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ENERGIENETZE UND
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European Workshop on Underground Energy Storage, Nov 7th 2019, Paris
Session 1: „Introtucing the technologies“

Technologies status and perspectives of Power-to-Gas in connection with seasonal underground storage

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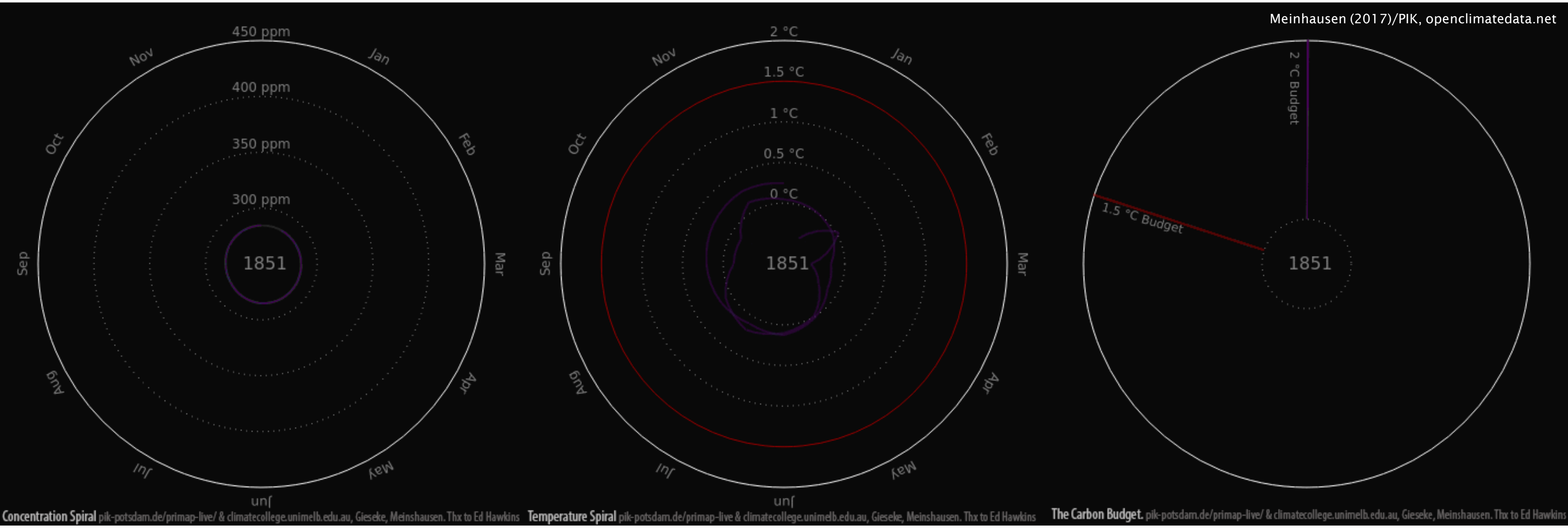
ORBIT
Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

Climate is changing

There is urgent need for action now

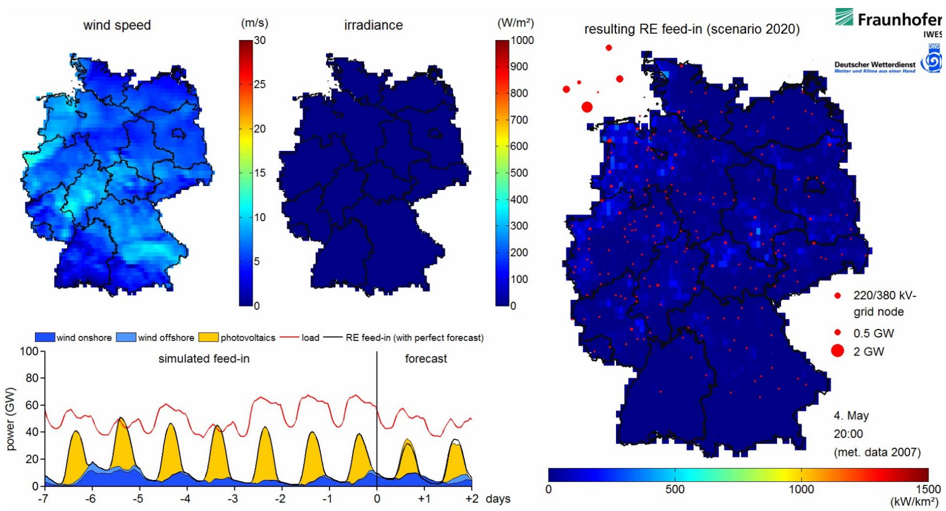
Causes



Effects

Fluctuations will increase with rising RE-generation

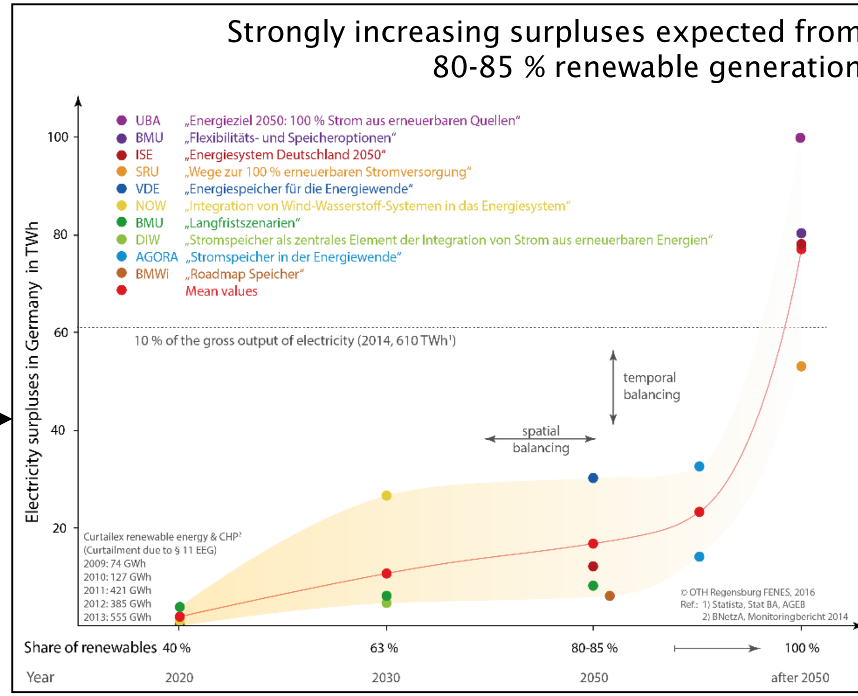
Surpluses or growing challenge for temporal and spatial balancing



