

A novel route for synfuels Power & Biogas to Liquid (PBtL)

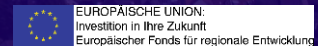
Dr. Andreas Waibel – CAPHENIA GmbH
May 13, 2022



**Process⁴
Sustainability**

**Cluster for climate-neutral
process industries in Hesse**

Supported by:



EUROPAISCHE UNION:
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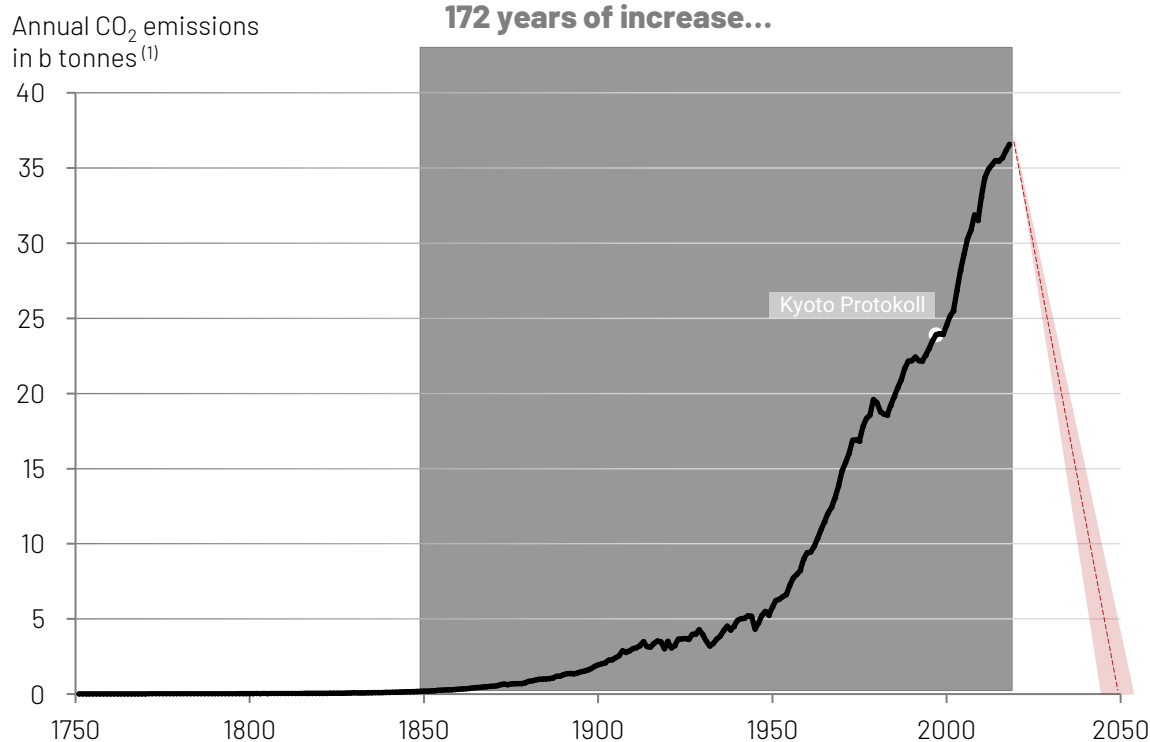


CAPHENIA

Turning CO₂ into fuel

Net zero by 2050 is a challenge of unprecedented scale

Annual global CO₂ emissions are currently around 36 billion tonnes.



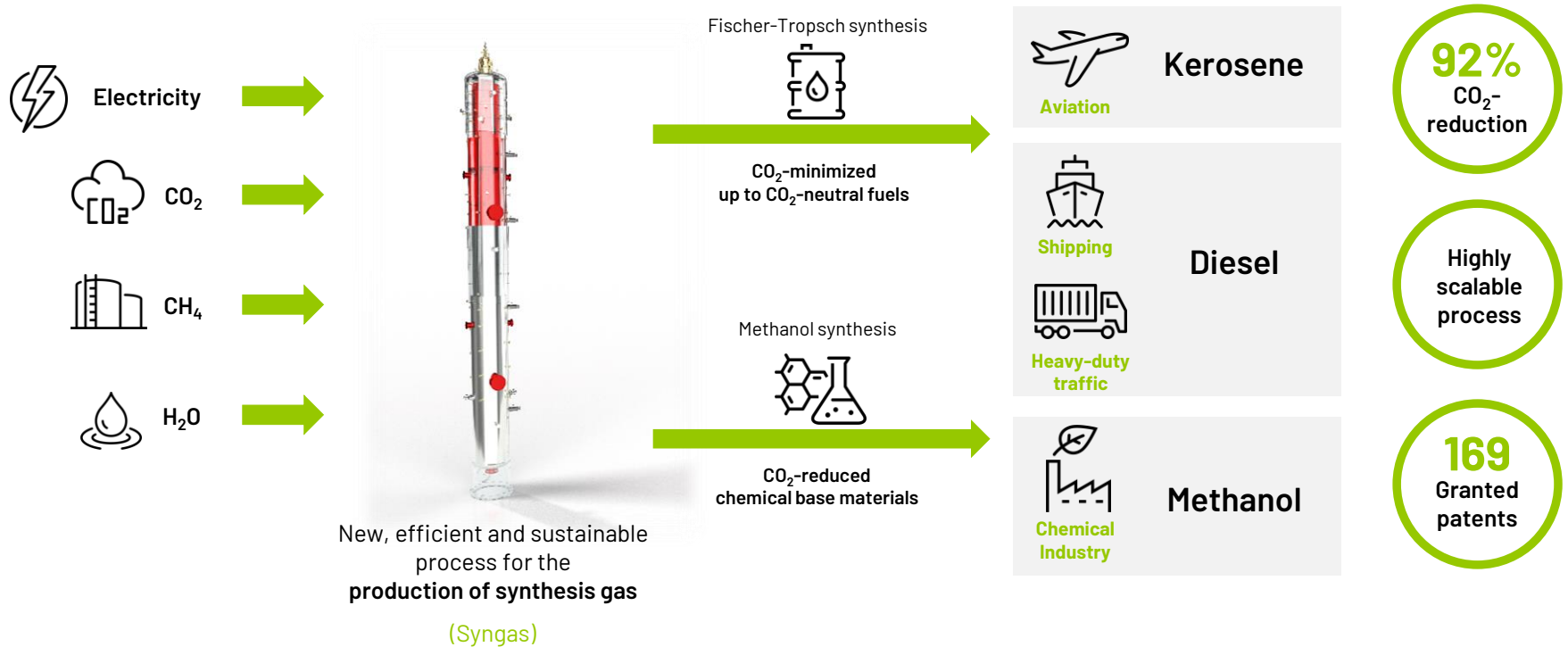
Bringing CO₂ emissions to zero by 2050 is a huge challenge.

