EIC Biomethane Study

Stage 3: Market Analysis & Cost Assessment

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Our mission is to provide sector leading strategic business consultancy; analysing, explaining and de-risking the bioeconomy for our clients.

Established by the UK Government in 2003 as the National Non-Food Crops Centre, NNFCC has grown to become a leading commercial bioeconomy consultancy serving an international client base across bioenergy and bio-based products.

Our initial focus on the development of the rural economy, through the development of industrial crop applications, has widened over the years to embrace climate change mitigation through biofuel and bioenergy deployment. We cover land and marine based bio-based feedstock from agriculture and forestry through to municipal and industrial wastes.

We are driven by our belief that the bioeconomy will create sustainable business opportunities and deliver wide ranging environmental and societal benefits.

Our objective is simple: to provide clients with a strategic view of feedstock, technology, policy and market development across the bioeconomy, enabling them to make informed business decisions and develop sustainable business strategies.

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About this report

Report aim

This report covers stage 3 of a broader study considering the potential for increasing the volume of biomethane available for injection from existing anaerobic digestion facilities, detailed below:

- Stage 1 Adapting and reviewing the CSL central injection hub model and associated economics to be applicable for the GB regime. Includes comparison with Revenue Compression to create capacity
- Stage 2 Adapting and reviewing CSL work on sewage biogas conversion of utilisation from electricity generation to biomethane injection
- Stage 3 Report on the mandatory requirements:
  - Including biogas to electricity plants
  - Identifying areas with highest potential for new AD
  - Identifying commercial barriers and opportunities

Participating Parties

Lead Partner	*Participating Partner*	*Project Coordinator*	*Supported By*
NGN	WWU	EIC	ENA

Northern Gas Networks · WALES&WEST UTILITIES · EIC Together we innovate · ena energynetworks association

Report structure

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Acronyms

AD	Anaerobic digestion
BEIS	Department for Business, Energy and Industrial Strategy
BtG	Biomethane to Grid
BUU	Biomethane Upgrading Unit
CAPEX	Capital Expenditure
CHP	Combined Heat and Power
C&I	Commercial & Industrial
EE	East England
EM	East Midlands
FIT	Feed-in Tariff
GGC	Green Gas Certificates
GGSS	Green Gas Support Scheme
HP	High Pressure
IP	Intermediate Pressure
LND	London
NE	North East
MP	Medium Pressure
MSW	Municipal Solid Waste
NGN	Northern Gas Network
OPEX	Operational Expenditure
RHI	Renewable Heat Incentive
RO	Renewable Obligation
ROC	Renewable Obligation Certificates
RTFO	Renewable Transport Fuel Obligation
SC	Scotland
SE	South East
SW	South West
WA	Wales
WM	West Midlands
WWU	Wales & West Utilities
YH	Yorkshire and the Humber

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Definitions

The definitions used in this report are set-out below, aligned with the categorisation, classifications and narrative used in NNFCC's AD Deployment in the UK annual report and accompanying database.

Plant Scale

- **'Small scale'** refers to installations with an installed capacity of 250kWe and below in accordance with the Feed-in Tariff small scale banding.
- **'Medium scale'** refers to installations with an installed capacity of above 250kWe to 500kWe in accordance with the Feed-in Tariff medium scale banding.
- **'Large scale'** refers to installations with an installed capacity of above 500kWe in accordance with the Feed-in Tariff large scale banding.
- **'Biomethane-to-Grid'** refers to a plant that injects biomethane directly into the gas grid.

Plant Type

- **'Waste-fed'** refers to installations where the contribution of municipal (e.g. food waste; green waste), commercial (e.g. food waste) and industrial wastes (e.g. brewery waste; animal processing wastes) towards the total feedstock requirement is greater than 50%.
- **'Farm-fed'** refers to installations where the contribution of agricultural feedstocks (e.g. manure; slurry; energy crops; crop wastes) towards the total feedstock requirement is greater than 50%.

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Definitions

Feedstock

- **'Crop'** refers to any plant purposefully grown for generating energy from anaerobic digestion. This includes, but is not limited to, maize; grass silage; wholecrop cereals; and sugar beet. The terms 'energy crop' and 'crop' are used synonymously in this report.

- **'Crop waste'** refers to any plant matter that is not deliberately grown for the purpose of anaerobic digestion and is used to encompass both residues (e.g. apple pomace, straw) and wastes (e.g. vegetable outgrades)

- **'Food waste'** refers to any waste food collected from, or contained within, municipal solid waste (MSW) or commercial and industrial (C&I) waste.

- **'Other waste'** refers to any other waste or residue used as a feedstock for anaerobic digestion. Most commonly this includes green waste and industrial wastes (e.g. brewery effluent) and processing residues.

- **'Crop area'** is the estimated area of farmland required to grow the crop feedstock requirement for anaerobic digestion.

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Introduction

Currently, support for anaerobic digestion (AD) with CHP projects is weakening; RO (Renewables Obligation) support will start expiring within the next 5 years for the early adopters and FIT (Feed-In Tariffs) supported projects have been unable to replace ageing CHP engines without compromising their FIT accreditation. Furthermore, capacity in the distribution networks is a significant issue, limiting opportunities for new biomethane connections in certain areas whilst at the same time waste, as the preferred feedstock, is becoming constrained.

Many AD facilities are underperforming due to technical, logistical or financial challenges and recent consolidation efforts in the industry have led to consideration of new opportunities, to maximise heat decarbonisation efforts.

Considering viable means of better valorising existing assets and resources provides a significant opportunity for the sector, to prolong the life of ageing developments and to strengthen existing activities. This work will consider such opportunities and could impact on a significant proportion of the AD industry if successful in the future.

To support the broader study into biomethane potential, NNFCC were subcontracted by CNG to:

- Assess GB Biogas sites (Part 1) and:
  - Quantify the scale of the opportunity, at regional and national level
  - Identify three clusters of activity that warrant further investigation.
- Perform a cost assessment (Part 2) to:
  - Model whether conversion costs are economically viable for each plant.
  - Understand the level of support required for conversions to be economically viable.
  - Evaluate economical viability of clusters with a common upgrading and injecting point.

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Approach

Part 1: Assessment of AD sites in Great Britain

NNFCC monitors the AD market in the UK and publishes an annual AD Deployment in the UK report[1] which is underpinned by a database of all operational and planned AD facilities in the UK. Information held on each site includes location, type, scale, feedstock type & volume, commissioning date and current status. This database underpins the market analysis conducted in this study, to assess the scale of the opportunity, the distribution of capacity, and the feasibility of conversion based on capacity, type and age of plant.

The database is updated on a monthly basis and compiled using a number of data sources including: press announcements; regular discussions with technology providers, suppliers, investors and developers; the Department for Business, Energy and Industrial Strategy (BEIS) Renewable Energy Planning Database (REPD), Planning Portals and Council planning registers; Ofgem statistics; and the Official Information Portal on AD, Biogas Map. Combined, these data sources provide an accurate insight into the various types, scales and status of AD projects in the UK.

The scope of this analysis extends to both the agricultural and non-sewage waste AD sectors and includes both combined heat & power and biomethane-to-grid projects. However, traditional sewage waste treatment AD plants are not included.

All data and maps presented in this report are based on NNFCC AD Deployment data published in April 2021.

The key tasks in this part of the study were to:

- Assess the technical and economic viability of each CHP facility in Great Britain to convert from CHP to biomethane, based on scale, type and location.
- Quantify the scale of the opportunity for conversion from CHP to biomethane, at regional and national level
- Map all sites showing a high or medium likelihood of switching, to identify three clusters of activity that warrant further investigation.

[1] NNFCC (2021) AD deployment in the UK, annual report. Available from https://www.nnfcc.co.uk/publications/report-anaerobic-digestion-deployment-in-the-uk

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Approach

Part 2: Cost assessment

NNFCC has recently undertaken an extensive industry survey and conducted in-depth interviews with many key players and producers in the biogas and biomethane industry, to assess the costs for AD and biomethane plant development, to inform BEIS tariff setting activity for the future Green Gas Support Scheme (GGSS). Furthermore, NNFCC and CSL staff are actively engaged in key industry groups both in the UK and Europe, and have a comprehensive understanding of the UK and European policy and regulatory landscape for biogas and biomethane.

Using this knowledge and data NNFCC considered the costs of conversion on a case-by-case basis, to build on the market assessment tasks and to further refine the assessment of the likelihood of switching, based on the commercial evaluation.

The key tasks in this part of the study were to:

- Model whether conversion costs are economically viable for each plant, based on the scale, type and location of plants identified as technically suitable in the previous task.
- Evaluate the cost of conversion and direct injection, on an individual plant scale, or the cost of clustering biogas facilities around a central upgrading and injection facility.
- Evaluate economical viability of clusters with a common upgrading and injecting point.
- Understand the level of support required for conversions to be economically viable.

[1] NNFCC (2021) AD deployment in the UK, annual report. Available from https://www.nnfcc.co.uk/publications/report-anaerobic-digestion-deployment-in-the-uk

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Part 1: Market Analysis

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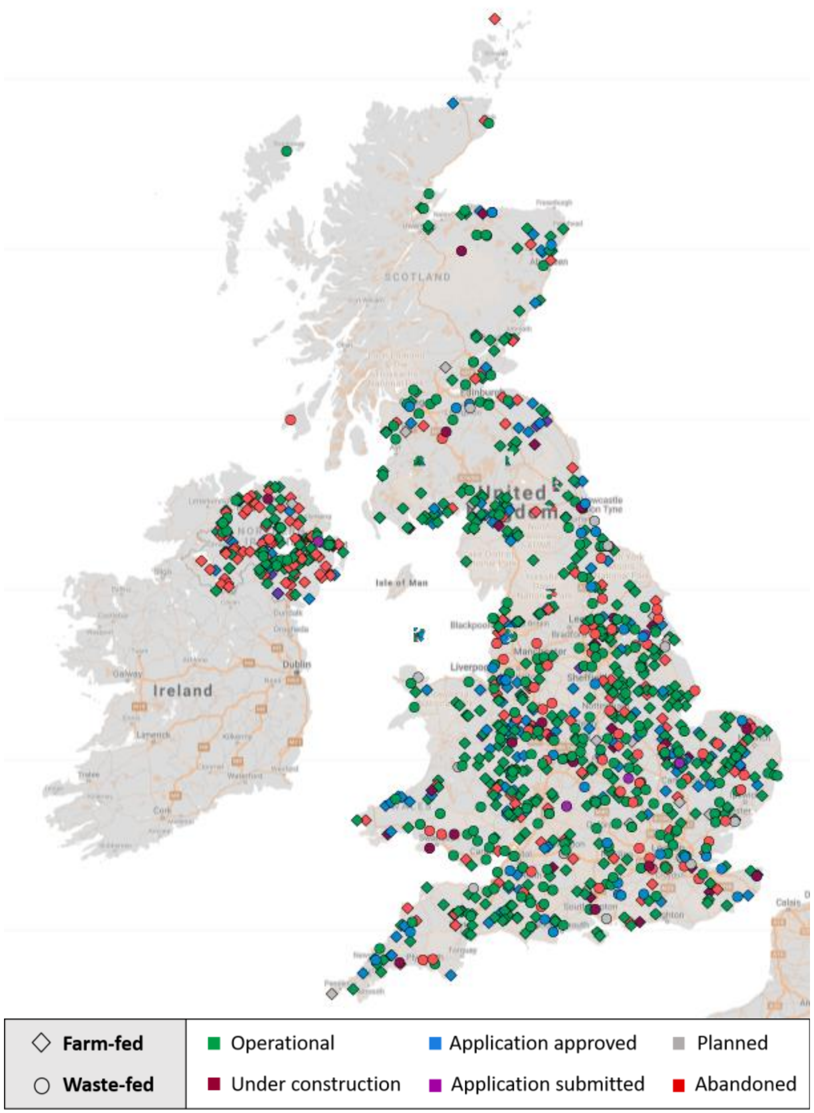
GB Market analysis

- In Great Britain there are 562 AD facilities
  - 455 with CHP only
  - 106 with BtG (although these also typically include a smaller-scale CHP to provide process energy for on-site use).

Region	Number of plants	Capacity (Mwe)
NE	12	11
NW	46	34
Y&H	37	32
EM	60	54
WM	63	35
EE	49	69
SE	33	36
SW	54	37
LDN	2	2
SC	61	40
WA	38	20
TOTAL	**455**	**370**

This analysis will focus on the sub-set of 455 CHP-only sites; the regional distribution of which is illustrated in the table and on the adjacent map.



Source: NNFCC (2021) AD deployment in the UK, annual report (https://www.nnfcc.co.uk/publications/report-anaerobic-digestion-deployment-in-the-uk)

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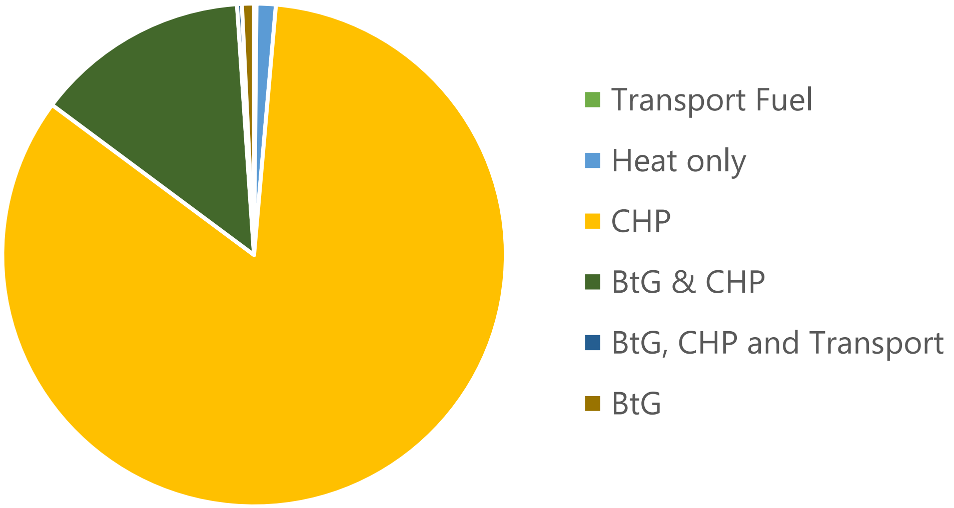
GB AD Market Breakdown, by type



- CHP-only facilities dominate the AD market in the UK due to the early introduction of the Feed-in-Tariff and more recent phase in of the non-domestic Renewable Heat Inventive (NDRHI) which supported electricity and heat output respectively.
- Introduction of support for biomethane injection to the grid (BtG) came later and economies of scale prevailed with the technology, so fewer larger scale plants were established, compared with a larger number of small- to medium-scale CHP facilities.

Source: NNFCC (2021) AD deployment in the UK, annual report (https://www.nnfcc.co.uk/publications/report-anaerobic-digestion-deployment-in-the-uk)

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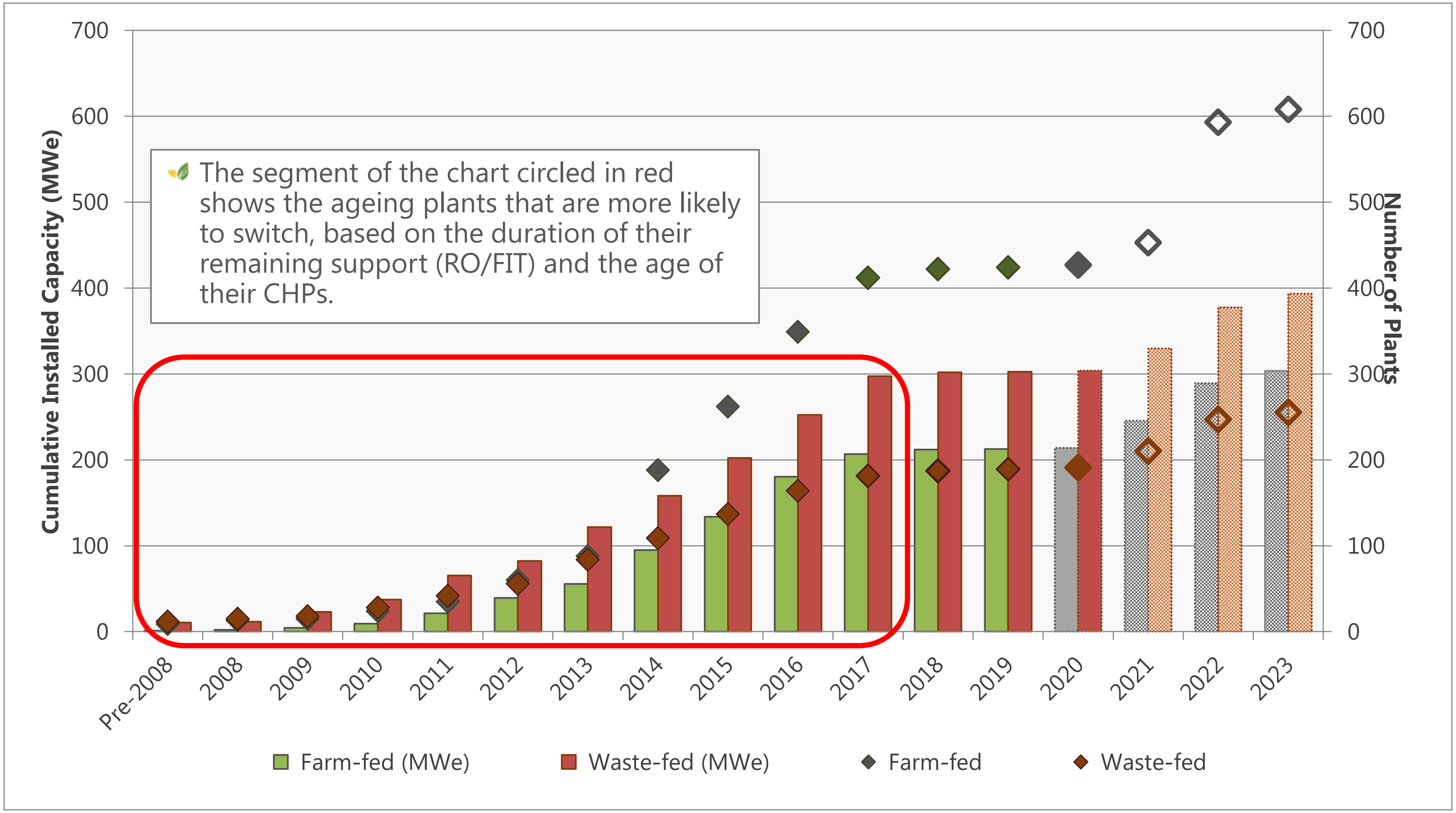
Total Installed Capacity



Source: NNFCC (2021) AD deployment in the UK, annual report (https://www.nnfcc.co.uk/publications/report-anaerobic-digestion-deployment-in-the-uk)

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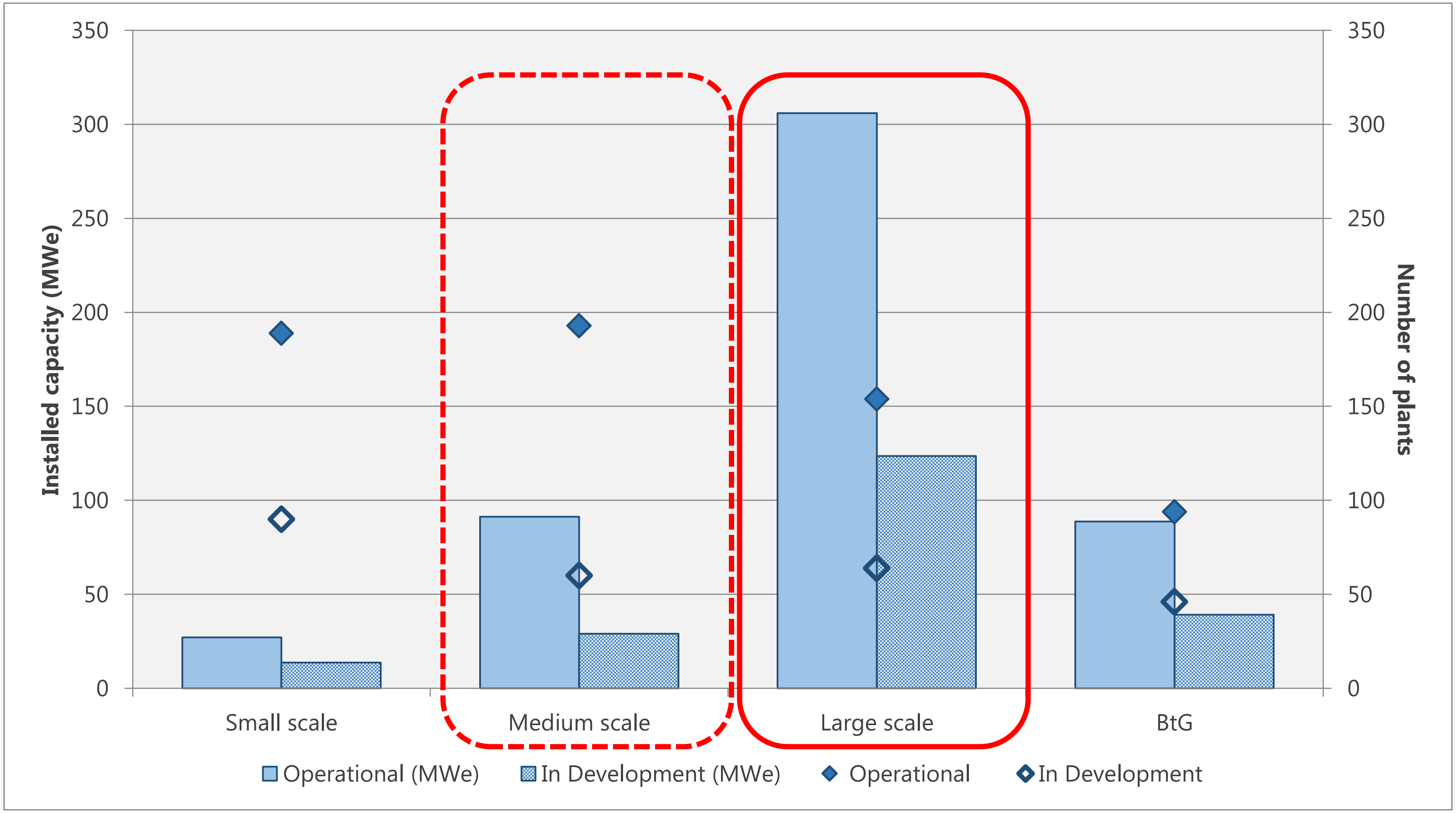
Scale distribution

- The segments of the chart circled in red show the optimum (*solid line*) and suitable (*dotted line*) scale of CHP plants most suited for conversion, due to the cost and scale of biomethane upgrading and injection equipment, and physical injection demands.



Source: NNFCC (2021) AD deployment in the UK, annual report (https://www.nnfcc.co.uk/publications/report-anaerobic-digestion-deployment-in-the-uk)

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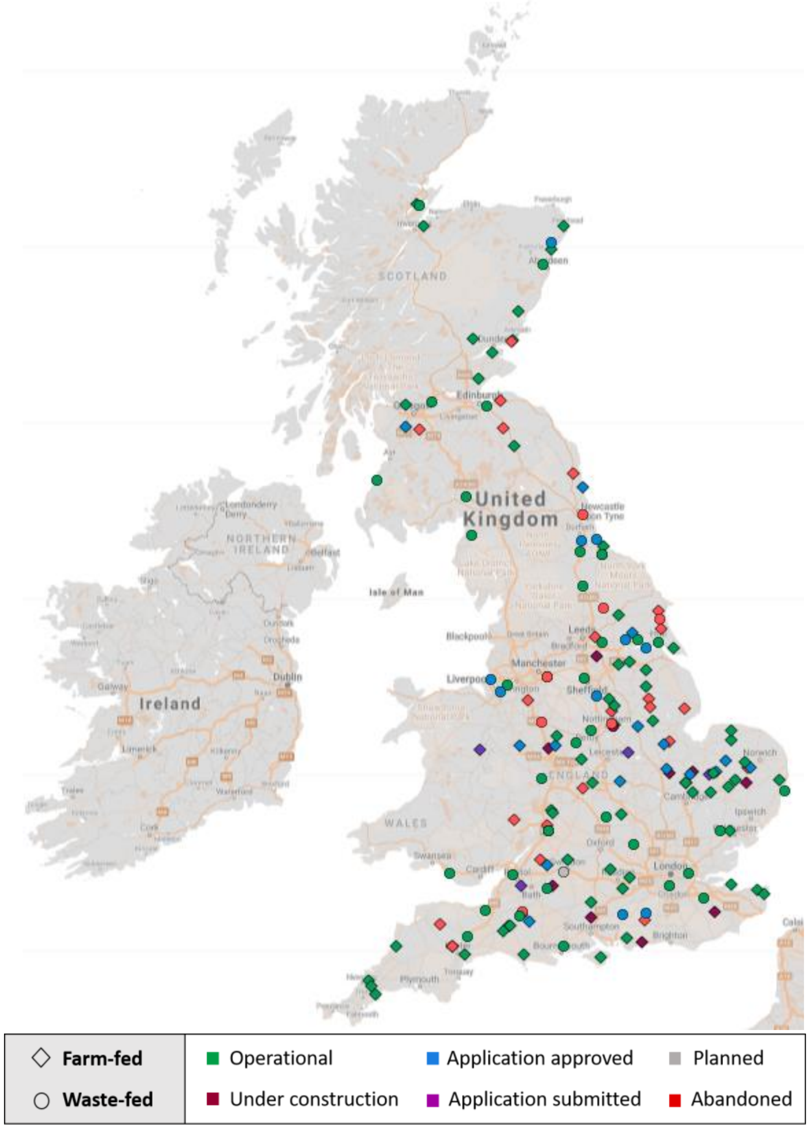
Biomethane Injection

- In Great Britain there are 106 biomethane injection facilities, broken down by region as follows:

Region	Number of plants
NE	5
NW	2
Y&H	13
EM	9
WM	9
EE	14
SE	13
SW	20
LDN	1
SC	19
WA	1
TOTAL	**106**

These facilities are excluded from the subsequent analysis as they are already contributing to the gas mix; however, their locations and distribution are considered in the capacity assessment.