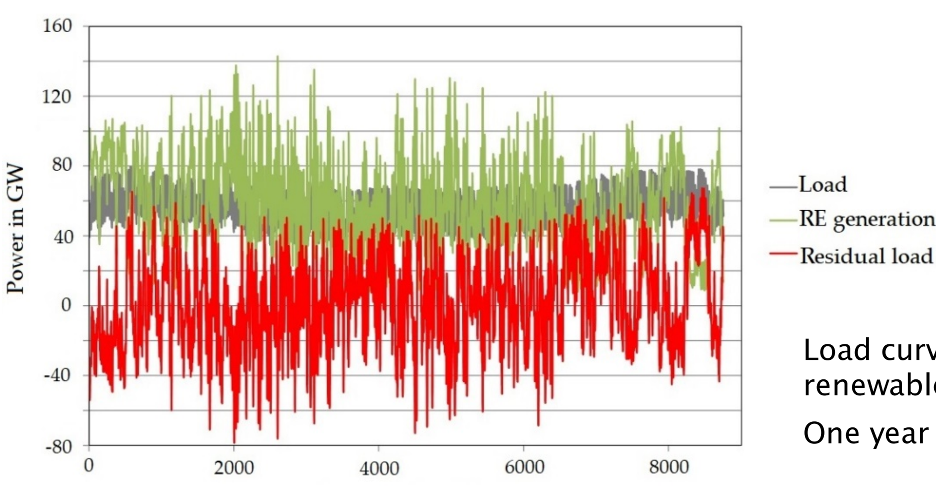
Fraunhofer IWES, Deutscher Wetterdienst: Nationaler Aktionsplan erneuerbare Energien

Renewable energy feed-in for a German power system at 39 % RE (IWES/DWD scenario 2020)

One month: may



Sterner and Stadler (eds., 2019)



Adamek et al. (2012)

Load curves for a German power system fed by 100 % renewable energies.

One year

analogue results for other European countries

Extension of renewable generation alone not sufficient

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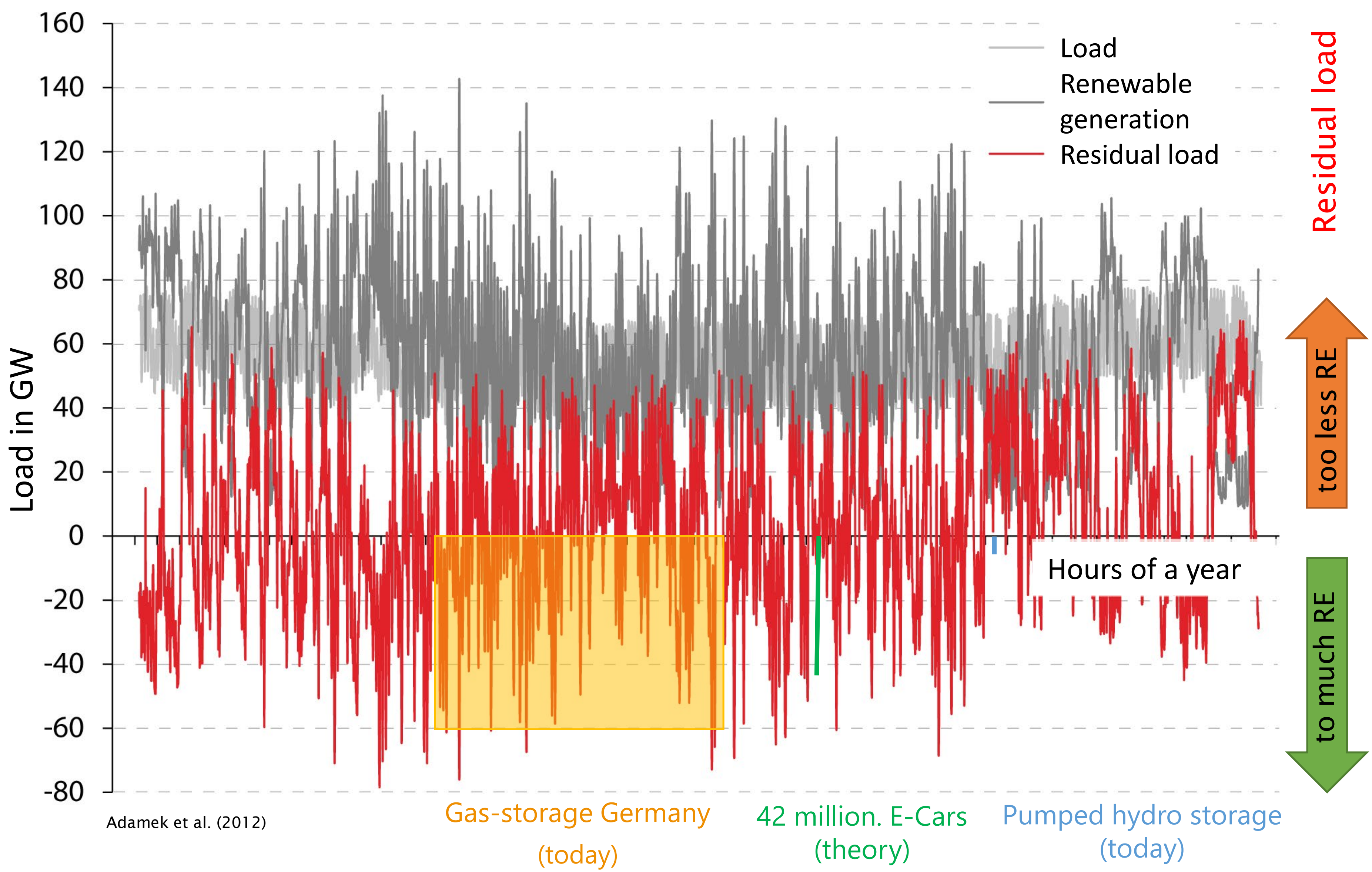
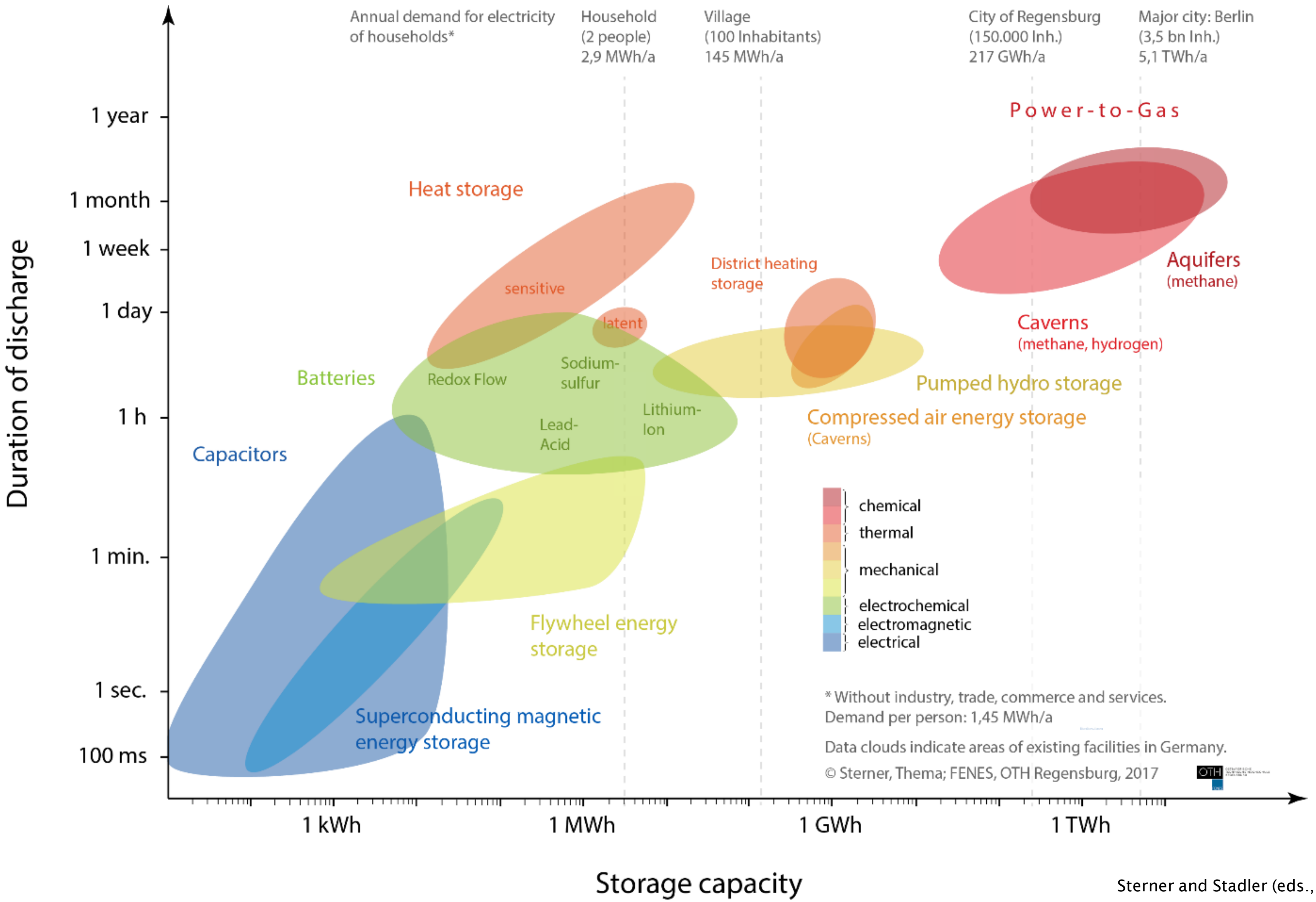
Intermittent generation will lead to demands for *new* flexibility