... in 28 years to zero!

(1) Our World in Data. (2019). *Annual CO₂ Emissions*.

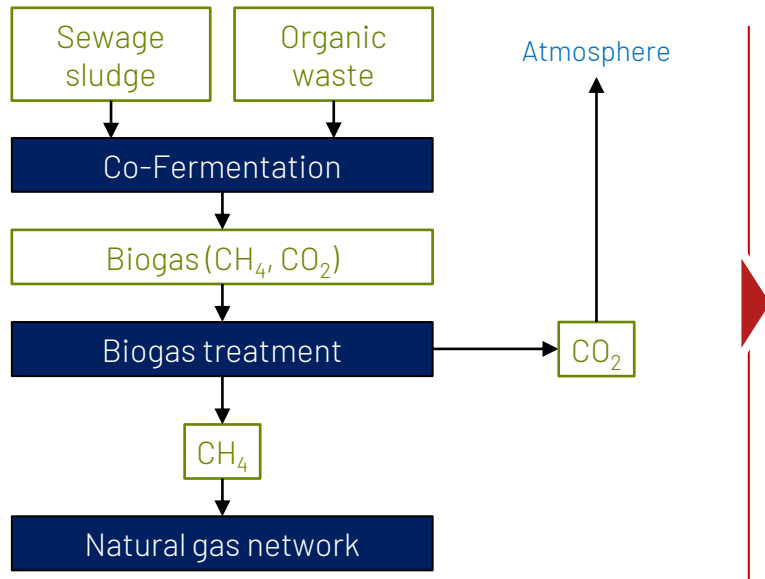
CAPHENIA 's Technology: Novel Route to Produce Fuels

Syngas is the basis to produce all kinds of fuels and chemicals addressing customer needs in various industries

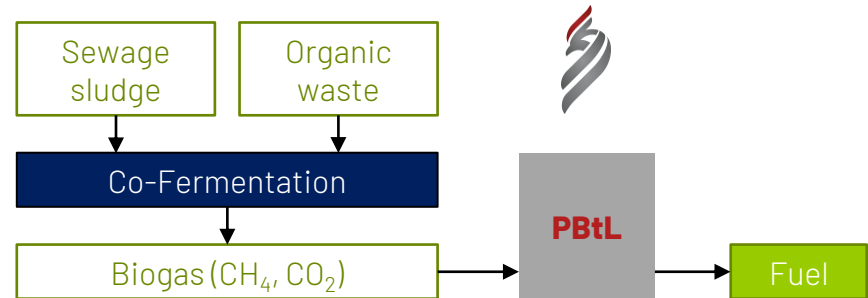


Biogas is the ideal raw material for a PBR synthesis gas reactor

This combination enables a systemic improvement of biogas plants



Showpiece for metropolitan areas



"A Power-and-Biogas-to-Liquid (PBTl) process allows the overall use of a biogas material flow, as both CO₂ and CH₄ are processed simultaneously."

CAPHENIA's Technology: One Technology, several Options

First option: genetically green. Second option: CO₂-free cement and steel industry

Plasma-Boudouard-Reactor CAPHENIA

PBtL

Power-and-Biogas-to-Liquid



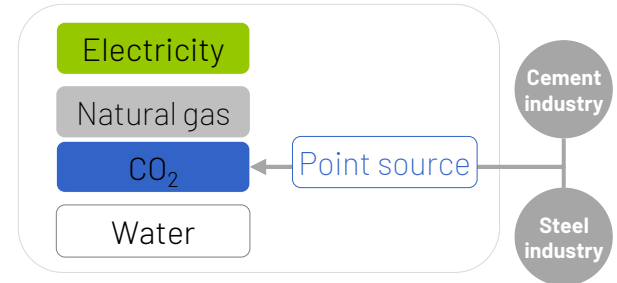
The advantages

- ✓ Uses biogas as the entire material flow
- ✓ Reduces the need for renewable electricity
- ✓ Reduces manufacturing costs
- ✓ Produces fuel with an extremely low CO₂ footprint
- ✓ Process scalable



