
Current technological status of biogas upgrading

Michael Beil,
Fraunhofer-Institute for Energy Economics and Energy System Technology (IEE)

Bioenergy Association of
Ukraine and BIOFIT project
Workshop:

“Biomethane:
transfer of technologies,
policies and best practices
from European experience”



2021-11-10, Online

[Haase Energietechnik AG, 2011]

© Fraunhofer IEE

 **Fraunhofer**
IEE

Research Topic: Gas cleaning, upgrading and grid injection

■ Intention of our work

- Integration of biomethane in future energy supply systems
- Improving efficiency of biogas upgrading
- Sustainable biomethane provision

■ R&D topics:

- Technology and system analysis
- Simulation and modeling of technologies and systems
- Assessment of new technologies such as power-to-gas
- CO₂ management



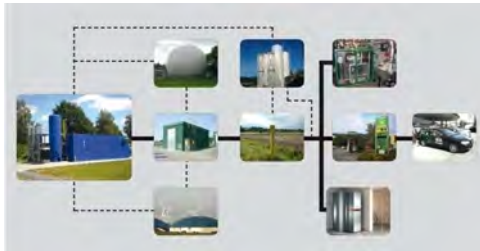
[Fraunhofer IWES | Beil]

© Fraunhofer IEE

 **Fraunhofer**
IEE

What we are doing in the field of biomethane

Research and consulting along
the whole value chain of
biomethane...from well to
wheel.



- Political consulting
- Feasibility studies for upcoming plant operators, utilities and investors
- Profitability analysis and due diligences (e.g. for investors)
- Surveys of new technologies for technology providers before market implementation
- Trainings in the fields of biomethane provision, distribution and utilization
- Technology and system evaluation and optimization
- Infrastructure for field tests of pilot plants

© Fraunhofer IEE

 **Fraunhofer**
IEE

Contents

- Current status biogas upgrading in Germany
- Biogas upgrading technologies
- Reduction of emissions
- Biomethane grid injection

© Fraunhofer IEE

 **Fraunhofer**
IEE

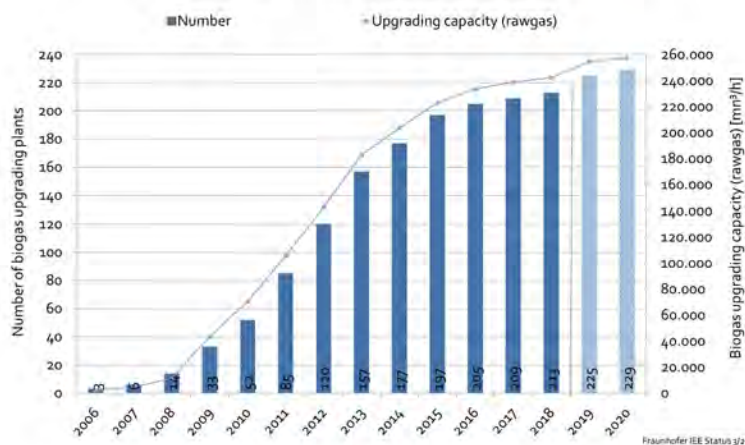
Current status of biogas upgrading in Germany

© Fraunhofer IEE



State of biomethane production in Germany

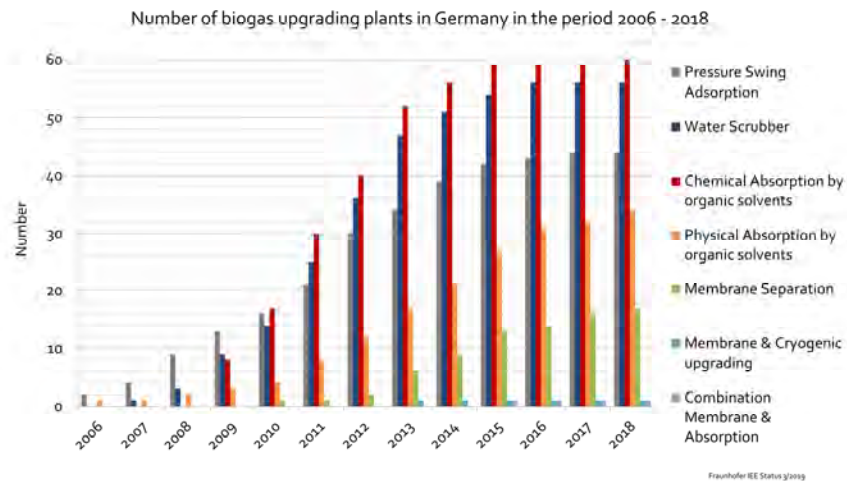
Number and upgrading capacity of biogas upgrading plants in Germany in the period 2006 - 2018 with an estimation for 2019/2020



