RIIO NIC NETWORK INNOVATION COMPETITION

Project Code/Version No:
NGGDGN01

Gas Network Innovation Competition Full Submission Pro-forma

Section 1: Project Summary

1.1 Project Title: BioSNG Demonstration Plant

1.2 Funding Licensee: National Grid Gas Distribution

1.3 Project Summary:

This project seeks to prove the technical and economic feasibility of thermal gasification of waste to renewable gas (bio-substitute natural gas or BioSNG), through constructing a demonstration plant to take an existing stream of syngas and upgrading it to GSMR quality gas. If successful this will increase the potential availability of renewable gas in the UK by 100TWh.

It will test and demonstrate this by taking a waste derived syngas from Advanced Plasma Power's (APP) Gasplasma® demonstration facility, located at Swindon and upgrade it through a dedicated conversion and clean up plant to a pipeline quality (Gas Safety Management Regulation Specification or GSMR) gas.

The build and operation of the processing plant and test programme will test and demonstrate the concept and design of how syngas from waste can be converted to pipeline quality gas. It will inform the design and economics of subsequent commercial plants that could significantly increase the potential of renewable gas in the UK.

The project follows on from IFI79 (Feasibility and Design of a BioSNG Demonstration project). The project is expected to take approximately 3 years, split into a number of phases including final design and safety, build, commission and detailed test programmes. The planned start date is the 1st April 2014 with an expected completion date of 31st March 2017.

The project will by demonstrating technology to show how biogenic waste and biomass can be converted into a BioSNG gas stream which can provide renewable gas into the grid at the correct pipeline specifications. By doing this it will ensure that there is an alternative source of fuel to deliver low carbon heat other than converting domestic and commercial heat demand to electric heat pumps. The avoided costs of conversion to electric heat sources for gas customers has been estimated at £25bn, whilst the cost of decommissioning the gas distribution networks would be a further £8bn.

1.4 Funding

1.4.2 NIC Funding Request (£k): 1875.15

1.4.3 Network Licensee Contribution (£k):0

1.4.4 External Funding - excluding from NIC/LCNF (£k): 2125.50

1.4.5 Total Project cost (£k):4251.00

Section 1: Project Summary continued

1.5 Cross industry ventures: If your Project is one part of a wider cross industry venture please complete the following section. A cross industry venture consists of two or more Projects which are interlinked with one Project requesting funding from the Gas Network Innovation Competition (NIC) and the other Project(s) applying for funding from the Electricity NIC and/or Low Carbon Networks (LCN) Fund.

1.5.1 Funding requested from the LCN Fund or Electricity NIC (£k, please state which other competition):

1.5.2 Please confirm if the Gas NIC Project could proceed in absence of funding being awarded for the LCN Fund or Electricity NIC Project:

☐ **YES – the Project would proceed in the absence of funding for the interlinked Project**

☐ **NO – the Project would not proceed in the absence of funding for the interlinked Project**

1.6 List of Project Partners, External Funders and Project Supporters:

- Advanced Plasma Power
- Progressive Energy
- BEST F ERANET– funding application in progress
- Discussions are also at an advanced stage with a further potential project partner

1.7 Timescale

1.7.1 Project Start Date:	**1.7.2 Project End Date:**
1st April 2014	31st March 2017

1.8 Project Manager Contact Details

1.8.1 Contact Name & Job Title:	**1.8.3 Contact Address:**
Steven Vallender Asset Strategy and Investment Manager	National Grid House, Warwick Technology Park, Gallows Hill, Warwick, CV34 6DA
1.8.2 Email & Telephone Number: steven.vallender@nationalgrid.com 01926 654893 07773 822561	

Gas Network Innovation Competition Full Submission Pro-forma

Section 2: Project Description

This section should be between 8 and 10 pages.

2. Project Description

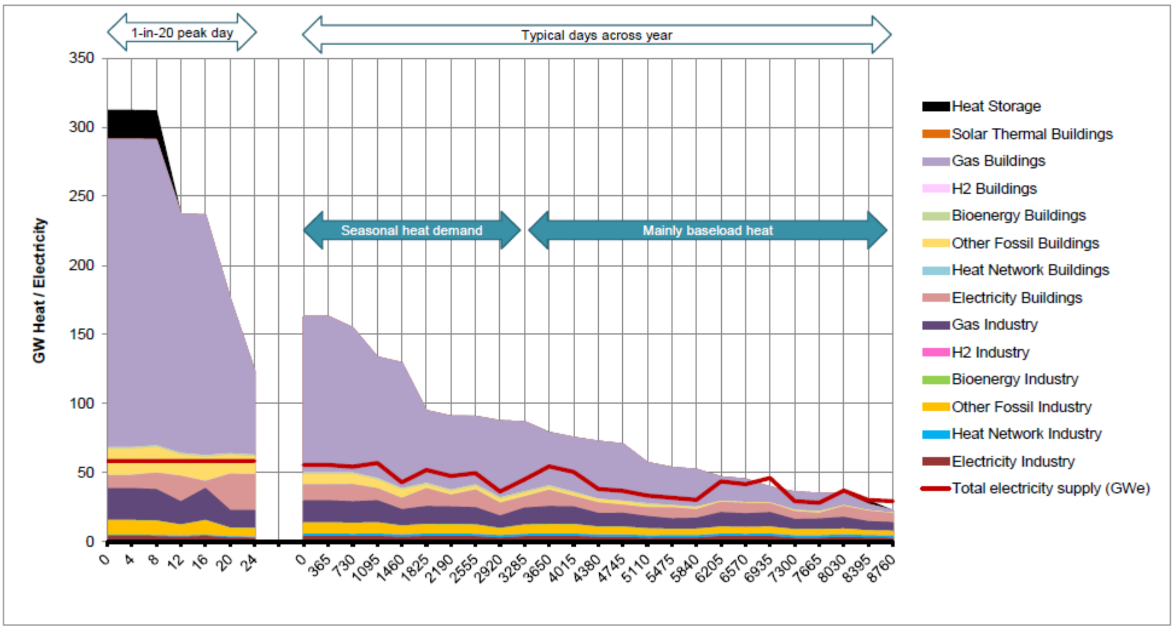
2.1. Aims and objectives

2.1.1. The Problem(s) which needs to be resolved

The imperatives of climate change demands substantial reduction in CO2 levels; specifically the UK has committed to an 80% reduction on 1990 levels by 2050, along with interim targets.

In the UK, historically, the focus has been on decarbonising the electricity supply, yet almost 50% of final energy use, is utilised supplying heat demand. Furthermore, whilst there are clear, multiple potential pathways for decarbonisation of electricity, the options for low carbon heat are more limited and challenging.

The key issue in supplying heat energy is the highly variable nature of heat demand, as can be seen by heat demand curves shown below.



Peak and seasonal heat demand is extremely variable, with the peak capacity load on a daily basis being over 500% the lowest day, and the peak capacity hour being >1000%. Currently gas dominates the heat supply curve. The UK has one of the most mature and extensive gas transmission and distribution networks in the world sized to meet this heat demand. As a result gas has become the vector of choice with 83% of the UK's buildings heated by gas, typically using efficient modern gas boilers, and similarly, most industrial heat demands are fuelled by gas.

The options to decarbonise heat are:

Project Description continued

- **Electrification of Heat:** Through the widespread roll out of efficient electric heat pumps. However, this solution is limited by the ability to build sufficient low carbon generation to meet the peaks, the amount of reinforcement required on the electricity transmission and distribution systems, and the need for a mass change out of end user appliances. It is neither practical nor cost-effective to meet this peak demand through electrification of heat alone as is recognised in the DECC Heat Strategy, 'The Future of Heating: Meeting the Challenge' which proposes a balance of electrification (starting in off gas grid areas, gas and heat networks) [DECC 2013].

- **Biomass**: While solid biomass installations have an important role in decarbonisation of heat, it requires heat consumers with sufficient space for the equipment, and in particular fuel storage, and is expected to be constrained in urban areas. Like electrification, this is likely to have a more significant role for off-gas grid locations and/or larger heat users.

- **Heat Networks**: Heat networks would require a low carbon source of heat (either recovered heat from industry or thermal generation) and new network and sufficient heat density of the load i.e. urban only.

- **Renewable Gas**: Conversely, the gas network is ideally suited to transmitting and distributing such variable levels of energy. 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. Renewable gas manufactured from biogenic sources would provide this.

Biomethane derived from anaerobic digestion is already being upgraded and being injected into the grid with a pipeline of projects enabled by the RHI support regime. 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. Typical projects are 3-10MWth maximum, with a project of ~3MWth requiring 25,000 tonnes pa of feedstock and giving rise to almost as much digestate requiring outlets to enable beneficial use to land. These factors limit the expected potential of renewable gas to a maximum of ~40TWh (11% of current annual domestic gas demand).

The challenge therefore is providing cost-effective bio-methane at sufficient scale to meet a greater proportion of the future heat demand and thereby avoid the significant costs to the consumer of decarbonisation via other routes.

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

This project seeks to prove the technical and economic feasibility of thermal

Project Description continued

gasification of waste to renewable gas (bio-substitute natural gas or BioSNG), through constructing a demonstration plant to take an existing stream of syngas and upgrading it to GSMR quality gas. If successful this will increase the potential availability of renewable gas in the UK by 100TWh.

Following extensive feasibility work National Grid, along with its partners have identified that the production of BioSNG, which has the potential to provide substantial volumes of biomethane required to provide low carbon cost-effective gas and therefore heat to customers via the existing gas networks and existing customer appliances.

BioSNG is produced using thermal processes. The dry biomass, or biomass-rich waste is gasified to produce a bio-rich synthesis gas. This intermediary product is similar to fossil derived town's gas, used in the network until the 1970's, and is predominantly a mixture of carbon monoxide and hydrogen. However, recognising the need for a fungible fuel which can be used in consumers' appliances with no modifications, this gas is purified, upgraded and converted to a methane-rich substitute natural gas using catalysis. Following final polishing this is suitable for injection into the grid. This provides a low carbon heat solution to customers.

Compared with anaerobic digestion, however, this ability to process other more abundant sources of biogenic feedstock such as residual black bag & commercial wastes (more than 98% of the UK's potential biogenic resource is found in waste products - Gill et al, Biomass Task Force Report, 2005) has the potential to significantly increase the availability of renewable gas by ~100TWh (30% of current domestic demand). This waste still has a high biogenic content (>60%) and through thermal gasification and methanation could produce BioSNG which is pipeline quality (GSMR), low carbon and cost competitive with other renewable energy sources.

The Pilot facility being developed in this project builds on extensive work carried out by the consortium, specifically a Feasibility study sponsored by National Grid, Centrica and NEPIC [Progressive Energy 2010] and an extensive development programme under IFI79 [PE/APP 2013 – Appendix 12]. This process of stage gated project development has provided a process design concept, confidence in its commerciality gained through economic modelling of a full-scale plant together with sustainability credentials and pre-FEED and detailed design of the demonstration plant.

- This work has demonstrated that a waste-derived facility at 50MWth would be commercially viable under prevailing support regimes under the RHI. In time, larger scale, Nth of a kind facilities will be deliverable with competitive gas prices, even where support levels are reduced, as would be expected for all renewable technologies. Few other low carbon technologies are able to deliver solutions to consumers at prices competitive with conventional fossil fuels. This analysis is shown in more detail in Appendix 10. Therefore the partners have confidence that the proposed project learning can be deployed commercially.

Project Description continued

- The work has also provided confidence in the sustainability attributes of the approach. An independent report assessing the GHG emissions from the BioSNG process was produced by NNFCC [NNFCC 2010]. Within it the emissions have been calculated using the BEAT2 and EC RED methodologies. BEAT 2 includes alternative disposal of the feedstock e.g. to landfill and therefore provides a greater GHG saving than EC RED and also accounts for the significant difference in emissions observed between the two methodologies. For BioSNG from waste (MSW RDF pellets) the carbon intensity as referenced to the point of use in a gas boiler at 85% efficiency are as follows:
  - BEAT2: -0.01896 kg eq CO_2/MJ, -68.3 kg CO_2 eq/MWh
  - EC RED: 0.02302 kg eq. CO_2/MJ, 82.9kg CO_2 eq/MWh

  For comparison, Natural Gas has the following carbon footprint:
  - BEAT 2: 0.06975 kg eq. CO_2/MJ 251kg CO_2 eq /MWh
  - EC RED: 0.06743 kg eq. CO_2/MJ 243 kg CO_2 eq /MWh

  It is seen that, irrespective of the methodology used, the proposed BioSNG represents a significant saving over natural gas of either 127% (BEAT 2) or 66% (RED). Therefore there is confidence that this approach will provide a low carbon, sustainable solution for heat.

- The previous work has provided detailed process designs for the pilot plant as well as a well-structured testing programme. The Pilot project is deliverable and well-conceived, to a sufficient level of detail that the partners are prepared to invest significant levels of their own resources and funds to undertake the programme.

2.2. The Trial(s) being undertaken to test that the Method works

2.2.1. *Overview of Project ('Trial')*

The objective of this project is to construct a demonstration plant that will prove the techno-economic feasibility of the transformation of a waste-derived syngas into a pipeline quality substitute natural gas.

It will test and demonstrate this by taking a waste derived syngas from Advanced Plasma Power's Gasplasma® demonstration facility, located at Swindon and upgrading it through a dedicated conversion and clean-up plant to a pipeline quality (GSMR Spec) gas.

The process modelling, engineering design and empirical work on catalyst performance that has been undertaken by the consortium partners during the last two years and will

Project Description continued

be embodied in the proposed demonstration plant. The construction and operation of this plant together with associated test programme will demonstrate the way in which waste-derived syngas can be transformed into pipeline quality gas. Beyond the initial proof of concept, the test programme also plans to explore the operational envelope of the technologies employed in order to identify the key optimisation parameters for the overall performance of the system. These activities will inform the design and economic viability of subsequent commercial plants that could significantly increase the potential of renewable gas in the UK as discussed above.

The project follows on from IFI79 (Appendix 12) and is expected to take approximately 3 years, split into 3 phases: build, commission and test programme. Planned start date 1st April 2014; expected completion 30th March 2017.

2.2.2. The solution(s) which will be enabled by solving the problem: Pathway to deliver the Solution

Conversion of coal-derived syngas to methane is in commercial operation globally, as are examples of waste gasification for the purpose of producing power. However, the end-to-end process of waste feedstock through catalytic methanation and refining to pipeline quality gas has not been demonstrated before anywhere in the world. The commercial attributes of a such a project are such that the process optimisation parameters are significantly different from conventional applications of methanation (see Appendix 2); (a) the product specification is for GSMR quality gas, not pure methane which is typically required as a chemical feedstock in large scale coal facilities, (b) the smaller scale demands simpler once-through processes operating at lower pressures, (c) capital cost at moderate scale is a key requirement of success, (d) process optimisation is not simply waste-gas efficiency, but importantly integration of servicing internal heat and electricity demands. The previous work including that under IFI79 has developed a process based on these attributes.

In order for projects to come to the market, technology demonstration is required. Without proving the techno-economic feasibility through a demonstration project it is very unlikely that commercial projects would reach fruition and hence the potential benefits to the UK from increased availability of GB sourced renewable gas would not be realised. Therefore, through the demonstration and dissemination of knowledge from this project it is envisaged future commercial projects will be developed.

2.2.3. Technical Description: Proposed Pilot Plant

The proposed pilot plant is based upon APP's existing Gasplasma® process for the production of syngas, which has been extensively demonstrated at its Swindon facility, which is an advanced conversion technology (ACT) that has been developed to achieve best available technology (BAT) status. The core of the Gasplasma® process comprises a fluidizing bed gasifier which converts solid feedstock to a crude syngas, followed by a

Project Description continued

plasma converter that efficiently cracks the tars entrained in the crude syngas, to produce syngas of sufficient quality to fuel an efficient turbo-charged gas engine.

The detailed process design has been developed from a conceptual design and defines the process flow scheme, mass and energy balance and layout for the BioSNG demonstration plant at the APP Swindon facility, where the existing Gasplasma® plant will be used to supply the syngas derived from waste as a feedstock for the SNG process. This existing facility will be used intermittently to fill a high-pressure syngas store that will have capacity to run the BioSNG demonstration plant for a sustained period.

The "engine quality" syngas produced by the Gasplasma® facility is well understood from its operational history. In the proposed demonstration plant this syngas will undergo further gas cleaning prior to compression and high-pressure storage. Thereafter the hydrogen:carbon monoxide ratio of the syngas will be adjusted to the stoichiometric 3:1 composition required for methane production by means of a conventional catalytic water-gas shift reaction prior to methanation. A number of methanator design configurations have already been evaluated by the consortium, the principal challenges being the paucity of literature for the low pressure / high molar concentration conditions required in this application, coupled with the large heat release that is a feature of the catalytic methanation reaction. To reduce the uncertainty in reactor design, test runs on representative syngas samples have been undertaken by a catalysis specialist research laboratory in the UK, to provide empirical data to inform the design of the methanation reactor. In addition to this precaution the design incorporates provisions to evaluate a number of reactor configurations and a variety of catalyst bed geometries during the testing period.

In the transformation of syngas to SNG, approximately half the carbon in the feedstock will be converted to carbon dioxide which in turn must be separated from the product stream emerging from the methanation reactor. The design work has identified pressure swing absorption as the preferred technique for this. In order to minimise the parasitic power demand the process is designed for operation at a moderate pressure, with SNG compression to gas network injection pressure undertaken only on the final SNG product at the end of the process.

Throughout the experimental phase of the project, data will be generated to prove the durability and efficient performance of all the component unit operations working in combination. The technical, economic and ecological performance of the final process will be determined utilising life cycle assessment (LCA) and whole life costing (WLC) for the integrated system. Rigorous performance tests will be conducted to attest to the low emissions of the system, cost effectiveness and efficiency compared to established alternatives.

This project is truly innovative by considering feedstocks, scale and product gas.

Project Description continued

Conversion of coal to methane via catalytic methanation is practiced internationally at 3000MWth scale, for example at the Dakota synfuels plant in the USA, as well as other large scale, coal fuelled facilities in China, primarily for the ultimate production of ammonia. The objective here, however is to provide renewable and low carbon sources of substitute natural gas, that is the system must be designed to use biomass rich feedstock rather than coal. Given the nature of waste arisings, BioSNG must be able to be produced commercially at a smaller scale than this, in 50-200MWth scale units.

This therefore represents a significant innovative developmental challenge; delivering technically and commercially viable methanation of syngas derived from waste-derived biomass. This must be able to accommodate the different set of contaminants arising from waste gasification, be able to be deployed at much lower scale than conventional methanation facilities and deliver an output product which meets GSMR requirements (which is different from the production of pure methane for chemicals applications).

The only BioSNG projects under development in the world are from pure biomass feedstocks, specifically a small scale research facility at Gussing and a larger biomass fuelled plant under construction in Gothenburg. As is shown graphically below, the UK is very different from Sweden and the most abundant and cost effective sources of biomass come from waste streams and not forestry; the most cost effective solution for the UK gas consumer is one which can process biomass-rich wastes.

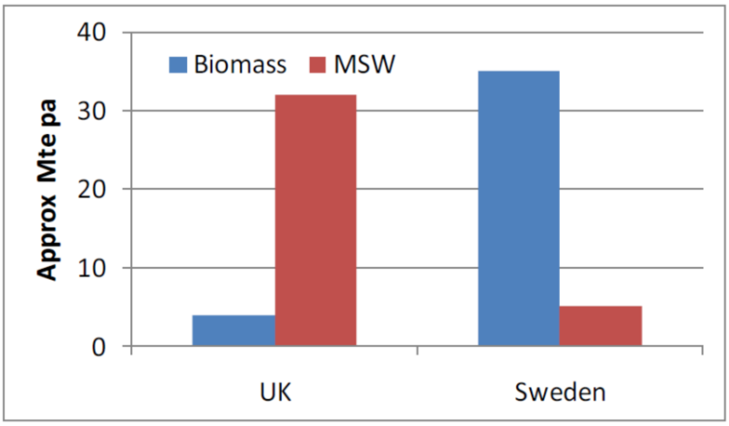


Figure 2.1

Through the work undertaken previously by the partners, specifically under IFI79, a process design has been developed specifically designed to meet the requirements of waste-derived syngas, moderate scale and to meet GSMR requirements.

To achieve widespread deployment, and achieve the benefits to the gas consumer described above, demonstration and optimisation of the technology is required. This project will build a demonstration gas processing plant to be connected to an existing supply of syngas from waste provided by APP's gasifier.

Project Description continued

This provides the platform for deployment of cost effective, low carbon heat delivery to the UK gas consumer

2.3. Design of the Trial: Programme

The purpose of this programme is to: (a) demonstrate technically that waste-derived syngas can be converted to grid quality gas using a design appropriate for commercial scale operation (b) optimise the process operational parameters (c) confirm the final process is commercially viable, and provide tangible demonstration to the low carbon investment community and other stakeholders.

The steps involved are: (a) procure and build Pilot SNG facility, (b) connect to syngas source and commission, (c) extensive technical test programme, (d) review and refine commercial project specification, design and ecological attributes (e) showcase the proposed solution as part of a knowledge transfer programme. Items (c-e) are not expected to be sequential; but to be undertaken in parallel.

2.3.1. Procure and build Pilot facility as specified in the detailed design (IFI79).

The extensive programme undertaken in IFI79 means that the consortium has a well-developed detailed design and specification for the facility. The team is already engaged with potential equipment suppliers and fabricators. Value for money will ensured by good procurement practice; the team is well experienced in tendering and contracting processes to deliver a good quality, yet flexible pilot facility at a competitive cost.

Long lead time items have already been identified and specified such that orders can be launched once final design is complete to provide a timely construction programme which can deliver on time. Construction has been scheduled to take 12 months to connection to the existing facility, that is April 2015, on the assumption of an award on 1stApril 2014.

2.3.2. Connect to APP's existing gasifier and commission the plant

The project programme shows connection of the methanation facility to the existing gasification plant in April 2015. A 2 Month commissioning programme has been developed for completion ready for June 2015. This programme will comprise control interface testing, cold and hot commissioning.

