Flexible Biogas Systems

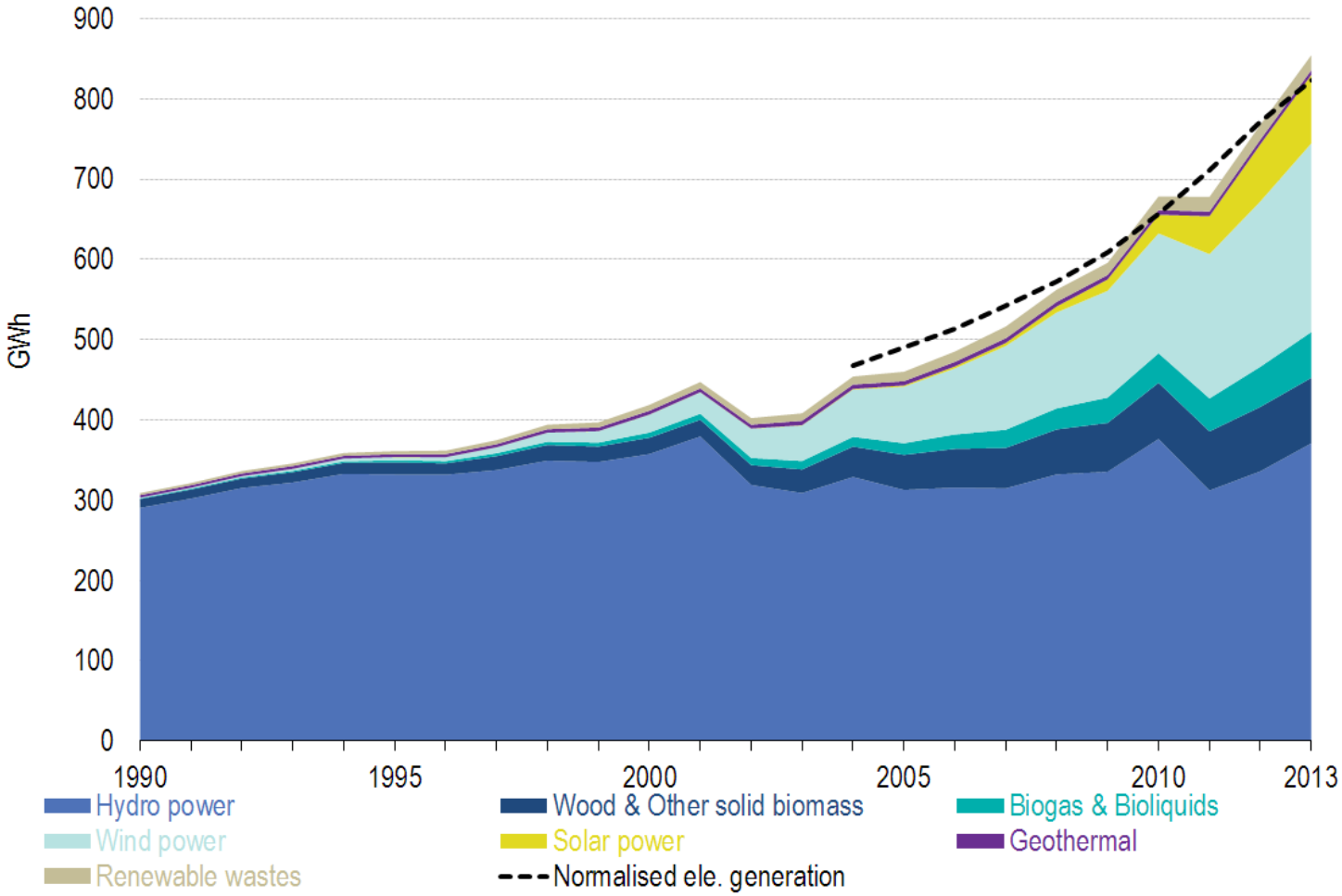
IEA Bioenergy: Flexible Bioenergy, Graz, Austria, 24th January 2020

Presenter: Dr Richard O'Shea, MaREI, University College Cork

Authors & Contributors
Dr Jan Liebertrau, Rytec GmbH, IEA Task 37
Prof Jerry D. Murphy, MaREI, University College Cork, IEA Task 37 Lead

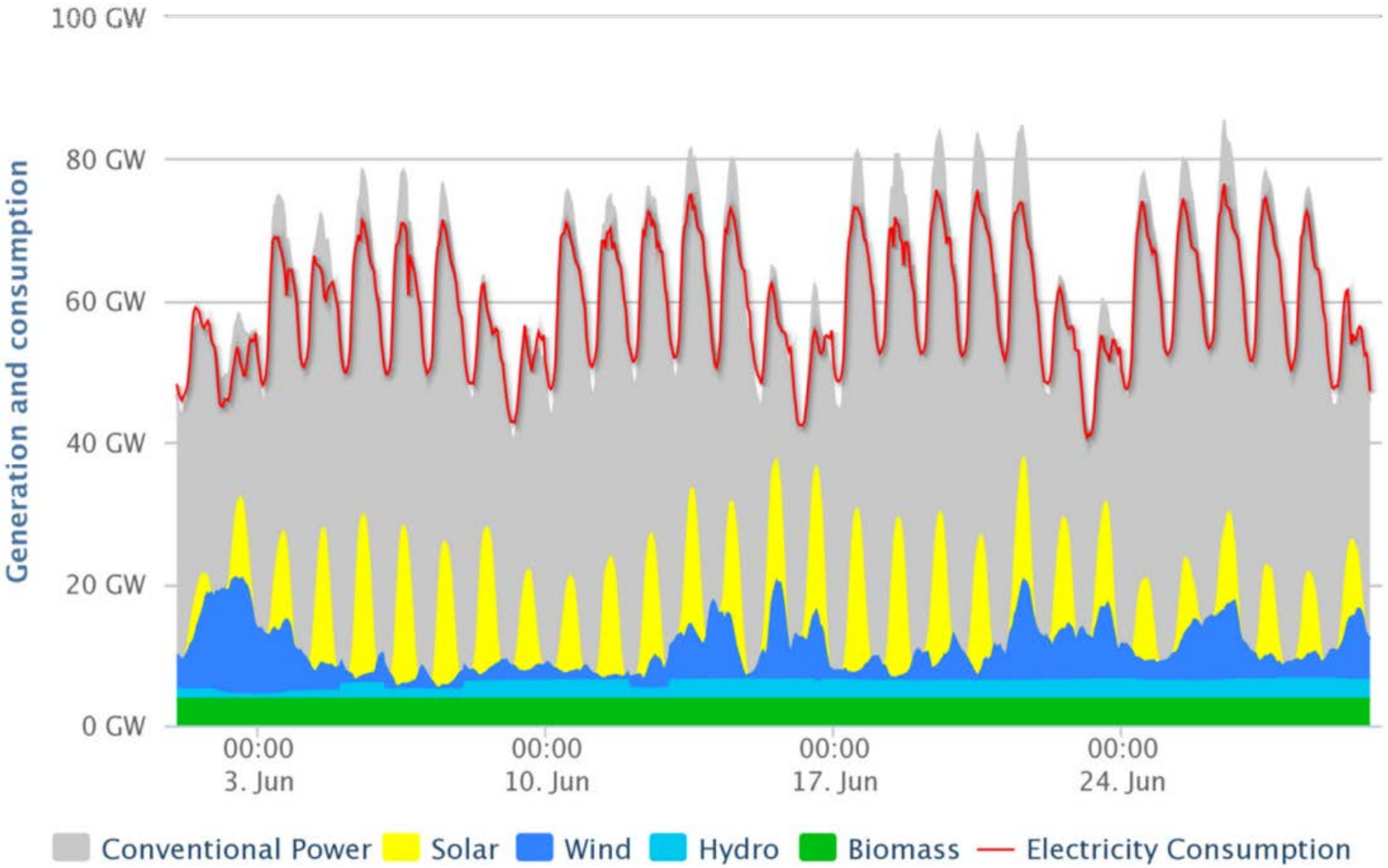
IEA Bioenergy
iea Energy Technology Network
Task 37

