Energy for generations

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University College Cork, Ireland

# WEBINAR

## Role of Hydrogen in a secure low carbon ecosystem in Ireland

27th January 2026 | 12-1pm

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## Webinar Agenda

| Speaker | Topic |
|---|---|
| ESB | Welcome Introduction |
| Dr Paul Deane | Energy System: Security of Supply, Storage and decarbonising the energy system . |
| Prof Jerry Murphy | The potential roles of hydrogen in hard to abate sectors |
| Dr Nathan Gray | Hydrogen Business Models and a Cork Hydrogen Cluster |
| Discussion Chaired by ESB | Question and Answer Session |

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# RESEARCH TEAM



220+ Multidisciplinary Researchers

215 PhDs Graduated by End of Award

40% Trainee Departures from Academia

39% Gender Balance Across All Categories

13 Institutional partners

109 Industry partners

€85M Research funding

37 Collaborating countries

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# Key Points

- Climate policy is based on averages, but energy security is influenced by extremes.

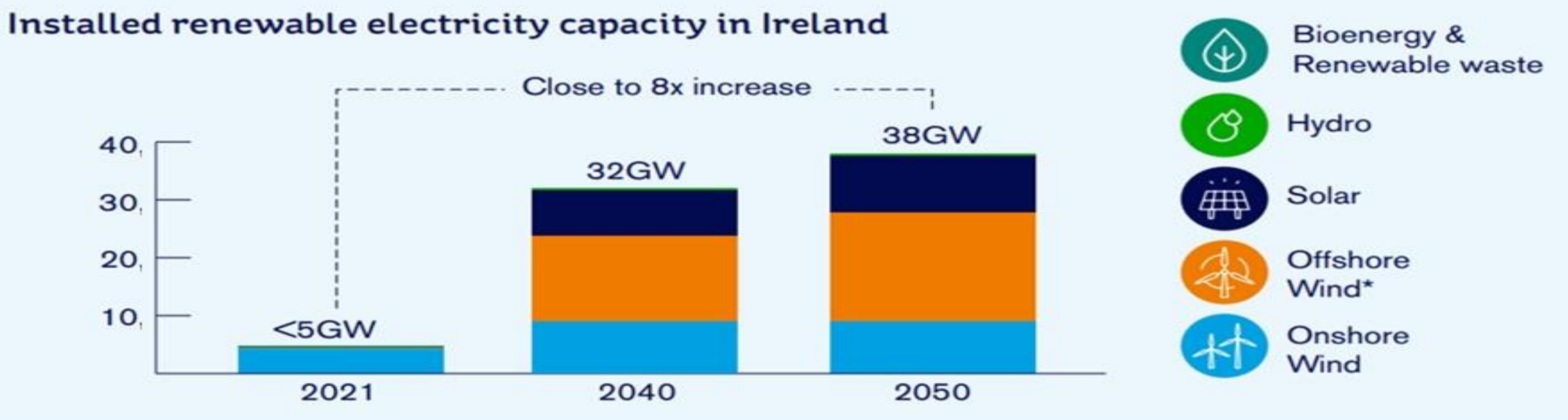
- Flexibility, resilience, and security of supply are key requirements for current and future electricity systems.

- Renewables reduce the use of conventional power plants, but not the need for them.

- Over the next decade, being able to operate the Irish power system during times with 100% renewable generation is key to reducing emissions. Beyond that, being able to operate the system at times with close to 0% renewable generation is essential for reliability.

- Strategic storage, as well as seasonal storage of clean energy is needed in Ireland to deliver a reliable decarbonised energy system (just in time… vs just in case).

- Long-duration storage should not be seen as an "add-on" to the system; it is inherent in managing the system.



Installed renewable electricity capacity in Ireland
Close to 8x increase
40
30
20
10
<5GW
32GW
38GW
2021
2040
2050
Bioenergy & Renewable waste
Hydro
Solar
Offshore Wind*
Onshore Wind


Renewable electricity production in Ireland
125
100
75
50
25
0
13.5TWh
86TWh
110TWh
2021
2040
2050
Bioenergy & Renewable waste
Hydro
Solar
Offshore Wind*
Onshore Wind

# Wind Droughts/Dunkleflaute/Aimsir shuaimhneach

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- Extended periods of low-wind conditions already occur today
- Europe experienced a long period of dry conditions and low wind speeds, through summer and early autumn 2021
- April to September 2021 was the **least windy period for most of the UK and parts of Ireland in the last 60 years**.
- January 2021 in the UK saw the lowest wind speeds for at least 20 years and as a result offshore wind generation was 16% lower than the same period a year before
- The possibility of more frequent and severe wind droughts due to **global climate change cannot be ruled out**
- **Future systems thinking must therefore plan for these, and other climate risks**


# The potential roles of hydrogen in hard to abate sectors

Prof Jerry d Murphy, 27th January 2026

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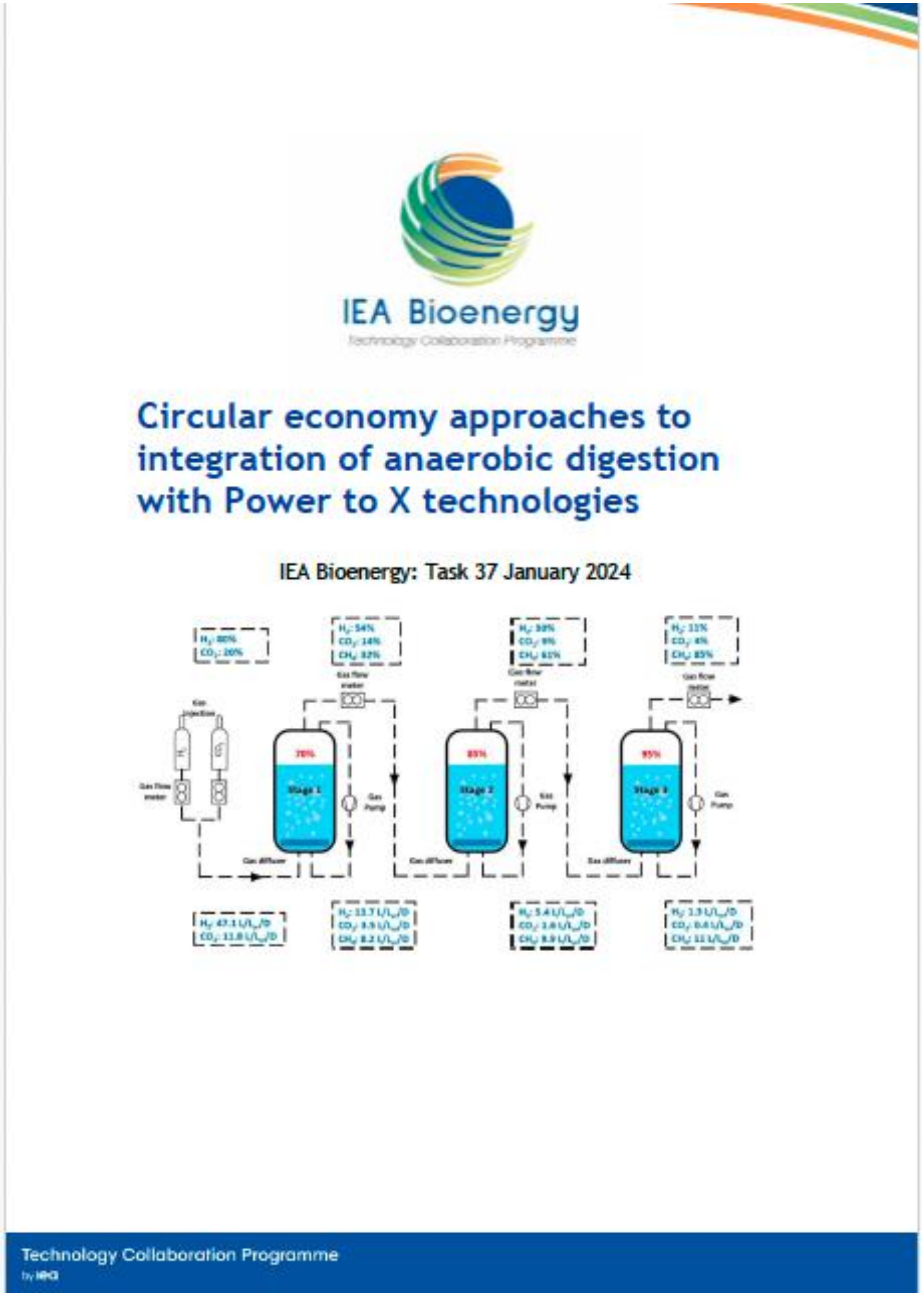
# THE CHALLENGES OF NET ZERO AND RATIONALE FOR BIOGAS & POWER TO X