2.3.3. An extensive, staged technical test programme

The test programme has been carefully constructed to provide both early confirmation of feasibility, to underpin commercial development of full scale project, whilst also providing deep technical evaluation of the process to allow optimisation of a detailed robust process design. This is outlined in more detail below. Early data is to be provided

Project Description continued

within 6-9 months, whilst the overall programme is 24 months. Specifically, the programme is designed to understand and confirm:

- The impact on plant design and product quality of a variety of syngas compositions, feedstocks and a range of operational conditions as well as the associated carbon accounting. These early tests will underpin the commercial assumptions required to expedite the development of a full-scale facility. This programme is planned to provide the necessary information within 9 months that is by December 2015.
- Further investigations into the technical and commercial effectiveness of the syngas cleaning, converting and upgrading techniques specified in the IFI79 process design and alternatives that may be identified through the planned optimisation programme:
    a. Mapping of the performance envelope of the key process operations to provide a basis for value engineering to reduce unit SNG production cost.
    b. Evaluation of the performance of alternative catalyst types with respect to longevity, reactor design configurations, cost effectiveness, and product slate.
    c. Investigation into the effects on plant design and product quality of a variety of syngas compositions and a range of operational conditions of temperature and pressure.
- Further investigations into the technical and commercial effectiveness of the syngas cleaning techniques specified in the Stage 2 process design and alternatives that may be identified. Confirmation of the optimal techniques for removal of CO_2 from the product stream to produce CCS-ready CO_2 for transportation and sequestration.
- Investigations into control of the gas quality to ensure reliable delivery of pipeline quality gas e.g. Wobbe Index, nitrogen, hydrogen content etc.
- Refinement of the overall process control system for safe and reliable operation.

Further detail of this programme can be found in Appendix 7.

2.3.4. Review and refine commercial project specification, design and attributes

Using the confirmatory data from the initial 6-9 months of the test programme, the commercial and sustainability attributes of a full scale facility will be reviewed. This is designed to confirm the economic profile of such a project which will underpin commercial development activities for the first project, which can then be progressed in parallel. This compresses the lead time to deployment and the realisation of value to the

Project Description continued

UK consumer.

2.3.5. <u>Showcase the proposed solution as part of a Knowledge transfer programme</u>

The Consortium is committed to a knowledge sharing programme. The purpose of this programme is to maximise the value to the UK consumer by facilitating deployment of BioSNG. This is best achieved through communication of the benefits offered by BioSNG developments as well as the results from this project. The audience of such a programme is:

- Policymakers. Deployment of renewable technologies requires an appropriate policy environment. This project aims to provide early tangible demonstration of the opportunity offered by this approach. The current policy environment is conducive to the development considered; show-casing progress demonstrates progress towards low carbon heat outcomes and the confidence to ensure the policy environment endures.

- Other network owners, gas suppliers, local authorities and project developers. The consortium will welcome commercial entities to witness operation of the technology. Understanding of the potential of the technology assists in providing a supportive environment for local connections and commercial pull from gas off-takers. In order to maximise the benefit to the UK consumer it is expected that the technology may be used in conjunction with other gasification technologies and to be applied by other developers. This maximises the speed and scope of roll out.

- Customers. The showcase is designed to inspire consumers, communicating the carbon benefits of converting waste arisings from their own local area to low carbon renewable gas being delivered through their local gas distribution network.

The primary means by which this will be achieved is through showcasing the demonstration plant which will take waste input, convert to grid quality gas and then combust it in a conventional consumer appliance.

This tangible demonstration will be backed up by appropriate dissemination of information through publically available reports, journals, website, NIC conference and appropriate industry conferences. These will be targeted at appropriate sectors, ranging from the waste industry, the energy industry and also policymakers.

Section 3: Project Business Case

This section should be between 3 and 6 pages.

3. Project Business Case

3.1. Background

In order to meet UK's climate change commitments by 2050 heat will require to be substantially decarbonised. As already identified in Section 2, there are challenges to all the current technologies that could deliver low carbon heat, and in particular electrification, the primary route in most scenarios, would have a significant impact on customers from a cost and disruption perspective. Renewable gas which is currently limited by feedstocks and technology could provide a lower cost route if this could be scaled up.

The benefits that flow from this project are based on a successful demonstration that leads to subsequent commercial projects coming to market. There is clearly a knowledge benefit from the trial even if it is unsuccessful.

Due to the nature of the project and the integrated nature of the UK energy system and the uncertainties of other technologies over time it is challenging to quantify the benefits of this project directly. However, if we look at the counterfactual costs and potential avoided costs by widespread deployment of the Method the benefits are compelling.

3.2. UK Energy system benefits:

A cost optimal pathway to meet the UK's climate change targets in a secure manner was published in the Redpoint report Pathways for Decarbonising Heat [Redpoint 2012] and subsequently used by DECC in producing the 2013 Heat Strategy. The modelling to support that uses the RESOM model which is a cost optimisation tool, modelling the whole energy system in 5 year slices out to 2050. Within the baseline solution biomethane was constrained to 11TWh due to limits on feedstock. A subsequent sensitivity to that modelling has been undertaken Appendix 3. By allowing up to 100TWh of BioSNG to be utilised within the model, with costs based on Nth of a kind facilities the benefits are £1bn pa saving over the base case in 2030 rising to £8.5bn pa in 2050 due to avoided costs at other points in the energy system. The majority of this benefit will be realised by gas customers as it would allow more domestic customers to remain on gas and higher flows through the gas networks. This avoids the costs for incremental reinforcement of electricity networks, heat networks or additional low carbon generation.

In addition, it would avoid or reduce the potential need to decommission part or the entire gas distribution network, a cost largely ignored in most economic analysis. By the continued use of the gas network by fossil fuel and enhanced by BioSNG the potential need to decommission parts of the gas network would be avoided or at least deferred. Our high level analysis of the cost of decommissioning the gas distribution networks would be in the order of £8bn.

Project Business Case continued

3.3. Direct gas customer benefit

Biomethane and 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 3 bedroom semi detached house are a minimum of £4,000 in appliance costs. As evidenced in the 2012 ENA DELTA report: '2050 Pathways for Domestic Heat'. The installed cost of a typical gas boiler is £2,250 - £2,570 the equivalent sized air-sourced heat pump would cost £8,500 today, reducing to potentially £6,624 in 2040 [Delta ee 2012]. If 100TWh of BioSNG were available this could supply 6.25m properties, which would not have to make this change, giving a direct benefit to gas consumers of £25bn.

3.4. Network licensee benefit

Making best use of the gas network in a low carbon economy and supporting the usage of renewable gas aligns with the National Grid vision "Connecting you to your energy today and trusted to help you meet your energy needs tomorrow". Also our stakeholders have told us that they would like us to focus on removing barriers for the development of renewable and other sources of gas, and to help educate stakeholders to the future role of gas in a low carbon economy [National Grid 2013, 2012A/B]. As custodian, National Grid is committed to safe guarding the network for future generations whilst playing our part in delivering a low carbon economy.

National Grid believes the role of the NIC is to demonstrate the ideas, technologies or concepts that would otherwise be considered to risky for the network or market to currently commercialise that have the prospect of material financial and environmental benefit. We would like to use the NIC to further explore methods in which the gas system as a whole may transition to a more sustainable basis and promote market opportunities that have clear economic benefits to gas customers.

This project is designed to enable wider market benefits and benefits to the business and its customers over a long period of time. The benefits directly associated with the project are largely knowledge based and facilitate greater stakeholder engagement.

Should the project enable the development of a series of commercial plants then National Grid Gas Distribution and all network licensees are likely to benefit through continued utilisation of the gas network beyond 2050, ensuring efficient usage of the asset base.

In the nearer term network licensees may benefit from lower NTS Exit Capacity costs that would influence the businesses incentive position, as it is anticipated that any plants would connect to the distribution system and therefore offset flows from the NTS. However, such benefits are not anticipated to be significant in the RIIO period and future benefits would be subject to future price control settlements.

Project Business Case continued

For example, National Grid Gas Distribution is charged £102 million pa for NTS Exit Capacity. Assuming an individual gasification plant has a capacity of 100MWth and operates for 90% of the time, a single plant would contribute 0.8TWh pa of gas (0.29% of total demand for National Grid Gas Distribution in 2012/13) and a peak day contribution of 0.11% or approximately £0.1m cost avoided.

If deployment is more widespread and assuming 40 gasifiers connect (half the number of anaerobic digestion plant connections estimated under RIIO) to the Gas Distribution network some 31TWh pa of BioSNG (11% of 2012/13 or 13% of 2020/21 demand) and 95GWh/d or 4.3% of peak day demand. Such a level would equal a £4.4m saving on NTS charges annually (double the cost of the project each year).

3.5. Potential for new learning

The project will determine whether or not it is possible to upgrade gas from waste to a pipeline quality. It will also identify technical performance of the plant and any issues that network licensees would need to address if connecting such a plant, such as pressure, temperature, quality, ramp up ramp down type parameters.

3.6. Developer benefits

The other project partners are Advanced Plasma Power Ltd (APP) and Progressive Energy Ltd. APP is the Gasplasma® technology owner and developer of projects using this technology in the waste to energy field. Progressive Energy, as described in the Appendix 9 is a power generation, waste to energy and renewable energy specialist with engineering and project development skills. The involvement within this project will enable both parties to be able to consider new projects using the BioSNG technology to produce GMSR grade gas for grid injection from either existing gasification plants or from new plants utilizing all aspects of the technology. The project will provide alternative routes to market for their in house skills with the emphasis on broadening the market.

Part of the project work will be to develop an engineering scheme for the full scale plant which will provide more information on the engineering and financial modeling as useful indicators of the likely outcomes of pursuing BioSNG projects.

Financial modeling of the process has been undertaken to establish that the project offers an attractive return on investment which is a pre-requisite for commercial exploitation of the technology. A number of different scenarios have been considered as summarised in Table 3.1:

Project Business Case continued

Table 3.1: Scenario analysis of BioSNG Gas Prices

Development Status		First of a Kind		Nth of a Kind				Wood Pellets
Fuel		MSW	RDF	RDF	RDF	RDF	RDF	RDF
Scale		Single	Single	Single	Double	Single	Double	Double
Subsidies		With	With	With	With	Without	Without	With
Post-tax project returns		16.0%	15.8%	19.0%	22.5%	8.1%	11.4%	16.6%
Required gas price - £/MWh		22	22	22	22	39	39	22
MSW Processed (tonnes per annum)		168,840						
RDF Processed (tonnes per annum)		101,304	101,304	101,304	202,608	101,304	202,608	168,840

From this table it is possible to see that, with the base-line "first of a kind plant" with current costs of gas at £22/MWh, the project returns, whether taking in residual waste or a prepared RDF, are around 16%, unlevered. The detailed assumptions that underpin these numbers are given in Appendix 10.

Key points to note from the financial analysis are as follows:

- The Nth of a kind assumptions include: capital savings resulting from multiple orders, reductions in project management costs due to change from an EPC to EPCm type contract, reduced operating costs resulting from increase in efficiency and experience of operating the plant. This maintains gas prices at £22/MWh but increases returns to 19%.

- We also tested the scenario of no subsidies from Government, so revenues from RHI and ROC's are zero (this also does not factor in any carbon benefit that may accrue). The results still show that an 8.1% project IRR can be achieved with a £39/MWh gas price, which is a rise of 77% from today's gas prices.

- The "Double Scale" models are for a larger plant size at 113MWth input size, equivalent to 336,000 tonnes per annum (tpa) of residual waste (202,000tpa of RDF) or a town the size of Coventry. Assuming a cost of gas at the same as the current price, this project will give a project IRR of 22.5% with subsidies. However a no subsidies "Double Scale" facility, with an assumed gas price of £39/MWh still gives a significant 11.4% project IRR.

- It would be possible to increase the size of plant to multiple lines although the constraining factor is likely to be the availability of waste. The largest incinerator plant in the UK will take in around 450,000 tonnes per annum of RDF, which would be the equivalent of around 250MWth gasifier thermal capacity. This is equivalent to the total waste arisings, (Municipal and Commercial & Industrial) from a town with 250,000 households, such as Sheffield. This would give around 123MWth of BioSNG output or 925GWth per annum. This would be sufficient to provide for nearly a quarter of that town's gas requirements at 16.5MWhrs pa per

Project Business Case continued

household) or for a town the size of Loughborough.

- We have also considered a model for wood pellets at a double capacity thermal input scale, being an estimated 169,000 tonnes per annum of wood pellets, to give the same thermal input as 202,000 tonnes of RDF. (The implied assumption is that the CV of wood pellets is 18MJ/Kg versus 15MJ/kg for RDF.) At $130/£84 wood pellet feedstock cost and 100% biogenic content the gas price can remain at the same level as current gas prices whilst giving returns at 16.6%. The capital and operational costs for this model has the same or similar assumptions as for first of a kind MSW/RDF but at double the scale.

Given this information the project partners consider that there is a significant cost benefit for the gas customer and the Network Licensees whilst also providing a useful potential business case for developers utilising this technology and thereby ensuring the longevity of the gas grid and the benefits to the gas customer.

Project Business Case continued

Section 4: Evaluation Criteria

This section should be between 8 and 10 pages.

4. Evaluation Criteria

4.1. Accelerates 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

How the Project could make a contribution to the Government's current strategy for reducing greenhouse gas emissions, as per the document entitled "the Carbon Plan" published by DECC, in particular:

The project demonstrates technology that facilitates a number of key parts of the Carbon Plan [DECC A 2010]

- **Chapter 2: Drive the deployment of renewable energy across the UK**. BioSNG Provides fungible renewable fuel at substantial scale to meet the UK's renewable commitments in a cost effective way, meeting the requirements for renewable heat in particular. By utilising the existing gas networks that already have the capacity it is significantly more cost effective than large scale electrification of heat or building heat networks as it avoids the need for new network infrastructure.
- **Chapter 3: Saving energy in homes and communities**. Making the move to low carbon heat. BioSNG injected into the gas network is a low customer impact approach to reducing carbon emissions in buildings. It would allow consumers to reduce the reliance on fossil fuels and reduce carbon emissions without the need to replace existing appliances or heating emitters.
- **Chapter 4: Reducing emissions from business and industry**. As for building heat, BioSNG can directly replace fossil gas in business and industry which could be particularly important for high temperature process loads that are not easily switched to electricity or biomass fuels.
- **Chapter 5: Towards low carbon transport**: Compressed natural or renewable gas is suitable for reducing carbon and NOX emissions in transport whilst using existing internal combustion engine technology. The application in the HGV sector is particularly compelling as there are shortages of alternatives that can do the duty required and reduce CO_2.
- **Chapter 6: Cutting emissions from waste:** BioSNG supports the transition to a 'zero waste' economy and provides a route for ensuring "nothing is actually 'wasted' and that all resources are fully valued – financially and environmentally." It reduces waste to land fill – cutting methane emissions and land take whilst harnessing energy from waste more efficiently and with less emissions than

Evaluation Criteria continued

incineration.

- **Chapter 8: Reducing emissions in the public sector**: As chapters 3 & 4 BioSNG can directly substitute fossil gas reducing building level emissions for the public sector. This is already recognised by Government, with the Government Procurement Service being one of the initial signatories to the Biomethane Procurement Compact **http://www.cpsl.cam.ac.uk/Business-Platforms/The-Prince-of-Wales-Corporate-Leaders-Group-on-Climate-Change/UK-Procurement.aspx**

The roll-out of the project across the UK could play a significant part in facilitating the above aspects of the Carbon Plan.

Over 98% of the UK's potential biogenic resource is found in waste products [Gill et al, Biomass Task Force Report 2005]. If UK residual MSW and Commercial & Industrial waste was directed to this process potentially 100TWh of grid quality Substitute Natural Gas could be produced, a significant proportion of which would be low carbon. This is roughly 12% of current GB gas demand and 1/3 of potential gas demand in 2050.

The impact could be substantial because adoption is easier and more cost effective than other options for decarbonising heat as it doesn't rely on customer changes at all. It works with existing technologies, allowing customers to switch without the need for any additional point of use changes, unlike other technologies such as electric heat pumps, heat networks and biomass.

It can be delivered immediately by the existing gas network with either no or minimal change to operating approaches, as has already been demonstrated by the injection of biomethane from anaerobic digestion.

As gas demand is projected to fall over time, due to appliance efficiency improvements and insulation the networks already have the capacity to meet the need for heat without the need for reinforcement or expansion, unlike electricity networks that will require substantial expansion or heat networks which require new infrastructure.

(i) 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.

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.

(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 connection of plants are made on the

Evaluation Criteria continued

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:

As identified in Section 2 and Section 6.2.2 the expected environmental benefits to customers are green house gas savings over natural gas of either 127% (BEAT2) or 66% (RED).

Additionally it converts an environmental liability (landfill space and emissions etc) to low carbon valuable fuel. Also by being predicated on waste there are none of the sustainability issues compared with grown biomass such as land use change and competition with food crops.

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

Generically BioSNG delivers a low carbon solution at a cost which compares with conventional gas. Initially it would require support from the RHI but over time it is expected to be cost competitive with unconventional gas, LNG or renewable electricity without subsidy.

As detailed in Section 3 Business Case, at a macro economic level 2050 pathways that include gas for building heat are more cost effective than those that remove gas from buildings when balancing carbon targets, affordability and security. This is recognised in DECC's March 2013 heat strategy document "The Future of Heating: Meeting the challenge" [DECC B 2013]. The main rationale for this is the contribution that gas makes to supplying heat demand at the winter peak, which avoids the need for building very low load factor generation and expanding both electricity transmission and distribution to supply heat for a short period of time. The potential benefit of more renewable gas being available through BioSNG increases this benefit. In BioSNG sensitivity to Redpoint's analysis including up to 100TWh of BioSNG saves over £1bn pa in 2030 rising to over £8.5bn pa by 2050 compared to the base case. See Appendix 3.

By continued use of the gas network by fossil and enhanced by BioSNG the potential need to decommission parts of the gas network would be avoided or at least deferred. Our high level analysis of the cost of decommissioning the gas distribution networks would be in the order of £8bn.

More directly, BioSNG allows customers to reduce their carbon emissions without the need for any investment at the point of use. As outlined in Section 3, the avoided costs for a typical customer are a minimum of £4,000 in appliance costs alone. This is evidenced in the 2012 ENA DELTA report 2050 Pathways for Domestic Heat [Delta ee 2012]. Accordingly, if 100TWh of BioSNG were available this could supply 6.25m properties, which would avoid altering their heating systems giving a direct benefit to gas consumers of £25bn.

Evaluation Criteria continued

In addition as BioSNG is most likely to be injected into the gas distribution network it has the potential to reduce NTS network charges borne by the distribution network and potentially avoid the need for additional NTS investment, again benefiting gas customers.

4.2. Provides value for money to gas Customers

The 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.

The scale and cost of the project is low compared to the learning and the potential benefit that learning could deliver to the country. The ~£2m of NIC funding aims to unlock a revolution in readily adoptable low carbon heat delivery, which, as shown above saves gas customers billions compared with alternative low carbon energy scenarios.

The processes being employed to ensure the project is delivered at competitive cost are:

- The project is the continuation of an existing project to design the plant, and is therefore, a significant amount of the design and costing has been completed. Additionally, some pre testing of catalysts at laboratory scale has been undertaken to inform the design and reduce risk and cost to the project and improve the overall likelihood of success. See Section 6 Project Readiness.
- The earlier IFI79 project has been managed effectively through phases 1 and 2 with no cost overruns and timescales being met. A similar disciplined approach to project and budget management is proposed.
- The project utilises an existing gasifier and site which can produce a known quality of syngas from waste. This significantly this reduces the overall cost to the project and risk to the project compared to building a completely new end to end facility that would require, land capex, permits etc. The cost of a dedicated gasifier at this size would be greater than £5m.

4.3. During the project appropriate industry tendering approaches will be used to procure the capital equipment. How the partners were selected:

Due to the specialised nature and relative maturity of the technology there are very few organisations capable of undertaking such a project at present. The 2010 BioSNG feasibility study showed that commercial deployment of BioSNG could only take place with a demonstration project. That work concluded that the most cost-effective and risk-managed means by which this could be achieved would be by identifying an existing source of waste-derived syngas suitable to feed the BioSNG methanation demonstrator. This avoids very significant additional costs and substantial programme management risks associated with construction and operation of a new gasification facility.

Evaluation Criteria continued

Following the report, National Grid and Progressive Energy undertook an investigation into potential UK sources of suitable syngas. This work identified only one source of currently available, high-quality waste-derived syngas suitable for methanation, which was from Advanced Plasma Power's facility in Swindon.

In this investigation, and in light of limited options, an alternative approach was considered, which was to use a generic research facility, the High Temperature Metals Centre in Teesside, run by Tata. This had the technical capability to produce a synthesis gas, however this did not have the infrastructure to process suitable quantities of waste feedstock, so would not met the core requirement of demonstrating waste-BioSNG production. Furthermore, the facility has since been closed by Tata.

Through discussions with Advanced Plasma Power it also became clear that not only could they provide a source of good quality waste-derived syngas, and had the facilities and capabilities to install and operate the BioSNG plant, but they were also willing to invest their own funds and effort into the project.

Therefore, both, Progressive Energy and APP participated in the project that followed, IFI79, the feasibility and design phase of this project.

(v) Outline the costs associated with protection from reliability or availability incentives and the proportion of these costs compared to the proposed benefits of the Project.

Not applicable, as the demonstration project does not connect to the network

(vi) The Network Licensee must also set out where it has or plans to undertake open competitive procurement processes for services or items required for the Project. The Network Licensee must also outline other steps it has taken to ensure that the NIC funding request represents the best value for money to gas transmission and gas distribution customers.

Equipment will all be procured using industry best practice with appropriate competitive tendering

(vii) Where a Network Licensee has not undertaken a competitive procurement process for services or items, it should explain why not and how they are ensuring best value for money in the provision of these services or items

See above section on partner selection

4.4. Generated knowledge that can be shared amongst all relevant Network Licensee

The key areas of learning are the demonstration of taking residual waste to produce a pipeline quality gas by:

Evaluation Criteria continued

- Proving the end to end concept of taking waste and converting it to a pipeline quality GSMR specification gas; this includes the associated learning of what the optimal process design, the performance and operating conditions are necessary to produce gas to the correct specification leading to and informing the commercial design.

