I Chem E
Biomethane and Grid Injection

1st February 2018

John Baldwin

CNG Services Ltd

john.baldwin@cngservices.co.uk
www.cngservices.co.uk

UK Biomethane Day 2018 - 2nd May 2018

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CNG Services Ltd

- Supports projects to inject biomethane into the gas grid
  - 86 projects by Dec 2017, we have worked on 75
  - 28 staff
- Supports back-up gas generation projects
  - Dash for gas engines underway
- Whisky industry projects
  - Distillery CNG project
  - Islay Biomethane Island Project
  - Speyside Power to Gas Project
- Part owner of CNG Fuels Ltd, a company set up to build national network of Bio-CNG stations on the high pressure grid
  - Leyland CNG Station
  - 84% saving in GHG compared to diesel

THE QUEEN'S AWARDS FOR ENTERPRISE: INNOVATION 2016

Innovation in Natural Gas

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Agenda

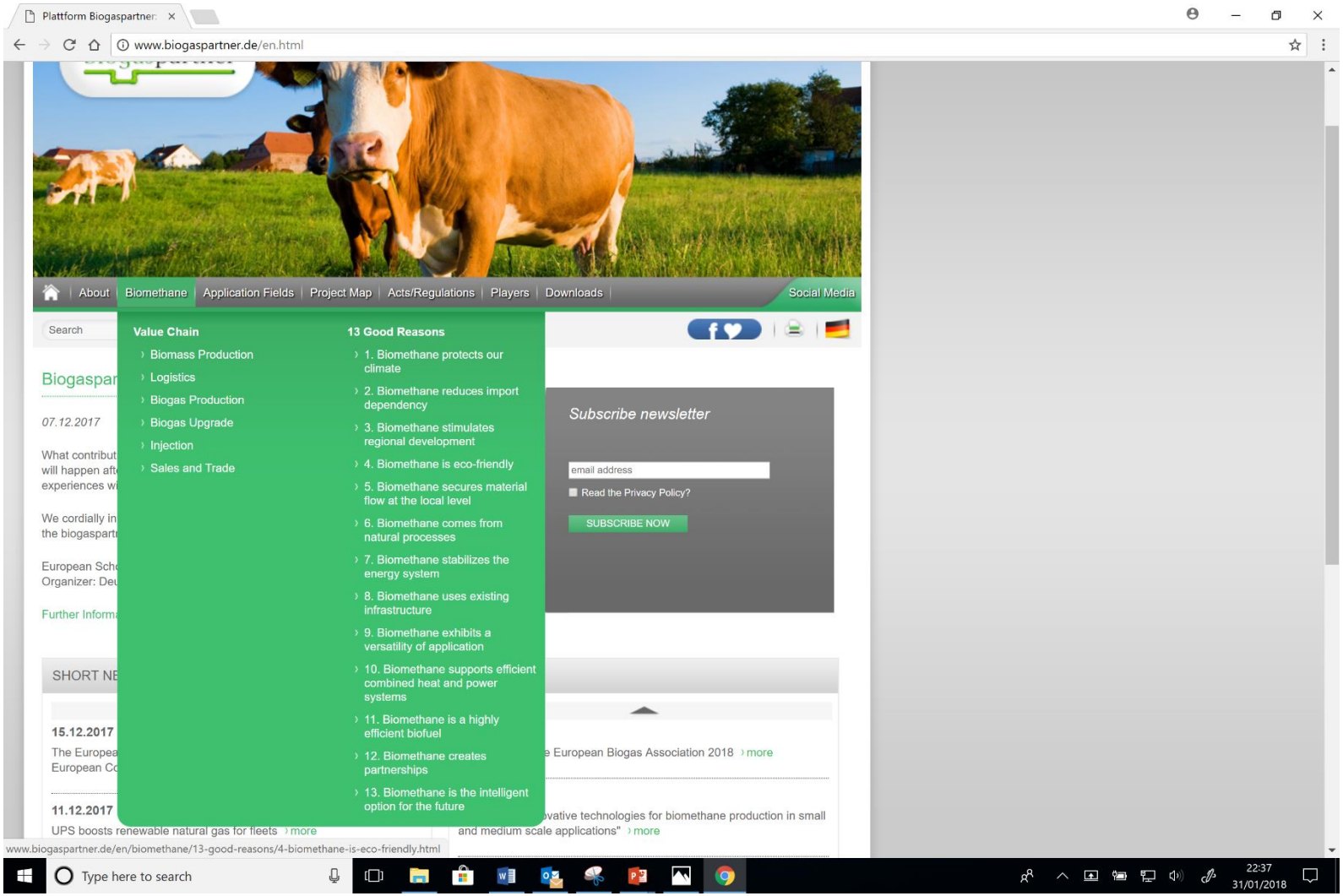
1. Introduction (feedstock, benefits and grid Injection)
2. Biomethane in the UK – update/trends/total capacity etc
3. The challenges: technical (gas cleaning, capacity, grid injection) and regulatory (including Gov incentives)
4. Current and emerging technologies (cleaning, upgrading, bio-cng trucks)
5. Case studies
6. Demand for Biomethane
7. Summary

http://www.cngservices.co.uk/index.php/news/cng-events

- UK Biomethane Day 2018 - 2nd May 2018
- UK Biomethane Day 2017 - 24th May 2017
- UK Biomethane Day in 2016
- UK Biomethane Day 2015
- Natural Gas Vehicle Day 2014
- UK Biomethane Day 2014
- UK Biomethane Day 2013
- Crewe CNG Filling Station Official Opening
- UK Biomethane Day 2012

1. FEEDSTOCK AND BENEFITS

www.biogaspartner.de



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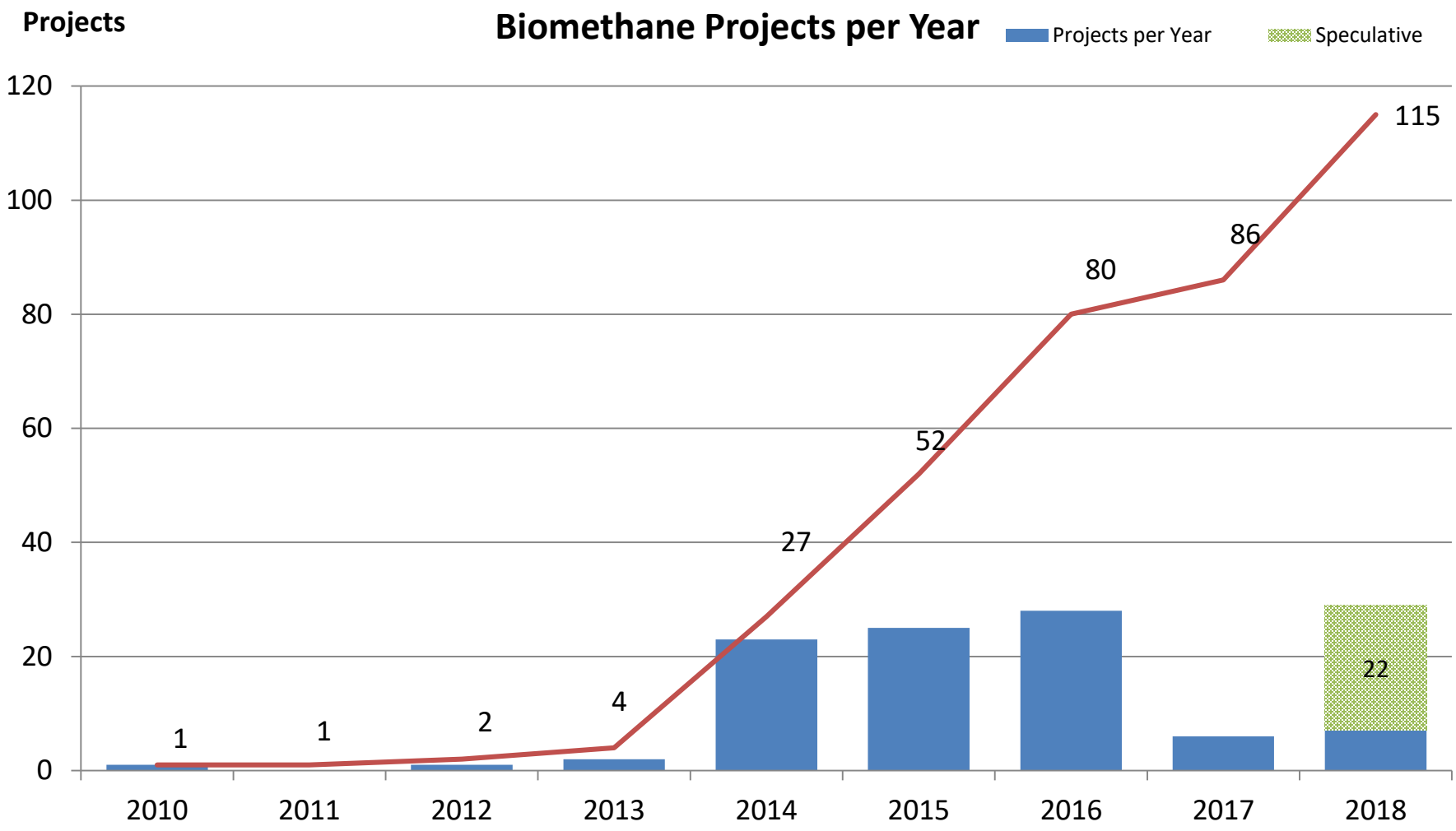
2. BIOMETHANE PROJECT UPDATE
85 PROJECTS BY END DEC 17

