ofgem

RIIO NIC NETWORK INNOVATION COMPETITION

Project Code/Version Number:
NGGDGN02/1

1. Project Summary

1.1. Project Title	Commercial BioSNG Demonstration Plant		
1.2. Project Explanation	The Project will construct a commercial demonstration plant to produce renewable, low carbon methane (BioSNG) by gasification of household waste. BioSNG could eventually meet 40% of UK domestic gas demand, resulting in customers being able to benefit from the continued use of the gas network into the future.		
1.3. Funding licensee:	National Grid Gas Distribution		
1.4. Project description:	**Problem:** The UK has committed to reduce greenhouse gas (GHG) emissions to 80% of 1990 levels by 2050. However, decarbonising heat and transport is challenging because of the highly variable demand for heat and energy dense vectors required for transport, particularly for Heavy Goods Vehicles. Finding a cost effective solution to these challenges is required to meet the emissions target. **Method:** The Project enables the production of sustainable, low carbon substitute natural gas (BioSNG) from waste using thermal processes. Independent analysis shows that BioSNG results in substantial GHG emissions savings and techno-economic modelling indicates that the cost of BioSNG will match fossil natural gas prices. **Solution:** The Project will provide a commercial reference facility and dissemination of knowledge to allow funders, engineering contractors, waste operators and gas off-takers to quantify the risks, costs and rewards of full scale plants. This is an essential pre-requisite to enable the roll-out of a large number of BioSNG plants across the UK addressing the critical issue of cost-effective provision of renewable fuel. **Benefits:** BioSNG can increase UK renewable gas production by 100TWh per annum. Successful roll-out will help the UK achieve its GHG targets, provide savings to gas consumers through avoidance of costs associated with moving to other solutions for low carbon heat and transport, and maintain the grid as the most efficient means to transport gas to customers.		
1.5. Funding			
1.5.1 NIC Funding Request (£k)	5,362	*1.5.2 Network Licensee Compulsory Contribution (£k)*	600
1.5.3 Network Licensee Extra Contribution (£k)		*1.5.4 External Funding – excluding from NICs (£k):*	17,058
1.5.5. Total Project Costs (£k)	23,058		

<table>
<tr><td>1.6. List of Project Partners, External Funders and Project Supporters</td><td colspan="3">National Grid Gas Distribution
Wales & West Utilities
Progressive Energy Ltd
CNG Services Ltd
Advanced Plasma Power (£6.5m of Funding)
Department for Transport (£10.6m of Funding)</td></tr>
<tr><td colspan="4">1.7 Timescale</td></tr>
<tr><td>1.7.1. Project Start Date</td><td>1st December 2015</td><td>1.7.2. Project End Date</td><td>30 November 2018</td></tr>
<tr><td colspan="4">1.8. Project Manager Contact Details</td></tr>
<tr><td>1.8.1. Contact Name & Job Title</td><td>David Pickering
BioSNG Project Manager</td><td>1.8.2. Email & Telephone Number</td><td>david.c.pickering@nationalgrid.com
07867 537360</td></tr>
<tr><td>1.8.3. Contact Address</td><td colspan="3">Network Strategy, National Grid Gas Distribution, 3 Brick Kiln Street, Hinckley LE10 0NA.</td></tr>
</table>

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Section 2: Project Description

2.0 Introduction

BioSNG (bio-substitute natural gas) is an energy vector which can deliver cost effective, low carbon heat and transport using the existing gas network. A full chain Project is proposed which will demonstrate, under commercial conditions, the conversion of waste through to delivery of renewable gas using thermal gasification and methanation. This will be sold to specific end users via the gas grid and will provide a national reference plant addressing commercial, legal and funding barriers. As such this Project will facilitate investment in full scale operational plants, with the potential to increase the availability of renewable gas in the UK by 100TWh.

In 2013, the Project Partners successfully applied for £1.9m of NIC funding to construct a BioSNG Demonstration Plant (the "Pilot Plant Project"). That project is proceeding well as described in Section 6.4 of this submission. The objective of the Pilot Plant Project was to prove the technical and economic feasibility of thermal gasification of waste to renewable gas.

Over the last year, the Project Partners focussed on commercialisation of the technology. The Pilot Plant Project business case envisaged that the next step in the development of the technology would be a large scale plant producing 300GWh/a of gas, funded commercially. As described in Section 4d, feedback from funders, waste suppliers and gas off-takers shows that they will only support this large scale plant if the technology is demonstrated at intermediate scale on a continuous basis. The experiences of other waste to energy technologies such as those developed by Enerkem, Nexterra and AlterNRG show that a facility of the scale proposed in this Project has enabled the development of fully commercial, large scale plants.

Therefore the Project Partners now believe that the construction and operation of a demonstration plant at a scale of around 20–25GWh/a is an essential intermediate step in the commercialisation of the technology.

The timing of this application has been driven by the current Department for Transport (DfT) Advanced Biofuels Competition. The Project Partners have applied for around £11m of funding from this competition. The DfT project will produce compressed BioSNG (BioCNG) which will be transported on tube trailers by road to CNG filling stations for use by heavy goods vehicles. The project has been successfully shortlisted and the DfT intends to announce final competition winners in early September 2015. The BioSNG project is very well placed to be successful.

One of the key advantages of natural gas as a transport fuel is the ability to exploit the existing gas network to take gas produced at plants located close to waste arisings and deliver it to appropriately sited filling stations. Analysis by National Grid shows that commercial scale BioSNG plants are likely to inject gas into the local transmission system; the volumes are too high for lower pressure tiers and there is too much gas to be used directly in trucks. The DfT focus is primarily on the fuel production and its direct use, rather than on the needs of the distribution system. As described in Section 4e, with NIC funding it will be possible to amend the design of the DfT facility so that it produces both BioCNG for direct fuelling of vehicles and BioSNG for injection into the grid.

Because of the expected DfT funding and investment by APP shareholders, the Project represents an opportunity to demonstrate grid injection of BioSNG for heat and transport for relatively little additional investment, offering extremely good value for money.

2.1. Aims and objectives

2.1.1 The Problem(s) which needs to be resolved

The problem to be resolved is the achievement of substantial reductions the UK's greenhouse gas emissions. Heat and transport are key sectors to address, and which the gas network is well placed to facilitate. To do this requires commercially deliverable and substantial volumes of renewable gas beyond that which can be achieved by conventional biogas. These factors are laid out below.

Greenhouse gas emissions: The imperatives of climate change demand substantial reduction in CO_2 levels; specifically the UK has committed to an 80% reduction on 1990 levels by 2050, and to 15% renewable energy production by 2020. The Carbon Plan[1] specifically identifies needs for low carbon heat and transport in order to meet these targets.

Low-carbon heat: Currently gas dominates the UK heat supply curve, with 83% of the UK's buildings heated by gas, typically using efficient modern gas boilers. Similarly, most industrial heat demands are fuelled by gas. Heat demand is highly variable, as can be seen by heat demand curves in National Grid research[2]. These show that the peak capacity load on a daily basis is more than five times the lowest day, and the peak capacity hour is more than ten times the lowest hour, which places particular challenges on low carbon solutions. The options to decarbonise heat are:

Electrification: Efficient electric heat pumps will make an important contribution, but, as recognised in DECC Heat Strategy[3], major investment will be required to replace current consumer equipment and for the electric network to handle the variable demand for heat, making them an expensive solution to meet all heat demand.

Biomass: Biomass installations require heat consumers with sufficient space for equipment and storage meaning their use is limited in urban areas.

Heat networks: Heat networks require a low carbon source of heat, new infrastructure and sufficient heat density of the load which constrains their use.

Renewable gas: The gas network is ideally suited to transmitting and distributing variable levels of energy, and is already sized to meet UK demand. Therefore, a solution which utilises the existing gas network to deliver low carbon fuel to existing, efficient installations with no modification to either the grid or end use equipment, offers the prospect for best value to gas customers.

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1 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/47621/1358-the-carbon-plan.pdf

2 http://www.eua.org.uk/sites/default/files/11%20Marcus%20Stewart.pdf

3 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/190149/16_04-DECC-The_Future_of_Heating_Accessible-10.pdf

Low-carbon transport: In transport, the electrification of vehicles has a key role to play in decarbonisation. However, this will not provide a comprehensive solution. Electrification needs to be complemented by low carbon fuels that can provide the low mass, energy-dense storage required by sectors such as Heavy Goods Vehicles (HGVs). First-generation biofuels (made from traditional crops, starch, sugars or vegetable oil) have given rise to concerns around food security and land use change. Therefore, as set out in a report for the Department for Transport[4], there is a need for biofuels produced from feedstock such as wastes and residues that do not compete with land for food production. Alternative advanced low carbon fuels such as hydrogen, or waste derived biodiesel, rely on the development of new technologies and refinery infrastructure.

Compressed Natural Gas is a fuel vector which offers carbon, noise and emissions benefits in the short term, and through the adoption of renewable gas, a more extensive low carbon solution. The number of HGVs and buses in the UK and internationally adopting gas powered vehicles is increasing substantially as shown by work by the Low Carbon Vehicle Partnership[5], and in the UK can exploit the extensive gas network for fuel distribution. A renewable source of fuel for these vehicles is therefore a key step towards low carbon transport. The recently announced National Grid-supported NIA project at Leyland to supply BioCNG to John Lewis using the Local Transmission system, and the new dedicated CNG trucks made by Scania are important developments that aim to showcase the benefits of the LTS to supply CNG for trucks.

Cost-effective low carbon gas at scale: Cost-effective sources of sustainable, low carbon gas at scale are required to secure the long-term future of the gas network. Biomethane derived from anaerobic digestion (biogas) is already being upgraded and being injected into the grid with over 36 projects already connected to the grid and with an expectation that by the end of 2015 there will be over 50 delivering over 2TWh of renewable gas. However, there is a limit to the types of waste that can be treated in this way i.e. primarily food/agricultural wastes and sewage. Grown crops (such as maize) suffer from concerns over land use, though the use of the whole crop and the digestate as a fertiliser provides mitigation. Analysis by ADBA[6] has indicated the expected potential of biomethane from AD as around 40TWh, 12% of current annual domestic gas demand.

Commercialisation hurdles: Commercial demonstration is a key enabling step for the deployment of new technologies (see Section 4d), being necessary before commercial sources of finance will consider investment.

It is clear that a cost-effective, sustainable source of biomethane must be found and commercially demonstrated that is capable of producing sufficient quantities to make a meaningful contribution to low carbon heat and transport.

2.1.2 The Method(s) being trialled to solve the Problem

As demonstrated above, renewable gas provides an important solution for delivery of low carbon energy. Specifically because:

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4 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/383577/Advanced_Biofuel_Demonstration_Competition_-_Feasibility_Study_FINAL_v3.pdf

5 http://www.lowcvp.org.uk/projects/fuels-working-group/infrastructure-roadmap.htm

6 http://www.detini.gov.uk/anaerobic_digestion_and_biogas_association-2.pdf

- The UK's extensive gas network provides an ideal distribution system allowing renewable fuel to be produced where the feedstock arises, and delivered cost-effectively with low carbon impact to consumers.
- A gas vector is ideal for handling peaks of demand much more cost effectively than other low carbon solutions.
- Heat consumers do not need to make expensive changes to existing appliances and infrastructure.
- Renewable gas offers a step change in carbon reduction for the HGV transport sector in particular which cannot exploit electrification.

Unsurprisingly therefore, the Carbon Plan identifies biomethane as an important low carbon technology solution. However, it recognises the limited amount of biomethane that anaerobic digestion (AD) can provide; the BioSNG production route addresses this issue. In particular, the thermal process enables conversion of a much more extensive range of feedstocks, both waste-derived and other lignocellulosic biomass material. Furthermore, a much greater proportion of the feedstock is converted, without the need to address the requirements associated with digestate management in the AD process. Together these factors also enable enhanced economies of scale, meaning the BioSNG route is an important enabling technology to increase renewable gas production which can then be distributed, using the gas network to heat and transport customers.

This Project is a full chain project which demonstrates, under commercial conditions, the conversion of waste, a sustainable and secure feedstock, to renewable gas using thermal gasification and methanation, meeting the Carbon Plan's desire for biomethane.

The technology will address the specific aspects of the Problem identified above as follows:

Greenhouse gas emissions: An independent report assessing the GHG emissions from the BioSNG process for Heat and Transport was produced by NNFCC[7], described in more detail in Section 4(a). This demonstrates that the BioSNG route provides between 66-127% carbon savings compared with fossil alternatives for heat and 74-123% savings for transport, depending on the analytical methodology used. Therefore, there is confidence that this approach will provide a low carbon, sustainable solution for both heat and transport.

Cost-effective low carbon gas at scale: The low-carbon gas produced by the technology will be purified, upgraded and converted to a methane-rich substitute natural gas using catalysis. This will produce a fungible fuel which can be injected into the grid and used in consumers' appliances with no modifications, as the Project will demonstrate (see Section 2.1.3). The ability to process residual black bag and commercial wastes as well as other lignocellulosic biomass material has the potential to significantly increase the availability of renewable gas by around 100TWh[8], 30% of current domestic demand, to a total, including biomethane from AD, of 140TWh/a. The BioSNG process therefore provides the low carbon gas at scale that is necessary to secure the long-term future of the grid.

[7] http://www.nnfcc.co.uk/tools/analysis-of-the-ghg-emissions-for-thermochemical-biosng-production-and-use-in-the-uk-nnfcc-10-009

[8] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/277436/feedstock-sustainability.pdf

Once the technology is established, by virtue of the negative price associated with the waste feedstock, **BioSNG facilities will be able to produce gas at current market prices**. More details on economic performance are given in Section 3.2.

2.1.3 The Demonstration being undertaken

The Project Partners will construct a facility that produces SNG from refuse derived fuel (RDF) and will deliver it to customers directly and via the gas grid. This will demonstrate to developers that the technology will operate reliably and that commercial plant technical performance, operating cost and capital cost can be accurately forecast. The Project will prove that the production can be sustained for long periods of continuous operation and is of sufficient scale to be used as a reference for large scale facilities.

The Project objectives are to:

- Demonstrate the production of 21.6GWhr of BioSNG per annum from a refuse derived feedstock. This will be the first plant in the world to produce SNG from household waste on a commercial basis.
- Provide an operating reference layout and show consents can be granted.
- Deliver the facility on budget and in accordance with the Project plan.
- Operate the facility under commercial operating conditions, demonstrating that using contracted feedstock, the plant can operate consistently and reliably to deliver GSMR quality gas to contracted customers via the grid.
- Demonstrate that commercially viable facilities will be able to achieve GHG savings in excess of 100% using BEAT 2 methodology.
- Disseminate the results of the Project and take other actions in order to enable the roll-out of large scale commercial facilities

The technical details of the facility are given in Section 2.2, along with further information in Section 4d on the previous development of the technology and the importance for commercial demonstration. The core element of the Project is expected to take approximately 35 months. A costed design and delivery plan have been agreed and the facility is expected to start commercial operations in January 2018 and deliver 19,800MWh by the conclusion of the Project in November 2018. The consortium expects to then continue to operate the plant for the following four years.

By operating at scale under commercial conditions, with commercial contracts in place for feedstock supply and gas delivery, the Project will generate important knowledge on the contractual, commercial and engineering issues associated with the technology. This will bring the technology to a maturity where full scale operational plants can be invested in as business as usual.

2.1.4 The solution(s) which will be enabled by solving the problem:

This Project is the key enabling step in deploying BioSNG to provide an important renewable solution for low carbon heat and transport. The commercial demonstrator will increase confidence in the production of BioSNG and this, along with the extensive programme of dissemination set out in Section 5, will enable the roll-out of BioSNG projects, not only by the Project Partners but also by other developers. The evidence from the facility will enable the roll-out of commercial projects at 330-660GWh/a (4100-8200m^3/hr) scale, which, as discussed in Section 3.2, could result in the production of

37TWh of BioSNG by 2030, which is equivalent to over 10% of current UK domestic heat or transport energy demand and up to 100TWh by 2050.

The production of 100TWh per annum of BioSNG will result in savings in excess of 30 million tonnes of carbon dioxide equivalent per annum if the gas is used to supply heat. This is a substantial saving compared with the current emissions of around 80 million tonnes pa from residential gas usage. For a typical household using 14MWhrs of gas per annum, savings will be 4.5 tonnes of carbon per annum.

If the gas is used for transport, savings in excess of 35 million tonnes of carbon per annum will be achieved by 2050. This shows that from a UK energy system perspective, either end use offers substantial carbon savings, and by 2050 could be a substantial contributor to carbon savings to meet the target annual emissions from energy of 100 million tonnes per annum[9].

As set out in Section 3.2, BioSNG provides a low cost route to decarbonisation by displacing fossil gas, reducing the requirement for electrification of heat and increasing the use of gas in transport. Independent analysis shows that it will reduce energy costs by £4 billion per annum by 2050 compared to the current baseline approach to meeting GHG targets.

2.2. Technical description of the Project

This Project builds on the extensive work carried out by the partners to date, as described in Sections 2.0 and 2.1.3, and the learning developed described in Section 6.4 particularly relating to the Pilot BioSNG facility. The process is described below.

The Project will construct a waste to BioSNG plant that will produce 2.9MWth (GCV) of gas from an input of 10ktpa of waste. Where possible, the processes used mirror those that will be used for commercial deployment of the technology. The initial design of the facility is set out in Appendix 4.

The proposed facility comprises three process blocks:

- Gasification - production of synthesis gas (syngas) from biomass-rich waste-derived fuels, followed by cooling, cleaning and polishing.
- Methanation - including chemical shift and methanation of the clean synthesis gas which are established technologies.
- Upgrading and distribution - ensuring product meets grid standards and injecting it into the grid.

Gasification

The first step in the process is the gasification of waste, in the form of Refuse Derived Fuel (RDF), to produce a syngas that can be used in the methanation process.

Baled RDF will be loaded onto a conveyor and delivered to a bale breaker. The liberated RDF is dried in a band drier and converted by a fluidised bed gasifier to crude syngas, rich in carbon monoxide and hydrogen (similar to the fossil-derived town gas used in the

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[9] http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/Future-Energy-Scenarios/

gas network until the 1970s). The gasifier uses high purity oxygen and steam, to prevent introduction of nitrogen into the system (which would be difficult to remove later on). The syngas exiting the gasifier includes high levels of contaminants, notably condensable hydrocarbons, heavy metals, sulphur and halogens. The syngas delivered to the methanation process must be free of such contaminants; removal is accomplished through the use of a plasma converter, which exposes the syngas to high temperatures and levels of excitation, reforming problematic species and allowing the constituent sulphur and halogens to be removed by conventional techniques, along with heavy metals. SNG projects elsewhere in Europe have identified organo-sulphur compounds and chlorine species as being particularly problematic; the plasma conversion step deals with these and breaks down tars and vitrifies the inorganic ash forming fraction.

After plasma treatment, the syngas is cooled in a heat recovery boiler and passed to a ceramic particulate filter dosed with sodium bicarbonate and activated carbon, removing volatile metals and reducing the acid gas content. An alumina bed hydrolyses COS species and a two-stage scrubber removes ammonia and residual acid gases. The gas is then compressed to 13bar, before a further carbon bed removes residual condensable hydrocarbons and heavy metals, and a zinc oxide guard bed provides final removal of sulphur compounds.

Because of this approach to dealing with contaminants, the process is able to use fuels that are unsuitable for other processes; the gasification technology has been tested on a range of feedstocks including MSW, RDF, solid recovered fuel, commercial and industrial waste, wood, landfill recovered waste, bagasse, corn stover, and used cooking oil, greatly expanding the commercial potential of the technology.

The basic gasification technology has been tested and technically proven at a pilot plant in Swindon. This has operated for more than 2,500 hours over the last eight years and has been used to develop solutions to technical problems, validate models of the process, optimise performance and build up operational experience. The gasification pilot plant processes 100kg of waste per hour, around one tenth the scale of the proposed Project.

Gasification pilot plant

Methanation

Methanation of fossil-derived syngas is well-established at large scales as is shown in the Great Plains Synfuels Plant[10].The Pilot Plant Project was designed to investigate the technical designs necessary for methanation at more moderate scales associated with biomass and waste. On-going engineering work by the partners has resulted in the construction and start of commissioning of a small scale technical demonstration facility producing around 50kW of BioSNG.

The methanation reaction requires a $CO:H_2$ ratio of 1:3. The syngas from the gasifier has an excess of carbon monoxide, so steam is introduced and the gas is passed through an iron catalyst water gas shift reactor, reducing the carbon monoxide content and increasing the hydrogen content. Different feedstocks produce syngases with different $CO:H_2$ ratios; the shift reaction can be 'tuned' to cater for different feedstocks.

Pilot Plant Project

The shifted gas passes through an integral downstream zinc oxide guard bed, before entering a succession of methanation reactors with nickel catalysts. A major challenge of methanation is the extremely exothermic reaction; in these reactors, the quantity of catalyst and the gas flow rates are carefully selected to ensure a controlled reaction.

Through their work to date, the partners have developed a methanation solution designed to operate at the scale required for BioSNG and provide the control necessary. Amec Foster Wheeler have also been identified as a potential supplier of the water gas shift and methanation stage, which they have demonstrated in Nanjing, China processing 1.3MW of coal syngas, which has operated for 200 hours since construction in 2014. Their approach is under evaluation by the partners with AFW as a potential supplier for this element of the Project. The positive experience that AFW have gained from their pilot significantly reduces the technical risks of the overall process.

Upgrading and distribution

The gas exiting from the reactors has significant quantities of CO2, which will be removed using a chemical scrubbing system, to produce a product that is high in methane content. Similar plants have achieved syngas-to-SNG conversion efficiencies of 76% and product gas purities of 96%.

[10] http://www.netl.doe.gov/research/coal/energy-systems/gasification/gasifipedia/great-plains

Part of the product gas will be compressed to 250 bar and then transported by road to Howard Tenens, who operate a local CNG filling station currently servicing 50 trucks using gas from the WWU grid. A significant proportion will be injected into WWU's gas network and sold, via a gas shipper and supply company, to CNG Services who will use it to fuel heavy goods vehicles including John Lewis vehicles at the Leyland CNG station. Use of the existing transmission network ensures continued utilisation of that asset and removes the need for investment in additional infrastructure.

The product gas will meet the Gas Safety Management Regulations requirements in terms of composition and Wobbe Index. If necessary, further upgrading through the addition of propane will be employed to meet the local target calorific value. The upgraded gas will have an odorant added and will be passed through a network compliant meter to check quality before being injected into the WWU network.

2.3. Description of design of trials

The commercial demonstration facility will provide a set of technical and commercial data which will be disseminated to enable the large scale roll out of the technology. The key performance indicators (KPI) are summarised in the following table.

Cold Gas Conversion Efficiency (CGCE)	The CGCE is defined as the ratio of the chemical energy of the cool, clean syngas to the energy content of the feedstock. Measurements from the Swindon plant and results of process modelling show efficiencies of 75-90% are achieved in the pilot plant. The target for the commercial demonstration plant will be 80%.
SNG Conversion Efficiency	The SNG conversion efficiency is the ratio of the energy in the SNG to the energy in the cool clean syngas. Experiment and modelling in the BioSNG project indicate this will be between 70-80% with an expectation of achieving 76%, as independently achieved in the AFW Nanjing pilot plant.
Parasitic Load	The main consumers of electricity in the process are the plasma converter and gas compression. In a commercial plant heat energy recovered from the process will be used to offset the parasitic energy demands. For operational reasons, the demonstration plant will not include this level of heat integration, but the energy flows will be monitored to substantiate the commercial position. The expected parasitic load of the demonstration plant is 15% to 25% of the thermal input with an expectation of 23%.
Availability	The plasma converter requires periodic maintenance to renew the refractory lining, and other equipment will require cleaning and routine maintenance. Once the demonstration plant is fully commissioned and ramped to full operation, the target overall availability is 85%, including unplanned outages.
Consumable Utilisation	The process uses chemicals (such as sodium bicarbonate to remove impurities from the syngas) and catalysts in the water gas shift and methanation processes that will require periodic replacement. The target cost of these is £0.2m per annum.
Injection of BioSNG to grid	The demonstration Project will establish that BioSNG is able to meet the stringent gas quality requirements to allow injection into the grid.

The design of the demonstration facility, set out in Appendix 4, includes appropriate meters and processes to capture each of these KPIs on a regular basis during the commissioning and operation of the plant. They will be reported to the Project Steering Committee each month with explanations of how the targets will be achieved. When appropriate they will be disseminated more widely.

These KPIs support the techno-economic models of the process and the large scale facilities that will be built as the technology is commercialised. If the demonstration plant achieves the target KPI values shown in the table above it will provide good evidence of the robustness of the model and confidence that the expected performance of large scale facilities will be achieved.

2.4. Changes since Initial Screening Process (ISP)

The objectives and vision of the Project remain unchanged. There have been some changes since the ISP was submitted relating to Project Partners, funding and costs.

Wales & West Utilities have agreed to join the Project as a Project Partner. They are the local gas distribution company at Swindon, and will connect the proposed facility to their medium pressure distribution system. The Project will help to realise their objective of making the process of connecting distributed gas from sustainable sources as easy as possible.

Following notification from Ofgem that the Project had passed the ISP:

- A site has been secured for the Project.
- Swindon Council has confirmed that planning permission for the facility will fall under a Local Development Order, a relatively simple process.
- Agreements have been reached for supply of waste from Swindon Borough Council and off-take of gas by Howard Tenens and CNG Services.
- Otto Simon has been appointed Construction and Project Manager for the Project.
- AFW has proposed a methanation solution for the Project using their Vesta technology.

The Project budget has increased from £21.1m to £23.1m. There has been a substantial amount of design work since the ISP submission including contributions from Otto Simon Ltd, who have been appointed Construction Manager. The increase is primarily due to the additional delivery costs that will be incurred through the use of Otto Simon but their experience substantially improves the likelihood of delivering an operational plant on time and on budget.

Section 3: Project Business Case

3.1 Network Licensee Benefits

Summary

The Project represents an important step on the journey to decarbonising the supply of heat and transport through the gas distribution networks (GDNs) which will help ensure their long term future. There will be substantial benefits to energy consumers from the displacement of fossil gas and transport fuels, avoidance of the costs of electrification and increased utilisation of GDNs. Independent analysis by National Grid's Energy Strategy and Policy Group values the benefits at £4bn per annum by 2050.

The benefits that flow from this Project are based on a successful commercial demonstration that leads to subsequent large scale projects coming to market. The work that will be carried out to use the demonstrator to enable large scale projects is described in Section 3.2.

Near Term Benefits

National Grid will realise benefits from the Project in the near term through public awareness and a reduction in costs.

Making best use of the gas network in a low carbon economy and supporting the use of renewable gas aligns with the NG vision, "Connecting you to your energy today and trusted to help you meet your energy needs tomorrow". NG stakeholders have said that they would like NG to focus on removing barriers for the development of renewable and other sources of gas, and to help educate stakeholders as to the future role of gas in a low carbon economy[11]. As custodian, NG is committed to safeguarding the network for future generations whilst playing its part in delivering a low carbon economy. This Project will play a key role in meeting stakeholder expectations.

The Project will lead to the roll-out of large-scale facilities, most of which will connect to the Local Transmission System and hence will result in lower NTS Exit Capacity costs for NG and other GDNs. This benefit would begin to be realised from 2020 when the first plants start operation as shown in the roll out plan in Section 3.2. If Exit Capacity Charges continued at their current levels the saving would be £6m per annum for NGGD by 2030 in addition to the wider benefits discussed below.

Long Term Benefits

The roll out plan set out in Section 3.2 forecasts 37TWh/a of BioSNG production in 2030, growing to 100TWh/a in 2050. The injection of this quantity of low carbon, sustainable gas into the UK energy system would result in significant savings. The expected impact is discussed in this section and the overall benefits are quantified in the following section.

