Energie mit Zukunft.
Umwelt und Verantwortung.

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Transformation pathways to greenhouse gas neutrality of gas networks and gas storage to COP 21

Modeling of cost-optimal transformation pathways for the greenhouse gas neutrality of the gas networks and gas storage within the technology paths “green” hydrogen and “green” methane

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Preliminary results

Sector coupling concrete-intelligent and cost-effective implementation | Brussles | 14th June 18

DVGW

Agenda

1. Climate goals worldwide and in Germany
2. Project characteristics
3. First project results
   - Development of the use of “green” PtG gases and the installed power-to-gas power
   - Development scenarios for installed power-to-gas power
   - Preliminary modelling results
4. Preliminary conclusion

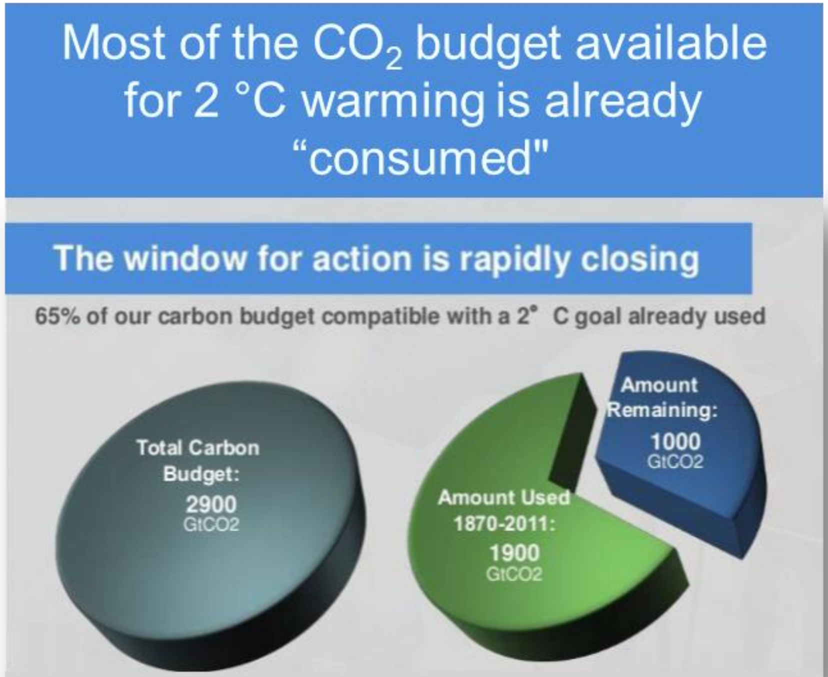
CLIMATE GOALS WORLDWIDE AND IN GERMANY

Limiting global warming to “far below 2 ° C", preferably 1.5 °C

- Reduction of greenhouse gases (GHG) CO_2, CH_4, N_2O, ... emissions
- COP 21 climate target entered into force with Paris Agreement in Nov 2016
- also binding for Germany

What does this goal mean for Germany?

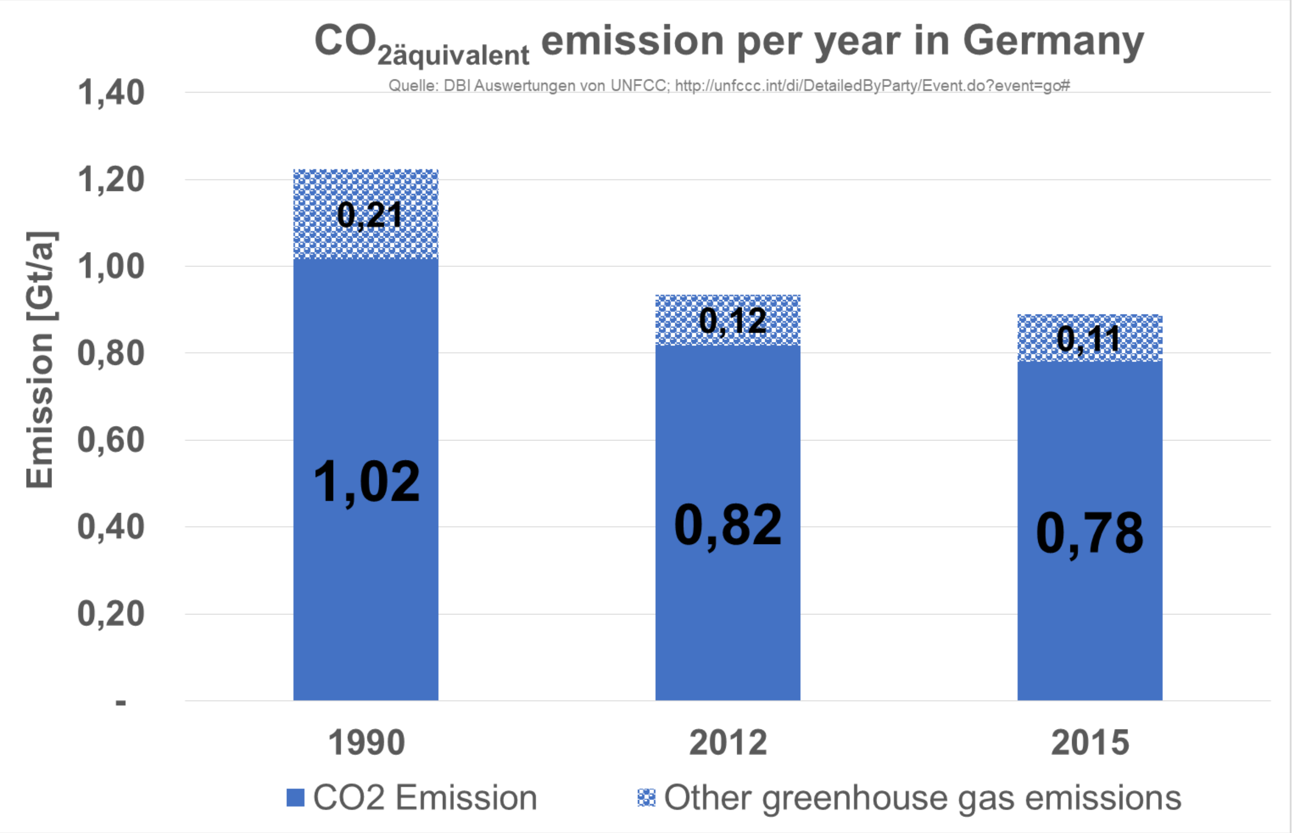
- Reduce GHG emissions
  by ~~80~~ - **95%** in 2050
  (related to primary energy consumption in 1990)