- Proving the development of the technical and economic performance of a commercial scale plant including innovation around:

  - Syngas purification & polishing

  - Water gas shift and Methanator Reactors

  - Methane polishing and upgrading to Gas Quality

  - Operation of the above at the relatively moderate scales appropriate for waste-derived fuel operation (Compared with conventional fossil fuel methanation facilities)

- The gas networks will learn about the expected quality and operating conditions of such a plant.

- Commercial developers/local authorities/DECC will be able to understand the performance and commercial viability of such a plant across a range of operating conditions and duties which will build confidence in the process in order for commercial projects to come forward.

- Key learning will be captured in 6 monthly project reports and published on the project's web portal details of which will be sent to all GB network licensees and shared at the annual innovation conference, the ENA R&D working group and presented at Energy from Waste industry conferences. In addition open days will be held at the plant. Knowledge dissemination is detailed in Section 9.

4.5. 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

The project is innovative, untested at the scale and circumstance proposed and new learning will arise from the project, specifically:

The processes to be demonstrated by this project to produce BioSNG from variable residual waste streams to a quality and consistency that can be safely injected into the existing gas system have not been attempted anywhere in the world before. The 2010 Progressive Energy report, BioSNG Feasibility study - The establishment of a regional project [Progressive Energy 2010], reviewed the various technologies that could produce

Evaluation Criteria continued

BioSNG and identified that the full end to end process from waste to GSMR gas had not been done before. No developments of this type have come to market since. Therefore, new learning will result for this project.

However, due to the very high quality demands on the syngas, owing to the sensitivities to contamination of methanation catalysts, particularly when using a highly variable feedstock such as waste, investment of tens of millions of pounds in a fully integrated commercial plant will not be attracted without proven testing of the technology. Therefore, this project is needed to establish and prove the technology to provide that certainty and confidence for commercial investors, local authorities and government to establish follow on projects.

Due to the complex nature of the project and the interdependencies between the performance of the plant and the requirements of the network it requires involvement of both the technology provider and the network to ensure a successful project. The network will provide guidance and support on the gas quality, flows and pressure characteristics needed to connect to the gas network. Therefore, it is essential that this project is funded in part by the Network Innovation Competition fund as well as by potential project developers to ensure end to end issues are addressed at this demonstration stage and to reduce the risk for subsequent commercial projects that will connect to the GB gas network. Specific gas network owner involvement will include:

- Commercial – costs, metering requirements, instrumentation, contractual arrangements
- Technical/Operational– flows, pressures
- Regulatory – gas quality (CV), gas quality (Wobbe), interaction with Health and Safety Executive, Ofgem, Environmental Agency etc.

As there are no direct routes for National Grid to commercially benefit from the development of this technology, we would not invest in this project as part of our normal course of business.

4.6. Involvement of other parties and external funding

The project partners are:

Advanced Plasma Power (APP) owns and operates the Gasplasma® facility in Swindon, UK. This is a two stage thermal process producing power from a gas engine with a diverse range of feedstocks from biomass to a prepared waste derived feedstock. The plant was built in 2007 and became fully operational in 2008. APP has significant internal process engineering capability as well as plant operational experience that are unique. APP will assist with the procurement of equipment and on-site erection, whilst providing a lead role in commissioning and operating the plant. Further detail in

Evaluation Criteria continued

Appendix 9.

Progressive Energy is an internationally recognised clean energy project development company with a particular focus on decarbonisation of the energy sector through carbon capture and storage and renewables. Progressive Energy has particular skills in projects utilising emergent technologies, with the breadth of experience vital for assessing the commercial balance of risk and reward that such approaches offer. Using these skills Progressive Energy's highly qualified process engineering team have provided invaluable guidance in the design of the BioSNG project and will continue to provide technical engineering services to the project. Further detail in Appendix 9.

4.7. Funding:

Additional funding options to the NIC funding request are being finalised during 2013. Therefore the project partners are requesting a 50% contribution from the Gas Network Innovation Competition. As it stands the £1.875m NIC request is supported by firm build up of the capital costs of the plant plus working estimates of the man hours needed to operate both the Gasplasma® syngas supply plant and the BioSNG plant. Other estimates have been included for project management and dissemination. The partner contributions have bee agreed by APP up to 100% of their labour costs which are shown to be £871,000. National Grid will contribute 10% towards the NIC costs and Progressive Energy will contribute 10% of their labour costs amounting to some £20,000.

4.8. Further potential contributions to the project

The project partners are in mature discussions with a further potential project partner, who has indicated that they would provide funding up to £1m subject to a successful NIC application. They are currently performing due diligence on the project and expect to be in a position to make a decision during the autumn 2013.

A funding application to the BESTF - ERANET call for matched funding has also been submitted on the recommendation of DECC. We have succeeded in the stage 1 application and the stage 2 application is being submitted on the 16th August. Awards for this programme are made in December 2013.

4.9. Process NG undertakes to assess suitable project ideas.

The project ideas we have looked at align with our view that there is a role for gas and gas networks in the low carbon economy, and that utilising the gas networks through renewable gas and more efficient gas appliances is more cost effective than moving all building heat demand away from gas to electric or heat networks. This is evidenced in the work we have been doing under IFI projects such as Redpoint: 'Pathways for Decarbonising Heat' (IFI81) and Delta EE: '2050 Pathways for Domestic Heat' (IFI89) [Redpoint 2012, Delta ee 2012]. This view has now been accepted by DECC in their

Evaluation Criteria continued

March 2013 heat strategy paper: The Future of Heating: Meeting the challenge [DECC 2013]. We believe demonstration of these technologies is essential for accelerating the low carbon economy and understanding the impact on the gas network.

From the outset the build test and demonstrate phase of this project was always planned to be undertaken as an NIC project. The project was therefore selected over other potential ideas as it is in an advanced state of development and with lower deliverability risk and, as with IFI79, the partners are also prepared to contribute financially to the project.

The rationale we used for selecting project ideas was based on an assessment of:

- is it aligned to the view above?
- does it meet the NIC criteria - i.e. does it accelerate low carbon economy, does it benefit gas customer, is it innovative?
- how deliverable is the project - level of risk attached to achieving the outcome, clear scope outputs defined?
- is it collaborative and are the partners credible and are they willing to contribute funds?

National Grid Gas Distribution assessed 4 projects for submission to NIC ISP. The other 3 were discounted as they were at earlier stages of development, or because there was sufficient uncertainty of the method to apply making it more prudent to initiate them as NIA studies in the first instance, to gather the relevant information to allow scoping of a potential NIC project at a later stage. The BioSNG project was selected because it was in an advanced state of development, due to the completion of the first 2 Stages. Therefore there is greater certainty of the project being delivered successfully; also, as with earlier stages the project partners were willing to contribute financially. It supports the development of low carbon economy and the project also has the support of DECC.

4.10. Relevance and timing

(viii) The network licensee must outline how the project aims to investigate or solve environmental challenges the gas sector faces…

The project aims to investigate an option to solve one of the 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, its role 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

Evaluation Criteria continued

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. Whilst Biogas from AD has an important role in meeting this target, BioSNG has the potential to accelerate development considerably and make a substantial contribution to this and 2050 targets by opening up the possibility for mixed wastes to be processed into gas. A Pilot project commencing in 2014, would enable investment decisions in 2016 for commercial facilities. This would enable a number of plants to be operational by 2020. Further delay would significantly hinder roll out by 2020, and thus a significant shortfall in renewable heat production.

The current incentive structure (RHI) enables Bio-Methane and does include BioSNG, however, there is a need for tangible evidence of progress to maintain strategic focus on this route by DECC.

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 amount for low carbon gas via BioSNG.

The learning will also feed into the networks business planning assumptions around scale, and location of gas entry connections, operating conditions/pressures and gas quality from these types of plants.

Section 5: Knowledge dissemination

This section should be between 3 and 5 pages.

☐ Please cross the box if the Network Licensee does not intend to conform to the default IPR requirements.

5. <u>Knowledge Dissemination</u>

The Consortium is committed to a knowledge sharing programme. The purpose of this programme is to maximise the value to the UK consumer by facilitating widespread deployment of BioSNG. This is achieved through communication of the opportunity it holds, as well as the output from the programme

5.1. The audience

The audience for Knowledge Transfer comprises:

- Policymakers. Deployment of renewable technologies requires an appropriate policy environment. This project aims to provide early tangible demonstration of the opportunity offered by this approach. The current policy environment is conducive to the renewable gas approach being deployed in this project; show-casing progress demonstrates progress towards low carbon heat outcomes and the confidence to ensure the policy environment endures.
- Customers. The showcase 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 showcase 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.
- Gas network owners/operators. These are important stakeholders in enabling deployment of the technology. Whilst a key objective of the project is to ensure that the renewable gas delivered is truly fungible with existing gas on the network, there may be specific issues where the most cost-effective deployment is enabled through a partnership between the network operators and the gas supplier. Understanding of the potential of the technology as well as specific details of requirements assists in providing a supportive environment for local connections.
- Potential gas suppliers and Project Developers. Widespread deployment of the proposed process requires uptake by developers of facilities and potential gas suppliers. The consortium will welcome such commercial entities to witness

Knowledge dissemination continued

operation of the technology to inspire their interest in deployment. Knowledge will also be shared to enable such entities to understand the technical and commercial attributes of the approach necessary to develop the appropriate business cases to take projects to financial investment decisions.

- Technology vendors and Original Equipment Manufacturers. Deployment also relies on an appropriate supply chain. Commercial deployment is expected to encompass a wider range of equipment vendors than utilised on the demonstration facility. Specifically, it is expected that the technology may be used in conjunction with other gasification technologies and to be applied by other developers. This maximises the speed and scope of roll out. To do this requires sharing appropriate information regarding equipment specification etc. to enable such entities to engage in supply.
- Academic Institutions. This project relies on deployment of novel technologies. Whilst the work carried out to date provides confidence in the ability to deliver a viable renewable gas solution, there may be follow on activities to further optimise Nth of a kind projects. The consortium will engage with academia, primarily through the Supergen Bioenergy Hub to provide a means through which such developments could take place

5.2. 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.

5.3. The means of dissemination

5.3.1. Showcase facility

The primary means by which this will be achieved is through showcase operating unit which will take waste input, convert to grid quality gas and then combust it in a conventional consumer appliance. This facility will be designed to provide an inspiring demonstration of how discarded material can be harnessed to deliver renewable, low carbon outcomes. It will include an appropriate seminar area which allows consortium members to share appropriate specific information with the audience – whether it be policy makers, consumers, network operations, developers or members of the putative supply chain.

5.3.2. Face-to-face events

Knowledge dissemination continued

This facility will then provide a basis for specific face-to-face events whereby Key Knowledge can be shared through personal interactions, for example, in discussion with small specialist groups or through larger scale presentations. The Consortium intends to provide specific knowledge sharing events, which will enable interested parties to access relevant information and to visit the site. There are expected to be 6 formal dissemination events, including presentation at the NIC conferences during the latter phases of the projects, once the facility has been operating.

5.3.3. *On-going involvement in networks*

With regard to Network licensees, information will be shared at the annual innovation conference as well as the ENA R&D working group. The Consortium Partners have on-going involvement in industry networks and these will form a valuable means of disseminating Key Knowledge. These include the Renewable Energy Association, Chartered Institute of Waste Management, the Energy Institute, Institute of Chemical Engineers, as well as the EPSRC Supergen Bio-energy programme. Through key conferences across the waste and energy sectors the Consortium will share more widely the project findings.

5.3.4. *Papers and Journal articles*

Through involvement with Supergen it is expected that the consortium members will disseminate appropriate technical information through academic journals in order to engage the academic community. In addition trade journals will be used to engage industry professionals with technical and commercial information to facilitate deployment.

5.3.5. *Web-presence*

The Consortium will set up a website dedicated to the project, and through this portal provide public visibility of objectives and aspirations of the project, as well as progress through the project life. This will be linked to appropriate social media and press releases to reach out to audiences in an appropriate and appealing way. Details of this web portal which will be sent to all GB network licensees, as well as promoted at wider industry conferences.

5.3.6. *Progress and Close Out Reports*

Key learning will be captured in 6 monthly publically available project reports. These will be made available through OFGEM's required channels, as well as directly from the participants, including the web-portal.

Knowledge dissemination continued

5.4. Intellectual Property Rights (IPR)

We aim to conform to the default IPR arrangements set out in the Gas NIC Governance Document. For the avoidance of doubt we have summarised the significant default conditions below but have reiterated the section 9 IPR conditions from the NIC governance document (Appendix 13).

IPR is material information and knowledge gained from the learning in respect of the project. It may come in the forms of information, understanding or skills necessary to reproduce the outcome of the project, or with the deployment of the IPR leading to the reduction of costs or difficulty of reproducing the outcome of the project. Project Partners' shall retain all rights in and to its Background IPR. Foreground IPR will be all results and Intellectual Property therein produced from work done during the Project. Each Project Participant shall own all Foreground IPR that it independently creates as part of the Project, or where it is created jointly then it shall be owned in shares that are in proportion to the effort made and work done in its creation as evidenced by the final project report in milestone 10.

5.4.1. *Licensing of Background IPR*

Where access to a Project Participant's Background IPR is required to undertake the Project, the Project Participant shall grant a non-exclusive licence to this Background IPR (Relevant Background IPR) to the other Project Participants, solely for the purposes of the Project during the term of the Project. Once the Project is over, Relevant Background IPR will be licensed for use by the Project Participants in connection with another Project Participant's Foreground IPR solely to the extent necessary to use that Foreground IPR, upon terms to be agreed.

5.4.2. *Licensing of Foreground IPR*

Foreground IPR which is produced by the Project will comprise of IPR which describes the application of the process to a network and the benefits that can accrue. It will also include the IPR that describes how the process achieves its functionality. Foreground IPR will to a greater extent include informal knowledge, e.g. Know How, whilst the Back Ground IPR has already been registered. Relevant Foreground IPR is Foreground IPR that other Licensees will need to utilise in order to implement the methods being developed and demonstrated in the Project.

Licensing of the Foreground IPR shall be agreed between the Network Licensee and Project Partners consistent with the principles above. All other Network Licensees will have the automatic right to use Relevant Foreground IPR for use within their network royalty-free. Where the Relevant Foreground IPR can only be used with a Project Participant's Background IPR, other Licensees will have the automatic right to request a limited licence of such Background IPR for that sole purpose on fair and reasonable

Knowledge dissemination continued

commercial terms to be agreed. If commercial terms cannot be agreed between the parties they shall use good faith efforts to resolve any disagreement by reference to the senior executives of the relevant parties who have authority to settle. If the matter is not resolved through such negotiation, it shall be settled as agreed either by:

- Mediation in accordance with the Centre for Dispute Resolution ("CEDR") Model Mediation Procedure (the "Model Procedure"). To initiate mediation a party must give notice in writing to the other parties to the dispute requesting mediation pursuant to the CEDR Model Procedure. A copy of the request shall also be sent to CEDR. The mediation shall be before a single, independent mediator appointed by agreement of all parties to the dispute or, in the absence of agreement, by the President for the time being of the Law Society of England and Wales; or
- In the event that mediation of the dispute does not result in its resolution, by reference to the jurisdiction of the Courts in England, each of the Parties shall have the right to take proceedings in any other jurisdiction for the purposes of enforcing a judgement or order obtained from the Courts in England.

The licensees of IPR may be required by the licensor to enter into a confidentiality agreement to protect the IPR licensed to it. Other parties (who are not Project Participants and are not a Network Licensee) may request a licence to use Relevant Foreground IPR, such licence to be on arms-length terms, which may include payment of a commercial license and royalty.

5.4.3. Right to protect IPR

Each Project Participant will warrant that it has the right, power, title and authority to license its Relevant Background IPR on the terms of the licence agreement. Each Project Participant will warrant that use of the Relevant Background IPR in accordance with the terms of its licence agreement will not infringe any third party rights. Each Project Participant will warrant that it will pay all fees necessary to maintain registered rights that form part of the licensed Relevant Background IPR. Each Project Participant will undertake to protect Relevant Foreground IPR (subject to the transfer options included in Appendix 13) in the terms as set out in the Appendix 13.

The technological process for converting a relatively clean syngas to methane has been developed by the Project Participants who have registered the intellectual property rights with the authorities in the UK surrounding the process for producing substitute natural gas from syngas and in particular to manufacture renewable BioSNG from biogenic waste sources. We consider this to be classed as Background IPR.

For the avoidance of doubt the APP Gasplasma® process is a syngas supplier to the Project and the IPR relating to the gasification of waste is not considered part of this Project and therefore all IPR relating to Gasplasma® is owned solely by APP and does not form part of the IPR relating to the BioSNG Demonstration Project. Therefore no rights are conferred by the use of the syngas from the Swindon Gasplasma® plant to this Project, its participants or funders.

Section 6: Project Readiness

This section should be between 5 and 8 pages.

Requested level of protection require against cost over-runs (%):
5%

Requested level of protection against Direct Benefits that they wish to apply for (%):
0%

6. Project Readiness

The project partners for the BioSNG programme, NG, APP and PEL, co-operated to develop a detailed design and an associated programme for the delivery of a BioSNG demonstration facility for which current funding is being sought under the Network Innovation Competition. This section refers to the management systems that have already been established and the detailed design and associated planning work conducted under IFI79 during 2012-2013. There will be close technical and financial monitoring throughout the project to review progress against the programme and budget. Deviations, either from the project scope/timing or in expenditure will be reviewed at the regular meetings held by the Steering Group Committee and actions effected to rectify the issue. The following additional supporting documentation is given in the Appendices relating to the management of the project and the systems in place to assess, monitor and control any potential problems that may occur over the course of the project:

- **Project Management:** A description of the Project Management system is presented in Appendix 4.
- **Project Plan:** A high level project programme is given in Appendix 7.
- **Risk Register:** This document, given under Appendix 8 highlights the potential risks associated with the project and the mitigating controls that will be in place.
- **Process Description:** A description of the process, with associated process flow schematic and high level Mass and Energy Balance (MEB) in Appendices 5 and 6
- **Partner Information:** Relevant background experience of the project partners and key Personnel is given in Appendix 9.
- **Cost and financial modelling data:** Appendix 10 provides high level capital and operating costs for a commercial BioSNG facility for a single and double line facility (ie 150ktpa and 300 ktpa).
- **Capital Cost for Demonstration Pilot Plant:** Appendix 11 provides a breakdown of cap[ital costs for the proposed Pilot Plant.

6.1. Evidence as why the Project can start in a timely manner.

The project partners have collaborated on the “BioSNG project” since March 2012 and it is well developed technically and commercially and ready to commence in a timely manner.

Project Readiness continued

6.1.1. Technical System and component design readiness

The process engineer Otto Simon Limited (OSL) has been employed to work with the project partners to complete the design and cost estimate for the demonstration plant. The IFI79 BioSNG project was delivered on time and to budget despite some significant additions to the project specification as defined in the Technical Contract. Under IFI79, the detailed process engineering of the water gas shift (WGS) and methanation reactors has been completed by APP, supported by PEL and OSL. The exothermic reaction in the methanator has necessitated additional work to determine the best way of designing and operating the reactor. A kinetic model has been developed by APP which has been integrated into the Aspen Plus process simulation model developed for the project. We also commissioned a catalyst specialist laboratory to test catalytic processes and materials, to undertake trials in order to improve understanding of the temperature profile and light off temperature of the exothermic reaction for a range of input variables. Detailed layouts for the plant have also been developed to determine where the equipment will be placed. The main equipment items will be constructed off site as discrete sled mounted units which will enable rapid installation and service link-up once installed on site.

6.1.2. Procurement Readiness

From the design knowledge base established, Functional Design Specifications have been prepared for all major equipment and services and quotations were obtained from suppliers to establish expected costs. Competitive tendering processes will be used for procurement. These will be expedited in advance of the formal project start date to allow early placement of orders for the long delivery items – e.g. syngas compressor and gas storage system. This should enable the plant to be erected within the scheduled period of 10 months.

6.1.3. Syngas provision and services

An important attribute of the project is the existing Gasplasma® facility on APP's site which will provide the required quality of syngas for the BioSNG process. This facility, which is more complex than the proposed BioSNG facility, was installed and commissioned on site within an 8 month period. The quality of the raw syngas from the Gasplasma® facility is well understood from its operational history, allowing reliable definition of input design specifications required for the BioSNG facility. The main infrastructure requirements, including power and water are already available on site and we have determined that there is adequate power and water cooling capacity to meet the ratings of the combined facility.

6.1.4. Planning and Permitting Readiness

As part of IFI79 a planning consultant was engaged to investigate any possible obstacles

Project Readiness continued

regarding planning and permitting for the proposed future operating facility. With respect to planning application, the consultant concluded that "...any additional storage compounds, pipeline, any required alterations [to plant] and regularisation of outstanding alterations.... would be considered to be a low planning risk". On the permit side they stated that the facility is expected to comply as a Research and Development activity, consistent with the existing Gasplasma® facility.

6.1.5. *Commercial arrangements*

The consortium partners are already using an Research and Development (R&D) collaboration agreement which forms the on-going basis for collaboration and commercial implementation of the technology. Given the established collaborative track record of the project partners on the IF179 project, whose purpose was to develop a detailed design and scheduled programme for the proposed BioSNG programme, we have every confidence that the project will proceed in a timely and tightly managed fashion.

6.2. Evidence of how costs and benefits have been estimated (this can be supplemented in the appendices).

The expected financial and environmental benefits that the project will deliver have been detailed in Section 4.

6.2.1. *Evidence of Costs*

The installed capital cost of the proposed demonstration facility has been established at the detailed design stage with suppliers providing quotations against equipment design specifications. These costs are summarised under Appendix 11. With respect to determining labour costs, a project work programme, (see under Project plan, Appendix 7) has been constructed which covers the major tasks, their duration and the associated deliverables. The plan also includes the resource manpower allocation, for each partner, against each allocated task to establish both the total manpower requirements and associated labour costs of the project (see Budget Spreadsheet).