PGtL

Power-and-Gas-to-Liquid

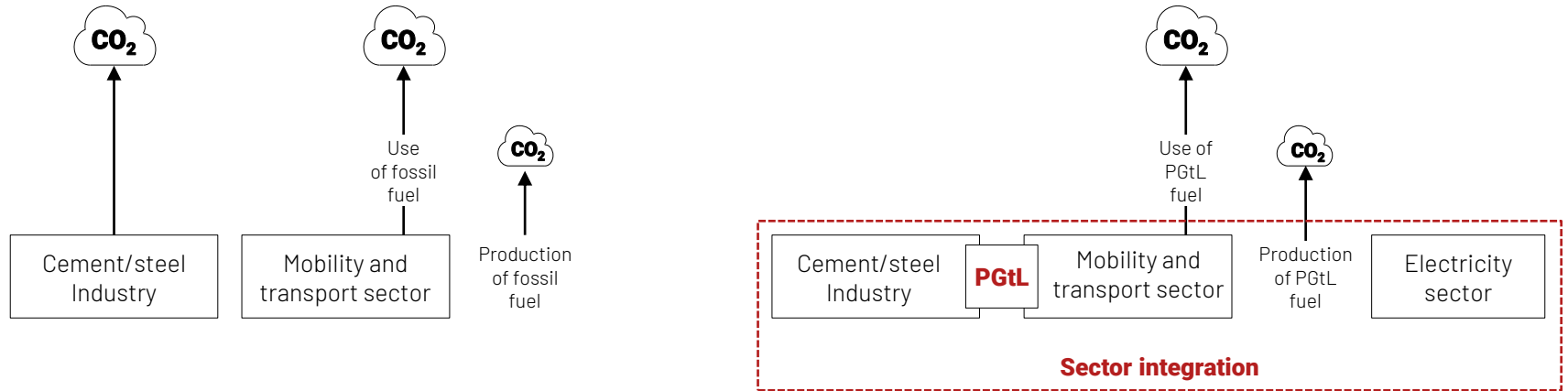


The advantages

- ✓ Uses large local CO₂ emitters
- ✓ Recycles CO₂
- ✓ Results in a CO₂-free cement and steel industry
- ✓ Produces fuel with reduced CO₂ footprint
- ✓ Has enormous capacity potential due to natural gas

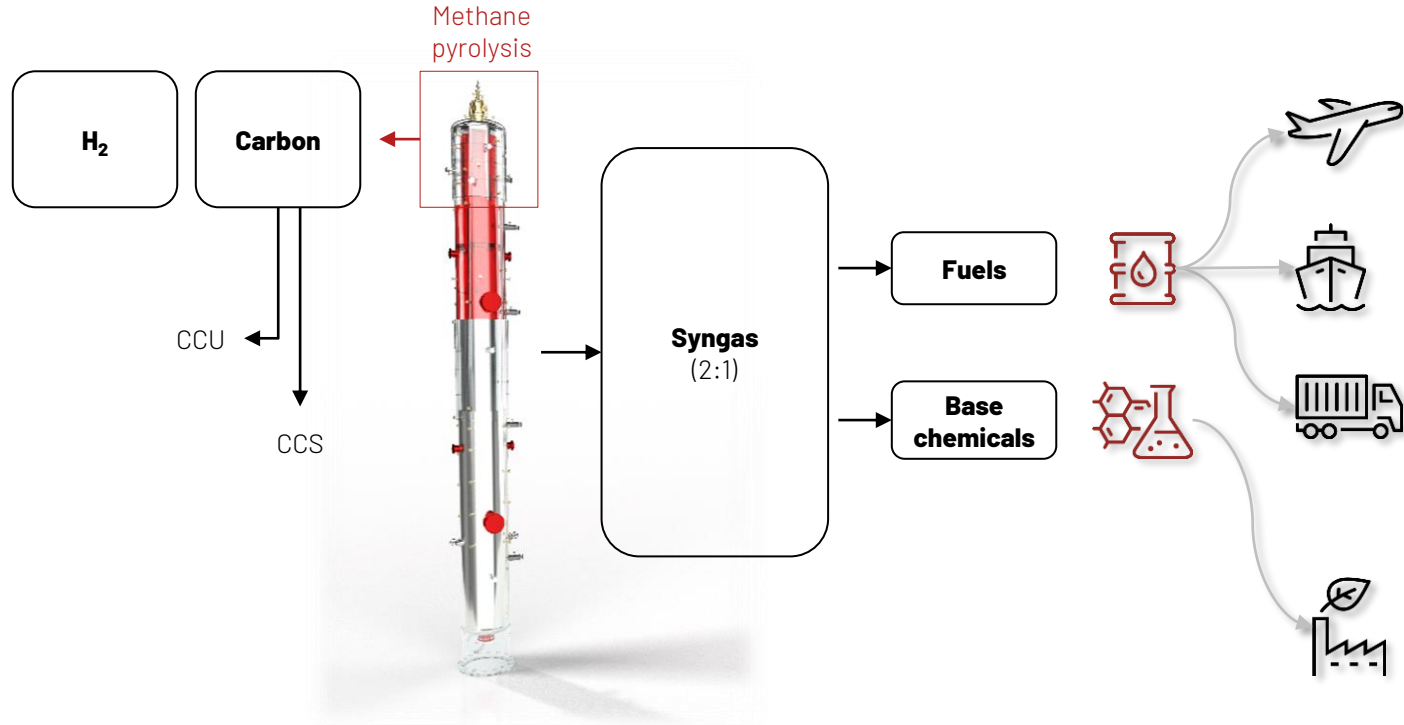
Sector integration via CCU reduces the CO₂-input into the atmosphere

