Plasma Cracking of Methane and Biogas for Sustainable Hydrogen Carbon Black or Syngas Production

Jan-Malte Kapust, Hendrik Zachariassen, *Torsten Birth-Reichert*

www.cc4e.de

Agenda

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung
FORSCHUNG AN FACHHOCHSCHULEN

1. CC4E @ HAW – Pioneer for the energy transition
2. Methane Cracking with a low temperature microwave plasma – project MEDEA
3. Brief Introduction: Biogas Cracking with a low temperature microwave plasma and following Fischer-Tropsch and Methanol-Synthesis – project Plasma2X

Pioneer for the energy transition

Competence Center for Renewable Energies and Energy Efficiency

www.cc4e.de

We are passionate about developing possibilities and chances of sustainable energy supply

– in order to preserve an environment worth living in.

Bild: PieterPan

Innovations for the energy transition

Vision and strategic goal of the CC4E

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung
FORSCHUNG AN FACHHOCHSCHULEN

VISION

The CC4E at HAW Hamburg develops sustainable solutions for society's energy problems.

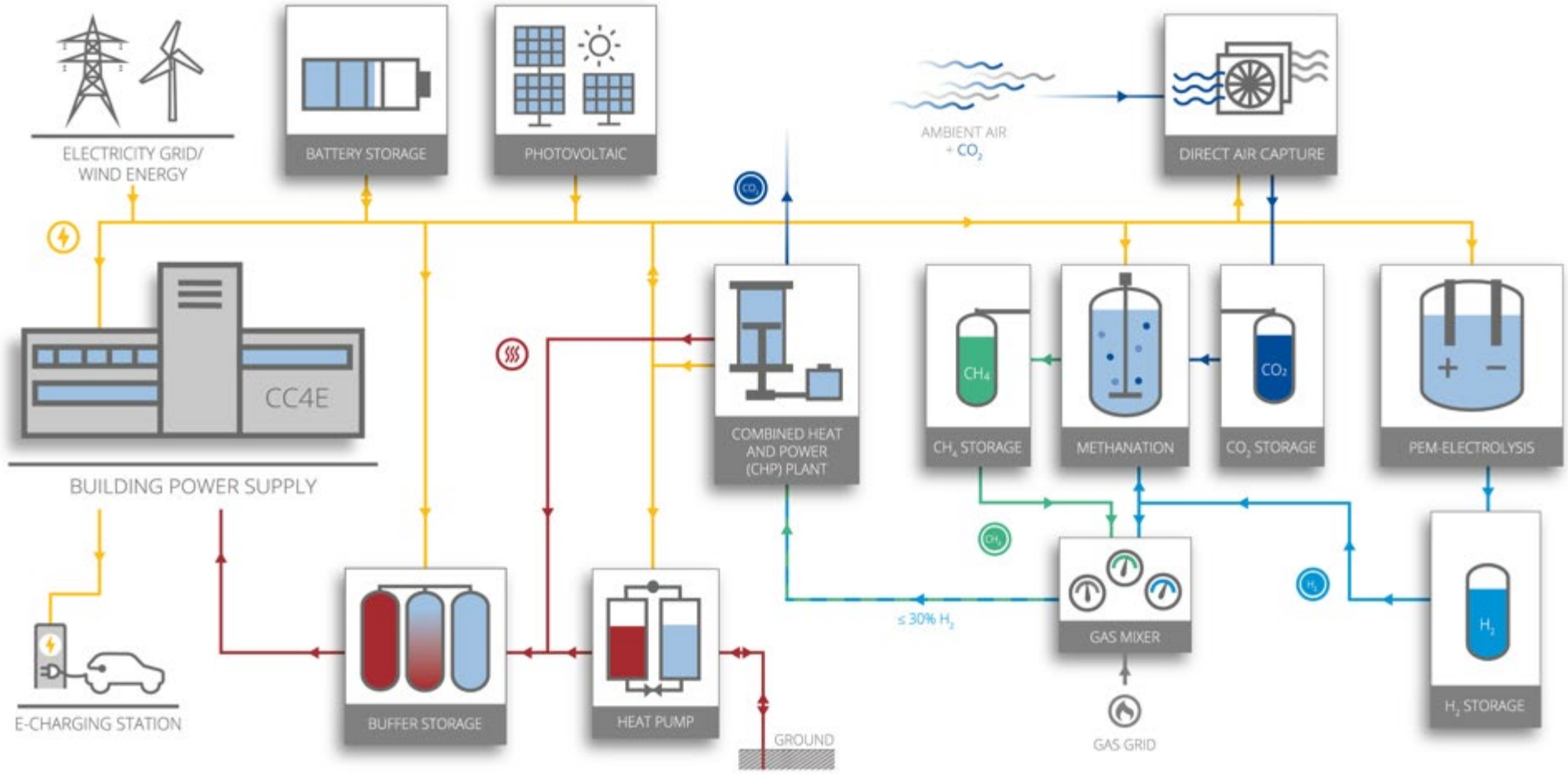
GOAL

HAW Hamburg is to become the North's leading university for renewable energies and energy efficiency (4E).

Energy Campus Technology Center

In Hamburg-Bergedorf

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung
FORSCHUNG AN FACHHOCHSCHULEN

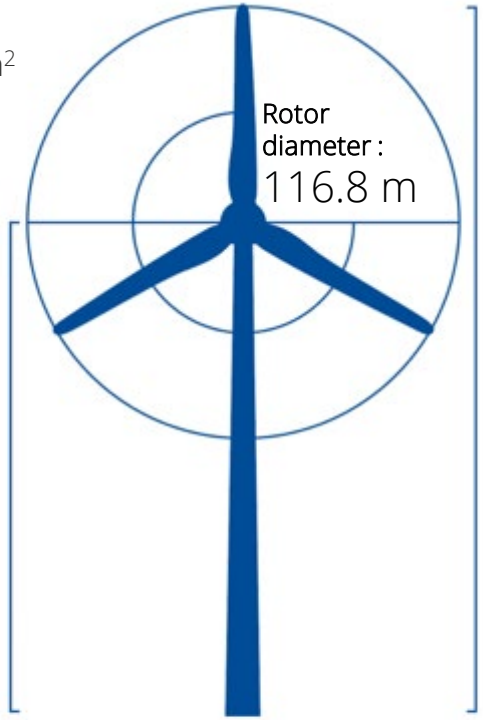


Grafik: Louis Fraser (CC4E)