© Fraunhofer IEE



State of biomethane production in Germany



© Fraunhofer IEE

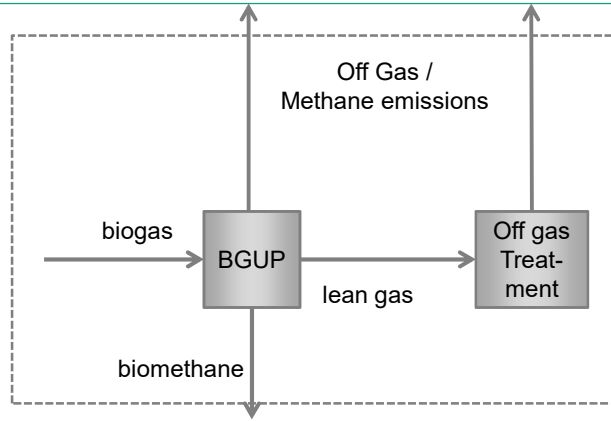
Fraunhofer
IEE

Biogas upgrading technologies

© Fraunhofer IEE

Fraunhofer
IEE

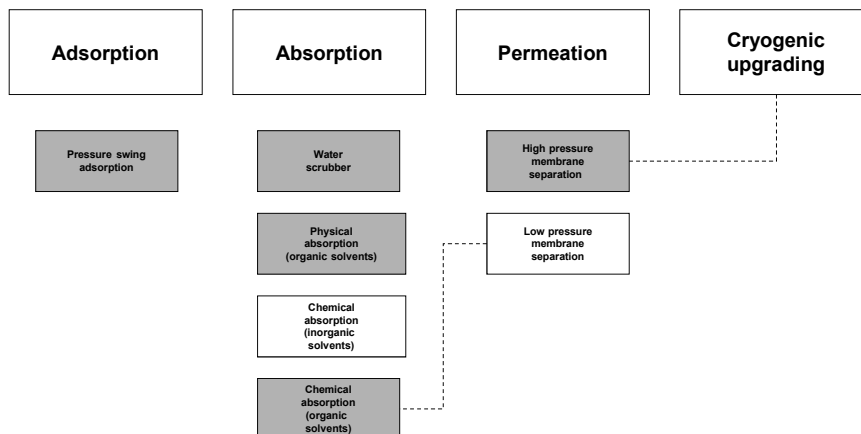
Definition mass flows



© Fraunhofer IEE

Fraunhofer
IEE

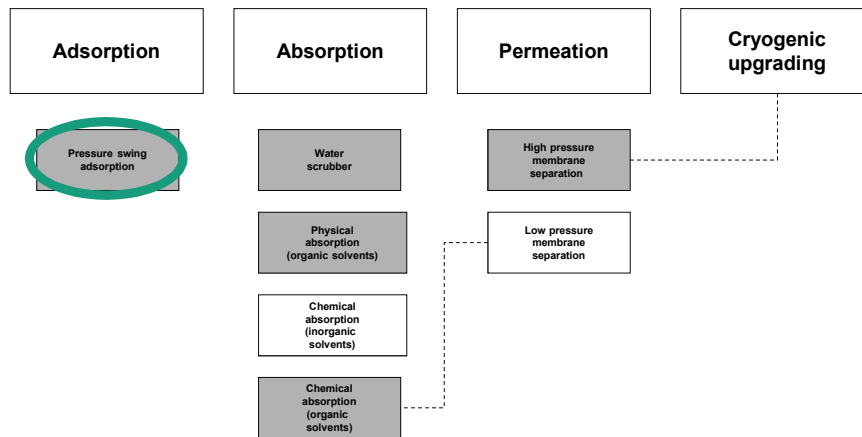
Biogas upgrading - Technology overview 5 methods state of the art



© Fraunhofer IEE

Fraunhofer
IEE

Biogas upgrading - Technology overview



© Fraunhofer IEE

Fraunhofer
IEE

Pressure Swing Adsorption (PSA)