Energy storage ≠ energy storage: capacity vs. power

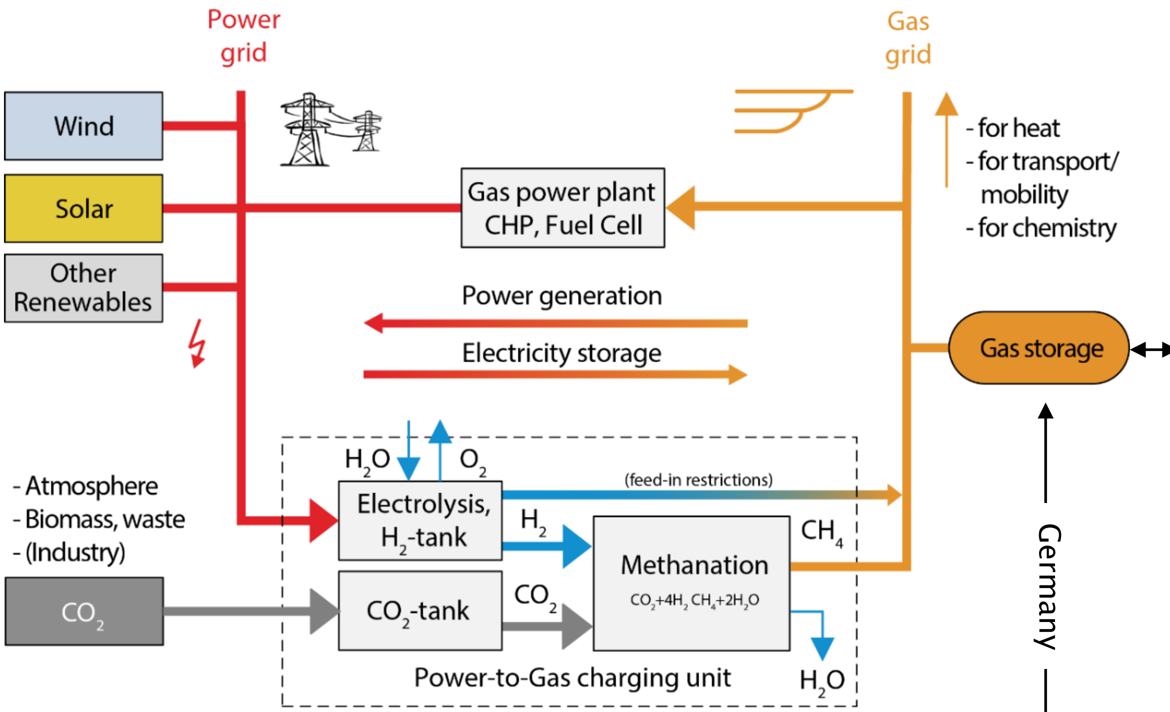
Chemical energy storage by far highest capacity per facility



Sterner and Stadler (eds., 2019)

Power-to-Gas concept

Convertering and storing energy in analogy to natures way of energy storage



Sterner and Stadler (eds., 2019)

Type of facility total Europe acc. to GIE (2018) incl. non EU28	Total capacity (CH_4) (operational, under constr., planned) TWh	no.
Aquifer	214,45	29
Crystalline	52,20	1
Depleted fields	1195,42	121
Rock cavern	0,10	1
Salt cavern	370,20	83
Total Europe	1832,37	235

GIE (2018)

entsog transparency platform: transparency.entsog.eu

Storage technology	Storeable volume (long-term)	Containing: Storage capacity for hydrogen in TWh	Storage capacity for methane in TWh
Pore storage/aquifers	10,8 bn m³(V_n)	--	119
Caverns	19,8 bn m³(V_n)	70,3	218
Sum	30,6 bn m³(V_n)		337
Gas storage total 2 Vol.-%-hydrogen	612 m m³(V_n)	2,17	
Gas storage total 10 Vol.-%-hydrogen	3,06 bn m³(V_n)	10,9	

Long-term available PtG storage capacity in German gas storages.

