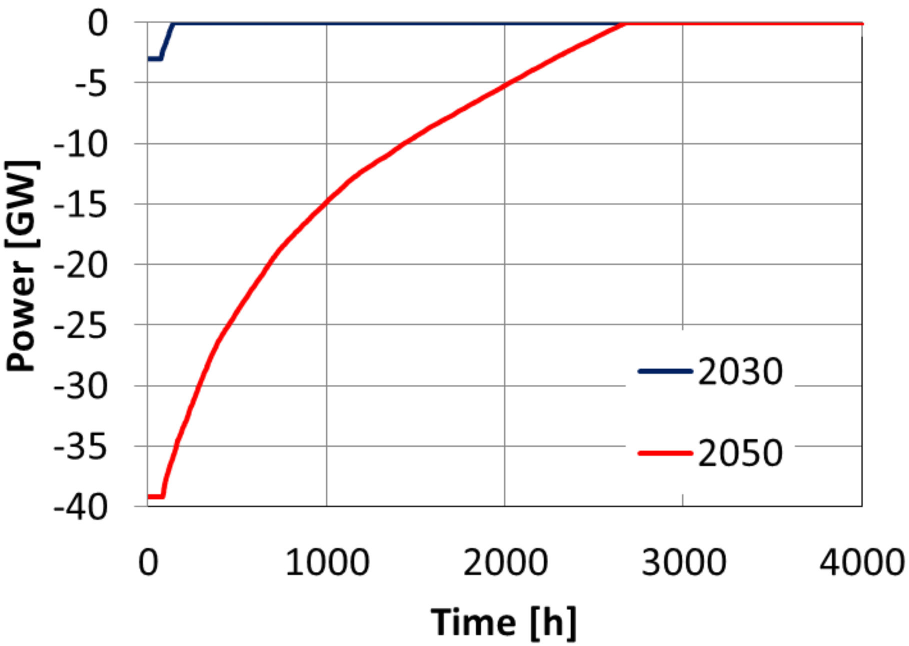
Power-to-Methane



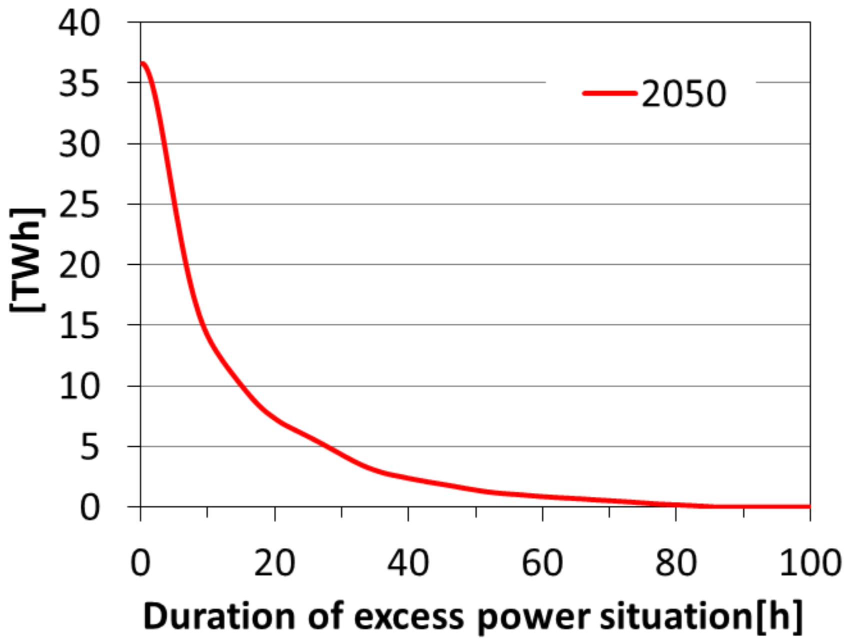
→ See Poster #48

Energy systems study – Forecast of future excess power generation

Annual load duration curve



Duration of excess power situation

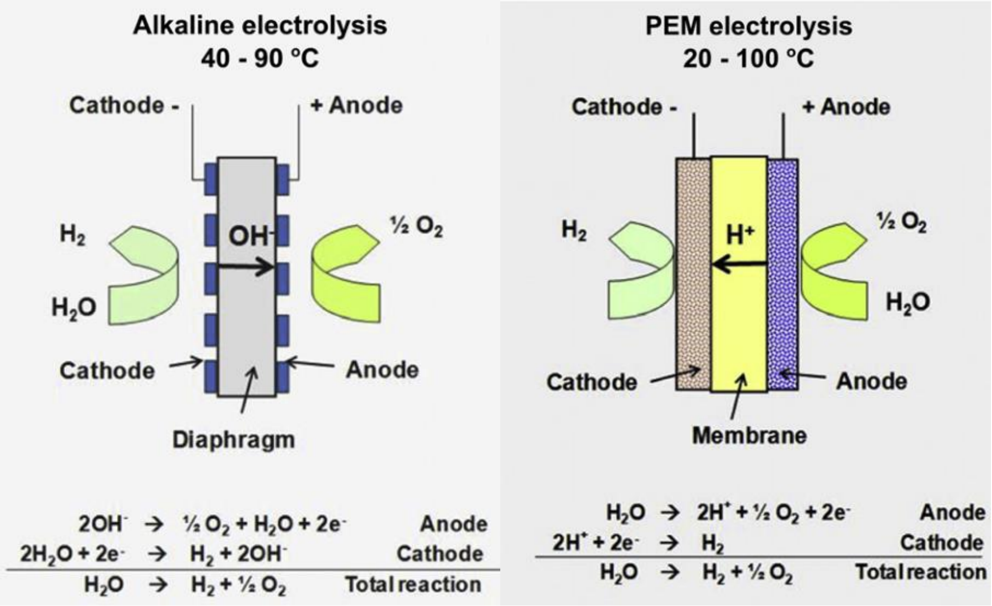


→ **Negative residual loads up to 2700 FLH (2050)**

→ **Excess power situations with a duration of up to 86 h (2050):**

>1h: 35.7 TWh   12 h: 12.2 TWh   >24 h: 6.1 TWh

Electrolysis



Alkaline vs. PEM EL

Dynamic operation

Cost reduction

Scale

Long-term stability

Material issues

Power density

Integration in storage concepts

HTEL

Optimization of process parameter

Hybrid systems

Catalysts/Membranes

Electrolysis – research need and approach

PEM electrolysis	KOH electrolysis
