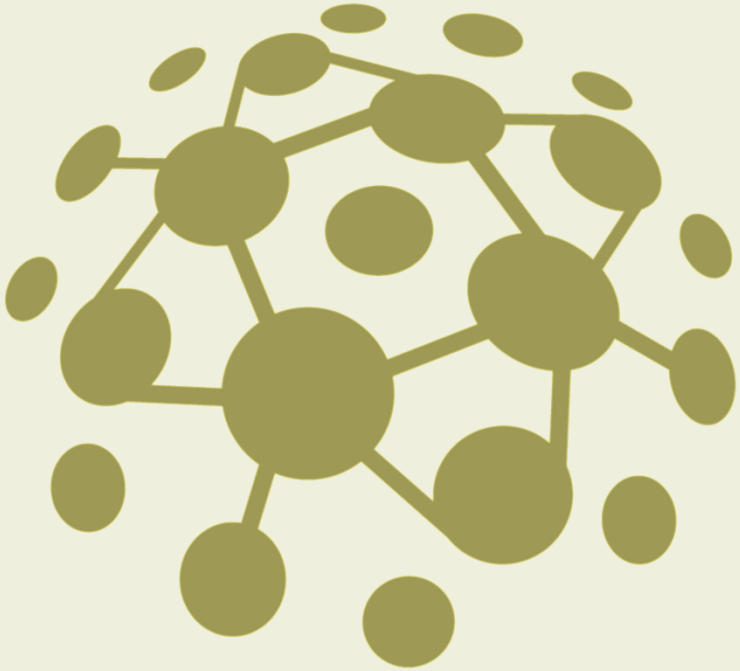
ENERGIEINSTITUT
an der Johannes Kepler Universität Linz

JOHANNES KEPLER UNIVERSITÄT LINZ



Johannes Lindorfer

IEA Bioenergy Task 39, 29.09.2016

Research Studio Austria „OptFuel“

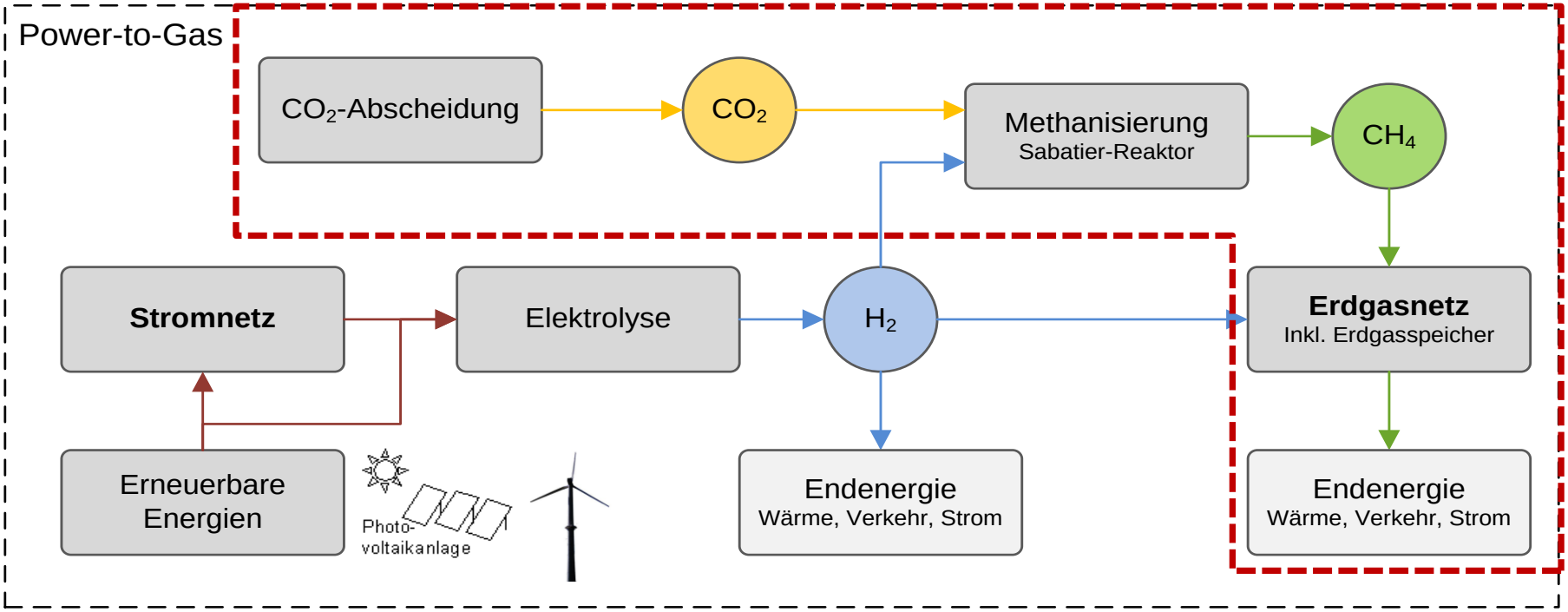
2-stage anaerobic digestion of biowaste combined with power-to-gas