A major cost-benefit to the project, as described in Sections 4, is that a syngas facility is already in place at APP's site in Swindon which will produce the feedstock for the BioSNG facility. The cost of engineering and installing such a plant is around £5 million. A further advantage which flows from this is that there is a highly skilled and experienced team of operators and engineers on site who have direct experience and knowledge in the operation of an advanced thermal facility which incorporates gas cleaning/ refining. This not only de-risks the project but is also likely to greatly reduce the time and manpower resources needed to reach the experimental proving stage.

6.2.2. *Benefits: Environmental*

Project Readiness continued

A preliminary analysis has been undertaken to evaluate the projected overall reduction in green house gas (GHG) emissions when producing BioSNG from renewable sources as compared to use of natural gas. The emissions have been calculated using the BEAT2 and EC RED methodologies which follow the approach reported by NNFCC to assess the environmental impact of the production of BioSNG from renewable sources (such as biomass and RDF of MSW and cardboard). BEAT 2 includes alternative disposal of the feedstock e.g. to landfill and therefore provides a greater GHG saving than EC RED which accounts for the significant difference in emissions observed between the two methodologies [NNFCC 2010].

This is based on BioSNG from solid RDF waste where the carbon intensity is calculated at point of use in a gas boiler at 85% efficiency. The main findings were shown in section 2. It is seen that, irrespective of the methodology used, the proposed BioSNG process route represents a significant saving over natural gas of either 127% (BEAT 2) or 66% (RED).

One of the major benefits that the project could deliver to customers is as a significant provider of commercial BioSNG plants that may be connected at any point within the GB network.

6.2.3. Benefits: Cost

If UK residual MSW and Commercial & Industrial waste was directed to this process potentially 100TWh of grid quality Substitute Natural Gas could be produced, a significant proportion of which would be low carbon. This is roughly 12% of current GB gas demand and 1/3 of potential gas demand in 2050. The benefit is cost-effective renewable gas.

6.3. Evidence of the measures a Network Licensee will employ to minimise the possibility of cost overruns or shortfalls in Direct Benefits.

Management systems, established under project IFI79, are in place to minimise the possibility of costs exceeding the budgeted limits. The installed capital cost of the proposed demonstration facility was established at the detailed design stage with suppliers providing quotations against equipment design specifications. These costs are summarised under Appendix 11.

With respect to determining labour costs, a project work programme, (see under Project Plan, Appendix 7) has been constructed which covers the major tasks, their duration and the associated deliverables. The plan also includes the resource manpower allocation, for each partner, against each allocated task to establish both the total manpower requirements and associated labour costs of the project (see Budget Spreadsheet).

The financial monitoring of the project will be carried out on a day-to-day basis by a designated financial controller who will directly advise the Project Manager. The funding

Project Readiness continued

requirements will include the provision of a (5%) contingency fund. Project review stages shown on the work programme give the Project Manager the authority to draw down funding in line with the planned expenditure profile, however, access to contingency funding for any purpose is only possible with direct Steering Committee approval.

The Project Plan identifies a series of Project review stages for monitoring progress and expenditure and to take any necessary actions to direct changes to the Project Plan. Particular Project review stages are designated as Project Gateways at which commitment to the ensuing stage of development is formally approved. In order to protect the interests of any of the Parties, approval at a gateway stage implies that all the Parties agree to continue with the planned work until the completion of the stage, subject to the terms relating to termination or withdrawal.

The allocation of the External Funding will be as set out in the Project Plan and the Funding Conditions unless the Parties unanimously agree otherwise in writing.

A risk register has also been established based on the knowledge gained over the course of the detailed design stage of the project. The key technical, economic and health safety and environmental (HSE) risks are presented in Appendix 8. In respect of safety and environmental risks, a robust HSE Management system was established at the onset of the project design stage, to ensure best engineering practice at every stage of the project. HSE work that has been carried out to date includes HAZAN/HAZOP, SIL, DSEAR/area classification and risk assessment studies of the integrated system. This has allowed for systematic evaluation and mitigation of process hazards/risks as well as improved overall system reliability and operability. The findings of the safety documentation will be reviewed and a detailed Hazop study, chaired by an independent expert, will be carried out prior to final sign-off of the process design. Plant training and detailed operating procedures will be in place to ensure safe running of the plant. Any changes to the plant equipment and/or operation will be subject to a formal risk assessment.

Given that this phase of the project is pre-commercial, focussed on the proving and subsequent development of the BioSNG process, there will no revenue streams and hence no direct economic benefit from the project.

6.4. A verification of information included in the proposal (the processes a Network Licensee has in place to ensure the accuracy of information can be detailed in the appendices).

6.4.1. Technical Information Verification

All design data and performance of the BioSNG facility have been rigorously verified

Project Readiness continued

through all stages of the design process.

The viability of commercial deployment depends critically on the mass and energy balance (MEB). The MEB for a projected commercial BioSNG plant is shown in Appendix 5. This was generated utilising the Aspen plus simulation model. In respect to the syngas generation stage of the process, the simulation model itself has been validated against experimentally observed data for the Gasplasma® process. The Swindon syngas generation plant has extensive monitoring in place for key process operating data including: solid fuel feed rates, oxy-steam flows, pressures, temperatures, plasma power input, syngas flows and compositions which are recorded and stored through a SCADA monitoring system.

PEL have considerable experience in the development of gasification and syngas refining systems. They provided an important technical review and verification function especially at the initial concept design stage when the essential process flow sheet was developed.

Additionally, the process engineering organisation Otto Simon Limited (OSL) was engaged during IFI79. They have directly relevant experience in gas to liquid applications (GTL) which have very similar syngas cleaning and catalytic reaction processes to those that will be used in the BioSNG process. OSL in conjunction with the project partners, completed the design and build budget for the demonstration plant. This work included preparing the functional design specification for the major equipment items and associated services and obtaining competitive quotations from equipment suppliers. OSL also critically reviewed all design documentation produced by the project partners.

The detailed process engineering of the catalytic water gas shift (WGS) and methanation reactors undertaken by APP, was closely reviewed by PEL and OSL. The highly exothermic reaction that occurs in the methanator has necessitated additional work to determine the best way of designing and operating this reactor. A kinetic model has been developed by APP which has been integrated into the Aspen Plus BioSNG process model.

The services of a catalysis specialist company, Catal Limited, were employed to run a number of methanation trials, including a 3 day extended trial. Specific variables evaluated were: composition of gas, effect of dilution of bed, operating pressure and space velocity of the bed. This experimental work was carried out in order to provide guidance on: i) on the most appropriate catalyst(s) to use in the methanator stage, ii) to indicate the light-off temperature of the methantion exotherm and iii)to help define the geometry and thermal management system for the reactor envelope for the demonstrator rig. The results of the scoping tests have also been used as inputs to the process simulation models that we have developed to help inform the detailed design. The final extended run conducted over 3 consecutive days also incorporated $CO/CH_4/CO_2/H_2$ analysis on the product stream. The key findings from this experimental

Project Readiness continued

work were as follows:

- **High methane recoveries**: We observed nearly a 100% conversion of CO to methane with residual levels of CO being ~40ppm and there was no discernible reduction in catalyst activity over the period of the trial.
- **Effect of pressure:** It was established that the (virtually complete) methanation reaction occurred at low pressure (i.e. at 2 bar which is the projected level for the commercial plant).
- **Ignition temperature:** The recorded "light-off" temperature was only 200-230°C. This is lower than is observed in high pressure / low molar concentration conditions adopted in large scale chemical facilities. Such low ignition temperatures for the low pressure, high molar concentration conditions in this project is strongly beneficial for the process design, as it should allow stable isothermal operation of the methanation reactor.
- **Reactor configuration and space velocities:** Successful operation was based on gas hourly space velocities (GHSV) of 2000 which has provided the basis for the design activities
- **Process operation (start-up etc):** Valuable experience was gained with regard to initial preparation and reduction of the catalyst.

We also commissioned Catal to advise on the preferred methods of handling certain impurities in the process stream and to provide more general information about the chemistry and other properties of the most likely syngas impurities

6.4.2. <u>Environmental Benefit verification</u>

The environmental benefits of the project concept were independently verified by the National Non-Food Crop Centre, using techniques developed by North Energy Associates, as outlined in NNFCC 2010.

6.4.3. <u>Commercial Information verification</u>

As outlined in Section 6.2 above, under IFI79 the commercial information (costs of the demonstration facility, as well as the future costs of renewable gas) was carefully developed with the assistance of third party specialists such as Otto Simon and Catal.

6.5. How the Project plan would still deliver learning in the event that the take up of low carbon technologies and renewable energy in the Trial area is lower than anticipated in the Full Submission.

The proposed demonstration stage of the project is pre-commercial. The primary aim is to demonstrate the technical feasibility of the thermochemical conversion of biomass containing wastes to BioSNG for injection into the grid and to show that this can be

Project Readiness continued

achieved sustainably and with a reduction in carbon impact when compared with natural gas.

The Project does not rely on field trials, because it is in itself a single demonstration plant. As described elsewhere, this is a well-developed project, and execution of the demonstration plant itself is fully risk managed.

The results from this project will provide valuable learning, whatever the outcome of the demonstration plant operation; if the plant operates successfully, or specifically defines the issues for resolution then this provides the platform for commercial deployment and low cost renewable gas for consumers.

6.6. The processes in place to identify circumstances where the most appropriate course of action will be to suspend the Project, pending permission from Ofgem that it can be halted.

Under the terms of the project partners' research and development collaboration agreement which is already in force for this project, specific provisions are defined for dealing with termination of the work in the event that it becomes clear to the Project Steering Group (PSG) that the project objectives would be seriously compromised or else simply unattainable. Moreover, the research and development collaboration agreement sets out the principles to be followed if any of the partners wishes to retire from the project whilst the other parties wish to continue. The Collaboration Agreement also defines in either of these eventualities the basis for determining a settlement of the project financial accounts. As a general principal, a sequence of project phases is defined in terms of objectives and budget and each of these is sanctioned by the unilateral agreement of the PSG, where after consortium participants undertake thereby to complete their defined contributions to the work scope approved for the stage in question. A decision to terminate the project would in the normal course of events only be taken at a formal project stage gate. The termination provisions can be referenced in the Partners' research and development Collaboration Agreement.

Section 7: Regulatory issues

This section should be between 1 and 3 pages.

☐ Please cross the box if the Project may require any derogations, consents or changes to the regulatory arrangements.

7. Regulatory Issues

The demonstration plant will not be connected to the gas network and therefore no regulatory issues relating to the network licence are anticipated during the life of the project.

However, the project will investigate whether there are likely to be any regulatory issues arise from the deployment of commercial scale plants that do connect to the network. It is expected that operating parameters, CV, Wobbe number. of the potential product gases will be identified and any potential regulatory issues identified and investigated as the project progresses.

Section 8: Customer impacts

This section should be between 2 and 4 pages.

8. Customer Impacts

As identified in Section 7, the demonstration plant will not be connected to the gas network and therefore will not have any impact on gas customers during the life of the project. As per Section 7 any potential customer impacts as a result of the operating parameters of the plant will be investigated as part of the project although none in particular are anticipated.

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

Section 9: Successful Delivery Reward Criteria

This section should be between 2 and 5 pages.

9. Successful Delivery Reward Criteria

The successful delivery reward criteria for this project are set out below and relate to the objectives of the project which are to design, build, test and operate a BioSNG demonstration facility using stored syngas from APP's Swindon Gasplasma® plant. The successful delivery and achievement of these objectives are clearly measurable and will be reported to the Authority as part of the project. The specific criteria by which we wish to be measured are:

9.1 Dissemination of knowledge and understanding gained from the construction and operation of the BioSNG plant via a specific website/portal
9.2 Final Design and Safety Review
9.3 Construction and installation
9.4 Commissioning of plant
  i. Storage of syngas
  ii. Purity level of syngas
  iii. Water gas shift success = purity and levels of CO and H2
  iv. Methanotor operation and production of substitute natural gas
9.5 Test & Optimisation Programme
9.6 Assessment of scale up risks
9.7 Engineering Scheme for a full scale plant risks
9.8 Levelised Cost of Gas for a full scale plant in the UK
9.9 Operating showcase - dissemination

All of these criteria are linked to project milestones or included within milestone reports as set out below:

9.1. Dissemination Portal

The consortium will create a National Grid BioSNG Website dedicated to the project, and through this portal provide public visibility of the objectives and aspirations of the project, as well as progress through the project life. Details of this web portal will be sent to all GB network licensees, as well as promoted at wider industry conferences. Already the project has received publicity in this way through a number of industry related conferences that promote waste to energy and fuels. We would expect this to continue and increase during the project. A key element of dissemination is also the 'showcase' Visitors' Centre – which is considered as a separate criteria, see Item 9.0.

- In terms of measuring this criterion the key measurable evidence is (a) setting up of a portal, and (b) presentations at conferences.

9.2. Final Design and Safety Review

Successful Delivery Reward Criteria continued

The work of the project will include completing the final designs and drawings prior to fabrication and assembly along with the completion of the safety review of the plant in accordance with the APP site safety procedures and regulations. This work will be completed as part of task one.

- Announcement to be made on the National Grid BioSNG Website that the Final Design and Safety Review has been completed.

9.3. Construction and Installation

This is a clear criterion that will require the delivery to the site of completed equipment packages and the integration of these to make a complete BioSNG plant as set out in the final design document. Tasks two and three will show evidence of the completion of the tasks whilst the start of commissioning will be further confirmation that the required equipment has been procured and brought to site.

- Announcement to be made on the National Grid BioSNG Website that the equipment has been delivered to site – progress can be shown with pictures. Construction and Installation completion will be announced on the website.

9.4. Commissioning of plant

a. Storage of syngas
b. Purity level of syngas
c. Water gas shift success = purity and levels of CO and H_2
d. Methanator operation and production of substitute natural gas

The major success delivery criterion will be seen once the plant has been commissioned and produces natural gas which will be fired in a household boiler in the exhibition area of the plant. There will be a number of different stages of the commissioning as each new piece of equipment is commissioned in sequence.

- We have timed the completion of the commissioning to be at the end of the first year of the project in March 2015. An announcement will be made on the National Grid BioSNG website with evidence shown in the Visitors' Centre.

9.5. Test & Optimisation Programme

The testing phase of the project will be completed during task 5 in the 2015/2016 year. The successful delivery of this criterion will be measured by the details as shown in the task 5 work package and reported in the milestone 5 report.

- Highlights of the results will be shown on the National Grid BioSNG website.

Successful Delivery Reward Criteria continued

9.6. Assessment of scale up risks

Once the project testing programmes have been completed the scale up risks to a commercial plant will be assessed during the report stage incorporating all of the learning that has been achieved during the project. A separate part of the final report will include scale up risks, their effect and the route to mitigation.

- The final project report will be submitted at the end of March 2017. The executive summary of the Final Report will be put onto the National Grid BioSNG website.

9.7. Engineering scheme for a full scale plant

The basic design of a full scale plant will be included in task 8 and will submitted within the final report incorporating the learning that has been achieved during the project as milestone 10 report. The basic design will include high level process flow diagrams, mass and energy balance, functional specifications and generic layout drawings.

- Consistent with 9.6 above, the final project report will be submitted at the end of March 2017. The executive summary of the Final Report will be put onto the National Grid BioSNG website.

9.8. Levelised Cost of Gas for a full scale plant in the UK

As part of the project we will be developing the levelised cost of gas for a full scale plant which would be integrated with a 170,000 tonnes per annum waste capacity Gasplasma® plant taking the syngas output and then producing BioSNG. The objective is to show that the commercial scale plant will deliver value to the gas consumer and will demonstrate the commercial viability of the technical approach of the project. Furthermore this information will be used in the dissemination of the project information leading to the development of follow on commercial scale projects utilising the knowledge learned in this project.

- This work will be completed as part of task 8 and provided within the milestone 8 report and highlights of the results will be shown on the National Grid BioSNG website.

9.9. Operating showcase – dissemination

Part of the project design will be a visitor's centre with a household boiler, a set of radiators and a showroom exhibiting the technology of the project whilst also showing the potential future opportunities for the technology. The plant will be operated on a regular basis to demonstrate the technology to gas network licensees as well as to potential owners, developers and municipal authorities considering developing projects utilising the technology. This will allow the consortium to share both the vision of the

Successful Delivery Reward Criteria continued

opportunity created by BioSNG from waste, but also how projects can be deployed on the network. This will be accompanied by a programme of workshops planned onsite to explain the features and benefits of the BioSNG process for interested stakeholders including other network licensees.

Section 10: List of Appendices

1. **Reference List**
2. **SNG Projects Under Development**
3. **RESOM Base Case and BioSNG Scenario Cost Analysis**
4. **Project Governance & Organogram**
5. **Process Description and Mass Balance**
6. **Process Flow Schematic**
7. **Project Plan**
8. **Risk Register**
9. **Partner Information**
10. **Cost and Financial Modelling Data**
11. **Capital Cost of Demonstration Plant**
12. **Executive Summary – IFI79**
13. **Default IPR**

Reference List

DECC A 2010 – Carbon Plan, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/47621/1358-the-carbon-plan.pdf

DECC B 2013 – The Future of Heating: Meeting the Challenge

https://www.gov.uk/government/publications/the-future-of-heating-meeting-the-challenge

Delta ee 2012 – 2050 Pathways for Domestic Heat,

http://www.energynetworks.org/modx/assets/files/gas/futures/Delta-ee_ENA%20Final%20Report%20OCT.pdf.pdf

NNFCC 2010 – Mortimer, N,D. Evands A,K,F.. Mwabonje, C,L. Whittaker, C, L.. Analysis of the Greenhouse Gas Emissions for Thermochemical BioSNG Production and Use ion the United Kingdom. North East Associates Limited – 5 Boarl Farm, Stocksfield, NE43 7AJ, UK

Gill et al, Biomass Task Force Report 2005 - http://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=1&ved=0CC8QFjAA&url=http%3A%2F%2Fwww.lowcvp.org.uk%2Fassets%2Freports%2FBiomass%2520Task%2520Force%2520Report%2520-%2520October%25202005.pdf&ei=Tq8DUsj4AaXA7Aa_0oHoAw&usg=AFQjCNHwQY77Pgn4zQiCJsu6VjcOW0mdmg&sig2=qJ2kcz9JkCoRU92oqylWQg

National Grid 2013A – Committing to you for 2013,

http://www.talkingnetworksngd.com/assets/downloads/2013_Committing.pdf

National Grid 2012A – Acting on Your Ideas,

http://www.nationalgrid.com/NR/rdonlyres/10D8EF08-1EC2-415F-BDC8-882E46AC6874/57873/NationalGridGasDistributionActing_on_your_ideas041212.pdf

National Grid 2012B – A Summary for Our Stakeholders,

http://www.talkingnetworksngd.com/assets/downloads/Stakeholder_Summary.pdf

Progressive Energy 2010- BioSNG Feasibility Study – Establishment of a Regional Project, http://www.northeastbiofuels.com/_assets/file/BioSNG_report.pdf

PE/APP 2013 – IFI79 – Documents can be provided upon request.

Redpoint 2012 – UK Heat Economics Study: Pathways for Decarbonising Heat, Baringa

http://www.baringa.com/our_point_of_view/item/uk-heat-economics-study-pathways-decarbonising-heat

Appendix 2

SNG Projects Under Development

Project	Thermal input (MW)	Technology supplier	Product / output	Fuel type	Operating history	Approximate capital cost (as reported)
Gussing, (Austria)	8	Repotec	CHP	Wood chip	2002 – date - 60k hours	Unknown
Gussing SNG pilot plant	Side stream from above	Repotec	BioSNG	Syngas slip stream from host facility	Unknown	Unknown
Gobigas, Phase 1 (Sweden)	32	Repotec, Haldor Topsoe	BioSNG	Wood pellets	Projected start in late 2013	£75m
Gobigas, Phase 2 (Sweden)	120	Repotec, Haldor Topsoe	BioSNG	Wood pellets	Developer estimate 2016	£150m
Choren (Germany)	50	Choren	Syngas / liquid transport fuels	Wood chip	Project abandoned	£56m
Enerkem (Edmonton, Canada)	50	Enerkem	Alcohols	RDF	In commissioning	£50m
Enerkem (Mississippi, USA)	50	Enerkem	Alcohols	RDF	In commissioning	£88m

(Note that syngas to liquid transport fuels are also included as these are generically similar from a process design standpoint)

Appendix 3

RESOM Base Case and BioSNG Scenario Cost Analysis

Table 1 compares scenarios with and without BioSNG technology. The scenario without BioSNG is the All UK Action (AUKA) scenario that was published in the Heat Economics report in September 2012. In this scenario carbon targets are satisfied without purchasing carbon credits. The scenario with BioSNG is the AUKA scenario, which includes the model for a BioSNG plant that can produce up to 100TWh of BioSNG per annum by 2050.

£bn / Year	without BioSNG - 2030	with BioSNG - 2030	without BioSNG - 2050	with BioSNG - 2050
Transport	87.6	87.6	120.7	120.4
Power and CHP	22.5	21.6	46	42.3
Heat - including efficiency, storage and heat networks	11.1	11	16.5	15
Conversion technologies	2	3.8	6.8	10.7
Electricity Network	5.2	5.2	8.7	8.3
Electricity Storage	0.1	0.1	0.3	0.3
Gas Network	3.6	3.6	3.6	3.6
Gas Storage / LNG	0.6	0.6	0.9	0.6
H2 Network	0.2	0.1	1.3	1.3
Fossil Resources	46.6	46.1	36	34.9
Non Fossil Resources	2.4	0.5	1.3	-3.7
Other	3.6	3.9	2.4	2.5
Total	**185.5**	**184.1**	**244.5**	**236.2**
Incremental cost compared to 2050 no GHG target			*38.8*	*30.6*
Incremental cost as % of 2050 GDP			*1.1%*	*0.9%*
MtCO2/year	263	263	63	63
£ per household energy costs (normalised to 2011 occup	913	909	1331	1273

Table 1.Cost comparison of the AUKA scenario with and without BioSNG technology.

The aggregated annual saving across the whole energy system with the BioSNG technology is around £1.4bn per annum in 2030, this saving grows to £8.3bn per annum by 2050.

The energy system costs are lower with the BioSNG technology as additional income is generated from the gate fee charged for collecting waste (£26 per MWh), which offsets other energy system costs. The BioSNG plant takes waste that would have otherwise 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 releases of landfill gases, the net carbon emissions are close to zero. This near zero carbon gas can be used to generate power avoiding the need to build as much CCS plant. This contributes towards a saving in the power sector of £0.1bn and £1.5bn in 2030 and 2050 respectively.

