Project Code/Version No:
WWU GN 01 v2

Gas Network Innovation Competition Full Submission Pro-forma

Section 1: Project Summary

1.1 Project Title:

Clean Energy Balance (CEB) - Hydrogen Injection for Carbon Displacement

1.2 Funding Licensee:

Wales & West Utilities Ltd. (WWU)

1.3 Project Summary:

The Future of Heating strategy, published by the Department of Energy and Climate Change, recognises the potential of hydrogen, produced using renewable energy sources, and injected into the gas network as an effective and efficient means of decarbonising heat. If successful, this exciting new source of energy can exploit installed and future renewable generating capacity and maximise the continued use of the existing gas infrastructure.

A key aim of this programme is to test and demonstrate the practical feasibility of injecting hydrogen into the WWU gas distribution system using a unique electrolyser powered by a renewable electricity source to produce the hydrogen.

The key benefits from the programme are:

- Local community benefits and a significant investment opportunity for the Wales & West Region
- Learning that will reduce the environmental impact of using gas for generation and heat. This will help WWU and the UK achieve greenhouse gas emissions targets
- Avoidance of future costs for the local community and UK if the project is successful and replicated on a commercial scale
- Improved security of supply by displacing imported and non-renewable sources of gas with a sustainable alternative
- Demonstrating the sustainable role the gas distribution network can play in facilitating the more efficient use of intermittent renewable electricity generation.

This innovative proposal is an exciting opportunity for WWU and its partners to provide key learning on the road to a more secure, affordable and sustainable energy mix. You will note this is a joint LCNF and NIC submission and clear demonstration of cross sector intent from WWU and WPD to develop innovative energy wide solutions utilising new thinking from expert third parties.

1.4 Funding

NIC Funding Request (£k): 3,565 (£3,565,180)

1.4.3 Network Licensee Contribution (£k): 0 (£0)

1.4.4 External Funding - excluding from NIC/LCNF (£k): 213 (£213,220)

1.4.5 Total Project cost (£k): 4,290 (£4,290,370)

Gas Network Innovation Competition Full Submission Pro-forma

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): 12,750 (£12,749,790) from LCN Fund (WPD T2 05 v1)

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:

Partners:

CGI IT UK Ltd (£35k)

ITM Power Plc (£41k)

Toshiba International (Europe) Ltd (£188k) will provide the energy management systems and overall programme management via Cornwall Development Company (£24k) and learning via TRL (£39k)

Wadebridge Renewable Energy Network Ltd (WREN) (£23k)

Wales & West Utilities Ltd (as detailed in 1.4.3)

External Funding: £10m WREN privately sourced funding into wind farm

Please note: the amounts shown within this section indicate our partner investments, over and above any funding highlighted within Section 1.4.

This is a joint LCNF and NIC programme. In response to Ofgem's comments following the ISP, the allocation of costs between strands based on customer benefits has been further refined. Detailed in Appendix A.

1.7 Timescale

1.7.1 Project Start Date:	**1.7.2 Project End Date:**
1st January 2014	31st December 2017

1.8 Project Manager Contact Details

1.8.1 Contact Name & Job Title: Dr John Newton (Development Manager)	**1.8.3 Contact Address:** ITM Power PLC Unit H Sheffield Airport Business Park Europa Link Sheffield S9 1XU
1.8.2 Email & Telephone Number: jn@itm-power.com 0114 261 5960 07730 761353	

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Section 2: Project Description

This section should be between 8 and 10 pages.

2.1 Aims and Objectives:

The Context

Clean Energy Balance (CEB) has been developed as an overarching programme of work with three funding strands (The Low Carbon Network Fund (LCNF), The Network Innovation Competition (NIC) and The Network Innovation Allowance (NIA)). Each strand has associated activities and delivery projects. Henceforth this bid refers to the CEB Programme, funding strands and component projects.

All participants in this programme fully recognise the need to innovate to deliver secure, sustainable and affordable energy for the UK. It is hoped that this programme is the first of several innovative schemes that will make a major contribution to overcoming energy challenges.

This programme will provide specific learning within the Wales and West geography. The programme will also provide the local community with a significant investment opportunity and support local employment. The outputs of the programme will be learning about the technical feasibility of hydrogen injection into gas networks and the development of sustainable, safe, secure and more affordable energy for generation requirements and heating homes. By displacing a volume of natural gas with hydrogen from a renewable source, a small reduction in local environmental emissions will also be achieved.

The Future of Heating strategy, published by the Department of Energy and Climate Change, recognises the potential of hydrogen, produced using renewable energy sources, and injected into the gas network as an effective and efficient means of decarbonising heat. If successful, this exciting new source of energy can exploit installed and future renewable generating capacity and maximise the continued use of the existing gas infrastructure.

The existing world class GB gas network has the capacity to transport renewable energy away from points of constraint on the electricity network and, in doing so, provide a means of displacing fossil natural gas and distributing a source of low-carbon heat for domestic and industrial use.

By utilising the renewable generating capacity at times when the renewable electricity is not required, the outcomes from this programme may also significantly improve the productivity of current and future renewable energy generating plant. This, coupled with the exploitation of existing gas network assets, will minimise the costs to customers of providing secure, safe and sustainable energy, for both generation and domestic heating and cooking.

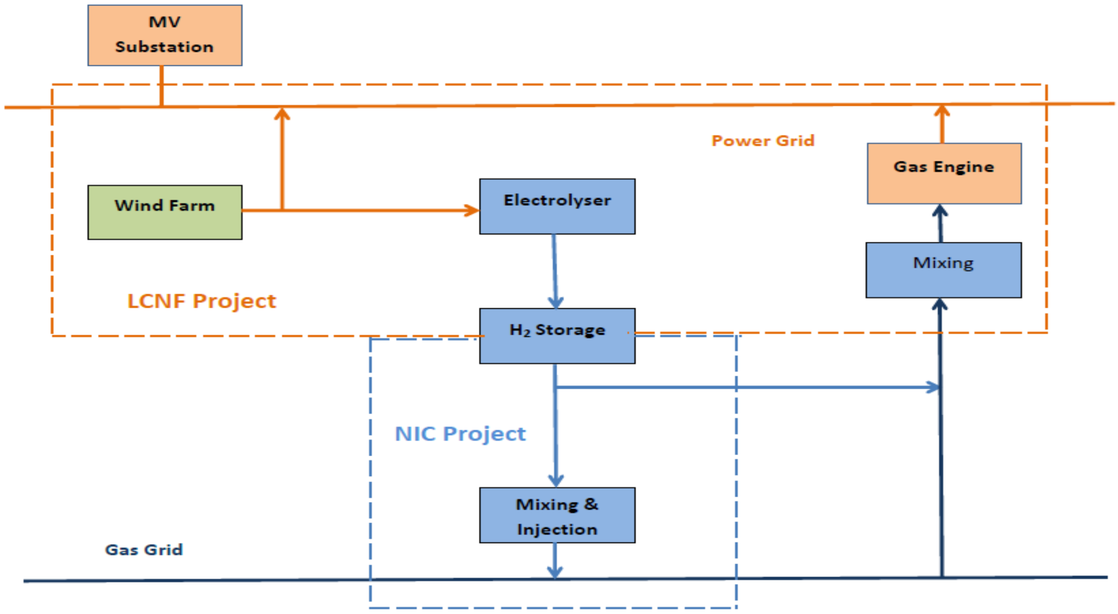
Hydrogen gas injection technology has not been demonstrated in the UK. In addition, the volume of hydrogen currently permitted in the natural gas network is too low for these needs. This programme will seek to increase this limit. In parallel, it will examine the potential of cross-sector working to demonstrate hydrogen's ability to enable the storage of renewable energy and overcome constraints in the electricity network while providing benefits to gas consumers and helping to meet UK carbon reduction targets.

The LCNF strand uses electrolysis to absorb excess electrical energy that the electrical network cannot support due to a local constraint. The NIC strand will then test hydrogen storage and injection technologies which will allow the hydrogen generated by the electrolyser, operating as an electricity demand side load, to be injected into the natural gas network and transported beyond the electricity network constraints benefiting both gas but also electricity customers. The gas will be used by existing gas customers or used by newly installed CHP to generate electricity at the point of use. The programme will explore, using the Wales & West Utilities (WWU) Fuel poor Connection Allowance, to see if fuel poor customers can be connected to the gas network and have CHP installed, thereby addressing the needs of some off-gas fuel poor customers. Appendix B illustrates an electrolyser unit.

A separate but related Network Innovation Allowance (NIA) strand will run to obtain an exemption from the Gas Safety (Management) Regulations (GS(M)R) to allow higher levels of hydrogen to be injected into the Wadebridge medium pressure network.

This programme is expected to start in January 2014 and run for four years.

The diagram below shows the project elements and the division between the LCNF and NIC strands.



We envisage that the renewable generation, electrolyser, gas mixing and injection will all be owned by one operator who will choose the best option depending on wind, generation constraints, electricity wholesale price, gas storage availability, gas wholesale price and gas network capacity

The Problem:

The current UK target to decarbonise building heating requires either a method to decarbonise the gas supply chain or an expensive change of heating systems for millions of premises. The latter option is likely to be unpopular with existing gas consumers as well as requiring reinforcement of the electricity distribution system and decarbonisation of electricity generation. In turn, the current UK target to deliver 15% of the UK's energy consumption from renewable sources by 2020 will necessitate significant electricity network reinforcement and/or generation curtailment unless other means of overcoming constraints in the existing electricity networks can be found. A recent study by Imperial College for DECC ('Understanding the Balancing Challenge' (2012)) projects that surplus renewable power that cannot be moved from the point of generation to the areas of demand could reach 50 TWh pa by 2030, with 60-100 TWh pa curtailment possible by 2040-50 (i.e. 20-30% of renewable output).

However, practical energy storage technologies are few, are generally expensive and/or limited in their capacity/duration and/or location. A further complication of available energy storage solutions is that energy is put into them and taken out at the same physical point. Although this allows a level of time-based smoothing of supply/demand, it ignores the fact that, in the main, certain areas will be generation (supply) dominant while others will be demand dominant. The most significant limitation that needs to be overcome is that effective energy storage needs to be not only time-specific but also location-specific.

The Solution:

The solution proposed by the CEB programme is to use electricity generation that would otherwise be constrained off, convert it to hydrogen, store it and inject it into the gas distribution system displacing fossil methane. This low-carbon gas will then be utilised by gas consumers for heating and/or electricity generation. This solution therefore helps to decarbonise the gas supply chain as well as addressing the electricity network constraints of time and geography. In parallel it enables the optimum use of the existing gas and electricity networks to deliver benefits to customers. It is an innovative example of “sweating the assets” and across two networks rather than one. In doing so, it will support the core theme of this programme of delivering benefits to both networks and their customers.

The combined LCNF and NIC programme will comprise two zones, a *Generation Zone* and a *Demand Zone*. The NIC strand will trial a solution that allows hydrogen produced by the LCNF electrolyser in the *Generation Zone* to be stored and subsequently mixed with natural gas, to the regulated limits, and then be injected into the natural gas network. The solution will comprise the following:

Electrolyser

This will be part of the LCNF strand. The electrolyser will be connected to the WPD 33kV network and will utilise electricity generated by the renewable generator but which is constrained off the WPD network

The following elements will be part of the NIC strand

<u>Gas Storage and Mixing</u>

Natural gas will be taken from the WWU network and blended with electrolyser-produced hydrogen from pressurised storage. The gases will be mixed to ensure the permitted 0.1% (or higher if a GS(M)R exemption is granted) hydrogen level is consistently maintained.

<u>Gas Injection</u>

The hydrogen/natural gas mixture will then be injected into WWU’s medium pressure gas network. The rate of injection will be carefully controlled to ensure that the pressure within the network is maintained within the regulated limits.

<u>Gas Export and Usage</u>

Gas containing hydrogen will be withdrawn from the gas network in the *Demand Zone* at a point beyond the electricity network constraint, either to be burnt by existing gas consumers displacing fossil natural gas or used to fuel CHP units, subsequently returning an element of electrical energy back to the electricity network. The net effect is increased flows through the existing gas distribution network.

Control System

A control system will be up in place to manage the end-to-end flow of energy from generation, through electrolysis to storage, mixing and gas injection. The system will be optimised to maximise generation export and hence gas injection potential.

The Discrete Methods and Trials:

The discrete Methods within the above solution that will be tested by the programme include:

Energy Storage and Transport via the Gas Network

This Method will use hydrogen produced by the LCNF electrolyser in the *Generation Zone* as a means of converting constrained renewable energy to a form that can be stored, transported and reused.

The hydrogen will be stored and subsequently mixed with natural gas and injected into the gas network at the prevailing regulated levels at a time when there is available gas network capacity to accommodate it.

The Method will be trialled in the following way:

- The gas mixing and injection equipment will be deployed and the ability to inject hydrogen at regulated levels when headroom allows evaluated with particular attention paid to achieving blending at low flow rates
- The capacity of the resultant gas injection system to consume the generated hydrogen will be evaluated over time and the subsequent impact on optimal hydrogen storage determined.

Regulatory Impact of Hydrogen Gas Injection

An evaluation of the current UK Regulatory framework on hydrogen injection will be evaluated from a WWU perspective and a wider perspective.

The Method will be trialled in the following way:

- The consequences of mixing hydrogen with natural gas on CV, Wobbe Index and any potential impact on metering and billing will be evaluated
- Any impacts on the operation of the system will be noted and evaluated.

Gas Export: De-Carbonisation of the Gas Network

The gas network has the capacity to transport a source of low-carbon heat for domestic and industrial use. This would utilise existing investment in the gas network assets and thereby minimise the costs to customers of the continued maintenance of the gas network.

The Method will be trialled in the following way:

- The potential decarbonisation benefits for domestic and industrial use in the programme area will be evaluated compared to the theoretical benefits obtainable if

the target level of injection was achieved
- Hence the potential wider UK decarbonisation benefits will be evaluated.

Gas Export: Gas Network Life Extension & Wider benefits

Benefits will accrue to the gas network through the deployment of this Method.

The Method will be trialled by investigating:

- The decarbonisation benefits to gas consumers
- The benefits of reduced methane leakage due to displacement by hydrogen
- The benefit of keeping gas consumers connected to the network in terms of sharing fixed costs
- A more detailed assessment of the number of sites to which this Method is applicable.

Commercial Modelling and the End to End Value Chain

This Method will look at the optimal cost, efficiency and commercial models for the end-to-end value chain from renewable generation through to end-user consumption.

The method will be trialled in the following way:

- Through operation of the discrete Methods, above, and wider analysis, system sensitivities against key variables will be assessed and the optimal end-to-end operating model identified for a given set of performance parameters (e.g. Carbon reduction, reinforcement avoidance, renewable energy connections, energy lost)
- A key determinant of whether hydrogen injection is commercially viable is the price of hydrogen so the value chain from generation, through electrolyser and energy storage and gas injection will be modelled. Potential barriers to the development of the optimum model will be identified (e.g. ownership, regulation, technology costs/limitations, the ability to provide cross-subsidies across the value chain) and mitigations determined
- The impact of increasing the permitted level of hydrogen content in the natural gas network will be evaluated and the potential benefit for the wider rollout of gas injection determined. This will include assessment of the economic viability from a Distribution Network Operator (DNO) and a Gas Distribution Network (GDN) perspective and also the wider benefit of decarbonising the UK gas network
- The current and future opportunities for alternatives to one party owing the the end-to-end system from generation to hydrogen injection will be assessed and contrasted against opportunities for the discrete Methods in isolation, for example where gas storage and injection are owned separately from the electrolyser.
- Subsequently, the optimal rollout strategy will be devised and the net benefit to the UK determined.

2.2 Technical Description of the Project

The combined LCNF and NIC programme will comprise two zones, a *Generation Zone* and a *Demand Zone*. The NIC strand will trial a solution that allows hydrogen produced by the LCNF electrolyser in the *Generation Zone*, to be stored and subsequently mixed with natural gas, to the regulated limits, and then be injected into the medium pressure natural gas network.

To maximise the use of the current gas transportation assets in the *Generation Zone*, a rapid response Polymer Electrolyte Membrane (PEM) electrolyser (Appendix B) will be installed and will be connected to the local electricity distribution network in the *Generation Zone.* The electrolyser will present a 1MW load on the electrical network that can be controlled in response to a signal from the overarching control system. In this manner, it can also be used to absorb renewable energy that would otherwise be curtailed as a consequence of electricity distribution network constraints. The electrolyser's ability to rapidly respond means that it can earn demand side management revenue.

The hydrogen produced by the electrolyser will be sent to a pressurised hydrogen store, capable of storing up to 400kg of hydrogen at a pressure of 300bar. The store will consist of steel k-type vessels and represents the best compromise between pressure and footprint (m^2/kg of hydrogen stored). The storage system will provide a buffer between hydrogen production and the technologies which will utilise it, consequently allowing time shifting to accommodate electricity network constraints (gas engine) and/or gas pressure/hydrogen content constraints (gas injection).

From the store, hydrogen will either be sent directly to the gas engine or sent to a gas mixing installation where it will be mixed with natural gas withdrawn from the medium pressure gas network, hence ensuring that the total hydrogen fraction stays within the existing regulatory concentration limit.

The hydrogen/natural gas mixture will then be injected into the medium pressure gas network via a network entry point. The gas mixture will be analysed and metered before injection. The medium pressure gas network in the area identified for the location of the electrolyser (and hydrogen storage) and the siting of the gas mixing and injection facility, transports gas at pressure <2 bar. Consequently, the gas mixing and injection equipment will be less complex due to the low pressure requirement and the hydrogen will not require compression before mixing, instead pressure reduction prior to mixing will be necessary. Appendix C illustrates the gas network in the Wadebridge area.

The rate of injection will be carefully controlled to maintain the regulated hydrogen fraction and the network pressure within the regulated limits. WWU may need to make changes to the operation of the medium pressure network in the area to facilitate this.

The overarching CEB control system will be in place to manage the end-to-end flow of energy from renewable generation, through electrolysis to storage, mixing and gas injection. The objective of the CEB control system will be to maximise generation export and hence gas injection potential. Given the trial nature of this system, failsafe for key elements of the process will remain with the primary equipment and/or the network operators. A separate NIA strand will run in parallel, to obtain an exemption from the GS(M)R necessary to allow higher levels of hydrogen to be injected.

The network entry point will be designed drawing on WWU's experience of biomethane injection with, broadly speaking, the same equipment, measurement devices, telemetry and protection systems. WWU sees hydrogen injection as being a logical extension of biomethane injection although there will need to be some differences to take account of there being two different gases in the mixture. The network will be protected by Remotely Operable Valves and information required for the operation of the network will be passed to the WWU control centre by telemetry. There will be a network entry agreement between WWU and the operator of the entry facility which will stipulate gas quality and other key requirements such as metering and gas quality measurement. Ofgem will be asked to agree not to require installation of CV measurement equipment at the site in order to reduce cost, but Ofgem may not agree to this. The shipper injecting the gas into the network will be charged using the same principles as for biomethane although allowance will need to be made to take account of the gas being taken out of the network, blended and then re-injected.

2.3 Description of Design of Trials

The programme will initially trial the injection of up to 0.1% by volume hydrogen in order to test the functionality of the hydrogen mixing and injection technology. If this is successful and the linked NIA strand gains an exemption from the GS(M)R to allow higher levels of hydrogen injection, then higher levels of hydrogen will be injected.

The Location of the trial

Wadebridge was selected for the following reasons

- The initial thinking was that the programme would deliver most value in a location where the electricity network was constrained, as is the situation in Wadebridge. As described in section 2.1, the modelling will seek to determine if there is more general applicability
- In April 2013 Wadebridge was short-listed as one of Britain's top eco-towns (ITV, 2013, *Wadebridge short-listed as top-eco towns* (sic)[online] http://www.itv.com/news/westcountry/update/2013-04-26/wadebridge-short-listed-as-top-eco-towns/ Retrieved 31 July 2013) and is home to Wadebridge Renewable Energy Network (WREN) - a grass roots enterprise aiming to make the town the first solar powered and renewable energy powered town in the UK (Independent, 2011, *Cornish town aims to be UK's first to adopt solar power – struggle becomes YouTube series* [online] http://www.independent.co.uk/environment/cornish-town-aims-to-be-uks-first-to-adopt-solar-power--struggle-becomes-youtube-series-2289830.html Retrieved 31 July 2013). WREN is the key party in developing the renewable generation project and also provides crucial local community involvement
- The constrained 33kV electricity distribution line runs very close to the WWU medium pressure (up to 2Bar(g)) pipeline that serves the Wadebridge low pressure network
- Wadebridge is representative of a growing number of communities where commercial generators are dominant and hence capacity for community generation is limited. Hence the community has the inconvenience of wind and PV farms on its doorstep but none of the benefit. With more power being given to communities to veto wind farm developments, it is critical to find a willing community with which to prove a viable community model to address this.