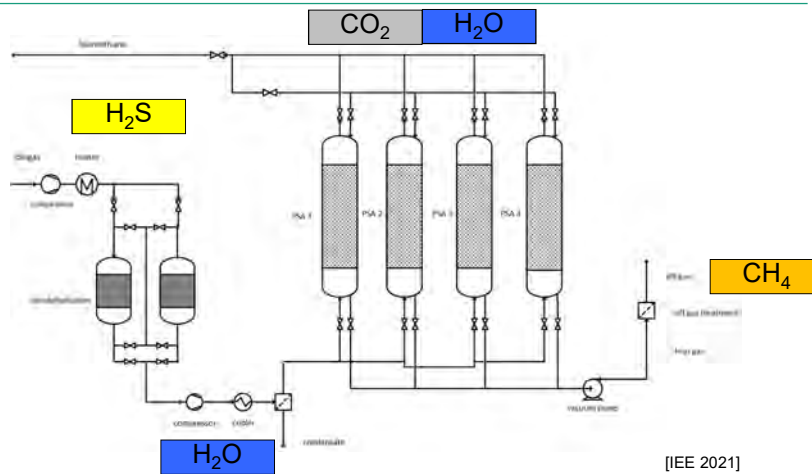


[Fraunhofer IEE | Beil]

© Fraunhofer IEE

Fraunhofer
IEE

Pressure Swing Adsorption (PSA)

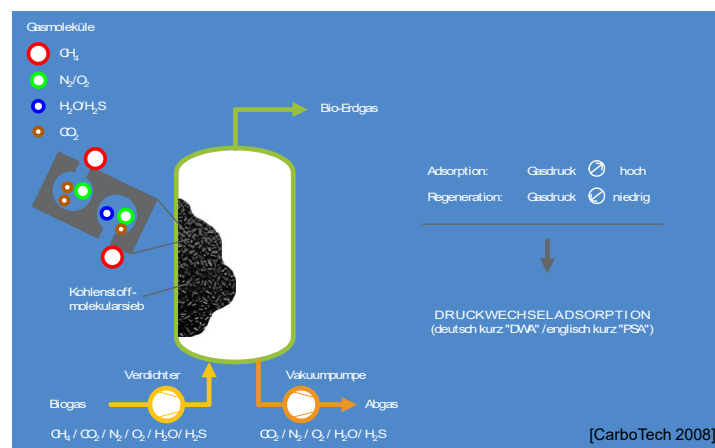


[IEE 2021]

© Fraunhofer IEE

Fraunhofer
IEE

Pressure Swing Adsorption (PSA)



[CarboTech 2008]

© Fraunhofer IEE

Fraunhofer
IEE

Pressure Swing Adsorption (PSA)



	Electricity demand	Heat demand	Water demand	Demand on chemical substances	Operation pressure	Methane loss	Methane recovery rate	Off-gas treatment recommended	Precision desulphurization required
	[kWh/m ³ BSG]				[bar]	[%]	[%]		
ranges	0.16-0.35	0	No	No	1-10	1.5-10	90-98.5	Yes	Yes
typical values	0.2-0.25	0	No	No	4-7	1.5-2.5	97.5-98.5	Yes	Yes

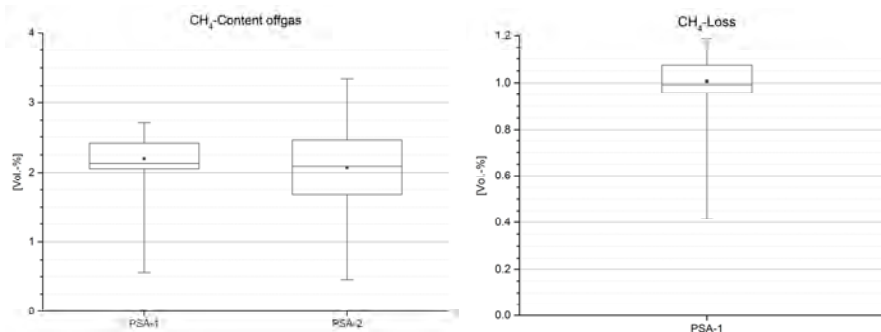


[Fraunhofer IEE | Beil]

© Fraunhofer IEE

Fraunhofer IEE

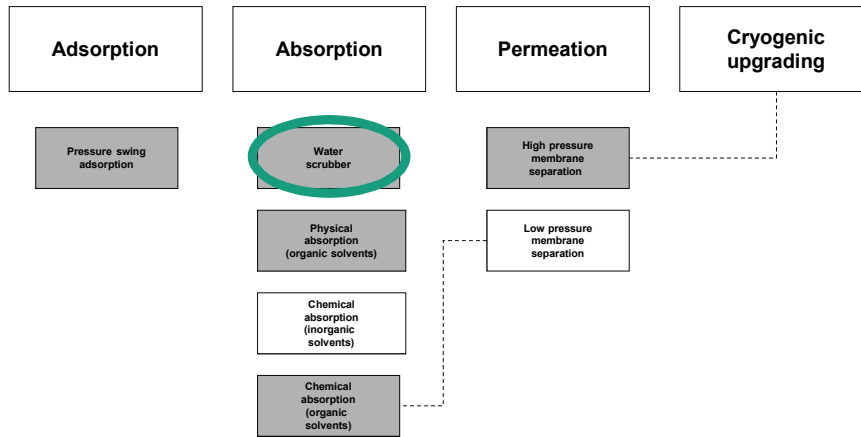
Pressure Swing Adsorption (PSA): CH₄-concentration off-gas versus CH₄-loss (slip) → results of a 2-week measurement campaign at 2 large scale plants