20% of energy is in the form of electricity. In a net zero world it is unlikely that this will rise above 55% of energy. We need molecules

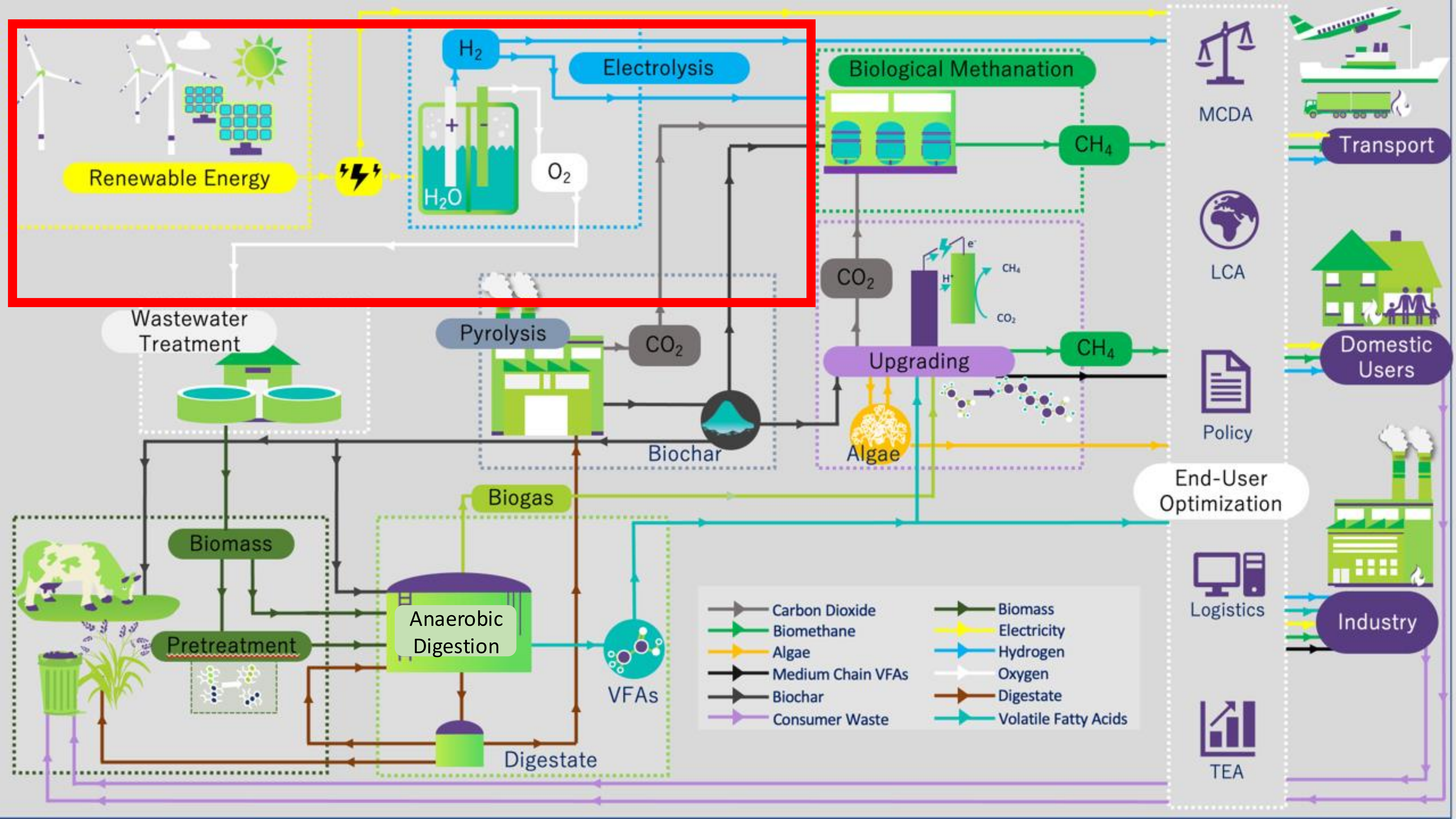
X = 1 Hydrogen ($H_2$):
- We need renewable hydrogen to replace fossil hydrogen.

X = 2 Methane ($CH_4$):
- Energy consumed from natural gas grid is up to twice that from electricity grid in EU and USA

X = 3 Methanol ($CH_3OH$):
- Worldwide production of 110 million tonnes in 2021 used to make plastics, paints, cosmetics and fuels

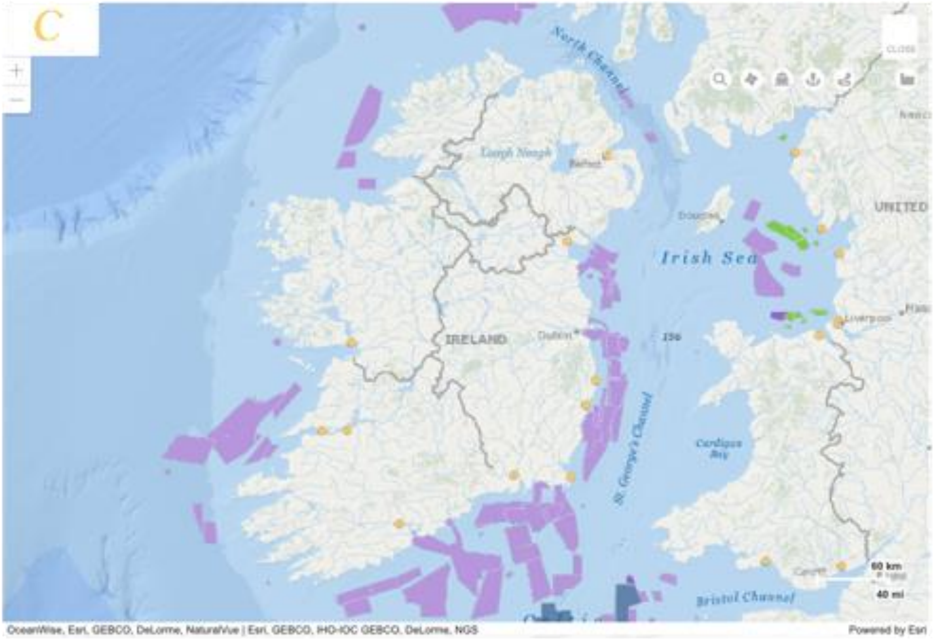
X = 4 Ammonia ($NH_3$):
- World production 150 million tonnes; 80% used for fertiliser, 20% for plastics, fibres, explosives, nitric acid

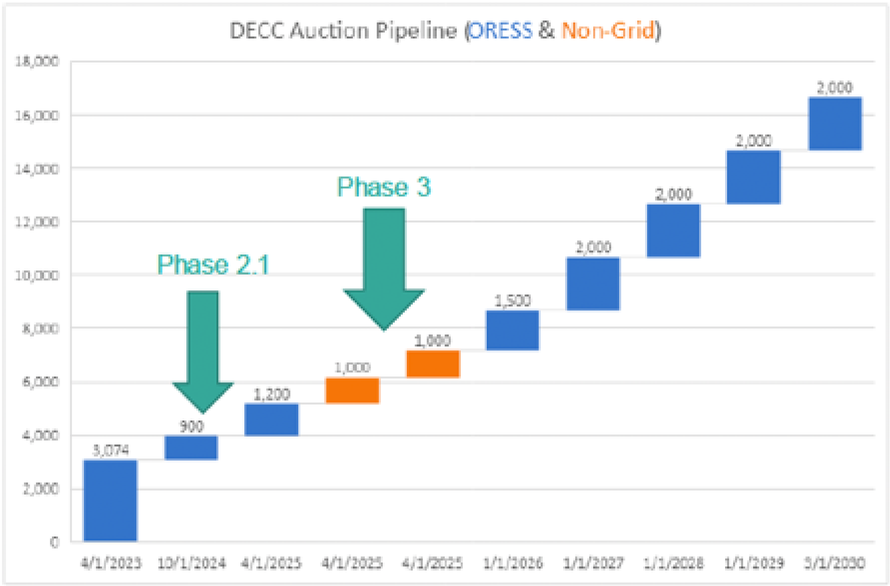
X = 5 Jet Fuel and Shipping Fuel
- Together responsible for 5% of CO2 emissions and even more warming