Replication potential

- An analysis of the WWU and Western Power Distribution (WPD) network maps in Appendix E shows that there are approximately 50 locations in Cornwall and 30 around Cardiff where the WPD 132kV or 33kV lines cross or run very close to the WWU intermediate pressure (up to 7Barg) or medium pressure (up to 2Barg) pipelines. While many locations will not be suitable for this type of scheme owing to planning, water supply and other reasons, this suggests that the Wadebridge location is not an isolated example. As renewable generation is rolled out, it is likely that more of these electricity lines will become constrained. Although this a small sample, it nevertheless suggests that there will be many more potential sites across GB where this solution could be utilised.
- The programme will determine the effectiveness of the system design in delivering the gas mixing and injection solution. In order to reduce, so far as possible, the technology risk of up-scaling, the technology-specific aspects of the technology will be tested to determine function, reliability and performance in particular:

- Gas mixing – The robustness of the technology at various flow rates and how closely it can meet the regulatory limits
- Gas injection – how the gas injection performs with a hydrogen methane blend, whether existing systems and processes need modification, whether a direct injection solution may be worth looking at in future
- Control system – the overarching CEB control system is delivered by the LCNF strand of the programme, to manage the end-to-end flow of energy from renewable generation, through electrolysis to storage, mixing and gas injection. The trials will seek to understand and develop the control algorithms necessary to maximise the gas injection potential and ensure compliance with regulatory requirements.

2.4 Changes since ISP submission

The following changes have been made in response to points raised during the review process:

- Although the programme deliverables and Methods have been refined since the ISP, the learning expected to be gained from the programme remains the same
- The target level of hydrogen injection sought has been reduced from 20% to 2% since this is seen as a more likely to be achieved in the timescales and does not unduly impact the programme.
- The model has been updated to include a CPI rate of 2.5%, a 0.5% PA energy price increase as standard (based on DECC's future fossil fuel price projections) and the discount rate used for NPV has been increased to 3.5%. Additionally all results have now been calculated post tax and depreciation
- Various changes to LCNF strand have been made including the µCHP arrangements and the assumptions about Demand Side Management revenues payable to the electrolyser and gas engine, and wind farm modelling. These are detailed in the LCNF submission.
- The control system costs are now modelled on a shared service model
- The Gas mixing costs have been reduced by approximately £400k and are now all in 2014/15 as we are now using German suppliers rather than UK based who would have needed to design the system.

The allocation of costs between the NIC and the LCNF strands of the programme based on customer benefits has been further refined. The detailed logic behind this allocation can be found in Appendix A. However, in summary, cost allocation has been undertaken based on the following principles:

- Gas Inject is the core technology required by the NIC strand to extend gas network life. However, it is an optional solution to LCNF. Hence all costs have been allocated to NIC
- Gas mixing supports gas injection and hence is an NIC cost
- The electrolyser and gas engine provide a means of storing/time-shifting electrical generation and hence are LCNF costs
- Gas Storage is required by both the gas injection system and the gas engine. Hence costs are shared
- Shared activities (PM, IT, Learning) have been allocated approximately 20% NIC and 80% LCNF

The above has resulted in a proportion of the control system costs being allocated to NIC where none were previously, given the benefit this provides in maximising the potential gas injection rate. The NIC cost has therefore increased accordingly.

Gas Network Innovation Competition Full Submission Pro-forma

Section 3: Project Business Case

This section should be between 3 and 6 pages.

3.1 Business Case Context

The main aim of this programme is to test and demonstrate the practical feasibility of injecting hydrogen into the WWU gas distribution system, using a unique electrolyser powered by a renewable electricity source to produce the hydrogen. This will reduce the environmental impact of using gas for generation and heat. In turn, this will make gas a more attractive option as the UK government considers its energy policy options.

The two key benefits from the programme are:

- Demonstrating that hydrogen injection is technically feasible under the GB safety regime
- Providing learning than can be used to enable a UK wide rollout

We recognise that the benefits of decarbonising the gas network will only be seen with levels of hydrogen injection higher than the 2% proposed; therefore this project should be seen as a project that demonstrates the feasibility of hydrogen injection.

3.2 Benefits of the Project

The hydrogen output from an electrolyser connected to the distribution network in the Generation Zone can be stored and subsequently injected into the gas grid, provided it stays below an existing regulatory concentration limit.

Therefore, the programme:

- provides a demonstration of a means of decarbonising the existing gas network and the heating load of customers connected to the gas network in turn avoiding reinforcement of the electricity distribution network which would be required if customers converted to electricity based heating and cooking
- avoids customers having to spend money converting their in house heating and cookng systems to another energy source
- prolongs the network's useful life by enabling the total cost of ownership of the network
- is apportioned over the widest possible customer base.

3.3 Overall Financial Benefits

The main financial benefits would be future cost avoidance for gas consumers if this programme is successful and developed on UK wide scale. The following sections provide further detail of the potential values.

A more immediate benefit is the small reduction in carbon emissions from reduced methane leakage and a reduction in Carbon Dioxide emissions from burning hydrogen rather than natural gas In Appendix G we calculate this benefit as £142,000 over 20 years in a rollout scenario.

3.4 Benefits of Wider Rollout

The success of the programme will enable the overall solution to be applied across other GB gas networks, subject to the required regulatory permissions, and has the potential to assist in delivering the UK greenhouse gas emissions targets. Notwithstanding the customer and carbon benefits described later, this programme will provide the following benefits: <u>Helping to achieve UK greenhouse gas emissions targets</u>

The wider rollout will contribute to this target without customer resistance. DECC's report, 'The Future of Heating' (2013), acknowledges the importance of the gas network in meeting peak heat demand. Page 24 of the evidence annex demonstrates that when asked spontaneously what system they would install, 90% of existing gas customers responded by saying a gas boiler. This shows that a policy that requires gas customers to move away from gas is likely to be very unpopular. Hydrogen injection offers a way to offset this requirement.

Avoiding future costs

The cost of converting the existing gas system to include a proportion of hydrogen is likely to be much less than the cost of converting customers from a gas based system to other systems. While we do not claim that hydrogen by itself will decarbonise the gas supply chain it can be part of the solution together with biomethane and potentially synthetic methane from the gasification of waste. Together, with energy efficiency measures, these technologies could provide sufficient decarbonisation to enable the continued use of the gas network

Costs of converting customers from a gas based system to other systems would include:

- The cost of converting 21 million premises from gas heating and cooking to non-gas systems is probably a minimum of £2000, which is the approximate cost of having a new gas boiler installed. This equates to £42bn
- The cost of decommissioning the gas network
- Cost of developing sufficient renewable generation and the associated electricity reinforcement to support electricity based heating systems.

Although many of these costs are uncertain, there appears to be a significant benefit of utilising the network compared to alternative non gas solutions.

Improving Security of Supply

Hydrogn injection will provide a degree of increased energy security and reduce the reliance on the import of gas into the UK. Reducing the UK's reliance on foreign imported gas has the potential to reduce price volatility and deliver further value for GB gas customers, as well as improving the UK balance of trade. Notwithstanding the possible need for appliance inspection and modification, using hydrogen will ensure carbon reduction at the point of use with minimal customer involvement and inconvenience, since the generation of the low-carbon fuel occurs upstream of the consumer.

3.5 Customer benefits

Customers that disconnected from the gas network would need to be provided with heating and would therefore have to install replacement heating systems. It is unlikely that this would be less than £2000 a customer (the price of having a new gas boiler installed) and we estimate that this would cost a minimum of £330,000 over 20 years.

It is likely that that the electricity distribution system would need to be reinforced to support the increased load from systems, such as heat pumps, and the customers supplied by the electricity distribution network would have to pay for this reinforcement. Based on figures from WPD we have estimated this in Appendix G for transformer reinforcement only ; however the current estimates are small in comparison to other costs. In addition, the work by Delta EE for the Energy Networks Association, '2050 Pathways to Domestic Heat' (2012), shows that the operating costs of the alternative systems are likely to be higher than the cost of operating a gas boiler because electricity per KWh costs much more than gas and modern condensing gas boilers are up to 90% efficient.

Customers that stayed connected to the gas network would have to share the higher unit costs of maintaining the system over a decreasing number of customers and then pay for decommissioning any parts of the network that was no longer required. WWU's cost of maintaining the gas network for its 2.5m supply points is circa £400m per annum. This is circa £160 per supply point per annum. Wadebridge currently has 2,500 gas supply points (last census data); albeit another 800 homes are planned within the next ten years. One scenario within the DECC Future of Heating predicts a 25% reduction in customer numbers by 2040. If the number of supply points reduced by 25% by 2040, the cost per supply point would increase to £213 (a £55 increase per supply point). We estimate in Appendix G that over 20 year this equates to an additional cost of approximately £1.5M.

Therefore, customers will see considerable benefits from staying connected to the gas distribution system, they will not have to

- Finance the installation of an alternatively heating and cooking system
- Pay for reinforcement to the electricity distribution system.
- Pay for decommissioning of the gas system

Of these, appendix G shows that the first and the last points comprise the majority of the benefit.

This programme, which investigates whether hydrogen injection to decarbonise the gas network is feasible, offers considerable customer benefit.

3.6 Carbon Benefits

The biggest contribution by far to the carbon footprint of GDNs, including WWU, is the volume of leakage from their mains. The primary reason for this is that methane is a more potent greenhouse gas than CO_2. WWU's carbon footprint is illustrated in Appendix F. If methane is displaced by hydrogen, then any leakage of hydrogen will not contribute to greenhouse gas emissions. In terms of the project, introduction of 0.1% hydrogen in the Wadebridge network would save the equivalent of 1 tonne of Carbon Dioxide a year. Appendix F shows that WWU's primary emissions to atmosphere equal just over 500,000 tonnes of Carbon Dioxide equivalent over 95% of which is attributable to network losses of natural gas. If 0.1% hydrogen was introduced throughout WWU's network, the reduced leakage of methane would be equivalent to 500 tonnes/year of CO_2. If Hydrogen is then used across all gas distribution networks, this benefit would increase ten-fold.

The project could also lead to indirect carbon savings from avoiding the carbon emissions associated with installing new systems in customers' premises; avoided reinforcement of the electricity distribution system and avoided decommissioning of the gas network.

3.7 Licensee learning benefits and alignment with business objectives

WWU's RIIO GD1 business plan identified the following as a priority for innovation based on outputs from its stakeholder engagement programme:

- The sustainability challenge of ensuring that there is a longer term viability of gas networks, with lower environmental impact

The benefits of this programme for WWU are:

- Understanding the operational challenges of introducing hydrogen into the network and whether this is a long term viable option
- Understanding the commercial (including Uniform Network Code) challenges of introducing hydrogen into the network
- There may be learning that could be applied to the development of hydrogen-only standalone systems
- Evaluate the pros and cons of working with the community and/or other third-party organisations to deliver solutions to what are inherently network problems.

3.8 Industry Benefits

The gas industry will benefit from demonstrating for the first time in the UK the injection of hydrogen, produced by electrolysis using renewable energy, into the natural gas distribution network.

This programme contributes directly to providing information to DECC on whether hydrogen can be injected into the gas network.

The hydrogen will displace natural gas from the network and be available to be transported away from the point of the constraint, used as a means of decarbonising local heat production and reduce greenhouse gas emissions due to gas leakage from the network. The hydrogen will also be available for subsequent re-conversion locally to energy and heat in distributed domestic CHP and electricity in a gas engine as a means of smoothing renewable generation output. This will demonstrate the beneficial role the gas distribution network can play in supporting the planned growth in renewable energy generation. The programme will provide valuable learning from the physical integration and operation of the individual system components which include a pressurised hydrogen store and gas mixing and injection technology.

3.9 Direct Benefits

There are three direct benefits for gas consumers which will materialise if the project is successful and is rolled out throughout the gas distribution networks:

- De-carbonisation of the energy usage and reduced greenhouse gas emissions as a result of leakage
- Avoided costs of electricity reinforcement (included as all gas customers will also be electricity customers)
- Lower costs by avoiding future decommissioning
- Improved security of supply by using a non-imported, sustainable source of energy into the existing gas network.

The benefits of the programme to the network are long-term and will not be realised in the current price control period, they will accrue if hydrogen injection becomes a developed technology. This depends on a number of developments, not least government policy which itself will only develop as the capabilities and benefits of alternative technologies such as hydrogen are developed and demonstrated. Therefore, while hydrogen injection may not be adopted, it is clear that unless this technology is demonstrated, it will remain as a possibility and there will be no possibility of gas customers benefiting from hydrogen injection.
The development of local sources of gas, may, in time, allow changes to the operation of the network, such as reduced reliance on the Local Transmission System with consequent reduction in maintenance and capital expenditure on renewal.

Project Business Case continued

Section 4: Evaluation Criteria

This section should be between 8 and 10 pages.

The gas industry has faced and overcome threats to its existence in the past. In the 1920s, the spread of electric lighting forced the industry to develop new uses for gas as gas lighting declined; in the 1960s/70s the industry went through a fundamental change, converting to natural gas. If this programme is successful, it will be an opportunity for the industry to develop expertise in hydrogen conversion that will be marketable outside the UK.

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

Supporting the Carbon Plan

Hydrogen injection can drive increased decarbonisation of the gas network across the UK.

The Carbon Plan aims to reduce carbon emissions by 34% on 1990 levels by 2020 and to generate 30% of the UK's electricity from renewable sources in the same timeframe in order to meet EU targets. In addition, DECC's report, 'The Future of Heating' (2013), has targeted the decarbonisation of heating in the UK and recognises the potential benefits to be gained from changing the content of the UK gas grid. DECC believes that low carbon fuels like hydrogen could be deployed through the national gas network in a similar way as natural gas is delivered today.

The Government recognises the potential of the UK gas network as a means of storing and transporting electricity generated by renewable sources in the form of hydrogen. By using the existing gas network as a means of decarbonising the production of domestic and commercial heat, this programme could initiate fundamental change in the industry by being truly innovative and providing relevant learning.

As a source of heat, gas has a higher instantaneous power output and higher temperatures than electrical heat pump alternatives, this allows more flexible controls within buildings. Gas (hydrogen) mix offers increased functional utility and substantial savings in annual energy; SAP predicts a 15-20% saving depending on property (https://www.gov.uk/standard-assessment-procedure), Energy Savings Trust field trials predict a 5-10% saving (http://www.energysavingtrust.org.uk). This is particularly important for commercial buildings with a high temperature hot water distribution system. This is also consistent with consumer demand for combi-boilers, which produce instantaneous heat and so require little or no hot water storage.

Encourage local communities to host renewable energy projects

Ed Davey recently stated that 'Community groups know their local area best, so I want to see them taking control of their own energy projects, generating their own power and shielding themselves against the rising cost of wholesale energy prices. This type of collective action has great benefits for local economies, creating jobs, offering the opportunity to develop new skills and injecting investment across the country.' (https://www.gov.uk/government/news/putting-local-communities-at-the-heart-of-energy-use).

The WREN community energy cooperative is seen by central and local government as a flagship initiative for its level of ambition and its success in raising community interest in their energy economy. However, WREN is constrained from achieving its ambitions by local grid constraints.

CEB is one of the first energy schemes to formally involve a local community energy cooperative as a delivery partner, and design the scheme around both technical and economic outcomes sought by the local community. CEB aims to develop a Method that enables the community to benefit through ownership of the community wind project at the heart of the scheme, as well as developing an infrastructure for unlocking further community generation across the area.

WREN held a major exhibition on the theme of Wadebridge Energy Futures from 19th – 21st September which was attended by 463 people. Visitors gave feedback on some questions including:

Do you want a locally owned Energy supply company	94% in favour
Should Wadebridge own more of its energy generation	90% in favour
Should Wadebridge lead the way in developing smart grid	90% in favour

These responses clearly show the local interest in local involvement in the energy supply chain.

Contribution of rollout to achieving Carbon Plan

The solution is replicable throughout GB and could be implemented at sites where the electricity and gas networks of appropriate capacities cross or are very close together. Maps of the WPD and WWU networks in Cornwall have been examined and approximately 50 locations where the WPD 132kV or 33kV cables cross the WWU intermediate pressure (up to 7Bar(g)) or medium pressure (up to 2Bar(g)) pipelines have been identified. A similar exercise in South East Wales covering an area of about 15 miles around Cardiff identified 30 locations. The population of Cornwall is about 532,000 and that of Cardiff approximately 330,000. Both these very different areas give a figure of approximately one possible site per 10,000 of population. Based on a GB population of 63M this suggests that there could be around 6,300 possible sites in GB. It is important to note that the electrolyser and gas injection does not have to be located close to the location of the renewable generation. The model works as long as they are on the same part of the electricity network, so the main constraints on location will relate to the requirement for a water supply and planning consents.

If the Method is successful, there would appear to be considerable scope to roll this out across GB, delivering decarbonisation benefits to the gas supply chain as well as enabling the connection of constrained renewable generation to the electricity distribution network.

How rollout will deliver a solution quicker than the most efficient current solution in the UK

Currently, the only Method of decarbonising the gas supply chain is through the injection of biomethane. This is very much in the development phase and WWU received gas from the first biomethane plant connected to its network in August 2013. Biomethane is eligible for the Renewable Heat Incentive (RHI), which is not currently available to hydrogen injection, and, based on the current subsidy, is competitive with natural gas. Unfortunately, there is only a limited volume of suitable material for Anaerobic Digestion and therefore biomethane can only be part of the overall solution. DECC's 'Future of Heating' (2013) paragraph 4.25 page 105 estimates that biomethane could contribute up to 20TWh compared to an annual total gas demand of 550TWh; however, this figure also includes gas from gasification of biomass which is currently an unproven technology. Biomethane injection is therefore a key part of the solution but is not sufficient on its own.

Hydrogen injection therefore offers an additional way of decarbonising the gas supply chain and there is no current solution to provide this additional decarbonisation. The current solution is therefore "do nothing". Since there is no current method, hydrogen injection will be the quickest method to achieve this additional decarbonisation.

The expected financial benefit the Project could deliver to customers

At 0.1% or 2% injection the benefits to customers of the first 3 benefits described in Section 3.9 (avoided conversion costs, avoided electricity network reinforcement, and continued use of the gas network) will not be realised as the level of decarbonisation will not be large enough. This programme will demonstrate that the technology is feasible and that it could lead to higher levels of hydrogen being injected. At 10% or 20% then the level of decarbonisation starts to become significant and it is reasonable to start claiming some of the decarbonisation benefits. As shown in Appendix G we have assumed that rollout is achieved at 10% volume of hydrogen and the benefits assumed below are based on 10% of the benefits of full decarbonisation.

The benefits from a rollout in the Wadebridge area using rollout costs and 10% injection could be as shown below (see Appendix G).

Carbon	£141k
Avoided conversion	£330k
Avoided electricity network reinforcement	£9k
Continued use of gas network	£1500k
Total Gross Benefit	**£1980k**
Cost	**£600k**
Net Benefit	**£1380k**

<u>Overall efficiency</u>

The Electrolyser system efficiency is 75%. This includes the transformer losses stepping down from 33kV and the electrolyser Power Supply Unit efficiency. The gas storage is about 94% efficient due to energy losses in the compressor. The need for compression is due to a desire to minimise foot print and avoid the need to comply with COMAH regulations. Under some scenarios some of hydrogen the gas may not go into storage and in this case the storage energy losses will be less. Based on experience in Germany the gas mixing and injection is 98% efficient. Overall efficiency is therefore about 70% (75%x94%x98%) so 10kWh of constrained off (wasted) wind generation will produce 7kWh of hydrogen injected into the gas network.

4.2 Provides Value for Money to Gas Customers

This section shows, for plausible parameter values, both the hydrogen injection and the electrolyser can make returns over reasonable periods. Although the electrolyser is funded under the LCNF strand it is useful to include the analysis in this submission to demonstrate the end to end feasibility of the programme.

The LCNF strand assumes that the wind farm and electrolyser are owned by the same operator and therefore makes the simplifying assumption that the constrained off wind generation is provided free to the electrolyser. Given that electricity distribution use of system charges are largely fixed at 33kV which is the connection voltage of the wind farm and electrolysers, this is reasonable.

The table in Appendix shows M various scenarios and the returns for the various methods. Method 3 (Gas inject) shows an acceptable rate of return in some scenarios but is outperformed by Method 6 which looks at the end to end returns assuming that all parts of the system are owned by one operator provides the best option. Method 5 (CHP) outperforms both but since it involves installing CHP using natural gas it does not contribute to any carbon reductions or environmental benefits other than any benefits from gas being a lower carbon fuel for generation than coal. The modelling suggests that Methods 6 and 3 could offer customers value for money.