A PGtL fuel makes the cement/steel industry CO₂-free



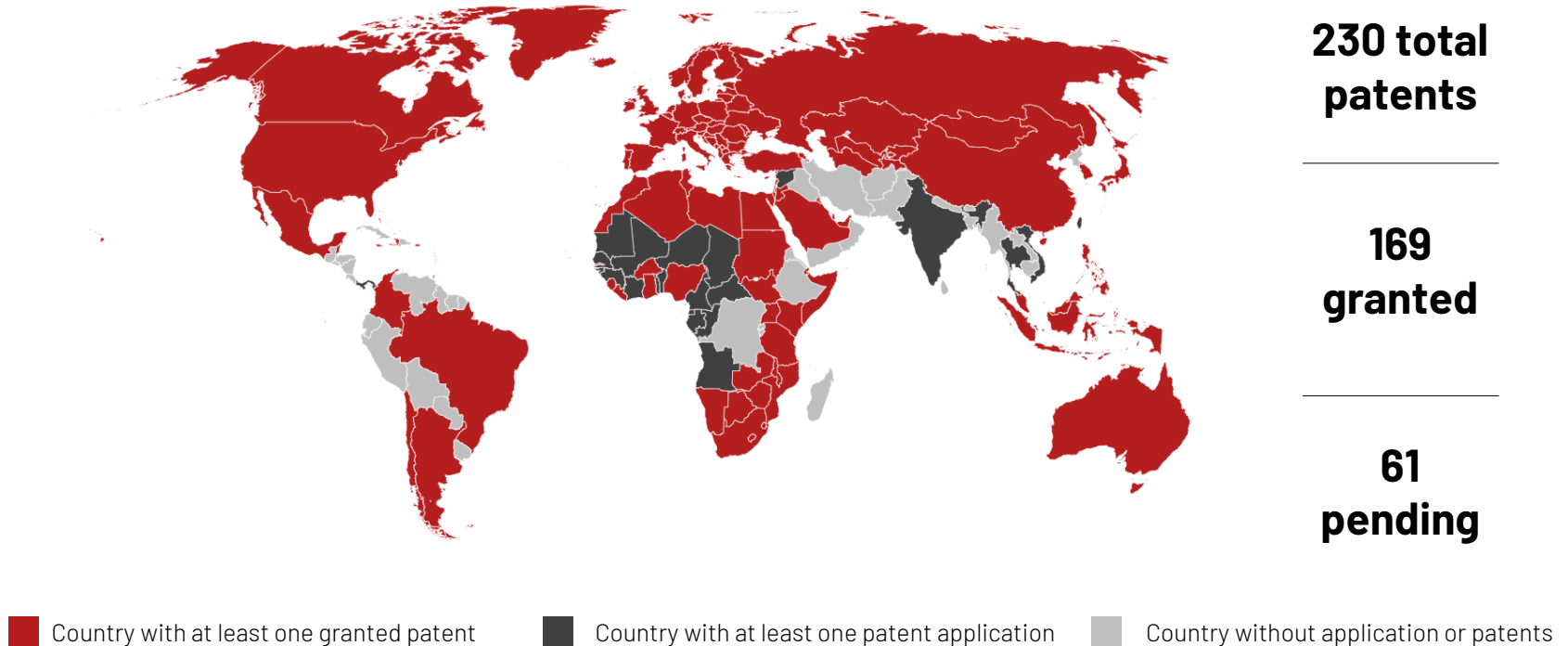
A novel syngas process has implications for entire industries and sectors

Chemical industry, Aviation Industry, Transportation Sector, ...



CAPHENIA's future economic viability- Global IP protection

The CAPHENIA process is patent protected in all relevant global markets



Tomorrow's energy must meet several criteria



renewable | storable | transportable

Limited possibilities of a battery in a commercial aircraft

Using the Airbus A350-900ULR (Ultra Long Range) as an example

280 tons

Maximum take-off weight ⁽¹⁾

6.768 tons

Mass of a battery to achieve the same energy content as kerosene ⁽²⁾⁽³⁾

In Germany, cargo trains usually run with gross weights of about 1,600 tons.



