Gas Processors Association Europe
Biomethane Briefing

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Summary

- CNG Services
- CNG Fuels Ltd Network
- GB gas networks and ownership
- What is biogas and biomethane?
- Biogas upgrading to biomethane
- Options for getting biomethane into the gas grid
- Dry biogas networks
- Cheshire Biomethane Project
- Conclusions

CNG Services Ltd

- CNG Services Limited (CSL) provides consultancy, design and build services to the biomethane industry, all focused on reducing Greenhouse Gas (GHG) emissions
- In the past 10 years our efforts have produced a material impact with an estimated 20 year project life reduction in CO_2 emissions of 17,500,000 tonnes through:
  - Biomethane injection into the gas grid
  - Running trucks on Bio-CNG
  - Acting as developer and design and build contractor for the Highlands CNG Project
- Part owner of CNG Fuels Ltd, a company set up to build a national network of Bio-CNG stations on the high pressure grid
  - National network of CNG Stations
  - 84% saving in GHG compared to diesel
- Part owner of Barrow Shipping Ltd, GB's leading shipper of biomethane and a company that only buys and sells biomethane, no fossil gas
- CSL is an ISO 9001, 14001 and 45001 approved company and has also achieved Achilles certification. CSL is GIRS accredited for design and project management and has been certified as a competent design organisation for high pressure UK onshore natural gas works by DNVGL
- Working on a number of H_2 and CCUS innovation projects

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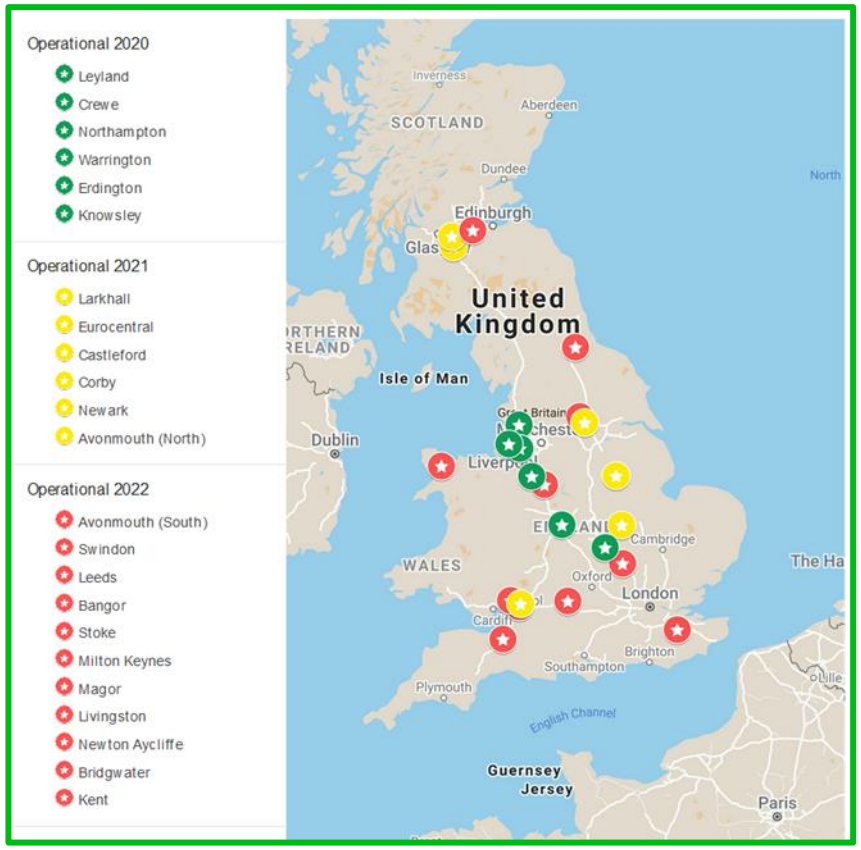
CNG Fuels Bio-CNG Station Roll-out Plan



HGV & Van Fleets:
- Waitrose
- ASDA
- John Lewis
- Royal Mail
- Hermes
- Clipper
- New Look
- Home Bargains
- Argos
- Suma Foods
- DHL
- Cadent
- HPH
- Dixon Transport
- Virginia Logistics
- Brit-European
- Howard Tenens
- Ocado
- Farmfoods

Waste/City Council Fleets:
- Liverpool City Council – 20 RCV's & New Small Fleet
- Various Councils ordering vehicles in next 12 months
- Veolia operate a fleet of 20 CNG RCV's in London
- Warrens & Bio-Collectors are other Waste companies currently running CNG vehicles in their fleet

CNG FUELS

Royal Mail to add 29 biogas HGVs to delivery fleet

Royal Mail is adding 29 biogas-powered trucks to its fleet in a bid to reduce emissions while saving costs on fuel, while it has been confirmed that the world's largest biofuel station is set to open in Bristol this year.

HGVs account for 4.2% of UK carbon emissions

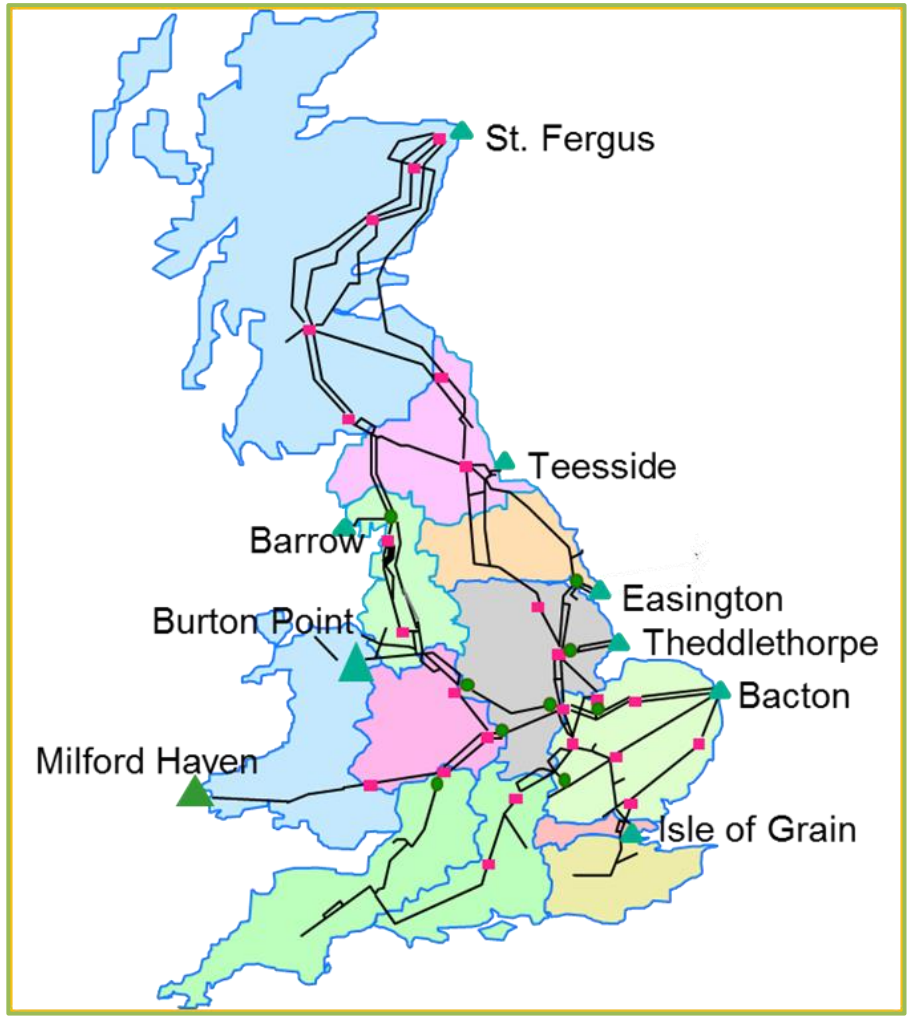
Royal Mail is adding 29 gas-powered trucks to its fleet, fuelled by Bio-Compressed Natural Gas (Bio-CNG). The fuel can reduce vehicle emissions by 84% compared to diesel Heavy Goods Vehicle (HGVs) equivalents and a 99% reduction in polluting particulate matter.