Rise of Intermittent Generation



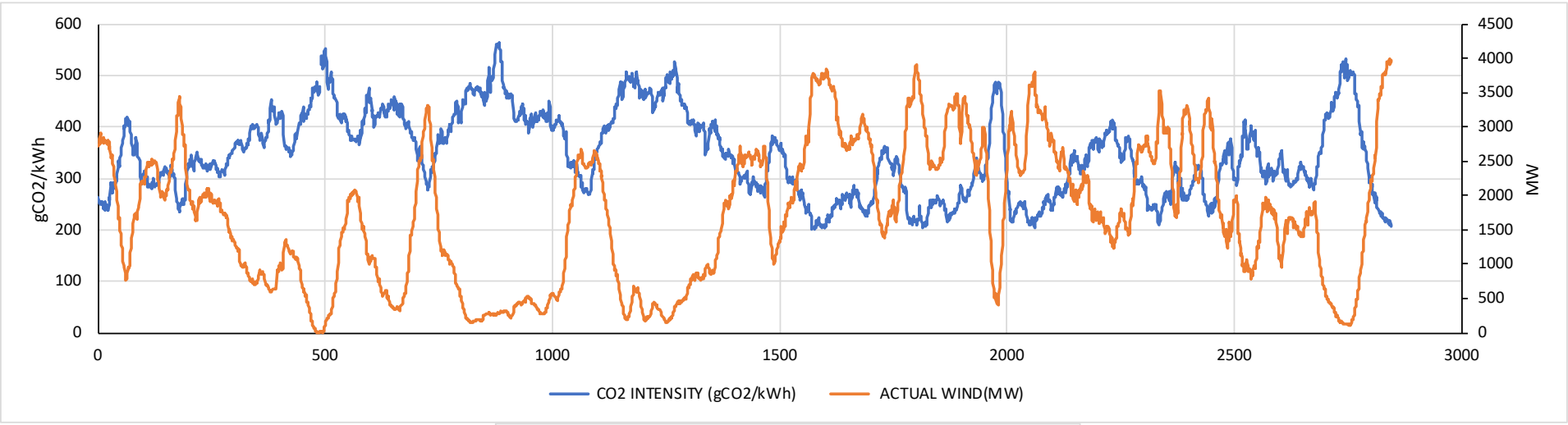
https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:RENEWABLES-ELECTRICITY-PRODUCTION-2013.png

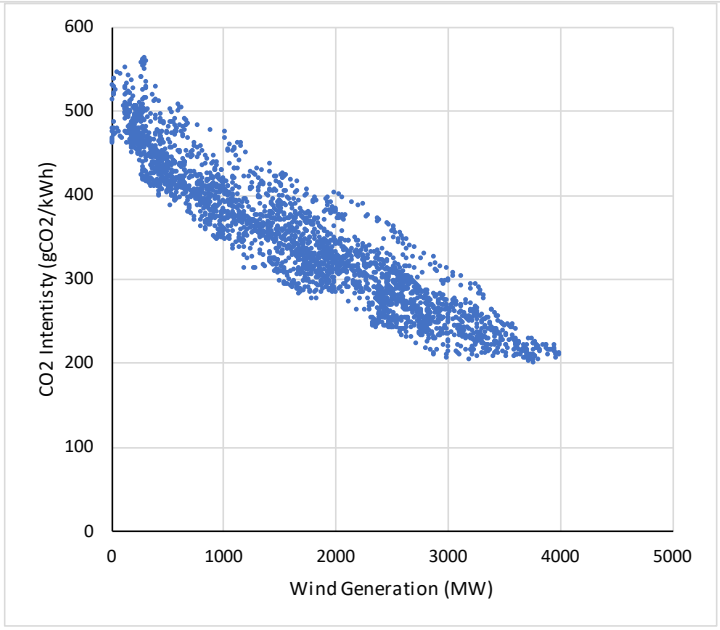
Mismatch Between Supply and Demand



Persson T, Murphy J, Liebetrau J, Trommler M, Toyama J, Lannasch A-K, et al. A perspective on the potential role of biogas in smart energy grids. IEA Bioenergy Task 37. 2014.

Low Wind Means High Carbon





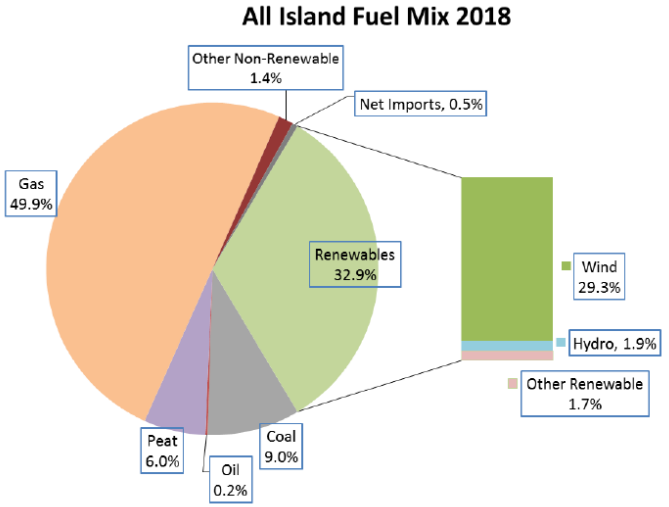
Adapted from:
http://smartgriddashboard.eirgrid.com/#all/wind

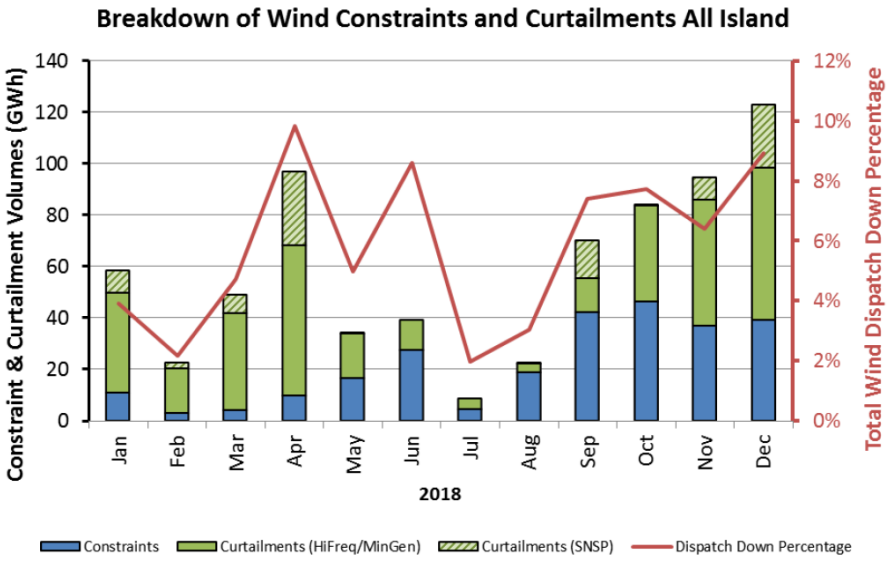
Dispatch Down: Constraint and Curtailment

