A perspective on power to methane in a circular economy system

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BioSweet Conference September 10 2020

MaREI Centre for Energy, Climate and Marine






Carbon Efficient Farming / Carbon Neutral Breweries / Advanced Biofuel from parklands

Milk from 140 cattle farm assessed as GHG negative at -0.82 kg CO2/ l produced.

Carbon Neutral Brewery
In Austria

65 cars fueled by grass cuttings from 400 ha of campus parkland in Brazil

Biogas in Circular Economy

How do we account for the social and environmental benefits of anaerobic digestion?

Anaerobic digestion is not merely a source of renewable energy.

It can not be compared to a wind turbine or PV array.

Anaerobic digestion is a means of treating waste, is a means to reduce greenhouse gas in agriculture and in energy.

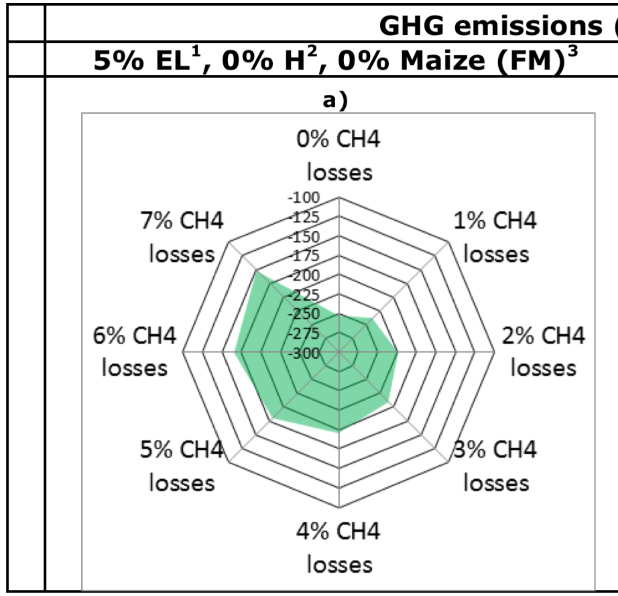
It is a source of biofertilizer, through mineralisation of nutrients in slurry to optimise availability.

It is a means of protecting water quality in streams and aquifers.

It is a source of renewable dispatchable electricity, heat and of advanced gaseous biofuel.





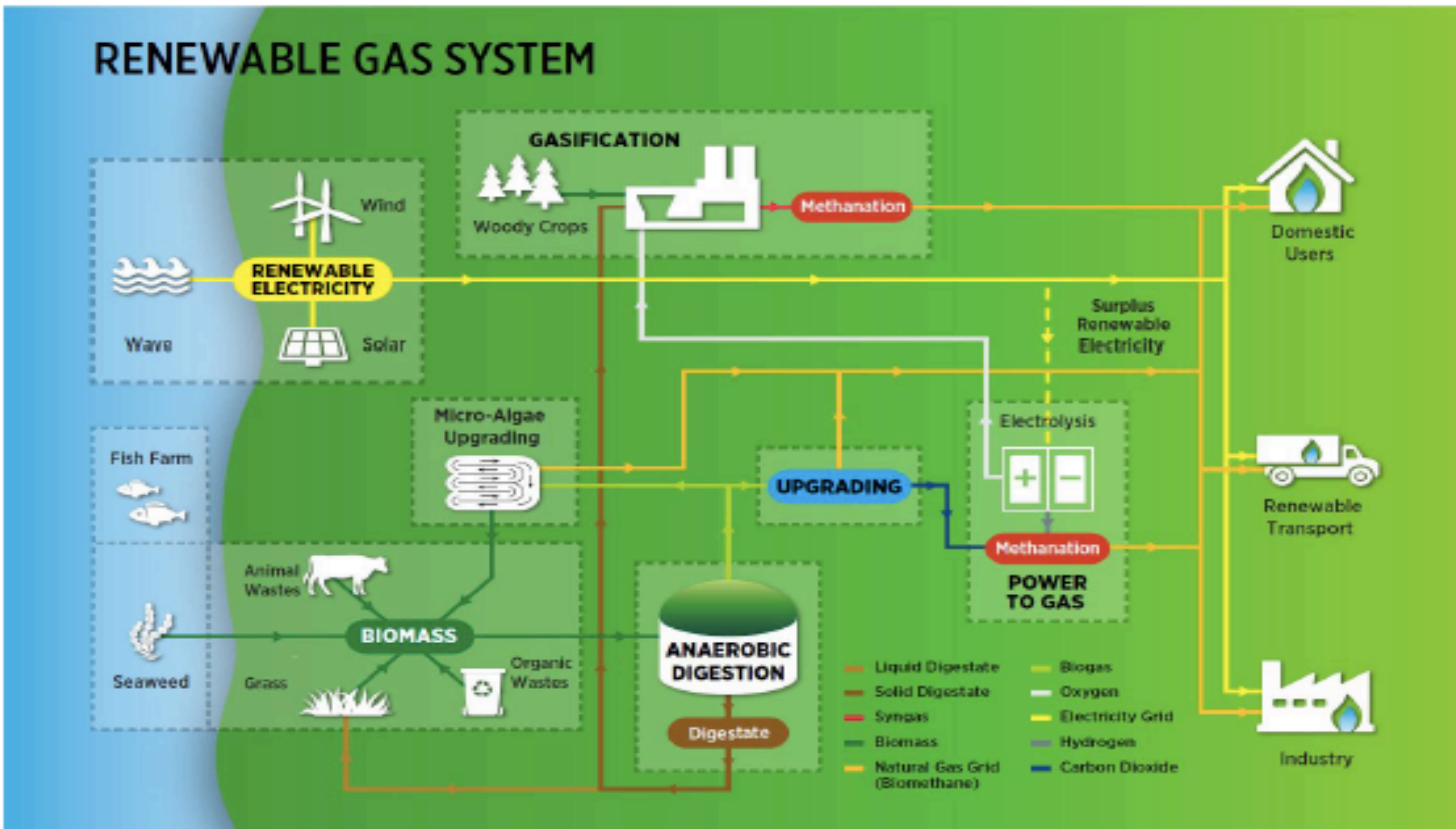
GHG negative biomethane for advanced transport biofuel.