CO_2 Budget weltweit | Quelle: IPCC 2014, AR5, WGI, SPM

GERMANYS CO_2 BUDGET ONLY LASTS A FEW YEARS

- remaining CO_2 budget for Germany according to WWF & WBGU from 2015
  - [1,5 °C target] 2,34-2,67 Gt_{CO2}
  - [1,7 °C target] 5,23 Gt_{CO2}
  - [2 °C target] 9,9 Gt_{CO2}



- assumptions for CO_2 budget allocation: Germany can emit approximately 1.1% of the world's remaining CO_2 budget (target achievement with 66% probability)

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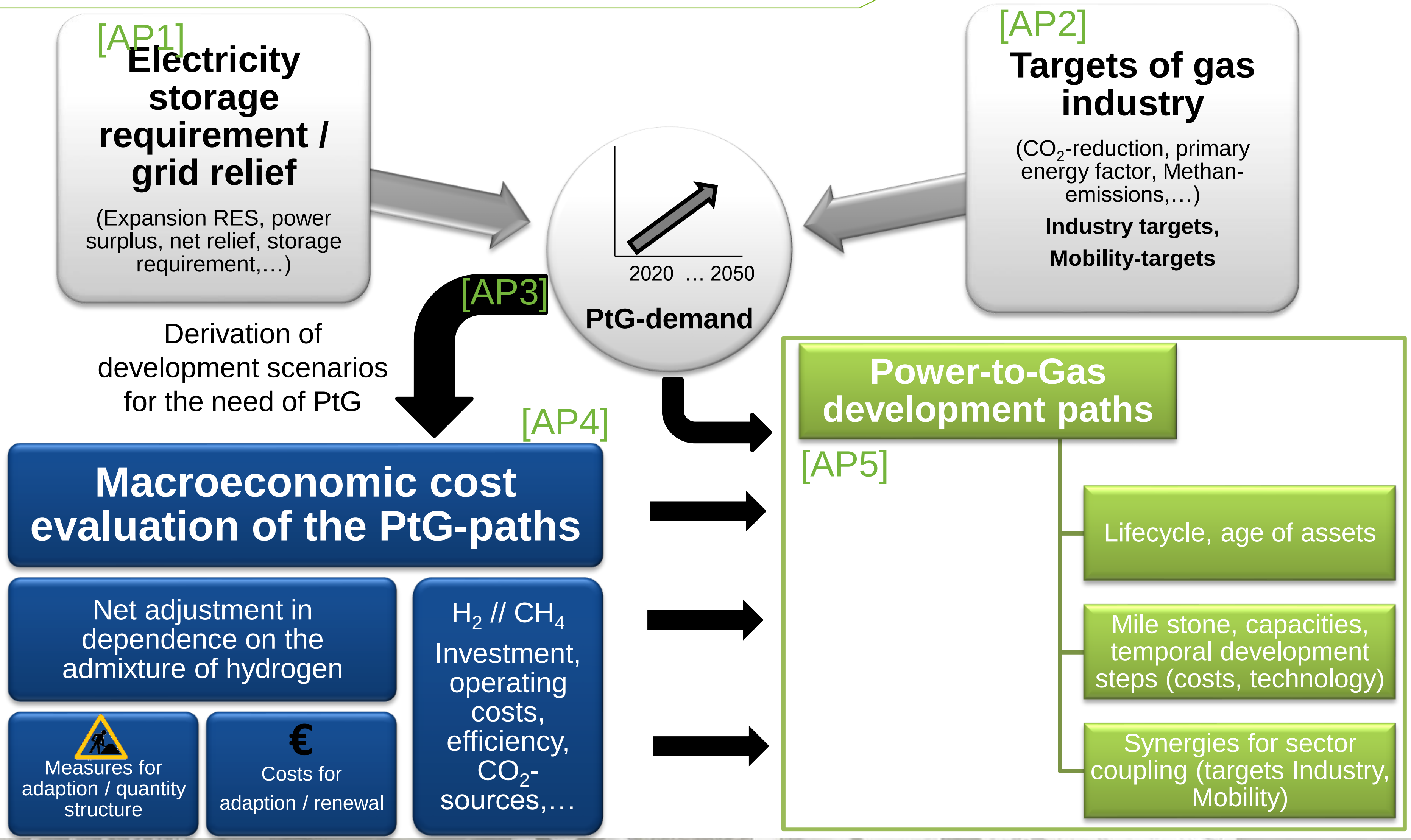
- **Fuel Switch:**
  Substitution of GHG-heavy fossil fuels such as coal and oil with natural gas
  → **Reduction of GHG emissions incl. prechains compared to hard coal and lignite between 41 and 44%[1]**

- **Content Switch:**
  Integration of renewable gas into the gas supply - long-term transition to a GHG-free energy source through the use of biomethane, hydrogen and SNG
  → **Reduction of the CO2 footprint of gas by 47% (by 2050)[2]**

- **Modal Switch:**
  Sector coupling by gas-fired combined heat and power systems to cover the heat demand and residual loads in the renewable energy supply
  → **Coverage of Residual Load Electricity from CHP Systems to 79%[3]**

OVERVIEW AND KEY DATA OF THE PROJECT

- Project partners:
  - DBI Gas- und Umwelttechnik GmbH
  - Lehrstuhl für Elektrische Energieversorgungstechnik (EVT) der Bergischen Universität Wuppertal
  - DVGW-Forschungsstelle am Engler-Bunte-Institut (EBI) des Karlsruher Instituts für Technologie (KIT)
- Project support Group:
  - Uniper Energy, Thüga Energie, Westnetz, ENCON.Europe, DREWAG, Thyssengas, Open Grid Europe, thyssenkrupp, GASCADE Gastransport, ONTRAS Gastransport, DWV (Deutscher Wasserstoff- und Brennstoffzellen Verband), EWE NETZ
- Running time: 08/01/2016 – 03/31/2018 (20 months)