Biomethane projects per year 2010-2017



80 projects by 2016 – the election has delayed Project 100 until 2018/9

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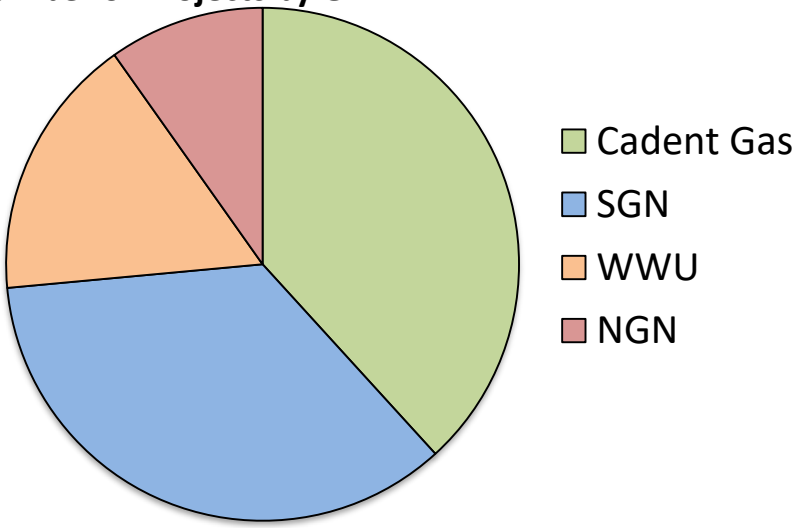
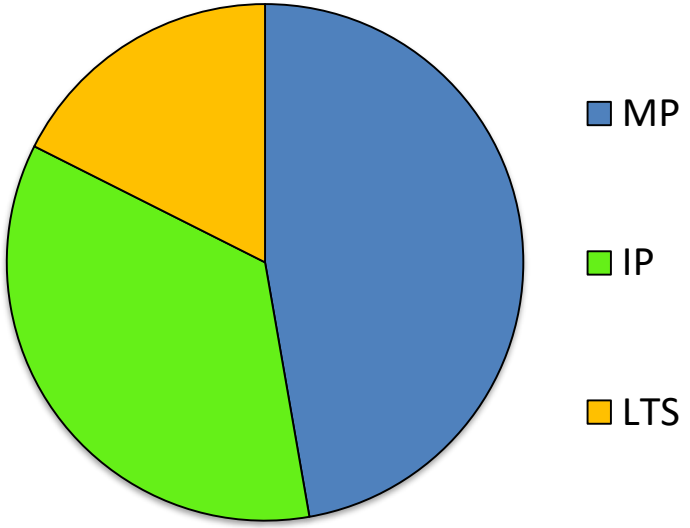
GDN, LDZ, Pressure, Flow-rate

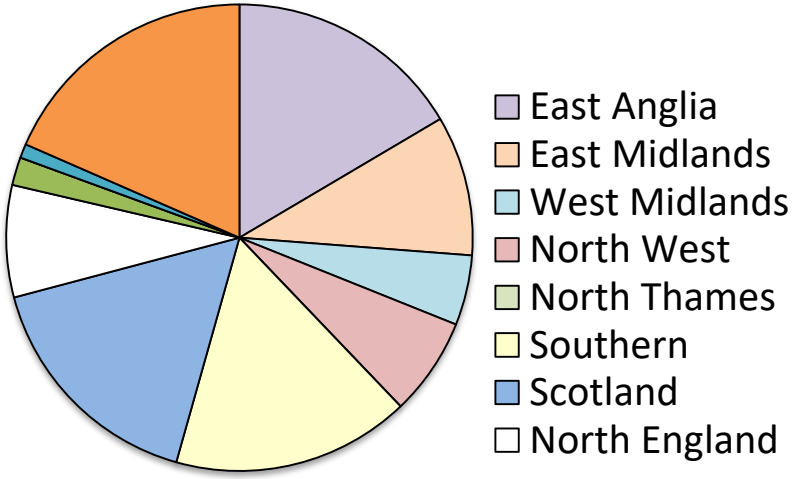
Number of Projects by GDN



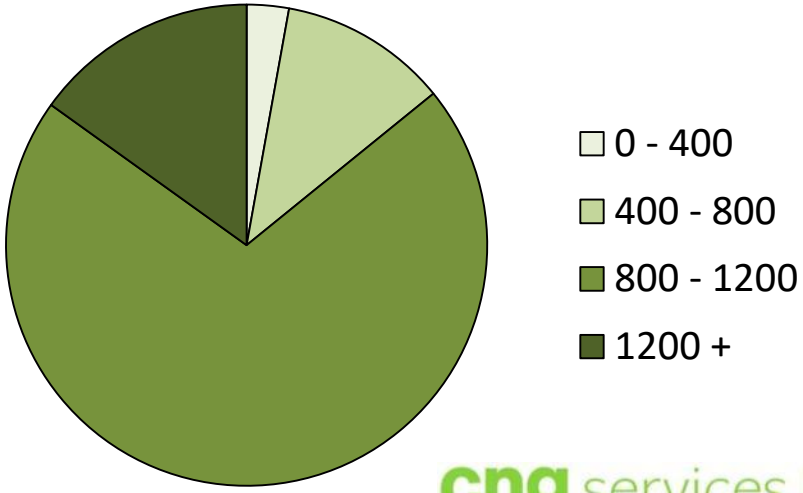
Number of Projects by Pressure Tier



Total Number of Projects by LDZ



% Projects by Biogas Flow Rate



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3.1 CHALLENGES - THE RHI

New RHI

1. New RHI was expected March 2017, delayed due to a drafting error and then the General Election
2. Now expected in Q1 2018
3. Only 2 new projects in 2017
4. Potential for 25 - 30 projects in next 2 years subject to life of RHI
   - Needs to make >50% of biogas from waste
   - Ability to lock in tariff subject to:
     - Planning
     - Connections contract
     - Finance
   - Complete by 31 Dec 2019
     - Request to extend into 2020

Potential New 2018-19 Projects

- Energy Networks Biomethane working group gave numbers of projects in each GDN area that have signed Connection Agreements:
  - Cadent – 16
  - SGN – 11
  - WWU – 5
  - NGN – 3

  Total - 35
- Signing a Connection Agreement does not mean the project is certain to go ahead as the cost is refundable
- Key Feasibility issues are:
  - Is there capacity in the grid?
  - Can the 50% biogas from waste target be met?
  - Is planning consent in place?

The market is waiting for the RHI

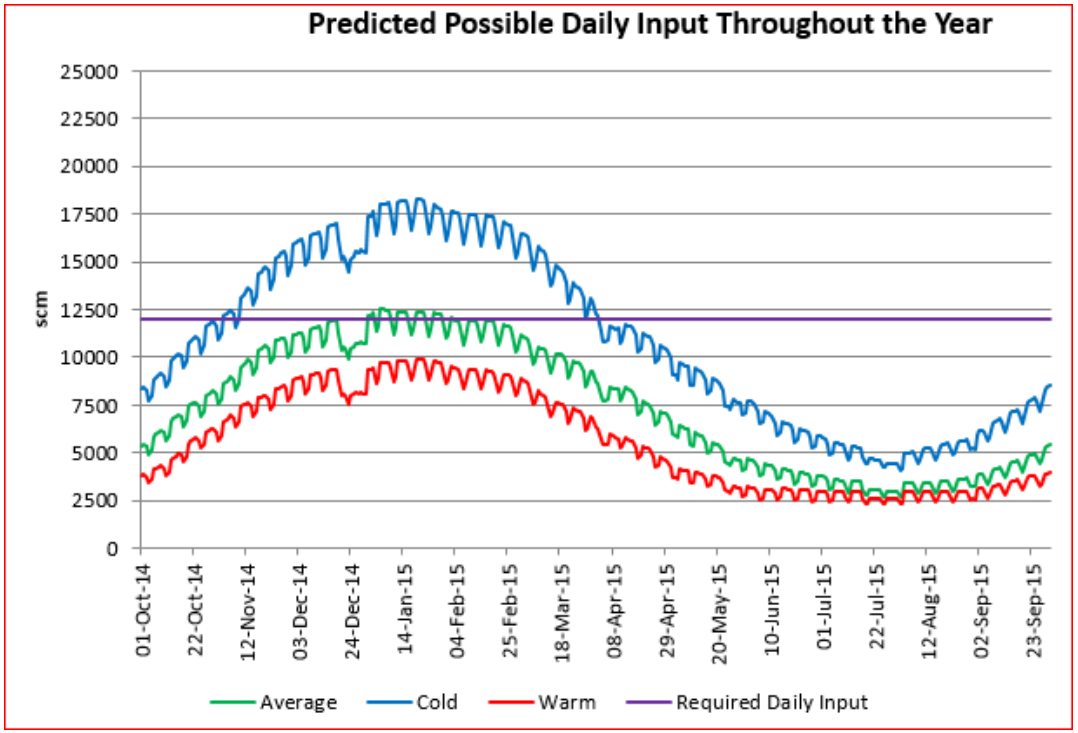
3.2 CHALLENGES
THE CAPACITY QUESTION

New RHI – impact on capacity

1. With new biomethane projects needing to make >50% of biogas from waste, the location of the AD has to be where the waste is
   - This reduces the number of sites and means that grid capacity is critical
2. For >150 years gas has flowed through the grid from high pressure to low pressure…..time to change that
3. The gas pipeline networks are not designed for smaller distributed sources such as biomethane:
   - Very limited metering or knowledge of real flows at sites that feed the IP and MP pipelines (and any metering designed for peak so not accurate at low flow)
   - No concept of a summer "1 in 20" – so the network analysis models still use winter peak which can only give theoretical issues at grid extremities
   - Some 'guaranteed' pressures for I&C customers prevent lowering of pressure to accept injection of biomethane
4. Finally, there is no financial incentive on GDNs in relation to biomethane

Capacity is the key issue facing the industry

GDN Capacity Reports



Above is a typical graph showing a typical project where there is not enough capacity in summer due to insufficient demand in the network

