Integration of biogas systems into the energy system

Power to X: the role of electricity in fuel production

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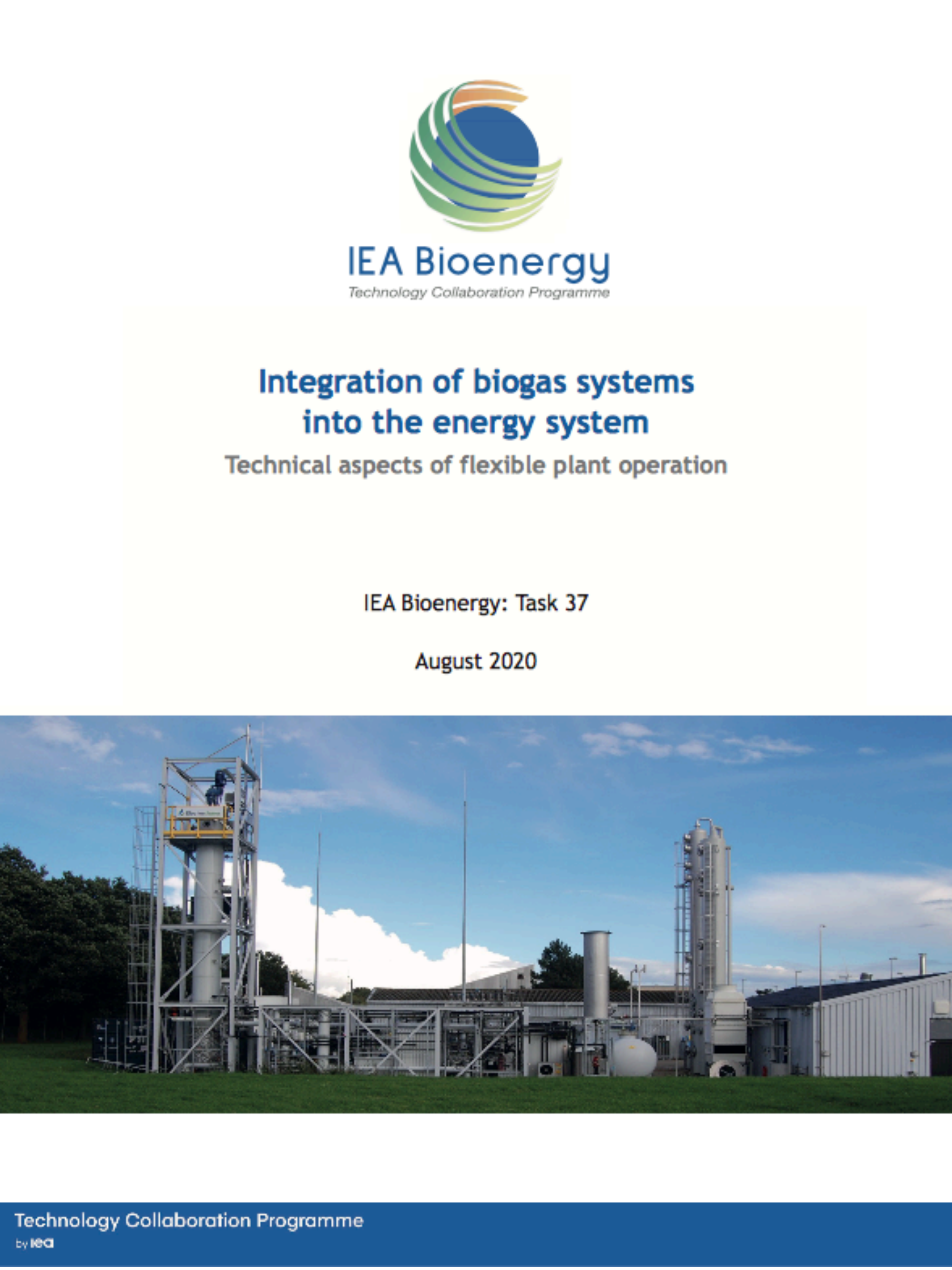
IEA Bioenergy Webinar January 21 2021



IEA Bioenergy
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Integration of biogas systems into the energy system

Technical aspects of flexible plant operation

IEA Bioenergy: Task 37

August 2020

Technology Collaboration Programme
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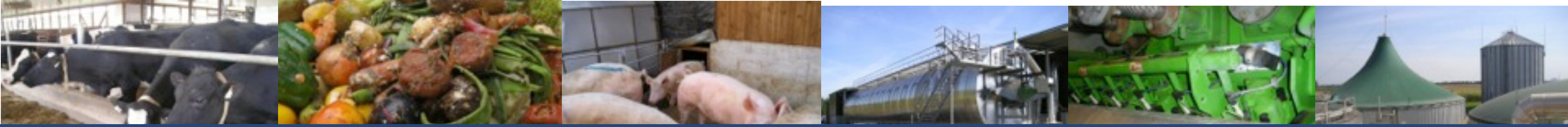
Available at: http://task37.ieabioenergy.com/technical-brochures.html



Managing large levels of intermittent renewable electricity

- Ireland in 2017 had 25% RES-E; in 2030 expected to have 70% RES-E including for extensive plans for off shore wind.
- As an island grid have achieved c. 70% system non synchronous penetration (SNSP).
- Assuming 35% capacity factor then peak production **could at times** be 200% of average demand. Exacerbated by peak production at periods of low demand.
- Power to X can be a biological battery, can lead to integration of electricity and gas infrastructure and a means of changing the energy vector from electricity to gas or liquid for use in sectors that are hard to electrify such as trucks, ferries and planes

Is there such a thing as free decarbonized electricity to make free decarbonized hydrogen? Impact of run hours and price on sustainability

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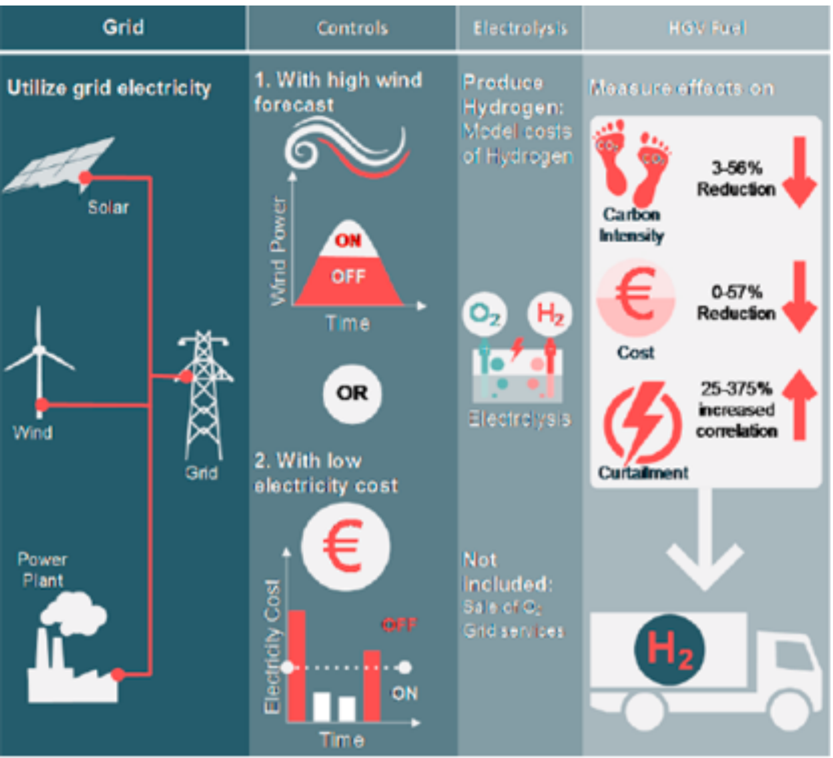
Are electrofuels a sustainable transport fuel? Analysis of the effect of controls on carbon, curtailment, and cost of hydrogen

