The role of biomethane in supporting intermittent renewable electricity

Professor Jerry D Murphy
Director of MaREI centre
Chair of Civil, Structural & Environmental Engineering
Leader International Energy Agency Bioenergy Energy from Biogas Task 37

The Irish Bioenergy Association
National Conference 2019

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Bioenergy Future Ireland 2019
13th February 2019, Croke Park

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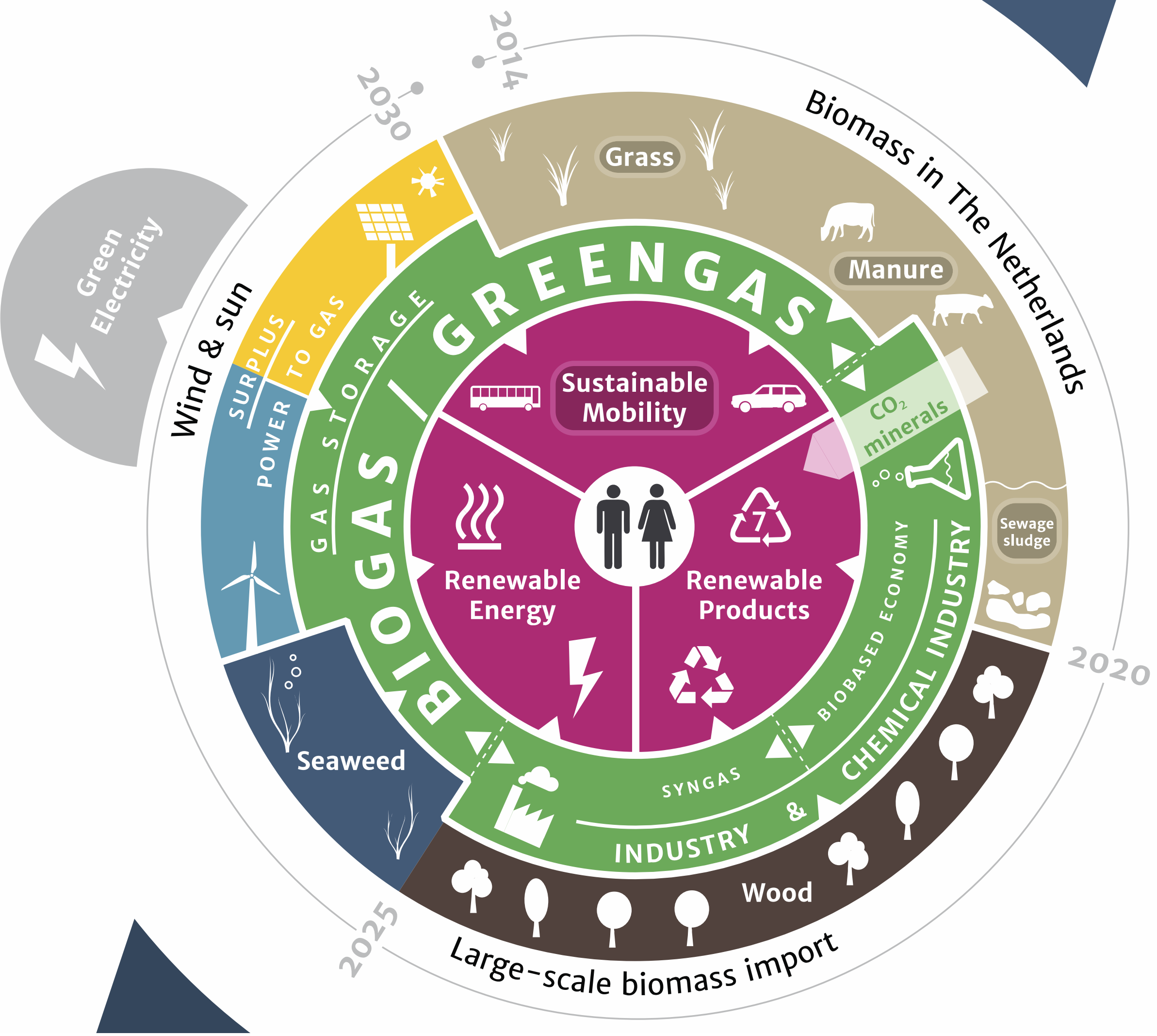
Mobilising Bioenergy with
Policy & Action

MaREI
Centre for Marine and Renewable Energy



6 European gas grids have committed to 100% green gas in the gas grid by 2050

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Centre for Marine and Renewable Energy

First stage of Industry

Digestion of wet organic biomass

Grass to transport fuel

harvest →

weigh bridge →

silage storage ↓

Biogas service station ← Scrubbing & storage ← anaerobic digester ← macerator

Source: energiewerkstatt, IEA and personal photos

Applied Energy 182 (2016) 394–408

Contents lists available at ScienceDirect

Applied Energy

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

Assessment of the impact of incentives and of scale on the build order and location of biomethane facilities and the feedstock they utilise

Richard O'Shea [a,b], David Wall [a,b,*], Ian Kilgallon [c], Jerry D. Murphy [a,b]

[a] MaREI Centre, Environmental Research Institute, University College Cork, Cork, Ireland
[b] School of Engineering, University College Cork, Cork, Ireland
[c] Gas Networks Ireland, Gasworks Road, Cork, Ireland

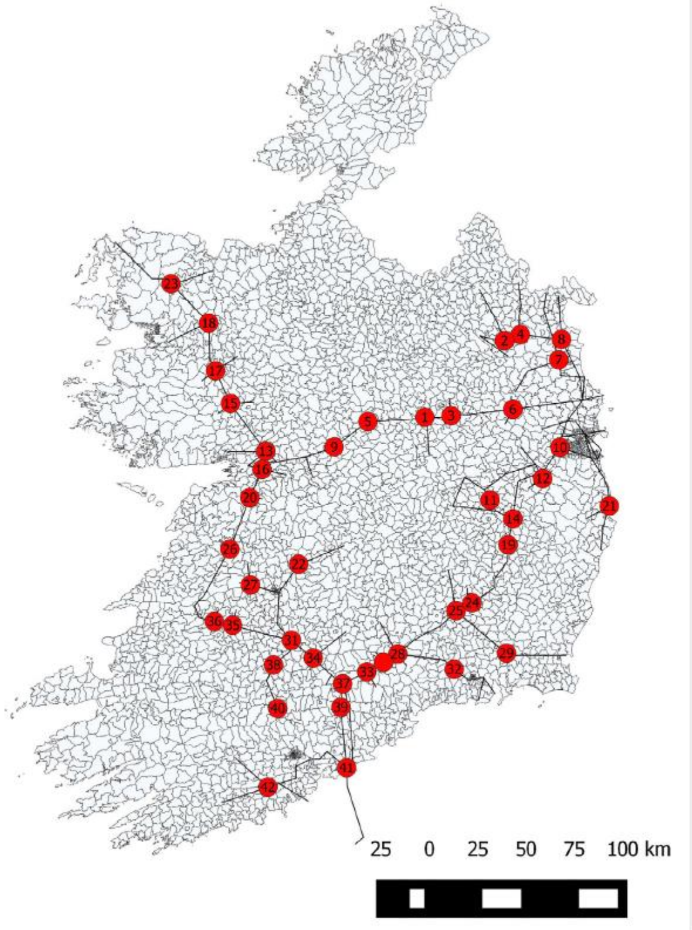


Fig. 1. Locations of potential biomethane injection points to the gas transmission network.

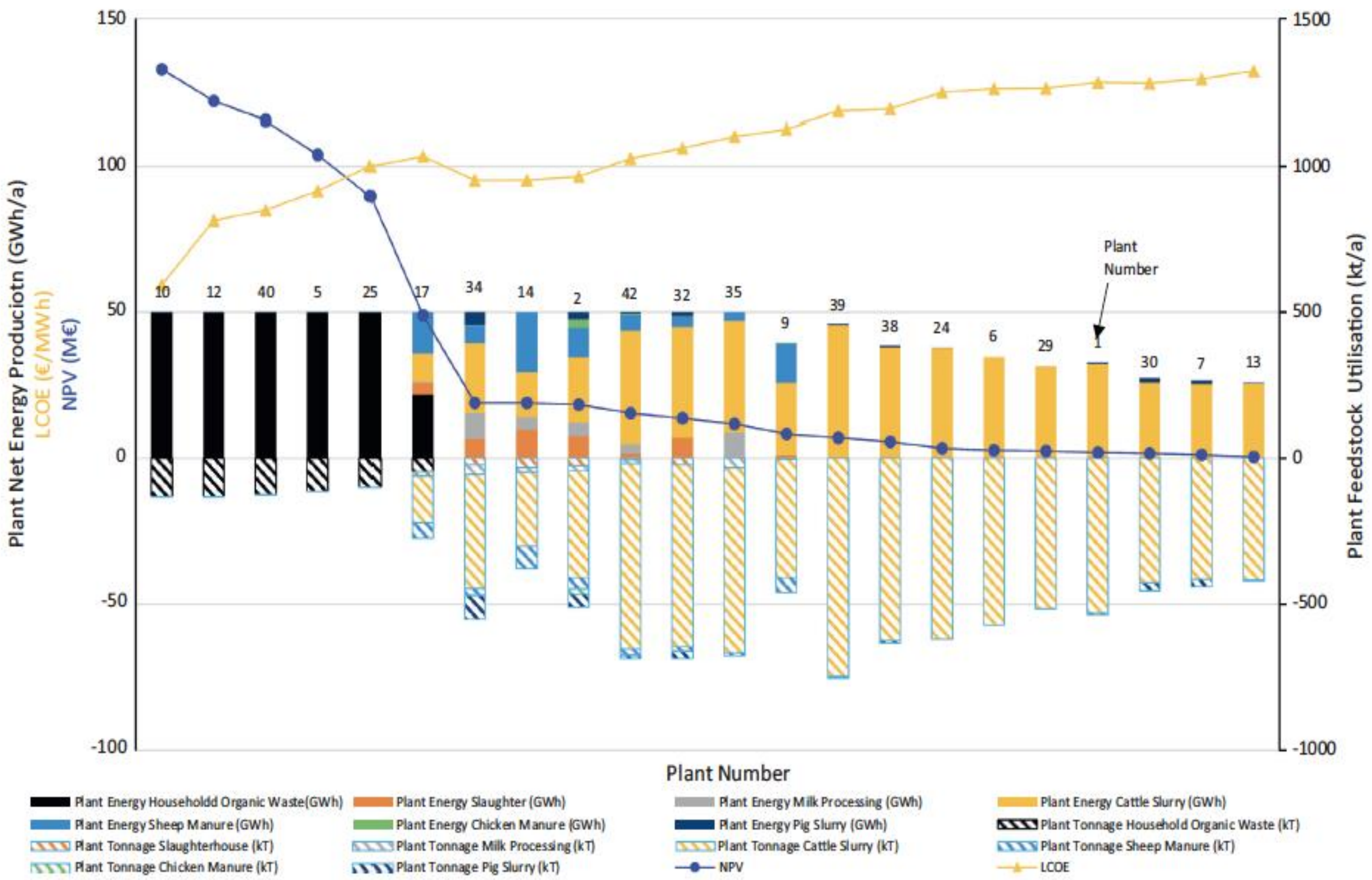


Fig. 6. Plant energy production, net present value (NPV), levelised cost of energy (LCOE), and feedstock utilisation for scenario 9a.