Altenberger Straße 69, HF-Gebäude, 3. Stock , A-4040 Linz | Tel.:+43-732 / 24 68 5653 | email: lindorfer@energieinstitut-linz.at | www.energieinstitut-linz.at

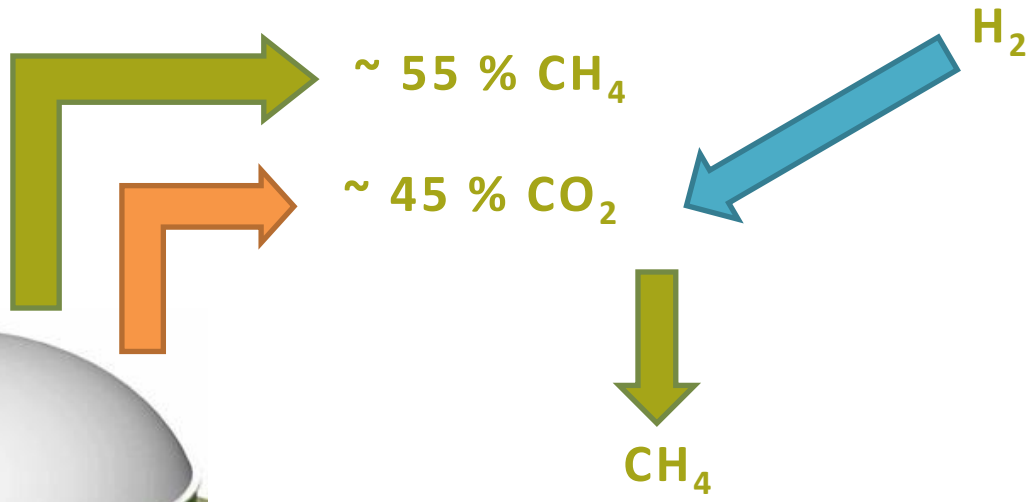
content

- Project concept & principal idea
- Laboratory experiments
- Implementation in pilot plant scale
- Results of 2-stage fermentation
- Economic & ecological assessment
- Future prospects

The concept of power-to-gas



RSA-OptFuel – concept power-to-gas



biogas = CH_4 + CO_2

integration of power-to-gas

4 H_2 + CO_2 → CH_4 + 2 H_2O

Goal: Increase the useable carbon production out of biomass and the conversion to a storable energy carrier!

The division of work within the project RSA-‚OptFuel'

Biogas production	Methanation	Gas processing
fermentation of waste materials 2-stage (vs. single-stage) hydrogen stage methane stage simple process control mesophilic, unsterile, mixed culture, no additives	chemical catalytic catalyst commercially available process optimization process pressures space velocities loads methane in educt gas	raw gas conditioning drying and adsorption gas processing by membrane separation technology operation optimization & simulation pressure, amount of modules, etc.

Financing	Research Studios Austria FFG
consortium management	Verein Energieinstitut an der Johannes Kepler Universität Linz
project partner	MUL, TU Wien, Profactor, christof group, OMV, EVN
funded by	Österreichische Forschungsförderungsgesellschaft FFG
project duration	**start: 01/2013** **end: 04/2016**