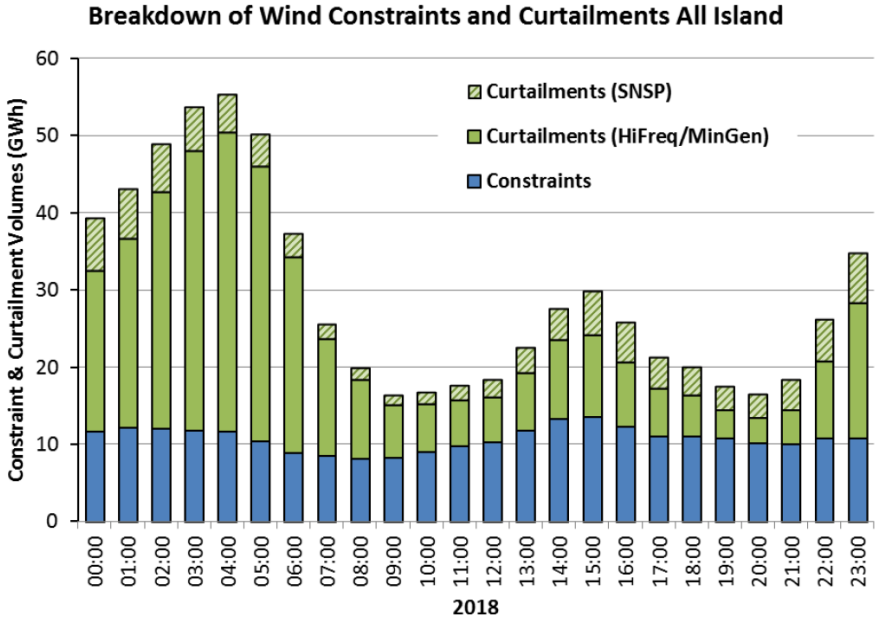
Dispatch Down: Reduced power generation from variable renewable sources

Constraint: Localised network stability

Curtailment: System wide issues (Frequency, stability, demand-supply mismatch)

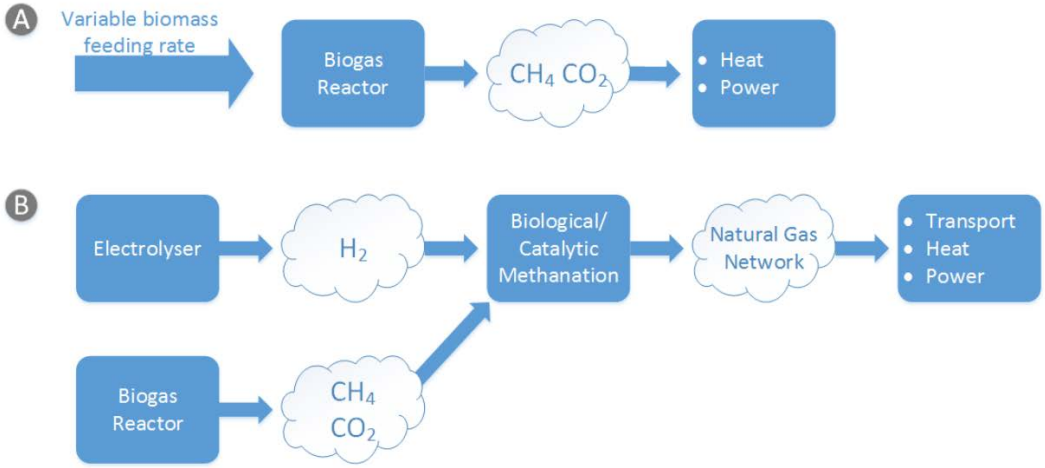


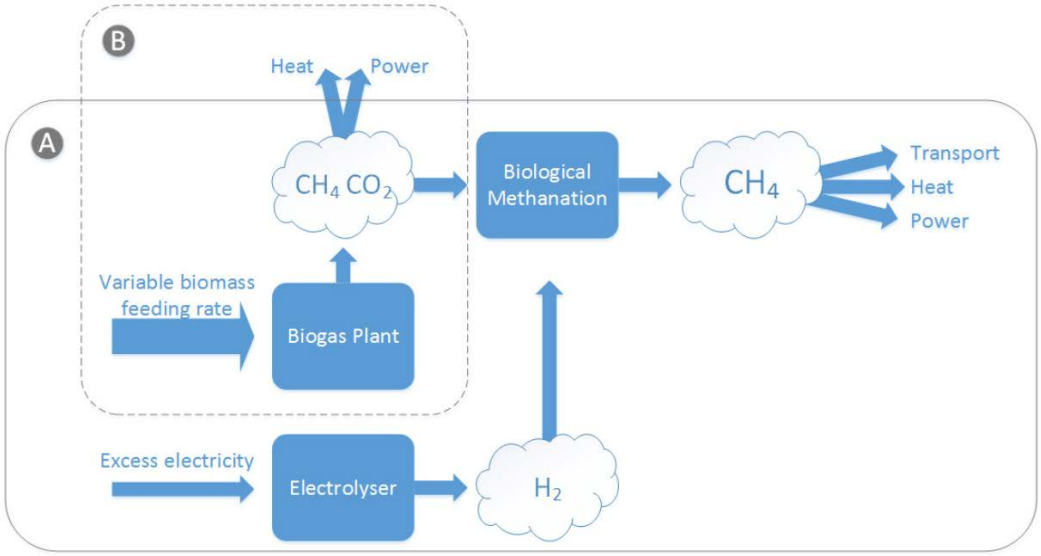


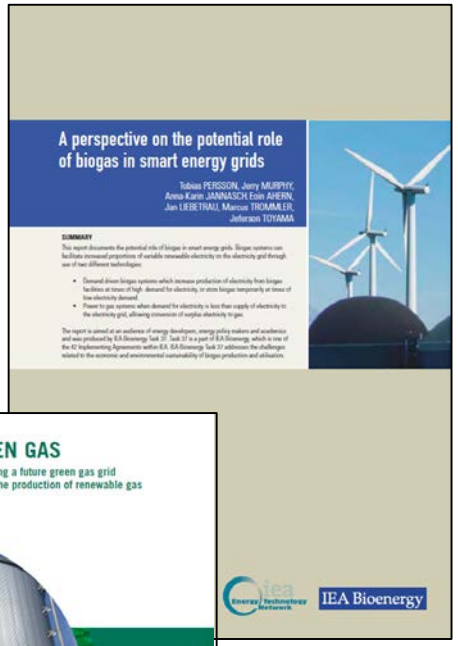


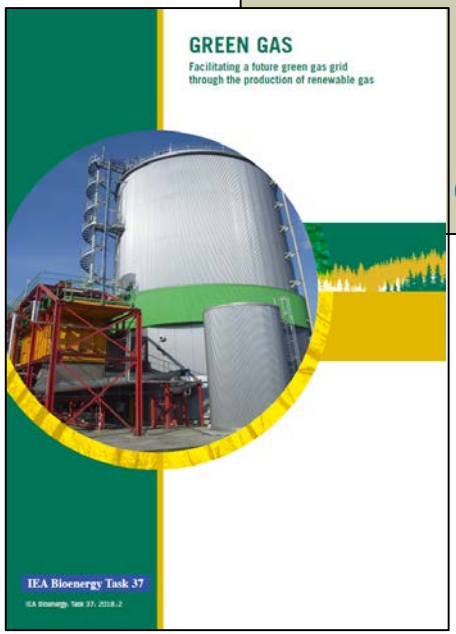
Annual Renewable Energy Constraint and Curtailment Report 2018, Eirgrid, May 2019