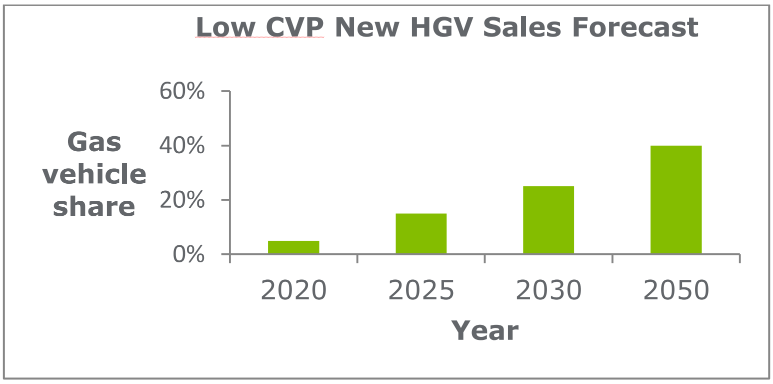
At the most basic level, the principal effect of the availability of BioSNG would be a reduction in the volume of fossil natural gas imported into the gas network. The evaluation in Section 3.2 shows that BioSNG prices will be below the expected fossil gas and carbon price. The 2015 Future Energy Scenarios[12] sets out an expected price for fossil fuel and carbon of £30/MWh compared to the £18/MWh for BioSNG resulting in a saving of £0.4bn by 2030 for this simple substitution.

BioSNG allows customers to reduce their carbon emissions without the need for any investment at the point of use. For example, the avoided costs for a typical customer in a three bedroom semi-detached house are at least £4,000 in appliance costs using a calculation based on costs from the 2012 ENA DELTA report[13].

[11] http://www.talkingnetworksngd.com/assets/downloads/2013_Committing.pdf
[12] http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/Future-Energy-Scenarios/
[13] http://www.energynetworks.org/gas/futures/2050-pathways-for-domestic-heat.html

The installed cost of a typical gas boiler is at most £2,570 while the equivalent sized air-source heat pump would cost £8,500 today, reducing to potentially £6,624 in 2040. If 100TWh of BioSNG were available this could potentially supply around 7m properties, which would not have to make this change, giving a direct benefit to gas consumers of £28bn or £1.1bn per annum spread over 25 years.

The Low Carbon Vehicle Partnership is forecasting[14] that gas vehicles will make up 40% of new heavy goods vehicle sales by 2050. The key drivers of the increase in share are the lower cost and carbon emissions of fossil natural gas compared to diesel. BioSNG greatly improves the carbon savings of natural gas and enhances its attractiveness over diesel.



Increasing the use of natural gas as a transport fuel has been identified as a strategic priority by NG. NG has begun to invest in new infrastructure, such as gas filling stations, to encourage transport customers to move to compressed natural gas. In 2012, goods and passenger vehicles used 13.6 million tonnes of oil equivalent[15] which is 158TWh or around 28% of domestic and industrial natural gas demand. If the Low CVP forecasts are correct transport will be one of the largest consumers of natural gas in 2050.

The additional demand that transport creates will increase the overall use of gas networks resulting in new revenues for NG and WWU. The higher gas flows will increase the cost effectiveness of the network, resulting in lower prices for customers.

The investment in new infrastructure and technology by Government, vehicle manufacturers, transport companies, and filling station operators that is required to move a significant number of vehicles from diesel to gas will only be made if stakeholders are convinced that gas is a sustainable, affordable, low carbon fuel. This Project demonstrates that large quantities of gas can be generated from sustainable sources cost effectively, providing evidence to stakeholders that gas can play an important part in the transport fuel mix far into the future. This will greatly increase the current adoption of fossil natural gas for transport.

Finally, use of BioSNG decarbonises the gas supply chain and therefore extends the life of the gas system. This avoids or reduces the potential need to decommission part or all of gas distribution networks, a cost largely ignored in most economic analysis. NG's high level analysis of the cost of decommissioning the gas distribution networks would be in the order of £8bn.

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14 http://www.lowcvp.org.uk/resource-library/reports-and-studies.htm
15 https://www.gov.uk/government/statistical-data-sets/env01-fuel-consumption

Quantification of Benefits

The Project Partners commissioned National Grid's Energy Strategy and Policy Group to independently quantify the benefit of BioSNG.

This group used the RESOM model, a cost optimisation tool which models the whole energy system in 5 year slices to 2050, to carry out the analysis. They selected the Gone Green scenario, set out in the 2015 Future Energy Scenario, as a baseline for analysis. This scenario assumes a high level of Government support for green policies, including electrification of heat and transport, and is likely to give a conservative view of the impact of BioSNG.

The impact of the availability of 37TWh/a of BioSNG in 2030 and 100TWh/a of BioSNG in 2050 has been considered, with costs based on the nth of a kind facilities set out in Section 3.2. The benefits were found to be a £0.5 billion p.a. saving over the base case in 2030 rising to £3.9 billion p.a. in 2050 due to avoided costs across the energy system and equating to cumulative savings of £46 billion by 2050 (Appendix 1). The majority of this benefit would be realised by gas customers and would represent a total saving per household of £282 over the period from 2030 to 2050.

Details of the modelling are provided in Appendix 2.

3.2 Project Partner Benefits

BioSNG technology has the potential to supply 100TWh of low carbon, sustainable substitute natural gas cost effectively by 2050. This will require the construction of more than 150 BioSNG facilities over the next 35 years but offers significant savings to UK energy users compared to the lowest cost proven alternative.

In order for the technology to be commercialised it must show the following:

- It must be technically proven.
- The business case must meet funders hurdle rates of return.
- Commercial risks must be mitigated.
- Companies must be motivated to develop facilities.

Overall, the Project Partners believe that the technology is extremely well placed to achieve widespread adoption and make a strong contribution to the decarbonisation of heat and transport but appreciate that achieving this will require ongoing efforts to promote BioSNG to stakeholders.

Demonstrated Technical Readiness

The evidence from the Swindon gasification pilot plant, the Amec Foster Wheeler methanation pilot plant, and work to date on the BioSNG Pilot Plant project shows that the production of BioSNG is feasible. The long history of production of SNG from coal and other fossil fuels shows that commercial SNG plants can operate successfully. However, stakeholders are very risk adverse and require more evidence on the performance of the BioSNG technology.

The Project will directly address this issue by demonstrating the production of 21.6GWh/a of BioSNG in a commercial environment.

Provide Business Case Confidence

The Project Partners have been developing the techno-economic model for commercial facilities since 2010. Three commercial facilities have been modelled:

- A first of a kind (FOAK) facility producing 310GWh of gas from 60MW of waste.
- An nth of a kind (NOAK) facility producing 328GWh of gas from 60MW of waste.
- An nth of a kind (NOAK) facility producing 658GWh of gas from 120MW of waste.

The model results are summarised in the following table. More detail is provided in Appendix 8.

	Input		**Commercial**		
		Demo	**FOAK**	**NOAK**	**NOAK**
Gas produced	GWh/y	**22**	**310**	**328**	**658**
		£m	**£m**	**£m**	**£m**
Post-tax real project return		0%	14%	10%	10%
Gas price	£/MWh	20.0	21.0	26.0	18.0
Revenue		1.6	25.8	18.7	32.3
Costs		(2.1)	(10.2)	(9.0)	16.5
Profit/(loss) per year		(0.5)	15.6	9.7	15.8
Capex		23.1	107.9	96.3	150.7

Evidence from the Government studies[16] show that first of a kind technologies supported by intermediate scale commercial demonstrators have hurdle rate of project return of 14%. First of a kind BioSNG plants can achieve this with the levels of Government support available under the Renewable Heat Incentive.

Current waste to energy facilities, which represent established nth of a kind technologies, have hurdle rates of 10%. The 658GWh facilities can achieve this return if the gas price is £18/MWh while smaller 328GWh facilities require a gas price of £26/MWh.

DECC forecasts[17] suggest that the gas price should remain above £18/MWh for the foreseeable future which means that the large plants should be able to attract funding. The central DECC forecast suggests prices will reach £26/MWh in 2029 and smaller plants will be able to operate without any support when this occurs.

Addresses Commercial Risks

As a result of the losses incurred in the financial crisis of 2008, aversion to risk from banks and other funders increased significantly. Lack of liquidity meant that funding was not available for any project for several years and more recently, as liquidity has returned to the market it has become clear that it is extremely challenging to obtain funding for projects that involve technical or commercial risks. This conservatism is now

16 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/267606/NERA_Report_Assessment_of_Change_in_Hurdle_Rates_-_FINAL.pdf

17 https://www.gov.uk/government/publications/fossil-fuel-price-projections-2014

reflected in the attitudes of project developers, waste operators and gas supply companies.

This Project directly addresses the risks of developing, funding or operating a BioSNG facility as shown in the following table. It will:

- Show the technology operates on a full time basis at scale.
- Prove the quality of the gas.
- Provide a reference for Engineering and Operations contractors to use in developing proposals for larger facilities.
- Show that regulatory issues such as planning and permitting can be handled.

The evidence and learning that will be generated from the demonstration plant will ensure that the risks associated with the technology should not form a significant barrier to its adoption.

Enables Commercialisation

There will be two parallel streams aimed at commercialising the BioSNG technology in addition to the development of the commercial demonstrator. The first will focus on the development of a single, fully commercial plant by some of the stakeholders in this Project and the second will focus persuading other developers to construct a plant.

The development activity will start in 2017 and aim to begin construction of a large scale, commercially funded plant by 2020. This will act as an example to other developers that the technology represents a good investment.

The second stream will be to persuade project developers to begin development of BioSNG facilities. The key activity to achieve this is the communication of project results which is described in Section 5 but will also involve direct engagement with stakeholders.

Resultant Forecast Roll-Out of Technology

The expected initial roll-out of large scale commercial plants is shown in the following table. Demand will be driven by the strategic need for low carbon heat and transport fuels.

	2020	2021	2022	2023	2024	2025
UK						
328GWhr	2	3	3	2	2	2
658GWhr				1	1	1
Overseas						
328GWhr		1	2			
658GWhr				2	3	4
Total	2	4	5	5	6	7

By 2025, BioSNG will be a mature technology with a large number of references supplied by multiple companies. At this point the adoption of the technology is expected to accelerate as it will offer the best returns for waste treatment. By 2030, it is expected there will be 56 large scale plants in operation producing 37TWh/a of BioSNG.

In 2050, BioSNG plants are assumed to have saturated the market and will use the majority of available feedstock. This will result in 100TWh/a of production.

Section 4: Benefits, Timeliness, and Partners

The Project will facilitate the commercial deployment of renewable gas which can exploit the UK's existing world class gas distribution and transmission system to deliver low carbon heat and transport fuel. Through a demonstration plant operating under commercial conditions at near commercial scale, this Project will catalyse deployment of technology by addressing the delivery risks to enable roll-out. This approach is able to make a timely contribution to meeting the UK's 2020 renewable energy targets and become a significant element in the wider low carbon heat and transport targets in 2030 and 2050.

The Project is founded on a strong consortium whose partners have collaborated together over the last four years and who have an effective track record of delivery. To deliver this Project, the consortium is augmented by two further expert companies, and comprises a delivery team including two gas distribution companies demonstrating commitment to wider network roll-out and the benefits of the Project to other Network Licensees. Funding from NIC is leveraged by a factor of four through the Department for Transport and partner contributions to deliver excellent value for money for the gas consumer.

The following sections outline the benefits, timeliness and Partners in the form required by the Governance Document. The paragraphs describing how the Project is innovative (Section d) and the partners (Section e) are particularly important elements for this Project.

(a) Accelerate the development of a low carbon energy sector and/or delivers environmental benefits whilst having the potential to deliver net financial benefits to future and/or existing customers

i) How the Project could make a contribution to the government's current strategy for reducing greenhouse gas emission, as set out in the document entitled 'the Carbon plan' published by DECC

What aspect of the Carbon Plan the Solution facilitates

The Carbon Plan[18] provides a comprehensive review of what is required across many sectors to achieve UK Carbon targets. BioSNG directly contributes to the following aspects of the Carbon Plan:

- Low carbon heating – renewable gas is a low impact approach to reducing carbon emission from heat.

18 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/47621/1358-the-carbon-plan.pdf

- Low carbon transport – BioSNG offers a cost effective route to decarbonising heavy good vehicles.
- Low carbon industry – BioSNG can directly substitute for fossil natural gas.
- Reduction in emission from land-filling of waste.

The Carbon Plan identifies a need for low carbon heat delivered through networks and identifies biomethane as the least disruptive technology. Similarly the more recent Heat Strategy[19] identifies biomethane injection, utilising the grid to provide a low carbon solution direct heating use, but also in the wider energy system.

However, the Carbon Plan recognises that anaerobic digestion can only meet a proportion of heat and transport demand, particularly after allowing for competing demands for digestible biomass. Thermal gasification can produce BioSNG from feedstocks such as mixed general waste or lignocellulosic material that are unsuitable for anaerobic digestion, expanding the overall contribution that low carbon substitute natural gas can make.

<u>The Contribution the roll-out of the Method across the GB can play in facilitating these aspects of the Carbon plan</u>

The roll-out of the method will result in the use of low carbon BioSNG for heating, transport and industry and reduction in the volume of waste sent to landfill. A forecast of the roll-out is presented in Section 3.2 and this predicts 37TWh/a of BioSNG will be produced in the UK by 2030. Adoption is expected to accelerate after this date until the full 100TWh potential described in Section 2.1.2 is produced by 2050.

<u>How the roll-out of the proposed Method across GB will deliver the Solution more quickly than the current most efficient method in use in GB.</u>

As the roll-out of commercial BioSNG plants is not dependent on consumer behaviour change and does not require additional network infrastructure it has the potential to accelerate the move to low carbon heat quicker than electrification of heat or the development of heat networks. In terms of transport, there are already a number of CNG filling stations operating and being developed, initially operating on CNG, but which could contract for SNG across the network.

(ii) If applicable to the Project, the network capacity released by each separate Method:

Not directly applicable to the distribution network. The roll-out of the method could, however, potentially release capacity on the NTS if plants are connected on the distribution networks. This would be evidenced by reduction in capacity bookings and would need to be calculated on a case by case basis.

(iii) The expected environmental benefits the Project can deliver to Customers:

This is a particular important aspect of this Project, as outlined in Section 2, with the primary benefits being substantial carbon savings. An independent report assessing the GHG emissions from the BioSNG process for heat and transport was produced by

19 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/190149/16_04-DECC-The_Future_of_Heating_Accessible-10.pdf

NNFCC[20]. In this report, the emissions have been calculated using the BEAT2 and EC RED methodologies. BEAT 2 includes alternative disposal of the feedstock to landfill and therefore provides a greater GHG saving than EC RED, accounting for the significant difference in emissions observed between the two methodologies.

As shown in the table below, the greenhouse gas savings over natural gas for heat have been assessed to be either 127% (BEAT2) or 66% (RED). For a typical household using 14MWhrs of gas per annum, this equates to a saving of between 2.2 and 4.5 tonnes of carbon per annum.

If the gas is used for transport, the savings are assessed at either 123% (BEAT2) or 74% (RED). For a typical vehicle using 250MWh per annum, this will result in a saving compared to diesel of 60 tonnes of carbon per annum.

Methodology	BioSNG	Fossil Fuel	Total saving at 37TWh pa in 2030	Total saving at 100TWh pa in 2050
	kg CO_2 eq/MWh	*kg CO_2 eq/MWh*	*mte CO_2 eq pa*	*mte CO_2 eq pa*
Heat (Natural Gas base case)				
BEAT2	-68	+251	11.8	31.9
RED	+83	+243	5.9	16.0
Transport (Diesel base case)				
BEAT2	-61	+299	13.3	36.0
RED	+78	+299	8.2	22.1

This shows that from a UK energy system perspective, either end use offers comparable carbon savings, and by 2050 could be substantial contributor to carbon savings against the annual energy emission target of 100 million tonnes.

It should be noted that this process also provides transport and storage ready CO_2. Subject to available infrastructure, the use of Bio-CCS would result in 'negative' carbon emissions, substantially augmenting the environmental benefits, and demonstrating Bio-CCS a key plank of the wider 2050 Carbon strategy.

(iv) The expected financial benefit the Project could deliver to Customers

The roll-out of BioSNG is substantially more cost effective than alternative pathways to decarbonising heat and transport and will result in savings in the overall energy system that will be ultimately reflected in customer bills. These benefits are discussed and quantified in Section 3, showing a saving of £4bn per annum by 2050 and a cumulative benefit by this time of £46bn.

[20] http://www.nnfcc.co.uk/tools/analysis-of-the-ghg-emissions-for-thermochemical-biosng-production-and-use-in-the-uk-nnfcc-10-009

(b) Provides value for money to gas/electricity distribution/transmission Customers

i. How the Project has a potential Direct Impact on the Network Licensee's network or on the operations of the GB System Operator

This Project has a potential direct impact on all GB gas networks. If successful, it would pave the way for follow on plants at commercial scale that could be connected to anywhere on the GB gas network. It is notable that this Project already entails collaboration between two Network Licensees companies: National Grid and Wales & West.

ii. Justification that the scale/cost of the Project is appropriate in relation to the learning that is expected to be captured

The scale and cost of the Project is low compared to the learning and the potential benefit that learning could deliver. The £5.4m of NIC funding facilitates a readily adoptable low carbon heat delivery and transport solution, which, as shown above could save gas customers billions of pounds compared with alternative low carbon energy scenarios. A demonstration project operating under commercial conditions at scale is vital to enable this. The pilot project already undertaken provides the foundational technical platform, however organisations such as the Green Investment Bank, Linde and Veolia have made it clear there are insurmountable barriers to supporting a commercial BioSNG development without carrying out due diligence on a plant operating on a continuous basis at a significant scale. This is required to demonstrate that a commercial-scale plant can be built within budget and operate reliably.

The requirement for a commercial demonstration unit is evidence by other successful gasification technologies used by companies such as Enerkem, Nextera and Energos that have used medium size facilities as a stepping stone to fully commercial plants, typically within ten times scale up of final commercial plants. The DfT have also recognised this, by setting their target scale for a commercial demonstrator to be in excess of 1 million kg of gas per annum, which is what this Project provides.

iii. The processes that have been employed to ensure that the Project is delivered at a competitive cost

The cost will enable a major increase in the amount of low carbon substitute natural gas in the network and represents very good value for money for the overall impact it will have.

The overall budget leverages work carried out in the on-going Pilot Plant Project and the experience of the Project collaborators. The extensive work carried out under the Pilot Project has enabled significant progress already on the commercial demonstration plant design, and crucially the commercial position to ensure that everything from feedstock through to end customer is in place and risk managed. This substantially reduces risk and cost to the Project.

The partners have a track record of collaborating effectively together. Construction of the pilot facility has been managed effectively within budget and delivering on a very tight timeframe. A similar disciplined approach to project and budget management is proposed.

The Project budget includes a significant amount of 3rd party expenditure on equipment. This will be procured through a competitive tender process to ensure the lowest price is achieved. The management of the internal costs of the Project collaborators will follow the same approach that has been used in the Pilot Plant Project to ensure they are proportional to the work involved.

The Funds provided by the Network Innovation Competition are geared by a factor of four through other funds. The Department for Transport is expected to fund the majority of Project costs through its Advanced Biofuels Competition; this together with a substantial contribution from one of the partners (APP) provides excellent value for money for the network. There will be some additional costs in meeting the requirement to produce BioSNG for injection into the gas network compared with the requirements for DfT, but the Project will, as a result, demonstrate both the use of BioSNG for domestic heat and as a transport fuel. This will show the grid's ability to be an efficient method of delivering heat and future transport fuels, benefitting all users.

iv. What expected proportion of the potential benefits will accrue to the gas network as opposed to other parts of the energy supply chain, and what assumptions have been used to derive the proportion of expected benefits

Currently the revenues associated with the use of the gas network account for around 18-20% of the total gas price to consumers, and it is expected that this proportion is likely to remain approximately the same into the future. As noted in 3.1, it is anticipated that the main benefits of BioSNG will be seen in the reduced need to develop alternative, more expensive low carbon sources of energy for heat and transport.

However, the main benefit to the gas network from BioSNG is that it underpins its continued utilisation. By providing a low carbon energy, deliverable over the existing network, the gas network itself, with an asset value of around £25bn, retains its importance in the wider mix of low carbon heat solutions. In future, the ability to exploit the network as a fuel distribution system for transport provides a new business opportunity for the gas networks. Ultimately the distribution of transport fuel using a pipeline offers clear benefit over road hauled tankers.

v. How Project Partners have been identified and selected including details of the process that has been followed and the rationale for selecting Project Participants and ideas for the Projects

This is covered in more detail in Section (e) below. In summary, this is a mature project which National Grid has been pursing through development over the last four years, having first identified renewable gas as a key strategic development area prior to that. Progressive Energy and CNG Services provided an independent assessment of the prospect of BioSNG in 2010[21] . NG acted on this, and sought out an existing provider of syngas to pilot the technology. Through this process Advanced Plasma Power was identified as the only UK based provider of existing, high quality syngas as a precursor

[21] http://www.cngservices.co.uk/assets/Bio-SNG-Feasibility-Study.pdf

vi. The costs associated with protection from reliability or availability incentives and the proportion of these costs compared to the proposed benefits of the Project.

The Project has no impact on reliability or availability incentives.

(d) Is innovative (i.e. not business as usual) and has an unproven business case where the innovation risk warrants a limited Development or Demonstration Project to demonstrate its effectiveness

i Justification for why the Project is innovative and evidence it has not been tried before;

The Project is innovative, untested anywhere at the scale and under the commercial conditions proposed and new learning will arise from the Project.

There are examples of very large scale methanation facilities from coal, such as the Dakota Synfuel Plant, but the only 'biomass scale' SNG projects being developed by others operating on renewable feedstock are pure biomass plants, such as a pilot facility at Gussing with a phased commercial plant in Gothenburg. The key innovation in this Project is the use of a waste derived feedstock which contains contaminants, such as heavy metals or chlorine, and has a variable composition.

The elements of the Project which have never been proven before are:

- Construction of the full chain SNG process with all the interfaces between process elements on budget and to schedule.
- Conversion of commercially contracted conventionally processed waste to a substitute natural gas
- Demonstration of safe and reliable operation under commercial conditions and compliance with Environment Agency permitting requirements.
- Plant availability and operation over a protracted period with sufficient consistency to form the basis for commercial contracting for the product.
- Upgrading of the SNG to GSMR grid specification and physical injection into the gas grid, specifically:
    - Physical demonstration of meeting the metering requirements, instrumentation, and in particular the contractual arrangements, as well as meeting the gas flows and pressure requirements under actual operational conditions.
    - Physically meeting the regulatory requirements for gas export under commercially operating conditions to the satisfaction of the Health and Safety Executive and Ofgem.

A key element of this Project is demonstration of successfully managing the interdependencies between commercial waste contracts, the performance of the plant and the requirements of the network to which it is connected. It is therefore essential that this Project is delivered by a partnership of distribution companies as well as project developers, enabled by Network Innovation Competition funding.

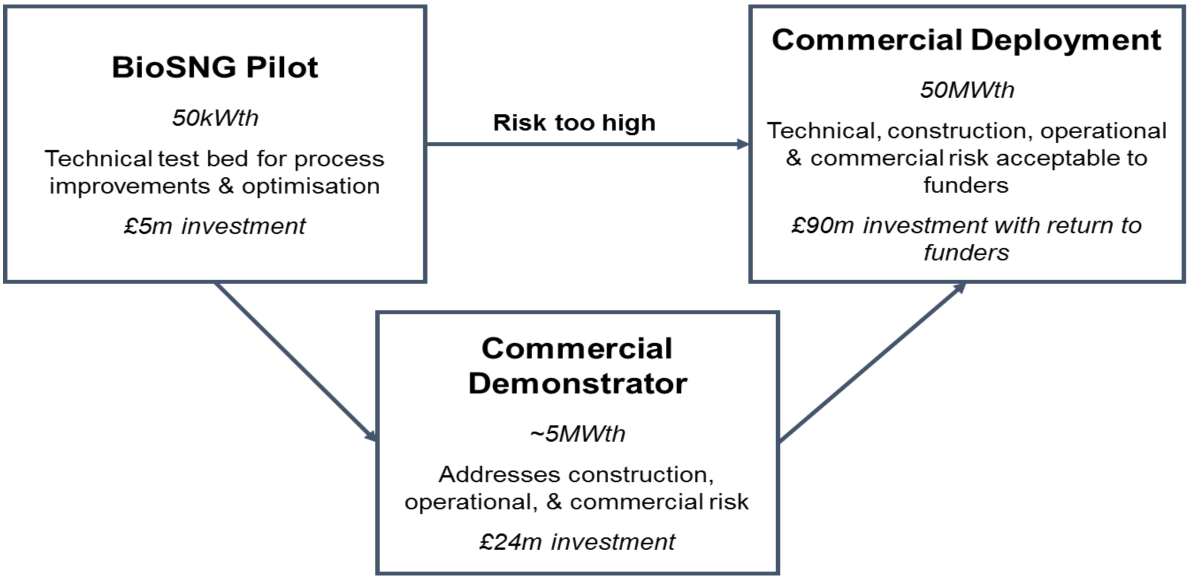
ofgem RIIO NIC NETWORK INNOVATION COMPETITION

ii. Justification for why the Project can only be undertaken with the support of the NIC, including reference to the specific risks (e.g. commercial, technical, operational or regulatory) associated with the Project.

There are no routes for National Grid to commercially benefit directly from the development of this technology, so they would not invest in this Project as part of its normal course of business.

The Project will not provide a return to its funders. Revenues from accepting waste and selling gas will cover the majority of the operational costs of the plant, but the plant will make a loss so unrecovered capital investment is required. The case for this investment cannot be made under business-as-usual conditions.

Any single company is unable to fully capture the benefits of the future plants. The Project would enable a number of companies to develop and benefit from BioSNG, including the Project partners but the rewards to any single company would be insufficient to enable them to fully fund the costs. The contribution from NIC is required because it bridges this gap.



This is a demonstration project, developed to provide the key enabling step to commercialisation, as shown in the figure above. The important role of the existing pilot plant is addressed more fully in Sections 6.4. The proposed Commercial BioSNG Demonstration Plant is intended to address key construction, operational and commercial risks. Construction of the facility will demonstrate that the design and contracting approach can be delivered on budget and to schedule, that the facility can operate on a commercial basis, taking conventionally processed waste under contract and deliver gas both to the grid and to end customers consistently to specification and against a commercial contract. These are vital pre-requisites to providing confidence in deployment of commercial scale projects as described in Section 3.2. The scale of the demonstrator has been selected to be within a factor of twelve of commercial scale, a balance between providing investor confidence and minimising capital outlay.

The key risk to a successful outcome from the Project is the level of Government support available to BioSNG plants. Initially, commercial plants will need support in order to compete with fossil natural gas. The Government will need to maintain its commitment to the sector through the Renewable Heat Incentive (RHI) for the carbon savings expected from the Project to be achieved. Project partners have been and continue to engage with DECC to demonstrate the importance of maintaining support.

Support also needs to be provided for SNG which is used as a transport fuel. The DfT has demonstrated its support for advanced biofuels through the recent competition, which complements the Renewable Transport Fuel Certificates (RTFCs), with advanced biofuels such as waste derived BioSNG receiving enhanced support. Currently this only supports direct delivery and does not support supply of transport fuel over the gas grid, but a key outcome of this Project is to demonstrate the benefits to the transport industry as well as UK consumer more generally of capitalising on this world class transmission and distribution network. This engagement is directly and via biomethane working groups within the Renewable Energy Association covering both heat and transport applications. By 2025, full scale BioSNG plants are expected to be fundable without support.