MaREI BIOENERGY: VIRTUAL PIPELINE

Applied Energy xxx (2019) xxx-xxx

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com

ELSEVIER

Feasibility study of an off-grid biomethane mobile solution for agri-waste

Laura Gil-Carrera[a,*], James D. Browne[a], Ian Kilgallon[a], Jerry D. Murphy[b,c]

[a] Gas Networks Ireland, Gasworks Road, Cork, Ireland
[b] MaREI Centre, Environmental Research Institute, University College Cork, Ireland
[c] School of Engineering, University College Cork, Ireland

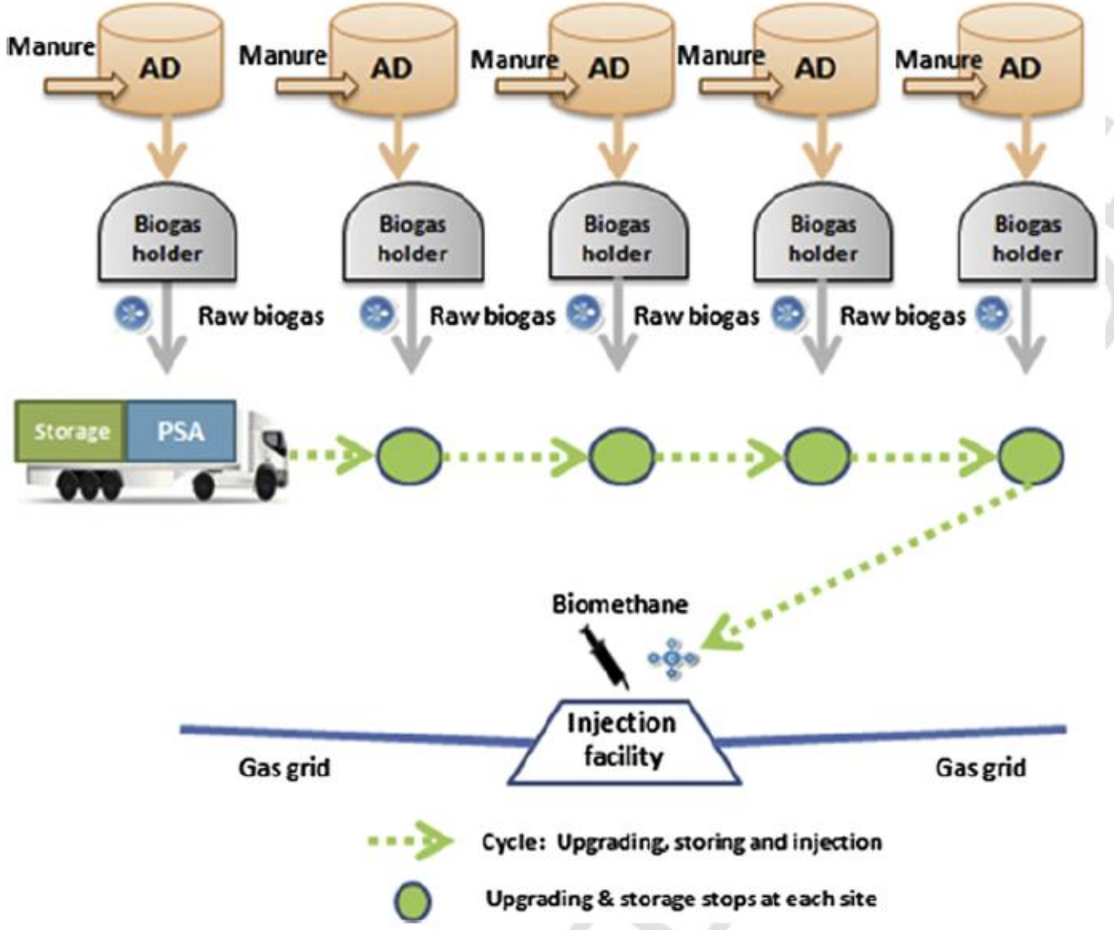
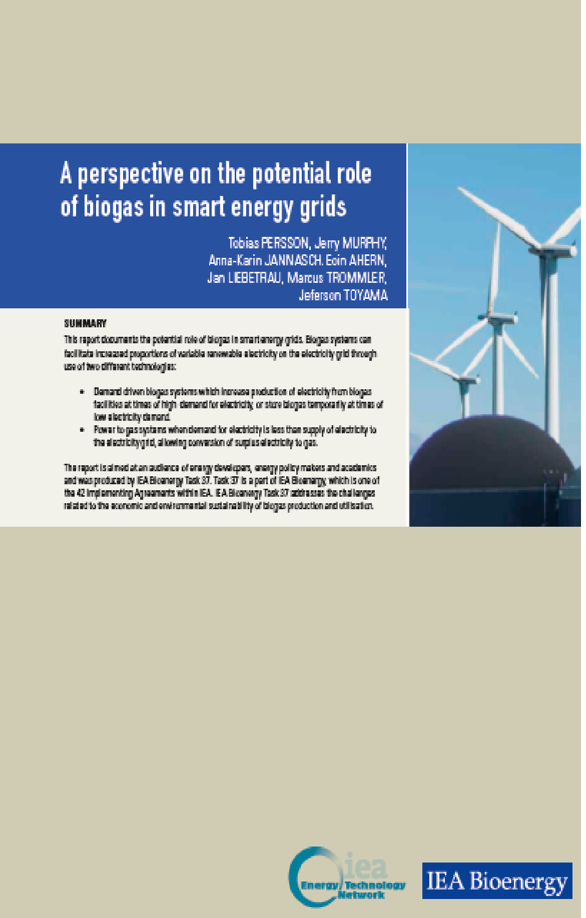


Fig. 3. Logistics of off-grid cooperative biomethane production applying mobile upgrading plant and storage tanks (mobile solution/virtual pipeline).


A perspective on the potential role of biogas in smart energy grids

Tobias PERSSON, Jerry MURPHY, Anna-Karin JANNASCH. Eoin AHERN, Jan LIEBETRAU, Marcus TROMMLER, Jeferson TOYAMA

SUMMARY

This report documents the potential role of biogas in smart energy grids. Biogas systems can facilitate increased proportions of variable renewable electricity on the electricity grid through use of two different technologies:

- Demand driven biogas systems which increase production of electricity from biogas facilities at times of high demand for electricity, or store biogas temporarily at times of low electricity demand.
- Power to gas systems when demand for electricity is less than supply of electricity to the electricity grid, allowing conversion of surplus electricity to gas.

The report is aimed at an audience of energy developers, energy policy makers and academics and was produced by IEA Bioenergy Task 37. Task 37 is a part of IEA Bioenergy, which is one of the 42 Implementing Agreements within IEA. IEA Bioenergy Task 37 addresses the challenges related to the economic and environmental sustainability of biogas production and utilisation.

iea Energy Technology Network

IEA Bioenergy

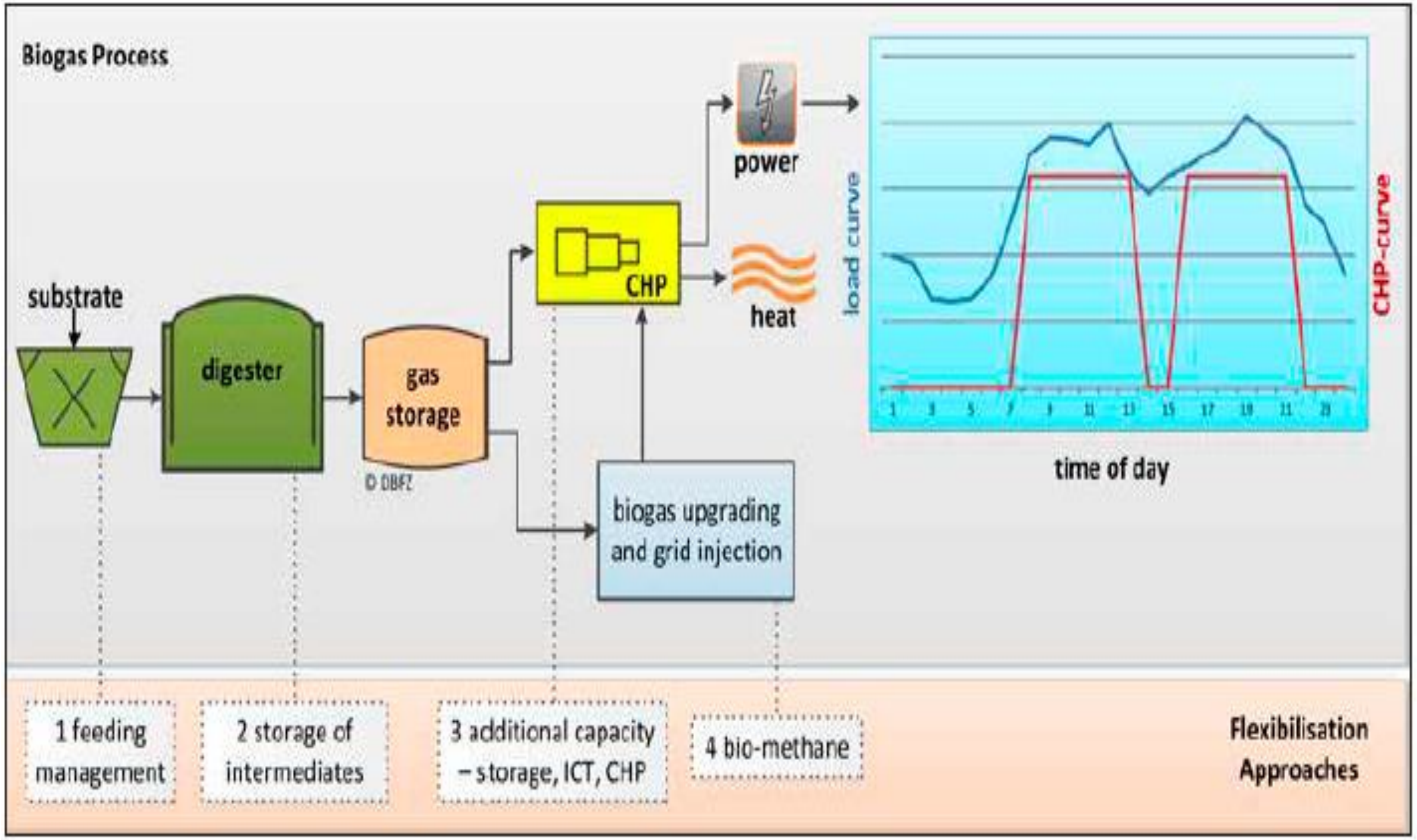
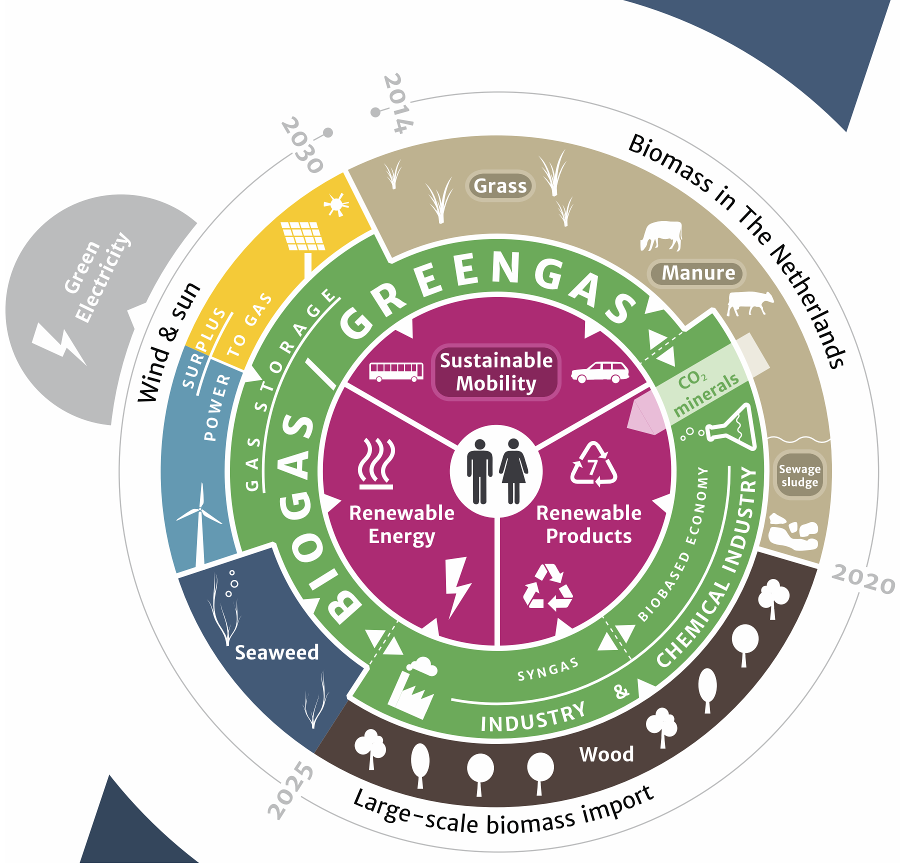