Potential Role of Flexible Biogas: Source and Sink



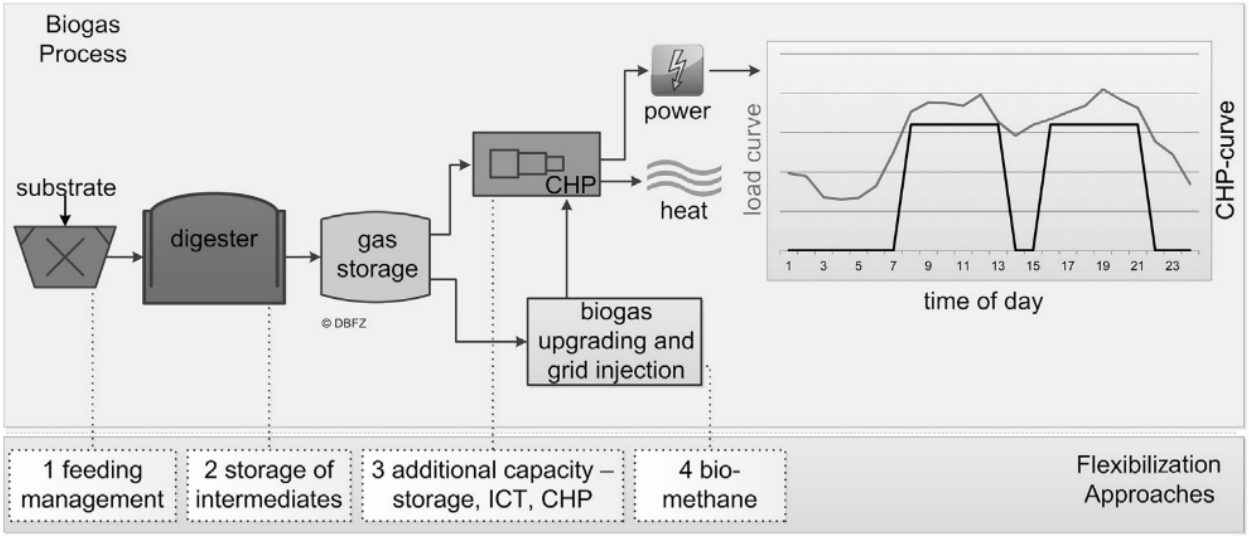






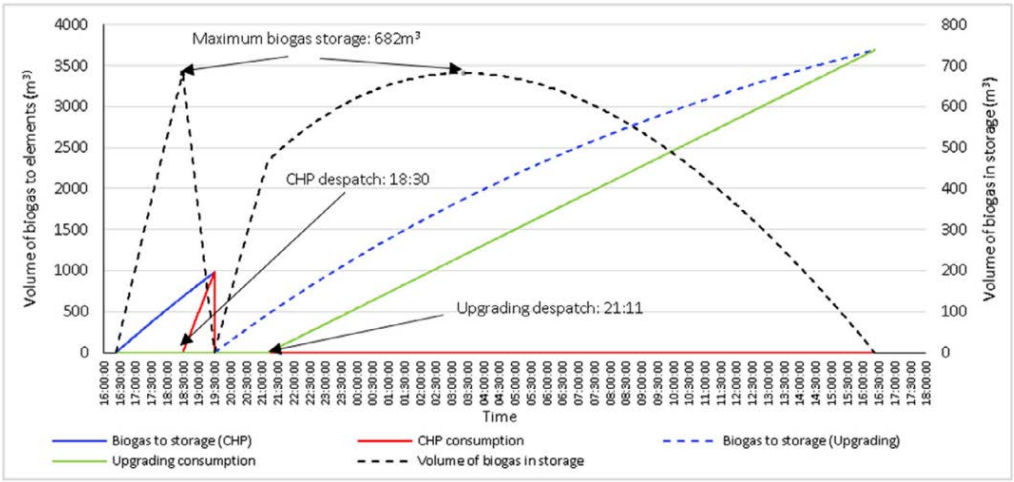
Demand Oriented Biogas

- Increase CHP capacity and grid access (constant annual energy output)
- Increase gas storage capacity
- Control biogas production (Alter feeding regime, store intermediates)
- Must be flexible



Szarka N, Scholwin F, Trommler M, Fabian Jacobi H, Eichhorn M, Ortwein A, et al. A novel role for bioenergy: A flexible, demand-oriented power supply. Energy 2013;61:18–26. doi:10.1016/j.energy.2012.12.053.

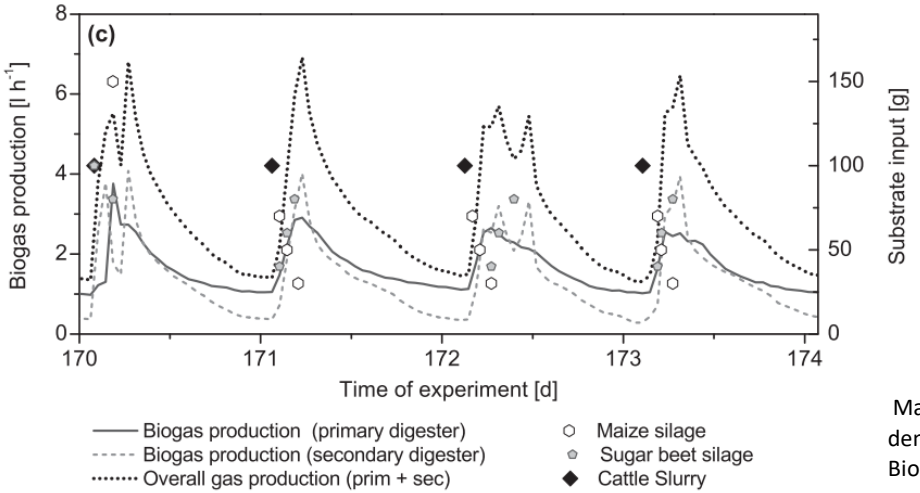
Demand Oriented Biogas



Minimise storage volume required

- Pulse feed a single substrate knowing kinetics

O'Shea R, Wall DM, Murphy JD. Modelling a demand driven biogas system for production of electricity at peak demand and for production of biomethane at other times. Bioresour Technol 2016;216:238–49. doi:10.1016/j.biortech.2016.05.050.