(e) Involvement of other partners and external funding

Partners

This Project is necessarily collaborative, drawing together the skills and experience of companies and personnel who are expert in their field, grounded on a proven core partnership for delivery.

As early as 2008 National Grid identified Biomethane as an important vector in delivering renewable heat and transport using the existing gas grid. In collaboration with Centrica, NEPIC and CNG Services, they initiated a feasibility study undertaken by Progressive Energy into BioSNG as means to augment substantially the volumes of biomethane available from conventionally produced Biogas from Anaerobic Digestion.

Following the success of this project, National Grid retained Progressive Energy to act as advisors as to how take this feasibility study on to enable deployment. Through this process Advanced Plasma Power (APP) was identified as the only existing provider in the UK of waste-derived syngas of sufficient quality to enable downstream methanation. Whilst initially, it was anticipated the partners would simply contract for syngas, APP wished to collaborate more actively, significantly enhancing the strength of the Project and providing a more coherent integrated solution. National Grid, Progressive Energy and APP formed a collaborative consortium which led to the construction of the current pilot plant.

This foundational core team has been augmented by CNG Services and Wales & West Utilities to deliver this commercial demonstration plant. CNG Services has unparalleled experience in both facilitating grid connection of biomethane facilities, as well as provision of offtake contracts for gas, including via filling stations for transport applications. Wales & West Utilities is the local gas distribution company, and this NIC proposal includes two gas distribution companies in collaboration, providing a platform for wider roll out and deployment across the networks.

Details on Project Partners are given in Appendix 9.

External Funding

The funds provided by NIC are geared by a factor of four through other funds. The Department for Transport is expected to provide the majority of Project costs through its Advanced Biofuels competition. The balance is provided by the Project Partners, in particular by APP and its shareholders who have committed to support this Project. This provides excellent value for money for the network.

The objectives of the DfT project and this Project are similar, but not completely identical. The DfT project aims to produce a transport fuel and demonstrate its direct use in vehicles. Whilst in the longer term the gas grid provides an excellent fuel distribution system for BioSNG, this is not something required or envisaged to fulfil DfT's requirements at this stage. Conversely OFGEM and the gas distribution companies have an interest in seeing value for customers by expanding the use of the Gas Grid whether for transport fuels, or simply as delivering renewable heat.

Compared with direct supply to vehicles, small scale injection to the grid is technically and commercially more complex. The specifications for UK grid quality gas are more onerous than the requirements for vehicles and differ in some key respects. In particular, the calorific value required for the grid requires addition of propane to the gas product which reduces the methane number of the gas, which is a target for vehicle use. The transport of gas by the grid requires the additional costs associated with a grid connection, quality monitoring and assurance and the involvement of a gas shipper and supply company. These result in additional capital and operating costs associated with a grid connection.

A major source of revenue for the Project is renewable transport fuel certificates which provide support to renewable fuels. These are not currently available for gas that is transferred via the grid and the equivalent support for gas injected to the grid is not available because the project is funded through a Government grant. This means that injecting gas to the grid reduces the revenues of the project significantly.

The Project Partners recognise that the grid will represent the most cost effective method of distribution BioSNG as the technology rolls out and that it is important to demonstrate the use of the grid as part of the commercialisation of the technology. In order to provide confidence in the technology, it is vital to show that the contaminants present in waste can be successfully removed in the production of BioSNG, and that it can meet GSMR standards for long periods by actual injection to the grid.

The NIC funding will contribute to the capital costs, operating costs and loss of revenues from adding grid injection to the DfT project. More importantly, it will be making a contribution the establishment of a technology that will result in enormous benefits to grid users.

(f) Relevance and timing

The Project aims to solve one of the key environmental challenges the gas sector faces. Gas provides 80% of GB heat demand today through the most extensive gas network in the world. Whilst there is a long term need for gas for seasonal heat as identified in the

DECC Heat Strategy, the role of fossil-derived natural gas will need to diminish if environmental targets are to be met. If more renewable or low carbon gas can be piped through the gas network then the life and utilisation of the network can be extended. BioSNG has the potential to provide that low carbon gas supplying secure low carbon heat to millions of homes and businesses in a cost effective manner. Low carbon gas could play an important role alongside other technologies such as CCS, gas heat pumps and hybrid heat pumps in ensuring the heat and energy we derive from gas has the lowest carbon footprint possible.

DECC have targeted 7TWh from renewable gas as part of its plan to meet the 2020 renewable energy targets. Biogas from AD has an important role in meeting this target, and is forecast to deliver around over 3TWh/a by 2017[22] from over 50 projects. However BioSNG has the potential to augment biomethane production substantially. The demonstration Project itself will be operating and contribution to this target, with commercial projects delivering between 280-560GWh per annum. If enabled now, early projects will be contributing material renewable gas supplies in the early 2020s, further delay would significantly hinder roll out, and thus lead to a significant shortfall in renewable heat production.

The expected short term roll out both in the UK and internationally is given Section 3.2 and would result in 37TWh of SNG injected into the UK grid in 20305, over 10% of current domestic demand. Ultimately this route provides an important pathway to meet the 2050 carbon targets through roll out over the following 25 years.

In relation to the wider energy debate, there are discussions with Government and the wider industry around the long term role of gas networks and it is likely decisions will need to be made about the future approach to gas networks within this RIIO period. This project will inform those discussions through demonstrating the potential for low carbon gas via BioSNG.

Section 5: Knowledge dissemination

5.1. Learning generated

The Project will generate a significant amount of incremental learning. This knowledge will be disseminated to other Network Licensees and organisations such as BioSNG project developers, waste companies and policymakers to ensure it has an impact on the amount of renewable gas injected into the network.

The technology underlying the Project is addressed in the ongoing Pilot Plant Project and it is not expected that there will be any significant new technical knowledge generated by the Project. However, the Project will demonstrate at substantial scale that grid quality natural gas can be produced from waste on a full time basis, reinforcing the learning from the Pilot Plant Project. Stakeholders in the development of the technology require a large scale demonstration in order for them to accept technology risk.

The Project will provide new commercial learning arising from the construction and operation of the facility. This covers the following:

- The cost, timescales and contracting structure of constructing the facility.

[22] Biomethane Day, Birmingham 15th June 2015 John Baldwin

- The performance guarantees that could be provided for the facility.
- The waste and feedstock contracting structures.
- The revenues and costs of operation of the facility.
- The grid network entry agreement and the costs of complying with it.

This learning will be applicable to all full scale commercial facilities which use thermal processes to generate BioSNG, informing their integration into the local network, whichever Licensee operates it.

There will also be new learning on the operation of the facility. This will cover important areas such as:

- Safe operation of the technology at a large scale.
- Roles, responsibilities and procedures for plant staff.
- Meeting environmental and planning conditions.
- Automation of plant operation.
- Maintenance routines.

Each of these must be well understood to enable large scale plants to be developed.

Overall, the Project will produce the learning required to move the technology from a small scale pilot facility (TRL4-6) via a demonstration plant (TRL 7-8) to a process that is able to be implemented at large scale on a fully commercial basis.

5.2. Learning dissemination

5.2.1 The audience

The audience for knowledge transfer is shown in the following table.

Project Developers	Widespread deployment of BioSNG requires companies to secure sites, agree feedstock and fuel supply contracts, engage with contractors and obtain funding for commercial facilities. These developers may be large waste, property, gas supply companies or small independents. In each case they will require evidence that each of the elements of the development can be achieved with minimal risk.
Funders	In most cases BioSNG facilities will require the support of banks and other finance providers. Funders require a reference facility to show the technology can work at scale and detailed evidence to support the business case for the plant they are funding.
EPC contractors	Commercial facilities will generally require large engineering, procurement and design contractors who are willing to provide fixed price contracts with performance guarantees. These contractors require a large scale reference site to allow due diligence to be carried out and robust evidence of the cost of constructing a plant using industry standard approaches to delivery.
Operating contractors	Some commercial facilities will require operating contractors able to run the plant for a fixed price under contracts with penalties for failure to achieve operational targets. These contractors require evidence of the costs of processes of running a similar facility.
Policymakers	Deployment of renewable technologies requires an appropriate

	policy environment. Governments and Government agencies require reliable evidence of the costs and performance of technology in order to make policy decisions.
Gas network owners/operators	The gas produced by the plant will meet the appropriate standards but compositions and volumes will differ significantly to the gas currently injected into the UK grid and network operators will need to formulate appropriate technical and commercial solutions for accepting it. Data from the operation of the facility will be used to define these solutions.
Competing equipment manufacturers and the supply chain	Suppliers of alternative gasification and methanation solutions and the wider supply chain will be keen to provide solutions to commercial facilities. The knowledge from the Project will increase confidence in all BioSNG technologies.
Academic Institutions	Academic institutions provide a useful channel to disseminate knowledge more broadly and have influence on policymakers and project developers. Data from the operation of the facility will provide institutions with an opportunity to calibrate technical and economic models of the process and commercial results will help develop academic work on energy and greenhouse gas infrastructure and policy.
Customers	The facility is designed to inspire consumers, communicating the carbon benefits of converting discarded waste from their own local area to low carbon renewable gas being delivered through their local gas distribution network.
Schools	Engaging young people in the issues associated with energy supply and its carbon implications, as well as resource stewardship is vital. This not only educates future consumers regarding choices they will make, but also inspires the next generation of scientists, technologists and energy professionals. The facility will be a tangible and exciting means to inspire their interest. National Grid has an active programme to provide engaging and informative material relevant to the National Curriculum.

5.2.2 Knowledge Capture

Capturing knowledge is an important facet of any programme such as this. The Consortium members are experienced in the capture of knowledge through previous projects including those supported by the Technology Strategy Board, the Energy Technology Institute as well as government departments such as DECC and BIS. Capture will be achieved through the work programmes, recorded using a regular reporting structure, and provide the basis for follow on dissemination as described below.

5.2.3 The means of dissemination

Dissemination of the knowledge gained from the Project is essential for the Network Licensees and the Project partners in order for them to benefit from the Project. The primary objective of the Project is the roll out of large scale commercial plants and this will only be achieved if the knowledge is disseminated widely.

A supplier and technology neutral brand – Go Green Gas – has been developed in the current Pilot Plant Project to promote the technology. A website domain has been secured and logo developed. This brand will continue to be used in dissemination activities.

gogreengas

www.gogreengas.com
(domain secured)

The channels for disseminating knowledge are set out in the following table.

Facility	• The most valuable method of disseminating knowledge. • Visitor centre will provide simple explanation of the knowledge gained from the Project. • Tours will be organised to provide more detail. • Stakeholders requiring more detailed information will be able to carry out detailed due diligence.
Branding & Messaging	• To provide an entity for the Project that various audiences can relate to. • Alignment of all gogreenfuels communication, including website, brochures, letterheads etc.
Time-lapse Video	• A video which provides a time-lapse of the gogreenfuels plant build. • This will bring the Project to life and can be used on websites, social media and for the visitor centre.
PR & Lobbying	• Articles secured in appropriate publications, including industry, national and international. • PR & Lobbying activities as required to appropriate Influencers.
Project Website	• A Project website to highlight the key Project benefits to corporates such as: petrochemical, transport fuels, large waste companies etc. • Project website will use the secured domain of www.gogreengas.com. • The site will be professional and will provide the business case for investing in the technology as well as the confidence in the general demand for green transport fuels and the reliability of the technology. • The site will reflect the gogreengas branding and will provide an area for enquiries to be generated. • The website will also be accessible and informative to the general public and will contain high-level information relating to, for example, the environmental benefits.
Image Development	• The development of an image library which can be used for PR, literature and website as well as Project reports.
Literature Development	• Development of literature such as factsheets, flyers, brochures to help communicate the Project to the various audiences.
Formal Document Support	• Project update reports and presentations.
Newsletter Development	• Development of Project newsletter to be disseminated electronically, which will provide updates on the Project to interested parties, website subscribers etc.
Events	• Speaking engagements at targeted conferences, in order to raise the profile of the Project to various stakeholders,

	peers, academia and corporates. • Events such as Sustainable Transport and Alternative Clean Transportation "ACT" Expo will be targeted.
Whiteboard	• A hand drawn animated story depicting the need for gogreengas and the process. • Easily understandable video for all audience types.
Animated process diagram	• Interactive diagram to communicate the gogreengas process.
Whitepapers/technical papers	• Aimed mainly at the technical audience such as academics and the technical divisions of the end users, whitepapers will provide more in-depth detail about the technology and the process.

The communication methods will be tailored to the target audience. For example, communication to academics will use journals and academic events while communication to the general public will rely on the website and press.

5.3. Intellectual Property Rights

NG, WWU, the other Project partners and other participants in the Project will conform to the default IPR arrangements set out in Section 9 of the Gas NIC Governance Document. The definitions of Project Partners, Project Participants, Project Suppliers, Foreground IPR, Background IPR, Relevant Foreground IPR, Relevant Background IPR and Commercial Product are taken from that document.

This will be achieved through the following agreements:

- The Project Partners will contract to meet the default arrangements through the Project collaboration agreement.
- The contracts for supply of services and equipment with the Project Suppliers will incorporate the relevant IPR terms and conditions from the Governance Document under the assumption that any Background IPR they contribute relates to a Commercial Product.
- The waste supply and fuel off-take agreements will include relevant Governance Document arrangements.

These agreements will cover all Project Participants with relevant Background IPR or who will be involved in the creation of any Foreground IPR. The only participant who will not agree to conform to the default arrangements is the Department for Transport. However, their involvement is limited the provision of funding and they will not contribute any Background IPR or be involved in the creation of any Foreground IPR, nor have required any rights to IPR more generally.

The approach to producing BioSNG used in this Project requires Background and Foreground IPR owned by Project Partners and Project Participants. However, other approaches are possible using commercially available technologies based on IPR owned by other organisations. For example, Advanced Plasma Power's gasification technology will be used in the Project but other gasification technologies such as those supplied by AlterNRG, Chinook or Europlasma could be used in other BioSNG plants. It is expected that all of the Project Foreground IP will relate to Commercial Products with several alternative suppliers.

Commercial Products will be made available to other Network Licensees under the standard terms and conditions of the supplier. The Network Licensee will be able to ensure these are fair and reasonable through a competitive tender process.

It is assumed that only Project Partners will own any Background IP that is required for the production of BioSNG and is not related to a Commercial Product. If such Background IP is required the Project collaboration agreement will require the Project Partner to provide a non-exclusive licence to the Background IP solely to the extent necessary to use the Foreground IP on agreed terms. The collaboration agreement will provide that the parties appoint an independent expert to determine the terms of the licence if the parties fail to agree them. If the parties are unable to agree the identity of an expert he or she will be nominated by the President for the time being of the Chartered Institute of Patent Agents.

Section 6: Project Readiness

6.1 Required Level of Protection

The Network Licensee does not require any protection against cost over-runs and unrealised direct benefits. These risks have been accepted by Advanced Plasma Power, one of the external funders.

6.2 Requested appendices

A detailed Project plan can be found in Appendix 5 and a risk register, management, mitigation and contingency plan in Appendix 6.

6.3 Project Management Structure, suspension process

The top Project management priorities are safety, health and environmental (SHE) issues. All participants in the Project will be required to demonstrate a robust SHE culture. Further details of SHE management are given below.

The aim of the Project structure is to closely match the approach used in commercial projects to provide evidence that the technology can be implemented at large scales. In addition, the structure provides the Network Licensee the level of control required to meet the requirements of the Ofgem Governance Document.

The Project organisation is summarised in the management diagram in Appendix 3.

The Project partners and Department for Transport (the Owners) will all be represented on the Project Steering Committee which will provide strategic direction to the Project. The Steering Committee will meet on a monthly basis to review Project progress reports, performance against budget, key Project risks and material issues. The rules of the Steering Committee will be set out in the Project Collaboration agreement.

The Steering Committee will have the power to suspend the Project in the event that:

- Insufficient progress is being made compared to the Project Plan.
- It cannot be delivered within its budget and additional funds cannot be raised.
- Risks are identified which cannot be mitigated and make deliver of the Project objectives unlikely.

After any suspension, Ofgem will be approached to discuss and agree termination of the Project.

Progressive Energy will act as technical advisors to the Project and will produce reports on Project progress to the steering committee and funders.

The design, construction, commissioning and operation of the Project facility will take place in a division of APP which will maintain separate accounts and organisation to the rest of the company. This division will enter into agreements for waste supply, fuel off-take, property leases and other contracts relating to the Project.

Project delivery will be managed by Otto Simon (OSL), the Construction Manager (a role which encompasses project, design and construction supervision). It will carry out detailed design work, project management, procurement, installation and commissioning based on the design outlined in Appendix 4. It will take the role of CDM Principal Contractor and be responsible for SHE management until the plant has completed commissioning and handed over. OSL will also take responsibility for delivering the Project on time and within budget.

The equipment and services to deliver the Project will be divided into several packages. Package providers will be responsible for design, fabrication, installation and commissioning of their scope of supply. APP will be responsible for delivery of the gasifier and plasma converter. The supplier for other packages will be decided by competitive tender.

There will be clear agreements setting out the rights and responsibilities of each of the Project participants. These will clearly identify the responsible person or persons for delivery of the contract in each organisation and the method of communication to be used. At Project commencement agreements will cover committed funding, the steering committee, project delivery and the technical advisor. Other agreements will be put in place as the Project develops.

OSL will maintain a master document register and each package supplier will maintain their own document register. Any changes to approved documents will be authorised using the agreed change control procedure.

6.4 Readiness to Proceed

Good progress has already been made on the development of the BioSNG facility. A site has been secured, the route to obtaining consents is well understood, an initial design has been completed, counterparties for supply of feedstock and off-take of gas have been found and a construction manager has been appointed.

Further work is expected to commence on the Project in September 2015 following agreement of funding from the Department for Transport. Further information is provided below on progress to date and expected progress by the date of the NIC decision.

Technological Readiness

This Project is mature, with a firm foundation built over 5 years of development since its inception. The Project commenced with an initial aspiration by National Grid to increase volumes of biomethane in 2008, followed by a feasibility study in 2010, a detailed design exercise carried out in 2011-12, and most recently the Pilot Plant project now constructed in Swindon and in the process of being commissioned.

Furthermore, the technology builds on work beyond the confines of these projects, specifically APP's operating gasification facility which, as described in Section 2.2 has operated for in excess of 2500 hours. Additionally, and in parallel with the integrated BioSNG pilot facility developments at Swindon, AFW have also developed an operating pilot methanation facility also described in Section 2.2. Crucially this development mirrors much of the understanding developed by the Project partners in the development of a process suitable for operation at 50-100MWth scale, providing additional confidence in the technical approach, but more importantly providing a commercial delivery route for this element of the Project.

Some of the specific learning points from the existing integrated BioSNG pilot facility have been:

<u>The cost, schedule, quality and risk management benefits of process system packaging and pre-fabrication</u>

Compared with the initial plan for the pilot BioSNG facility, there was a specific move during 2014 to move towards a design built up of discrete packages. This not only enabled appreciably more fabrication to take place offsite in a factory environment, but also enabled clearer lines of responsibility. This learning outcome has been embodied in the procurement and contracting strategy proposed for the commercial demonstration plant. For example this has led to the identification of AFW as a provider of the shift and methanation element, and also the appointment of Otto Simon as responsibility for the integration and delivery of the individual packages.

<u>The importance of Project communication</u>

Whilst dissemination was seen as important in the in initial plan for the BioSNG plant, this was developed from a technical standpoint, rather than recognising the importance of wider engagement, including the 'softer' elements of the Project. Through this project the team developed a marketing and branding approach, which has been used to develop the comprehensive strategy proposed for the demonstrator as outlined in Section 5.

Learning from this pilot facility will continue to flow into the commercial demonstrator. Not only does this encompass technical learning, but crucially will enable development of Health and Safety protocols and will provide a platform for operating training. Longer term, the existing pilot plant will provide the technical test bed for process improvements and optimisation. The commercial demonstrator must run consistently as it will have offtake contracts for waste and product. Optimised operating parameters and technical refinements however can be developed offline on the pilot plant. This is an extremely valuable configuration, underpinning successful delivery.

Consortium Formation

The consortium collaboration agreement will follow the format established for the Pilot Plant Project. National Grid, APP and PEL have collaborated on the small scale pilot plant project for several years using the same form of agreement and are comfortable that it provides a framework for beneficial collaboration.

Procurement Need and Procedures

The initial design document, which can be found in Appendix 4, sets out the Project's packages, gives a broad specification of what is required, and identifies potential suppliers. APP carried out a procurement exercise covering 70% of these packages in 2014 for a project it was developing in Tyseley, Birmingham, and the detailed specification for that project will form the basis for the requests for proposals for this Project. Discussions have been held with possible suppliers for each package to check that the specifications can be met.

APP will provide the integrated gasifier and plasma converter package. Amec Foster Wheeler is the preferred supplier for the gas shift and methanation package and that package will have an early and condensed procurement process.

OSL will manage the procurement process based on its proven systems and procedures and utilising its comprehensive supply chain database.

Site

A site has been secured for the facility close to the current small scale BioSNG plant.

Planning Permission and Permitting

Enzygo has been engaged to advise on planning and permitting of the facility. In terms of planning, Swindon Council are supportive and the process is underway. An initial meeting has been held with Swindon Council with regard to the environmental permit.

The Project site is covered by the South Marston Park Local Development Order (LDO). This order allows for fast tracked planning permission for developments that fit within the requirements of the order. The Council has confirmed that the Project development meets these requirements.

Swindon Council Environmental Health department is responsible for regulating the environmental impact of the facility, which will be permitted as a Small Waste Incineration Plant. Enzygo has held discussions with the Council on obtaining a permit and expects the process to take five months and work will commence in September 2015. The permit is likely to impose conditions on emissions to air, monitoring those emissions, noise, odour, emissions to water, and air pollution control residues produced by the plant. The design of the facility takes into account the expected conditions in each of these areas.

The planning and permitting status of the facility are confirmed in a report from Enzygo, a respected environmental consultancy.

Feedstock Supply

Swindon Council has confirmed that it will supply waste to the facility and has agreed outline terms in a confirmation letter. The Project Partners will continue discussions with the Council and expect to conclude a feedstock off-take agreement before January 2016.

Gas Off-take

CNG Services operate natural gas filling stations and have agreed to purchase fuel produced by the facility in preference to fossil natural gas. The gas will be supplied via the grid under a tri-partite agreement involving APP, CNG and a gas supply company.

The remainder of the gas will be sold to Howard Tenens, a truck operator in Swindon. This fuel will be delivered in compressed gas tube trailers by road.

The letters of intent with Howard Tenens and CNG Services will be converted to firm off-take agreements by January 2016.

Project Design

The initial Project design has been completed, work packages have been identified and discussions have been held with suppliers.

Otto Simon will be responsible for completing the detailed design and integrating subcontract detailed designs as procurement proceeds. In its view this will be completed by February 2016.

Delivery Contractor Agreement

Otto Simon will act as delivery contractor and has agreed to participate in the Project through a letter of support. It will provide service under a standard NEC Professional Services or similar agreement.

The full contract will be agreed by Quarter 1 2016. However, initial design work will commence immediately under a letter agreement while the final contract is negotiated.

6.5 Project Delivery Plan

The Project plan, found in Appendix 5, has been agreed with the Construction Manager and will be reviewed regularly and updated as agreements are reached with package suppliers and others. If any slippage in the plan is identified it will be reported to the steering committee together with a mitigation and recovery plan.

It is assumed that the Department for Transport will confirm funding for the Project in September 2015 and work on design, obtaining consents and commercial agreements for the facility will commence shortly thereafter. In the event that the Department for Transport announcement is delayed there will be a similar delay in the Project.

The overall programme presented here therefore starts on 1st September 2015 and the plant is expected to start full operation in January 2018. It is noted that the NIC element of the Project funding only commences after a Project Direction is agreed, assumed to be 1st January 2016.

The activities and milestones are set out in Appendix 5.

6.6 Risk

A risk register can be found in Appendix 6 which identifies risk, risk management and mitigation plans. The major risks are:

Health, Safety and Environmental. The Project includes risks associated with handling of explosive and poisonous gases.

A rigorous health, safety and environmental management system has already been established to ensure that best practices are maintained using HAZAN/HAZOP assessment, risk register, and DSEAR assessment. The Project Partners and Construction Manager have experience of working with potentially dangerous gases and have applied this experience in the Project design and programme. Mitigation of this risk will continue throughout the Project design and delivery and operation of the plant. The Construction Manager is responsible for mitigating the risk.

Gas quality risk. This Project must provide in-specification natural gas.

Work has been carried out existing equipment to establish the required specification of the product and mass and energy balances have been calculated to demonstrate that specification is met as detailed in the Technical Description found in Appendix 4. Amec Foster Wheeler as delivery supplier for the gas shift and methanation package is confident of meeting these specifications. The risk that the gas does not meet the required specification will be mitigated through the refinement of process design and models. It is the responsibility of the Construction Manager's process engineers to oversee this process.

Commercial outcome risk. The Project must be delivered within the capital budget and revenues should cover the costs of operation.

The capital budget has been refined through the appointment of Construction Manager; further engagement with the supply chain, in particular identification of Amec Foster Wheeler as a delivery supplier for the gas shift and methanation package; and more detailed design work. The budget will be refined through the tendering process and this is the responsibility of the Construction Manager.

Draft agreements with Public Power Solutions for waste and CNG Services for fuel off-take, together with information that has been obtained from Connect Oil on renewable transport fuel certificates, have increased the certainty of revenues. Quotations from BOC for oxygen and Good Energy for electricity and development of the mass and energy balance have improved certainty over costs. Risk around the commercial performance of the plant will continue to be mitigated through finalisation of off-take and supply agreements and development of the design. Commercial agreements are the responsibility of the APP Commercial Manager.

Partner collaboration risk. The Project Partners need to work together effectively.

The core members of the delivery consortium have worked together successfully over the last three years, under an extensive collaboration agreement. This collaboration agreement has been adapted to be used for this Project and a draft has been accepted in principle by all Project Partners. The partners have worked together well during the bidding process. Remaining risks in this area will be mitigated through ongoing communication through the Steering Committee. Responsibility for addressing this risk lies with the Steering Committee.

Project management and delivery risk. This Project requires the design delivery and operation of complex innovative equipment.

Otto Simon, an experienced engineering company, has been appointed as Construction Manager of the Project and will take overall responsibility for design and delivery. The Project will follow best practices for delivery of complex projects. The design of the facility has been refined and modelled and validated through measurements from a pilot plant and engagement with the supply chain as shown in the Design Document found in Appendix 4. This risk will require ongoing mitigation through good project management which is the responsibility of the Construction Manager.

6.7 Cost estimation, cost overrun approach (Direct Benefits are not applicable to this Project)

6.7.1 Delivery budget

A conservative approach has been taken to produce a robust cost plan for delivering the facility. A not-to-be-exceeded estimate has been developed to allow funding contributions to the Project to be determined.

The starting point for the cost plan is the design detailed in Appendix 4. This design is based on the scale up of existing pilot plants and takes into account the known conditions of the site and the well understood conditions associated with health, safety, planning, environmental permit and water discharge consent. The design has been reviewed by APP, Progressive Engineering and Otto Simon to check its completeness and that it meets the Project requirements.

This design breaks the facility down into discrete packages with well-defined battery limits and functionality. Third party quotes have been obtained for each of these packages, frequently from more than one vendor, to provide a base cost. This cost has then been reviewed and adjusted by APP and OSL to reflect the specific requirements of the Project. For example, adjustments have been made to scale equipment size and allowances have been made for ventilating equipment which will be housed inside.

OSL has then made allowance for delivery costs such as scaffolding, cranes and temporary site accommodation using industry standard estimates. The Project Partners have forecast the cost of dissemination and Project.

Finally, the detailed risk register for the Project has then been reviewed and conservative allowances have been made for specific areas of risk as shown in Appendix 6.

The overall cost plan is £23.1m as summarised in the following table.