The conclusions above, based on modelling and trials, would demonstrate whether the modelling assumptions are valid or whether in practice different methods are optimal.

GB shale gas may have an impact on the gas price but the effect is unclear for two main reasons. First the amount of shale gas that is recoverable and the cost is very unclear and second it seems likely that there will be a need for more gas fired electricity generation in the medium term and this may use all the shale gas that may be available.

Direct impact on network or GB system Operator

The programme will affect the WWU network by providing a new source of distributed gas. To date, the WWU system has received all its gas from the National Transmission System; however, the growth of biomethane injection requires WWU to manage injection points embedded in its system, so this will be another point to be managed. In the long term, distributed gas will affect investment decisions and slowly require changes in the way WWU designs and operates its network.

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

The programme will deliver significant learning. It has the potential for providing the basis for the development of a substantial change to the GB gas industry and the cost is relatively small for such a large potential gain.

DECC's own research (see section 3.4) and the Energy Networks Association project with Delta EE (Pathways for Domestic Heat, 2012) shows that gas customers like gas as a means of heating their homes and have no appetite for change. Therefore, there is significant value to them in continuing to use a gas-based system. In addition, using a gas-based system avoids significant capital conversion costs. The Delta EE study showed that, owing to the higher cost of electricity, heat pumps were more expensive to run than a gas boiler. DECC recognises that there will be a continuing requirement to use gas for peak heat and therefore many customers will need to remain on gas and bear the cost of maintaining the system. It is therefore far better value for money for them to use their gas-based heating system for all their heating requirements. This programme offers a way, together with other low carbon gases such as biomethane and synthetic methane, of enabling them to do that.

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

Partners, such as ITM Power (ITM), are providing equipment at cost. Where partners use established subcontractors, they will have been subject to the partners' procurement procedures. The IT integration service provider has been sourced by Toshiba using WPD's procurement processes.

Cornwall Development Company has been appointed to programme manage CEB and will have robust programme management processes to regularly review progress and monitor costs by means of monthly project manager meetings and quarterly programme review boards. Payments to partners will be back-loaded and paid on completion of outputs rather than expenditure and so partners will have a strong incentive to manage costs and ensure delivery of outputs relevant to the programme's aims. See Appendix G.

Expected proportion of potential benefits accruing to the gas network as opposed to other parts of the energy supply chain and the assumptions used to derive the proportion of expected benefits;

If hydrogen injection enables the gas network to be decarbonised and therefore remain in use rather than be decommissioned, in whole or part, then substantial benefits accrue to the gas network. The programme will also indirectly benefit the electricity distribution network customers (which will comprise of the gas customers plus others not connected to the gas network) and renewable electricity generators; however, in designing and costing the programme, joint costs have been allocated in an equitable way. Hydrogen producers will benefit insofar as they can inject hydrogen but they will not receive any subsidy from the network and the charges they pay for entering gas will be cost reflective as they are for biomethane entry.

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

This NIC strand is led by a third party: ITM. WWU was approached by ITM and the partners in the linked LCNF strand.

The rationale for selecting the partners was as follows:

ITM Power – NIC lead and therefore not selected as they initiated the strand.

Toshiba – lead for LCNF strand and therefore not selected as they initiated the strand. Toshiba's Bristol-based research facility, TRL, will be responsible for trial management and information dissemination.

Wadebridge Renewable Energy Network (WREN) – Community group and developer of renewable generation. Provides close links to the community in Wadebridge. A key requirement for the LCNF strand was a renewable generator on a constrained network and therefore, as the connecting party, WREN effectively self-selected as without a renewable generator, the programme was not viable. An additional benefit of WREN is the community contacts which will assist in the customer engagement for appliance inspections if required.

Cornwall Development Company (CDC) – procured through Toshiba's procurement procedures to provide Programme Management.

CGI– procured through Toshiba's procurement procedures to provide IT services integration.

The costs associated with protection from reliability or availability incentives and the proportion of these costs compared to the proposed benefits of the Project.
None claimed.

4.3 Generates Knowledge that can be shared amongst all relevant Network Licensees

What new knowledge is intended to be generated from completing the programme
The core learning generated by the programme and shared among UK GDNs will be three-fold:

- Technical Learning – the programme will determine the technical issues and opportunities associated with the injection of hydrogen into the medium pressure gas network. This will include the engineering and safety challenges of integrating the mixing and injection equipment and the inter-operation of the hydrogen storage and the gas mixing stage with the medium pressure network and the subsequent safe transport of the natural gas/hydrogen mixture through the network. In addition, comprehensive learning will be developed in the steps necessary to seek an exemption to the Gas Safety (Management) Regulations 1996 (GS(M)R) necessary to inject hydrogen at a higher concentration than the current statutory limit.
- Commercial Learning – the programme will demonstrate the financial viability of the technologies deployed. It will explore Methods that enable achievable reductions in carbon emissions from both the gas network (through leakage) and the gas transported through the network, while minimising network impact.
- Programme Learning – the programme will provide learning on how to run a cross-competition programme both in terms of governance and in terms of demonstrating benefits to gas and electricity customers, when, in some cases, the benefits are inter-related.

It should be noted that all the learning from the programme will be foreground IPR (e.g. control algorithms, commercial models, etc.) and as such will be shared amongst GDNs.

Knowledge will be captured and disseminated by means of the processes described more fully in section 5. In summary, learning can be divided into planned learning that is expected to occur and unplanned learning that is not expect but which occurs during the course of the programme.

We confirm that the IPR arrangements conform to the default arrangements.

4.4 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 programme is innovative in several ways:

- Injecting carbon-free hydrogen produced by the electrolysis of water powered by renewable energy, into the medium pressure gas network has never been demonstrated in the UK
- The programme will trial a technology solution for the safe mixing of low concentrations of hydrogen with natural gas extracted from a representative UK medium pressure gas network and the subsequent re-introduction of the mixture back into the network at the same point
- Working in conjunction with the Health & Safety Laboratory, as part of the NIA strand, the programme will develop the methodology necessary to demonstrate to the regulatory authority that an exemption to GS(M)R is required, how the potential hazards can be understood and demonstrate the steps necessary to assess risks and address knowledge gaps
- Although similar technologies are being demonstrated in Germany, in response to the Energiewende ('energy transition') initiative launched by the Federal Government, UK companies are unwilling to fund the necessary development work required to prove them

in the UK.

The project make use of two major projects, NaturalHy and work by the European Gas Research Group, to inform the NIA strand to obtain an exemption to the GS(M)R to allow injection of greater than 0.1% hydrogen by volume. ITM's involvement in power-to-gas projects in Germany and their participation in the HIPS project, means that this programme can draw on its experience to reduce risk. NaturalHy was a 5 year €17m European project funded by the European Commission's 6th Framework Programme which ran from 2004 – 2009. The purpose of the project was to determine the conditions under which hydrogen can be added to the natural gas system (<40-8 bar) with acceptable consequences. Work packages studied the impact of hydrogen addition on: durability (pipelines), integrity (pipelines), safety & end use. The project concluded that the max. % hydrogen that can be added to natural gas is limited by (in order of increasing importance): 1. Pipeline, materials, 2. Safety, 3. End user appliances. The project concluded that for properly adjusted appliances and favourable natural gas quality can accommodate up to 20% hydrogen although stationary gas engines and gas turbines (based on state of the art at the time) would require adjustment and/or modification. The final report (www.naturalhy.net/docs/project_reports/Final_Publishable_Activity_Report.pdf) concluded that admixtures of 10-15 % are not critical in most cases, except for:

1. Modern gas turbines with pre-mixed burners (but on-going work is addressing this)
2. Steel storage tanks in NCVs and CNG fuelling stations (the current limit is 2% but activities to increase the value are underway)
3. Underground porous rock storage facilities (recent studies have been initiated to determine a reliable limit value although each case is unique based on the geology)

The recently concluded European Gas Research Group (GERG) project Admissible Hydrogen Concentrations in Natural Gas Systems also known as Hydrogen in Pipeline Systems (HIPS) undertook an analysis of the issues/impacts of hydrogen addition to natural gas on the end to end gas supply chain. UK participants included ITM Power, National Grid, KIWA Gastech and E.ON New Build & Technology Ltd. The study focused on gaps in knowledge related to the addition of up to 10 vol. % hydrogen to natural gas with the following results:

- Infrastructure (transmission & distribution pipelines) – For steel Pipes no impact of hydrogen on external repairs currently used for existing NG pipelines was observed, hydrogen induced stress corrosion cracking was only relevant for high-tensile steels, up to 10 vol.% hydrogen has no impact on lifetime. For plastic pipes (PE) the hydrogen permeation was higher than in steel but no demonstrated impact on safety was observed. No impact on lifetime has been found to date and leak tests show no impact on safety aspects
- Pressure regulation systems - DIN EN 437 min. 60 vol.% hydrogen, a slight decrease in pressure was observed when hydrogen was blended with natural gas.
- Domestic installations - The Ameland project (Netherlands) showed after 4 years testing of max. 20 vol. % hydrogen in natural gas, no problems were reported. There were two leakages were due to incorrect installation and a construction fault. No significant effects were reported on copper pipes, brass couplings, valves or rubber hoses.
- Gas metering & billing - Gas meters showed <2% difference in flow rate for hydrogen/natural gas mixtures. Analysis suggests explosion frequency could increase by factor of 2 by adding 20 vol. % hydrogen, however the current risk of explosions was very low and even with this increase, the risks remains within acceptable limits. No expected design lifetime reductions for meters, gas chromatographs and volume conversion devices for up to 10 vol. % hydrogen.

WWU is not able to fund the programme as part of its business as usual activities for the following reasons:

- The programme is unlikely to deliver any benefits to customers in the current price control period
- The programme will not deliver any benefit to shareholders and therefore there is no reason for them to fund the programme
- Other parties will gain from the programme and therefore it is appropriate that they should provide contributions of expertise and products at cost.

The programme is appropriate for NIC funding for two main reasons:

- There is considerable uncertainty over the timing of financial benefits to customers owing to uncertainty with government policy
- The regulatory, environmental and cross sector nature of the programme is too risky for commercial funding.

4.5 Involvement of Other Partners and External Funding

The programme will exploit learning developed by the individual partners over several years of operation, including, in ITM's case, external funding from institutions and organisations such as DECC, The Technology Strategy Board and The Carbon Trust, which has enabled the partners to develop and increase the Technology Readiness Levels (TRL) of their proprietary technologies. Funding for the programme includes:

Partner Contribution – Each partner will provide a 10% cost reduction in addition to the considerable efforts already invested in designing and modelling the systems, components and Methods to be deployed by this programme. These contributions are detailed within the costings of the overall programme.

WWU will make a contribution of 10% to the cost of the NIC strand and will also contribute the learning it has gained from playing a leading role in the development of biomethane connections, including leading the two studies in 2012/13 to demonstrate that raising the GS(M)R limit on Oxygen to 2% was safe. It is anticipated that the experience gained from that work will be of considerable help when conducting the NIA strand to seek an exemption to increase the hydrogen limit.

4.6 Relevance and Timing

DECC is demonstrating increased interest in the exploitation of hydrogen. Greg Barker (Climate Change Minister) commented, 'Hydrogen and fuel-cell technologies are at the cutting edge of new low carbon energy solutions. We need to see how these technologies can be integrated with other energy and transport products.' (cited by the Technology Strategy Board, July 2012, *Accelerating the introduction of fuel cells and hydrogen energy systems* [online] http://webarchive.nationalarchives.gov.uk/20130221185318/www.innovateuk.org/content/competition-announcements/accelerating-the-introduction-of-fuel-cells-and-hy.ashx Retrieved 31 July 2013).

Other companies involved in the hydrogen industry have demonstrated support such as KIWA Gastech.

Sweden, Austria, Switzerland, Germany, France and Holland all permit higher concentrations of hydrogen gas in their gas networks than does the UK. In Germany, hydrogen gas injection is being adopted widely and the German parliament now permits up to 9.99% vol. hydrogen to be injected, achieving ~3% carbon saving. Several German utilities, including parent companies of two of the UK 'big six' electrical utilities, are actively involved in power-to-gas projects. In addition, several of the largest Stadtwerk (municipal utility companies) are also actively involved in developing projects and trialling the technology. Trials currently underway in the Netherlands are demonstrating the incorporation of up to 20% hydrogen in the Dutch natural gas distribution network.

On a national scale, therefore, the programme is relevant, as it addresses government requirements and it draws on experience of other European countries.

The programme is relevant for WWU as it fits in with its business plan objectives, which were developed as a result of stakeholder engagement. In particular:

- The sustainability challenge of ensuring that there is a longer term viability of gas networks, with lower environmental impact.

The WWU network has many rural areas that currently do not enjoy the benefit of gas connections. If successful, this programme has the potential to lead to standalone hydrogen-only networks or standalone hydrogen and biomethane networks and which could bring the benefit of gas to areas that currently are too far from the gas network to be connected. These customers tend to use carbon intensive heating systems, such as coal, oil or LPG, which are all more carbon intensive than natural gas and obviously much more carbon intensive than hydrogen-form renewable generation or biomethane. Inasmuch as some of these customers are fuel poor, they could benefit from reduced energy costs by being connected to a gas distribution network.

Appendix H demonstrates the Learning Approach to be adopted through CEB.

Gas Network Innovation Competition Full Submission Pro-forma
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.

5.1 Learning Dissemination

Knowledge Capture and Dissemination Plans for NIC Clean Energy Balance

Knowledge capture is a very important aspect of this programme, which requires a robust methodology and plan for delivery. Due to the nature of the programme new knowledge will be produced that relates to various stakeholders. Knowledge will generally be of two forms; planned and unplanned. The approaches for capturing these types of learning are discussed below.

Planned learning:

- Will be integrated into the programme plan for each part of the programme.
- By the end of the design phase, each project team should have a framework and method in place for capturing learning. The key learning objectives must be included in the use-case document to ensure system design links to learning objectives. Each team will also have a clear method on how the key questions will be answered.
- Outcomes of these activities will be shared through reports published on the programme website.
- These documents will be available to all partners via an online document collaboration service such that documents can be read, edited and used as required.

Unplanned learning:

- It is very difficult to anticipate the nature of these lessons learned and, as such, issuing a standard template will be counterproductive.
- Instead, the learning lead for the programme will conduct diarised interviews with work package (and project) leads and project teams to identify lessons learnt. The advantage of having a project team together is that the discussion brings out a far richer context which when captured in a coherent manner is very valuable. It is imperative that these interviews are integrated into the programme plan and happen at regular intervals. This will make it a part of normal programme activity thus highlighting the importance of knowledge capture.
- This means that it will be a relatively quick process to capture knowledge and lessons learned with the majority of the work in post-processing and collating the information.
- These commentaries will be organised into a coherent structure and any recurring issues will be investigated where necessary. At agreed stages in the programme, learning will be collated and shared amongst the programme participants to enable implementation of any relevant lessons learned.
- This will capture issues that occur on an ongoing basis but that are likely to be forgotten after a period of time. This will be shared via a lessons learned document at various phases throughout the programme.

Knowledge dissemination continued

Aspects of the planned learning objectives for this programme have already started; Appendix H outlines the system-level use cases for the programme and how they relate to primary learning objectives. Maintaining this link between use cases throughout the programme is imperative to ensuring successful learning. Appendix H also shows primary use cases that are built below the system-level use cases. During the mobilisation phase, these system and primary-level use cases will be finalised with the programme partners. This will inform the use case specification which will be necessary at the design stage to ensure the trial operation and the objectives are compatible. Please note that NIC Appendix H actually shows the use cases across both NIC and LCNF strands, as this is the best way to ensure that learning objectives and aims are not omitted. Clearly, some areas will be more relevant to NIC, which will be the focus of GDNs and related parties and will be reflected in the dissemination outputs.

As part of capturing learning, regular interviews with project leads (or teams if appropriate) will be integrated into the programme plan. This ensures that learning objectives remain as a priority throughout the programme. The regular interviews will focus around what issues the project teams faced and how they dealt with them, as well as what aspects have gone well and what factors contributed to this. This type of experience will be very valuable to other parties interested in rolling out similar systems (e.g. GDNs, equipment providers). Combining this with a periodic (throughout the programme) written report collating experiences and evidence across different projects will make it easier for other parties to learn from CEB’s experience.

Figure 1 shows the overarching strategy to achieve the learning objectives of this programme. Key themes, as described earlier, cut through the entire programme period. Learning will be recorded in a log for ease of reference, which will include reference to whether there is an impact on GDN strategy or policies. Due to the integrated nature of LCNF and NIC, it has been decided to make the learning strategy follow the same principles, to ensure that both strands benefit from a rigorous learning methodology and robust framework.

Knowledge dissemination continued

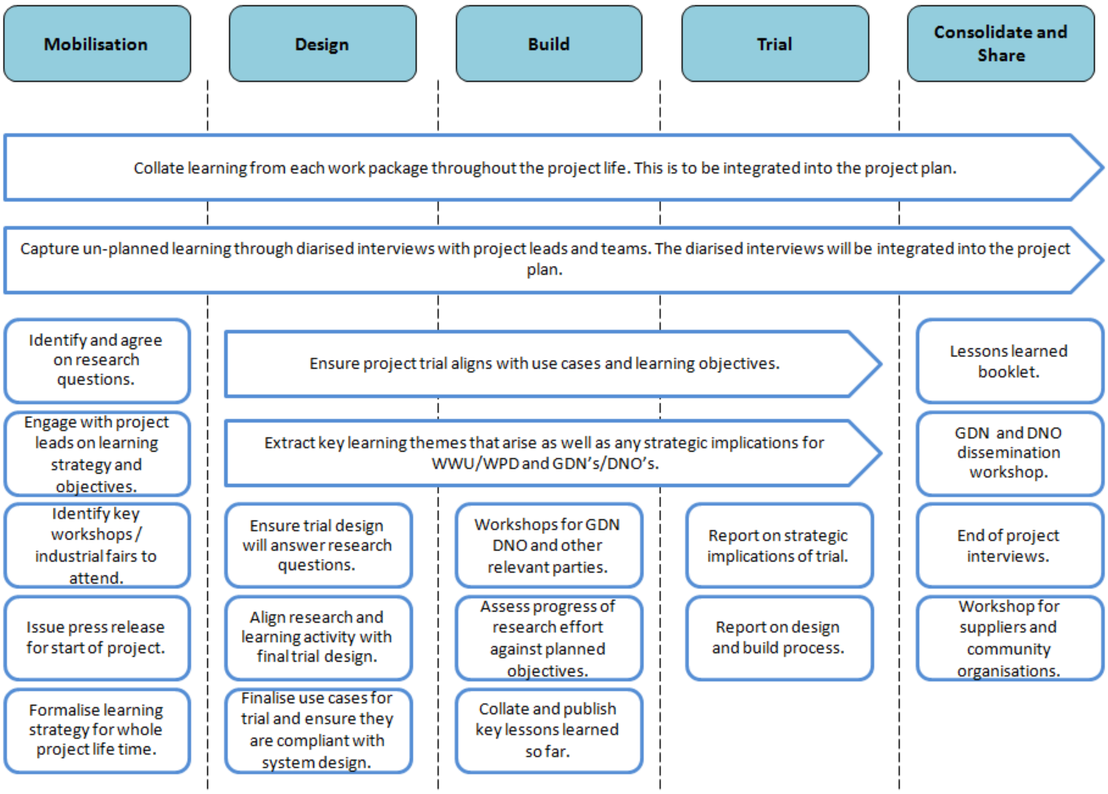


Figure 1 Overview of Learning Strategy for CEB

<u>Key Learning Outcomes:</u>

Each stakeholder will have different interests in the programme, so the outcomes will be varied along those lines. Likewise, in terms of dissemination, external parties will have different interests. Here, the broad impacts for a range of stakeholders are captured.

GDN: Given the likelihood of increased capacity in the gas network, this programme will investigate how it can be used to provide a service for a constrained electrical network. The programme will investigate how this novel use of the gas network may affect its lifetime and commercial impacts it may have. For example, the programme will investigate the effect which the planned take-up of µCHPs (as a result of the CEB method) will have on the gas network capacity. Supporting a gas–based energy balance at a national scale will also require analysis into commercial arrangements for injecting gas (at the generation zone) and consuming gas (at the demand zone); any differences in the connection costs for customers needs to be addressed as well.