[AP1]
Electricity storage requirement / grid relief
(Expansion RES, power surplus, net relief, storage requirement,…)
[AP2]
Targets of gas industry
(CO_2-reduction, primary energy factor, Methan-emissions,…)
Industry targets,
Mobility-targets
2020 … 2050
PtG-demand
[AP3]
Derivation of development scenarios for the need of PtG
[AP4]
Macroeconomic cost evaluation of the PtG-paths
Net adjustment in dependence on the admixture of hydrogen
H_2 // CH_4
Investment, operating costs, efficiency, CO_2-sources,…
Measures for adaption / quantity structure
€
Costs for adaption / renewal
Power-to-Gas development paths
[AP5]
Lifecycle, age of assets
Mile stone, capacities, temporal development steps (costs, technology)
Synergies for sector coupling (targets Industry, Mobility)

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First results

Development of the use of “green” PtG gases and the installed power-to-gas Capacity

Sectors | Heat + Electricity + Fuel + Material use (NEV)

Use of “green” PtG gases in future

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Use of “green” PtG gases

Sectors

- Electricity
- Heat
- Fuel
- Feedstock

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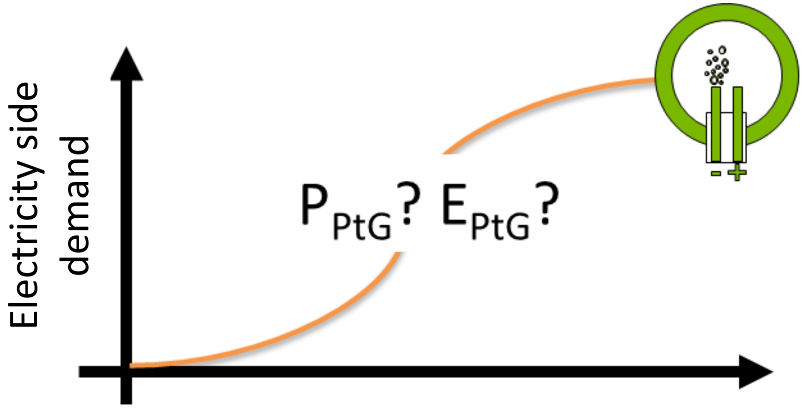
- PtG gases include “green” hydrogen und “green” methan (SNG)
- Distribution (admixture) in the gas network and local (direct) use
- Gradual conversion of natural gas to “green” PtG gases and use of “green” PtG gases in new technologies (e.g. fuel cell mobility)
- Restriction: feedstock is not considered (natural gas use is assumed); simplification due to proportionately low gas demand

Target of the work package

- **Estimation** of the **electricity side** power-to-gas demand in power systems with high greenhouse gas reduction (GHG reduction) compared to 1990
- **Quantification** of electrical work and resulting PtG demand



Method

Power-to-Gas demand

In the electricity system

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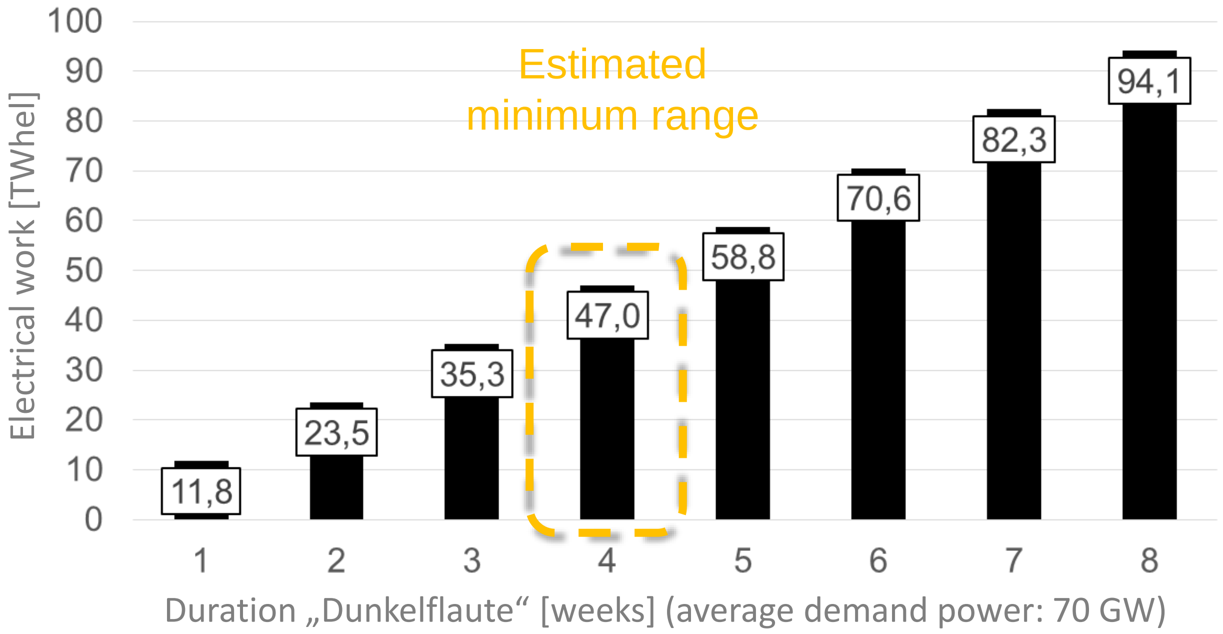
Estimation of the PtG demand for the coverage of “Dunkelflauten” in future energy systems



Required backup power from power plants

- 60-70 GW (Wind-gas-study 2015)
- 70 GW (Backup-power of power plants, BMU 2014)
- Ca. 65 GW (required. power conv. Power plants. on the 01/24/2017)
- → Chosen: **70 GW**

Required duration

- No exact limitation possible according to literature
- **Several weeks** per year (Leopoldina-study 2016, ew 2017)

Appraisal

- Duration: ca. four weeks → ca. 47 TWh_{electr}
- 47 TWh_{electr} for „Dunkelflaute“ < 60 TWH_{electr} lt. study „Die Energiewende nach COP 21“ / Sz. „Klima 2050“

