ATKINS

Anaerobic Digestion Feasibility Study

Bracknell AD Plant Technical Feasibility

Bracknell Forest Council

DATE 07 December 2021

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Document History

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Client Signoff

Client	Bracknell Forest Council
Project	Anaerobic Digestion Plant – Feasibility Study
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Glossary of Terms

AD	Anaerobic Digestion
ADBA	Anaerobic Digestion and Bioresources Association
BtG	Biogas to Gas
BFC	Bracknell Forest Council
CAPEX	Capital Expenditure
CHP	Combined Heat and Power
CNG	Compressed Natural Gas
COD	Chemical Oxygen Demand
CfD	Contract for Difference
EPR	Environmental Permitting Regulations
GGSS	Green Gas Support Scheme
GHG	Greenhouse Gas
IRR	Internal Rate of Return
LNG	Liquefied Natural Gas
NPV	Net Present Value
O&M	Operation and Maintenance
OPEX	Operational Expenditure
PFD	Process Flow Diagram
RTFO	Renewable Transport Fuel Obligation
SWOT	Strengths, Weaknesses, Opportunities and Threats
TDS	Tonnes Dry Solids
UK	United Kingdom
VOC	Volatile Organic Compound

Executive Summary

Bracknell Forest Council (BFC) is interested in the potential to use the food waste collected from BFC, Reading and Wokingham Councils and produce biogas. Atkins was commissioned by BFC to undertake a high-level Feasibility Study into the technical viability of a number of options including a potential development of its own Anaerobic Digestion (AD) plant. The intended purpose of the plant would be to treat collected food waste from approximately 47,000 households, that is currently disposed of through the re3 partnership with Wokingham and Reading Councils. 19,000 tonnes of food waste per year is the current collection expectation for 2021/22 for the combined total of the three councils.

The report is split into three main sections, firstly an introduction presenting the structure of the report, background information and scope of the study. Secondly, an assessment of three strategic options is investigated looking at the advantages and disadvantages of the following three options:

- Continue with current contract.
- Build own AD plant.
- Public/private partnership - collaborate with a third party

Lastly, an optioneering study assessing three different AD process configurations is performed, designed to inform BFC of the most desirable process option to employ in a scenario where the council decides to build their own AD plant.

The main conclusions and key findings for the strategic options assessment and the options evaluation are outlined below.

Strategic Options Assessment

Before BFC decides whether to go ahead with another option other than continue with the existing contract, it will be necessary to supplement the findings of this report with some further investigations including but not limited to the following:

- Gather data from commercial/industrial waste producers in Bracknell Forest Council and its surroundings to better understand the options of the potential third party who are already active in the AD industry and partner with BFC. The potential partners could be dairy farms, breweries, supermarkets, water treatment utilities and food production/processing facilities among others.
- Once the third party is identified, estimate the potential biogas yield from mixing the different feedstocks (BFC's food waste and third party's feedstock) which will determine the size of the plant, and any additional investment and capital costs but also additional revenues.
- Develop a more detailed understanding and certainty of existing and future incentive schemes and governmental support for the use of biogas especially in conjunction with the timescales necessary to develop, construct and commence an AD plant.
- If there is interest from BFC to go ahead, then a study would be needed to consider the practicalities and costs of logistics of bringing the materials to the AD plant's location.
- BFC should perform a study of how many vehicles they are need and how many they own that could transport food waste to the AD plant's location.
- Examine in more detail the regulatory framework for the digestate. The current regulatory framework is complex and fragmented separating Biosolids digestate (originating from the water industry) and waste digestate (originating from. The Environment Agency National Sludge Strategy, which is currently in consultation, intends to simplify the regulatory framework is in consultation.
- A cost-benefit analysis will be necessary, taking into account all the technical, financial and economic characteristics of the selected option which will estimate the investment's payback time, Net Present Value (NPV) and Internal Rate of Return (IRR) and ultimately inform BFC's business decision.

Options Evaluation

Atkins agreed an optioneering evaluation template with BFC and subsequently conducted an optioneering study based on the following shortlisted process options:

- Option 1: Anaerobic Digestion with Electricity to Grid
- Option 2: Anaerobic Digestion with Biomethane to Grid
- Option 3: Anaerobic Digestion with Biogas Export to Third Party

Supporting information such as process description, typical site layout, CAPEX, OPEX and revenue potential estimates are provided to facilitate the optioneering study. Summary of the key findings is portrayed in the table below.

Option	Footprint	CAPEX	OPEX	Annual Revenue Potential
1	9,755 m^2	£9,016,795	£255,000	£454,550
2	7,953 m^2	£8,734,359	£369,300	£1,398,314
3	7,556 m^2	£7,569,441	£255,000	£351,697*

*Note that this value is based on wholesale gas price. A premium would likely be agreed between BFC and the third party to distribute some for the revenue generated from sale of biomethane under the Green Gas Support Scheme (GGSS). The exact premium is subject to negotiation between both parties and therefore cannot be accounted during this assessment.

A summary of the weighted options evaluation results is portrayed in the table below. It can be seen that Option 3 has the highest total weighted score, making it the recommended process option, in a scenario where BFC decides to build their own AD plant. This option has a moderate associated CAPEX and OPEX. It requires the least amount of footprint when compared to the alternative options. Moreover, it provides the unique opportunity for BFC to avoid operating the considerably complex biogas upgrading facility by exporting it to a third party.

Option	Process	Total Weighted Score	Ranking
1	Anaerobic Digestion with Electricity to Grid	70	3
2	Anaerobic Digestion with Biomethane to Grid	110	2
3	Anaerobic Digestion with Biogas Export to Third Party	125	1

1. Introduction

1.1. Structure of Report

The document provides a high-level pre-Feasibility Study, performed by Atkins for the potential development of Bracknell Forest Council's (BFC) own Anaerobic Digestion (AD) plant. Following this introduction, the report is set out in the following sections:

- Strategic Options Assessment – explores legal framework and policy associated with AD, assesses three strategic options and proposes a recommendation.
- Options Evaluation – describes the optioneering methodology employed and provides a summary of the options evaluation, as well as the recommended AD process options.

1.2. Background

BFC is interested in investigating the feasibility and viability of building its own AD plant in the Borough. The Borough has recently commenced food waste collections for 47,000 households. Currently, this food waste is disposed of through a re3 partnership with Wokingham and Reading Councils. Food waste is collected at doorstep and taken to sites in Bracknell (Longshot Lane HWRC) and Reading (Smallmead HWRC) for bulking before being transported to an AD plant in Wallingford, Oxfordshire. Current collection expectations for 21/22 would be around 19,000 tonnes for the combined total from the three Councils.

1.3. Scope of Work

Atkins scope is to complete optioneering of suitable food waste treatment alternatives, including 'do nothing or minimum option' for the potential AD plant.

Three strategic options were identified by Atkins and agreed with BFC prior to the commencement of the study. These are as follows:

- Continue with current contract.
- Build own AD plant.
- Public/private partnership- collaborate with a Water Utility (i.e. Thames Water, Severn Trent etc.) to share Capital Expenditure (CAPEX) investment and benefit from their operational expertise.

2. Strategic Options Assessment

This section provides a background to AD as a process, including details of desirable feedstock(s) for the AD process. The quantities and characteristics of waste available to BFC are then identified and assessed, along with an overview of the legislation regulations associated with AD. The concluding part of this section is a Strategic Options Analysis (SWOT), which looks to conclude which of the three strategic options identified, is most desirable for BFC at this time.

2.1. Anaerobic Digestion Process Overview

AD is based on the degradation of organic substances by micro-organisms in the absence of oxygen to produce methane (CH_4), carbon dioxide (CO_2), water (H_2O), digestate and other minority products. AD is a globally proven technology, well-suited to treating the effluent arising from many industrial processes and produce valuable by-products for example an soil conditioner/alternative fertiliser (digestate) and renewable fuels from Biogas and/ or renewable energy/heat from the burning of biogas produced.

AD is used to treat a wide range of biodegradable organic substances and especially in effluent treatment is used to reduce the Chemical Oxygen Demand (COD). Typically, AD can reduce the COD level of an effluent by up to around 90% thus, reducing the costs of effluent treatment with the additional benefit of biogas production.

AD can occur under cryophilic (<25ºC), mesophilic (25-45ºC) or thermophilic conditions (around 55ºC). The higher temperature processes are typically faster but less stable and require a higher level of instrumentation and control in order to maintain process conditions. However, the typical operating conditions for these processes employed to process industrial and domestic residuals are:

- Temperature range of 32 to 42ºC (i.e. mesophilic conditions);
- Retention time up to 20 days, depending on feedstock and process;
- Neutral pH value (e.g. pH 6.7 to 7.7);
- Ready supply of organic and inorganic nutrients in the form of degradable carbon, nitrogen, phosphorous, potassium and essential trace metals.

Depending on local conditions at site, the digester may require external heating or cooling in order to maintain a stable temperature. Performance of anaerobic systems can be adversely affected by the presence of toxic compounds in the effluents (e.g. cleaning agents).

Biogas generated in the process is typically rich in CH_4, (around 60%) and its chemical energy can be recovered using a gas engine, gas turbine or gas boiler. The biogas also contains other gases including CO_2, hydrogen sulphide (H_2S) and water vapour. Pre-treatment at either the pre-combustion or pre-digestion stage may be required to reduce H_2S and water levels to mitigate corrosion, operational problems and emissions to air resulting from combustion of the biogas.

Feedstocks for AD are commonly solid waste (Biosolids) from wastewater treatment processes and/or municipal or industrial solid waste (from this point to be referred to as organic waste) for example waste food, fats, oils. The AD of organic waste is undertaken at scale in both the water and waste industry across the globe. Co-digestion, mixing of organic waste with Biosolids, is technically feasible and can enhance digestibility. Co-digestion is more practicable when municipal and/or industrial organic waste is pre-conditioned, for example screened and mixed to form an organic ‘soup’ like substance in order to minimise the impact of variances in digestibility from one waste feedstock to another.

The basic principles of the process are outlined in the Process Flow Diagram (PFD) shown in Figure 2-1*.

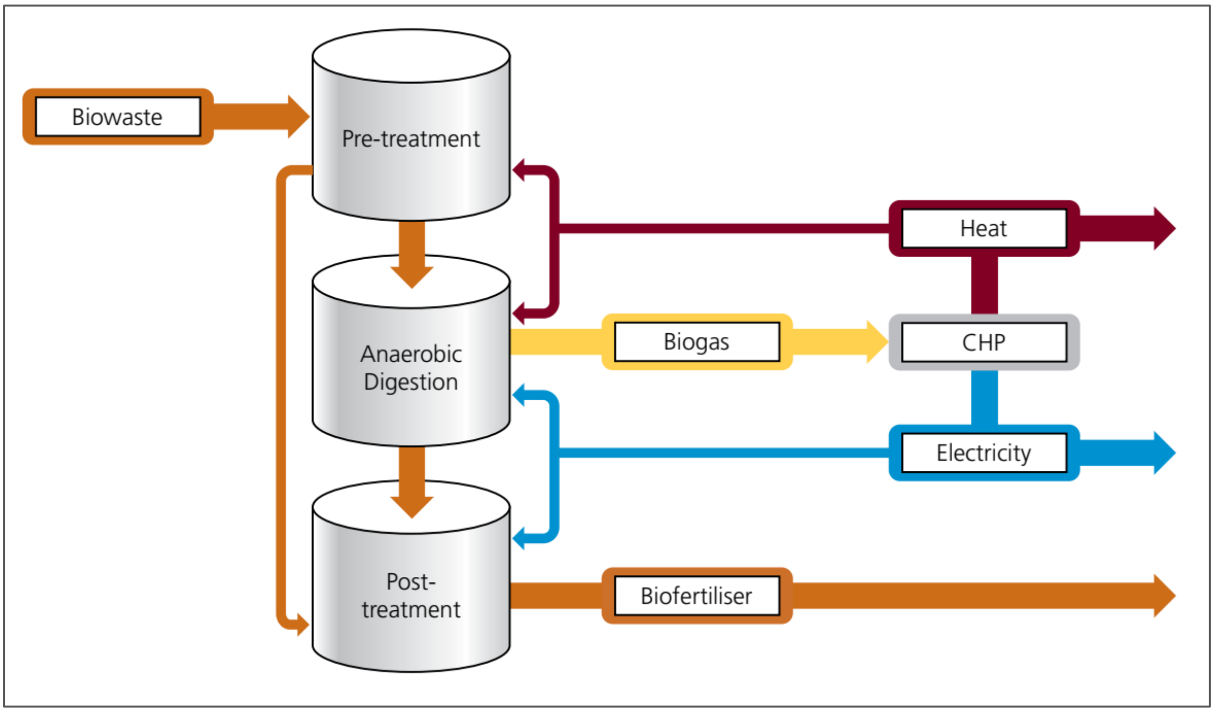

Figure 2-1 – Typical AD Process Flow Diagram

**CHP (Combined Heat and Power) engines has been highlighted in the schematic, there are however alternative approaches which could be deployed for example gas turbines, gas to grid or biofuel production especially if waste heat is not required in the treatment process.*

AD produces digestate, which can be a valuable bio-fertiliser depending upon the feedstocks used and has potential to be used as a renewable source of critical fertiliser elements such as nitrogen and phosphorus. The nutrient composition of the digestate depends on the feedstock but generally speaking, the digestate would be rich in nitrogen, phosphorus, potassium and trace elements.

