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HYDROGEN SUPPORTED BIOCONVERSION OF BIOGAS CO_2 TO UPGRADE BIOMETHANE IN FUEL FOR VEHICLES: RECENT FINDINGS IN FARMERS SURVEY

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CONTENT OF THE PRESENTATION

- Main challenges for usage of renewable gaseous fuels in transport sector;
- Biogas upgrading – traditional methods;
- Biogas upgrading – biochemical methods;
- PtG projects worldwide
- Survey results and discussion of biogas producers in Latvia;
- Conclusions.

MAIN CHALLENGES FOR USAGE OF RENEWABLE GASEOUS FUELS IN TRANSPORT SECTOR

- Transport represents almost a quarter of Europe's greenhouse gas emissions and is the main cause of air pollution in cities.
- Greenhouse gas emissions from the EU’s transport increased in 2018 and 2019 and have not followed the EU’s general decreasing emissions trend.
- European Green Deal aims to reduce car fleet emissions by 37.5% by 2030 compared with 2021.
- The biomethane could be named as one of the most promising for short and mid-term transport decarbonisation solutions both in the EU and Latvia.

BIOGAS UPGRADING – TRADITIONAL METHODS 1

- Currently, biogas upgrading is starting with water scrubbing, chemical scrubbing, and physical scrubbing in first stage, after what the biogas is ready for combustion to produce electricity and heat in cogeneration.
- Water scrubbing represents the highest share in Europe, with about 40%. The scrubber utilises a mixture of caustic soda, polyvinyl alcohol and water as desulfurization solvent.
- An activated carbon filter allows removing the remaining traces of H_2S and volatile organic compounds.

BIOGAS UPGRADING - TRADITIONAL METHODS 2

In second stage biogas is upgraded to biomethane using pressure swing adsorption (PSA)-most popular. Zeolites adsorb strongly carbon dioxide and a weaker - methane, therefore can be applied as an effective CO_2 adsorbent in PSA applications.

Membrane separation using a carbon hollow fibre (CHF) membrane or a commercially available polymeric membrane (polyimide).

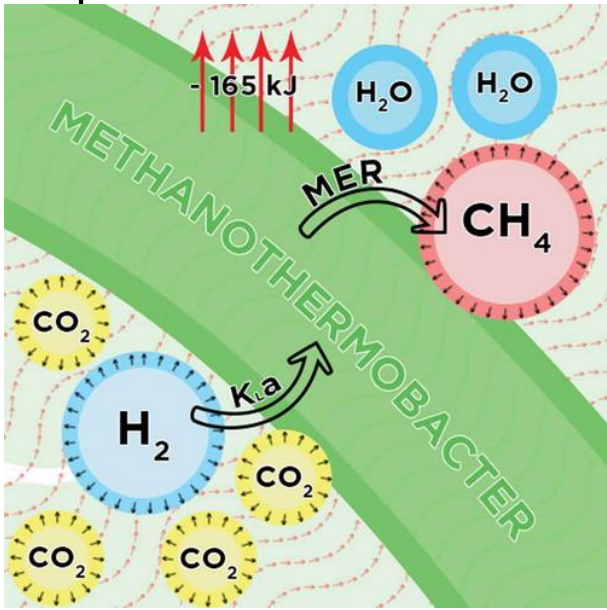
Another promising approach is currently seen in cryogenic upgrading technologies, in which simultaneously can be obtained high-purity biomethane and food-grade CO_2.

BIOGAS UPGRADING - BIOCHEMICAL METHODS

Biochemical biogas upgrading encompass biological hydrogen methanation (BHM) approaches where external H_2 is coupled with CO_2 from the biogas production process to form CH_4.