Other technical challenges also need to be investigated, such as: effects of injecting hydrogen into the network (e.g. maintaining pressure regularity), storage of hydrogen for injection into the network and commercial models to facilitate this. Future rollout potential of this solution and its effects on the network will also be investigated.

Knowledge dissemination continued

Technology vendors: This programme is a unique opportunity for vendors to understand what technical capability is required to address the challenge of using gas as an energy transportation medium to alleviate electrical constraints and utilise the gas network headroom. In addition, the commercial viability and agreements necessary for a large scale rollout will also be investigated (e.g. ownership of the gas mixing and injection equipment). Electrolyser performance and costs (operation, maintenance and capital) will also be evaluated in a real situation which will provide a better understanding of its capabilities for scaling-up of the solution.

Consumers: Take-up of µCHPs could increase the number of off-grid gas customers which reduces the fixed costs of the GDN. The programme will investigate how integrated energy systems such as CEB can cross-subsidise this to initiate and accelerate take-up of these technologies.

Gas Suppliers: Lowering electrical connection costs through innovative solutions that utilise the gas network would make it possible for renewable energy generators to connect to the grid in areas which would otherwise be uneconomical to do so. These generators would then (either directly or indirectly) ship gas through the network. Commercial arrangements to buy, sell and ship the gas need to be analysed along with asset ownership and operation.

Community: Communities being at the heart of this solution is a novel concept that CEB will explore in the hope of creating a repeatable model that can be implemented throughout the UK. Developing a rollout strategy will help secure the gas network infrastructure in the future as an integral component in the national infrastructure necessary to balance energy supply and demand. The programme will identify the key characteristics necessary to create this community solution as well as commercial aspects necessary for its success.

Dissemination Methods

Learning objectives of the programme will be formulated in terms of research questions, the results of which will be published in the following ways:

- Technical reports made publicly available on the programme's website
- Academic papers published in leading journals and conferences.

Learning objectives relating to novel commercial arrangements and strategic impacts will be shared in the following ways:

- Workshops with relevant participants
- Reports and white papers made available on the programme's website.

As this is the first time this type of end-to-end energy system is being implemented in the UK, the data set created will be hugely valuable to understand and develop similar systems for rollout in the UK. With such a vast amount of information being generated, its true value can only be realised through open access sharing. To enable ease of sharing, a web portal will be developed as part of the IT system to make data available (ensuring the necessary access and privacy controls are in place) either in its raw form (database) or through some basic analytics tool that will also be in the portal. This will be used by academics to simulate various scenarios to assess the economics and physical behaviour of such a system in order to develop more novel solutions. The information will also be useful for GDNs, consultants and equipment vendors to understand how rollout of this system can be achieved.

Knowledge dissemination continued

The outcomes relating to lessons learned in the practicalities of the programme will be shared as follows:

- Reports made publicly available on the programme's website
- Workshops with relevant participants
- End of programme lessons learned booklet.

In addition to this, social media channels (e.g. Twitter) will be used as a means of notifying and updating interested stakeholders on the progress of the project. As part of the dissemination plans, the CEB programme will utilise various routes as outlined in Figure 2.

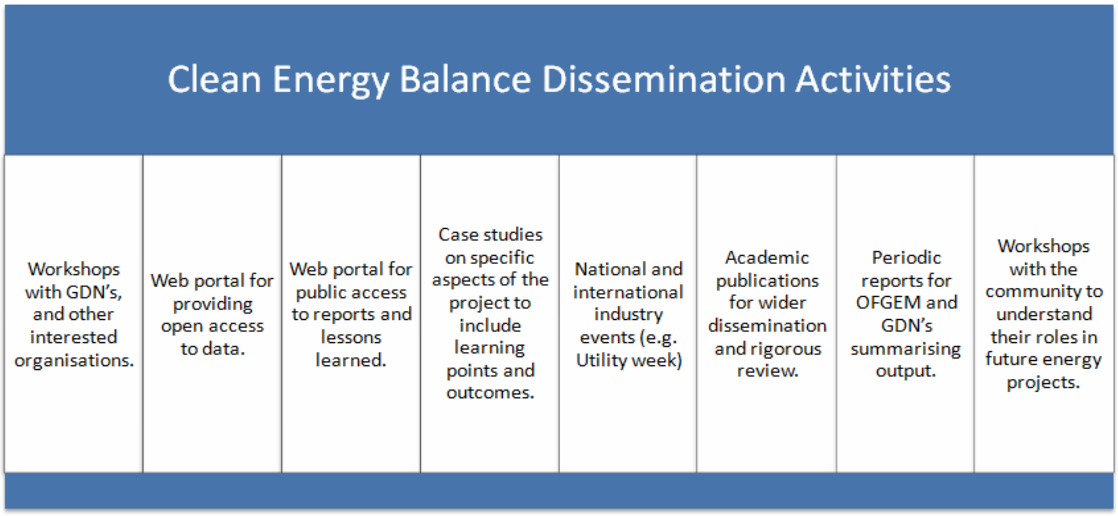


Figure 2 Dissemination Activity Outline for CEB

5.2 IPR

All parties agree to the default IPR agreements.

Gas Network Innovation Competition Full Submission Pro-forma

Section 6: Project Readiness

This section should be between 5 and 8 pages.

Requested level of protection require against cost over-runs (%): 0

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

6.1 Evidence of why the project can start in a timely manner

The following issues have been considered in planning for a timely start

- Seamless transition from bid to delivery
- Governance and Contractual model
- Relevant experience
- Mobilisation period
- Partner engagement
- Programme logistics
- Learning from WPD involvement in LCNF projects in 2010, 2011 and 2012.

The WWU executive board have reviewed the NIC strand of the CEB programme and signed off both the bid concept and the final submission. The CEB Programme is a collaborative venture and other key partners have also obtained the appropriate approvals in their organisations. The Programme Management team from Cornwall Development Company (CDC) will continue their role into the delivery which enable the programme to move smoothly from the bid phase to the delivery phase.

The following processes, frameworks and documents have already been put in place to ensure a smooth and timely transition from bid to delivery and an efficient mobilisation phase:

- Programme Management - CEB will be planned and delivered in accordance with tried and tested project management methodology (PRINCE 2, adapted) and within a robust governance structure. This framework will provide the partner delivery organisations with a system that gives total clarity and support for all strategic objectives, strong risk and issue management, quality assurance processes in place throughout, and control over programme budgets. Through the lead sponsor, Toshiba, CDC has been appointed to undertake the overarching Programme Management function. A key role for this team will be to ensure that all the partner organisations work together to deliver the milestones for both this NIC strand and the associated LCNF strand.
- Programme Plan - a high-level programme plan has been constructed, with input from CEB partners, covering the full extent of the programme and the key milestones and deliverables. It also highlights where key interdependencies exist. The collaborative manner in which the plan was produced ensures that all partners have agreed and signed up to the deliverability of the whole programme and to how their contributions fit into the wider picture. This is essential in giving everyone, including stakeholders not directly associated with the programme, the confidence that CEB will deliver. The Programme Plan is contained in Appendix I.
- Governance Structure – there will be a Programme Review Board (PRB), consisting of senior representatives from partner organisations; this ensures that the board has appropriate organisational authority and that there is senior management commitment to the programme. The PRB will meet quarterly throughout delivery and will be responsible for strategic objectives and overall programme vision, as well as signing-off

stage reviews, ensuring funding contracts are being delivered to the agreed standard and initiating action where key risks and issues arise. CEB is the overall programme, but it is made up of a number of projects (or 'workstreams'), run by CEB partners. Thus, a Project Team, consisting of all the project managers will also be set up. The Project Team will meet monthly and will focus on progress, risks, issues and opportunities. (For more detail on the Governance Structure see Appendix J.)

- Reporting Structure - a clear and concise reporting structure will ensure the Project Team meetings and the PRB meetings are well informed by accurate information. Highlight Reports, produced by the Project Team members, will be presented at each Project Team meeting; this will be coordinated through CDC, and further reports to the two sets of meetings will include a strategic overview by CDC, including review of programme risks / issues / budgets and stakeholder engagement and communications areas. The reports will focus on confirming deliverables and identifying risks (potential and experienced); this will allow for CDC to coordinate the sub-projects, which have many interdependencies, and also for CDC to escalate any strategic risks, issues and opportunities to the PRB.
- To support and enable the programme to start in a timely manner, whilst ensuring continuity, key members of the bid team will be transferred into the programme delivery phases. This will help mitigate the risk of losing knowledge and ensuring relationships that have been built with partners through the bid process continues.

WWU will be drawing on recent experience in connecting biomethane plants to the distribution network and while this process is not business as usual at present the advantage is that the team has recent experience in thinking about the issues and this approach will serve us well in addressing the related challenges of managing hydrogen injection.

A high level Programme Plan has been developed in conjunction with CEB partners and is contained in Appendix I. It is believed that this provides a robust and realistic plan for the delivery of the programme of activities. The plan contains a 5 month Mobilisation Phase, which is realistic for a programme of this complexity and is necessary for sufficient planning to take place to allow the programme to be ready to enter the Design Phase.

Partners are fully engaged across the programme and bring relevant experience of mobilising competitive projects. CDC has experience of delivering EU funded projects and, as a local organisation, has a clear incentive to ensure that the programme is delivered. Partners in the LCNF strand also have relevant experience of other LCNF schemes (WPD), and WREN, as a community organisation, has a very clear local incentive to ensure the programme starts in a timely manner.

Work has already taken place to engage other affected parties, such as landowners and equipment suppliers to ensure that during the Mobilisation Phase these initial discussions can be turned into firm agreements.

The involvement of WPD has been of great help in providing support to the NIC strand as it has been possible to draw on their experience of previous LCNF projects in such areas as working with partners, the practical experience of managing LCNF projects and the business requirements for the deliverables, such as six monthly reports.

Project Readiness continued

6.2 Evidence of how the costs and benefits have been estimated

Estimation of Costs

- Costs as given in Appendix G have been calculated using a bottom-up approach
- Partners have quoted fixed prices for the majority of their services
- Method costs have been calculated based on credible information from suppliers
- A large percentage of the costs of the equipment is driven by compliance and as such cannot be influenced by the programme, as detailed further in Appendix G.

A thorough and rigorous analysis of the costs and benefits of the CEB programme has been undertaken. Further detail is provided within Appendices G and M.

Experience that partners have brought to the programme planning has aided the completion of thorough, realistic and appropriate cost/benefit models. The approach to developing the analysis has been both bottom-up and top-down to give as rounded a view of the numbers as possible. This has ensured that all partners have confidence in the costs attached to their sections and are managing these, as well as having confidence that the overall programme costs have been analysed and will be managed and monitored centrally.

Partners have quoted fixed prices for the majority of their services and conventional costs, feeding into the Base Case, have been estimated based on previous experience of implementing traditional solutions. Method costs have been estimated based on credible information from suppliers and citable sources.

Estimation of Benefits

Benefits of the programme have been estimated using the current costs of running the WWU system and the value of Carbon.

6.3 Evidence of the measures a Network Licensee will employ to minimise the possibility of cost overruns or shortfalls in direct benefits

The programme has been broken down into discrete project packages and also into phases and deliverables, with each element having a cost allocated to it. This will allow cost management to individual items and enable action to be taken by the relevant project manager to address any potential cost overruns.

The Programme Management team will identify any actions that other parties could take in the event of cost overruns in one part of the programme to bring overall costs back within budget. The PRB will review the budget at each meeting and will only authorise each stage of the programme and spend when evidence is provided that the current stage is delivering the required outputs and is on budget.

Risk management processes will be in operation throughout the programme. Each risk will be assigned to an owner based on the risk rating and the ability of the individual to manage the risk. A risk register is given in Appendix K and a contingency plan is given in Appendix L.

6.4 A verification of all information included in the proposal

1. The proposal has been prepared by WWU in conjunction with CDC and information has been provided by programme partners and equipment suppliers.

2. The bid has been prepared by a dedicated team of experts from across the partner organisations.

3. The proposal has been through independent checking processes, peer review processes and sent to programme partners to ensure the accuracy of information.

4. Information provided from partners has been reviewed by WWU to ensure accuracy.

6.5 How the Project plan will 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

There is a risk that some aspects of the LCNF strand will not be delivered (for example take-up of domestic Combined Heat and Power boilers (CHP)). While this will mean that the increased demand for gas may be less and this will affect the volume of hydrogen that can be injected, it will not affect the learning from this programme which is related to the practical issues of the connection and management of hydrogen injection into the gas network.

The main risk for this NIC strand is that the planned wind farm component of the programme is delayed, in this case, the contingencies of both a constraint model using an existing wind farm and also a solar PV farm would be developed and the programme would still be able to deliver learning as to the viability or otherwise of the gas injection. In the unlikely event that none of these options are viable, the NIC strand will not be able to be delivered; however, even in this case, there would be some useful learning in terms of the development of a governance and contractual model for programmes across LCNF and NIC. Best practice and experiences will inevitably build up and logs of lessons learned and continual capture and transfer of knowledge will ensure that experience and best practice emerges from the programme in any event. TRL, in their role as 'learning and dissemination partner', will ensure that learning outcomes are maximised.

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.

Gateway Reviews have been scheduled for the end of each of the key programme delivery phases, as indicated in the Programme Plan (Appendix I), and are designed to determine whether or not the programme can successfully progress to the next phase of delivery. They provide assurance both to stakeholders and to programme team members that the scheme is on track, with regards to deliverables, and on budget.

At the point of a Gateway Review, CDC will coordinate a thorough examination of the phase, including:

1. Reviewing the Programme Plan, cost model and risk register;

2. Reviewing the outputs of the stage;

3. Assessing outputs against the Successful Delivery Reward Criteria; and

4. Ensuring that the best available skills and experience are deployed on the programme.

The above assessments will be carried out against the budget and the Programme Plan. As well as reviewing the current phase, the review process will take a forward look to the next stage, determining whether everything is in place for that phase to begin. Where the review highlights that remedial action is required by the PRB, this can take place, and this will also feed into the high level reporting to Ofgem.

In the event that the programme has moved beyond being a viable scheme, with Exception Reports and recommendations not being able to keep the deliverables as expected by partners and funders, the programme will report this to Ofgem via the DNO and request that the programme be halted. This stage review approach will ensure that CEB does not drift too far from proposal without review, be it the formal stage review or the ongoing monthly monitoring.

The PRB will review and agree the level of risk associated with the programme and determine a Delivery Confidence Assessment. This assessment will then provide the Project Team with recommended actions. The actions fall into the following categories.

1. Critical (Do Now): to increase the likelihood of a successful outcome, it is of the greatest importance that the programme should take action immediately
2. Essential (Do By): to increase the likelihood of a successful action, the programme should take action in the near future. Wherever possible, essential actions should be linked to a milestone and / or a specified timescale
3. Recommended: the programme would benefit from carrying out the recommendation. If possible, recommended actions should be linked to a milestone and / or a specified timescale
4. Halt the programme: either
    a. the programme has exceeded the tolerances set and agreed at the programme initiation and the situation is deemed as irrecoverable. The programme is halted and WWU senior management will contact Ofgem to discuss and agree the way forward. Or
    b. the related LCNF strand has been halted thereby meaning that the NIC strand cannot proceed. The programme is halted and WWU senior management will contact Ofgem to discuss and agree the way forward.

The Clean Energy Balance programme team has developed a strong position from which to deliver this scheme over the four year timeline. The relevant expertise in programme delivery, senior level partner representation and governance structures are all in place. There has been significant planning and preparation from all partners to support the vision, objectives, tasks and the interdependencies between teams and the budgets to undertake these activities.

The overarching CEB Programme has aligned LCNF, NIC and NIA strands; with the NIA derogation being based on a much broader set of deliverables and requirements through the NIC / LCNF strands, so it is essential to undertake these interdependent aspects of the Programme at this point in time, in line with the Programme timescales set out in this submission. The level of partner readiness and commitment of key resource to the Programme also underlines the ability and need to commence the Programme in line with these timescales from January 2014.

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.

Uniform Network Code

The Uniform Network Code is the contractual agreement that controls the commercial operation of the GB gas transportation system. The connection of the hydrogen injection will require gas to be taken off the WWU system to blend it and ensure that the hydrogen and methane are intimately mixed to avoid hydrogen in excess of the permitted limit being delivered to customers. This mixing will require an exit point from the WWU system to take off the methane and an entry connection downstream to put back in the slightly larger volume of mixed gas. This is currently not allowed by the Uniform Network Code, and would require a modification raising to allow it. WWU will need to determine the best way to achieve this. Appendix C illustrates the gas network in the Wadebridge area.

Direction of site for the purposes of measurement of the energy content (CV) of the gas injected

Under Section 12 of the Gas Act, Ofgem has the power to direct sites that inject gas to measure the CV of the gas injected. This information is then used to calculate the energy content of the gas metered at customers' premises. This equipment is expensive and, based on the industry's experience with bio-methane injection, it is unlikely that Ofgem will decide not to direct this hydrogen injection point; however, given the low volumes of hydrogen that will initially be injected, WWU will seek clarification from Ofgem as to their intentions.

Exemption to GS(M)R Regulations

WWU will require a exemption to GS(M)R to enable it to put greater than 0.1% by volume of hydrogen into the network. This will be the subject of the NIA strand. Currently, the GS(M)R Schedule 3 prohibits hydrogen in excess of 0.1% from being transported in the network. The systems can be demonstrated while conforming to this constraint and it seems likely that size of the wind farm will mean that injection of hydrogen in excess of the limit will not be possible on a regular basis, however, it would still be useful to obtain an exemption to enable the full potential of this innovative programme to be tested.

In order to obtain an exemption it will be necessary to demonstrate that "the health and safety of persons likely to be affected by an exemption will not be prejudiced in consequence of it" The experience of Wales & West Utilities in obtaining and exemption form GS(M)R to allow the limit on Oxygen in biomethane to be raised from 0.2% to 1% will be invaluable in obtaining an exemption for hydrogen.

The programme will need to:

1. Demonstrate that an exemption is required

WWU will need to provide a compelling argument to demonstrate why the gas conveyed can't meet the gas specification. This 'statement of need', linked to the overall objectives of the power to gas project, will need to provide evidence to demonstrate the following:

a) Why can't the Hydrogen content be kept to <0.1%?

Regulatory issues continued

b) Why can't the hydrogen be reprocessed to make methane?

c) Why can't the hydrogen be conveyed outside the network i.e. to non-domestic premises or to an electricity generating station only?

Our consultant will provide an independent review of the 'statement of need' and provide commentary on the adequacy of the supporting evidence.

2. Demonstrate the integrity of the assets to be used by the hydrogen methane mix

WWU will need to demonstrate the integrity of the existing assets, their design specification, maintenance and inspection history etc.

This will produce a list of assets that will need to be investigated as to their suitability to carry the hydrogen methane mix. It will also eliminate some classes of assets that exist elsewhere on the WWU network but that do not exist in the Wadebridge area, such as over 7Bar pipelines.

3. Understand the Regulatory requirements

WWU will need to understand the regulatory requirements (beyond compliance with the GS(M)R 1996), along the value chain and across the life cycle of the programme, where compliance could be affected by conveying gas outside the gas specification.

4. Understand the hazards and who could be affected and existing work done

In order to demonstrate that health and safety standards are not being prejudiced, WWU will first need to identify 'health and safety issues' and 'persons affected' by the change in gas quality, considering all aspects of the value chain and life cycle. Some work has already been done, notably by NaturalHy and CERG, and some findings have been published. These will be reviewed to establish what work has been done, how far it goes to demonstrate the safety or otherwise of various classes of asset and appliances at various proportions of hydrogen. This will include work on hydrogen embrittlement of metallic pipes.

Workshop 1
This will systematically identify the 'health and safety issues' and 'persons affected'. Outputs from the workshop will include:

- A matrix of persons affected and the hazards that they are exposed to
- An initial identification of key risk control and mitigation measures available
- An initial semi-quantitative ranking of these hazards including the identification of any 'show stoppers'
- Identification of potential sources of information to support the risk assessment and demonstration process for specific hazards identified (e.g. work from CERG and NaturalHy)
- An assessment of hazards for end-users based on the existing network operation – to allow for comparisons with the hazard, including a comparison with the 'issues' and 'persons affected' for the existing gas distribution system (based on existing assessments).

Regulatory issues continued

5. <u>Work on specific issues to develop the evidence base to demonstrate that the risks for specific issues would not increase.</u>

   It is anticipated that Workshop 1 will identify specific issues that require additional consideration and development, including by means of literature review, incident analysis, and specific detailed risk comparison studies.