Shane McDonagh[a,b,c,*], Paul Deane[a,b], Karthik Rajendran[a,d], Jerry D. Murphy[a,b]

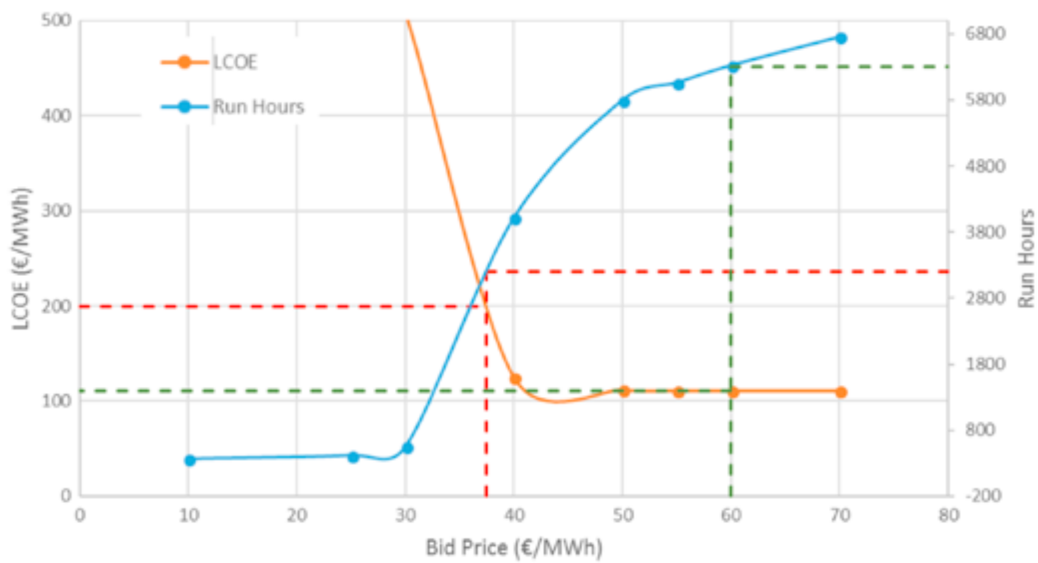
Table 3: Selected technical characteristics for different electrolysers in a Power to Gas system in 2020 (adapted from Buttler & Spliethoff, 2018, Schmidt et al., 2017, and McDonagh et al., 2018)

Electolyser type	AEC	PEM	SOEC
Operating cell temperature (°C)	60-90	50-80	700-900
Operating pressures (bar)	10-30	20-50	1-15
Hydrogen production rate (m^3 H_2/hour)	<1400	<400	<10
System energy consumption (kWh/m^3 $H_{2(HHV)}$)	4.3-5.4	4.3-5.3	3.9-4.4
Hydrogen purity (%)	>99.5	99.99	99.9
Cold start time (min)	60-120	5-10	hours
Maturity of technology	Mature	Commercial	Demonstration
Process efficiency ($\%_{(HHV)}$)	65-82	67-82	80-90

Electrolysis: $2H_2O = 2H_2 + O_2$



€100/MWh = €4/kg$_{H2}$ ≈ €1.00/L$_{diesel}$



Integration of electricity with biogas systems: In-situ or ex-situ biomethanation