Source: NNFCC (2021) AD deployment in the UK, annual report (https://www.nnfcc.co.uk/publications/report-anaerobic-digestion-deployment-in-the-uk)

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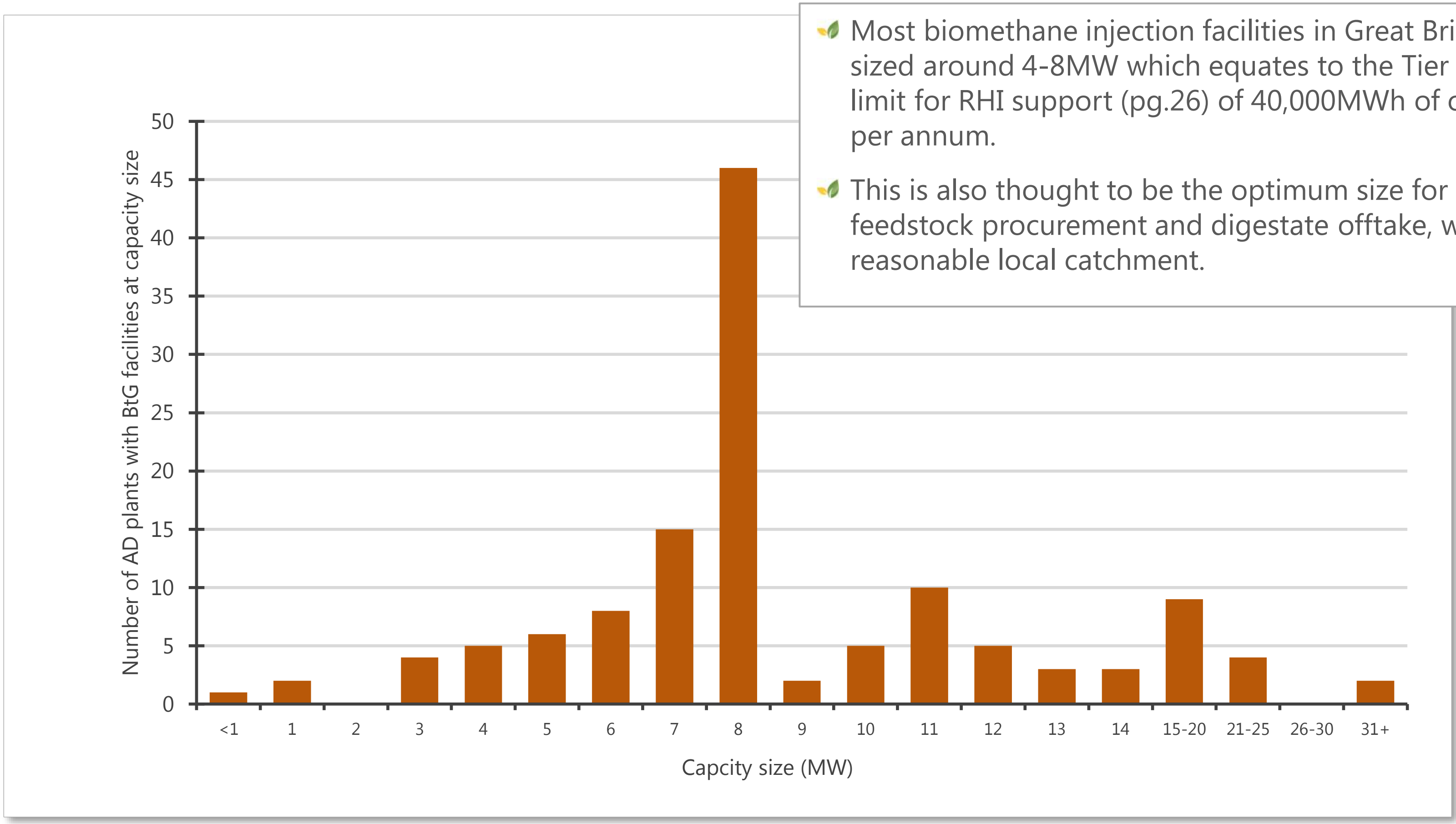
BtG Plants – Capacity distribution



- Most biomethane injection facilities in Great Britain are sized around 4-8MW which equates to the Tier 1 upper limit for RHI support (pg.26) of 40,000MWh of output per annum.
- This is also thought to be the optimum size for feedstock procurement and digestate offtake, within a reasonable local catchment.

Source: NNFCC (2021) AD deployment in the UK, annual report (https://www.nnfcc.co.uk/publications/report-anaerobic-digestion-deployment-in-the-uk)

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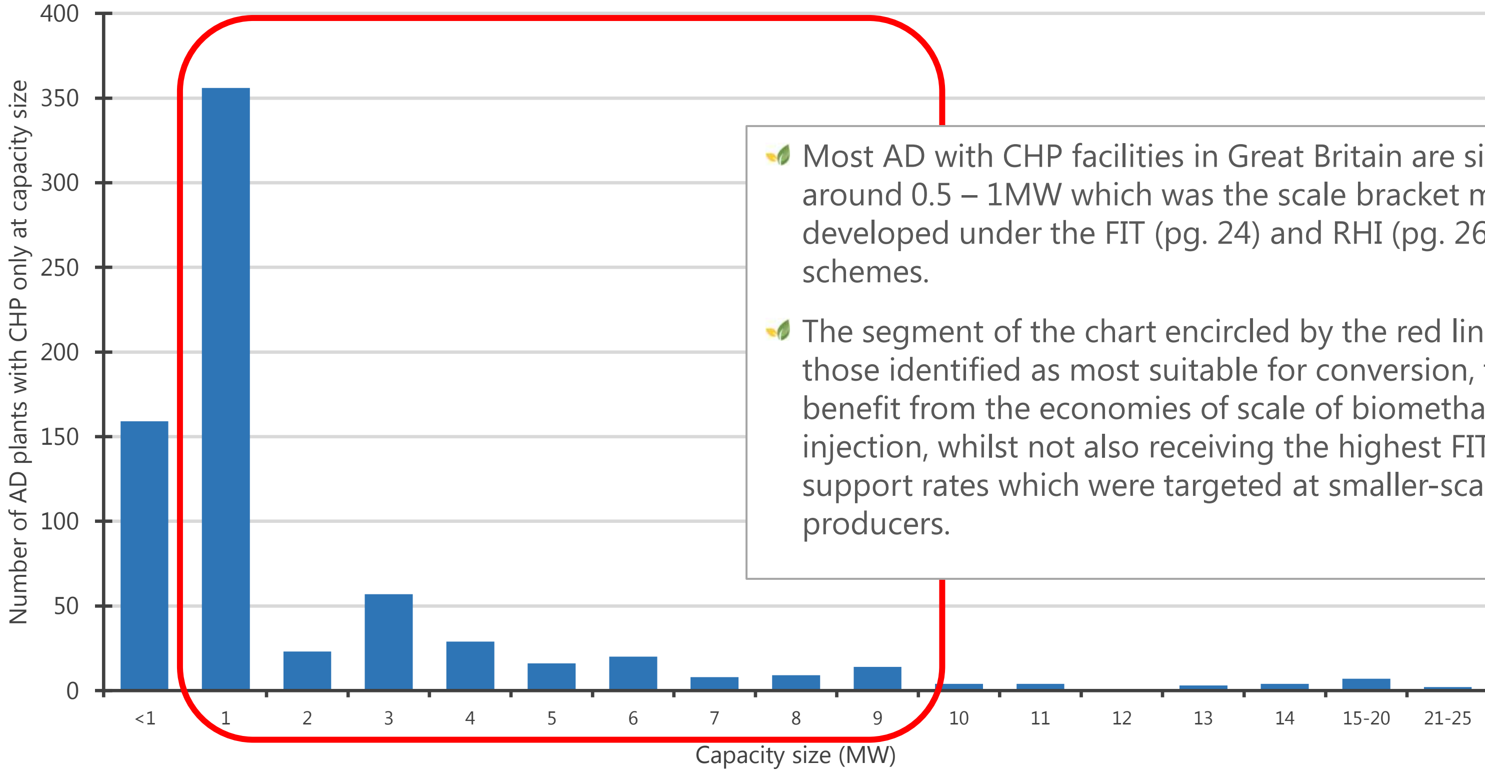
CHP Plants – Capacity distribution



- Most AD with CHP facilities in Great Britain are sized around 0.5 – 1MW which was the scale bracket most developed under the FIT (pg. 24) and RHI (pg. 26) schemes.
- The segment of the chart encircled by the red line are those identified as most suitable for conversion, to benefit from the economies of scale of biomethane injection, whilst not also receiving the highest FIT support rates which were targeted at smaller-scale producers.

Source: NNFCC (2021) AD deployment in the UK, annual report (https://www.nnfcc.co.uk/publications/report-anaerobic-digestion-deployment-in-the-uk)

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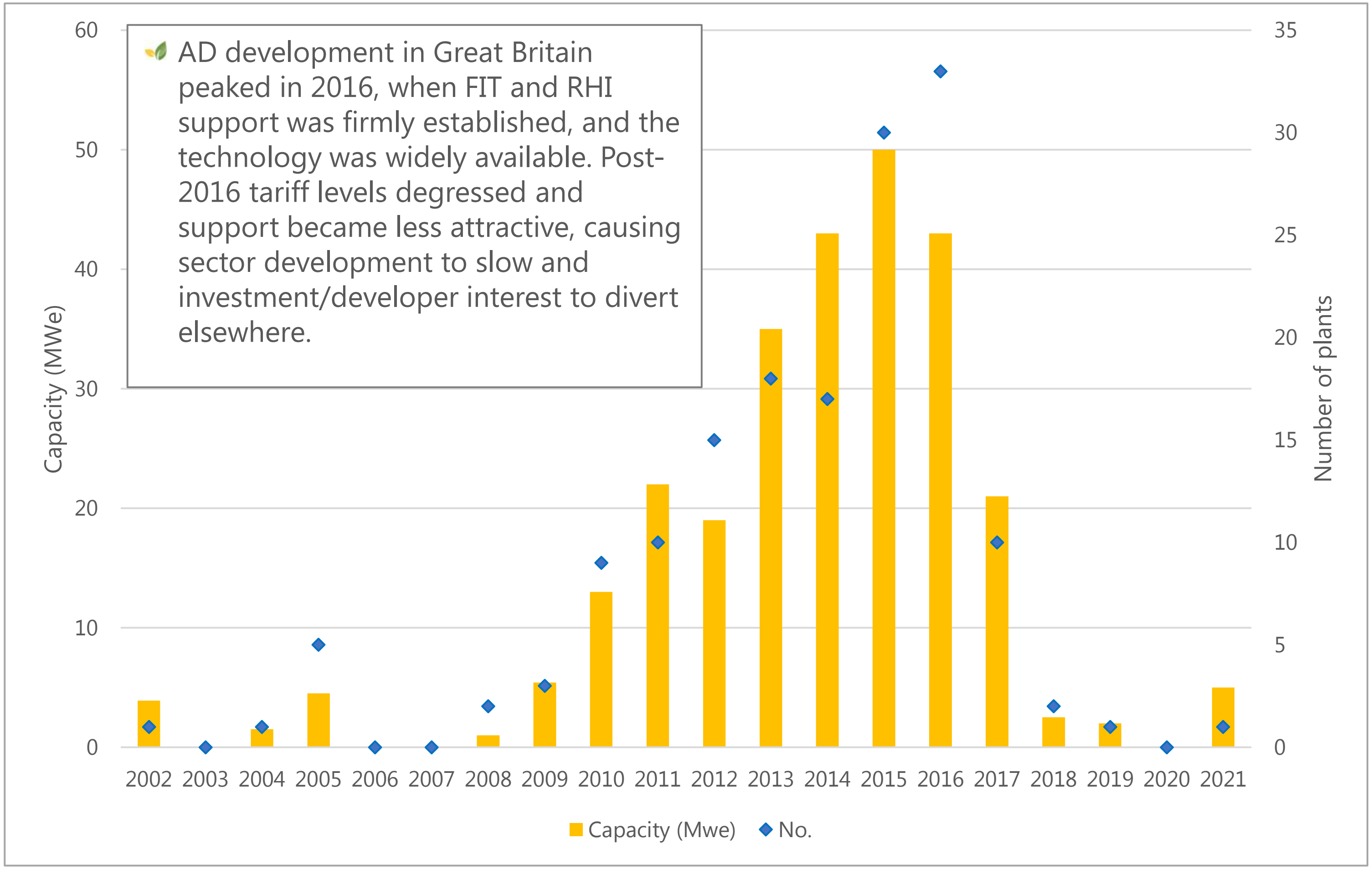
Accreditation Date



Source: NNFCC (2021) AD deployment in the UK, annual report (https://www.nnfcc.co.uk/publications/report-anaerobic-digestion-deployment-in-the-uk)

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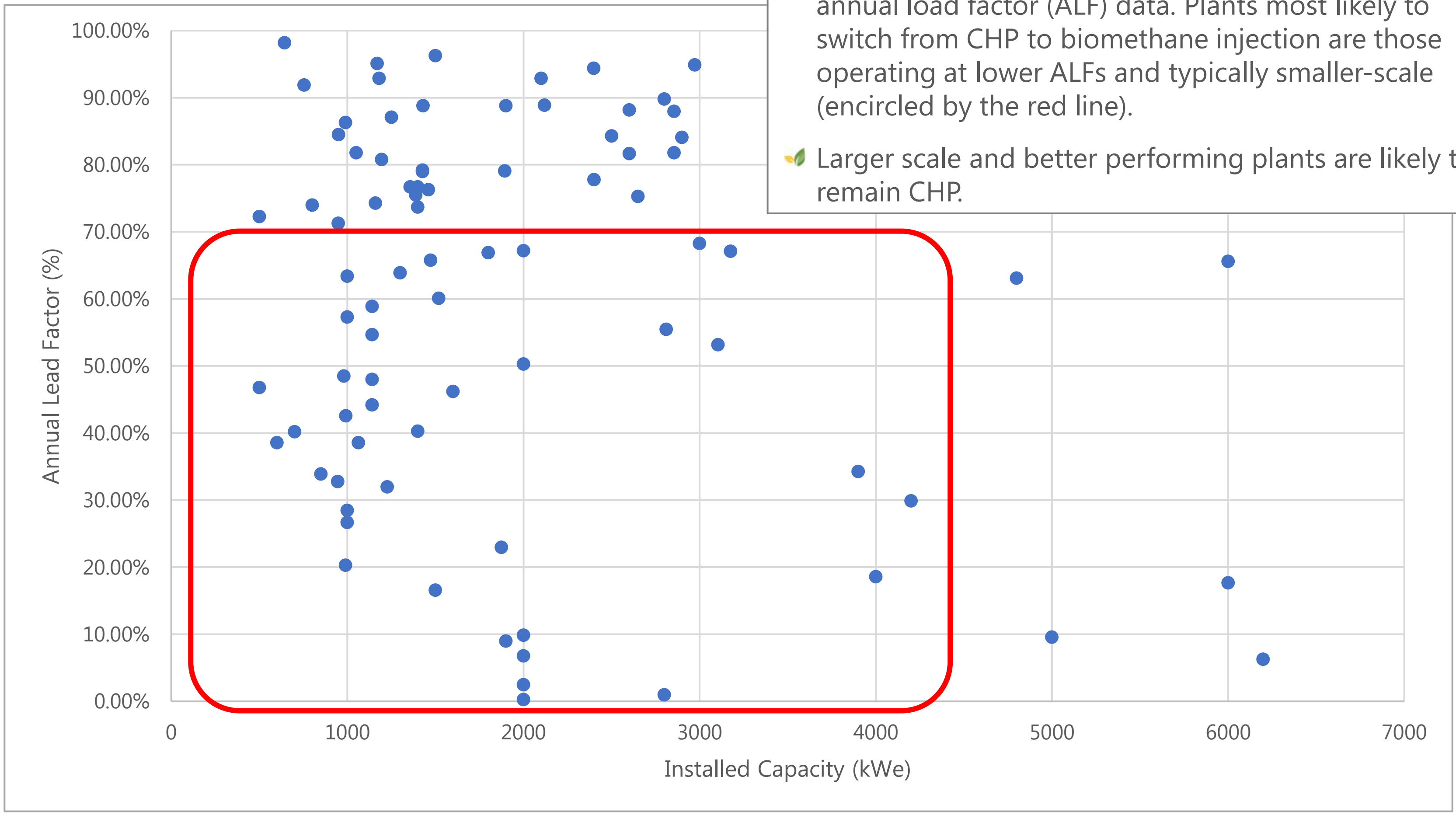
Plant performance



- Plant performance is evaluated based on published annual load factor (ALF) data. Plants most likely to switch from CHP to biomethane injection are those operating at lower ALFs and typically smaller-scale (encircled by the red line).
- Larger scale and better performing plants are likely to remain CHP.

Source: NNFCC (2021) AD deployment in the UK, annual report (https://www.nnfcc.co.uk/publications/report-anaerobic-digestion-deployment-in-the-uk)

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AD Support Schemes

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Renewables Obligation (RO)

- Support scheme for renewable energy generation 50kWe and above
- Opened in 2002 and closed to new applications on 31st March 2017
- ROCs awarded for every MWh generated, banded by technology type and scale
- ROCs granted for 20 years from the accreditation (commissioning) date
- ROC value varies; valued around £45-50 per MW based on supply and demand in the market.
- AD facilities received 2 ROCs per MWh until April 2015, then 1.9 ROCs per MWh until April 2016 and 1.8 ROCs per MWh thereafter (see below)

Band	13/14 support (ROC/MWh)	14/15 support (ROC/MWh)	15/16 support (ROC/MWh)	16/17 support (ROC/MWh)
Advanced gasification/pyrolysis	2	2	1.9	1.8
Anaerobic Digestion	2	2	1.9	1.8

- *There are 26 AD facilities in Great Britain accredited on the RO, one of which was commissioned 20 years ago so RO support will expire during 2022.*
- *A total of 22 of these facilities were accredited more than 10 years ago, so will likely have ageing CHPs and fewer than 10 years of support remaining.*

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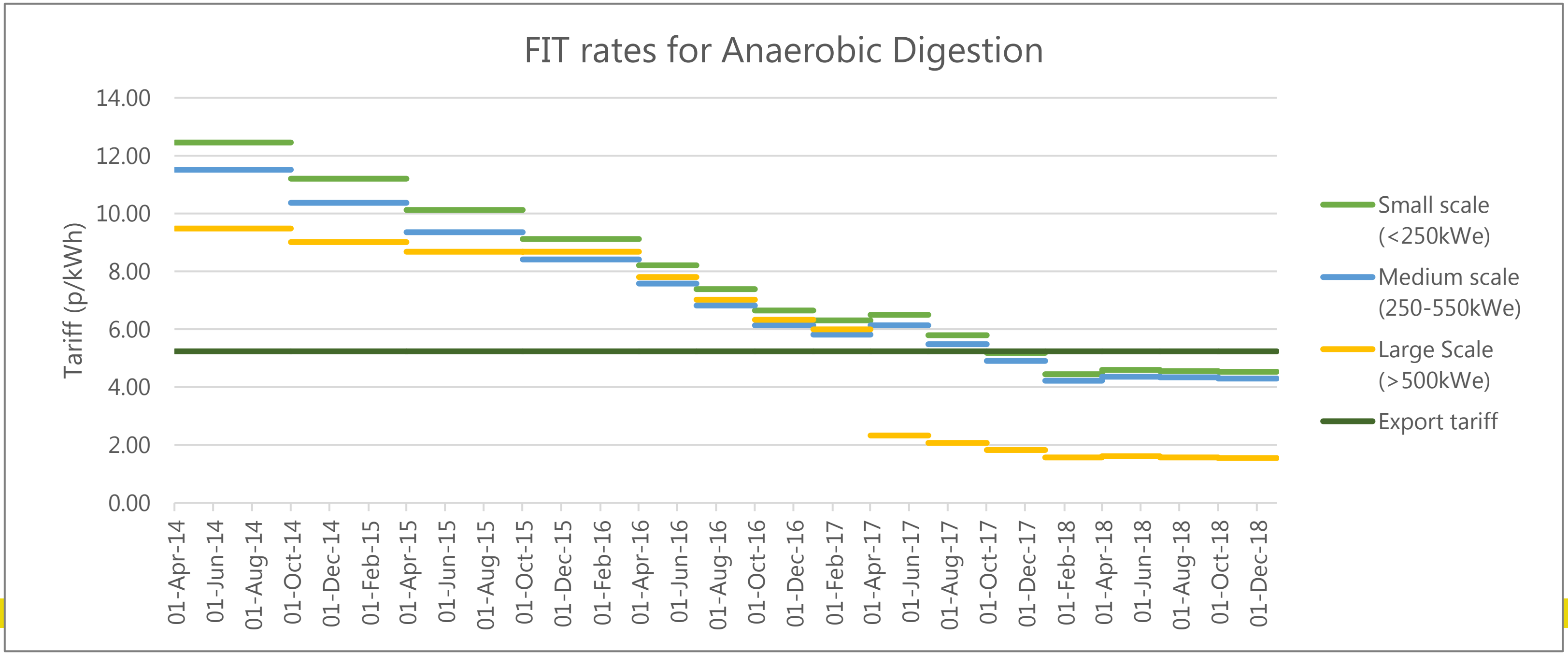
Feed in Tariff (FIT)

- Opened to AD capacity in 2010; tariff levels banded by scale (small, medium, large)
- Provides a fixed price for 20 years to small-scale (< 5MW) electricity producers;
    - Generation Tariff – the generator is paid for every kWh of electricity generated
    - Export tariff – for electricity exported onto the National Electricity Grid
- FIT rates have reduced over time; as accredited capacity increased, tariffs were adjusted to control spend and slow growth.