Digestate contains nitrogen in a form that is readily available for crop uptake and can help reduce reliance on industrially produced sources of nitrogen. Inorganic phosphate fertilisers are derived from non-renewable sources and will become more expensive as increasing pressures are placed on limited current supplies. The phosphate content of digestates is likely to become increasingly attractive in the near to medium term. Use of digestate as renewable fertilisers offers a potential saving in Greenhouse Gas (GHG) emissions from the mining of and the transport and production activities associated with the manufacture of inorganic fertilisers.

The following list provides details on desirable feedstock properties for AD:

- Stable composition/properties- more consistent processing time, conditions and more reliable yield of biogas and consistent digestate.
- Steady and secure supply of feedstock.
- High energy content- the energy content will determine the biogas yield
- Low contaminants- ensures that bacteria in the AD are not poisoned and the digestate product is free from harmful contaminants.
- High organic content- sufficient organic content needs to be present for the process to be efficient.

- Controlled moisture content- there needs to be a minimum amount of moisture in the feedstock to sustain the moisture levels required for efficient AD to take place.

Co-digestion of biosolids, municipal and/or industrial organic waste is undertaken to varying degrees across the globe, this is primarily due to local waste collection strategies, National or Regional waste strategies and/or regulatory frameworks, rather than any specific barriers to the process.

2.2. Quantities and Characteristics of Feedstock Available

To determine whether an AD plant is feasible or not, it is important to first assess the quantities and characteristics of the inputs (or potential inputs) that would feed the AD plant. BFC have so far advised that 19,000 tonnes of collected food waste per year is currently available as feedstock (with potentially some extra when all properties are served, though this amount is understood to be minimal) from the three councils (Bracknell, Reading and Wokingham). BFC understands that it may be necessary to supplement this feedstock with other potential sources of waste in order to make the AD plant viable. No data has been made available to Atkins on the quality of the food waste collected by the re3 partnership at the time of writing this report. However, it is understood that to date no quantities of food waste have been rejected by the Contractor. It should be noted though, that pre-treatment of food waste is an integrated part of the feedstock's preparation before it enters the digester. Subject to the type of feedstock used, the pre-treatment includes size reduction, extraction of any impurities and/or harmful materials such as ferrous metals using a magnet and sand using a filter and floating particles (plastics, textiles, wood) by a hydraulically operated rake. The level of pre-treatment will impact also the quality of the digestate. Any contaminants that pass through the process and end up in the digestate will need to be minimised and provide a high-quality product to the end user.

Other sources of food waste potentially suitable for supplementing the 19,000 tonnes/year food waste include:

- Food shops/supermarkets (separated food waste)
- Restaurants/Cafes
- Commercial properties that serve food such as hospitals, caterers, schools etc.
- Food production/processing facilities

In addition to food waste, there are other feedstocks that could be desirable to AD plants, though they will influence the process performance of the AD plant as well as end use of the digestate product. These include:

- Agricultural sources
- Dairy farms
- Production facilities for paper/wood/cardboard
- Green waste collected from kerbside
- Commercial green waste
- Sludge from Sewage Treatment Works.

BFC was not able to provide a list of industries within their borough that could supplement the 19,000 tonnes of food waste per year currently collected from the three councils. Nonetheless, to understand the feasibility of using the above feedstocks, an investigation would need to be carried out to determine the quantities and predicted characteristics of these types of waste that would be available to BFC and how it could impact the AD process. However, this investigation is outside the scope of this report.

From publicly available information it is noted that there are at least five waste AD plants within a 20 miles radius from BFC which process domestic and commercial food waste. Figure 2-2 depicts the waste AD plants on the map and Table 2-1 summaries a few key details of the AD plants. It is unknown if these five waste AD plants operate at their full capacity or if there is a headroom capacity available. In any case, they could be considered potential partners for the expansion of their own AD facilities and to process the additional food waste generated by the three councils.

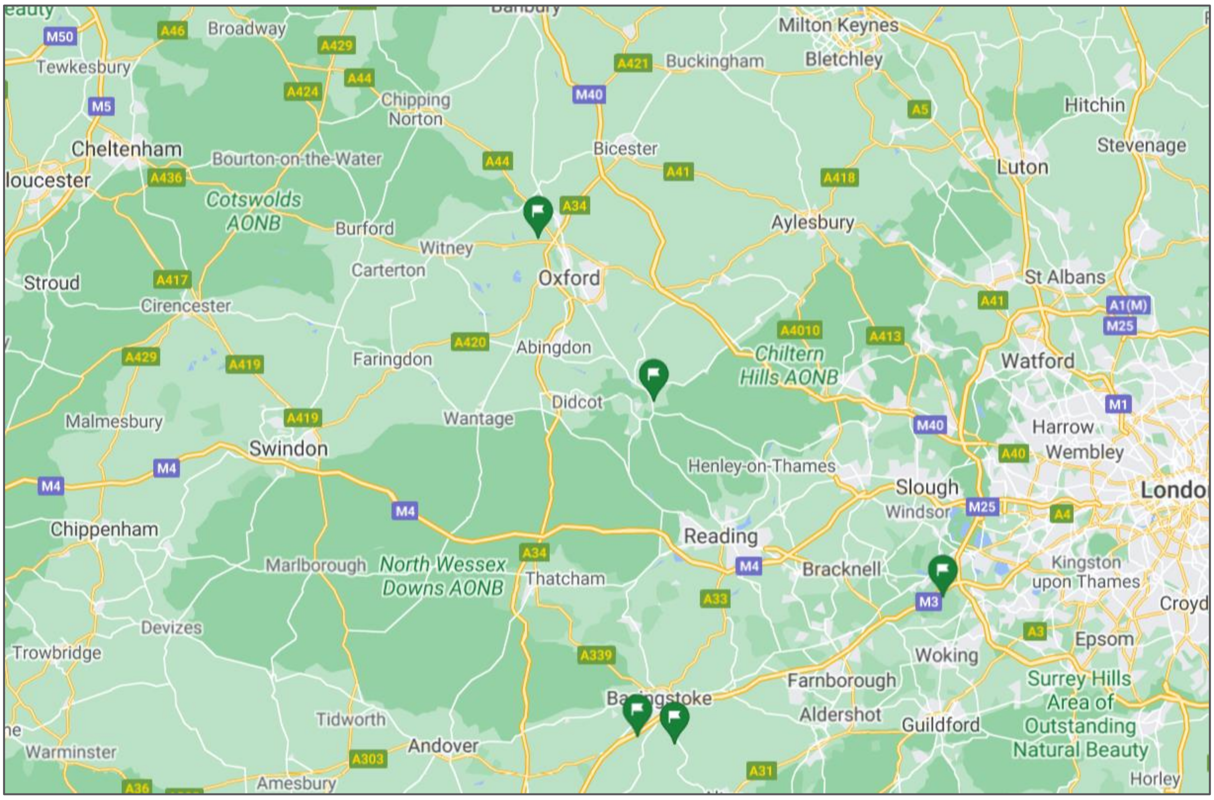

Figure 2-2 – Waste AD Plants within a 20 miles radius from Bracknell Forest Council

Table 2-1 – List of Waste AD Plants[1]

No.	Plant	Operator	Capacity (tonnes)	Technology	Electricity Generation Capacity (kW_e)	Specific Energy Generation (kWh/tonne)
1	Agrivert Wallingford AD Plant & Composting Site Benson Lane Wallingford OX10 6SQ	Severn Trent Green Power Limited	50,000	CHP	2400	420
2	Agrivert West Cassington AD Facility Worton Farm, Witney, Oxon, OX29 4FL	Severn Trent Green Power Limited	50,000	CHP	2100	370
3	Agrivert West London AD Facility Trumps Farm Kitsmead Lane Londcross KT16 0EF	Severn Trent Green Power Limited	48,500	CHP	2119	380

1 https://www.google.com/maps/d/u/0/viewer?mid=1PMuhQ28ZLIiZohXjQ0nhTUfLMZ2PvjQP&ll=51.55635166737446%2C-0.6843163286276965&z=9

4	Herriard AD Bio-Power Ltd Little Bushywarren Lane Herriard Basingstoke RG25 2NS	Herriard Bio Power Ltd	29,000	CHP	1195	360
5	Tamar Energy Limited Basingstoke AD Facility Dummer Basingstoke RG23 7LW	Biogen (UK) Limited	40,000	CHP	1430	315
6	Icknield Farm, Icknield Road, Ipsden, Oxfordshire, OX10 6AS	Green Gas Oxon	34,000	BtG and CHP	360	95

In addition to the waste AD plants listed above, Atkins identified the following facilities from Thames Water Utilities Limited (TWUL) which process sewage sludge in AD plants (Figure 2-3). These facilities could also be considered as potential facilities that could expand to accommodate the food waste from the three councils.