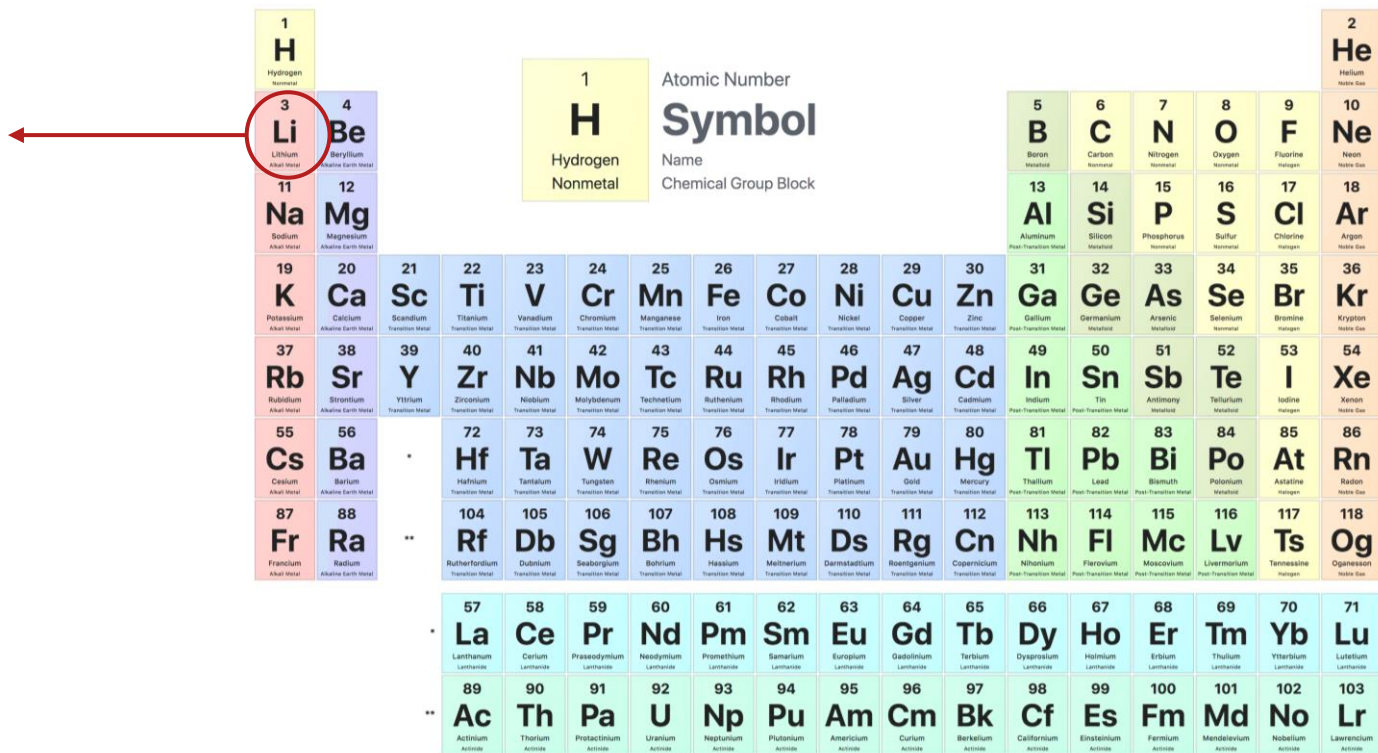
Maximum landing weight	207,0 tons
Maximum weight without fuel	195,7 tons
Maximum fuel quantity	141.000 litres
	112,8 tons ⁽¹⁾

- (1) A350-900. [Airbus](#).
- (2) „Batteries are about sixty times heavier than kerosene with the same the same energy capacity.“(Own translation, p. 22, Revolutioniert der Elektroantrieb die Luftfahrt?(2019). [DLR-Magazin - Das Magazin des Deutschen Zentrums für Luft- und Raumfahrt.](#))
- (3) Thielmann, A., Wietschel, M., Funke, S., Grimm, A., Hettesheimer, T., Langkau, S., ... Edler, J. (2020). [Batterien für Elektroautos](#):

No more quantum leaps possible in battery development

A look at the periodic table

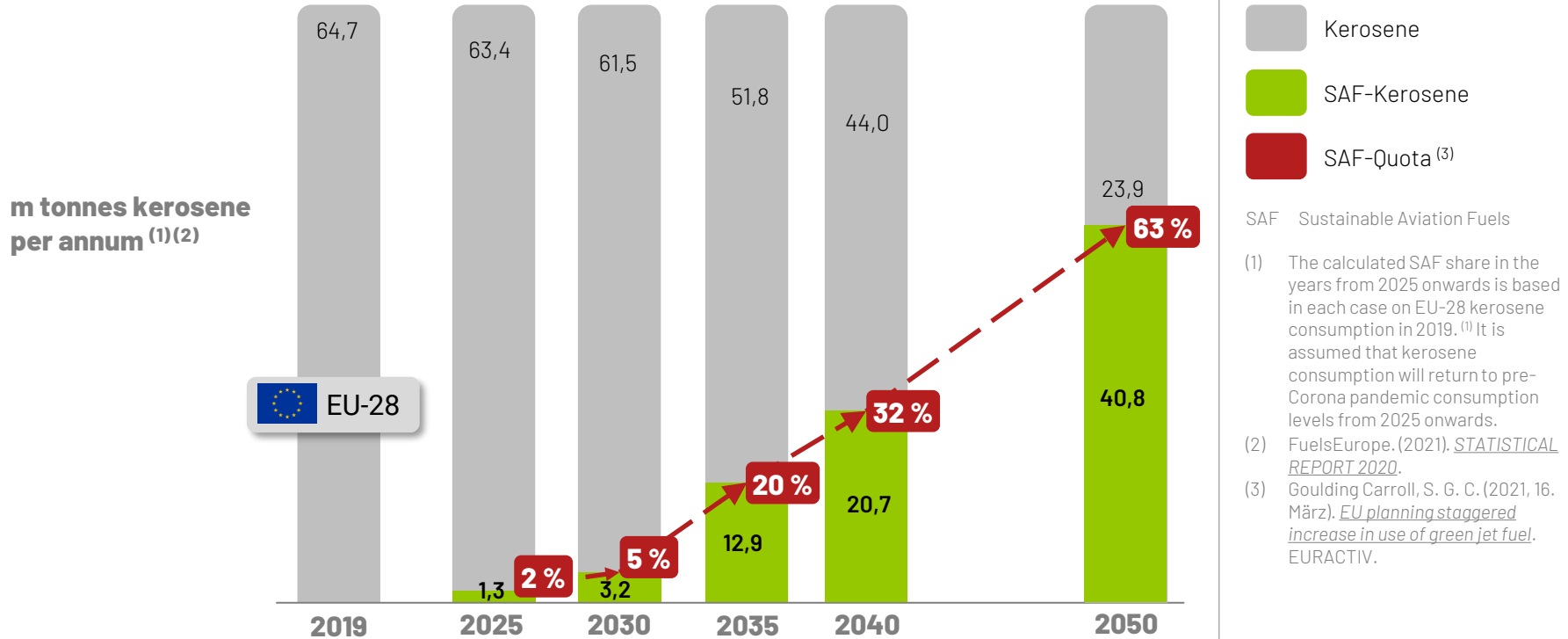
Lithium is the lightest metal



National Center for Biotechnology Information(2021). PubChem Periodic Table of Elements