The 40-tonne vehicles can travel up to 400 miles at a time and Royal Mail states the trucks will also be quieter and offer cheaper refueling.

Gas Network Owners

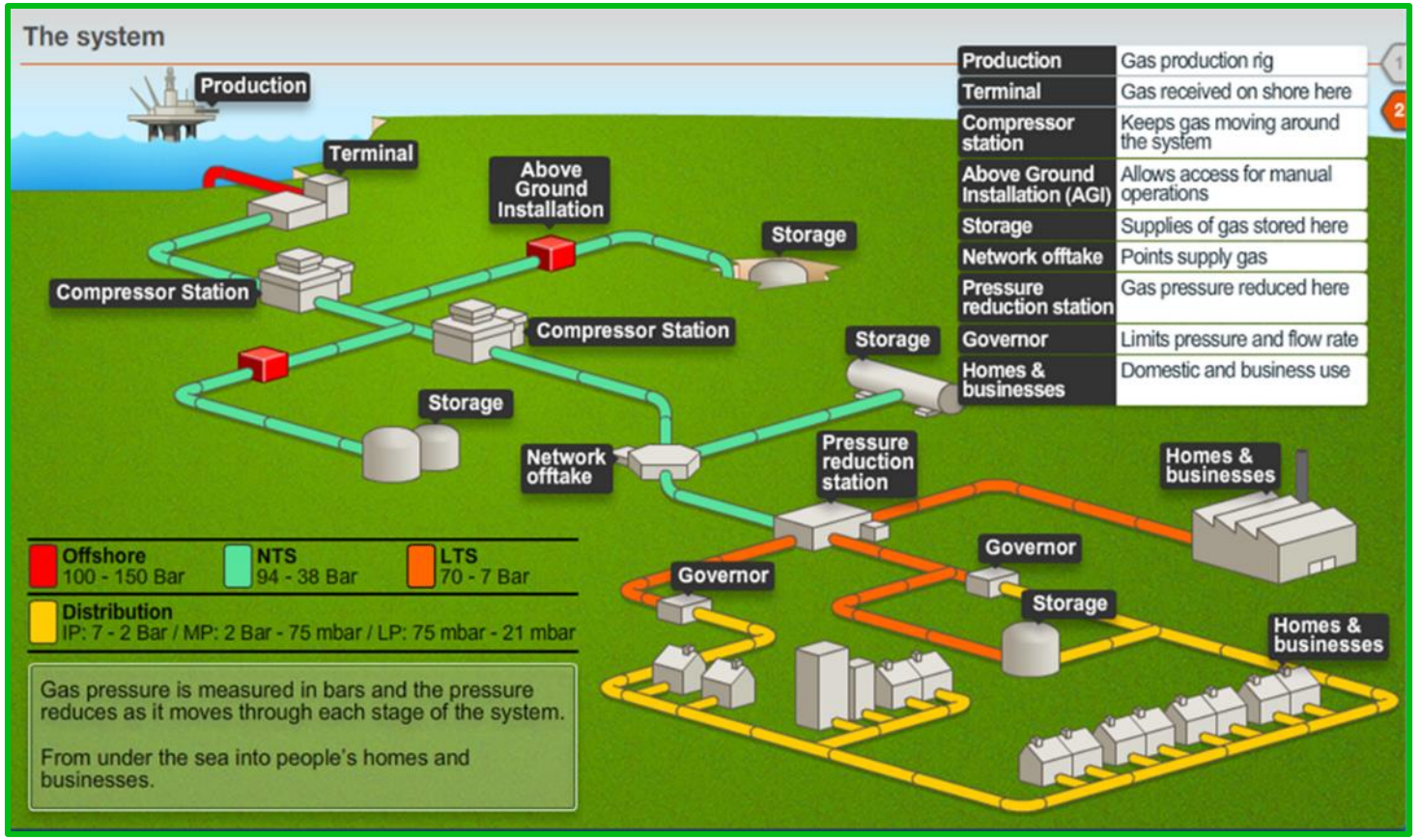
National Transmission System

Owned and operated by National Grid



Gas Distribution Networks

UK Gas Network



- **MP**
  - Lowest pressure tier used
  - Very high coverage across UK
  - PE or metal construction
  - 35 biomethane projects
- **IP**
  - 6.9bar Good coverage across UK
  - PE or metal construction
  - 40 biomethane projects
- **LTS**
  - Ranges from >12bar to 70bar
  - Usually 19 bar or 38 bar systems
  - All metal – however new high pressure PE up to to 100 bar is now approved
  - 25 biomethane projects
  - **Ideal for Bio-CNG (eg Leyland/Erdington)**
- **NTS**
  - 50 – 85 bar
  - 1 biomethane injection and 1 Bio-CNG Mother station (Air Liquide Fordoun)

Best option is to inject biomethane into MP or IP (no compression needed) and then take out of LTS or NTS to make Bio-CNG

What is Biogas

- Biogas is a mixture of gases produced by organic matter in the absence of oxygen (anaerobically), primarily consisting of methane and carbon dioxide (Wikipedia)
- Typical composition:

Component	Typical Range (mol%)
Methane	50 to 60
Carbon Dioxide	40 to 50
Nitrogen	0 to 10
Hydrogen	0 to 1
Oxygen	0 to 0.5
Hydrogen Sulphide	0 to 0.5

- Other components include water, siloxanes, terpenes, ammonia depending on feedstock to AD

Uses for Biogas

- Fuel gas for heat and / or power generation (or both e.g. CHP) – this accounted for ~90% biogas use (2018 figures, IEA) but falling
  - Some basic pre-treatment required (e.g. H_2S removal, CO_2 removal, dehydration) some partial not complete
  - But CO_2 and NO_x , etc. emissions
  - No financial support for new projects in UK
- Upgrade to Biomethane – this accounts for ~10% biogas use (2018 figures, IEA) and increasing

Gas Type	Typical Gross Calorific Value (MJ/m3)
Biogas	20
Biomethane	37
Natural Gas	39
Methane	38
Carbon Dioxide	0
Nitrogen	0

What is Biomethane?