Wind farm Curslack

Research wind farm in real operation

10,715 m²
Rotor area



Rotor diameter :
116.8 m

Total energy yield per year :
33 GWh
11.000 households supplied

Total capacity :
12.75 MW
Over 10% of installed wind energy capacity in Hamburg

Full-load hours per year :
2,600

Avoided $C0_2$ emissions :
22,000 tons

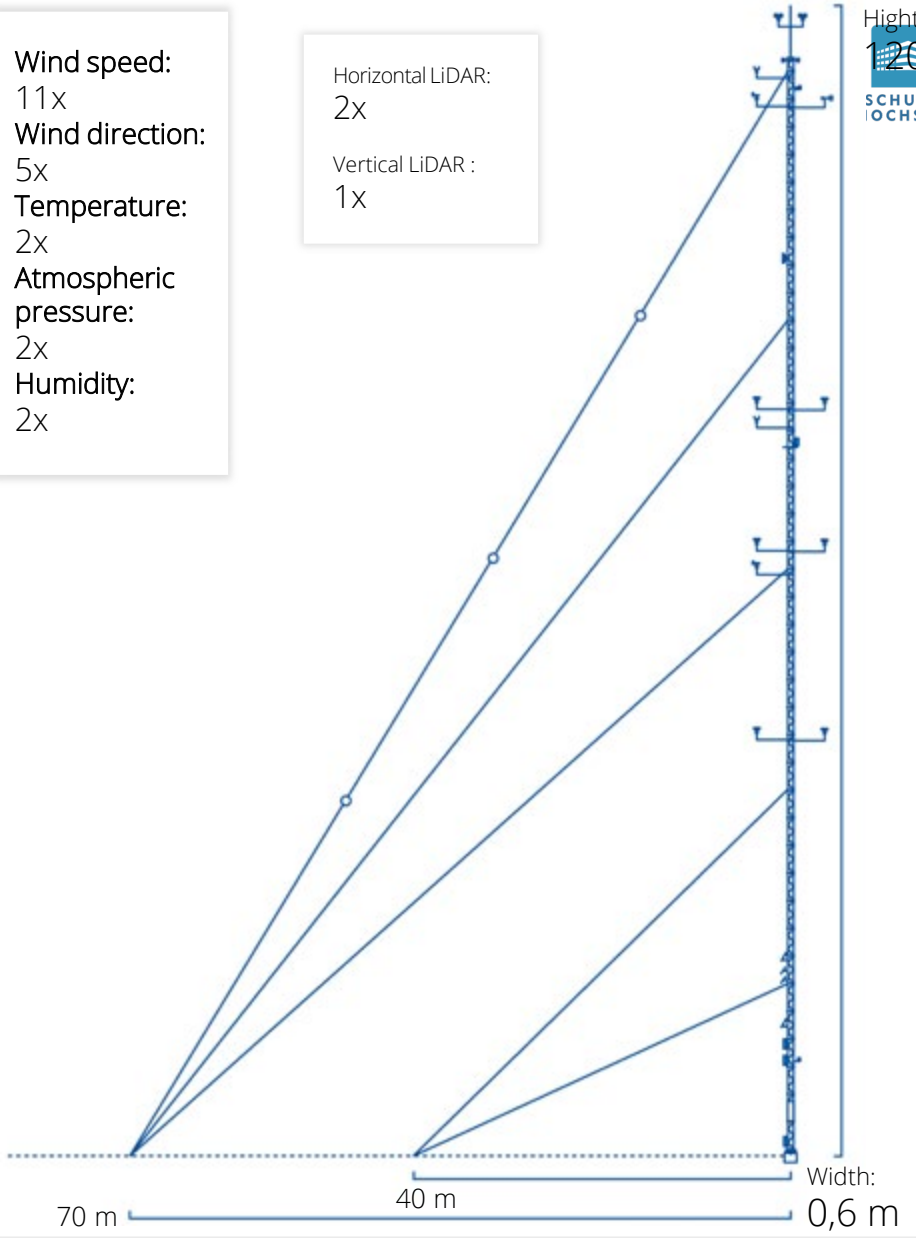
4x Nordex N117/2400 (Gamma generation)
Rated power 2.4 MW

1x Nordex N117/3000 (Generation Delta)
Rated power 3.15 MW

Wind speed:
11x
Wind direction:
5x
Temperature:
2x
Atmospheric pressure:
2x
Humidity:
2x

Horizontal LiDAR:
2x

Vertical LiDAR :
1x



Demonstration Center Sector Coupling

Location, laboratories and equipment

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung
FORSCHUNG AN FACHHOCHSCHULEN

Location: Am Schleusengraben, 21029 Hamburg

- Construction of the Demonstration Center Sector Coupling at the Energy Campus in Hamburg Bergedorf
- In the direct vicinity of the existing facilities of HAW/CC4E and Fraunhofer IWES as well as the (research) wind farm Curslack
- Electrolyzer planned on the same site

Laboratory and equipment

- Power-to-gas
- Demand-side management
- Heat and heating networks
- Biological methanation
- Fascination center

- Building utilization through: HAW HAMBURG | CC4E and Fraunhofer IWES

CC4E Factsheet

Sustainable solutions for a future worth living

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

FORSCHUNG AN FACHHOCHSCHULEN

HAW HAMBURG | CC4E

FIVE wind turbines supply energy at the Curslack research wind farm

60:30:60
employees, professors, student assistants

17
years CC4E

41 millions of euros in funding

150 cooperation partners from science, business and politics

FOUR competence teams form the focus of the CC4E:

sector coupling & hydrogen, heat, wind energy, social transformation and acceptance

29
(sub-)project

Medea

Methane Decarbonization Using Microwave Low-Temperature Plasma Cracking

Jan-Malte Kapust, Hendrik Zachariassen, Torsten Birth-Reichert

HAW HAMBURG | CC4E

X-ENERGY

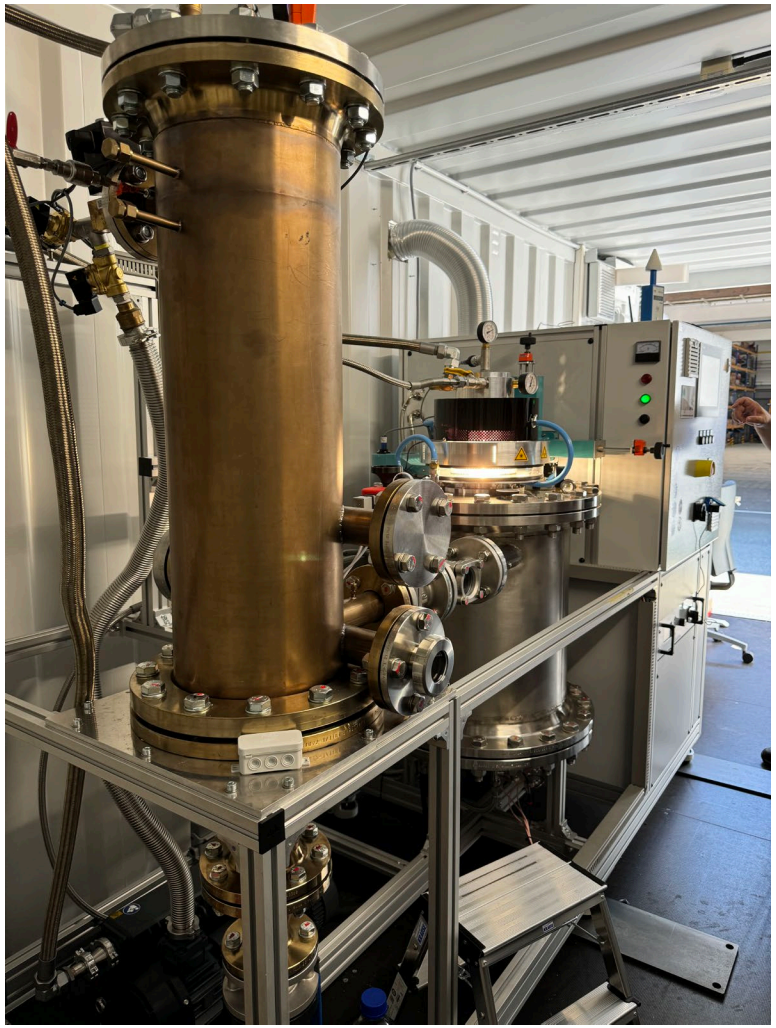
MEDEA

Basic Data

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

FORSCHUNG AN FACHHOCHSCHULEN

- Duration: November 01, 2021 - April 30, 2025
- Project partners: Hamburger Energienetze GmbH & iplas GmbH
- **Objective:** Testing and scientific investigation of climate-friendly and energy-efficient production of hydrogen (H_2) and carbon black (C) from methane (CH_4) using microwave plasma