6. <u>Demonstrating that the risk have been assessed and do not prejudice persons health and safety</u>

   Building on the outputs from Workshop 1, WWU will need to demonstrate to the HSE, through risk assessment (and/or deterministic arguments), that the hazards identified can be managed to a level which does not prejudice the health and safety of persons affected i.e. that the risk levels are comparable to the risk profile of the existing gas distribution network. This could include, for example:

   - Integrity assessment for the distribution network operation with methane/hydrogen mixtures
   - Risk assessment for different persons, e.g. end-users, maintenance workers etc
   - Comparison of risks between the existing gas network and the gas network conveying a hydrogen/methane mix.

7. <u>Specifying a programme of work to address any gaps identified</u>

   It is foreseeable that the work above will identify a number of issues, including areas where the relative risks associated with conveying a hydrogen/methane mix are greater than those for normal operations of the network.

   Workshop 2

   A second workshop to examine in more detail the risk control and mitigation measure and identify any key gaps. The outputs of this workshop will include further experimental work and also specific mitigating actions that may be required to mitigate the risks for the Wadebridge area, for example inspection and modification of appliance.

For completeness and the bigger picture Appendix E shows the electricity and gas networks across Cornwall.

Gas Network Innovation Competition Full Submission Pro-forma

Section 8: Customer impacts

This section should be between 2 and 4 pages.

As part of the overall programme we will be developing the appropriate detailed customer communications plans for both power and gas customers where there is any likelihood of an impact on them and the plan will be shared with Ofgem for approval before any customer engagements.

There may be two major impacts on customers
- Appliance inspection
- CHP installation.

Appliance inspection

A process of appliance inspection and adaptation may be required if the work on obtaining an exemption to the GS(M)R to inject higher than the current limit identifies that this is required. This would require significant planning and resource to accomplish and it is envisaged that close working with WREN to plan this work and obtain customer co-operation would be necessary; however, at this stage, this is only a potential impact and the hope is that the work on obtaining an exemption will not require this approach, for example we may be able to demonstrate that 2% hydrogen / natural gas mixture does not burn differently from natural gas. It is recognised that some customers in Wadebridge are served by networks owned by Independent Gas Transporters and WWU would need to engage with these companies before conducting inspections for these customers. WWU has a workforce that delivers its emergency service in the area but these employees are not trained to work on gas burning appliances and would therefore require training. It is anticipated the programme will use a company such as Kiwa Gastech based in Cheltenham to provide this training to WWU. Owing to potential problems that may be found with appliances these inspections would need to be done in the summer to minimise the impact on customers.

We assume that it will be relatively easy to gain access to premises owned or occupied by WREN members but recognise that gaining access to those owned or occupied by non-WREN members will be more difficult.

In order to improve access rates we will make use of the following:

- Demographic profiling to target high risk premises. Appliances built since 1996 have been tested on 23% hydrogen mixture and therefore it is likely that premises built after 1996 will not have pre 1996 appliance although this would need investigating
- Rental property have to have landlord safety checks and this may provide some useful information that will reduce the number of inspections required

The following should increase awareness and hence willingess to provide access:

- The WREN 'community shop' in Wadebridge will provide a point of engagement
- We expect that there will be local interest and awareness of the project and that appliance inspections are required and WREN will be key to creating and sustaining this awareness
- We will market the benefits of having annual gas inspections especially for older appliances and hence the value of our free inspection
- We may offer incentives for example free Carbon Monoxide alarms as part of the inspection and organise prize draws

We will make use of WWU's systems to ensure the necessary inspections are made and properly recorded. The high density of the inspections will require an fairly intensive

Customer impacts continued

operation and this will assist in obtaining for the following reasons:

- It will be easy to call back to premises because we will be in the area for a number of weeks
- We may be able to make appointments owing to local contact

We recognise that there are likely to be a number of hard to access properties, for example holiday lets and we will have to put in resources to address these issues as and when they arise.

Some customers may be reluctant to provide access and in these cases we would seek to speak to them in person to understand their concerns, explain why we want to inspect their appliances and provide reassurance.

We have budgeted £416k including a 50% contingency for this activity. This comprises:

- 3,000 inspections taking one hour will be required
- 10% or 300 will require a return visit of 2 hours to do modifications
- £15,000 for materials such as burner replacement or appliance replacement

The budget for material is relatively small because we have assumed that in the vast majority of cases only burner replacements will be needed.

During the course of the inspections we may come across some appliances that are "immediately dangerous" for example those that are producing carbon monoxide. We will deal with these in line with the procedures we use during our normal activities. While customers who are informed that their appliance is immediately dangerous may be frustrated at the inconvenience and expense they are also likely to be grateful that this potentially life threatening fault was identified.

We may also come across appliances that are "not to current standards"; theses appliances are not dangerous and we would offer advice to customers in these cases.

For rollout, it will be impractical to inspect appliances so it would be necessary to establish that all appliances could burn the hydrogen / natural gas mixture. Additionally the government may legislate to force burners to be able to burn hydrogen / natural gas mixtures and phase out old appliances; precedents include smokeless zones forcing customers to use smokeless fuels and the phasing out of incandescent light bulbs

Gas Network Innovation Competition Full Submission Pro-forma

Section 9: Successful Delivery Reward Criteria

This section should be between 2 and 5 pages.

Criterion 9.1 (NIC SDRC 1)
Specific: Complete the Delivery Phase Project Plan (also into contracts)
Measureable: Document produced and circulated to all organisations within the programme.
Achievable: The Programme structure will see a fully developed set of project plans covering programme, budget and scope of works with clear actions and risk review incorporated.
Relevant: The criterion responds to the Programme objectives of being well positioned and deliverable for all project partners. This SDRC will set the Programme out on a solid basis for the Design phases onwards.
Timely: Completed by 24th June 2014
Lead: Cornwall Development Company
Evidence 9.1

1. Full Delivery Phase Project Plan and associated detailed documentation.

Criterion 9.2 (NIC SDRC 2)
Specific: Trial Design
Measureable: Document produced and signed off by all the organisations within the programme.
Achievable: The trial design will build on the initial Use Case document in order to specify the full range of planned trials to be undertaken by the project under each of its Methods.
Relevant: This deliverable is critical for ensuring that the investment in this trial delivers valuable learning that is of benefit to both WPD and the industry as a whole.
Timely: Completed by 31st March 2015
Lead: TRL
Evidence 9.2

1. Trail design document produced and signed off by the project partners
2. Trial design document made available for wider industry circulation

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Criterion 9.3 (NIC SDRC 3)
Specific: IT architecture and System Design
Measureable: This SDRC is measureable by the delivery of specific outputs (design documents) of the IT design work stream – see evidence 9.5
Achievable: These are typical design documents. There is nothing unique in their structure nor anything extraordinary in terms of the design issues they address
Relevant: The IT architecture / design is a fundamental requirement of the solution. It is on the overall solution critical path
Timely: Completed by 31st March 2015
Lead: CGI
Evidence 9.3

1. Solution Architecture Diagram
2. Communications Network Design document
3. Security design document for CGI solution
4. SCADA solution design document
5. Data store and Analytics design document

Successful Delivery Reward Criteria continued

Criterion 9.4 (NIC SDRC 4)
Specific: Gas Mixing & Injection passes Factory Acceptance Test
Measureable: Gas Mixing & Injection Factory Acceptance Test certification.
Achievable: Approval is based on standards which the CEB Programme, through ITM Power as lead project team, are qualified and experienced to deliver. Timescales projected are based on experience of such work in other projects.
Relevant: The Gas Mixing & Injection technology is an essential component of the CEB Programme overarching technological requirements.
Timely: Completed by 31st March 2016
Lead: ITM Power
Evidence 9.4

1. Final design and specification documentation
2. Certification from the Factory Acceptance Test

Criterion 9.5 (NIC SDRC 5)
Specific: Achieve first hydrogen injection
Measureable: Hydrogen successfully injected into WWU network.
Achievable: This is based on appropriate levels of hydrogen as set out in the bid submission, which is in line with recommended guidance at this point in time.
Relevant: It is a core objective of the CEB Programme, and essential as a deliverable for the scheme.
Timely: Completed by 31st March 2016
Lead: WWU
Evidence 9.5

1. Measured flow of hydrogen into WWU network

Criterion 9.6 (NIC SDRC 6)
Specific: Trials Completed
Measureable: Report produced outlining the Commercial Models for the project, including options for the scheme which have been reviewed as well as the preferred option for potential roll-out of CEB to other communities.
Achievable: This SDRC is a core deliverable of the project at the end of the 4 year programme, which all parties are committed to achieving.
Relevant: The application of the CEB Programme through a role out of the full scheme, or components of it, is a core objective of the scheme.
Timely: Completed by 29th December 2017
Lead: Toshiba
Evidence 9.6

1. Report produced and dissemination of findings

Criterion 9.7 (NIC SDRC 7)
Specific: Reports on the community engagement approach and customer experience with hydrogen natural gas mixtures
Measureable: Report produced outlining the benefit, risks and opportunities in the delivery of the CEB Programme which can influence the planning and delivery of comparable projects and programmes. Report outlining customer's experience of the inspections programme if required and using hydrogen / natural gas mixtures
Achievable: This will be one of a series of such deliverables which WREN are positioned to deliver throughout the 4 year programme. Their community based remit aligns with this

Successful Delivery Reward Criteria continued

SDRC and is a core strand of work throughout the scheme. WWU will contribute experience from the inspection programme and any experience from customers' use of hydrogen / natural gas mixtures

Relevant: The CEB Programme is community focussed, and through the lead of WREN will ensure that this programme and future activities can deliver meaningful community benefits.

Timely: Completed by 29th December 2017

Lead: WREN/WWU

Evidence 9.7

1. Report produced
2. Report and findings disseminated to relevant audiences and made publicly available
3. Presentation of findings in formal events as part of the wider programme dissemination process

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Criterion 9.8 (NIC SDRC 8)

Specific: Reports on the learning about hydrogen mixing and injection

Measureable: Report produced outlining the technical and commercial learning related to the hydrogen mixing and injection.

Achievable: This will be one of a series of such learning deliverables and will be delivered by ITM Power and WWU.

Relevant: The successful delivery and learning from the hydrogen mixing and injection is the key element of the NIC strand of the project and is key to achieving wider rollout.

Timely: Completed by 29th December 2017

Lead: ITM Power & WWU

Evidence 9.8

1. Report produced
2. Report and findings disseminated to relevant audiences and made publicly available
3. Presentation of findings in formal events as part of the wider programme dissemination process

Section 10: List of Appendices

Appendix A **Apportionment of Costs**

Appendix B **Indicative Images of Electrolyser**

Appendix C **Gas Network in the Wadebridge Area**

Appendix D **Not used**

Appendix E **Gas and Electricity Networks Cornwall and Cardiff**

Appendix F **WWU's Primary Emissions to Atmosphere**

Appendix G **Financial Spreadsheet**

Appendix H **Use Cases**

Appendix I **Programme Plan**

Appendix J **Governance and Reporting Structure**

Appendix K **Risk Register**

Appendix L **Contingency Plan**

Appendix M **Cost Benefit Analysis**

Appendix N **Base Cost Description and Value for Money**

Appendix O **CEB µEMS System Diagram**

Appendix P **CEB Demand and Generation Diagram**

Appendix Q **Partner Roles Summary**

Appendix R **Letters of Support**

Appendix S **Power Network in the Wadebridge Area**

Appendix A Apportionment of Costs between Strands

In summary, cost allocation has been undertaken based on the following principles:

Gas Inject is the core technology required by the NIC strand to extend gas network life. However, it is an optional solution to LCNF. Hence all costs have been allocated to NIC.

Gas mixing supports gas injection and hence is an NIC cost. The electrolyser and gas engine provide a means of storing/time-shifting electrical generation and hence are LCNF costs.

Gas Storage is required by both the gas injection system and the gas engine. Hence costs are shared. The gas injection can operate without the control systems and hence these are LCNF costs.

Shared activities (PM, IT, Learning) have been primarily allocated in line with the ratio of initial direct strand costs. This results in approximately 20% of shared costs being allocated to the NIC and 80% to the LCNF

Apportionment of Costs between Projects

On a cross-sector project of this nature it is critical that costs are apportioned in a manner that best reflects the underlying value they deliver to the customers of the respective networks. To achieve this, each of the logical components of the overall solution has been evaluated in terms of its value to both gas and electricity distribution customers. Costs were subsequently allocated on this basis.

The highlights of this analyse are provided below:

- **Constraint Scheme** – The constraint scheme is only pertinent to the electricity network hence any costs specifically associated with this will be allocated purely to the LCNF project
- **Electrolyser** – The electrolyser is a controllable load used to allow excess export from the wind farm to be accommodated when the electricity network is constrained. Although it is used in conjunction with gas injection, gas injection is not the primary reason it is there, the excess generation is the reason. It is appreciated that the argument could be made that without the electrolyser there is no hydrogen to inject, hence no NIC gas injection project and consequently all benefits associated with gas inject are lost. However when considering the direct benefits of the electrolyser these sit firmly with the LCNF project for the reasons stated above and hence all electrolyser costs have been allocated there
- **Gas Engine** – The gas engine provides a means for peak shifting electrical generation. It provides no direct benefit to the gas network. Hence all costs have been allocated to the LCNF project
- **Gas Injection** – The gas injection system, if successful, will reduce carbon for gas customers and extend the asset life of the gas network. For electricity customers it provides an alternative Method to the gas engine for accommodating otherwise-constrained generation. As such it is an optional resource for the electricity DNO to achieve the same benefit it can achieve in other ways but it is a compulsory resource for the gas network to achieve the benefits specific to its network. Hence the primary beneficiary, arguably, is the gas network and therefore all costs should be allocated to the NIC

- **Gas Storage** – The gas storage helps provide a buffer for both the gas engine and gas inject. Hence, following the logic deployed above, this is resource that is shared between both NIC and LCNF project components. As such its costs have been shared 50:50

- **Gas Measurement and Mixing** – Although the gas engine burns a blend of gas the mixing activity is supported by standard gas engine operation. Consequently the additional gas measurement and mixing equipment identified is required purely to support the gas injection process. All costs for these items have therefore been allocated to the NIC project

- **Demand Zone** – The purpose of the Demand Zone equipment is to provide a means of aligning CHP generation to the electricity demand peak while ensuring the subsequent apparent reduction in load doesn't create problems at higher electricity network levels. In doing so it aims to reduce the need for electricity network reinforcement and, as such, its primary benefit lies with the electricity network. Although the project is also seeking to identify means of stimulating CHP take up, which in turn can extend the life of the gas network, this is a consequential benefit and not the main purpose for the CHP inclusion in this trial. Consequently all Demand Zone costs (control system and CHP trial) have been allocated to the LCNF project

- **Generation Zone** – The Generation Zone control system is responsible for managing all of the discrete components within the Generation Zone and operating these as logical units that support each of the LCNF Methods being trialled. Included within this is the operation of the gas storage and injection, hence this cost needs to be apportioned across both projects. This has been done based on an assessment of the complexities and associated learning value that each will deliver to its respective customers. Given the LCNF learning encompasses multiple Methods each with the potential to deliver customer value where as NIC is focused on one specific technical Method and its associated learning, the costs have been allocated as described above for shared costs.

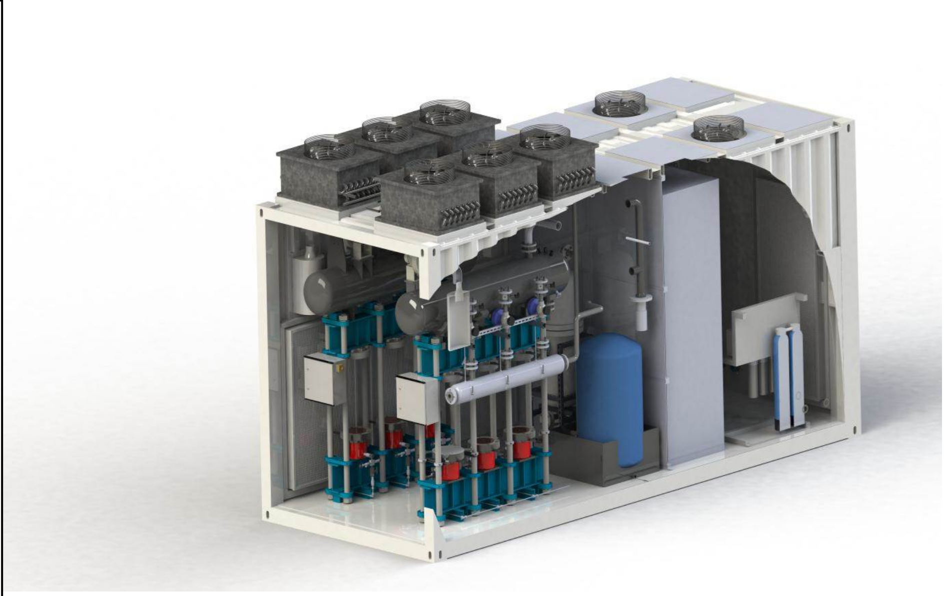
- **Knowledge Capture and Dissemination** – Learning applies across both the LCNF and NIC projects. Given learning costs have not been broken down based on specific trials at this stage but have been derived based on appropriate resourcing levels, it is difficult to accurately predict to allocation between LCNF and NIC. Consequently the costs have been allocated as described above for shared costs.

- **Programme Management** – Programme Management have been apportioned in the same manner as Knowledge Capture and Dissemination costs following the same logic

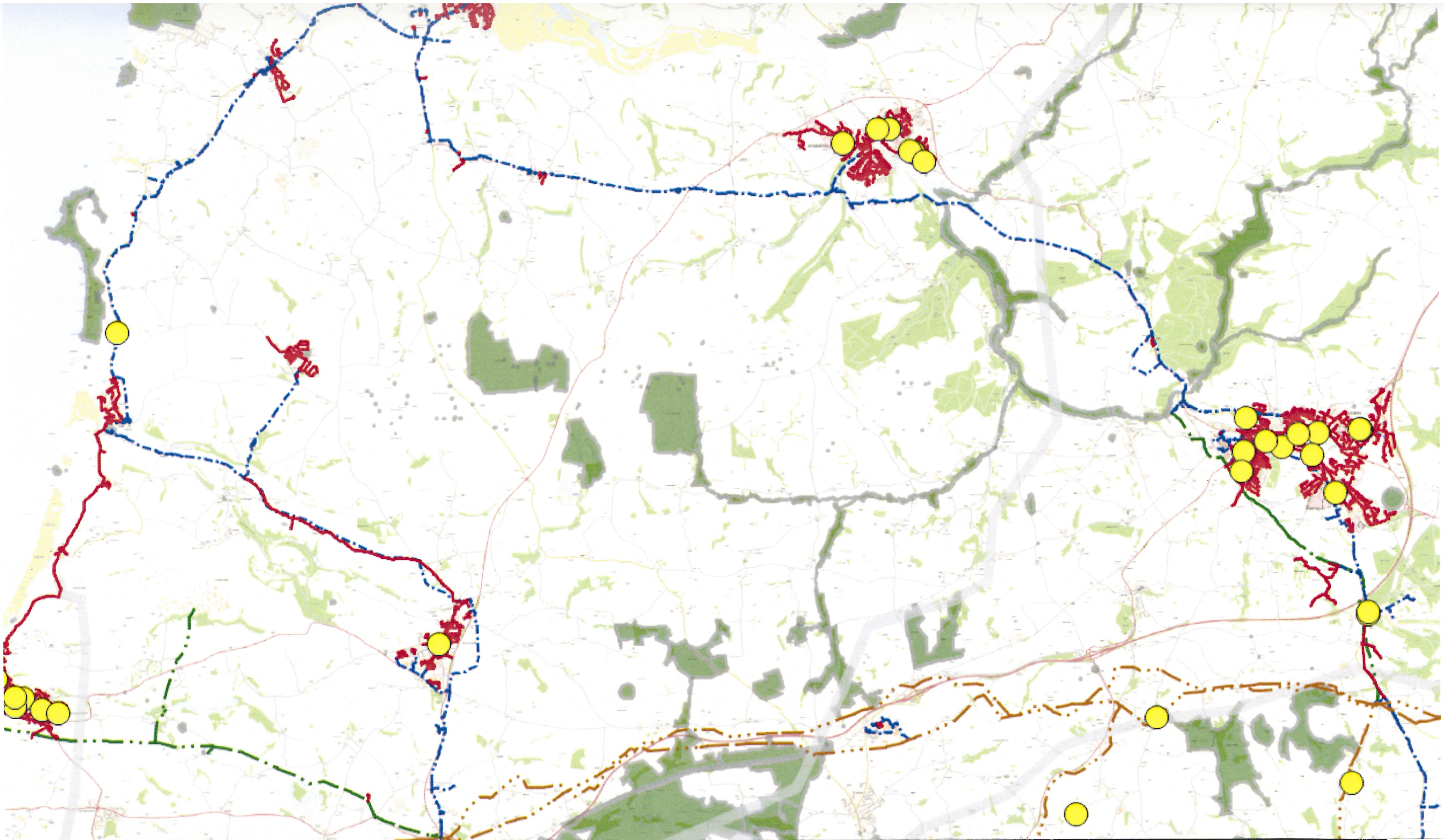
- **Information Technology** –IT the costs have been allocated as described above for shared costs. which is felt to be a good approximation of the level of IT enablement and integration complexity required for each and also a good approximation of the associated learning and hence customer benefits delivered

Appendix B Illustrative Images of the Electrolyser Unit

Schematic diagram of containerised 0.3MW PEM electrolyser. Electrolysis stacks and gas separation on left, balance of plant (including water treatment) in the centre and right.