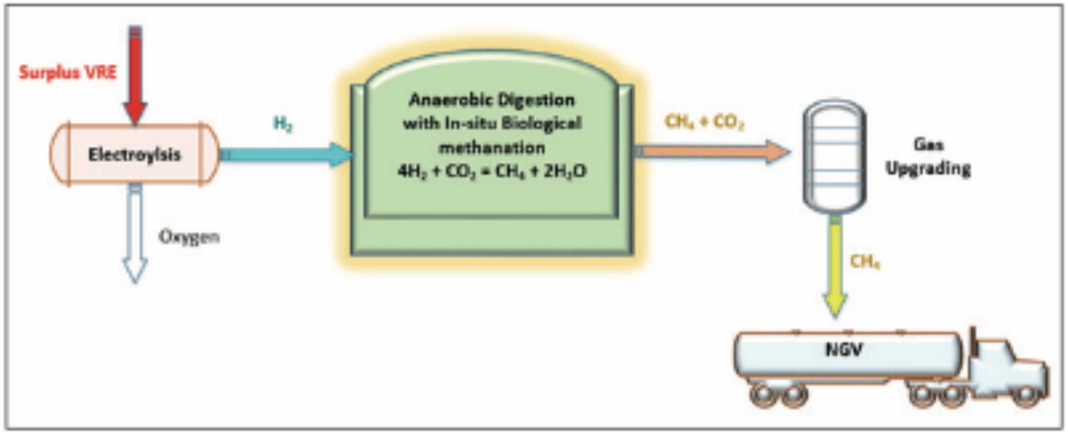


Figure 15: In-situ biological methanation system

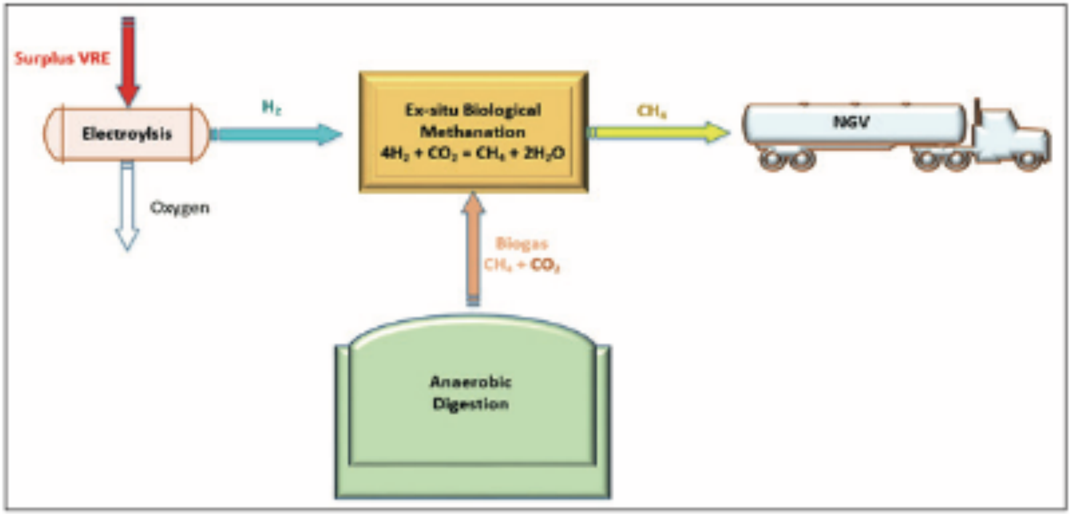
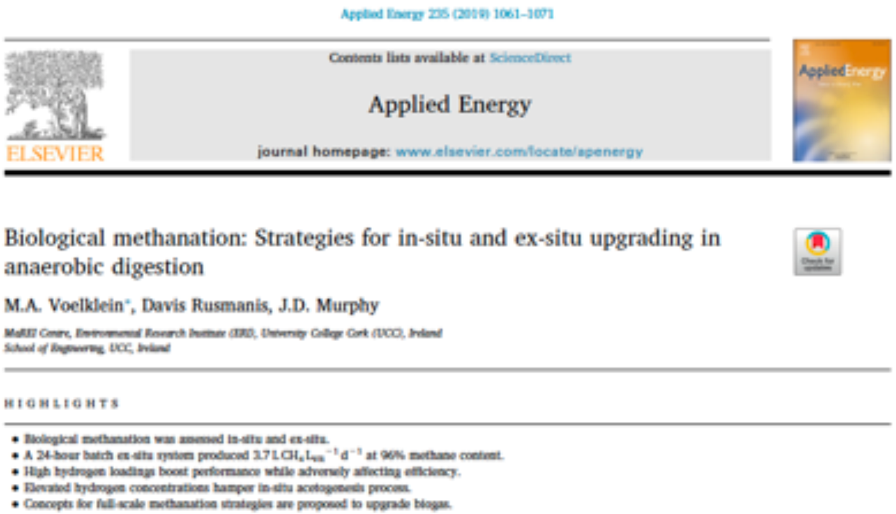


Figure 16: Ex-situ biological methanation system

Biomethanation

$4H_2 + CO_2 = CH_4 + 2H_2O$

Laboratory assessment of biological methanation configurations: in-situ vs ex-situ, batch vs cts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Biological methanation: Strategies for in-situ and ex-situ upgrading in anaerobic digestion

M.A. Voelklein*, Davis Rusmanis, J.D. Murphy

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School of Engineering, UCC, Ireland

HIGHLIGHTS

- Biological methanation was assessed in-situ and ex-situ.
- A 24-hour batch ex-situ system produced 3.7 L CH_4 L_{VR}^{-1} d^{-1} at 96% methane content.
- High hydrogen loadings boost performance while adversely affecting efficiency.
- Elevated hydrogen concentrations hamper in-situ acetogenesis process.
- Concepts for full-scale methanation strategies are proposed to upgrade biogas.

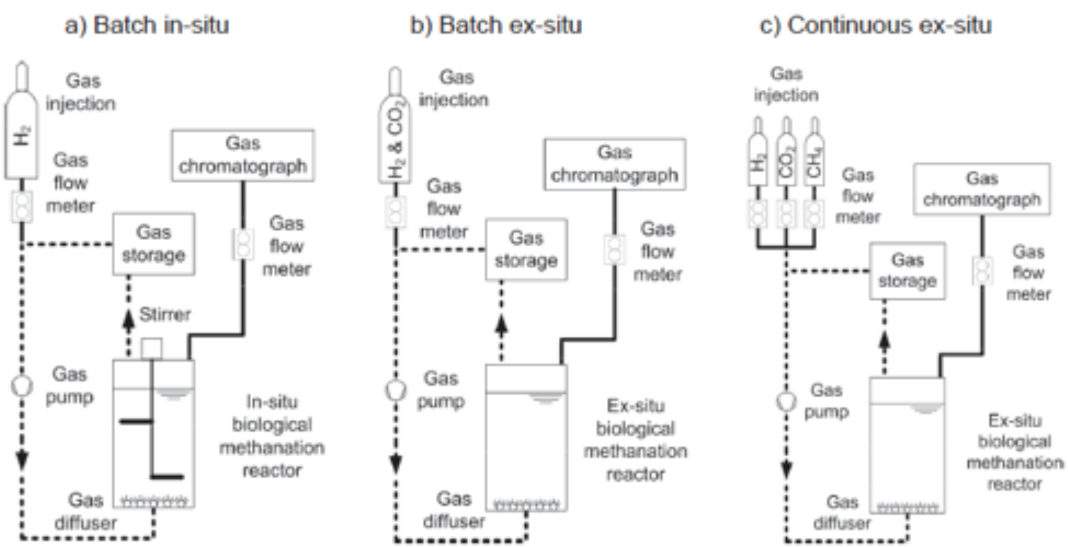

Fig. 2. Schematic of experiment lay out: (a) Batch in-situ (BIS 1–BIS 6), (b) Batch ex-situ (BES 1–BES 2), (c) Continuous ex-situ (CES 1–CES 6).

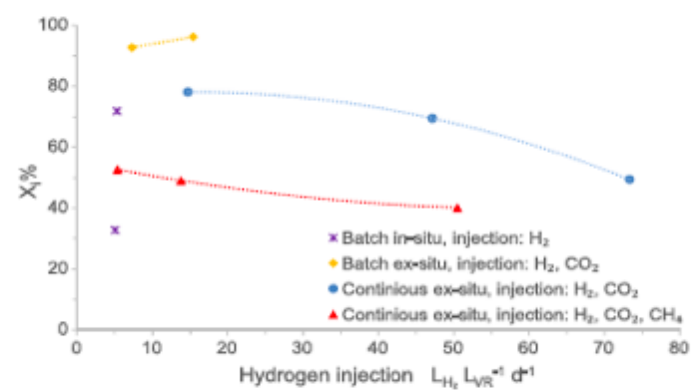

Fig. 5b. Gas conversion of in- and ex-situ upgrading strategies displaying efficiencies (X_i: gas conversion).