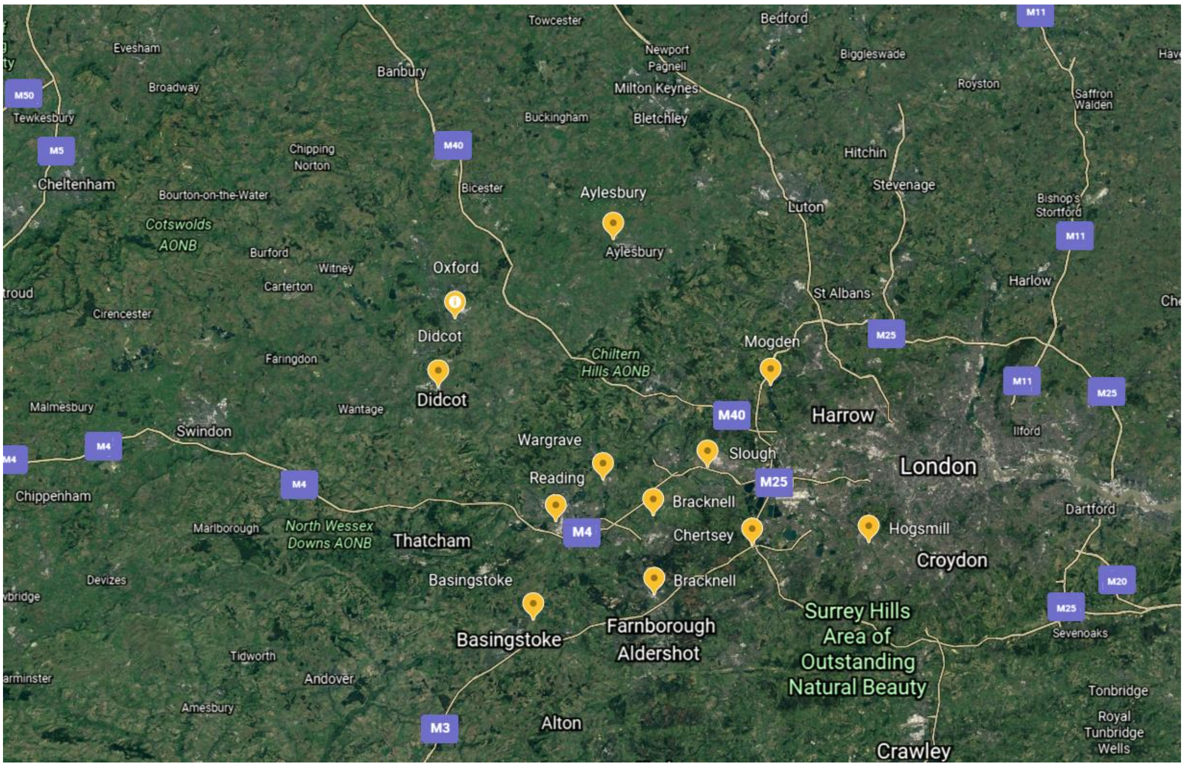

Figure 2-3 – Sewage sludge treatment centres with AD facilities

Table 2-2 summaries a few key details of the sewage sludge treatment centres with AD plants owned by Thames Water Utilities Limited (TWUL) including their headroom capacities. The closest facility in Bracknell has a capacity of 3,504 tonnes dry solids/annum (tds/a) which is equivalent to ym3/d feed; with a headroom capacity of only 356 tds/a. The largest AD plant is in Mogden with a capacity of 63,180 tds/a and a headroom capacity of 9,035 tds/a. The equivalent estimated tds of 19,000 tonnes of food waste would be approximately 4,700[2] tds. Hence, from that list, it is clear that there are a few sewage sludge treatment centres (Mogden, Oxford, Slough) with enough headroom capacity that could accommodate the required 4,700tds of food waste. However, considering the different types of feedstocks mixed in the process, certain upgrades would be necessary to be done including the erection of a pre-treatment centre for the removal of any impurities and perhaps the upscale of the equipment downstream of the digester as food waste would produce more biogas compared to sewage sludge. Considering that, an expansion would be required in all these sewage sludge treatment centres if it would be decided to partner with one of them to accommodate the food waste produced by the three councils. It should be noted that the identification of 'head room' in the table below is considered inconsistently across the industry. We have significant operational experience of operating and maintaining Biosolids digestion systems and recognise the requirement for Water Companies to maintain operational headroom to accommodate for seasonal fluctuations in Biosolids production, operational outages, and maintenance interventions across the fleet of assets. Thus, making predictions of head room is difficult to quantify at any given point. Hence, in order to gain a true sense of capacity further engagement with a preferred Water company is advised.

Table 2-2 – Sewage sludge treatment centres with AD facilities

No.	Facility Name	Technology	Capacity (tds)	Headroom capacity (tds)	Specific Electricity Generation (kWh/tds)
1	Aylesbury	Conventional AD	4,928	365	450-800
2	Basingstoke	Advanced AD	18,603	4,255	650-1000
3	Bracknell	Conventional AD	3,504	356	450-800
4	Camberley	Conventional AD	4,380	114	450-800
5	Chertsey	Advanced AD	10,179	2,333	650-1000
6	Didcot	Conventional AD	2,701	347	Gas to Grid
7	Hogsmill	Conventional AD	14,856	2,808	450-800
8	Mogden	Advanced AD	63,180	9,035	650-1000
9	Oxford	Advanced AD	23,517	4,946	650-1000
10	Reading	Advanced AD	10,670	2,707	650-1000
11	Slough	Conventional AD	15,221	7,738	450-800
12	Wargrave	Conventional AD	5,147	2,001	450-800
Total TDS			**176,884**	**37,006**	

Source: Thames Water Utilities Limited

[2] 19,000 tonnes x 26.2% of dry matter x 6% impurities

The UK Water industry are required to provide detailed market information on their Biosolids assets and operations by the regulator Ofwat as part of the drive to increase competition with the sector.

The drive for greater competition in the sector and the changing regulatory framework in England is leading to greater appetite within the Water industry to explore synergies with adjacent markets in order to leverage the benefits of co-treatment, to support funding to mitigate Biosolids growth and/or to leverage their experience to develop new business models.

2.3. Current Food Waste Disposal Contract

Although part of Atkins' scope was a high-level review of the existing food waste contract, that was not possible to be conducted as BFC advised that the contract could not be shared. However, through the QA process the following characteristics of the contract were understood:

1) Duration of the contract: From 2006 to 2031.
2) Baseline cost of existing arrangement (£ per tonne of waste processed) and scope included: £0p/t until end of March 2022, £7p/tonne from April 2022.
3) Details of any early termination clause (cost and minimum notice period): No termination clause in the food waste element.
4) Range of waste processed (minimum and maximum quantities per year): The arrangements were based on an expectation of 10ktpa. Current inputs will broadly double that. However, there are no minimum tonnages.
5) Signatory parties: Severn Trent Green Power and the Contractor

From a broader perspective from 2023 the Local Authorities in England will have to collect separately all the food waste produced in their jurisdictions. BFC advised that currently they do not collect food waste from flats, but it is expected not to dramatically increase the current volumes of food waste collected once collection commences. In terms of the baseline cost of the existing arrangement, in our view the disposal cost reported by BFC is very low (assuming that the quoted price refers to £7/tonne rather than 7p/tonne). As a comparison, based on Wrap's gate fees 2019/2020 report, the average gate fee paid by Local Authorities in AD plants was £35 per tonne[3] in 2019. For waste that contains packaging, an extra £5 to £15 per tonne should be considered for processing the food waste and managing the segregated packaging[4]. Hence, BFC's current disposal cost would be considered very competitive compared to the average market gate fee in other AD plants paid by other Local Authorities across the UK. It should be noted though that every contract is unique reflecting the market conditions at the time of signature, quantity and quality of waste, local competition and negotiations.

2.4. Legal Framework and Policy

As detailed on the government's Anaerobic Digestion Portal (run by the National Non-food Crops Centre (NNFCC), all anaerobic digestor operators in the UK must comply with regulations concerning[5]:

- Environmental Protection
- Animal by-products
- Duty of Care
- Health and Safety
- Waste Handling

[3] Excluding haulage costs
[4] https://wrap.org.uk/sites/default/files/2021-01/Gate-Fees-Report-2019-20.pdf
[5] Regulation | Anaerobic Digestion (biogas-info.co.uk)

2.4.1. Food waste AD Treatment and By-products Disposal Legislation Overview

All AD Plants that use any type of waste as feedstock currently fall under the scope of Environmental Permitting Regulations (EPR)[6]. In England, anaerobic digestion of waste is regulated by the Environment Agency and subsequently, the EPR (England and Wales) 2010. Operators of AD plants under these regulations, may fall under one of the following; Exemption, Standard Rules Permit, Bespoke Permit or Regulatory Position Statement. If building their own AD plant, BFC are likely to require a Standard Rules Permit, which is a fixed set of rules for common and defined activities and have fixed application fees. The scope of the EPR includes the handling, storage, disposal or use of any wastes produced through the AD process, including digestate unless it meets the relevant 'end of waste' criteria and is therefore no longer considered 'waste'. Currently end of waste can only be achieved if the waste is of source segregated origin. Thus, sewage sludge (considered non-source segregated at this time) would preclude end of waste status if co-treated. Any liquors produced or digestate returned via a sewer to a wastewater facility will need to meet Trade Effluent requirements and agreements made, and charges agreed with the relevant water company.

2.4.2. Environmental Impact (Benefits and Risks) of an AD plant Within the Borough

The key environmental impacts of an AD plant could be summarised in two main categories:

- GHG emissions
- Discharge of digestate

The GHG emissions associated with AD process includes methane and CO_2. Methane is the gas produced from the anaerobic degradation of organic matter. Methane emissions are estimated to be 23-28 times more powerful than CO_2 emissions in the global warming effect and therefore it is considered a gas of primary importance. Typically, methane being the main gaseous product of an AD process, is either combusted in a gas engine or is upgraded and injected into the gas grid to aid decarbonisation of the National Grid. However, methane can be released due to incomplete combustion or leak from the biogas storage and/or the digestate management.

CO_2 is produced primarily from the conversion of methane via the combustion process in a gas engine and to a lesser extent from the AD process itself. However, it should be noted that in both cases the CO_2 released from the AD process is considered as biogenic and therefore it does not account as fossil CO_2 and subsequently contributing to climate change.

For the GHG emissions flue gas treatment equipment is generally included in modern biogas equipment. In terms of CH_4, considering its global warming potential compared to CO_2 a flare is installed which ensures that CH_4 is always converted to CO_2 in case there is an excess of biogas which cannot be stored or used. Hence, flaring eliminates both environmental and safety risks.

Overall, from a GHG perspective, the use of biogas prevents the emission of GHG which would be generated from equivalent amount of GHG intensive fossil sources.

One of the main advantages of the AD process is the reduction of waste volume and associated costs for waste disposal. The main by-product of the process is the digestate which is typically rich in nitrogen, phosphorus and to a lesser extent potassium. Under certain circumstances the digestate can be spread in agricultural fields or forests as a manure.

Key risks associated with AD plants are those associated with bad practices and poor operation and maintenance which include: i) emissions to the aquatic environment - surface and ground water pollution due to a leakage, ii) emissions to the atmospheric environment - increased risks of CH_4 emissions due to leaks, iii) harm to the environment and human and animal health - increased risk of contamination through contamination of the product and odour pollution.

[6] https://adbioresources.org/policy-regulation/regulators/#1606603896037-5691895f-0cec

2.4.3. Project Sponsor, Governance and Resource Management.

The UK Government has made available a document list and procurement procedure created by Walker Morris[7]). It is advised that if BFC proceed with building their own AD facility that they consult this documentation for guidance on project governance and resource management.

2.4.4. Build/Procurement Options to Meet Legislative Requirements

For the development of an AD plant, there are a number of regulations that must be met, mainly with regards to the environment. Several regulatory controls are detailed below under the following headings: Duty of Care, Planning Permission, EIA Requirements, Permitting, Waste Management Licence and Animal By-Products regulations.

Environmental and regulatory impacts of AD of MSW depend to some extent on site specific issues and waste type considerations. The following subsections discuss the key legislation which will must be considered for most AD projects and to some extent is relevant for AD processes using other types of materials as well.

2.4.4.1. Duty of Care

Every holder of waste has a Duty of Care to ensure that any waste they have is removed and disposed of in a controlled and licensed manner. Waste transfer documents must be signed and it may be necessary to be a registered waste carrier if the waste material is to be transported.

2.4.4.2. Planning Permission

The Town and Country Planning Act 1990 (TCPA), as amended, provides the legislative framework in England and Wales requiring planning permission to be sought for a development or substantial change of use for a range of classes of activities or structures. Permission must be sought from the Local Planning Authority (LPA) in which the development is located which in this instance is Bracknell Forest Council (BFC).

An Environmental Impact Assessment may also be required; the types of development and the thresholds are defined in the Town and Country Planning (Environmental Impact Assessment) Regulations 2017 (EIA Regulations) (

As well as publicising the application in order to invite comments from third parties, the LPA may consult various other parties with relevant interests or expertise, depending on the location, size and likely impacts of the development, including statutory consultees such as the Environment Agency (EA), Natural England and Historic England. This consultation period could identify further areas that need to be considered during any planning application. LPAs have the power to grant conditional planning permission and to seek planning conditions from developers, in order to make development proposals acceptable which would otherwise be unacceptable. Planning conditions are used to ensure that a proposed development is made to accord with published local, regional or national policies.