Ideal for haulage and bus services.

California Air Resources Board awarded a Carbon Intensity score of -255 gCO2e/MJ for a dairy waste to vehicle fuel pathway.

Open slurry storage emits 17.5% of methane. At 2% methane slippage: biomethane from slurry GHG negative (-250 g CO2/MJ)

We have renewable electricity; now we need Green Gas



Conversion of electricity to hydrogen and on to methane

Audi E-gas at Wertle, Germany

Food waste biomethane

Production of hydrogen in 6 MW electrolysis

Production of methane via Sabatier

1000 Audi NGVs

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

Biomethanation assessed in a batch system

Bioresource Technology xxx (2016) xxx-xxx

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Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com

Study of the performance of a thermophilic biological methanation system

Amita Jacob Guneratnam[a], Eoin Ahern[a], Jamie A. FitzGerald[a,d], Stephen A. Jackson[d], Ao Xia[c], Alan D.W. Dobson[d], Jerry D. Murphy[a,b,*]

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Fig. 3. Methane composition and volumetric productivity at 65 °C (fresh inoculum) for 24 h.

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

Applied Energy 228 (2018) 1046–1056

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

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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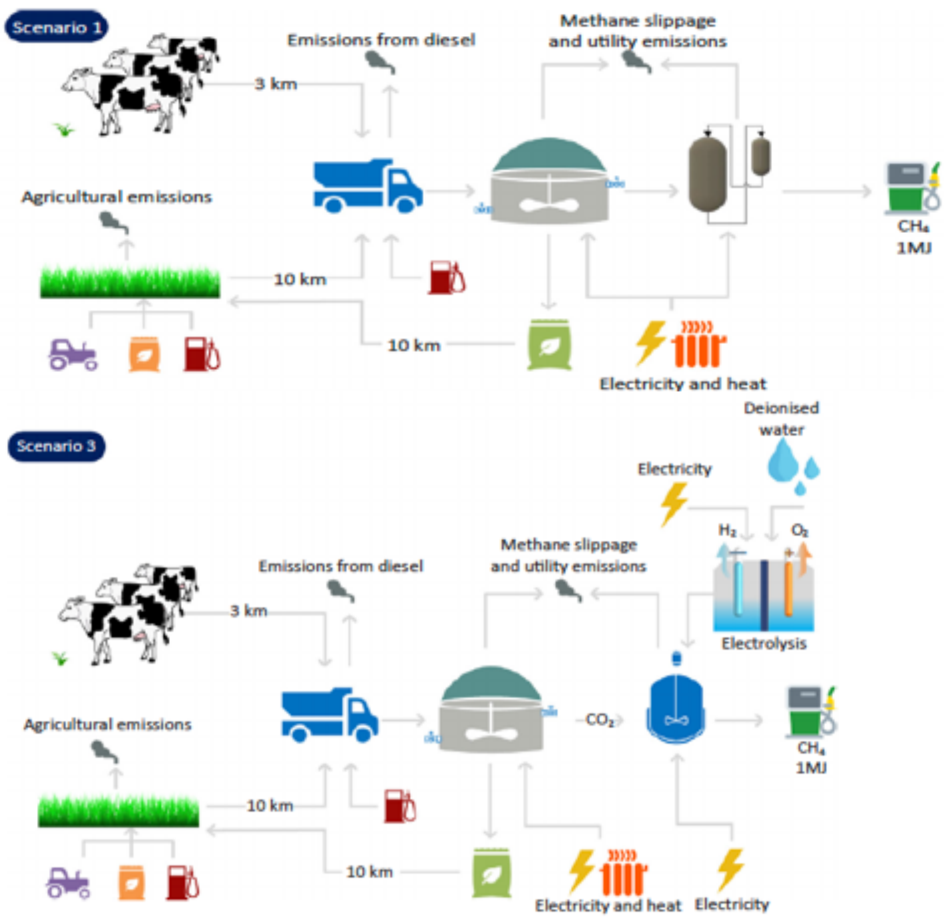
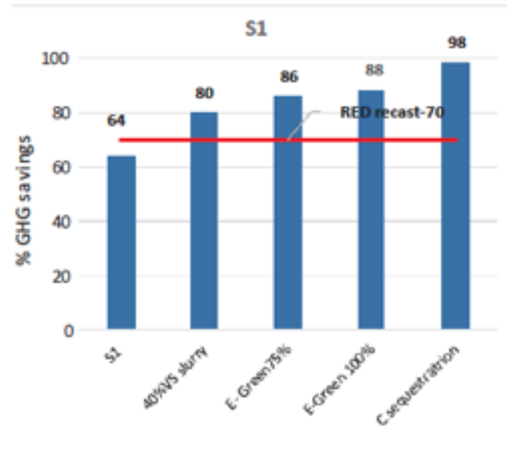
School of Engineering, University College Cork, Cork, Ireland

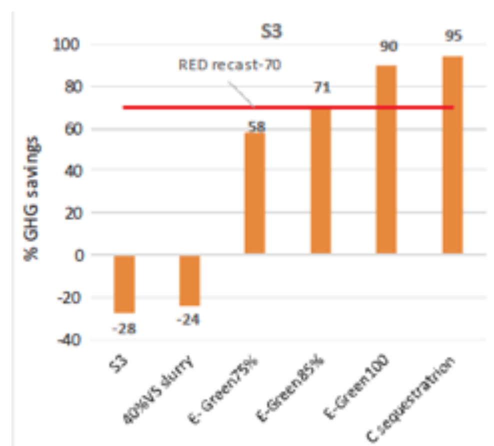
HIGHLIGHTS

- 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 improve efficiency of biogas systems





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?