Renewable Energy
$H_2$
Electrolysis
$H_2O$
$O_2$
Biological Methanation
$CH_4$
MCDA
Transport
LCA
$CO_2$
Wastewater Treatment
Pyrolysis
$CO_2$
Upgrading
$CH_4$
Domestic Users
Policy
Biochar
Algae
End-User Optimization
Biogas
Biomass
Logistics
Industry
Anaerobic Digestion
Pretreatment
VFAs
Digestate
TEA
Carbon Dioxide
Biomethane
Algae
Medium Chain VFAs
Biochar
Consumer Waste
Biomass
Electricity
Hydrogen
Oxygen
Digestate
Volatile Fatty Acids

# X= 1: GENERATION OF HYDROGEN FROM OFFSHORE WIND IN IRELAND



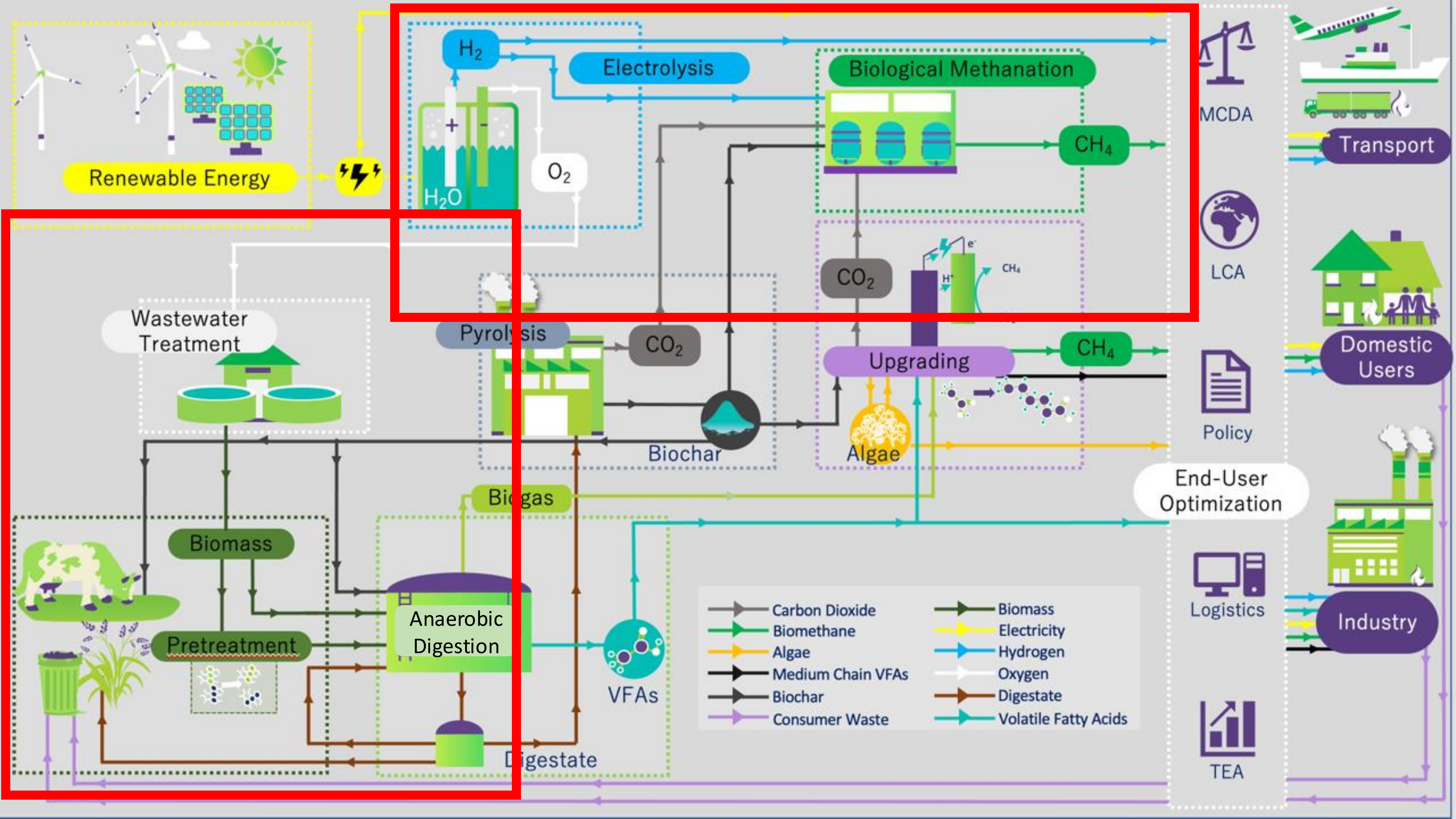


Plans for 17 GW of offshore wind to be auctioned by 2030 for a country that has rarely used more than 7.5 GW.

Ireland's electricity grid has **already** experienced some of the highest system nonsynchronous penetration (SNSP) in any national electricity grid at 40% renewable. How will it manage at 80% renewable?