3 Months of power supply from gas storage

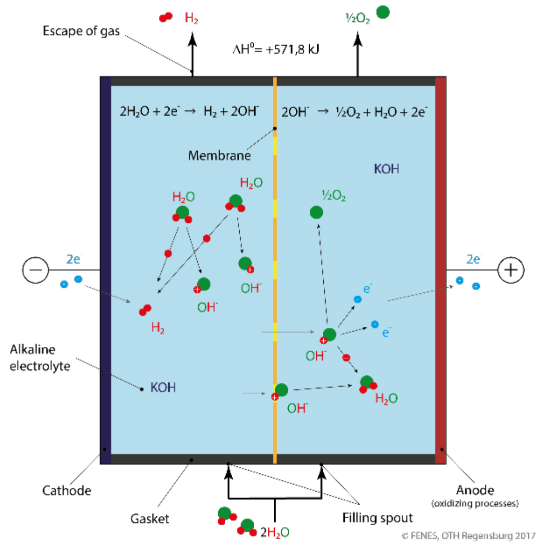
Calculations based on gross calorific values of hydrogen and methane.

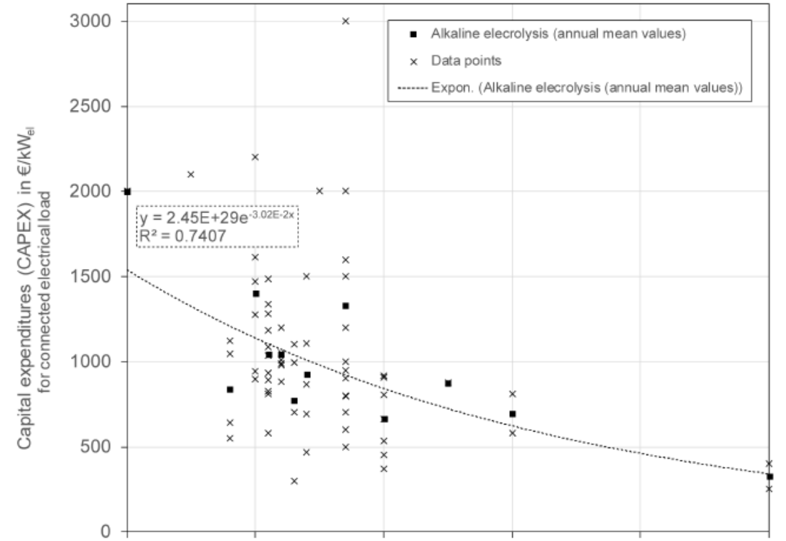
Thema et al. (2016)

Electrolysis of water

Two technologies dominating: AEL- and PEM-electrolysis

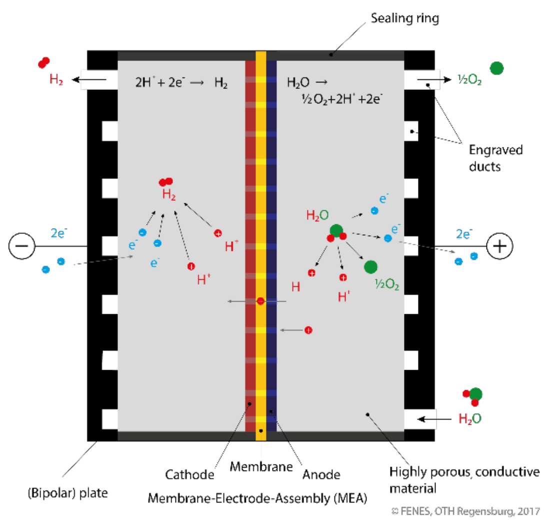
Alkaline electrolysis (AEL)
- two electrodes separated by a proton-permeable membrane
- alcaline electrolyte

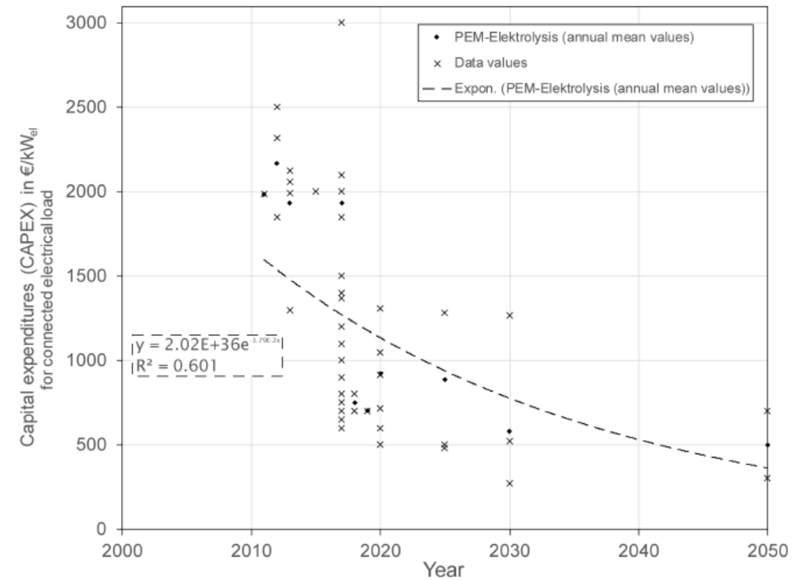




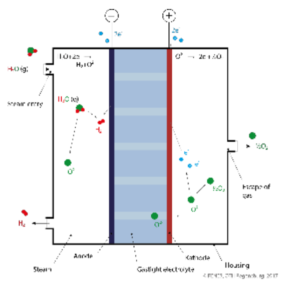
Thema et al. (2019b)

Membrane electrolysis (PEM)
- Solid membrane-electrode-assembly
- Separation of membrane and electrodes by porous, conductive material





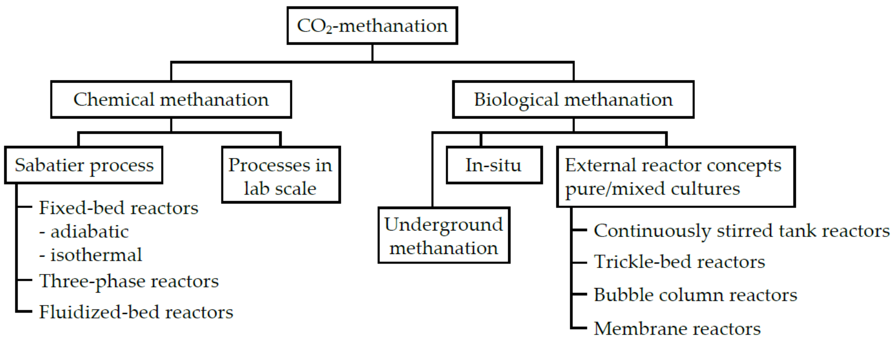
High-temperature electrolysis (HTES)