- Ireland has ca. 8 GWe electrical capacity, target of 30% RES-E by 2020
- Ireland has plans for 12 GWe off shore wind by 2030 leading to 70% RES-E
- Assuming 40% capacity factor then peak production 175% of average demand.
- Exacerbated by peak production at periods of low demand

Contents lists available at ScienceDirect

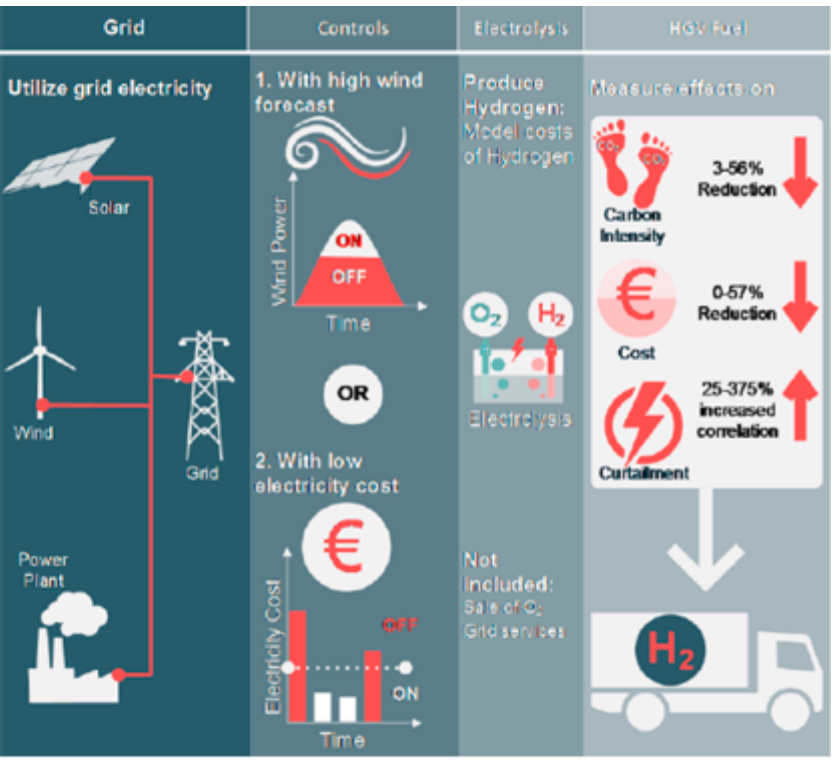
Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

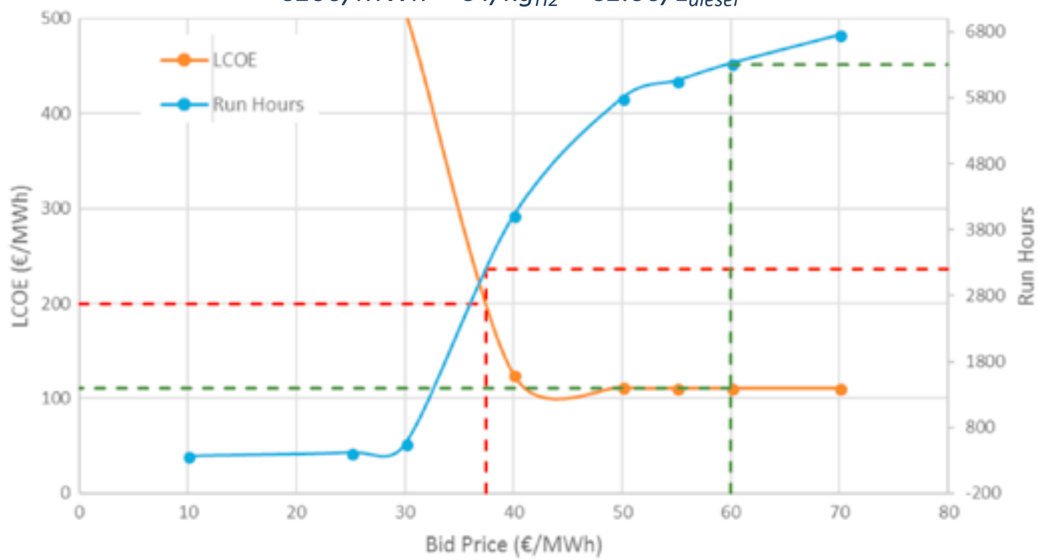
Power to hydrogen, run hours, price, sustainability

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]



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



Efficiency of Biomethanation

Applied Energy 235 (2019) 1061–1071

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Biological methanation: Strategies for in-situ and ex-situ upgrading in anaerobic digestion

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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.