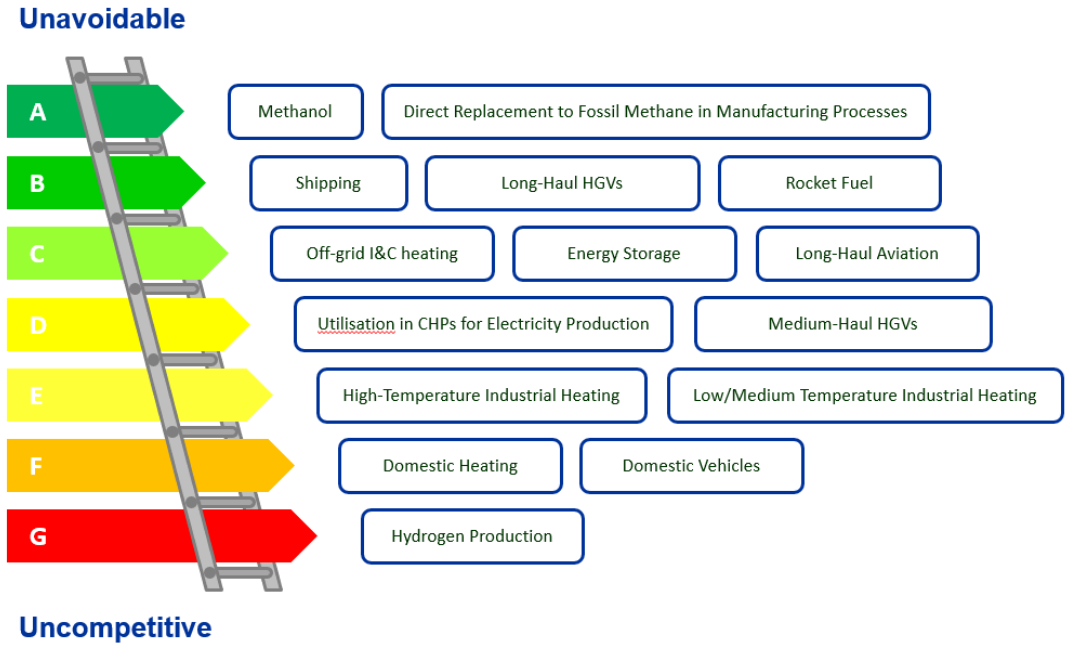
- Biomethane is upgraded biogas and is similar in quality to natural gas; it is also called renewable natural gas (RNG)
- Typical composition:

Component	Typical Range (mol%)
Methane	97 to 98
Carbon Dioxide	1 to 2
Nitrogen	0 to 1
Oxygen	0 to 0.5

- Gasification and methanation can also be used to make biomethane but there are few Bio-SNG projects

Uses for Biomethane

- Substitute for fossil based natural gas for heating, cooking, power generation
  - Biomethane to Grid – inject biomethane into existing gas transmission system
  - Virtual pipeline for smaller / isolated users - transport as compressed biomethane e.g. via road trailer
- Vehicle fuel (e.g. for HGVs and displace diesel)
  - Bio-CNG Truck and farm Tractors
- Feedstock for hydrogen production via SMR



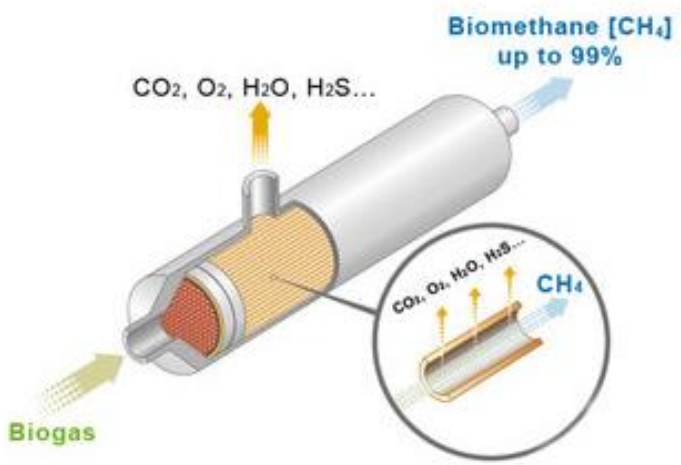
Biogas Upgrading to Biomethane

- The technologies for upgrading biogas to biomethane are:
  - Water wash scrubbing
  - Amine wash absorption
  - Pressure swing adsorption
  - Membrane separation

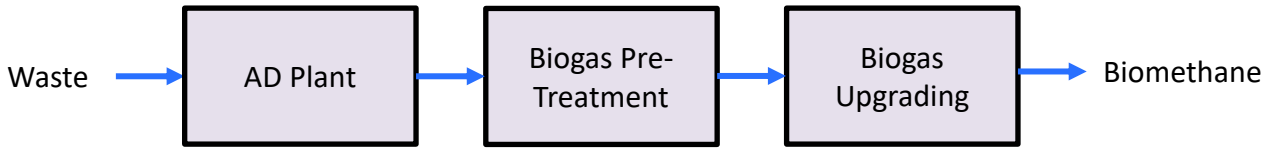
Technology	Quantity (UK)
Water wash scrubbing	24
Amine wash absorption	5
Pressure swing adsorption	9
Membrane separation	70

- Pre-treat biogas before upgrading to remove:
  - H_2S
  - VOCs, siloxanes, terpenes
  - Ammonia / ammonium carbonate
  - Water

- Membrane separation is generally preferred for upgrading biogas to biomethane
- One big advantage is the relatively pure and dry CO_2 vent stream
  - Readily suitable for CO_2 capture either as part of initial design or as retro fit
- Water wash uses air to flush the CO2 out of the water and so the waste CO2 is in a N2 stream and cannot be captured
- Amine technology is very efficient at separating CO2. This needs 120 deg C heat to regenerate the amine and so is good if there is high grade heat available