An array of 8 electrolysis stacks representing a load of 0.5MW capable of producing 200kg hydrogen/day. A 1MW electrolyser system contains 16 stacks.



User ID:	richard.pomroy
Date:	16/07/2013
Grid Ref:	Easting: 196317
	Northing: 67509
Internal Use Only	

Low Pressure
Medium Pressure
Intermediate Pressure
High Pressure

Some examples of plant items:

Valve — Diameter Change
Depth of Cover — Material Change
Syphon

TITLE: WWU network Wadebridge area

The plan shows those pipes owned by Wales & West Utilities (WWU) in its role as a Licensed Gas Transporter (GT). The information shown on this plan is derived from historic information and may have involved re-scaling plans, and the accuracy of it cannot be guaranteed. Service pipes, valves, syphons, stub connectors, etc. may not be shown but their presence should be anticipated. No warranties are therefore given in respect of it. WWU, its employees and contractors do not accept any liability for any inaccuracy or incompleteness in it.

You must use safe digging practices, in accordance with HS(G)47, to establish the actual position of mains, pipes, services and other apparatus on site before any mechanical plant is used. It is your responsibility to ensure that this information is provided to all persons (either direct labour or contractors) working for you or near gas apparatus. The information shown on this plan should not be used beyond 28 days from the date of issue of this plan as it is subject to updating.

The plan also provides indications of gas pipes owned by other GTs, or otherwise privately owned, which may be present in the area. This information is not information of WWU and WWU is unable to verify this information or to confirm whether it is accurate or complete. It is supplied voluntarily to assist the user in determining whether the make contact with other GTs or others. The user must obtain such information from the other GT or person concerned. WWU, its employees and contractors do not accept any liability for this information or any inaccuracy or incompleteness in it.

WALES&WEST UTILITIES

Wales & West Utilities Ltd., Wales & West House, Spooner Close, Celtic Springs, Coedkernew, Newport, NP10 8FZ.

PROJECT ID: 29614

SCALE: 1:250,000

USER ID: MVAGG

DATE: 18/06/2013

PROJECT PLAN

GRID REFERENCE:
Easting : 235698 Northing : 74058

Low Pressure — Medium Pressure — High Pressure — Intermediate Pressure

0 4,300 8,600 17,200 Meters

Some examples of Plant Items:
Valve, Depth of Cover, Syphon, Diameter Change, Material Change

TITLE : <Double click to enter title>

The plan shows those pipes owned by Wales & West Utilities or the relevant Gas Distribution Network in their roles as Licenced Gas Transporters (GT). Gas pipes owned by other GTs, or otherwise privately owned, may be present in this area. Information with regard to such pipes should be obtained from the relevant owners. The information shown on this plan is given without warranty, the accuracy thereof cannot be guarenteed. Service pipes, valves, syphons, stub connections, etc. are not shown but their presence should be anticipated. No liability of any kind whatsoever is accepted by Wales & West Utilities, the relevant Gas Distribution Network, or their agents, servants or contractors for any error or omission. Safe digging practices, in accordance with HS(G)47, must be used to verify and establish the actual position of mains, pipes, services and other apparatus on site before any mechanical plant is used. It is your responsibility to ensure that this information is provided to all persons (either direct labour or contractors) working for you or near gas apparatus. The information included on this plan should not be referred to beyond a period of 28 days from the date of issue.

Wales and West Utilities Ltd GIS

PROJECT ID:	30854
SCALE:	1:50,000
USER ID:	MVAGG
DATE:	18/09/2013
PROJECT PLAN	
GRID REFERENCE:	Easting : 315060 Northing : 175386

Low Pressure
Medium Pressure
High Pressure
Intermediate Pressure

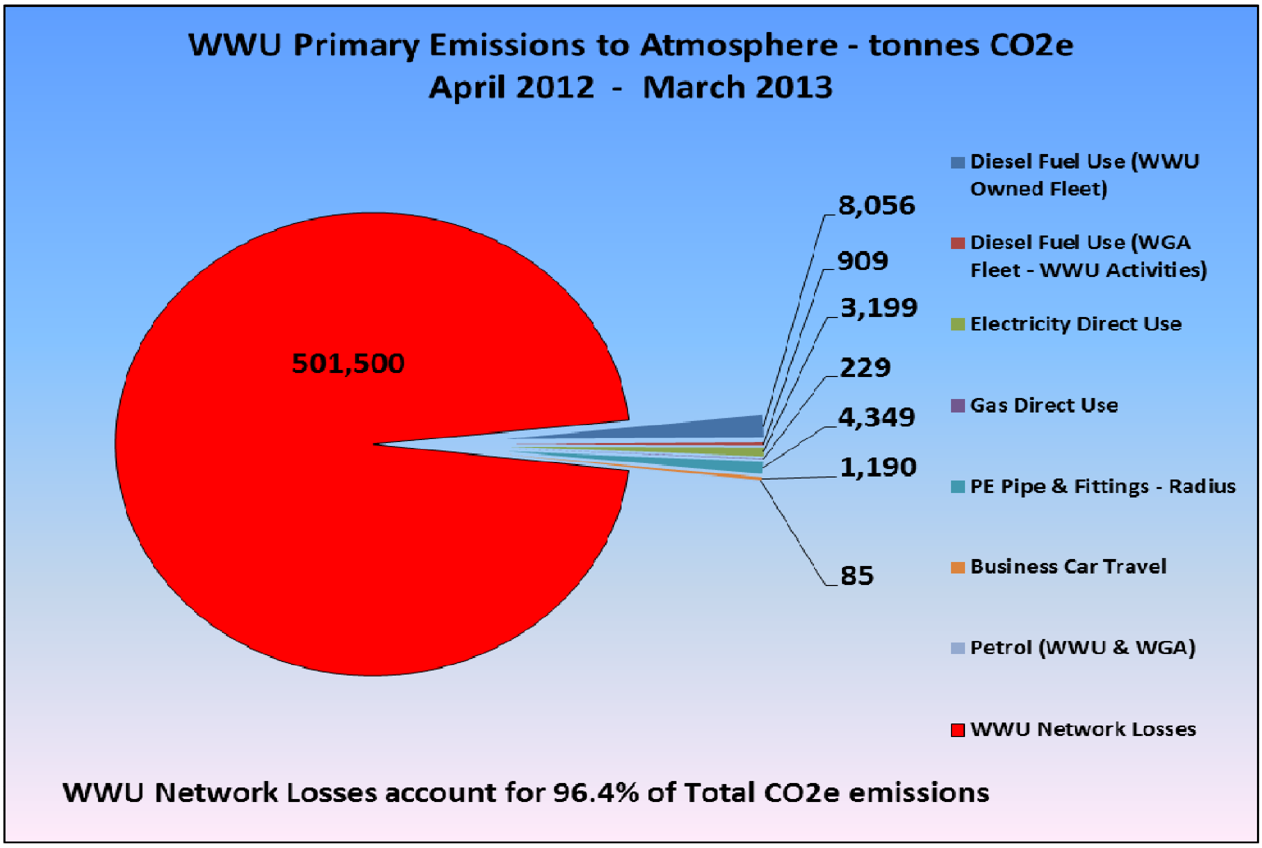
0 1,000 2,000 4,000 Meters

Some examples of Plant Items: Valve, Depth of Cover, Syphon, Diameter Change, Material Change

TITLE : <Double click to enter title>

Wales and West Utilities Ltd GIS

The plan shows those pipes owned by Wales & West Utilities or the relevant Gas Distribution Network in their roles as Licenced Gas Transporters (GT). Gas pipes owned by other GTs, or otherwise privately owned, may be present in this area. Information with regard to such pipes should be obtained from the relevant owners. The information shown on this plan is given without warranty, the accuracy thereof cannot be guarenteed. Service pipes, valves, syphons, stub connections, etc. are not shown but their presence should be anticipated. No liability of any kind whatsoever is accepted by Wales & West Utilities, the relevant Gas Distribution Network, or their agents, servants or contractors for any error or omission. Safe digging practices, in accordance with HS(G)47, must be used to verify and establish the actual position of mains, pipes, services and other apparatus on site before any mechanical plant is used. It is your responsibility to ensure that this information is provided to all persons (either direct labour or contractors) working for you or near gas apparatus. The information included on this plan should not be referred to beyond a period of 28 days from the date of issue.


WWU Primary Emissions to Atmosphere - tonnes CO2e
April 2012 - March 2013
501,500
8,056
909
3,199
229
4,349
1,190
85
Diesel Fuel Use (WWU Owned Fleet)
Diesel Fuel Use (WGA Fleet - WWU Activities)
Electricity Direct Use
Gas Direct Use
PE Pipe & Fittings - Radius
Business Car Travel
Petrol (WWU & WGA)
WWU Network Losses
WWU Network Losses account for 96.4% of Total CO2e emissions

Appendix F

Appendix H Clean Energy Balance: Use Cases

Clean Energy Balance: Learning Approach

Introduction

The CEB Programme

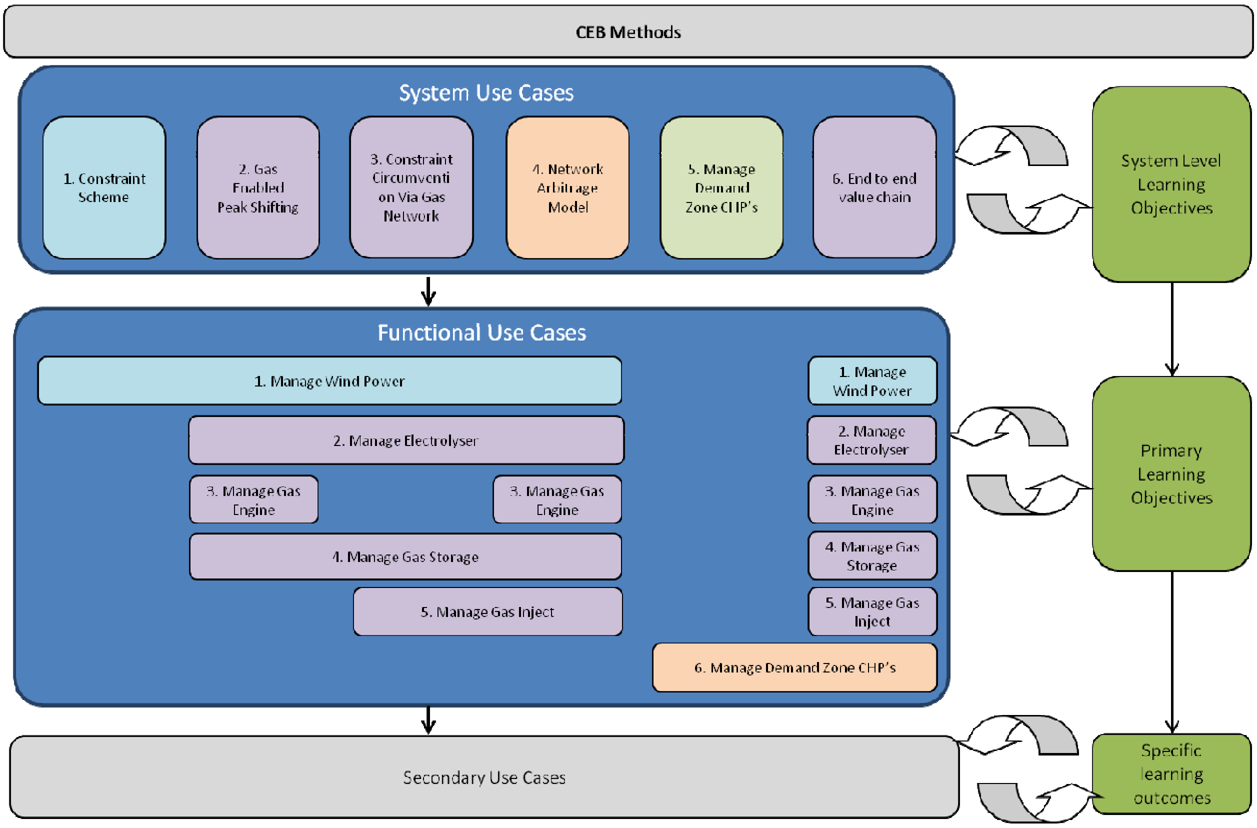
The CEB programme aims to trial a number of Methods which utilise both the gas and electricity distribution networks in order to maximise renewable generation, minimise network reinforcement and provide a mechanism for community energy engagement. To achieve this, a number of discrete technologies will be deployed, including: a hydrogen electrolyser, hydrogen storage, a gas engine, gas injection, CHP units and a number of control systems.

Purpose of this document

This document details the learning that CEB proposes to undertake. The aims and objectives of CEB and the Methods which support this have been translated into specific use cases which will be used to evaluate each Method. The use cases have been defined in the following categories:

- System use cases – These have been defined to evaluate the performance of the Methods which underpin CEB from both a technical and commercial view point
- Functional use cases – These have been defined to evaluate the performance characteristics of the discrete components upon which the system use cases rely

The diagram below provides an overview of how the programme’s Aims and Objectives and use cases align. It is the programme’s intention that this document forms the basis for the business requirements for CEB and, as such, will inform both programme and engineering design. In this manner, CEB can be assured that delivery of the programme and the supporting system will deliver the learning sought.



Documentation Approach

Within this document, the use cases have been defined in terms of:

- Summary – A high level summary of the use case
- The Opportunity – What are the key benefits of proving the use case?
- The Objectives – What is the key learning sought in order to demonstrate the benefit potential of the use case?
- The Trials – What are the trials that will be undertaken as part of the use case in order to achieve the objectives?
- The Actors – What are the key elements necessary to deliver the use case? – these may be either individuals or system components
- Roles and Responsibilities – What is expected of each actor in support of the use case? For example, the actions each is expected to undertake
- Data – This is the data required to feed the use case
- Information – The use case also needs to be considered in terms of the information it is expected to produce in order to achieve the objective

The above information has been specified on an incremental basis (i.e. the additional data/information required over and above that already specified for a previous Use Case upon which the current Use Case relies).

System Use Cases

ID	Name	Description
S1	Constraint Scheme	**Summary:** This Method will look to connect multiple generating resources above the available firm capacity and maintain the net export across these resources within available network capacity. **Opportunity:** It is anticipated that by combining different generation forms, such as solar and wind via this Method, the generation diversity will naturally provide a degree of export smoothing and therefore allow more generation to be connected sooner. **Objectives:** • To understand the key factors that influence the level of constrained energy within a constraint scheme. This will include the size and mix of solar and wind generation sets • To understand the level of control on a constraint scheme required to protect the network from limit excursions. This will include speed of response, the level of response and the need for advanced warning via forecasting • To understand wind farm viability at different levels of firm connection and with different levels of diverse generation within the scheme • To evaluate ownership structures and commercial models that might further improve scheme viability • To understand the key factors which influence the level of constrained energy within a constraint scheme. This will include the size and mix of solar and wind generation sets • Impact of the scheme on different levels of firm connection and sizes of generating sets • Wider impact of roll-out of the solution and its technical implications for both WPD and the UK as a whole **Trials:** • To connect the wind farm with a constrained connection and manage its export within available firm limits. The level of curtailed energy will be measured and the impact on wind farm viability will be assessed • Based on actual data, to simulate lower firm connection levels and determine the impact on curtailed energy and hence viability • Based on actual data, to simulate variations on the generating mix and controllable generation type (wind, PV) and its impact on curtailed generation and hence generation set viability • To monitor the scheme response to actual network events and refine the scheme to achieve optimal response actions and times **Actors' Roles and Responsibilities:** • Wind Farm – Willing to connect and operate in constrained mode • PV Farm – To provide real time generation data • Met Office – To provide wind and solar weather forecasts

		• uEMS – To forecast generation and manage the wind farm export to ensure network limits are not breached • DNO – To provide near-real time network measures and limits within which the constraint scheme must operate **Data:** • Generated power/power flow (kW) every five seconds from Wind Farm, PV Farm and 33kV feeder • Voltage (kV) every five seconds at 33kV constraint points • Frequency (Hz) every five seconds at Wind Farm, PV Farm and MV substation • Status and fault information on event occurrence from Wind Farm, PV Farm and 33kV feeder • Wind and Solar forecast from Met Office every 30 minutes for next 24 hours • Wind farm development and operating costs from Wind Farm developer/operator **Information:** • Forecast solar and wind generation from uEMS • Current and future available network capacity from uEMS • Potential curtailed generation (kWh) from analysis • Optimal constraint scheme fault responsiveness for different constraint levels/types from analysis • Assessment of comparative costs/responsiveness of controllable PV vs controllable wind • Assessment of responsiveness/costs/accuracy of proactive control based on forecasting Vs responsive control • Assessment of potential UK opportunities (based on generation mix, constraint level, constraint type, etc) from analysis • Control scheme install and operating costs based on different ownership structures and associated assumptions from analysis • Evaluation of Wind Farm viability from analysis • Evaluation of future cost/benefit (based on energy prices, carbon saving, component cost glide, commercial models) from analysis • Evaluation of customer benefits from analysis
S2	Gas Enabled Peak Shifting	**Summary:** This Method will utilise the constraint scheme in conjunction with an electrolyser acting as a controllable load, hence allowing the wind farm to increase export in line with electrolyser size. The gas generated will be stored and subsequently blended with natural gas and burned in a gas engine at a later date/time when the available network capacity allows. **Opportunity:** Through operating as described above, the gas micro-system deployed by this Method will provide a mechanism for generation peak shifting and smoothing which should have the potential to greatly reduce, if not remove, the need for network reinforcement and/or generation curtailment when connecting renewable generation. **Objectives:**

- To demonstrate the viability of using an electrolyser, gas storage and a gas engine to support generation peak shifting
- To determine the optimal sizing of equipment to maximise the commercial viability of the Method for different Wind Farm sizes
- To evaluate ownership structures and commercial models that might further improve scheme viability
- Evaluate current and future opportunities to optimise the economic model
- Future evolutions of the underlying technologies will be assessed and the impact of this on price and performance will be evaluated

Trials:

- To operate the electrolyser, gas storage and gas engine as a peak shifting scheme and evaluate performance, energy losses and commercial viability
- Based on actual data, to simulate increasing levels of constraint and review the scheme performance, losses and viability
- To simulate different comparative sizes of wind farm, electrolyser, energy storage and gas engine and model the optimal size from a performance and commercial viability perspective
- Based on actual data, to include the gas engine within the constraint scheme in order to maximise its generating output (based on both hydrogen and natural gas) and hence use Spark Spread to contribute to costs
- To utilise the electrolyser as a balancing tool when not required to offset Wind Farm curtailment
- To evaluate the commercial viability of the above based of changes in external factors such as wholesale energy prices
- To evaluate the implications of different ownership structures and the implications on contractual relationships and hence commercial viability (e.g. the impact on working with a non-bound gas engine)

Actors' Roles and Responsibilities:

- Electrolyser – To absorb excess wind generation to produce hydrogen gas
- Wind farm – To connect to electrolyser in order to maximise its output
- uEMS – To coordinate renewable generation, gas engine and electrolyser within constraint limit
- Gas storage – Provide capability to store hydrogen gas for burning in the gas engine
- Gas engine – Maximise generation output

Data:

- Generated power/power flow (kW) every five seconds from Wind Farm, PV Farm and 33kV feeder
- Voltage (kV) every five seconds at 33kV constraint points
- Frequency (Hz) every five seconds at Wind Farm, PV Farm and MV substation
- Gas storage capacity; pressure, temperature
- Electrolyser capital and operating costs
- Gas engine output (kW) and running costs

Information:

		• Current and future available network capacity • Potential curtailed generation (kWh) • Value of Spark Spread from wholesale market prices • Optimal gas engine operation • Optimal gas engine and gas storage sizing • Method install and operating costs based on different ownership structures and associated assumptions • Evaluation of Method viability • Evaluation of future cost/benefit (based on energy prices, Carbon saving, component cost glide, commercial models) • Evaluation of customer benefits
S3	Constraint Circum-vention via the Gas Network	**Summary:** This Method will employ the electrolyser to convert the electrical energy to hydrogen. The hydrogen will be stored and subsequently injected into the gas network at the prevailing regulated levels at a time when there is available gas network capacity to accommodate it. In support of this, an exemption to the Gas Safety (Management) Regulations (GSMR) will be sought to allow the injection of hydrogen at higher levels. **Opportunity:** If a cost-effective approach can be demonstrated, this will provide a viable means of transporting energy beyond a constraint in the electricity distribution network. **Objectives:** • To demonstrate the viability of using the electrolyser, gas storage and gas injection as a means of maximising generation output • To simulate different levels of constraint and subsequent effect on electrolyser behaviour • To evaluate the effect of injecting hydrogen on the gas network; pressure changes, effects on infrastructure • Evaluate ownership and commercial models **Trials:** • The gas mixing and injection equipment will be deployed and the ability to inject hydrogen at regulated and higher levels evaluated when headroom allows • The capacity of the resultant gas injection system to consume the generated hydrogen will be evaluated over time and the subsequent impact on optimal hydrogen storage determined • Current and future opportunities to optimise the economic model will be assessed. This will include options for ownership, impact of a potential hydrogen injection RHI tariff, scheduling injection for peak pricing and the impact of future energy prices rises • The impact of increasing the permitted levels of hydrogen content in the natural gas network will be evaluated and the potential benefit for the wider rollout of gas injection determined. This will include assessment of the economic viability from a DNO and GDN perspective and also the wider benefit of decarbonising the UK gas network • Evaluate ownership and commercial models.