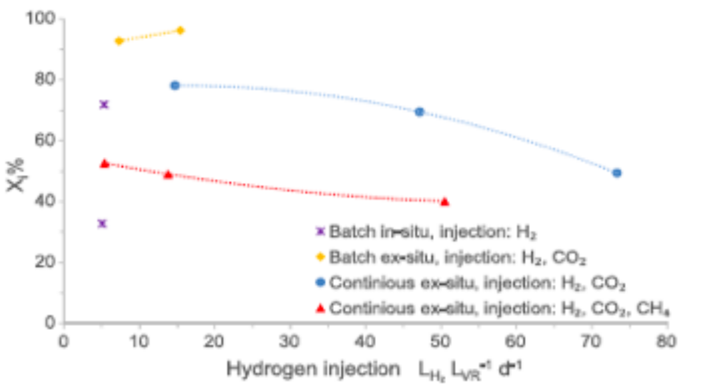

Fig. 5b. Gas conversion of in- and ex-situ upgrading strategies displaying efficiencies (X_i: gas conversion).

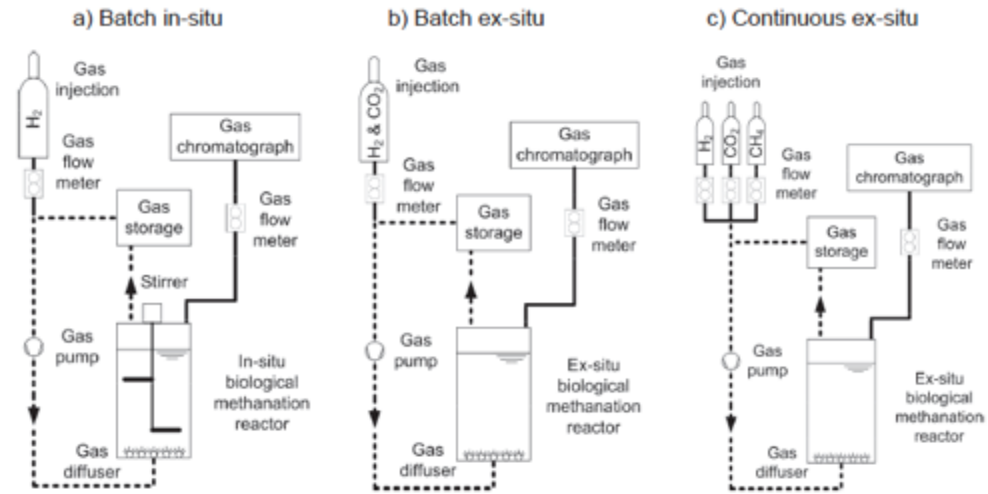

Fig. 2. Schematic of experiment lay out: (a) Batch in-situ (BIS 1–BIS 6), (b) Batch ex-situ (BES 1–BES 2), (c) Continuous ex-situ (CES 1–CES 6).

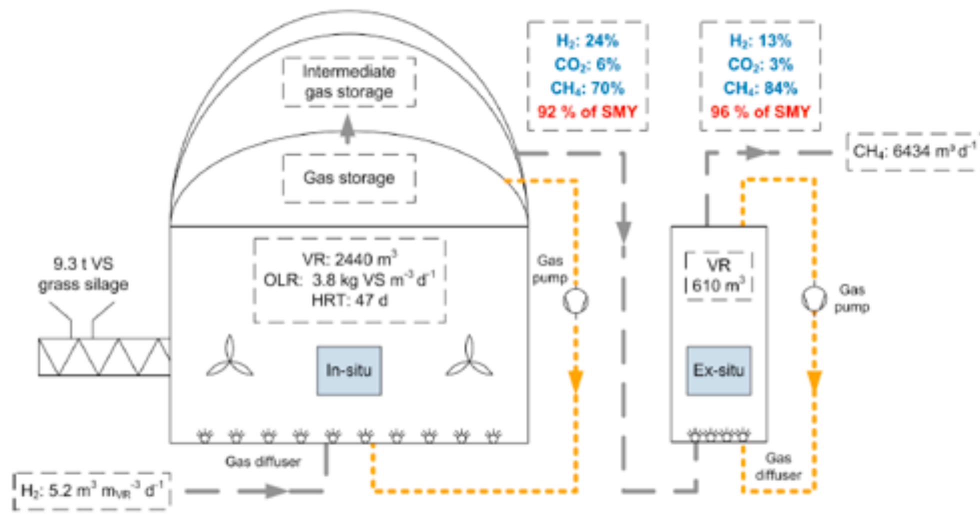

Fig. 7. Hybrid concept of sequential in-situ and ex-situ methanation with triple gas storage membrane on top of in-situ digester (SMY: specific methane yield, VR: reactor volume, OLR: organic loading rate, HRT: hydraulic retention time, VS: volatile solids).

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Renewable Energy
Volume 133, April 2019, Pages 951-963

What is the level of incentivisation required for biomethane upgrading technologies with carbon capture and reuse?