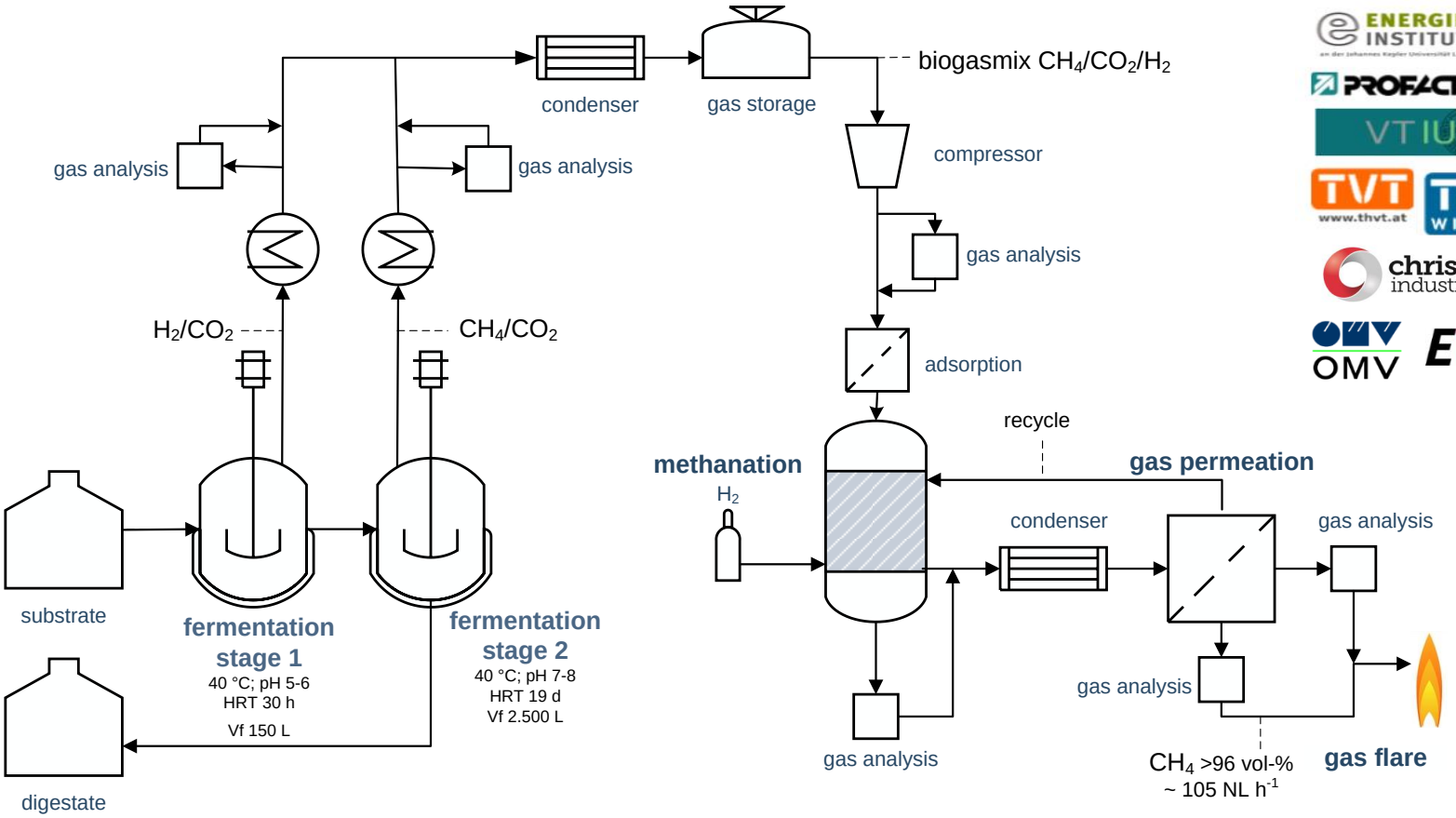
Project phase 1: Laboratory scale experiments

Setup for laboratory tests of fermentation stages:

- **2-stage CSTR** for flexible substrate input, automated feeding, pH, gas measurement with datalogger (quanti & quali)
- mesophilic conditions (38 ° C)
- hydraulic retention time 10-24 h
- organic load 19-50 g oDM / L / d
- pH 5.2 to 7.5
- **Stripping with N_2, CO_2 or CH_4 in the hydrogen stage**
- **Substrates: molasses, sulfite waste liquor, organic waste**

PROFACTOR®

Project phase 2: Overview of the realised pilot plant



Project partner

OptFuel – pilot plant at waste water treatment plant Asten

Biogas fermentation

ENERGIE
INSTITUT
an der Johannes Kepler Universität Linz

Methanation

Membrane gas separation and cleaning

Executed test campaigns in pilot plant Asten

- Production of biogas from household biowaste slurried in water (5.3 – 11.7 % DM, 66-82 % oDM) as "real world" substrate from biogas plant Leoben