Strategies for upgrading

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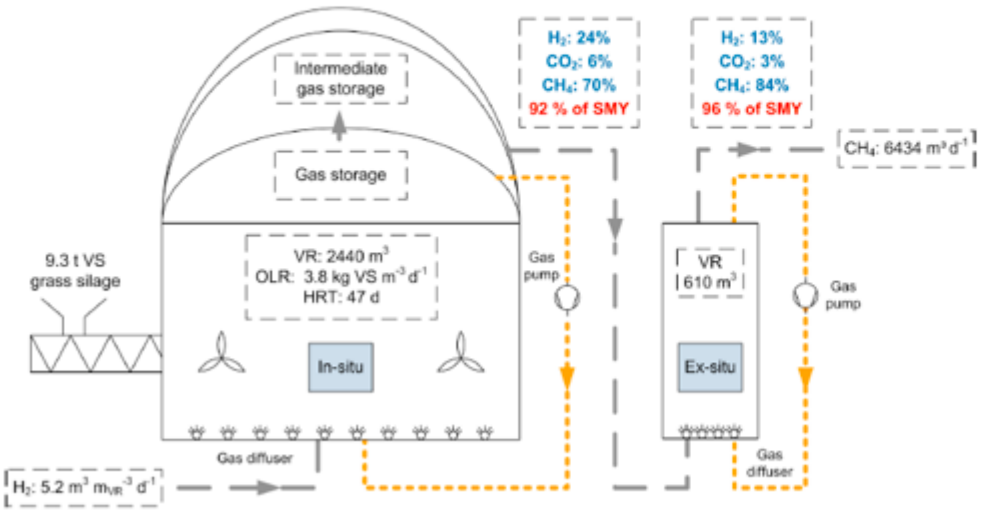
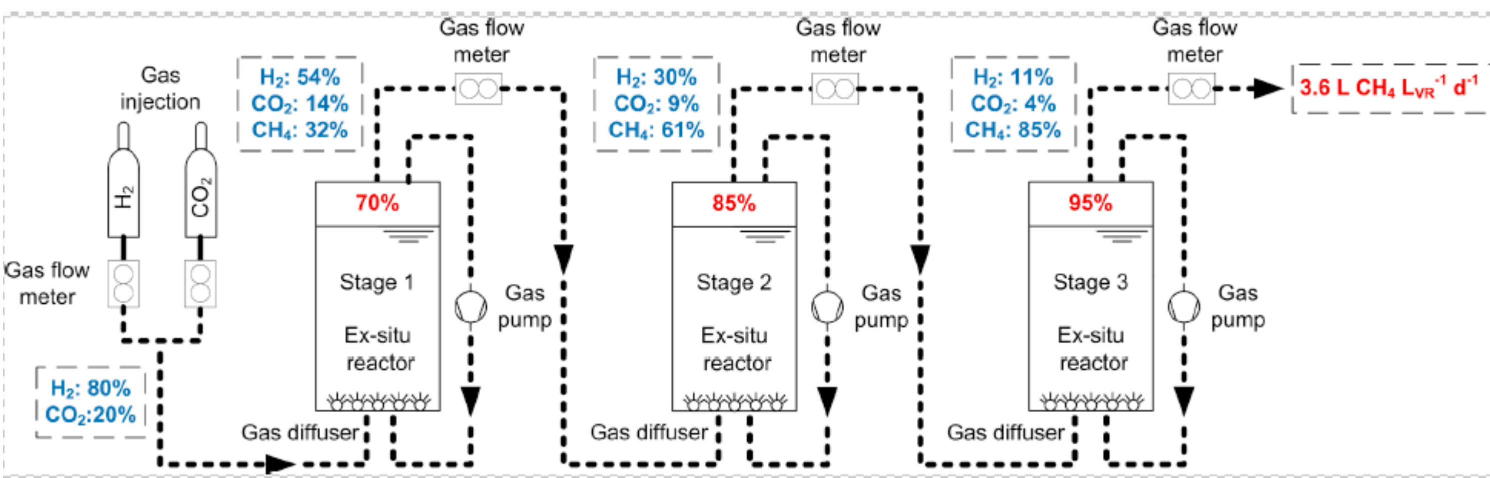
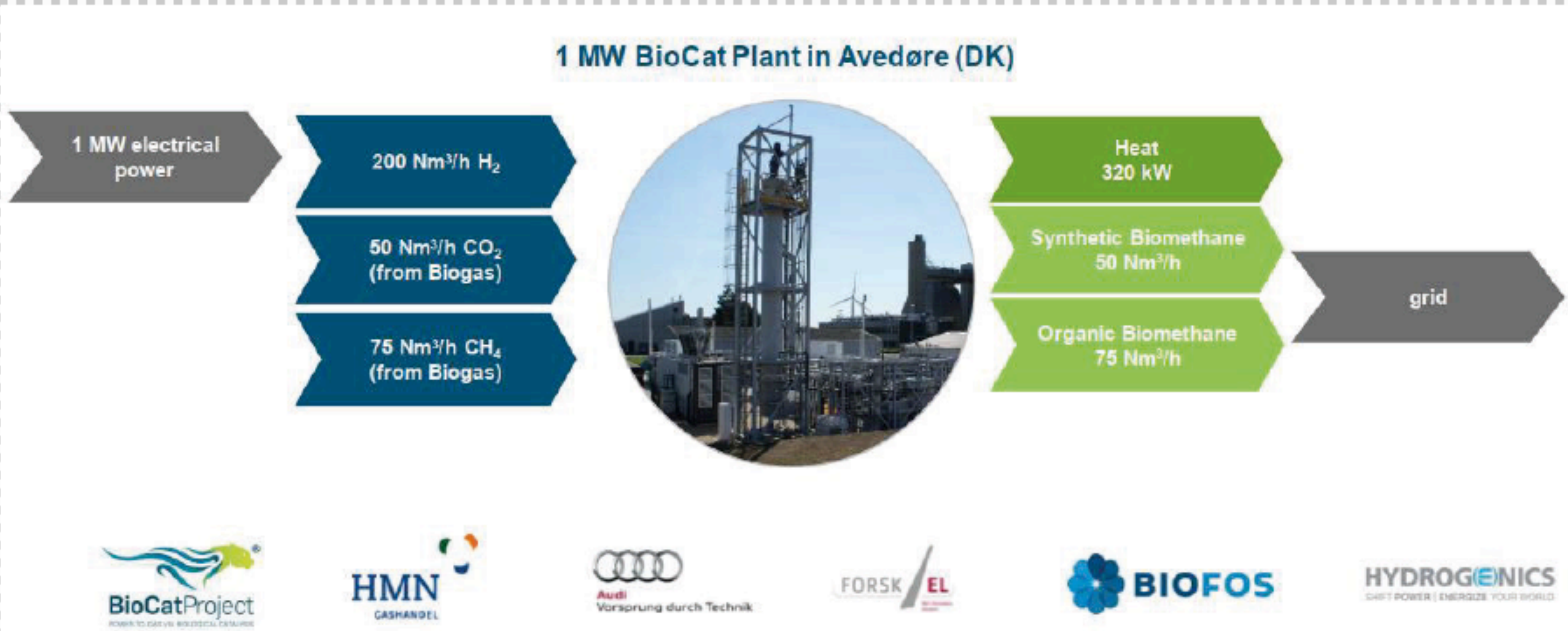


Fig. 7. Hybrid concept of sequential in-situ and ex-situ methanation with triple gas storage membrane on top of in-situ digester (SMY: specific methane yield, VR: reactor volume, OLR: organic loading rate, HRT: hydraulic retention time, VS: volatile solids).