Air Liquide Membrane Technology



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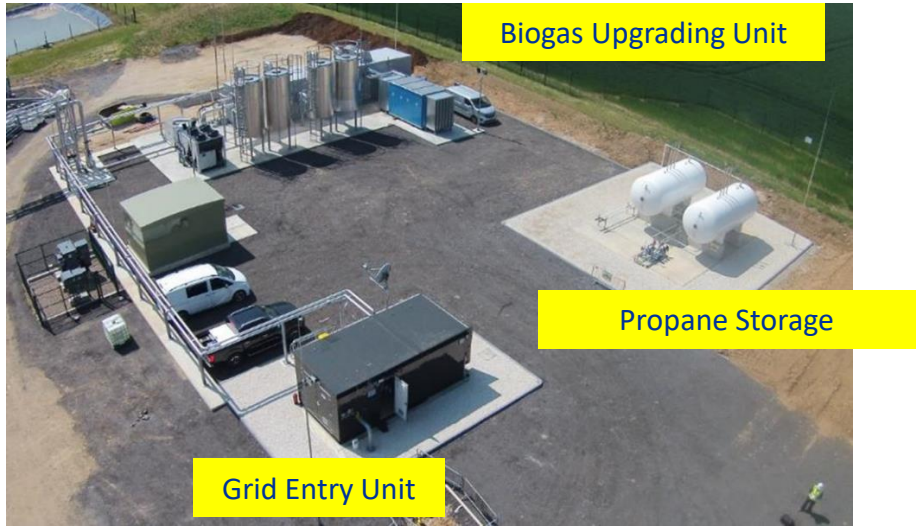
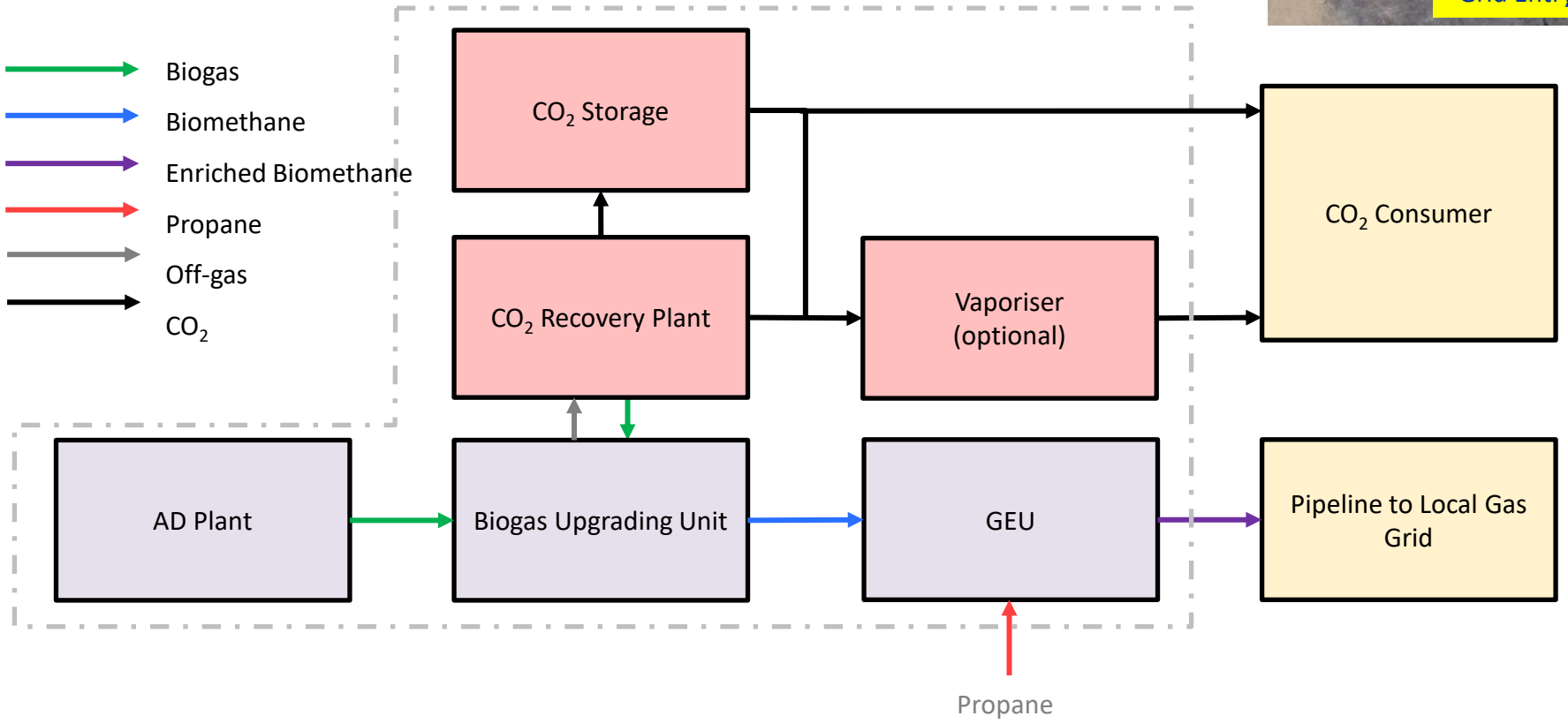
Biogas Upgrading to Biomethane – Membrane Separation + CO_2 Capture





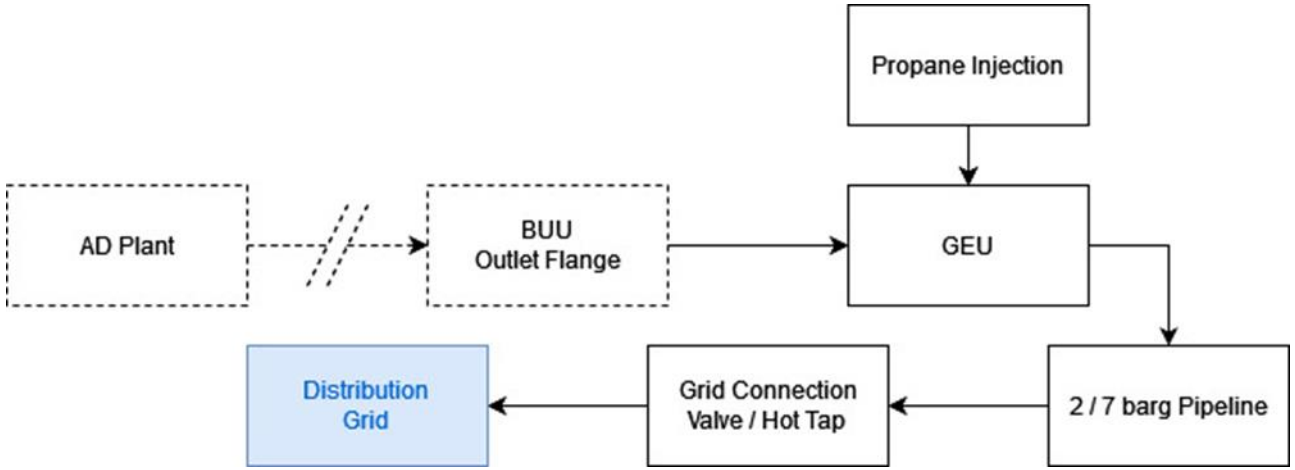
Biomethane Connection Types Overview

There are four main connection options for biomethane projects which are:

Scheme 1 Direct into 2 bar (distribution connection pipeline)
Scheme 2 Direct into 50 bar LTS (transmission connection pipeline)
Scheme 3 Virtual pipeline i.e. CBM by road (transmission connection)
Scheme 4 Direct into 2 bar for reverse compression