		• Current and future opportunities to optimise the economic model will be assessed. **Actors' Roles and Responsibilities:** • Electrolyser – absorb excess generation and produce hydrogen gas • Gas Injection – transfer hydrogen from storage into gas network • Gas storage – store hydrogen gas as required **Data:** • Hydrogen generation rate (mol/s) as a function of the available input power • Power available for hydrogen generation (kW) and its fluctuations • Level of pressure (bar) in the hydrogen storage tanks • Hydrogen flow (mol/s) from the storage system to the gas grid • Level of pressure (bar) and gas flow (mol/s) in the gas network • Ratio (%) of hydrogen and natural gas in the gas network • Parameters of quality measurement of the gas infrastructure (e.g. Level of corrosion, pressure, safety, etc) **Information:** • Fluctuations of the available power for hydrogen generation • Hydrogen generation capacity of electrolyser • Storage capacity and pressure variations in hydrogen storage tanks • Optimal conditions for electrolyser operation • Optimal electrolyser sizing • Maximum capacity of hydrogen injection into the gas network • Method install and operating costs based on different ownership structures and associated assumptions • Gas injection cost/benefit and sensitivity analysis to key variables • Evaluation of future cost/benefit (based on energy prices, carbon saving, component cost glide, commercial models) • Evaluation of customer benefits
S4	Network Arbitrage Model	**Summary:** This Method will combine each of the above Methods into one overarching solution set. This will then be operated to explore opportunities to exploit network availability and prevailing energy prices in order to offset an element of the cost of energy lost in the conversion process. **Opportunity:** If it is feasible to shift between gas injection and gas engine, an opportunity to utilise network availability to offset costs elements will be created. **Objectives:** • To demonstrate the ability to switch between gas injection and gas engine operation • To evaluate whether it is feasible to exploit differences in energy prices to overcome conversion losses • To evaluate commercial models to support network arbitrage **Trials:**

		• The ability to switch between gas injection and gas engine will be assessed operationally and the impact on overall efficiency of shorter operating timeframes on each energy route determined. The optimal responsiveness will be gauged and the most economic batch sizes determined • The comparative efficiency and economics of gas-enabled peak shifting Vs gas injection and the sensitivities of each method to key variables will be assessed • The opportunity to maximise returns and consequently minimise losses by providing a solution that effectively arbitrages across gas and electricity markets and trading windows will be assessed • The opportunity to maximise energy throughput by exploiting available capacity across both networks will be evaluated **Actors' Roles and Responsibilities:** • uEMS – utilise system constraints to manage generation • Electrolyser – provide conversion mechanism for electricity into hydrogen • Gas engine- utilise hydrogen and natural gas to produce electricity • Gas injection – inject hydrogen into the gas network **Data:** • Gas input flow for the gas engine (mol/s) • Output power from the gas engine (kW) • Demand profile characteristics in the electricity and gas grid • Historic and forecast energy pricing in the electricity and gas markets **Information:** • Energy efficiency of gas engine • Energy efficiency of gas injection • Associated cost of gas engine and gas injection operations • Restrictions of the volume on hydrogen that may be added to the gas network • Switching time from gas injection to gas engine and vice-versa • Analysis of gas and electricity price fluctuations for different markets/ contract volumes and hence sizing of arbitrage opportunities • Method install and operating costs based on different ownership structures and associated assumptions • Method cost/benefit and sensitivity analysis to key variables • Evaluation of future cost/benefit (based on energy prices, carbon saving, component cost glide, commercial models) • Evaluation of customer benefits
S5	CHP as a means of Reinforcement Avoidance	**Summary:** This Method will explore the ability of CHP systems to support local load and hence minimise the need for urban reinforcement. **Opportunity:** Subsidising micro CHP costs can stimulate unit take up and subsequently deliver increased levels of local generation capable of offsetting peak demand. This would reduce the cost of both location and regional reinforcement and also the need for central balancing reserve.

Objectives:

- To evaluate the level of incentive required to stimulate micro CHP adoption
- Investigate concerns over remote operation of CHP units through liaison with both domestic and commercial customers
- To demonstrate the ability to align CHP generation to peak electricity demand and the potential benefits to the network that may result
- Demonstrate the extent to which CHP generation can be controlled to avoid impacting constraints at higher network levels
- Identify viable commercial models including ownership of the units and the energy (heat and electricity) that is generated
- Analyse the operational efficiency of a model where heat is a by-product of generation and identify the conditions that maximise generation while minimising energy losses.
- Assess the current and future opportunities to optimise the economic model

Trials:

- The ability to stimulate demand for micro CHP will be assessed through the inclusion of additional incentives
- Concerns over remote operation of the CHP units will be assessed by direct customer liaison with both domestic and commercial customers
- The degree to which CHP generation can be aligned to electrical load will be assessed by remote management of the unit's generation
- The ability to control CHP output in line with generation at higher network levels will be assessed including the ability to smooth intermittent renewable generation profiles
- The operational efficiency of a model where heat is a by-product of generation will be assessed and the conditions identified that maximise generation while minimising energy losses

Actors' Roles and Responsibilities:

- Micro CHP – convert gas into heat and electricity at domestic sites
- Commercial CHP – convert gas into heat and electricity at commercial sites
- uEMS – control the demand zone CHPs
- Demand forecast – provide forecast of demand for planning CHP utilisation

Data:

- Efficiency of energy conversion in CHP
- Output power from CHP (kW)
- Output heat from CHP (kW)
- Gas flow input for CHP (mol/s)
- CHP thermal storage capacity and efficiency
- CHP generation responsiveness
- Local electricity demand (kWh)
- Household/property temperature
- Local weather/temperature data
- Demographic/site usage

Information:

		• Peak demand period in the local electricity network • Unit impact on peak gas demand • Impact of aligning energy to peak demand on hot water availability, system efficiency and customer benefits • Cost of deploying, operating and maintaining CHP based on different ownership structures, control scenarios and associated assumptions • Evaluation of Method viability • Evaluate impact of different technologies (CHP size, heat to energy ratio, separation of heat and electricity generation, etc) • Evaluation of future cost/benefit (based on energy prices, tariff models (RHI, ToU, etc), Carbon saving, component cost glide, commercial models) • Evaluation of customer benefits
S6	End to End Value Chain	**Summary:** This Method will look at the optimal cost, efficiency and commercial models for the end-to-end value chain from wind farm through to CHP. **Opportunity:** This Method aims to show the total benefit of maximising renewable energy output through the combined Methods developed by the CEB programme. **Objectives:** • To understand the system performance (economic and technical) for all the methods listed above and develop and optimal model • To evaluate the benefits and barriers to an end-to-end system • Develop an end-to-end rollout model • Investigate current and future opportunities for the end-to-end model and compare it to opportunities for the discrete methods in isolation. • Develop commercial models to optimise the risks and returns for all parties. **Trials:** • Through operation of the discrete methods above and wider analysis, system sensitivities against key variables will be assessed and the optimal end-to-end operating model identified for a given set of performance parameters • Potential barriers to the development of the optimum model will be investigated and mitigations determined • The current and future opportunities for the end-to-end model will be assessed and contrasted against opportunities for the discrete methods in isolation. Subsequently, the optimal rollout strategy will be devised and the net benefit to the UK determined **Actors' Roles and Responsibilities:** • Wind Farm – Willing to connect and operate in constrained mode • PV Farm – To provide real time generation data • Met Office – To provide wind and solar weather forecasts • uEMS – To forecast generation and manage the wind farm export to ensure network limits are not breached • DNO – To provide near-real time network measures and limits within

		which the constraint scheme must operate • uEMS – To manage demand-zone CHPs • Electrolyser – convert excess generation to hydrogen • Hydrogen storage - store hydrogen gas until it is needed for injection or burning via the gas engine • Gas engine – create electricity from hydrogen and natural gas • Gas inject – inject hydrogen gas into the gas network **Data:** • Cost of operating the overall system, including hydrogen generation, storage, and injection into the gas grid. As well as, the use of gas engine • Efficiency and saving provided in the different stage of the end-to-end value chain • Benefits derived from new business and commercial models **Information:** • Levels of interdependence between the gas network and the electric network • Defined key parameters to measure the overall technical and economic performance of the system • Energy saving contribution • Carbon reduction contribution • Monetary saving for final users and new business opportunities for actors • Limitation associated to the commercial and business models proposed • Renewable clean energy sources contribution

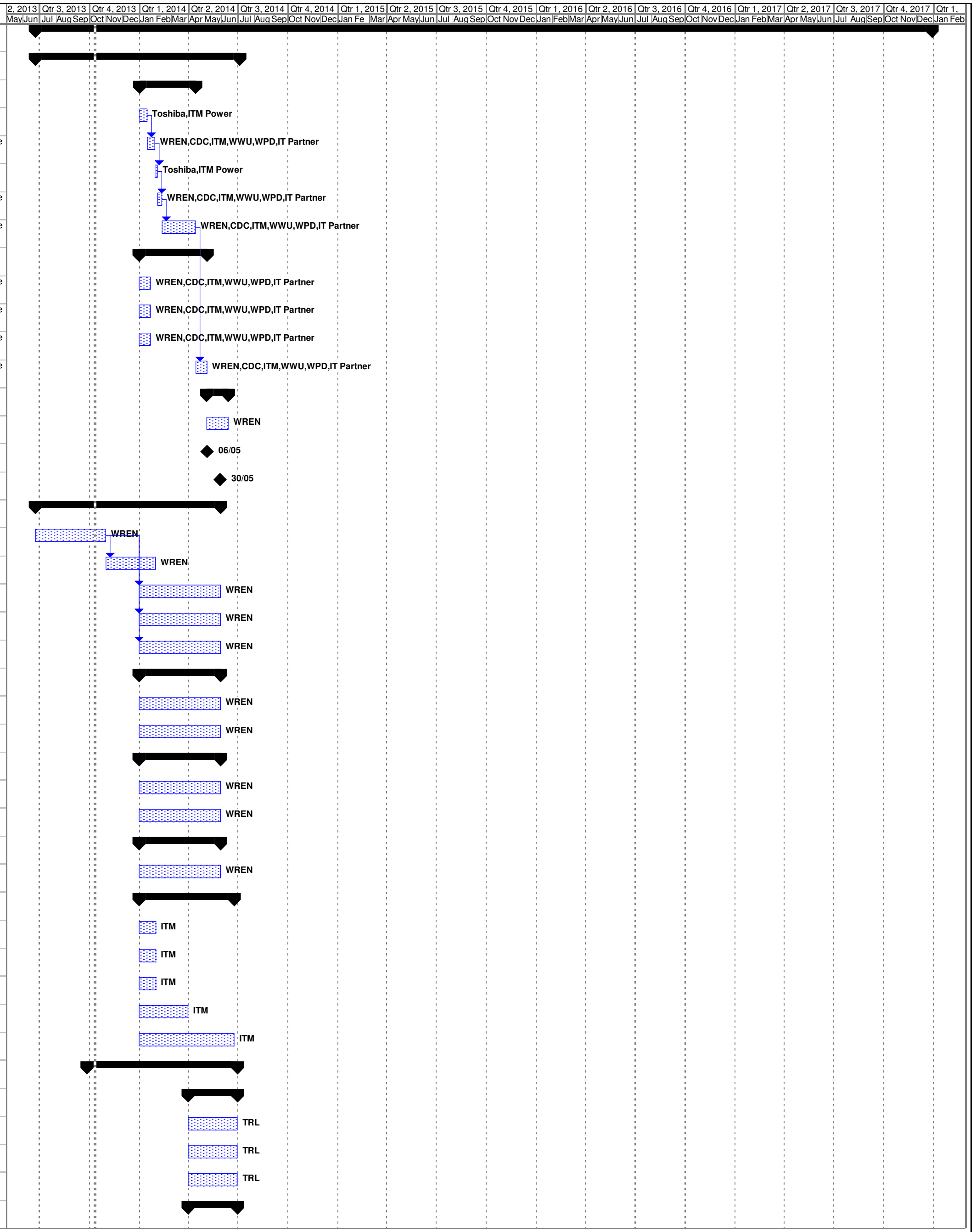
Functional-Use Cases

ID	Functional Use Cases	Actors	Description
1	Manage wind power	DNO, GDN, wind farm owner, gas engine, H2 Storage uEMS, commercial CHP owner, domestic CHP owner, consumer, Met office	Wind power integration to the grid (both electric and gas) is dependent on a number of key factors: wind generation, network headroom, electrolyser capacity, gas engine capability, H2 storage size. Key operating scenarios include: • Manage constraint scheme (turn wind export up/down based on PV capacity not utilised) • When wind power exceeds the capacity of the constraint scheme, divert it to the electrolyser and convert to hydrogen • When wind power exceeds capacity of the constraint scheme and electrolyser, turn CHP generation down • When wind power drops off, removing generation constraints, utilise the gas engine and CHP to generate • Use wind forecasts to manage gas storage, i.e. lower H2 storage levels when strong wind is expected next day (using gas engine or gas inject) Key outputs from analysis: • Impact of forecast on gas storage management • Level of constraint and its impact on wind power economics

			• Added benefit of constraint scheme and electrolyser compared to business as usual
2	Manage Electrolyser	GDN, H2 storage, H2 electrolyser, H2 injector, uEMS.	The electrolyser plays a key role as the interface in the power-to-gas system. The electrolyser operation can be operated under various scenarios: • If over generation from renewable energy, then utilise electrolyser to create hydrogen • Utilise electrolyser as variable load to solve other network constraint issues • Utilise electrolyser above firm to determine cost/benefit by increased capacity Vs asset degradation Key outputs from analysis: • Performance in terms of operation costs, maintenance costs, operation patterns, system efficiency, asset degradation, and availability • Identification of minimum spares inventories for different levels of O&M contracts (bronze, silver, gold), minimum remote monitoring requirements and min/max staff attendance on site • Electrolyser stack and system efficiency changes due to varying load profiles (part/full/overload) • Ability to use the electrolyser as a controllable load to generate revenue from the balancing market
3	Manage Gas Engine	Gas Engine, H2 storage, Wind farm, PV, H2 injector	The gas engine mixes H2 gas and natural gas to produce electricity that can be fed into the distribution network. Key operating scenarios include: • If H2 storage capacity is low use gas engine to create headroom when network constraints allow and gas injection is not the preferred option • Control gas engine such that headroom created by PV and wind variability is utilised Key outputs from analysis: • Analyse the effects of hydrogen content on the gas engine performance and maintenance cost • Using the gas engine to provide other grid level services • Analyse the economics of using the gas engine by considering the cost of natural gas and the benefit of generating electricity at a given time
4	Manage Gas Storage	Wind farm, H2 storage, H2 injector, Gas engine	Gas storage will enable flexibility in using and transferring wind power. Key operating scenarios include: • Manage excess capacity via electrolysis into gas storage • Release from storage via route forecast to be most economically viable (assuming capacity exists either to inject or generate) Key outputs from analysis: • Use the data to develop methods to estimate size requirements of gas storage • Impact of CEB roll-out on gas storage requirements and sizing

5	Manage gas inject	DNO, GDN, H2 storage, H2 injector, uEMS, commercial CHP owner, domestic CHP owner, consumer.	The gas network is a medium by which energy is transported from the generation site to the demand zone. Key operating scenarios include: • Gas demand high: Gas injection can be used to shift excess electricity generation • Gas Demand Low/Electricity demand high: Gas injection can be used to support electrical demand via the use of CHPs in the demand zone hence creating demand to enable more injection • Gas storage capacity low: Assuming there is capacity to inject, it can be used to reduce stored H2 levels Key outputs from analysis: • Operation of the gas inject due to constraints of hydrogen storage size, gas injection percentages and CHP operability • The effects on the gas network due to the location of hydrogen injection can be evaluated using data from the trial • Evaluation of viable locations of gas injection and hence scalability of this solution
6	Manage demand zone CHPs	GDN, DNO, consumers, uEMS, commercial CHP owner, domestic CHP owner.	Domestic and Commercial CHP within the Demand Zone will provide a release for hydrogen injected into the gas network and a tool to further balance intermittent generation. Key operating scenarios include: • Gas demand low: Utilise the CHP to convert gas to thermal storage in order to alleviate predicted gas peak periods • Electricity demand high: Utilise the CHP to convert gas to heat and electrical output for local use • Manage generation against higher-level constraints to avoid increasing the problem Key outputs from analysis: • Methods of cross-subsidising CHPs in order to accelerate CHP adoption • Benefits of CHP operation for domestic consumers • Develop methods to ensure safe operation of remotely controlled CHPs