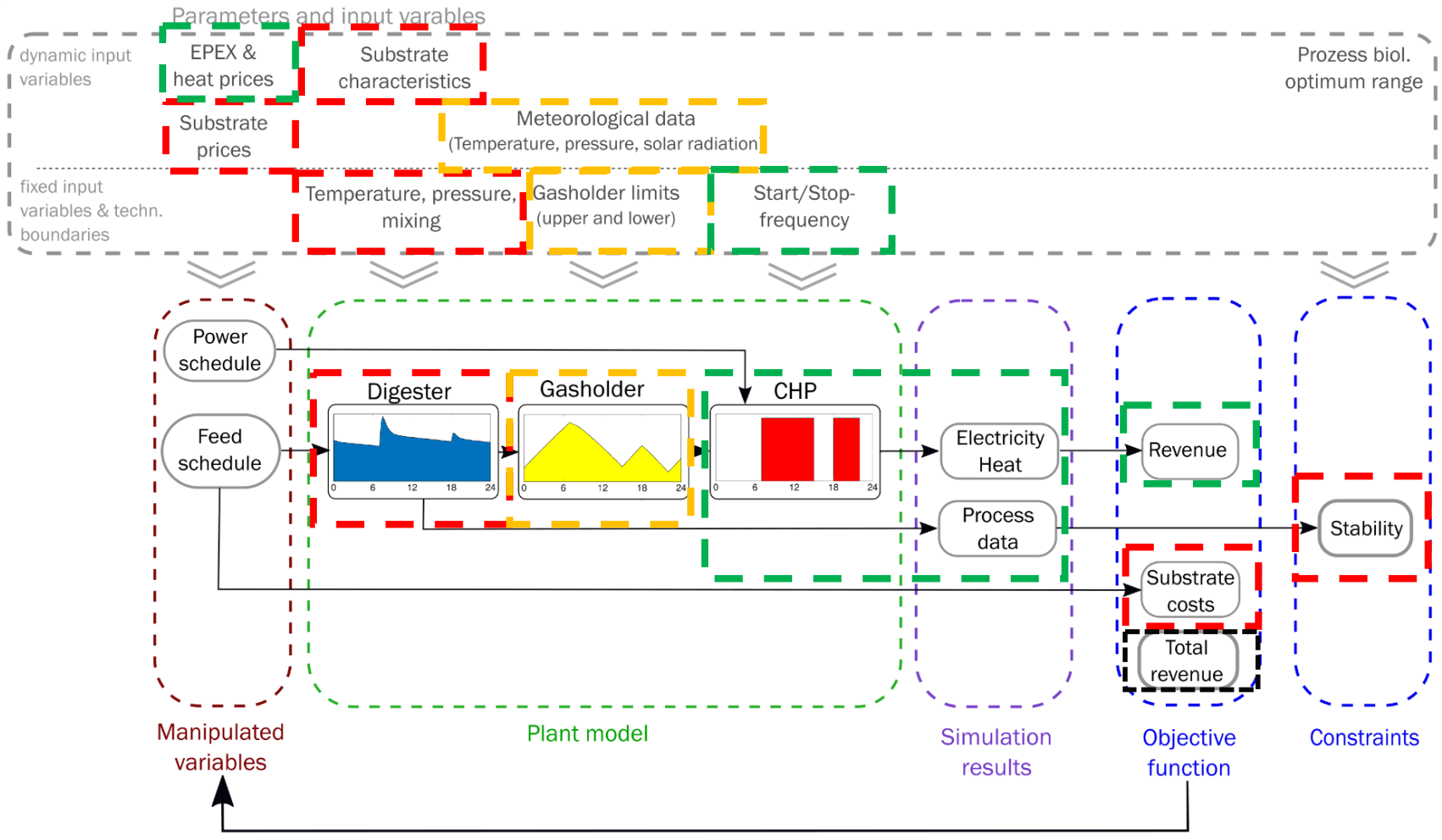


- Pulse feed several substrates substrate knowing kinetics to enable increased gas production at time of use

Mauky E, Jacobi HF, Liebetrau J, Nelles M. Flexible biogas production for demand-driven energy supply – Feeding strategies and types of substrates. Bioresour Technol 2015;178:262–9. doi:10.1016/j.biortech.2014.08.123.

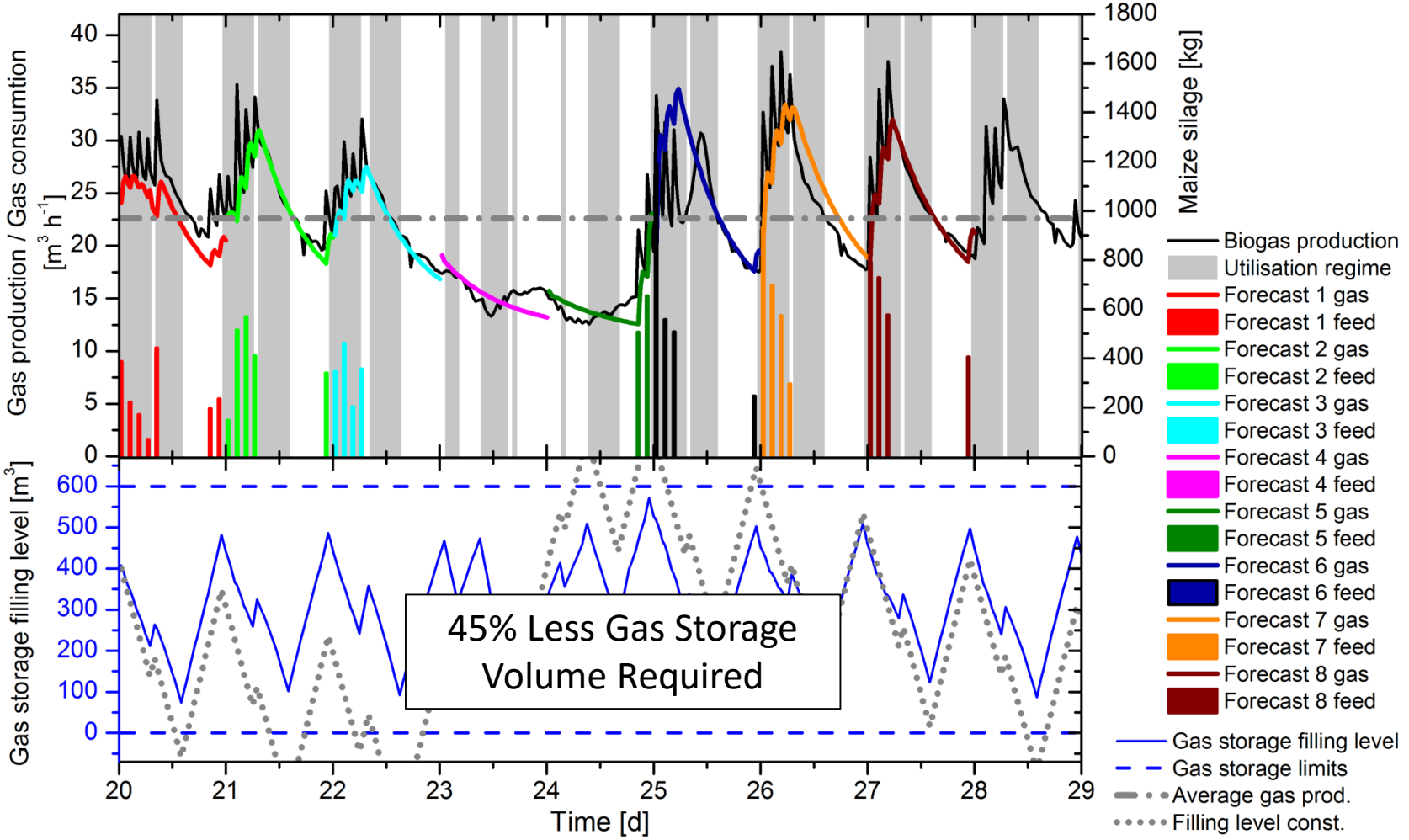
Demand Oriented Biogas

Integrate external factors and internal limitations to obtain optimal flexible use

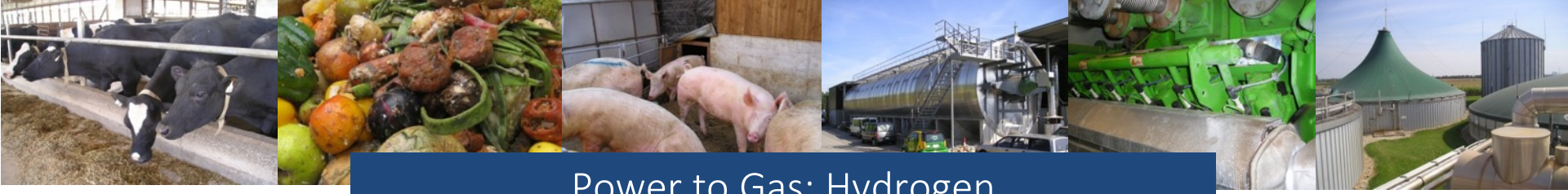


Source: DBFZ 2019

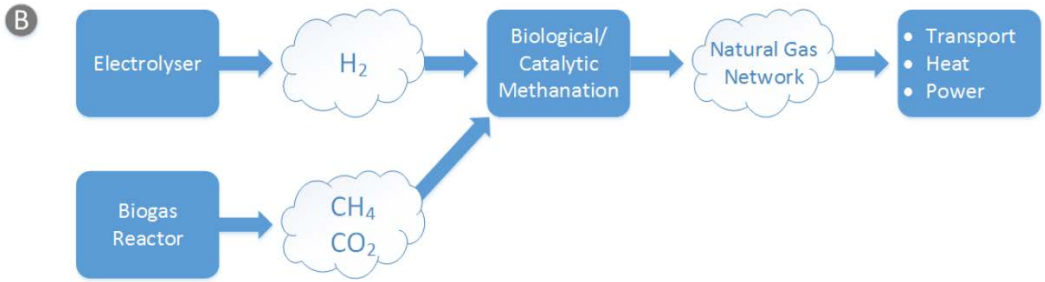
Demand Oriented Biogas



Mauky E, Weinrich S, Nägele HJ, Jacobi HF, Liebetrau J, Nelles M. Model Predictive Control for Demand-Driven Biogas Production in Full Scale. Chem Eng Technol 2016;39:652–64. doi:10.1002/ceat.201500412.