+ high differential p_{H2}	- requires $p_{H2} \approx p_{O2}$
+ “easy“ shut-down	- complex shut-down
+ high currents (1.5-2 A/cm²)	- low currents (0.5 A/cm²)
+ easy handling	- concentrated KOH
- high PGM loadings	+ non-PGM catalysts
- expensive titanium plates	+ stainless steel plates

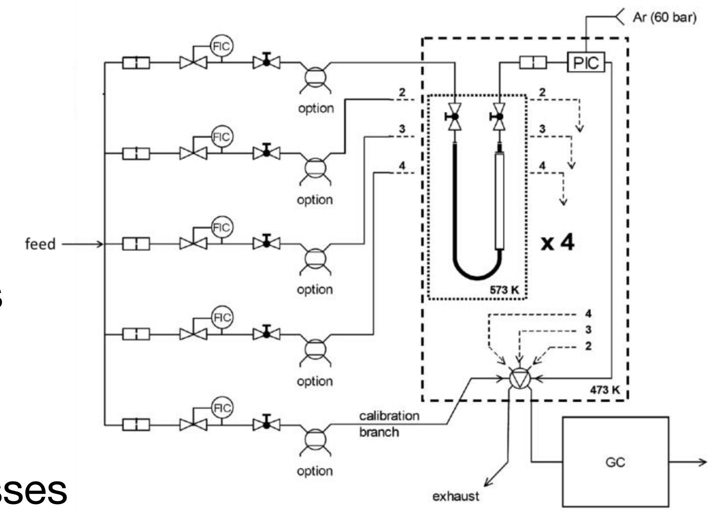
→ Anion-exchange membrane based electrolysers combine all the +

→ Alkaline membrane electrolysis (AM) attributes ultra-low PGM / noble-metal free, stainless steel plates, high current, high differential p_{H2}

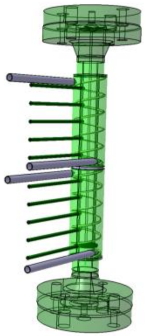
Research focus on:

- Membrane-electrode-assembly (MEA): optimization & characterization
- Electrocatalyst development
- Performance modeling (voltage & permeation losses)
- Effect of feed composition/location