HAW HAMBURG | CC4E

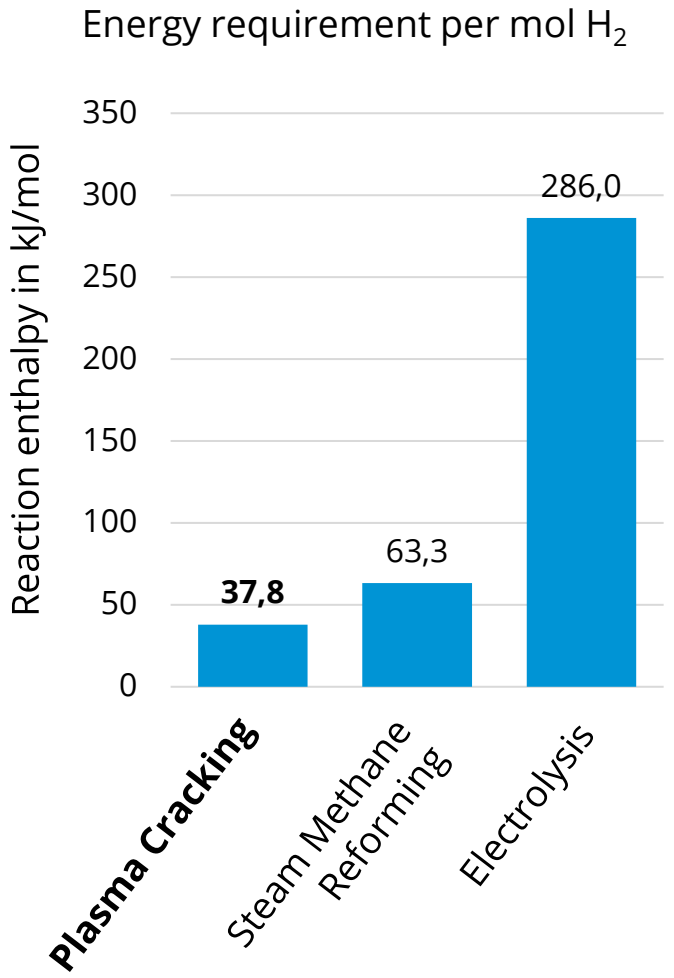
iplas innovative plasma systems gmbh

HAMBURGER ENERGIENETZE

MEDEA

Why Plasma Cracking?

- Only 1/7 of the energy required for electrolysis is needed for the same hydrogen yield
- Utilization of the high H_2 to carbon ratio in methane (CH_4)
- No consumption of water as a resource
- No direct CO_2 emissions



MEDEA

Overview and Functionality

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung
FORSCHUNG AN FACHHOCHSCHULEN

Inlet gas volume flow:
5 - 20 Nm3/h CH_4
Pressure range:
1000 - 1500 mbar abs.
Microwave power range:
4 - 10 kW

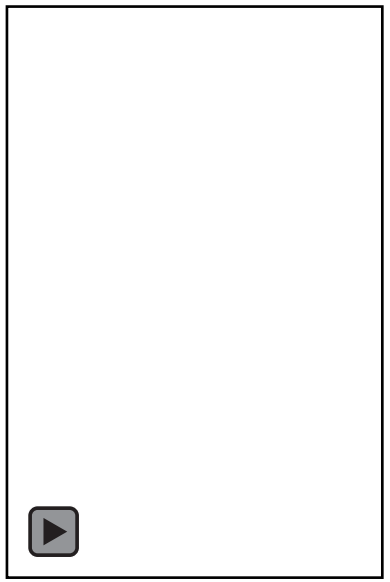


Photo of the MEDEA plasma cracking plant

iplas GmbH, 2023

MEDEA

Test Evaluation – Influence of Microwave Power

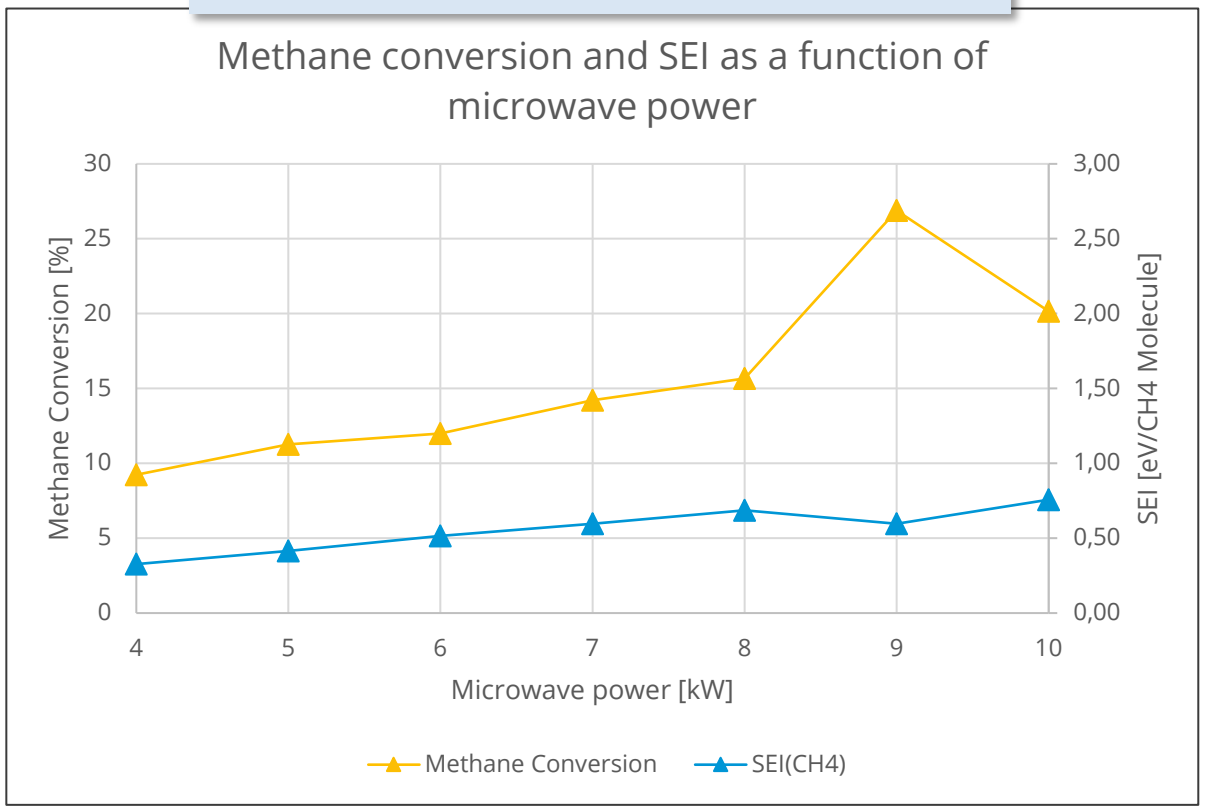
GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