Scheme	Description	Comments
1	2/7 barg Grid	A typical biomethane connection into a local distribution network (80 GB Projects)
2	19-75 bar LTS Connection	As scheme 1 but the site connects into a nearby high-pressure transmission pipeline. The site will need on-site or remote compression (20 GB Projects)
3	Virtual Pipeline	The produced biomethane is processed on site and then compressed to 250 bar for transport via CBM trailer. When arriving at the injection site, the biomethane is decanted to transmission grid pressure and injected into the grid following final analysis and metering (1 GB Project)
4	Reverse Compression	As scheme 1. To free up capacity in the 2 barg grid, compression is carried out at or near a local AGI to recompress gas from 2 barg grid into a higher-pressure tiered network to create appropriate capacity for biomethane injection (no GB Projects to date)

Scheme 1 – Distribution Connection (2 bar MP)

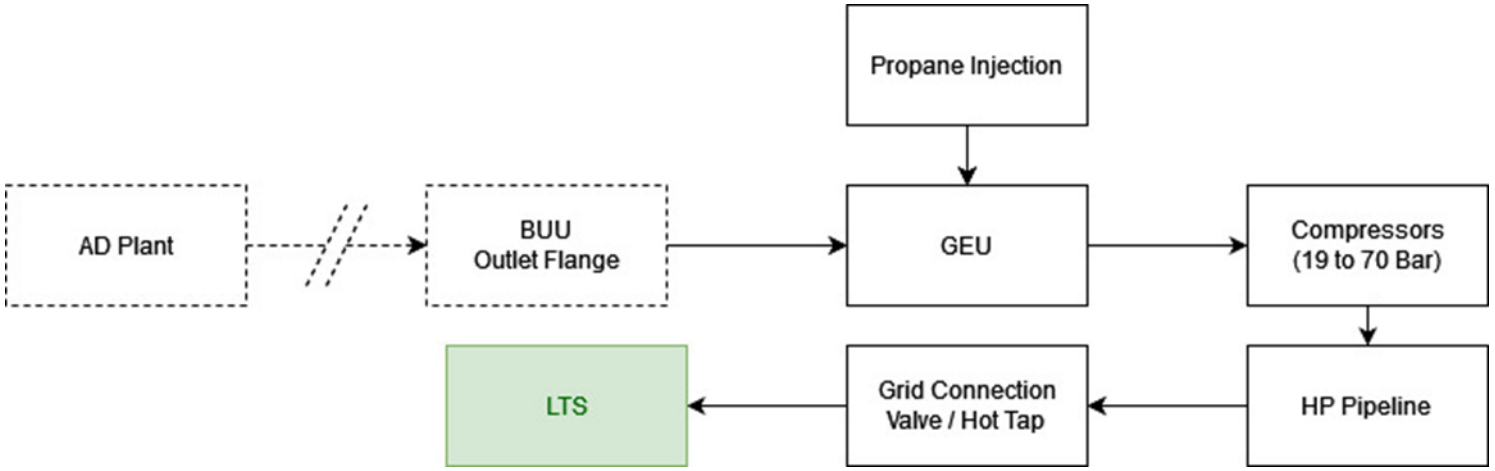


Basic Operational Process

1. Biogas flows from the AD and is treated in the Biogas Upgrading Unit (BUU), removing contaminants and CO_2
2. The upgraded biogas from the outlet of the BUU is fed through the Grid Entry Unit (GEU) which enriches, odorises, meters and analyses the gas. This GEU is situated at the same site as the BUU and ensures that biomethane produced is within grid specifications
3. The resultant biomethane is fed through a Medium Pressure (75mbarg to 2 barg) or Intermediate Pressure (2 barg to 7 barg) pipeline, taking gas from the AD site to the proposed connection point on the GDN network
4. Gas is then injected into the grid at the connection provided there is capacity in the distribution grid

Air Liquide Northwick – 7 bar gas grid

Scheme 2 – Transmission Connection (LTS)

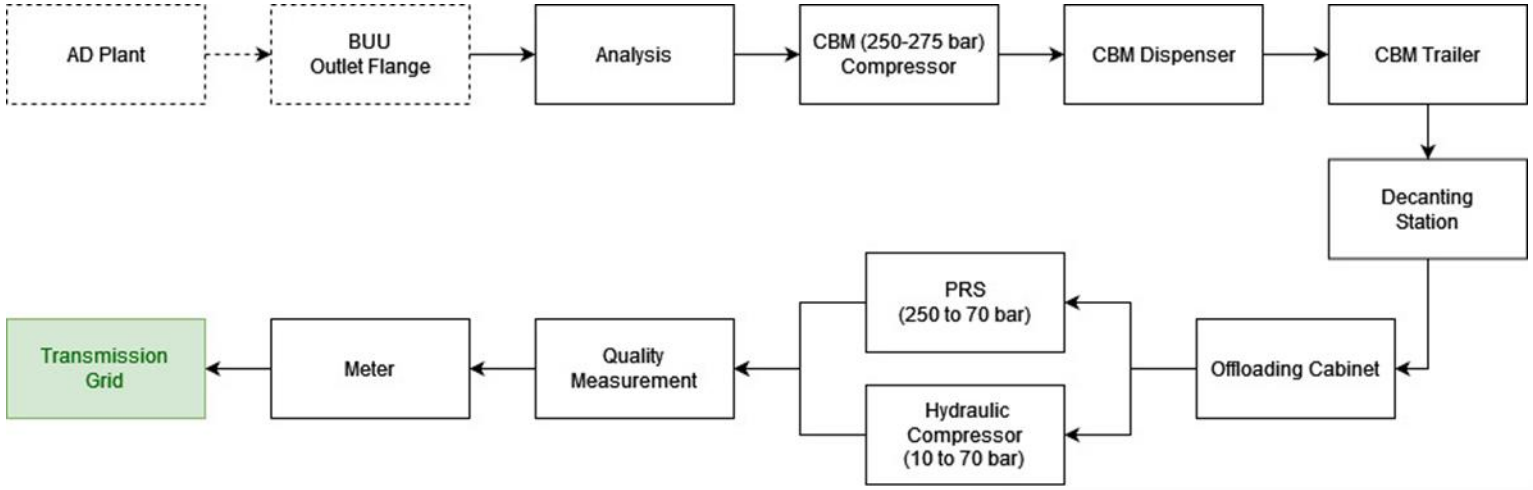


Basic Operational Process

1. Biogas flows from the AD and is treated in the Biogas Upgrading Unit (BUU), removing contaminants and CO_2
2. The upgraded biogas from the outlet of the BUU is fed through the Grid Entry Unit (GEU) which enriches (*LTS only not NTS*), odorises (*LTS only not NTS*), meters and analyses the gas. This GEU is situated at the same site as the BUU and ensures that biomethane produced is within grid specifications
3. The biomethane is then compressed (either at the AD site or at a remote compression compound) up to the pressure of the transmission grid
4. NTS ONLY - No propane or odorant is added into the gas stream at the GEU
5. Downstream of the compressors, the metered biomethane is fed through an HP pipeline from the AD site to the transmission grid connection point. This pipeline can be quite short if the compression process is carried out at a remote compression compound
6. The connection into the grid requires an operable valve connection. This can be carried out using an existing tee/valve assembly or a hot tap procedure. The use of an existing tee/valve is preferred.
7. In GB there is one NTS Injection Project, Somerset Farm (75 barg) and around 20 projects involving injection into the LTS (19 – 70 bar)