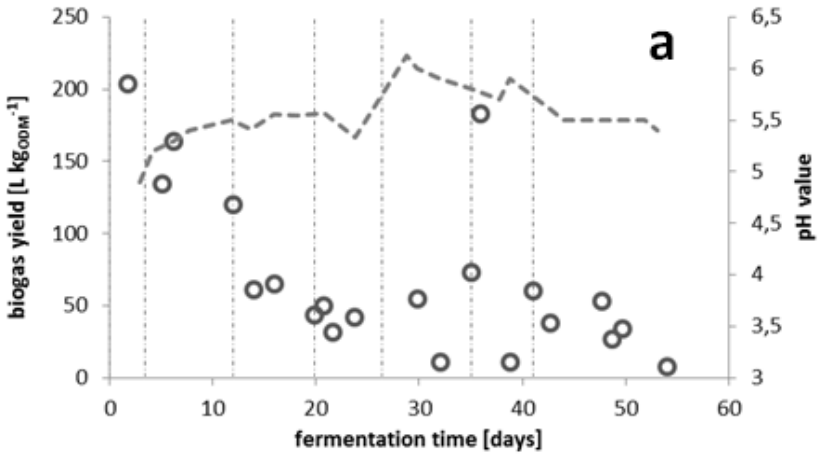
- Utilization of raw biogas (CH_4, CO_2 and H_2-mixtures) as input in methanation + membrane gas separation and cleaning at different operating conditions of methanation:

pressure	6 bar	8 bar	10 bar	12 bar	14 bar
space velocity*	2000	2000	2000	2000	2000
space velocity*	2500	2500	2500	2500	2500
space velocity*	3000	3000	3000	3000	3000
space velocity*	4000	4000	4000	4000	4000

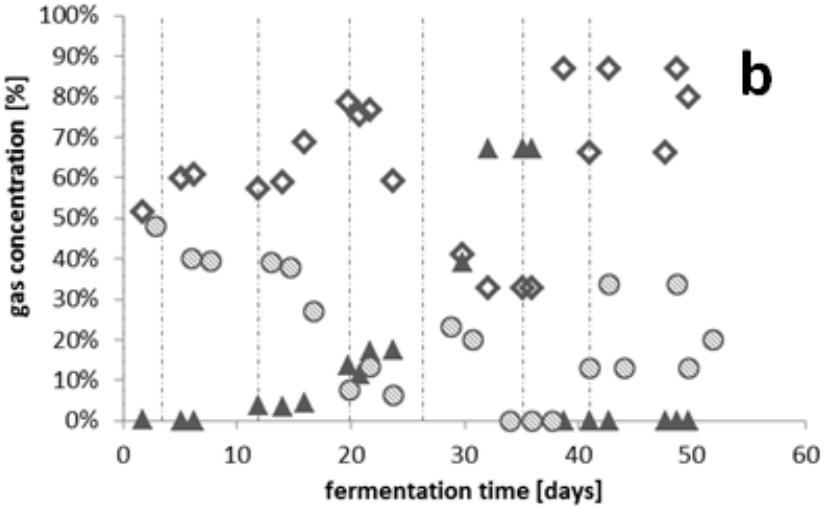
*Gas hourly space velocity (GHSV = Reactant Gas Flow Rate/Reactor Volume)

- Test with methane stripping (looping) as input for H_2-fermentation (1st stage)

Gas production in the H_2-Fermentation



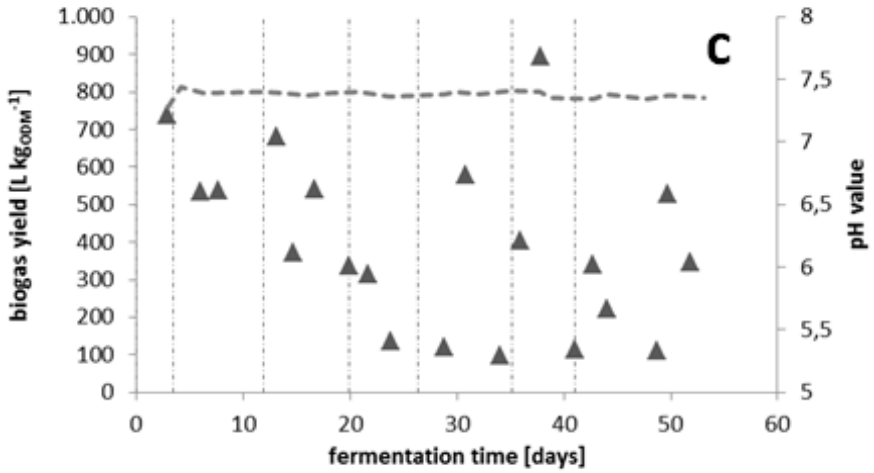
The short HRT and acidic pH in the H_2-fermentation stage inhibits methane production and leads to hydrogen and CO_2 fermentation