FORSCHUNG AN FACHHOCHSCHULEN

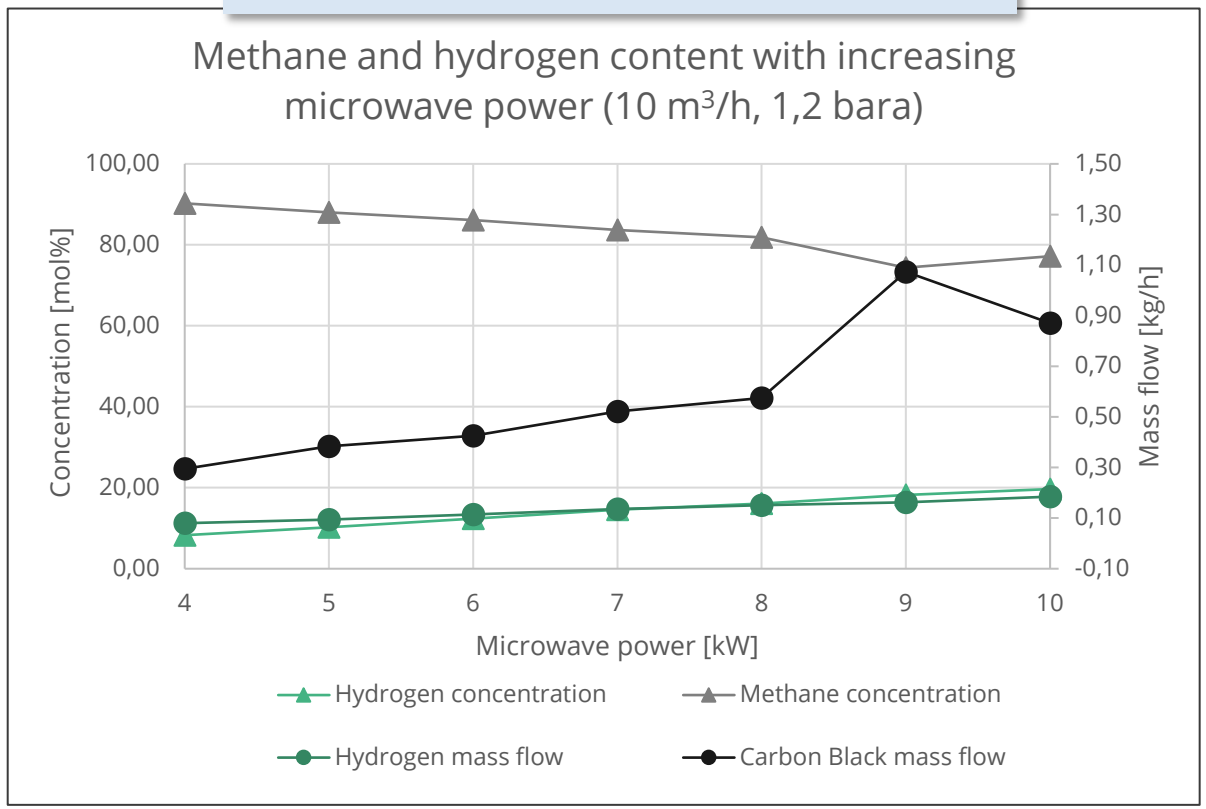
SEI – Specific Energy Input

Measure of the energy input per methane molecule in eV/CH_4.

P ↑ ⇒ SEI ↑ ⇒ Methane Conversion ↑



P ↑ ⇒ mass flow H_2 ↑ & CB ↑ ⇒ %CH_4 ↓



HAW HAMBURG | CC4E | X-ENERGY

MEDEA

Test Evaluation – Influence of Volume Flow

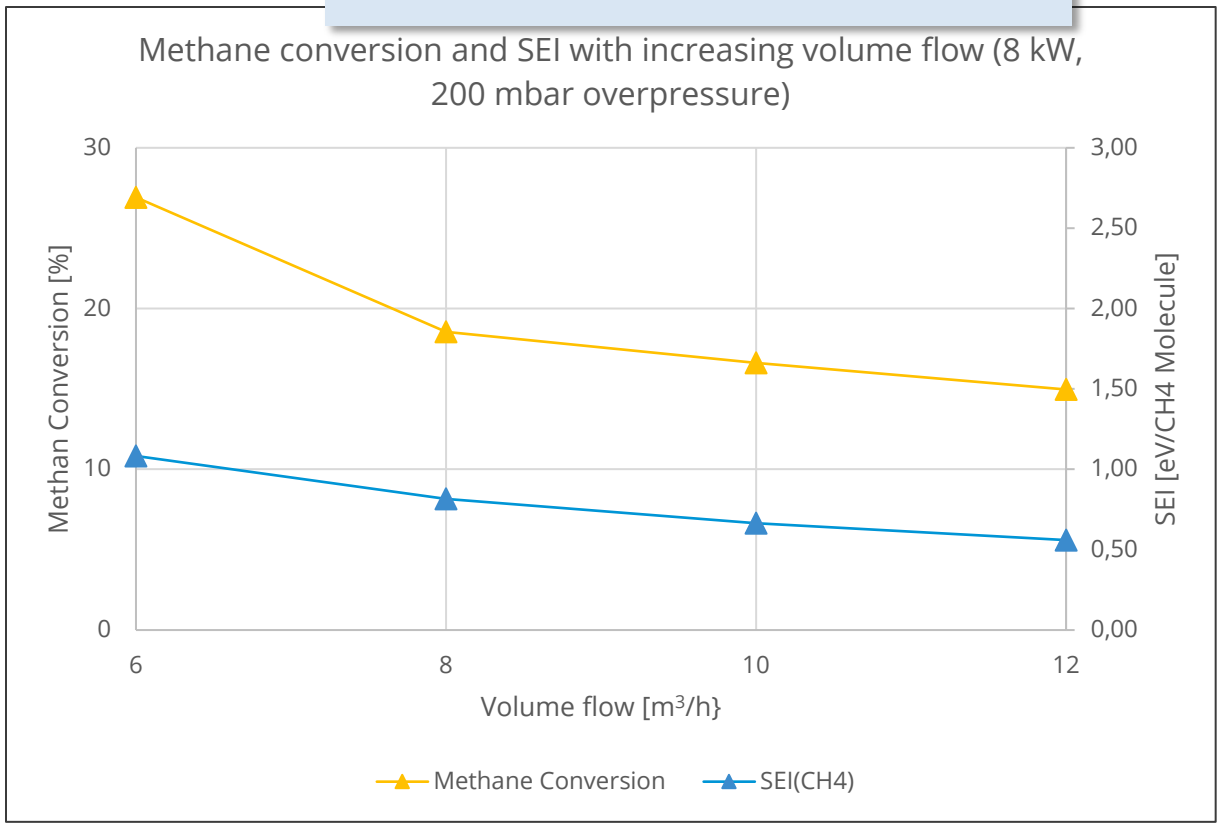
GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

