Techno-Economic Analysis of H_2 use in the existing Gas Turbine Power Plant Fleet in Germany

C. Goßrau | L. May | N. H. Petersen | A. Sebastian | Univ.-Prof. Dr.-Ing. habil. M. Wirsum

Motivation

- Gas turbines (GT) are suitable to maintain grid stability in future energy systems, but will face less operation and more cycles
- ! Phase-out of other fossil power plants (PP) suggests lifetime extension of GTPP
- Natural gas (CH_4) fired GTPP come at the disadvantage of emitting CO_2
- ! Use of hydrogen (H_2) as viable solution to meet future climate goals
- ➢ Assessment of financial viability of existing GTPP with H_2 or Carbon Capture (CC)

Method

- ➢ GTPP performance and emission data from an in-house code
- ➢ Levelized cost of electricity ($LCOE$) for retrofitted GTPP

$$LCOE = \left(\sum_{t=1}^{N} \frac{I_{0,R} + C_M + C_F + C_{CO_2}}{(1+\mathrm{WACC})^t}\right) \Big/ \left(\sum_{t=1}^{N} \frac{W_{el}}{(1+\mathrm{WACC})^t}\right)$$

$I_{0,R}$	$= (i_{0,R,CC} + i_{0,R,H_2}) \cdot P_{el}$	$i_{0,R,CC}$	$= 550$ €/kW$_{el}$ [2,3]
$I_{0,GTPP}$	$= i_{0,GTPP} \cdot P_{el}$	i_{0,R,H_2}	$= 500$ €/kW$_{el}$ [4]
C_M	$= 0.04 \cdot (I_{0,GTPP} + I_{0,R})$ [1]	$i_{0,GTPP}$	$= 1100$ €/kW$_{el}$ [5]
C_F	$= \sum_{S,T} C_{F,i}$	WACC	$= 5.8$ % [1]
C_{CO_2}	$= \sum_{C,T,St} C_{CO_2,i}$	N	$= 20$ a

I_0: investment cost, i: specific cost, C: cost, WACC: weighted-average cost of capital, N: lifetime, R: retrofit, M: maintenance, F: fuel, S: supply, T: transport, C: certificate, St: storage