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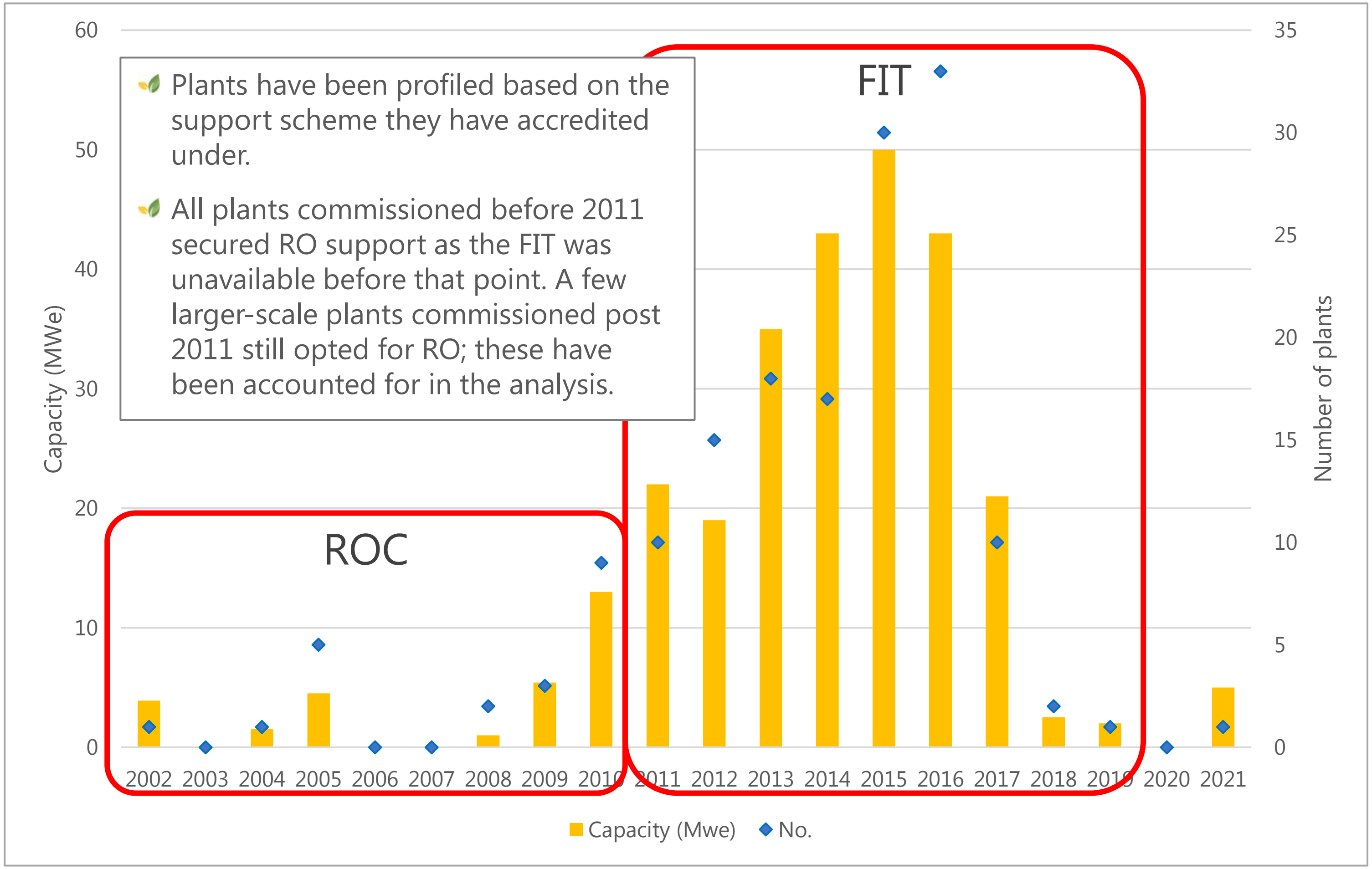
Accreditation Date analysis



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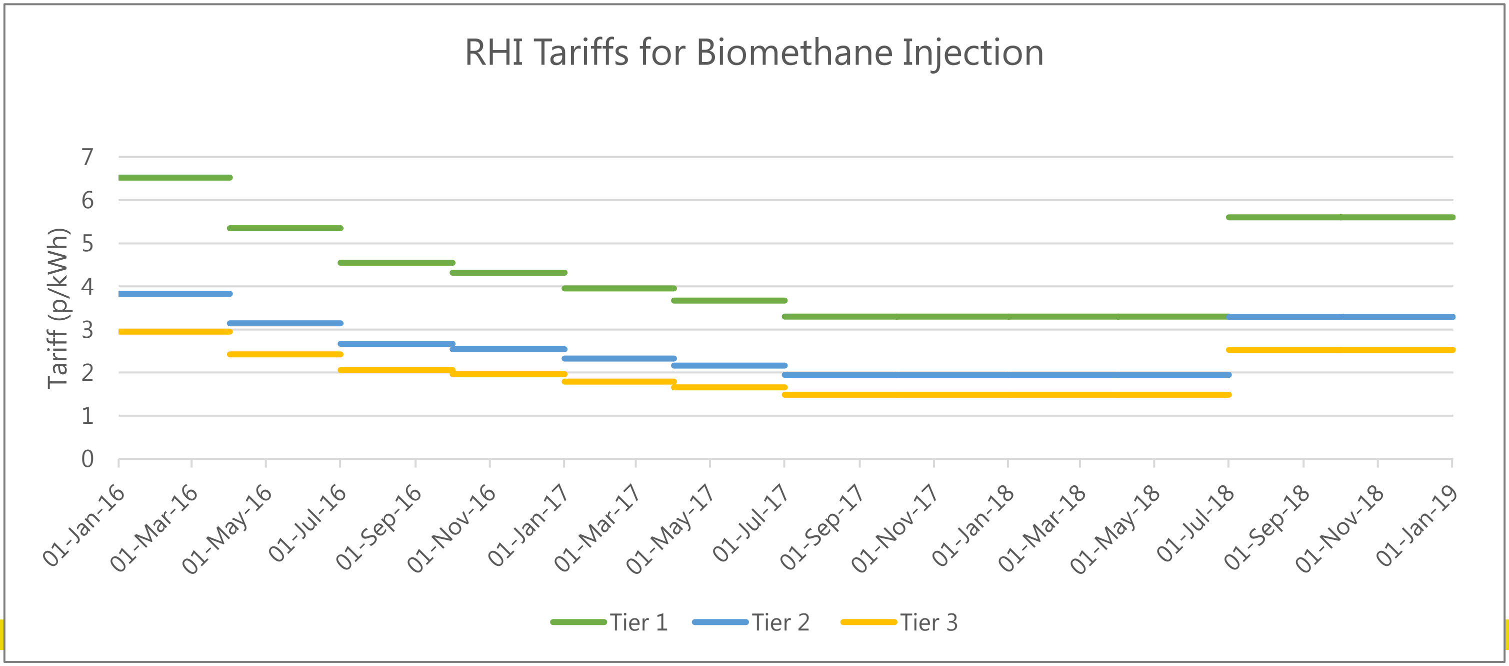
Renewable Heat Incentive (RHI)

- Support was available for biogas combustion from CHPs from 2011 and for biomethane injection from 2014.
- Biomethane injection is supported under a structure of tiered tariffs; with breaks at 40,000MWh and 80,000MWh.
- The biomethane producer is paid a fixed rate per kWh of biomethane injected, for eligible gas.
- The rate is fixed (index-linked) for 20 years from the commissioning date.
- Tariffs reduced over time as more capacity was accredited, and reinstated in 2018 to 2016 levels to encourage further growth.



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Renewable Transport Fuels Obligation (RTFO)

- Suppliers of fuel to road vehicles and non-road mobile machinery, amounting to >450,000 litres per annum must ensure an increasing proportion of the fuel they supply comes from renewable sources (obligation levels currently fixed to 2032).
- RTFO is a certificate-based mechanism under which obligated suppliers can either:
  - a) Supply biofuel and earn certificates which can then be traded with other fuel suppliers and users;
    - 1.9 certificates per kg biomethane
    - 3.8 certificates per kg biomethane when waste-derived
  - b) Buy certificates from others who have supplied the fuel, to offset against their supply if they fail to meet their obligation; or
  - c) Pay the "buy-out" price, currently 50ppl, for failing to meet their obligation.
- There is a crop-cap that limits the volume of fuel that can be derived from crop feedstocks, encouraging greater use of wastes over time.
- Development fuels are more heavily rewarded and encouraged, to advance the industry towards more efficient pathways over time.
- *Producers of biomethane can put any amount, up to 100% of their output into the grid for distribution, and claim RHI (or GGSS) on some or all of that amount. If not all gas is claimed on RHI (or GGSS), RTFCs can be claimed on the balance. This decision and claim process can be made monthly, given producers flexibility of support. However, whilst RHI (and GGSS) offer guaranteed levels of support, RTFC values are variable and are therefore less attractive and less bankable for such projects.*
- *The biomethane producer sells fuel to a fuel supplier; the fuel supplier receives and trades the RTFCs and passes some of the value back down to the producer, split typically based on level of investment made by each party.*

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Green Gas Support Scheme (GGSS)

- Launched in November 2021
- Designed to support the deployment of new anaerobic digestion (AD) biomethane plants to increase the proportion of green gas in the gas grid, for heat decarbonisation purposes.
- Regular payments will be made to registered biomethane producers based on the volume of eligible biomethane injected into the gas grid; 15-year tariff period.
- The initial tariff that will apply where the tariff start date is on or before 30 June 2022 will be:

  Tier 1: Up to 60,000 MWh - 5.51 p/kWh
  Tier 2: Next 40,000 MWh - 3.53 p/kWh
  Tier 3: Over 100,000 MWh - 1.56 p/kWh

- A significant budget has been allocated to the scheme (as outlined in the table opposite).
- Uptake to date has been slow, with 10 applications for support made and all these projects aiming to commission during FY2022/23.
- It is expected a further 10-20 plants may apply during the scheme lifetime.
- GGSS is set to close to new applications on 30th November 2025.

	FY 21/22	FY22/23	FY22/23	FY24/25	FY25/26
Budget available	£37,000,000	£37,000,000	£65,000,000	£97,000,000	£130,000,000
Budget allocated (based on applications received)	£18,228	£1,236,213	£19,224,606	£25,709,057	£26,944,483
Budget committed (based on applications granted)	-	-	-	-	-
Remaining budget available	£36,981,771	£35,763,786	£45,775,393	£71,290,942	£103,055,516

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CHP Conversion potential

Interrogation of market data to determine the likelihood of switching from CHP to biomethane injection

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Why will CHPs convert to BtG?

- Better aligned with the current policy intent, focussing on decarbonisation of the heat sector, energy security and Net Zero (in heat & transport fuels)
- Greater efficiencies can be achieved, especially where CHPs are unable to use heat on-site or locally; due to the rural nature of many AD facilities (for planning consent purposes), heat use is limited.
- CHPs are ageing and cost of replacement will be significant; plants may consider installing a smaller-scale CHP for on-site energy demand only, and diverting the bulk of the energy output via biomethane for injection.
- Markets may be more attractive and/or more flexible, giving optionality around supply for heat or transport fuel use, supported by RHI/GGSS and RTFO
- Option to expand capacity which has previously been constrained by electricity grid offtake.
- *Initial evaluation applied the following criteria to each individual plant, to consider the likelihood of them switching*

Likelihood	High	Medium	Low
Age	6 years +	6 years +	<6 years
Capacity	1,000 kWe +	800 kWe +	450 kWe +
Support rate	0-10 p/kWh	10-13 p/kWh	>13 p/kWh
Feedstock	Waste-fed	Waste-fed/farm-fed	Farm-fed/waste-fed
Distance to grid	<10 km (IP/MP)	<150 km (IP/MP/HP)	Any

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Results, by Region (Number of sites)

Likelihood	High	Medium	Low
Number of plants	**78**	**88**	**61**
EE	13	22	6
WA	9	2	4
SC	9	7	7
SE	9	9	7
WM	9	9	9
NW	9	7	7
EM	8	13	7
YH	5	6	4
SW	4	10	5
NE	2	2	4
LDN	1	1	1

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Results, by Region (Capacity)

Likelihood	High	Medium	Low
Capacity (kWe)	**163,394**	**139,815**	**39,571**
EE	32,898	38,211	3,644
WA	10,980	4,650	2,600
SC	15,940	7,590	4,500
SE	17,036	16,645	3,900
WM	19,850	8,488	5,555
NW	18,400	11,739	4,790
EM	14,519	25,616	5,000
YH	13,039	8,411	2,682
SW	8,632	15,073	3,400
NE	10,100	1,992	3,000
LDN	2,000	1,400	500

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Distribution Analysis

Assessing generation and offtake distribution

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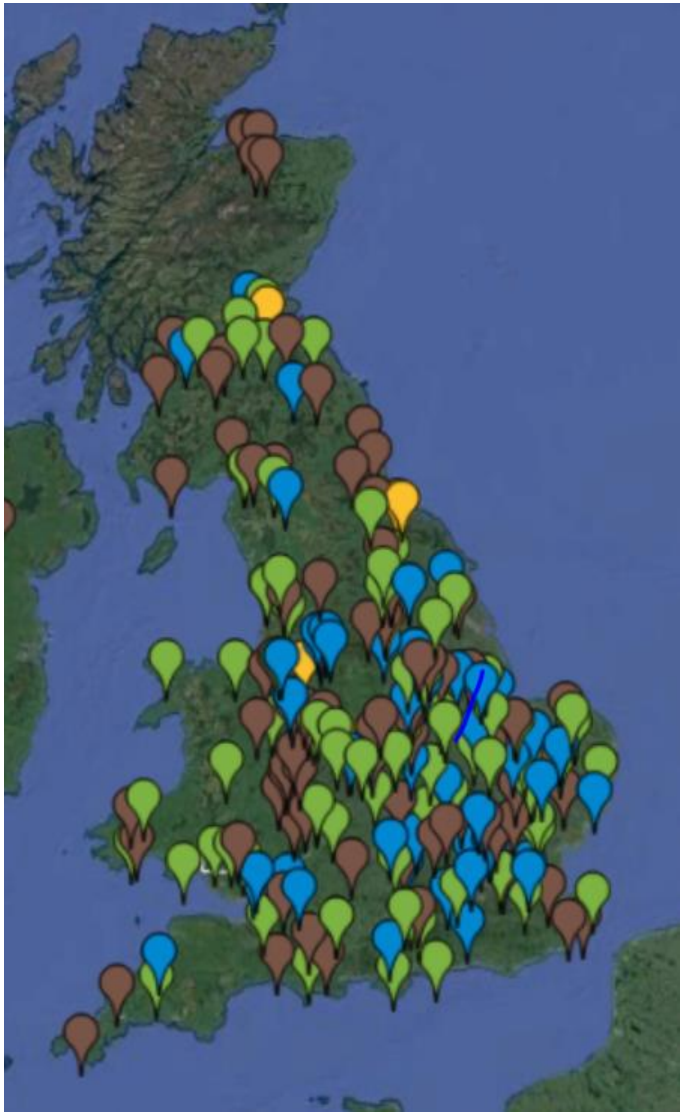
Mapping CHP Plants

- Using NNFCCs AD Deployment in the UK database, all CHP facilities in Great Britain were mapped using Google earth.
- Layers include:
  - Size of CHP
  - Feedstock type (waste/non-waste)
  - Likelihood of switching (based on criteria set out above)
- Each pin can be clicked on to provide full site details; linked to main database.



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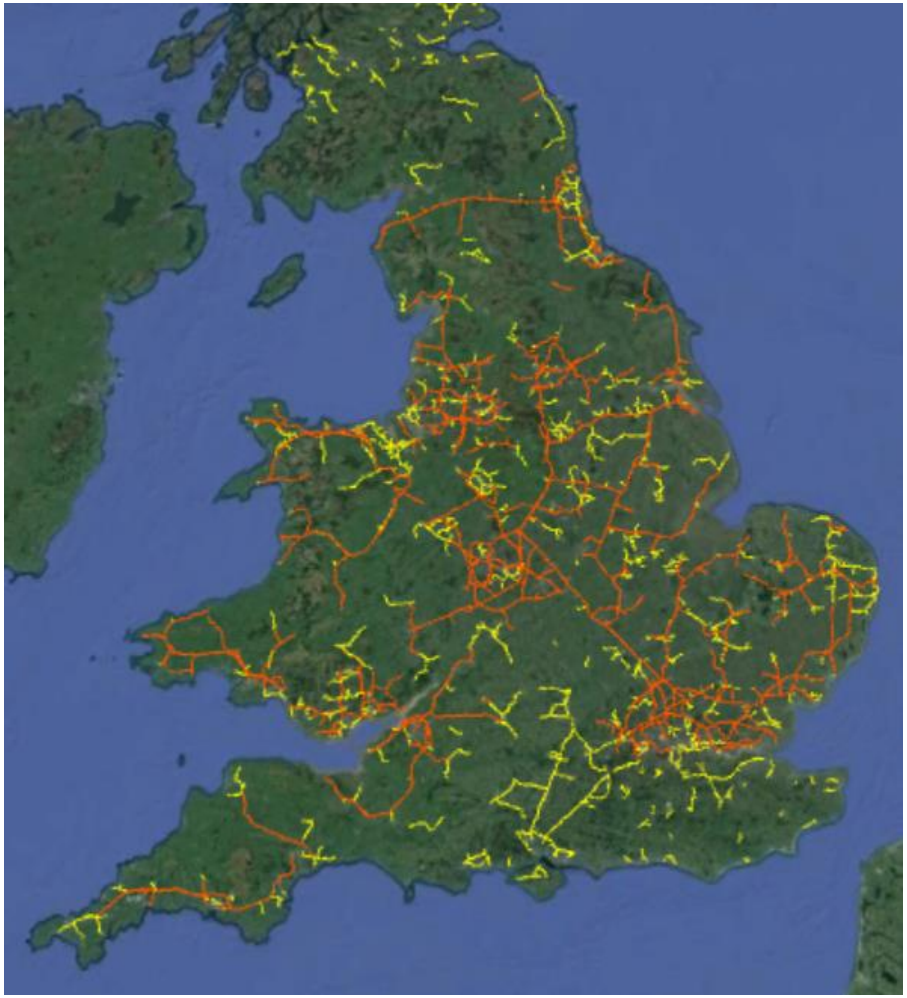
Gas Networks

- Gas grid maps were kindly provided by the gas distribution networks (GDNs) in the form of Shapefiles, compatible with Google earth.
- Maps were combined to illustrate the location and distribution of the different grid types across Great Britain.
- Layers include:
  - High pressure (HP)
  - Intermediate pressure (IP)
  - Medium pressure (MP)



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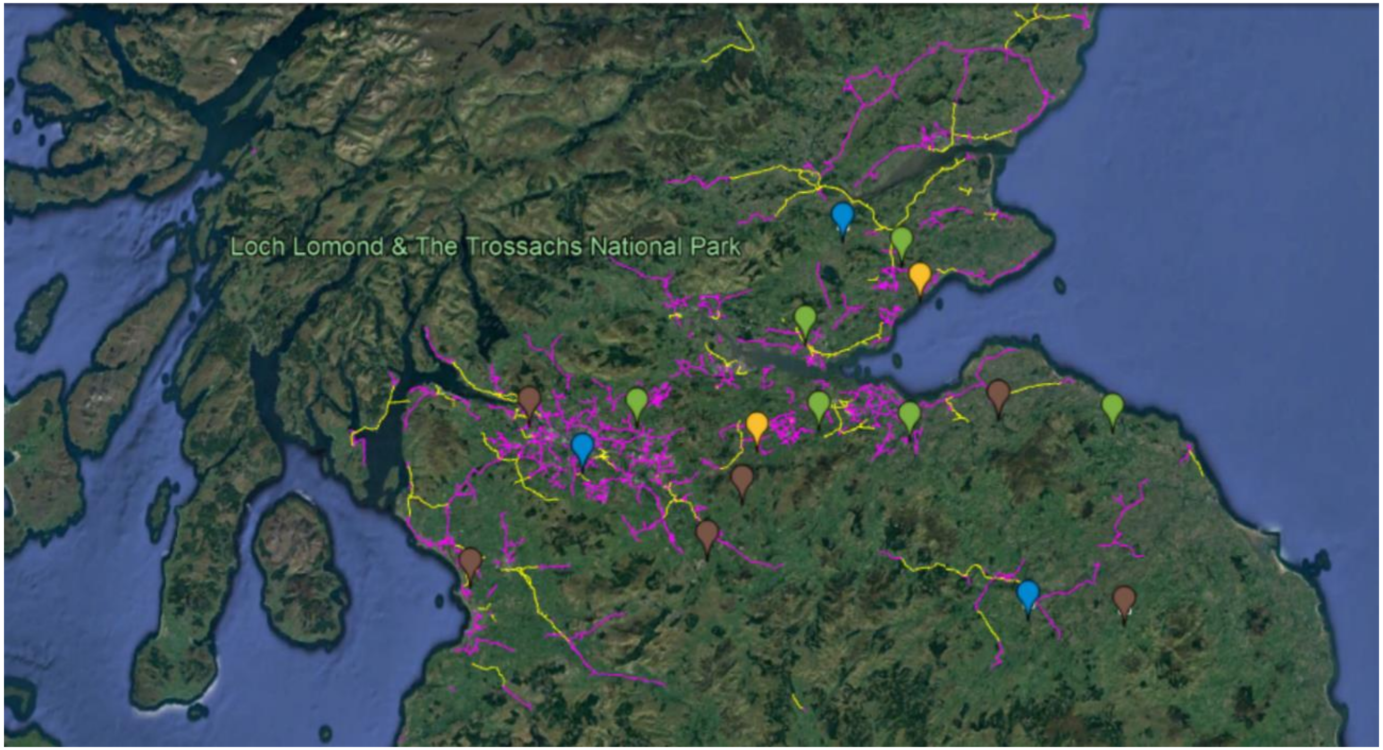
Mapping results

- All map layers were combined to give a comprehensive picture of the grid and plant distribution, which could be filtered according to likelihood of switching and grid type.
- From these maps, the distance to the nearest suitable grid connection was determined.



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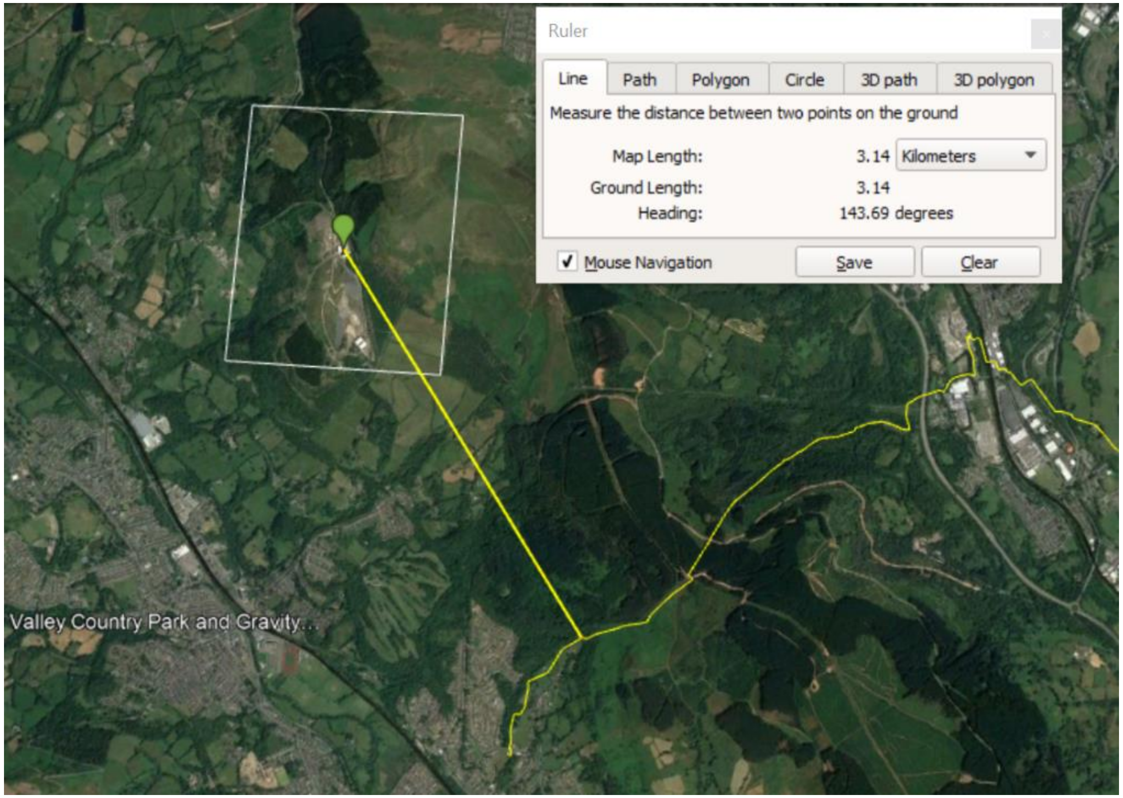
Distance from grid analysis

- The distance to the nearest suitable grid connection point was determined for each site using Google Earth, and the grid type captured for subsequent commercial analysis.



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Part 2: Cost Assessment

Considering the costs and financial viability of converting to gas grid injection, on a direct injection, individual plant basis.