Figure 6: Approaches for biogas-based demand driven power production (Szarka et al, 2013)



Second stage of Industry

Green Gas from gasification of woody crops

Gothenburg Biomass Gasification Project (GoBiGas)

MaREI
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Applied Energy 108 (2013) 158–167

Contents lists available at SciVerse ScienceDirect

Applied Energy

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

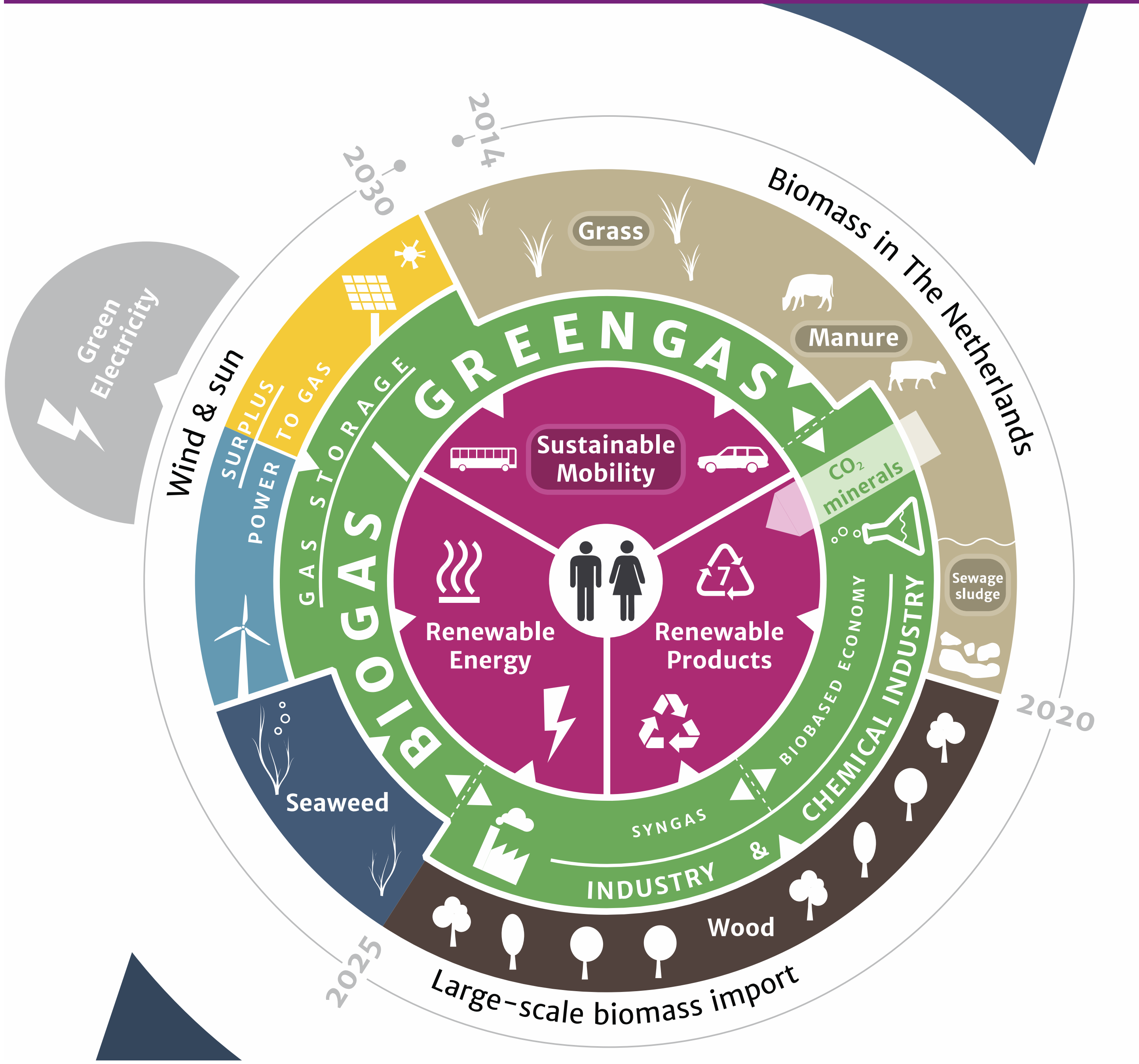
What is the realistic potential for biomethane produced through gasification of indigenous Willow or imported wood chip to meet renewable energy heat targets?

Cathal Gallagher[a], Jerry D. Murphy[b,c,*]

Plant Size MW	50
Land area (ha)	6800
Number of plants required	11
As a % Energy in Transport	5.5%
As a % of agricultural land	1.7%

Third stage of Industry

Green Gas from seaweed



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Centre for Marine and Renewable Energy

Waste Management 33 (2013) 2425–2433

Contents lists available at SciVerse ScienceDirect

Waste Management

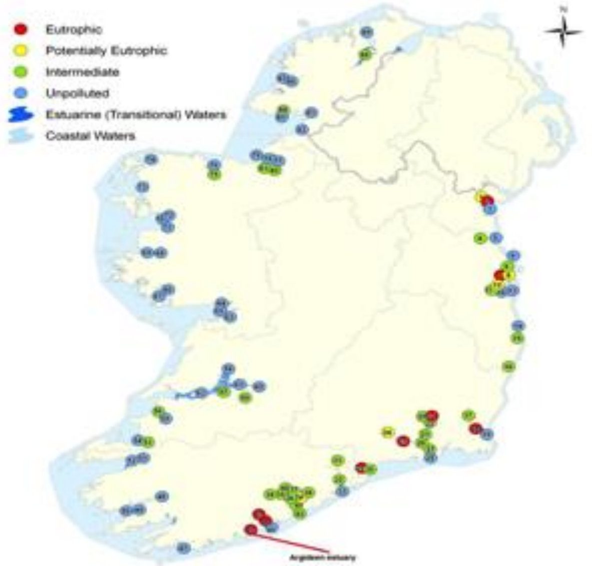
journal homepage: www.elsevier.com/locate/wasman

MaREI BIOENERGY: SEAWEED

The potential of algae blooms to produce renewable gaseous fuel

E. Allen [a], J. Browne [a], S. Hynes [a], J.D. Murphy [a,b,*]

[a] Environmental Research Institute, University College Cork, Cork, Ireland
[b] Department of Civil and Environmental Engineering, University College Cork, Cork, Ireland



Bioresource Technology 209 (2016) 213–219

Contents lists available at ScienceDirect

Bioresource Technology

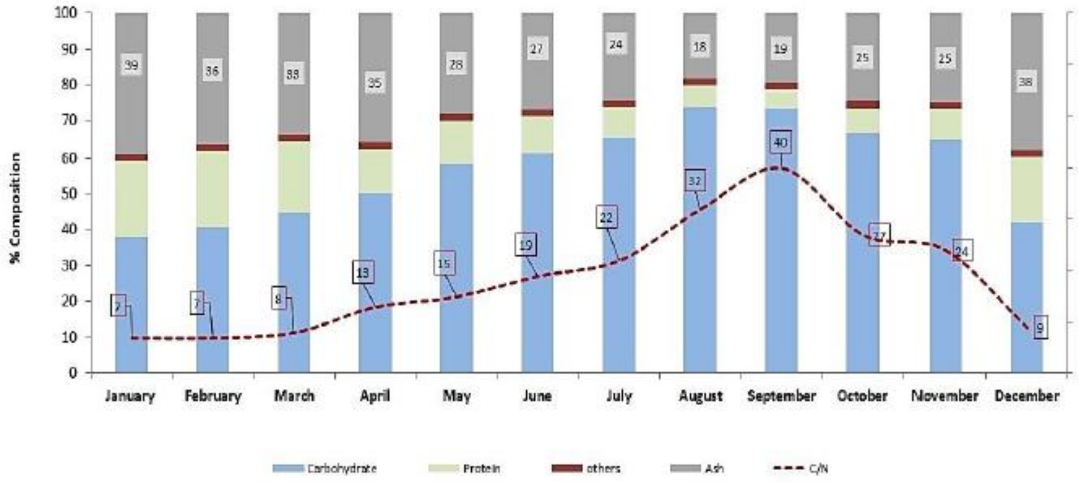
journal homepage: www.elsevier.com/locate/biortech