2.4.4.3. EIA Requirement

A proposed AD facility is likely to be categorised as a Schedule 2 development under part 11 'Other projects' in Schedule 2 of the EIA Regulations:

'(b) Installations for the disposal of waste (unless included in Schedule 1);

(ii) the area of the development exceeds 0.5 hectare; or

(iii) the installation is to be sited within 100 metres of any controlled waters.

In order to determine if an EIA is required for Schedule 2 development a screening opinion could be requested from the planning department of BFC . BFC who would then decide if the project impacts warrant a full EIA having regard to the selection criteria in Schedule 3 of the EIA Regulations.

Schedule 4, of the EIA regulations, describes the requirements of an EIA and these are outlined below:

1. A description of the development, including in particular:
    a. a description of the location of the development;

[7] Precedent Document (biogas-info.co.uk)

b. a description of the physical characteristics of the whole development, including, where relevant, requisite demolition works, and the land-use requirements during the construction and operational phases;

c. a description of the main characteristics of the operational phase of the development (in particular any production process), for instance, energy demand and energy used, nature and quantity of the materials and natural resources (including water, land, soil and biodiversity) used;

d. an estimate, by type and quantity, of expected residues and emissions (such as water, air, soil and subsoil pollution, noise, vibration, light, heat, radiation and quantities and types of waste produced during the construction and operation phases.

2. A description of the reasonable alternatives (for example in terms of development design, technology, location, size and scale) studied by the developer, which are relevant to the proposed project and its specific characteristics, and an indication of the main reasons for selecting the chosen option, including a comparison of the environmental effects.

3. A description of the relevant aspects of the current state of the environment (baseline scenario) and an outline of the likely evolution thereof without implementation of the development as far as natural changes from the baseline scenario can be assessed with reasonable effort on the basis of the availability of environmental information and scientific knowledge.

4. A description of the factors specified in regulation 4(2) likely to be significantly affected by the development: population, human health, biodiversity (for example fauna and flora), land (for example land take), soil (for example organic matter, erosion, compaction, sealing), water (for example hydromorphological changes, quantity and quality), air, climate (for example greenhouse gas emissions, impacts relevant to adaptation), material assets, cultural heritage, including architectural and archaeological aspects, and landscape.

5. A description of the likely significant effects of the development on the environment resulting from, inter alia:

   a. the construction and existence of the development, including, where relevant, demolition works;

   b. (b) the use of natural resources, in particular land, soil, water and biodiversity, considering as far as possible the sustainable availability of these resources;

   c. (c) the emission of pollutants, noise, vibration, light, heat and radiation, the creation of nuisances, and the disposal and recovery of waste;

   d. (d) the risks to human health, cultural heritage or the environment (for example due to accidents or disasters);

   e. (e) the cumulation of effects with other existing and/or approved projects, taking into account any existing environmental problems relating to areas of particular environmental importance likely to be affected or the use of natural resources;

   f. (f) the impact of the project on climate (for example the nature and magnitude of greenhouse gas emissions) and the vulnerability of the project to climate change;

   g. (g) the technologies and the substances used.

6. The description of the likely significant effects on the factors specified in regulation 4(2) should cover the direct effects and any indirect, secondary, cumulative, transboundary, short-term, medium-term and long-term, permanent and temporary, positive and negative effects of the development.

7. A description of the forecasting methods or evidence, used to identify and assess the significant effects on the environment, including details of difficulties (for example technical deficiencies or lack of knowledge) encountered compiling the required information and the main uncertainties involved.

8. A description of the measures envisaged to avoid, prevent, reduce or, if possible, offset any identified significant adverse effects on the environment and, where appropriate, of any proposed monitoring arrangements (for example the preparation of a post-project analysis). That description should explain the extent, to which significant adverse effects on the

environment are avoided, prevented, reduced or offset, and should cover both the construction and operational phases.

9. A description of the expected significant adverse effects of the development on the environment deriving from the vulnerability of the development to risks of major accidents and/or disasters which are relevant to the project concerned. Where appropriate, this description should include measures envisaged to prevent or mitigate the significant adverse effects of such events on the environment and details of the preparedness for and proposed response to such emergencies.
10. A non-technical summary of the information provided under paragraphs 1 to 8.
11. A reference list detailing the sources used for the descriptions and assessments included in the environmental statement.

The next stage of the EIA process is to request a scoping opinion from the LPA to determine which issues could potentially experience a significant effect from the project and therefore require assessment of the impact. Early consultation with statutory authorities is recommended to identify the requirements for specialist studies and to discuss alternative designs and methods that could reduce or remove the need for certain studies.

2.4.4.4. Permitting

In order to operate a waste treatment facility such as an AD plant the operator will be required to apply to the EA for a permit under the Environmental Permitting (England and Wales) Regulations 2018 (EP Regulations).

Regulation of the site will be dependent on the plant capacity. It is recommended that the exact type of permit is discussed with the Environment Agency prior to permit application via their pre application advice service.

There are two types of permit available, standard rules or bespoke. If the proposed plant is able to meet the rules and requirements set out for the Standard Rules Permit then the application should be quicker and easier to process. However, if the plant is determined to be more unusual or high risk then a bespoke permit will be required which will be a longer and more expensive process.

The EA is allowed a statutory period of four months to determine an application made under the EP Regulations once considered duly made. This does not include time to determine as duly made nor any time taken by the operator to respond to requests for further information. The Environmental Permit must be in place before commissioning starts on the site.

2.4.4.5. Waste Management

Various legislation relating to waste management will be applicable to the AD plant depending on the final design. The plant operator must ensure that anyone transporting waste to or from the AD plant must be registered with the EA as a Waste Carrier under the Controlled Waste (Registration of carriers and Seizure of Vehicles) Regulations 1991 (as amended), that waste is stored correctly onsite and that waste produced on site is removed by an authorised waste management company and disposed of correctly.

Digestate is the waste by-product resulting from the AD process. This can be disposed of via a number of routes including composting, agricultural land spreading, contaminated brownfield site remediation or simply sent to landfill. The AD process may also produce a liquid waste stream. This may require further treatment before discharge either to surface water or to the foul sewer system. Biosolids digestate is managed via the Sludge Use in Agriculture Regulations 1989 (amended 1990) associated Codes of Practice and Assurance schemes (Biosolids Assurance Scheme). If Biosolids and organic waste are mixed, then the digestate will be managed under the Environmental Permitting Regulations (England and Wales) Regulations 2018 (EP Regulations). Historically the transition to an alternative regulatory framework has reduced Water Companies interest in co-digestion, in addition impacts upon previous incentive schemes, for example Renewable Obligation Certificates have further reduced the desire. The Environment Agency National Sludge Strategy[8], which intends to modernise and simplify

[8] https://www.gov.uk/government/publications/environment-agency-strategy-for-safe-and-sustainable-sludge-use/environment-agency-strategy-for-safe-and-sustainable-sludge-use

the regulatory framework, namely bringing Biosolids digestate and waste digestate under the same regulatory framework is in consultation. The single regulatory framework and the Regulatory Market reform driven by Ofwat has already stimulated the interest of the Water industry in the organic waste opportunity.

2.4.5. Government Funding Opportunities and Commercial Exploitation of the Digestate

The UK government have designed various incentive schemes to support the deployment of renewable energy generation to help meet its target of 80% reduction in greenhouse gas emissions by 2050[9] . There are three incentives relevant to AD plants. They are:

1. **Green Gas Support Scheme (GGSS)**
   Following the closure of the Non-Domestic Renewable Heat Incentive Scheme for new applicants, on 31 March 2021, the British Government has recently completed the consultation period for the introduction of the Green Gas Support Scheme (GGSS). A new scheme which will further promote the decarbonisation of the gas grid via the incentivisation of AD biomethane injection into the gas grid through a 15-year fixed tariff per kWh. This scheme will be open for new applications from autumn 2021 until autumn 2025. The scheme will be based on a three-tier structure with the associated tariff for each tier:

   - Tier 1 limit to 60,000MWh: 5.51 p/kWh plus inflation
   - Tier 2 limit to 100,000MWh: 3.53 p/kWh plus inflation
   - Tier 3 limit above 100,000MWh 1.56 p/kWh plus inflation

   Please refer to section 3.3.1 for more information related to the description of the process converting biogas to biomethane.

2. **Green Gas Levy**
   In order to finance the GCSS, the British Government will introduce the Green Gas Levy and it will launch it alongside the GCSS in autumn 2021. This scheme will place a levy on all licenced fossil fuel gas suppliers. Gas suppliers who have provided between 95% to 100% of their methane with green gas will be exempt from the levy. Hence, it is expected that if BFC proceeds with the construction of their own AD plant (either individually or partnering with a third party) producing more than 95% biomethane, the plant will be exempt from the Green Gas Levy.

3. **Renewable Transport Fuel Obligation (RTFO)**
   The use of biomethane as a transport fuel is supported under the RTFO at a level of 3.8 Renewable Transport Fuels Certificates (RTFCs) per kilo of biomethane. The RFTO is a trading scheme, which requires fuel suppliers for road transport to deliver a certain level of biofuels as an obligation. Biofuel producers are awarded RFTCs, which can be traded in order to fulfill the obligations of non-renewable fuel suppliers. RTFCs are subject to market forces, which means that the price is variable although throughout 2020, RTFCs traded at circa £0.29 per certificate. The predicted incentive for biofuel suppliers until 2032 would be:
   £0.30 x 3.8 / kg biomethane
   The scheme and its continuation are subject to review in 2032. Claiming RFTCs requires opening an account with the Administrator, applying to a relevant certification scheme (or sourcing an appropriate external reviewer), and consistently capturing the required carbon and sustainability data to meet verification requirements. Please refer to section 3.3.1 for more information related to the description of the process converting biogas to biomethane.

4. **Contract for Difference (CfD)**
   The government's main mechanism for supporting new, low carbon electricity generation projects in the UK. This would involve a competitive auction process to bid for CfD allocation. This is done in 'pots', where if using Anaerobic Digestion (>5MWe), BFC would compete in Pot 2 (less

[9] Financial incentives | ADBA | Anaerobic Digestion & Bioresources Association (archive.org)

established technologies)[10]. However, it should be noted that the fourth CfD allocation round is scheduled for 2021. from a high-level estimate conducted by Atkins, an AD plant processing around 19,000 tonnes per year of food waste would be equivalent to a design capacity of approximately 850kW of gross electricity. As a comparison, in the UK, the average size of an AD plant is approximately 1.45MWe (excluding AD plants that process sewage sludge). Hence, it would not meet CfD's capacity threshold of 5MWe and would not be eligible to bid in a CfD auction. Please refer to section 3.2.1 for more information related to the description of the process converting biogas to electricity.

Commercial Exploitation of the Digestate

Typically, the digestate from AD is considered a waste product under Article 1(1)(a) of the EU Waste Framework Directive (WFD) (2006/12/EC) which means that it cannot be moved or sold without a waste exemption; this obviously limits the use of a potentially valuable resource. The Environment Agency (EA) has drafted a Quality Protocol to assure the quality of the digestate for use as a fertiliser that confirms to the business community what legal obligations they must comply with in order that the treated waste material is classified as a product rather than a waste.

Accreditation will involve using source segregated organic waste from a given list of acceptable sources with the additional keeping and retaining of records. The person using the digestate must be able to demonstrate that full account has been taken of the environmental impacts of using the digestate and this may include testing and record keeping. This represents a significant liberation of the industry and whilst the keeping of records and meeting the quality standards will require an amount of effort, it is not considered sufficiently onerous as to jeopardise the viability of AD schemes. Further information in the AD Quality Protocol is available at the EA Website. Nonetheless, for commercial sites, most often the digestate is provided either free of charge to off-site users or at a cost to the operator with a minority of AD plants profiting from the sale of digestate.