	2015/16	**2016/17**	**2017/18**	**Total**
	£'000	**£'000**	**£'000**	**£'000**
Labour	920.25	1,249.26	786.14	2,955.65
Equipment	1,286.55	10,441.72	3,043.91	14,772.18
Contractors	504.25	1,478.28	802.97	2,785.50
Travel & Expenses	9.95	111.55	38.77	160.27
Contingency	70.00	1,751.33	428.67	2,250.00
Other	67.04	67.04	-	134.08

Total	**2,858.04**	**15,099.19**	**5,100.45**	**23,057.68**

Further details of these costs can be found in Appendix 7.

The cost plan has been reviewed in detail by APP Shareholders and the Department for Transport and they have agreed that it represents a conservative estimate of the Project cost. APP Shareholder accepted the risk of any cost overruns from the Project.

6.7.2 Operating Budget

The Project Partners have engaged with customers and suppliers to establish the likely revenues and cost of operating the facility. Its forecast profit and loss is shown in the following table.

Revenue		**Cost**	
	£'000		**£'000**
Gate fees	0.7	Labour	0.5
Natural gas sales	0.4	Parasitic load	0.8
Renewable transport fuel certificates	0.5	Oxygen	0.3
		Other consumables	0.2
		Maintenance	0.1
		Other costs	0.2
Total	**1.6**		**2.1**

This shows that the facility is expected to lose around £0.5m per annum which will be funded by APP shareholders.

Gate fees are earned from acceptance of waste from Swindon Borough Council. Ten thousand tonnes per annum will be processed and the Council will be £65/tonne. This is supported by the letter of support.

Natural gas will be sold in compressed form to Howard Tenens and via the grid to CNG Services. Letters of support has been obtained from both companies. Howard Tenens will pay £0.30 per kilogram of gas which is equivalent to £22 per MWh but the value of gas distributed via the grid will be sold at the system buy price which is currently 16/MWh.

Renewable transport fuel certificate are issue for gas that is used directly in vehicles. They are not available for gas distributed via the grid. Gas that is transported to Howard Tenens is expected to earn around £0.51 per kilogram from RTFCs in 2018.

Labour relates to the fifteen full time staff who will operate the facility. Parasitic load is the cost of the electricity uses and oxygen will be brought to the facility in liquid form by BOC. Other consumables include propane for upgrading the gas for grid injection, catalyst replacement and chemical for removing contaminants from the syngas.

Maintenance will cover the ongoing activities of the plant. The intention is to run for five years so no lifecycle maintenance activities will be carried out.

Other costs cover rent, rates and insurance.

6.8 Verification of information provided

All the data presented in the proposal has been rigorously verified. In general, third party evidence has been used to support assertions and the entire document has been reviewed by Project Partners. In addition, the Construction Manager for the Project, Otto Simon, has reviewed relevant sections. All of the information presented here and in the Appendices has been checked by at least two Project Partners.

The following table summarises the areas of the proposal and the verification process followed.

Design of commercial demonstration facility	All design documents prepared by APP and then reviewed internally. NG, PEL and OSL then carried out third party review.
	Design is based on data from the Swindon and Amec Foster Wheeler pilot plant performance. The models used to prepare mass and energy balances for the plant have been verified against results from pilot plants.
	All equipment items used in the plant is currently operating at scale and is available from multiple vendors. The performance of equipment used in the design has been verified against 3rd party supplier proposals.
	Trials carried out by Catal have confirmed expected performance of catalysts used in methanation process.
Environmental benefits	Environmental benefits are based on NNFCC reports and reviewed by PEL. NG and APP then carried out 3rd party review. All environmental information is based on 3d party reports referenced in the proposal.
Delivery and Operating Budget	Budgets were prepared jointly by APP and OSL and reviewed internally. NG and PEL then carried out a 3rd party review.
	Cost information is based on independent proposals from suppliers adjusted using commonly used methods.
Commercialisation	Commercialisation information was prepared by APP and reviewed internally. PEL and NG then carried out a 3rd party review.
	The designs, costing and operating information of the commercial plants has been reviewed in depth by several independent 3rd party assessors such as Fichtner, Amec Foster Wheeler and M + W. The costs are supported by proposals by suppliers and the performance is supported by process models that have been validated against pilot plant data.
Business Case	The business case was prepared by NG and then reviewed internally. NG, APP and WWU have all carried out a 3rd party review.
	The business case is built on 3rd party models and reports.

In addition, the majority of the information in the proposal has been assessed by the Department for Transport and responses to their questions have been incorporated into the document.

6.9 Delivery of learning if take-up is lower than expected

Learning from this Project is not dependent on take-up, so would be delivered even under low take-up.

Section 7: Regulatory issues

The demonstration plant will be connected to the WWU local Medium Pressure gas network and the construction and operation of the connection will closely follow the existing practices in relation to biomethane plants. The output from the Commercial BioSNG Demonstration plant will be at a similar scale (280m^3/h) to a typical biomethane plant.

The plant operator will ensure that the gas quality of the BioSNG meets the GSMR standard for injection into the local network, and a remotely operated slam-shut valve will protect the WWU network from any gas quality excursions beyond GSMR limits.

In addition, in relation to the calorific value (CV) of the BioSNG, the existing policy in relation to biomethane plants will be followed, which involves adjusting the CV of the injected renewable gas, using propane if necessary, to target the local Flow Weighted average CV of the network. This ensures that local gas customers are not disadvantaged by receiving gas of a different heating value to 'normal' grid gas, nor are gas suppliers disadvantaged by the CV of the network being declared at a lower value than the FWACV, which would result in a loss of revenue to them.

For the above reasons it is not expected that there will be any novel regulatory issues associated with the delivery of BioSNG into the WWU gas network, but the plant operator will keep the situation under review and will inform WWU and Ofgem of any unexpected issues that might arise.

Section 8: Customer Impact

As noted in Section 7, it is not anticipated that there will be any adverse effects on gas customers from the connection of the Commercial BioSNG Demonstration plant to the WWU network.

The gas quality of the BioSNG output will be closely monitored to ensure that (in line with the GSMR requirements) it does not contain any substances that could harm consumers, consumer appliances or the WWU local gas network.

It is anticipated as per the Section 3 Business case and Section 4 Benefits, timeliness and partners, that subsequent commercial projects could have a very significant beneficial impact on customers in the move to a low carbon economy.

Section 9: Successful Delivery Reward Criteria (SDRCs)

The proposed SDRCs for this Project are shown below and relate to the objectives set out in section 2.1.3 and the Project plan set out in Appendix 5. The successful delivery and achievement of these objectives are clearly measurable and will be reported to Ofgem as part of the Project.

It is important to note that the timescales against the proposed SDRCs are provided on the assumption that the Department for Transport funding award is made in September 2015 and that the Project can proceed from that date, prior to any NIC award in late 2015. To the extent that the DfT award is received later than September 2015 it will be necessary for the Project plan to be amended to start and finish later, and for the timings of the SDRCs to be rescheduled.

The specific criteria which we propose are as follows:

9.1	Planning and permitting completed and commercial contracts agreed and finalised	1 May 2016
9.2	Detailed design and safety review completed	1 September 2016
9.3	Equipment procurement process completed	1 May 2017
9.4	Construction completed and commissioning started	1 February 2018
9.5	Successful operation of plant demonstrated	1 July 2018
9.6	Dissemination of project learnings and commercialisation strategy	30 November 2018

These criteria are further detailed below:

9.1 Planning and permitting completed and commercial contracts agreed and finalised

This SDRC covers tasks 1 and 3 in the Project plan.

In relation to planning and permitting, this will include completion of the planning and environmental permitting processes, and to gain agreement for the necessary trade effluent discharge consent. This will be evidenced by obtaining the relevant documentation.

In relation to the commercial contracts, this will include the collaboration agreement between the partners, the Construction Manager contract, the waste supply and the gas grid Network Entry Agreement, and the electric and water grid connection agreements. This will be evidenced by signature of all of the relevant contracts.

This SDRC will be achieved by 1 May 2016.

9.2 Detailed design and safety review completed

This SDRC covers task 2 in the Project plan.

This will involve the completion of process flow diagrams, mass and energy balance documentation and plant layouts. These will be supported, inter alia, by output from the primary testing phase of the Pilot Plant. It will also cover process and instrumentation diagrams, control philosophy and electrical system specifications, data sheets for major items of equipment, project management manuals and completion of HAZOP and other safety reviews. This will be evidenced by sign off of all relevant documents.

This SDRC will be achieved by 1 September 2016

9.3 Equipment procurement process completed

This SDRC covers task 4 in the Project plan.

This will involve the finalisation of work package definitions, the development of functional specifications and an interface register, preparation of tenders for packages, negotiation of commercial conditions and appointment of suppliers. This will be followed by management of suppliers through equipment manufacture, Factory Acceptance Testing of equipment and a pre-construction Hazop. This will be evidenced by issuing of ITT information, placement of orders, delivery of materials to manufacturers, and completion of FATs.

This SDRC will be completed by 1 May 2017.

9.4 Construction completed and commissioning started

This SDRC covers task 5 in the Project plan.

This will involve mobilisation of resources, civils and building modifications, gas rid connection, on-site installation of equipment including interconnecting pipework, electrical and control installation. This will be evidenced by photographs of the installation of equipment on site and site visits.

This SDRC will be completed by 1 February 2018.

9.5 Successful operation of the plant demonstrated

This SDRC covers tasks 6, 7 and 8 in the Project plan.

This will involve control system testing, pre-commissioning checks, cold and hot commissioning, extended operational tests, confirmation of performance of plant, delivery of in-specification pipeline gas, monitoring of product quality and system performance. This will be evidenced by delivery of in-specification gas to WWU network and by KPI reports on plant operations.

This SDRC will be completed by 1 July 2018

9.6 Dissemination of Project learnings and commercialisation strategy

This SDRC covers tasks 9 and 10 in the Project plan.

This will involve maintaining and updating the gogreengas website, showcasing the facility by organising site visits for government, industry and potential investors, preparation of process and Project final reports, and by presentations, technical papers and journal articles. It will also include preparation of an outline design of, and commercial assessment for, a full-scale commercial plant. This will be evidenced by reports on the gogreengas website, customer feedback, by the Project final report and by the documentation supporting a full-scale plant.

This SDRC will be completed by 30 November 2018.

Section 10: List of Appendices

1. **Benefits Table**
2. **RESOM Scenario Cost Analysis**
3. **Organogram**
4. **Design Document**
5. **Project Plan**
6. **Risk Register**
7. **Project Cost**
8. **Financial Models**
9. **Project Partners**

ofgem

RIIO NIC NETWORK INNOVATION COMPETITION

Appendix 1 – Benefits Table

KEY

Method	Method name
Method 1	BioSNG

Gas NIC – financial benefits

Financial benefit (£m)								
Scale	**Method**	**Method Cost**	**Base Case Cost**	**Benefit**			**Notes**	**Cross-references**
				2020	**2030**	**2050**		
Post-trial solution *(individual deployment)*	Method 1			0	0	0	The demonstration will not provide any financial benefits.	
	Method 2							
	Method 3							
Licensee scale *If applicable, indicate the number of relevant sites on the Licensees' network.*	Method 1			0	0	0	The method will not be deployed specifically on the National Grid network. All sites are included in the GB rollout below.	
	Method 2							
	Method 3							
GB rollout scale *If applicable, indicate the number of relevant sites on the GB network.*	Method 1			0	1,071	46,349	The number of sites is set out in Section 3.2. The Method has been compared to the Gone Green Scenario from the latest National Grid Future Energy Scenario using the RESOM model. Details are provided in Appendix 2. Details of the Method Cost and Base Case Costs from the RESOM model are confidential. The analysis assumes heat demand is met predominately from electricity so the benefits from avoidance of the cost of heat pumps or reinforcement of the electricity network set out in Section 2.1.2 are not included.	Section 3.2 Appendix 2
	Method 2							
	Method 3							

Gas NIC – carbon and/ or environmental benefits

Carbon and/ or environmental benefit (MtCO2e)								
Scale	**Method**	**Method Cost**	**Base Case Cost**	**2020**	**2030**	**2050**	**Notes**	**Cross-references**
Post-trial solution *(individual deployment)*	Method 1			0	0	0	The trail will not result in significant carbon savings.	
	Method 2							
	Method 3							
Licensee scale *If applicable, indicate the number of relevant sites on the Licensees' network.*	Method 1						The method will not be deployed specifically on the National Grid network. All sites are included in the GB rollout below.	
	Method 2							
	Method 3							
GB rollout scale *If applicable, indicate the number of relevant sites on the GB network.*	Method 1			0.2	40.1	482.1	The number of sites is set out in Section 3.2. The figures presented here compare BioSNG to natural gas used for heating using BEAT 2 methodology.	Section 3.2 Section 4i(iii)
	Method 2							
	Method 3							
If applicable, indicate any environmental benefits which cannot be expressed as MtCO2e.	**Post-trial solution:** [Explain any environmental benefits which cannot be expressed as MtCO2e]						The volume of waste sent to landfill will be reduced resulting in reduced impact on air and water. Adoption of CNG will be increased possibly resulting in lower pollutant emissions to air compared to other transport fuels.	
	Licensee scale: [Explain any environmental benefits which cannot be expressed as MtCO2e]							
	GB rollout scale: [Explain any environmental benefits which cannot be expressed as MtCO2e]							

Appendix 2 – RESOM Scenario Cost Analysis

Using the RESOM model, the value of BioSNG has been evaluated between now and 2050 against a base scenario that has none. The cost differences between the two scenarios have then been compared. The analysis has all been on an annualised basis.

The base scenario is National Grid's 2015 Gone Green Scenario, published in July 2015. This scenario does not have BioSNG. This scenario has been rerun to include 100TWh of BioSNG in 2050, which also develops 37TWh BioSNG in 2030.

The extra costs from building the conversion technologies and generating BioSNG are more than offset by the further savings elsewhere. In total these result in savings of £0.5bn per annum in 2030, rising to £3.9bn per annum by 2050.

Extra costs of heat arise from the fact that BioSNG generation is more expensive than gas; however, this is offset by cost savings from the gas ("Fossil Resources") which is no longer required.

The energy system costs are lower with the BioSNG technology as additional income is generated from the gate fee charged for collecting waste, which offsets other system costs. The BioSNG plant takes waste that otherwise would have gone to landfill, thereby avoiding GHG emissions from leaking gases such as methane. Once the carbon dioxide released from burning BioSNG at the end consumer is offset with the avoided release of landfill gases, the net carbon emissions are close to zero. This near zero carbon gas can be used towards heating, transport and power generation, reducing the need for some electrification of transport and the use of hydrogen in large vehicles such as HGVs, which appear in the base Gone Green 2015 scenario to a considerable degree by 2050.

There is also a smaller saving in the power sector; as more transport and heating is from low carbon sources, power generation can have a slightly higher carbon intensity.

The total savings across the 2030 to 2050 period are shown in Table 2:

Table 2 – Cost Savings Summary with BioSNG.

Cost Savings	2030	2035	2040	2045	2050
Total UK Cost (£bn/r)	0.5	1.1	2.4	3.2	3.9
Average Dual Fuel Bill per houshold (£/yr)	2.9	6.2	12.7	16.4	19.2

In 2050 there is a saving of £3.9bn per year from BioSNG.

Over the period 2030 to 2050 (including 2050), this equates to an average savings per household of £13.40.[23]

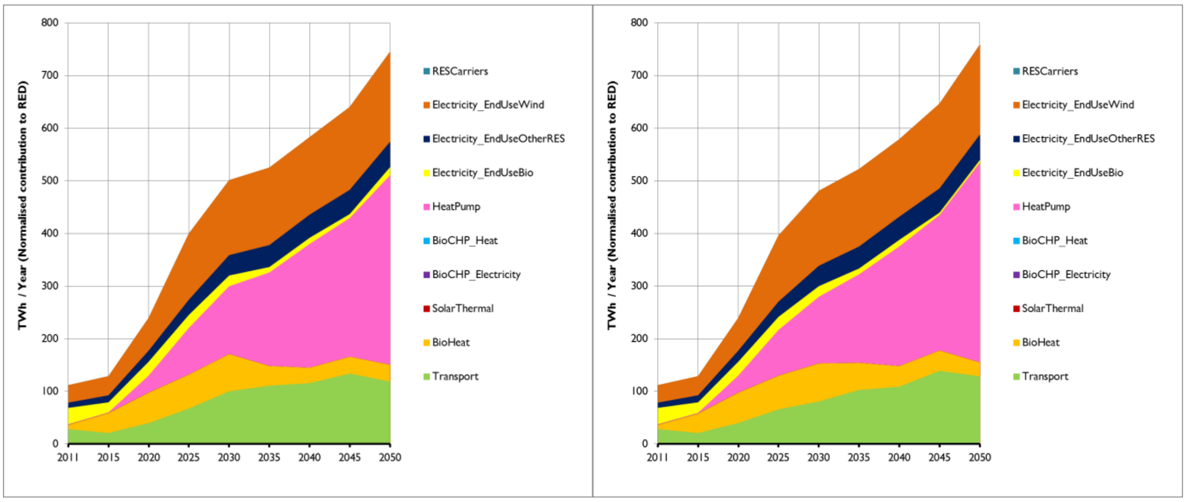
This equates to a total saving for each household of £282 over this 21 year period.

[23] This is not a straight average as of the value above as 2030 applies to 2030 to 2034, 2035 applies to 2035-2039 and so on hence the 2050 value only applies to 1 year.

Addition of BioSNG reduces the need for around 10TWh of renewable electricity in 2050, and adds this into renewable transport.

This in turn makes balancing the electricity system easier, as there is less intermittency of renewable generation to manage. The amount of renewable energy generated in both scenarios is show in Figure 1.

Figure 1 – Renewable Energy Generated without BioSNG (left hand side) and with (right)



Transport is where BioSNG has the largest impact. This is displayed in the "Road Gas" category in Figure 2, which shows fuels utilised for transport. This impact is mainly via BioSNG fuelling HGVs. In 2050 this replaces the need for more costly hydrogen production to fuel HGVs (around half of which comes from gas conversion in the base scenario).

Figure 2 –Annual Energy Demand for transport without BioSNG (left hand side) and with (right)

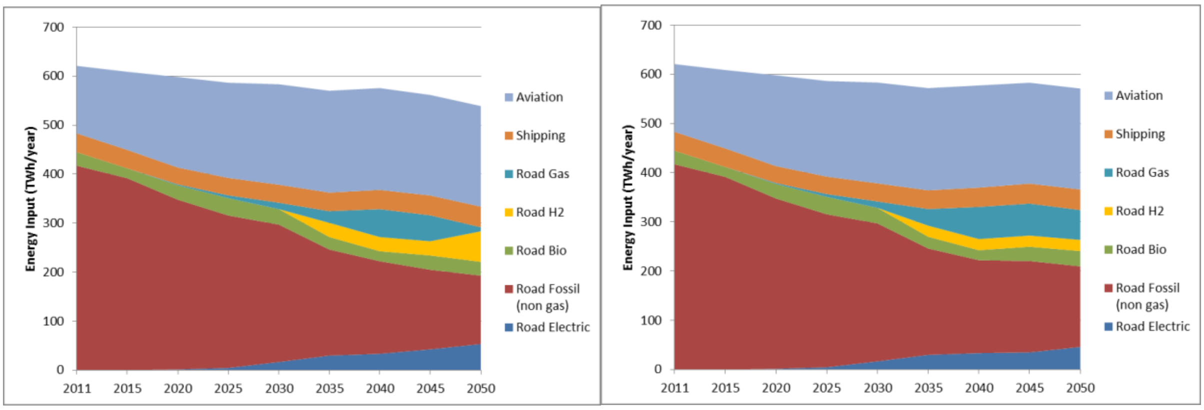
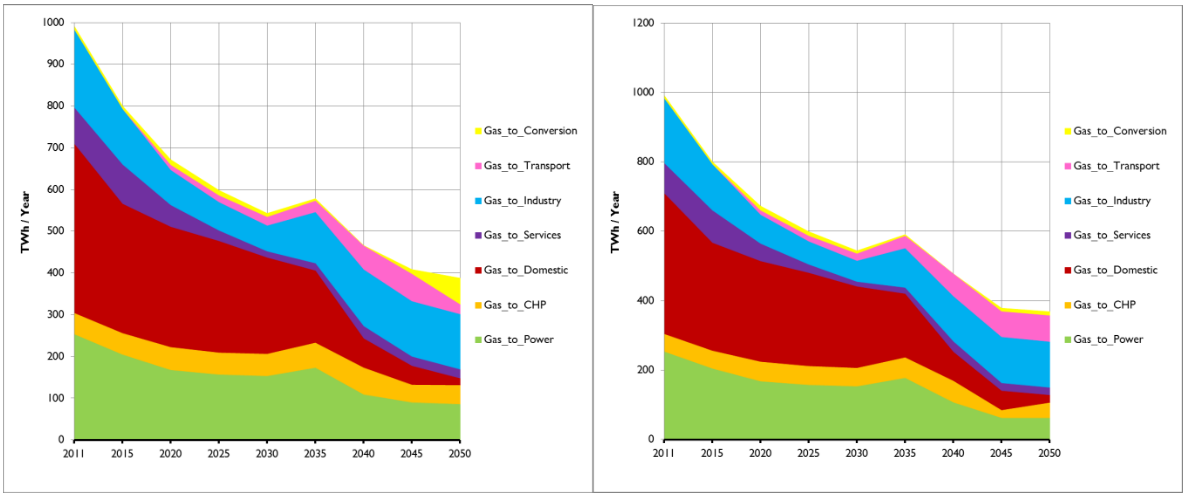
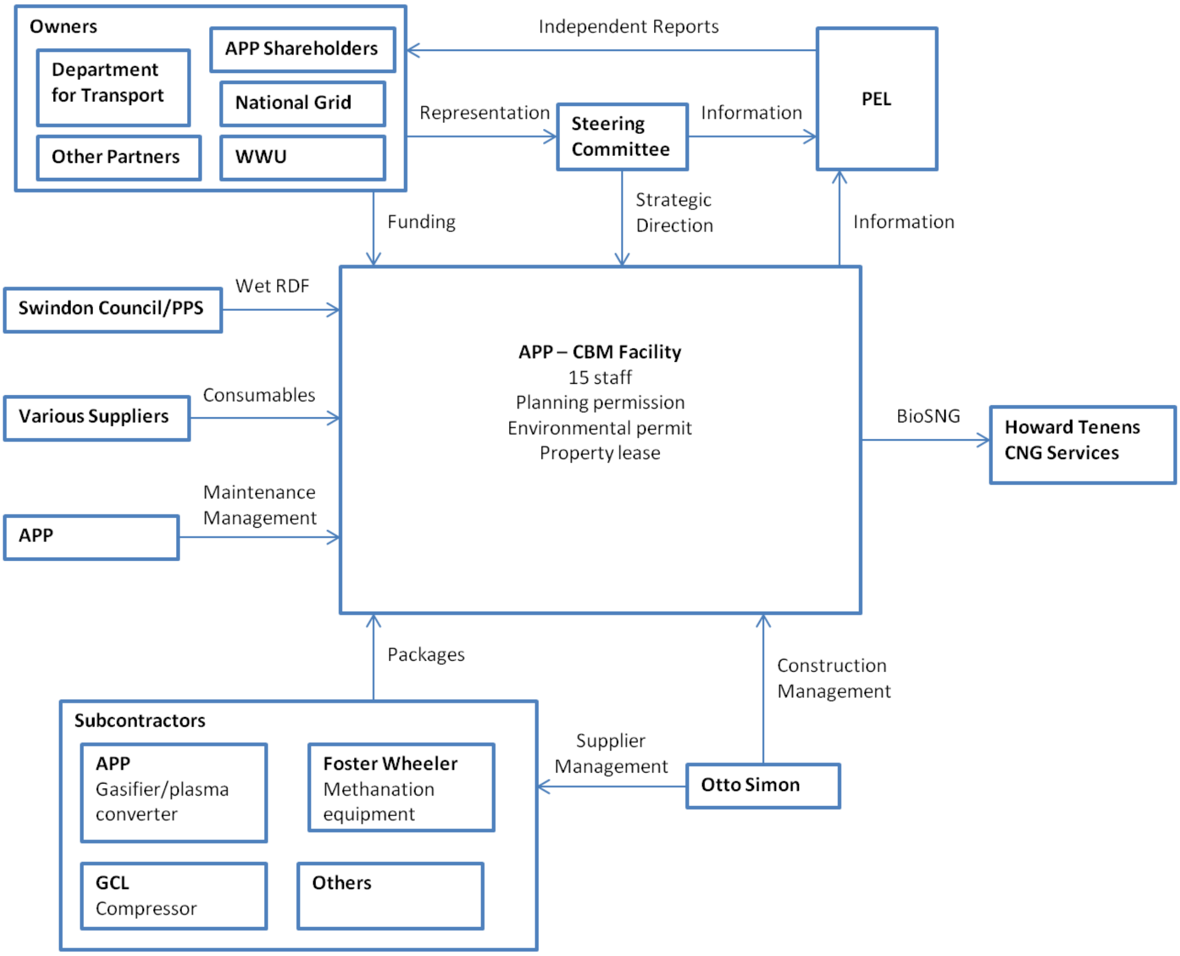


Figure 3 shows the annual gas demand usage. As 100 TWh of gas in 2050 is BioSNG this gas is lower carbon. As a result more of it can be used for transport in 2050, which more than triples and shows the highest increase in annual energy demand. Gas for transport increases by over 50 TWh/yr in 2050, due to BioSNG replacing hydrogen. This also reduces the "Gas to conversion" section which corresponds to around half the hydrogen production in the base scenario. Gas to industry is largely unchanged, but is now lower carbon. Gas for power generation is almost all via CCS in both scenarios. In the BioSNG scenario CCS is reduced, because BioSNG decarbonising unabated gas lessens the need to abate fossil fuels, and there is also slightly less electricity demand. Domestic gas demand increases by around 25% in 2050 in the BioSNG scenario, with the majority of gas for domestic heating being used for top up heat in conjunction with a heat pump. This is illustrated in Figure 3.

Figure 3 – Annual Gas Demand scenarios without BioSNG (left hand side) and with (right)



Appendix 3 – Organogram



Network Innovation Competition

Commercial BioSNG Demonstration Plant

Design Document

Table of Contents

Revision Summary

Revision	Summary of changes	Date	Author	Reviewer	Approved
A	First issue	10/7/15	RT	MB	AC

1 - Executive Summary

The project will convert RDF into substitute natural gas using three distinct processes:

1. **Fuel Drying** dries a prepared RDF to produce a dried RDF feedstock for the Gasplasma® process.
2. **Gasification** converts the RDF into a syngas through the Gasplasma® gasification process which includes cooling, cleaning and conditioning of the syngas.
3. **Methanation** processes the cool, clean syngas from the gasification process to synthesise compressed biomethane for use as a transport fuel. This is achieved by compression and polishing of the syngas to remove catalyst poisons, a water gas shift reaction to obtain the correct ratio of hydrogen to carbon monoxide, further polishing, a methanation stage, a methane purification stage and a final additive stage to ensure that the bio-substitute natural gas (BioSNG) complies with the specifications for injection into the gas grid.

The project has been designed to process 1,350 kg/h of RDF and dry it to give 1,000 kg/h of dried RDF for feeding into the gasifier, equivalent to 4.4 MWth of energy input. Through the gasification and methanation processes this will yield 2.9 MWth on a gross CV basis or 200 kg/h of BioSNG, giving a process efficiency of 59%.

The figures are derived from mass and energy balances, which encompass the entire process operation from the receipt of RDF through its transformation to a clean syngas and the onward conversion to BioSNG. These balances are underpinned with detailed models developed to include equipment suppliers' experiences and with validation from extensive direct pilot plant observations. As such, these models have been demonstrated to provide a high degree of confidence as to their accuracy and reliability in predicting the transformation of solid wastes to calorific gases.