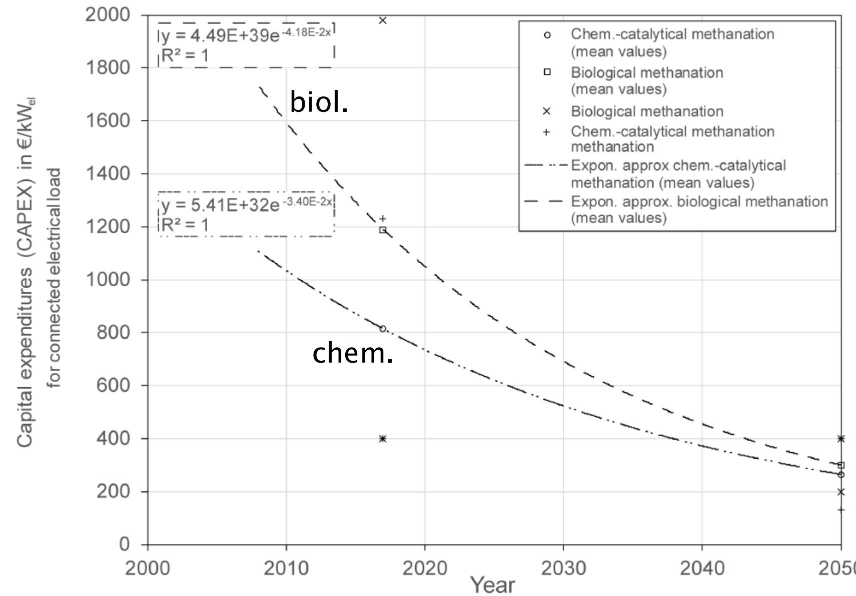


Sterner and Stadler (eds., 2019)

Methanation-technology

Chemical vs. biological methanation



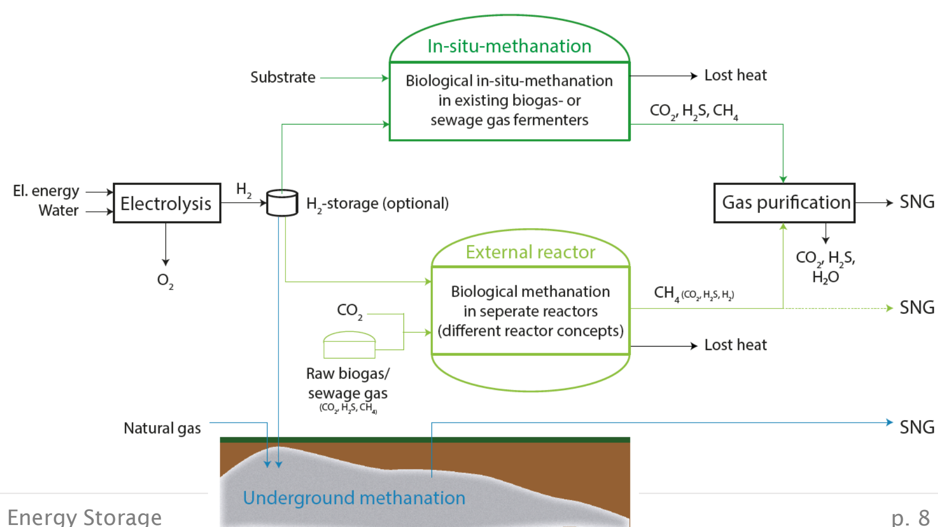


Thema et al. (2019b)

	Chemical methanation	Biological methanation
Catalyzer	Metals (e.g. Nickel)	Microorganisms
Temperature	250-500 °C	37-65 °C
Pressure	>10 bar	1-15 bar and higher
Development status	Commercial (TRL 2-9)	Pilot-/demo scale (TRL 2-7)
GHSV	500-5000 h^{-1}	<110 h^{-1}
Methane production rate MPR	1000 h^{-1}	2-10 h^{-1}
Limitation	Thermodynamics	Gas-liquid mass transfer H_2
Feed-in gas quality*	possible	possible
Energy efficiency	70 %	58 %
Tolerance feed-gas impurity	low	high
Load change tolerance	moderate	flexible
Power consumption (16 bar)	<0.4 kWh/m^3_{SNG}	0.4-1.8 kWh/m^3_{SNG}
CAPEX (110 MW scale)	125-450 €/kW_{SNG}	350-1200 €/kW_{SNG}
SNG production costs	1-3 €/kWh	3.5-6 €/kWh

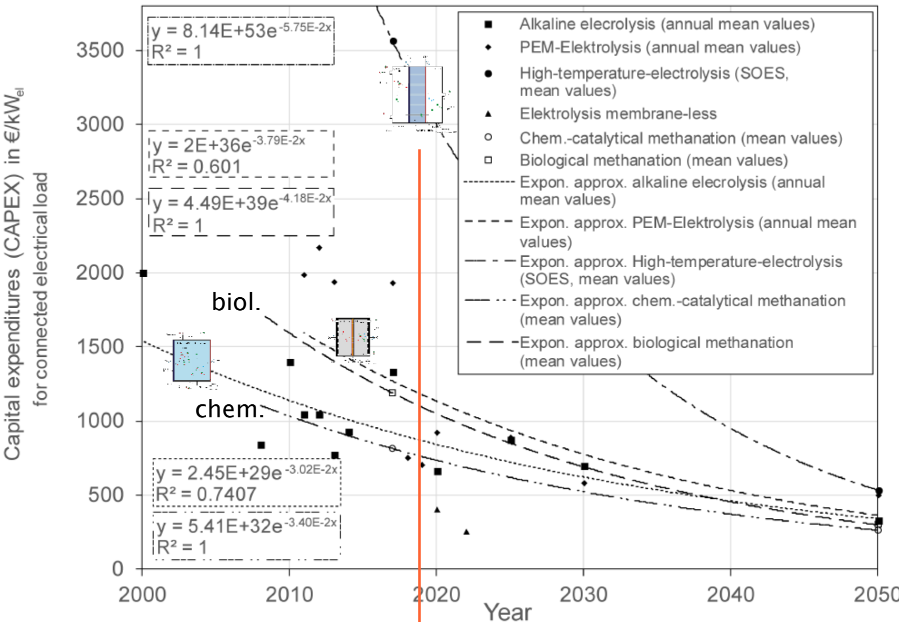
$^{*}y_{CH_4,max} > 95\,\%$

Thema et al. (2019a)