© Fraunhofer IEE

Fraunhofer IEE

Water scrubber



© Fraunhofer IEE

Fraunhofer
IEE

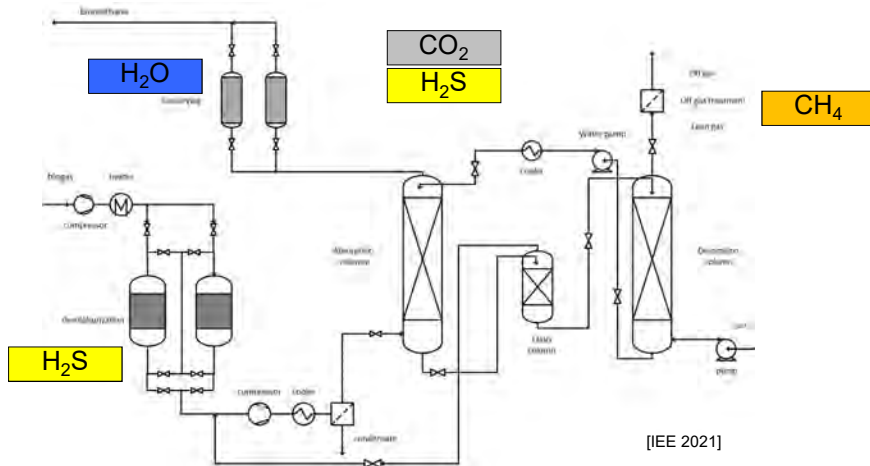
Water scrubber



© Fraunhofer IEE

Fraunhofer
IEE

Water scrubber



[IEE 2021]

© Fraunhofer IEE

Fraunhofer IEE

Water scrubber



	Electricity demand	Heat demand	Water demand	Demand on chemical substances	Operation pressure	Methane loss	Methane recovery rate	Off-gas treatment recommended	Precision desulphurization required
	[kWh/m ³ gas]				[bar]	[%]	[%]		
ranges	0.20 - 0.30	0	Yes	No	4-10	0.5 - 2	98-99.5	Yes	No
typical values	>0.2 - <0.3	0	Yes	only e.g. anti-scaling/fouling agents on demand	4-10	0.5 - 2	98-99.5	Yes	No



[Fraunhofer IEE | Beif.]

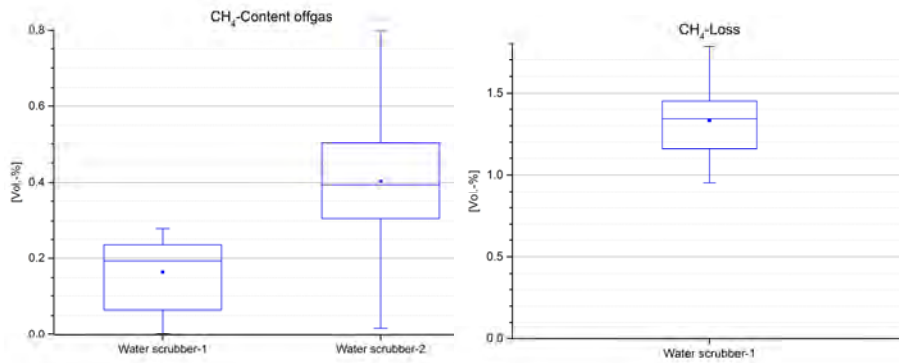
© Fraunhofer IEE

Fraunhofer IEE

Water scrubber:

CH₄-concentration off-gas versus CH₄-loss (slip)