$$SNSP = \frac{Wind \;\; generation + Imports}{System \;\; demand + Exports}$$

2 GW of private wire/hydrogen (Phase 3). Likely 1 GW to Cork



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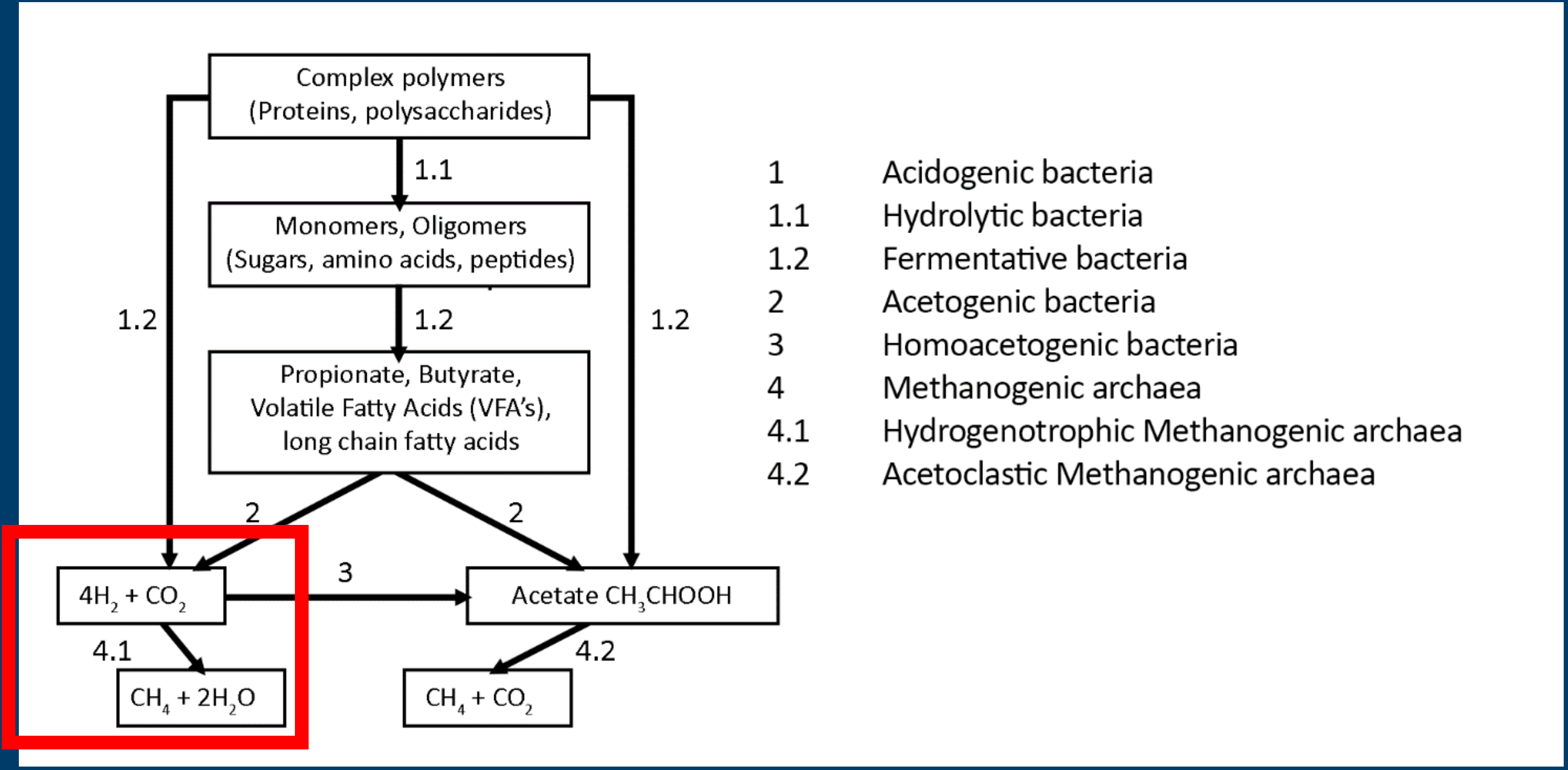
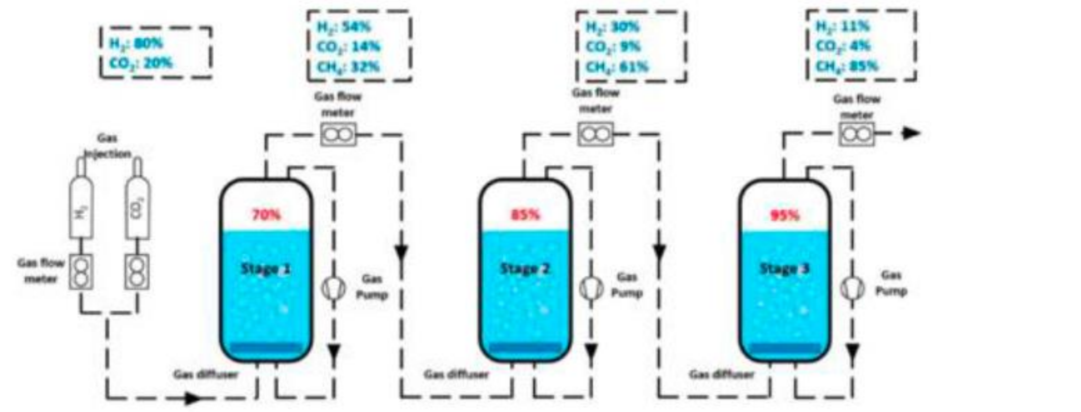
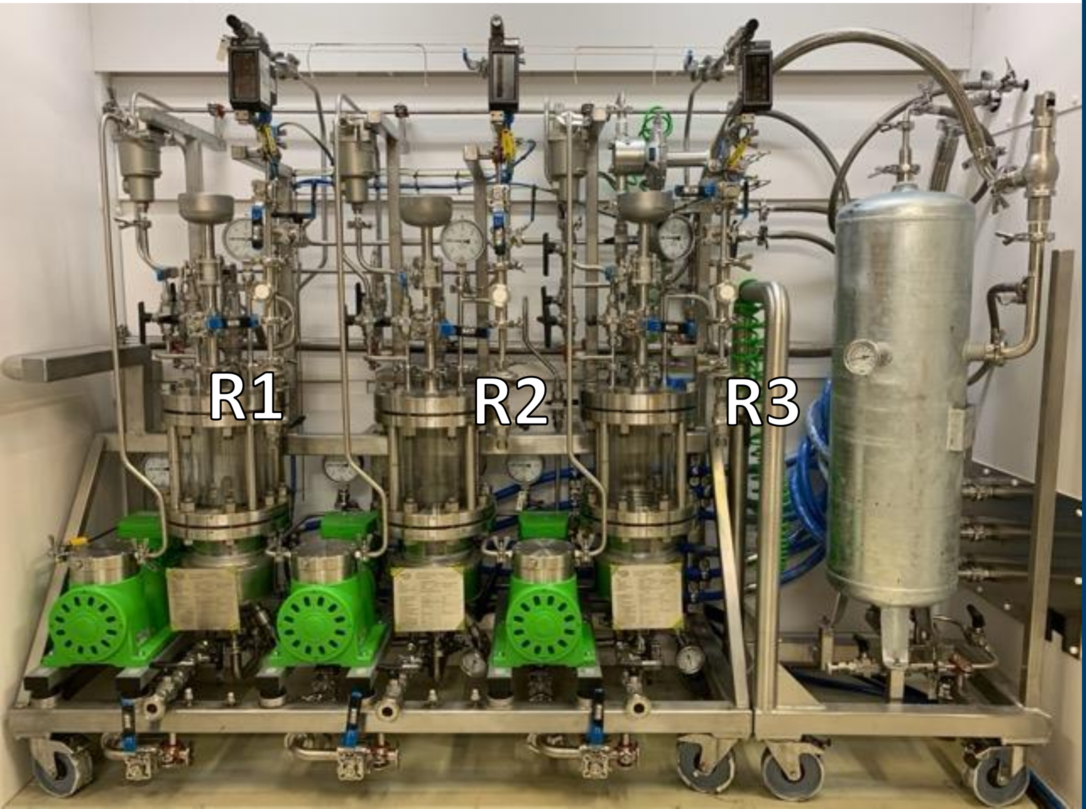
# THE BEAUTY OF ARCHAEA WITHIN THE ANAEROBIC DIGESTION PROCESS

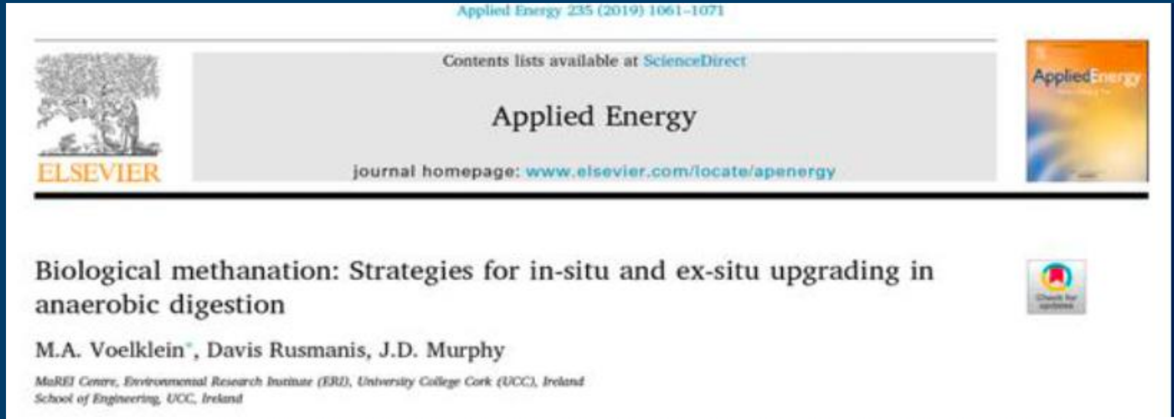



| | | | | ΔG (kJ/reaction) |
|---|---|---|---|---|
| Species 2 | $CH_3CH_2OH + H_2O$ | = | $CH_3COO^- + H^+ + 2H_2$ | +5.95 |
| Species 4.1 | $2H_2 + 0.5CO_2$ | = | $0.5CH_4 + H_2O$ | −65.45 |
| Species 4.2 | $CH_3COO^- + H^+$ | = | $CH_4 + CO_2$ | −28.35 |
| Net | $CH_3CH_2OH$ | = | $1.5CH_4 + 0.5CO_2$ | −87.85 |