PtG efficiency & cost

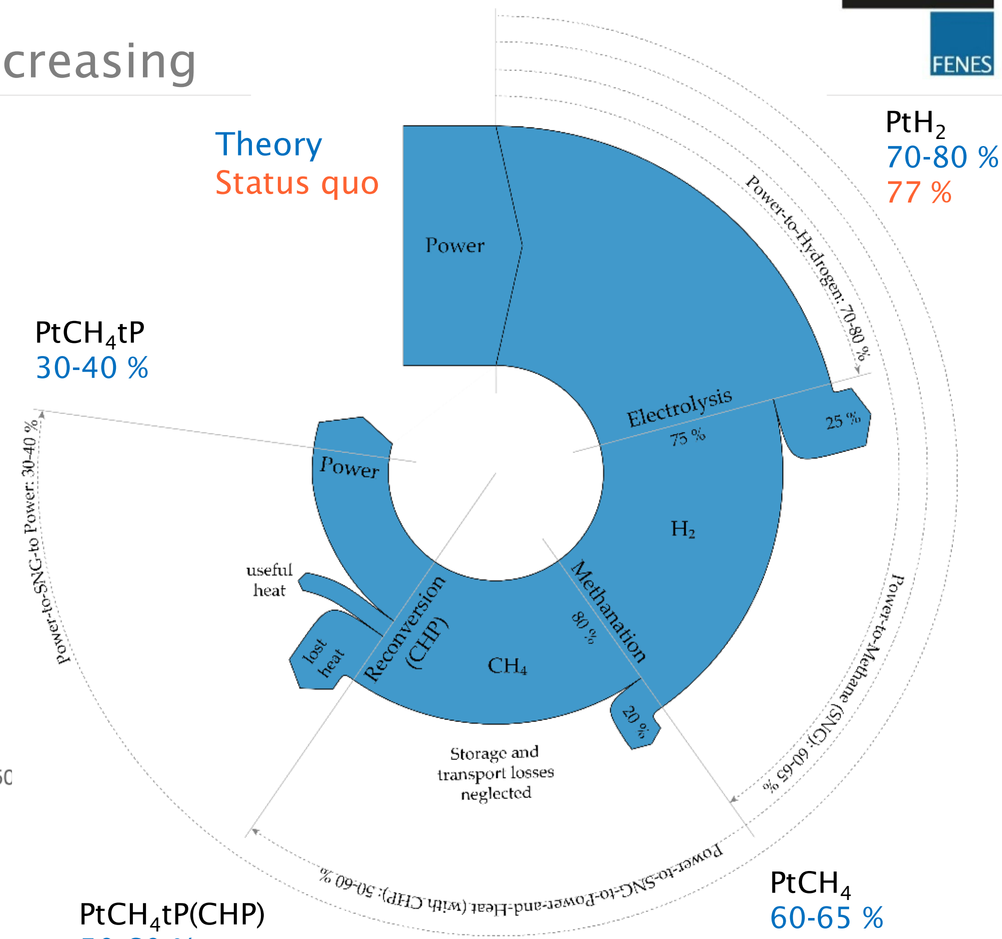
Theory and status quo: costs (still) decreasing



Status quo

	Hydrogen-projects	Methanation-projects
Feed-in projects (number)	21	36
No. of active projects in 2019	56	36
Installed production capacity	6205 m^3/h 18.6 $MW_{ch,LHV\text{-}H_2}$	590 m^3/h 6 $MW_{ch,LHV\text{-}CH_4}$
Installed electrical load	24.1 MW	14.5 MW
Efficiency electricity-to-gas	77 %	41 %

Theory
Status quo



PtH_2
70-80 %
77 %

$PtCH_4tP$
30-40 %

$PtCH_4tP(CHP)$
50-60 %

$PtCH_4$
60-65 %
41 %

Efficiency for re-conversion at 63 %

Power-H_2-Power: 48 %

Power-CH_4-Power: 26 %

Thema et al. (2019)

Power-to-Gas projects: global review

Exponential development since 2008, main drivers in Europe (yet)