We must solve this problem…next slides show developments

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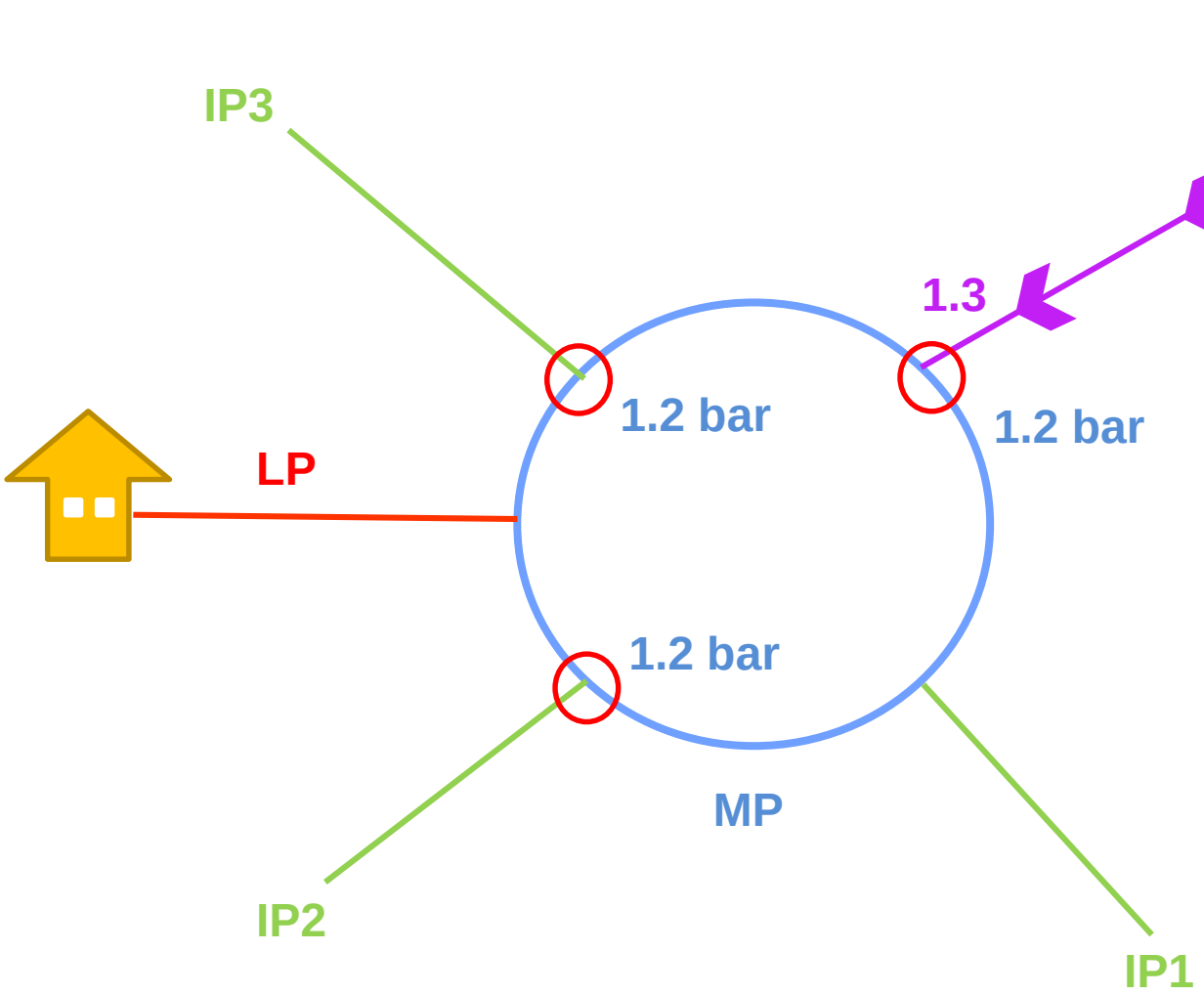
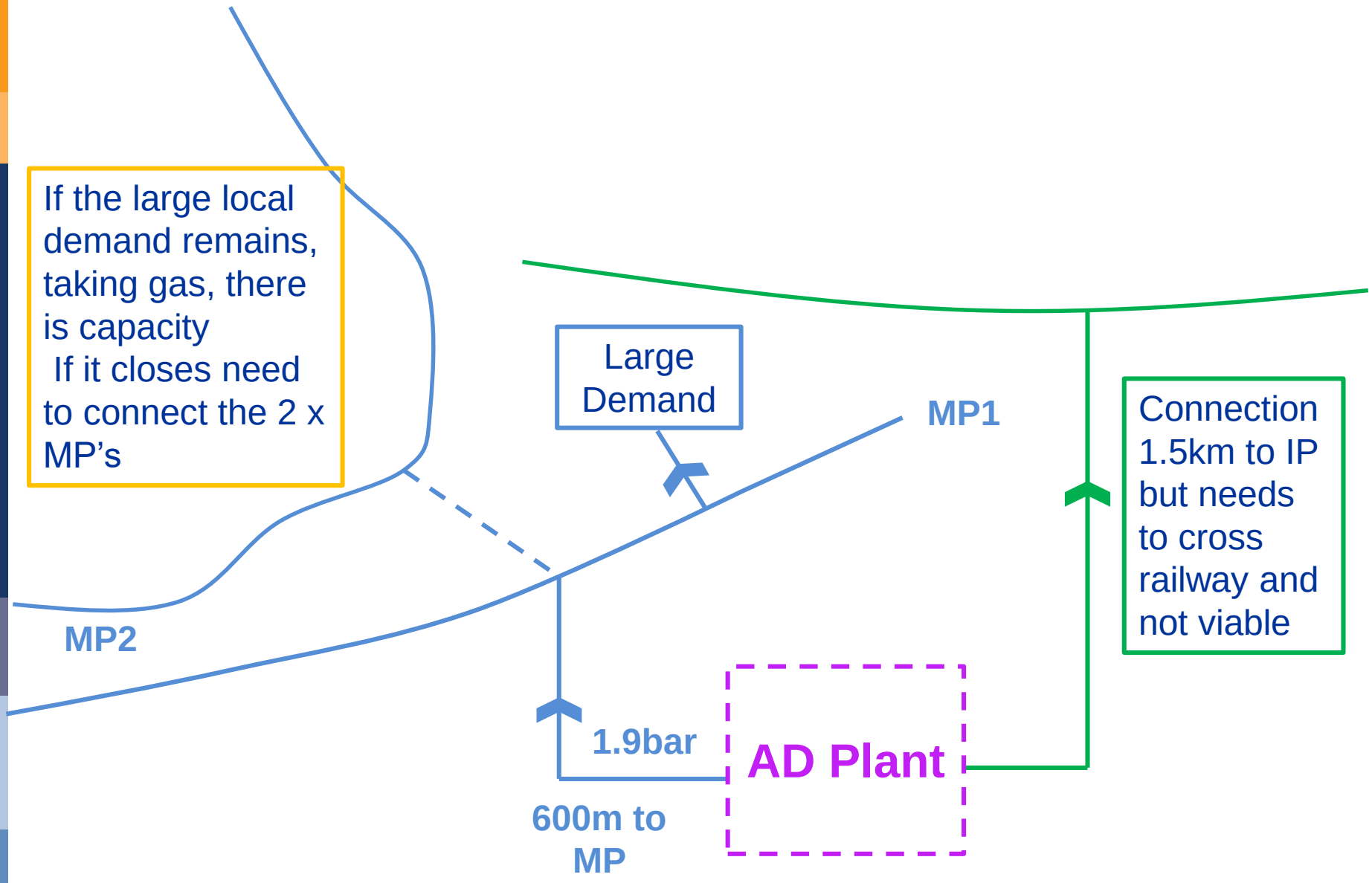
Project 1 – Biomethane into MP with Regulator Adjustment



Low point sets the IP to MP pressure – as long as the Low point has enough pressure, the MP setting is low to avoid any gas from the IP pipelines flowing into the MP low – so the biomethane project has the capacity

Project 2 – Capacity provided by Local Factory



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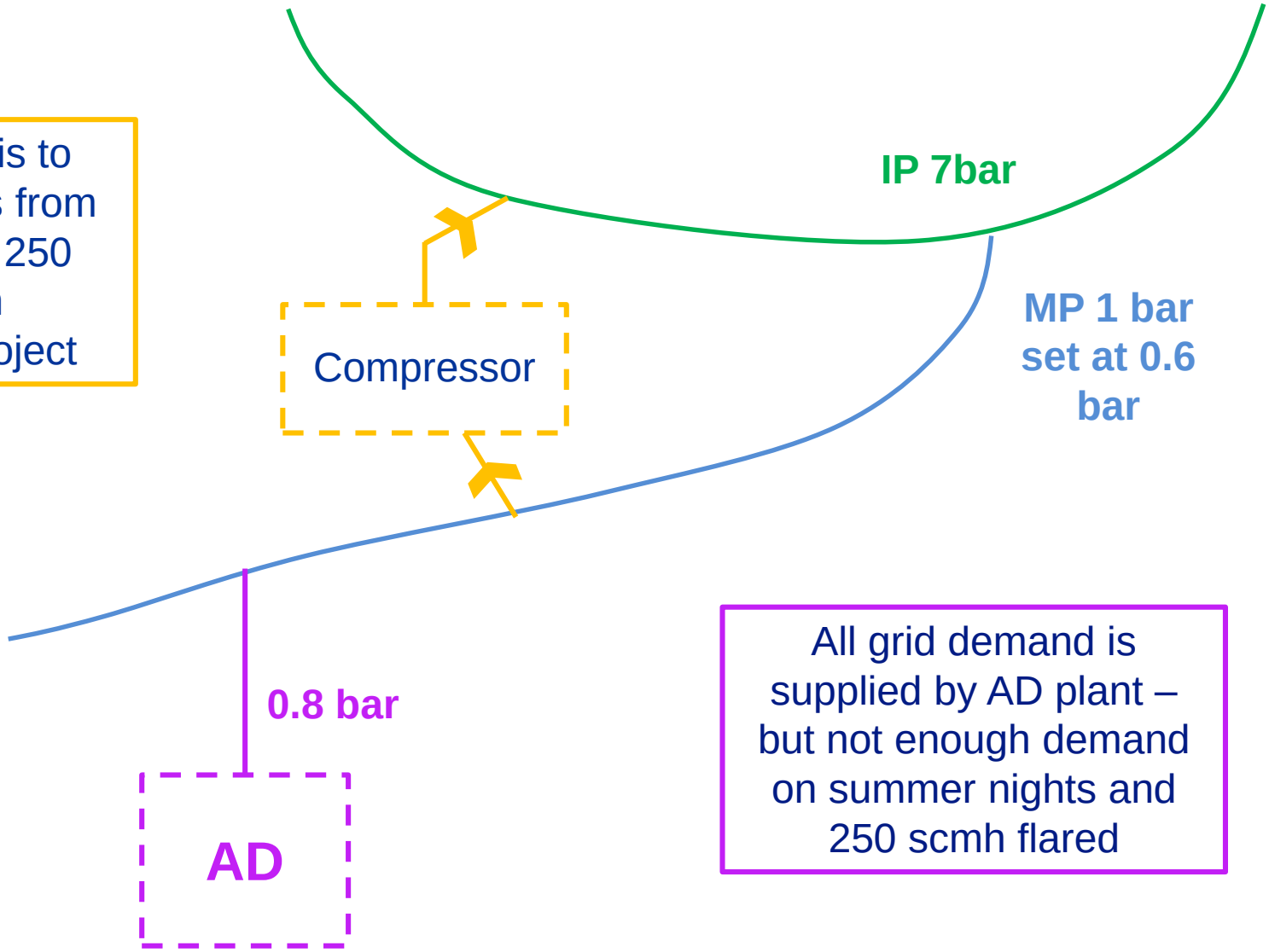
Project 3 – MP to IP Compression