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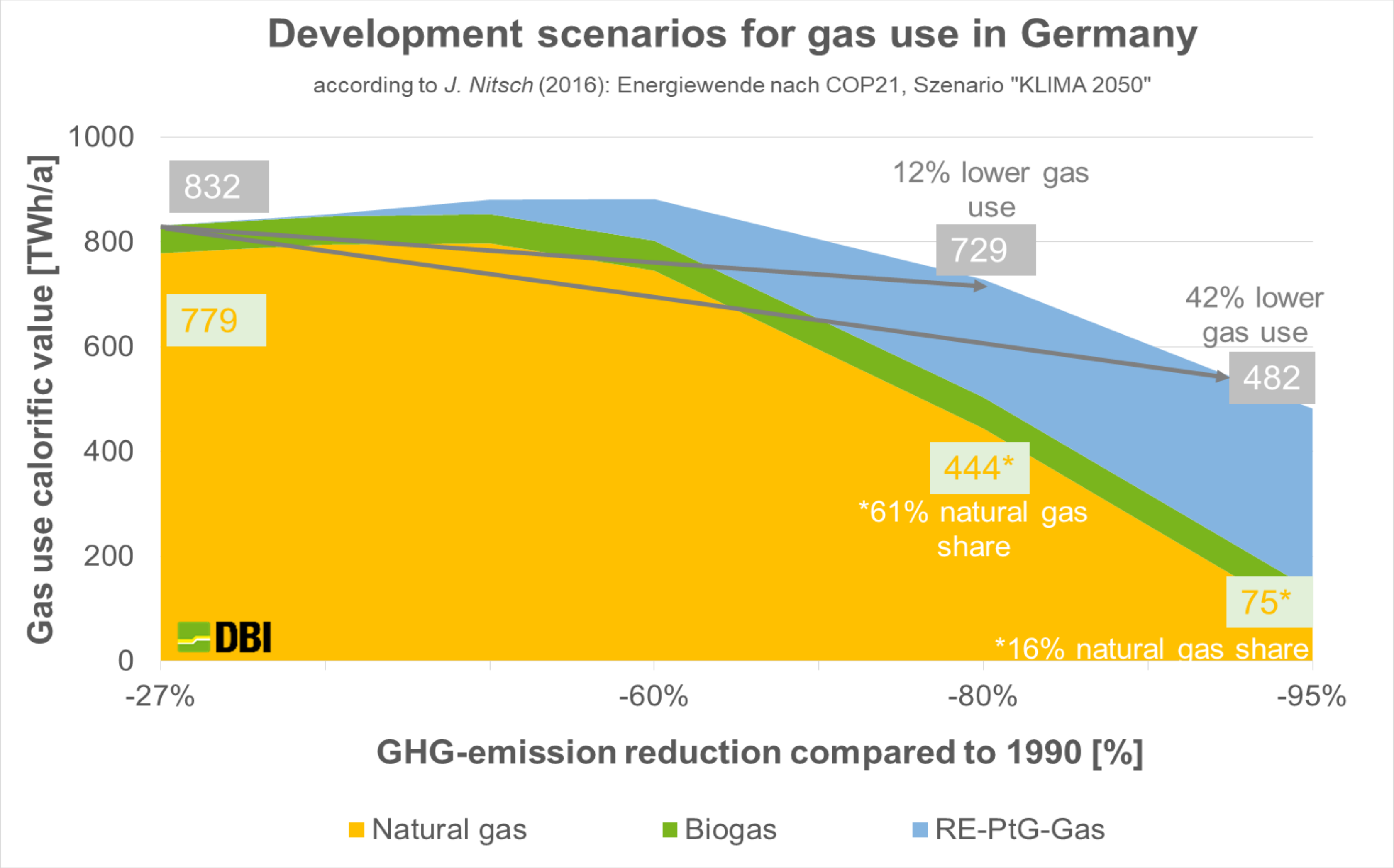

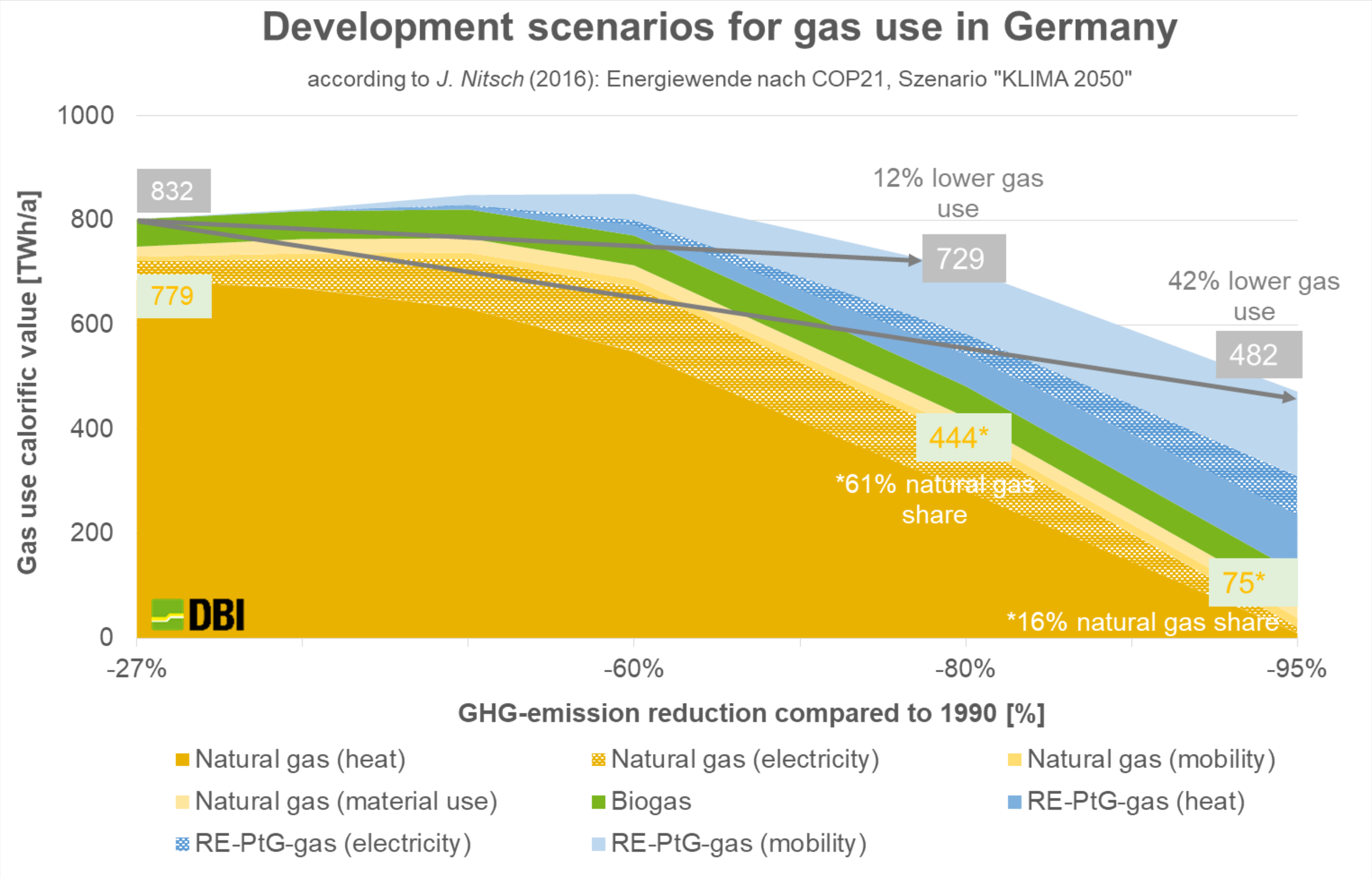
Development scenarios for gas use in Germany
according to J. Nitsch (2016): Energiewende nach COP21, Szenario "KLIMA 2050"
1000
800
600
400
200
0
Gas use calorific value [TWh/a]
832
779
12% lower gas use
729
42% lower gas use
482
444*
*61% natural gas share
75*
*16% natural gas share
DBI
-27%
-60%
-80%
-95%
GHG-emission reduction compared to 1990 [%]
Natural gas (heat)
Natural gas (electricity)
Natural gas (mobility)
Natural gas (material use)
Biogas
RE-PtG-gas (heat)
RE-PtG-gas (electricity)
RE-PtG-gas (mobility)