Air Liquide Bonby – 42 bar gas grid

Scheme 3 – Virtual Pipeline / Central Decanting Hub

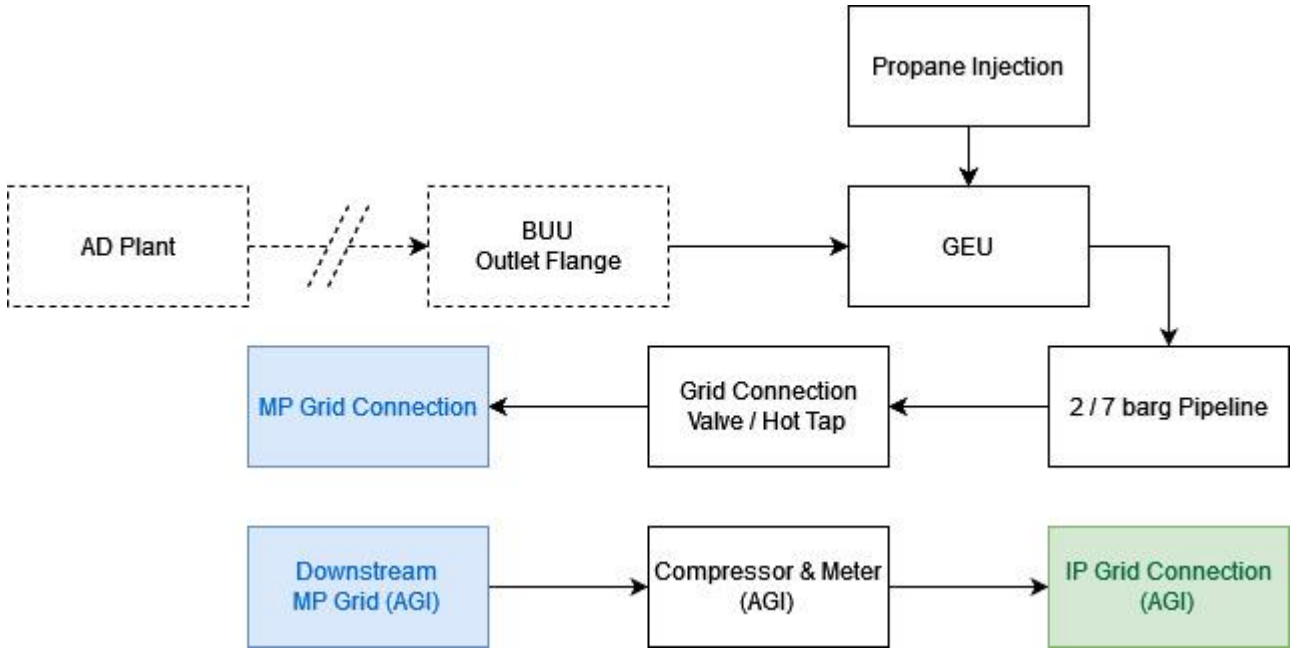


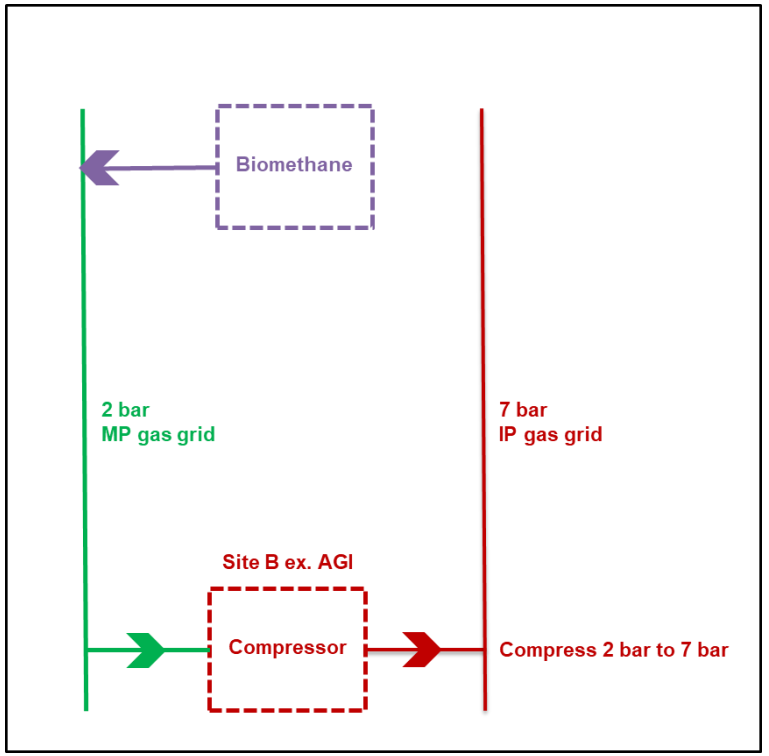
Basic Operational Process

1. Biogas flows from the AD and is treated in the Biogas Upgrading Unit (BUU), removing contaminants and CO_2.
2. Upgraded biogas quality is measured to ensure it is within specification prior to compression
3. Upgraded biogas is compressed up to 250 - 275 barg using a Compressor
4. Biomethane is dispensed into trailers using dispensers
5. The trailers transport the gas to a decanting site
6. At the decanting station, biomethane is decanted from the trailer through an offloading cabinet
7. Biomethane is decanted down to grid pressure through a pressure reduction system (PRS)
8. When the trailer pressure reaches the grid pressure, a hydraulic compressor can take over to deplete the trailer down to [20] barg. This is not necessarily done as it can be more expensive to do this than leaving residual gas in the trailer.
9. Gas is then measured, metered, [odorised and enriched] prior to injection into the grid via an existing valve or a new connection point