Power to Gas: Hydrogen



Conversion of renewable electricity to gaseous energy vector

$$2H_2O \rightarrow 2H_2 + O_2$$

1

Direct injection of H_2 into gas grid

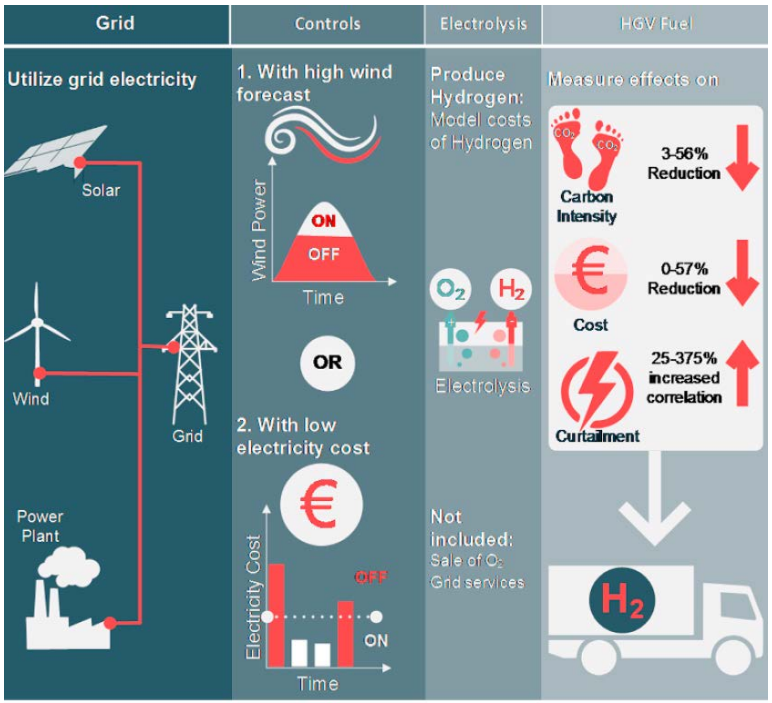
2

Heide Oil Refinery 30MW$_e$ for H_2, use in production of advanced aviation fuel and for gas grid injection

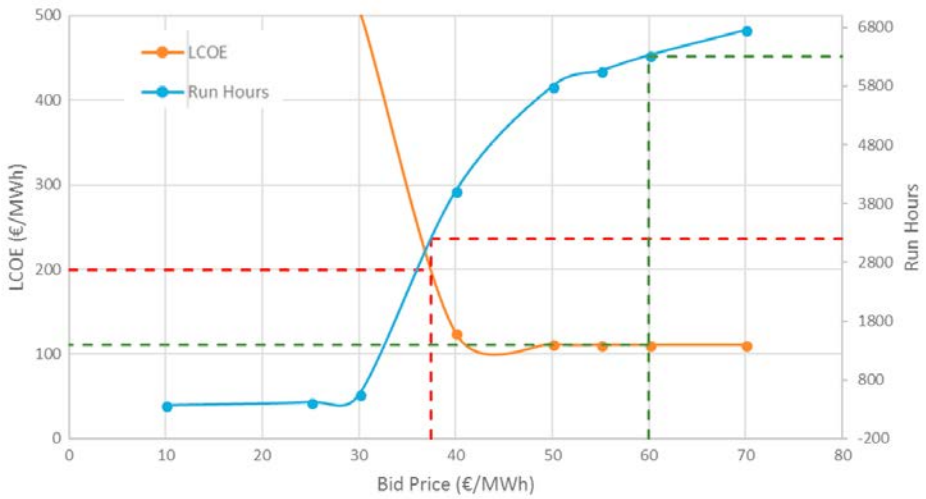
[1]A Persoectinve on the potential role of biogas in smart energy grids. Persson T, Murphy J, Jannasch A, Ahern E, Libertrau J, Trommler M, Toyama J. IEA Bioenergy Task 37. 2014

[2]https://www.heiderefinery.com/en/press/press-detail/cross-sector-partnership-green-hydrogen-and-decarbonization-on-an-industrial-scale/

Power to Hydrogen: Operation



McDonagh S, Deane P, Rajendran K, Murphy JD. Are electrofuels a sustainable transport fuel? Analysis of the effect of controls on carbon, curtailment, and cost of hydrogen. Appl Energy 2019;247:716–30. doi:10.1016/j.apenergy.2019.04.060.



Cannot use only “curtailed “ electricity (Lack of run hours)

Bid for electricity based on;

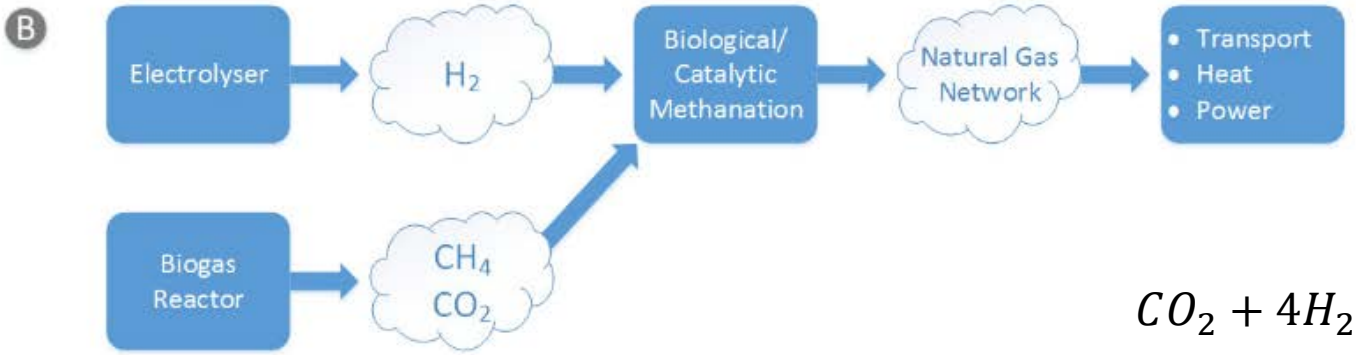
1. Max price
2. Minimum VRE on Electricity Grid

Allows for use of curtailed electricity (low price) and viable economics (higher run hours)

Power to Gas: Methane

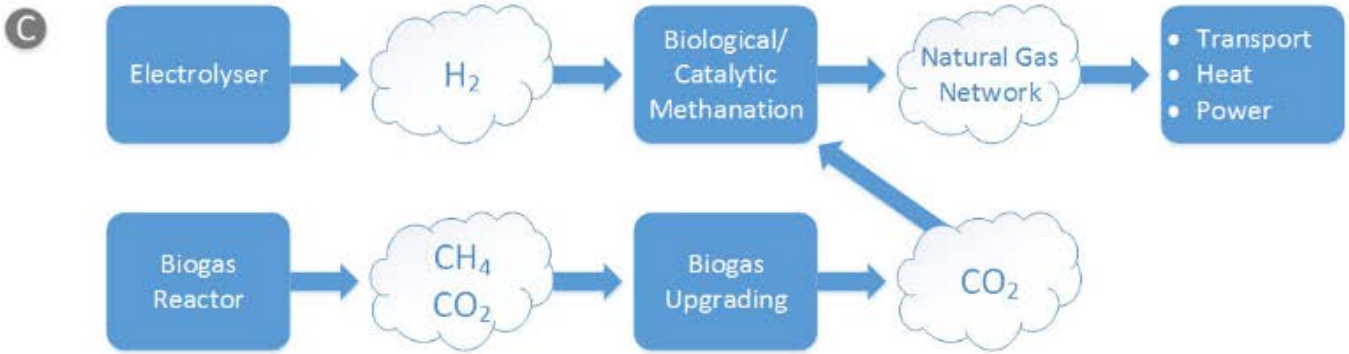
In-situ Methanation: Biological

Ex-situ Methanation: Biological or Catalytic



$$CO_2 + 4H_2 \rightarrow CH_4 + 4H_2O$$

Ex-situ Methanation: Use of "pure" CO_2?