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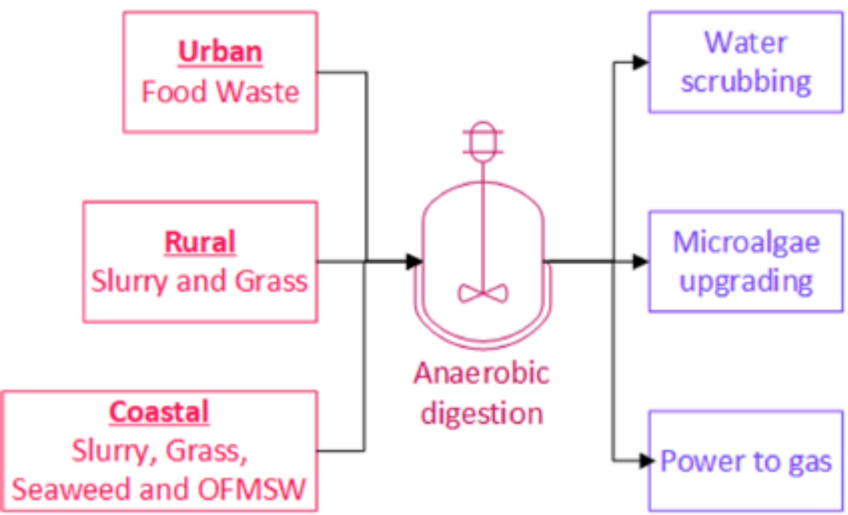
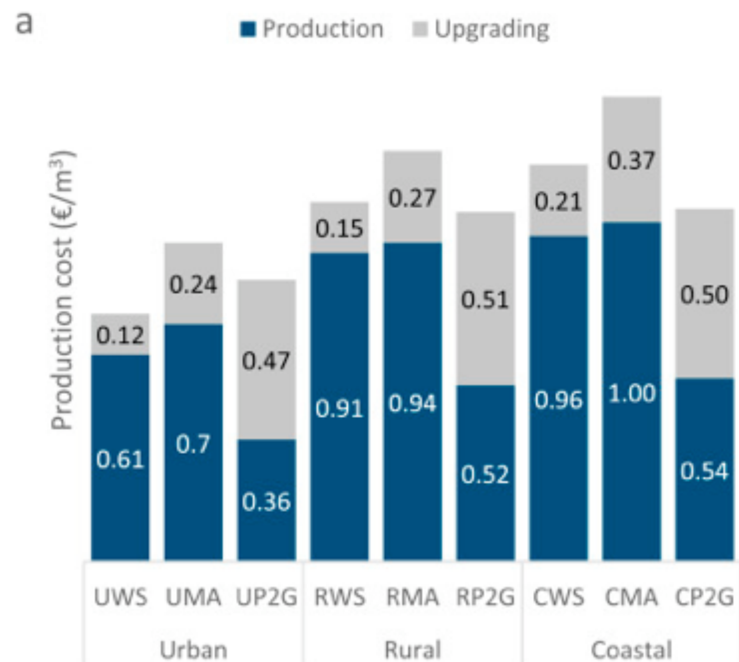
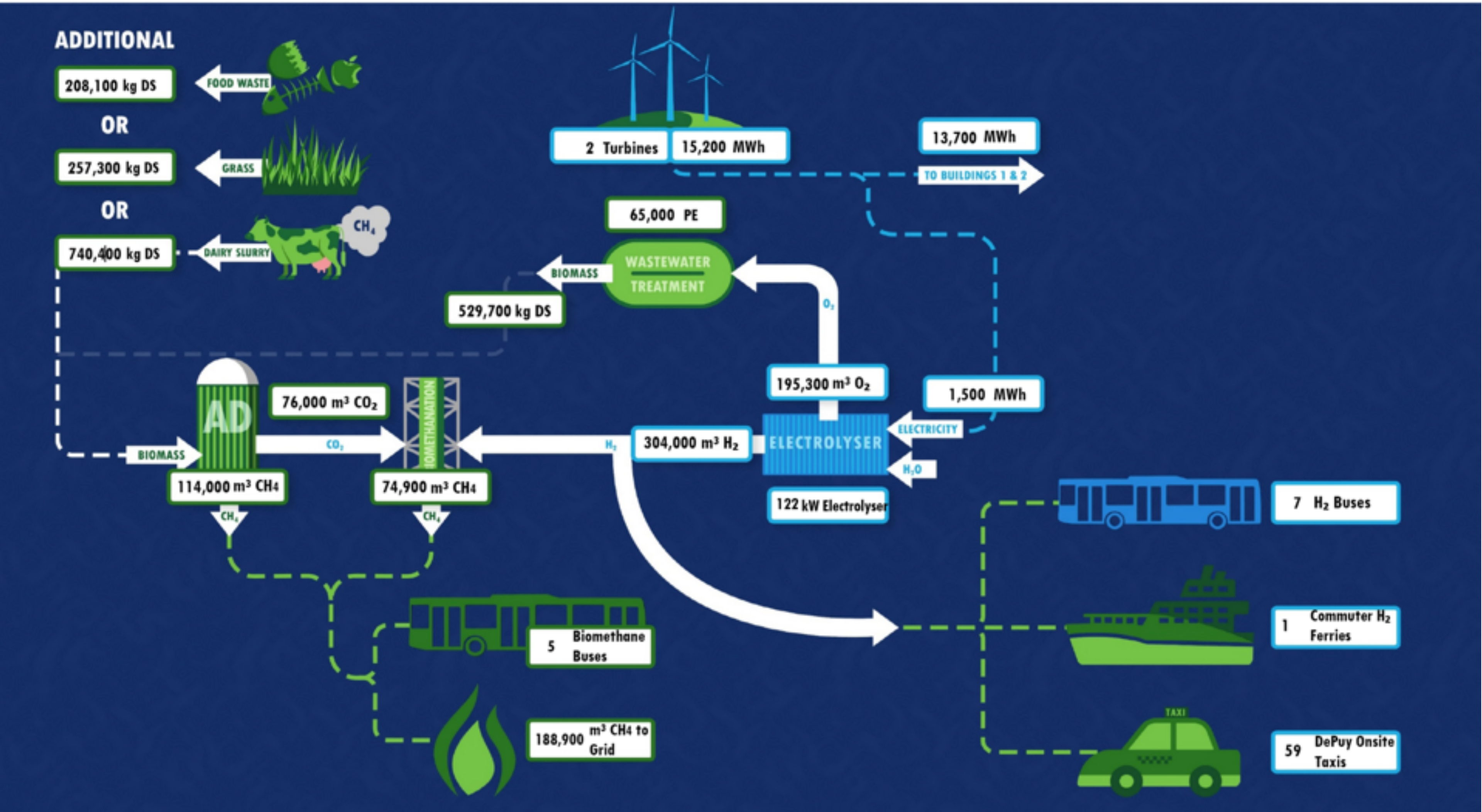
Can power to methane be economically feasible?