The near zero carbon BioSNG gas can also be used effectively in the heating sector to avoid some of the cost of insulation retrofitting to existing housing stock. Since the gas supply now has lower carbon intensity there is a reduced requirement for decarbonisation through the electrification of heat. This translates into £0.4bn per annum saving on electric heat pumps by 2050. In addition further savings are made through costs avoided, reinforcing the electricity distribution networks and the build of low load factor power generation just to meet the peak.

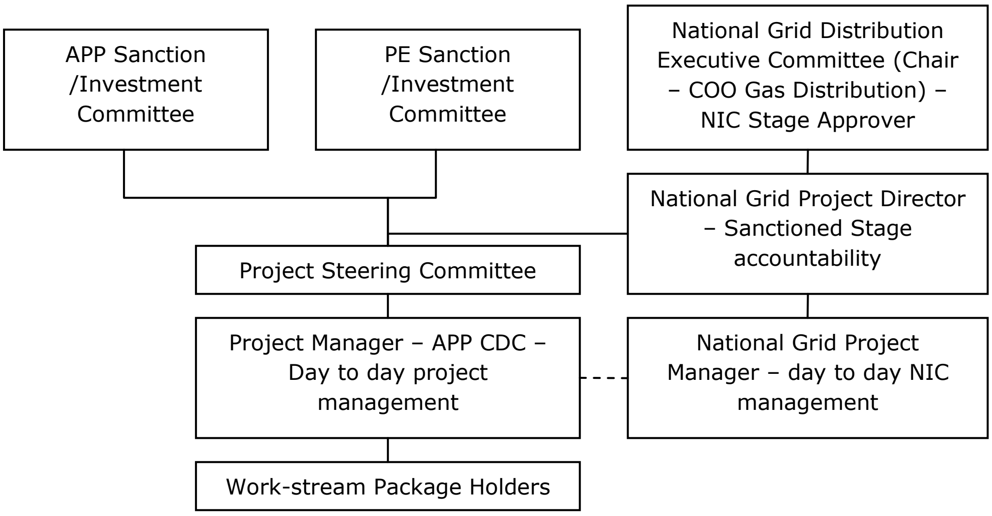
Appendix 4

Project Governance & Organogram

A summary of the proposed management structure for the project is shown below. The core partners have a detailed collaboration agreement in place since March 2012, which provides the platform for the development.

The necessary project management processes have already been established and have governed the operation of the programme to date and follow best practice guidelines as outlined by the Prince2 methodology. The governance framework is in place to ensure appropriate oversight and control over key decisions and to delegate authority for scope delivery to a Steering Committee.

The Steering Committee made up of two representatives nominated by each of the project partners. The Chair of the Steering Committee shall be the Project Director for National Grid, should the Chair not be available the Chair shall be delegated to the project Director for APP.



The role of the Steering Committee is to assure delivery of all the activities undertaken on the project to scope, time and budget, to provide overall direction to the work, and to sanction project expenditure at each project gateway. Members may participate via tele-conference, video-conference or other technological means when necessary. Should a nominated member become unable to attend the member may appoint an alternate. Any alternate attending for a period of more than two months is to be approved by the Chair.

The Steering Committee shall provide assurance on, and reports to the partners:

- Safety and environmental management – incidents, loss time injuries, any breaches of environmental controls etc.
- Progress against deliverables and plan – mitigation of issues arising, review of open issues, sanction for closing open issues.
- Review of subsequent plan for coming 6 month period and potential to accelerate activities or manage issues arising.
- Evidence of project task completion and review of achievement of research outcomes.

- Review progress against budget, risks register (proposed inclusion or removal of, change in impact / probability), communications plan.
- Evidence of project milestone progression as appropriate (progression to be tabled at each partner internal sanction bodies as outlined below).
- Vote on whether the project is to progress to subsequent stages.

For the Project programme as outlined here, the parties will ensure that the Steering Committee meets at the project review stages defined in the Project Plan or at least every 2 months or at any other time at the request of any of the Parties to the Project Manager specifying in reasonable detail the reason why the meeting is required.

Meetings of the Steering Committee will be convened with at least twenty one (21) days written notice in advance. That notice must include a standing agenda (described below) and additional agenda items on request of any project partner – such requests are to be heard. Minutes of the meetings of the Steering Committee will be prepared by the Project Manager and sent to each of the parties within 14 days after each meeting.

The Project Manager will be the Chief Technology Officer from APP, Chris Chapman, and he will produce monthly reports summarising the progress of the project in accordance to the standing agenda of the Steering Committee, progress concerning research results, and plans to disseminate information / progress beyond the project partners. A copy of the monthly report will be circulated to each member of the Steering Committee with the written notice for the relevant meeting by the Project Manager.

Each partner will have one vote in the Steering Committee. Decisions will be taken by a simple majority of a quorate meeting of the Steering Committee except where a decision necessitates a change to the project plan or a change to the allocation of any funding or change to any contribution. Quorate is defined as including at least one nominated member from each respective partner organisation. In any of those cases, any decision must be unanimous and may only be made where the representatives of all of the partners are present. In a tied vote, the chairman will have a casting vote.

The Project Manager is responsible for the day to day operations of the project, the financial management and procurement of the project, coordinating and reporting to the Steering Committee, and acting upon decisions, and submitting requests for Milestone completion and sanctions to progress to subsequent project stages (request for subsequent stage funding from each of the partner organisations).

The Project Director for National Grid is accountable for the successful allocation of Milestones and allocation of stage funding under the NIC allowance. The Project Director shall report to National Grid's Distribution Executive Committee progress of each Milestone and sanction for subsequent Milestone funding.

The Project Manager shall commence stage activities upon unanimous agreement to continue to fund the subsequent stage.

Appendix 5

Process Description

A simplified Process Flowsheet of the combined gasification and BioSNG process is given in Figure A6.1 below whilst the Process Flow Diagram (PFD) for the proposed BioSNG facility is given in Figure A6.2 below. The main stages of the BioSNG process, as indicated within the project boundary shown under Figure A6.1P, are as follows:

i) **Syngas purification and compression:** An active carbon guard bed is employed on the inlet side of the compressor. This should enable removal of the main contaminants in the syngas like ammonia, HCl, HBr, HCN and condensable hydrocarbons to <0.1ppmv. The guard bed is effective at removing a significant proportion of the reduced sulphide species i.e. H_2S. The syngas is compressed at up to 90 Bars in a multistage compressor unit. The storage vessels are sized to allow the BioSNG plant to operate on a continuous basis between Gasplasma® runs. The pressure of syngas exiting the storage vessel is reduced to the system operating pressure, (nominally 2 Bar gauge, but with a capability of operating up to 20 Bar gauge). The syngas is heated to around 350°C using an electrical heater.

ii) **Water gas shift reactors**: A high temperature (sweet) water-gas shift (HT WGS) reactor operating at around 430°C conditions the syngas, to attain a stoichiometric H2:C0 ratio of around 3:1, as required at the methanator stage. An iron based catalyst is used which is tolerant to H2S levels of up to 100 ppm. A steam generator provides saturated steam at up to 25 Bar which reacts with CO in the syngas to produce hydrogen and CO2 according to the following reaction:

$$H_2O\ (g) + CO(g) = H_2(g) + CO_2(g) \quad \text{eqn 1)}$$

The conditions within the reactor also enable the catalytic conversion of COS according to:

$$H_2O\ (g) + COS(g) = H_2S(g) + CO_2(g) \quad \text{eqn 2)}$$

The WGS reaction is mildly exothermic, the estimated temperature of the products exiting the unit is projected to be ~430°C.

iii) **Syngas Polishing:** A ZnO based guard bed enables final polishing of the syngas reducing sulphur and chloride impurities to below the 20ppb and limiting the rate of poisoning of the methanator reactors.

iv) **Methanator reactors**: A number of possible alternative reactor designs for the methanation stage have been considered. The reaction is highly exothermic with the CO reacting with H_2 to form CH_4 and water according to:

$$3H_2\ (g) + CO(g) = CH_4(g) + H_2O(g) \quad \text{eqn 3)}$$

Two factors that influence the methane equilibrium concentration are:

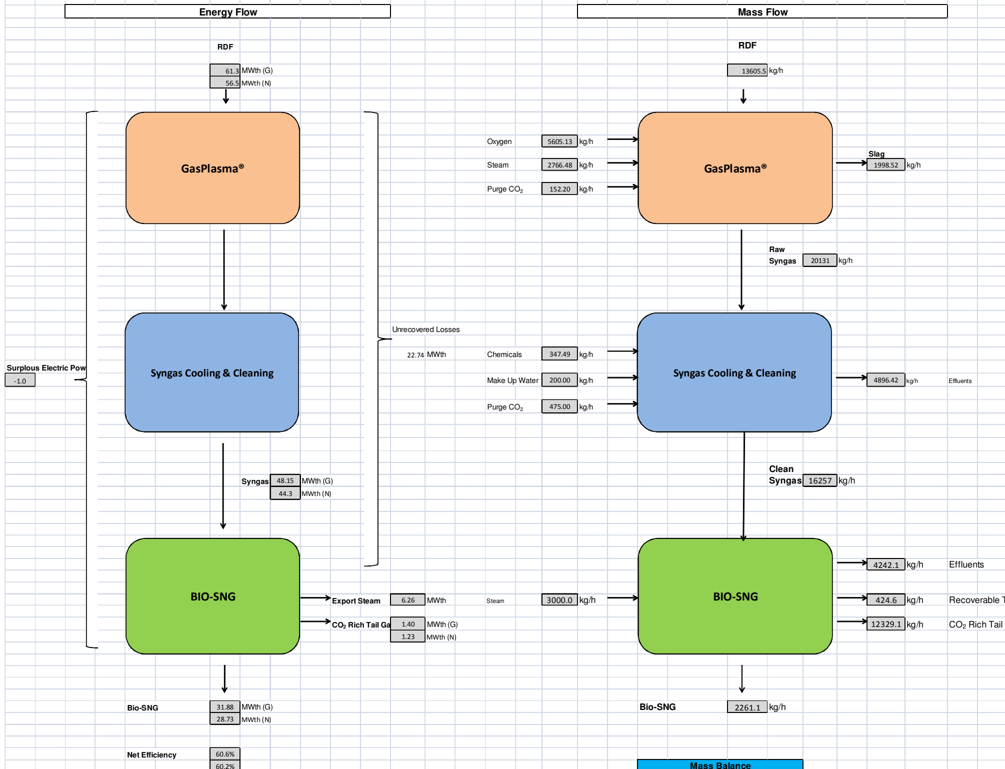
- Formation of CH_4 due to the reaction of H_2 and CO.
- Back reaction of CH_4 due to the increase in temperature (i.e. steam reforming of methane).

There are a number of different catalyst materials that can be used which may vary depending on the supplier and the specific process requirements, and this will be evaluated and selected for, at the detailed design stage. In the test work which we undertook, with a catalyst research and development laboratory, to inform the detailed reactor design, a conventional nickel oxide catalyst was employed containing ~20% Ni on an alumina substrate.

A multi-stage reactor is required in order to ensure high conversion efficiencies to methane. The reactor temperature may be controlled by a number of techniques, including: multi-stage injection of the reactant; recycling a part of the product stream to control the extent of the equilibrium reaction; the use of inter or intra stage cooling or diluting the catalyst bed to reduce the average heat flux within the bed. The preferred method for controlling the exotherm temperature is to be developed as part of the testing programme. The aim is to make the flowsheet as simple as practical whilst ensuring that there is not an excessive temperature rise within the bed.

v) **Methane separation and storage:** The methane separation is undertaken using a pressure swing absorption unit, operating at a pressure of up to 20 Bar. The methane exiting the unit is around 97% pure and is sent to a buffer storage vessel for feeding to a boiler unit for heating the building. The tail gas contains some residual methane and other combustion gases and in the demonstration plant is combusted in the thermal oxidiser (TO). In any future commercial application, a further separation would be undertaken on the tail gas to recover the major part of the remaining fuel from the first separation stage and ideally, a high purity CCS ready CO_2 stream would be produced, that could be released directly to atmosphere.

Process Mass Balance



Energy Balance		
	In	Out
RDF	61.3	
Unrecovered Losses		22.7
CO_2 Rich Tail Gas		1.4
Export Steam		6.3
Surplous Electric		-1.0
Bio-SNG		31.9
Total	61	61

Mass Balance		
	In	Out
RDF	13605.5	
Oxygen	5605.1	
Steam	5766.5	
Purge CO_2	627.2	
Chemicals	347.5	
Make Up Water	200.0	
Slag		1998.5
Effluents		9138.6
Recoverable Tail Gas		424.6
CO_2 Rich Tail Gas		12329.1
Bio-SNG		2261.1
Total	26151.8	26151.8

RDF analysis

Ultimate & Proximate analysis

RDF Composition	Mass % of Total Feed
Basis	As Recieved
	wt%
C	37.34
H	5.23
O	26.94
N	0.88
S	0.17
Cl	0.81
F	0.0025
H2O	12.00
Ash	16.62
Fixed Carbon	7.58
Volatile Matter	63.80
Moisture	12.00
Ash	16.62
NCV, MJ/kg	14.950
GCV (Dry basis), MJ/kg	18.430
GCV, MJ/kg	16.218

Product Gas Compositions

	Clean syngas	BIO-SNG Product
[Vol %]		
CH_4	0.64%	95.50%
CO	36.13%	0.00%
CO_2	17.01%	1.46%
H_2O	8.40%	0.57%
H_2	37.27%	0.00%
N_2	0.48%	2.46%
O_2	0%	0%
[PPM]		
SO_2	0.08	0
H_2S	9.10	0
COS	38.22	0
HCl	0.95	0
HCN	169.06	0
NH_3	1.40	0
NO	512.91	0

Appendix 6 – Process Flow Schematic (PFD)

Figure A6.1Simplified Gasification-BioSNG flowsheet

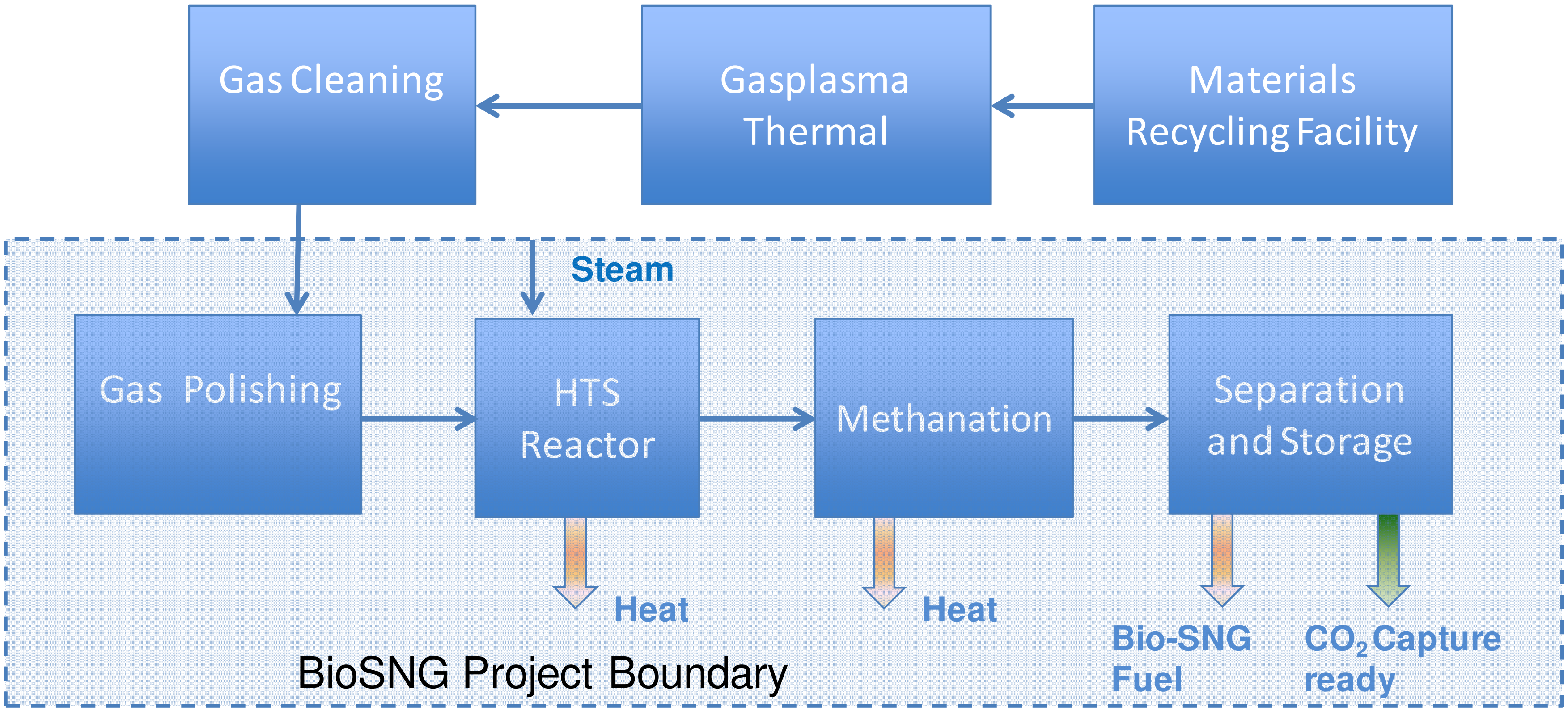
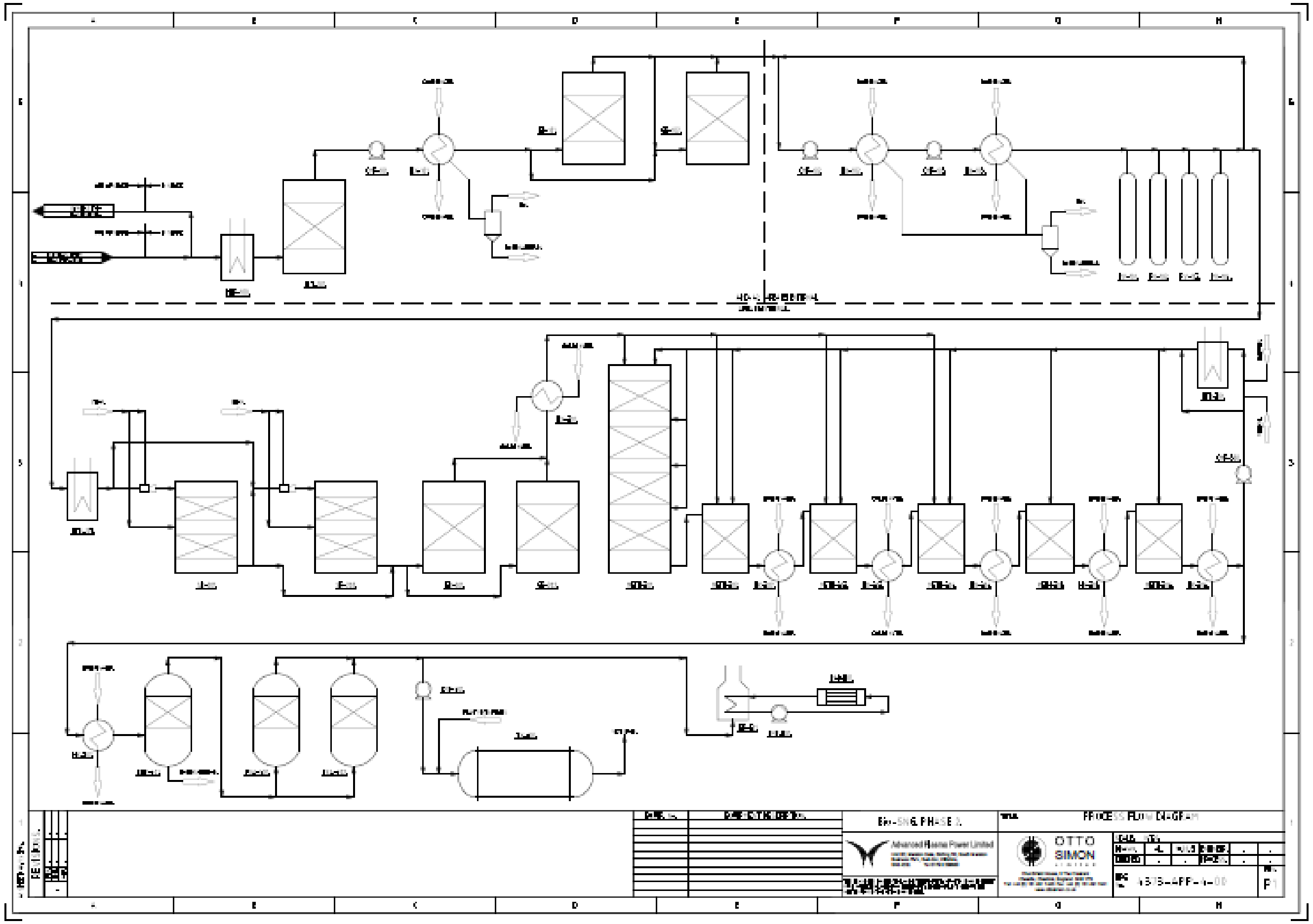
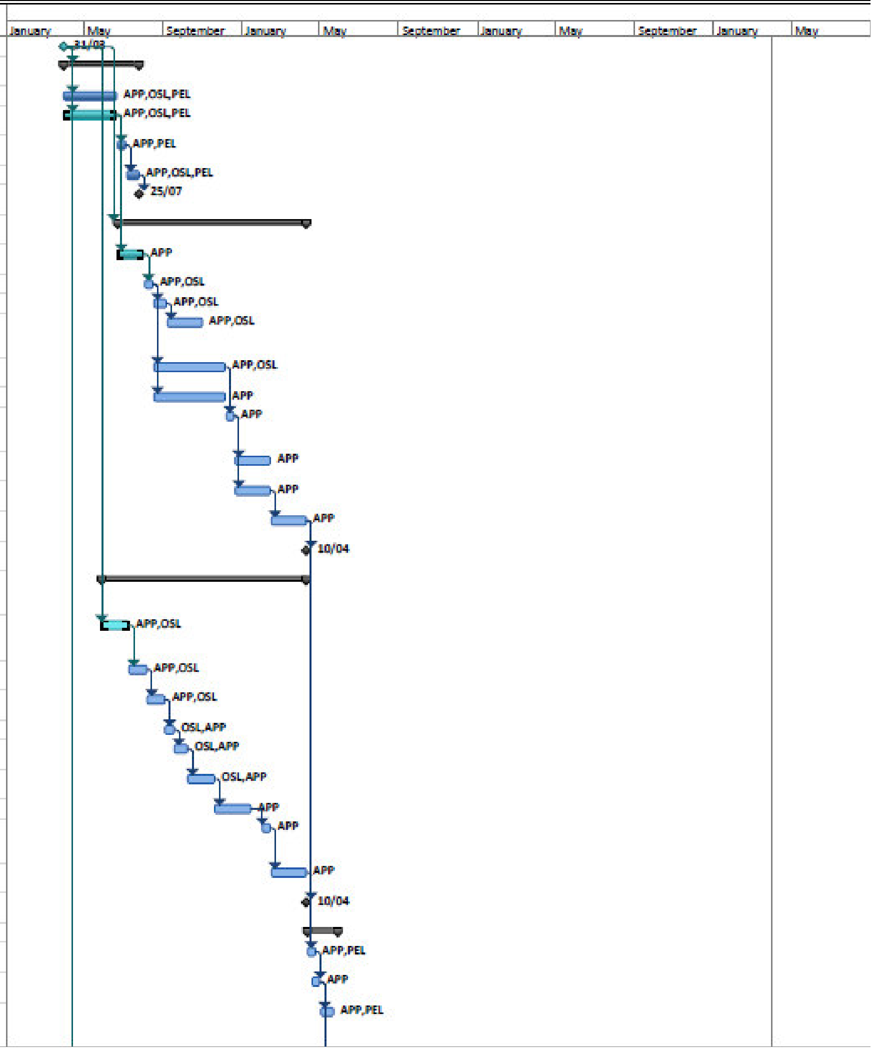