The project will be developed at APP's facility at Marston Gate, Swindon. A seven year lease agreement for units A3 and A4 is in place, giving security of tenure. The partners have applied the benefit of their experience from constructing and operating the facilities in Swindon to develop a layout for the project. A preliminary review for both buildability and operability of the system has been conducted and the partners consider that the proposed layout is robust, deliverable and has adequate contingent area to accommodate further developments and improvements.

The project partners have engaged Enzygo to provide advice on planning and permitting requirements. Planning permission is to be granted under the Local Development Order covering the Marston Gate industrial estate.

The plant will be permitted to operate as a Small Waste Incineration Plant and regulated by Swindon Borough Council (SBC). The key requirement will be for the emissions to air arising from the waste processed by the facility to meet the Industrial Emissions Directive. Enzygo have engaged with SBC and confirmed this is the case.

The feedstock for the project is Refuse Derived Fuel (RDF), produced from municipal solid waste that is collected in the catchment of Swindon Borough Council. The waste is collected by Public Power Solutions who operate a materials recovery facility (MRF) to produce a dried RDF that is currently exported to Europe. APP has agreed with Public Power Solutions (PPS) the supply of RDF for this project. The PPS RDF off-take agreement will specify the allowable variations in key fuel quality parameters, including particle size distribution, ash, moisture, biogenic energy content, and NCV, together with acceptable levels of chlorine and sulphur.

The partners have engaged with the supply chain for several years to optimise the number and definition of packages based on the process flow diagrams. Quotations have been obtained for all of these packages and have been used to develop a cost plan for the project. Specification for each package will be refined in consultation with the Construction Manager and potential suppliers.

In general, procurement will be managed through open, competitive tender processes. There are two exceptions: APP will deliver the core Gasplasma® package as proprietary enabling technology, albeit which comprises subcomponents which have been competitively selected. To ensure deliverability, a selection process has already been undertaken to secure Otto Simon Ltd for delivery of the Construction Management package.

Amec Foster Wheeler (AFW) has submitted a proposal for the gas shift, methanation and methane purification processes. Their design mirrors the design developed by the project partners and appears to be robust and cost effective. It is expected that AFW will be the delivery partner for this element, but it is important to maintain the commercial freedom to secure the best performance and terms during the procurement process. Moving between the AFW and the project partner's design has no significant impact on the process flow, layout or mass and energy balances.

2 - Site

The project will be developed at APP's facility at Marston Gate, Swindon. The site is home to a Gasplasma® demonstration plant and the new development will be built adjacent to it, allowing for synergy between the two where possible. A map showing the location of the site can be found in Annex 4.

Marston Gate consists of two industrial type buildings, blocks A and B, made up of warehouse areas, with office and service cores. Each block has been subdivided into four separate units numbered 1 to 4.

Both blocks are of a braced structural steel portal frame construction, with cold rolled purlins and sheeting rails spanning between the main structural frames. The foundations for the steel structure are of mass concrete pad design.

The ground floor slab is of reinforced concrete construction on a layer of compacted stone which is supported on the underlying subsoil. The ground floor slab is assessed to accept a maximum uniform loading of 25 kN/m^2, together with a point load of 50 kN.

Both blocks are clad with profiled sheet steel cladding.

The frame allows for single clean span of 35.6 m over the main operating area with an internal clear height of 6.25 m to haunch from finished floor level. The combined floor area for A3 and A4 is 2053m^2 including service cores.

There is a service yard between the blocks which provides vehicular access for commercial vehicles enabling loading into and out of the buildings via powered roller shutter doors.

Pedestrian access and car parking is to the front of the buildings.

The adjacent unit A2 houses the existing demonstration plant which has shared use by APP and Tetronics. Externally and within the yard is a fenced compound containing gas cleaning, storage and methanation plant associated with the operation; the palisade fencing continues in front of A3/A4.

A seven year lease agreement for A3/A4 has been made with Tetronics Holdings Ltd. Landlord's permission is required for any works that impact the structure of the buildings. This has been given for previous work on other units and no issues are expected.

APP has engaged Enzygo to provide advice on planning and permitting requirements. They have met with Swindon Council, who is responsible for both planning permission and environmental permitting, and produced a report setting out the expected requirements and route to obtaining consent.

Planning permission is to be granted under the Local Development Order covering the Marston Gate industrial estate. To support this process the following are to be provided:

- An Air Quality Assessment
- Details of traffic movements
- Details of odour control
- Details relating to noise generation
- Plans and drawings

The plant will be permitted as a Small Waste Incineration Plant. The key requirement will be for the emissions to air arising from the waste processed by the facility to meet the Industrial Emissions Directive. Other requirements are likely to limit the:

- Odour arising from waste processed by the facility.
- Emissions to air from the drying of the waste.
- Noise produced by the facility.

The design will need to ensure that these requirements are met.

3 - Feedstock

The feedstock for the project is Refuse Derived Fuel (RDF), produced from municipal solid waste that is collected in the catchment of Swindon Borough Council. The waste is collected by Public Power Solutions who operate a materials recovery facility (MRF) to produce a dried RDF that is currently exported.

The project partners have agreed with Public Power Solutions (PPS) the supply of RDF for this project. A historical analysis data set for the dried RDF that PPS have produced at their Swindon facility has been provided and is summarised below.

This data set has been corrected for moisture content to be representative of the RDF that the facility will receive. This correction has been determined in consultation with PPS and the project partners will undertake a monitoring campaign to ensure that the moisture content of the pre-dried RDF is understood sufficiently to allow the drying system for this project to be specified accurately.

Table 1 below summarises the historic data set from PPS and shows the RDF specification, after drying, that has been used to develop the mass and energy balances for this project.

Quality parameter		Average RDF waste quality			
		Historic data for as received RDF		Specification for dried RDF	
		As received	Dry basis	As received	Dry basis
Proximate Analysis					
Fixed Carbon	wt%	8.36	12.86	11.32	12.86
Volatile Matter	wt%	47.66	73.33	64.53	73.33
Ash	wt%	8.98	13.81	12.15	13.81
Moisture	wt%	35.00	0.00	12.00	0.00
TOTAL	wt%	100.00	100.00	100.00	100.00
Ultimate Analysis					
Carbon	wt%	29.02	44.64	39.28	44.64
Hydrogen	wt%	4.31	6.63	5.84	6.63
Oxygen	wt%	21.15	32.54	28.64	32.54
Nitrogen	wt%	0.81	1.25	1.10	1.25
Chlorine	wt%	0.28	0.43	0.37	0.43
Sulphur	wt%	0.45	0.70	0.61	0.70
Ash	wt%	8.98	13.81	12.15	13.81
Moisture	wt%	35.00	0.00	12.00	0.00
TOTAL	wt%	100.00	100.00	100.00	100.00
Energy Analysis					
LHV	MJ/kg	11.78	18.13	15.95	18.13
HHV	MJ/kg	12.94	19.91	17.52	19.91

Table 1 Feedstock specification used for design basis

The PPS RDF off-take agreement will specify the allowable variations in key "as received" fuel quality parameters, including particle size distribution, ash, moisture, biogenic energy content, and NCV, together with acceptable levels of chlorine and sulphur. The proposed values and limits are shown in Table 2.

Lower Heating Value (LHV)	MJ/kg	10 – 17.07
Moisture	wt%	< 45
Ash	wt%	10-20
Chlorine (Cl)	wt%	0 – 0.8
Sulphur (S)	wt%	0 – 0.48
Density	kg/m³	100 - 200
Size Range	All fuel passes through a manual 50mm screen and maximum dimension of 50mm x 50mm x 25mm	
	No more than 10% of all fuel will pass through a manual 15mm screen	
	No more than 0.5% of all fuel will pass through a manual 1mm screen	

Table 2 RDF Quality Specification, all on an 'As Received' basis for wet RDF received at the plant

4 - Product Requirements

The plant is required to produce a substitute natural gas (BioSNG) that is suitable for injection into the gas grid and use, following compression, in heavy good vehicles.

Grid natural gas varies in its composition and properties from one national jurisdiction to another. In the UK high-pressure gas transmission system and the lower pressure distribution network the specification and properties of natural gas broadly defined, (but not definitively specified) by the GS(M) Regulations (Schedule 3), published by the HMSO[24].The current specification is shown in the table 3.

Gross calorific value	In the range 36.9 to 42.3 MJ/m^3 at 15°C and 1.01325 atmospheres. A target CV in this range will be set by the network operator. Currently this is 39.3MJ/m^3 for the SW region.
Wobbe number	In the range 47.20 to 51.41 MJ/m^3
Hydrogen sulphide	Not more than 5 mg/m^3
Total sulphur	Not more than 50 mg/m^3
Hydrogen	Not more than 0.1% molar
Oxygen	Not more than 0.2% molar
Hydrocarbon dewpoint	Not more than -2 °C at any pressure up to 85 barg
Water Dewpoint	Not more than -10°C at 85 barg
Inerts	Not more than 4.0% (molar)
Organo halides	Not more than 1.5 mg/m^3
Siloxanes	Below 0.1mg/m^3

Table 3 Product Gas Specification

The process is designed to meet these requirements. There are no agreed specification for gas that is used as a transport fuel but currently trucks use CNG that is produced by grid quality gas and it is assumed that a product that meets the grid specification will be meet vehicle requirements.

5 - Design Discussion

The key design decisions that have been taken are:

- An oxy-steam blown fluidised bed gasifier has been selected because it offers a technically mature solution that has been proven on waste feedstocks at commercial scale and produces low levels of tars compared to other gasification solutions.
- A direct current plasma converter is used to polish the syngas from the gasifier and remove tars and other contaminants because it provides a very pure syngas which is free of compounds such as organo-sulphides and unsaturated hydrocarbons that are difficult to remove using conventional gas cleaning techniques.
- Standard gas cleaning techniques such as wet scrubbing, activated carbon and zinc oxide sorbent beds are used to remove pollutants that might poison the catalyst.
- A standard high temperature water gas shift is used to adjust the hydrogen to carbon monoxide ratio in the syngas as this requires a cheaper, more robust catalyst than the low temperature shift.

[24] http://www.legislation.gov.uk/uksi/1996/551/schedule/3/made

- A once through methanation approach is used as this reduces capital and operating costs.

Overall, the design philosophy is to use proven technologies in each stage of the process while focusing on delivering a solution that offers value for money.

6 - Process Description

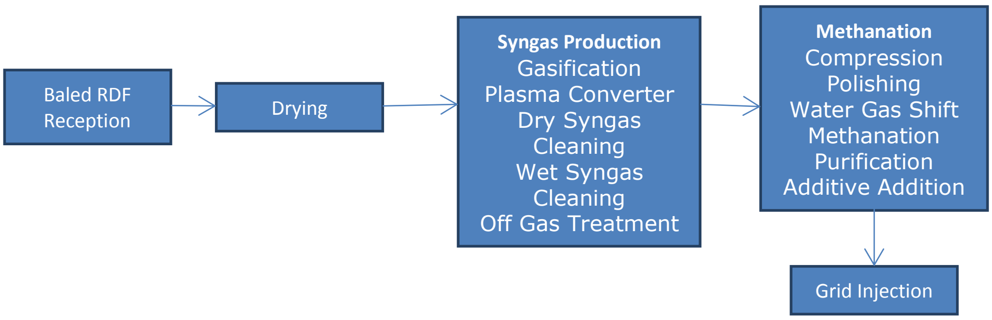
Facility Overview

The overall facility can be viewed as comprising three distinct processes as is illustrated below.

1. **Fuel Drying** is based on a prepared fuel input which is dried after reception to produce an RDF feedstock for the Gasplasma® process.
2. **Syngas Production** converts the RDF into a syngas through the Gasplasma® process which includes cooling, cleaning and conditioning of the syngas. During the syngas cooling stage, steam is produced. This steam is used in the drying of RDF and in the Gasplasma® process.
3. **Methanation** processes the cool clean syngas from the Gasplasma® process to synthesise compressed biomethane for use as a transport fuel or for injection into the gas grid. This is achieved by compression and polishing of the syngas to remove catalyst poisons, a water gas shift reaction to obtain the correct ratio of hydrogen to carbon monoxide, further polishing, a methanation stage and a methane purification stage, a methane purification stage and a final additive stage to ensure that the BioSNG complies with the specifications for injection into the gas grid.

A set of process flow diagrams is provided as Annex 1 to this Document.

Each of these areas is explored in more detail in the following sections.



Fuel Preparation

RDF Reception

The RDF reception area receives baled RDF deliveries during the agreed operating hours for the facility. To allow for fluctuations in delivery volumes the RDF reception area is sized to hold baled RDF sufficient to feed the gasifier for 5 days. The RDF is loaded as bales by a fork lift truck onto a conveyer and delivered to a bale breaker. This opens the bales and ensures the RDF is liberated and blended prior to feeding into the drier.

Drying

The RDF is dried using a band drier with steam batteries providing the heat source; the heat input for steam production is recovered from the Gasplasma® process. After drying, the dry RDF is fed into the gasifier feed hoppers.

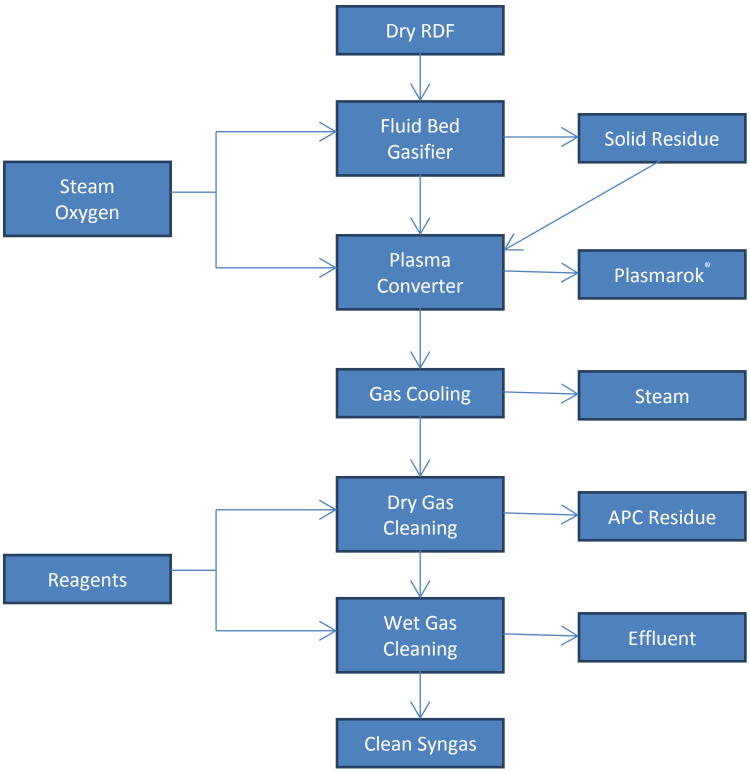
The moisture-laden air removed from drying the RDF is treated through a bag filter and a regenerative thermal oxidiser (RTO) to remove odour before release to atmosphere.

Syngas Production

The syngas production system as shown below operates for 24 hours a day, 7 days per week.

At the heart of the facility is the advanced Gasplasma® thermal process that produces a syngas. This is a crude but low-tar syngas which is cooled and refined to remove particulate matter, acid gases and volatile metal vapours. Within the syngas production section of the facility there are four main process groups

- Gasplasma®
- Gas Cooling System
- Dry Gas Cleaning System
- Wet Gas Cleaning System



Gasplasma®

Gasification of RDF

RDF is fed into the fluidised bed gasifier along with steam and oxygen to convert the mixed materials into raw gases. The process conditions are maintained by control of oxygen, steam and RDF feed rate. This process provides sufficient heat to maintain the fluidised bed temperature and produce a "crude syngas". The syngas contains significant quantities of long chain and cyclic hydrocarbons which would condense as tars and residues if it was allowed to cool.

The ash component of the RDF is automatically removed from the base of the gasifier through the bed screening process and conveyed to a hopper where it is metered into the plasma converter. There are no residues, chars or ash removed at this stage of the process.

The oxygen used to fluidise the gasifier bed material is supplied in bulk and stored on site in a liquid storage tank. The steam used to fluidise the gasifier bed material is generated with heat recovered from cooling the syngas. Both the steam and the oxygen oxidise the fuel.

Plasma Conversion of Gas

The crude syngas is transferred from the gasifier to the plasma converter via a refractory lined duct. In the centre of the plasma converter is a graphite electrode from which a thermal plasma arc is generated. The syngas is exposed to elevated temperatures and intense ultra violet light. The effect is to "crack" and reform the tars and chars contained in the syngas into their basic composition of hydrogen (H_2), carbon monoxide (CO), carbon dioxide (CO_2), and water (H_20). The Gasplasma® also breaks down sulphur-containing organic compounds. This a key performance attribute of the system where the syngas will ultimately pass over catalysts that and would be poisoned by such substances if they were present even in ppm quantities in the gas. This is a unique and particular advantage of the Gasplasma® system where the syngas is to be used for chemical synthesis.

The syngas is then drawn via a refractory lined duct to the inlet of the gas cooling system. At all times the gasifier and plasma converter operate at a negative pressure of -5 to -10 mbarg.

The design of the plasma converter has been optimised by computerised fluid dynamics (CFD) modelling to obtain maximum residence time for the syngas within the converter, whilst allowing time for ash and dust particles to drop out of the gas stream. These particles are incorporated into a molten slag pool which builds up in the base of the converter. This molten material is continuously removed from the plasma converter via an overflow weir and cooled for use as a vitrified and stable material. This material has been approved by the UK Environment Agency as a product and is trademarked under the name Plasmarok®.

Gas Cooling System

The gas cooling system comprises a heat recovery boiler designed to reduce syngas temperatures from circa 1,100°C to 160°C and generate saturated steam at 10 bar(g) pressure. The basis of the design is a water tube boiler using proven techniques employed in the energy-from-waste industry with specific attention given to the materials of construction to ensure long service life and to minimise down time caused by fouling and corrosion. Some of the steam generated is used in the Gasplasma® process; the remainder is used for fuel drying.

Dry Gas Cleaning System

The dry gas cleaning system, operating at 150 to 180°C, removes fine particulate materials from the syngas stream, neutralises acid gases, and removes heavy metal vapours.

The syngas passes to the ceramic particulate filter via an insulated duct into which the reagents sodium bicarbonate and activated carbon are injected. The duct provides sufficient residence time and turbulence to allow good reaction and collection, providing high capture rates for acidic components and volatile metals. Particulate matter, including the by-products from the reagent reactions, is trapped on the ceramic candle filter elements and periodically removed using a carbon dioxide reverse pulse system.

Wet Gas Cleaning System

From the dry gas phase, the syngas based through an alumina bed, which will hydrolyse carbonyl sulphide to hydrogen sulphide. After this step the syngas is cooled by direct contact with scrubbing liquor in a condenser scrubber. The unit is used to drop the fuel gas temperature to circa 30°C. The condenser operates as an acid scrubber, absorbing ammonia. To ensure complete absorption and neutralising of the ammonia the pH is maintained as acidic; sulphuric or nitric acid can be dosed into the scrubber to ensure this.

The gases are passed through a second, alkaline scrubber to remove acid gases - in particular, sulphur dioxide and hydrogen sulphide. The hydrogen sulphide is chemically oxidised to produce a stable effluent. The syngas leaving the wet cleaning system is a cool, clean syngas ready for compression and feeding into the methanation process. The effluent from this scrubber and the condensate from the condenser scrubber are discharged from the system for neutralisation, treatment and discharge to sewer (meeting all local regulatory requirements).

Methanation Process

As a general operating condition during start up and shutdown and periods of process stabilisation, syngas and combustible waste gas streams may generally be diverted to an enclosed flare where they are oxidised prior to release to atmosphere. In this way the upstream gas generation processes can be brought up to a stable operating condition and syngas quality brought up to the required specification before they are admitted to the catalytic water gas shift and methanation reactors. Equally, during periods when the methanation process may be unavailable to take any or all of the full syngas flow, the surplus can be routed to flare. The enclosed flare is rated for the design output of the Gasplasma® process and is used as a control during normal operation of the Gasplasma® process.

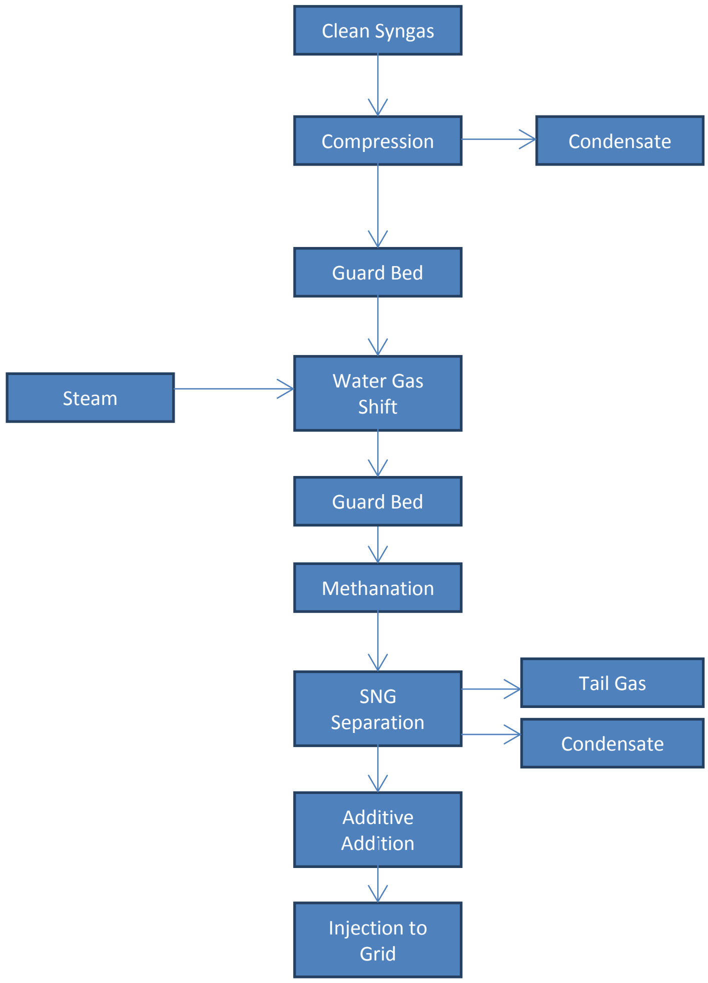
The syngas methanation process is designed to operate continuously.

The methanation process takes the cool, clean syngas and transforms it into a methane-rich gas that can be either used as transport fuel or injected into the gas grid. There are 6 steps in this process:

- Compression
- Syngas polishing

- Water gas shift reaction
- Shift gas polishing
- Methanation
- SNG separation, compression and export

The project partners have developed a solution for the conversion process and have additionally identified Amec Foster Wheeler as a potential supplier of the water gas shift and methanation stage using their proprietary Vesta technology. The process flows for the project partner's and Vesta processes are not significantly different and the process description below is representative of both approaches at this high level to both technologies. The partners consider that the Vesta process is the preferred option, but are not bound to this as a sole source of supply.



Compression

The compression stage will use a compressor, which receives syngas at 0.175bar(g) and delivers the outlet at 13 bar(g). The compressor includes inter-stage cooling and is specified to ensure there is no oil carry over with the compressed gas. Condensate arising from the inter-stage cooling process will be collected and sent to drain.

Syngas polishing

Syngas from the compressor is passed through a carbon bed to capture any remaining heavy metals. After the carbon bed the gas is heated to 350°C through a heat exchanger, with the heat source being provided by the gas exiting the methanation process.

Water gas shift reaction

After being heated on exiting the initial syngas polishing stage the gas passed into the high temperature water gas shift reactor, which is a reactor vessel packed with iron-chromium catalyst. Prior to the water gas shift, steam is mixed with the gas in sufficient quantity to drive the forward water gas shift reaction and give the gas leaving the reactor a nominal hydrogen to carbon monoxide molar ratio of 3:1. The gas leaves the reactor at c. 460°C.

Shift reaction gas polishing

On exiting the shift catalyst, the gas is passed through a guard bed, which contains a zinc oxide catalyst which removes any remaining sulphur species down to the ppb level demanded by the methanation catalysts.

Methanation

The methanation stage consists of four methanator vessels, each of which includes a catalyst bed packed with a proprietary nickel-iron methanation catalyst. The gas flows through each of the methanator vessels with both in-bed cooling and a gas cooling heat exchangers between each vessel. The heat exchangers are shell and tube units, with a thermal heat transfer fluid as the cooling medium. The inlet temperature to the methanator is at a temperature of approximately 210°C and the gas leaving the final methanator vessel will be at a temperature below 450°C. The reactors are configured to allow progressive introduction of shifted product to manage the exotherm. Provision is also been made for introduction of recycled product gas to quench the reaction under upset conditions.

SNG separation, additive addition and injection

After leaving the methanation final stage the gas is cooled to 40°C. The gas is passed into a condensate removal vessel, which removes free moisture, giving a gas saturated with water vapour. The condensate is returned to the de-aerator of the steam system where it is re-used for steam generation and injected as steam upstream of the water gas shift reactor.

Cooled gas from the methanation train flows to the acid gas removal (AGR) process where CO_2 content of the gas is reduced to the level required to meet product specifications. CO_2 removal will be by means of a conventional chemical solvent with absorber and desorber towers . The CO_2 containing gas is passed through a liquid scrubber, where the scrubbing liquor is c. 40-60°C and has the propensity to absorb the CO_2. The liquor is then heated to above 70°C, which reduces the liquors ability to hold the CO_2 hence, releasing it as a tail gas stream. From the tail gas the majority of the CO_2 will be vented to air but a small stream will be released at sufficient pressure to allow it to be used as a sealing and purge gas in the Gasplasma® and SNG process. The syngas compressor duty point of 13 bar(g) is sufficient to overcome system friction losses with a designed exit pressure of 7 bar(g).

The output from the facility is analysed to ensure it meets the required specifications, an odouriser is added and propane injected to ensure the calorific value meets the requirements for grid injection. Following this the gas is injected into the Wales and West Utilities Network.

Non-compliant gas will be sent to the flare.

Heating and cooling system

The SNG process incorporates a process integrated heating and cooling system. This is a water based system that generates steam for injection into the gas upstream of the water gas shift reactors. The system is designed to maximise process efficiency by recovering heat from the exothermic reactions to help raise the temperature of gases to the reaction light off temperatures.

There will be an excess of heat from the process, which will be dissipated through a closed loop system using air blast coolers, although in a commercial plant this would be used for power generation through an Organic Rankine Cycle.

7- Layout

There are a number of factors that have been considered in developing a plant layout that can be built and operated safely. These include:

- Existing constraints – such as the existing building envelope to be used and roadways. This is important to ensure that the facility will fit the criteria for the local development order, as discussed in the Site section above. By complying with the local development order APP are able to develop the site without the need for a full planning application.
- Positioning equipment so that the process flows around the site in the same arrangement as on the process flow diagram – this avoids excessive pipe runs and bends.
- Ensuring there is adequate access to plant and equipment to safely maintain the plant.
- Considering the construction sequence to ensure the layout does not constrain the construction programme (such as ensuring areas of the site do not become isolated due to the sequence of equipment installation).
- Location of services into the plant i.e. making sure there is adequate space for the services to enter the building and be metered.
- Considering access during operation for routine inspections and replenishing process consumables to be completed safely and efficiently.
- Constraints likely to introduced through the planning and permitting process – such as hours when waste can be received and so ensuring there is adequate storage.
- Location of sensitive receptors relative to the plant and ensuring plant and equipment is positioned to minimise the impact on these receptors.
- Positioning plant and equipment to benefit from existing drainage.

- Regulatory compliance – particularly the requirements of DSEAR.
- Site security – ensuring that access into the plant is controlled at all times.