Solution is to export gas from MP to IP 250 scmh
£300k project

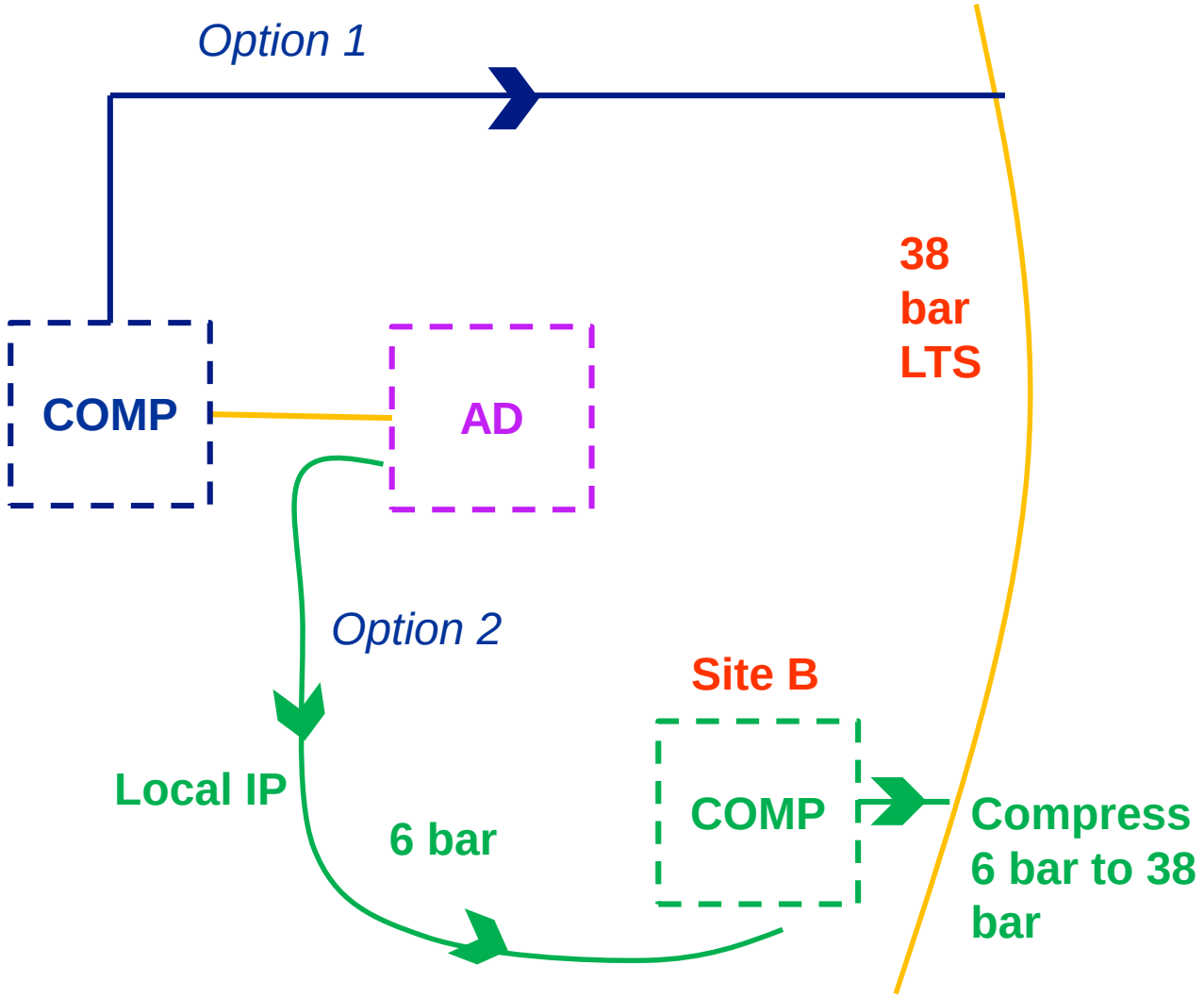


All grid demand is supplied by AD plant – but not enough demand on summer nights and 250 scmh flared

Project 4 – IP and within Grid Comp

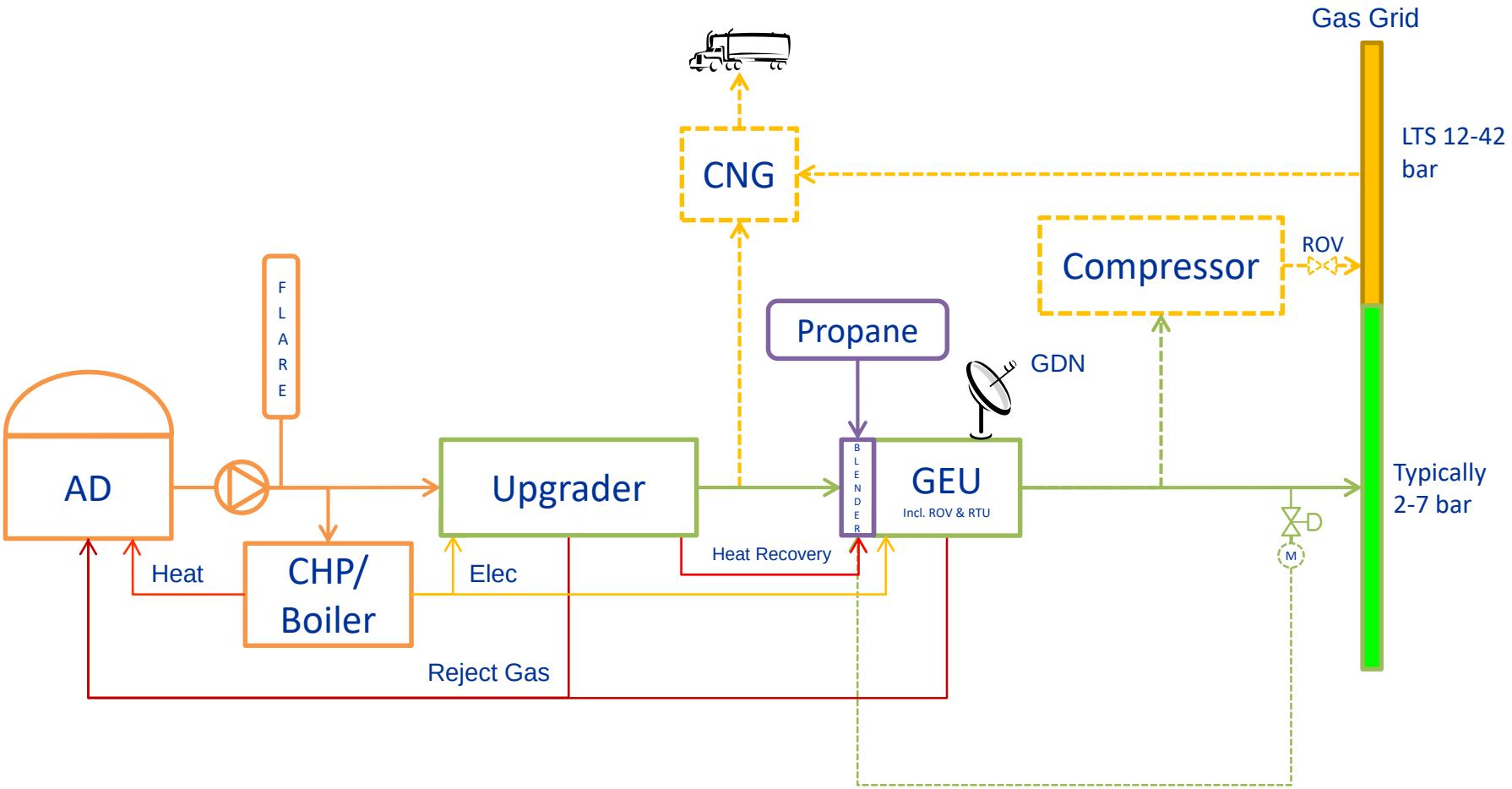
Option 1
Compress all gas into LTS
£2.5 million capex, high opex, 365 day compression

Option 2
Inject into local IP GDN compresses from IP to LTS at site B
£1 million capex
Low opex as <1,000 hours



4. DESIGN OF BIOMETHANE PLANTS

Overall Concept



Options

- CHP or Boiler – CHP less attractive now <499 kW FIT removed
- CNG – either before propane or from high pressure grid