# X = 2: CONVERSION OF HYDROGEN AND $CO_2$ TO METHANE



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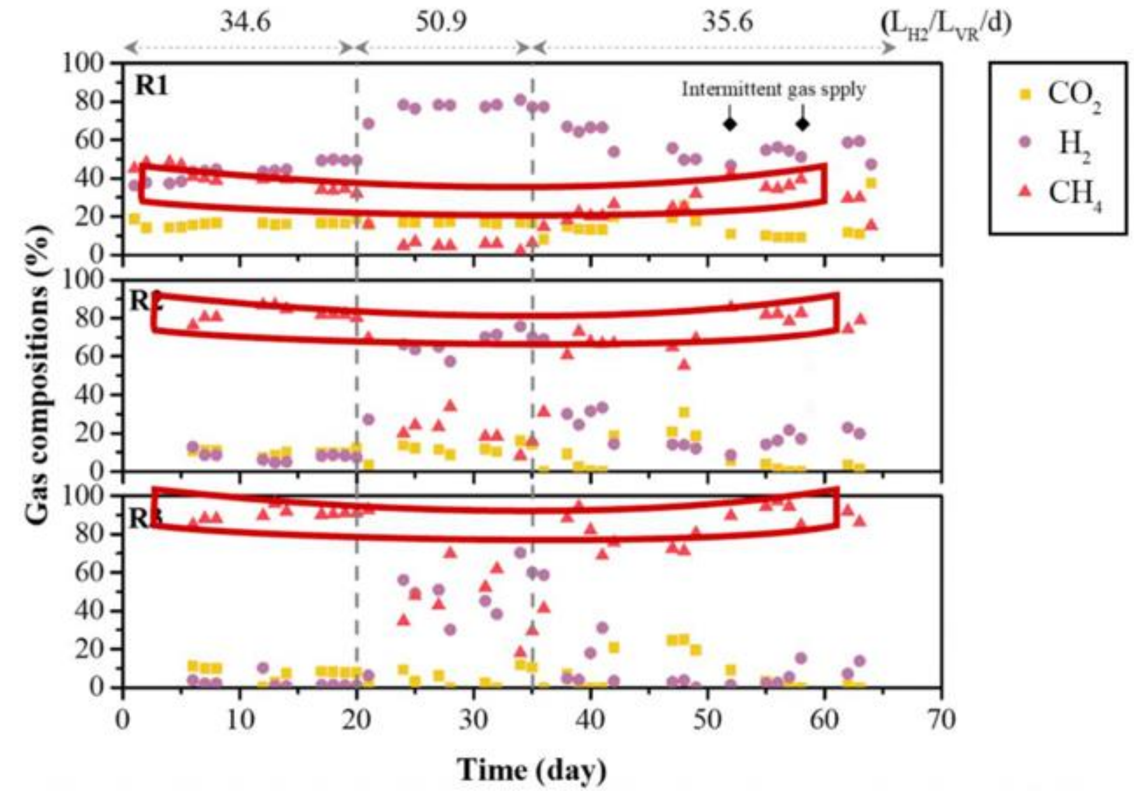
Biological methanation: Strategies for in-situ and ex-situ upgrading in anaerobic digestion


M.A. Voelklein*, Davis Rusmanis, J.D. Murphy
MaREI Centre, Environmental Research Institute (ERI), University College Cork (UCC), Ireland
School of Engineering, UCC, Ireland

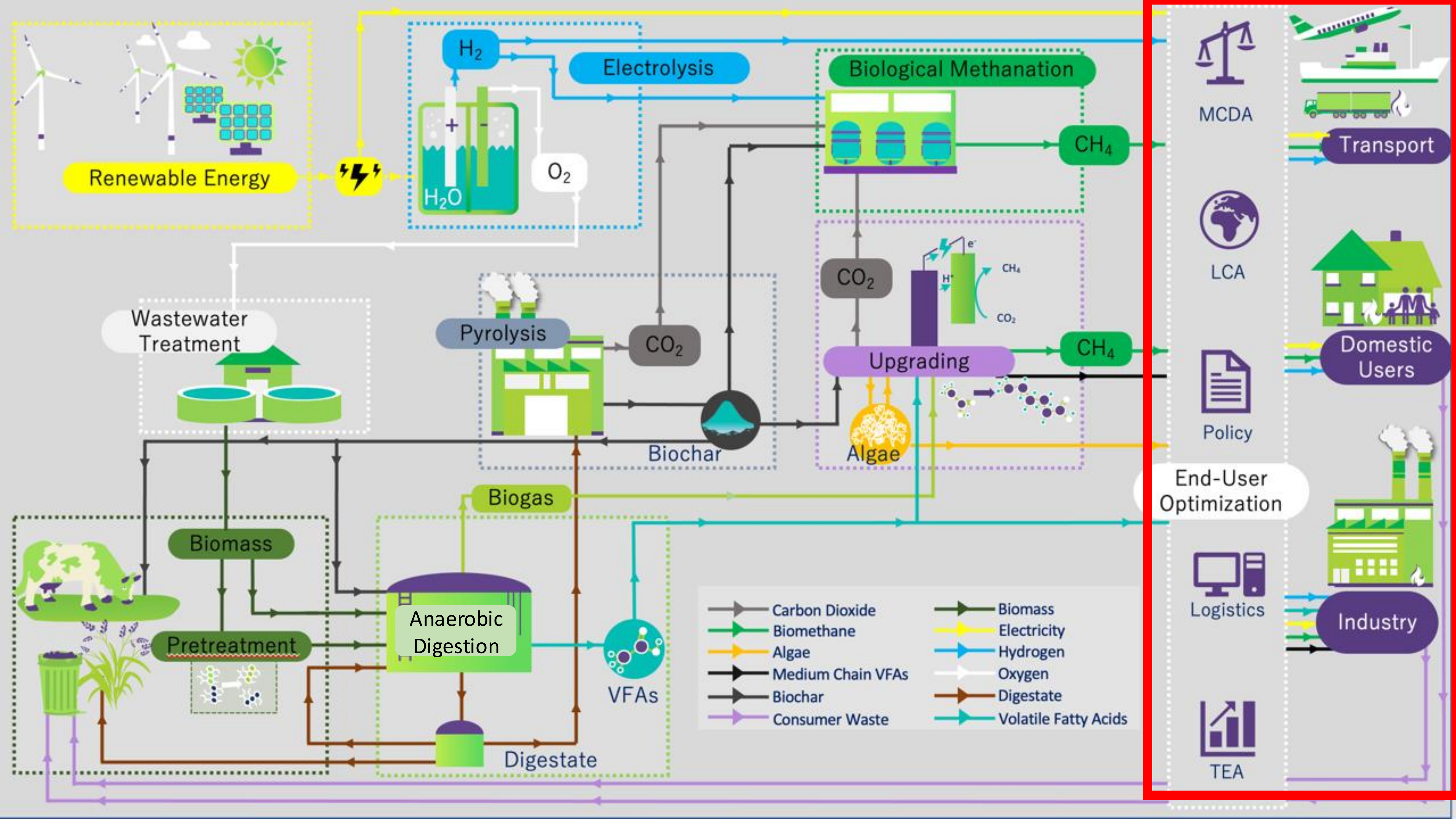

$$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O \quad \Delta H_R = -165\ kJ/mol$$



# X=2: UPGRADING BIOGAS TO BIOMETHANE IN BIOLOGICAL METHANATION SYSTEM. CASE STORY: BIOCAT, AVEDØRE, DENMARK

| | Alkaline Electrolysis Cell Electrolyser | Methanation reactor |
|---|---|---|
| Theory | $2H_2O = 2H_2 + O_2$<br>$H_2$ LHV of 3kWh/m³ or 33.33kWh/kg | $4H_2 + CO_2 = CH_4 + 2H_2O$ |
| Input | 1 MW electrolyser using 1000 kWh of electricity per hour | 125 m³ raw biogas/h<br>75 m³ $CH_4$/h & 50 m³ $CO_2$/h |
| Output | 1000 $kW_e$h at 60% capacity = 600 kWh = 200 m³ $H_2$ /h | 75 m³ $CH_4$ from biogas plus 50 m³ $CH_4$ from biological methanation facility |

$$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O \quad \Delta H_R = -165\ kJ/mol$$



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# DECARBONISATION PATHWAYS IN FOOD AND BEVERAGE INDUSTRY

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Journal of Cleaner Production

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

ELSEVIER

Assessing decarbonisation pathways in the food and beverage sector: A multi-criteria decision analysis approach

Richard O'Shea [a,b,*], Richen Lin [c], David M. Wall [a,b], Jerry D. Murphy [a,b]

[a] MaREI Centre, Environmental Research Institute, University College Cork, Cork, Ireland
[b] Civil, Structural, and Environmental Engineering, School of Engineering, University College Cork, Cork, Ireland
[c] Key Laboratory of Energy Thermal Conversion and Control of Ministry of Education, School of Energy and Environment, Southeast University, Nanjing, 211189, China

To achieve GHG emissions savings greater than 67%, biogas from the anaerobic digestion of distillery feed products is required.