Hydrogen upgrading can be economically competitive when the feedstock in the biogas facility is expensive (grass silage or seaweed) or has a low specific methane yield (slurry). This is because c. 70% of methane is produced from electricity and as such we are comparing power to methane with the more expensive sources of biogas

Integration of power to gas with wastewater treatment in circular economy system



Improved biological performance due to Direct Interspecies Electron Transfer (DIET)

ELSEVIER
Contents lists available at ScienceDirect
Chemical Engineering Journal
journal homepage: www.elsevier.com/locate/cej

Improved efficiency of anaerobic digestion through direct interspecies electron transfer at mesophilic and thermophilic temperature ranges

Richen Lin[a,b], Jun Cheng[c,*], Lingkan Ding[c], Jerry D. Murphy[a,b,d]

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[d] International Energy Agency Bioenergy Task 37 "Energy from Biogas", Ireland

Table 2
Changes in Gibbs free energy values for ethanol conversion to methane at different temperatures.

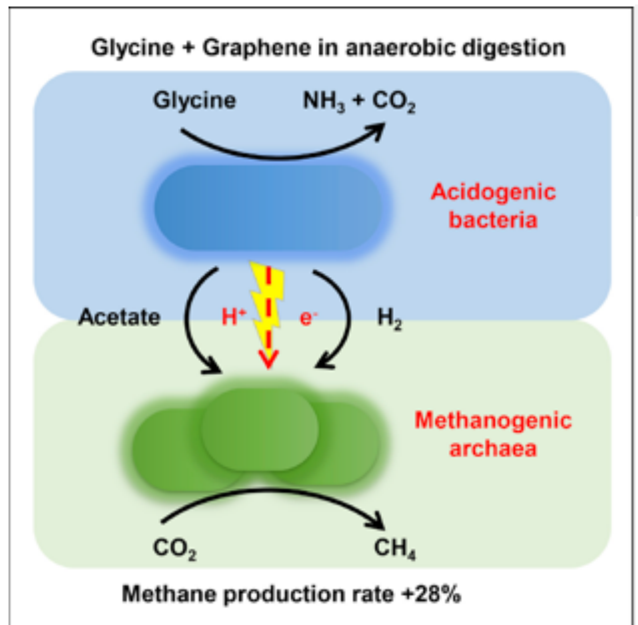
Microbes	Reactions	$\Delta G^{0,a}$ (kJ/mol)		
		25 °C[b]	35 °C[c]	55 °C[d]
Electron producing acidogens	1. MIET: $CH_3CH_2OH + H_2O \rightarrow CH_3COO^- + H^+ + 2H_2$	9.7	10.4	12.3
	2. DIET: $CH_3CH_2OH + H_2O \rightarrow CH_3COO^- + 5H^+ + 4e^-$	−149.6	−151.4	−152.9

iScience
Volume 10, 21 December 2018, Pages 158-170
open access

Article

Graphene Facilitates Biomethane Production from Protein-Derived Glycine in Anaerobic Digestion

Richen Lin[1, 2, 7], Chen Deng[1, 2], Jun Cheng[3], Ao Xia[4], Piet N.L. Lens[5], Stephen A. Jackson[1, 6], Alan D.W. Dobson[1, 6], Jerry D. Murphy[1, 2]



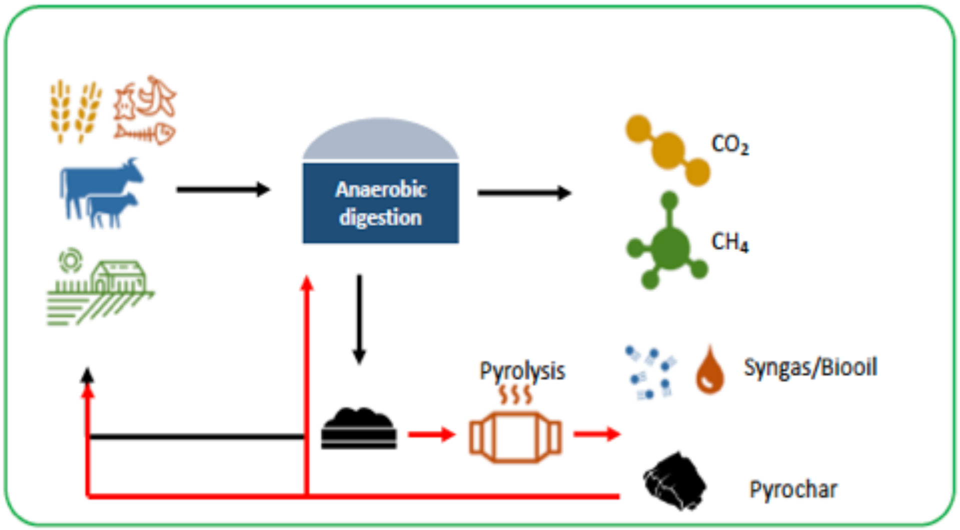
HIGHLIGHTS
Graphene led to an increase in peak bio-CH_4 production rate from glycine by 28%

Renewable and Sustainable Energy Reviews
Volume 128, August 2020, 109895

Improving gaseous biofuel yield from seaweed through a cascading circular bioenergy system integrating anaerobic digestion and pyrolysis

Chen Deng [a, b], Richen Lin [a, b], Xihui Kang [a, b, c, d], Benteng Wu [a, b], Richard O'Shea [a, b], Jerry D. Murphy [a, b]

Pyrochar as a conductive material in DIET?