Electrochea biomethanation system upgrading biogas to biomethane

Sabatier Equation: $4H_2 + CO_2 = CH_4 + 2H_2O$



67% increase in methane output

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Can power to methane systems be sustainable and can they improve the carbon intensity of renewable methane when used to upgrade biogas produced from grass and slurry?

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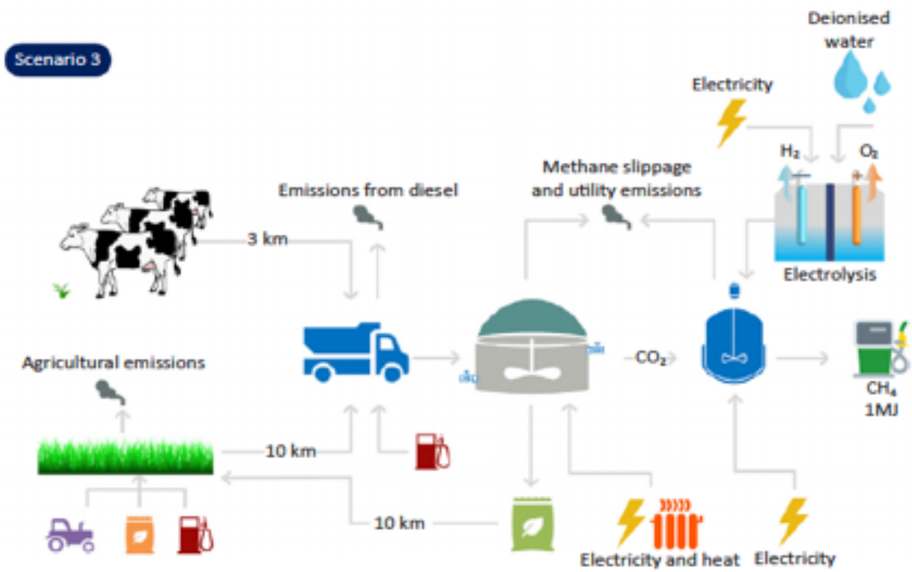
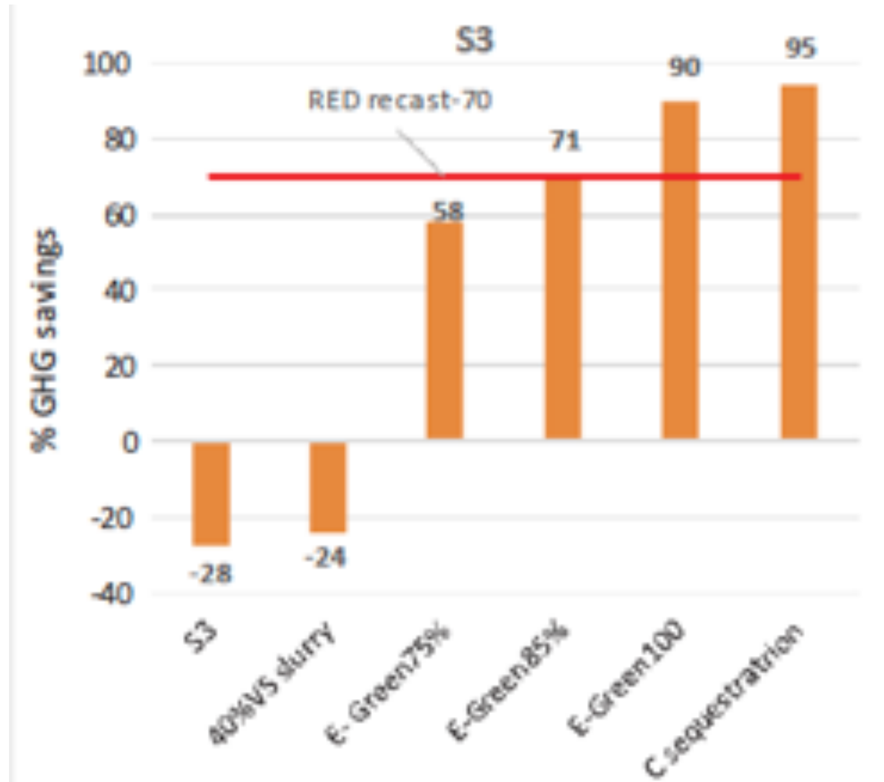
School of Engineering, University College Cork, Cork, Ireland

HIGHLIGHTS

- Increasing the slurry to grass ratio improves sustainability of biogas.
- Power to gas (P2G) can be used to upgrade biogas to biomethane.
- The carbon intensity of hydrogen is higher than the electricity it is produced from.
- P2G systems using the Irish electricity mix reduce sustainability of biomethane.
- Renewable electricity levels of 85% allow biomethane be sustainable.

Can power to methane meet sustainable criteria?