MaREI BIOENERGY: SEAWEED

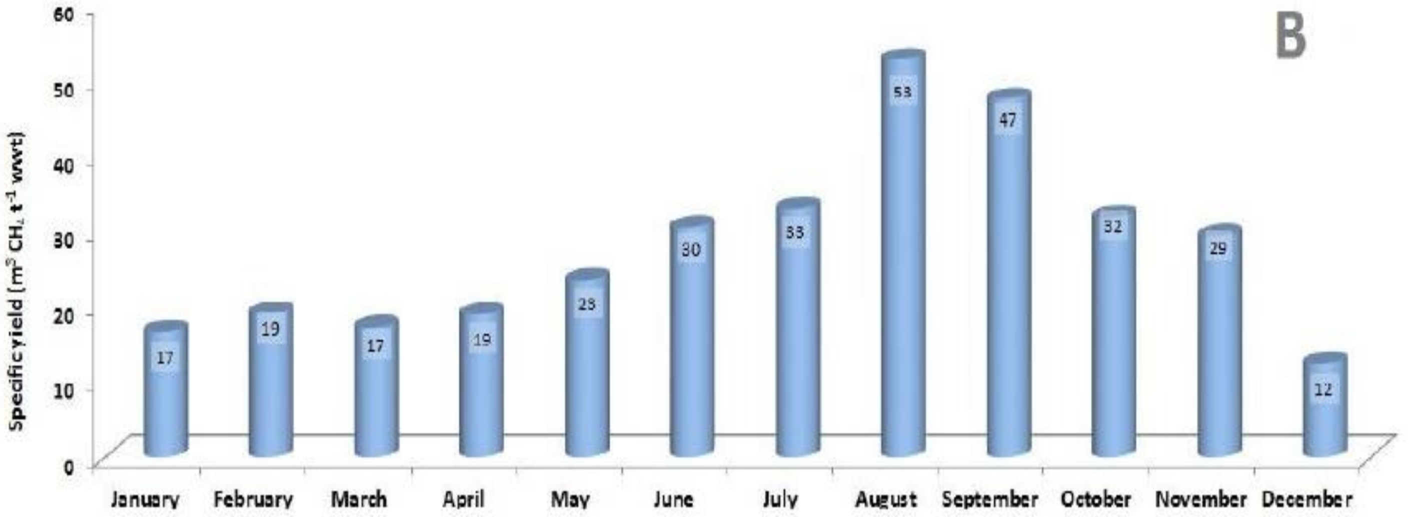
The effect of seasonal variation on biomethane production from seaweed and on application as a gaseous transport biofuel

Muhammad Rizwan Tabassum [a], Ao Xia [b,*], Jerry D. Murphy [a,c]

[a] MaREI Centre, Environmental Research Institute, University College Cork, Cork, Ireland
[b] Key Laboratory of Low-grade Energy Utilization Technologies and Systems, Chongqing University, Chongqing 400044, China
[c] School of Engineering, University College Cork, Cork, Ireland



Seasonal Variation in composition of Laminaria Digitata



Seasonal Variation in biomethane yield from Laminaria Digitata

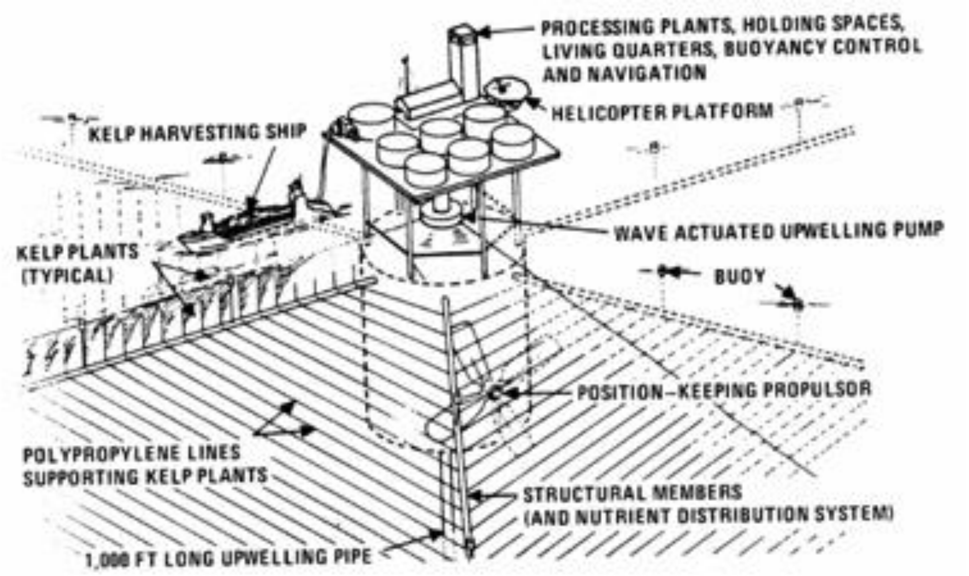


Figure 1. Conceptual design of 405 ha (1,000 acre) ocean food and energy farm unit. (Leese 1976) Source: David Chynoweth.

Position adjacent to fish farms, protect fish from jelly fish

Increased yields of seaweed as compared to pristine waters

Clean water of excess nutrients

Harvest when yield is highest

Bioresource Technology 196 (2015) 301–313

Contents lists available at ScienceDirect

Bioresource Technology

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

ELSEVIER

Ensiling of seaweed for a seaweed biofuel industry

CrossMark

Christiane Herrmann [a], Jamie FitzGerald [a], Richard O'Shea [a], Ao Xia [a], Pádraig O'Kiely [b], Jerry D. Murphy [a,*]

[a] Science Foundation Ireland (SFI), Marine Renewable Energy Ireland (MaREI), Environmental Research Institute, School of Engineering, University College Cork, Cork, Ireland
[b] Teagasc Animal & Grassland Research and Innovation Centre, Grange, Dunsany, Co. Meath, Ireland

Higher methane yields after ensiling can compensate for silage fermentation losses.

No losses in methane yield occurred during 90 day storage for 4 of 5 species.

Applied Energy 196 (2017) 34–50

Contents lists available at ScienceDirect

Applied Energy

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

Life cycle assessment of seaweed biomethane, generated from seaweed sourced from integrated multi-trophic aquaculture in temperate oceanic climates

Magdalena M. Czyrnek-Delêtre [a,b,*], Stefania Rocca [c], Alessandro Agostini [d,e], Jacopo Giuntoli [c], Jerry D. Murphy [a,b]

Sustainability criteria require

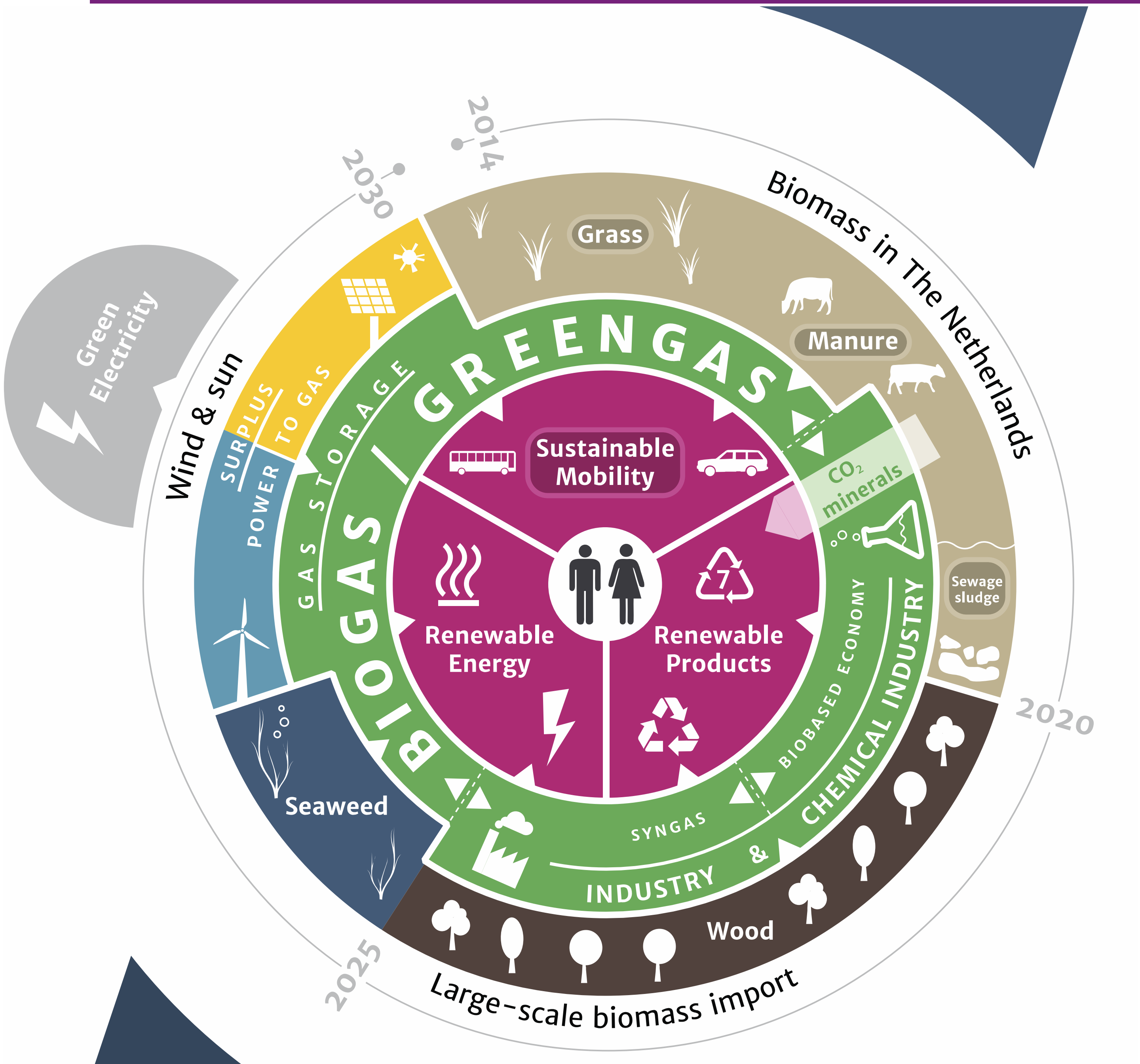
Bioenergy with Carbon Capture Sequestration (BECCS)

Or

Bioenergy with Carbon Capture and Reuse

Fourth stage of Industry

Green Gas from electricity



MaREI Centre for Marine and Renewable Energy

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

MaREI Centre for Marine and Renewable Energy

Cascading bioenergy, circular economy, carbon capture.