ReFuelEU draft indicates ambitious SAF quotas

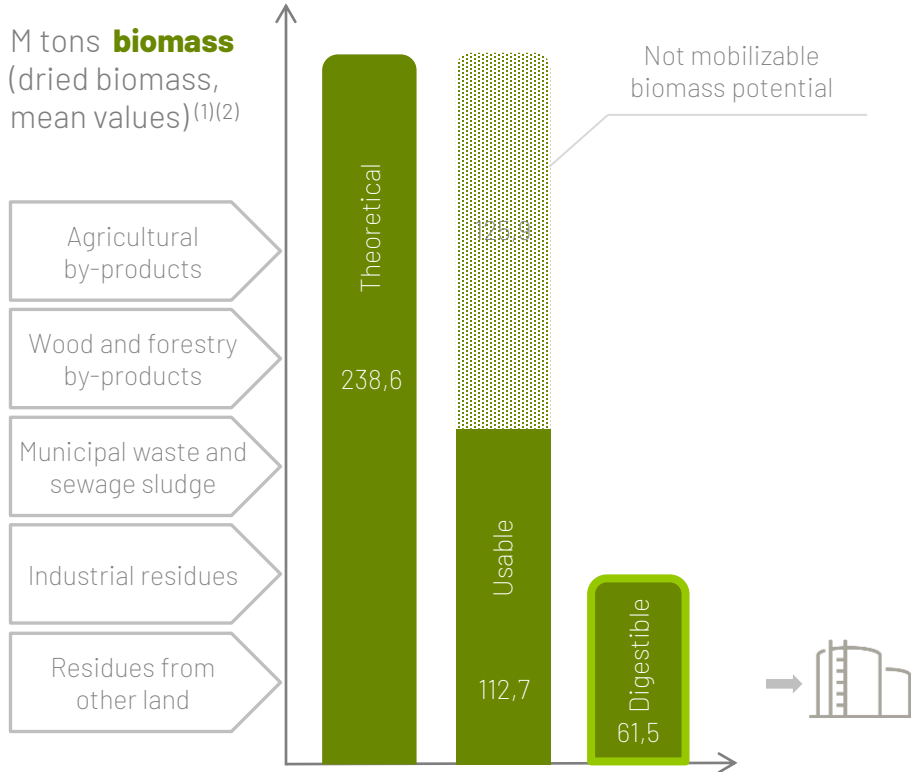
This would create a SAF demand of 40 million tonnes kerosene in 2050



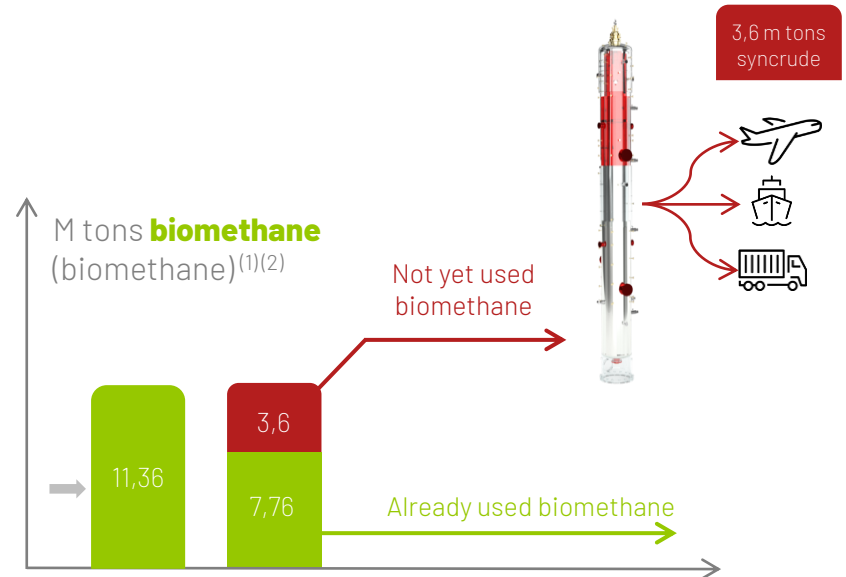
Biomass potential in Germany for the production of biogas

Digestible Biomass from the biomass potential of 77 feedstocks – mean values

M tons **biomass**
(dried biomass,
mean values)⁽¹⁾⁽²⁾



- (1) Deutsches Biomasseforschungszentrum gemeinnützige GmbH. (2015). *Ressourcendatenbank Biomassepotenzialen*. DBFZ
- (2) Biomass potentials of biogenic residues, by-products and wastes in Germany – What we do know and what we do not know. (2021, Januar). Deutsches Biomasseforschungszentrum DBFZ.



eFules – What makes CAPHENIA better than all the others?

A crucial USPs

We produce **6 times more renewable fuel** from a given amount of electricity than conventional electricity-based PtL processes



PBtL reduces the need for electricity from renewable energies (RE)

Lower dependency on the scarce resource RE electricity

Power consumption
for fuel production⁽³⁾
[MWh / t Fuel]

PtL⁽¹⁾
25.1

via
rWGS

PBtL⁽²⁾
3.9

"A Power-and-Biogas-to-Liquid (PBtL) process has a **6.4 times lower demand for** RE electricity for the production of fuel than a pure Power-to-Liquid (PtL) process via rWGS."