DEVELOPMENT SCENARIOS FOR INSTALLED POWER-TO-GAS CAPACITY

$$\text{installed PtG capacity } [GW_{el}] = \frac{\text{demand of „green“ PtG gases [TWh/a]} * 10^3}{\text{efficiency x full load hours [h/a]}}$$

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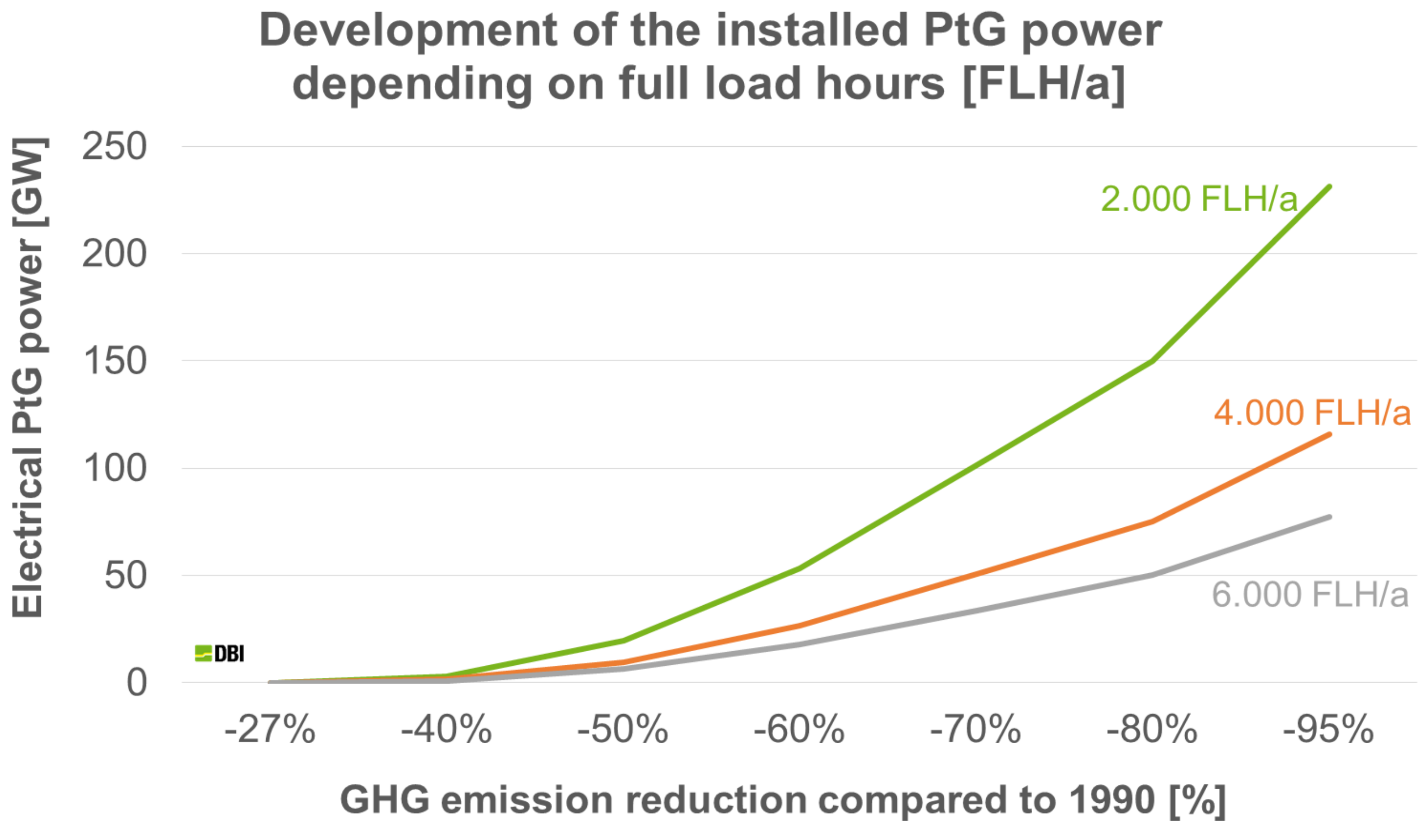
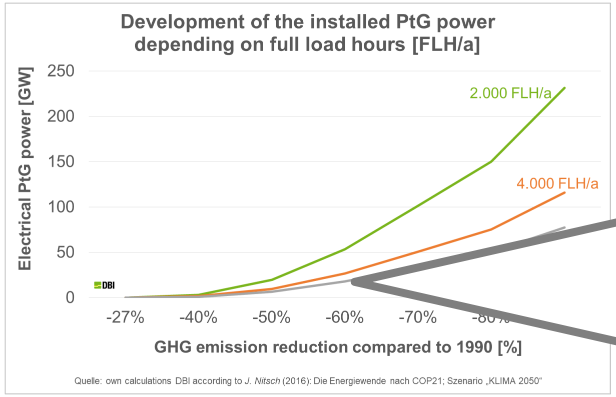
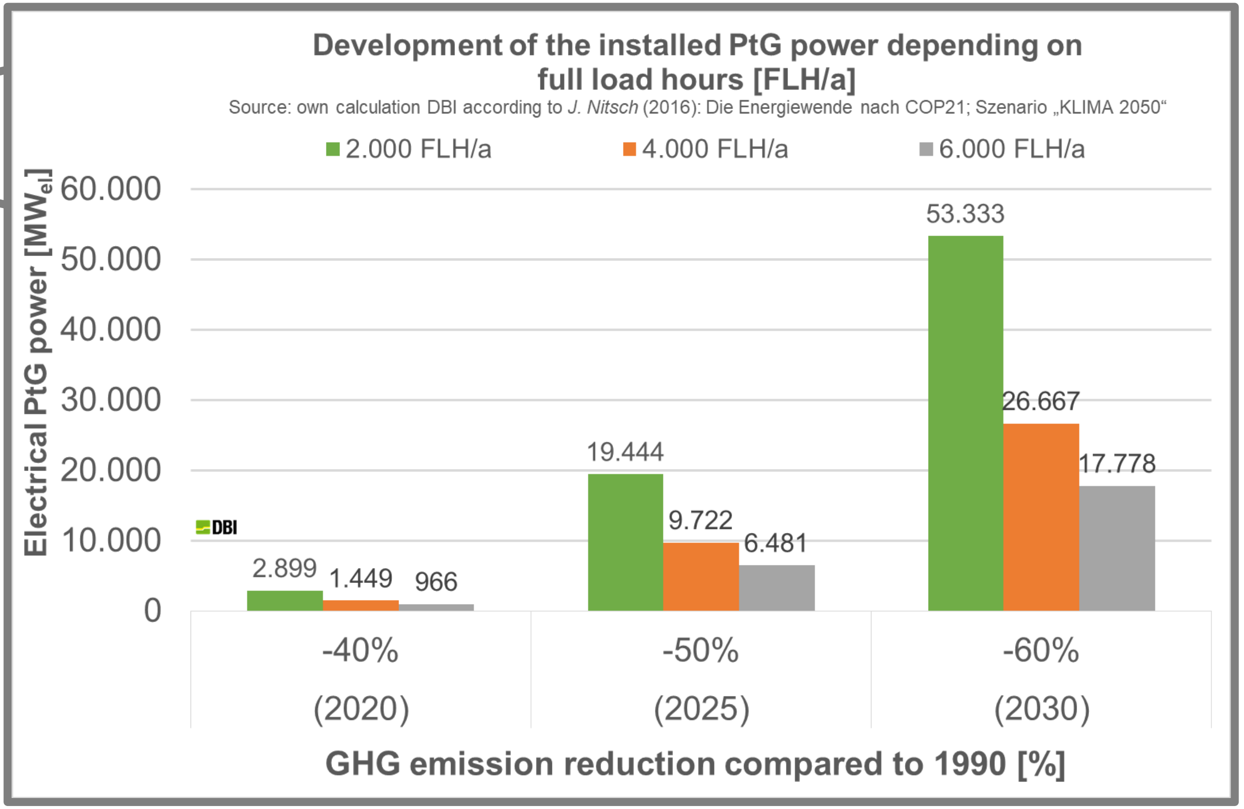