2.5. Strategic Options Analysis

This section presents a high-level evaluation of the three strategic options in the form of a Strengths, Weaknesses, Opportunities & Threats (SWOT) analysis.

2.5.1. Continue with Current Contract

This option evaluates the benefits and risks of carrying on with the existing Re3 contract. At the time of writing this report, the contract specifics were not shared with Atkins and where assumptions have been made, these have been highlighted.

Table 2-3 – SWOT Analysis for Continuing with Current Contract

Strengths	Weaknesses
• Requires least amount of resource. • Cheaper than incineration or landfill[11] • Management of digestate and liquors risk sits with AD Contractor • Health and Safety risk sits with AD Contractor • Simplistic operation requirement on BFC – contract management only	• Has limited contribution to BFC's 2050 Net Zero target • Energy or gas created not utilised in BFC • No opportunity to develop BFC capability • Benefits of digestion not owned by BFC • Missed incentive opportunity – timeframe limited
Opportunities	**Threats**

[10] Contracts for difference for low carbon electricity generation: consultation on proposed amendments to the scheme (publishing.service.gov.uk)

[11] BFC informed Atkins that the disposal cost of food waste under the re3 partnership contract is currently £0/tonne and will increase to £7p/tonne from April 2022. The landfill tax is currently £96.7/tonne with a typical landfill cost between £17 to £26 per tonne. The gate fee in a EfW plant is around £85 to £105 per tonne.

• To change contract to enhance BFC position due to limited retraction constraints	• Future change in contract T&Cs • Rising cost for disposal of food waste • Guarantee of additional capacity availability if food waste collection increases dramatically

2.5.2. Build Own AD Plant

This option evaluates the benefits and risks of BF Council building their own AD plant.

Table 2-4 – SWOT Analysis for Building Own AD Plant

Strengths	Weaknesses
• Can profit from AD plant subject to a cost-benefit analysis • Contribute towards Net Zero 2050 target • Can generate income from other councils paying for food waste disposal. • Atkins understands that there is no commercial penalty if the three councils stop sending their food waste to the AD contractor	• Capital expenditure required which sits with BFC • Operational cost sits with BFC • Potential complexity regarding availability of a suitable site that could accommodate an AD plant • Lack of council's expertise with regards to development, construction and operation of an AD plant
Opportunities	**Threats**
• Different types of process options, CHP, Gas to Grid etc. • Flexible technology, room to incorporate new feedstocks at a later date. Modular design would leave room for • Gate fee from provision of capacity to manage other organic waste • Stakeholder – excellent example to other Councils of BFC green credentials • Production of renewable energy or gas for potential utilization in vehicles in BFC fleet	• Requires expertise outside of those currently within BFC • Potentially insufficient feedstock to provide required rate of return on investment • Requires permit applications approvals • Stakeholder perception of waste management facility in BFC region treating waste from other Councils • Duty of care sits with BFC – for waste management and disposal.

2.5.3. New Partnership

This option evaluates the benefits and risks of entering into a new contract with an external partner to either combine sources of feedstocks and/or to utilise existing assets that the external partner owns.

Table 2-5 – SWOT Analysis for New Partnership

Strengths	Weaknesses
• Share capital/operational cost • Expertise from partner company can be utilized • Would ensure sufficient quantity of feedstock for AD facility viability. • Potential access to existing site or expansion of existing facility • BFC benefit from incentives and revenues • Controls risk • Shared investment risk • Shared operational risk	• May involve mixing feedstocks of different qualities which can negatively impact biogas yield if not managed effectively • Mixing different qualities of feedstock could lead to increased pre-treatment capex and Opex to create a homogenous mix of feedstock • Digestate end use may be limited if mixing feedstocks
Opportunities	**Threats**
• Could utilize existing assets of partner if applicable (e.g. AD plants at Sewage Treatment Works) • Economies of scale favour larger plants and in some cases it may be beneficial for several farms to club together and have a Centralised Anaerobic Digestion (CAD) plant. Larger plants have far lower cost per operational hour and return on investments can be more safely assured, reducing the associated financial risk • Potential to expedite delivery	• Potential mix of feedstocks leading to limited end use of digestate product • Negotiation of contract to ensure both parties benefit

2.6. Indicative Programme

Figure 2-4 presents an indicative development schedule (from planning up to commencement of operations) of an AD plant for strategic options 2 and 3. For strategic option 3 (partner with a third party for the construction of an AD plant) it is assumed that the duration is the same as if a new plant would have to be constructed. However, the actual construction schedule will be determined by a plethora of factors including the site location (greenfield or brownfield), size of the plant, any unplanned delays in the planning and construction phase, any changes in the legislation, the contractual arrangement and the competence of the project company and the contractors. In addition, the programme does not include the time for securing a site (lease of purchase) and any pre-existing contamination as this is very project specific.

No.	Description	Month 0	M 1	M 2	M 3	M 4	M 5	M 6	M 7	M 8	M 9	M 10	M 11	M 12	M 13	M 14	M 15	M 16	M 17	M 18	M 19	M 20	M 21	M 22	M 23	M 24	M 25	M 26	M 27
1	**Stage 1 - Planning**	★																											
2	OE Phase 1 NTP	■																											
3	Critical review of work previously done	■																											
4	Review previous geotechnical surveys	■	■																										
5	Planning & Permitting Screening.		■	■																									
6	Preparation of technical ITT documents			■	■																								
7	Drafting of Agreements (if required).			■	■																								
8	Permit Prep & Application				■	■	■																						
9	Permit Determination							■	■	■	■	■	■																
10	Planning Prep & Application				■	■	■																						
11	Planning Determination							■	■	■	■	■	■																
12	Issue ITTs						■																						
13	EPC tender period							■	■																				
14	Receipt of EPC tenders proposals, evaluation and negotiation									■	■	■	■	■															
15	Support Owner interface with IE/Lenders engineer (if applicable)							■	■	■	■	■	■	■															
16	Financial Close													■															
17	**Stage 2 - Execution**														★														
18	EPC NTP														■														
19	OE stage 2 NTP														■														
20	Detailed design														■	■	■	■	■										
21	Mobilisation, site access and ground preparation															■	■	■	■										
22	Procurement/manufacturing/transportation:															■	■	■	■	■	■								
23	◦Pre-treatment equipment															■	■	■	■	■	■								
24	◦Tanks															■	■	■	■	■	■								
25	◦CHP or biogas upgrade system & boiler															■	■	■	■	■									
26	◦M&E BoP															■	■	■	■										
27	Civil construction (general)																	■	■	■	■								
28	Tank construction																				■	■	■						
29	CHP & Generator or biogas upgrade install																				■	■	■						
30	M&E BoP systems erection																			■	■	■							
31	Cold commissioning																							■	■				
32	Digester seeding and Hot commissioning																									■	■	■	
33	Performance test and reliability run																												■
34	**Stage 3 - Commercial Operation**																												★

Figure 2-4 – Typical project schedule of an AD plant

2.7. Conclusions

Before BFC decides whether to go ahead with another option other than continue with the existing contract, it will be necessary to supplement the findings of this report with some further investigations including but not limited to the following:

- Gather data from commercial/industrial waste producers in Bracknell Forest Council and its surroundings to better understand the options of the potential third party who are already active in the AD industry and partner with BFC. The potential partners could be dairy farms, breweries, supermarkets, water treatment utilities and food production/processing facilities among others.
- Once the third party is identified, estimate the potential biogas yield from mixing the different feedstocks (BFC's food waste and third party's feedstock) which will determine the size of the plant, and any additional investment and capital costs but also additional revenues.
- Develop a more detailed understanding and certainty of existing and future incentive schemes and governmental support for the use of biogas especially in conjunction with the time necessary to develop and build an AD plant.
- If there is interest from BFC to go ahead, then a study would be needed to consider the practicalities and costs of logistics of bringing the materials to the AD plant's location.
- BFC should perform a study of how many vehicles they are needed and how many they own that could transport food waste to the AD plant's location.
- Examine in more detail the regulatory framework for the digestate. As it was mentioned, the current regulatory framework is complex and fragmented separating Biosolids digestate (originating from the water industry) and waste digestate. The Environment Agency National Sludge Strategy, which is currently in consultation, intends to simplify the regulatory framework.
- A cost-benefit analysis will be necessary, taking into account all the technical, financial and economic characteristics of the selected option which will estimate the investment's payback time, Net Present Value (NPV) and Internal Rate of Return (IRR) and ultimately inform BFC's business decision.

3. Options Evaluation

This section discusses the optioneering methodology employed. Process options are subsequently presented with supporting information such as process description, typical site layout, CAPEX, OPEX and revenue potential estimates. An optioneering exercise, consisting of the process options was conducted, and the results are discussed. This section concludes with a recommendation with regards to the most desirable process option for BFC, in a scenario where the council decides to build their own AD plant.

3.1. Optioneering Methodology

The optioneering methodology employed involved the use of an options evaluation template which was derived following a workshop discussion with BFC on Monday, 12 July 2021. A number of key criteria were identified against which a score of 1 to 5 was given for each high-level process option. The criteria were then each allocated a weighting of 1 to 5, and the raw score multiplied by that factor. The weighted score for each high-level process option were then summed and total scores for the options produced. The key criteria and weightings used are presented in Table 3-1.

Table 3-1 – Evaluation Criteria and Weightings

Key Criteria	Weighting
Capex (1-Very High to 5-Very Low)	5
Opex (1-Very High to 5-Very Low)	5
Revenue Potential (1-Low to 5-High)	5
Complexity of Operation (1-Difficult to 5-Easy)	3
Footprint (1-Large to 5-Small)	5
Constructability (1-Difficult to 5-Easy)	2
Environmental Impact (1-High to 5-Low)	5

The following process options were shortlisted for the optioneering process, based on Atkin's engineering judgement:

- Option 1: AD with Electricity to Grid
- Option 2: AD with Biomethane to Grid
- Option 3: AD with Biogas Export to Third Party.

The optioneering evaluation results are presented in Section 3.5

3.2. Option 1 – AD with Electricity to Grid

3.2.1. Process Description

AD plants typically operate under mesophilic conditions, where a temperature range of 25-45ºC must be maintained. To satisfy this heating requirement, some AD plants fully consume the biogas produced onsite in a CHP system to simultaneously produce heat and electricity. The electricity generated in a CHP can be consumed onsite but it is generally exported to the national grid to gain revenue.

There are several CHP technologies available such as internal combustion engines, micro-turbines and fuel cells. For the purposes of this feasibility study, Atkins chose to explore internal combustion engines due to the elimination of biogas pre-treatment requirement and it being the current industry's technology of choice when compared to alternatives.

In an internal combustion engine facility, raw biogas from the AD plant is directly fed into the internal combustion engine without the need for biogas pre-treatment. A safety flare system is installed on the feed line to the internal combustion engine to provide emergency pressure relief when required. Atmospheric air is compressed, heated and subsequently fed into the internal combustion engine, where it produces an air-biogas mixture which is burnt to convert chemical energy into kinetic and thermal energy. The internal combustion engine is connected to a generator which converts the kinetic energy into electricity that is exported to the national grid. The hot flue gas (exhaust gas) exiting the internal combustion engine is fed into a series of heat exchangers for heat recovery before it is discharged to the atmosphere via a stack. The first heat exchanger is used to increase the temperature of the compressed air before it is injected into the internal combustion engine. The second heat exchanger is used to produce hot water which is used as a heat source for onsite users such as the AD process.