FORSCHUNG AN FACHHOCHSCHULEN

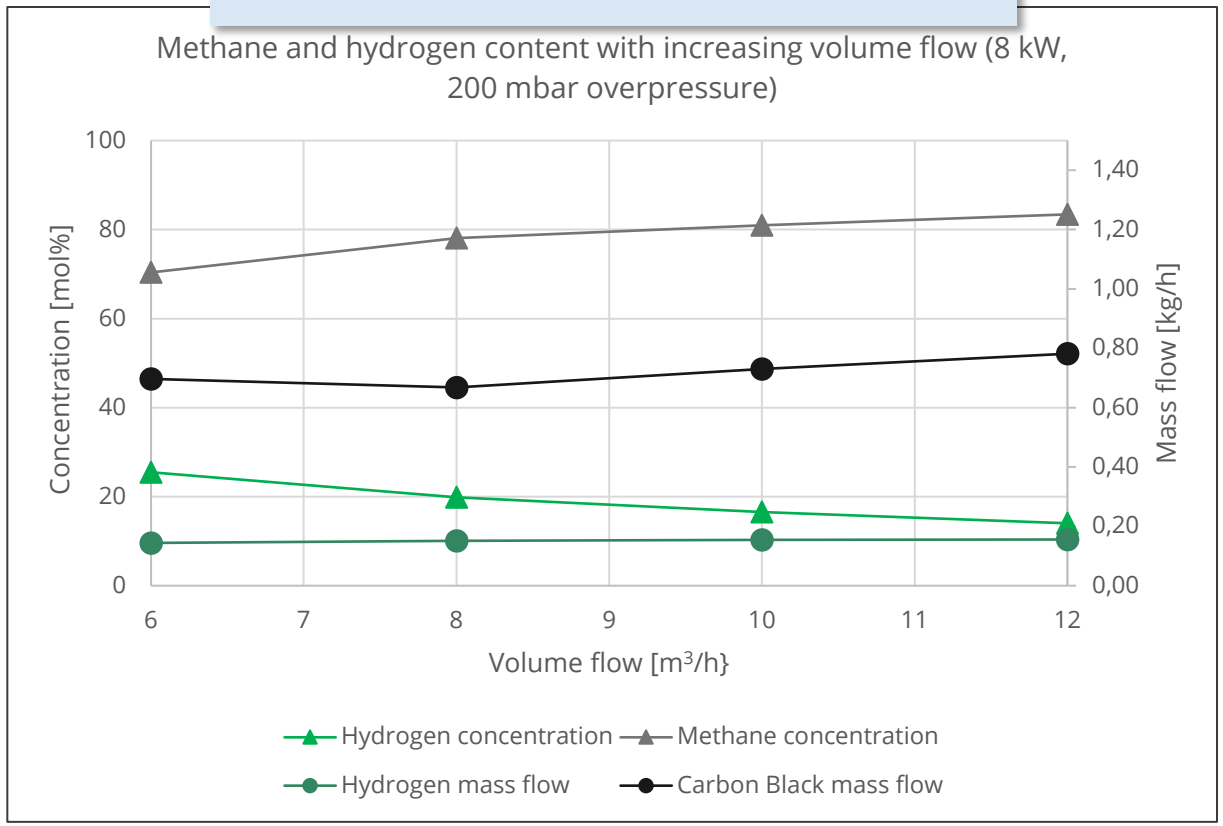
SEI – Specific Energy Input

Measure of the energy input per methane molecule in eV/CH_4.

V ↑ ⇒ SEI ↓ ⇒ Methane Conversion ↓



V ↑ ⇒ mass flow H_2 ↑ & CB ↑ ⇒ %CH_4 ↑



HAW HAMBURG | CC4E

MEDEA

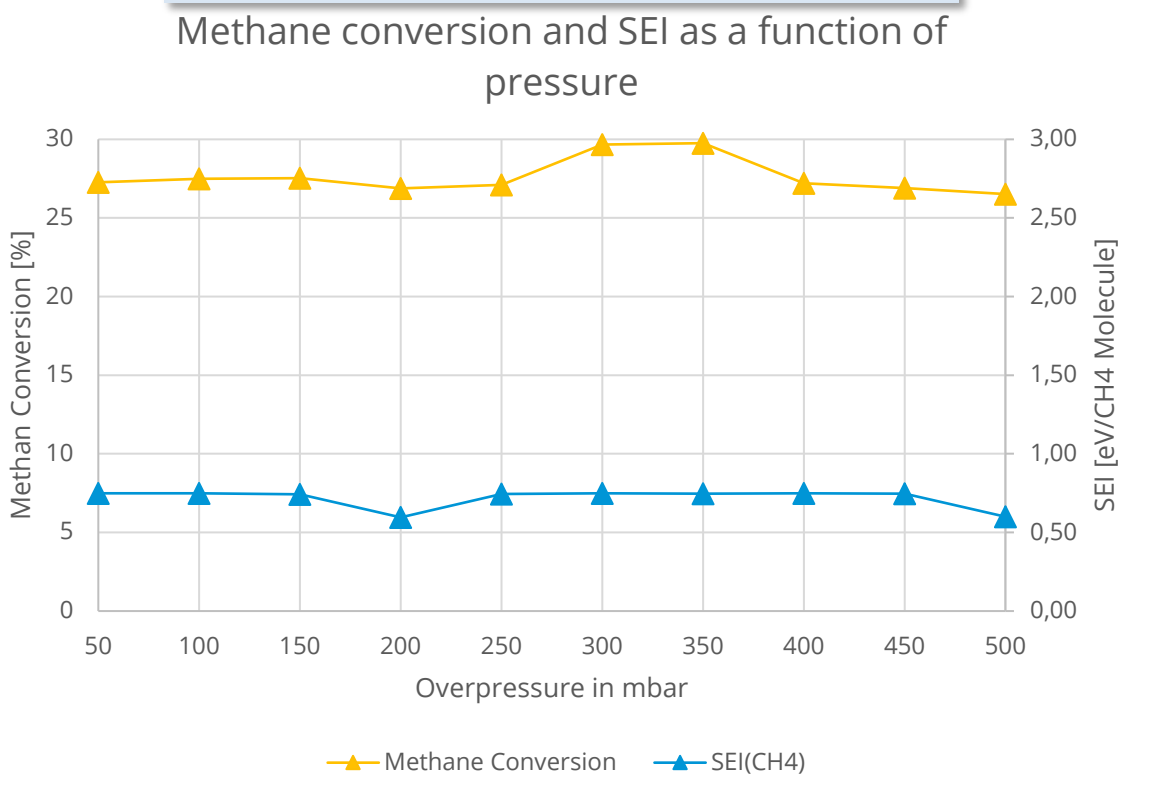
Test Evaluation – Influence of Pressure

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung
FORSCHUNG AN FACHHOCHSCHULEN

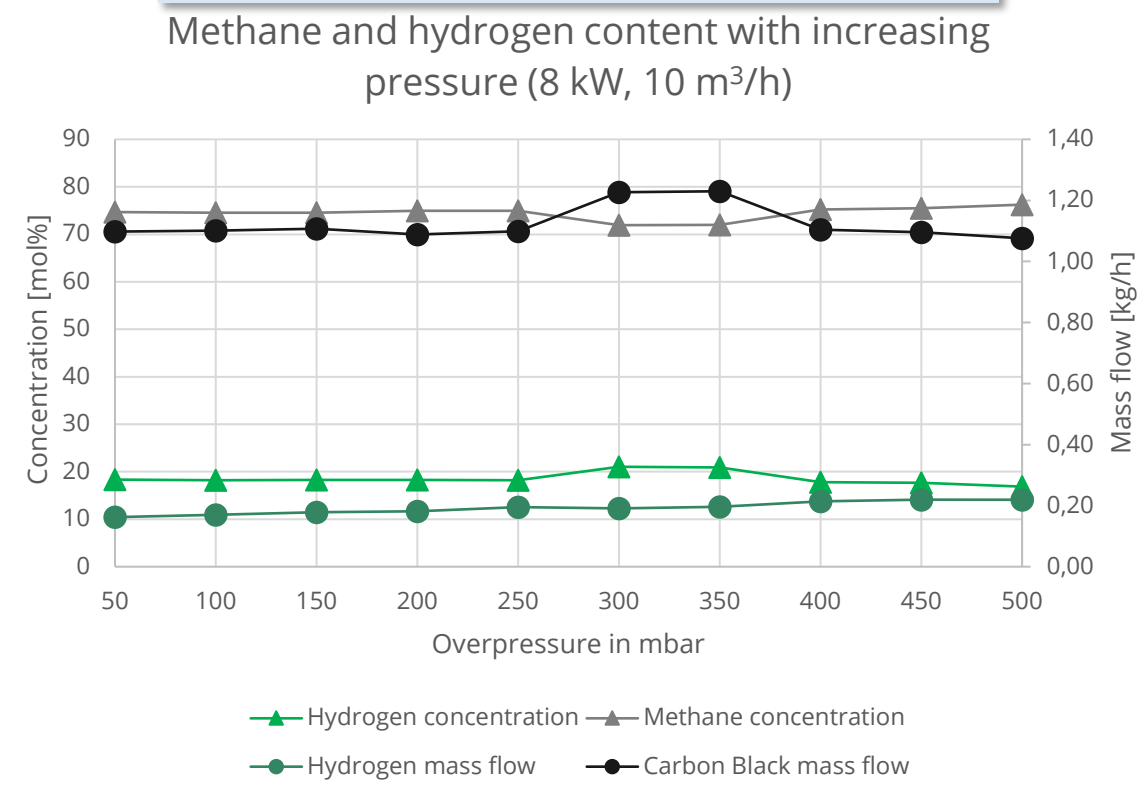
SEI – Specific Energy Input

Measure of the energy input per methane molecule in eV/CH_4.