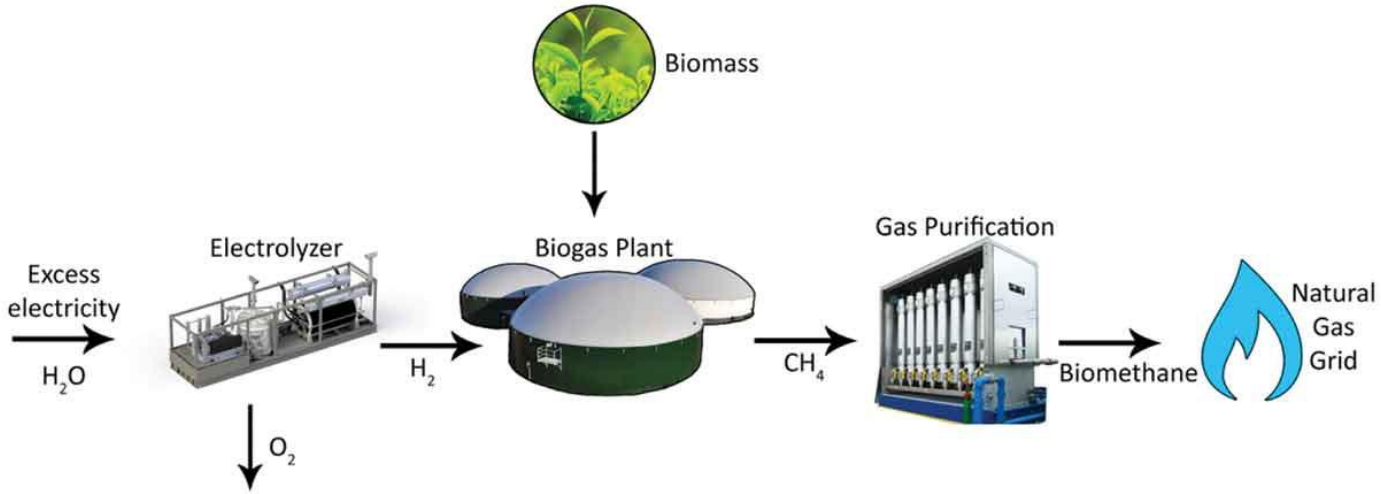
$$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O, \quad \Delta G_0 = -165 \text{ kJ/mol}$$

According to the Sabatier reaction *hydrogenotrophic methanogenic archaea* are able to consume an equimolar amount of four times hydrogen (H_2) to carbon dioxide (CO_2) and generate biomethane of natural gas quality.



BIOGAS UPGRADING - BIOCHEMICAL METHODS

The circular economy combination of hydrogen produced via electrolysis of curtailed/constrained electricity, biogas production from the digestion of organic waste upgraded to gas grid specification through the reaction of biogas and the aforementioned hydrogen provides a decentralized form of energy storage .



BIOGAS UPGRADING - BIOCHEMICAL METHODS

The BHM process is capable of being carried out both within an anaerobic digester system known as in-situ, or in a separate, adjacent reactor known as ex-situ.

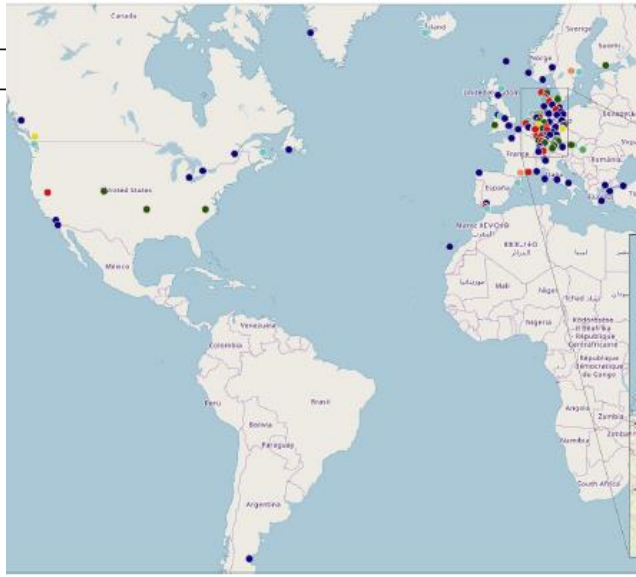
In-situ bio-methanation takes place within the anaerobic digester. H_2 gas is introduced typically through mixing or diffusion, to maximize the contact area with hydrogenotrophic methanogenic archaea, which produce CH_4 from CO_2 and H_2.