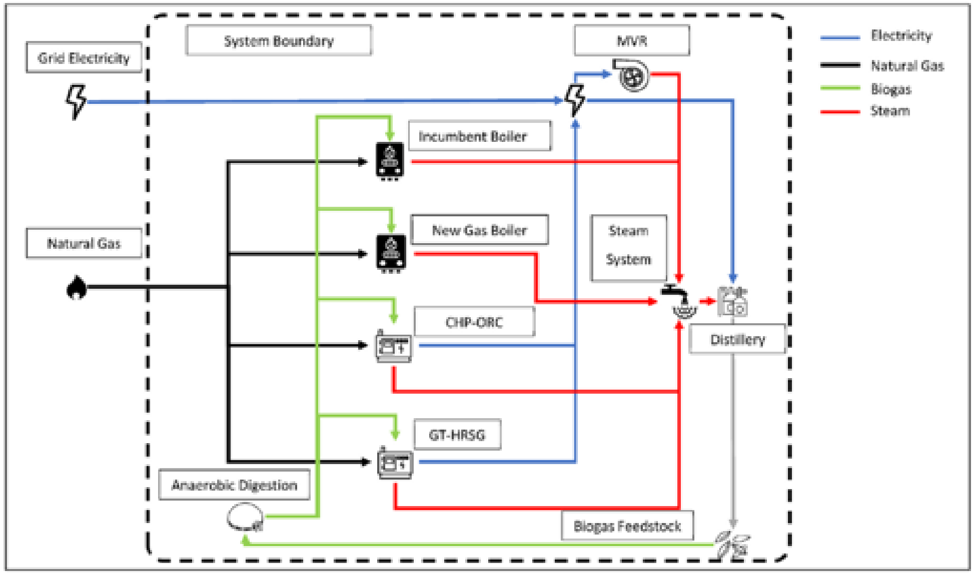
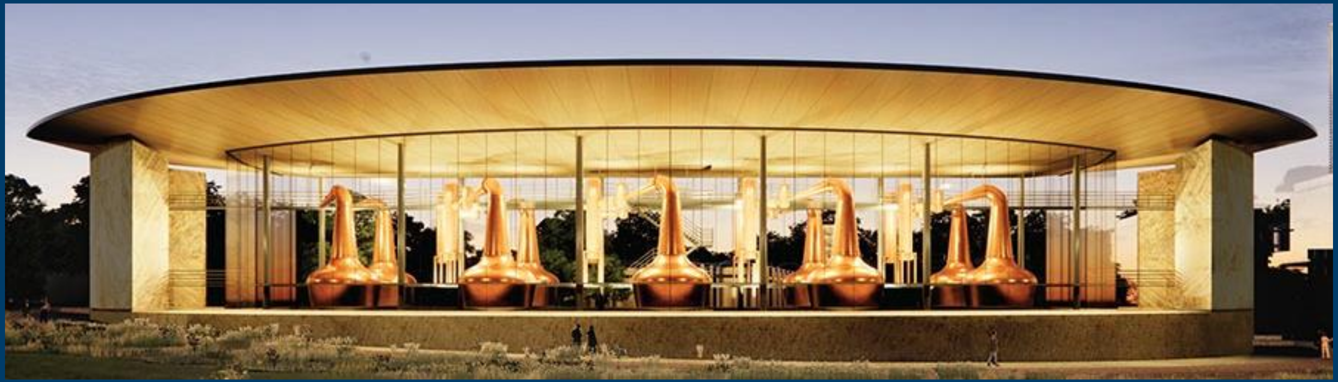



**Fig. 2.** Energy system schematic. CHP: Combined heat and power. ORC: Organic rankine Cycle.GT: Gas turbine. Hrsg: Heat recovery steam generator. MVR: Mechanical vapour recompression.

***The move to carbon neutrality follows extensive research in partnership with MaREI** energy institute in UCC, to determine the biomethane potential of the by-products of distillation and design the required anaerobic digestion process necessary to produce biogas"."*

***The Irish Times***

# X = 3: POWER TO METHANOL ($CH_3OH$)

Worldwide production of methanol is 110 million tonnes

We need renewable hydrogen (such as from offshore wind) and "climate neutral" $CO_2$

Direct Air Capture of $CO_2$ is expensive (450€/t)

We need biogenic $CO_2$ (from biogas or distilleries) which costs c. 20€/t

Reforming biomethane to biomethanol
$3CH_4 + CO_2 + 2\,H_2O = 4\,CH_3OH$

E-Methanol

$CO_2 + H_2 \rightarrow CO + H_2O$
$CO + 2\,H_2 = CH_3OH$

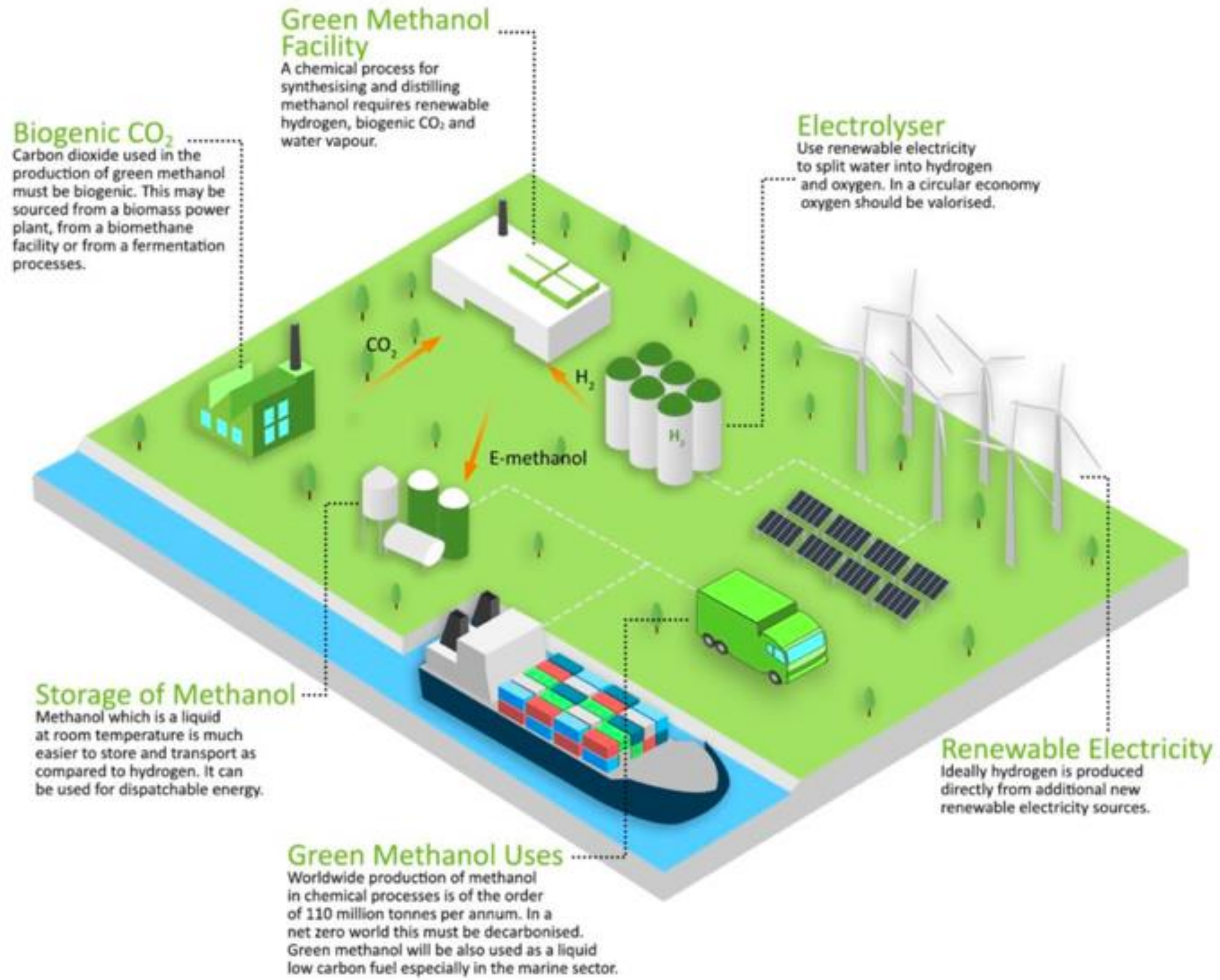



*Figure 5.1. Green Methanol production system, adapted from:*
*https://www.iberdrola.com/documents/20125/2056775/metanol-verde-infografia-EN.pdf*

# X = 4: GREEN AMMONIA FROM GREEN HYDROGEN AND NITROGEN (FROM AIR)

Haber Bosch Process used to react Hydrogen (typically from natural gas) with Nitrogen (from air) at high temperatures & pressure over an iron catalyst to produce $NH_3$

World production of $NH_3$ 150 million tonnes.