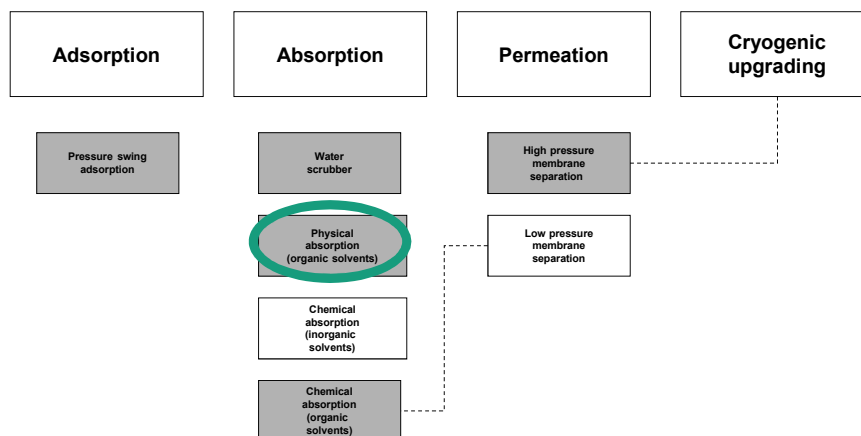
→ results of a 2-week measurement campaign at 2 large scale plants



© Fraunhofer IEE

Fraunhofer
IEE

Biogas upgrading - Technology overview



© Fraunhofer IEE

Fraunhofer
IEE

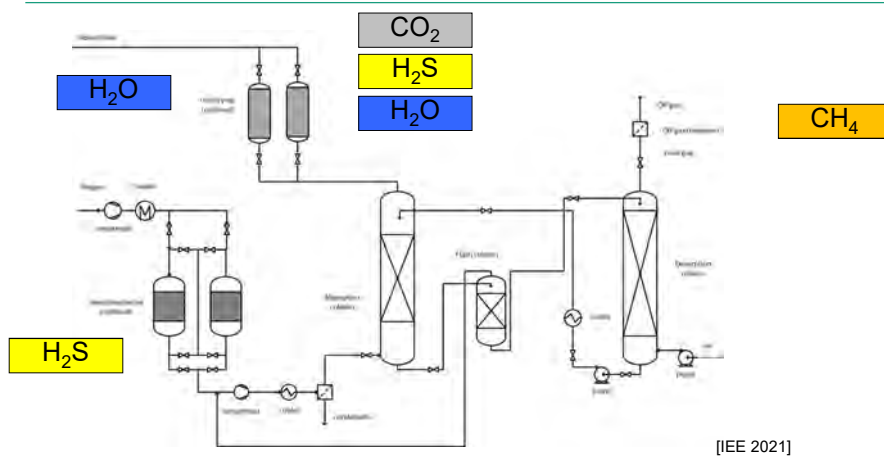
Physical Absorption (using organic solvents)



© Fraunhofer IEE

Fraunhofer
IEE

Physical Absorption (using organic solvents)



[IEE 2021]

© Fraunhofer IEE

Fraunhofer
IEE

Physical Absorption (using organic solvents)



	Electricity demand	Heat demand	Temperature level process heat (in the column)	Water demand	Demand on chemical substances	Operation pressure	Methane loss	Methane recovery rate	Off-gas treatment recommended	Precision desulphurization required
	[kWh/m ³ gas]		[°C]			[bar]	[%]	[%]		
ranges	0.23-0.33	0.10-0.15	40-80	No	Yes	4-8	1-4	96-99	Yes	No
typical values	0.23-0.27	0.10-0.15	40-50	No	Yes	6-7	~1.5	~98.5	Yes	No

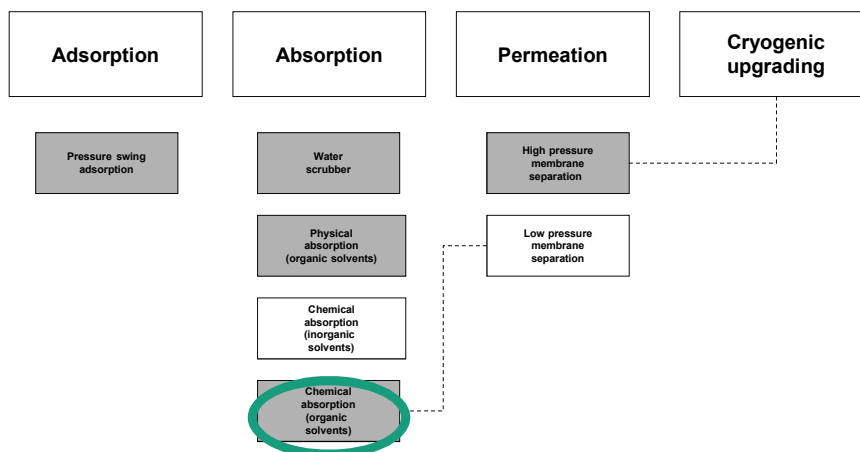


[Fraunhofer IEE | Beil]

© Fraunhofer IEE

Fraunhofer IEE

Chemical Absorption (using organic solvents)