Data base

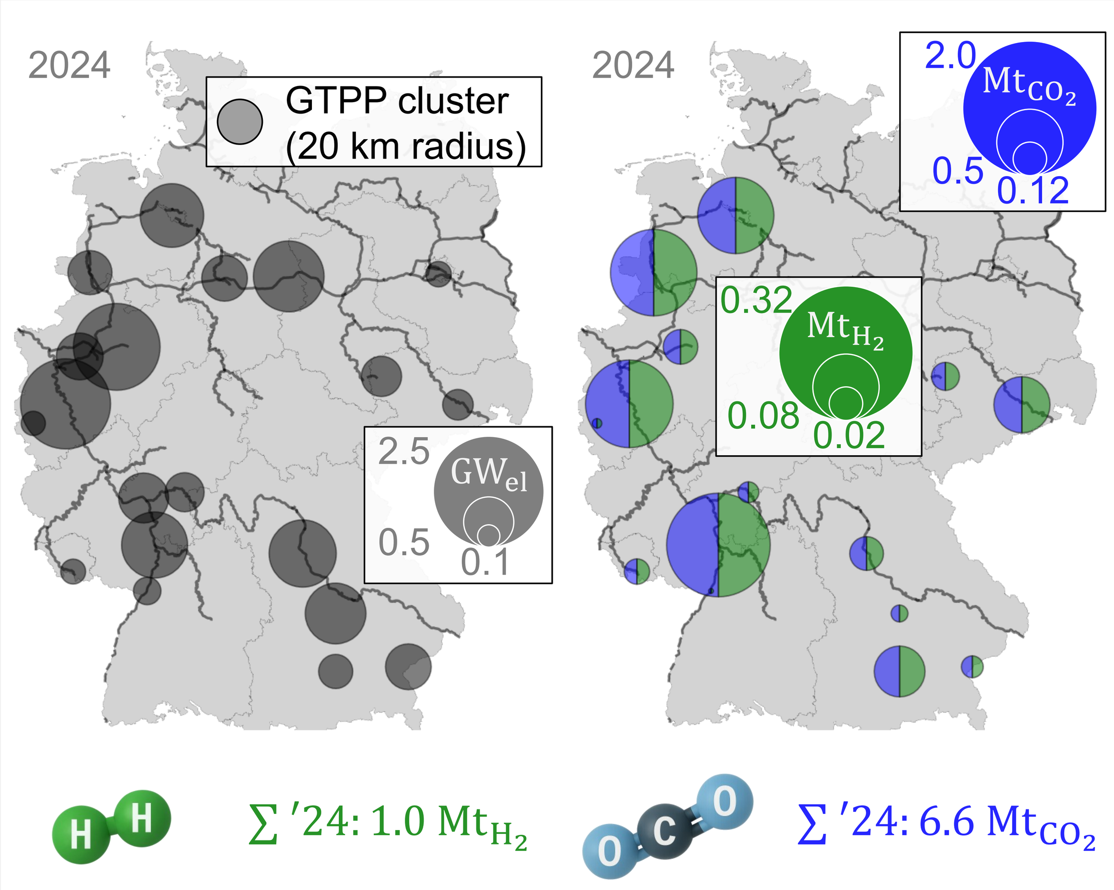
Retrofit implications on GTPP

CC	r_{CO_2} : 90 %	η_{GTPP} : −10 %−pts
H_2	r_{CO_2} : 100 %	η_{GTPP} : ±0 %−pts

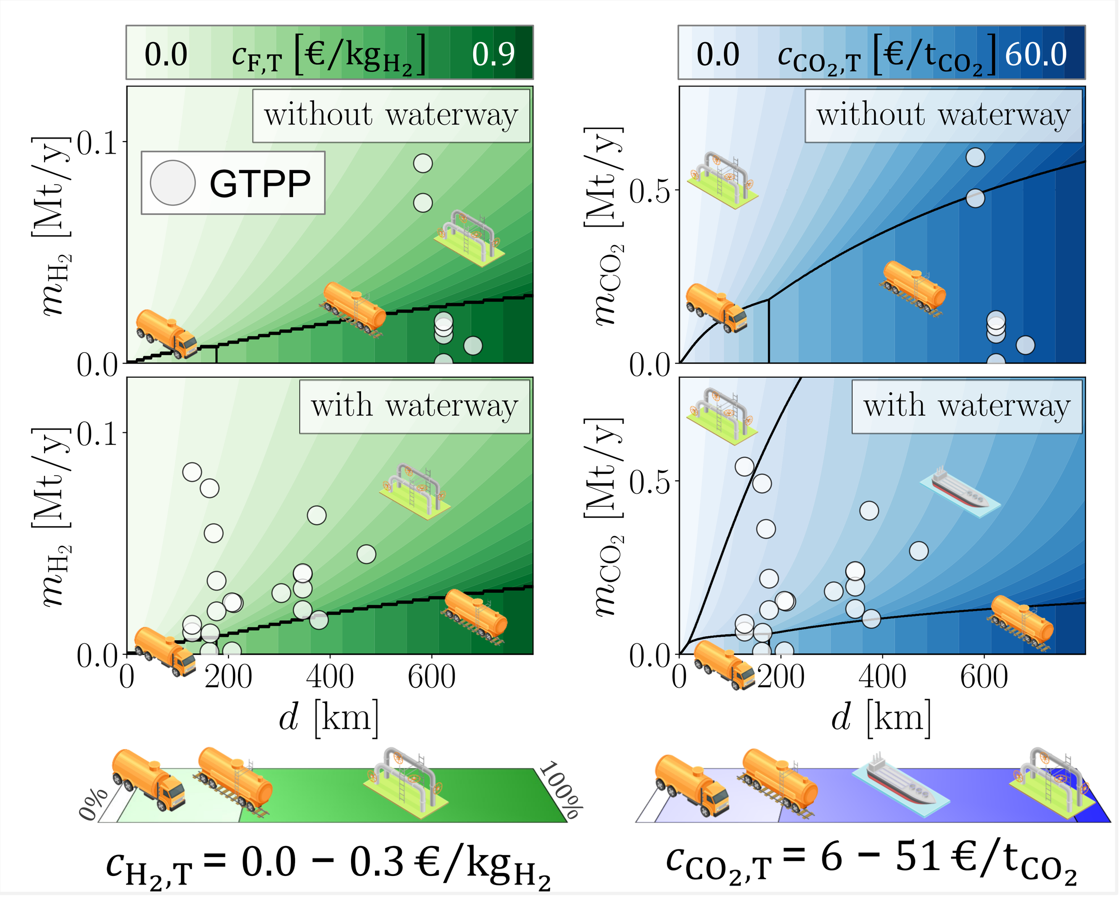
Fuel and CO_2 cost		2030	2040	2050
$c_{CH_4,S}$ [6]	[€-ct./kWh]	5.9	9.0	10.4
$c_{H_2,S}$ [6]	[€-ct./kWh]	19.0	13.8	13.0
$c_{CO_2,C}$ [6]	[€/t_{CO_2}]	105	150	215
$c_{CO_2,St}$ [7]	[€/t_{CO_2}]	20	20	20