MaREI BIOENERGY: ELECTROFUELS

Bioresource Technology xxx (2016) xxx-xxx

Contents lists available at ScienceDirect

ELSEVIER

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, *]

[a] The MaREI Centre, Environmental Research Institute, University College Cork, Ireland
[b] School of Engineering, University College Cork, Ireland
[c] Key Laboratory of Low-grade Energy Utilisation Technologies and Systems, Chongqing University, Chongqing 400044, China
[d] School of Microbiology, University College Cork, Ireland

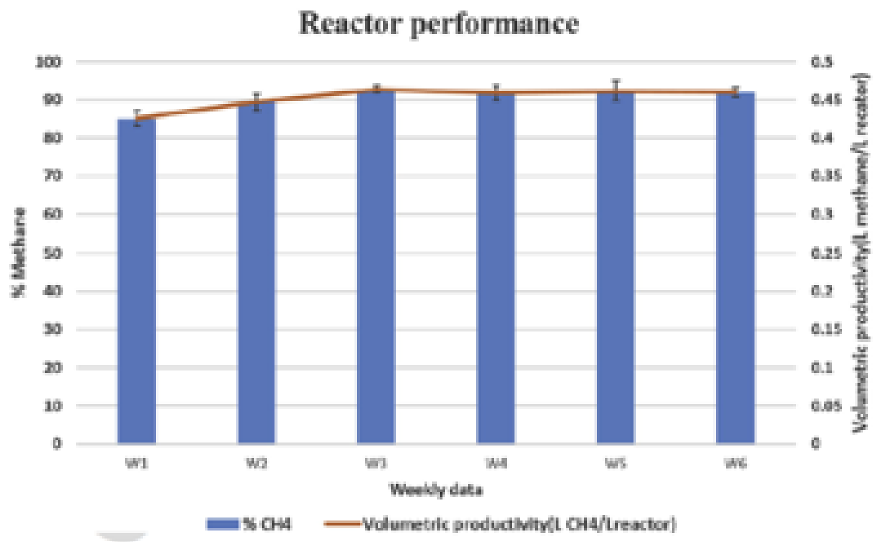


Fig. 3. Methane composition and volumetric productivity at 65 °C (fresh inoculum) for 24 h.

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

MaREI BIOENERGY: ELECTROFUELS

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

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

MaREI Centre, Environmental Research Institute (ERI), University College Cork (UCC), Ireland
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.

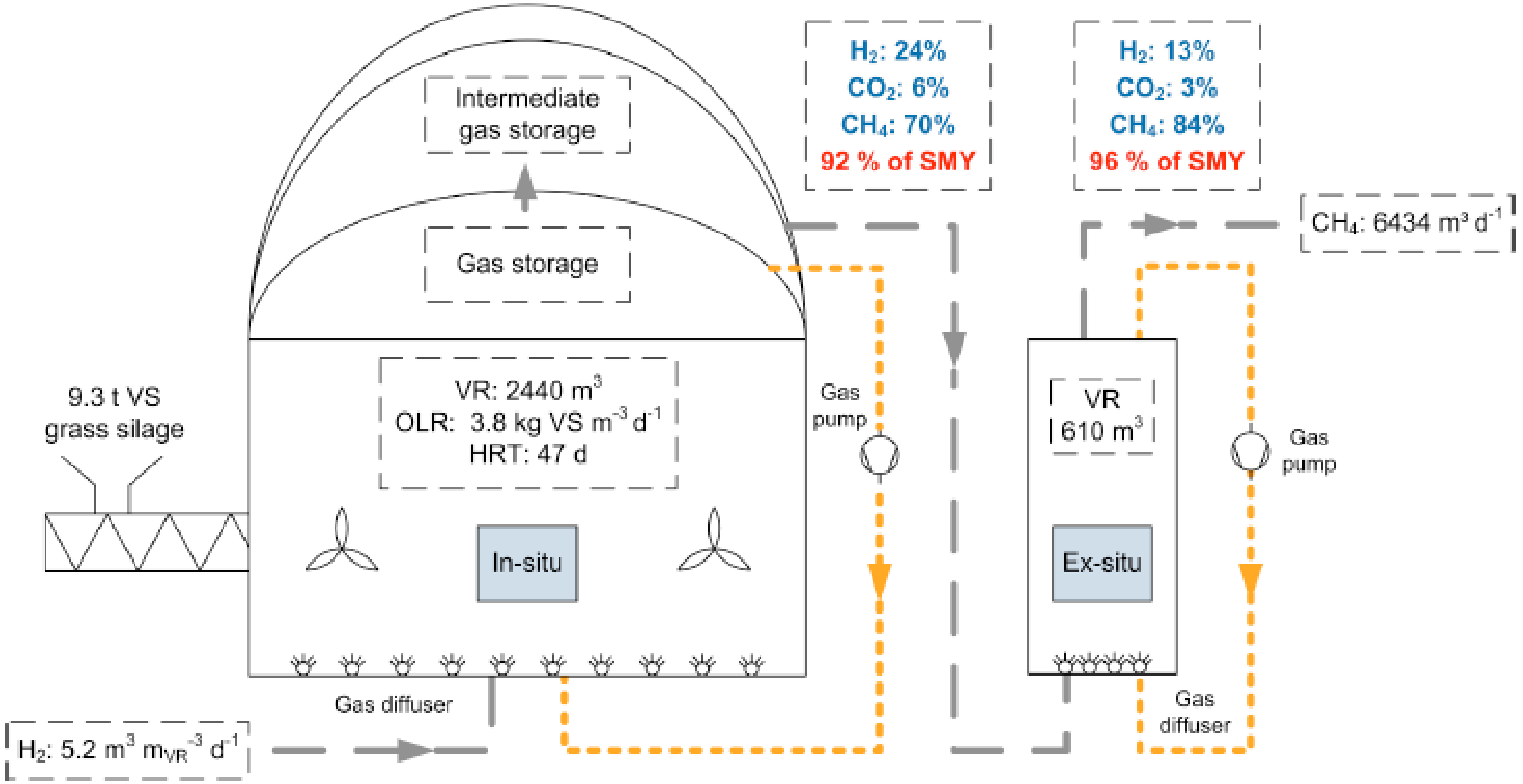


Fig. 7. Hybrid concept of sequential in-situ and ex-situ methanation with triple gas storage membrane on top of in-situ digester (SMY: specific methane yield, VR: reactor volume, OLR: organic loading rate, HRT: hydraulic retention time, VS: volatile solids).

MaREI BIOENERGY: ELECTROFUELS

Applied Energy 215 (2018) 444–456

Contents lists available at ScienceDirect

Applied Energy

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

Modelling of a power-to-gas system to predict the levelised cost of energy of an advanced renewable gaseous transport fuel

Shane McDonagh[a,b,c], Richard O'Shea[a,b,c], David M. Wall[a,b], J.P. Deane[a,b], Jerry D. Murphy[a,b,*]

[a] MaREI Centre, Environmental Research Institute, University College Cork, Ireland
[b] School of Engineering, University College Cork, Ireland
[c] Gas Networks Ireland, Cork, Ireland

HIGHLIGHTS

- LCOEs of €124/MWh in 2020, €105/MWh in 2030, and €93/MWh in 2040 were found.
- Electricity is by far the largest contributor to the LCOE of a P2G system.
- Zero cost electricity for 6500 h/annum leads to an LCOE of €55/MWh.
- A 20% fall in LCOE requires a drop of 76.2% in CAPEX or 35.9% in electricity costs.
- Integration, secondary incomes, and incentives are essential for competitive P2G.

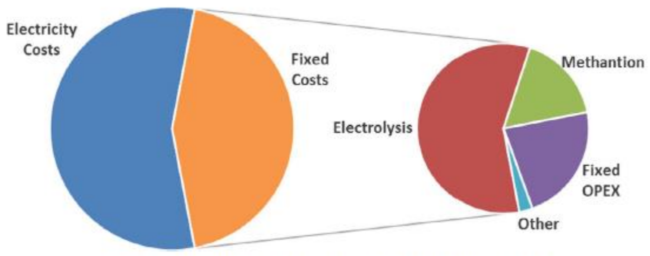


Fig. 3. Breakdown of the system LCOE into its components for 2020 base scenario.

Renewable Energy 131 (2019) 364–371

Contents lists available at ScienceDirect

Renewable Energy

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

The effect of electricity markets, and renewable electricity penetration, on the levelised cost of energy of an advanced electro-fuel system incorporating carbon capture and utilisation

Shane McDonagh [a,b,c], David M. Wall [a,b], Paul Deane [a,b], Jerry D. Murphy [a,b,*]

[a] MaREI Centre, Environmental Research Institute, University College Cork, Ireland
[b] School of Engineering, University College Cork, Ireland
[c] Gas Networks Ireland, Cork, Ireland

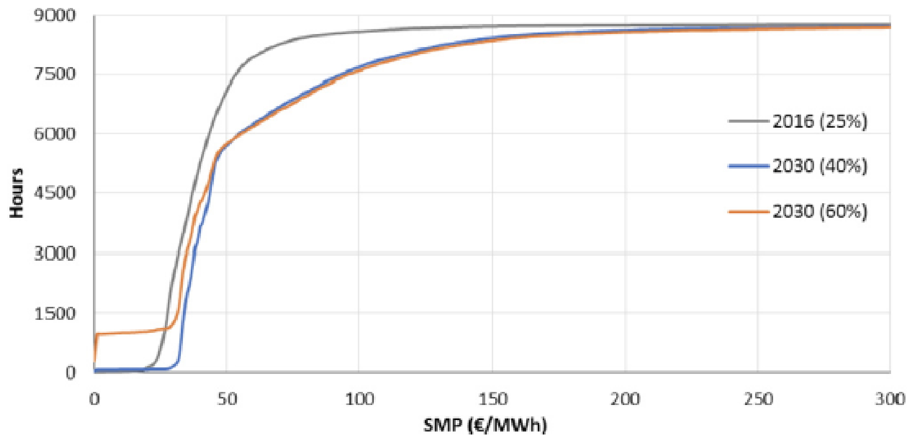


Fig. 3. Cumulative number of hours for which electricity is available at a given SMP.

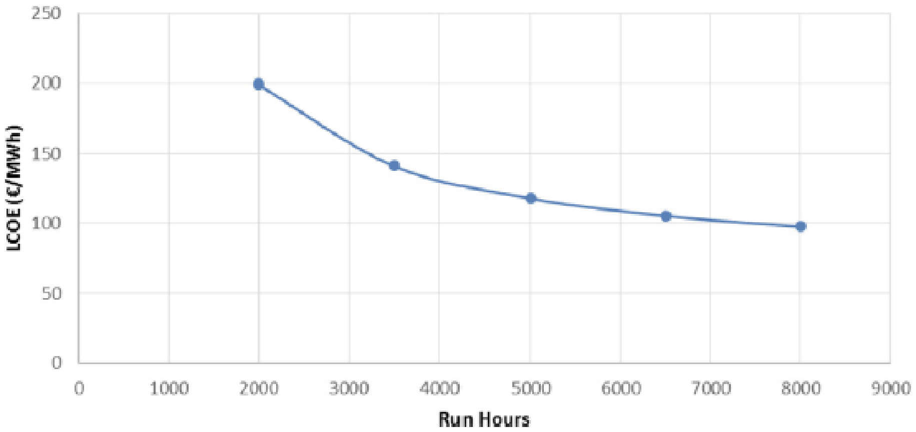


Fig. 7. Change in LCOE with increasing run hours and a fixed cost of electricity of €35/ $MW_e h$.