© Fraunhofer IEE

Fraunhofer IEE

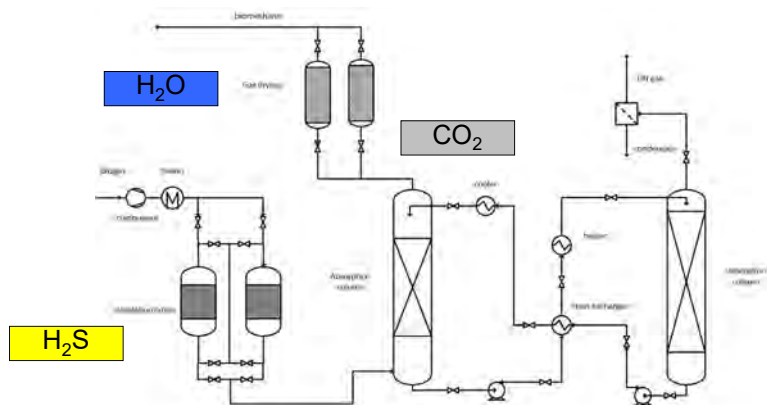
Chemical Absorption (using organic solvents)



© Fraunhofer IEE

Fraunhofer
IEE

Chemical Absorption (using organic solvents)



© Fraunhofer IEE

Fraunhofer
IEE

Chemical Absorption (using organic solvents)



	Electricity demand	Heat demand	Temperature level process heat (in the column)	Water demand	Demand on chemical substances	Operation pressure	Methane loss	Methane recovery rate	Off-gas treatment recommended	Precision desulphurization required
	[kWh/m ³ gas]		[°C]			[bar]	[%]	[%]		
ranges	0.06-0.17	0.4-0.8	106 - 160	Yes	Yes	0.05 - 4	~0.1	~99.9	No	Yes (Depending on manufacturer)
typical values	0.09-0.11	~0.5-0.7	106 - 160	Yes	Yes	0.05 - 4	~0.1	~99.9	No	Yes (Depending on manufacturer)



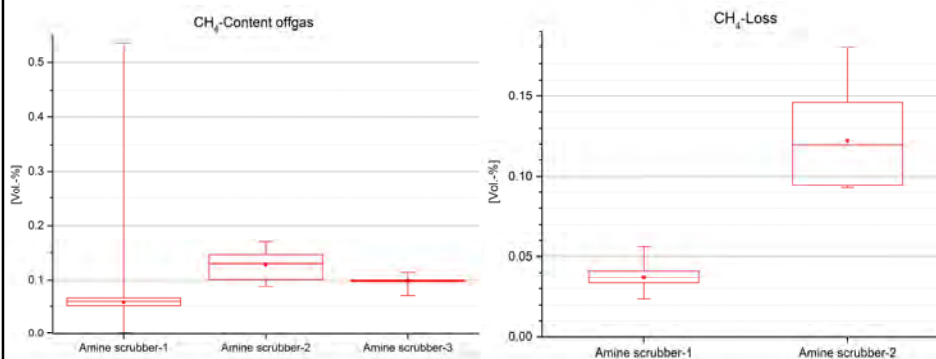
© Fraunhofer IEE

Fraunhofer IEE

Amine scrubber:

CH₄-concentration off-gas versus CH₄-loss (slip)

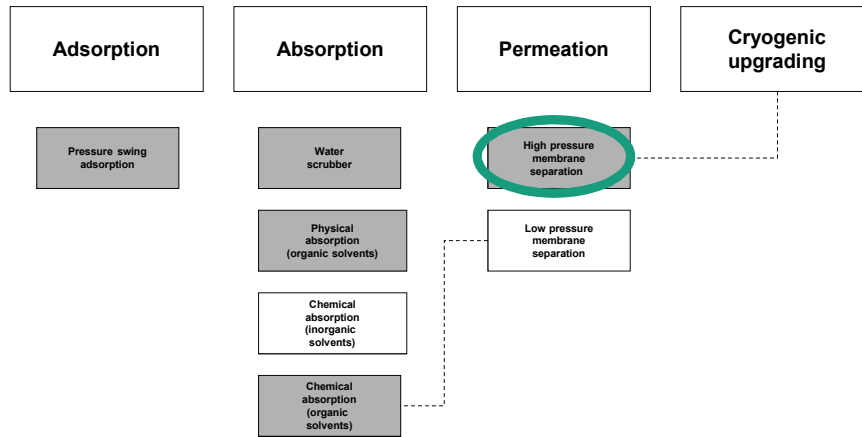
→ results of a 2-week measurement campaign at 3 large scale plants