A typical PFD of an internal combustion engine facility is portrayed in Figure 3-1

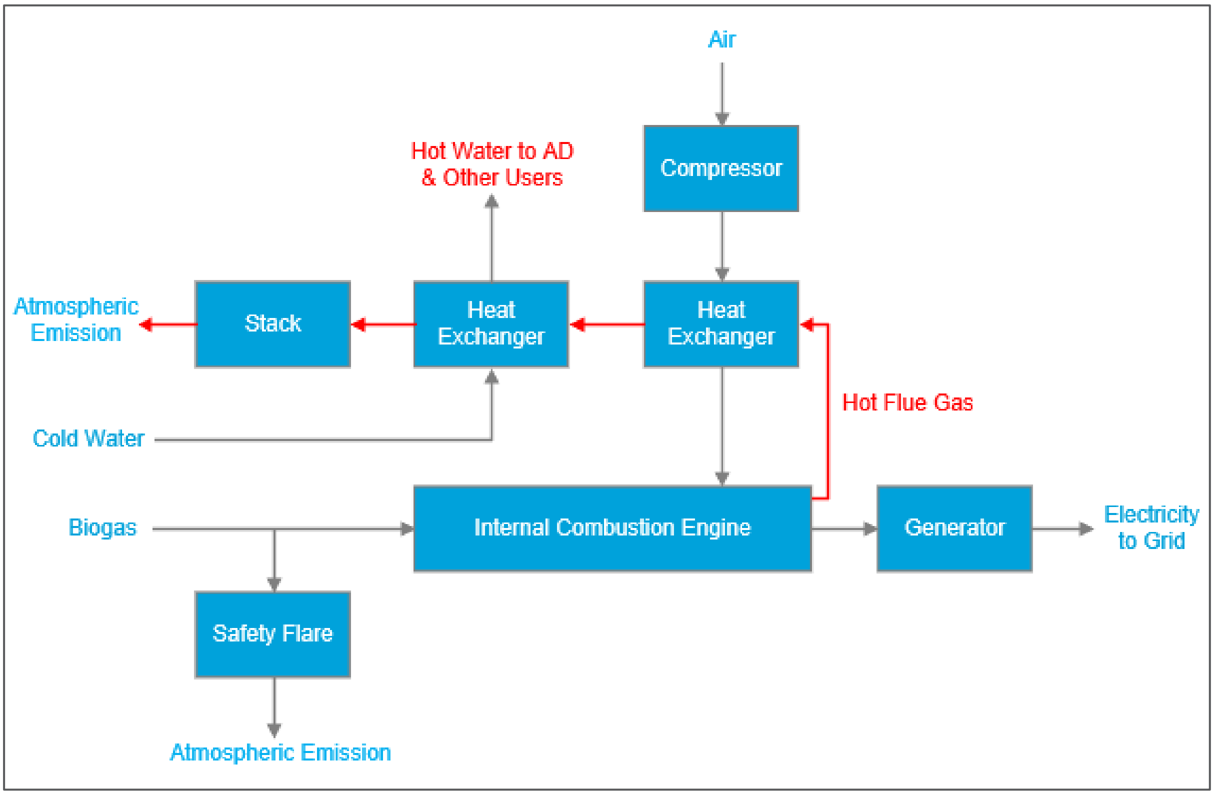

Figure 3-1 – Typical PFD of an Internal Combustion Engine CHP Facility

3.2.2. Typical Site Layout and Space Requirement

A typical site layout of an AD plant with electricity to grid can be seen in Figure 3-2.

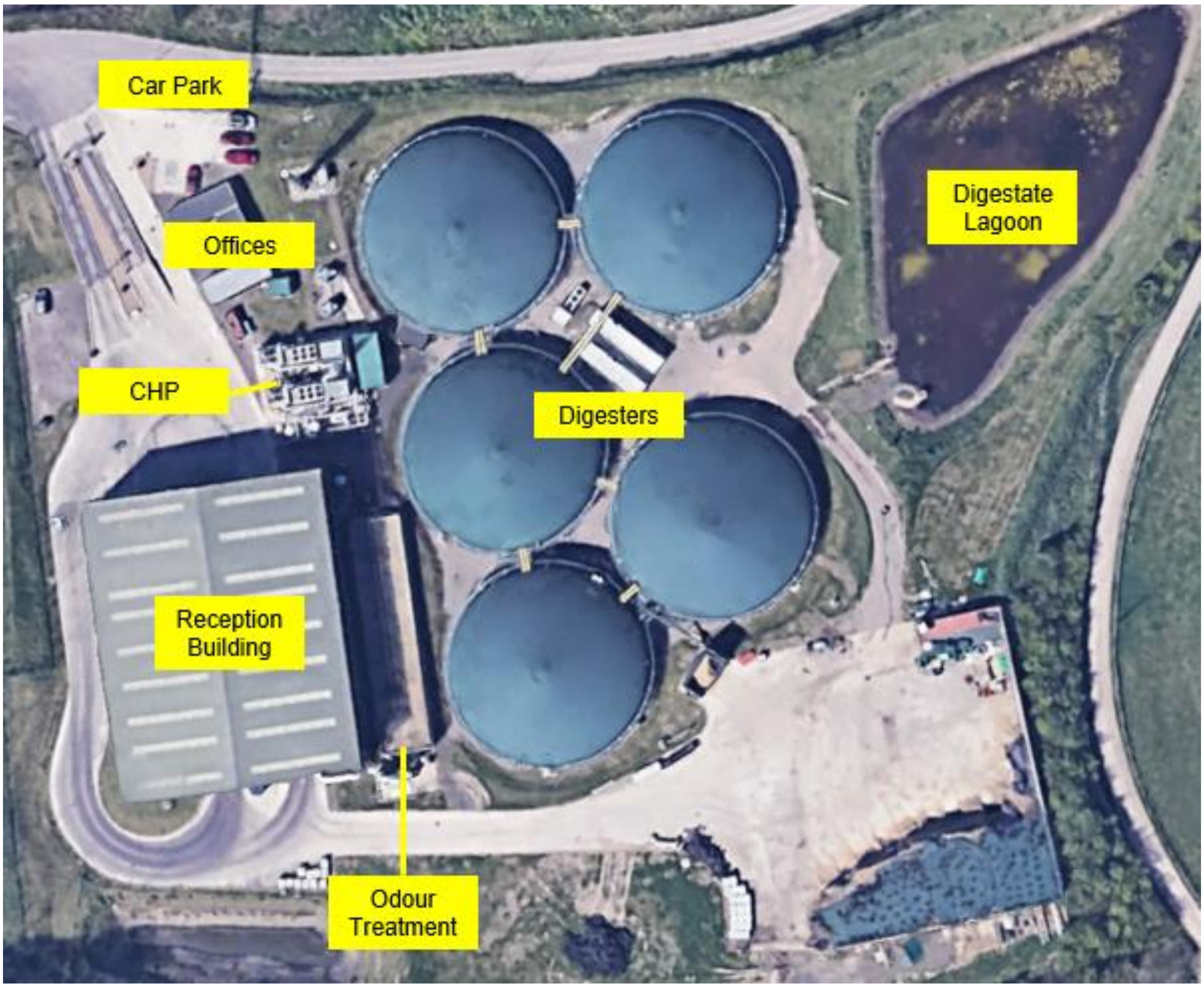

Figure 3-2 – Site Layout of an AD Plant with Electricity to Grid

To determine a high-level estimate of the space required for an AD plant with electricity to grid, an assessment was conducted which involved obtaining the footprint of a number of existing plants. Based on the assessment, it was established that the average footprint required per plant's annual capacity is approximately 0.51 m^2 per tonnes/yr. Therefore, for a plant with an annual capacity of 19,000 tonnes, the estimated footprint required is approximately 9,800 m^2 (equivalent to approx. 2.42 acres).

3.2.3. High Level CAPEX and OPEX

A report entitled "*Biomethane: The Pathway to 2030"* was published in March 2020 by the Anaerobic Digestion and Bioresources Association (ADBA), providing the average CAPEX and OPEX associated with an AD Plant that exports electricity to the grid. The information is based on the average calculated from a sample of 41 AD plants across the UK and is presented in Table 3-2.

To determine the high-level CAPEX and OPEX associated with Option 1, it was necessary to estimate the CHP capacity. Based on Atkins' high-level calculations, it was estimated that the CHP requires a capacity of approximately 850kW. Therefore, the plant's scale is considered to be 'medium' as per the categorisation guidance of Table 3-2. In accordance with the report authored by the ADBA, the average CAPEX and OPEX per installed CHP capacity is £4,300/kW and £300/kW respectively. Hence, the high level CAPEX and OPEX estimates for Option 1 are approximately £3,655,000 and £255,000 per year respectively. Given that the AD plant is required to process food cost, an additional high-level CAPEX of approximately £850,000 is required to purchase the necessary reception facility and pre-treatment equipment. This is based on a proportional scaling factor of the £1 million required for a 1MW CHP[12]. The high-level cost of land acquisition for the required 9,800 m^2 footprint was estimated to be within a range of £1,804,718 and £7,218,873, giving an average of approximately £4,511,795.

In summary, the high level OPEX estimate for Option 1 is approximately £255,000 per year. The total high level CAPEX estimate for Option 1 is approximately £9,016,795. Note that these high-level estimates should be treated as indicative values. The estimates are equivalent to an AACE class 4 estimate. AACE describes the estimate accuracy as follows:

Typical accuracy ranges for Class 4 estimates are -15% to -30% on the low side, and +20% to +50% on the high side, depending on the technological complexity of the project, appropriate reference information, and other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks.

Table 3-2 – Average CAPEX and OPEX of an AD Plant with Electricity to Grid[13]

Scale	CHP Capacity (kW)	Average CAPEX (£/kW)	Average OPEX (£/kW)
Micro	10-50	9,800	1,000
Small	50-500	6,300	400
Medium	500-1,000	4,300	300
Large	1,000-2,000	3,000	200
Very Large	>2,000	3,800	400

3.2.4. Revenue Potential

3.2.4.1. Contract for Difference

This government incentive is applicable to AD plants with a minimum CHP capacity of 5MWe. However, from a high-level estimate conducted by Atkins, an AD plant processing around 19,000 tonnes per year of food waste would be equivalent to a design capacity of approximately 850kW of electricity. Hence, it would not meet CfD's capacity threshold of 5MWe and would not be eligible to bid in a CfD auction.

3.2.4.2. Wholesale Electricity

According to Ofgem[14], the wholesale electricity price is approximately £70.59/MWh as of 30 July 2021. An AD plant with an installed gross capacity of 850kW is expected to generate 6,439MWh of electricity per year, based on a parasitic load and plant availability of 6% and 90% respectively. Therefore, the estimated revenue from the wholesale electricity is £454,550 per year. This estimation is based on the quoted wholesale electricity price which is subject to fluctuation.

3.2.4.3. Digestate

The liquid digestate produced from the AD plant requires pasteurisation to make it safe for use by consumers. For commercial sites, most often the digestate is provided either free of charge to off-site users such as farmers or at a cost to the operator with a minority of AD plants profiting from the sale of digestate. This generally required additional investment to process the liquid digestate into dewatered sludge cake.

[12] http://staging.adbioresources.org/docs/Biomethane_-_Pathway_to_2030_-_Full_report.pdf
[13] http://staging.adbioresources.org/docs/Biomethane_-_Pathway_to_2030_-_Full_report.pdf
[14] https://www.ofgem.gov.uk/energy-data-and-research/data-portal/wholesale-market-indicators

3.3. Option 2 – AD with Biomethane to Grid

3.3.1. Process Description

Biogas produced at an AD plant typically contains around 60% methane (CH_4) on a volume basis. The remaining volume primarily consists of water vapour (H_2O) and carbon dioxide (CO_2) with small amounts of hydrogen sulphide (H_2S) and traces of other components such as Volatile Organic Compounds (VOCs).