p ↑ □ SEI → □ Methane Conversion→



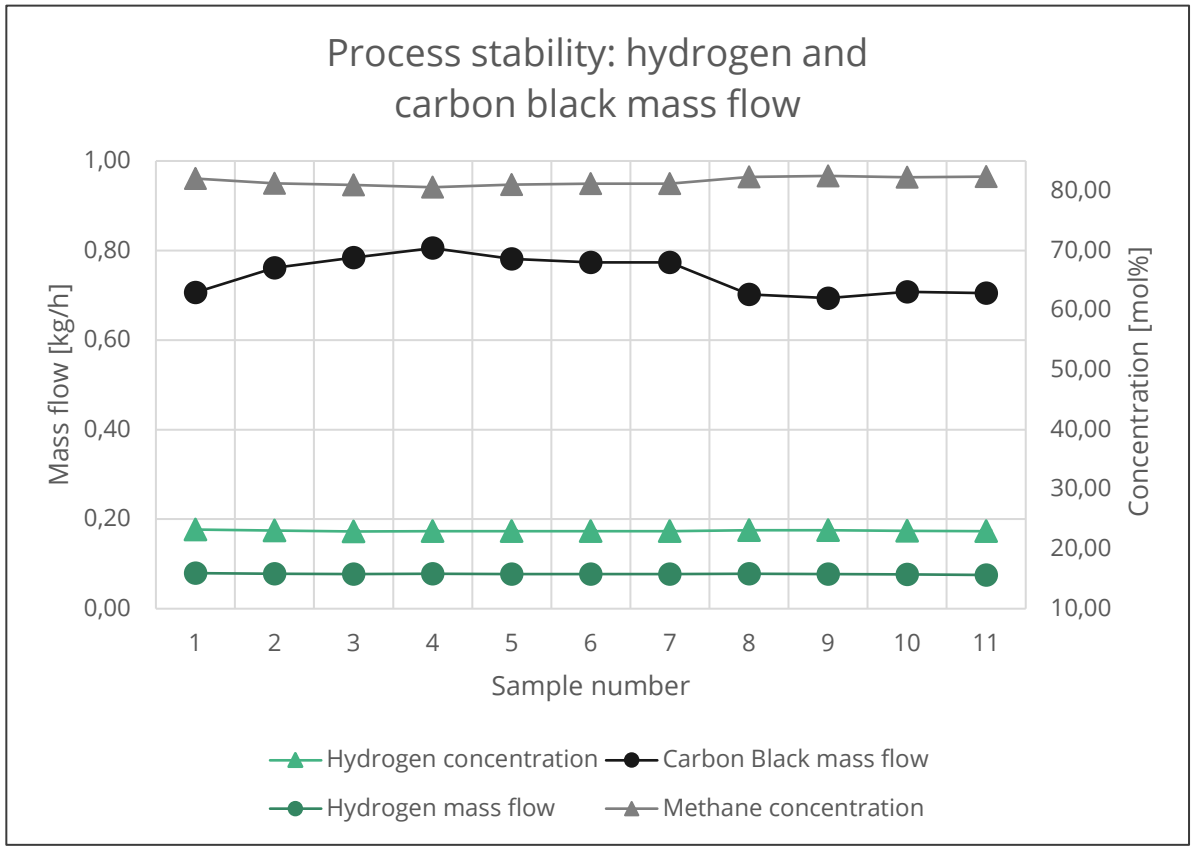
p ↑ □ Mass H_2 ~↑ & CB ~↑ □ %CH_4 ~↓

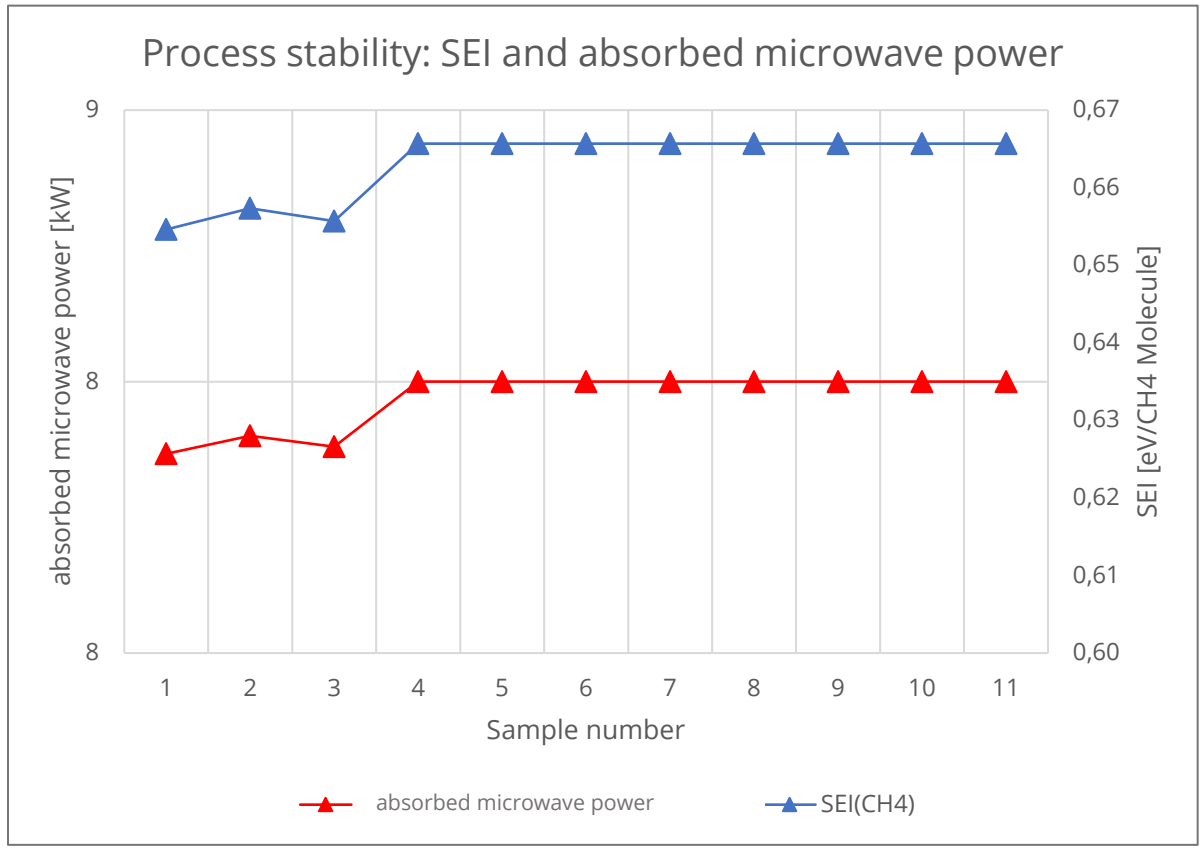


MEDEA

Process Stability

- Process point: 8 kW, 10 m3/h, 1.2 bar absolute
- 3:04h continuous operation





MEDEA

Plasmacracking – Theoretical Yield

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung
FORSCHUNG AN FACHHOCHSCHULEN