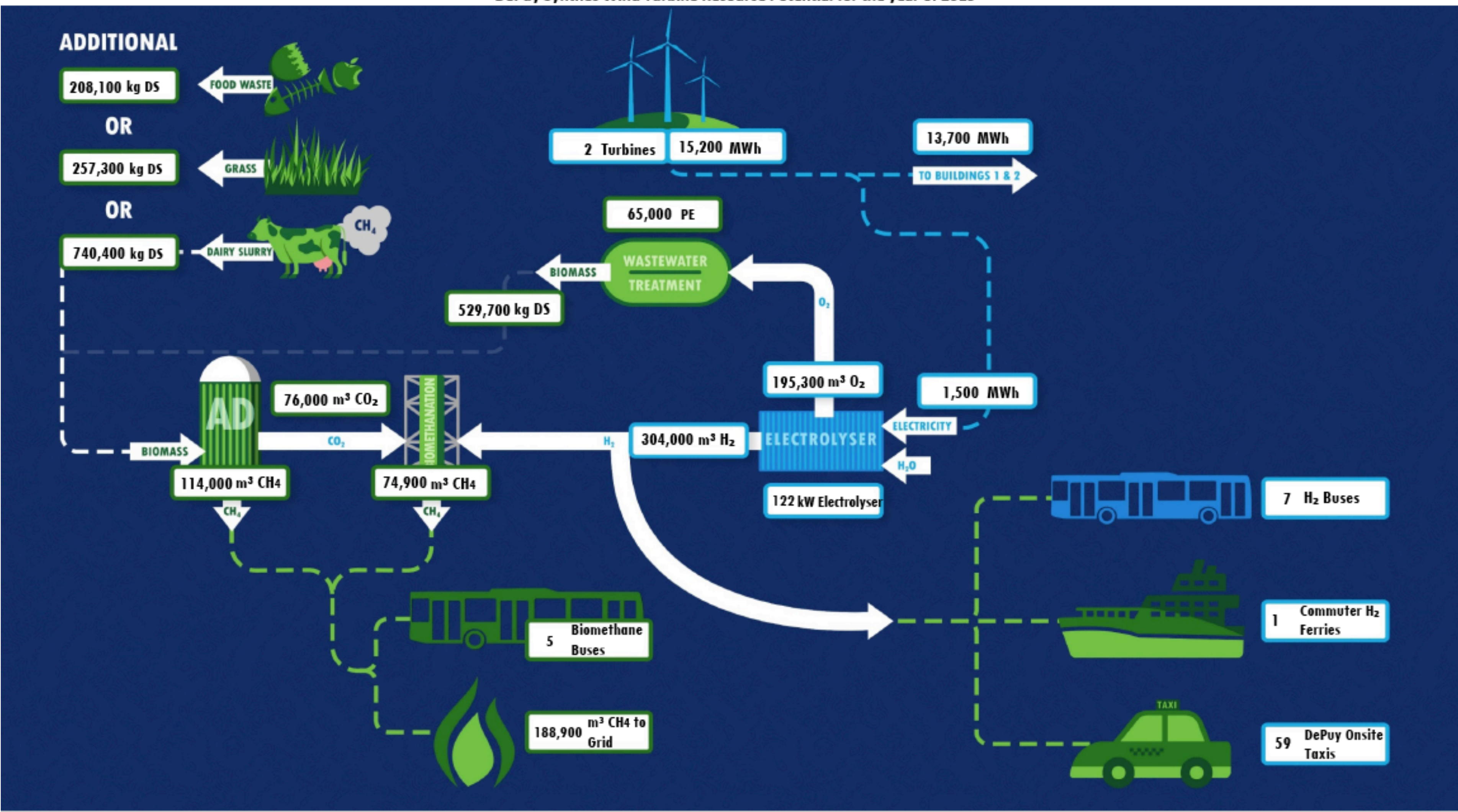


Base case: 80:20 Grass: Slurry on a VS basis; 2% fugitive CH4 losses; 41% green electricity; Sequestration of 2.2tCO2/ha/a

Is there such a thing as free decarbonized electricity to make free decarbonized hydrogen?

Applications of power to methane in circular economy system valorizing co-products

DePuy Synthes Wind Turbine Resource Potential for the year of 2019



Renewable and Sustainable Energy Reviews xxx (xxxx) xxx-xxx

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Renewable and Sustainable Energy Reviews

journal homepage: http://ees.elsevier.com

Integrating biological, thermo-chemical and power to gas systems in a circular cascading bioenergy system

Production of advanced fuels through integration of biological, thermo-chemical and power to gas technologies in a circular cascading bio-based system

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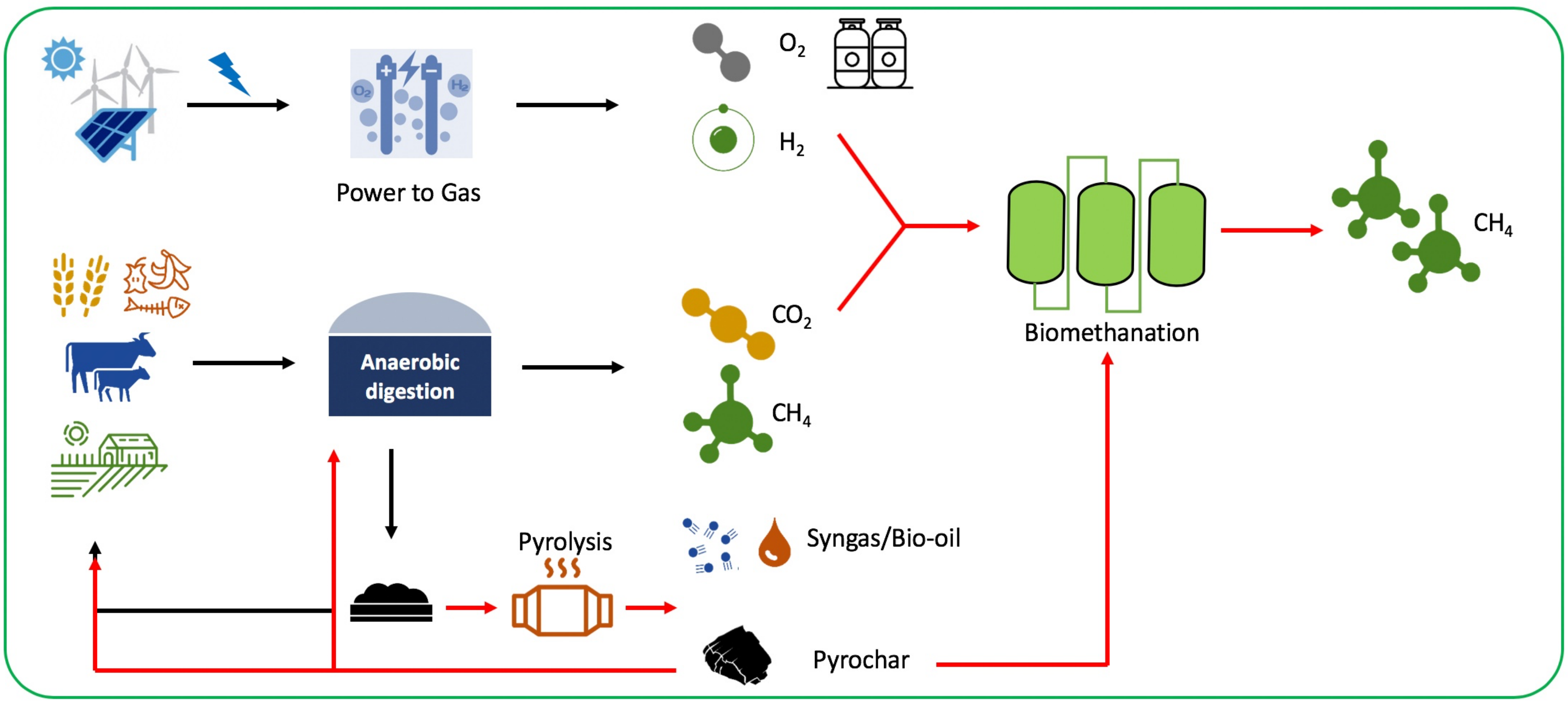
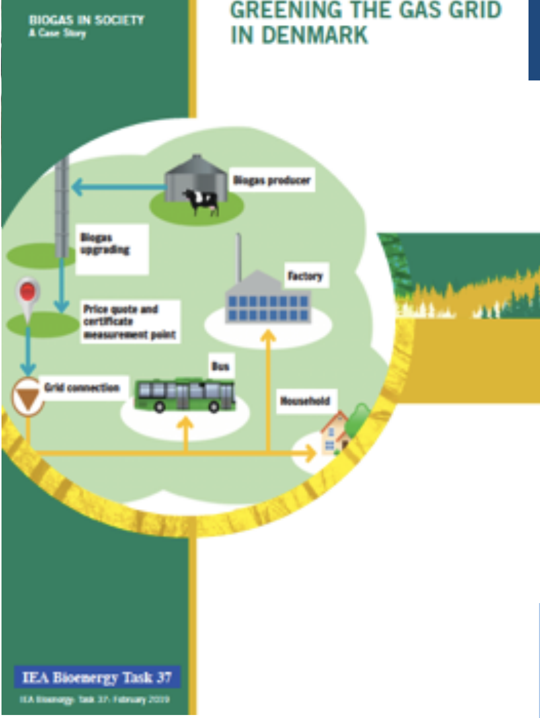
[c] Department of Environmental Science, SRM University-AP, Amaravati, Andhra Pradesh, 522503, India