APP has applied the benefit of their experience from constructing and operating the facilities in Swindon in developing the layout. The layout has been separated into three separate areas.

1. The waste reception and Gasplasma® plant. This is located within the A4 building and includes the bale breaking and drying equipment. The area is maintained under negative pressure to prevent fugitive emissions and egress of odour.
2. The syngas cooling and cleaning plant. This is located externally, with the syngas cooling boiler providing the transition from internal to external plant. By locating the plant externally it is naturally ventilated. This natural ventilation coupled with the low operating pressure of the system means that it is classified as zone 2 negligible extent rating for the system for the purposes of DSEAR, which reduces the specification of the equipment, making it less expensive. This is also the basis of existing Swindon plant.
3. The conversion process. This is located within the A3 building area and includes gas compression, methanation and final product compression and storage. This element of plant will be DSEAR zone 2 rated and additionally requires forced ventilation to maintain operating temperatures by dissipating process heat from the vessel shells. This is the reason for locating it within the separate A3 building area.

Following a preliminary review for both buildability and operability of the system APP consider that the proposed layout is robust, deliverable and has adequate contingent area to accommodate further developments and improvements.

8 - Mass and Energy Balances

The mass and energy balance for the plant encompass the entire process operation from the receipt of RDF through its transformation to a clean syngas and the onward conversion of this to SNG.

The balances are underpinned with detailed models developed to include equipment suppliers' experiences and with validation from extensive direct pilot plant observations. As such, these models have been demonstrated to provide a high degree of confidence as to their accuracy and reliability in predicting the transformation of solid wastes to calorific gases. In addition, the models have been extensively tested and validated by independent third parties to provide assurance of their use.

The starting point for the mass and energy balance is the waste feedstock. The basis for this is set out in Section 4. This feedstock is regarded as being in the typical range of RDFs found in the UK. The feedstock is dried from 35 wt% to 12 wt% utilising heat recovered from the downstream process. This dried feedstock is then fed to the Gasplasma® process where is it gasified using oxygen and steam. The syngas generated is cooled and cleaned before it is transformed to SNG through a series of catalysed reaction stages. The performance of these individual reaction stages can be predicted with a high degree of confidence as the reaction kinetics of these transformation is relatively simple, but is based on specific catalyst performance under specific operating conditions. The final SNG results from a separation process in which a tail gas containing largely inert products is separated out.

The composition of these gas streams is summarised in the following table.

Gas component	**Gas composition (volume %)**		
	Gasplasma® syngas	**SNG product gas**	**SNG tail gas**
Hydrogen (H_2)	38.80	0.57	0.00
Carbon monoxide (CO)	36.60	0.01	0.00
Methane (CH_4)	0.70	97.38	0.00
Water vapour (H_2O)	7.30	0.00	0.84
Propane (C_3H_8)	0.00	0.00	0.00
Other	0.2	0.00	0.2
Inerts			
Carbon dioxide (CO_2)	15.70	0.13	98.87
Other inerts	0.70	1.92	0.06
TOTAL	100.0	100.0	100.0
Gross calorific value (MJ/m^3)	-	38.6	-
Wobbe index (MJ/m^3)	-	58.0	-

Propane is then added to the gas to lift the calorific value to $39.3MW/m^3$ to meet the required grid CV.

The conversion efficiency is given in the table below. Of the energy content of the incoming waste some 58.8% is converted into the SNG product, while only 15.3% of the mass is captured in this product stream, indicating the generation of a considerably higher energy density product than is provided by the waste stream.

	Conversion efficiency relative to waste received (%)			
	RDF as received	Dried RDF used in the Gasplasma® process	Syngas	SNG product gas
Mass basis	100%	73.9%	88.0%	15.3%
Energy basis	100%	100%	77.6%	58.8%

As such, of the 4.4 MW of energy input as RDF, the yield of SNG product will be 2.59 MW on a net basis.

9 - Package Identification and Specifications

The project partners have reviewed the process flow diagrams and defined packages of equipment that are suitable for procurement. The key principles in identifying packages are:

- Clear battery limits – packages must be amenable to clear definition of their battery limits and their requirements at those limits.

- Separation – packages must be capable of being delivered without any reliance on any other packages.
- Supply chain availability – multiple suppliers must be available to deliver the specified package.
- Scope of supply – in general, packages should include design, procurement, fabrication, and installation on prepared foundations and cold commissioning.

The partners have engaged with the supply chain for several years to optimise the number and definition of packages. The following table sets out the packages that will be used for delivery of the facility.

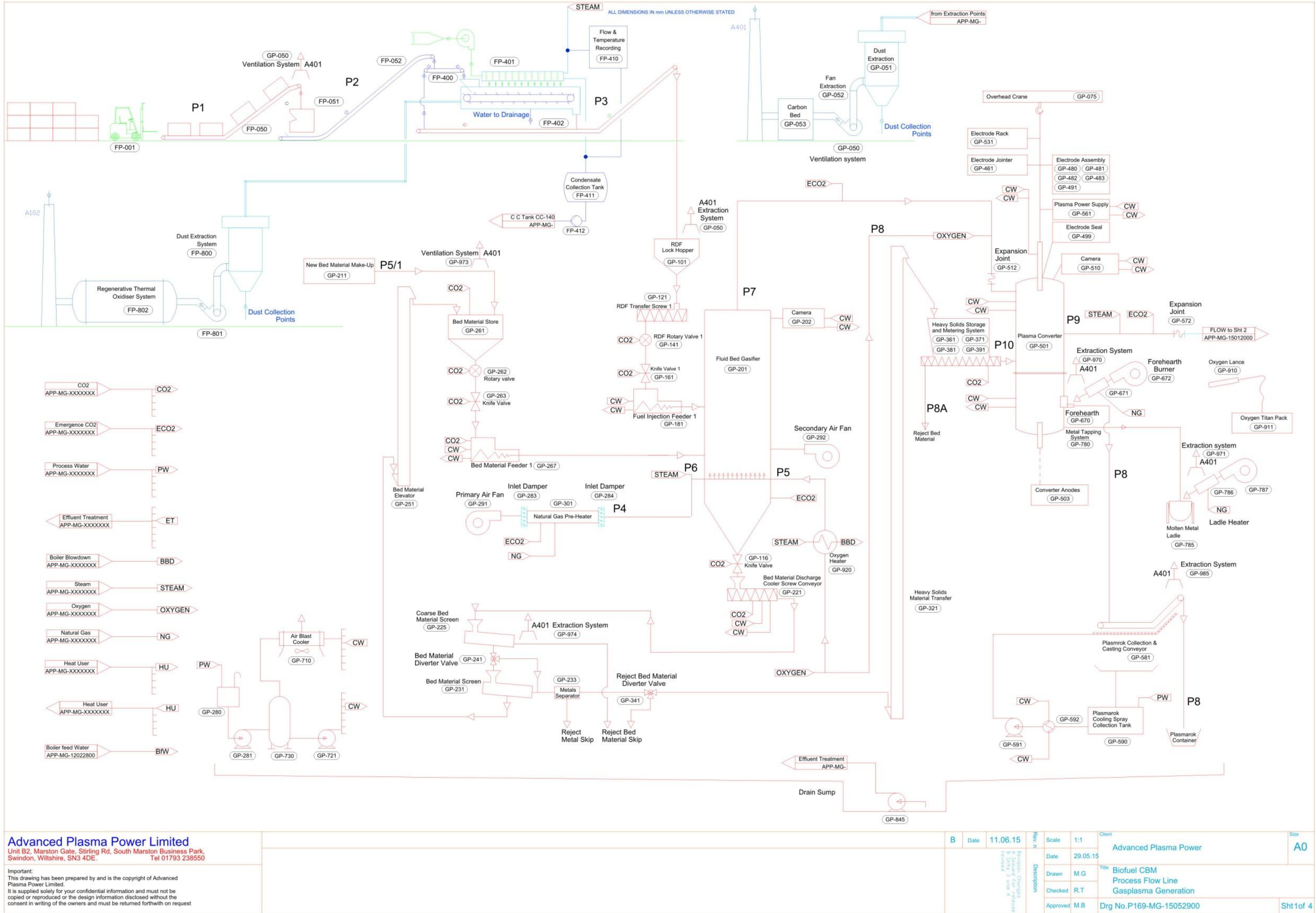
Package	Outline Specification	Potential Suppliers
Shredder and conveyors	Delivery and shredding of wet baled waste to the dryer.	Machinex, O.Kay Engineering
Odour control	Removal and treatment of air from waste storage and drying.	ERG, Megtec
Drier	Drying of wet RDF.	Mitchells, Alvan Blanch
Dry storage	Storage of dried RDF and delivery to gasifier.	Machinex, O.Kay Engineering
Gasplasma® package	Gasification of dried RDF using fluidised bed gasifier and plasma converter.	Tetronics
Waste Heat Boiler	Cooling of syngas and generation of steams.	Greens Power, TIBS
Dry gas cleaning	Syngas cleaning to remove particulate and vapours	Glosfume, Megtec
APC discharge / collection	Conveyance of solids to storage for offsite removal	Saxlund
Wet Syngas cleaning	Syngas cooling and acid scrubbing	ACWA
Water Treatment	Onsite treatment of process water	Hager & Elsasser, Elga
CEMS	Continuous emission monitoring of flue gas	Envirotech, Servomex
ID Fan	Gas induction following cleaning	Halifax Fans
Syngas buffer vessel		Gas Compressors
Auxilary boiler	Process start up	Fulton
Weighbridge	Weighing in of feedstock and outgoing product	Avery Weightronix, Shering
Diesel tank	Bunded storage of fuel	
Cooling Systems		Aqua cooling, Carter Environmental
Compressed air	Supply of compressed air to	Atlas Copco, Boge

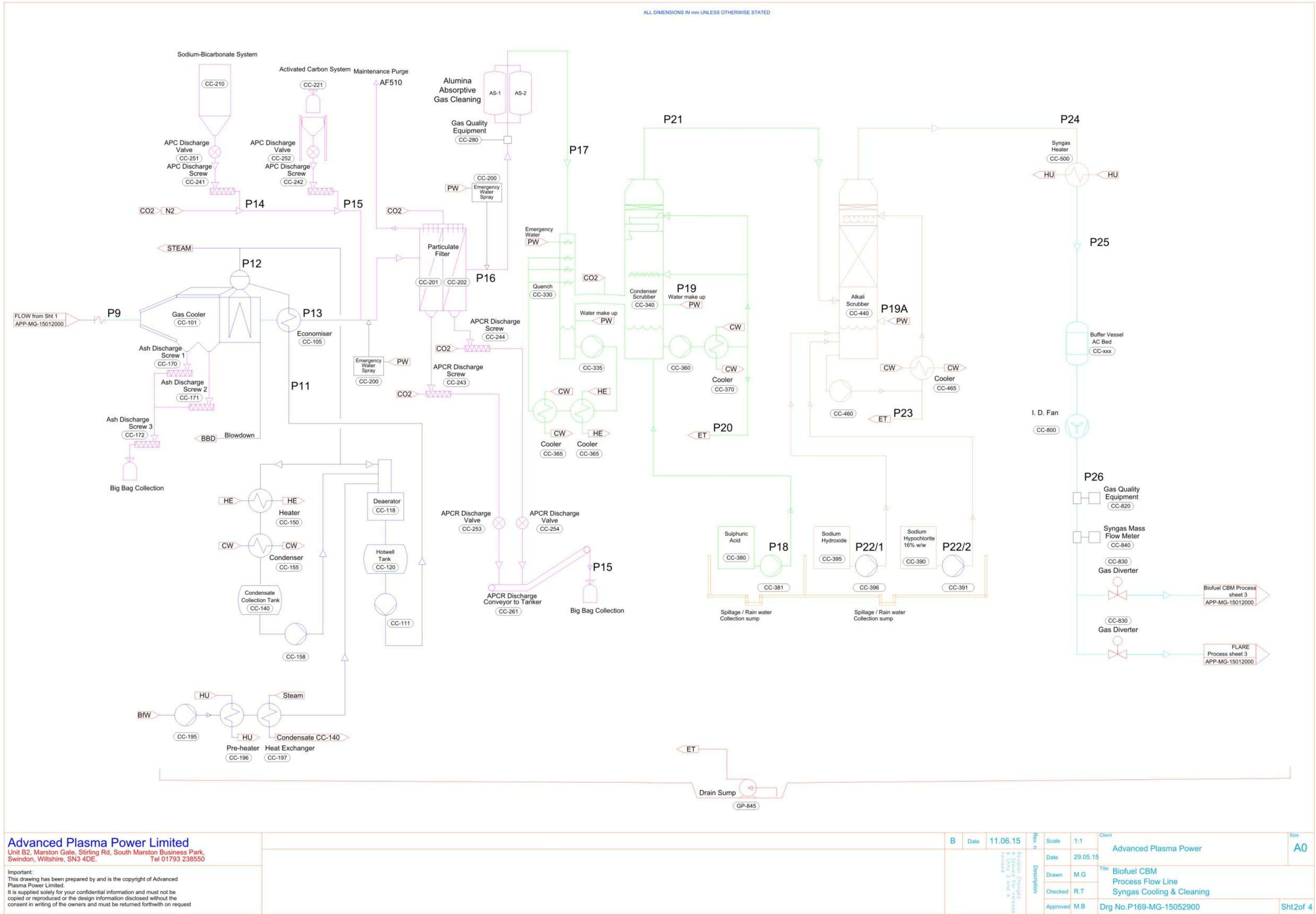
	pneumatic devices	
Flare	Oxidisation of gases during start up/shutdown	Flare Products, Uniflare
Oxygen plant	Oxygen supply for gasifier & convertor consumption	Linde, Air Products
Civils	Localised strengthening of slab, additional steel work and building modifications	
Gas measurement	Analyser	Servomex
Syngas compressor, enclosure and storage	Compression of clean syngas and storage	Gas Compressors
Water gas shift, methanator and CO2 removal	Depressuring and reheating of syngas for methanation	Foster Wheeler
Cooling circuits for methanator		Foster Wheeler
Ventilation equipment	Ventilation of Bio-SNG area	ERG
Natural gas compressor	Compression of natural gas prior to storage	Gas Compressors
Natural gas storage	Gas storage tanks on Two skids	Gas Compressors
Power & controls	Supply of plant control system	
Mechanical installation	Installation of procured plant and equipment together with interconnections	
Construction Management	Management of onsite works	Otto Simon

Quotations have been obtained for all of these packages and have been used to develop a cost plan of the projects. Specification for each package will be refined in consultation with the Construction Manager and potential suppliers.

In general, procurement will be managed through an open, competitive tender process. There are two exceptions: APP will deliver the Gasplasma® Package and Otto Simon Ltd will deliver the Construction Management package.

Annex 1 – Process Flow Diagram

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Activated Carbon System
Maintenance Purge
AF510
Alumina Absorptive Gas Cleaning
Gas Quality Equipment
APC Discharge Valve
APC Discharge Screw
Particulate Filter
Gas Cooler
Economiser
Quench
Condenser Scrubber
Alkali Scrubber
Water make up
Syngas Heater
Buffer Vessel AC Bed
I. D. Fan
Syngas Mass Flow Meter
Gas Diverter
Biofuel CBM Process sheet 3 APP-MG-15012000
FLARE Process sheet 3 APP-MG-15012000
FLOW from Sht 1 APP-MG-15012000
Ash Discharge Screw 1
Ash Discharge Screw 2
Ash Discharge Screw 3
Big Bag Collection
Blowdown
Deaerator
Heater
Condenser
Hotwell Tank
Condensate Collection Tank
APCR Discharge Screw
APCR Discharge Valve
APCR Discharge Conveyor to Tanker
Emergency Water Spray
Cooler
Sulphuric Acid
Sodium Hydroxide
Sodium Hypochlorite 16% w/w
Spillage / Rain water Collection sump
Pre-heater
Heat Exchanger
Condensate CC-140
Drain Sump
P9 P11 P12 P13 P14 P15 P16 P17 P18 P19 P19A P20 P21 P22/1 P22/2 P23 P24 P25 P26
Advanced Plasma Power Limited
Unit B2, Marston Gate, Stirling Rd, South Marston Business Park, Swindon, Wiltshire, SN3 4DE. Tel 01793 238550
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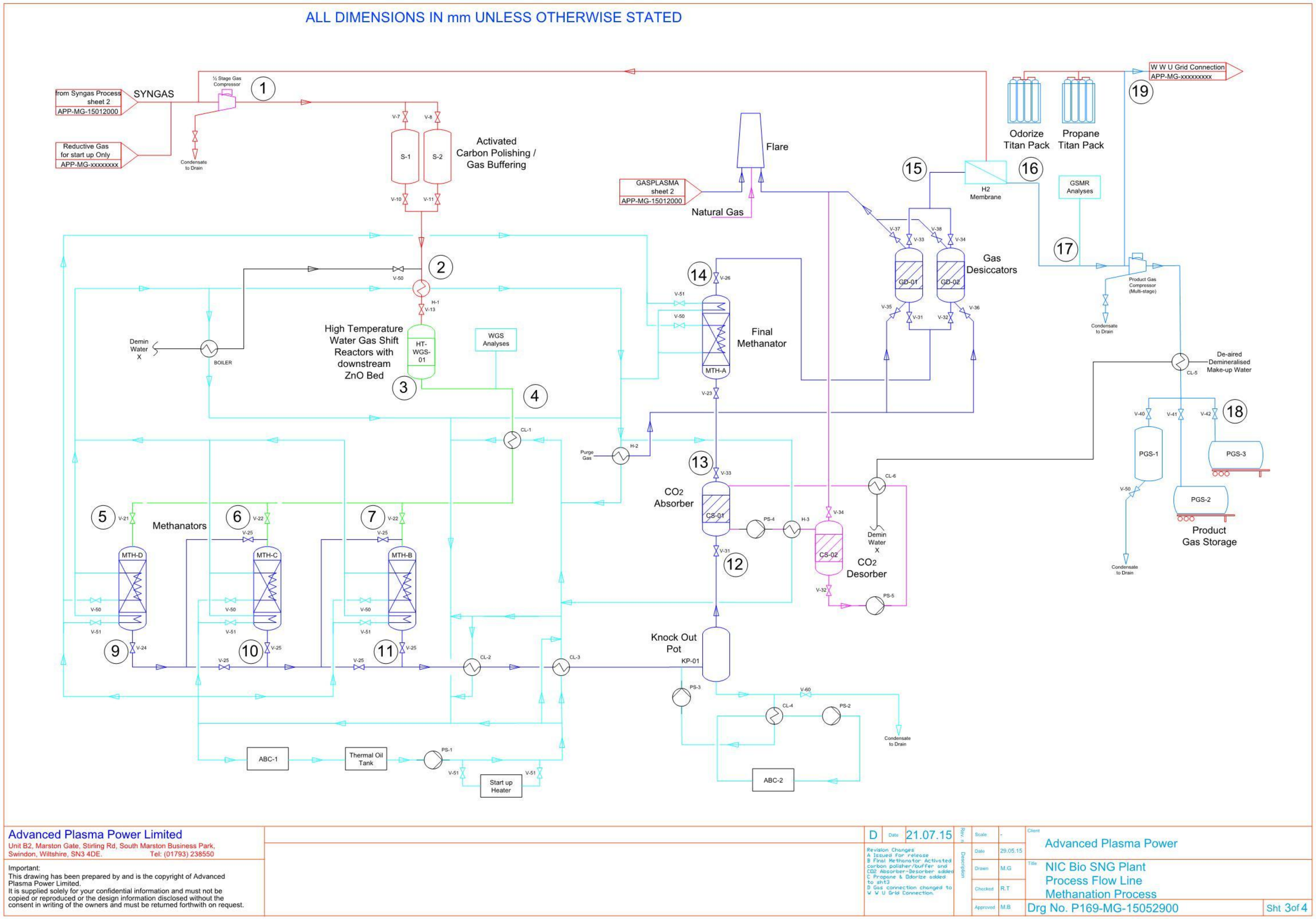
B Date 11.06.15
Scale 1:1
Date 29.05.15
Drawn M.G
Checked R.T
Approved M.B
Client Advanced Plasma Power
Size A0
Title Biofuel CBM Process Flow Line Syngas Cooling & Cleaning
Drg No.P169-MG-15052900
Sht2of 4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from Syngas Process sheet 2
APP-MG-15012000
SYNGAS
Reductive Gas for start up Only
APP-MG-xxxxxxxx
½ Stage Gas Compressor
Condensate to Drain
Activated Carbon Polishing / Gas Buffering
S-1
S-2
GASPLASMA sheet 2
APP-MG-15012000
Natural Gas
Flare
H2 Membrane
Odorize Titan Pack
Propane Titan Pack
W W U Grid Connection
APP-MG-xxxxxxxxx
GSMR Analyses
Gas Desiccators
GD-01
GD-02
Product Gas Compressor (Multi-stage)
Demin Water
BOILER
High Temperature Water Gas Shift Reactors with downstream ZnO Bed
HT-WGS-01
WGS Analyses
Final Methanator
MTH-A
De-aired Demineralised Make-up Water
PGS-1
PGS-2
PGS-3
Product Gas Storage
Purge Gas
CO2 Absorber
CS-01
CS-02
CO2 Desorber
Methanators
MTH-D
MTH-C
MTH-B
Knock Out Pot
KP-01
ABC-1
Thermal Oil Tank
Start up Heater
ABC-2
Condensate to Drain
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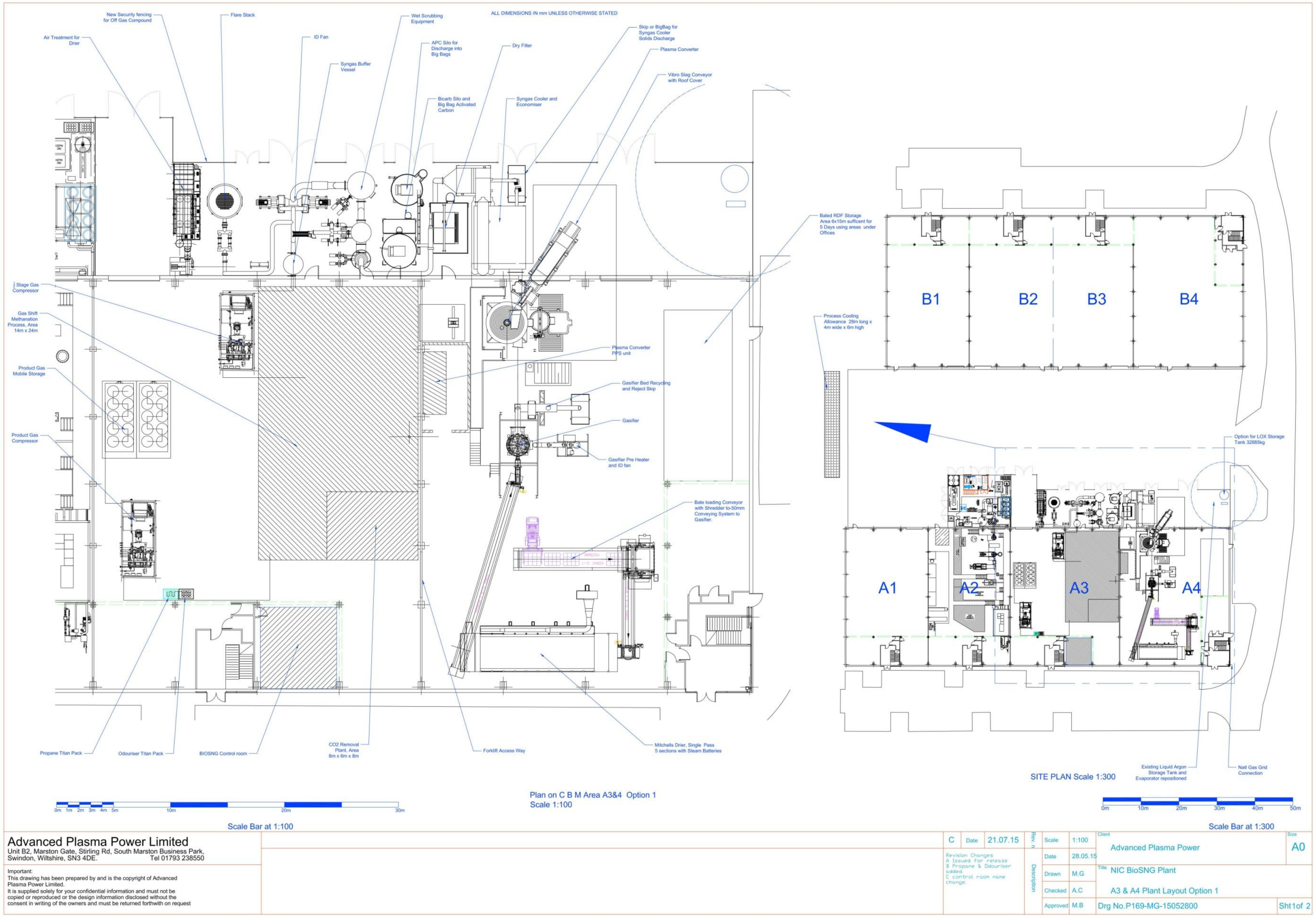
D Date 21.07.15
Revision Changes
A Issued for release
B Final Methanator Activated carbon polisher/buffer and CO2 Absorber-Desorber added to sht3
C Propane & Odorize added
D Gas connection changed to W W U Grid Connection.
Date 29.05.15
Drawn M.G
Checked R.T
Approved M.B
Client Advanced Plasma Power
Title NIC Bio SNG Plant
Process Flow Line
Methanation Process
Drg No. P169-MG-15052900
Sht 3 of 4

Annex 2 – Layout



Annex 3 – Mass and Energy Balances

The mass and energy balance for the plant encompass the entire process operation from the receipt of waste through its transformation to a clean syngas and the onward conversion of this to SNG.

The balances are underpinned with models developed to include equipment suppliers' experiences and with validation from extensive direct pilot plant observations.

The starting point for the mass and energy balance is the waste feedstock. This feedstock is regarded as being in the typical range of RDFs found in the UK. The feedstock is received as a 'wet' material, possessing a moisture content of some 35 wt%. This is then reduced to 12 wt% using a thermal drying process, utilising heat recovered from the downstream process.

The dried feedstock is fed to the Gasplasma® process where is it gasified using oxygen and steam, generated from heat recovered from the process. The Gasplasma® process is fed with 4.4 MWth of feedstock, equivalent to 993 kg/h of material. This in turn equates to 1344 kg/h of undried, 'wet' feedstock.

The autothermal gasification process is undertaken with carefully controlled flows of steam and oxygen. The oxygen is of 99.5% purity. Steam is supplied from a heat recovery steam generator downstream of the plasma converter, which recovers sensible energy from the syngas and generates 10 bar(g) pressure steam for use in the feedstock drying and the gasification steps.

The action of the gasification process on the feedstock is such that a hydrogen-rich syngas is generated. Having passed through the gasification and plasma conversion stages of the Gasplasma® process, the syngas is then passed through a number of stages of gas cooling and cleaning, resulting in a syngas with a net calorific value of 10.39 MJ/kg (10.79MJ/kg on gross basis). This gas is summarised below in the table below.

Gas component	**Syngas composition**		
	Volume (vol%)	**Mass (wt%)**	**Energy content (%)**
Hydrogen (H_2)	38.8	4.0	46.2
Carbon monoxide (CO)	36.6	52.2	50.6
Carbon dioxide (CO_2)	15.7	35.1	0.0
Methane (CH_4)	0.7	0.5	2.6
Water vapour (H_2O)	7.3	6.7	0.0
Other	0.9	1.8	0.6
TOTAL	100.0	100.0	100.0

In addition to syngas, the Gasplasma® process also produces 79 kg/h Plasmarok®. This stream is the inert portion (i.e. the ash containing residues) of the RDF that is vitrified by the plasma converter. This material is a saleable product that is suitable for use in secondary aggregate applications.