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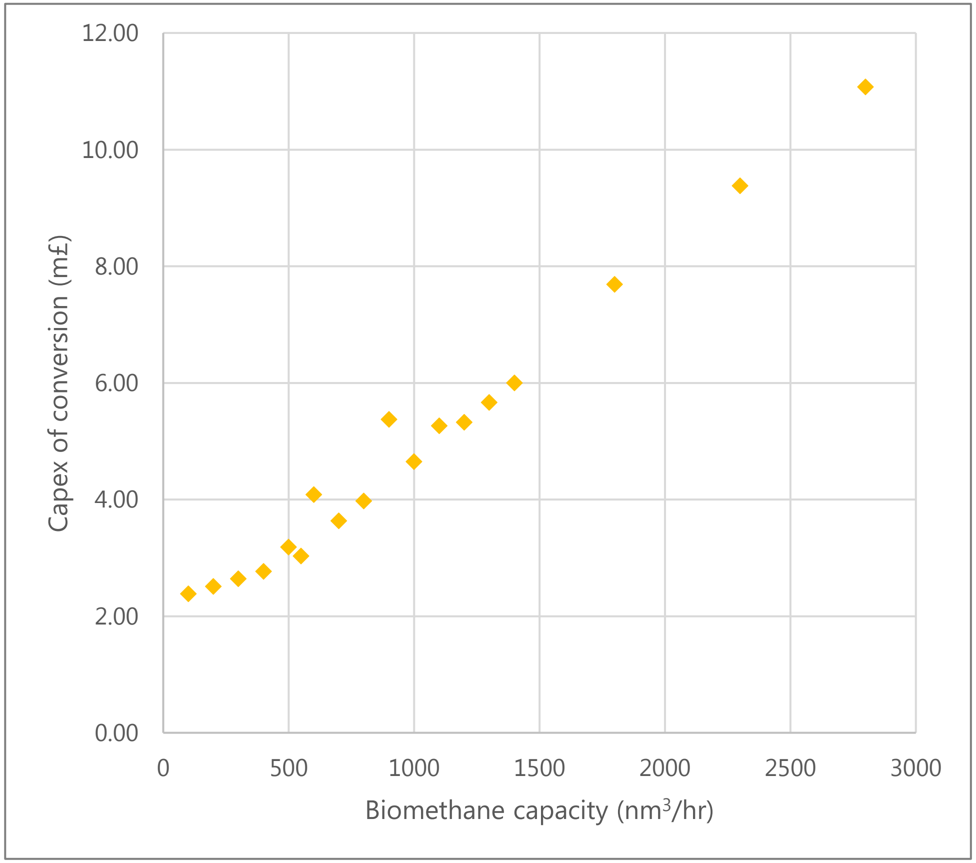
Cost of conversion to biomethane production



- Conversion costs we calculated for each plant deemed technically feasible, using data gathered from operational sites, for previous model developed internally to inform BEIS tariff setting activity for the GGSS.
- Includes Capex costs for:
  - Biogas upgrading unit (BUU)
  - Grid entry unit (GEU)
  - Grid connection
  - Labour
  - Fraction of development costs
  - Other relevant costs
- Excludes Capex or AD development (assumed already operational)

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Potential for conversion to biomethane

Plants	Number of plants	Share of total plants (%)
High likelihood plants	**78**	**34%**
Medium likelihood plants	**88**	**39%**
Low likelihood plants	**61**	**27%**

Total **Biomethane Capacity (Nm^3/hr)** for all plants with high likelihood to switch	**40,764**
Total CAPEX required **(£ million)** for all plants with high likelihood to switch	**256.3**

- Values reflect number of plants and likelihood of switching to biomethane production, based on technical parameters and level and duration remaining on current financial incentives only.
- Economic viability of switching not considered for these calculations.
- Total additional biomethane would deliver a 78% increase in current capacity.

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Potential if all ‘high likelihood’ plants switch to biomethane production

256.3

Total CAPEX required to convert high likelihood AD CHP plants to biomethane Injection (£m)

78%

Increase in the UK’s biomethane capacity if all high likelihood financially viable plants switched

78

Number of plants that have a high likelihood of switching to biomethane production

780k

tonnes CO_2eq saved per year compared to using natural gas, if all high likelihood plants switched

280k

Extra medium sized UK homes heated using renewable biomethane, if all high likelihood plants switched

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Cost of conversion to biomethane production

Plants	Number of plants	Share of total plants (%)
High likelihood plants	**78**	**34%**
Medium likelihood plants	**88**	**39%**
Low likelihood plants	**61**	**27%**

- Values reflect number of plants and likelihood of switching to biomethane production, based on technical parameters and financial incentives only.
- Economic viability of switching not considered for these calculations.
- Total additional biomethane would deliver a 145% increase in current capacity.

Total additional **Biomethane Capacity (Nm^3/hr)** for all high likelihood to switch plants	**40,764**
Total CAPEX required **(£ million)** for all high likelihood to switch plants	**256.3**
Total additional **Biomethane Capacity (Nm^3/hr)** for all medium likelihood to switch plants	**34,881**
Total **CAPEX** required **(£ million)** for all medium likelihood to switch plants	**262.2**

Total (high and medium likelihood plants):

Total **Biomethane Capacity (Nm^3/hr)** for all high and medium likelihood to switch plants	**75,645**
Total **CAPEX** required **(£ million)** for all high and medium likelihood to switch plants	**518.5**

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Potential if all ‘high’ and ‘medium’ likelihood plants switch to biomethane production

518.5

Total CAPEX required to convert all high and medium likelihood AD CHP plants to biomethane Injection (£m)

145%

Increase in the UK’s biomethane capacity if all high and medium likelihood plants switch to biomethane

1.45m

tonnes CO_2eq saved per year compared to using natural gas, if all high and medium likelihood plants switched

166

Number of plants that have a high or medium likelihood of switching to biomethane production

519k

Extra medium sized UK homes heated using renewable biomethane, if all high and medium likelihood plants switched

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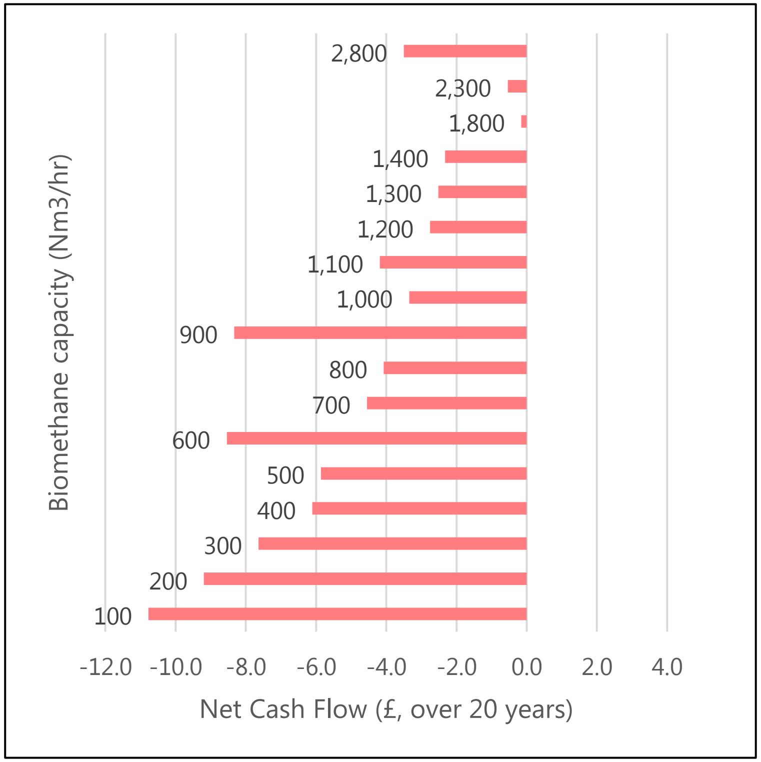
Economic viability of conversion

- Additional analysis considered the individual plant costs of converting and the additional revenue potential from gas sales (assuming no support is available); plants were grouped by scale for ease of analysis.
- Conversion to biomethane production is not economically viable for any of the existing plants, regardless of plant capacity, without financial support.

Capacity (Biomethane NM^3/hr)	Net Profit* (£)	Net Cash Flow* (£)
200	-8,941,796	-9,192,664
300	-7,373,041	-7,636,874
400	-5,827,877	-6,104,674
500	-5,539,809	-5,857,912
600	-8,135,299	-8,543,562
700	-4,184,269	-4,547,658
800	-3,674,203	-4,071,399
900	-7,792,342	-8,329,344
1,000	-2,878,347	-3,343,155
1,100	-3,652,831	-4,179,245
1,200	-2,223,632	-2,756,053
1,300	-1,952,895	-2,519,122
1,400	-1,724,139	-2,324,173
1,800	617,824	-151,241
2,300	397,886	-540,211
2,800	-2,393,696	-3,500,825

* Lifetime values (20 years)



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Financial scenario modelling

- We developed a series of scenarios to understand how **different support mechanisms** would affect the economic viability of switching.
- The scenarios considered no support, and support from the RTFO and/or GGSS, at full or reduced levels as the expectation by industry and Government is that if the GGSS scope is broadened to include expansions or conversions, it would likely be at reduced tariff levels due to the capital costs for the AD already being covered by their original support mechanism.

Scenario A	RTFO support, no GGSS
Scenario B	100% GGSS, no RTFO
Scenario C	50% GGSS, no RTFO
Scenario D	no incentive support

- *Other revenue streams do not change between scenarios; including wholesale revenue from biomethane sales and Green Gas Certificate (GGC) revenue.*
- *Assumed natural gas wholesale price = 52p per therm*

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Economic viability of conversion under different scenarios

- With **full GGSS support**, at current levels, conversion becomes economically viable for plants of ≥200Nm3/hr when considering the cost of conversion and the additional revenue they would receive.
- GGSS is not available for conversions and the expectation is that if the scheme scope does broaden to include this type of development it may be at a reduced rate. Therefore, with **GGSS support at 50% of current levels**, we determined that conversion becomes economically viable for plants of ≥300Nm3/hr.

Capacity (Biomethane NM^3/hr)	RTFO support, no GGSS		Scenario B: 100% GGSS, no RTFO		Scenario C: 50% GGSS, no RTFO		Scenario D: no incentive support	
	Net Profit (£,only RTFO)	Net Cash Flow (£, only RTFO)	Net Profit (£, GGSS only)	Net Cash Flow (£, GGSS only)	Net Profit (£, 50% GGSS)	Net Cash Flow (£, 50% GGSS)	Net Profit (£, no support)	Net Cash Flow (£, no support)
100	-2,167,198	-2,405,101	-4,001,858	-4,239,761	-7,266,367	-7,504,269	-10,530,875	-10,768,778
200	6,306,302	6,055,434	3,334,152	3,083,285	-2,412,779	-2,663,647	-8,941,796	-9,192,664
300	14,351,571	14,087,739	9,893,347	9,629,515	1,960,592	1,696,760	-7,373,041	-7,636,874
400	22,377,733	22,100,936	16,433,434	16,156,637	5,856,427	5,579,630	-5,827,877	-6,104,674
500	29,385,646	29,067,543	21,955,273	21,637,170	8,734,014	8,415,911	-5,539,809	-5,857,912
600	34,057,878	33,649,614	25,141,430	24,733,166	9,275,919	8,867,655	-8,135,299	-8,543,562
700	44,032,790	43,669,401	33,630,267	33,266,878	15,120,504	14,757,116	-4,184,269	-4,547,658
800	51,220,522	50,823,326	39,331,924	38,934,729	18,177,910	17,780,715	-3,674,203	-4,071,399
900	54,659,408	54,122,406	41,284,736	40,747,734	17,486,469	16,949,468	-7,792,342	-8,329,344
1,000	65,518,859	65,054,051	49,937,372	49,472,564	23,855,224	23,390,416	-2,878,347	-3,343,155
1,100	71,648,480	71,122,065	52,680,512	52,154,098	24,904,315	24,377,901	-3,652,831	-4,179,245
1,200	79,699,532	79,167,111	57,345,084	56,812,663	27,874,838	27,342,417	-2,223,632	-2,756,053
1,300	86,739,471	86,173,243	60,998,542	60,432,315	29,834,247	29,268,020	-1,952,895	-2,519,122
1,400	93,742,040	93,142,007	64,614,631	64,014,597	31,756,288	31,156,254	-1,724,139	-2,324,173
1,800	123,046,828	122,277,763	76,657,251	75,888,186	38,880,835	38,111,770	617,824	-151,241
2,300	156,845,821	155,907,724	84,069,801	83,131,704	42,550,160	41,612,063	397,886	-540,211
2,800	188,355,768	187,248,639	89,193,304	88,086,175	43,930,440	42,823,311	-2,393,696	-3,500,825

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Economically viability of conversion under different scenarios

Type of plant	Total number of plants	Number of financially viable (scenario A)	Number of financially viable (scenario B)	Number of financially viable (scenario C)	Number of financially viable (scenario D)
High likelihood plants for biomethane upgrading with direct grid injection	78	70	70	62	0
Medium likelihood plants for biomethane upgrading with direct grid injection	88	77	77	54	0
Low likelihood plants for biomethane upgrading with direct grid injection	61	17	17	3	0

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Potential if all 'high likelihood' plants that are economically viable under Scenario B switch to biomethane production

237

Total CAPEX required to convert high likelihood AD CHP plants to biomethane Injection (£m)

76%

Increase in the UK's biomethane capacity if all high likelihood financially viable plants all switched

761k

tonnes CO_2eq saved per year compared to using natural gas, if all high likelihood plants switched

70

Number of plants that have a high likelihood of switching to biomethane production

273k

Extra medium sized UK homes heated using renewable biomethane, if all high likelihood plants switched

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Potential additional benefits if ‘high’ likelihood plants that are economically viable switch to biomethane production

Total additional **Biomethane Capacity (Nm³/hr)** for all highly likely to switch plants	40,764
Total CAPEX required **(£ million)** for all highly likely to switch plants	256.3

Type of plant	Scenario A	scenario B	Scenario C	Scenario D
Total additional Biomethane Capacity (Nm^3/hr) of plants that have a **high likelihood** to switch and that **are financially viable**	39,766	39,766	35,170	0
Total CAPEX required (£ million) for high likelihood to switch plants	237	237	193	0
Biomethane capacity (Nm^3/hr) "lost" due to lack of support	998	998	5,594	40,764
Number of UK medium-sized house not heated due to lack of support	7,000	7,000	38,000	280,000
Non-prevented emissions due to lack of support (CO_2 tonnes eq/yr)	19,000	19,000	107,000	780,000
Non-prevented emissions due to lack of support (% of total UK emissions)	0.01	0.01	0.03	0.24

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Potential additional benefits if ‘medium’ likelihood plants that are economically viable switch to biomethane production

Total additional **Biomethane Capacity (Nm^3/hr)** for all medium likelihood to switch plants	**34,881**
Total **CAPEX** required **(£ million)** for all medium likelihood to switch plants	**262.2**

Type of plant	Scenario A	scenario B	Scenario C	Scenario D
Total additional Biomethane Capacity (Nm^3/hr) of plants that have a **medium likelihood** to switch and that **are financially viable**	**34,881**	**34,881**	**33,160**	**0**
Total CAPEX required (£ million) for medium likelihood to switch plants	**228**	**228**	**152**	**0**
Biomethane capacity (Nm^3/hr) "lost" due to lack of support	**0**	**0**	**1,721**	**34,881**
Number of UK medium-sized house not heated due to lack of support	**0**	**0**	**12,000**	**239,000**
Non-prevented emissions due to lack of support (CO2 tonnes eq/yr)	**0**	**0**	**33,000**	**667,000**
Non-prevented emissions due to lack of support (% of total UK emissions)	**0.00**	**0.00**	**0.01**	**0.20**

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Potential additional benefits if 'high' and 'medium' likelihood plants that are economically viable switch to biomethane production

Total additional **Biomethane Capacity (Nm^3/hr)** for all high and medium likelihood to switch plants	**75,645**
Total **CAPEX** required **(£ million)** for all high and medium likelihood to switch plants	**518.5**

Type of plant	Scenario A	scenario B	Scenario C	Scenario D
Total additional Biomethane Capacity (Nm^3/hr) of plants that have a **high and medium likelihood** to switch and that **are financially viable**	74,647	74,647	68,330	0
Total CAPEX required (£ million) for medium likelihood to switch plants	465	465	345	0
Biomethane capacity (Nm^3/hr) "lost" due to lack of support	998	998	7,315	75,645
Number of UK medium-sized house not heated due to lack of support	7,000	7,000	50,000	519,000
Non-prevented emissions due to lack of support (CO_2 tonnes eq/yr)	19,000	19,000	140,000	1,447,000
Non-prevented emissions due to lack of support (% of total UK emissions)	0.01	0.01	0.04	0.44

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Financial position of existing plants

- Although some plants were considered economically viable to switch to biomethane production based purely on the additional capex, opex and revenue streams incurred and received for converting, it is necessary to consider the additional benefits they would receive from converting.
- A revenue comparison was made, comparing the current revenue from electricity (and heat) sales, FIT, RHI (for biogas combustion where appropriate) against the new revenue streams, including gas sales, green gas certificates, GGSS (at full and reduced rates, and/or RTFO.
- The financial position was calculated as:

$$Financial\ position(\%) = \frac{Gained\ revenue\ (£)}{Lost\ revenue\ (£)}$$

- This analysis aimed to determine whether each plant would receive more, the same or less revenue under each scenario, to allow a more accurate financial position to be understood.
- The analysis showed that, in some cases where typically smaller-scale plants that had secured a favourable FIT rate and RHI for biogas combustion, and they had more than 10 years of their existing support remaining, gained revenue would be lower after conversion from biomethane injection, and therefore it is unlikely that those plants would switch to biomethane on a purely economic basis .

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Financial scenarios

- The plants considered viable for conversion on a technical and standalone cost & revenue basis, without considering current activities, are shown in the top section of the table below. The lower section of the table refines these numbers to account for the change in financial position, based on lost and gained revenue, when plants switch from CHP to biomethane injection.
- Under scenario C, with only partial GGSS support, no plants show a positive financial position; however as illustrated on the next slide, a number of these sites show a comparable position which would be strengthened if wholesale gas prices remain high; they are faced with increasing maintenance or equipment replacement costs; or CO_2 output can also be valorised, for example.

Type of plant	Total number of plants	Number of financially viable (scenario A)	Number of financially viable (scenario B)	Number of financially viable (scenario C)	Number of financially viable (scenario D)
High likelihood plants for biomethane upgrading with direct grid injection	**78**	**70**	**70**	**62**	**0**
Medium likelihood plants for biomethane upgrading with direct grid injection	**88**	**77**	**77**	**54**	**0**
Low likelihood plants for biomethane upgrading with direct grid injection	**61**	**17**	**17**	**3**	**0**
High likelihood plants for biomethane upgrading with direct grid injection	**78**	55	40	0	0
Medium likelihood plants for biomethane upgrading with direct grid injection	**88**	22	4	0	0
Low likelihood plants for biomethane upgrading with direct grid injection	**61**	4	10	0	0

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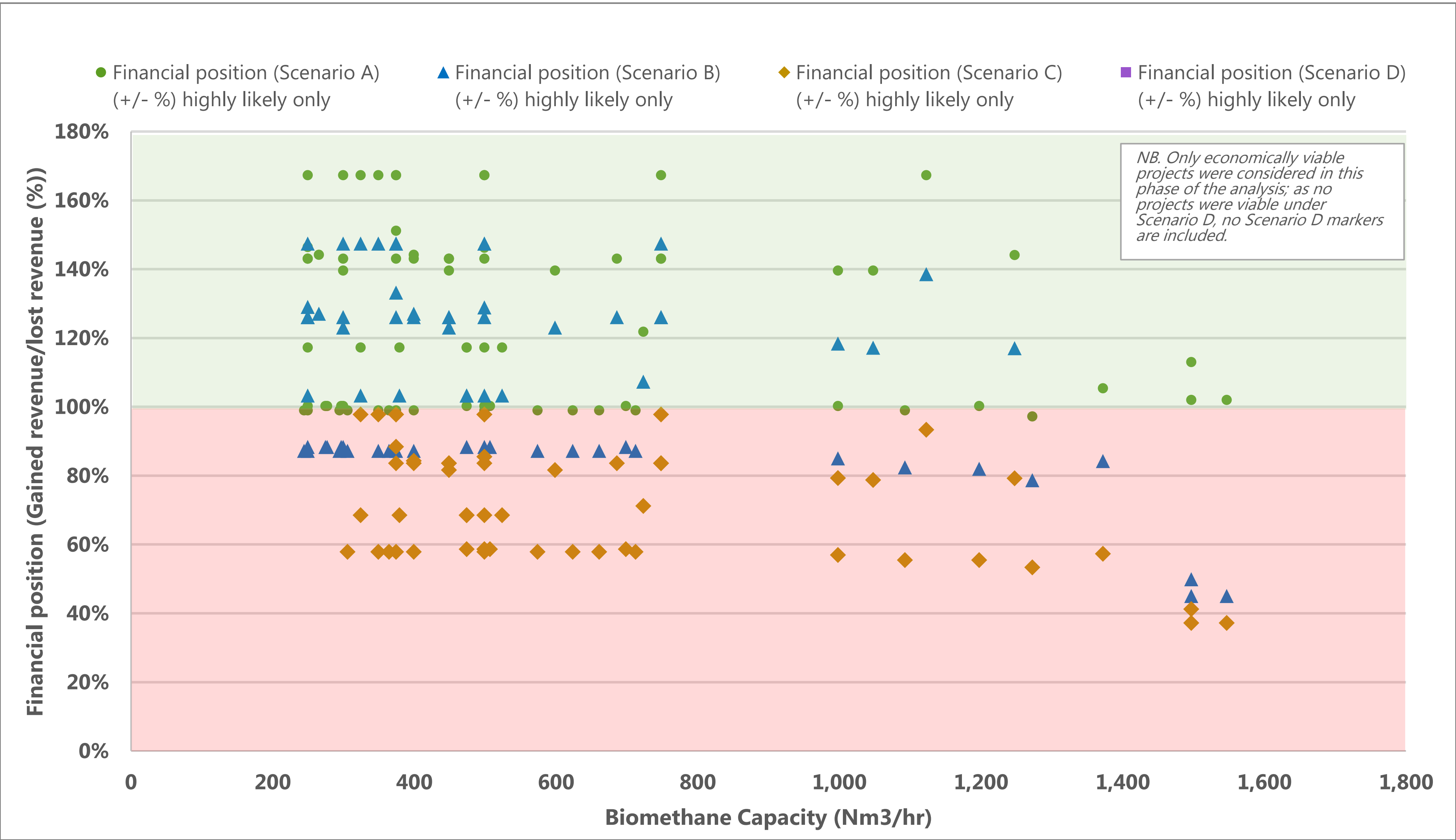
Financial scenario comparisons, for AD plants that have a high likelihood and are economically viable to convert to biomethane production



Potential additional benefits if 'high' likelihood plants that are economically viable and with a positive financial position switch to biomethane production

Type of plant	Scenario A	scenario B	Scenario C	Scenario D
Total additional Biomethane Capacity (Nm^3/hr) of plants that have a **high likelihood** to switch, **are financially viable and have a positive financial position**	**31,750**	**20,066**	**0**	**0**
Total CAPEX required (£ million) for high likelihood to switch plants	**186**	**126**	**0**	**0**
Biomethane capacity (Nm^3/hr) "lost" due to lack of support	**9,014**	**20,697**	**40,764**	**40,764**
Number of UK medium-sized house not heated due to lack of support	**62,000**	**142,000**	**280,000**	**280,000**
Non-prevented emissions due to lack of support (CO2 tonnes eq/yr)	**172,000**	**396,000**	**780,000**	**780,000**
Non-prevented emissions due to lack of support (% of total UK emissions)	**0.05**	**0.12**	**0.24**	**0.24**