To make biogas suitable for use as vehicle fuel and/or direct injection into the natural gas grid, the biogas must undergo a process known as "upgrading". Biogas upgrading is the process in which methane is separated from other constituents present in the biogas, producing a highly concentrated methane product (>97%), referred to as "biomethane". The biomethane gas can be further processed to produce Compressed Natural Gas (CNG) or Liquefied Natural Gas (LNG) for vehicle fuel or injected with propane and subsequently fed into the natural gas grid.

There are four main technologies used for producing biomethane from biogas, these are membrane separation, pressure swing adsorption, amine scrubbing and water wash. For the purposes of this feasibility study, Atkins chose to explore membrane separation. This is due to the opportunity to recover CO_2 as a by-product in liquid form, making the facility an almost zero-emission system which aligns with BFC's climate change strategy to be carbon neutral by 2050.

In a membrane separation facility, raw biogas from an AD plant undergoes a pre-treatment process in which it is chilled and condensed to remove water vapour and subsequently fed into activated carbon filters to remove other contaminants such as H_2S and VOCs. After pre-treatment, the biogas stream is compressed to create a driving force for the downstream process. Upon compression, the biogas is treated in a 3-stage membrane filtration system which consists of highly selective membranes that produces a concentrated biomethane stream (>97%) and a concreated carbon dioxide stream (>99%). The biomethane stream is then further processed to produce CNG or LNG for vehicle fuel or enriched with propane to increase its calorific value and subsequently supplied into the natural gas grid.

As shown in Figure 3-3 which presents a typical PFD of a membrane separation facility, the concentrated carbon dioxide stream can be further processed to produce liquefied CO_2 and sold to consumers such as carbonate drinks manufacturers to generate additional revenue.

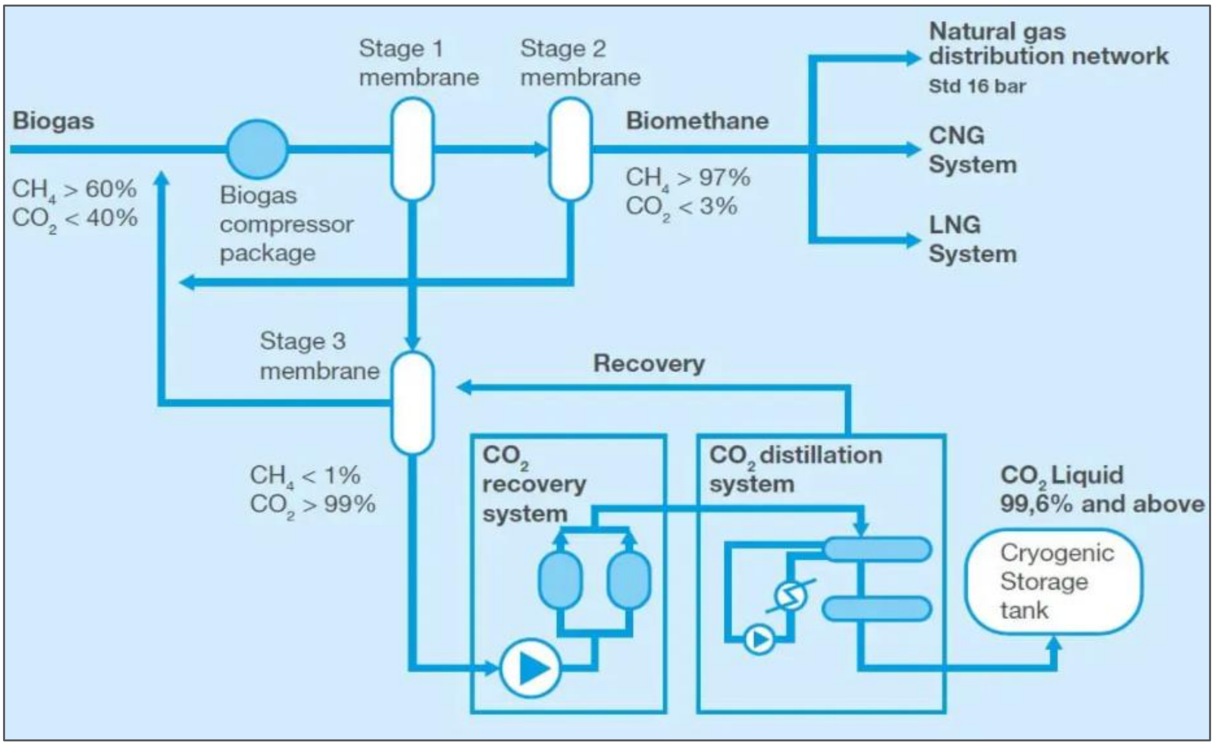

Figure 3-3 – Typical PFD of a Membrane Separation Facility for Biogas Upgrading

3.3.2. Typical Site Layout and Space Requirement

A typical site layout of an AD plant with biomethane to grid can be seen in Figure 3-4. Note that the plant shown below also has a CHP for satisfying the process heat requirement onsite and electricity export to the grid.

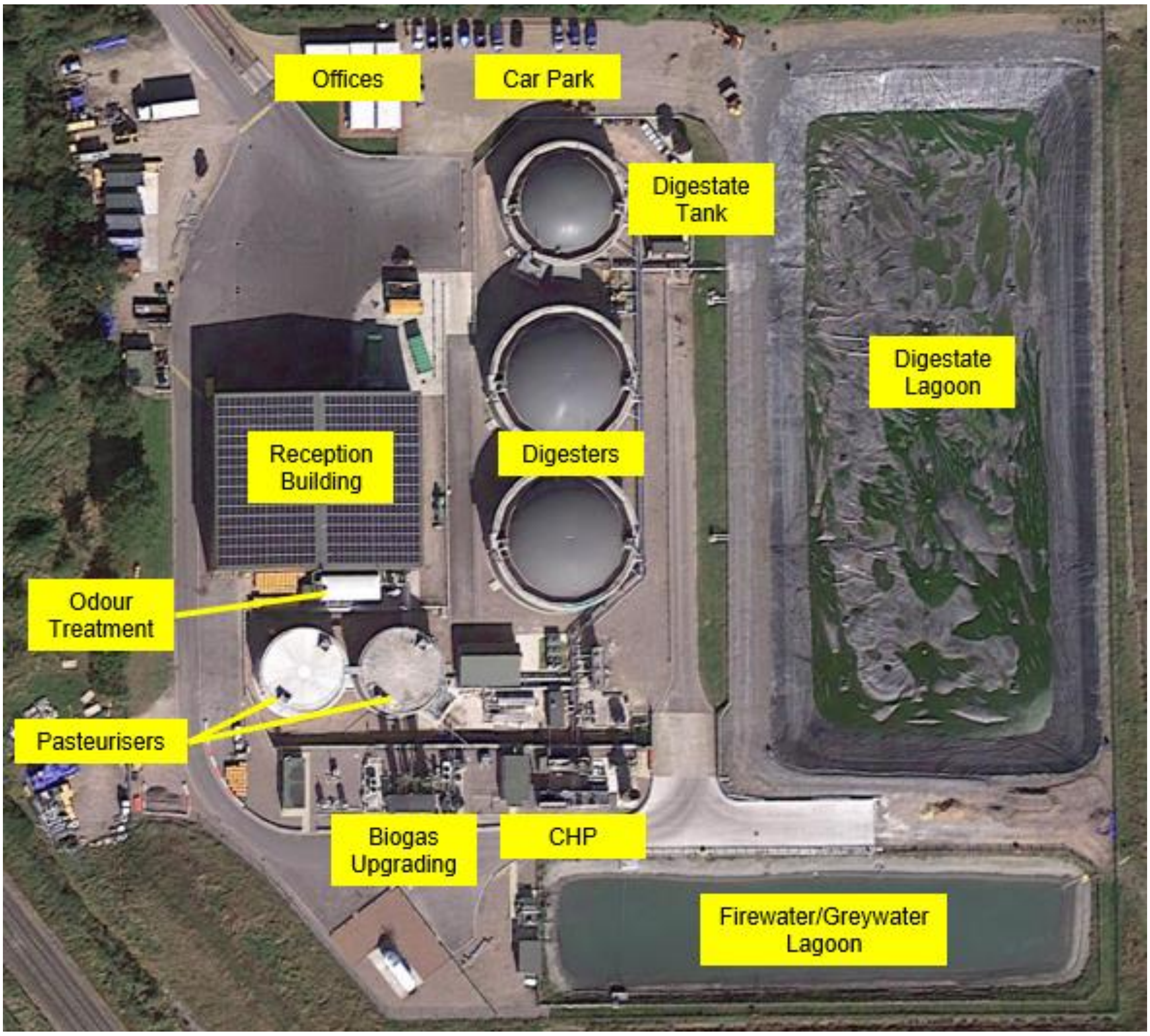

Figure 3-4 - Site Layout of an AD Plant with Biomethane to Grid

To determine a high-level estimate of the space required for an AD plant with biomethane to grid, an assessment was conducted which involved obtaining the footprint of a number of existing plants. Based on the assessment, it was established that the average footprint required per plant's annual capacity is approximately 0.42 m^2 per tonnes/yr. Therefore, for a plant with an annual capacity of 19,000 tonnes, the estimated footprint required is approx. 8000 m^2 (equivalent to 1.97 acres).

3.3.3. High Level CAPEX and OPEX

The methodology used to determine the high-level CAPEX and OPEX associated with Option 2 is similar to that used for Option 1.

As discussed in Section 3.2.3, the plant's scale is considered to be 'medium' as per the categorisation guidance of Table 3-2. In accordance with the report authored by the ADBA, the average CAPEX and OPEX per installed CHP capacity is £4,300/kW and £300/kW respectively. Hence, the high-level CAPEX and OPEX estimates for Option 2 are approximately £3,655,000 and £255,000 per year respectively. Since the estimated values are based on an AD plant with electricity to grid, modifications were made to account for an AD plant with biomethane to grid. The first modification was to subtract the CHP related CAPEX, which was estimated to be approximately £340,000. This is based on a proportional scaling factor of the £400,000 required for a 1MW CHP[15]. The second modification was to add the biogas upgrading facility related CAPEX, which was estimated to be approximately £900,000. This is based on requirement for 6 biogas upgrading units, each with a CAPEX of £150,000. Therefore, the CAPEX value which excludes the CHP facility and includes the biogas upgrading facility was estimated to be £4,215,000.

Given that that the AD plant is required to process food cost, an additional high-level CAPEX of approximately £850,000 is required to purchase the necessary reception facility and pre-treatment equipment. The high-level cost of land acquisition for the required 8,000 m^2 (equivalent to 1.97 acres) footprint was estimated to be within a range of £1,471,344 and £5,885,374, giving an average of approximately £3,678,359. Hence, the total high level CAPEX estimate for Option 2 is approximately £8,743,359.

The additional OPEX related to the enrichment of the biomethane with propane prior to it being supplied into the natural gas grid was estimated to be approximately £114,300. This is based a biomethane production rate of approximately 191 Nm^3/h. Therefore, the total high level OPEX estimate for Option 2 is approximately £369,300 per year

In summary, the total high level OPEX estimate for Option 2 is approximately £369,300 per year. The total high level CAPEX estimate for Option 2 is approximately £8,743,359. Note that these high-level estimates should be treated as indicative values. The estimates are equivalent to an AACE class 4 estimate. AACE describes the estimate accuracy as follows:

Typical accuracy ranges for Class 4 estimates are -15% to -30% on the low side, and +20% to +50% on the high side, depending on the technological complexity of the project, appropriate reference information, and other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks.

3.3.4. Revenue Potential

3.3.4.1. Green Gas Support Scheme

Atkins' high-level calculations suggest that the AD with biomethane to grid plant would produce biomethane which has an annual output of approximately 18,356 MWh. This implies that the plant would be eligible for GGSS Tier 1 fixed tariff which equates to £0.0551/MWh. Therefore, the estimated high-level revenue from GGSS is £1,011,448 per year.