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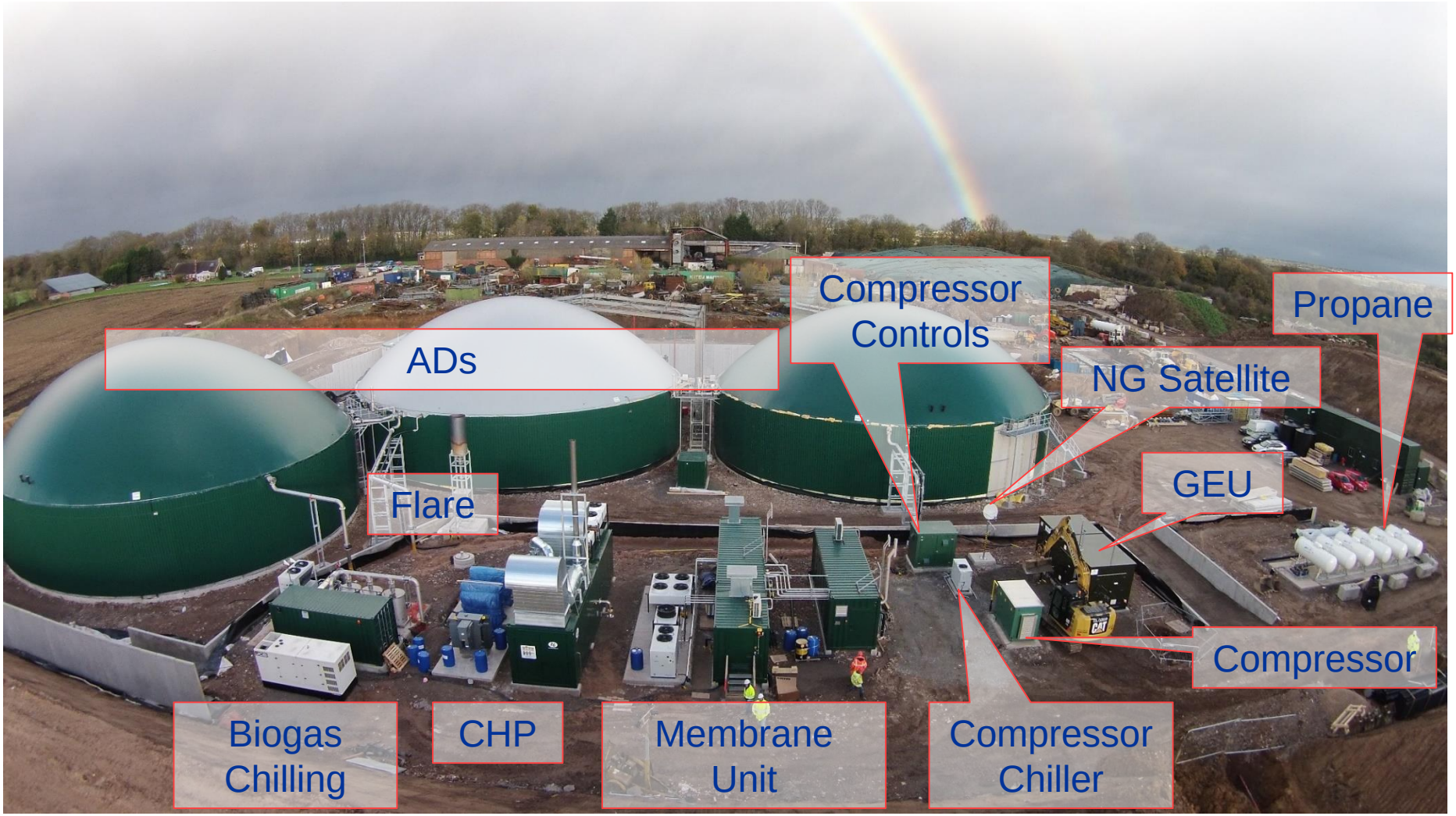
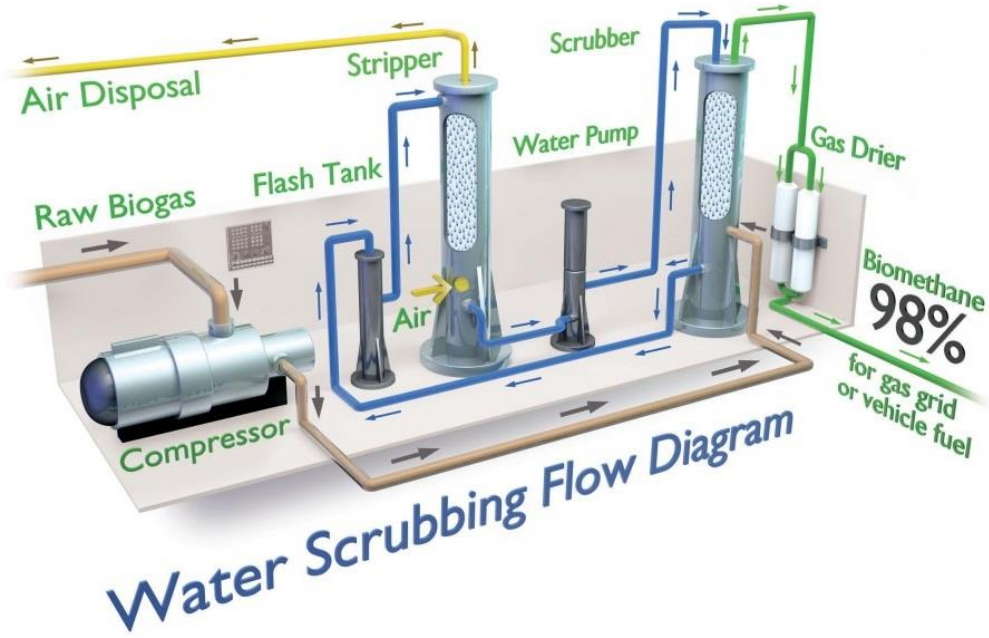
Overall Concept



CO_2 REMOVAL TECHNOLOGY

Water Wash



- 99% of biomethane goes into grid
- <1% methane slip
- 14 - 16m high towers
- Plant also removes H_2S and Siloxanes
- 2 suppliers active in UK
- Proven and low risk

Water Wash

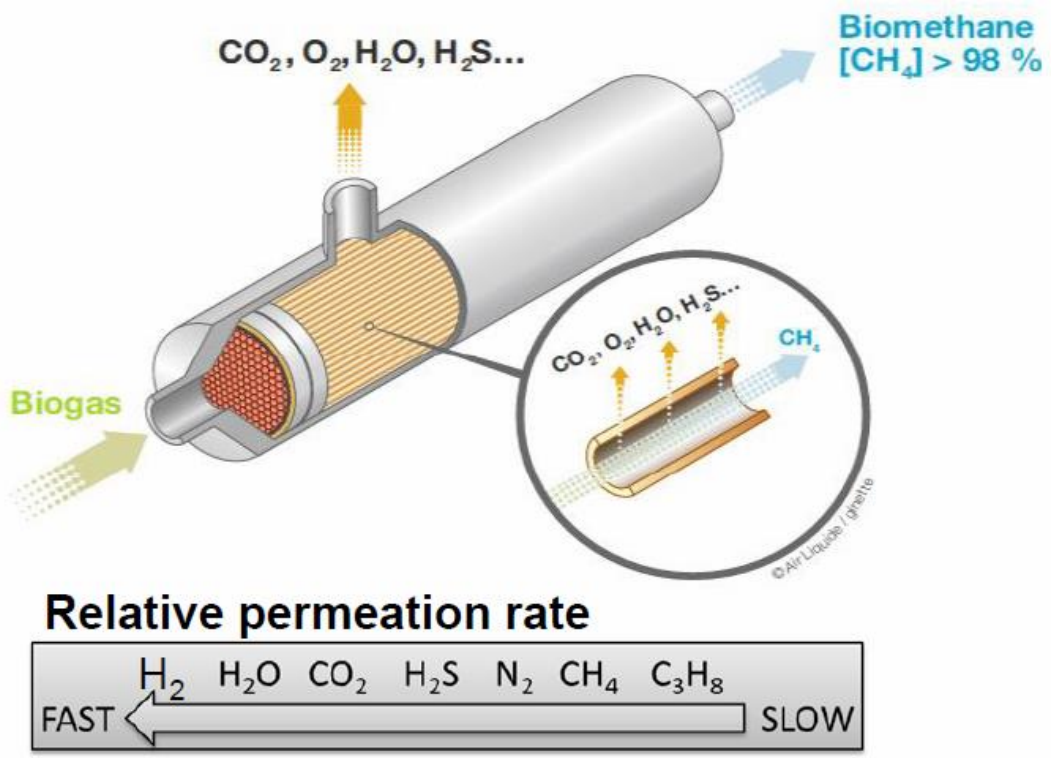
Advantages

- Simple, proven technology with many plants in operation
- No pre-treatment for H_2S
- 2 suppliers with many UK & international projects

Disadvantages

- CH_4 emissions to air
  - Higher than Chemical Wash and membrane
  - <1% methane slip
- Tall towers for CO_2 removal
  - 12-18 metres
- Water supply and disposal

Membrane Separation



- 3 variants now in UK
  - Two stage with CO_2 liquefaction
  - Three stage with <0.5% CH_4 vented
- Well suited to plants with <1,500 m^3/hr biogas flow rate
- Benefits from lower profile for planning

Membrane Separation

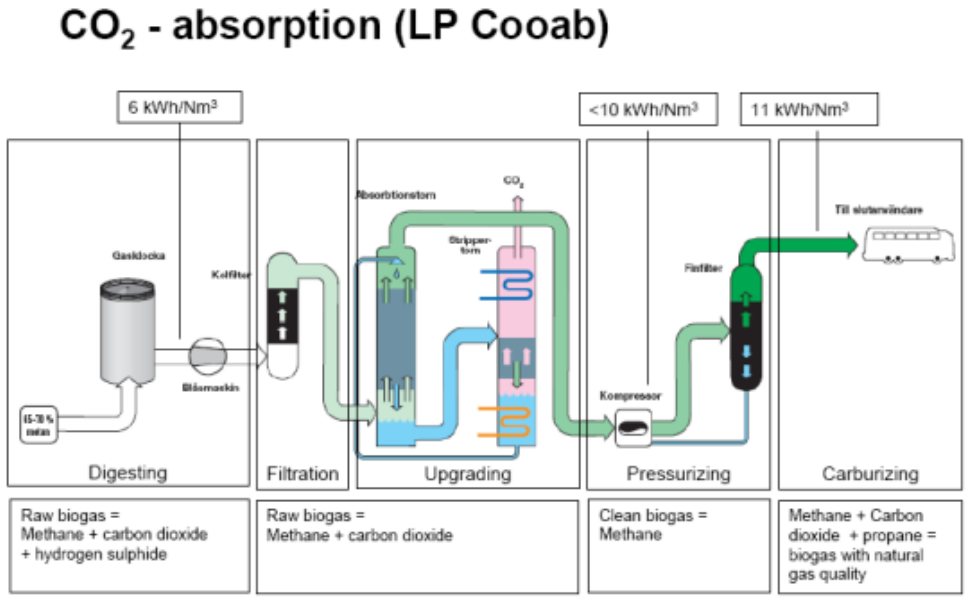
Advantages

- Compact
  - No need for large towers
- Food grade liquid CO_2 produced (Haffmans plant)
- Low methane slip
  - <0.5%
- Simple plant - modular
- Good turndown
- 6 suppliers can compete
  - 3 different types of system

Disadvantages

- Higher electricity costs
- Biomethane quality
  - CO_2 removal
  - May have up to 1% CH_4 in off-gas
- Higher H_2S & contaminant removal costs
  - All done upfront
- Membrane life 5-10 years
  - Expensive item, though prices should come down