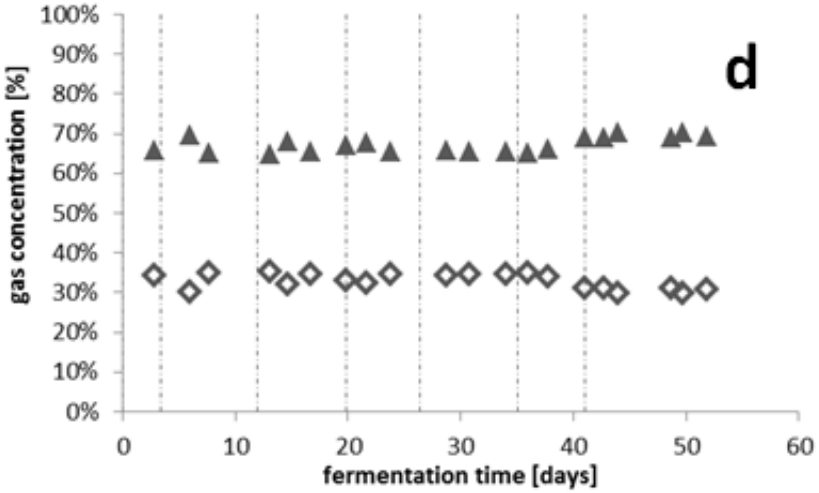
The hydrogen content ◎ of the first stage biogas varied between 0 and 48 %

The gas output in stage 1 (H_2 fermentation) was max. 30 % of overall gas production.

Gas production in the CH_4-Fermentation



The methane content in the CH_4-fermentation was relatively stable with high methane content ▲



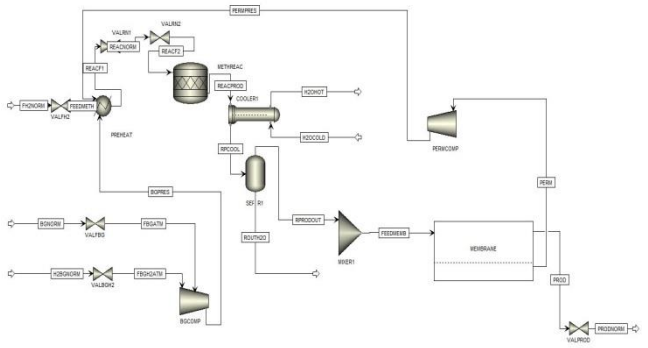
Results

- **Proof of concept by interconnection of all facility parts in pilot plant scale in continuous operation**
- **in 20 out of 30 test campaign conditions gas quality according to ÖVGW G31 was achieved - natural gas substitute**
- **The operation of the overall system was possible with fluctuating biogas composition**
- **Optimization of the system setup and identification of further synergies by simulation of the overall process was accomplished**
- **Difficult practicability in the continuous fermentation because of extremely high fluctuations in composition of the bio-waste**

Table: Comparision 1-stage vs. 2-stage biogas process
+ power-to-gas for 120 kg substrate (bio-waste slurry) per day