A. Laminaria digitata

B. Saccharina latissima

Increased biomethane yield of 17% while effecting a 26% decrease in digestate, reducing the amount of agricultural land required to spread digestate.

Biochar achieved comparable performances to high cost graphene.

DIET effect depends on conductive material and substrate.


IEA Bioenergy
Technology Collaboration Programme

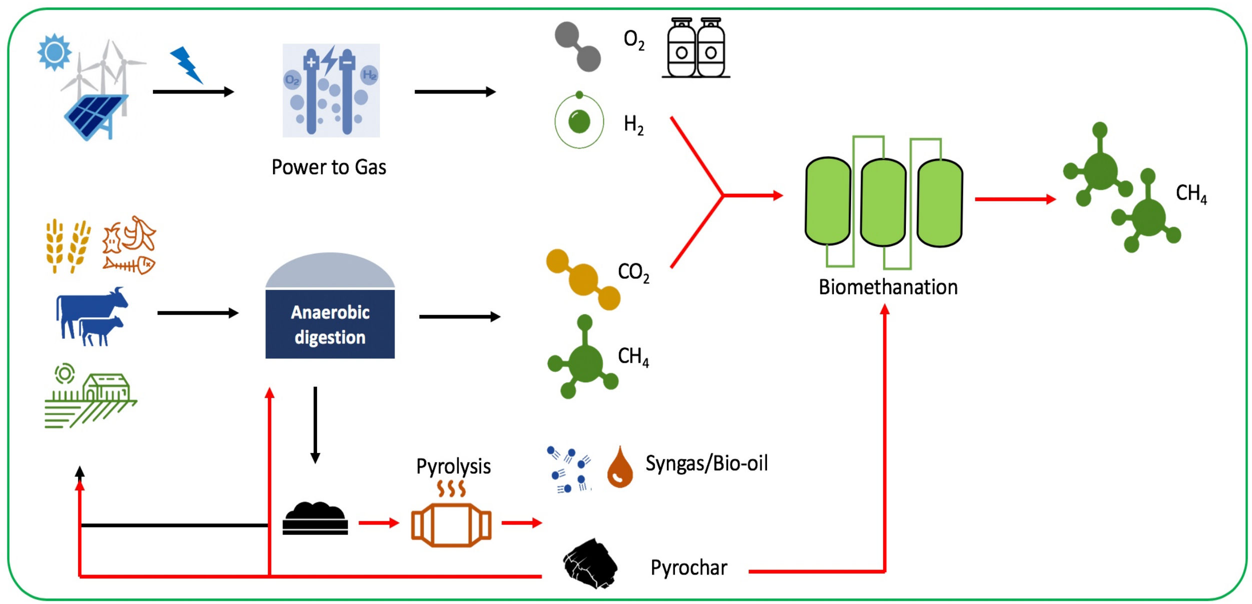
Drivers for Successful and Sustainable Biogas Projects:
International Perspectives
Report of a symposium held on March 26, 2020

