Incorporating renewable gaseous fuel in future energy systems

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Chair of Civil, Structural & Environmental Engineering
Leader International Energy Agency Bioenergy Biogas Task

8th International Renewable Energy Conference Thursday
October 10th, 2019
OUR MOTIVATIONS

Energy transition

Climate action

Blue economy
OUR Partner Institutions

- NUIG (Existing)
- UL (Existing)
- UCC (Existing)
- CIT (Existing)
- UCD (Existing)
- TCD (Proposed)
- TU Dublin (Proposed)
- DIAS (Proposed)
- The ESRI (Proposed)
- MU (Existing)
- DKIT (Proposed)
- Tyndall National Institute (Proposed)
<table>
<thead>
<tr>
<th>Progress</th>
<th>TO DATE</th>
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<tbody>
<tr>
<td>200</td>
<td>multi-disciplinary researchers across our institutional partners</td>
</tr>
<tr>
<td>50</td>
<td>industry partners including Start-Ups, SMEs, and Large Enterprises</td>
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<tr>
<td>12</td>
<td>institutional partners combining Ireland’s best talent in energy and marine research</td>
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<tr>
<td>36</td>
<td>collaborating countries across industry, academia, and government</td>
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<tr>
<td>40%</td>
<td>of departees moving to industry as a first destination</td>
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<td>€63m</td>
<td>funding secured from industry, exchequer, and non-exchequer sources</td>
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Ireland’s Low Carbon Pathway to 2050

Source: MaREI Energy Policy and Modelling Group
But 80% CO2 reduction = 50% GHG reduction

Source: MaREI Energy Policy and Modelling Group
Limiting temperature rise to 2D is challenging.

Limiting Emissions to 2DS

Limiting Emissions to B2DS-Bioenergy with Carbon Capture

Bioenergy with carbon capture & sequestration

CO2 neutral

CO2 negative

Open slurry storage emits 17.5% of methane
At 2% methane slippage:
- Biomethane from slurry GHG negative feedstock (-250 g CO2/MJ)
- Biomethane from 20% Maize and 80% Slurry GHG still negative

California Air Resources Board (CARB) awarded a Carbon Intensity (CI) score of -255 gCO2e/MJ for a dairy waste to vehicle fuel pathway.
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
1. GHG savings required by the recast RED are lower for transport than heat (65% vs 80%);

2. The FFC is higher for transport than heat (94gCO2/MJ vs 80 g CO2/MJ) making it easier to satisfy transport.

3. The efficiency of heat conversion must be included; this is not the case for transport.

4. For transport the recast RED methodology employs a field to tank analysis as opposed to a field to wheel. If the analysis were field to wheel typically biomethane underperforms as compared to diesel by about 75%.

5. This effect is further exacerbated by the fact that the recast RED counts advanced transport biofuel as twice the energy in the fuel.

<table>
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<tr>
<th>Table 9</th>
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<tbody>
<tr>
<td>Sustainability of biomethane for heat and transport.</td>
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<td></td>
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<tr>
<td>Emissions before conversion (g CO2-equivalent/MJ biomethane)</td>
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<tr>
<td>Conversion efficiency</td>
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<tr>
<td>Total emissions (g CO2-equivalent/MJ biomethane)</td>
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<tr>
<td>Fossil Fuel Comparator (g CO2-equivalent/MJ)</td>
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<tr>
<td>Emissions Saving</td>
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<tr>
<td>Emissions Saving Criteria 2026</td>
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Modelling a demand driven biogas system for production of electricity at peak demand and for production of biomethane at other times

R. O’Shea, D. Wall *, J.D. Murphy

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Fig. 4. Example of biogas flows in pulse fed reactor. Feedstock is grass silage, organic loading rate of 2 kg VS/m³/day, reactor volume of 4000m³.
6 European gas grids have committed to 100% green gas in the gas grid by 2050
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, Jerry D. Murphy

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Plant Size MW</td>
<td>50</td>
</tr>
<tr>
<td>Land area (ha)</td>
<td>6800</td>
</tr>
<tr>
<td>Number of plants required</td>
<td>11</td>
</tr>
<tr>
<td>As a % Energy in Transport</td>
<td>5.5%</td>
</tr>
<tr>
<td>As a % of agricultural land</td>
<td>1.7%</td>
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The effect of seasonal variation on biomethane production from seaweed and on application as a gaseous transport biofuel

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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 biomethane yield from Laminaria Digitata
How to optimise photosynthetic biogas upgrading: a perspective on system design and microalgae selection

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\textsuperscript{b} School of Engineering, University College Cork, Cork, Ireland
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\textsuperscript{*}Corresponding author.