Figure A6.2. Process Flow Diagram for the demonstration BioSNG plant

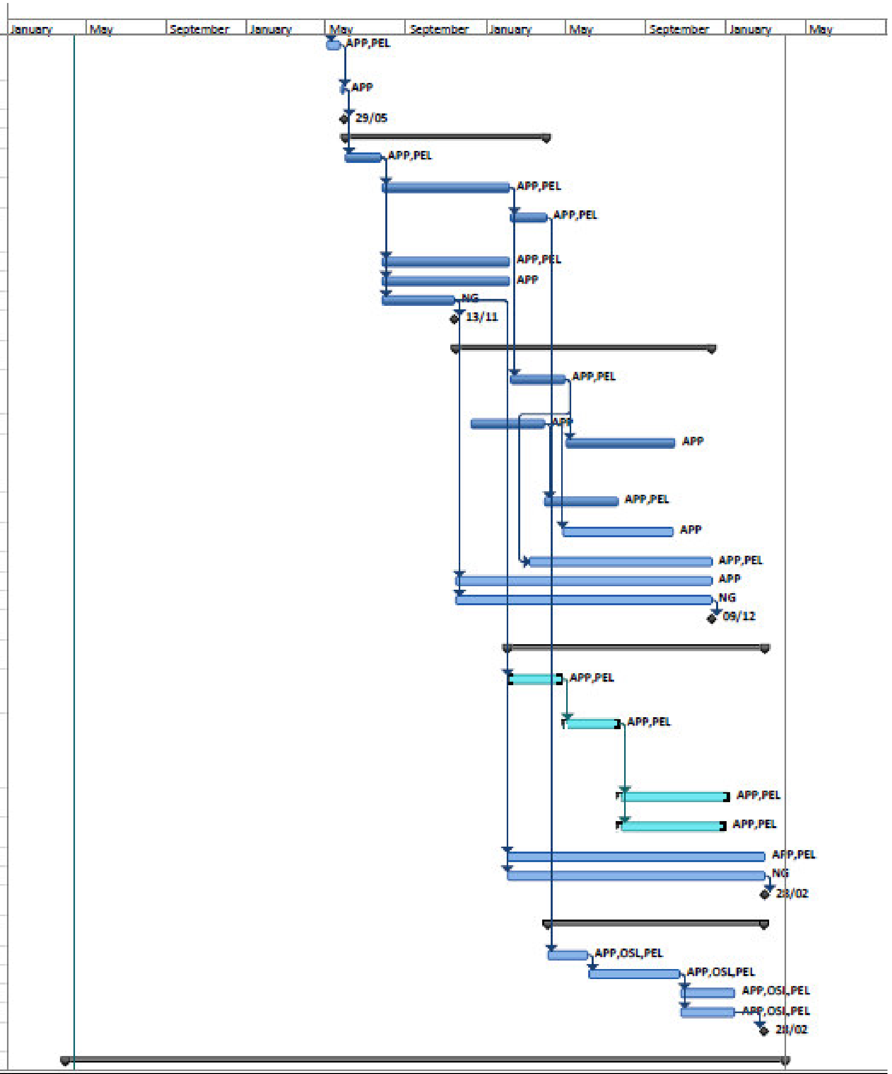


Appendix 7 – Project Plan

ID	Task Numbe	Task Name	Duration	Resource Names	Predec	Start	Finish
1		**Start of project**	0 days			Mon 31/03/14	Mon 31/03/14
2		**Task 1: Final Design and Safety Review Assessment**	85 days		1	Mon 31/03/14	Fri 25/07/14
3	T1.1	Complete detailed Bio-SNG design	12 wks	APP,OSL,PEL	1	Mon 31/03/14	Fri 20/06/14
4	T1.2	Review and update existing P and I D's and PFDs	12 wks	APP,OSL,PEL	1	Mon 31/03/14	Fri 20/06/14
5	T1.3	Confirm equipment sizing and finalise layouts	10 days	APP,PEL	4	Mon 23/06/14	Fri 04/07/14
6	T1.4	Final Safety Review including Hazop	15 days	APP,OSL,PEL	5	Mon 07/07/14	Fri 25/07/14
7	MS1	**Completion of Design and safety review task**	0 days		6	Fri 25/07/14	Fri 25/07/14
8		**Task 2: Equipment procurement, fabrication and installation of SNG generation plant**	210 days		1	Mon 23/06/14	Fri 10/04/15
9	T2.1	Issue functional design and enquiry documents for equipment vendors	6 wks	APP	4	Mon 23/06/14	Fri 01/08/14
10	T2.2	Select equipment suppliers	10 days	APP,OSL	9	Mon 04/08/14	Fri 15/08/14
11	T2.3	Procure long lead equipment items	15 days	APP,OSL	10	Mon 18/08/14	Fri 05/09/14
12	T2.4	Procurement of remaining equipment inc. piping , control and instrumentation	2 mons	APP,OSL	11	Mon 08/09/14	Fri 31/10/14
13	T2.5	Manufacture of equipment skids off-site, including reactor vessels	4 mons	APP,OSL	10	Mon 18/08/14	Fri 05/12/14
14	T2.6	Civil works on-site	4 mons	APP	10	Mon 18/08/14	Fri 05/12/14
15	T2.7	Inspection and mechanical and electrical acceptance testing of the equipment skids off-site	10 days	APP	13	Mon 08/12/14	Fri 19/12/14
16	T2.8	Installation on-site of equipment skids	2 mons	APP	15	Mon 22/12/14	Fri 13/02/15
17	T2.9	Interconnecting of piping and fittings installation	2 mons	APP	15	Mon 22/12/14	Fri 13/02/15
18	T2.10	Electrical and instrumentation installation	2 mons	APP	17	Mon 16/02/15	Fri 10/04/15
19	MS2	**Complete installation of the SNG generation plant**	0 days		18	Fri 10/04/15	Fri 10/04/15
20		**Task 3: Equipment design, procurement, fabrication and installation of SNG refining plant**	227 days			Thu 29/05/14	Fri 10/04/15
21	T3.1	Evaluate options, and subsequently define baseline (design point) process concept for SNG refining plant	6 wks	APP,OSL	1FS+43 days	Thu 29/05/14	Wed 09/07/14
22	T3.2	Complete detailed process design including PFDs, P and I Ds, MEBs etc.	4 wks	APP,OSL	21	Thu 10/07/14	Wed 06/08/14
23	T3.3	Prepare reactor detailed design inc materials specifications (Mechanical)	4 wks	APP,OSL	22	Thu 07/08/14	Wed 03/09/14
24	T3.4	Confirm equipment sizing and layouts	10 days	OSL,APP	23	Thu 04/09/14	Wed 17/09/14
25	T3.5	Functional design specification of equipment	15 days	OSL,APP	24	Thu 18/09/14	Wed 08/10/14
26	T3.6	Procurement of materials and equipment	6 wks	OSL,APP	25	Thu 09/10/14	Wed 19/11/14
27	T3.7	Fabrication of the equipment skids	2 mons	APP	26	Thu 20/11/14	Wed 14/01/15
28	T3.8	Inspection and mechanical and electrical acceptance testing of the equipment skid	10 days	APP	27	Mon 02/02/15	Fri 13/02/15
29	T3.9	Installation and assembly and integration of the skid within site	2 mons	APP	28	Mon 16/02/15	Fri 10/04/15
30	MS3	**Complete installation of the SNG generation plant**	0 days		29	Fri 10/04/15	Fri 10/04/15
31		**Task 4: Commissioning of the Bio SNG plant**	35 days			Mon 13/04/15	Fri 29/05/15
32	T4.1	Functional cold testing and reporting of all SNG plant items	10 days	APP,PEL	18	Mon 13/04/15	Fri 24/04/15
33	T4.2	Calibration and testing of monitoring sensors and controls	10 days	APP	32FS-5 days	Mon 20/04/15	Fri 01/05/15
34	T4.3	Progressive testing of each unit operation for SNG generation bringing each on line in sequence	15 days	APP,PEL	33	Mon 04/05/15	Fri 22/05/15

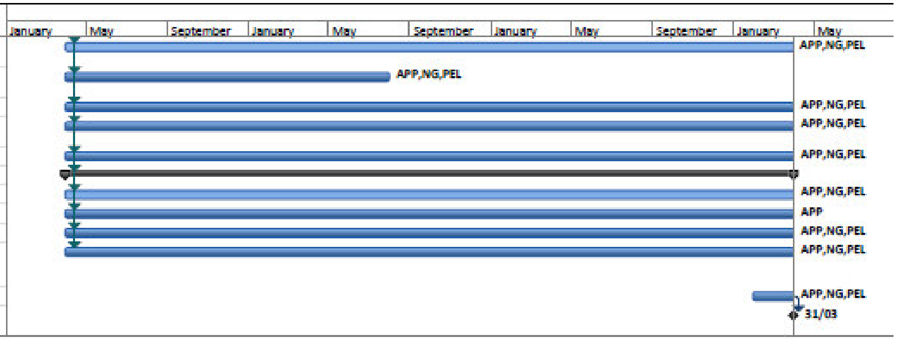


ID	Task Number	Task Name	Duration	Resource Names	Predecessors	Start	Finish
35	T4.4	Progressive testing of the SNG refining system to integrate with the SNG generation plant	15 days	APP,PEL	33	Mon 04/05/15	Fri 22/05/15
36	T4.5	Performance test, operator training and hand over to operating staff	5 days	APP	35	Mon 25/05/15	Fri 29/05/15
37	MS4	Complete Commissioning of the plant	0 days		36	Fri 29/05/15	Fri 29/05/15
38		**Task 5: Testing and Proving of the equipment**	**220 days**			**Mon 01/06/15**	**Fri 01/04/16**
39	T5.1	Compliance testing of plant to design point condition	2 mons	APP,PEL	36	Mon 01/06/15	Fri 24/07/15
40	T5.2	Detailed testing of the methanation reactor and preparation of a report	7 mons	APP,PEL	39	Mon 27/07/15	Fri 05/02/16
41	T5.3	Attainment of the design and operating parameters for use in a commercial plant	2 mons	APP,PEL	40	Mon 08/02/16	Fri 01/04/16
42	T5.4	Data collation and report writing	7 mons	APP,PEL	39	Mon 27/07/15	Fri 05/02/16
43	T5.5	Ecological study and report writing	7 mons	APP	39	Mon 27/07/15	Fri 05/02/16
44	T5.6	Guidance on grid injection issues	4 mons	NG	39	Mon 27/07/15	Fri 13/11/15
45	MS5	Complete Testing and Proving of equipment	0 days		44	Fri 13/11/15	Fri 13/11/15
46		**Task 6: Detailed investigations on SNG generation plant**	**280 days**			**Mon 16/11/15**	**Fri 09/12/16**
47	T6.1	Mapping of the process envelop to provide basis for value engineering to reduce SNG production cost	3 mons	APP,PEL	40	Mon 08/02/16	Fri 29/04/16
48	T6.2	Evaluate performance of catalyst types	4 mons	APP		Wed 09/12/15	Tue 29/03/16
49	T6.3	Effect of plant configuration and change of operating variables (i.e. Temperature and pressure) on product syngas quality and yield	6 mons	APP	47	Mon 02/05/16	Fri 14/10/16
50	T6.4	Investigations into the control of the Wobbe index	4 mons	APP,PEL	48	Wed 30/03/16	Tue 19/07/16
51	T6.5	Refinement of the automated process control concept	6 mons	APP	48FS+20 days	Wed 27/04/16	Tue 11/10/16
52	T6.6	Data Collation and report writing	10 mons	APP,PEL	47FS-40	Mon 07/03/16	Fri 09/12/16
53	T6.7	Ecological impact study	14 mons	APP	44	Mon 16/11/15	Fri 09/12/16
54	T6.8	New Guidance on grid injection issues	14 mons	NG	44	Mon 16/11/15	Fri 09/12/16
55	MS6	Complete Detailed investigations on SNG generation plant	0 days		54	Fri 09/12/16	Fri 09/12/16
56		**Task 7: Detailed investigations on SNG refining plant**	280 days			Wed 03/02/16	Tue 28/02/17
57	T7.1	Mapping of the process envelop to provide basis for value engineering to reduce production cost of SNG refining	3 mons	APP,PEL	44	Wed 03/02/16	Tue 26/04/16
58	T7.2	Further investigations as to the technical effectiveness of the syngas cleaning inc. effect of adsorbent type, pressure and temperature on gas cleaning performance	3 mons	APP,PEL	57	Tue 26/04/16	Fri 22/07/16
59	T7.4	Investigations into the control of N2/CO2 content in the product stream	6 mons	APP,PEL	58	Mon 18/07/16	Fri 06/01/17
60	T7.6	Refinement of the automated process control concept for gas refining stage	5.8 mons	APP,PEL	58	Mon 18/07/16	Fri 30/12/16
61	T7.7	Data collation and report writing	14 mons	APP,PEL	44	Wed 03/02/16	Tue 28/02/17
62	T7.8	Guidance on grid injection issues	14 mons	NG	44	Wed 03/02/16	Tue 28/02/17
63	MS7	Complete Detailed investigations on SNG generation plant	0 days		62	Tue 28/02/17	Tue 28/02/17
64		**Task 8: Commercial Plant Scheme Development**	**236 days**			**Mon 04/04/16**	**Tue 28/02/17**
65	T8.1	Basis of design	45 days	APP,OSL,PEL	41	Mon 04/04/16	Fri 03/06/16
66	T8.2	Basic Process development	5 mons	APP,OSL,PEL	65	Mon 06/06/16	Fri 21/10/16
67	T8.3	Basic process layouts	3 mons	APP,OSL,PEL	66	Mon 24/10/16	Fri 13/01/17
68	T8.4	Preliminary financial modelling	3 mons	APP,OSL,PEL	66	Mon 24/10/16	Fri 13/01/17
69	MS8	Complete Report on commercial plant development	0 days		68	Tue 28/02/17	Tue 28/02/17
70		**Task 9: Dissemination**	**785 days**			**Mon 31/03/14**	**Fri 31/03/17**



Gas Network Innovation Competition Full Submission Pro-forma

ID	Task Number	Task Name	Duration	Resource Names	Predecessors	Start	Finish
71	T9.1	Set-up and updating of the website portal	785 days	APP,NG,PEL	1	Mon 31/03/14	Fri 31/03/17
72	T9.2	Design and development of the showcase facility	350 days	APP,NG,PEL	1	Mon 31/03/14	Fri 31/07/15
73	T9.3	Progress and close-out reports	785 days	APP,NG,PEL	1	Mon 31/03/14	Fri 31/03/17
74	T9.4	Presentations, technical papers and journal articles	785 days	APP,NG,PEL	1	Mon 31/03/14	Fri 31/03/17
75	T9.5	Network development	785 days	APP,NG,PEL	1	Mon 31/03/14	Fri 31/03/17
76		**Task 10: Project Management**	**785 days**		1	Mon 31/03/14	Fri 31/03/17
77	T10.1	Technical project management	785 days	APP,NG,PEL	1	Mon 31/03/14	Fri 31/03/17
78	T10.2	Financial control of budget	785 days	APP	1	Mon 31/03/14	Fri 31/03/17
79	T10.3	Steering group management	785 days	APP,NG,PEL	1	Mon 31/03/14	Fri 31/03/17
80	T10.4	Other activities including sourcing feed material , getting site permissions etc.	785 days	APP,NG,PEL	1	Mon 31/03/14	Fri 31/03/17
81	T10.5	Final Report for the project	45 days	APP,NG,PEL		Mon 30/01/17	Fri 31/03/17
82	MS9	Complete project with sign-off of final report	0 days		81	Fri 31/03/17	Fri 31/03/17



Appendix 8

Risk Register

	OWNER	PROBABILITY Pre-Mitigation	MITIGATED PROBABILI	IMPACT
1. ***FAILURE OF GASPLASMA UNIT OR PRODUCTION OF OFF-SPECIFICATION SYNGAS LEADING TO SHUTDOWN*** of the BioSNG plant. **MITIGATION:** The Gasplasma® demonstration plant is already proven and reliable as a source of syngas. Furthermore the BioSNG demonstration plant will incorporate a large buffer-tank storage for the syngas, ensuring thereby a continuous syngas supply. Continuous monitoring of syngas composition will be undertaken to ensure that throughput and quality of the gas introduced to the process are maintained within design limits.	APP	H	L	H
2. ***FAILURE OF METHANATOR PLANT SYNGAS CLEANING AND PROCESSING SYSTEM TO PRODUCE SYNGAS OF SUFFICIENT QUALITY*** for use in the catalytic reactors. This would have high impact, since the catalysts would quickly become poisoned and cease to function. However, likelihood of complete failure is rated low since the partners have already established at the design stage that a combination of known gas-cleaning processes can produce purity levels required for optimal functioning of the methanator. **MITIGATION:** APP's Gasplasma® facility already produces a syngas of sufficient quality for use in its onsite gas engine which has been extensively tested. The process for producing ultra clean syngas at ppb level for S and Cl in a cost effective way is well established and has been carefully considered in the design including monitoring of the gas quality. Each unit operation will be brought on line and stabilised sequentially and continuous inlet gas quality monitoring will initiate bi-pass of catalytic reactors if off-spec gas conditions occur. Additional protection can be incorporated into the catalyst beds by means of a portion of inert or sacrificial bed material.	APP	M	L	H
3. ***FAILURE OF CATALYTIC REACTORS DUE TO OVER-TEMPERATURE*** caused by the high temperature of the exotherm in the methanator which could potentially cause significant damage to the catalyst which would require replacement. **MITIGATION:** The system incorporates automated control loops which, if the reactor temperature falls outside the permitted design limits, lead to automated quenching of the reaction to ensure safe shut-down. The design of the reactor has also been informed by experimental pilot work conducted using similar catalysts and gas mixtures to those that will be employed in the proposed demonstration test-work. The reactor design allows the evaluation of a variety of adiabatic and	APP	M	L	M

isothermal configurations to achieve exotherm control. This design is informed by a kinetic model of the methanator, developed by APP, which has been incorporated into their Aspen plus process simulation model for the complete flow-sheet.				
4. ***BioSNG DOES NOT MEET THE GSMR STANDARD***. The compliance levels of certain species, such as hydrogen are low and may be expensive to attain in practice. The GSMR specification that governs the quality of the gas injected into the grid is reflective of gas produced from the North Sea rather than that required for efficient use in gas burners. **MITIGATION** is multi-tiered. Firstly, the test programme includes application and evaluation of a variety of techniques identified at the design phase to modify and control the product gas Wobbe Index. Secondly, National Grid will provide guidance as to what limits may be allowable in practice to give the best techno-economic solution that would be acceptable to the regulator.	NG	H	M	M/H
5. ***HEALTH, SAFETY AND ENVIRONMENTAL RISKS ASSOCIATED WITH HANDLING OF EXPLOSIVE AND (FOR CO) POISONOUS GASES.*** **MITIGATION:** A rigorous health, safety and environmental management system (HSEMS) has already been established in the design phase to ensure that best practices are maintained throughout the procurement, installation, commissioning and operating stages. The partners have extensive experience and exemplary safety records in the handling of explosive/ poisonous gases. Specific measures that form part of the HSEMS include: HAZAN/HAZOP study to systematically identify and mitigate hazards, a risk register, DSEAR assessment. The demonstration plant design has taken into account hazardous area classifications, and ventilation requirements. Continuous monitoring and fail-safe systems will be installed to ensure the system is maintained within design limits or shut down safely in the event of a process excursion.	ALL	M	L	H
6. ***FAILURE TO ACHIEVE TIMELY DECISION-MAKING.*** **MITIGATION:** The small number of parties involved (i.e. 2 technical partners, 1 commercial partner, 1 subcontractor) have agreed clearly defined management roles and communications procedures; an approach which has worked very effectively under IPI79. Under the terms of the agreement, there is a commitment to resort to tested dispute resolution procedures, where necessary, to ensure that such problems do not adversely affect project outcomes.	All	L	NA	M
7. ***INADEQUATE PROCESS AND ENVIRONMENTAL PERFORMANCE MONITORING*** on the project and no assessment of the process against competing technologies. It is essential that the technical, environmental and economic performance of the plant is determined and shown to have significant benefits in comparison with alternative	APP/PEL	L		M

process options. **MITIGATION:** Comprehensive instrumentation, monitoring and data acquisition systems will be installed to generate data that will allow thorough analysis of the process including gas quality, energy efficiency and environmental performance.				
8. ***INABILITY TO COMMERCIALLY EXPLOIT THE RESULTS OBTAINED FROM THE PROJECT*. MITIGATION:** The routes to market are covered in the business plan. A strong advisory panel drawn from waste management, gas processing and financial sectors will advise on end-user requirements and expectations, and will provide guidance during the execution of the project, with scope for the forming of alliances at a successful conclusion to the project.	ALL	L		H
9. ***FAILURE TO ADHERE TO WORK-PLAN TIMETABLE.*** **MITIGATION:** The project tasks and deliverables are all planned and agreed by persons with sufficient experience to determine realistic timetables. All partners have experience of participation in collaborative projects and understand the need for cooperation. However, to ensure that the timetables are firmly adhered to, under the terms of the Consortium Agreement, the partners have contractually committed to implement their tasks in accordance with the Consortium Plan. Regular monthly monitoring meetings will be undertaken to review the progress in the project against the scheduled plan and to take mitigating action if there is any deviation from the project critical path.	ALL	L		M

Appendix 9

Partner Information

Chris Chapman CEng , MSc, BSc, MIM3 (Chief Technical Officer APP)

Chris Chapman has been Chief Technical Officer (CTO) and a board member of APP since its establishment in 2005. He has 25 years' experience working on commercial environmental plasma projects in the UK, the Far East, US and Europe.