Quelle: own calculations DBI according to *J. Nitsch* (2016): Die Energiewende nach COP21; Szenario „KLIMA 2050“

DEVELOPMENT SCENARIOS
INSTALLED POWER-TO-GAS CAPACITY





Preliminary modelling results

PRELIMINARY MODELLING RESULTS
(VERY) ROUGH MODEL LOGIC

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€
Macroeconomic optimisation

costs of hydrogen injection

Investment costs H_2
+ Operating costs H_2
+ Adjustments Infrastructure

vs/and

Costs of methane injection

Investment costs CH_4
+ Operating costs CH_4
+ Efficiency losses

transformation speed

What is the macroeconomic optimum of the PtG paths (hydrogen and methane) taking into account the transformation speed?

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Question

Which is the cost-optimal adjustment path for gas networks and gas storage (TSO / UGS, DSO) for the integration of "green" PtG gases ("green" hydrogen and "green" methane) in a realistic scenario considering the climate targets until 2050?

Gas infrastructure optimisation model for the integration of "green" PtG gases

Development Gas Demand

- According to Nitsch (2016): Energiewende nach COP21, Szenario "Klima 2050"
- Sectors dissolved

Resources Gas Infrastructure

- Quantity structure
- Age structure
- Useful life
- H_2-tolerance gas infrastructure
- Adjustment costs

Development Technology

- Methanisation
- CO_2-sources
- Injection station

Technology Paths

- Admixture "green" PtG-H_2
- Admixture "green" PtG-CH_4

Boundary Conditions

- Division PtG-feed TSO / DSO
- Starting year
- Annual steps
- Throughout Germany

Scenarios

- Benchmark
- Basis Scenario
- Sensitivities

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Benchmark

Which adjustment path for higher hydrogen tolerances for gas networks and gas storage facilities (TSO / UGS, DSO) can be achieved by 2050, if only replacement investments are used and climate targets are not taken into account?

Basis scenario

Which is the cost-optimal adjustment path for gas networks and gas storage (TSO / UGS, DSO) for the integration of demanded “green” PtG gases (“green” hydrogen and “green” methane) in a realistically assumed basis scenario considering the climate targets until 2050?

Sensitivities

How sensitive are the results of the basis scenario to selected changes of individual assumptions or boundary conditions?