Synthesis – Research areas (SNG, MeOH,…)

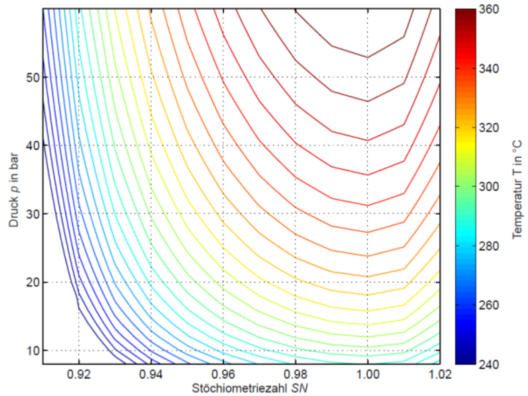


- Catalysis and reaction kinetics
  - Catalysts characterization
  - Kinetic modeling
  - Measurements of micro- and macro kinetics
  - Deactivation and poisoning effects
- Dynamic behavior
  - Investigation of startup and rundown processes
  - Structure-activity investigations under dynamic reaction conditions
  - Stability evaluation of catalysts under dynamic conditions
- Reactor design
  - Modelling and optimization of innovative reactor designs
  - Measurement and evaluation of hot spot and runaway mechanisms
  - Investigation of alternative reactor concepts like 3-phase reactors
- Waste heat utilization and heat integration



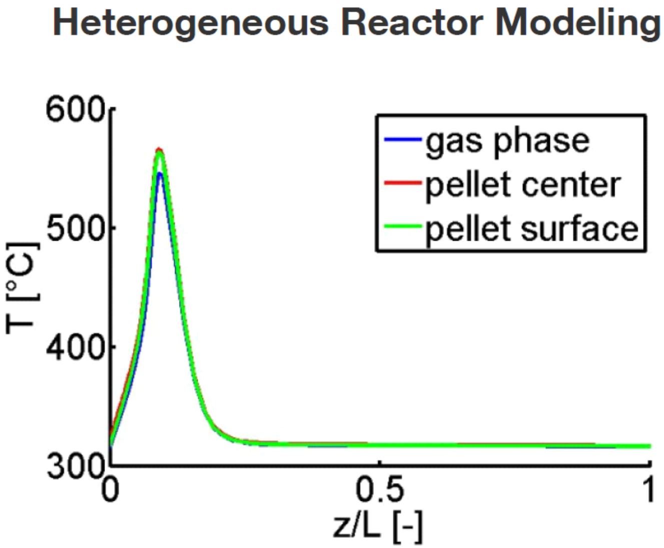
Synthesis

- Potential synthesis pathways:
  - **SNG (methane)**
  - MeOH
  - FT diesel
- Methanation promising option concerning the flexible usable end product (methane)
- Aim: Address all issues from fundamental kinetic to modeling of the system and design of the reactor



Gleichgewichtstemperaturen in Abhängigkeit der Stöchiometriezahl *SN* und des Drucks *p* bei einem Umsatz zu 90% Methan, Berechnung mit UniSim® Design Suite

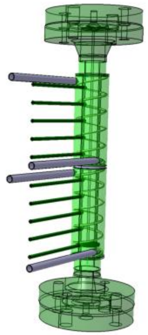
Klein (2014)