Power to Gas: Catalytic Methanation

Audi E-gas at Wertle, Germany

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

Food waste biomethane

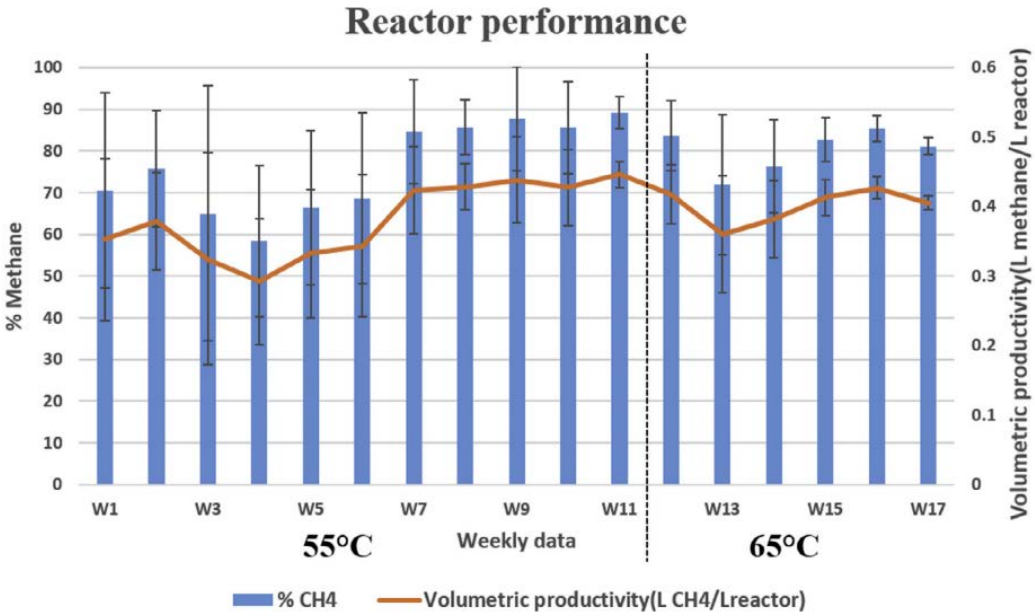
Production of hydrogen in 6 MW electrolysis

Production of methane via Sabatier

1000 Audi NGVs

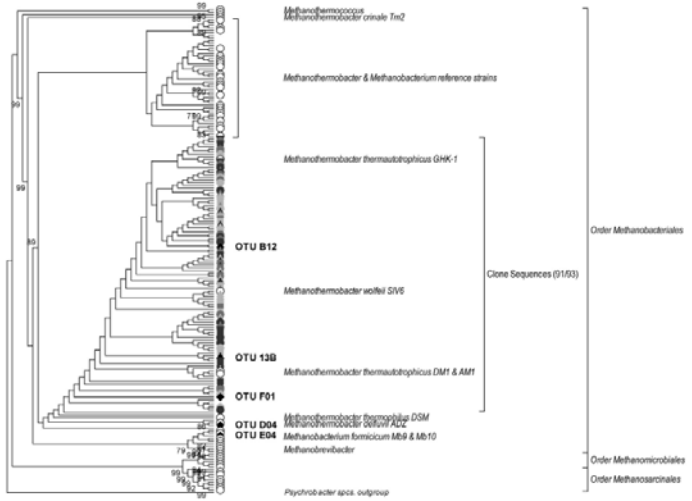
Reaction is exothermic
Required conditions of low temperature and high pressure
Couple with SOEC

Power to Gas: Biological Methanation



88%CH_4 MFR: 0.45L/$L_{Reactor}$

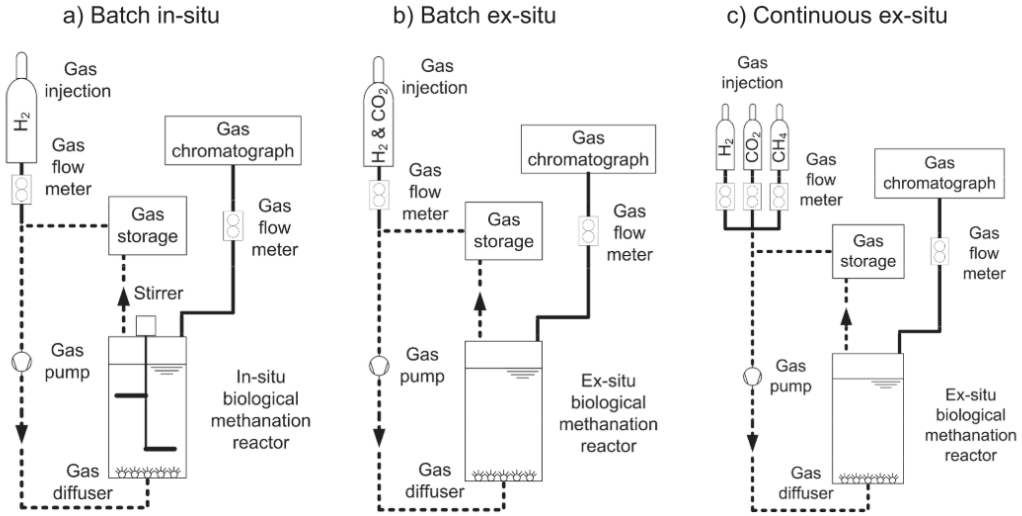
85%CH_4 MFR: 0.40L/$L_{Reactor}$



Methanothermobacter

Guneratnam AJ, Ahern E, FitzGerald JA, Jackson SA, Xia A, Dobson ADW, et al. Study of the performance of a thermophilic biological methanation system. Bioresour Technol 2017;225:308–15. doi:10.1016/j.biortech.2016.11.066.

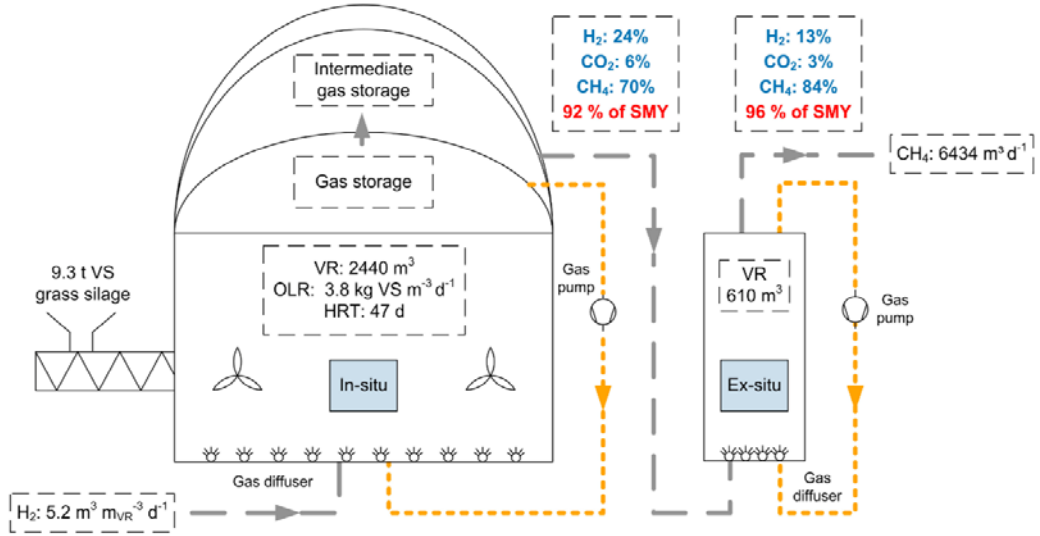
Power to Gas: Biological Methanation



VFA Inhibition of AD with in-situ methanation due to acetic and propionic acid accumulation

Methane formation rate inversely proportional to conversion efficiency

Hybrid in-situ & ex-situ biological methanation system



Voelklein MA, Rusmanis D, Murphy JD. Biological methanation : Strategies for in-si and ex-situ upgrading in anaerobic digestion. Appl Energy 2019;235:1061–71. doi:10.1016/j.apenergy.2018.11.006.