© Fraunhofer IEE

Fraunhofer IEE

Membrane separation



© Fraunhofer IEE

Fraunhofer
IEE

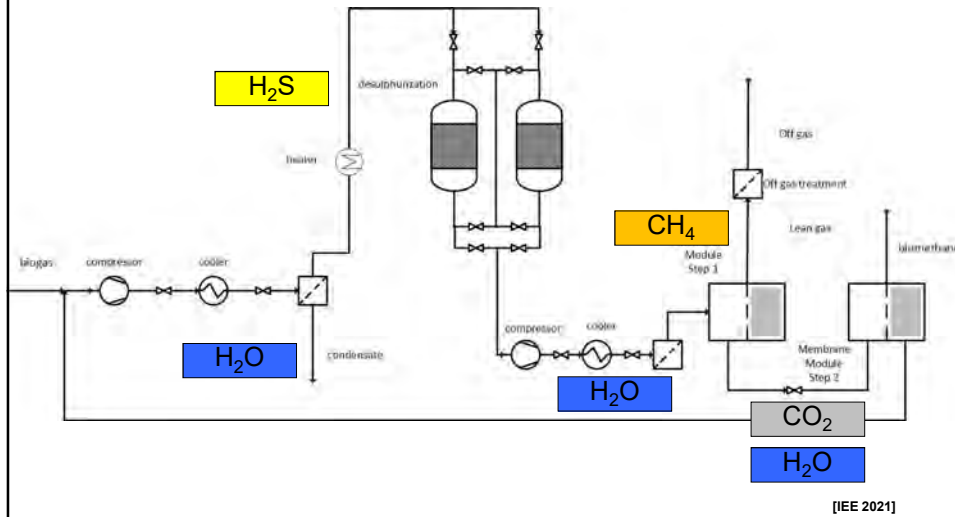
High Pressure Membrane Separation



© Fraunhofer IEE

Fraunhofer
IEE

Membrane separation



[IEE 2021]

© Fraunhofer IEE

Fraunhofer
IEE

Membrane separation



[IEE, 2011]

© Fraunhofer IEE

Fraunhofer
IEE

Membrane separation



	Electricity demand	Heat demand	Water demand	Demand on chemical substances	Operation pressure	Methane loss	Methane recovery rate	Off-gas treatment recommended (methane loss >1%)	Precision desulphurization required
	[kWh/m ³ sc]	[kWh/m ³ sc]			[bar]	[%]	[%]		
ranges	0.18-0.35	0	No	No	7-20	0.5-15	85-99.5	Yes	Recommended
typical values	0.18-0.29	0	No	No	7-20	0.5 - 2	98.0 - 99.5	(Yes)	Recommended



[Fraunhofer IEE | Beil]

© Fraunhofer IEE

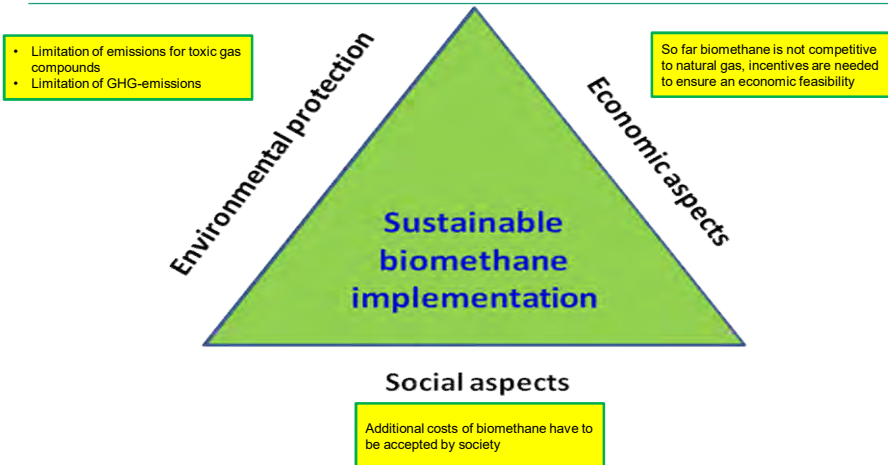
 **Fraunhofer**
IEE

Reduction of emissions

© Fraunhofer IEE

 **Fraunhofer**
IEE

Triangle of sustainable biomethane implementation



© Fraunhofer IEE

Fraunhofer
IEE

lean-gas treatment

Degradation of CH₄ in the off-gas using:

- **Regenerative thermal oxidation (RTO)**
 - Water scrubber, Phys. Absorption, PSA (new generation), Membrane (new generation)
- **Catalytic oxidation**
 - PSA, Membrane
- **Flameless oxidation**
 - PSA, Membrane
- Co-firing in combustion engines (e.g. micro turbines)
- others
 - E.g. biological systems, CH₄-recovery for scrubbers