Ex-situ methanation takes place in a separate external reactor, typically tailored to suit the hydrogenotrophic methanogens and can be used also in case of biomass gasification. Specific nutrient media are supplied to the microbial consortium, under a controlled environment. Gaseous reagent supply is also maintained to ensure optimal growth conditions and product concentrations.

PTG PROJECTS WORLDWIDE

The BHM process is tightly related with PTG projects. 153 projects in 22 countries (1993-2019) are analyzed in review by M. Thema, F. Bauer, M. Sterner, Renewable and Sustainable Energy Reviews 112 (2019) 775–787

Project name	Location		Product	Grid inject.	Proj. start	Power	Metha-nation	Literature, Reference
	Country	*City*	H_2/CH_4	*yes/no*	*Year*	*in MW_{el}*	*biol./chem*	
Hychico Hydrogen Plant	AR	Comodoro Rivadavia	H_2	no	2008	0.700	–	[24,25]
w2h	AT	Auersthal	H_2	yes	2014	0.100	–	[26]
Underground Sun Storage	AT	Pilsbach	H_2	yes	2015	0.600	–	[27,28]
Biological biogas upgrading in a trickle-bed reactor	AT	Tulln/Donau	CH_4	no	2016	n.r.	biol.	[29,30]
HARP System Bella Coola	CA	Bella Coola	H_2	no	2010	0.320	–	[31–34]
Power-to-Gas (for energy storage purposes)	CA	Ontario	H_2	yes	2014	0.005	–	[35–37]
Laboratory Plant HRI	CA	Quebec	H_2	no	2001	0.005	–	[34]
Ramea Wind-Hydrogen-Diesel (WHD) Project	CA	Ramea	H_2	no	2012	0.162	–	[34,38–40]
Wind-Hydrogen Village PEI	CA	Tignish	H_2	no	2009	0.300	–	[34,41]
IRENE System	CA	Victoria	H_2	no	2007	0.006	–	[34,42]
CHIC	CH	Brugg/Aargau	H_2	no	2011	0.300	–	[13,43]
Erstes Energieautarkes Haus der Welt	CH	Brütten	H_2	no	2016	0.015	–	[44]
n.r. (MicrobEnergy GmbH)	CH	Dietikon	CH_4	yes	2019	n.r.	biol.	[45]
SolarFuel-Alpha 5th site	CH	Rapperswil	CH_4	no	2015	0.025	chem.	[46]
Store&Go-Project, Hybridwerk Aarmatt	CH	Solothurn/Zuchwil	CH_4	yes	2018	0.350	biol.	[47,48]
RENERG2	CH	Villigen	CH_4	n.r.	2015	0.100	chem.	[15]
COSYMA	CH	Zürich/Werdhölzli	CH_4	yes	2017	n.r.	chem.	[49,50]
Hydrogen Island Aitutaki	CK	Aitutaki	H_2	no	n.r.	0.055	–	[34]
BioPower2Gas	DE	Allendorf (Eder)	CH_4	yes	2015	0.300	biol.	[45,51]
BioPower2Gas-Erweiterung	DE	Allendorf (Eder)	CH_4	yes	2016	n.r.	biol.	[45,51]
Smart Grid Solar	DE	Arzberg	H_2	no	2016	0.075	–	[52]
Ecytron Zero-Emission-Wohnpark	DE	Alzey	CH_4	no	2016	0.063	chem.	[52]
Methanisierung am Eichhof, SolarFuel-Alpha 4th site	DE	Bad Hersfeld	CH_4	no	2012	0.025	chem.	[46,52–54]
Direktmethanisierung von Biogas	DE	Bad Hersfeld	CH_4	yes	2017	0.050	chem.	[55]