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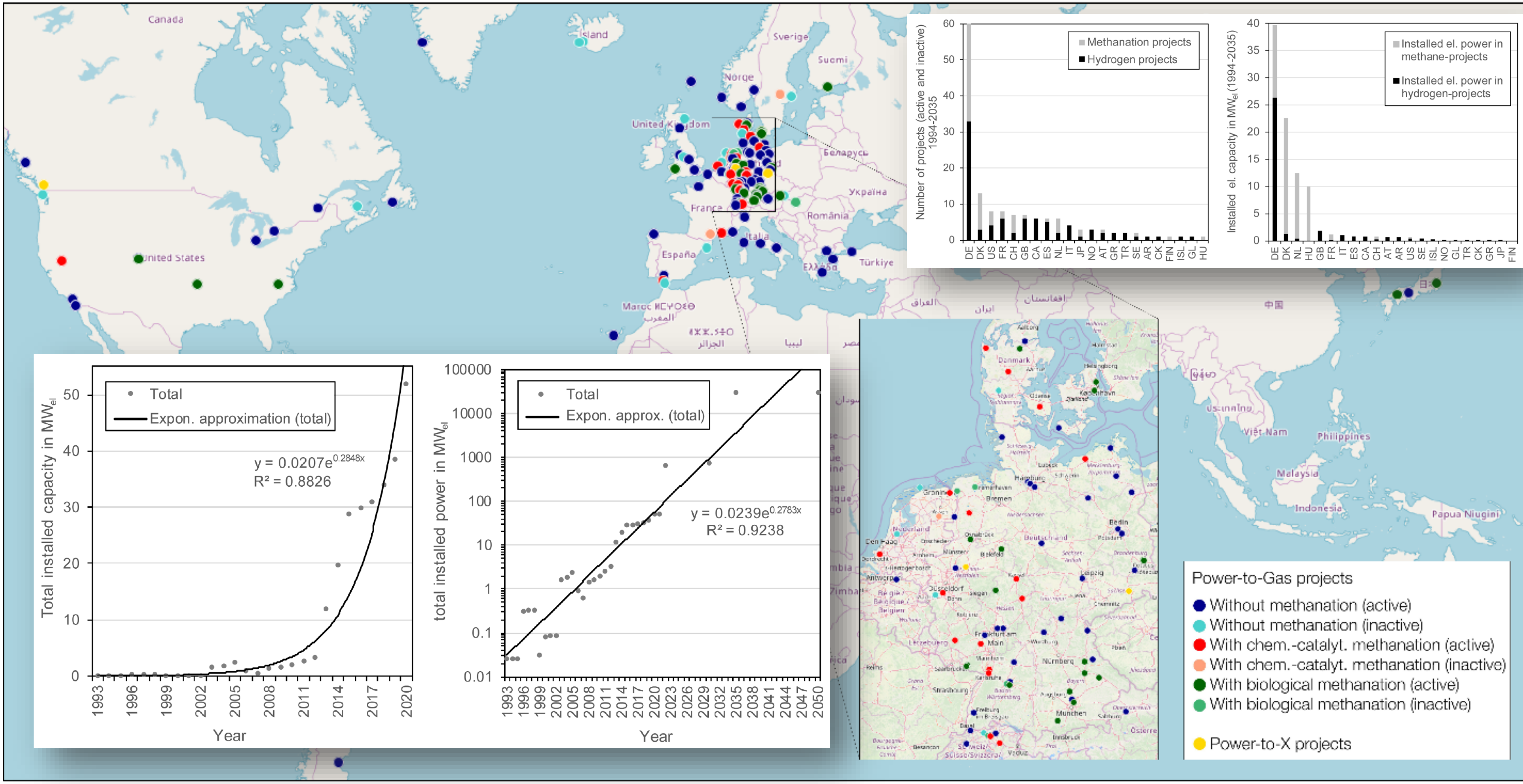
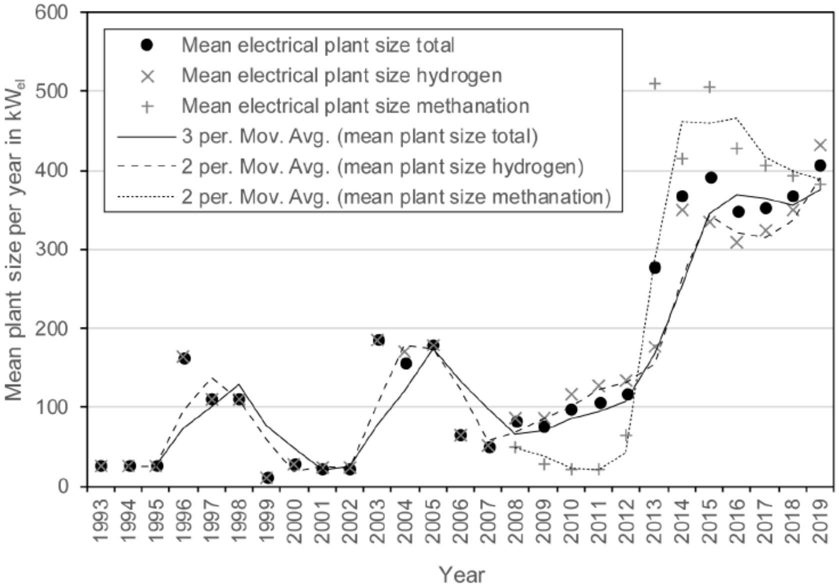


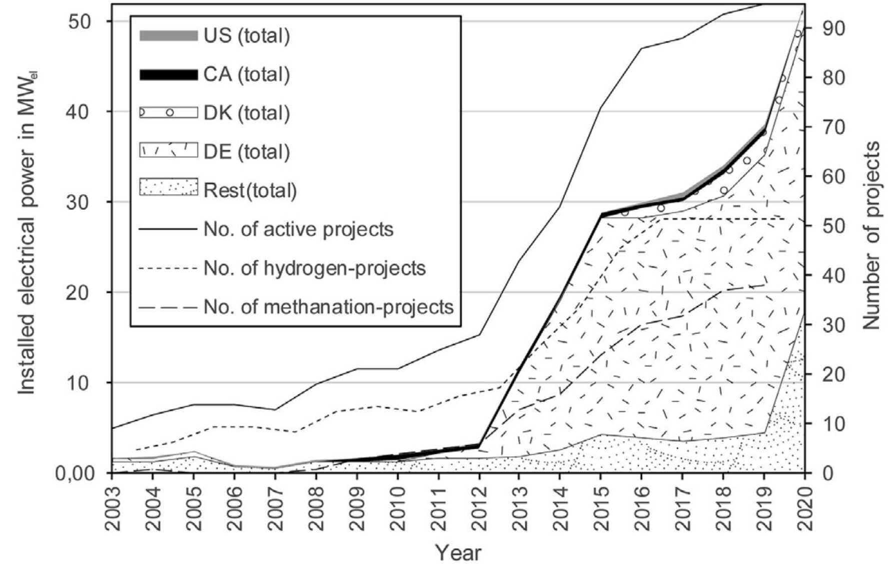
Link to geospatial data (Elsevier), Thema et al. (2019b)

- Exponential development in installed capacity and power
- Current project lifetime: 1-3 years (most of them funded), 10 years planned
- CAPEX for electrolysis- and methanation costs expected to fall to about 500€/kW$_{el}$ in the long term
- R&D-center (still) in Europe
- Mean plant size (2019): 300-500 kW (large-scale up to GW$_{el}$ in planning)

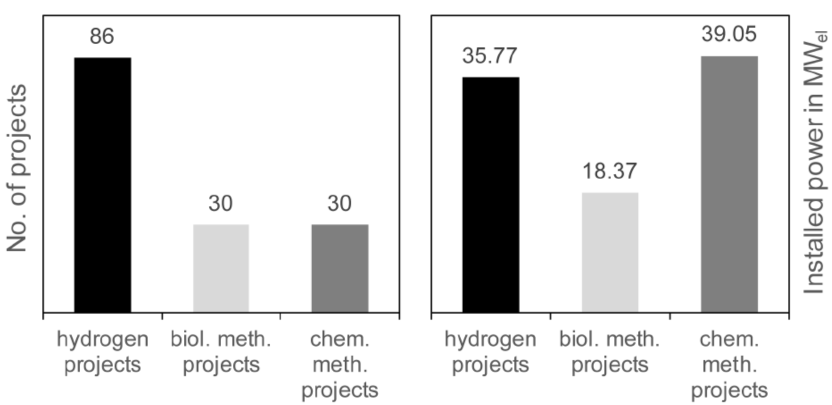
PtG-project details

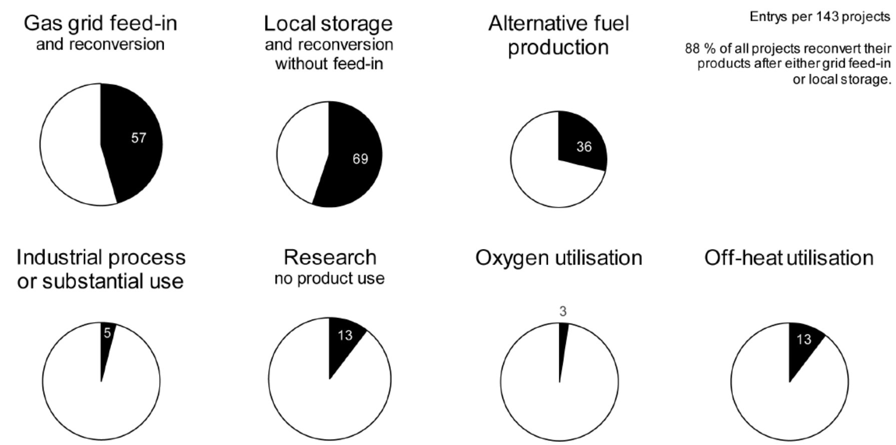
Plant size and project allocation, H_2 vs. CH_4, product utilization