Extent of Green Gas in Denmark

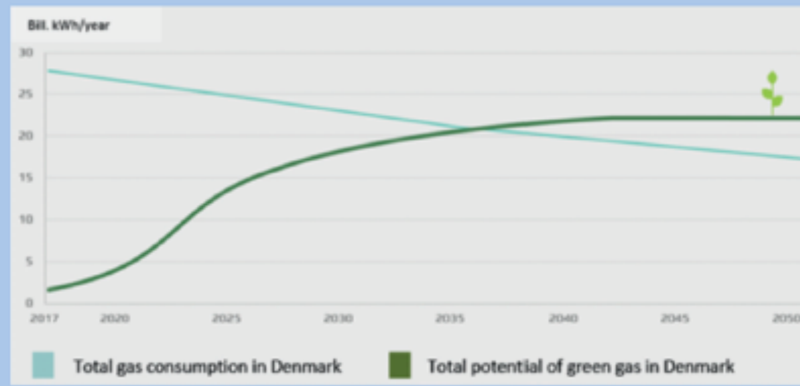


Figure 1: Gas consumption and potential of green gas in Denmark (from Green Gas Denmark)

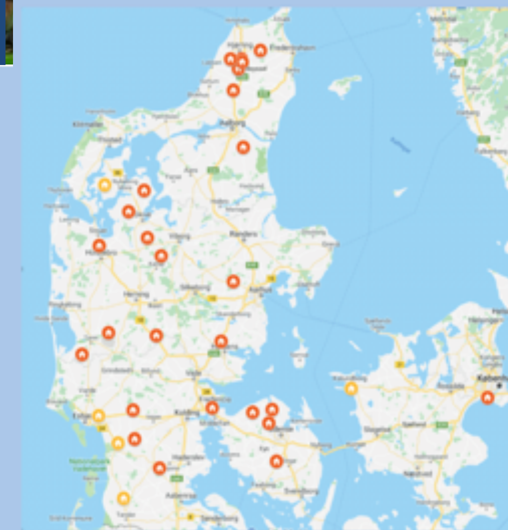
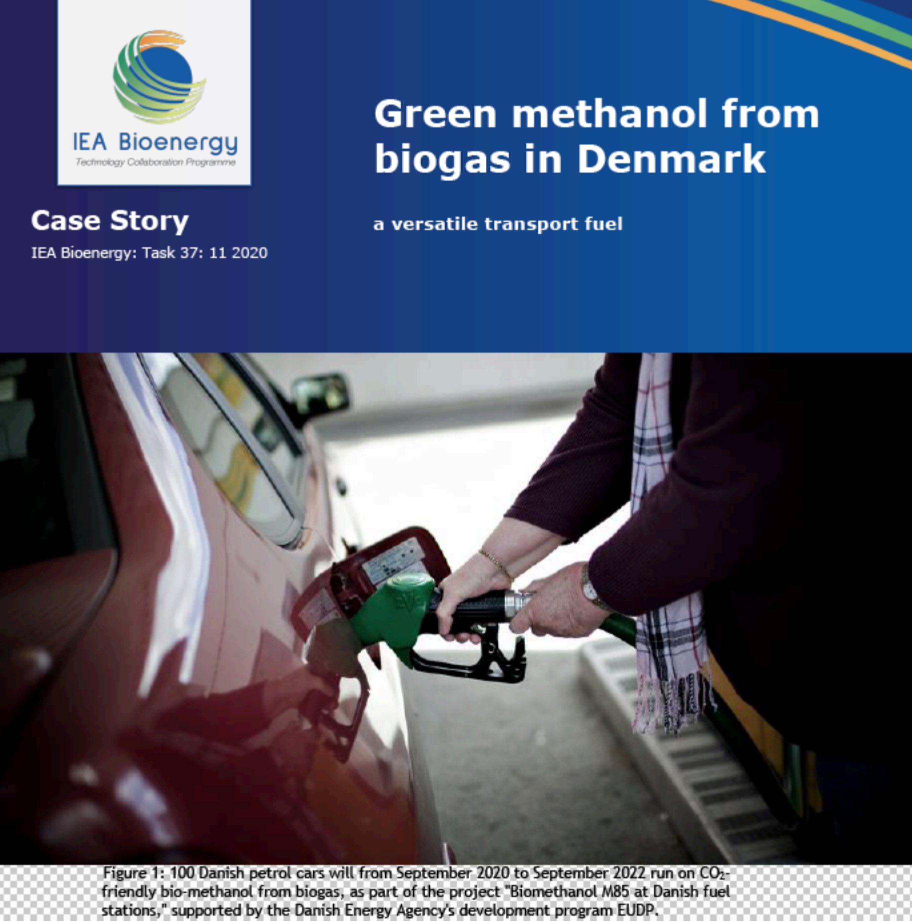


Figure 2: Grid connections for green gas in Denmark (yellow marks indicate connections established in 2017)

Figure 3: Holsted Biogas Plant, producing 20.7 million m³ gas / year. Source: Nature Energy

Denmark which at present intends decarbonising the gas grid with 72PJ of renewable gas by 2035. Addition of Power to Gas systems could see a resource of 100 PJ ,in advance of gas demand.



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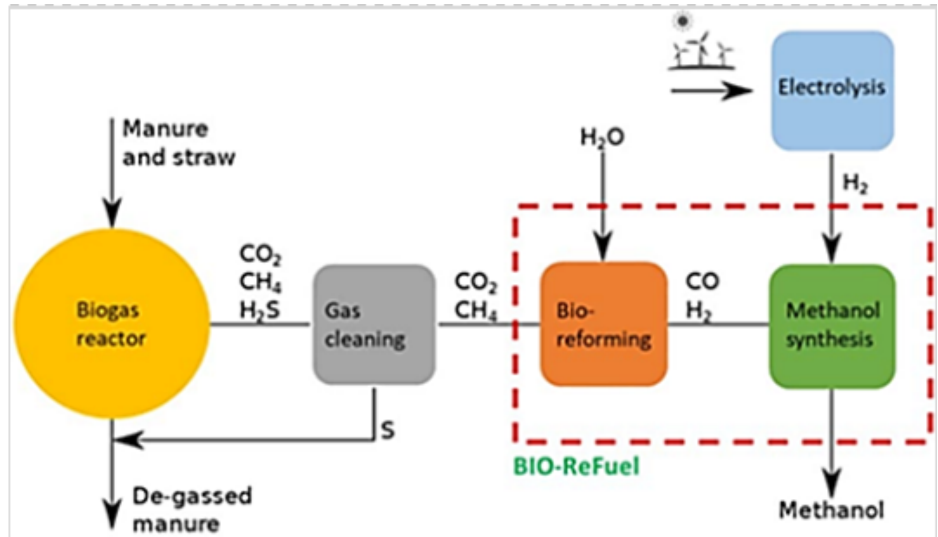
Case Story
IEA Bioenergy: Task 37: 11 2020

Green methanol from biogas in Denmark

a versatile transport fuel

Figure 1: 100 Danish petrol cars will from September 2020 to September 2022 run on CO_2-friendly bio-methanol from biogas, as part of the project "Biomethanol M85 at Danish fuel stations," supported by the Danish Energy Agency's development program EUDP.