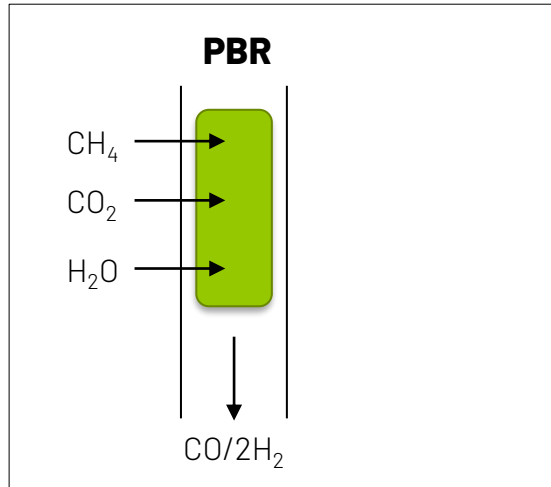
Process design and physics make this possible

The only energy source in the PtL process is electricity. CO₂ is energetically worthless. The energy of the fuel (Kerosene ~43 MJ/kg) therefore comes exclusively from the input of electricity. The PBtL process, on the other hand, additionally uses CH₄ (~55 MJ/kg) as energy source. This can drastically reduce the amount of energy required from electricity.

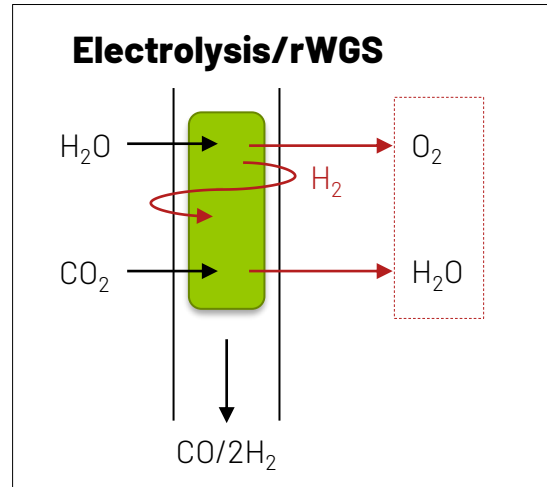
- (1) The electricity demand of the PtL process is calculated as follows: $11.06 \frac{t_{CO_2}}{t_{Kerosene}} / 0.44 \frac{t_{CO_2}}{MWh_{Germany's\ electricity\ mix}} = 25.1 \frac{MWh}{t_{Kerosene}}$ ⁽¹⁾
- (2) Own calculations.
- (3) Forschungsstelle für Energiewirtschaft e.V. (2019). [CO₂-Bilanz des CAPHENIA Prozesses](#).

Fundamental physical-chemical laws speak in favor of the PBtL process

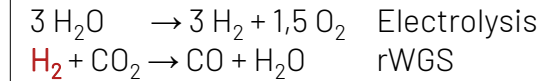
Plasma-Boudouard-Reactor (PBR) has the simpler and more efficient process design



Efficiency: 86 % ⁽¹⁾



Efficiency: 45 % ⁽¹⁾



PBR Plasma-Boudouard-Reactor
PtL Power-to-Liquid
rWGS reverse Water-Gas-Shift

(1) Forschungsstelle für Energiewirtschaft e.V. (2019).
[CO₂-Bilanz des CAPHENIA Prozesses.](#)

Advantage

No substance flow leaves the process

Disadvantage

- (1) Two substance flows leave the process. This reduces the substance yield and also causes the process to lose bond energy.
- (2) The process requires additional intermediate H_2 . H_2 is lost in the rWGS reaction or is needed for the reduction of CO_2 to CO .

The greatest CO₂ savings can be achieved with PBtL

Results of a Well-to-Wheel Analysis of the Hamburg University of Technology (TUHH)

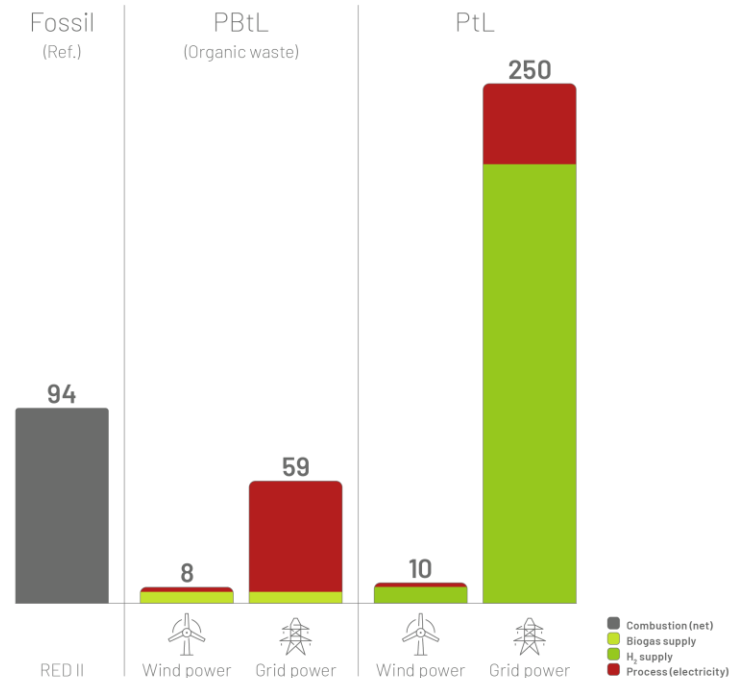
“A Power-and-Biogas-to-Liquid process has an extremely low CO₂ footprint and leads to **CO₂ savings of 91%** compared to the fossil reference. Even when using grid electricity, a CO₂ saving of **37%** is still achieved, while a PtL process⁽¹⁾ emits 2.6 times more than the fossil reference.”