Chemical Absorption



- 99.8% of biomethane to grid, <0.2% methane vented
- Needs significant heat to raise steam to recover chemicals and hence good fit if excess heat available from biogas CHP
- Less electricity required
- Requires less propane as less CO_2 remains
- 1 supplier in UK

Chemical Absorption

Advantages

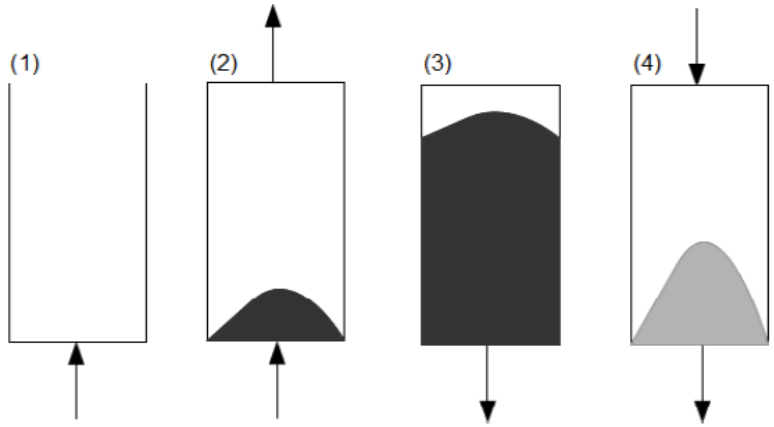
- Good quality Biomethane
- Low Methane slip
  - 0.2% lost
- Low electricity consumption
- Lower propane needed
- Good turndown

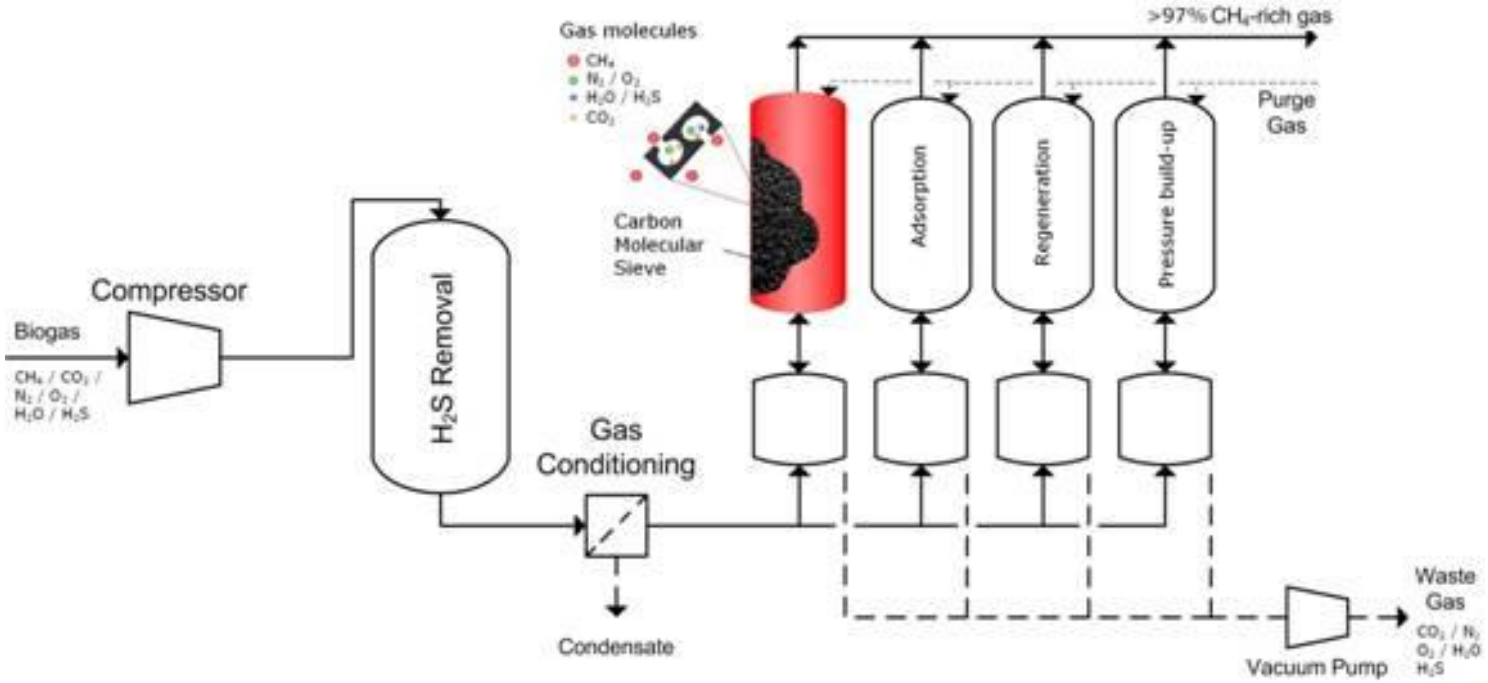
Disadvantages

- Heat energy needed to regenerate chemicals
- Tall towers for CO_2 removal
  - 12-18 metres
- Amine supply and disposal
- Low Oxygen concentration needed

Pressure Swing Adsorption

- Key issue is off-gas
- New multi stage system reduces methane slip
- 1 supplier in UK
- N_2 and VOC removal possible





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Pressure Swing Adsorption

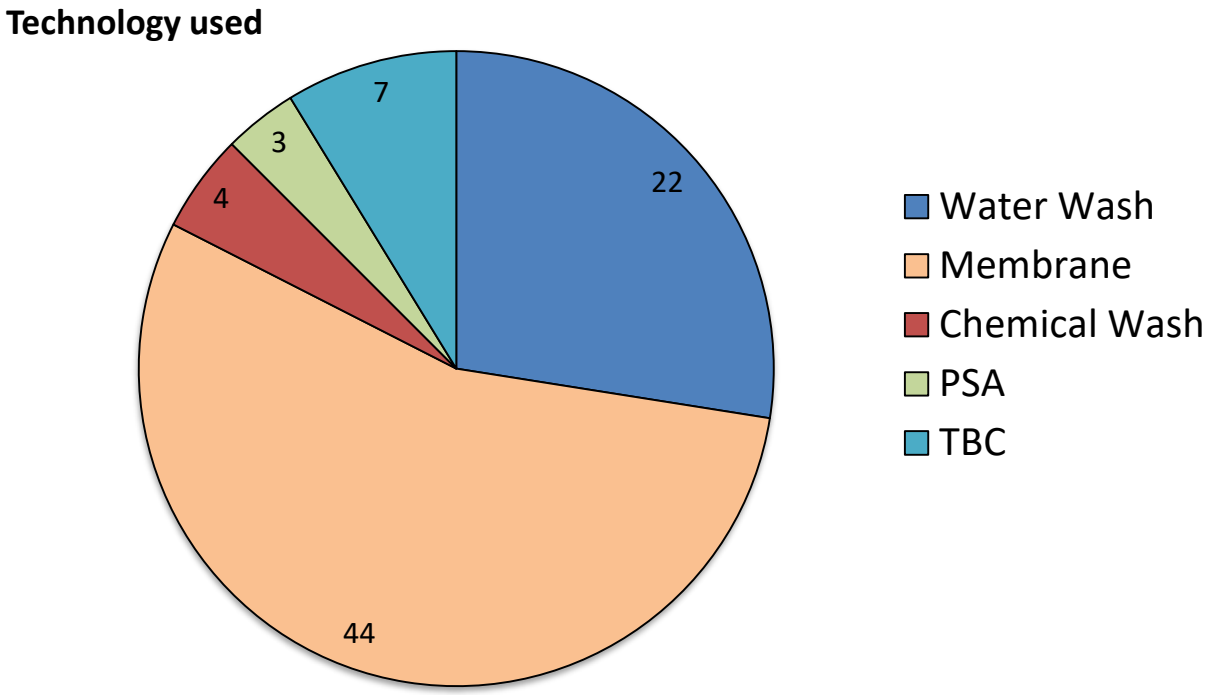
Advantages

- Compact
  - No need for large towers
- Lower operating pressure and therefore electricity demand
- Good turndown
- Can remove contaminants and N_2
  - Separate beds

Disadvantages

- Methane Slip
  - New system will reduce this
- Biomethane quality
  - CO_2 removal – May have up to 1% CH_4 in off-gas
- Batch process
  - High wear on valves and seals
  - Buffer vessel needed

Proportion of CO2 Removal Technologies in UK



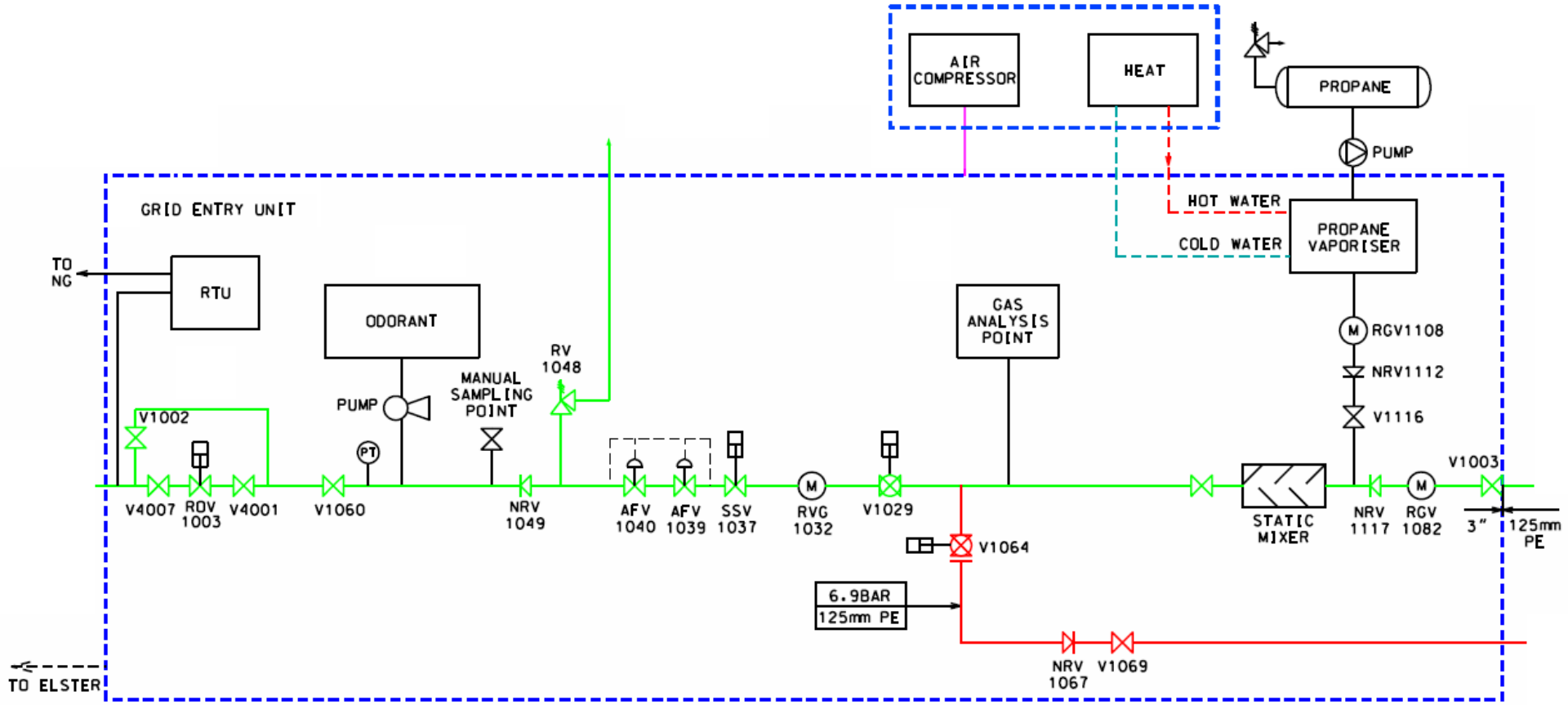
Technology	Number of Projects	%
Water Wash	22	28%
Membrane	44	55%
Chemical Wash	4	5%
PSA	3	4%
TBC	7	9%
Total Projects	**80**	