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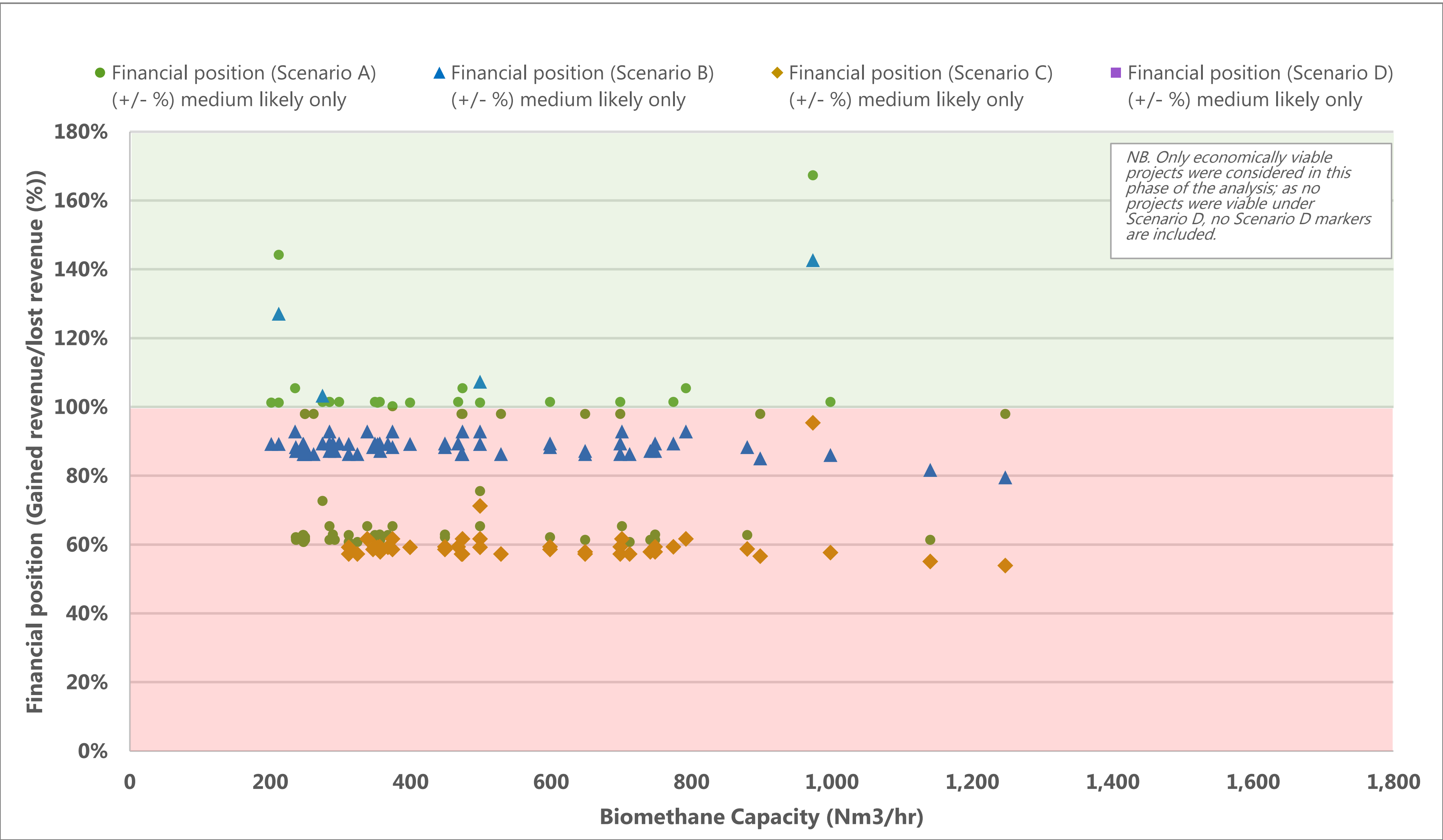
Financial scenario comparisons, for AD plants that have a medium likelihood and are economically viable to convert to biomethane production



Potential additional benefits if ‘medium’ likelihood plants that are economically viable and with a positive financial position switch to biomethane production

Type of plant	Scenario A	scenario B	Scenario C	Scenario D
Total additional Biomethane Capacity (Nm^3/hr) of plants that have a **medium likelihood** to switch, **are financially viable and a positive financial position**	**10,110**	**1,958**	**0**	**0**
Total CAPEX required (£ million) for medium likelihood to switch plants	**69**	**13**	**0**	**0**
Biomethane capacity (Nm^3/hr) "lost" due to lack of support	**24,771**	**32,923**	**34,881**	**34,881**
Number of UK medium-sized house not heated due to lack of support	**170,000**	**226,000**	**239,000**	**239,000**
Non-prevented emissions due to lack of support (CO2 tonnes eq/yr)	**474,000**	**630,000**	**667,000**	**667,000**
Non-prevented emissions due to lack of support (% of total UK emissions)	**0.15**	**0.19**	**0.20**	**0.20**

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Potential additional benefits if ‘high’ and ‘medium’ likelihood plants that are economically viable and with a positive financial position switch to biomethane production

Type of plant	Scenario A	scenario B	Scenario C	Scenario D
Total additional Biomethane Capacity (Nm^3/hr) of plants that have a **high and medium likelihood** to switch, **are financially viable and have a positive financial position**	**41,860**	**22,025**	**0**	**0**
Total CAPEX required (£ million) for medium likelihood to switch plants	**255**	**139**	**0**	**0**
Biomethane capacity (Nm^3/hr) "lost" due to lack of support	**33,785**	**53,620**	**75,645**	**75,645**
Number of UK medium-sized house not heated due to lack of support	**232,000**	**368,000**	**519,000**	**519,000**
Non-prevented emissions due to lack of support (CO2 tonnes eq/yr)	**646,000**	**1,026,000**	**1,447,000**	**1,447,000**
Non-prevented emissions due to lack of support (% of total UK emissions)	**0.20**	**0.31**	**0.44**	**0.44**

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Potential if all ‘high’ likelihood plants with economically viable conversions and a positive financial position after the conversion, switch to biomethane production (scenario B)

126.3

Total CAPEX required to convert all high likelihood AD CHP plants to biomethane Injection (£m)

39%

Increase in the UK’s biomethane capacity if all high likelihood financially viable plants all switched

384k

tonnes CO_2eq saved per year compared to using natural gas, if all high likelihood plants switched

40

Number of plants that have a high likelihood of switching to biomethane production

138k

Extra medium sized UK homes heated using renewable biomethane, if all high likelihood plants switched

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Potential if all 'high' and 'medium' likelihood plants with economically viable conversions and a positive financial position after the conversion, switch to biomethane production (scenario B)

139.3

Total CAPEX required to convert all high and medium likelihood AD CHP plants to biomethane Injection (£m)

42%

Increase in the UK's biomethane capacity if all high and medium likelihood financially viable plants all switched

421k

tonnes CO_2eq saved per year compared to using natural gas, if all high and medium likelihood plants switched

44

Number of plants that have a high and medium likelihood of switching to biomethane production

151k

Extra medium sized UK homes heated using renewable biomethane, if all high and medium likelihood plants switched

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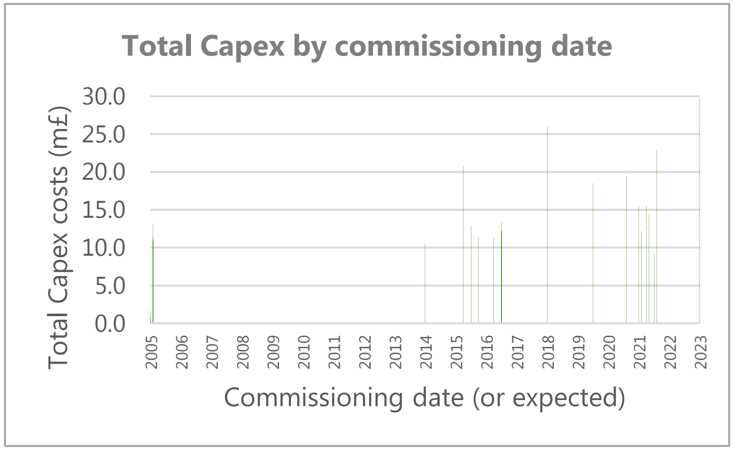
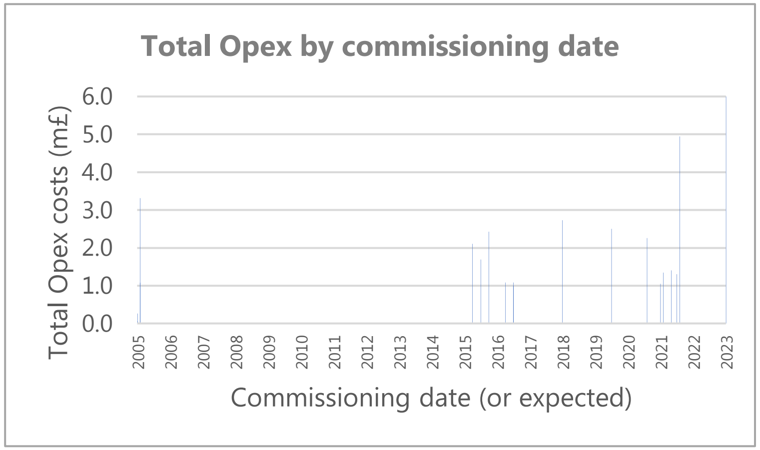
Learning curves





- Changes in costs over time, and by scale, we considered to identify trends and to plot learning curves, to illustrate how the capital and operational costs may change if deployment increases. Analysis was based on the previous industry survey conducted by NNFCC, to obtain capital and operational cost data for all operational and planned biomethane injection facilities located within Great Britain (not solely conversions, although costs were sufficiently granular to allow relevant costs to be extracted and interrogated in more detail).
- The cost analysis showed no firm trends, so it was not possible to plot a standard learning curve; however, key sensitivities were identified, and it was evident costs are likely to change over time, heavily influenced by the feedstock mix used in the plant and tightening regulations around construction and operation of such facilities.
- It is expected that significant increase in deployment and a more standard design for a high number of conversions would deliver a reduction in equipment costs; however, the main costs are driven by materials such as steel and concrete which will continue to vary regardless of deployment levels, due to the influence of external factors. Furthermore, operational costs are heavily influenced by the feedstock mix, so cost variances are more likely to be influenced by the type and scale of plant than the deployment rate at the time of development.

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Sensitivity analysis

- As the learning curve analysis showed no clear trends, it is difficult to evaluate the future cost profile of conversions based purely on time and deployment rate. Therefore, subsequent analysis on the data is required to identify the main cost sensitivities and to determine the likely level of variation that could be considered likely under future deployment scenarios.
- Data obtained during in-depth interviews with key stakeholders as part of previous work by NNFCC, showed that up to £4 million of additional Capex can be incurred when waste feedstock is used due to additional equipment, infrastructure and regulatory controls required for waste treatment. More specifically these additional costs result from:
  - The need to pre-treat and store the feedstock in specific ways before the digestion process.
  - Additional requirements being stipulated by the Environment Agency around permitting and operation.
  - Higher concrete and labour requirements, combined with changes in the Euro to GBP exchange rate as many developers and suppliers are based outside the UK.
  - Distance to the grid, where pipework requirements may vary and the associated civils cost, for labour and materials may rise significantly.
- Conversions of existing CHP capacity to biomethane injection would not be sensitive to the feedstock-related costs mentioned above; however, materials, labour and the exchange rate would be the main sensitivities to consider, potentially flexing the costs by +/- 30% overall.
- Operational costs are less sensitive to materials, labour and the exchange rate, and variation is more heavily influenced by the feedstock mix and scale of operation. On a per unit basis, operational costs can be significantly lower for large-scale facilities, where dedicated personnel are employed to operate the facility, and in such cases, efficiencies can also be improved. Based on previous analysis, plants can see an increase of up to £2 million when waste is included in the feedstock mix, but a much smaller flex of +/- 15% is likely when feedstock mix is not taken into consideration. For conversions, it is not envisaged the feedstock mix will change, as capacity is not assumed to increase.

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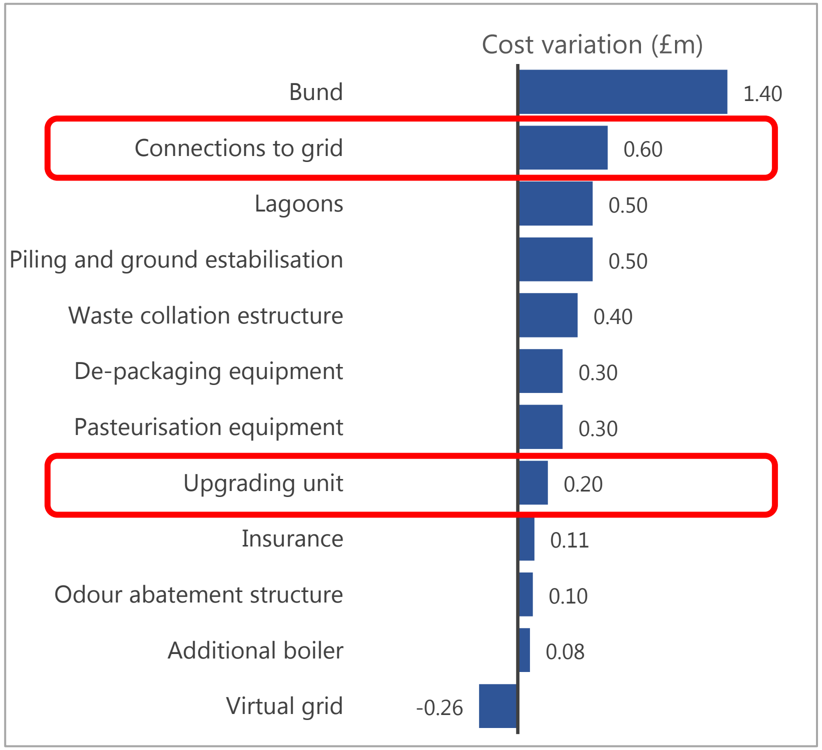
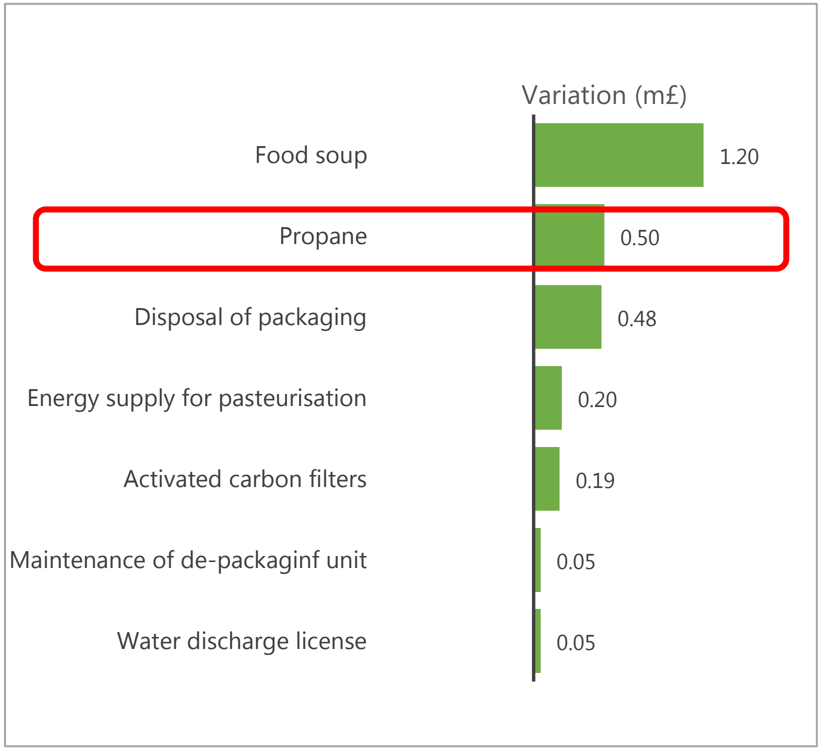
Sensitivity analysis





- The main sensitivities and expected level of variance are illustrated above, for capex (blue) and opex (green) respectively. The key costs of relevance to expansions are encircled in red.
- Based on operational and planned facilities, the variance for connection based on distance to grid and type of grid they are connecting into was as high as £0.6 million, whilst the equipment costs (mostly upgrading unit) showed a much smaller variance, regardless of scale and type of plant. Opex costs for conversions will be highly sensitive to propane addition, which is influenced by type, scale and location of plant.

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Cluster Analysis

Identifying promising clusters of biogas production facilities and their characteristics, to evaluate the potential of networking sites to reduce cost exposure at individual site level.

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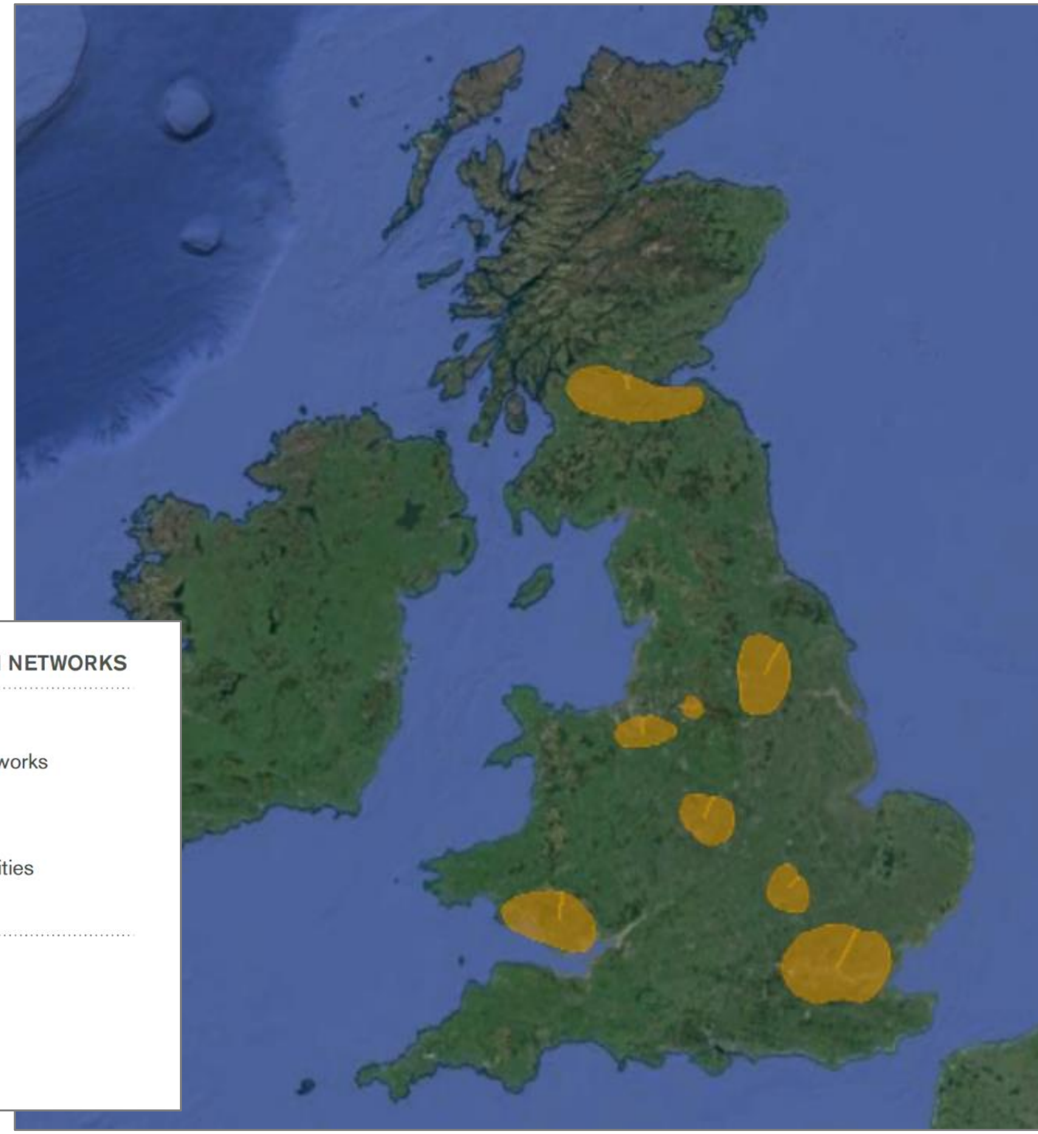
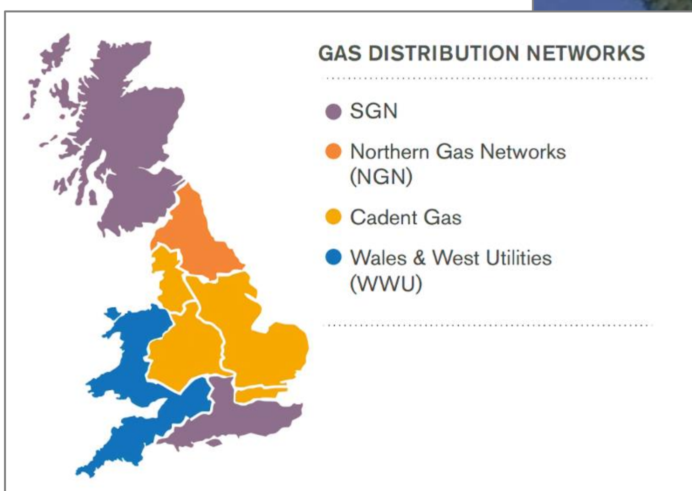
Clustering of biogas production facilities

- 8 clusters were identified in Great Britain for further investigation; distributed across the four network operators.
- Clusters were typically evident around some of the major conurbations, where most waste-fed AD activity is concentrated due to feedstock availability.





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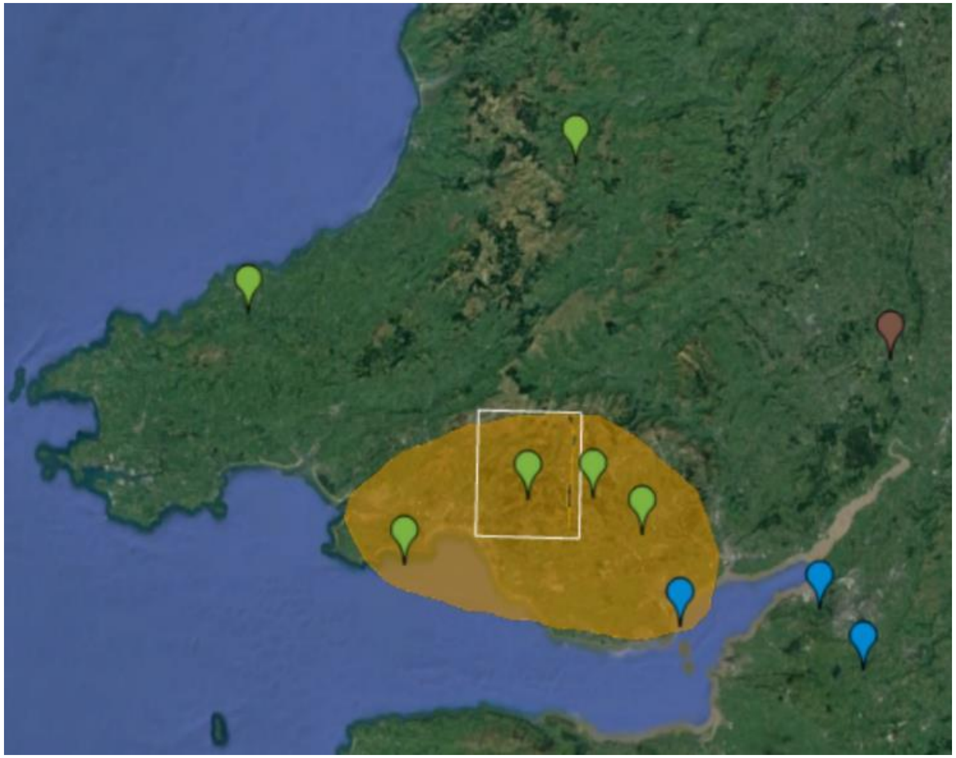
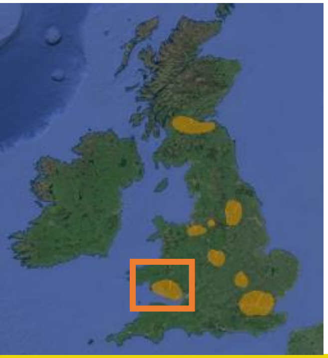
Cluster 1 – Wales – WWU

- 5 plants in the cluster. All with a **high likelihood** of switching to biomethane based on the technical and economic analysis.
- **Total capacity:** 6,580 KWe
- **Biomethane annual output:** 116,794 MWh/yr
- **Maximum distance (crow flies):** 65.69 km