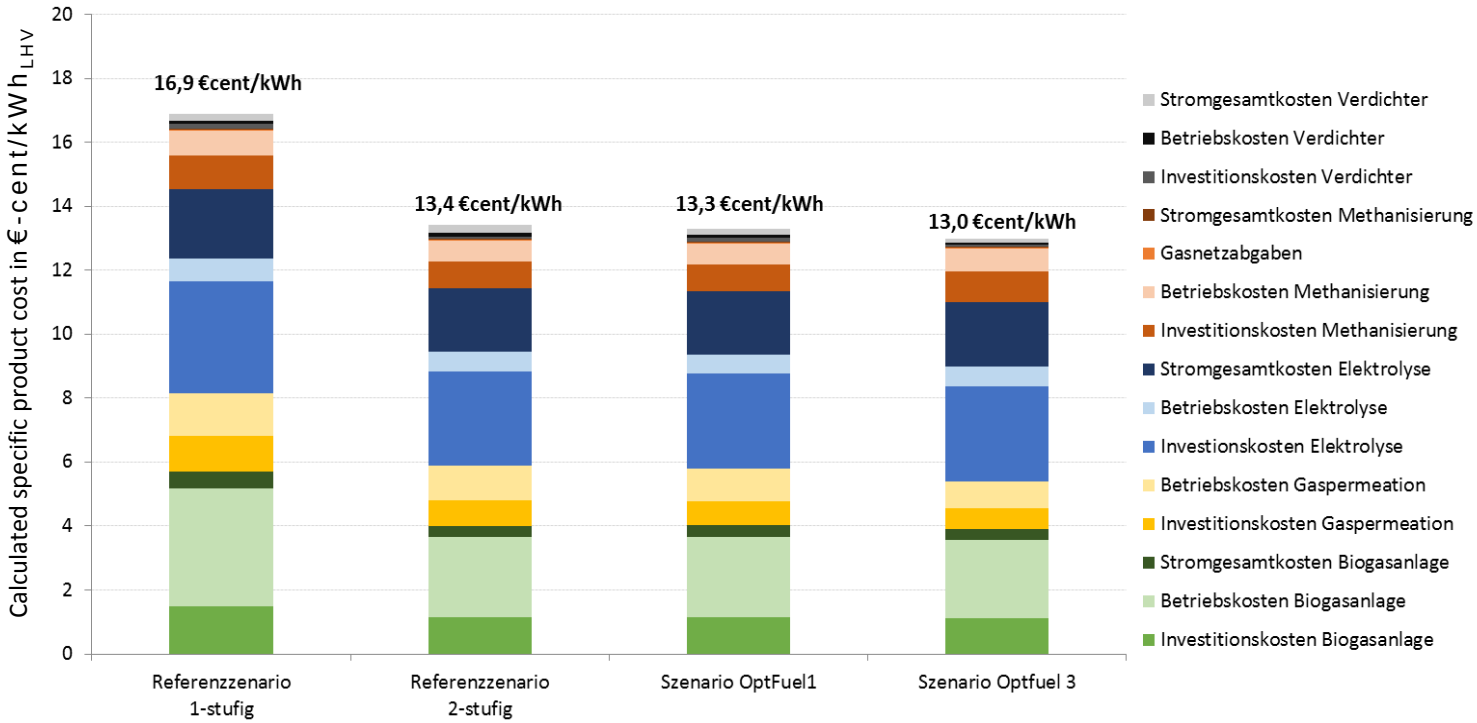
	1-stage	2-stage	
Methane total	114 L/h	215 L/h	+ 47 %
Methane from CO_2 *	69 L/h	88 L/h	+ 21 %
Methane biogas	71 L/h	125 L/h	+ 45 %
Additional hydrogen from electrolysis for methanation of CO_2 in the biogas mixture**	1,52 L/L CH_4	1,56 L/L CH_4	+ 3 %
Hydraulic retention time	25 days	30 h + 19 days	
Reactor volume	3.000 L	120 L + 1.800 L	
Process temperature	38°C	38°C	
pH-regulation	pH 7,2 regulation not necessary	pH 5,5 bzw. 7,2 regulation not necessary	