GRID INJECTION FACILITIES

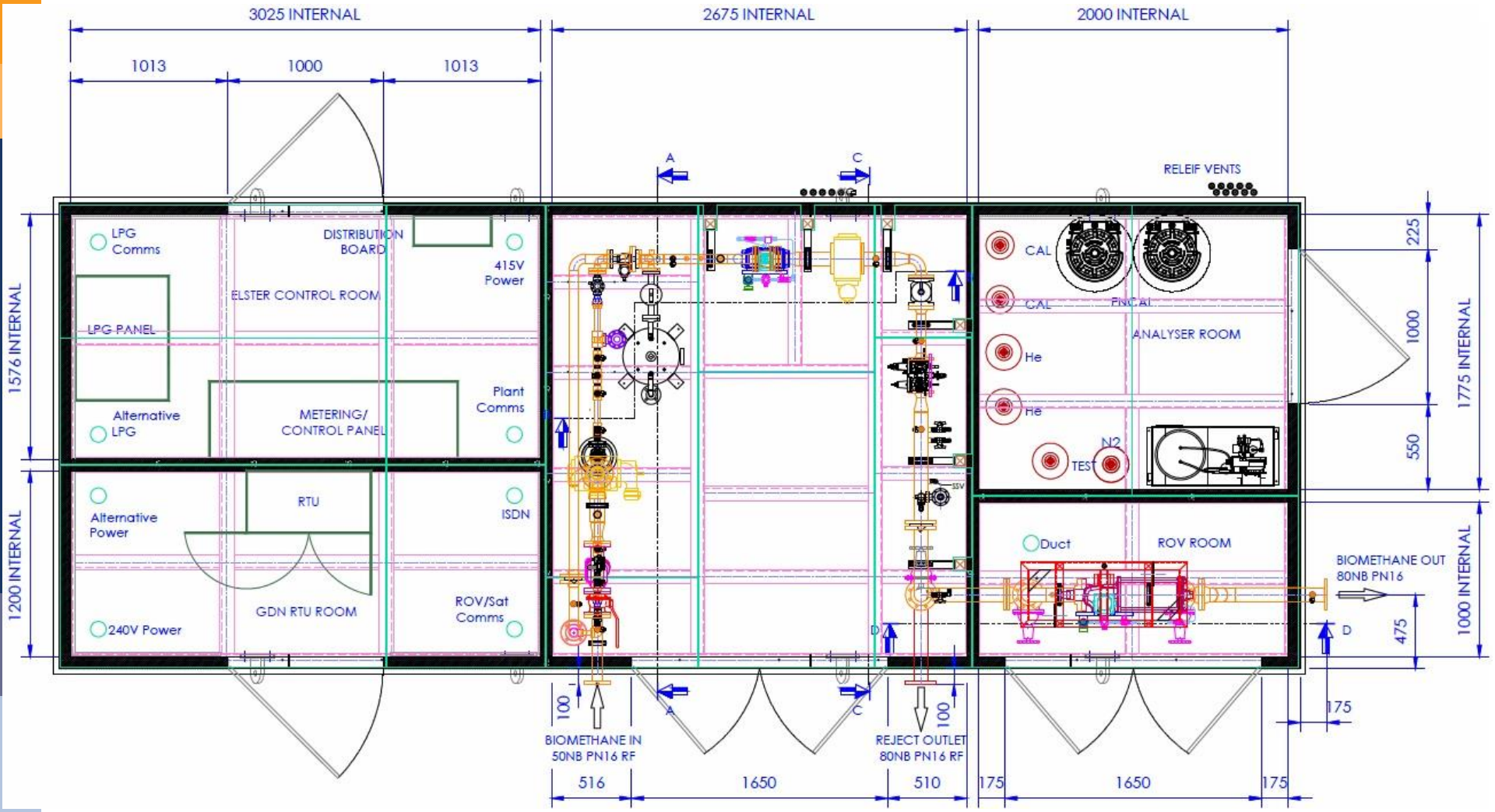
Grid Entry Unit

- Measure biomethane quality and ensures compliance
- Adds propane and odour
- Communicates with GDN
- Biomethane flow as follows:
  - Propane injection and blending
  - GS(M)R sampling
  - Fiscal Metering
  - Pressure reduction
  - Odorant injection
- Design now a one box solution – accepted by all GDNs
  - Reduces complexity

GEU PFD



1 Box GEU



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Propane Enrichment

Propane storage tanks


Propane mixing unit

- The Gross Calorific Value (GCV) in the GB gas grid is 38.8 – 39.5 MJ/m^3
- The typical biomethane GCV is 37 MJ/m^3 (98% CH_4 with 2% $CO_2/N_2/O_2$)
- Propane likely to be highest operating cost for biomethane project
- LTS and IP can offer blending in some areas

Propane Injection

- Two options for propane injection
  - Vaporiser – this uses hot water to heat the propane prior to injection and blending in biomethane stream
  - Liquid injection system which heats the biomethane and uses the latent heat to vaporise the propane after injection into the biomethane stream

- GEU will house propane system
  - Preferred system highlighted in tender specification

Propane Storage

- Three possible options for propane storage
  - Above ground – simplest installation
  - Buried or mounded – halves separation zone required
  - Part buried and part mounded

- 24 Tonnes storage max
  - If above this need COMAH regulations and planning permission and a water deluge system
  - 2x12 tonne more readily available but single tank can be used

- Free of Charge Installation possible
  - Cost paid over 5 years as part of consumption

Propane Storage

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GAS QUALITY & GSMR

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Biomethane Quality

- Most important with Food Waste feedstock
  - Good Feedstock – produces good quality biogas – around 60% CH_4
  - Reduces waste to landfill & harmful emissions
- High Contaminants
  - H2S levels
  - VOCs – Limonenes mask odour
  - Will damage upgrade plant
  - Not acceptable in grid
  - Spoons and Plastic Bags
- Higher contaminant removal cost
  - More pre-treatment steps incl. pasteurisation
  - Activated carbon for H2S and VOC removal
  - Can use other low cost options

More upfront equipment and engineering

GS(M)R Gas Specification

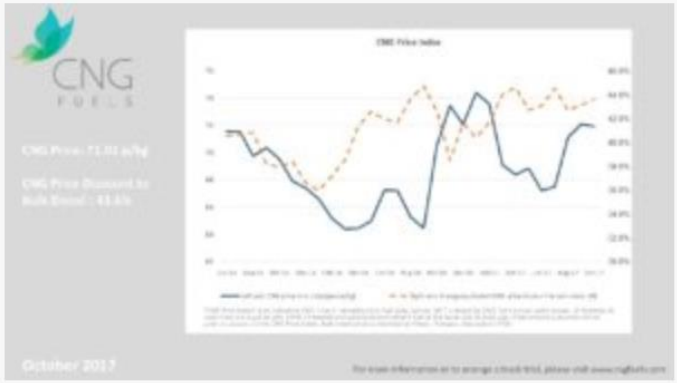
Parameter	Biomethane quality
Temperature	1- 38 °C
Pressure	Dependent on grid (2, 7, 19 or 38barg)
Odour	**No uncharacteristic or masking of odour**
Hydrogen sulphide	**<= 5mg/Sm3**
Hydrogen	< 0.1 % vol
Carbon Dioxide	≤ 2.5% vol
Oxygen	≤ 1.0% vol
Nitrogen	balance
Hydrocarbon dew temperature	≤ - 2°C at up to 85 barg
Water dew temperature	≤ - 10 °C at up to 10 barg
Incomplete combustion factor (ICF)	≤ 0.48
Sooting index (SI)	≤ 0.6
Wobbe Number (WN)	47.2 – 51.41 MJ/Sm^3
Gross CV	36.9 – 42.3 MJ/Sm^3
GSMR Contaminants	**No significant solids or liquids**
Total sulphur	**≤ 30 mg/Sm^3**
Organo Halides	**≤ 1.5 mg/Sm^3**
Hydrogen chloride	**≤ 1.5 mg/Sm^3**
Hydrogen fluoride	**≤ 5 mg/Sm^3**
Ammonia	**≤ 20 mg/Sm^3**
Xylenes (all isomers)	**<=100 mg/Sm3**
Arsenic	**≤ 0.1 mg/Sm^3**
Radioactivity	≤ 5 Bq/g
Siloxanes	**<= 5 mg Si/Sm3 ** expected**

https://www.cngfuels.com/about-cng-fuels/

CUSTOMER PRICING- OCTOBER 2017

CNG price inc. fuel duty- **71.91p**

Discount to bulk diesel- **43.6%**



BIO-CNG TRUCKS

CNG Fuels develops, owns and operates Bio-CNG distribution infrastructure including refuelling stations, trailers and vehicles. We are rolling out a UK wide network of reliable and convenient refuelling facilities to service customer's vehicle fleets and their off-grid energy needs. Our Bio-CNG is biomethane 100% sourced from food waste, independently verified and approved by the Department for Transport's Renewable Transport Fuel Obligation (RTFO)