Hydrogen + X

~ 1,8 kg H_2

Carbon Black

~ 5,2 kg C

(Bio-)Methane

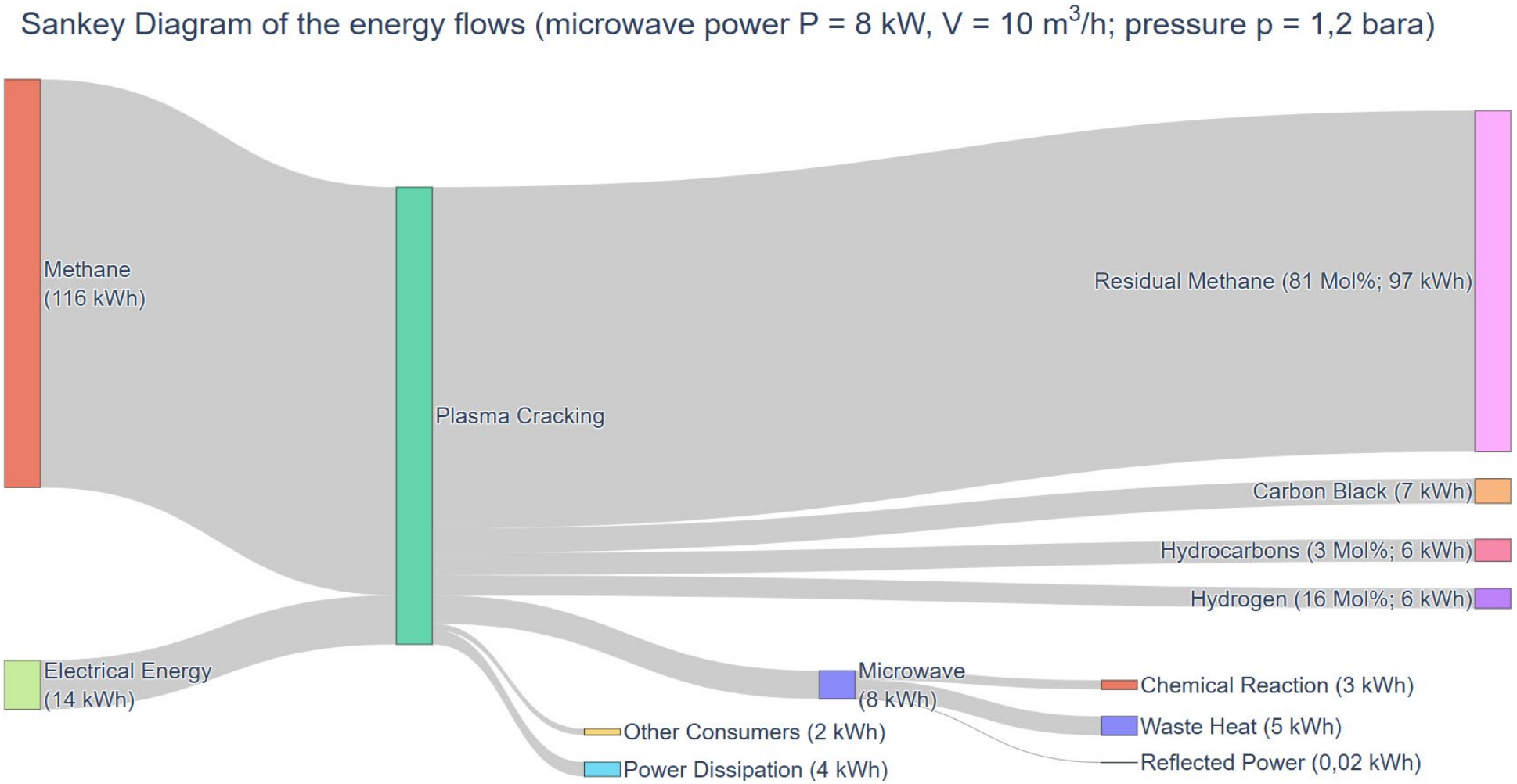
7 kg CH_4

Green Electricity

15 kWh

MEDEA

Sankey Diagramm of the energy flows



Overview of Test Operation Results

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung
FORSCHUNG AN FACHHOCHSCHULEN

Description	Value	Unit
H_2-yield	35,28	Mol%
H_2-mass flow	0,28	kg/h
Energetic H_2-efficiency	8,80	%
Energy consumption of H_2-production	58,70	kWh/kg H_2

Plasma2X

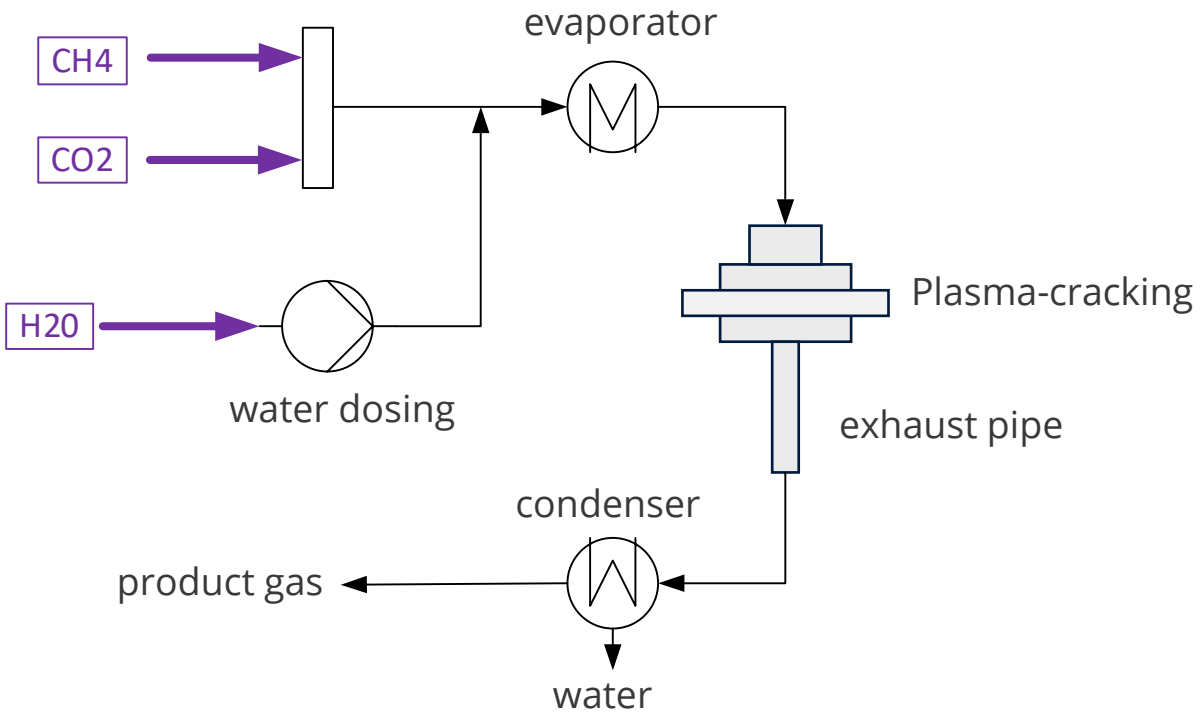
Scalable Production of Renewable Liquid Fuels with Low-Temperature Microwave Plasma

Jan-Malte Kapust, Hendrik Zachariassen, Torsten Birth-Reichert

HAW HAMBURG | CC4E
X ENERGY

Gefördert durch: Bundesministerium für Digitales und Verkehr aufgrund eines Beschlusses des Deutschen Bundestages
Koordiniert durch: NOW GMBH
Projektträger: VDI VDE IT, FNR
GESAMTKONZEPT ERNEUERBARE KRAFTSTOFFE