PtL Power-to-Liquid
rWGS reverse Water-Gas-Shift

(1) Electrolysis in combination with rWGS.
(2) TUHH. (2021). [Untersuchung der Umweltauswirkungen eines Power-and-Biogas-to-Liquid \(PBtL\) Prozesses zur Herstellung von erneuerbaren synthetischen Kraftstoffen.](#)

GHG emissions in g CO₂eq/MJ Fuel

Net emissions incl. combustion



Plasma Boudouard reactor technology shows technical advantages

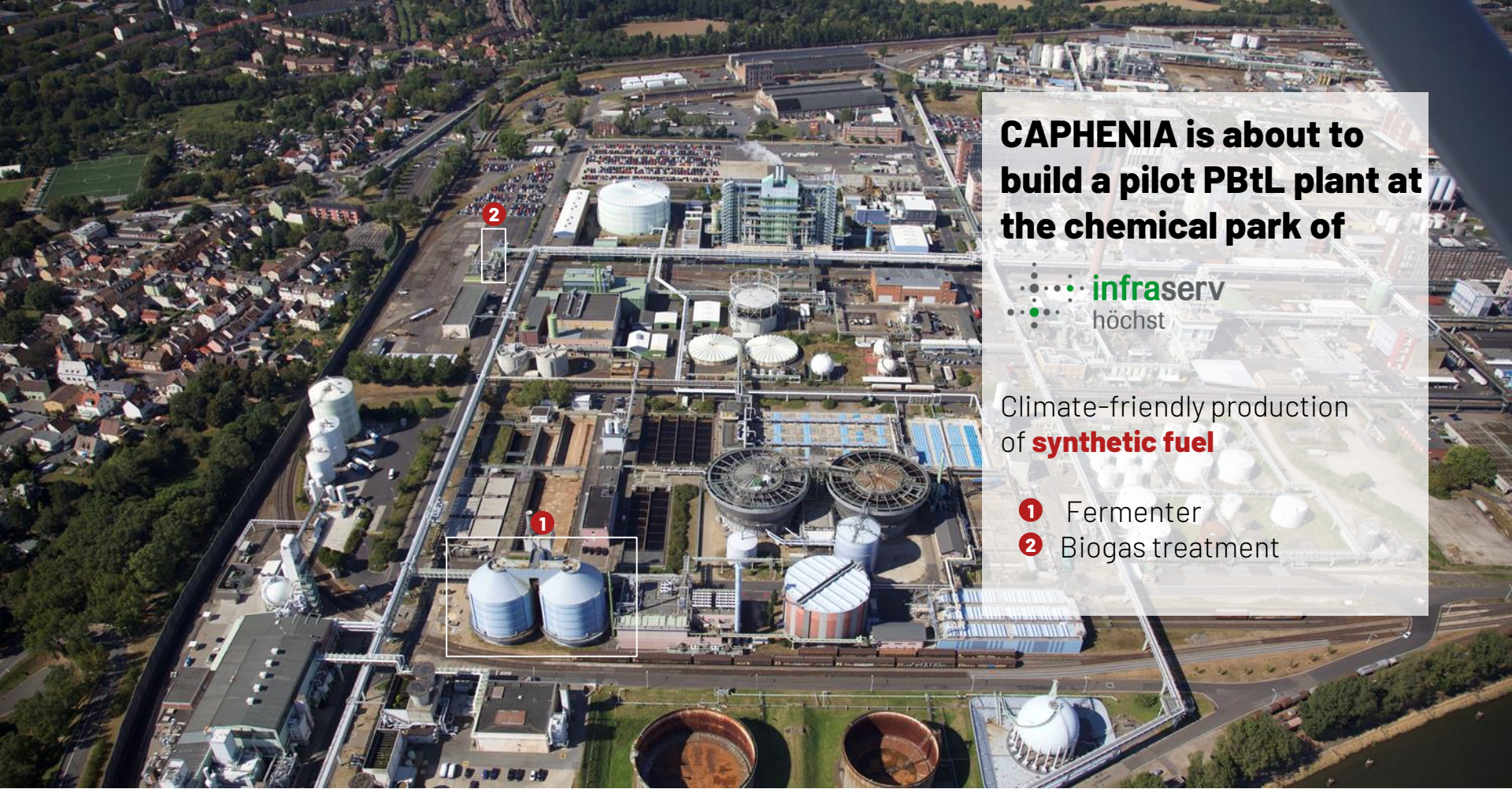
A novel, highly efficient and sustainable process for the production of synthesis gas



Advantages

- ✓ Process is realised in a single zone reactor
→ lower CAPEX costs, less complex
- ✓ Process does not release CO₂ intrinsically
→ most sustainable
- ✓ No by-products in general (100% selectivity)
→ no material losses, less energy losses, high efficiency
- ✓ No catalysts are needed
→ robust process
- ✓ 6-times less demand for electricity compared to conventional PtL process
→ Bottleneck resource renewable power is conserved and used efficiently
- ✓ Easily scalable through pressure increase
→ Technology suitable for large industrial scales
- ✓ High overall efficiency for syngas production → **86 %**

Detail Engineering of MAN Energy Solutions completed.



CAPHENIA is about to build a pilot PBtL plant at the chemical park of



Climate-friendly production of **synthetic fuel**

- 1 Fermenter
- 2 Biogas treatment



CAPHENIA

Turning CO₂ into fuel

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PBtL Power-and-Biogas-to-Liquid

Sustainable.

Affordable.

Scalable.