Air Liquide Fordoun Mother Station – shows trailer filling bay

Scheme 4 – Reverse Compression





Basic Operational Process

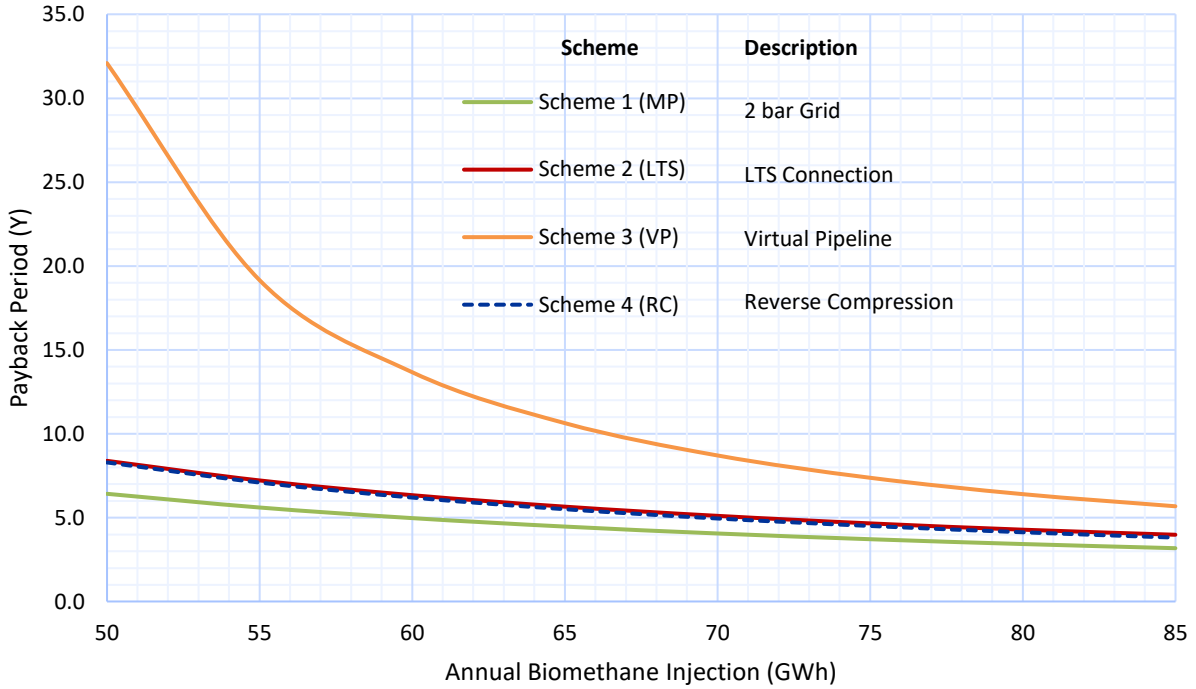
1. As per Scheme 1, biomethane is injected into an MP or IP grid
2. At an appropriate location (could be an Above Ground Installation), gas is compressed from the 2/7 barg grid into a higher pressure grid to create appropriate capacity for biomethane injection into the lower tier grid
3. To be clear, this compression occurs between two GDN owned and operated gas grids
4. Typical project would be between 7 bar grid and 42 bar LTS

GrDF Reverse Flow station in France (7 bar to 50 bar)

Cost Comparison

Key trends that were output from the model are as follows:

- Direct into a 2 bar MP is the best option.
- Next best is the Reverse Compression for a 2 bar MP network.
- This is followed by a HP LTS connection.
- The least attractive scheme is the virtual pipeline model.



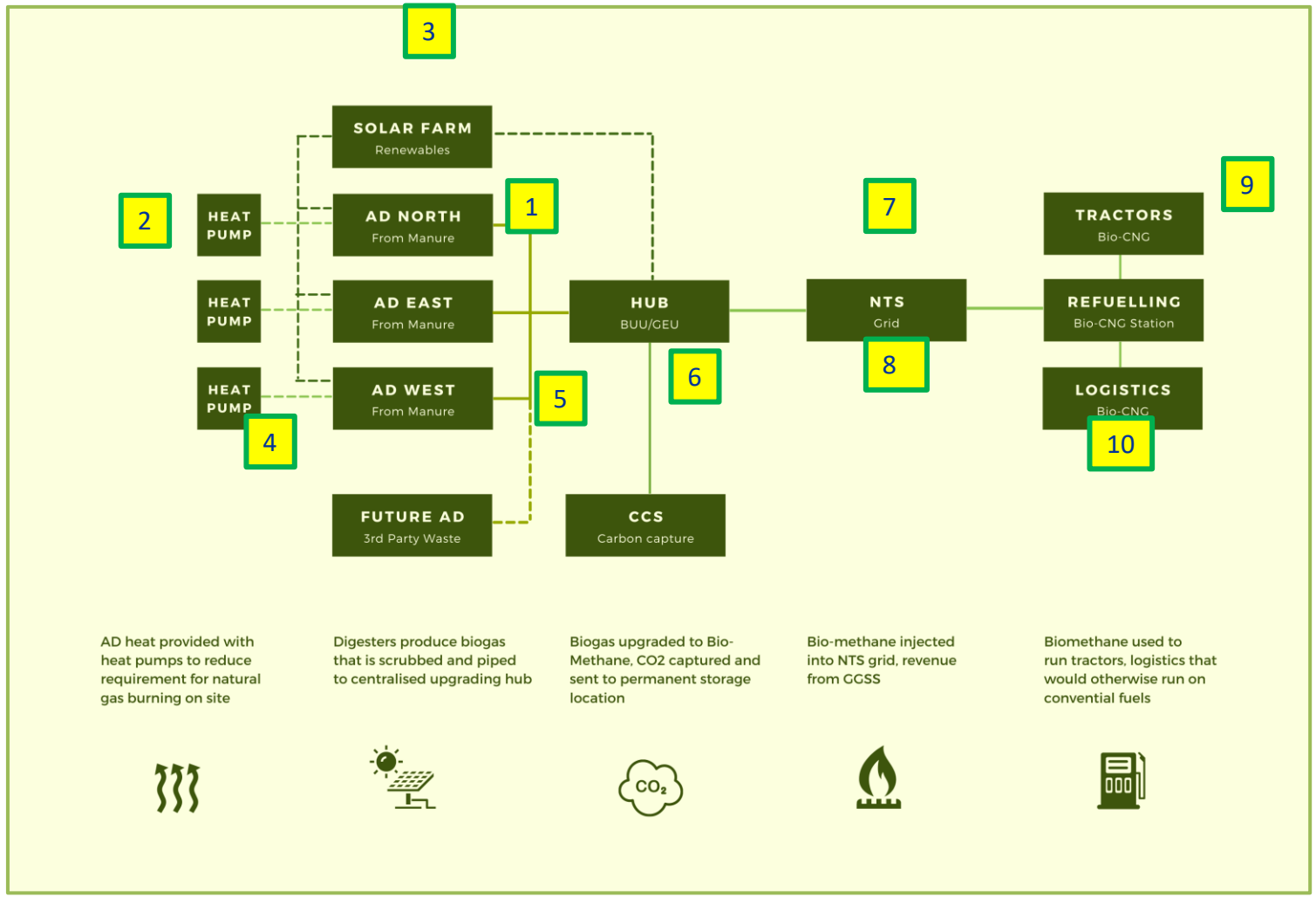
Pipeline Factor

- A virtual pipeline / central hub model will be the ideal and most economic scheme if the pipeline distance is significant. This report identifies this distance to be 26km for the model site analysed.
- There are also scenarios where a reasonable pipeline connection cannot be made due to the terrain or a trainline. This also leads to the virtual pipeline being ideal.