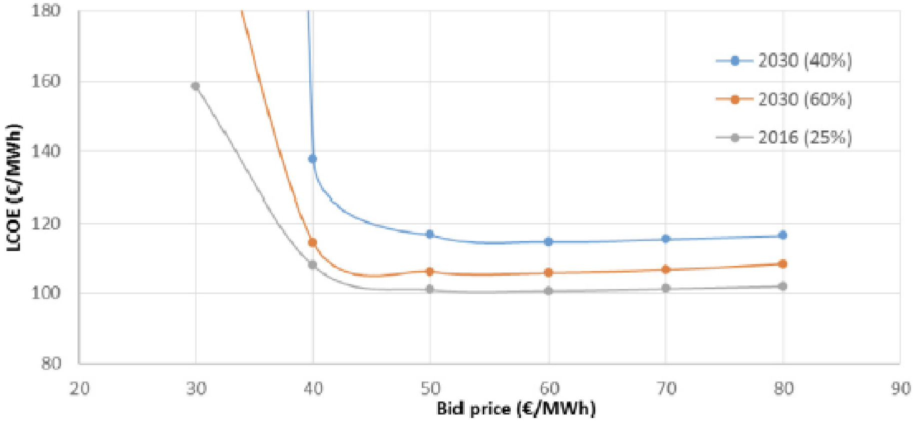


Fig. 8. Change in LCOE with increasing bid price including for associated variation in run hours and average cost of electricity.

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?

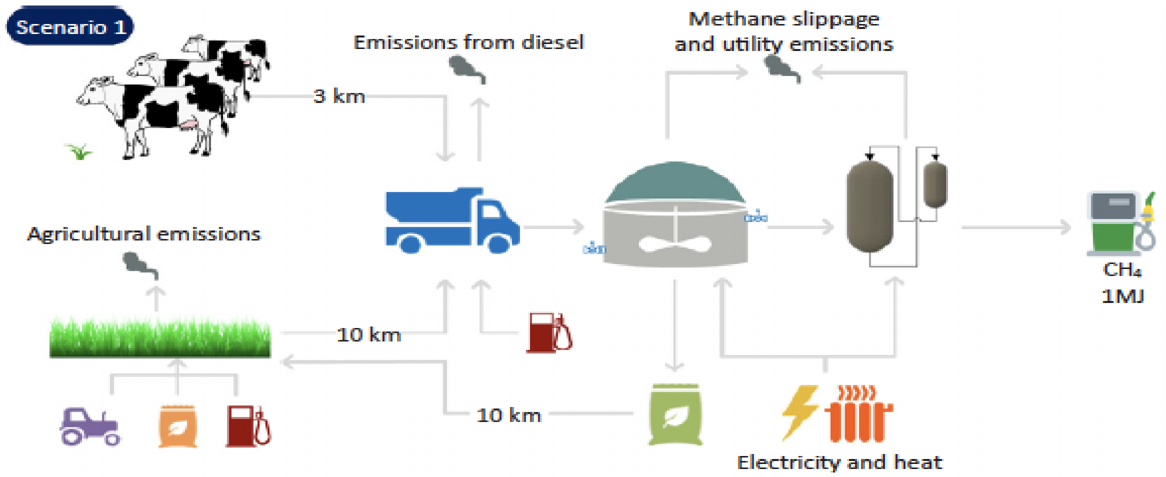
Truc T.Q. Vo, Karthik Rajendran*, Jerry D. Murphy

MaREI Centre, Environmental Research Institute, University College Cork, Cork, Ireland
School of Engineering, University College Cork, Cork, Ireland

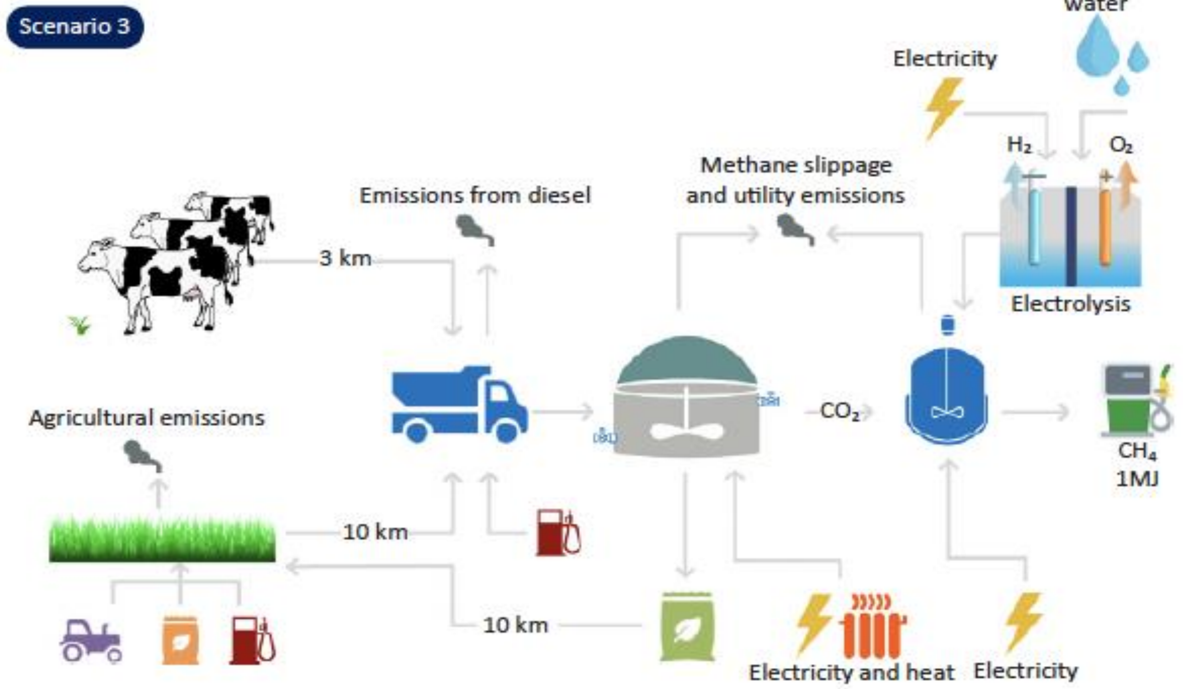
HIGHLIGHTS

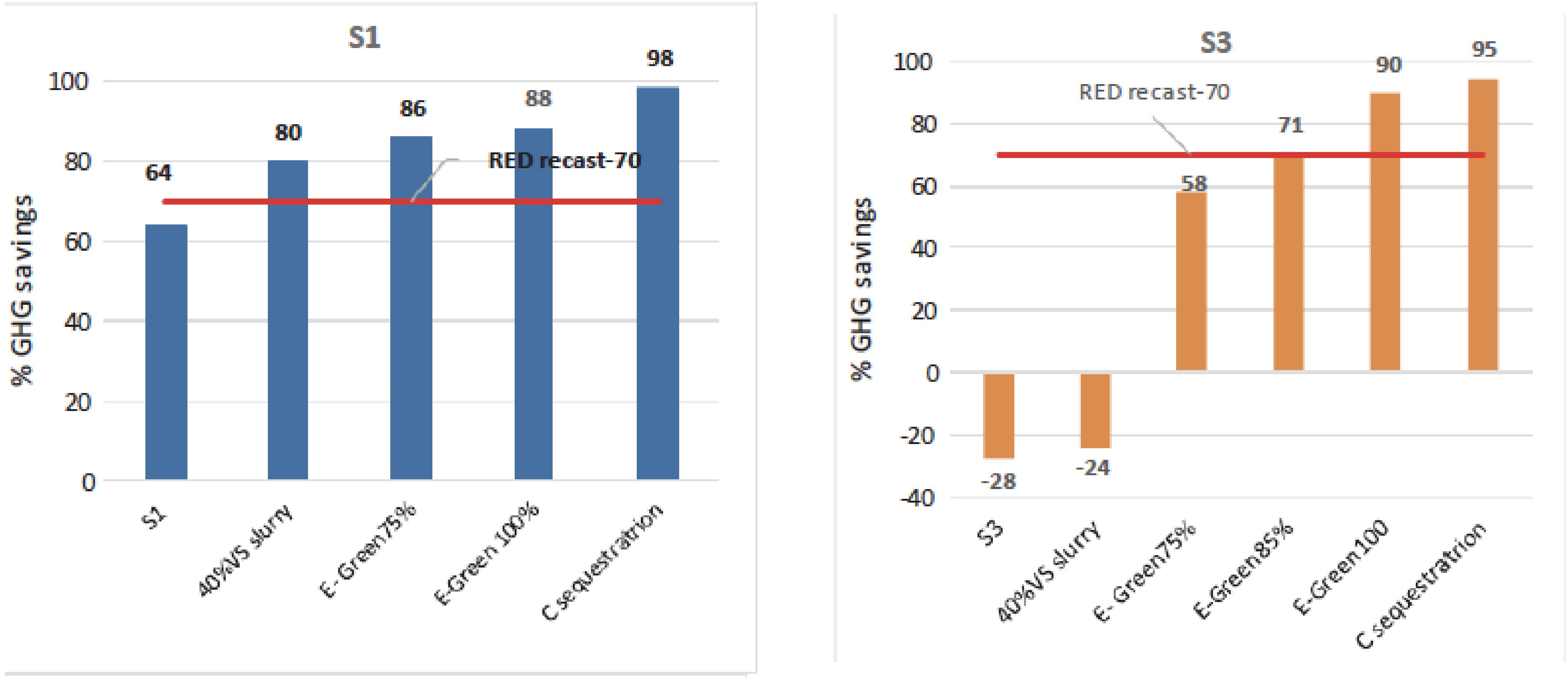
- Increasing the slurry to grass ratio improves sustainability of biogas.
- Power to gas (P2G) can be used to upgrade biogas to biomethane.
- The carbon intensity of hydrogen is higher than the electricity it is produced from.
- P2G systems using the Irish electricity mix reduce sustainability of biomethane.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

MaREI BIOENERGY: ELECTROFUELS

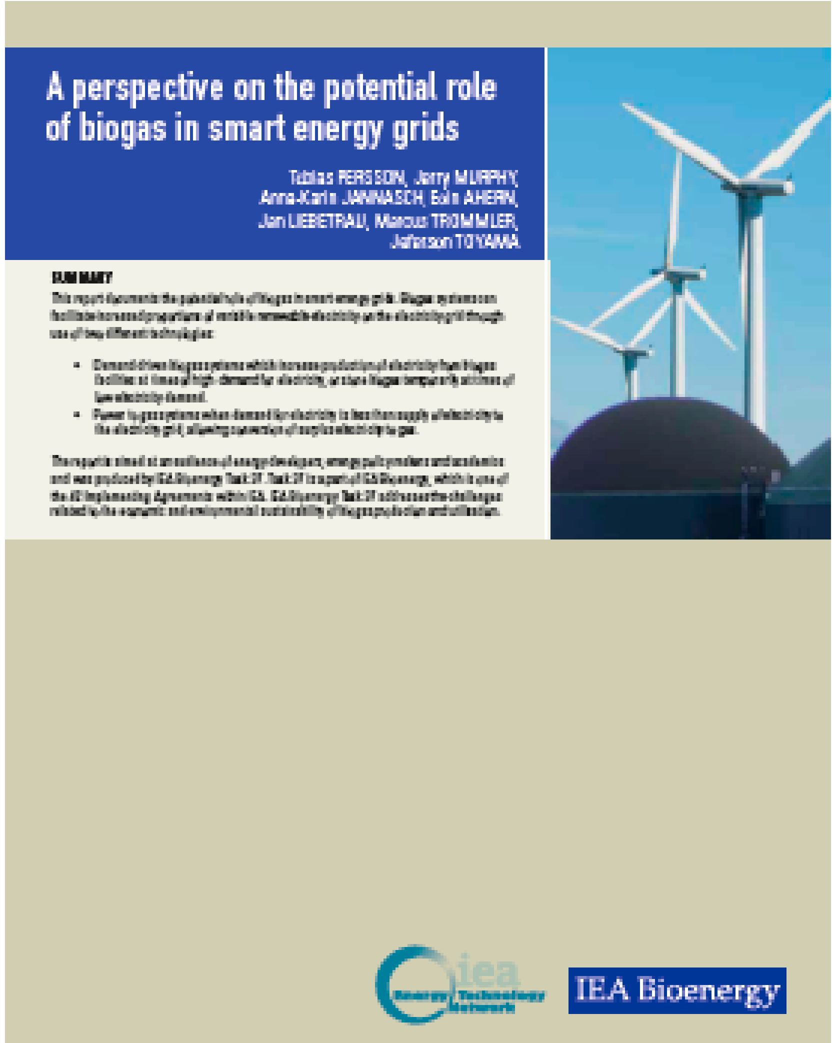


Bioenergy with Carbon Capture (BECCS)