Power to Gas: Biological Methanation

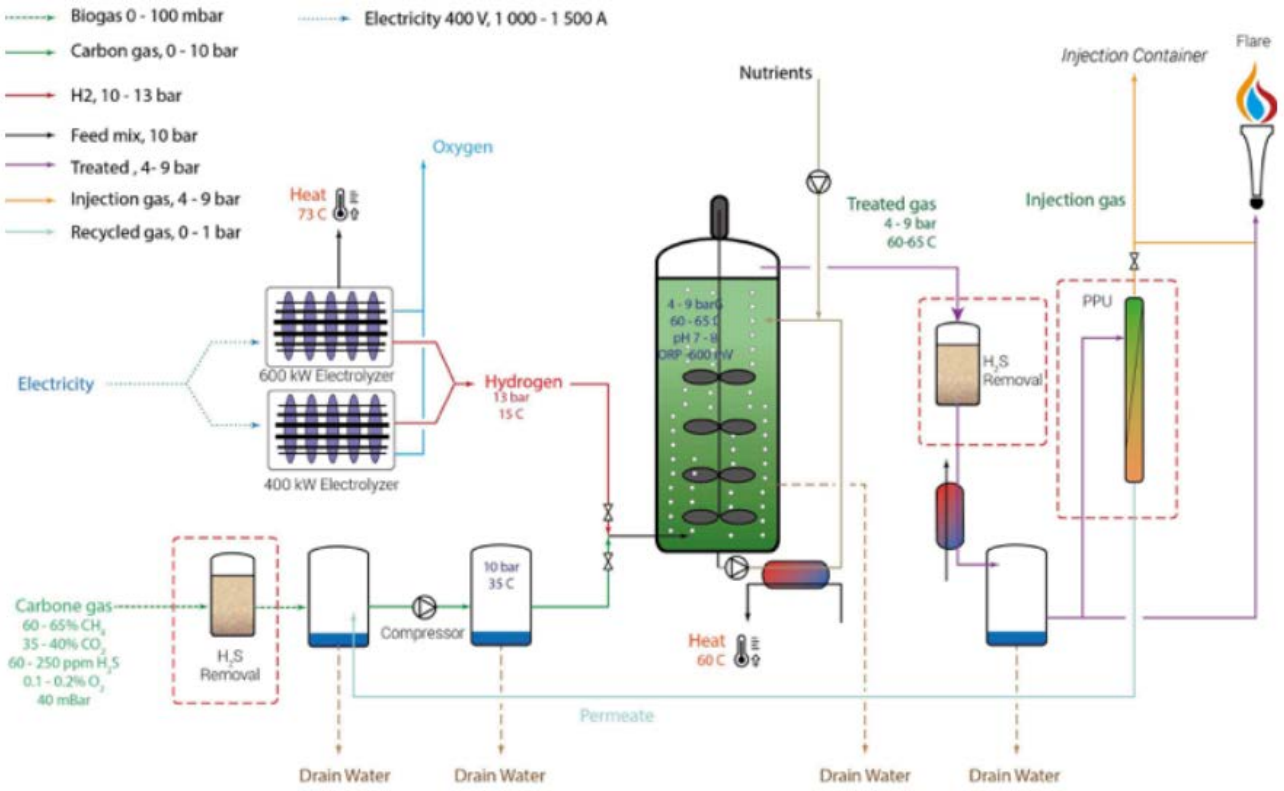
BioCat

1MW Capacity

42,193m^3 Biogas → 16,000m^3CO_2

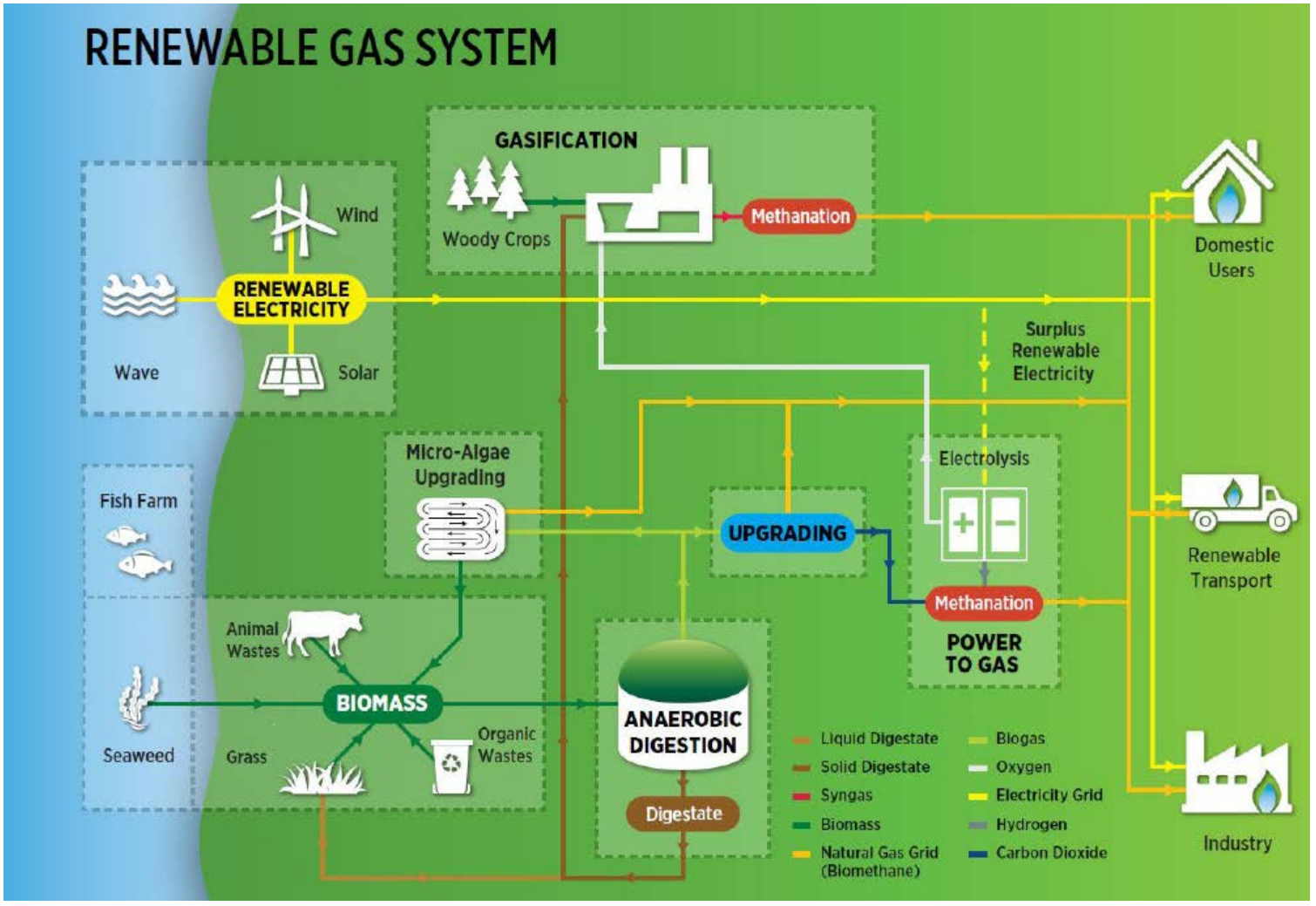
708,215kWh Electricity → 129,290m^3H_2

ca. 15,000m^3CH_4



https://energiforskning.dk/sites/energiteknologi.dk/files/slutrapporter/12164_final_report_p2g_biocat.pdf

Flexible Biogas Systems



Cascading circular bioenergy systems