Older RHI sites

- The above graphs are for new AD sites with 2021 tariffs. There are older sites with higher RHI and Scheme 4 is more attractive

Cheshire Biomethane Concept with 10 NetZero Innovations

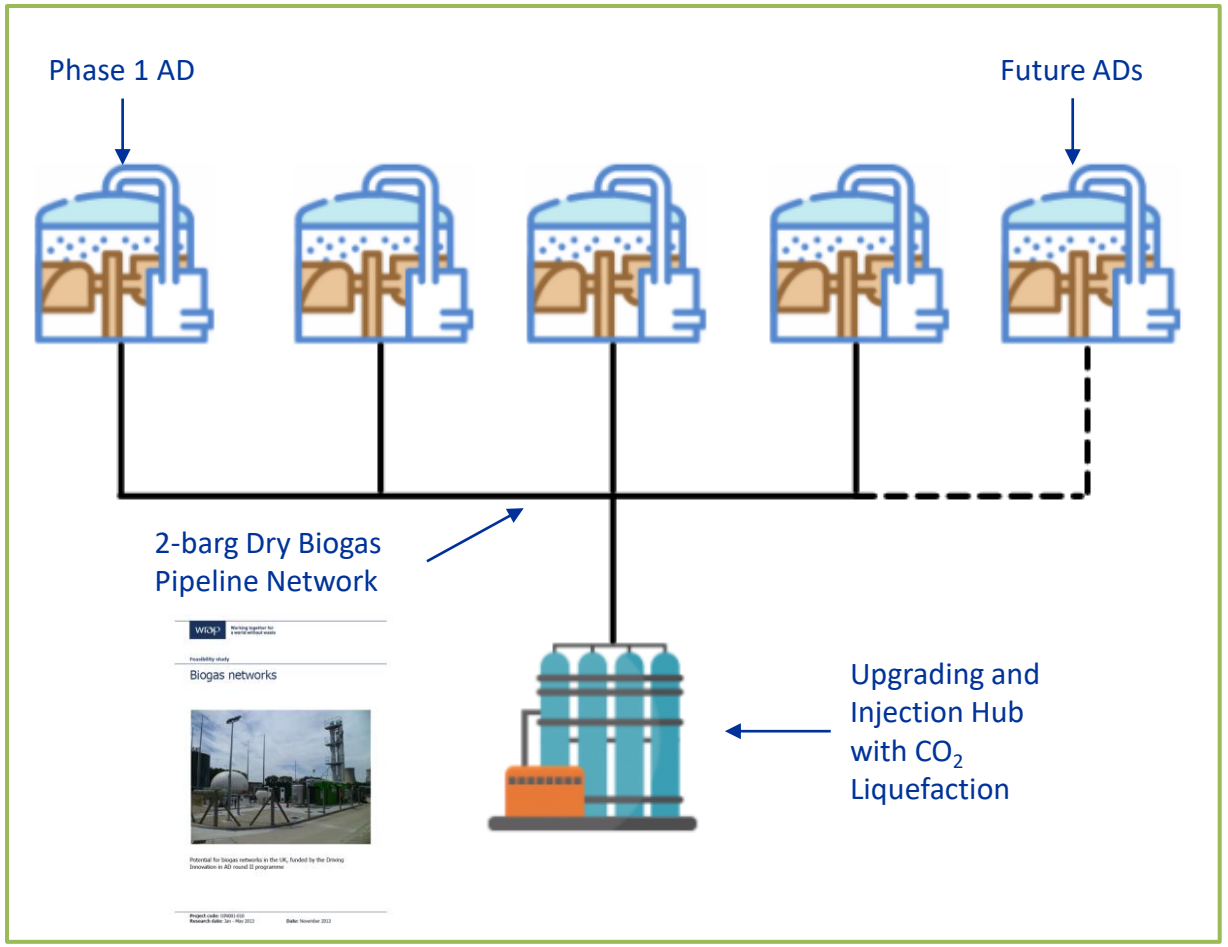


NetZero Innovations:

1. AD using manure (with no biogas combustion for heating and no biogas CHP)
2. River source heat pump
3. Direct wire network for ADs supplied by solar farm plus SP Networks back up
4. Pelletised fertiliser made from digestate and waste CO2
5. [50] km of dry biogas pipeline network (2 bar) with GT licence linking [10] ADs
6. Upgrading and injection hub with liquid CO_2 from manure to be sent to CCS
7. First NTS self-lay hot tap connection with innovative National Grid approach to compound size and design
8. Provision for H_2 injection into NTS
9. Farm tractors running on Bio-CNG made from manure with CCS – probably the lowest GHG fuel on planet earth
10. Bio-CNG made available via NTS Mother station and MRU model with circular economy – waste into the AD plants and Bio-CNG in return

Cheshire Biomethane Project
50 km of Dry Biogas Pipeline Network (2 barg) with 10 ADs

- Multiple biogas producing ADs across farms feeding into the same dry biogas network (with H_2S and water removed at the AD plant)
- IGEM standard in place for such networks
- Smaller ADs are generally not economic for biomethane market due to high unit cost of small (500 scmh biogas) biomethane upgrading units with CO_2 liquefaction
- Allows sharing cost of upgrading and liquefaction plant among multiple parties with all CH_4 and CO_2 separated at one location
- The Dry Biogas Network can keep expanding up to the capacity of the BUU, then build 2nd BUU etc
- Carbon capture to be designed in modular way with room for increasing number of plants in the future or by pipeline direct to HyNet



California Example

https://calbioenergy.com/wp-content/uploads/Kern-Cluster-Description-Sept-2020.mp4

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Upgrading and Injection Hub with Liquid CO_2 from Manure Sent to CCS

Key Points:

- CO_2 separated from the biogas using membrane technology
- Zero CH_4 to air as a result of the liquid CO_2 plant
- Biomethane compressed to 75 barg and injected into the NTS
    - No propane or odorant required
    - No capacity issue in Cheshire NTS
- The biogas waste CO_2 will be liquefied and sent to CCS facilities for permanent sequestration
- A number of options being considered for 2 year period prior to the first offshore CCS plants being available
- CO_2 can also be transported via pipeline when the HyNet CCS facility is built

Bio-CNG Farm tractor – made in Basildon

The Air Liquide CO_2 Tanker is an Existing Food Grade Example (Not Manure)

Photos from the first NTS Biomethane Injection Project at Somerset Farm Completed in 2020

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Conclusions

- An AD project makes 3 products:
  - Biomethane
  - CO2
  - Digestate (fertilizer)
- With high gas prices all 3 products are valuable
- With NetZero there are some key principles:
  - Never vent any CH4
  - Never vent any CO2 (use in Industry or send to CCUS)
  - Never burn any biogas – use heat pups to heat digesters
- Membrane plants are set to dominate:
  - No use of heat
  - When coupled with CO2 liquefaction no CH4 emissions
  - Can be linked to solar/battery direct wire networks with grid back up
- And finally
  - NTS is a great option for injection of H2 as there is no CV target , especially good if H2 made at an AD plant

Remember – Never burn any biogas, Never vent any CH4, Never vent any CO_2 and never burn any diesel