PTG PROJECTS WORLDWIDE

- Capital expenditures for various electrolysis technologies as well as for methanation technologies are estimated to fall to about 500 €/kWel in the long term.
- At present, the global focus of research and application of PtG technology lies in Europe, but the United States of America seem to catch up.
- Worldwide, projects with methanation appear to have about the same significance as projects without methanation. The same is true for the distinction between membrane and alkaline electrolysis or chemical and biological methanation.
- About half of the projects feed their product gases into the natural gas infrastructure.
- Other fields of utilization are alternative fuel production, then pure research applications and industrial processes or substantial use.
- Concerning efficiency, methanation projects show higher potential for improvement than pure hydrogen producing projects.

SURVEY RESULTS AND DISCUSSION OF BIOGAS PRODUCERS IN LATVIA 1

- Currently in Latvia there are around 48 biogas plants in operation, and biomethane is mostly used for the production of electricity. According to present estimates, transformation of biogas into biomethane for use in transport would be regarded as a more cost-effective option in terms of economy than the combustion of biogas locally.
- Survey was conducted during period January –March, 2021. From all biogas producers in Latvia for 35 the production permissions were found in database of State Environmental Monitoring Bureau, and they were approached, for several producers there were three invitations (after one week and then once more after two weeks) to answer the questions. During the survey it was received 10 responses on the survey questions.

SURVEY RESULTS AND DISCUSSION OF BIOGAS PRODUCERS IN LATVIA 2

- 1. **“For what practical reason was created your biogas production?”**: most of respondents have created their production of biogas for electricity and heat cogeneration; for own consumption and sale, several producers have created for electricity generation.
- 2. **“Do you think about change of aims of biofuel production in today’s situation (reduction of OIK, etc)?”**: most of respondents are planning to contribute with their produced biogas for care refuelling and for electricity and heat cogeneration, but only few are planning production of biogas for input into natural gas network and also only few producers plan to change their aims on production of biogas and planning for production of bio-hydrogen.

SURVEY RESULTS AND DISCUSSION OF BIOGAS PRODUCERS IN LATVIA 3

- 3. **“Do you plan investment into modernisation of technologies in production?”**: most of respondents are planning to invest in technologies to produce compressed bio-methane for car refuelling and some producers of biogas producers are planning to invest in technologies for biological upgrading of bio-methane, but very little interest is to invest in technologies for cogeneration in molten salt or solid oxide fuel cells (MCFC and SOFC respectively).
- 4. **“Are you interested in modernizing technology?”**: most of respondents are planning to think about technology upgrades, many of them follow the research results in scientific journals abroad, several respondents follow the research results in Latvian science, but not so many biogas producers collaborate with scientists.

SURVEY RESULTS AND DISCUSSION OF BIOGAS PRODUCERS IN LATVIA 4

Survey data indicate that producers think about technology upgrades not depending from years operating in the production of bio-gas. Results of correlation analysis between evaluations on initial plans when the company was created and changes in plans for car refuelling is very common with Sweden and Italy, where the main end-use application is transport.

https://www.la.lv/limbazos-auto-darbina-ar-kutsmeslu-gazi
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CONCLUSIONS

- Most of Latvian biogas producers have created (six to thirteen years ago) their production of biogas for electricity and heat cogeneration; nobody have created their production of biogas for car refueling.
- Recently (in 2021) the aims of producers are changed and the most possible way is production of biogas for car refueling, which is very common with Sweden and Italy.
- Half of the respondents will choose more membrane filters as pressure swing adsorption for biomethane enrichment; a quarter allows the choice of hydrogen biological methanization, but a quarter still nothing.
- Most of biogas producers think about technology upgrades, they follow on achievements in scientific findings, but not so many producers of biogas co-operate with scientists.

THANKS FOR ATTENTION !

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