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Question Preview Benchmark

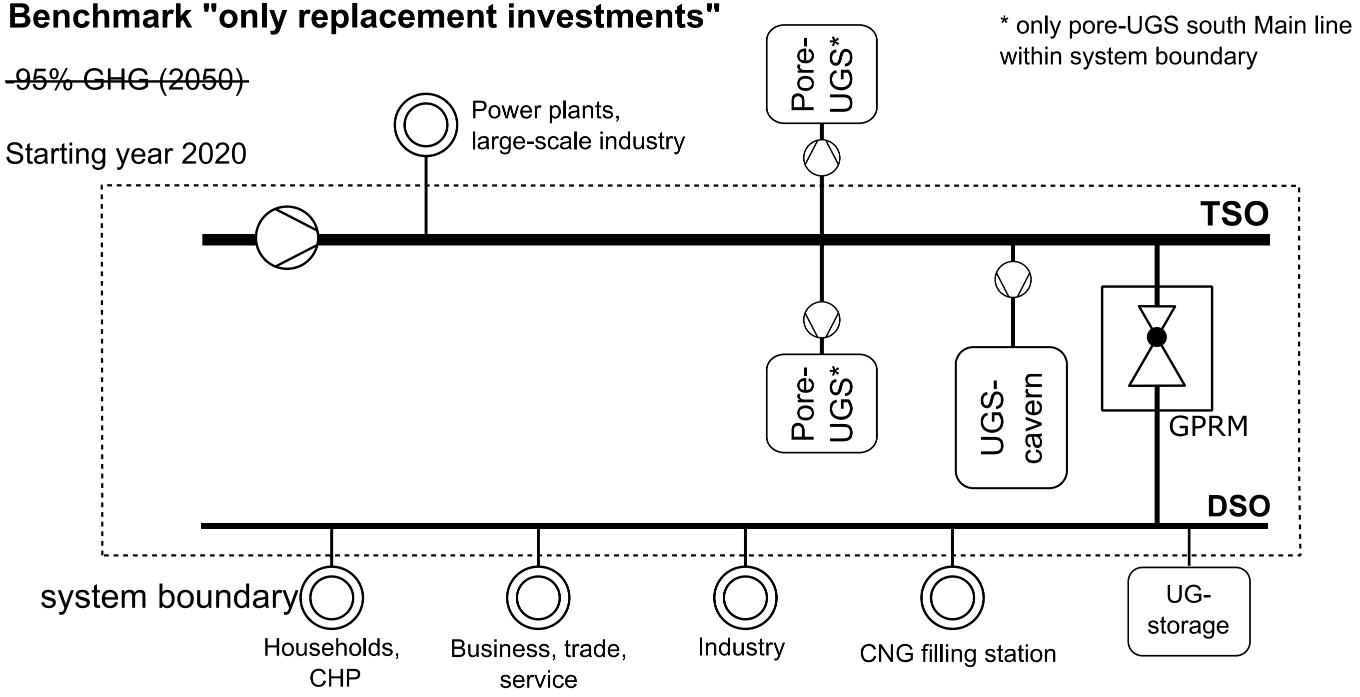
Which adjustment path for higher hydrogen tolerances for gas networks and gas storage facilities (FNB / UGS, VNB) can be achieved by 2050, if only replacement investments are used and climate targets are not taken into account?

System depiction

Benchmark "only replacement investments"

~~-95% GHG (2050)~~

Starting year 2020



Description

- **„Natural or regular exchange of elements in the natural gas infrastructure (exclusively through replacement investments)**
- **No consideration of the climate targets / gas demand**

→ **Serves as a benchmark for optimized transformation paths (s.b.)**

Replacement investments: Replacement of a pipe, machine or plant at the end of its amortization period;

TSO: Transmission System Operator;
DSO: Distribution System Operator

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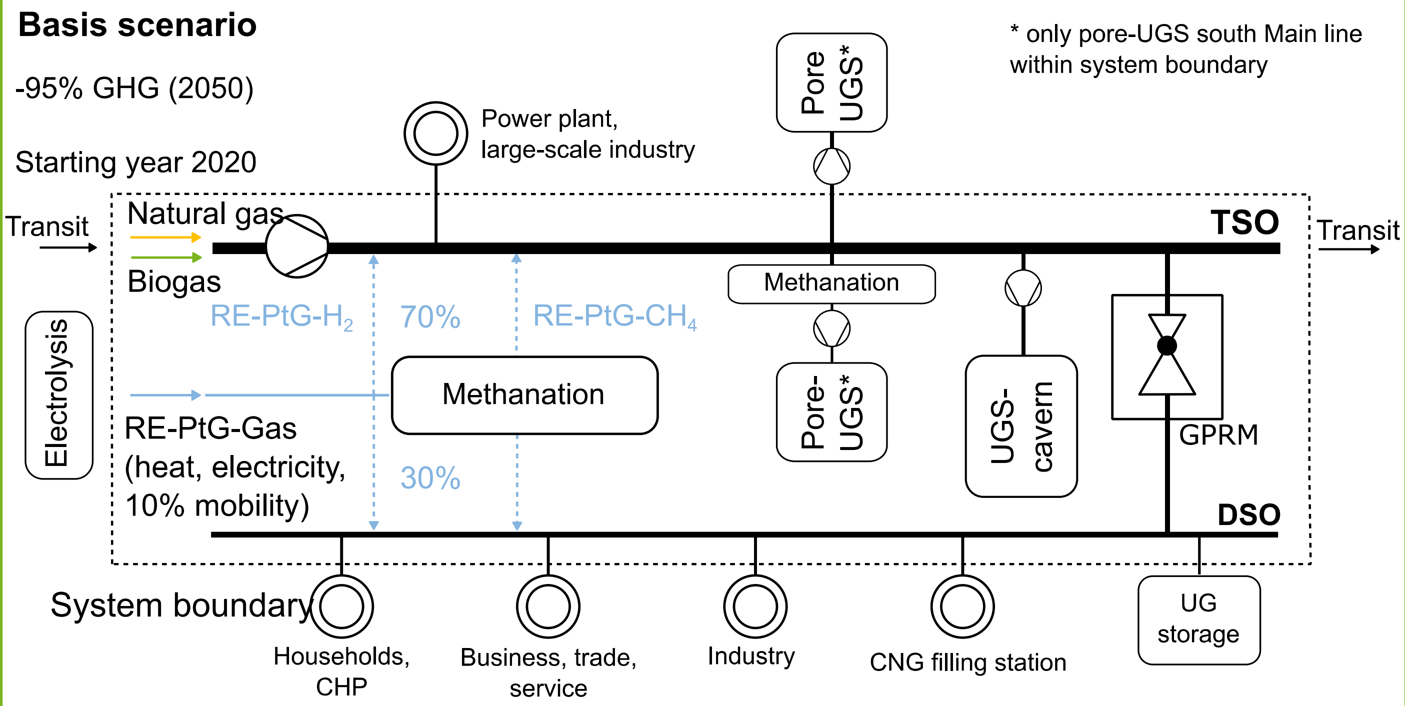
System depiction