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Compressed Biomethane

Gas Grid

Supply from gas grid

Compressors

250 bar

Dispenser

RTFCs Claimed

Biogas supply from Anaerobic Digester

Biogas Clean-up/upgrading plant

Renewable Transport Fuel Certificates (RTFCs) Issued

John Lewis Partnership

10

This is transformational using the LTS grid to make CNG

Dedicated Gas - Challenges

- Availability of trucks
- Availability of fuelling stations
- Fuel duty uncertainty – now fixed to 2024
- Biomethane reporting – now recognised
- Range – now 500 miles achievable

Outcomes

- 83% reduction in WTW CO_2
- 35% reduction in fuel cost (payback at 360,000 km)
- 50% (approx.) reduction in noise
- Good driver reaction

53 dedicated gas trucks

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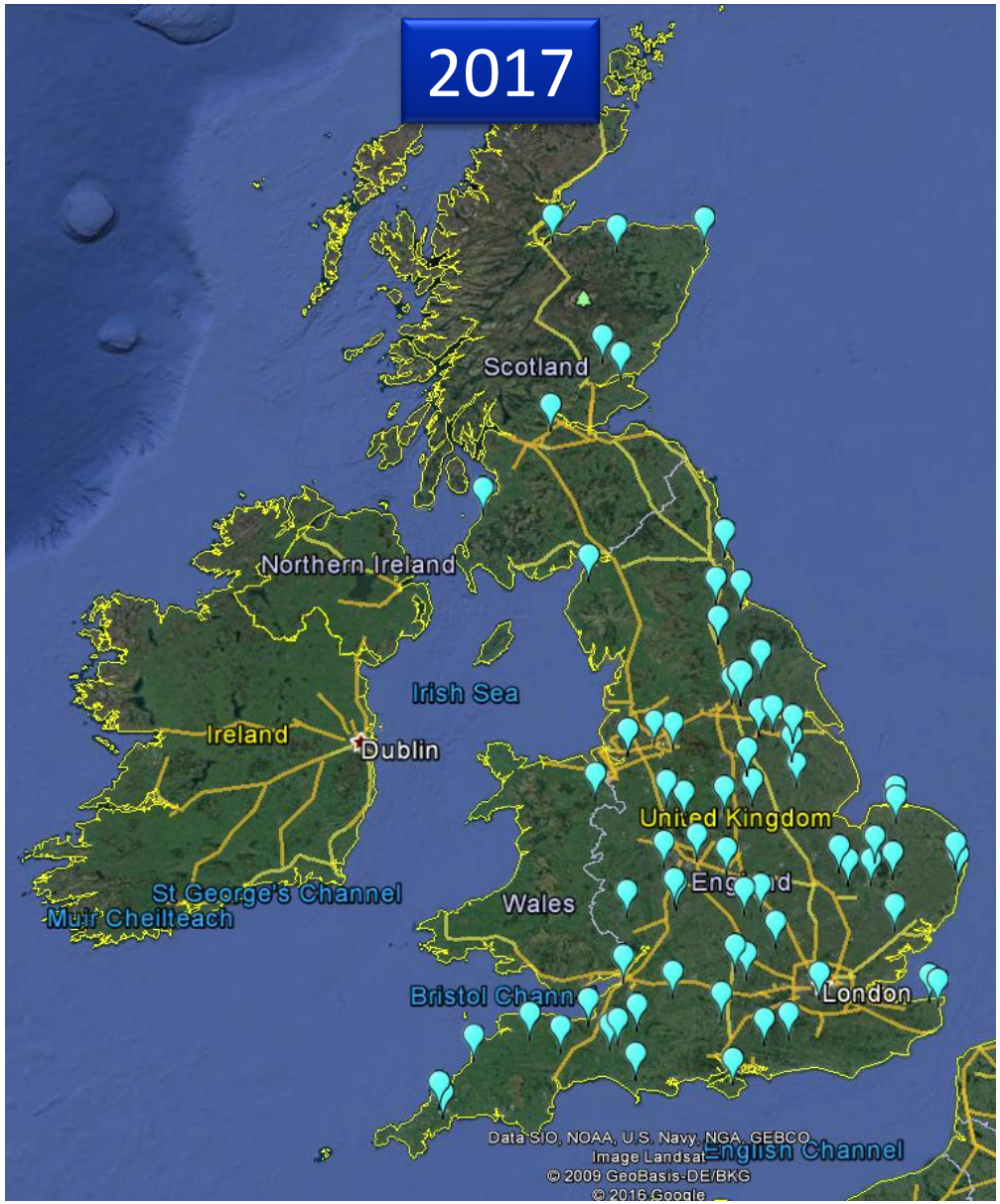
5. CASE STUDIES

UK Biomethane Projects 2012-17



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Saria Dagenham

1. One of (if not the largest) Europe's largest food waste to biomethane project
2. Injects gas into Cadent 7 bar pipeline

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Severn Trent Water

1. Their first biomethane project was at Minworth in 2014, with 4 new plants completed in 2016 – 17
   - All injecting biomethane into Cadent pipelines
2. Biogas Energy Centre with the option of biomethane injection and CHP to suit circumstances – eg in summer, less heat required and solar electricity, so biomethane attractive etc
3. Maybe CBM to follow in 2018 at sites with high vehicle use?

Severn Trent invests £15m in biomethane plants – Energy Live News – Energy Made Easy

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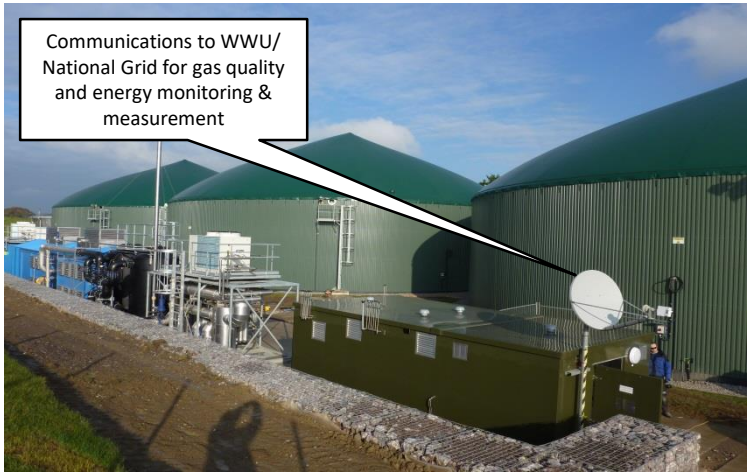
Wyke Farms Ltd



- Waste from making cheese
- Cattle waste
- Membrane

Flow of biogas – 1,500 m^3/hr

First gas to grid – Dec 2014

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Raynham

- Agricultural Feedstock
- Membrane with CO_2 recovery
- 19 bar LTS grid
- Hexel One Pipeline

Flow of biogas – 1,000 m^3/hr

First gas to grid – June 2015

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6. DEMAND FOR BIOMETHANE

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1. Gas Central Heating

1. RHI designed to support heating and it has been successful – around 4 TWh/annum
2. Typical house uses 12,000 kWh/annum so that's 120,000 houses
3. But there a lot of alternatives for domestic heating:
   - Insulation to reduce demand
   - Ground, water and air source heat pumps
   - Electric storage heating
   - CHP/District heating

There is a risk that too much focus on heating reduces investment in other options

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2. Back-up Power Generation

1. At present there is a huge boom in low load factor gas engine power stations, typically 20MW
2. Designed to run only when wind/solar etc needs support
3. 200 – 1,500 hours a year
   - No staff, scheduled to run by computer
4. Biomethane that has been stored and is delivered via the gas grid is a good option to fuel these plants as there is no other fuel apart from natural gas
   - Diesel not allowed as does not meet air quality standards

Developers of back-up generation are interested in Biomethane

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3. CHP in London

1. Most new London offices have a basement gas engine CHP plant which produces heating, cooling and electricity for the building
   - There is a gas pipeline in every street in London
2. Eg New Bloomberg HQ
   - Scores very high on sustainability due mainly to on site gas generation
3. The fuel for the CHP can only be natural gas in London and so could use biomethane
   - Already some buildings buy Green Gas Certs
4. There is a great option in London of using the Thames and Water Source Heat Pumps with District Heating

Gas CHP and Biomethane is an easy option – would it be better to encourage water source heat pumps?

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4. London Buses

1. There is no Biomethane bus in London, with a small number of EVs and H2 buses
   - Nottingham and Bristol have joined Reading with biomethane buses
2. There are 1,500 diesel hybrid buses which do not met the ULEZ requirements and will be banned or modified
3. New ASA ruling says that diesel hybrid vehicles are not clean which means they may have to be repainted
   - Better use of money would be biomethane buses
4. London has a great gas grid and could have biomethane buses using biomethane from the new Saria plant in Dagenham

Biomethane buses meet air quality and GHG targets and encourage recycling of food waste – much more honest paint job possible
They can also save money which is important – use savings to insulate houses

5. Trucks

1. Biomethane as truck fuel has many advantages
   - 84% saving in GHG
   - Very low NOX and PM10
   - 50% reduction in noise
2. Using the £10 billion Local Transmission System represents a great option for UK
   - for around £300 million can have enough CNG stations for 75% of big trucks

See Justin Laney slides for a view on alternatives to CBM from the LTS

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7. SUMMARY

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Summary

1. Biomethane Market set for growth in 2018-19
2. Uncertainty from 2020 onwards, key issues:
   - GDN actions to overcome capacity issues
   - Biomethane as a truck fuel gives huge GHG savings and has great fit with UK gas grid, need to confirm details of RTFC/RHI interaction
   - Bio-SNG
   - H2 injected into the gas grid
   - Possible move to larger projects (once capacity issues sorted) which allow economies of scale
3. There is significant demand for biomethane, vehicle use a compelling one because of limited alternatives and the ability to help create more supply

Almost 90 projects in 4 years 2014, 2015, 2016, 2017 and market looks set to continue at the 20 – 25 projects a year rate

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