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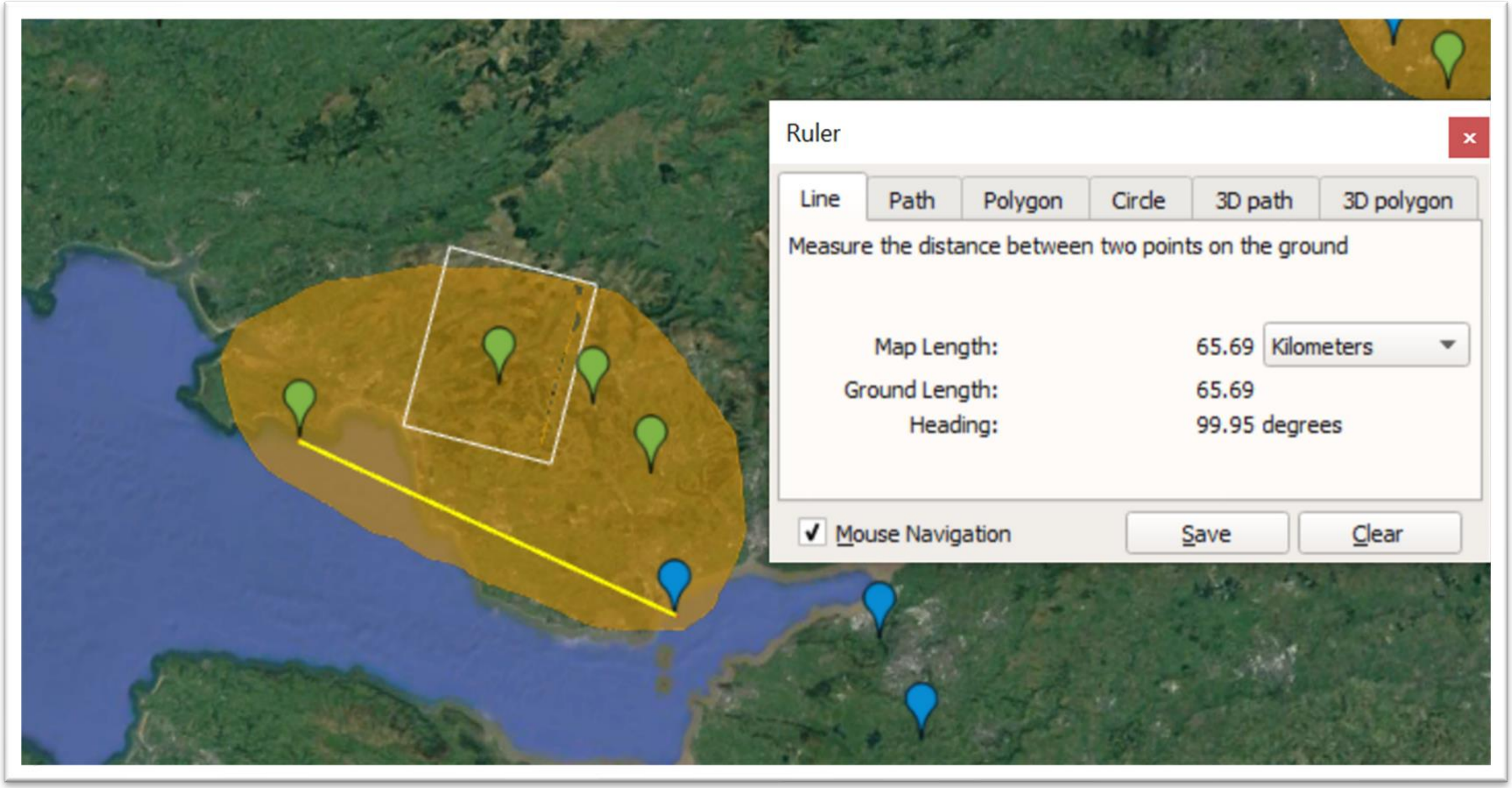
Cluster 1 – Wales – WWU



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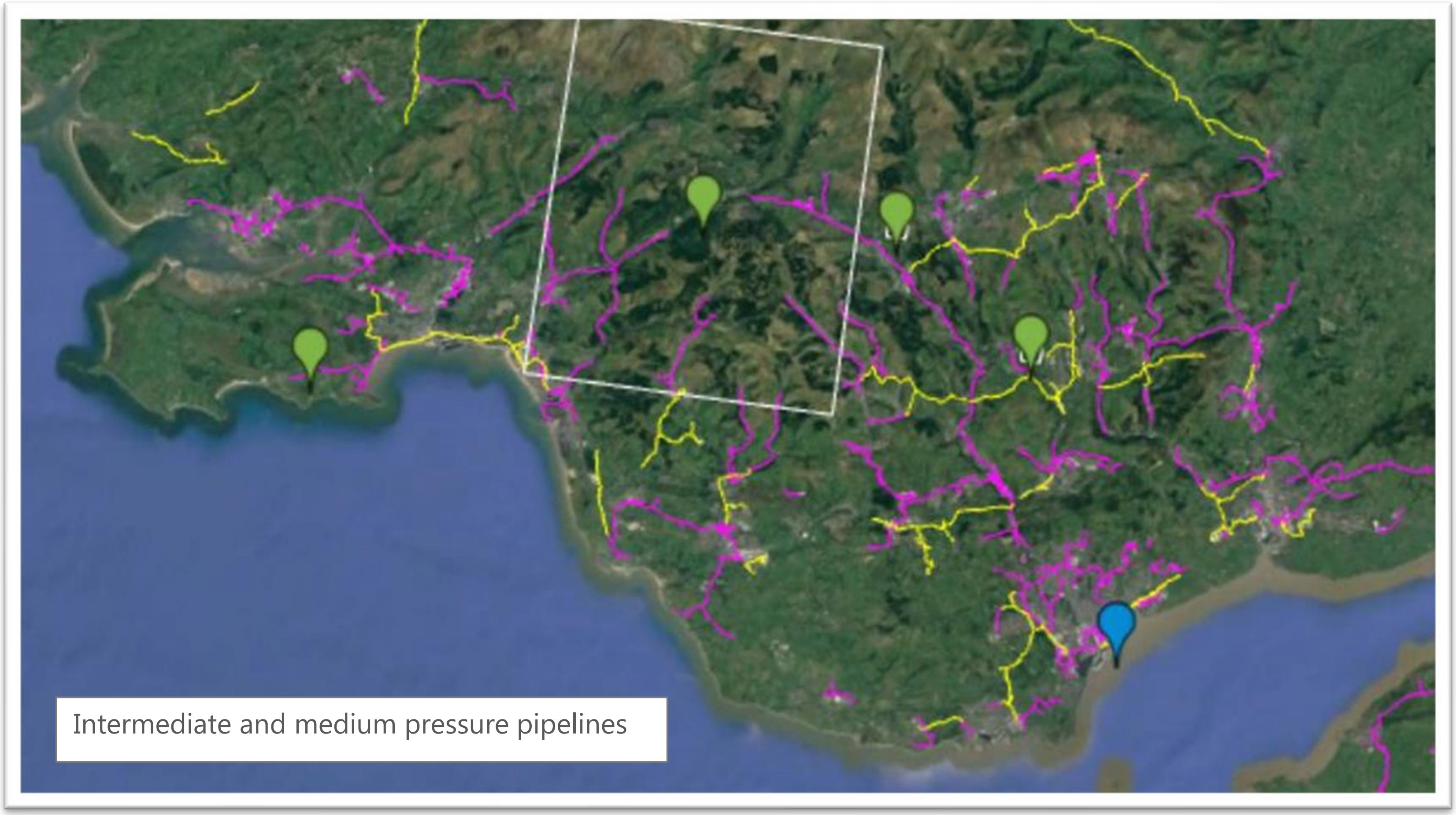
Cluster 1 – Wales – WWU



Cluster 1 – Wales – WWU

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Cluster 1 – Wales – WWU

- 6 plants in the cluster. All with a **high or medium likelihood** of switching to biomethane based on the technical and economic analysis.
- **Total capacity:** 10,180 KWe
- **Biomethane annual output:** 180,693 MWh/yr
- **Maximum distance (crow flies):** 65.69 km

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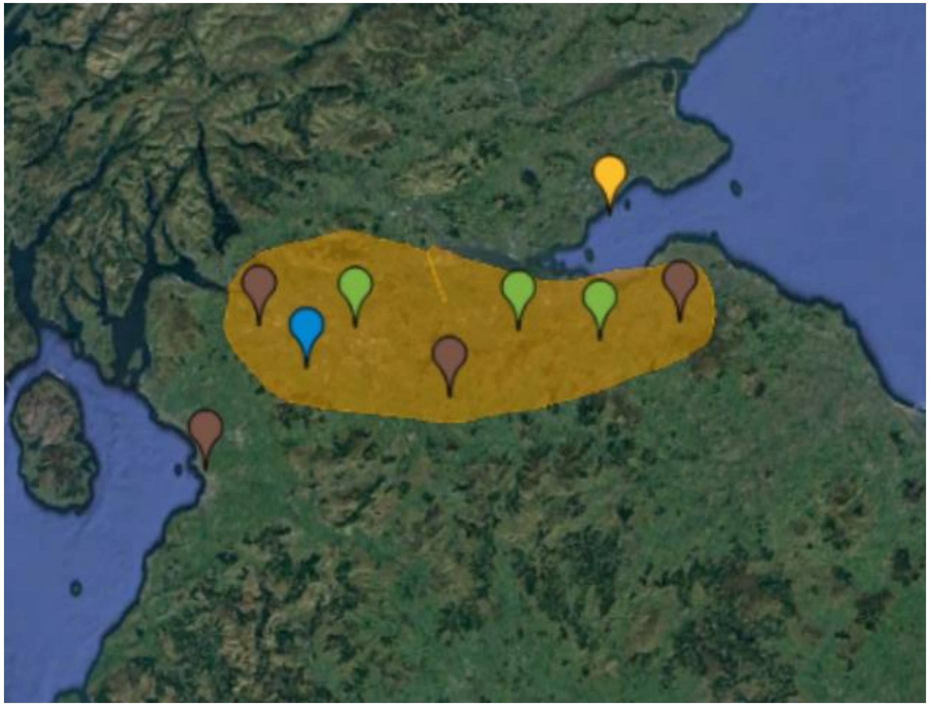
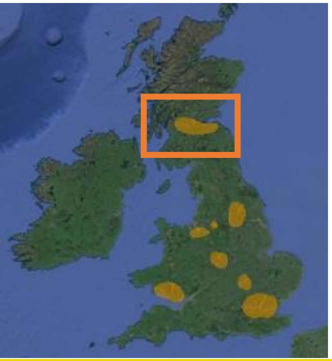
Cluster 2 – Scotland – SGN

- 7 plants in the cluster. All with a **high likelihood** of switching to biomethane based on the technical and economic analysis.
- **Total capacity:** 10,460 KWe
- **Biomethane annual output:** 167,912 MWh/yr
- **Maximum distance (crow flies):** 103.18 km
- No suitable plants with a **medium likelihood** of switching was identified.





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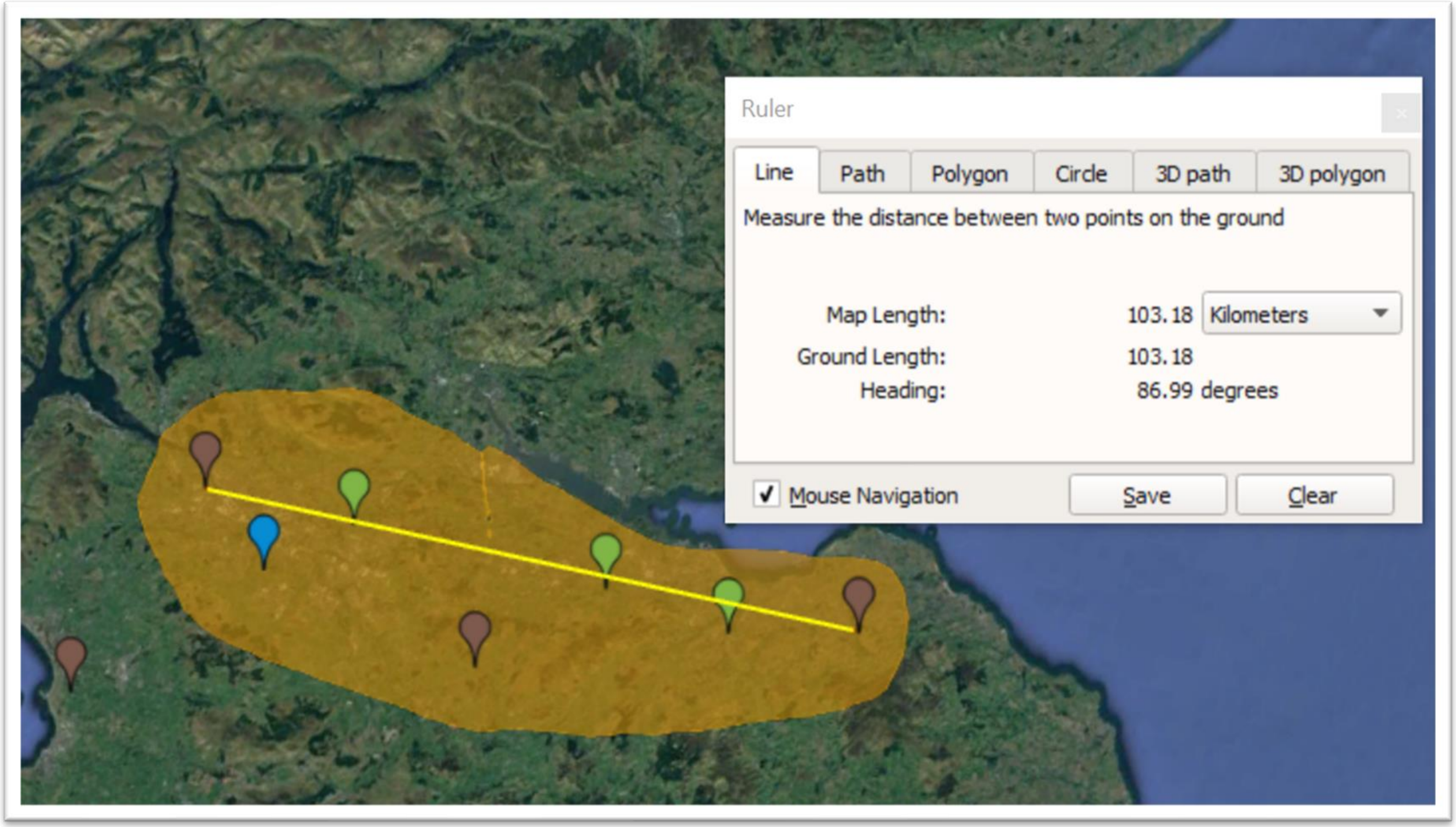
Cluster 2 – Scotland – SGN



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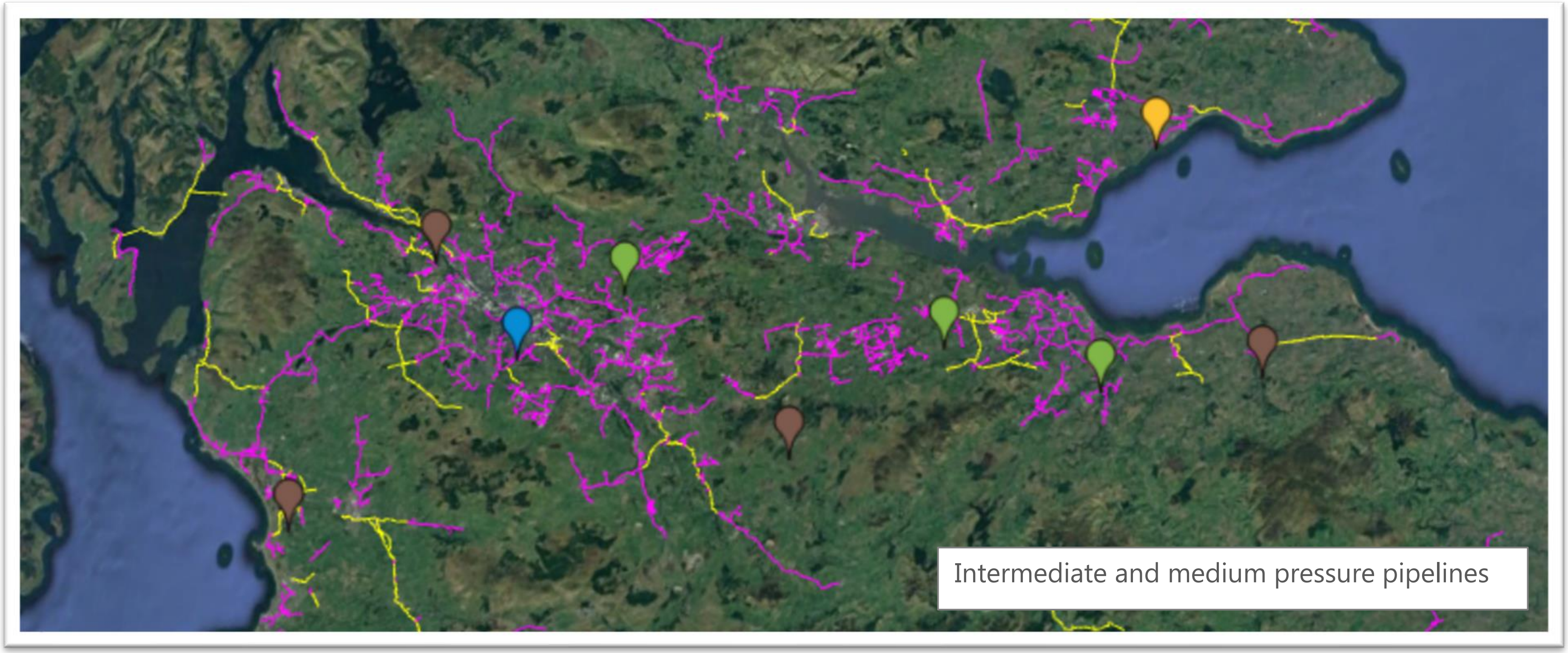
Cluster 2 – Scotland – SGN



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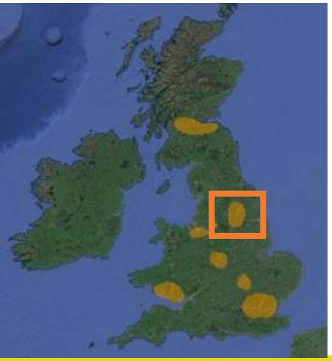
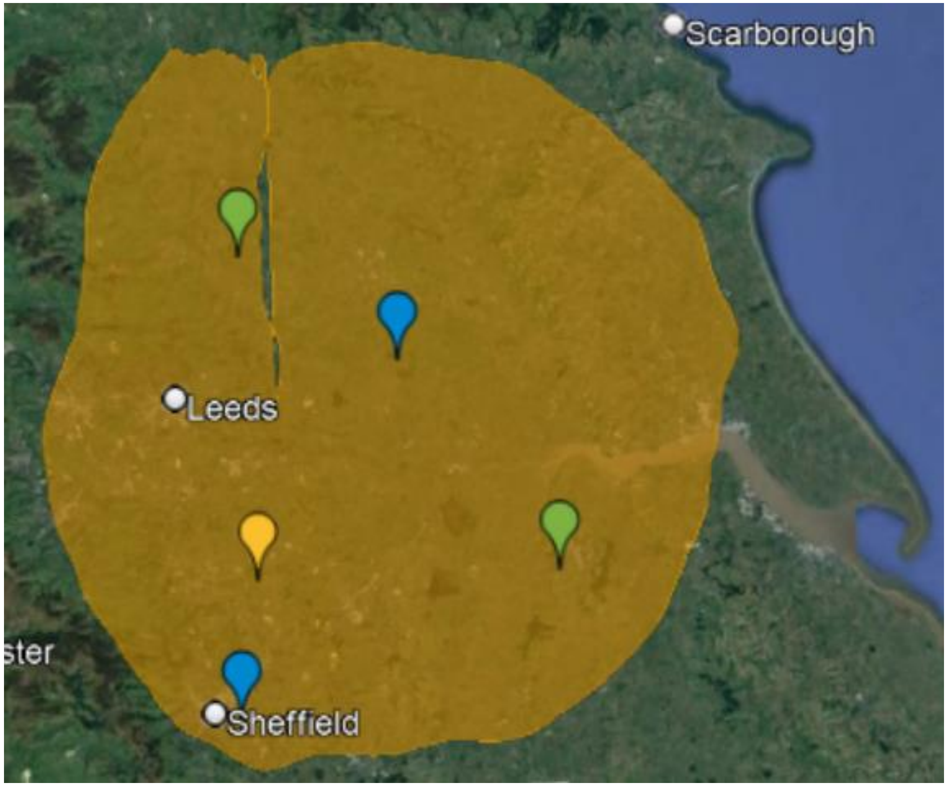
Cluster 3 – Yorkshire – NGN/Cadent

- 5 plants in the cluster. All with a **high likelihood** of switching to biomethane based on the technical and economic analysis.
- **Total capacity:** 13,039 KWe
- **Biomethane annual output:** 231,438 MWh/yr
- **Maximum distance (crow flies):** 68.65 km





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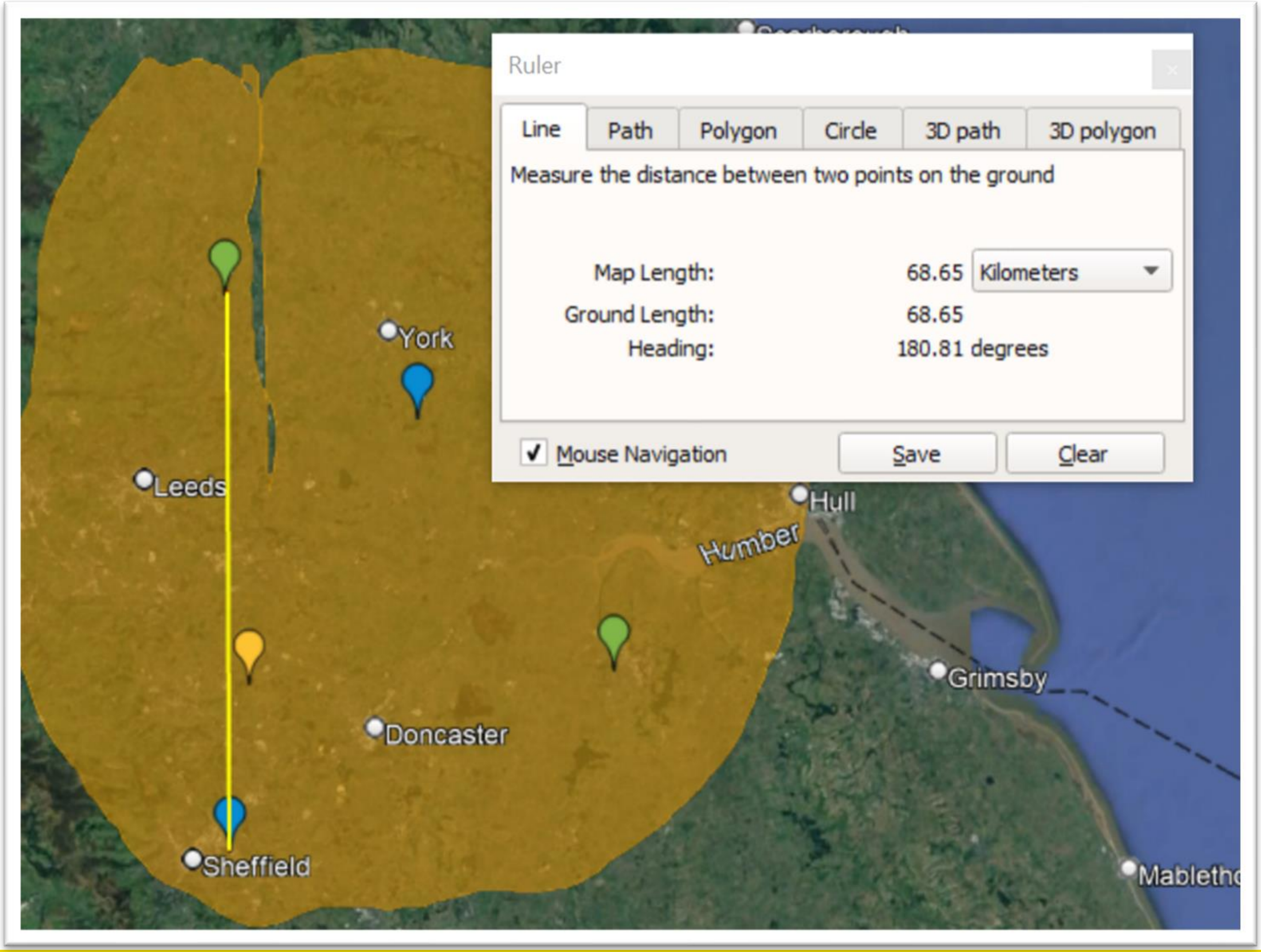
Cluster 3 – Yorkshire – NGN/Cadent