Chris oversees the company's technical development activities and provides expert advice and guidance to the commercial and engineering teams. He was responsible for the Gasplasma® energy from waste concept and in the subsequent proving and development of the process at APP's Swindon Plant. Before joining APP he worked for Tetronics International from 1987, and in 2002 was appointed as Technical Director of that company.

He has an impressive track record in technical innovation, being named inventor on 20 patents including being co- inventor of the Gasplasma® process and responsible for its subsequent technical development and proving of the integrated facility. One of the key areas of focus of his current role is to develop alternative uses for the syngas from the process and he has been project manager of the BioSNG project under IPI 79.

Chris works closely with the University sector to enhance fundamental understanding of the process and is currently industrial supervisor for an Eng.D and 2 PhD students from UCL. He encourages public dissemination of results and is a regular presenter at conferences. Is author of over 45 journal and peer reviewed conference papers.

Richard Taylor CEng, PhD, MBA, BEng (Technical Director APP)

Richard Taylor joined Advanced Plasma Power in July 2009 as Lead Process Engineer, becoming Technical Director in 2011 and now heads up the management of all aspects of technical innovation and implementation of full-scale Gasplasma® plants.

Richard is an Engineering professional with over 15 years experience in Chemical Engineering roles. He has worked on new product development, and the project management and implementation of new technologies for use in the minerals processing and environmental engineering fields.

Before joining APP Richard worked in the industrial minerals businesses of Australian China Clays, as General Manager Operations, and Imerys Minerals, as Process Development Manager. He was responsible for the introduction of new technologies and the optimisation of production assets.

Richard is a Chartered Engineer and a Fellow of the Institute of Chemical Engineers, with a 1st Class Honours Degree in Chemical Engineering and a Doctorate in Biochemical Engineering from the University of Birmingham. He has also gained a Masters in Business Administration from the Open University.

Phillip Cozens BSc. Head of Technology Development – Progressive Energy Ltd.

Phillip Cozens has nearly forty years experience in the energy industries – oil and gas production and processing, energy from waste and renewables as well as waste recovery and processing technologies. His extensive experience includes conceptual and detail design, project management, business development, development and implementation of novel technologies, project development, construction, economic modelling and feasibility analysis, and prospect evaluation. His most pertinent experience regarding this project is in the development and commercial implementation of novel process technologies within existing businesses.

With Progressive Energy Ltd. he has been engaged in technology development within a major carbon capture and storage project on Teesside, development of novel technology for carbon capture from steelmaking (Patent Granted 2013) and also in the development of biomass and energy from waste projects utilising advanced conversion technologies in electricity generation, second generation liquid transport fuels and in BioSNG. He has undertaken technology reviews and trouble shooting both for internal project developments and for third party investors. Phillip has extensive experience in collaboration with academia, for example in the successful award of the Supergen project to the consortium lead by Manchester University.

Phillip projects an active and detailed interest in energy technology developments generally and brings to the project a wealth of technical insight, enthusiasm and a problem-solving approach to help bring the project to a successful conclusion.

Chris Manson-Whitton, DPhil (Oxon) MEng, MA (Cantab)

Director - Progressive Energy Ltd

Chris was formerly Head of Biomass at Progressive Energy, in which role he created a new business stream with a pipeline of projects using both conventional and new technologies to provide renewable heat, electricity and advanced biofuels. This includes a diverse range of biomass energy projects that includes industrial biomass heat and power developments, feasibility studies into thermochemical BioSNG, second generation transport fuel and hydrogen production, advanced concepts for energy from waste, pioneering work on the adoption of ^{14}C measurements of renewable energy production, and a range of technical due-diligence assessments for industrial investors.

Chris has also been responsible for spearheading the company's activities in the creation and leadership of a blue chip consortium comprising a power utility, a leading offshore oil and gas operator and an international gas process provider, in response to major national and EU carbon capture and storage opportunities.

Chris brings to the BioSNG team an incisive intellectual contribution, not only to the technical development of the project but also a rigorous and thorough analytical approach to the development and optimisation of the techno-commercial profile of the BioSNG project.

Chris is author of a number of technical papers and presentations within the renewable energy industry and the recipient of a number of awards and scholarships.

Steven Vallender

Network Innovation & Investment - National Grid

Chartered Engineer with extensive experience of gas distribution activities in the UK. Led the national grid team to further develop the sustainable gas case in the UK and US, contributing to the definition of the Renewable Heat Incentive in the UK. Detailed knowledge of UK regulatory frameworks including the new RIIO-GD1 control having led the investment case for National Grid Gas Distribution under the last price control review. Extensive knowledge of asset and risk management including the PAS55 methodology. Currently responsible for setting the asset, innovation and investment strategy for the gas distribution network.

Andrew Newton

Innovation Manager (Network Innovation & Investment) – National Grid

Technical Engineer with a wealth of experience of all aspects of gas distribution in the UK. Experience working within the East Midlands leading the Connections and Planning team with responsibility amongst other things for signing off gas connection quotations. National Work Planning Manager for the mains replacement programme. Project Management role with the Gas Distribution Front Office project. Currently responsible for leading the definition and delivery of innovation in National Grid Gas Distribution. Responsible for innovation portfolio management, ideas generation, demonstration and implementation.

Advanced Plasma Power

APP was established in November 2005 to develop and commercialise Gasplasma® technology which had been invented by Tetronics, a well established supplier in the application of Plasma technology to metals and waste treatment and recovery, with 50 years experience in this sector.

The company vision is to become a leading player in the waste to renewable energy market by delivering innovative solutions for responsible resource management. Gasplasma® is a two stage thermal process producing power from a gas engine with a diverse range of feedstocks from biomass to a prepared waste derived feedstock. The technology has a sound underpinning, based on global patents granted and other international patent applications underway. Since 2008 a 1/100th scale Gasplasma® plant has been operating in Swindon on a wide range of feedstocks. It can now claim over 2500 operating hours.

Under IFI79, working in close collaboration with National Grid and PEL, APP managed the concept and FEED design phases of the BioSNG project. Under the proposed NIC programme, APP will assist with the procurement of equipment and on-site erection, whilst providing a lead role in commissioning and operating the plant.

APP has an extremely strong team with expertise in all key areas for project development - the process co-inventor is the Chief Technical Officer, and other key roles are filled by personnel with strong track records in Waste, Waste to Energy, Process Technology and Safety, Project Development and Financing. APP has been able to develop close links with Central Government and policy makers, with a view to ensuring such advanced technologies are understood in the appropriate organisations. The Swindon Site has hosted visits from a range of Government Agencies and political figures including the Secretary of State for Energy and Climate Change and Lord Howe. The technology has also passed technical due diligence scrutiny by global names in project construction such as Fluor, Technip, Black and Veatch, M&W and Shaw and Jacobs (Aker Solutions).

Progressive Energy

Progressive Energy is an established independent UK clean energy project development company.

Progressive Energy comprises a team of highly experienced power project developers providing the skill set necessary to undertake all aspects of the development cycle; project screening and selection, project definition and optimisation, project development including all aspects of contracting (including feedstock, EPC, and power purchase contracts), consenting and project financial evaluation and financing. The team has wide technology experience covering all large scale generation options, coal, gas, nuclear and renewables, including wind, biomass and CHP. Progressive Energy (PEL) has particular skills in projects utilising emergent technologies, with the breadth of experience vital for assessing the commercial balance of risk and reward that such approaches offer.

The Chairman of PEL is Dr Brian Count, previously CEO of Innogy, now RWE, the Managing Director is Peter Whitton, who headed up Business development at Magnox, and the team includes senior managers and experienced staff from most UK generators and several major project companies. PEL was formed in 1998 to commercialise key energy conversion technologies developed in the CEGB including coal gasification, waste to energy, and biomass conversion. PEL also has experience in wind farm development and is a leader in full chain carbon capture and storage (CCS) methodologies. These commercialisation efforts have brought a unique and experienced team of professionals together under the PEL organisation.

The following is a brief overview of PEL's Biomass and waste related experience.

Progressive has been active in the renewables and waste sector for over 10 years. The team is experienced in conventional combustion and advanced conversion technologies (gasification, syngas utilisation, pyrolysis and anaerobic digestion). It has also built a capability in the production of alternative energy vectors, such as hydrogen and liquid biofuels (including second generation) as well as projects which utilise renewable heat. Members of the team have also been instrumental in developing best practice in waste resource utilisation through both the establishment of the UK's first commercial MBT facility, and development of energy from waste projects. Progressive has undertaken various projects and studies with clients and partners including, National Grid, Advanced Plasma Power, Hills Waste Management, Infinis, ESB (Novus Modus), North East Biofuels, NEPIC, United Utilities, National Grid, Centrica, Climate Change Capital. Relevant Bioenergy projects are outlined below, and summarised in Table 1, which shows the feedstocks, products and technologies involved in each project.

Progressive Energy is a founding industrial partner in the current Supergen Bioenergy Hub, part of the Research Council UK SUPERGEN programme. This brings together industry, academia and other stakeholders to focus on the research and knowledge challenges associated with increasing the contribution of UK bioenergy (including waste) to meet strategic environmental targets in a coherent, sustainable and cost-effective manner.

Progressive Energy is primarily a Project Development company, developing projects either on its own behalf or in conjunction with others. Therefore it has particular experience of the challenges which face developers, with regard to government policies, technologies and feedstock supply chains. In particular experience of applying UK incentive structures to projects provides particular insights into the issues associated with the practicalities of how these apply to projects and their financing.

A key aspect of Progressive Energy's portfolio is Carbon Capture and Storage. Here the primary focus has been on predominantly fossil fuel based systems for the anchor projects such as the TLC Project and EU focused efforts on CCS. However, as outlined by the CCC Bioenergy Review, CCS is expected to play a crucial role in Bioenergy. Within its existing portfolio of Projects, its BioSNG project is carbon capture-ready, providing transport and storage quality carbon dioxide for abatement.

National Grid

National Grid is international electricity and gas company and one of the largest investor-owned energy companies in the world. We play a vital role in providing energy to millions of customers across Great Britain and the Northeast US in an efficient, reliable and safe manner.

We are committed to safeguarding the environment for future generations and providing all our customers with the highest standards of service. We achieve this through ongoing investment in our systems and through our talented, diverse workforce.

Our Gas Distribution UK segment comprises four of the eight regional gas distribution networks in Great Britain.

Our networks comprise approximately 132,000 kilometres of gas distribution pipelines and we transport gas on behalf of approximately 25 active gas shippers from the gas national transmission system to around 10.8 million consumers.

Appendix 10

Cost and Financial Modelling Data

Advanced Plasma Power Ltd		BioSNG Gas Price & Financial Performance						
Development Status		**First of a Kind**		**Nth of a Kind**				**Wood Pellets**
Fuel		**MSW**	**RDF**	**RDF**	**RDF**	**RDF**	**RDF**	**RDF**
Scale		Single	Single	Single	Double	Single	Double	Double
Subsidies		With	With	With	With	Without	Without	With
Post-tax project returns		16.0%	15.8%	19.0%	22.5%	8.1%	11.4%	16.6%
Required gas price - £/MWh		22	22	22	22	39	39	22
MSW Processed (tonnes per annum)		168,840						
RDF Processed (tonnes per annum)		101,304	101,304	101,304	202,608	101,304	202,608	168,840
Rejects		10%	-	-	-	-		-
Fly Ash		3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%
Biogenic content in fuel		65%	65%	65%	65%	65%	65.0%	100%
RDF energy		15	15	15	15	15	15	18
ROC parasitic load	MW	0.1	0.1	0.1	0.2	0.1	0.2	0.2
Operating hours		7,446	7,446	7,446	7,446	7,446	7,446	7,446
ROCs		1.9	1.9	1.9	1.9	-	-	1.9
RDF Power	MWth	56.7	56.7	56.7	113.4	56.7	113.4	113.4
BioSNG for export	MWth	31.9	31.9	31.9	63.8	31.9	63.8	63.8
Power generated	MWe	6.2	6.2	6.2	12.4	6.2	12.4	12.4
Overall parasitic load	MWe	7.5	6.0	6.0	12.0	6.0	12.0	12.0
ROC'able power output		6.1	6.1	6.1	12.2	6.1	12.2	12.2
		£m	**£m**	**£m**	**£m**	**£m**	**£m**	**£m**
Revenue								
Gate fee		13.5	6.1	6.1	12.2	6.1	12.2	- 14.2
Gas revenue		5.2	5.2	5.2	10.4	9.3	18.5	10.4
RHI		11.0	11.0	11.0	21.9	-	-	33.7
Power		2.7	2.7	2.7	5.5	2.7	5.5	5.5
ROCs		2.5	2.5	2.5	5.1	-	-	7.8
		34.9	27.5	27.5	55.0	18.1	36.1	43.2
Costs								
Staff costs		1.6	1.2	1.2	1.5	1.5	1.5	1.5
Parasitic load		4.2	3.4	3.4	6.7	3.4	6.7	6.7
Disposal		2.0	0.4	0.4	0.9	0.4	0.9	-
Other operating costs		2.5	2.1	2.1	4.2	2.1	4.2	4.2
Annual and lifecycle maintenance		3.0	2.5	2.1	3.6	2.1	3.6	3.5
Rent, rates and insurance		1.3	1.1	1.1	1.8	1.1	1.8	1.8
		14.6	10.7	10.3	18.6	10.6	18.6	17.8
EBITDA		20.4	16.9	17.3	36.4	7.5	17.5	25.5
Depreciation		(5.7)	(4.7)	(4.0)	(6.9)	(4.0)	(6.9)	(6.8)
Tax		(2.9)	(2.4)	(2.7)	(5.9)	(0.7)	(2.1)	(3.7)
		11.8	9.7	10.6	23.6	2.8	8.5	14.9
Capex								
Front end		10.0	1.1	1.0	2.0	1.0	2.0	2.2
Core Gasplasma® equipment		24.5	24.5	22.1	44.1	22.1	44.1	49.0
O2, N2, TO		6.0	6.0	5.4	8.2	5.4	8.2	9.1
Power generation		7.0	7.0	6.3	12.6	6.3	12.6	14.0
Syngas to BioSNG		15.6	15.6	14.0	21.3	14.0	21.3	23.6
Building and civils		15.0	8.9	8.0	12.1	8.0	12.1	13.5
Mechanical installation		4.6	4.6	4.1	8.3	4.1	8.3	9.2
EPC, Risk and Contingency		20.7	16.9	9.3	18.6	9.3	18.6	30.2
Grid connection		1.0	1.0	0.9	1.8	0.9	1.8	2.0
Development and funders fees		9.2	9.2	8.3	8.3	8.3	8.3	9.2
		113.6	94.8	79.4	137.3	79.4	137.3	135.7

Appendix 11

APP/PE/National Grid Bio-SNG
Swindon Pilot Plant
Equipment List and Cost Estimate

Status: **Phase 2**

Equipment Number	Item	Detail	APP	Comment
BIO-CMP-101 BIO-HX-101 inc	Syngas Compressor Stage 1 Compressor 1st Stage Intercooler	80 kg/h syngas from atmospheric to 4.5 barg. Full package system with intercoolers, ko pots, all instruments and controls. Condensate will be corrosive. Outside location (subject to noise) Zone 2	£247,000	Burton Corblin budget quote 2 x units 1st stage 3m x 1.9m x 2m €270,000 plus 2nd and 3rd stages 2.9m x 1.8m x 2m €300,000. Estimate based on detailed package quote from Gas Compressors Ltd. 1st stage 2.5mL x 2mW x 2 mH plus Subs stages 6mL x 2.4mW x 2mH
	Compressor Package Acoustic Enclosure		£9,000	Quote from Gas Compressors Ltd.
BIO-GB-101	Carbon Guard Bed	Fixed bed: 80 kg/h syngas, 50 C at 30 barg. 250mm diameter, 2475mm high. S.S. Design conditions 10 barg /100°C.	£10,000	Bed dimensions to be confirmed during detail design by discussion with activated carbon vendor. Budget Quotation from Gilwoods based on Vessel Sketch
BIO-GB-102	Carbon Guard Bed	Fixed bed: 80 kg/h syngas, 50 C at 30 barg. 250mm diameter, 2475mm high. S.S. Design conditions 10 barg /100°C.	£10,000	Bed dimensions to be confirmed during detail design by discussion with activated carbon vendor. Budget Quotation from Gilwoods based on Vessel Sketch
BIO-CMP-102/103 BIO-HX 102/103	Syngas Compressor Stages 2 & 3 Compressor 2nd Stage Intercooler Compressor After-cooler	80.2 kg/h syngas from 4.5 barg to 90 barg. Full package system with intercoolers, ko pots, all instruments and controls. Condensate will be corrosive. Outside location (subject to noise) Zone 2		Based on detailed package quote from Gas Compressors Ltd. 1st stage 6mL x 2.4mW x 2mH
BIO-PV-101	Syngas Storage	4000 kg of syngas in 46m3 volume arranged into 4 off 11.5 m3 vessels to allow segregation for filling, testing & discharging. Operating pressure 90 barg, 30 C. Design conditions 100 barg /150°C.	£200,000	MCS Technologies Quote for 20m^3 @ 200 Bar = £168,000. For 46m^3 @ 100 Bar = 2 x £168K less 15% for volume pressure balance = £300,000. Unit size = 2 x 12000 L x 1600 W x 2850 H
BIO-SR-201	HT Shift Reactor	Fixed bed: 11.5 kg/h syngas, 350 C inlet temperature, 430 C outlet temperature, operating pressure 2 to 20 barg. 150 mm dia, 2265 mm high. S.S. Design Conditions 25 barg /625°C. To accomodate 2 off catalyst bed canisters of variable size.	£10,000	Budget Quotation from Gilwoods based on Vessel Sketch
BIO-SR-202	HT Shift Reactor	Fixed bed: 11.5 kg/h syngas, 350 C inlet temperature, 430 C outlet temperature, operating pressure 2 to 20 barg. 150 mm dia, 2265 mm high. S.S. Design Conditions 25 barg /625°C. To accomodate 2 off catalyst bed canisters of variable size.	£10,000	Budget Quotation from Gilwoods based on Vessel Sketch
BIO-GB-201	Guard Bed	Fixed bed: 11.5 kg/h syngas, 550 C at 20 barg. 150mm diameter, 2240 mm high. S.S. Design conditions 25 barg/625°C.	£10,000	Bed dimensions to be confirmed during detail design by discussion with adsorbent vendor. Budget Quotation from Gilwoods based on Vessel sketch
BIO-GB-202	Guard Bed	Fixed bed: 11.5 kg/h syngas, 550 C at 20 barg. 150mm diameter, 2240 mm high. S.S. Design conditions 25 barg/625°C.	£10,000	Bed dimensions to be confirmed during detail design by discussion with adsorbent vendor. Budget Quotation from Gilwoods based on Vessel sketch
BIO-HTR-301	Start-up/Activation Heater	Electrical heater. Operating pressure 20 barg; max temp 350°C. Max electrical input - 10 kW	£20,400	
BIO-HX-301	Methanator Feed Cooler	Heat duty 1 kW, 550°C to 300°C at 20 barg. Coil in pipe. 3m 1/2" coil cooling surface suspended in a 150 mm dia x 500 mm high pot containing cooling water. Design conditions: coil 25 barg/650°C, pot atmospheric/100°C. MOC: coil S.S., pot C.S.	£5,000	Factored estimate from Gilwoods prices
BIO-MTH-301	Methanator Stage 1	Fixed bed: 11.5 kg/h syngas plus recycle, 300°C inlet temperature, up to 600°C outlet temperature, operating pressure 2 to 20 barg. 150 mm dia, 2140 mm high. MOC S.S. To accomodate 4 off catalyst bed canisters of variable size. Design Conditions 25 barg/650°C.	£12,000	Factored estimate from Gilwoods prices
BIO-MTH-302	Methanator Stage 2	Fixed bed: 11.5 kg/h syngas plus recycle, 300°C inlet temperature, up to 600°C outlet temperature, operating pressure 2 to 20 barg. 300 mm dia, 1750 mm high. MOC S.S. To accomodate 1 off catalyst bed canister of variable size. Design Conditions 25 barg/650°C.	£10,000	Factored estimate from Gilwoods prices
BIO-HX-302	Methanator Cooler	Heat duty 1 to 4.5 kW, 600°C to 300°C at 2 to 20 barg. Coil in pipe. 5m 1" pipe cooling surface suspended in a 300 mm dia x 800 mm high pot containing cooling water. Design conditions: coil 25 barg/650°C, pot atmospheric/100°C. MOC: coil S.S., pot C.S.	£12,000	Factored estimate from Gilwoods prices