Coupling of biogas and power to methanol



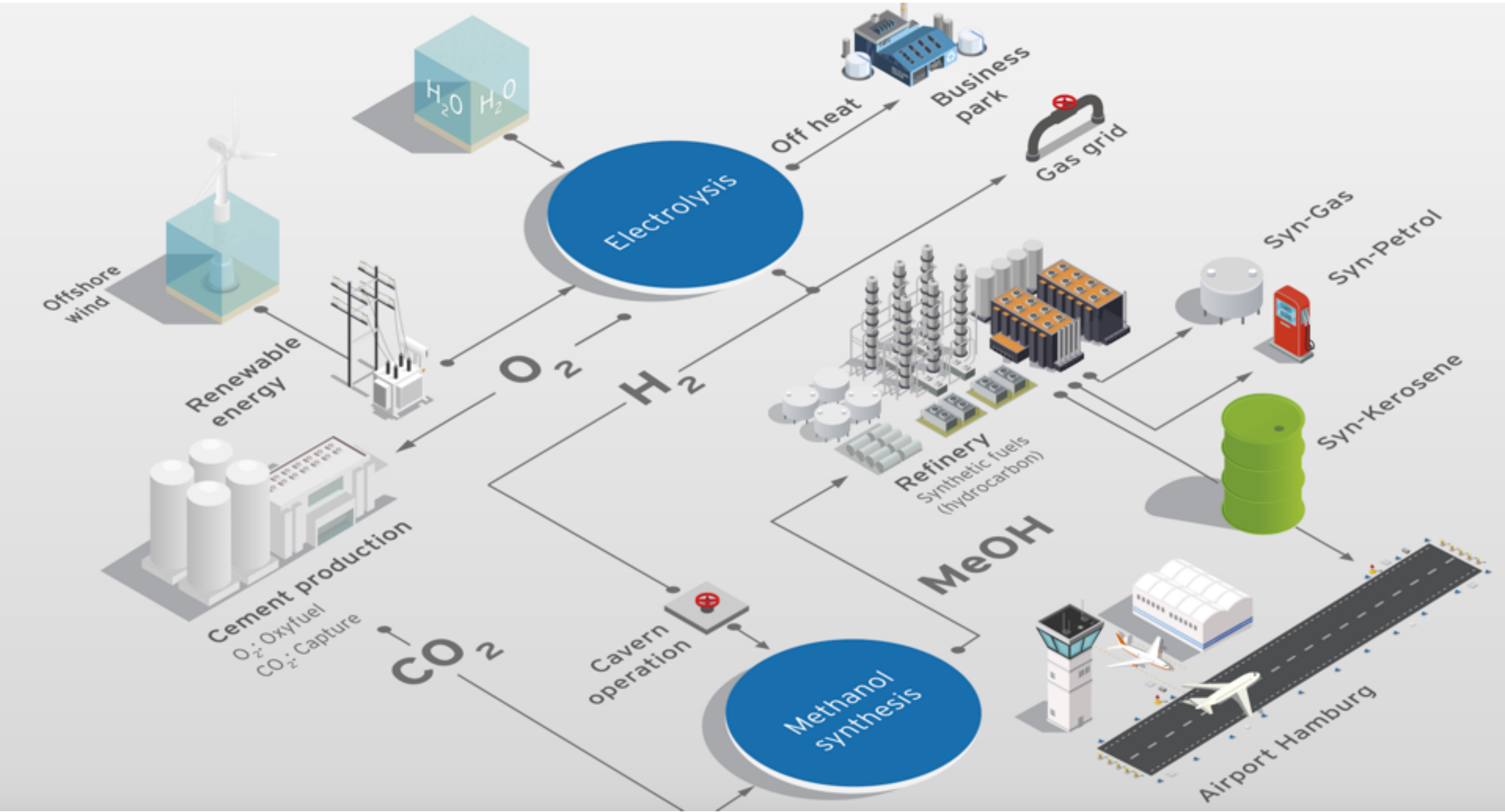
Green methanol from biogas requires 75% CH_4 and 25% CO_2 in biogas

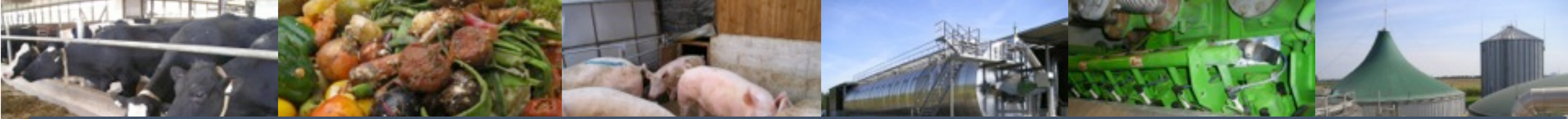
$3CH_4 \quad + \quad CO_2 \quad + \quad 2H_2O \quad = \quad 4\ CH_3OH$

Electrical driven catalytic conversion of biogas to CO and H_2 with additional energy from hydrogen via electrolysis

$CO \quad + \quad 2H2 \quad = \quad CH_3OH$

Circular economy: electricity, cement, carbon capture, aviation fuel (WESTKUSTE 100)





Conclusions

The **perception of the role of biogas** has changed from a means of treatment of a range of wet organic wastes towards a source of renewable energy and from end use as combined heat and power to a renewable gas in the form of biomethane.

Integration of energy vectors will be essential in **facilitating PV during daylight hours, wind power on windy days** and renewable sources of dispatchable energy such as from bioenergy.

The biogas plant operation itself can be **controlled extensively** and with this control comes high levels of flexibility. This is a huge advantage over other renewable energy provision systems. Biogas systems have a very positive attribute of being dispatchable but furthermore **can be ramped up and down to match the vagaries of temporal mismatch** between variable renewable energy supply with the demand for a variety of energy vectors.

Biogas systems can be a node of integration between electrical and natural gas grids in providing a sink for electricity (through power to gas systems) that would otherwise be curtailed or constrained. The flexibility of biogas systems can facilitate energy delivery to:

- the electricity grid as close as possible to the electricity demand profile
- heat to consumers facilitating the seasonal demand profile of heat;
- to the gas grid to decarbonize gaseous fuels for various purposes;
- Biomethane directly to local consumers such as for transport biofuel for haulage and buses;
- Biogas can play an essential role as part of a virtual power plants.

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Many thanks from IEA Bioenergy Task 37