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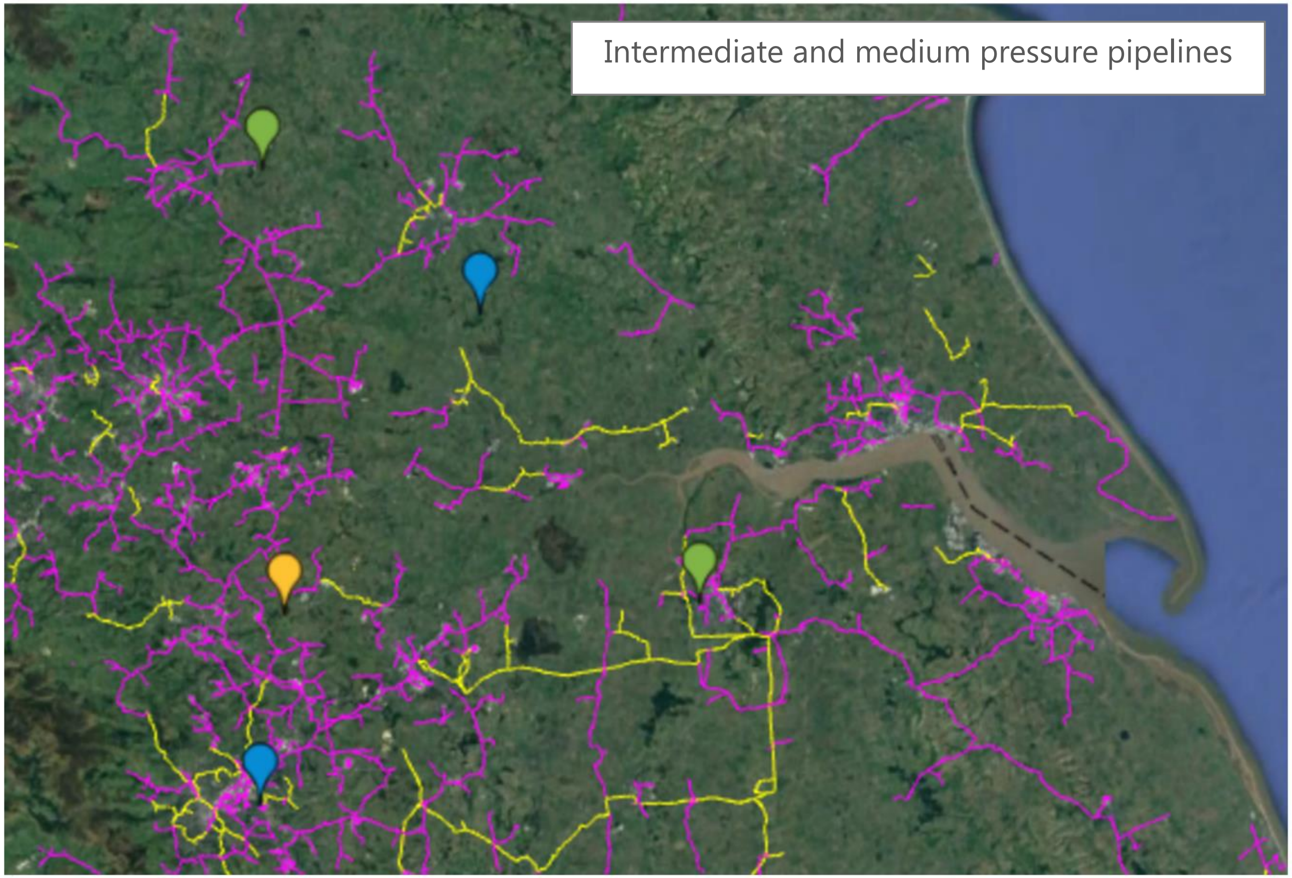
Cluster 3 – Yorkshire – NGN/Cadent



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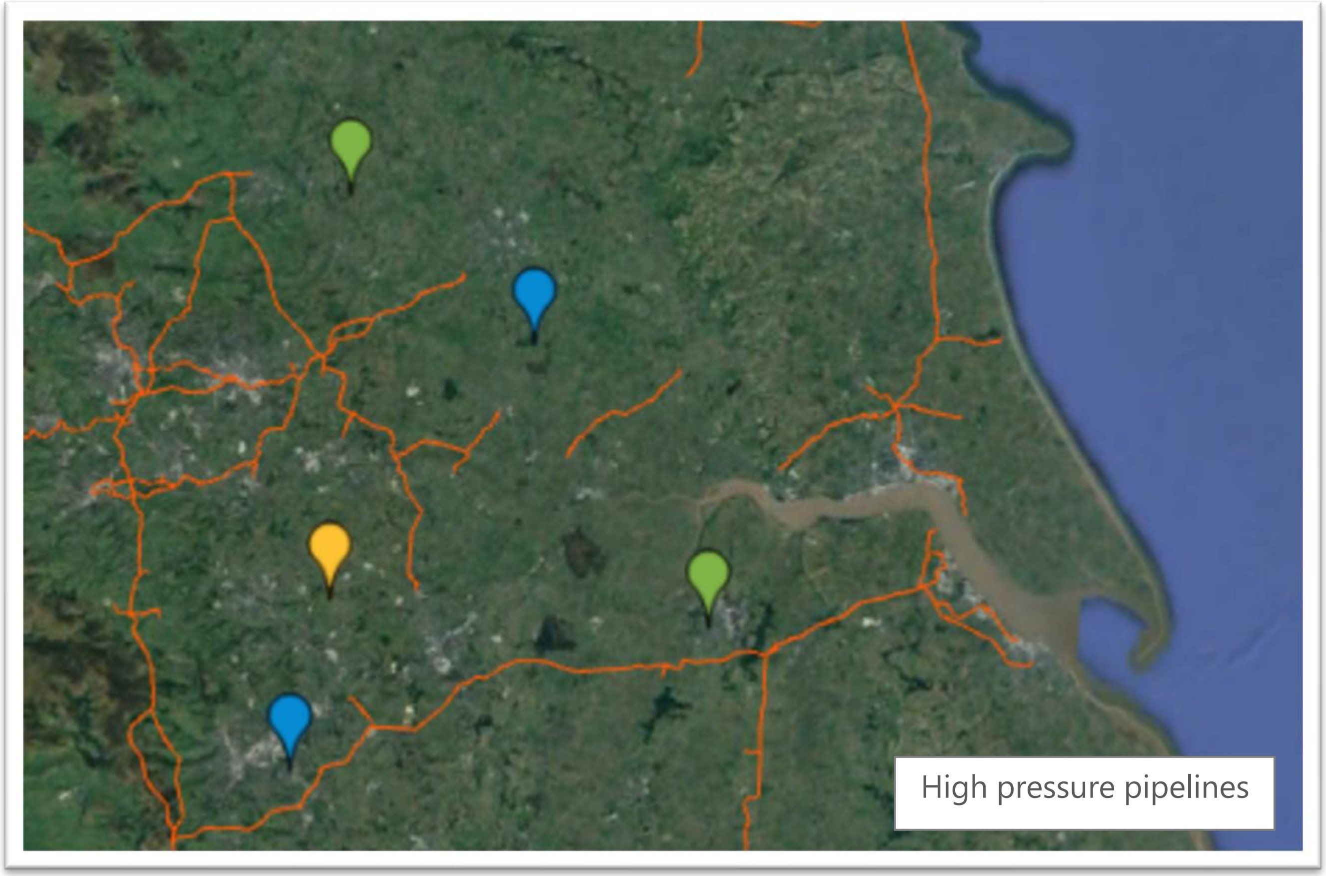
Cluster 3 – Yorkshire – NGN/Cadent



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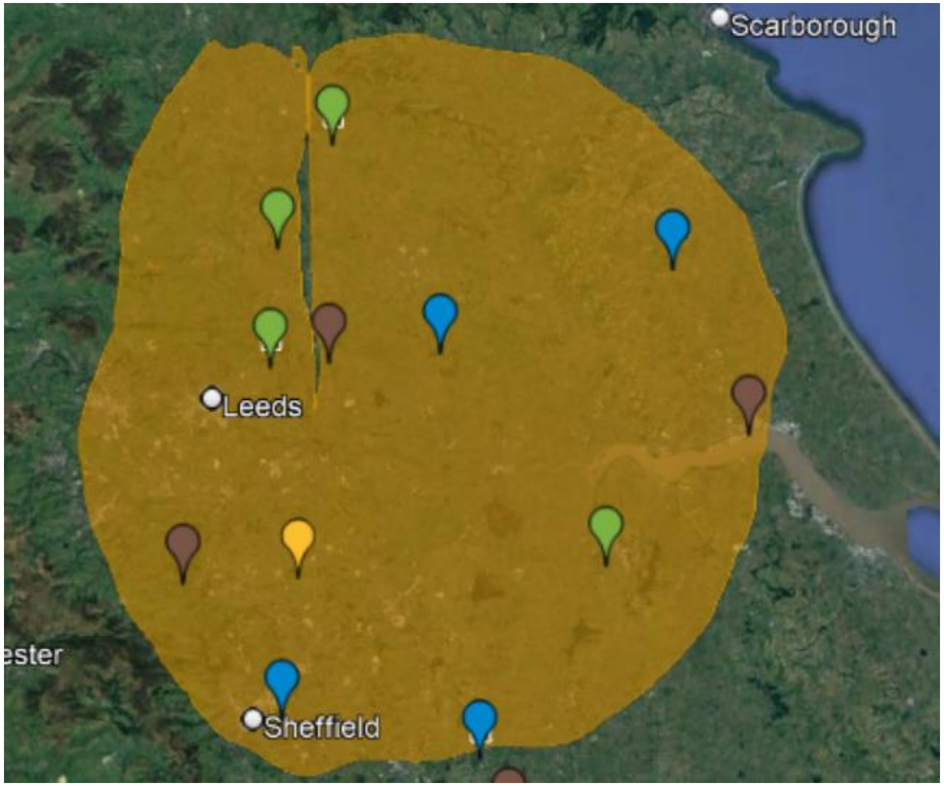
Cluster 3 – Yorkshire – NGN/Cadent

- 12 plants in the cluster. All with a **high or medium likelihood** of switching to biomethane based on the technical and economic analysis.
- **Total capacity:** 24,305 KWe
- **Biomethane annual output:** 431,390 MWh/yr
- **Maximum distance (crow flies):** 91 km
- Covers NGN and Cadent networks.



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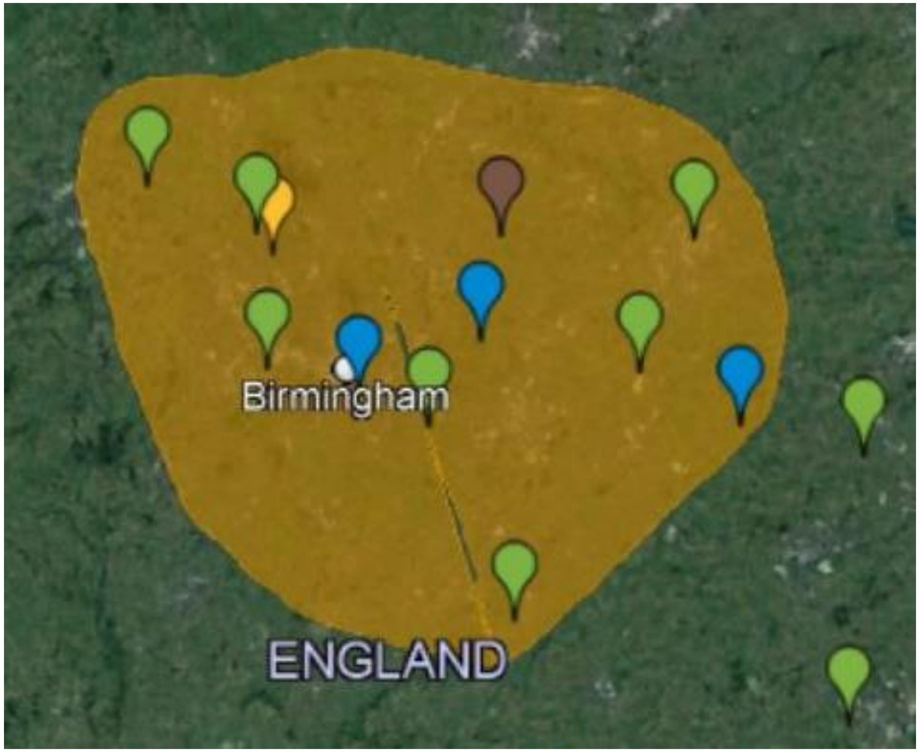
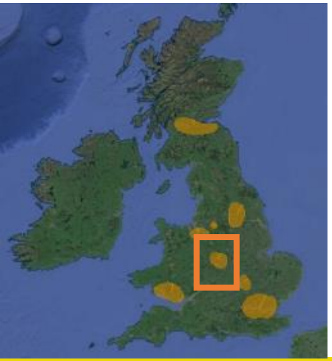
Cluster 4 – Birmingham – Cadent

- 11 plants in the cluster. All with a **high likelihood** of switching to biomethane based on the technical and economic analysis.
- **Total capacity:** 24,850 KWe
- **Biomethane annual output:** 414,455 MWh/yr
- **Maximum distance (crow flies):** 91.06 km





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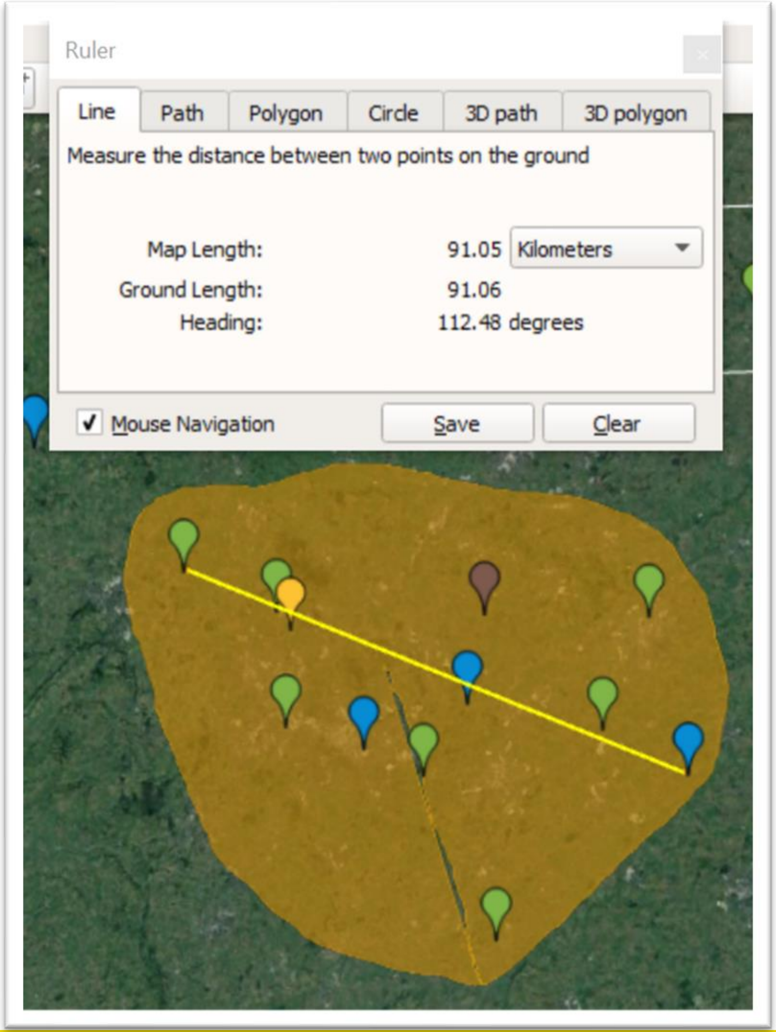
Cluster 4 – Birmingham – Cadent



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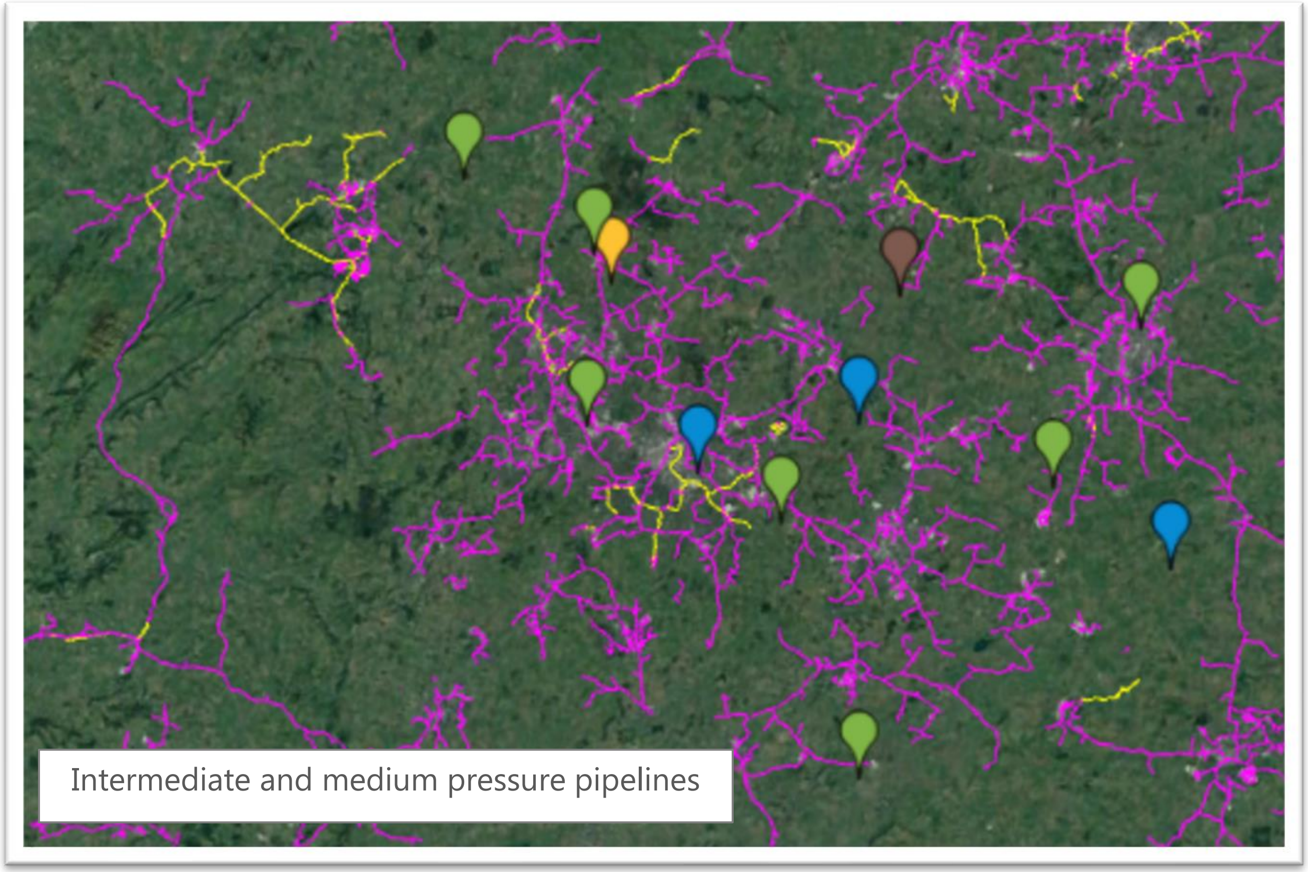
Cluster 4 – Birmingham – Cadent



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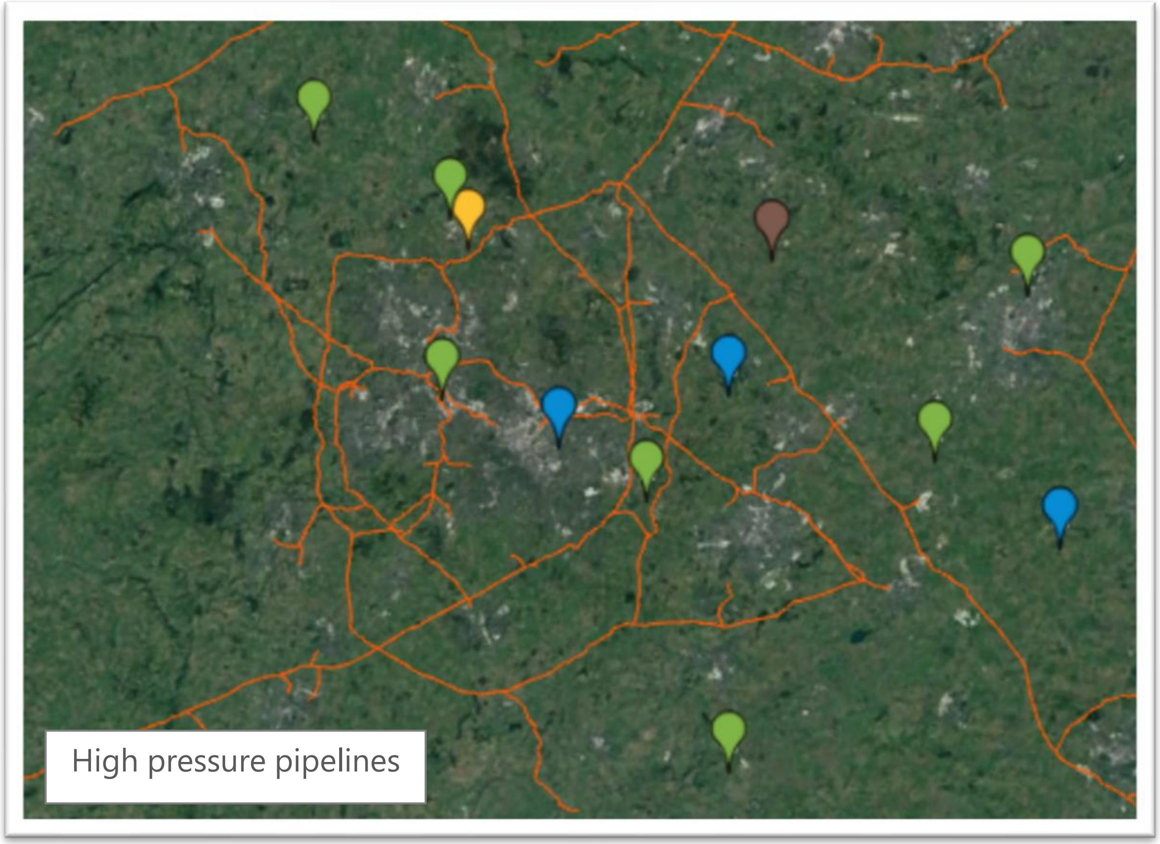
Cluster 4 – Birmingham – Cadent



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Cluster 4 – Birmingham – Cadent

- 15 plants in the cluster. All with a **high or medium likelihood** of switching to biomethane based on the technical and economic analysis.
- **Total capacity:** 28,720 KWe
- **Biomethane annual output:** 483,289 MWh/yr
- **Maximum distance (crow flies):** 91 km

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Strategic Injection Point

Considering the feasibility of establishing a central upgrading and injection point surrounded by a cluster of biogas production facilities supplying gas

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Common injection point

- Based on the clusters identified in the earlier tasks, consideration was given to the economics and technical feasibility of clustering production around a central upgrading and injection facility; surrounding biogas production plants would be connected into the central hub via dry biogas pipes, for ease of installation and to keep costs as low as possible.
- Two case clusters have been identified for this analysis, within regions where the grid is operated by Wales and West Utilities (WWU) and Northern Gas Networks (NGN). In both cases the cluster details were supplied to the GDN and individual connection points for each facility was considered, to allow a suitable central hub to be identified. This analysis could be applied more widely to the other clusters identified, by assessing the individual facilities and the local infrastructure requirements.
- The requirements for a central injection point surrounded by a number of biogas producers are:
  - Central upgrader and injection point with capacity for all offtake from the cluster; cost allocated to central plant
  - All biogas cleaned and dried at source, for transport via dry pipelines to the central injection facility.
  - Satellite plants bear the cost of gas compression and transport, via a network of new pipes, to the central injection facility.
  - Under the current regulations and typical business model, the central plant would have a biogas supply agreement in place with the satellite plants, and a proportion of the revenue would be passed back, split according to the level of investment made in the infrastructure by each respective party.
  - As the central injection hub would exceed the GGSS Tier 1 limit in all cases, discussions are underway with BEIS to determine whether there is a case for all biogas producers to receive GGSS support, thus expanding the scope of Tier 1 support beyond the limits of the cluster. As not yet confirmed, this is not assumed to be the case for this analysis.
- The analysis includes the costs incurred by each individual AD facility, the cost of establishing the injection hub, and the logistical infrastructure required to transfer the gas from source to injection point.