Other material outputs are associated with the syngas cleaning processes, whereby process effluents and gas treatment dusts are generated. These are summarised below in the table below.

By comparison, the inputs to the Gasplasma® process are dominated by the gasifying agents (steam and oxygen), water addition (to offset steam use in the gasifier, boiler blowdown, and chemical makedown), and gas scrubbing chemicals. The gas scrubbing chemicals comprise of the solid air pollution control additives (activated carbon and sodium bicarbonate) and chemical agents used in the multi-stage wet scrubbing columns, comprising individual columns for sulphuric acid, sodium hydroxide, and sodium hypochlorite.

Inflow	**Mass flow (kg/h)**	**Outflow**	**Mass flow (kg/h)**
RDF	993		
Gasifying agents	405	Plasmarok®	79
		Ash	30
Water	402	Air pollution control residues	48
Gas scrubbing chemicals	33	Effluent	492
		Syngas	1183
TOTAL	**1833**	**TOTAL**	**1833**

Mass balance for the Gasplasma® process

The energy conversion efficiency from incoming RDF to syngas is 77.6%. This represents the potential combustion energy available in the syngas relative to that contained in the RDF feedstock. This conversion equates to c. 3.8 MW of gross calorific energy per tonne of feedstock. Alternatively, a volumetric syngas yield may be used to describe efficiency – this is 1.36 Nm^3 of syngas per kg of feedstock.

The energy input to the Gasplasma® process is dominated by the RDF, which accounts for 91% of the energy input to the process. The RDF represents 4.4 MW of energy input on a net calorific value basis or 4.86 MW on a gross calorific value basis.

The other major energy input to the process is electrical load, which accounts for some 0.33 MW of energy.

By comparison, the syngas accounts for 71% of the energy output from the plant (on a gross basis) with other major contributions from heat recovery to steam (0.52 MW) or complete thermal losses (0.97 MW).

These results are summarised below.

Inflow	**Energy flow (MW)**	**Outflow**	**Energy flow (MW)**
RDF	4.86		
Gasifying agents	0.07	Plasmarok®	0.04
Condensate return	0.05	Steam generation	0.52
		Ash	0.00
Water	0.00	Air pollution control residues	0.00
Gas scrubbing chemicals	0.01	Effluent	0.02
		Syngas	3.79
Electrical load	0.57	Thermal losses	1.19

TOTAL	5.56	TOTAL	5.56

Energy balance for the Gasplasma® process (gross basis)

The syngas is then converted to SNG using a series of catalysed reactions. Firstly, the gas is compressed to the reaction pressure, where steam is added to the process line. The syngas is then subjected to a high temperature water gas shift reaction where the hydrogen to carbon monoxide molar ratio is adjusted from near unity to a significantly higher number. This shifted syngas is then fed to a cascade of methanation catalytic reactors where the syngas components are combined together to produce methane. These reactions are exothermic permitting the recovery of sensible energy to a steam generation system.

The final methanated gas product is purified through a chemical solvent CO_2 removal system and a small quantity of propane is added to produce the final SNG product. The gas composition for syngas, SNG product gas and tail gas from the separation process are provided below. The SNG product gas is pre propanation and odouriser.

Gas species	Gasplasma syngas			SNG product gas			SNG tail gas	
	%vol	%wt	%energy	%vol	%wt	%energy	%vol	%wt
H_2	38.80%	3.96%	45.58%	0.57%	0.07%	0.16%	0.00%	0.00%
CO	36.60%	52.26%	50.74%	0.01%	0.02%	0.00%	0.00%	0.00%
CO_2	15.70%	35.22%	0.00%	0.13%	0.35%	0.00%	98.87%	99.44%
CH_4	0.70%	0.57%	3.04%	97.38%	96.11%	99.84%	0.00%	0.00%
H_2O	7.39%	6.78%	0.00%	0.00%	0.00%	0.00%	0.84%	0.35%
C_2H_2	0.10%	0.13%	0.64%	0.00%	0.00%	0.00%	0.00%	0.00%
H_2S	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%
NO	0.01%	0.02%	0.00%	0.00%	0.00%	0.00%	0.02%	0.01%
N_2	0.60%	0.86%	0.00%	1.72%	2.98%	0.00%	0.17%	0.11%
Ar	0.10%	0.20%	0.00%	0.19%	0.47%	0.00%	0.09%	0.08%
TOTAL	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

The mass balance for this transformation is dominated by the air required and flue gas generated in the flare combustion equipment. In this equipment, any unwanted gas is exposed to a pilot light and flammable gas components are fully combusted before emission to atmosphere. This is shown below.

The SNG mass flow from process represents only some c. 17% of the syngas mass flow. The reduction in flow is largely attributable to the removal of inert gases (e.g. carbon dioxide) from the stream in both the reaction and separation stages.

Inflow	**Mass flow (kg/h)**	**Outflow**	**Mass flow (kg/h)**
Syngas	1183	Condensate	669
Water	542	SNG (pre-propanation)	206

Combustion air to flare	8692		
Natural gas supply to flare	3	Flue gas	9546
TOTAL	**10432**	**TOTAL**	**10432**

Mass balance for the syngas conversion process to SNG

The syngas has 11kg/h of propane added to achieve the target grid CV.

By comparison the energy content of the flue gas issuing from the flare equipment contains only a small proportion of the total plant energy output.

The bulk of the energy content is held within the SNG product gas stream. The energy conversion efficiency from incoming syngas (generated within the Gasplasma® process) to SNG is 75.7% (on a net calorific value basis).

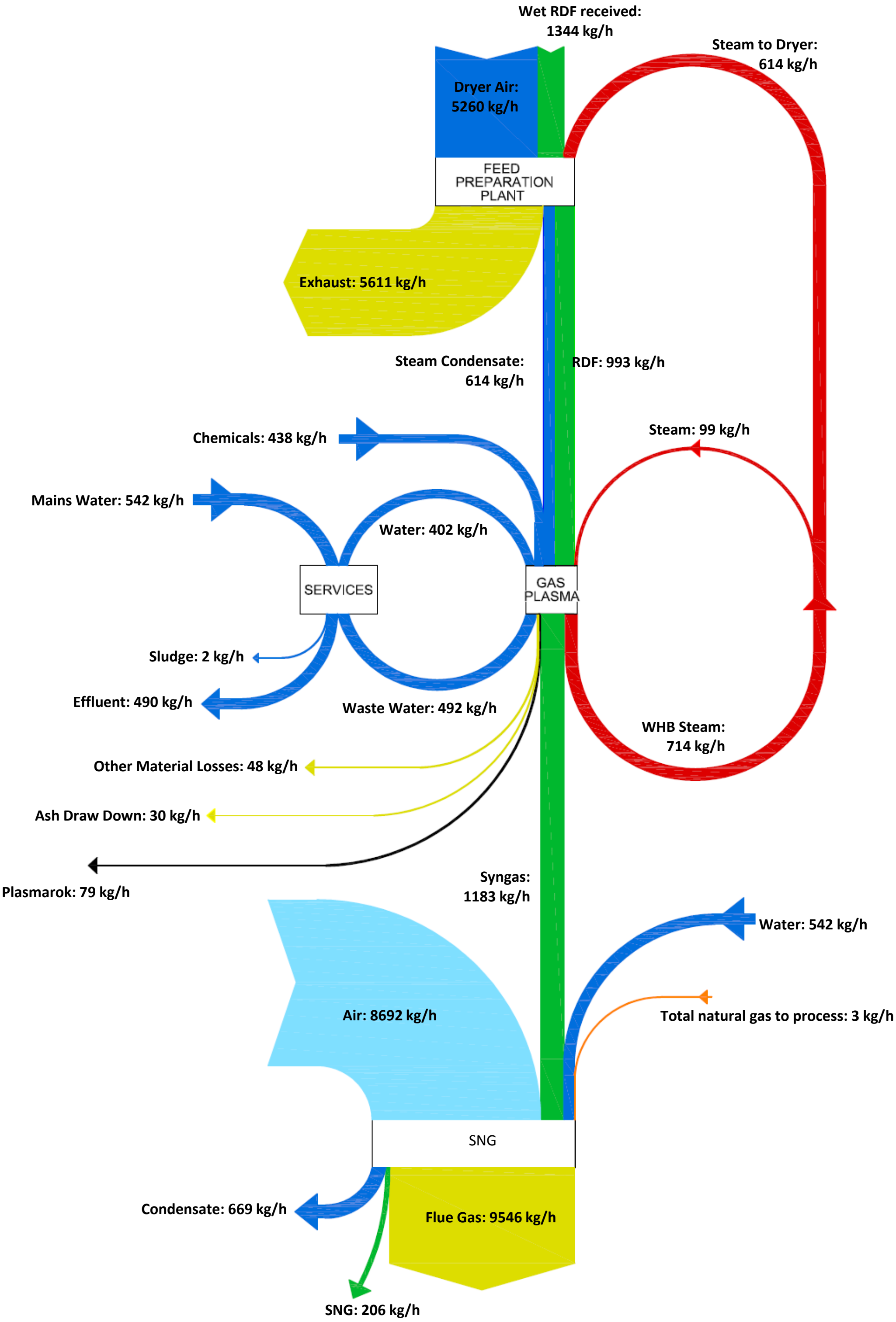
Inflow	**Energy flow (MW)**	**Outflow**	**Energy flow (MW)**
Syngas	3.79	SNG	**2.59**
Water	0.00	Condensate	0.01
Parasitic electrical load	0.63	Heat to cooling systems	1.73
Combustion air to flare	0.01	Flue gas from flare	0.15
Natural gas to flare	0.05		
TOTAL	**4.64**	**TOTAL**	**4.64**

Energy balance for the syngas conversion process to SNG

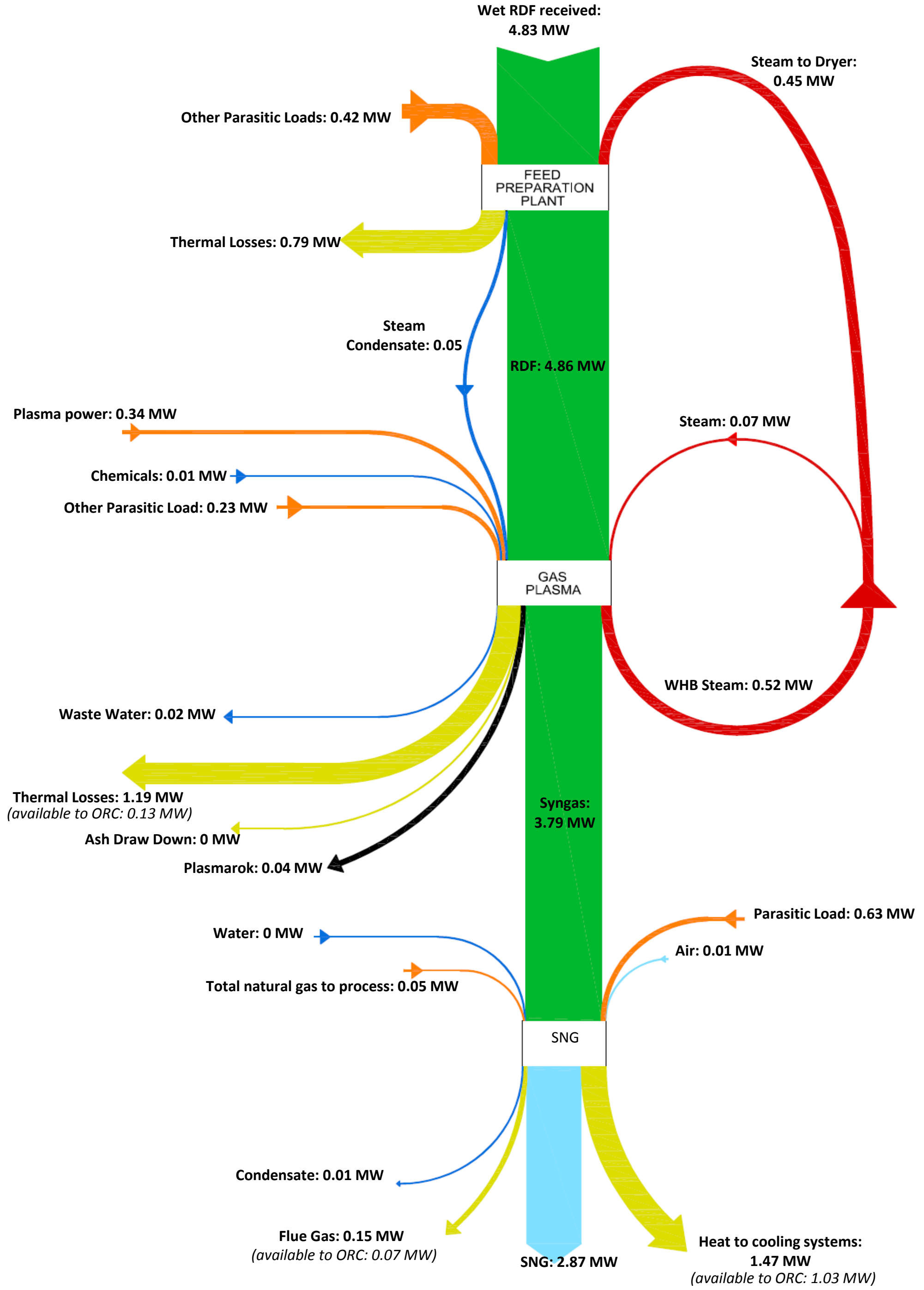
The syngas then has 0.11MW of propane added to achieve the target grid CV.

The energy conversion efficiency from incoming RDF to SNG is 58.8%. This represents the potential combustion energy available in the SNG relative to that contained in the RDF feedstock. This conversion equates to c. 2.6 MW of gross calorific energy per tonne of feedstock.

The overall mass and energy transformations from RDF to SNG can be seen in the Sankey diagrams provided in the Figures below. In these Sankey flow diagrams the width of the arrows is shown proportionally to the flows quantity. All energy flows are included, including those for ancillary systems (e.g. conveyors, etc.) whose contributions do not directly affect the process stream.



Sankey diagram for the conversion of RDF to SNG (mass basis) Excluding Propanation



Sankey diagram for the conversion of RDF to SNG (gross energy content basis) Excluding Propanation

Appendix 5a – Project Plan Description

Task 1: Secure Planning and Environmental Permits (1/16)

- Complete work started in August 2015.
- Complete planning process.
- Complete environmental permit process.
- Agree trade effluent discharge consent.

Milestones: Completed planning permission and permit, grid connections agreed.

Task 2: Detailed Design and Safety Review Assessment (1/16 – 7/16)

- Work commences in August 2015.
- Finalise waste composition.
- Finalise process flow diagram, mass and energy balance and layout.
- Define civil and building modifications.
- Prepare process and instrumentation diagram, control philosophy and electrical system specification.
- Create process data sheets for major equipment.
- Produce project management manuals.
- Finalise safety review including independently led Hazop.

Milestones: Sign off of design documents and Hazop.

Task 3: Commercial Contract Development (1/16 – 3/16)

- Work commences in August 2015.
- Finalise Construction Manager contract.
- Finalise grid and waste off-take agreements.
- Agree electric and water grid connection.

Milestones: Finalise contracts.

Task 4: Equipment Procurement (1/16 – 3/17)

- Finalise work package definition.
- Develop functional specifications and interface register.
- Tender for packages.
- Negotiate commercial conditions and appoint suppliers.
- Manage suppliers through equipment manufacture.
- Factory Acceptance Testing of equipment.
- Pre-construction Hazop.

Milestones: Issue ITT information, place orders, delivery of materials to manufacturer, completion of FATs.

Task 5: Construction (7/16 – 7/17)

- Mobilisation.
- Civils and building modification.
- Grid connections.
- Installation onsite of equipment.
- Interconnecting pipework, electrical and control installation.

Milestones: Installation of equipment, installation checks complete.

Task 6/7: Commissioning and system proving (7/17 – 12/17)

- Control system testing.

- Pre-commissioning checks.
- Cold and hot commissioning.
- Undertake a series of extended operational tests.
- Review lifecycle assessment.
- Confirm performance of commercial plant.

Milestones: Complete cold and hot commissioning, handover plant.

Task 8: Operational Phase (1/18 – 11/18)

- Delivery of in-specification product.
- Monitor product quality, customer feedback and system performance.

Milestones: Delivery of in-spec gas to grid, KPI reports.

Task 9: Commercial Plant System Development (8/15 – 11/18)

- Maintain outline design.
- Maintain financial model.
- Update and review the prevailing market conditions.

Milestones: Updated financial models.

Task 10: Dissemination Activities (8/15 – 11/18)

- Update gogreengas website.
- Showcase facility.
- Preparation of process and close-out reports.
- Monthly email update to contact database.
- Public relations and press/media work.
- Presentations, technical papers and journal articles.

Milestones: Delivery of website, showcase and media activity reports.

Task 11: Project Management (8/15 – 11/18)

- Technical project management to time and specification.
- Financial control of budget.
- Steering group management.

Milestones: Delivery of regular project reports.

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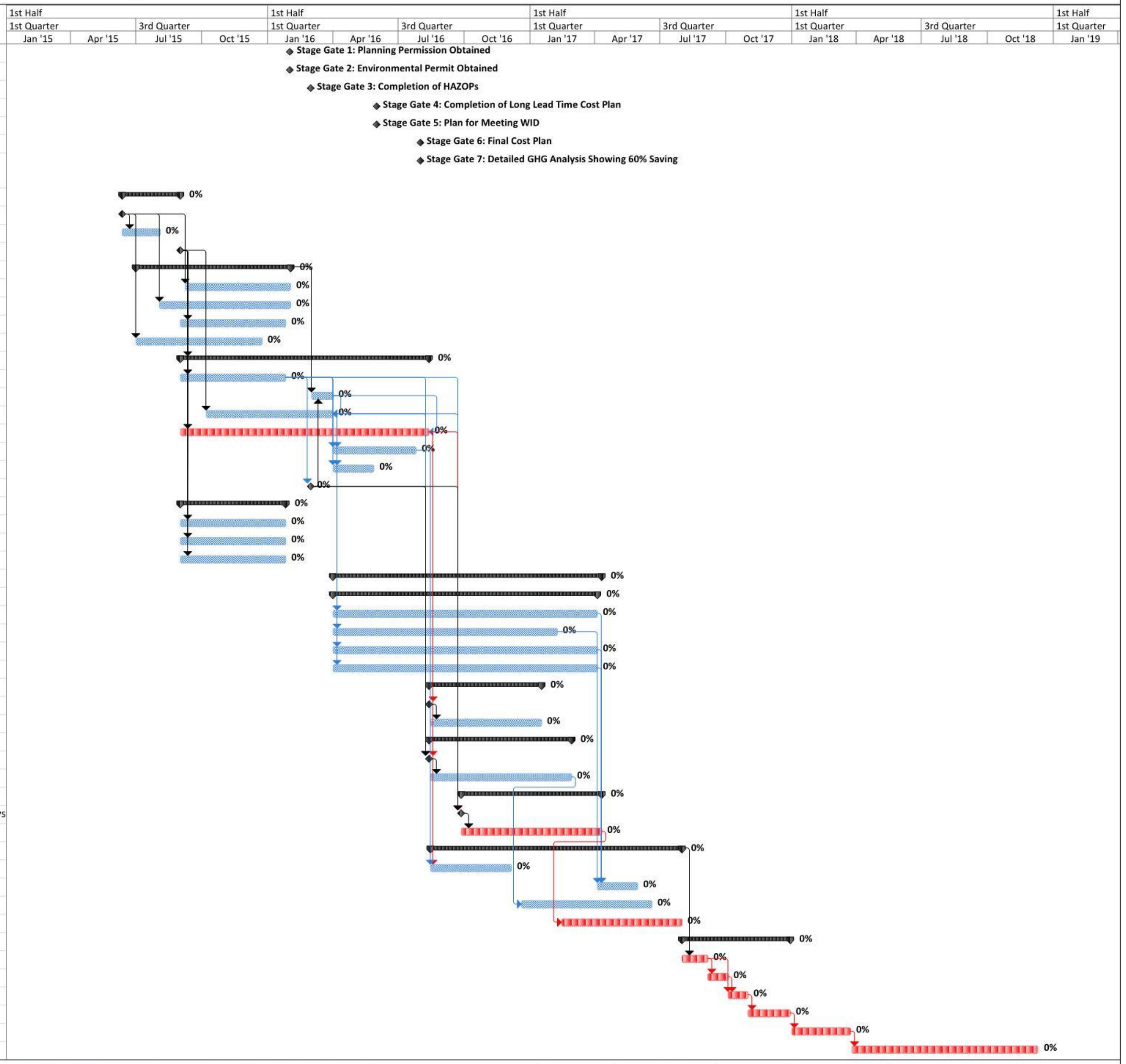
RIIO NIC NETWORK INNOVATION COMPETITION

Appendix 5b – Gantt Chart

Integrated Compressed Biomethane Facility | **1.5M Kg per annum CBM - Indicative Programme** | OSL Proposal Number 0446

ID	Task Name	Duration	Start	Finish	Predecessors
1	Stage Gate 1: Planning Permission Obtained	1 day	Mon 01/02/16	Mon 01/02/16	
2	Stage Gate 2: Environmental Permit Obtained	1 day	Mon 01/02/16	Mon 01/02/16	
3	Stage Gate 3: Completion of HAZOPs	1 day	Tue 01/03/16	Tue 01/03/16	
4	Stage Gate 4: Completion of Long Lead Time Cost Plan	1 day	Wed 01/06/16	Wed 01/06/16	
5	Stage Gate 5: Plan for Meeting WID	1 day	Wed 01/06/16	Wed 01/06/16	
6	Stage Gate 6: Final Cost Plan	1 day	Mon 01/08/16	Mon 01/08/16	
7	Stage Gate 7: Detailed GHG Analysis Showing 60% Saving	1 day	Mon 01/08/16	Mon 01/08/16	
8	**Proposal 446 - DfT Advanced Biofuels**	**56 days**	**Fri 12/06/15**	**Tue 01/09/15**	
9	Scheme Proposal Submission	0 days	Fri 12/06/15	Fri 12/06/15	
10	Finalise Project Funding	37 days	Fri 12/06/15	Mon 03/08/15	9
11	Project Commencement	0 days	Tue 01/09/15	Tue 01/09/15	
12	**Task 1 Consents**	**148 days**	**Wed 01/07/15**	**Mon 01/02/16**	
13	Planning Permission	100 days	Tue 08/09/15	Mon 01/02/16	9FS+61 days
14	Permitting	125 days	Mon 03/08/15	Mon 01/02/16	9FS+36 days
15	TEDC	100 days	Tue 01/09/15	Mon 25/01/16	11
16	Landlord Consent	125 days	Wed 01/07/15	Wed 23/12/15	9FS+13 days
17	**Task 2 Design**	**240 days**	**Tue 01/09/15**	**Fri 12/08/16**	**11**
18	Initial P&IDs	100 days	Tue 01/09/15	Mon 25/01/16	11
19	Update P&IDs following Consents and Hazops	20 days	Wed 02/03/16	Thu 31/03/16	12,24
20	Layouts / General Arrangements	120 days	Wed 07/10/15	Thu 31/03/16	11,19FF
21	Specifications / Data Sheets	240 days	Tue 01/09/15	Fri 12/08/16	11,19FF
22	Civil Design	80 days	Fri 01/04/16	Mon 25/07/16	18,20
23	Steelwork Design	40 days	Fri 01/04/16	Fri 27/05/16	18,20
24	HAZOP Reviews	1 day	Tue 01/03/16	Tue 01/03/16	18FS+25 days
25	**Task 3 Commercial Contracting**	**100 days?**	**Tue 01/09/15**	**Mon 25/01/16**	
26	Feedstock	100 days	Tue 01/09/15	Mon 25/01/16	11
27	Fuel Off-Take	100 days?	Tue 01/09/15	Mon 25/01/16	11
28	Contractor	100 days?	Tue 01/09/15	Mon 25/01/16	11
29	**Task 4 Procurement**	**254 days**	**Fri 01/04/16**	**Mon 10/04/17**	
30	**Long Lead Items**	**250 days**	**Fri 01/04/16**	**Tue 04/04/17**	
31	Gasifier	250 days	Fri 01/04/16	Tue 04/04/17	20
32	Plasma Converter	210 days	Fri 01/04/16	Tue 07/02/17	20
33	Compressor	250 days	Fri 01/04/16	Tue 04/04/17	20
34	PSA	250 days	Fri 01/04/16	Tue 04/04/17	20
35	**All Other Items**	**100 days**	**Fri 12/08/16**	**Mon 16/01/17**	
36	All Purchase Orders Placed	0 days	Fri 12/08/16	Fri 12/08/16	21
37	Manufacture	100 days	Mon 15/08/16	Mon 16/01/17	36
38	**Mechanical & Pipework Sub-Contract**	**130 days**	**Fri 12/08/16**	**Mon 27/02/17**	
39	Sub-Contract	0 days	Fri 12/08/16	Fri 12/08/16	18,20,21,24
40	Manufacture	130 days	Mon 15/08/16	Mon 27/02/17	39
41	**Electrical & Instrument Sub-Contract**	**130 days**	**Mon 26/09/16**	**Mon 10/04/17**	
42	Sub-Contract	0 days	Mon 26/09/16	Mon 26/09/16	18,20,21FS+30 days
43	Manufacture	130 days	Tue 27/09/16	Mon 10/04/17	42
44	**Task 5 Construction**	**240 days**	**Mon 15/08/16**	**Mon 31/07/17**	
45	Civil and Structural Works	80 days	Mon 15/08/16	Mon 05/12/16	22,21
46	Long Lead Items	40 days	Wed 05/04/17	Tue 30/05/17	31,32,33,34
47	Mechanical and Pipework	120 days	Tue 20/12/16	Mon 19/06/17	40FS-40 days
48	Electrical and Instrumentation	120 days	Tue 14/02/17	Mon 31/07/17	43FS-40 days
49	**Task 6 Commissioning**	**109 days**	**Tue 01/08/17**	**Fri 29/12/17**	
50	Inspections / Snagging	26 days	Tue 01/08/17	Tue 05/09/17	44
51	Completion Tests	20 days	Wed 06/09/17	Tue 03/10/17	50
52	Operational Tests	20 days	Wed 04/10/17	Tue 31/10/17	50,51
53	Cold & Hot Commissioning	43 days	Wed 01/11/17	Fri 29/12/17	52
54	**Task 7 Operational Ramp-Up**	60 days	Mon 01/01/18	Fri 23/03/18	53
55	**Task 8 Operation**	186 days	Mon 26/03/18	Mon 10/12/18	54



Critical	Task	Manual Task	Duration-only	Baseline Milestone	Summary	External Tasks	Inactive Milestone
Critical Split	Split	Start-only	Baseline	Milestone	Manual Summary	External Milestone	Inactive Summary
Critical Progress	Task Progress	Finish-only	Baseline Split	Summary Progress	Project Summary	Inactive Task	Deadline

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DFT - Programme Project July 15a