*….. efficiency methanation 85%
**…. stoichiometric ratio H_2:CO_2 = 4,1:1



Results of the economic assessment

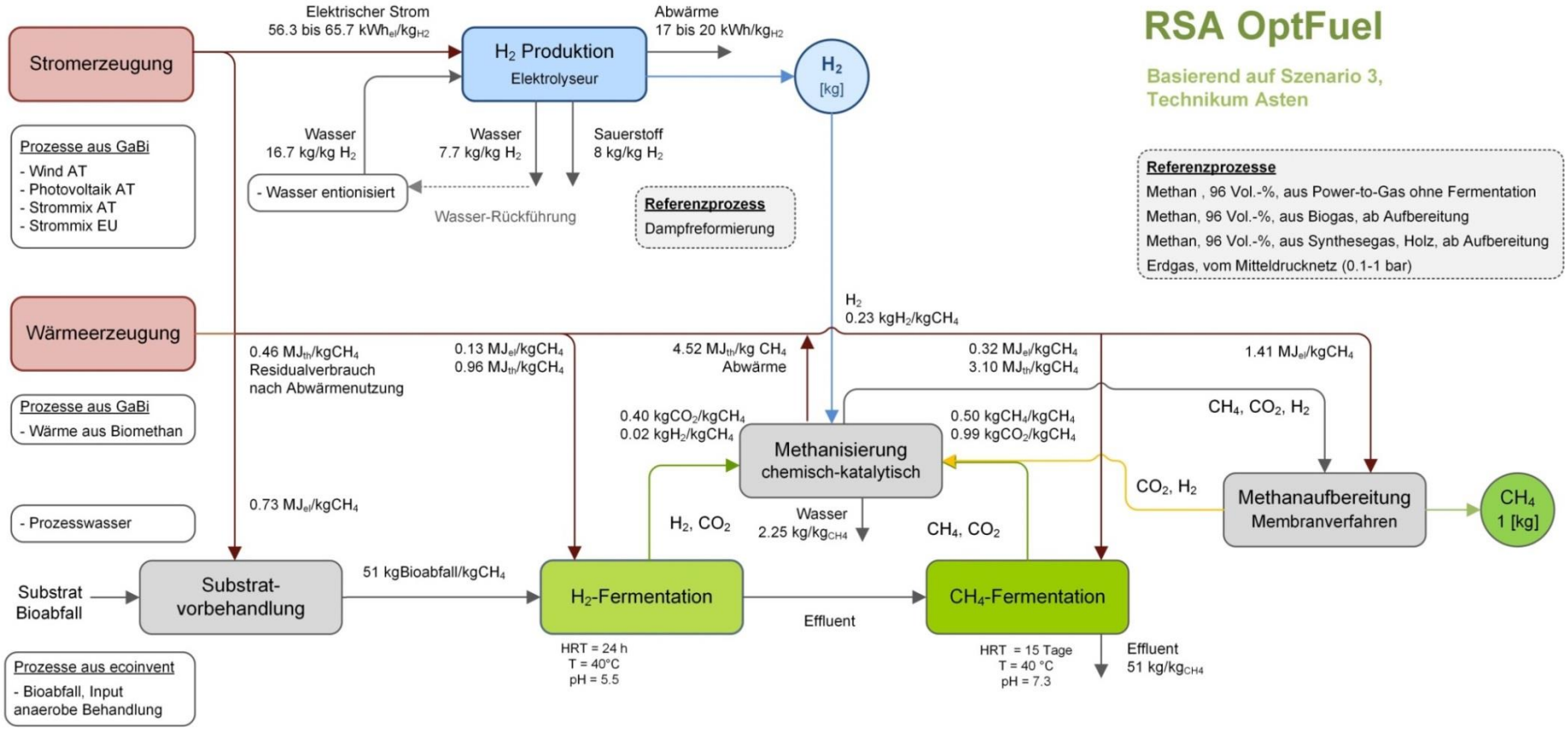
Figure: Cost distribution for the facility components fermentation, electrolysis and methanation,