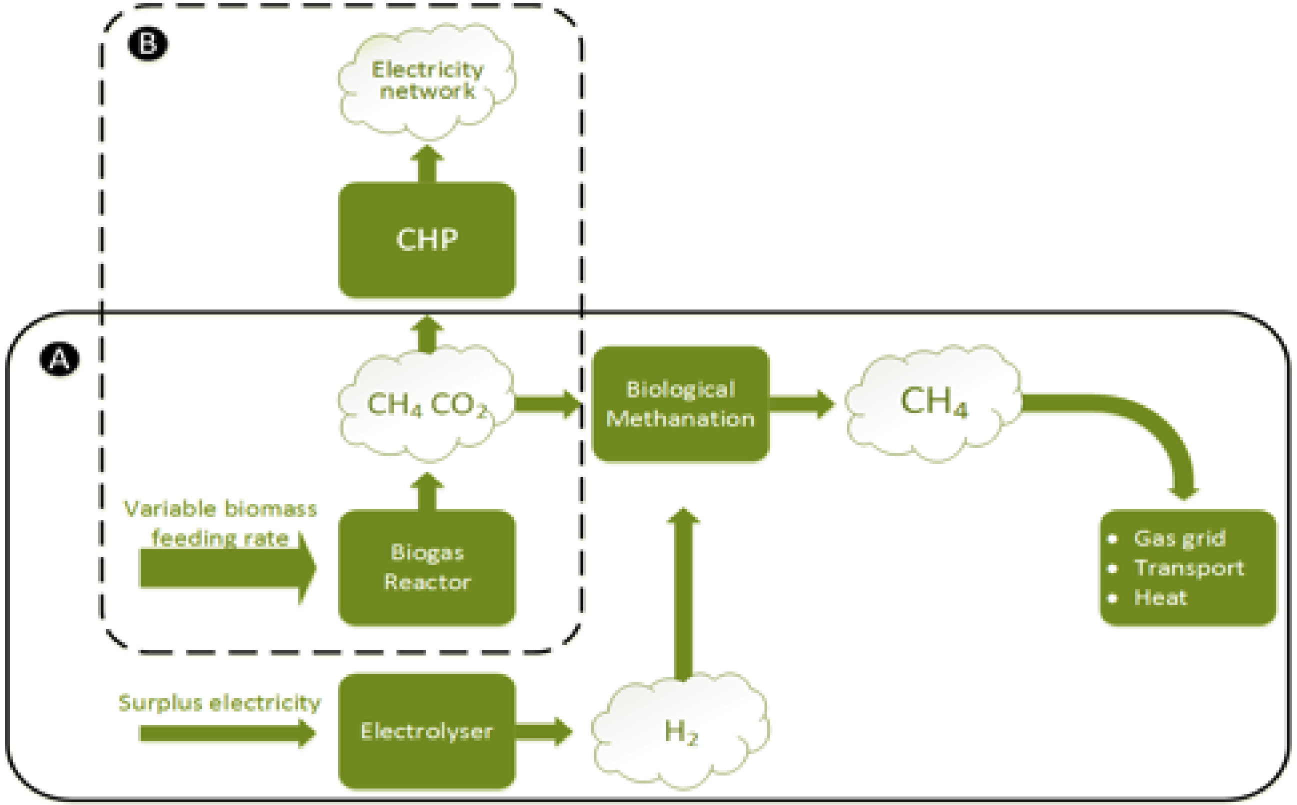
Base case 80:20 Grass: slurry on a VS basis; 2% fugitive CH4 losses: 41% green electricity
Sequestration of 2.2tCO2/ha/a considered


A perspective on the potential role of biogas in smart energy grids

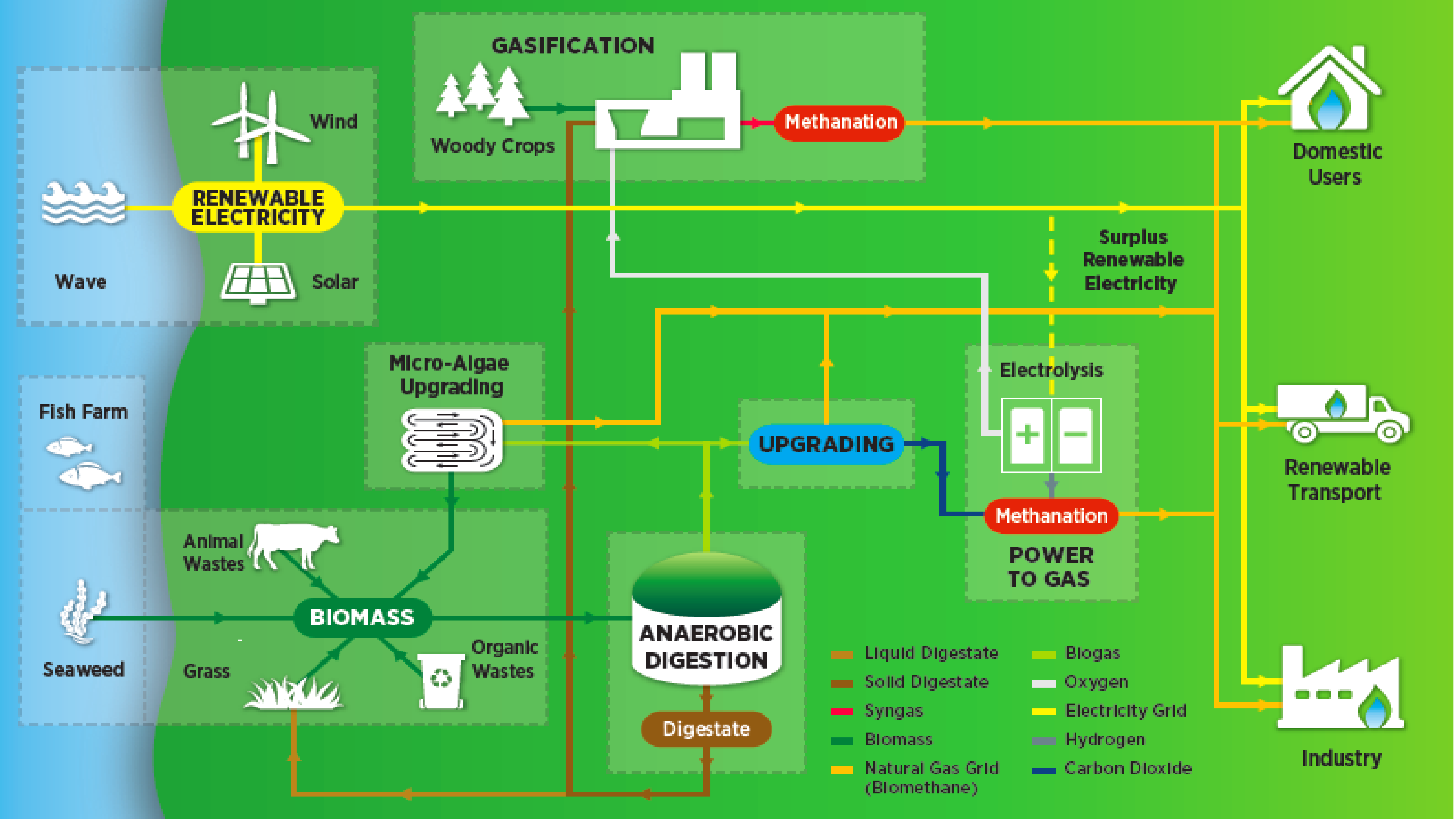
Tobias PERSSON, Jerry MURPHY, Anna-Karin JANNASCH, Eoin AHERN, Jan LIEBETRAU, Marcus TROMMLER, Jeferson TOYAMA

SUMMARY

IEA Bioenergy



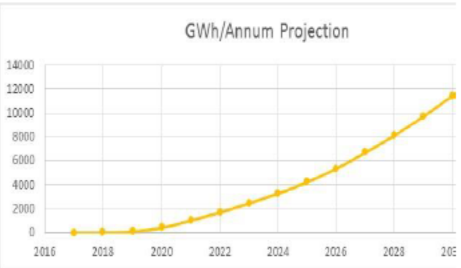
Combining demand driven biogas with Power to Gas


GASIFICATION
Woody Crops
Methanation
Wind
RENEWABLE ELECTRICITY
Wave
Solar
Domestic Users
Surplus Renewable Electricity
Micro-Algae Upgrading
Fish Farm
Electrolysis
UPGRADING
Renewable Transport
Methanation
POWER TO GAS
Animal Wastes
BIOMASS
Seaweed
Grass
Organic Wastes
ANAEROBIC DIGESTION
Digestate
Liquid Digestate
Solid Digestate
Syngas
Biomass
Natural Gas Grid (Biomethane)
Biogas
Oxygen
Electricity Grid
Hydrogen
Carbon Dioxide
Industry

GNI CASE STUDY

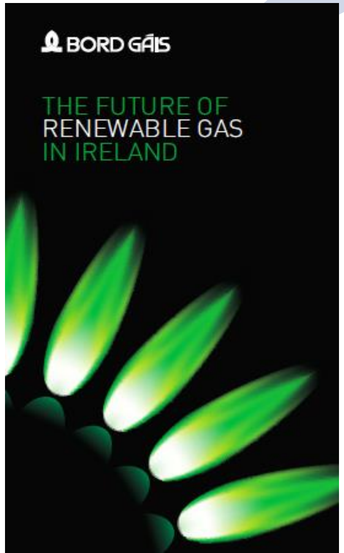
2018: 1st gas to grid site
Equivalent to 600 CNG buses

2019: Green gas certificates



2030: 20% renewable gas by 2030

2007: Future of Renewable Gas



2018: Causeway project
13 additional filling stations
3 additional digesters

"Unlocking the **potential** of our **marine** and **renewable energy resources** through the **power** of **research** and **innovation**"