Modification of the plasma cracking process for the production of syngas



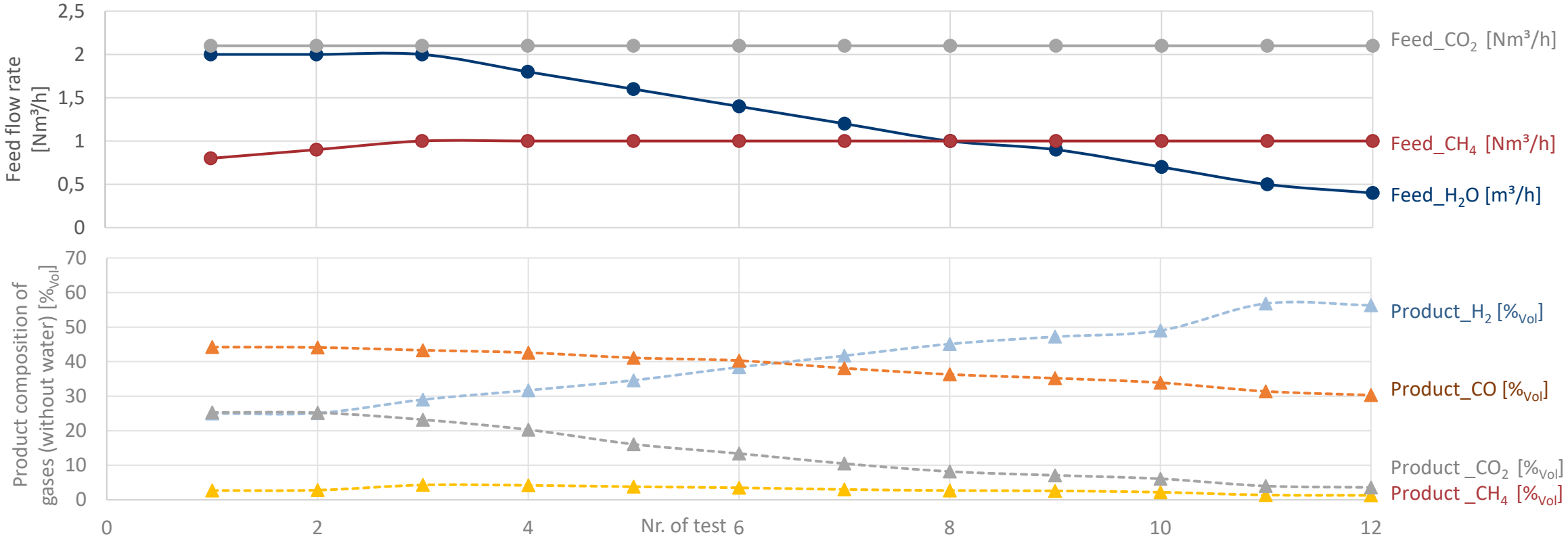
very simplified process flow diagram of the syngas plasma cracking process

Results and findings of the first experiments:

- syngas yield tested to date up to 85%
- variable adjustment of the syngas mixture from 0.5-3:1 (H2:CO) for FT- or methanol synthesis
- CO2 to CO possible but only up to approx. 8% yield in the first test
- stable process without wear of electrodes, contamination or similar
- very fast start-up possible for flexible application
- pressure tested up to 1.5 bara

Gefördert durch: Bundesministerium für Digitales und Verkehr aufgrund eines Beschlusses des Deutschen Bundestages
Koordiniert durch: NOW GMBH
Projektträger: VDI VDE IT, FNR
GESAMTKONZEPT ERNEUERBARE KRAFTSTOFFE

Adjustment of the syngas ratio (H_2:CO) via dosing the feed steam

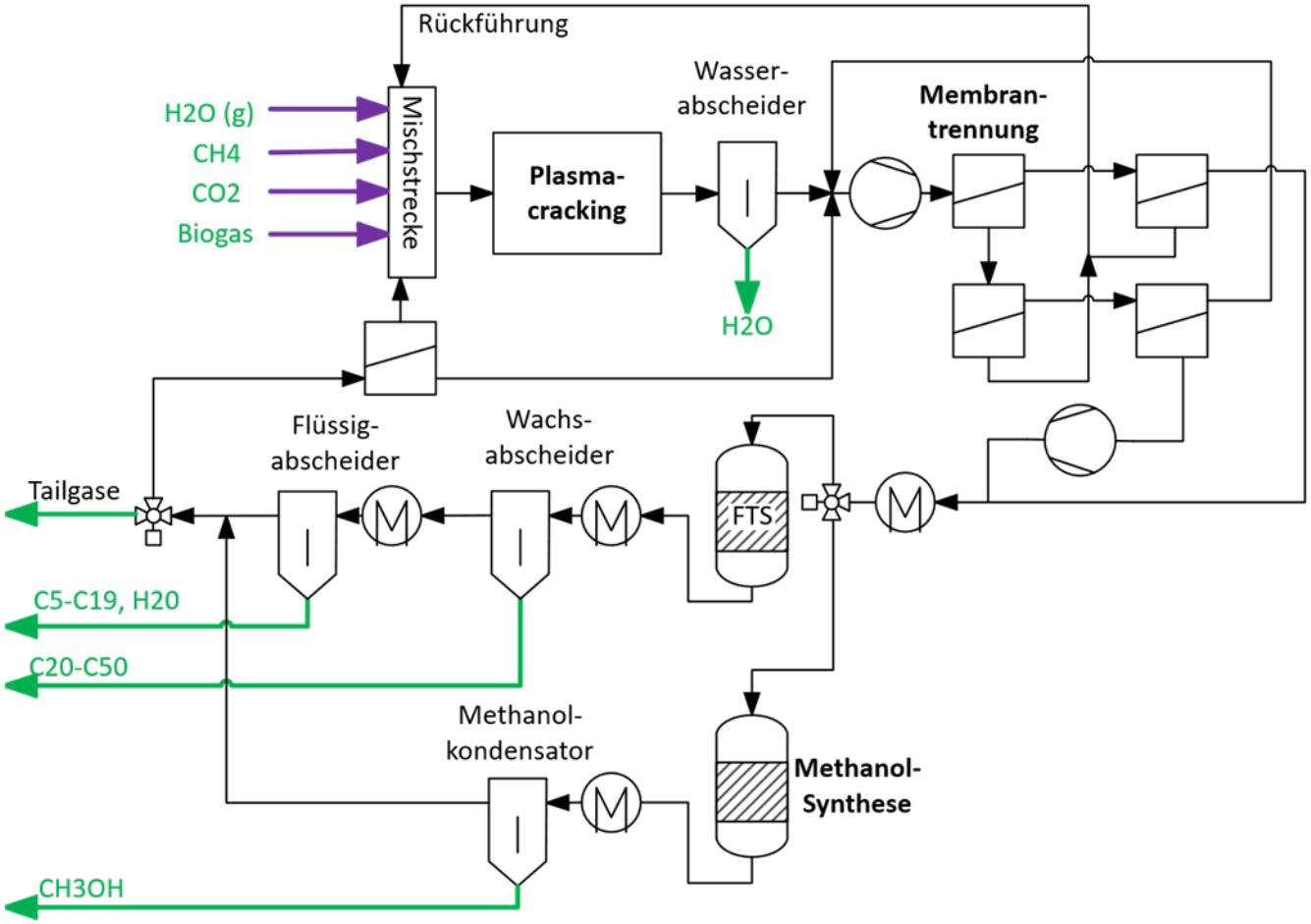


first test series for syngas production at ambient pressure, 9kW microwave power and 650K exhaust gas temperature. As the water content in the product was condensed out, it could not yet be measured at this time

Plasma2X

Process Flow Diagram

GESAMTKONZEPT ERNEUERBARE KRAFTSTOFFE
Gefördert durch: Bundesministerium für Digitales und Verkehr aufgrund eines Beschlusses des Deutschen Bundestages
Koordiniert durch: NOW-GMBH.DE
Projektträger: VDI|VDE|IT, FNR



HAW HAMBURG | CC4E | XENERGY

Contact details

Prof. Dr.-Ing. Torsten Birth-Reichert
torsten.birth-reichert@haw-hamburg.de

www.cc4e.de