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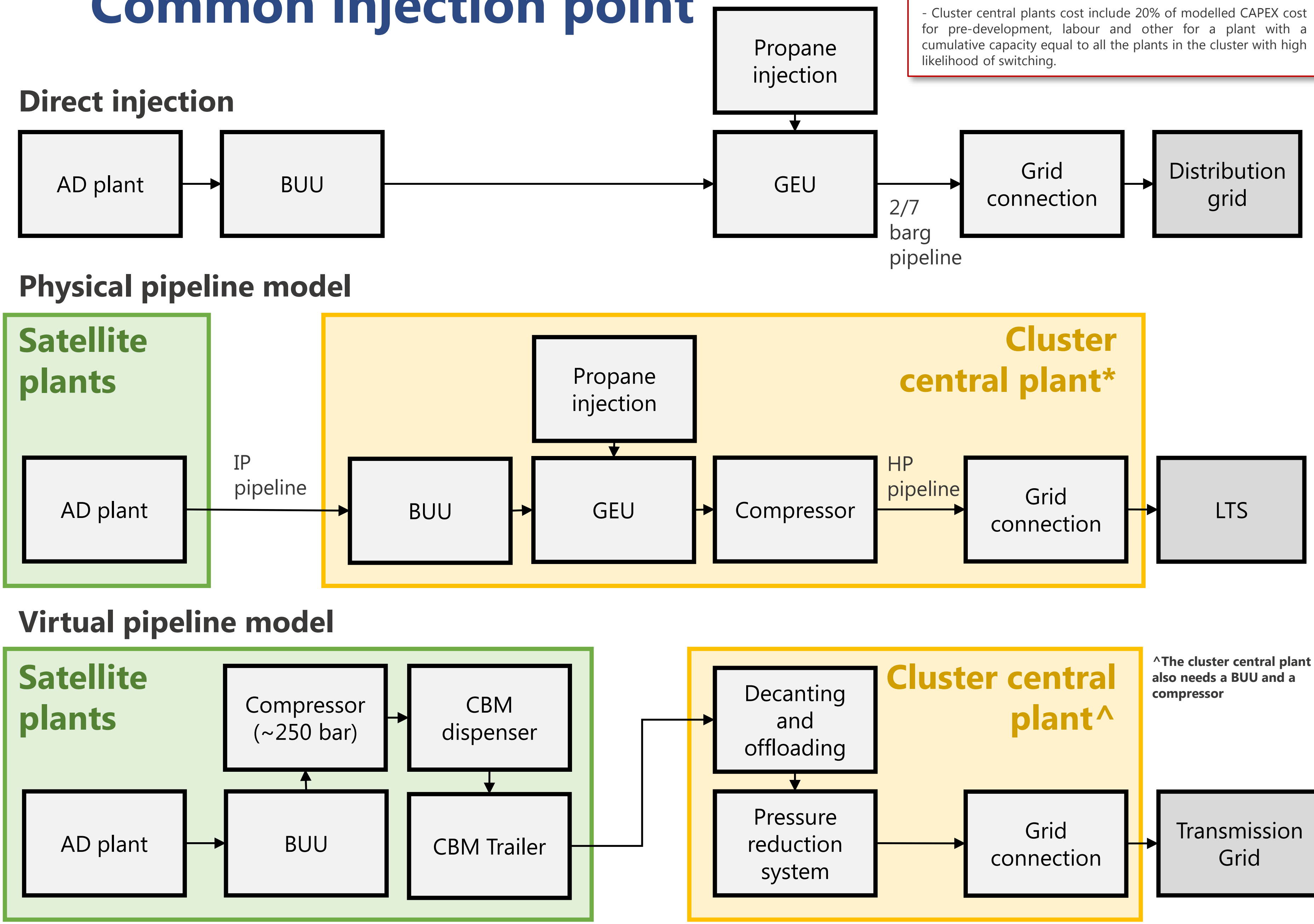
Common injection point

In addition to the equipment cost:

- Satellite plants cost include dry pipelines.

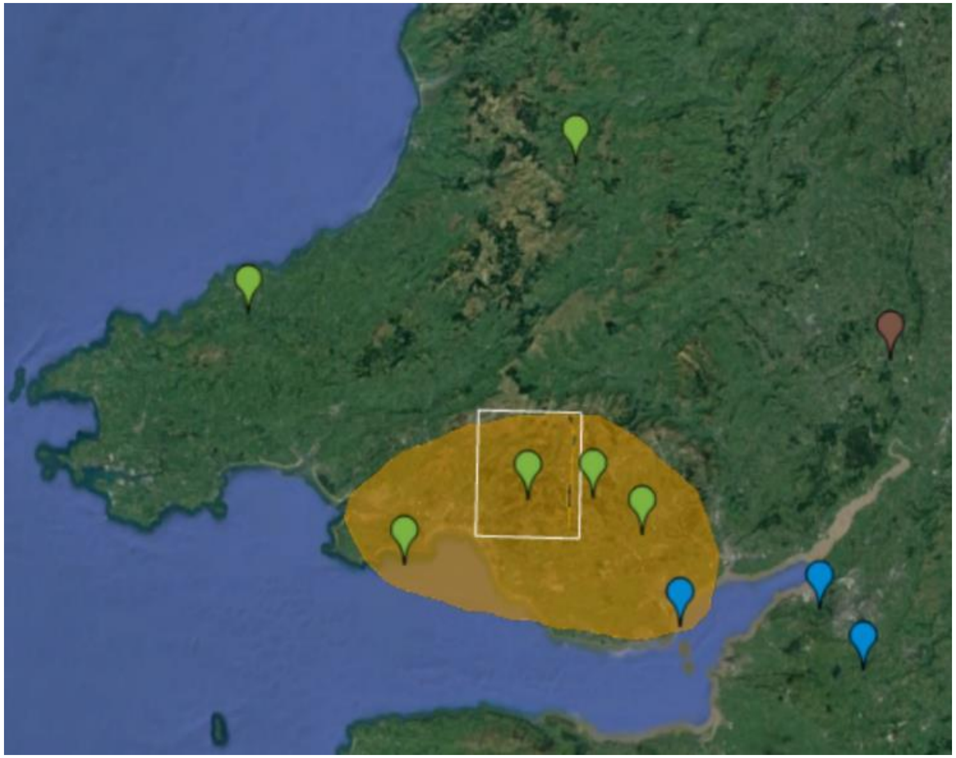
- Cluster central plants cost include 20% of modelled CAPEX cost for pre-development, labour and other for a plant with a cumulative capacity equal to all the plants in the cluster with high likelihood of switching.

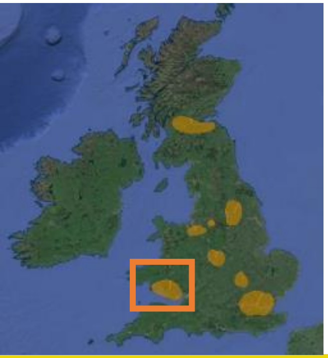


Common injection point analysis – Wales cluster - WWU

Based on the distance to grid and capacity limits confirmed by WWU, the cluster of 6 plants illustrated on the right (5 high likelihood, 1 medium likelihood based on current operations) could make the following contributions:

- **Total capacity:** 6,580 KWe
- **Biomethane annual output:** 116,794 MWh/yr
- **Maximum distance (crow flies):** 65.69 km





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Common injection point analysis – Wales cluster - WWU

- For most plants in the cluster, the Capex for conversion is higher for the physical pipeline model to transfer gas to the common injection point, than it would be for direct injection, due to allocation of costs (see pg. 84), distance from the grid and the current cost of pipework, which in this model is entirely borne by the biogas production facility.
- The physical pipeline model is only economical for plants close to injection point; in this case two plants fall within 20km of the central injection point, so pipework costs remain relatively modest, and the conversion would favour the centralised injection facility approach as opposed to direct grid injection. However, consideration should be given for practical challenges of piping gas this distance, and additional costs that may be incurred on a case-by-case basis where roads, railways, waterways or built-up areas are encountered on the most direct route and pipework needs to be diverted via a less direct route.

General information					Direct grid injection	Physical pipeline, to central injection point			Virtual pipeline, to central injection point		
Plant	Likelihood of switching	Distance to HP (km)	Rounded biomethane Capacity (NM3/hr)	Cluster central point	Cost of direct to grid (£)	Cost for each plant (m£)	Cluster more economical?	Investment difference (m£)	Cost for each plant (m£)	Cluster more economical?	Investment difference (m£)
Plant 1	high	80	200	No	£2.51	£8.80	No	£6.29	£3.98	No	£1.47
Plant 2	high	45	200	No	£2.51	£4.95	No	£2.44	£3.98	No	£1.47
Plant 3	high	34	300	No	£2.64	£3.74	No	£1.10	£4.11	No	£1.47
Plant 4	high	20	300	No	£2.64	£2.20	Yes	-£0.44	£4.11	No	£1.47
Plant 5	high	6.3	500	No	£3.18	£0.69	Yes	-£2.49	£4.65	No	£1.47
Plant 6	medium	0.35	900	Yes	£5.37	£9.40	No	£4.03	£10.26	No	£4.89

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Common injection point analysis – Wales cluster - WWU

- For all plants in the cluster, the Capex for conversion is higher for the virtual pipeline model than it would be for direct injection, due to the cost allocation and equipment requirements of the satellite plants (see pg. 84). In the case modelled here, each satellite plant requires a BUU, compressor and trailers to transport the CBM.
- In the cases where the satellite plant is more than 20km from the central injection point, the virtual pipeline model is more economically viable than the physical pipeline model, despite the higher investment required by each satellite plant.
- The higher capex by each satellite plant would need to be recognised in the commercial arrangements between the central injection point and the biomethane producer, as under current Regulations the injection hub would receive full support, and each contributing station would not secure full Tier 1 support on their contribution, which would be the case for direct injection.

General information					Direct grid injection	Physical pipeline, to central injection point			Virtual pipeline, to central injection point		
Plant	Likelihood of switching	Distance to HP (km)	Rounded biomethane Capacity (NM3/hr)	Cluster central point	Cost of direct to grid (£)	Cost for each plant (m£)	Cluster more economical?	Investment difference (m£)	Cost for each plant (m£)	Cluster more economical?	Investment difference (m£)
Plant 1	high	80	200	No	£2.51	£8.80	No	£6.29	£3.98	No	£1.47
Plant 2	high	45	200	No	£2.51	£4.95	No	£2.44	£3.98	No	£1.47
Plant 3	high	34	300	No	£2.64	£3.74	No	£1.10	£4.11	No	£1.47
Plant 4	high	20	300	No	£2.64	£2.20	Yes	-£0.44	£4.11	No	£1.47
Plant 5	high	6.3	500	No	£3.18	£0.69	Yes	-£2.49	£4.65	No	£1.47
Plant 6	medium	0.35	900	Yes	£5.37	£9.40	No	£4.03	£10.26	No	£4.89

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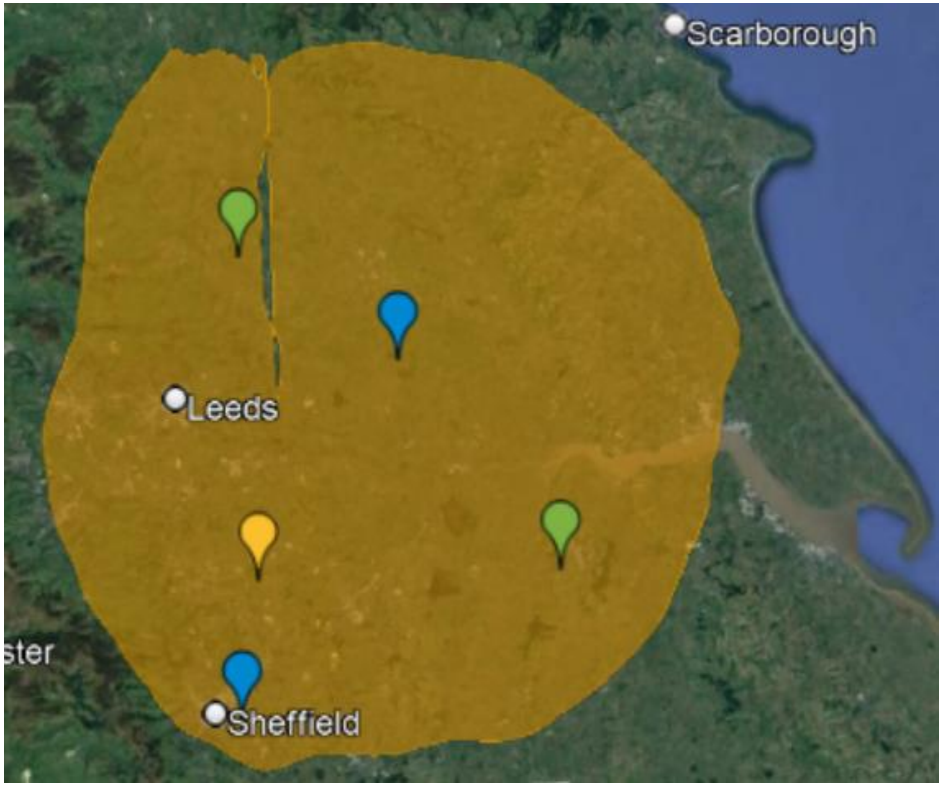
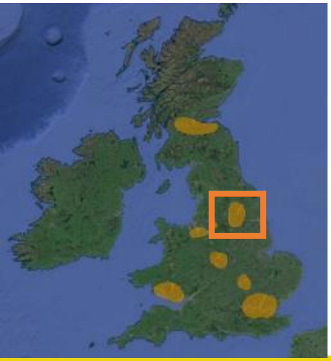
Common injection point analysis – Yorkshire cluster – NGN/Cadent

Based on the distance to grid and capacity limits confirmed by NGN, the cluster of 5 plants illustrated on the right (all with a high likelihood of switching based on current operations) could make the following contributions:

- **Total capacity:** 13,039 KWe
- **Biomethane annual output:** 231,438 MWh/yr
- **Maximum distance (crow flies):** 68.65 km





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Common injection point analysis – Yorkshire cluster – NGN/Cadent

- To expand the scope, on this case cluster the analysis was conducted on high and medium likelihood plants as the additional contribution from medium likelihood plants was significant.
- Due to the relative closeness of plants in the cluster, it becomes evident that the plants located within 18km of the central hub, or larger facilities located up to around 30km from the central hub favour the economics of the clustering approach, whereas smaller plants and those located more distant from the hub still favour direct injection.
- When comparing the physical and virtual pipeline approaches to a central injection point, the allocation of costs and equipment requirements of each site influence the preferred approach. In cases close to the injection point, physical pipeline appears more favourable, but the practical challenges and potential pipeline diversion costs need to be considered on a case-by-case basis.

General information					Direct grid injection	Physical pipeline, to central injection point			Virtual pipeline, to central injection point		
Plant	Likelihood of switching	Distance to HP (km)	Rounded biomethane Capacity (NM3/hr)	Cluster central point	Cost of direct to grid (£)	Cost for each plant (£)*	Cluster more economical?	Investment difference (£)	Cost for each plant (£)	Cluster more economical?	Investment difference (£)
Plant 1	medium	0.49	100	yes	£2.38	£12.91	No	£10.54	£9.51	No	£7.13
Plant 2	medium	62	200	no	£2.51	£6.82	No	£4.31	£3.98	No	£1.47
Plant 3	medium	38	200	No	£2.51	£4.18	No	£1.67	£3.98	No	£1.47
Plant 4	medium	8.5	300	No	£2.64	£0.94	Yes	-£1.70	£4.11	No	£1.47
Plant 5	high	18.3	300	No	£2.64	£2.01	Yes	-£0.63	£4.11	No	£1.47
Plant 6	high	50	300	No	£2.64	£5.50	No	£2.86	£4.11	No	£1.47
Plant 7	medium	31.7	400	No	£2.77	£3.49	No	£0.72	£4.24	No	£1.47
Plant 8	high	52	500	No	£3.18	£5.72	No	£2.54	£4.65	No	£1.47
Plant 9	medium	61.5	700	No	£3.63	£6.77	No	£3.13	£5.09	No	£1.46
Plant 10	high	16	700	No	£3.63	£1.76	Yes	-£1.87	£5.09	No	£1.46
Plant 11	medium	52	800	No	£3.97	£5.72	No	£1.75	£5.43	No	£1.45
Plant 12	high	31.5	1500	No	£6.00	£3.47	Yes	-£2.54	£7.43	No	£1.43

*Although both high and medium likelihood plants have been included in the table, the cost of the BUU, GEU, propane and grid connections have been estimated for a central point with a total capacity of around 3300nm^3/hr (total capacity of high likelihood plants only).

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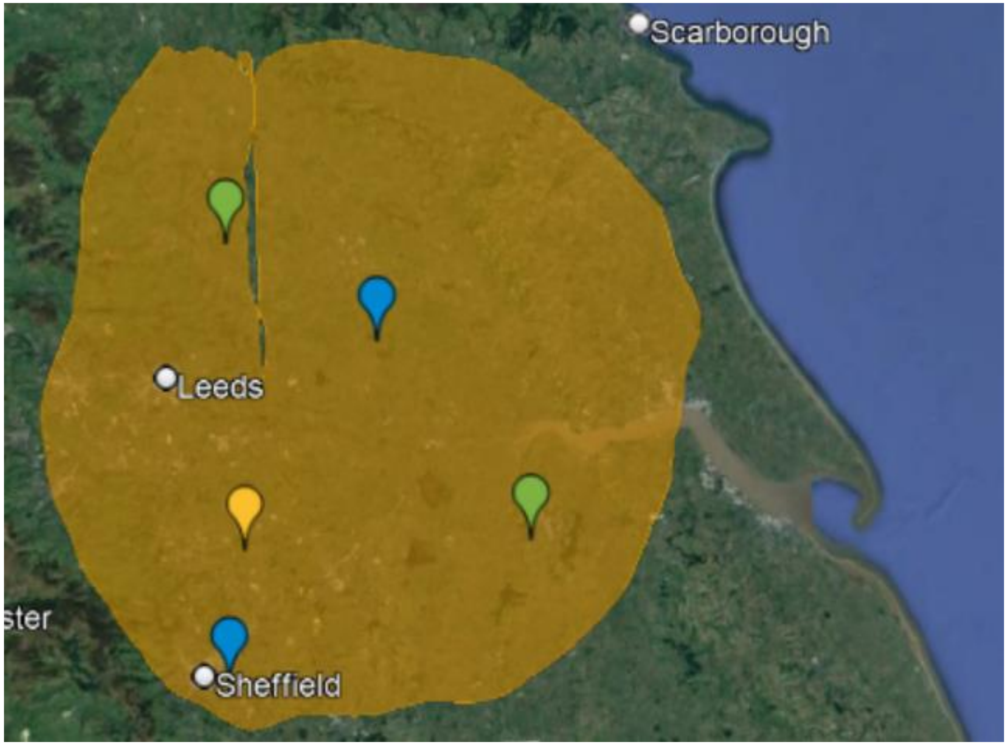
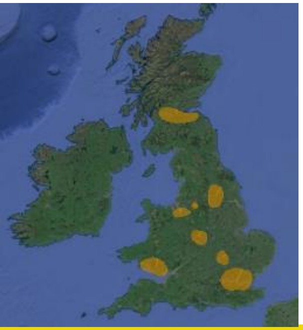
Common injection point analysis – Yorkshire cluster – NGN/Cadent

- For most plants in the cluster, Capex for conversion is higher if the project takes the common injection point approach; however, management and operational costs are not considered in depth, so it may be the case that some of the more distant or smaller facilities could make savings elsewhere and benefit from the central approach under such scenario.
- The high cost is associated with the pipework required to transport the gas from each induvial plant to central injection point, with the entire cost of this currently being borne by the producer.





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Conclusions

Market Opportunity

- Based on the technical potential and the standalone costs and revenue, not considering current activities, a total of 78 plants were identified with a high likelihood of switching rising to 166 plants if also considering those with a medium likelihood of switching.
- Collectively this would deliver an increase of 145% of current biomethane production capacity in UK.
- The likelihood of switching is highly dependent on the scale and type of plant, with larger-scale, waste-fed plants being favoured; furthermore, ageing plants incurring higher maintenance and equipment replacement costs, and with limited time (<10 years) left on their existing support mechanisms.

Cost assessment, based on direct grid injection

- With **no support**, no plants are economically viable for conversion from CHP to biomethane injection regardless of capacity and age of plant, as key revenue streams including electricity (and heat) sales, FIT and RHI support(for biogas combustion) would be lost.
- With **full GGSS support**, conversion becomes economically viable for all plants of ≥200nm3/hr based on the additional capex incurred for the upgrading and injection equipment, associated infrastructure and additional opex, considering the lost revenue streams from the original CHP facility mentioned above.
- With **partial (50%) GGSS support**, conversion becomes economically viable for most plants of ≥ 300nm3/hr, based on the additional capex incurred for the upgrading and injection equipment, associated infrastructure and additional opex, considering the lost revenue streams from the original CHP facility mentioned above.
- With **RTFO support** the case is similar to that of receiving full GGSS support, but the revenue is variable given certificate prices vary and the income is less secure; therefore, projects reliant solely on RTFO are less bankable.
- Development costs are highly sensitive to materials, labour and exchange rate, whilst revenue is highly sensitive to gas prices and the ability to valorise the CO_2, a side-stream from the biogas upgrading process. Given current energy price rises, the need for improved gas supply and security, and a move in the market to establish new outlets for and to support new producers of CO_2, the current outlook is highly sensitive and strong upsides could be seen in both of these areas in the near-term.

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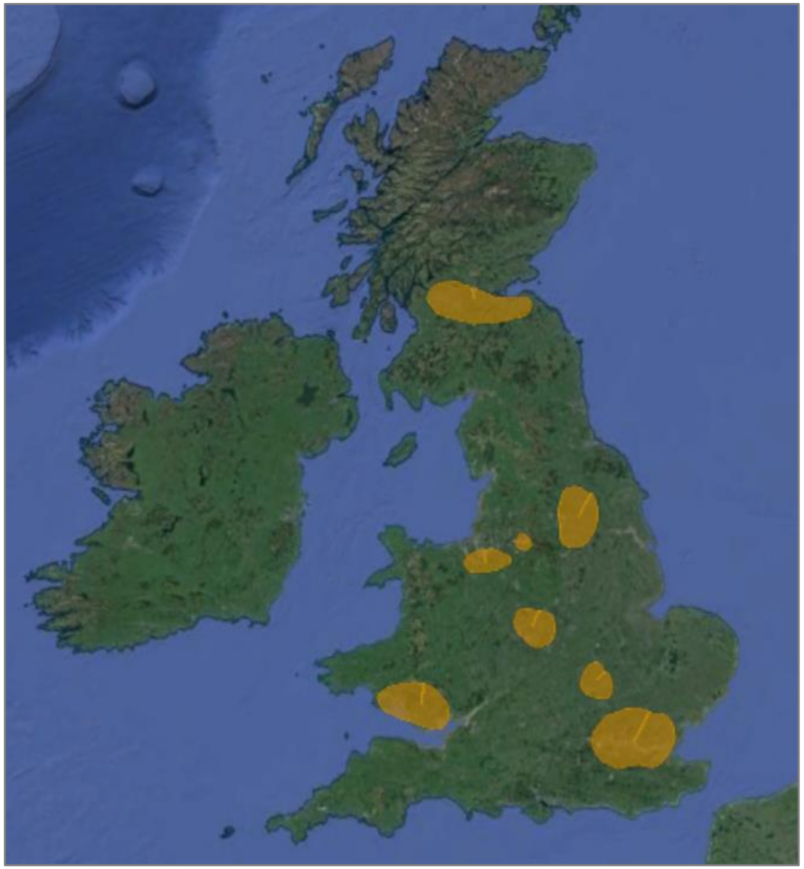
Conclusions

Cluster Analysis

- Based on the market analysis undertaken, 8 clusters were identified in Great Britain, distributed across the four GDN areas. The clusters were identified from the subset of plants deemed to have a high and medium likelihood of switching to biomethane production. Four clusters were selected for further analysis, one in each network area. These clusters were investigated in depth to understand the practicalities and economics of this collective approach.
- The contribution from each cluster is sizeable, illustrating strong opportunities to pursue this business model, to benefit from shared services, infrastructure, skills and wider resources. However, costs of clustering are still substantial, and there remains uncertainty around the distribution of support for such configurations under current schemes.



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Conclusions

Strategic Injection Point

- In both case clusters studied, for both physical and virtual pipeline approaches, the Capex costs are generally higher than they would be for direct injection, predominantly due to the additional equipment and pipework costs.
- However, the scale of opportunity that could be captured by clustering plants is higher, if the costs can be reduced and the revenue potential increased. Costs could be reduced by considering the pipework requirements, using dry biogas pipes rather than relying on steel pipework, and additional infrastructure costs can be reduced. Furthermore, discussions are underway with BEIS to determine whether the GGSS could be granted to biogas producers under a networked (cluster) scenario, rewarding all producers then at Tier 1 levels rather than pushing production at the central point into GGSS Tier 2, which is rewarded at lower levels.
- Alternatively, by using a virtual pipeline approach although pipework costs are eliminated, each satellite site would require gas upgrading and compression equipment, so costs can still be high. This approach also does not align with the current regulations and there would be no opportunity for all gas to be claimed at the Tier 1 rate as considered above – as the support is only paid at the point the gas enters the pipeline, all support would be paid to the central hub at Tier 1, 2 and 3 rates respectively. Therefore, under current regulations this approach would not be viable, but should be further explored and discussed with BEIS for consideration during the GGSS mid-scheme review, commencing later this year.
- Cost allocation and revenue split between the biogas producers and the injection site would need to be considered on a case-by-case basis, and capital costs borne by each party recognised in commercial arrangements.
- Finally, as gas prices continue to rise, gas security concerns increase and demand for domestic supply increases; clustering, to make upgrading and injection technically and practically more attractive for smaller-scale producers, should be further considered. In addition, as CO_2 markets develop and if support becomes available for its valorisation, there are likely to be significant benefits from having a centralised upgrader and CO_2 supply base as opposed to distributed production, easing logistics for collection vehicles. This could improve the economics and drive more producers to consider the clustering approach, potentially in partnership with a CO_2 offtaker, providing a stable and secure market to support the long-term investment in additional infrastructure.

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