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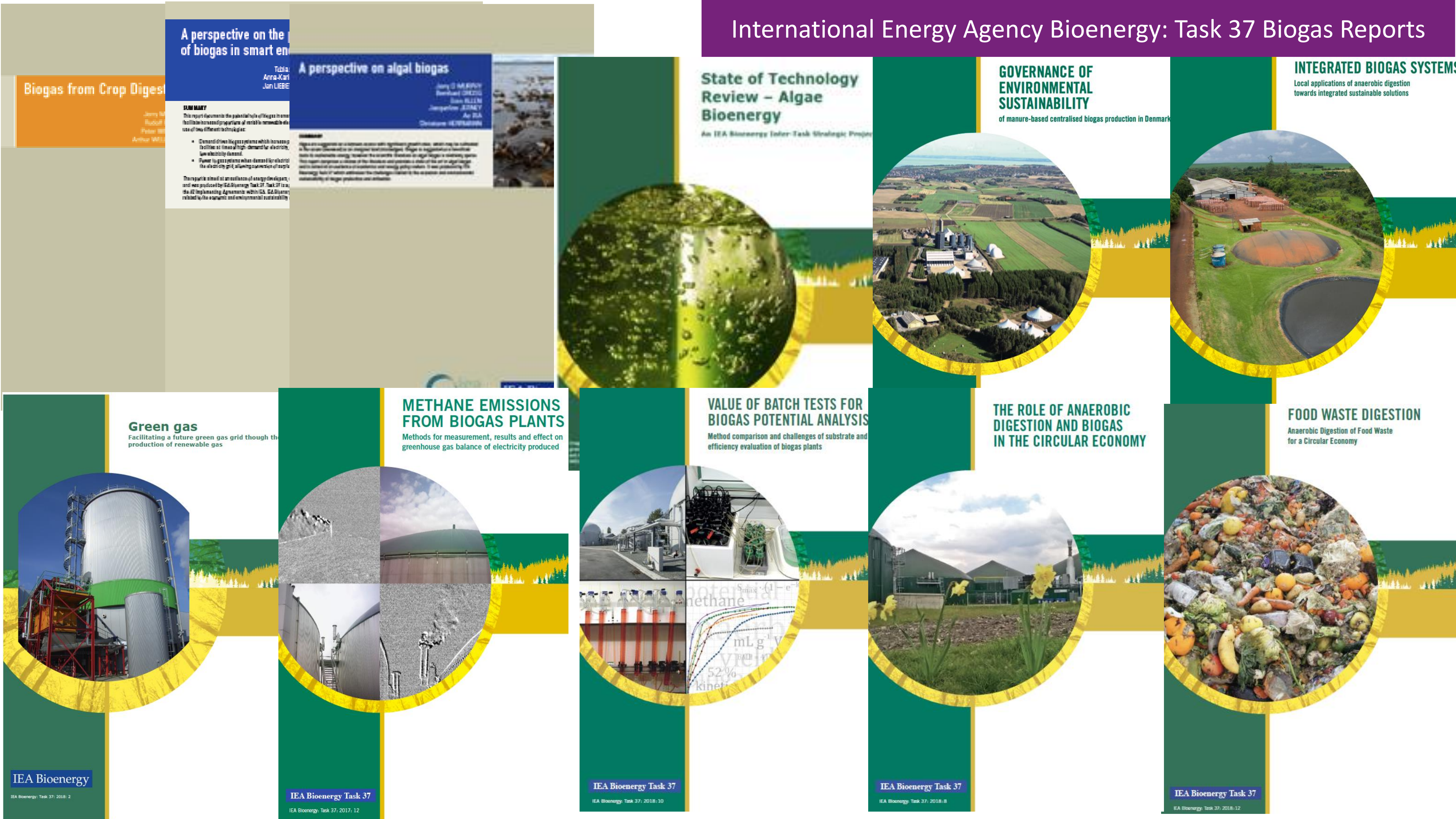
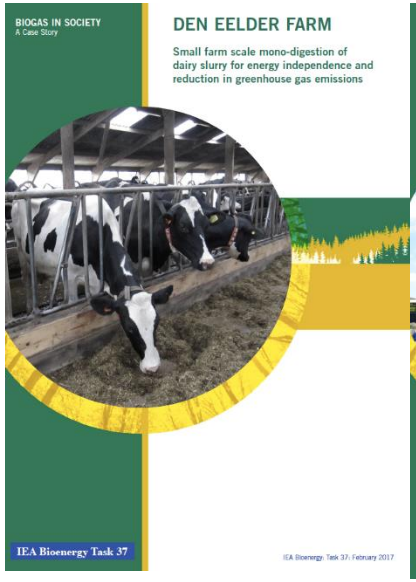
International Energy Agency Bioenergy: Task 37 Biogas Reports



International Energy Agency Bioenergy: Task 37 Biogas Success Stories



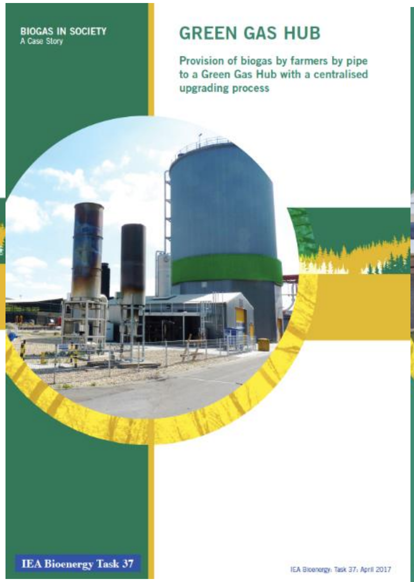
BIOGAS IN SOCIETY
A Case Story

DEN EELDER FARM

Small farm scale mono-digestion of dairy slurry for energy independence and reduction in greenhouse gas emissions

IEA Bioenergy Task 37

IEA Bioenergy: Task 37: February 2017



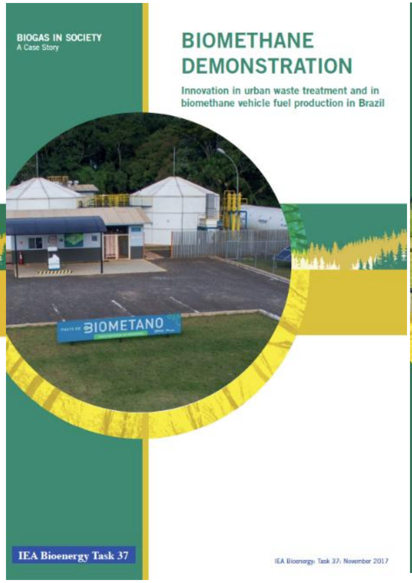
BIOGAS IN SOCIETY
A Case Story

GREEN GAS HUB

Provision of biogas by farmers by pipe to a Green Gas Hub with a centralised upgrading process

IEA Bioenergy Task 37

IEA Bioenergy: Task 37: April 2017



BIOGAS IN SOCIETY
A Case Story

BIOMETHANE DEMONSTRATION

Innovation in urban waste treatment and in biomethane vehicle fuel production in Brazil

IEA Bioenergy Task 37

IEA Bioenergy: Task 37: November 2017

Sønderjysk Biogas Bevtoft

Hi-tech Danish biogas installation a key player in local rural development

Source: Sønderjysk Biogas

IEA Bioenergy

IEA Bioenergy: Task 37:March 2018

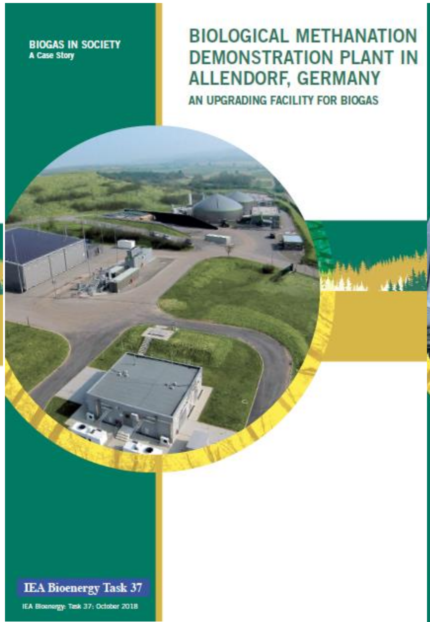
BIOGAS IN SOCIETY
A Case Story

ICKNIELD FARM BIOGAS

AN INTEGRATED FARM ENTERPRISE

IEA Bioenergy Task 37

IEA Bioenergy: Task 37: August 2018



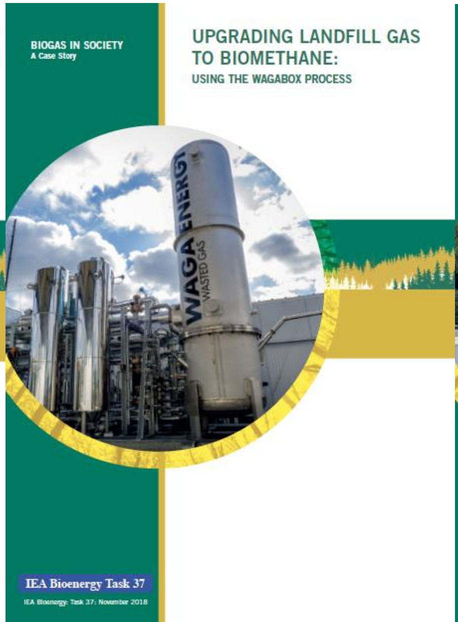
BIOGAS IN SOCIETY
A Case Story

BIOLOGICAL METHANATION DEMONSTRATION PLANT IN ALLENDORF, GERMANY

AN UPGRADING FACILITY FOR BIOGAS

IEA Bioenergy Task 37

IEA Bioenergy: Task 37: October 2018



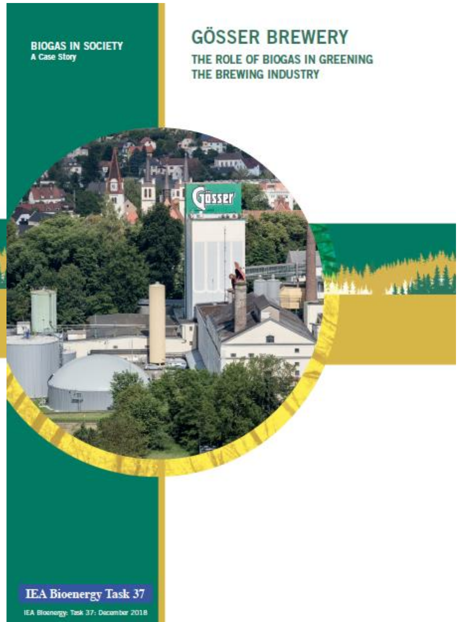
BIOGAS IN SOCIETY
A Case Story

UPGRADING LANDFILL GAS TO BIOMETHANE:

USING THE WAGABOX PROCESS

IEA Bioenergy Task 37

IEA Bioenergy: Task 37: November 2018



BIOGAS IN SOCIETY
A Case Story

GÖSSER BREWERY

THE ROLE OF BIOGAS IN GREENING THE BREWING INDUSTRY

IEA Bioenergy Task 37

IEA Bioenergy: Task 37: December 2018