IEA Bioenergy: Task 37

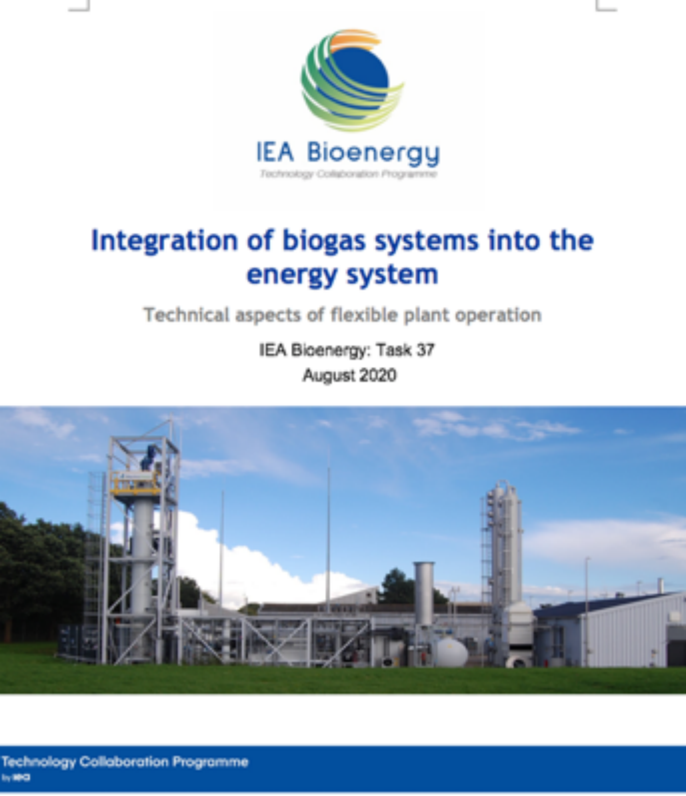
May 2020

Technology Collaboration Programme
by iea

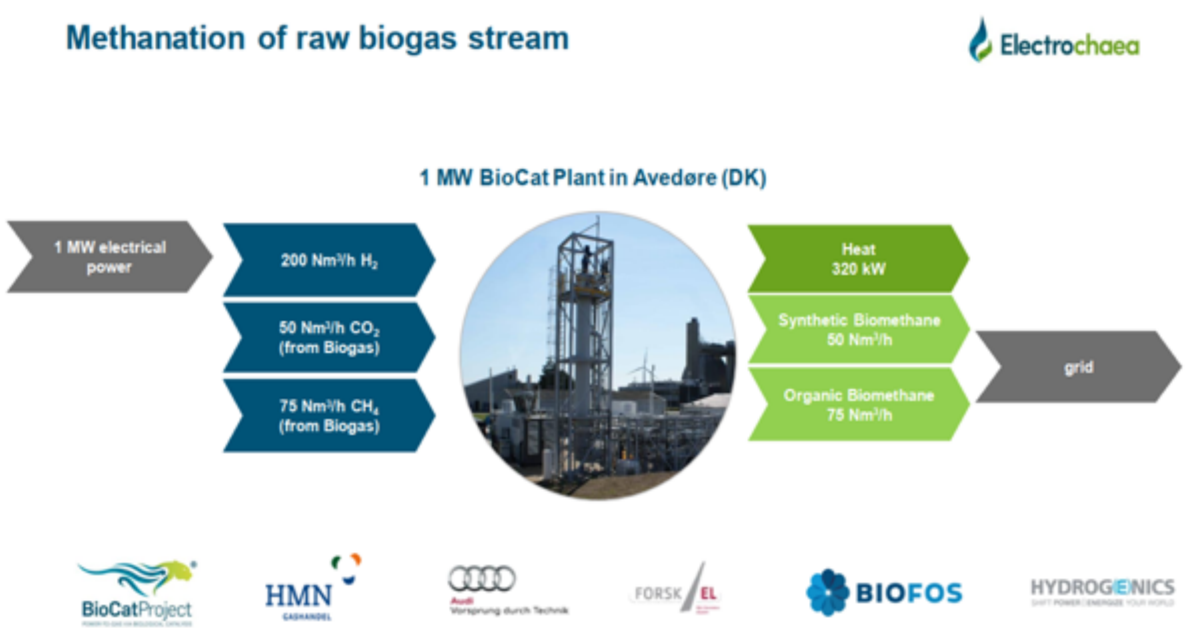
Advanced gaseous biofuel produced by integrating biological, thermo-chemical and power to gas systems in a circular cascading bioenergy system



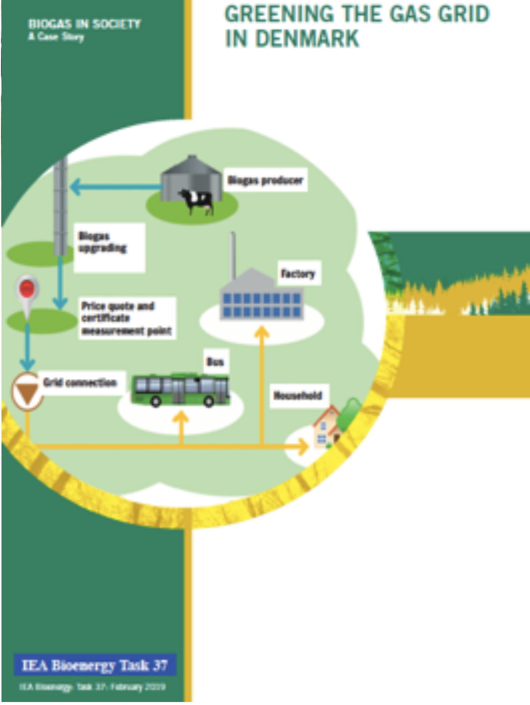
Integration of biogas systems into the energy system



Biogas can couple the electricity and gas grids when serving as a biological battery. Biogas systems have a role to play in the future electro-fuel market using hydrogen from electricity (preferable curtailed or constrained) to react with CO_2 in biogas producing biomethane (replacing the role of physio-chemical upgrading techniques) and increasing the output of biomethane (typically by 70%).



Extent of Green Gas in Denmark



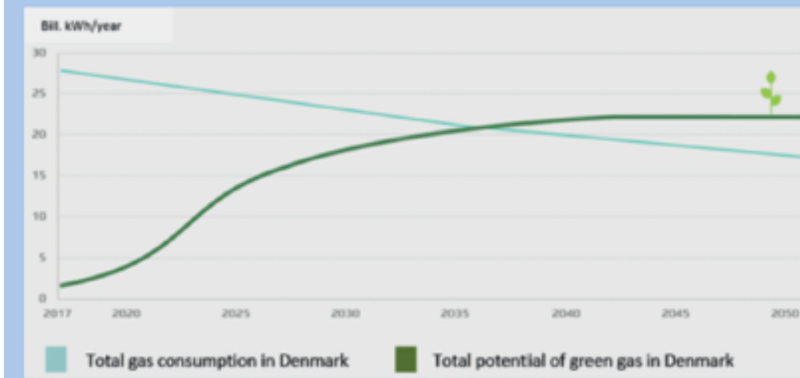


Figure 1: Gas consumption and potential of green gas in Denmark (from Green Gas Denmark)

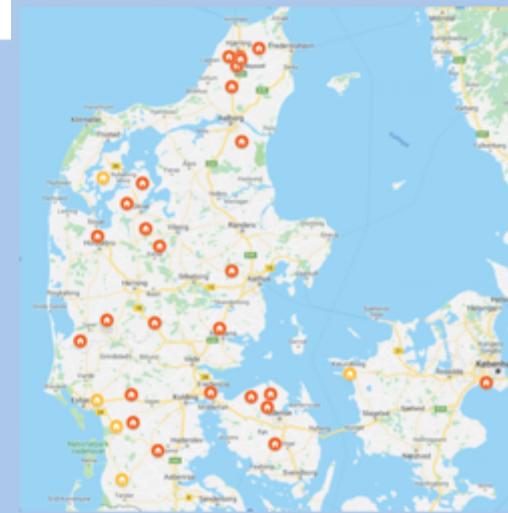


Figure 2: Grid connections for green gas in Denmark (yellow marks indicate connections established in 2017)

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.

IEA Bioenergy Task 37