Appendix 6 – Risk Register

Risk ID	Category	Description	Probability of risk	Impact of risk	Mitigation Measures Undertaken	Mitigation Measures Proposed	Cost Allowance
Con001	Task 1: Consent	Delay in obtain planning consent leads to delay in project.	L	M	Engagement with Swindon BC and letter of support obtained. Engaged consultant familiar with APP technology and Swindon site. EIA screening accepted and Council have confirmed planning can proceed under local dvelopment order.	Obtain consent under LDO.	-
Con002	Task 1: Consent	Conditions associated with planning consent are onerous or too costly to implement.	L	M	Engagement with Swindon BC and letter of support obtained. Engaged consultant familiar with APP technology and Swindon site. EIA screening submitted. No additional costs exptected from consultant.	Obtain consent under LDO.	-
Con003	Task 1: Consent	Delay in obtainining environmental permit leads to delay in project.	L	M	Consultant familiar with project and site engaged and inital discussions held with Swindon Council.	Follow consultant and council's advice on obtaining permit.	
Con004	Task 1: Consent	Environmental permit conditions are onerous or too costly to comply with.	L	M	Consultant familiar with project and site engaged and inital discussions held with Swindon Council.	Comprehensive application demonstrating competence and understanding of process to mitigate conditionality to cover uncertainty. Allowance made for industry standard approach to controlling emissions.	
Con005	Task 1: Consent	Grid connection not available or cost prohibitive	L	M	Discussion held with DNO and confirmation of capacity obtained. Application for quote for full connection submitted.	Obtain quote for connection. Make payment to secure capacity.	
Con007	Task 1: Consent	Trade effluent discharge consent not issued or too restrictive	L	M	Work undertaken to understand nature of effluent and likely treatment by water company.	Understand detailed effluent composition and clean up technology. Obtain cost for tanker disposal rather than to drain.	150,000
Des001	Task 2: Design	Space available does not allow safe operation within allocated site and requires reduction in scope or additional expense.	L	M	Layout developed with contingency area.	Engage with supply chain for equipment item space envelopes.	
Des002	Task 2: Design	Unacceptable hazard identified during design.	L	H	Existing process technology design Early engagement in consenting process Existing facilities on site utilising same technology	Complete detailed Hazop early in design process.	
Des003	Task 2: Design	Ground conditions require unexpected foundation design leading to higher cost	L	M	Current allowance based on knowledge of site and recent SI and groundworks nearby.	Establish ground bearing capacity and foundation concept early	100,000
Des004	Task 2: Design	Greater complexity to design than expected to enable continuous operation leading to increased capex.	M	M	Advice of Construction Manager incorporated into capex estimate.	Complete detailed Hazop early in design process.	150,000
Des005	Task 2: Design	Poor co-ordination between work packages leading to gaps or duplication in supply and so leading to over cost or delay in programme	L	M	Competent contractor engaged	Develop interface register and review regularly. Employ competent and experienced contractor	100,000
Des006	Task 2: Design	Availability not achieved, operations interrupted and production reduced	L	M	Availability requirements set early	Ensure Construction Manager and other sub-contractors understand availability requirements. Design in redundancy of critical components	

Risk ID	Category	Description	Probability of risk	Impact of risk	Mitigation Measures Undertaken	Mitigation Measures Proposed	Cost Allowance
Des007	Task 2: Design	Changes to design after commencement of manufacture/ installation	L	M		Construction Manager project management system to ensure appropriate gates are in place. Package suppliers to clearly understand their design responsibility. Regime for tracking any changes to interface register and ensuring all parties are informed of changes.	100,000
Des008	Task 2: Design	Design hours extend due to integration complexity	M	M	Engaged with Construction Manager experienced in the delivery of complex process plant to ensure that a prudent estimate of time is allowed.	Carefully manage design effort on project.	150,000
Des009	Task 2: Design	Landlord imposes requirements on project before granting consent.	L	M	Preliminary schedule of works prepared and reviewed against previous experience with landlord.	Maintain dialogue with Landlord	100,000
Des011	Task 2: Design	Ventilation provisions increase as a result of HAZOP	M	M	Reviewed gas and heat volumes of facility against current BioSNG plant and its ventillation requirements.	Work with Construction Manager and Hazop facilitor to fully define requirements and solution.	200,000
Des012	Task 2: Design	Amec Foster Wheeler unable to supply equipment at appropriate price so move to own design.	L	M	Engaged with Amec Foster Wheeler at senior level to obtain buy in.	Agree fixed price contract with Amec Foster Wheeler.	300,000
Des013	Task 2: Design	Slag handling requires modification based on HAZOP	L	M		Identification of potential alternative configurations/solutions to be identified early	150,000
Des014	Task 2: Design	Unable to CE mark the system	L	H	Existing plant in Swindon is CE marked.	Plan to CE mark the system from day 1 so that all contractors are bought into the process of providing adequate technical files.	
Des015	Task 2: Design	Electrical integration and controls design is comnplex and cost may exceed budget.	L	M	Cost estimated by experienced contractor	Detailed specification to be developed at an early stage and firm quotations to be obtained.	200,000
Des016	Task 2: Design	DSEAR/ ATEX compliance prohibitively expensive	L	H	Existing plant in Swindon is DSEAR/ ATEX compliant	Develop a DSEAR compliance plan and zoning map	
Proc001	Task 3: Commercial Contracting	Costs of packages exceeds budget due to inflation.	L	M	All estimates of package costs based on recent scaled 3rd party quotation or discussion with Construction Manager. Estimated include allowance for expected variations in package scope.	Defined process flow sheet Appropriate contingency allowance. Review capex once initial quotes received and reduce scale of plant if necessary. Communicate cost overruns to equity funders and arrange additional funding.	300,000
Proc002	Task 3: Commercial Contracting	SNG specification not met	L	H	SNG specification understood and can be met according to measurement from Swindon and Chinese pilot plants and AMEC Foster Wheeler assurances	Clearly articulate SNG spefication and ensure design focuses on meeting it.	

Risk ID	Category	Description	Probability of risk	Impact of risk	Mitigation Measures Undertaken	Mitigation Measures Proposed	Cost Allowance
Proc003	Task 3: Commercial Contracting	RDF supply agreement not adequate in quality, quantity or control of supply	L	H	Outline RDF specifications agreed with Public Power Solutions. Measurement taken from waste to check it currently complies.	Minimise constraints on waste receivable at site imposed by planning and or permitting. Independent measurement campaign on waste to check specification.	
Proc004	Task 3: Commercial Contracting	Patent challenges to the technology	L	M	Gasplasma - Patent 'free to operate' studies in all key areas. Amec Foster Wheeler have freedom to operate.		
Proc005	Task 3: Commercial Contracting	Failure to establish package suppliers	L	H	Quotes received and suppliers already engaged for all major equipment.	Early definition of packages Previous experience with existing plant Early liaison with suppliers	
Proc007	Task 3: Commercial Contracting	Exchange rate fluctuations drive capex up	M	L	Majority of packages priced in GBP.	Attempt to fix Amex Foster Wheeler price in GBP.	100,000
Proc010	Task 3: Commercial Contracting	Terms of DfT grant are unacceptable	L	H	Terms already provided by DfT and agreed by project partners.		
Proc011	Task 3: Commercial Contracting	Failure of package supplier before equipment delivery	L	M	Alternative suppliers identified for all equipment.	Due diligence in supplier selection process Contractor management through design and manufacture.	
Inst001	Task 5: Construction	Ground conditions worse than identified in site investigation work	L	M	Ground conditions well understood from previous project on site.	Ensure site investigations are carried our by experienced contractor.	
Inst002	Task 5: Construction	Construction delay due to delayed equipment delivery	L	L		Competent construction manager Contractual penalties for late delivery. Frequent project meetings	
Inst003	Task 5: Construction	Health and safety issues during construction	L	M		Design for construction CDM regulation compliance Competent construction manager Competent contractors Tool box talks Site inductions Permit to work system	
Inst004	Task 5: Construction	Environmental impact of construction	L	M		Competent contractor Environmental plan for construction and commissioning	
Inst005	Task 5: Construction	Transport to site and logistic more expensive due to due to local infrastructure	L	M	APP Swindon plant has excellent road infrastructure	Competent contractor too assess logistics at early stage	
Inst006	Task 5: Construction	Equipment tie ins between packages do not align during installation	L	L	Competent Construction Manager engaged.	Develop interface register Manage interface register to ensure it is complete with all necessary detail Regular review of interface register	100,000
Inst007	Task 5: Construction	Delivered equipment is not in accordance with equipment drawings	L	L	Competent Construction Manager engaged.	Robust procedure for acceptance of equipment on site Contractual consequences for failure to supply to specification. Clear definition of expectation for design documents. i.e. for construction means what will come to site.	

Risk ID	Category	Description	Probability of risk	Impact of risk	Mitigation Measures Undertaken	Mitigation Measures Proposed	Cost Allowance
Inst008	Task 5: Construction	Inadequate lay down area leads to hand to mouth delivery/ installation of equipment and slows down installation process	L	L	Competent Construction Manager engaged.	Identify laydown area on phased layout drawing Ensure all package suppliers are aware of available lay down area.	
Inst009	Task 5: Construction	Package equipment contractor unable to comply with conditions to be met when working on site	L	L	Competent Construction Manager engaged.	Early supply of conditions to be met when working on site Conditions to be in line with good industry practice - no excessive requirements	
Inst010	Task 5: Construction	Construction delay leading to cost increase	L	M	Competent Construction Manager engaged.	Robust construction schedule and sequence Regular review of programme and forthcoming actions including external scrutiny	50,000
Inst011	Task 5: Construction	Force majeure events	M	M		Allow acceptable programme and build-in appropriate float Secure performance derogations or insurances	
Com001	Task 6: Commissioning	Delivered RDF occassionally unable to be processed and rejected to landfill leading to increased cost	M	L	Public Power Solutions, Swindon have agreed to provide waste. Their MRF has been visited and their RDF analysed and shown be suitable for process.	Continuing analysis for RDF and testing at pilot plant.	
Com002	Task 6: Commissioning	RDF specification differs to that agreed	M	M	Agreed specification agreed to historical set of measurements.	Build some flexibility into the PFD to compensate for nominal changes in RDF spec.	
Com003	Task 6: Commissioning	Inadequate steam from syngas cooling to dry RDF and fluidise gasifier	L	L	Robust mass and energy balance based on measurement from pilot plant has been prepared.	Construction Manager to ensure steam balance works Auxiliary boiler in place for start up and assist in drying excessively wet RDF	
Com004	Task 6: Commissioning	Excessive refractory wear in plasma furnace leading to unplanned maintenance outage	L	L	Testing of slag composition from existing Swindon plant clearly shows levels of refractory wear.	IR cameras to detect early signs of refractory wear	
Com005	Task 6: Commissioning	Failure of plasma converter cooling circuits	L	M	Good design tested in large number of reference facilities.	Duty standby pump arrangements Ensure sufficient safety margin on ambient conditions used in the design	
Com006	Task 6: Commissioning	Life of syngas boiler body and water tubes	L	M	Engaged with competent boiler supplier and held meeting to discuss syngas composition and boiler design.	High corrosion allowance on body and tubes Inspection of tubes and body during maintenance outages Measure make up water flow to ensure any leakage is detected	
Com007	Task 6: Commissioning	Higher than anticipated ash deposits on syngas cooling boiler	L	L	Engaged with competent boiler supplier and held meeting to discuss syngas composition and boiler design.	Online cleaning of particulate Elevated boiler to allow for ash collection, removal and mixing with the APC residue	
Com008	Task 6: Commissioning	APC residue higher than expected due to higher ash content in RDF	L	L	Ash specification agreed with Swindon Council and supportedf by historical measurements.	APC residue conveying and storage system to include element of oversizing to be agreed with the Construction Manager	

Risk ID	Category	Description	Probability of risk	Impact of risk	Mitigation Measures Undertaken	Mitigation Measures Proposed	Cost Allowance
Com009	Task 6: Commissioning	APC residue and reagent consumption higher than expected due to higher chlorine and or sulphur in the RDF	L	L	Ash specification agreed with Swindon Council and supportedf by historical measurements.	APC residue conveying and storage system to include element of oversizing to be agreed with the Construction Manager	
Com010	Task 6: Commissioning	Waste water unsuitable for discharge	L	M	Trade effluent from pilot plant is well understood and discharge to sewer has been discussed with consultants.	Develop understanding of effluent composition Use on site effluent treatment Robust trade effluent discharge consent - with headroom above expected contaminants Holding tank and ability to discharge tanker	
Com011	Task 6: Commissioning	Syngas from Gasplasma unsuitable for processing through compressor and SNG plant	L	H	Over 2,500 hours of pilot plant operation giving measurements of syngas composition and quality. Guards beds included in desgin to ensure contaminants captured.	Monitor online all possible SNG positions and ensure control system has appropriate response times to divert contaminated gas to flare.	
Com012	Task 6: Commissioning	Temperature profile different to design expectation	L	M	Experience from pilot plants gives confidence of thermal profile. High integrity control system incldued in design.	Focus on thermal issues during design phase.	
Com014	Task 6: Commissioning	Catalysts poisoned by unexpected/ previously unconsidered component in syngas	L	M	Syngas compostion well understaood and discussed in depth with catalyst suppliers.	Continue to share information with suppliers.	
Com015	Task 6: Commissioning	Syngas from Gasplasma varies too much for SNG process to cope with	L	M	Experience from Swindon Gasplasma plant shows variation in composition is acceptable.	Final stage cleaning acts to blend syngas Compressor will mix syngas and introduce some homogenisation	
Com016	Task 6: Commissioning	RDF odour higher than acceptable levels	L	L	Experience from pilot plant gives confidence odour is acceptable.	Robust odour management system Receiving prepared RDF in wrapped bales.	
Com017	Task 6: Commissioning	Adequate staff unavailable or not sufficiently trained to enable commissioning and maintenance to commence	L	M	Existing operations team with experience of operating Gasplasma and SNG plant.	Early recruitment of operating team. Recruit full operating team 6 months before commissioning	
Com018	Task 6: Commissioning	Safety, health and environmental impact of commissioning	L	M		Competent commissioning manager to institute a structured commissioning plan. Competent commissioning personnel Liaison with regulatory authority during commissioning	
Ops001	Task 8: Operation	RDF specification differs to that agreed leading to process operation difficulties and or increased opex	L	M	Specification agreed to historical set of measurements.	Build some flexibility into the PFD to compensate for nominal changes in RDF spec.	
Ops002	Task 8: Operation	Failure of drier and or drier emissions control system causing interruption of operation	L	M		Select robust equipment Carry adequate spares Specify high availability of equipment Consider dry storage area to mitigate interruptions.	
Ops003	Task 8: Operation	More maintenance required than expected leading to increased downtime and reduced production	L	M		Develop robust maintenance plan with suppliers Ensure maintenance is conducted proactively.	

Risk ID	Category	Description	Probability of risk	Impact of risk	Mitigation Measures Undertaken	Mitigation Measures Proposed	Cost Allowance
Ops004	Task 8: Operation	Under estimated parasitic load	L	M		Close liaison with suppliers and continual review of motor list Operational improvement programme to monitor top 10 electricity consumers	
Ops005	Task 8: Operation	Failure to produce required quanity of gas by end 2018	L	H		Oversize plant's annual production Programme to start early	
Ops006	Task 8: Operation	Plant fire	L	H	Design incorporates appropriate management system.	HAZOP to assess risk. Fire management plan to be developed Fire protection system to be incorporated into the design Educate staff of fire risks	
Ops007	Task 8: Operation	Health and safety issues during operation	L	M	Current systems follow best practice. No reportable incidents in 7 years operation at Swindon.	Existing safe systems of work in Swindon Staff training Competent operations team	
Ops008	Task 8: Operation	Disposal of process by-products and residues not available or too costly	L	L		Disposal routes in place for existing operations Potential value added routes being explored for Plasmarok	
Ops009	Task 8: Operation	RDF supply interruptions	L	M	Swindon Council have a history of operating MRF successfully and providing RDF to other off-takers.	Develop alternative suppliers in case Swindon Council unable to meet contractual requirements.	
Ops010	Task 8: Operation	Grid gas CV flucutates and so the quantity of propane injected will fluctuate. High levels of propane injection will be econimically unsustainable.	M	M	Realisitic assumption on quantity of propane to be injected.	Forward planning of propane purchasing. Understand how grid operator calls for changing CV, and so higher propane injection.	
Ops010	Task 8: Operation	Off-takers unable or unwilling to purchase gas produced by the facility.	L	M	Draft agreements in place with two off-takes whose demand exceeds plant capacity.	Convert draft agreements to formal contracts. Develop alternate off-takes incase of failure or Howard Tenens or CNG Services to meet obligations.	
Pla001	Task 9: Commerical Plant Development	Commercial plant capex, opex or performance fail to meet expection making roll out of technology unviable.	L	M	Work to date on commercial plant by project partners and Amec Foster Wheeler show techology is viable.	Continue to monitor results of design and costing of commercial plant to ensure technology is cost effective.	
Pla002	Task 9: Commerical Plant Development	Government support for renewable biomethane withdrawn or reduced.	L	M	Support currently available from Renewable Transport Fuel Obligation and Renewable Heat Incentive.	Continue to engage with trade bodies and Government to understand regulatory framework.	
Pla003	Task 9: Commerical Plant Development	Alternative technology with superior performance developed.	L	M	Project partners maintain interest across sector and are confident no superior technology exists	Continue to monitor developments.	

Risk ID	Category	Description	Probability of risk	Impact of risk	Mitigation Measures Undertaken	Mitigation Measures Proposed	Cost Allowance
Dis001	Task 10: Dissemination and Reporting	Disinterest from the national and international media	L	M	Interest from trade press in initial release was high.	Develop a media engagement plan to identify the appropriate editors. Nurture the relationship with those editors. Develop the appropriate news angle to entice a story.	
Dis002	Task 10: Dissemination and Reporting	Resourcing - staff and accurate budgeting	L	M	Initial resource plan shows resource adequate.	Ensure adequate resources to implement the communications plan, including marketing resource, technical resource and leadership resource. Ensure external costings are accurately forecasted in order to deliver on the communications plan.	
Dis003	Task 10: Dissemination and Reporting	Securing speaking engagements	L	M	Initial disucssion with conference organisers whos interest.	Building relationships with key event organisers. Ensuring that the speaker slot is positioned as a project case study rather than sales pitch.	
Dis004	Task 10: Dissemination and Reporting	Time frames for delivery of communication items with multiple stakeholders in the consortium	L	M	Plan developedto deliver communications in good time.	Initiating clear timelines and milestones for all communication deliverables. Providing progress updates and outstanding items lists on a reoccurring basis.	
Proj001	Other: Project Management	Capital cost exceeded	L	M	Appointment of experienced Construction Manager.	Project manage buy in to project budget Supplier support in developing budget Frequent review of project spend compared to budget	
Proj002	Other: Project Management	Project delay	L	M	Appointment of experienced Construction Manager.	Supplier support to the project programme Active management of programme with frequent reviews against baseline. Experienced and competent construction manager. Project plan contain contingency for delays.	
Proj003	Other: Project Management	Failure to achieve project objectives	L	H	Appointment of experienced Construction Manager.	Ensure objectives are clearly understood by all parties involved. Regular review of objectives to ensure still achievable.	

Appendix 7 – Project Cost

Package	Cost £'000
Shredder and conveyors	320
Odour control	278
Drier	330
Dry storage	87
Gasplasma package	3,972
Waste Heat Boiler	554
Dry gas cleaning	133
APC discharge / collection	123
Wet Syngas cleaning	271
Water Treatment	185
CEMS	223
ID Fan	38
Syngas buffer vessel	25
Auxilary boiler	42
Weighbridge	29
Diesel tank	5
Cooling Systems	323
Compressed air	34
Flare	108
Oxygen storage	30
Building/civils	350
Gas measurment	200
Syngas compressor, enclosure and storage	664
Water gas shift and methanator	2,783
Cooling circuits for methanator	400
Ventillation equipment	200
Gas Network entry equipment	530
Power & controls	1,699
Mechanical installation	809
Risk	1,900
	16,645
Design and Delivery	
Insurance	134
PM	742
Procurement	775
Design	958
Construction Management	878
Commissioning	407
Expenses	98
Site establishment	285
Risk	350
	4,626
Other	
Supplier commissioning support	303
Grid connection	327
Spares	100
Expenses	10
Gas grid connection	97
Technical advisor	200
Commercial plant development	50
Disseminsation and reporting	400
Project governance	300
	1,787
Total	23,058

Appendix 8 – Financial Models

	Input		Commercial		
		Demo	**FOAK**	**NOAK**	**NOAK**
Gas produced	GWh/a	**22**	**310**	**328**	**658**
		£m	**£m**	**£m**	**£m**
Post-tax real project return		0%	14%	10%	10%
Gas price	£/MWh	20.0	21.0	26.0	18.0
Revenue					
Gate fee	£65/tonne	0.7	10.2	10.2	20.4
Gas price	See above	0.4	6.5	8.5	11.8
Green support	RTFC/RHI	0.5	9.1	0.0	0.0
		1.6	25.8	18.7	32.3
Labour		(0.5)	(1.6)	(1.5)	(1.8)
Parasitic load	£65/MWh	(0.9)	(3.0)	(2.5)	(5.3)
Consumables		(0.5)	(1.5)	(1.4)	(3.1)
Maintenance		(0.1)	(1.9)	(1.5)	(2.9)
Other		(0.2)	(2.2)	(2.1)	(3.5)
Profit/(loss) per year		(0.5)	15.6	9.7	15.8
Use of funds					
Fuel production		1.0	4.9	4.9	7.4
Gasification		6.1	28.3	26.4	42.7
Oxygen production		0.0	7.2	7.2	10.9
Methantion		4.8	14.8	14.0	22.6
Building and Civils		0.4	8.7	8.7	13.2
Install, power, controls		2.5	12.0	12.0	18.2
Grid connection		0.3	1.6	1.6	3.1
Construction management		4.3	16.8	13.5	21.2
EPC overhead and profit		-	3.8	2.2	3.4
Other		1.5	2.2	2.2	2.2
Risk		2.3	7.6	3.7	5.7
		23.1	107.9	96.3	150.7

Appendix 9 – Partners

National Grid

National Grid is an international electricity and gas network company based in the UK and north-eastern USA. The company plays a vital role in connecting millions of people to the energy they use, safely, reliably and efficiently.

National Grid's network comprises approximately 132,000 kilometres of gas distribution pipelines and transports gas on behalf of approximately 25 active gas shippers from the gas national transmission system to around 10.8 million consumers. It is committed to safeguarding the environment for future generations and to delivering value for money to its customers. National Grid has been at the forefront of the development of the biomethane market in the UK through its advocacy of the technology with government and through its active promotion of biomethane connections to its network. From small beginnings, it is now expected that there will be around 30 UK Anaerobic Digestion (AD) biomethane plants established by the end of 2015.

Following feasibility and design studies on the BioSNG project with PEL, CSL and APP, National Grid successfully gained substantial funding for the pilot plant via the Ofgem Network Innovation Competition, and is currently working in partnership with APP and PEL on the deployment of the project.

National Grid has a strong interest in maximising the production of renewable gas from AD and from gasification of waste, with a view to decarbonising energy supplies for heat and transport. Its extensive gas transmission and distribution network is ideally suited for interconnecting BioSNG plants and refuelling stations for heavy goods and passenger service vehicles.

Wales & West Utilities

Wales & West Utilities (WWU) is part of the CKI group and provides the safe and secure transportation of gas across its distribution network to more than 2.5m customers. The company is committed to the protection and enhancement of the environment and is always seeking new ways to minimise the environmental impact of its activities, as well as providing excellent value to its customers.

The long term future of gas distribution networks is best served by the development of sustainable sources of gas, and also new markets for gas, such as its use as a transport fuel. WWU are committed to making the process of connecting distributed gas from sustainable sources as easy as possible for developers, as well as seeking new off-takers.

Anaerobic digestion is providing an initial tranche of biomethane for injection to the grid, but WWU recognise that thermal gasification provides a route for the production of more substantial volumes of renewable gas from a wider range of input feedstocks. This technology has the potential to meet a significant amount of domestic gas and compressed natural gas demand and will be important in ensuring the long term future of their network. Better utilisation gives better value to WWU customers, as well as the direct benefits to them of renewable solutions without the need for investment in new infrastructure and equipment.

Advanced Plasma Power

Advanced Plasma Power Limited (APP) is a leading innovative waste to energy and advanced fuels technology provider. APP aims to revolutionise the way in which we treat waste sustainably by deriving the highest value from it as a source of materials and energy while greatly reducing the impact on the environment. APP has developed and patented the Gasplasma® process, a clean, modular and scalable advanced waste to energy and fuels platform, which delivers high efficiencies with low visual and environmental impact and plans to sell the technology to waste management, power, chemical processing, and fuel providers around the world.

APP has been operating a pilot plant in Swindon producing synthesis gas and electricity from waste and biomass since 2008 using its Gasplasma® technology and has been working with National Grid and Progressive Energy on the production of thermally produced low carbon natural gas since 2012.

APP has a long list of prospects in the UK and around the world for waste transformation plants. The biggest challenge the company faces is the perceived technology risk of scaling up the pilot plant to a commercial plant.

This project will provide a reference facility that acts as a stepping stone from the current pilot plant to a commercial scale plant. This will help UK companies, including APP, compete in the international BioSNG market and enable the development of further BioSNG plants in the UK.

Progressive Energy

Progressive Energy (PEL) comprises a team of highly experienced clean energy industry professionals providing the skill sets necessary to undertake and support all aspects of the development and implementation of an energy project: project screening and selection, project definition and optimisation, contracting (including feedstock, EPC, and power purchase contracts), consenting, project financial evaluation, financing, construction, commissioning, operations, maintenance, and venture management.

Progressive Energy produced the feasibility study that under-pinned the National Grid (NG) initiative to pursue the production of thermochemical biomethane in the BioSNG project. This study included the technical feasibility, the commercial and environmental viability and policy context. PEL initiated the formation of the NG/APP/PEL consortium now undertaking the demonstration of biomethane production from RDF and biomass at APP's Swindon facility.

As a member of the existing BioSNG consortium, PEL has provided an important advisory role in the execution of the pilot project. A key aspect of this work has been to act on behalf of National Grid, providing independent scrutiny of the technical, engineering and commercial direction of the project.

PEL has extensive experience in this type of advisory role for a range of organisation and projects. For example, PEL provided outsourced technical and commercial support relating to biomass and gasification projects for Infinis during its first 20 months as it was building its own team and developing its strategy. PEL routinely undertakes deep dive technical and techno-economic due diligence activities for a number of international investors, with a particular focus on new technologies, primarily in the biomass and waste sectors. It has also performed management and co-ordination roles for consortia of international companies developing Carbon Capture and Storage projects, such as the Teesside Low Carbon project, a £1.8billion full chain CCS project comprising BOC Linde, Premier Oil and GDF Suez.

CNG Services

CNG Services Limited (CSL) provides consultancy and project management services in relation to the use of natural gas as a vehicle fuel. CSL is independent from equipment suppliers and provides an 'owner's engineer' service including design, project specification and management.

CSL owns and operates the UK's largest CNG filling station which has the capacity to fill more than 300 dual-fuel vehicles per day. It has also designed and project managed another ten CNG filling stations and feasibility studies.

CSL has worked on several biomethane projects. It acted as designer and project manager for the UK's first biomethane to grid plant at the Thames sewage works in Didcot and provided design advice for the biomethane plant at the Adnams brewery in Suffolk. This gives CSL experience of cleaning and upgrading biogas.

The company has worked on CNG vehicle demonstration projects involving John Lewis, DHL, Argos and Eddie Stobart. CSL has developed a good understanding of the practical requirements of vehicles running on CNG during these projects. It has undertaken twelve UK and international projects relating to the full CNG vectors chain.

Overall, CSL provides expertise on the compression of biomethane, its distribution, and on the fuel requirements of CNG vehicles. It is also an active advocate of CNG and compressed biomethane as a transport fuel, both in the UK and the continent through the National Gas Vehicle Association Europe.

Addendum – Change in Resubmission

Pro-forma section and Topic	Expected amendment to submission	Reasons for amendment
Appendix 1, Section 3.1, Section 4a(iv)	Show benefits cumulatively rather than per annum	As requested by OFGEM
Section 9	Update SDRC 9.2 and SDRC 9.5/9.6	Update SDRC 9.2 in line with Panel Question following 2nd Bilateral. Move 'Customer feedback' from SDRC 9.5 to SDRC 9.6 as proposed in the response to CQ27