© Fraunhofer IEE

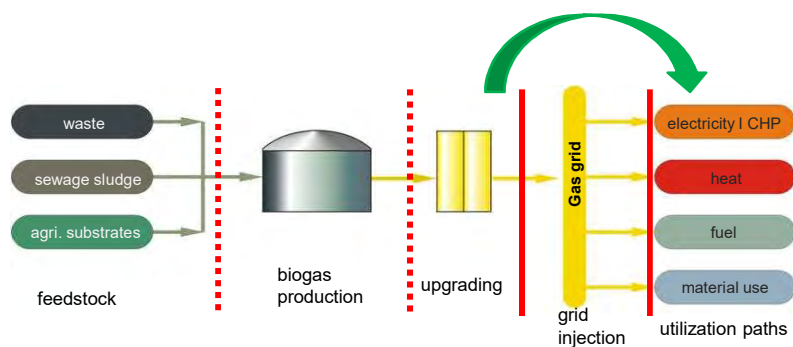
Fraunhofer
IEE

Biomethane grid injection

© Fraunhofer IEE

Fraunhofer
IEE

German system for biogas upgrading and grid injection



© Fraunhofer IEE

Fraunhofer
IEE

Limiting values biomethane grid injection according to German technical standard

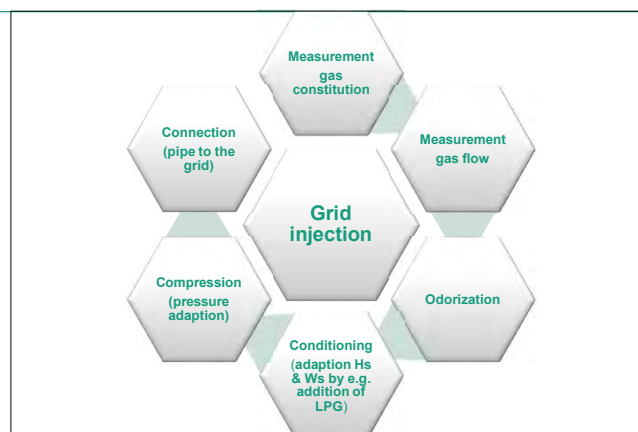
Parameter	Unit	Value
Methane	mol-%	≥ 95 (H-gas) ≥ 90 (L-gas)
Carbon dioxide	mol-%	4 (MOP < 16 bar) 2.5 (MOP ≥ 16 bar)
Water content	mg/m ³	200 (MOP ≤ 10 bar) 50 (MOP > 10 bar)
<u>Sulfur:</u>		
• Total (without / with odorant)	mg/m ³	• 6 / 10
• H ₂ S and COS (as sulfur)		• 5
Silicon	mg/m ³	0.3
Ammonia and amines	mg/m ³	10

Table shows examples for limiting values according to DVGW G 260 "gas quality" 09/2021

© Fraunhofer IEE

Fraunhofer
IEE

Biomethane grid injection (station): Tasks to fulfill



© Fraunhofer IEE

Fraunhofer
IEE

Biomethane grid injection station in Germany



© Fraunhofer IEE

 **Fraunhofer**
IEE

Summary

© Fraunhofer IEE

 **Fraunhofer**
IEE

Summary

- Gas cleaning is an essential part of biogas upgrading
- 5 biogas upgrading technologies dominate the market – in Germany and worldwide
- Most relevant developments with membrane systems
- Stagnation in the last years for new upgrading plants in Germany
- Liquefaction of biomethane will gain a higher relevance in future
- Share of BGUP with CO₂-utilization will increase
- A detailed analysis of the most efficient/appropriate biogas upgrading technology within the project planning process has a relevant influence on specific gas upgrading costs
- Gas cleaning concepts have an essential impact on operating performance and constitution of the upgrading plant and are therefore very sensitive on the economic efficiency of the project

© Fraunhofer IEE

 **Fraunhofer**
IEE

Thank you!



© Fraunhofer IEE

 **Fraunhofer**
IEE

Contact

Michael Beil
Deputy Head of Bioenergy System Technology department
Fraunhofer Institute for Energy Economics and Energy System Technology IEE
Energy Process Engineering R&D division
Königstor 59
34119 Kassel
Germany
+49 (0) 561 7294-421
Michael.Beil@iee.fraunhofer.de

https://www.iee.fraunhofer.de/en/business_units/energy_system_technology/plant-engineering.html

© Fraunhofer IEE