Produces 430 million tonnes of $CO_2$ when produced from natural gas

Green $NH_3$ is both a carbon free fuel and a source of fertiliser


Credit: Siemens Energy

*Figure 5.2. Green Ammonia Production System, from (Boerner, 2019)*

# X = 5: FISCHER TROPSCH FUELS FOR SUSTAINABLE AVIATION AND SHIPPING FUEL

$CO_2 + H_2 \rightarrow CO + H_2O$
$2nH_2 + nCO \rightarrow -(CH_2)\text{-}n + nH_2O$

| | |
|---|---|
| Gases < C4 | 16.5% |
| C5 < Naphtha < C10 | 34.3% |
| C11 < Diesel < C20 | 33.7% |
| Waxes > C20 | 15.5% |

| Carbon Number (n) | Weight Fraction (Wn) | Catopgory |
|---|---|---|
| 1 | 2.25% | Tail gas ($C_1$–$C_2$) 6.08% |
| 2 | 3.83% | |
| 3 | 4.88% | Liquified petroleum gas (LPG) ($C_3$–$C_4$) 10.38% |
| 4 | 5.53% | |
| 5 | 5.87% | Naphtha ($C_5$–$C_{10}$) 34.3% |
| 6 | 5.99% | |
| 7 | 5.94% | |
| 8 | 5.77% | |
| 9 | 5.52% | |
| 10 | 5.21% | |
| 11 | 4.87% | Diesel ($C_{11}$–$C_{20}$) 33.71% |
| 12 | 4.52% | |
| 13 | 4.16% | |
| 14 | 3.81% | |
| 15 | 3.47% | |
| 16 | 3.14% | |
| 17 | 2.84% | |
| 18 | 2.56% | |
| 19 | 2.29% | |
| 20 | 2.05% | |
| 21 | 1.83% | Wax ($C_{21}$+) 15.5% |
| 22 | 1.63% | |
| 22+ | 12.04% | |

# The Celtic Hydrogen Cluster Today

# An overview of business models and market development for a low-carbon hydrogen ecosystem in Ireland

**Presenter: Dr Nathan Gray**

**Date: 27/01/2026**

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# 1 Need for a Hydrogen Ecosystem in Ireland

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**Decarbonising our Economy**

- Hydrogen and hydrogen derivatives can be used to decarbonise sectors that are challenging to electrify

**Enhancing Energy Security and System Resilience**

- Hydrogen produced from domestic renewable resources can lessen reliance on imported fossil fuels

**Maximising Renewable Assets**

- Electrolysis can help maximise renewable assets by reducing the amount of wind energy spilled to curtailment

**Creating Industrial Opportunities**

- An indigenous hydrogen ecosystem could attract new industries; creating high-skilled jobs and economic growth

**Unified Renewables + H2 System leads to Energy Independence + Secure Transition**

# 2 Market Opportunities for Hydrogen

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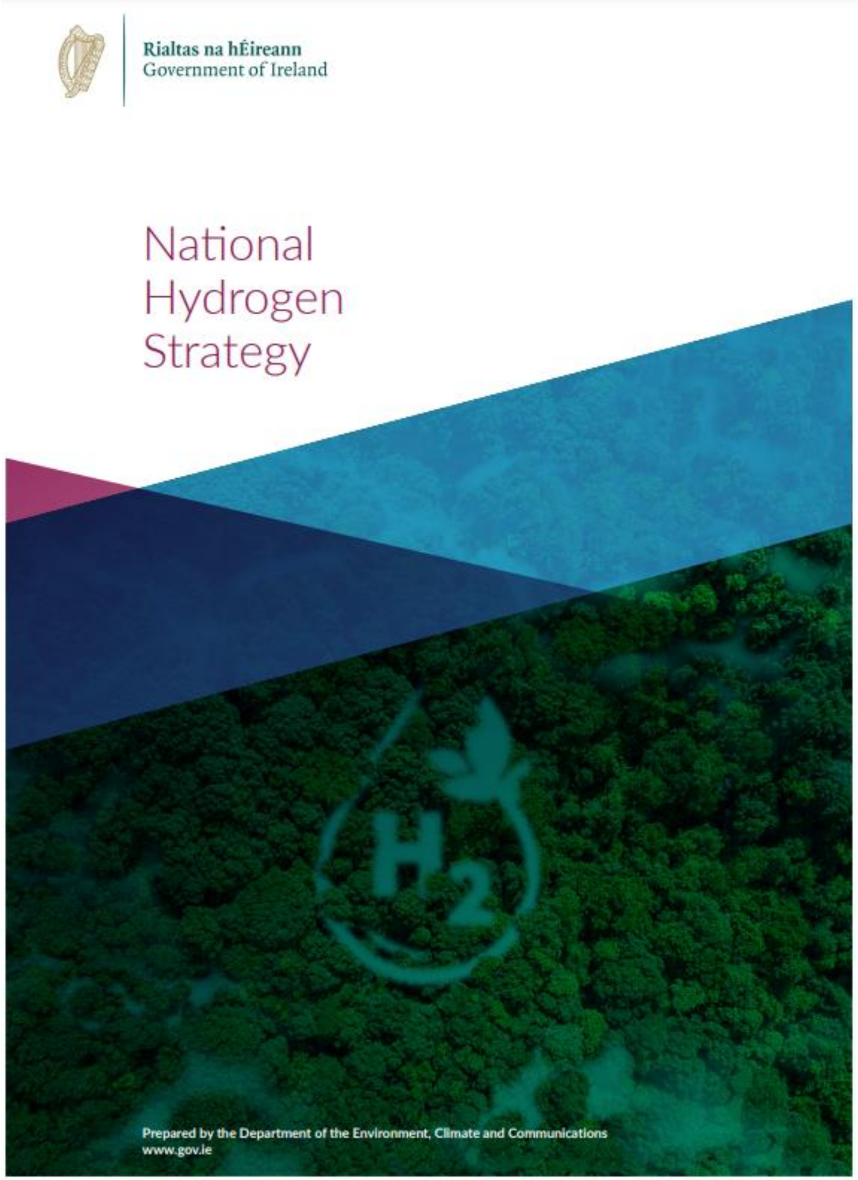


Table 7: Summary of hydrogen end uses envisioned

| End Uses | Priority Order | Role Envisioned | Alternative Technologies | Likely market entry timeframe |
|---|---|---|---|---|
| **Existing hydrogen end users** | 1 | Renewable hydrogen to replace the niche fossil fuel-based hydrogen uses currently in Ireland | N/A | 2025-2030 |
| **Flexible Power Generation and long duration energy storage** | 2 | Zero carbon flexible backup generation and long duration energy, enabling high penetrations of variable renewables and system security | Bioenergy-based generation, CCS enabled natural gas generation, system flexibilities (demand side management. etc.) | 2030-2035 |
| **Integrated Energy Parks for Large Energy Users** | 3 | As a backup to renewable electricity/ grid electricity to meet high reliability requirements | Bioenergy-based generation, battery storage | 2025-2030 |
| **Industrial heat and processing** | 4 | Supply for high temperature heating and other processing needs | Bioenergy-based generation, CCS enabled natural gas combustion, electrification | 2030-2035 |
| **Aviation** | 5 | As a zero carbon synthetic fuel alternative to jet fuel | Bio-based synthetic aviation fuels | 2035-2040 |
| **Maritime** | 6 | As a zero carbon fuel such as ammonia for international shipping | Liquid bio-based fuels, battery electric | 2035-2040 |
| **Road and rail transport** | 7 | Road movements requiring long duty cycles and longer distances. Rail where electrification not feasible/or as a backup | Battery electric, bio-CNG, biofuels, modal shift | 2025-2030 |
| **New non-energy uses** | 8 | Fertiliser production and other chemical processes not currently produced in Ireland | Import from third countries | N/A |
| **Exports** | 9 | Production in excess of domestic needs | N/A | 2035-2040 |
| **Blending** | 10 | Mitigation solution where excess production/end-use variability exists | Sufficient hydrogen storage and transportation | 2025-2030 |
| **Commercial and residential heating** | 11 | Niche areas where electrification, district heating not feasible | Heat pumps, district heating, biomass boilers, biomethane | 2035-2040 |

# Challenges of Developing a Hydrogen Market in Ireland

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## Challenge 1
## Chicken or Egg?