3.3.4.2. Wholesale Gas

According to Ofgem[16], the wholesale gas price is approximately £0.60/kWh as of 30 July 2021. The AD plant with biomethane to grid is expected to generate an equivalent annual output of 18,356 MWh. Hence, the estimated high-level revenue from wholesale gas price is £386,867 per year. This estimation is based on the quoted wholesale gas price which is subject to fluctuation.

3.3.4.3. Digestate

The liquid digestate produced from the AD plant requires pasteurisation to make it safe for use by consumers. For commercial sites, most often the digestate is provided either free of charge to off-site users such as farmers or at a cost to the operator with a minority of AD plants profiting from the sale of digestate. This generally required additional investment to process the liquid digestate into dewatered sludge cake.

[15] http://staging.adbioresources.org/docs/Biomethane_-_Pathway_to_2030_-_Full_report.pdf
[16] https://www.ofgem.gov.uk/energy-data-and-research/data-portal/wholesale-market-indicators

3.4. Option 3 – AD with Biogas Export to Third Party

3.4.1. Process Description

Refer to Section 2.1 for the process description of AD with biogas export to third party. In essence, the biogas produced at an AD plant is exported to a third party situated immediately adjacent to the site to avoid operating the considerably complex biogas upgrading facility. This option is suitable for clients that do not possess the technical expertise to operate such facility.

3.4.2. Typical Site Layout and Space Requirement

The typical site layout of Option 3 is similar to that of Option 2 with the exception of the biogas upgrading facility being owned and operated by a third party. Figure 3-5 displays the demarcation which represents the plant area that would be owned and operated by a third party.

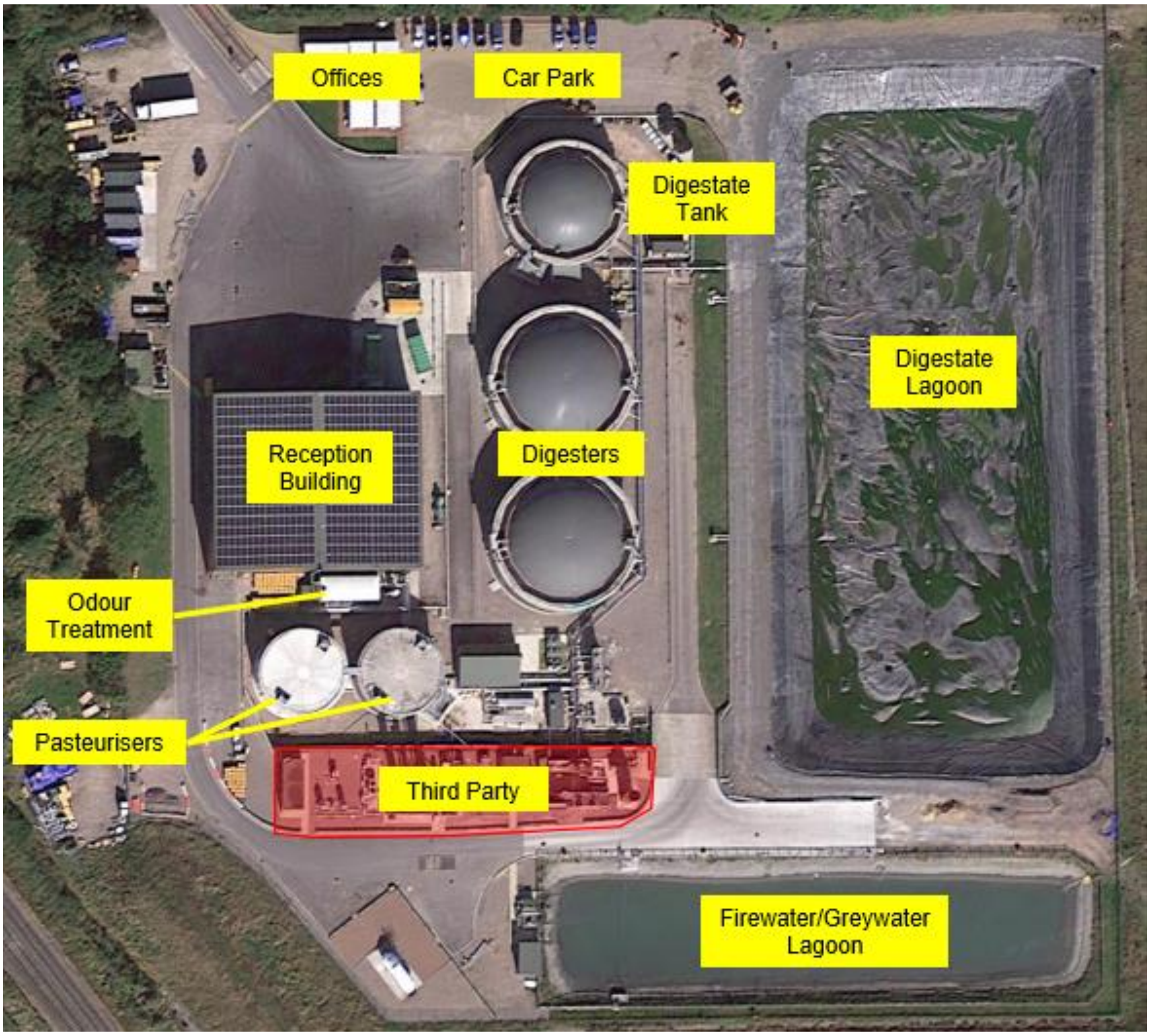

Figure 3-5 - Site Layout of an AD Plant with Biogas Export to Third Party

With regards to determining a high-level estimate of the space required for an AD plant with biogas export to third party, the average percentage of space used onsite to accommodate a biogas upgrading facility was estimated to be about 5%. Therefore, the high-level space requirement for Option 3 is 5% less than Option 2 which equates to approximately 7,600 m^2.

3.4.3. High Level CAPEX and OPEX

The methodology used to determine the high-level CAPEX and OPEX associated with Option 3 is similar to that used for Option 1.

As discussed in Section 3.2.3, the plant's scale is considered to be 'medium' as per the categorisation guidance of Table 3-2 and thus, the average CAPEX and OPEX per installed CHP capacity is £4,300/kW and £300/kW respectively. Hence, the high-level CAPEX and OPEX estimates for Option 3 are approximately £3,655,000 and £255,000 per year respectively. Since the estimated values are based on an AD plant with electricity to grid, it was necessary to subtract the CHP related CAPEX, which was estimated to be approximately £340,000. Therefore, the revised CAPEX value was estimated to be £3,315,000.

Given that the AD plant is required to process food cost, an additional high-level CAPEX of approximately £850,000 is required to purchase the necessary reception facility and pre-treatment equipment. The high-level cost of land acquisition for the required 7,556 m^2 footprint was estimated to be within a range of £1,397,776 and £5,591,105, giving an average of approximately £3,494,441. Hence, the total high level CAPEX estimate for Option 3 is approximately £.

In summary, the total high level OPEX estimate for Option 3 is approximately £255,000 per year. The total high level CAPEX estimate for Option 2 is approximately £4,210,333. Note that these high-level estimates should be treated as indicative values. The estimates are equivalent to an AACE class 4 estimate. AACE describes the estimate accuracy as follows:

Typical accuracy ranges for Class 4 estimates are -15% to -30% on the low side, and +20% to +50% on the high side, depending on the technological complexity of the project, appropriate reference information, and other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks.

3.4.4. Revenue Potential

3.4.4.1. Wholesale Gas

According to Ofgem[17], the wholesale gas price is approximately £0.60/kWh as of 30 July 2021. The AD plant with biogas to export to third party is expected to generate an equivalent annual output of 16,687 MWh. Hence, the estimated high-level revenue from wholesale gas price is £351,697 per year. This estimation is based on the quoted wholesale gas price which is subject to fluctuation.

It should be noted that a premium price which is higher than the quoted wholesale gas price would likely be agreed between BFC and the third party to distribute some of the revenue generated from sale of biomethane under the GGSS to BFC. The exact premium is subject to negotiation between both parties and therefore cannot be accounted during this assessment.

3.4.4.2. Digestate

The liquid digestate produced from the AD plant requires pasteurisation to make it safe for use by consumers. For commercial sites, most often the digestate is provided either free of charge to off-site users such as farmers or at a cost to the operator with a minority of AD plants profiting from the sale of digestate. This generally required additional investment to process the liquid digestate into dewatered sludge cake.

[17] https://www.ofgem.gov.uk/energy-data-and-research/data-portal/wholesale-market-indicators

3.5. Options Evaluation Results

A summary of the weighted options evaluation results is portrayed in Table 3-3. It can be seen that Option 3 has the highest total weighted score, making it the recommended process option, in a scenario where BFC decides to build their own AD plant. Brief justifications for the scoring of each process option against the key criteria is discussed to provide context.

Table 3-3 – Summary of Weighted Options Evaluation Result

Key Criteria	Weighting	Option 1	Option 2	Option 3
Capex (1-Very High to 5-Very Low)	5	5	15	25
Opex (1-Very High to 5-Very Low)	5	20	15	20
Revenue Potential (1-Low to 5-High)	5	5	25	15
Complexity of Operation (1-Difficult to 5-Easy)	3	6	6	12
Footprint (1-Large to 5-Small)	5	15	20	25
Constructability (1-Difficult to 5-Easy)	2	4	4	8
Environmental Impact (1-High to 5-Low)	5	15	25	20
Total Score		**70**	**110**	**125**

CAPEX

The high-level CAPEX estimates for each process option was used as a relative gauge to determine the preferred option in accordance with the key criteria. Based on Atkins' high-level estimations, Option 3 has the lowest CAPEX which is approximately £7,659,441. This is in comparison to Option 1 and 2 which have an estimated high-level CAPEX was £9,016,795 and £8,743,359 respectively. Therefore, Option 3 was given the best CAPEX score.

OPEX

The high level OPEX estimates for each process option was used as a relative gauge to determine the preferred option in accordance with the key criteria. Based on Atkins' high-level estimations, Option 1 and Option 3 has the same associated OPEX and were therefore given the same weighted score. Option 2 scored the lowest due the need to purchase propane to enrich the biomethane before it is supplied to the natural gas grid.

Revenue Potential

Although Atkins' high-level estimation suggests that the revenue potential of Option 3 is the lowest, it should be noted that the value is based on wholesale gas price. It was emphasised that a premium price would likely be agreed between BFC and the third party, increasing the revenue potential of Option 3, such that it is competitive with Option 1. This was the rationale used to justify giving Option 3 a better score than Option 1. It can be observed that Option 2 has the best revenue potential and thus was scored appropriately.

Complexity of Operation

Option 1 and Option 2 were considered to have the same complexity of operation due to the presence of process facilities such as CHP and membrane separation respectively. In contrast, Option 3 avoids the need for complex process facilities and was therefore given the best score, relatively speaking.

Footprint

The high-level space requirement estimates for each process option was used as a relative gauge to determine the preferred option in accordance with the key criteria. Based on Atkin's high-level estimations, Option 3 has the lowest footprint requirement.

Constructability

Option 1 and Option 2 were considered to have the same constructability due to the upstream AD process configuration which accounts for a significant proportion of the plant being identical. Option 3 was score less favourably due to the need to liaise with the third party during the construction phase.

Environmental Impact

Option 2 was given the best score due to the opportunity to recover CO_2 as a by-product in liquid form, making the facility an almost zero-emission system which aligns with BFC's climate change strategy to be carbon neutral by 2050. With that said, it should be noted that recovering the liquefied CO_2 requires additional CAPEX than the high-level value estimated in this feasibility study to purchase the necessary process equipment. Option 1 was considered to be the least favourably option due to the need to combust the biogas within the plant's boundary, producing GHG emissions which are discharged to the atmosphere.

END