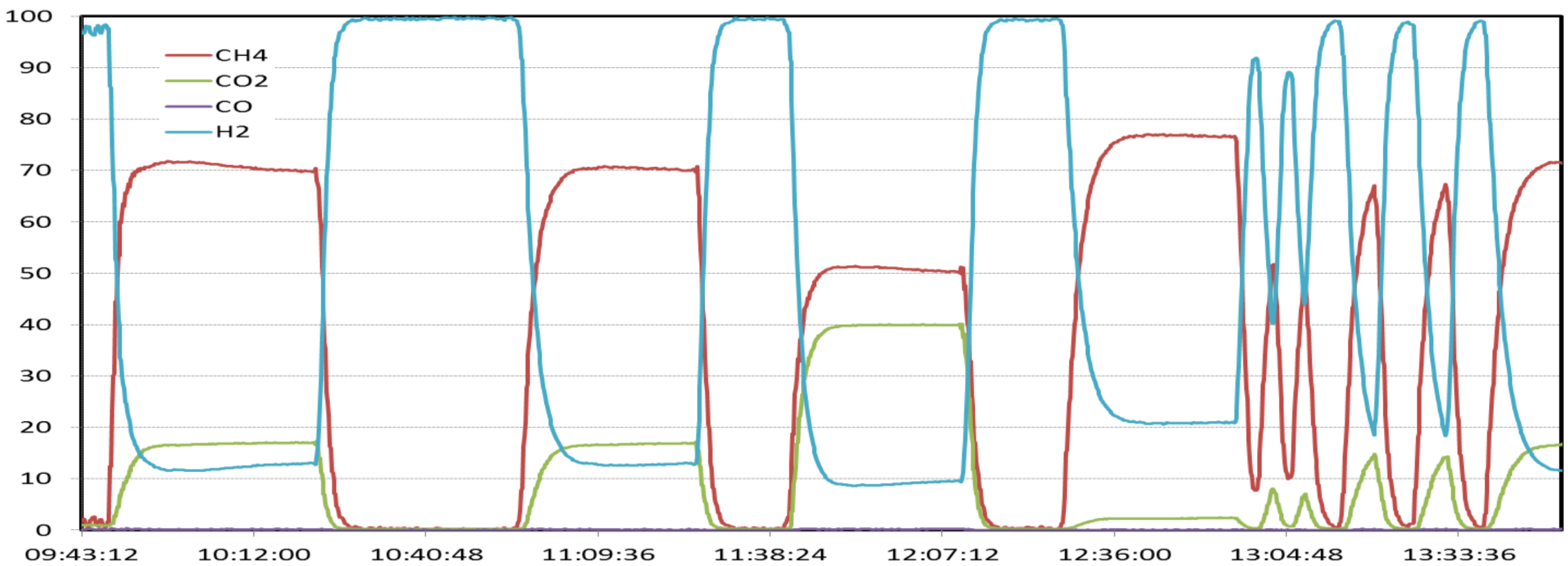
D. Schlereth, O. Hinrichsen, Chem. Eng. Res. Des., DOI: 10.1016/j.cherd.2013.11.014

Example: test results from dynamic methanation test

Methanation with dynamic CO_2-addition and air cooling



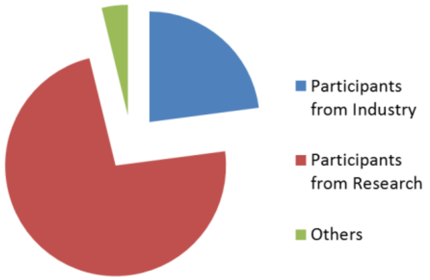
- Stable reactor, no runaway
- Stable gas comp: < 10 min
- Stable temperature profile: < 30 min



TUM-Workshop on SNG
„SNG as Key for Future Energy Systems“

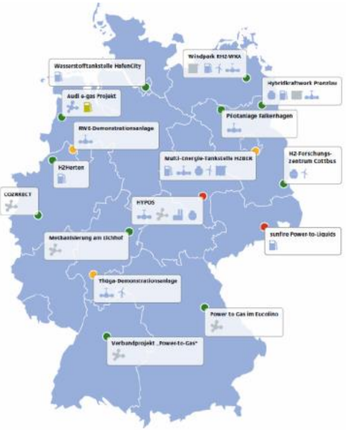
Presentations online

- Workshop on Power-to-Gas and Biomass-to-Gas
- More than 150 participants from research and industry



- Invited presentations from experts from industry and science together with a poster session
- Aim: bring together people to discuss results and progress, initiate new collaborations and share latest developments

Project initiatives



TUM research platform

- Interdisciplinary research platform at TUM regarding chemical storage of excess power from renewables
- Fundamental research coupled with applied science alongside the whole process chain and different end products (SNG, MeOH,…)
- Commonly usable, interdisciplinary experimental rest rig
- Unique selling point: open research with no constrains

Demonstration project Campus Garching

- Innovative energy supply for the Research Campus Garching, PtX as one technology to demonstrate integrated renewable power and heat supply on demand (in combination with e.g. ChengCycle)
- Accompanying research measures in combination with industry partners
- Unique Bavarian PtX demonstration project?!

Thank you for the attention!

Thanks to the MSE for funding ….
and thanks to the project partners
at APT, ENS, TEC, TC1 and
ZAE!!!

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