Specific product cost are ~ 13 €-cent/kWh$_{LHV}$ CH_4-Output

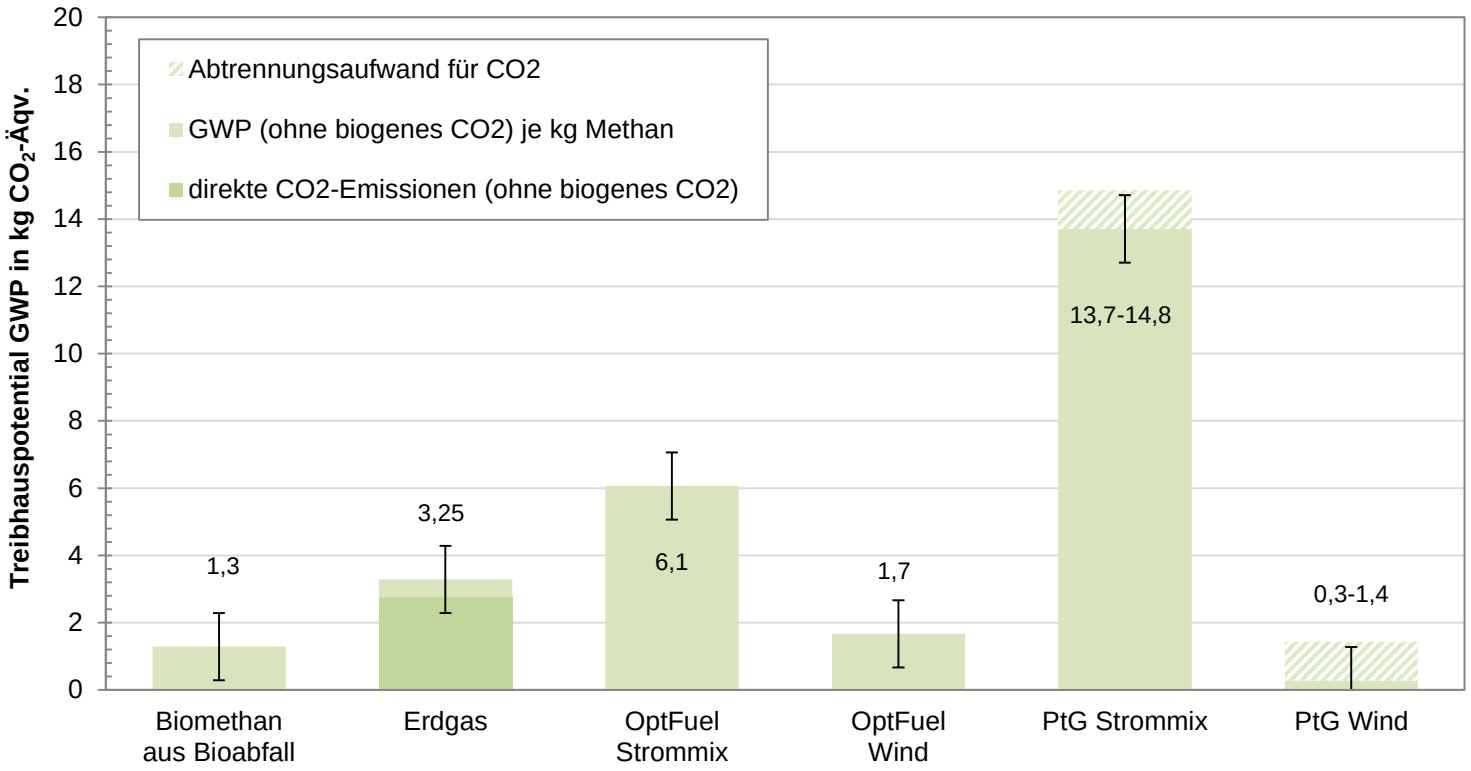
⇨ **energy cost for biogas products in the Austrian gas retail market are 4-6 €-cent/kWh$_{LHV}$**

Ecological analysis – Modelling in the LCA-software



Ecological analysis – Modelling in the LCA-software

Comparison of global warming potential GWP in kg CO_2-equivalent per kg methane



Methane from the OptFuel process concept / PtG with electricity purchased from renewable energy sources results in significant reduction potentials of greenhouse gas emissions compared to fossil benchmarks.

Final remarks – renewable energy from PtG as fuel

… the 10 % development goal may only be reached at a maximum of 7 % of the overall consumption by the use of biofuels …

⇨ H_2 or CH_4 from PtG can be taken into account for fulfilling the renewables target in the fuel sector

⇨ „advanced biofuels“

… Member States set their own goals for the energy content from advanced biofuels in the total final energy consumption for 2020 …

Guideline 2014/94/EU of the European Parliament and the Council from 22nd October 2014 about the set up of the infrastructure for alternative fuels:

… an appropriate number of refuelling points accessible to the public for the supply of CNG or compressed biomethane to motor vehicles (distance between gas stations max. 150 km) …

If you have any questions or suggestions regarding the project, please contact us!

http://www.energyefficiency.at/web/projekte/optfuel.html

a big thank you to the supporters:

christof industries

OMV EVN

This project is a Research Studios Austria promoted in the form of special invitation to tender under the Energy Research Initiative of the Austrian Federal Ministry of Economy, Family and Youth

bmwfi Bundesministerium für Wirtschaft, Familie und Jugend

FFG

Grant agreement no: 839175