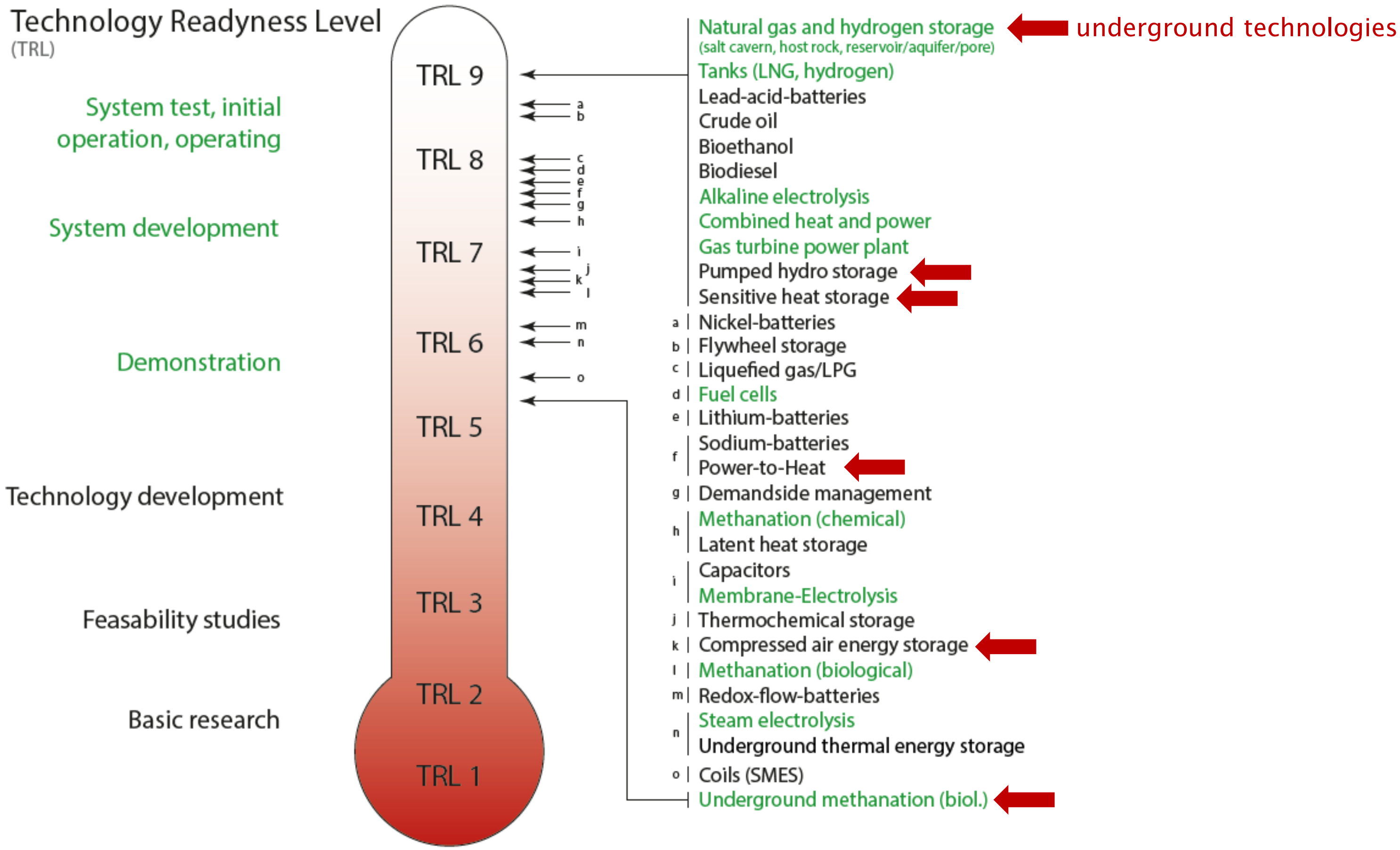
Thema et al. (2019b)





Technology readyness level

Energy storage technology is available political measures to be taken



TRL 1: Basic principles observed and reported
TRL 2: Technology concept and/or application formulated
TRL 3: Analytical and experimental critical function and/or characteristic proof-of-concept
TRL 4: Component and/or breadboard validation in laboratory environment
TRL 5: Component and/or breadboard validation in relevant environment
TRL 6: System/subsystem model or prototype demonstration in a relevant environment
TRL 7: System prototype demonstration
TRL 8: Actual system completed and qualified through test and demonstration
TRL 9: Actual system proven through successful operation

Storage technology is available…

…and now?

Updated. Sterner and Stadler (eds., 2019)

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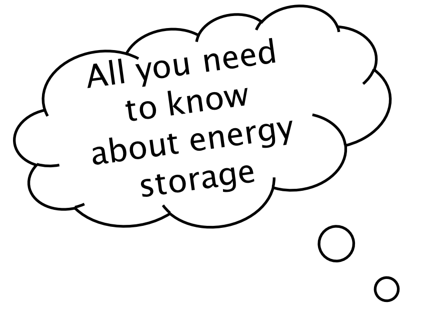
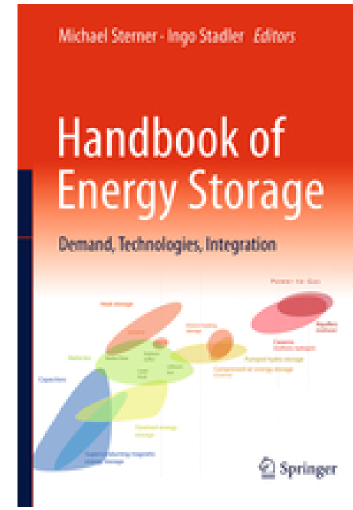
Many thanks for your attention





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