Equipment Number	Item	Detail	APP	Comment
BIO-MTH-303	Methanator Stage 3	Fixed bed: 11.5 kg/h syngas plus recycle, 300°C inlet temperature, up to 600°C outlet temperature, operating pressure 2 to 20 barg. 300 mm dia, 1000 mm high. MOC S.S. To accomodate 1 off catalyst bed canister of variable size. Design Conditions 25 barg/650°C.	£10,000	Factored estimate from Gilwoods prices
BIO-HX-303	Methanator Cooler	Heat duty 1 to 4.5 kW, 600°C to 300°C at 2 to 20 barg. Coil in pipe. 5m 1" pipe cooling surface suspended in a 300 mm dia x 800 mm high pot containing cooling water. Design conditions: coil 25 barg/650°C, pot atmospheric/100°C. MOC: coil S.S., pot C.S.	£12,000	Factored estimate from Gilwoods prices
BIO-MTH-304	Methanator Stage 4	Fixed bed: 11.5 kg/h syngas plus recycle, 300°C inlet temperature, up to 600°C outlet temperature, operating pressure 2 to 20 barg. 300 mm dia, 1000 mm high. MOC S.S. To accomodate 1 off catalyst bed canister of variable size. Design Conditions 25 barg/650°C.	£10,000	Factored estimate from Gilwoods prices
BIO-HX-304	Methanator Cooler	Heat duty 1 to 4.5 kW, 600°C to 300°C at 2 to 20 barg. Coil in pipe. 5m 1" pipe cooling surface suspended in a 300 mm dia x 800 mm high pot containing cooling water. Design conditions: coil 25 barg/650°C, pot atmospheric/100°C. MOC: coil S.S., pot C.S.	£12,000	Factored estimate from Gilwoods prices
BIO-MTH-305	Methanator Stage 5	Fixed bed: 11.5 kg/h syngas plus recycle, 300°C inlet temperature, up to 600°C outlet temperature, operating pressure 2 to 20 barg. 300 mm dia, 1000 mm high. MOC S.S. To accomodate 1 off catalyst bed canister of variable size. Design Conditions 25 barg/650°C.	£10,000	Factored estimate from Gilwoods prices
BIO-HX-305	Methanator Cooler	Heat duty 1 to 4.5 kW, 600°C to 300°C at 2 to 20 barg. Coil in pipe. 5m 1" pipe cooling surface suspended in a 300 mm dia x 800 mm high pot containing cooling water. Design conditions: coil 25 barg/650°C, pot atmospheric/100°C. MOC: coil S.S., pot C.S.	£12,000	Factored estimate from Gilwoods prices
BIO-MTH-306	Methanator Stage 6	Fixed bed: 11.5 kg/h syngas plus recycle, 300°C inlet temperature, up to 600°C outlet temperature, operating pressure 2 to 20 barg. 300 mm dia, 1000 mm high. MOC S.S. To accomodate 1 off catalyst bed canister of variable size. Design Conditions 25 barg/650°C.	£10,000	Factored estimate from Gilwoods prices
BIO-HX-306	Methanator Cooler	Heat duty 1 to 4.5 kW, 600°C to 300°C at 2 to 20 barg. Coil in pipe. 5m 1" pipe cooling surface suspended in a 300 mm dia x 800 mm high pot containing cooling water. Design conditions: coil 25 barg/650°C, pot atmospheric/100°C. MOC: coil S.S., pot C.S.	£12,000	Factored estimate from Gilwoods prices
BIO-CMP-300	Recirculation Compressor	10 kg/h syngas minimum, 80 kg/h maximum. Suction conditions 2 to 20 barg, 300°C, differential pressure up to 5 bar. Zone 2	£5,000	In House Estimate. No quote received. May need oversized unit with recirculation, including recirc cooler. Duty requires review to select the correct flow range to cover operation at 2 barg, 20 barg and start-up duties.
BIO-HX-307A/B	Methanator Product Cooler	Heat duty 2.3 kW, 300°C to 30°C at 2 to 20 barg. Coil in pipe. 10m 1/2" pipe cooling surface suspended in a 300 mm dia x 800 mm high pot containing cooling water. Design conditions: coil 25 barg/650°C, pot atmospheric/100°C. MOC: coil S.S., pot C.S. **2 off** required operating in series.	£5,000	Factored estimate from Gilwoods prices
BIO-TNK-301	Cooling Water Head Tank	1	£1,000	In House Estimate
BIO-KOP-401	KO Pot	300 mm dia x 850 mm h, stainless steel vessel with demister. Operating 20 barg, 30°C. Design conditions 25 barg /100°C.	£2,000	Budget quotation from Gilwoods based on Vessel sketch.
BIO-TNK-401	Condensate Drain Pot	Small 200 l CS vessel to separate dissolved syngas from condensate. Operating pressure, atmospheric. Design conditions 0.4 barg /100°C.	£500	In House Estimate
BIO-FTR-400	Gas filter	Cartridge type filter. Approx 4m3/h tail gas from PSA unit. Pressure 2barg max.	£500	In House Estimate
BIO-PSA-401/2	Methane Purification PSA Unit	PSA package to meet methane purity requirements set by national Grid. Nominal 10 kg /h crude methane feed at 2 to 20 barg, 50°C Full package system. Includes vacuum pump for off-gas desorption	£185,000	
BIO-CMP-401	PSA Vacuum Pump	2 off units required, one for each stage of the PSA. Vacuum required 0.3 bara	£4,000	Not included in Xebec quote. Bush quote: 2 @ £1978 Dimensions 480mm x 250mm x 300mm high
BIO-BR-501	Bio-SNG Boiler	Valliant Ecotec plus, open vent, model 418. 18.9 kW, 2 m3/h maximum gas rate at 20 mabrg	£1,500	On-line quote for supply <£1000 plus gas fitter
BIO-PMP-501	Boiler Pump	Centrifugal pump 1m3/h treated water; head 10m	£200	Nominal sum
BIO-RAD-501	Radiator	Air blast radiator with circulation pump and water tank. Duty 20 kW. Water flow 0.86 m3/h, water ΔT 20°C.	£1,000	In House Estimate, Fin Fan Radiator, Domestic type Water Pump & Head Tank
BIO-TOX-601	Thermal Oxidiser	Thermal oxidiser package to oxidise 1. off gas from the PSA unit - 8.6 kg/h; continuous. 2. abnormal venting -maximum 10 kg/h of off spec raw syngas plus 1 kg/hr product bio-SNG; periodic. 3. abnormal venting, start-up/shutdown purges, maximum 20 kg/h Total duty for design = 20 kg/h raw syngas equivalent. 2 seconds residence time at 850°C required.	£52,043	Based on CDEG quote €59850. Dimensions: 500mm D x 10m high.
BIO-TNK-601	Demin Water Tank	Rectangular stainless steel tank - 125 litres; 500mm x 500mm x 500mm. Design conditions ambient/atmospheric	£200	In House Estimate No change from phase 1
BIO-PMP-601	Demin Water Pump	Positive displacement metering pump - variable speed/stroke. 1.8 l/h normal, 0.5 l/h minimum, 3 l/h maximum. Delivery pressure 25-30 barg. S.S. Zone 2.	£4,500	AxFlow Quote Dimensions 560mm x 270mm x 820mm high No change from phase 1
BIO-HTR-601	Steam Generator	Electric heater: 2.1 kg/h demin water evaporation producing saturated steam at 25 barg. Heat duty 1.6 kW. Operating conditions, 25 barg/226°C. Design conditions 33 barg/260°C. S.S. Dimensions 150 / 80mm nb x 1200 mm high	£12,000	In House Estimate

Equipment Number	Item	Detail	APP	Comment
BIO-ABC-601	Air Blast Cooler	Package complete with tank and circulation pump. Thermal duty 30 kW, water inlet 40°C, outlet 30°C, design air temperature 25°C. Water circulation rate 2.6 m3/h.	£9,500	Thermal Exchange Quote Dimensions: 1060mm x 1350mm x 2247mm high No change from phase 1, duty dependant upon package quotations, particularlry compressor
BIO-TNK-603	Cooling Water Collecting Tank	Horizontal cylindrical vessel - S.S. Capacity 1m3, 1300mm long, 1000 mm diameter. Operating conditions: atmospheric pressure/30 - 60°C. Design conditions atmospheric/100°C.	£2,500	In House Estimate No change from phase 1
BIO-PMP-603	Cooling Water Return Pump	Centrifugal pump - 2.6 m3/h, 20m head.	£1,000	In House Estimate No change from phase 1
BIO-CMP-601	Instrument Air Compressor Package	Package complete with compressor, drier, filter and receiver. 40 Nm3/h air at 8 barg. Dew point -40°C. Class 1 oil filtration.	£8,900	Avelair quote Dimensions 1150mm x 600mm x 1200mm high plus dryer 500mm x 195mm x 917mm No change from phase 1, duty dependant upon package quotations and final instrument count
BIO-CMP-602	Ventilation Fan	Extraction fan for the standard shipping container which houses the reaction vessels. Cast steel. Duty 1200 m3/h, differential pressure 10 mbar.	£10,000	On line quote from Vent-Axia
	Instruments and control valves	Supply and delivery of field instruments and control valves See separate listing on Appendix A	£110,361	Should not significantly effect cost but ATEX zoning to be resolved with repect to temperature class / surface temperatures.
	Actuation of automatic shut off valves (on/off)	Supply and fitting of pnematic actuation and solenoids to mechanical valves that require automatic operation. See separate listing on Appendix A	£2,329	103 valves Identified on P & I. Cost of actual mechanical valves covered under mechanical valves
	Analysis	Continuous on line analysis on outlet of Shift Reactor Control	£23,000	ABB quote for optima range 2 off at £53 k each with 15 metres of heated sample line together with 5 k for test gas bottles,racks etc
	Analysis	Gas analysers, full syngas analysis with multiple analysis points complete with sample conditioners etc Plus on line analysis for Shift Reactor Control (2 off)	£200,000	ABB budget quote for Multipoint(17) GC system plus sample conditioning,heated lines, calibration gas system, housing etc
	PLC/MCC	Control panel with MCC, PLC and HMI for fully automatic control including programming, license and remote access system.	£135,529	Quote from igranics with allowance for some extras quote Includes for MCC,PLC and software. control of PSA and compressor is within this scope
	ESD System	Emergency shutdown system based on critical measurements and automatic isolation valves.	£0	Guard PLC system Included in above cost
	Gas detection system	Automatic shutdown system required for unmanned plant.	£5,000	21 detectors plus control panel and sounders/beacons. Plus cabling
	Instrumentation and electrical controls cabling installation	Full system cabling and supports including impulse lines and pneumatic piping. See separate listing in Appendix A	£71,820	Quotes received for standard costs and then applied to quantaties in the system
	Electrical Tracing	Trace heating suitable for high temperature.	£12,000	Shift and methanation reactors electrically traced (high temperature). Extent to be confirmed during detail design. Cost is for tracing only based on 462 metres of pipe plus vessels . Insulation cost included in Pipework costs
	Pipework, manual valves, on/off valve bodies, fittings, supports, insulation supply and Installation	See Separate listing in Appendix B	£250,000	Materials, pipe supports, labour, consumables, crane hire. Microtherm high temp, high efficiency lagging and insulated supports.
	Painting	Painting & Service Identification	£1,000	Stainless Steel - Unpainted Carbon Steel - 200 um DFT Pipe Banding Identification
	Structural steel		£8,000	No steel structure or access platforms envisaged. Pipe supports included in Pipework. Plant potentially housed in iso containers. 20 ft iso container with end doors £2150 (used), full side doors £2950 (used). Allow 2-off + Mods
	Civils/plinths			Existing concrete slab within building and outside yard area. Piping trench required across yard, with suitable engineered covers. Possible plinth upstands required for individual items of equipment. Compressor dynamic loads to be considered onto foundation. All other equipment will be relatively low, static loadings only.
	Fire Fighting system	Assumed existing		Will need high integrity automatic system for 24 hr unmanned operation.
	Inerting system	Assumed existing		
	Equipment Delivery	1% of Equipment Costs	£13,054	
		Subtotal equipment costs	**£1,801,836**	Including E&I and Mechanical installation
	APP engineering design, procurement, construction supervision.			
	APP management, overheads and labour costs			
	Progressive Energy costs			
	National Grid Costs			
	Commissioning costs			
	Otto Simon Ltd (OSL) Phase 3 Detail Design	Detail Design of Swindon Pilot Plant. Main process work by APP, OSL to provide review and assistance. Detailed design of reactors by OSL		Provisional sum. Actual work split still to be reviewed and agreed.
	OSL expenses for Phase 3	4 off progress meetings at Swindon, plus 3 days Hazop		
		Subtotal engineering, management and operating costs	**£0**	
		total	**£1,801,836**	

Appendix 12

IFI79 Executive Summary

The objective of this BioSNG project is to demonstrate the technical feasibility of the thermochemical conversion of biomass or waste-derived fuels to provide significant quantities of renewable gas for injection into the national gas grid, and to show that this can be accomplished sustainably and with a worthwhile reduction in carbon intensity compared with natural gas. BioSNG provides a valuable pathway to low carbon heat delivery without the demand side constraints associated with other renewable heat technologies.

This project is being developed by a consortium comprising National Grid, Advanced Plasma Power and Progressive Energy.

The completion of this Stage 2 report is a key milestone in the development of the BioSNG project in the justification to continue into Stage 3 - the practical delivery and operation of the BioSNG demonstration plant. The report covers the evolution of the project from the conceptual design status achieved in Stage 1.

This report represents the achievement of a level of design definition sufficient to specify the anticipated performance characteristics of the planned BioSNG demonstration plant (Stage 3 of the project) and to enable the procurement of materials and equipment for its construction and operation. Furthermore, the Stage 2 design documentation provides the means to estimate the technical and commercial performance of a full scale BioSNG facility, and thereby an objective basis by which to assess and justify further investment into Stage 3.

The Stage 2 process design has been developed from the Stage 1 conceptual design and defines the process flow scheme, mass and energy balance and layout for the BioSNG demonstration plant at the APP Swindon facility, where the existing Gasplasma® plant will be used to supply the waste-derived syngas as a feedstock for the SNG process. The existing facility will be used intermittently to fill a high-pressure syngas store that will have capacity to run the BioSNG demonstration plant for a sustained period.

The quality of the raw syngas from the Gasplasma® facility is well understood from its operational history and it will be further cleaned prior to compression and high-pressure storage. Thereafter the Stage 2 design specifies modification of the hydrogen / carbon monoxide ratio of the syngas by means of a conventional catalytic water-gas shift reaction prior to methanation. A number of methanator design configurations have been evaluated during Stage 2, the principal challenges being the paucity of literature for the low pressure / high molar concentration conditions required in this application, coupled with the large heat release that is a feature of the catalytic methanation reaction. To reduce the uncertainty in reactor design, test runs on representative syngas samples have been undertaken by Catal, a catalysis specialist, to provide empirical data to inform the design of the methanation reactor. In addition to this precaution, the Stage 2 design incorporates provisions to evaluate various reactor configurations and a variety of catalyst bed geometries during the testing period.

In the transformation of syngas to SNG approximately half the carbon in the feedstock will be converted to carbon dioxide which in turn must be separated from the product stream emerging from the methanation reactor. The Stage 2 work has identified pressure swing absorption as the preferred technique for this. In order to minimise the parasitic power demand the process is designed for operation at a moderate pressure, with SNG compression to gas network injection pressure undertaken only on the actual SNG product at the end of the process.

A preliminary assessment has been undertaken during Stage 2 into the reductions in GHG emissions that the waste to BioSNG concept would enable. According to the assessment methodology employed, the carbon intensity of BioSNG use at a gas boiler would amount to a figure in the range of -68 to 83 kg CO_2 per $MW_{th}h$, showing thereby a substantial GHG reduction compared with natural gas use (243 to 251 kg CO_2 per $MW_{th}h$, on the same basis).

The Stage 2 scope of work included the modelling of the financial performance of a possible full scale BioSNG facility fired by approximately 100,000 tonnes per annum of refuse-derived fuel. With a set of realistic market assumptions, including government backed revenue supports for renewables, the project could yield a simple (project) rate of return approaching 13% and a project of double the capacity, a return of greater than 16%. On this basis there would be an incentive to develop BioSNG projects of this type, although it is clear that in a first-of-a-kind realisation, in the near term government support for renewables is an important component of project commercial viability.

The market assessment used in the financial analysis included an appraisal of the availability of waste-derived fuels in the UK waste market. To this end it was established from reputable waste industry sources that there will exist for some time to come a large surplus of waste (in the order of 14 m tonnes per annum) in the market which needs to be diverted from landfill disposal beyond the capacity of existing waste management infrastructure.

The Stage 2 work scope has included investigation into the regulatory requirements that must be satisfied in the operation of the planned BioSNG demonstration facility. Having sought expert professional opinion the project steering group is satisfied that there would be no legal or regulatory impediments to the development and operation of the planned facilities.

The budget for Stage 3 covers the procurement of hardware and equipment, fabrication and installation, consumables, staffing and other operational costs for a period of up to 33 months. The total budget provision of £3.85m is comprised of the following:

- Equipment and materials £2.00m
- Fabrication / erection £0.30m
- Consumables £0.25m
- Manpower and Syngas £1.00m
- Contingency £0.30m

The programme for implementation of the BioSNG facility envisages installation and commissioning completed 12 months after project start. Section 10 of the report includes an outline of the test programme to be accomplished during the demonstration. This is targeted firstly at the realisation of the predicted Stage 2 design performance in the demonstration plant, forming thereby a robust basis of design for a commercially viable first-of-a-kind BioSNG facility. Beyond this initial 6 to 9 month testing phase an expanded scope of tests is envisaged that will explore the operational envelope of the technology and pursue a number of process optimisations to enhance the cost effectiveness of the process.

In summary the Stage 2 report indicates both the potential commercial and technical viability of the BioSNG concept and lays out a basis to form a view on investment in the succeeding Stage 3 work – the practical demonstration of BioSNG production from waste-derived syngas.

NOTE: The overall Pilot Plant and Stage 3 budget has been updated since the Final Report of IFI79 and as part of the preparation for this submission.

Appendix 13

Intellectual Property Rights (IPR)

- IPR is material information and knowledge gained from the learning in respect of the project. It may come in the forms of information, understanding or skills necessary to reproduce the outcome of the project, or with the deployment of the IPR leading to the reduction of costs or difficulty of reproducing the outcome of the project.
- Project Partners' shall retain all rights in and to its Background IPR as well as all improvements to its Background IPR.
- Foreground IPR will be all results and Intellectual Property therein produced from work done during the Project.
- Each Project Participant shall own all Foreground IPR that it independently creates as part of the Project, or where it is created jointly then it shall be owned in shares that are in proportion to the effort made and work done in its creation.
- A Funding Licensee can only transfer any of its right, title or interest in or to any Foreground IPR to any other person, subject to:
    - Having regard to the true commercial value of the IPR; and
    - The assignee/transferee agreeing to abide by these default IPR conditions.
- **Licensing of Background IPR**
- Where access to a Project Participant's Background IPR is required to undertake the Project, the Project Participant shall grant a non-exclusive licence to this Background IPR (Relevant Background IPR) to the other Project Participants, solely for the purposes of the Project during the term of the Project.
- Once the Project is over, Relevant Background IPR will be licensed for use by the Project Participants in connection with another Project Participant's Foreground IPR solely to the extent necessary to use that Foreground IPR, upon terms to be agreed.
- **Licensing of Foreground IPR**
- Foreground IPR which is produced by the Project could comprise of IPR which describes the application of a Method to a network and the benefits that can accrue. It could also include the IPR that describe how a product (for example a piece of equipment and or software), that is used to implement a Method achieves its functionality. Foreground IPR can be informal, (eg know how) or formal, (eg registered).
- Relevant Foreground IPR is Foreground IPR that other Licensees will need to utilise in order to implement the Method(s) being Developed or Demonstrated in the Project. This must be identified in the PPR in sufficient detail to enable others to identify whether they need to use that IPR. For clarification it is not expected that the

confidential details of IPR would be disclosed in the Project Progress Report, only sufficient information to enable others to identify whether the IPR is of use to them.

- Where Background IPR is required to use the Relevant Foreground IPR, this must also be clearly stated.
- Foreground IPR within Commercial Products is not deemed Relevant Foreground IPR. However these Commercial Products must be made available to other Network Licensees to purchase in line with the approach the Network Licensees outlines in its Full Submission.
- Licensing of the Foreground IPR shall be agreed between the Network Licensee and Project Partners consistent with the principles of this chapter.
- All other Network Licensees will have the automatic right to use Relevant Foreground IPR for use within their network royalty-free.
- Where the Relevant Foreground IPR can only be used with a Project Participant's Background IPR, other Licensees will have the automatic right to request a limited licence of such Background IPR for that sole purpose in line with the approach the Network Licensees outlines in its Full Submission.
- The licensees of IPR may be required by the licensor to enter into a confidentiality agreement to protect the IPR licensed to it.
- Other parties (who are not Project Participants and are not a Network Licensee) may request a licence to use Relevant Foreground IPR, such licence to be on arms-length terms, which may include payment of a commercial license and royalty.
- **Right to protect IPR**
- Each Project Participant will warrant that it has the right, power, title and authority to license its Relevant Background IPR on the terms of the licence agreement.
- Each Project Participant will warrant that use of the Relevant Background IPR in accordance with the terms of its licence agreement will not infringe any third party rights.
- Each Project Participant will warrant that it will pay all fees necessary to maintain registered rights that form part of the licensed Relevant Background IPR.
- Each Project Participant will undertake to protect Relevant Foreground IPR (subject to the transfer options above) in the following terms:
- A Project Participant must seek registered protection where that is available and maintain such registered protection for as long as the subject matter of that Relevant Foreground IPR is licensed and used by the other Project Participants;
- Where a Project Participant believes that registered protection should not be filed, they must agree terms with the other Project Participants setting out how this

unregistered IPR will be protected and demonstrate how this is consistent with the knowledge transfer and Dissemination of information requirements of the Project;

- A Project Participant must comply with agreed publication requirements, including as necessary to comply with academic requirements and co-authoring of publications;
- A Project Participant must set up a regime whereby unrelated third parties can access the Relevant Foreground IPR so that it can be further disseminated throughout the relevant industry whilst protecting the Project Participants' rights as owners and licensors.