TSO: Transmission System Operator; DSO: Distribution System Operator
Biogas: includes not only biomethane but also mine and sewage gases

Discription

- 95% GHG-Reduction by 2050
- **Inject "green" PtG-gases to 70% in TSO and to 30% DSO**
- **10% "green" PtG-gases (traffic) in the gas network**
- Porous rock UGS in South Germany included (H2 share of the gas to be stored is methanised); in North Germany porous rock UGS will be decommis-sioned because economically not viable.
- **No limitation of the H_2-concentration specified**

PRELIMINARY MODELLING RESULTS
ADDITIONAL INVESTMENT COMPARED TO BENCHMARK

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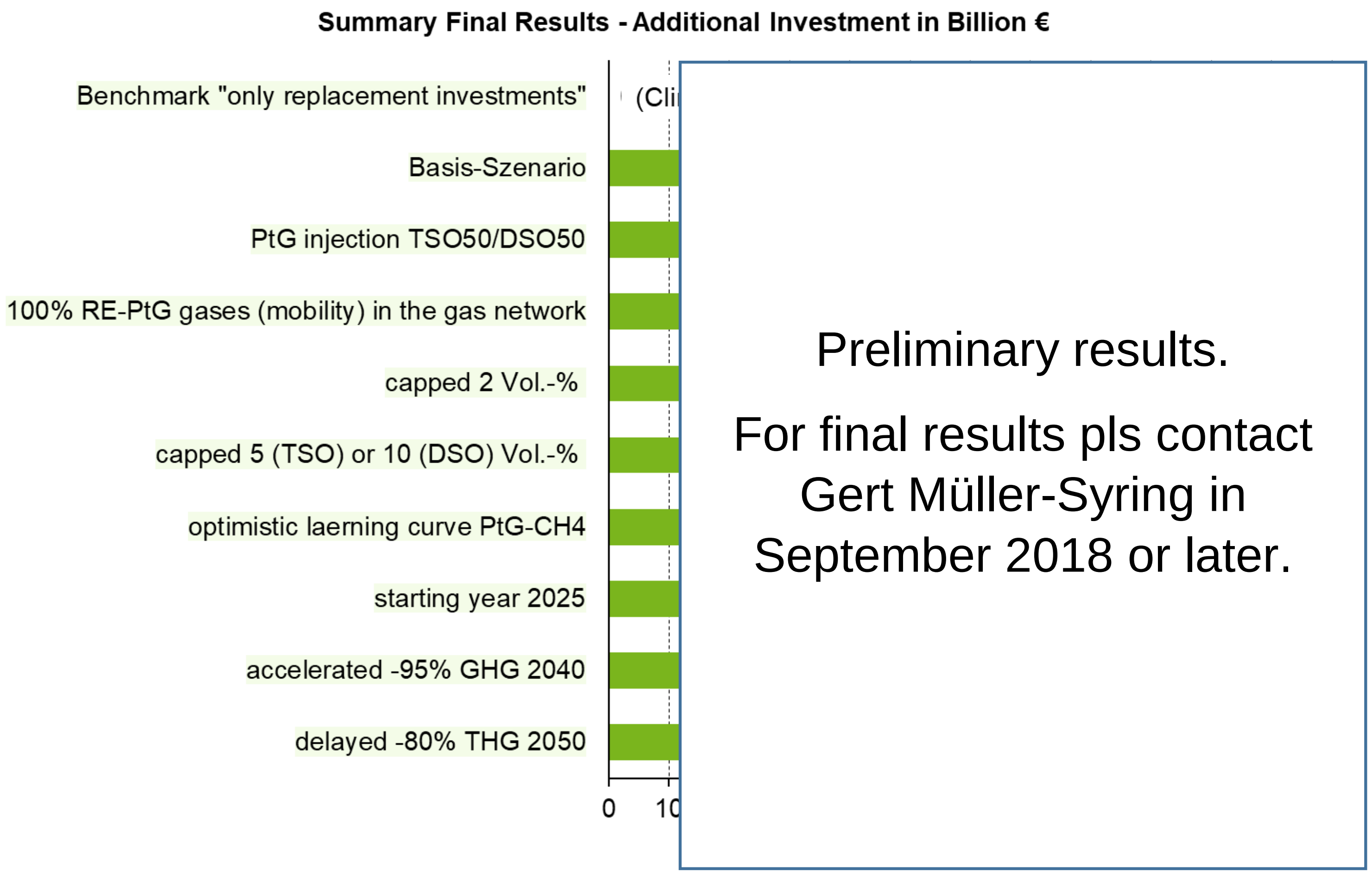

CONCLUSION

Conclusion (provisional) Gas as partner of the energy transition

Possibilities with gas

- Gas as an energy carrier and with its infrastructure can substantially support the achievement of the COP 21 climate targets - global warming below 2 °C
- The introduction of PtG technology is essential for the energy industry / energy transition (greenhouse gas neutrality of the heat, transport and chemical sectors is otherwise difficult and expensive) and should be macroeconomic as cost-effective as possible
- Preliminary project results show for gas network and gas storage transformations (gas users and H_2 production were not considered) cost-optimal pathways that predominantly inject “green” H_2 and, when limiting the H_2 concentration e.g. to 10 vol%, experienced significant cost increases
- the results provide a basis e.g. for the exchange with gas users and are to be further developed in a follow-up project to overall system statements
- The market introduction of PtG and a targeted stimulation of the production of “green” PtG gases should now take place (technology development)
- Concrete recommendations for market launch / incentives will be developed in another DVGW R&D project and presented in September 2018

Energy with Future.
Environment and Responsibility.

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THANK YOU FOR YOUR ATTENTION!

Your contact partner

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DVGW

Climate goals worldwide and in Germany
Commitment to COP 21

- Climate Action Plan 2050 for Germany follows the targets of COP 21
- Reduction of GHG emissions by 80-95% in 2050 (based on primary energy consumption in 1990)
- Natural gas support of major importance but long-term substitution by renewable gases

„... extensive greenhouse gas neutrality until the middle of the century. ...“