Figure 3. Biogas Upgrading by microalgae in an alkaline (Carbonate) algal solution via Carbonate/Bicarbonate cycle (The number of markings of each chemical species are indicative only to their relative quantity and not in absolute terms)
Walney wind farm extension, built in 2017, has a 659MW capacity and cost €1.4 billion.
Sabatier Equation:

$$4H_2 + CO_2 = CH_4 + 2H_2O$$
Electro fuels: Power to Methane

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

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School of Engineering, UCC, Ireland

Fig. 6. Theoretic model and approach for a full-scale three-stage sequential ex-situ methanation unit at a methane formation rate of 3.6 L CH\textsubscript{4} L\textsubscript{VR}\textsuperscript{-1} d\textsuperscript{-1}. The conversion of carbon dioxide to methane corresponds to 70% (after stage 1), 85% (after stage 2) and 95% (after stage 3).
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
Electro fuels - cost

- Low-cost/curtailed energy alone not economically viable...
- Bidding more reduces LCOE...
- Market interaction, not economies of scale...
- Minimised when bidding above marginal cost of generation...
Economically optimised PtG system using bid price control

5 to 25% decrease in carbon intensity of energy consumed.

Does not exacerbate the mismatch of supply and demand.

Uses otherwise curtailed electricity 50 to 100% more than average.

Passive control that doesn’t require shifts in policy.
Denmark which at present has c. 10% renewable gas (with an equal amount going to CHP) 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 which would be in advance of gas demand.
Pipeline systems consist of double pipes; slurry from collection tanks to digester and sanitized biodigestate from digester back to collection point. Piping system reduces the need for 50 – 70 deliveries per day and facilitates collection of diffuse sources of slurry.

Denmark set a target for 50% slurry digestion by 2020 and has already met this.
As a rule of thumb:
• 22c/m³ biomethane to make biogas,
• 22c/m³ to upgrade to biomethane,
• 11c/m³ biomethane to compress and 11c/m³ biomethane to distribute.
• This is 66c/m³ biomethane or 66c/L diesel equivalent or 6.6c/kWh.

If you **buy all the feedstock** this rises. Say €35/ t silage adds 33c/ m³. Overall cost of **99 c/m³** or 9.9 c/kWh.

For **food waste** there is a decrease in cost; fee of €35/t drops the cost by 33c/m³ to **33c/m³** or 3.3 c/kWh.

\[1 \text{ m}^3 \text{ CH}_4 = 10 \text{ kWh} = 1 \text{ L diesel equivalent}\]
1. **How do we cost the asset value associated with the circular economy benefits of anaerobic digestion?** Biogas systems include for waste treatment and can help decarbonise agriculture. The by-products include for organic biofertilizer & green CO2. Biogas systems improve both ground water and surface water quality. One third of Irish wells are contaminated.

2. **The EU requires 3.5% advanced biofuel by 2030.** Biogas produced from perennial rye grass is a viable commercially available advanced biofuel, which is cheaper than other advanced biofuels such as FT diesel. This is particularly important for haulage and coaches as there are few alternatives to decarbonise this sector of transport.

3. **Grass and slurry in a 60:40 VS ratio results in a 80% GHG savings.** This allows compliance with the 65% and 80% GHG savings required by the RED for transport and heat respectively.

4. **The cost of biomethane varies between 33 to 99 c/L diesel equivalent (3.3 to 9.9 c/kWh)**

5. **Policy such as the Danish target of 50% digestion of slurries by 2020 can increase the slurry resource significantly.** 80% of the geographical specific resource of grass and slurry is available within 25 km of the gas grid. With power to gas we can generate 40 PJ/a (in excess of HGV demand)
“Unlocking the potential of our marine and renewable energy resources through the power of research and innovation”