- There is only 1 major consumer of hydrogen (Whitegate Refinery) that could immediately utilise green hydrogen, acting as a baseload level of demand
- Without an assurance of a route to market, hydrogen producers may be reluctant to set up in Ireland

## Challenge 2
## Location, Location, Location

- Ireland's geographic location presents a challenge to the development of a hydrogen ecosystem (import and export)
- Pipelines may be suitable for transport over short distances ( < 500 km) but long-distance transport of pure hydrogen (e.g. by tanker) is technically challenging

## Solutions

- Multi-pronged approach needed to stimulate both supply and demand for hydrogen
- Focus on domestic demand initially, develop storage options, produce hydrogen derivatives (ammonia or e-methanol), attract new industries to Ireland and export surplus hydrogen and derivatives

# Benchmarking Options for Policy Interventions to Support Hydrogen Ecosystems

## Hydrogen Production

1. Price Supports
   a) Fixed premium (EU Hydrogen Bank) - Provides greater certainty for FOAK projects but are seen to be inflexible
   b) Variable premium (UK HPBM) - Similar to CfD schemes for electricity, offers better value for government money but can be challenging to set appropriate reference price

2. Volume Supports
   a) Sliding scale (UK HPBM) - Mitigates risk for producers if offtake volumes fall below anticipated levels by offering greater price support for low offtake volumes

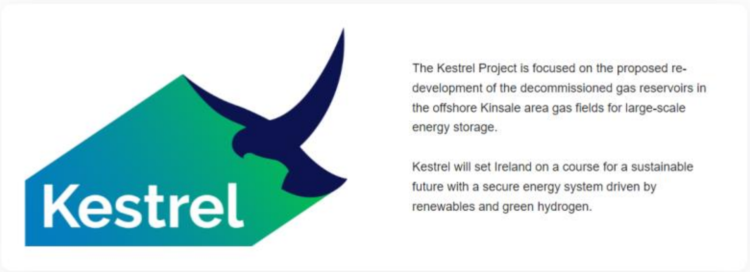
## Hydrogen Utilisation

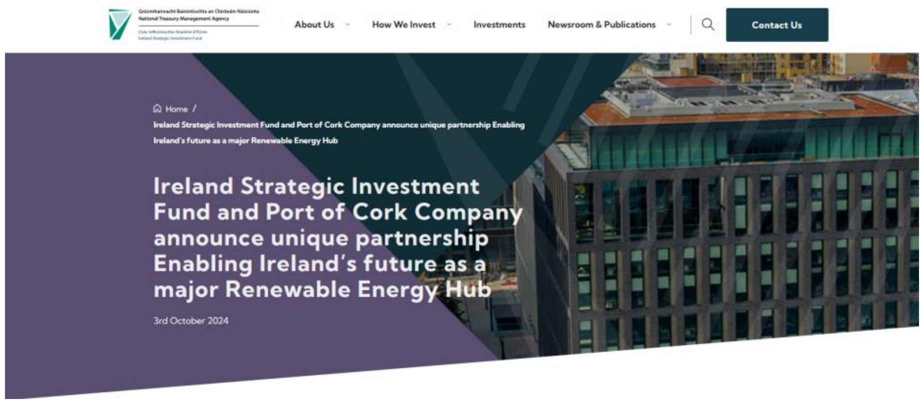
1. "Stick" interventions
   a) Make it more difficult to continue with business-as-usual practices
      i. EU ETS increases the cost of continuing to use fossil fuels
      ii. CBAM reducing high carbon imports
      iii. IMO sulphur control regulations ban the use of high-sulphur marine fuels
      iv. Fuel mandates
2. "Carrot" interventions
   a) Make it easier to invest in new technologies
      i. Subsidy to support the purchase of equipment with high CAPEX (fuel cell vehicles, $H_2$ turbine etc.…)

# A Cork Hydrogen Cluster

Supply → Storage → Demand

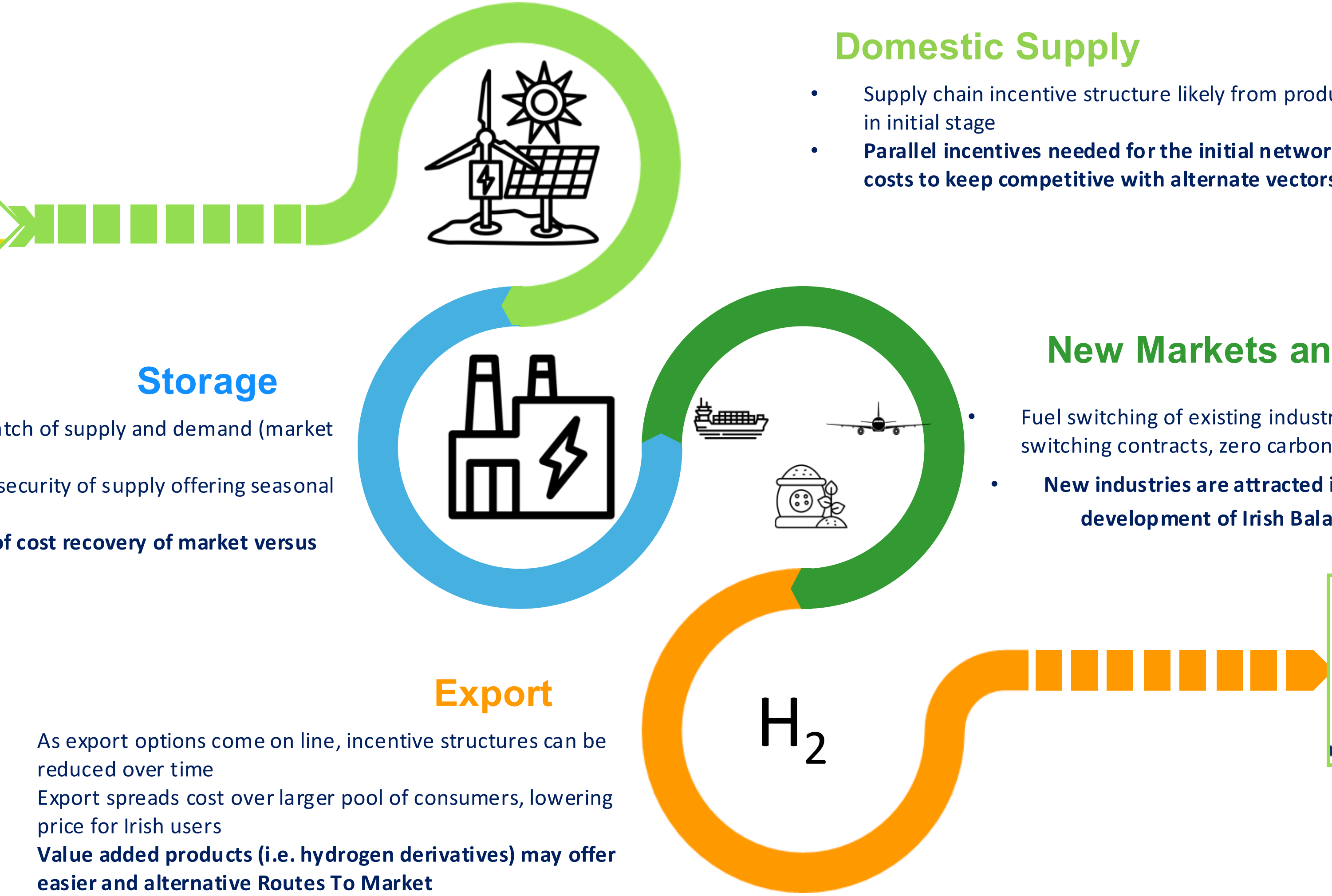
Overview




# Stages of Developing a Hydrogen Ecosystem in Ireland

**Path to a Unified Renewables and H2 System…**




## Domestic Supply

- Supply chain incentive structure likely from production to end user in initial stage
- **Parallel incentives needed for the initial network development costs to keep competitive with alternate vectors**

## Storage

- Storage value is in managing mismatch of supply and demand (market value)
- Longer term storage offers unique security of supply offering seasonal volumes (insurance value)
- **Key decision required on balance of cost recovery of market versus insurance value**

## New Markets and Offtakers

- Fuel switching of existing industries towards hydrogen (industrial switching contracts, zero carbon dispatchable generation)
- **New industries are attracted into Ireland which may lead to need for development of Irish Balancing Point – Hydrogen trading hub**

## Export

- As export options come on line, incentive structures can be reduced over time
- Export spreads cost over larger pool of consumers, lowering price for Irish users
- **Value added products (i.e. hydrogen derivatives) may offer easier and alternative Routes To Market**

**…Leads to Energy Independence and Secure Transition**

# Towards a Low-Carbon Hydrogen Ecosystem in Ireland


**For further information please see *Towards a Low Carbon Hydrogen Ecosystem in Ireland***

# Thank you for listening

*Questions?*

*In collaboration with*