GTPP fleet		Min	Mean	Max	Total
η_{el}	[%]	34	50	61	-
P_{el}	[MW]	42	390	934	16,003

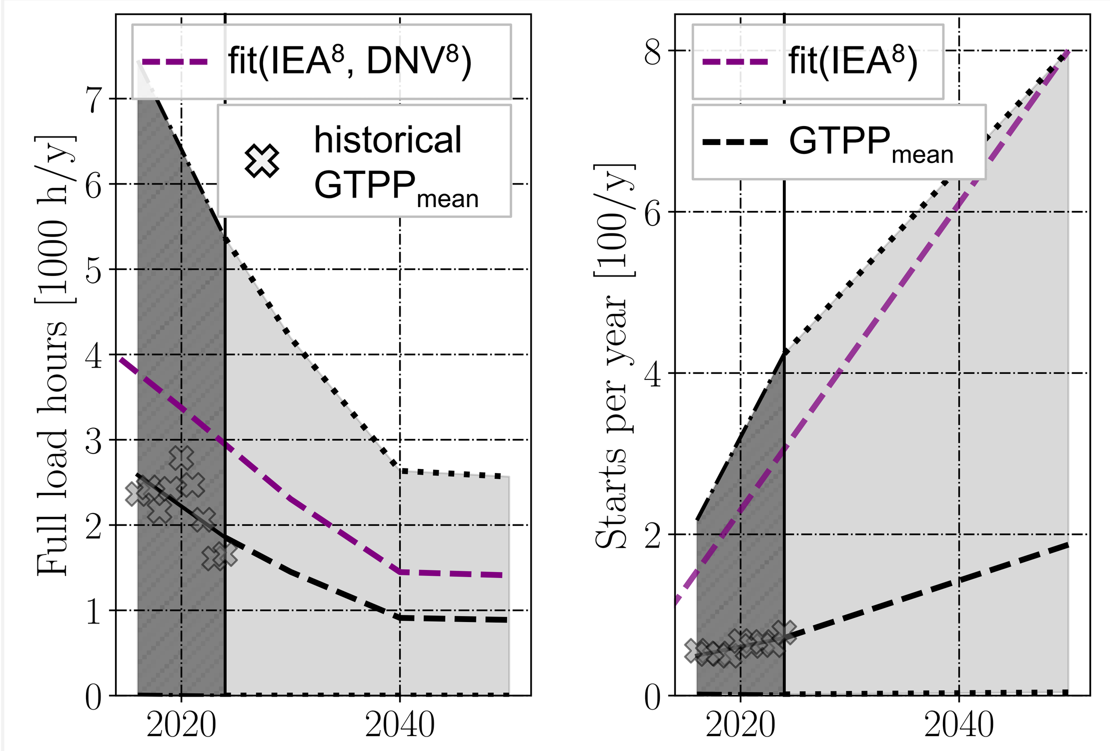
H_2 and CO_2 transport demands



H_2 and CO_2 transport costs

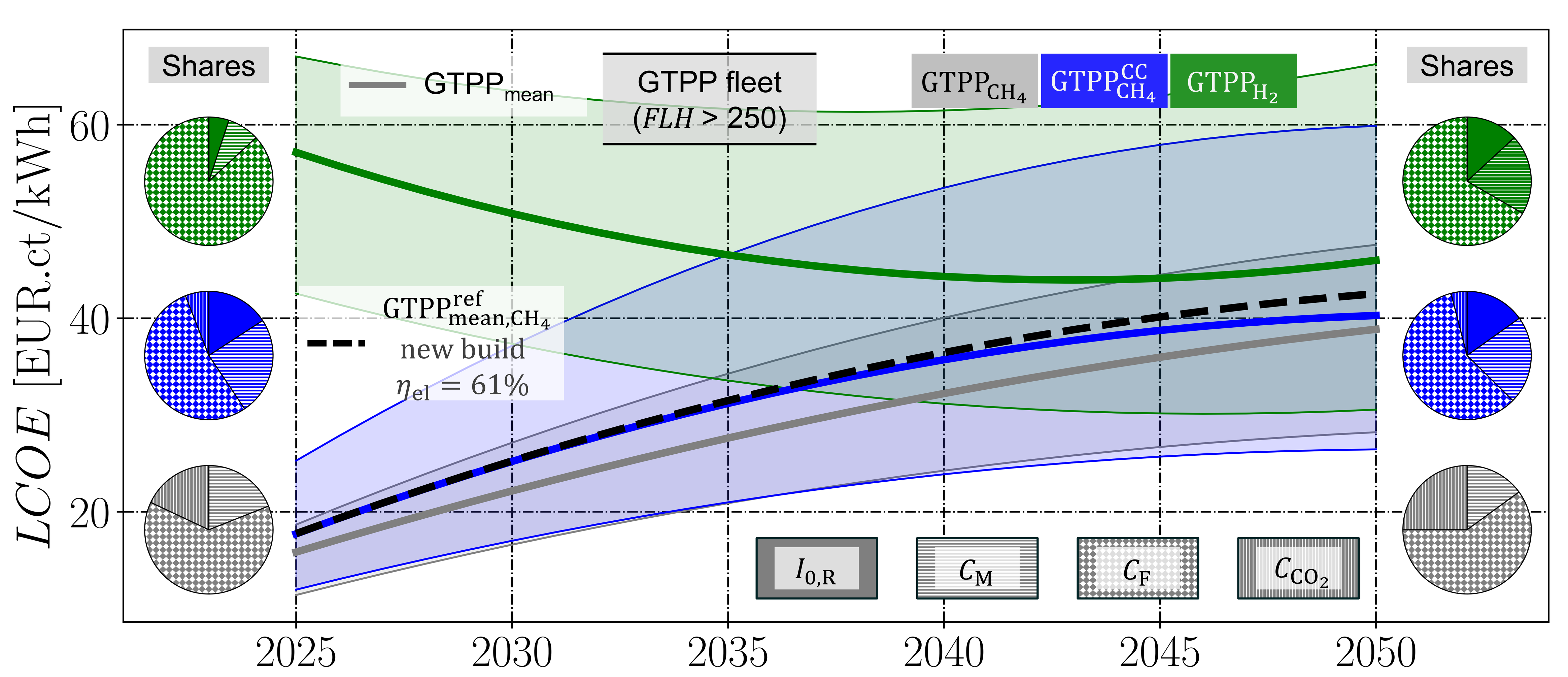


GTPP fleet operation scenarios

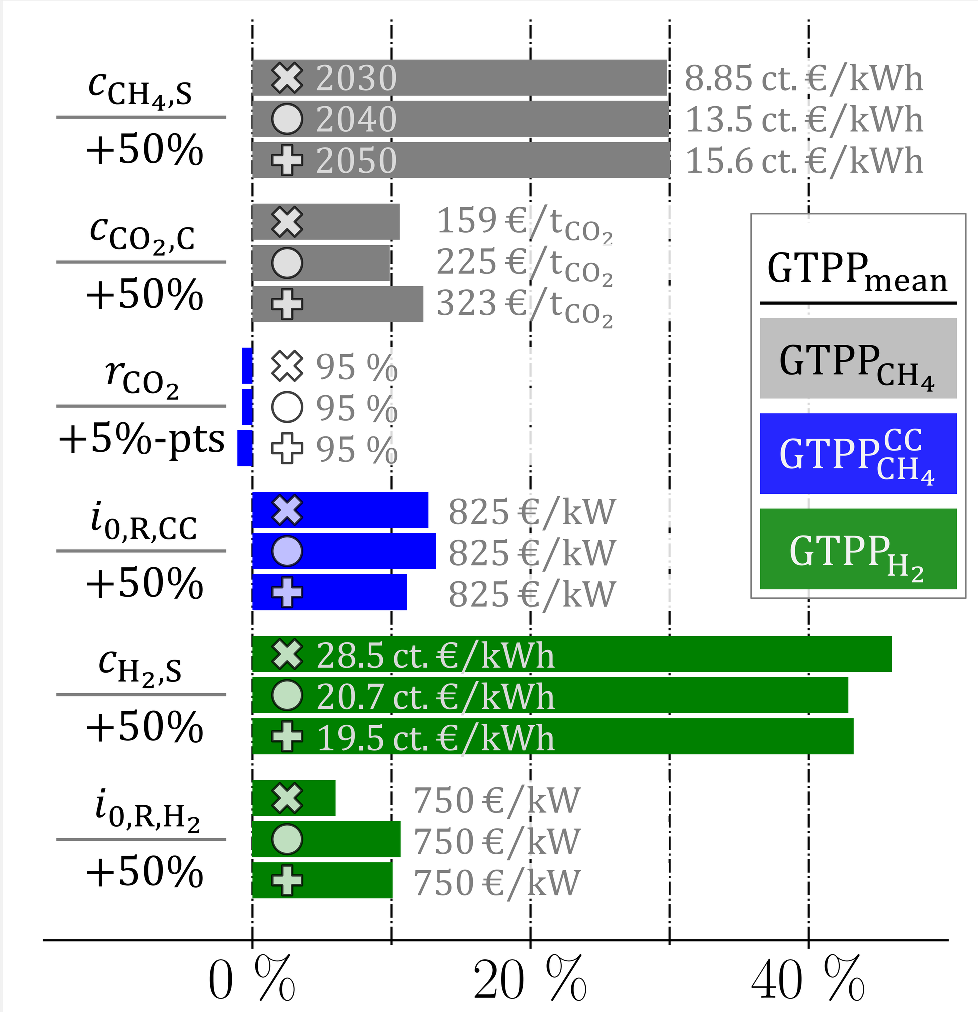


- ➢ FLH: -50 % for all power plants
- ➢ SPY: +136 % for all power plants (max. 800 SPY)

Levelised cost of electricity for GTPP fleet



LCOE sensitivity analysis



Conclusion

- Most optimal transport option for H_2: **pipeline** (70%) and for CO_2: **inland vessel** (63%)
- Significantly **less GTPP operation** (FLH -50%), but **more cycles** (SPY +136%) towards 2050
- $LCOE$ of GTPP with **CC slightly** (+3.7-13.8%) and with **H_2 retrofit significantly** (+18.3-225%) **higher**
- $LCOE$ sensitivity: (1) fuel costs (↑), (2) CO_2 certificate and retrofit costs (↗), (3) CO_2 capture rate (→)
- ➢ Evaluation of **each GTPP** and **different gas price scenarios** required to identify break-even points

References

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[6] DNV: "Energy Transition Outlook Germany 2025" (2025)
[7] Lockwood: „Kartierung der Kosten für CO_2-Abscheidung und Lagerung in Europa" (2023)
[8] ETN Global: „Rotor Lifetime Assessments: A Reference Report" (2024)

Institute of Power Plant Technology,
Steam and Gas Turbines
RWTH Aachen University
Mathieustraße 9, 52074 Aachen
www.ikdg.rwth-aachen.de

Christian Goßrau, M.Sc.
Group: Process Analysis and Systems
gossrau@ikdg.rwth-aachen.de
0214 80 26234