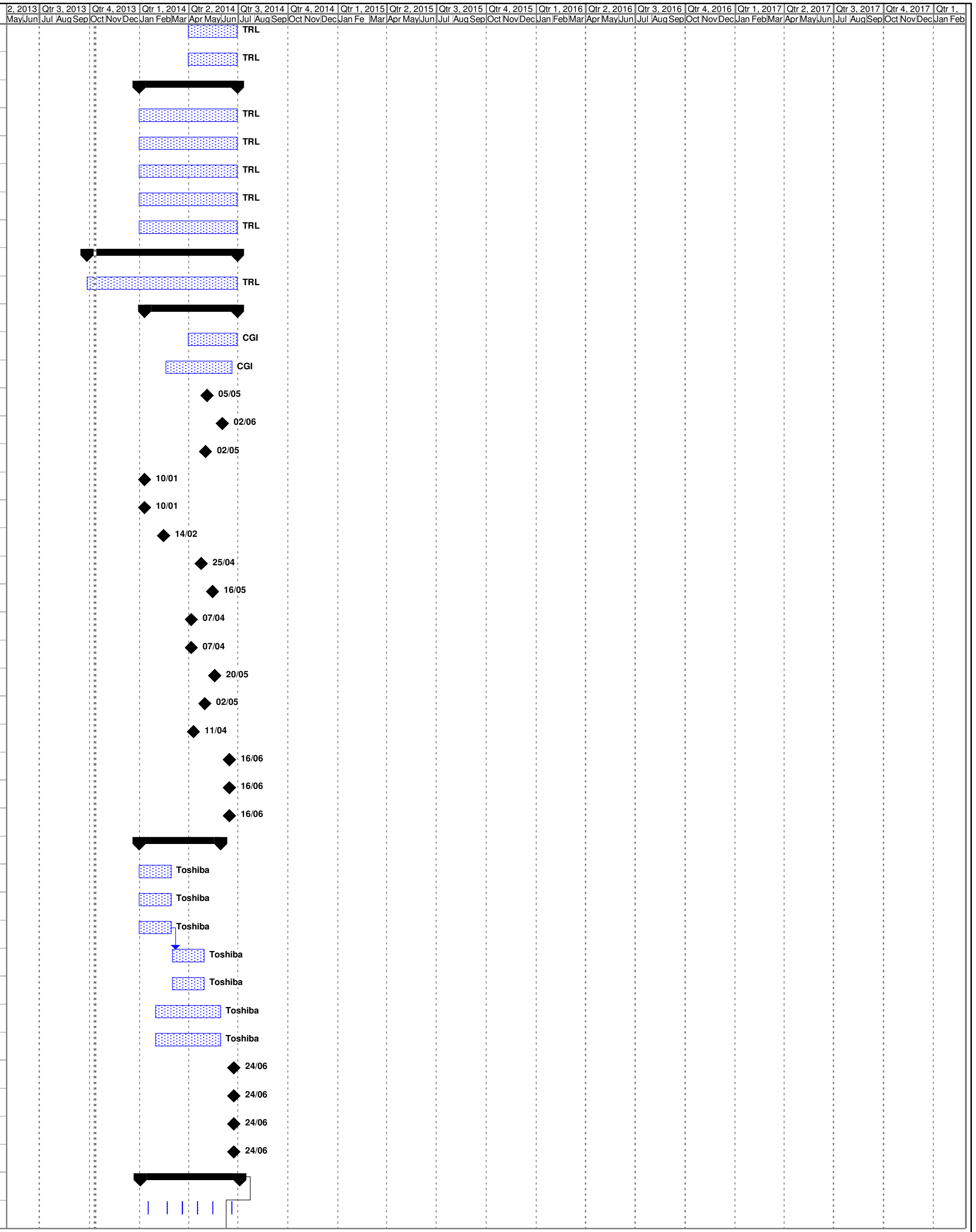
ID		Task Name	Duration	Start	Finish	Predecessors	Resource Names
1		**Clean Energy Balance - Overarching Programme**	**1180 days**	**Mon 24/06/13**	**Fri 29/12/17**		
2		**Mobilisation Phase**	**270 days**	**Mon 24/06/13**	**Fri 04/07/14**		
3		**Contracts**	**73 days**	**Thu 02/01/14**	**Mon 14/04/14**		
4		Draft Bi Laterals	10 days	Thu 02/01/14	Wed 15/01/14		Toshiba,ITM Power
5		Review Bi-Laterals	10 days	Thu 16/01/14	Wed 29/01/14	4	WREN,CDC,ITM,WWU,WPD,IT Partne
6		Redraft Bi-Laterals	3 days	Thu 30/01/14	Mon 03/02/14	5	Toshiba,ITM Power
7		Agree Bi-Laterals	6 days	Tue 04/02/14	Tue 11/02/14	6	WREN,CDC,ITM,WWU,WPD,IT Partne
8		Sign Bi Laterals	44 days	Wed 12/02/14	Mon 14/04/14	7	WREN,CDC,ITM,WWU,WPD,IT Partne
9		**Logistics**	**89 days**	**Wed 01/01/14**	**Mon 05/05/14**		**All**
10		Working location	15 days	Wed 01/01/14	Tue 21/01/14		WREN,CDC,ITM,WWU,WPD,IT Partne
11		IT	15 days	Wed 01/01/14	Tue 21/01/14		WREN,CDC,ITM,WWU,WPD,IT Partne
12		Team	15 days	Wed 01/01/14	Tue 21/01/14		WREN,CDC,ITM,WWU,WPD,IT Partne
13		Project Planning	15 days	Tue 15/04/14	Mon 05/05/14	8	WREN,CDC,ITM,WWU,WPD,IT Partne
14		**Community and stakeholder engagement**	**30 days**	**Mon 05/05/14**	**Fri 13/06/14**		
15		CEB display in WREN shop	30 days	Mon 05/05/14	Fri 13/06/14		WREN
16		CEB information to WREN website	0 days	Tue 06/05/14	Tue 06/05/14		WREN
17		Local CEB launch event	0 days	Fri 30/05/14	Fri 30/05/14		WREN
18		**Generation project**	**245 days**	**Mon 24/06/13**	**Fri 30/05/14**		
19		Complete feasibility studies (aviation, noise, ecology, etc) and decision to proceed to plar	94 days	Mon 24/06/13	Thu 31/10/13		WREN
20		Finalise land option	65 days	Fri 01/11/13	Thu 30/01/14	19	WREN
21		Neighbour engagement	108 days	Wed 01/01/14	Fri 30/05/14	19	WREN
22		Scoping submission	108 days	Wed 01/01/14	Fri 30/05/14	19	WREN
23		Input to generation zone trial design	108 days	Wed 01/01/14	Fri 30/05/14	19	WREN
24		**Commercial CHP**	**108 days**	**Wed 01/01/14**	**Fri 30/05/14**		
25		Community business model development (owner funded and WREN Energy Co funded)	108 days	Wed 01/01/14	Fri 30/05/14		WREN
26		Host engagement (technology feasibility, business model options and implications of CEI	108 days	Wed 01/01/14	Fri 30/05/14		WREN
27		**Domestic CHP**	**108 days**	**Wed 01/01/14**	**Fri 30/05/14**		
28		Community Business model development	108 days	Wed 01/01/14	Fri 30/05/14		WREN
29		Aiding TRL with engagement CHP suppliers and partners, including assessment of avail	108 days	Wed 01/01/14	Fri 30/05/14		WREN
30		**Electroliser and gas engine**	**108 days**	**Wed 01/01/14**	**Fri 30/05/14**		
31		Support WPD and ITM to engage landowners and secure site	108 days	Wed 01/01/14	Fri 30/05/14		WREN
32		**ITM Scope**	**125 days**	**Wed 01/01/14**	**Tue 24/06/14**		
33		Recruitment	23 days	Wed 01/01/14	Fri 31/01/14		ITM
34		Project IT	23 days	Wed 01/01/14	Fri 31/01/14		ITM
35		Project working method	23 days	Wed 01/01/14	Fri 31/01/14		ITM
36		Develop technoeconomic model	64 days	Wed 01/01/14	Mon 31/03/14		ITM
37		Compliance and Certification	125 days	Wed 01/01/14	Tue 24/06/14		ITM
38		**TRL Scope**	**197 days**	**Fri 27/09/13**	**Mon 30/06/14**		
39		**Use case scenarios, stakeholder and system requirements**	**65 days**	**Tue 01/04/14**	**Mon 30/06/14**		**TRL**
40		Use case model development	65 days	Tue 01/04/14	Mon 30/06/14		TRL
41		Stakeholder/business model development	65 days	Tue 01/04/14	Mon 30/06/14		TRL
42		Functional and system requirements	65 days	Tue 01/04/14	Mon 30/06/14		TRL
43		**System modelling and analysis**	**65 days**	**Tue 01/04/14**	**Mon 30/06/14**		**TRL**



Project: NIC Appendix M CEB Delivery
Date: Thu 10/10/13

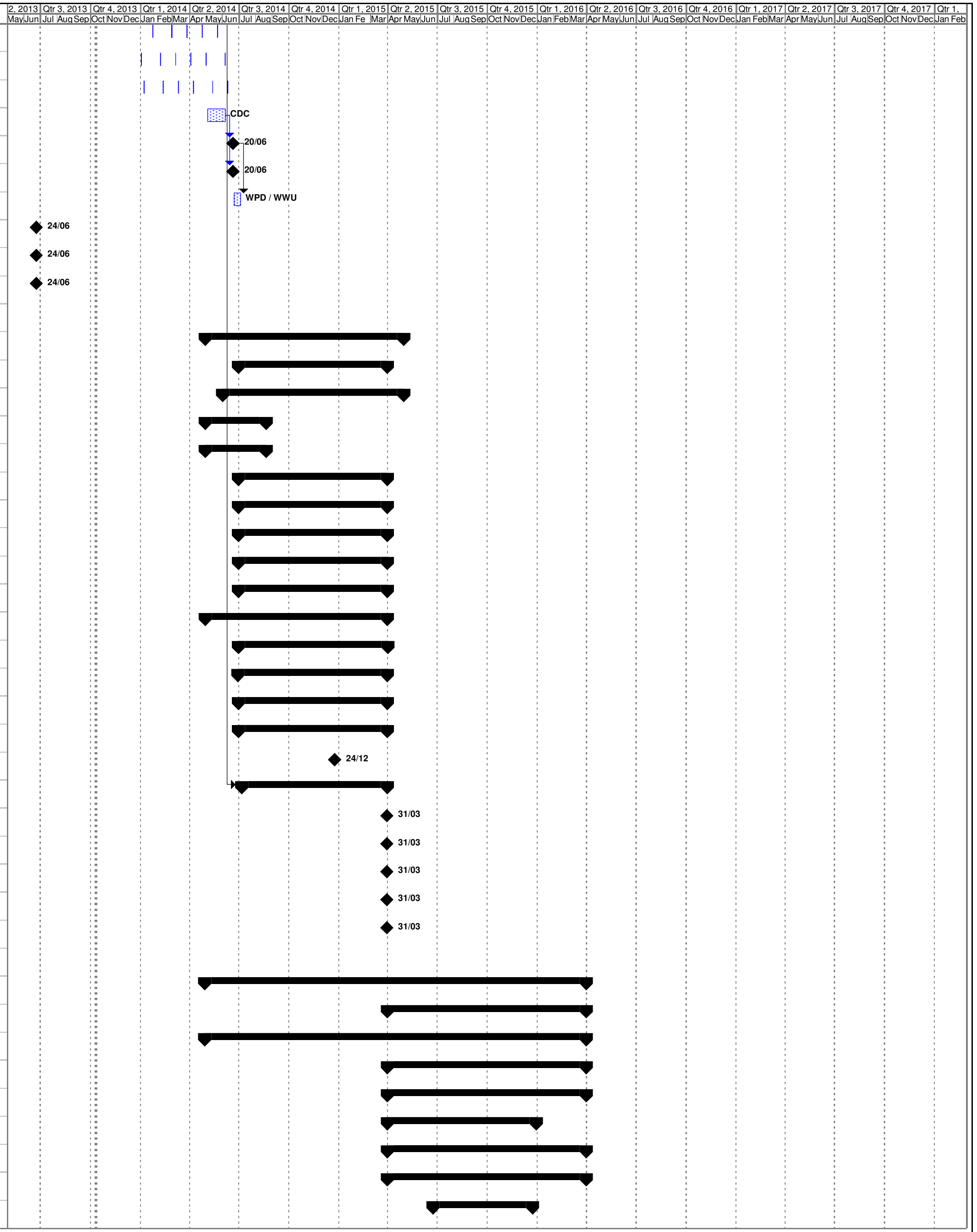
Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

ID		Task Name	Duration	Start	Finish	Predecessors	Resource Names
44		Developing electrical network models	65 days	Tue 01/04/14	Mon 30/06/14		TRL
45		Develop gas network models	65 days	Tue 01/04/14	Mon 30/06/14		TRL
46		**Knowledge Capture, dissemination and training**	**129 days**	**Wed 01/01/14**	**Mon 30/06/14**		**TRL**
47		Development of KC&D plan and methodology	129 days	Wed 01/01/14	Mon 30/06/14		TRL
48		Project communications and awareness	129 days	Wed 01/01/14	Mon 30/06/14		TRL
49		Capturing and recording project knowledge	129 days	Wed 01/01/14	Mon 30/06/14		TRL
50		Dissemination of project learnings and results	129 days	Wed 01/01/14	Mon 30/06/14		TRL
51		Design and delivery of awareness/promotional programmes	129 days	Wed 01/01/14	Mon 30/06/14		TRL
52		**Demand zone: microCHP trial (some parts sub-contracted to WREN)**	**197 days**	**Fri 27/09/13**	**Mon 30/06/14**		**TRL**
53		Trial Design + Participant Recruitment	197 days	Fri 27/09/13	Mon 30/06/14		TRL
54		**CGI Scope**	**121 days**	**Fri 10/01/14**	**Mon 30/06/14**		**CGI**
55		Trial Design + Participant Recruitment	65 days	Tue 01/04/14	Mon 30/06/14		CGI
56		Design activities	88 days	Wed 19/02/14	Fri 20/06/14		CGI
57		Solution architecture diagram	0 days	Mon 05/05/14	Mon 05/05/14		CGI
58		Communications network design	0 days	Mon 02/06/14	Mon 02/06/14		CGI
59		Security design for CGI solution	0 days	Fri 02/05/14	Fri 02/05/14		CGI
60		Hardware - bill of materials	0 days	Fri 10/01/14	Fri 10/01/14		CGI
61		Licences – list of requirements	0 days	Fri 10/01/14	Fri 10/01/14		CGI
62		CGI project plan (MS Project format)	0 days	Fri 14/02/14	Fri 14/02/14		CGI
63		IT/SCADA Requirement	0 days	Fri 25/04/14	Fri 25/04/14		CGI
64		IT/SCADA Architecture	0 days	Fri 16/05/14	Fri 16/05/14		CGI
65		I/O Schedule	0 days	Mon 07/04/14	Mon 07/04/14		CGI
66		Datastore & Analytics Design	0 days	Mon 07/04/14	Mon 07/04/14		CGI
67		SCADA Solution Design	0 days	Tue 20/05/14	Tue 20/05/14		CGI
68		Integration and Test Strategy	0 days	Fri 02/05/14	Fri 02/05/14		CGI
69		Master Test Plan	0 days	Fri 11/04/14	Fri 11/04/14		CGI
70		SIT [test] Specification	0 days	Mon 16/06/14	Mon 16/06/14		CGI
71		NFT [test] Specification	0 days	Mon 16/06/14	Mon 16/06/14		CGI
72		UAT [test] Specification	0 days	Mon 16/06/14	Mon 16/06/14		CGI
73		**Toshiba Scope**	**108 days**	**Wed 01/01/14**	**Fri 30/05/14**		**Toshiba**
74		Study of operational algorithm and how to learn optimum operation	43 days	Wed 01/01/14	Fri 28/02/14		Toshiba
75		Study and difinition of specification, how to operate and control for each equipment	43 days	Wed 01/01/14	Fri 28/02/14		Toshiba
76		Study and definition of transmission data contents and timing for each equipment.	43 days	Wed 01/01/14	Fri 28/02/14		Toshiba
77		Study and definition of required hardware resource and performance.	43 days	Mon 03/03/14	Wed 30/04/14	76	Toshiba
78		Study and definition of communication protocol	43 days	Mon 03/03/14	Wed 30/04/14		Toshiba
79		Study and definition for functions and performance of μEMS.	86 days	Fri 31/01/14	Fri 30/05/14		Toshiba
80		Study and definition of design for operator's display pictures.	86 days	Fri 31/01/14	Fri 30/05/14		Toshiba
81		**WWU Scope**	**0 days**	**Tue 24/06/14**	**Tue 24/06/14**		**WWU**
82		6 monthly report to Ofgem	0 days	Tue 24/06/14	Tue 24/06/14		WWU
83		**WPD Scope**	**0 days**	**Tue 24/06/14**	**Tue 24/06/14**		**WPD**
84		6 monthly report to Ofgem	0 days	Tue 24/06/14	Tue 24/06/14		WPD
85		**Programme Management**	**131 days**	**Fri 03/01/14**	**Fri 04/07/14**		**CDC**
86		**Highlight Reports submitted to CDC (inc risks, issues, costs, outputs)**	**111 days**	**Fri 17/01/14**	**Fri 20/06/14**		**CDC**



Project: NIC Appendix M CEB Delivery Date: Thu 10/10/13	Task	Split	Progress	Milestone	Summary	Project Summary	External Tasks	External Milestone	Deadline

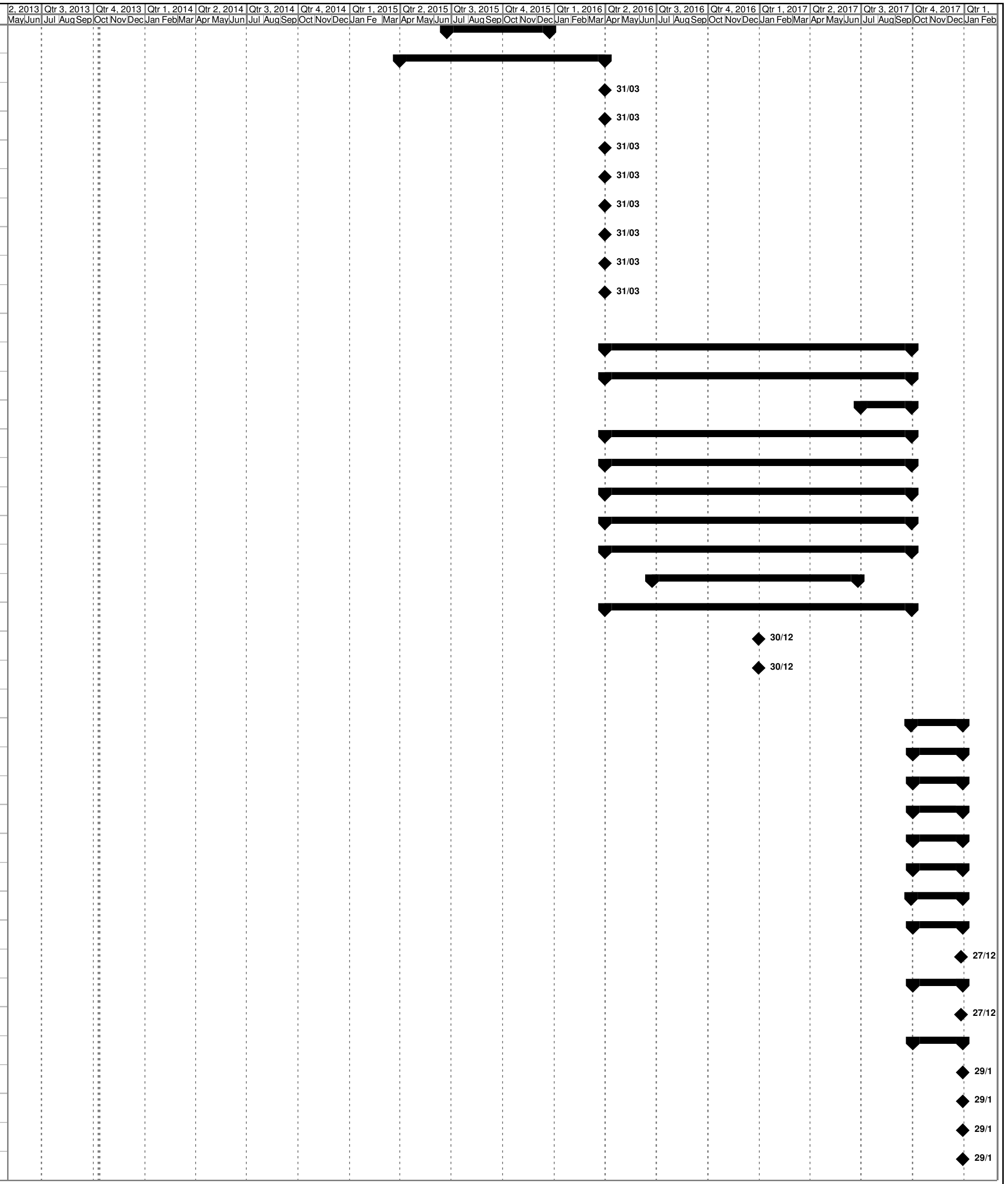
ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
93	**CDC internal review and production of overarching Highlight Report for CEB Prog**	**86 days**	**Fri 24/01/14**	**Fri 23/05/14**		**CDC**
99	**Agenda and reports - Project Mng mtg / Programme Mng Board (Quarterly)**	**111 days**	**Fri 03/01/14**	**Fri 06/06/14**		**CDC**
106	**Project Management mtg / Programme Management mtg (Quarterly)**	**111 days**	**Wed 08/01/14**	**Wed 11/06/14**		**CDC**
113	Assembly of full Gateway Review information	25 days	Mon 05/05/14	Fri 06/06/14		CDC
114	GWR1	0 days	Fri 20/06/14	Fri 20/06/14	113	WPD / WWU
115	SDRC Review	0 days	Fri 20/06/14	Fri 20/06/14	113	WPD / WWU
116	Sign off process within CEB Sponsor / Lead Organisations	10 days	Mon 23/06/14	Fri 04/07/14	114	WPD / WWU
117	**SDRC's for Mobilisation Phase**	**0 days**	**Mon 24/06/13**	**Mon 24/06/13**		
118	Finalise the Delivery Phase Project Plan	0 days	Mon 24/06/13	Mon 24/06/13		CDC
119	Knowledge Strand Paper on Cross Sector Working	0 days	Mon 24/06/13	Mon 24/06/13		TRL
120						
121	**Design Phase**	**261 days**	**Thu 01/05/14**	**Thu 30/04/15**		
122	**Community and stakeholder engagement**	**196 days**	**Tue 01/07/14**	**Tue 31/03/15**		**WREN**
127	**Wind Farm**	**239 days**	**Mon 02/06/14**	**Thu 30/04/15**		**WREN**
132	**Control Systems**	**80 days**	**Thu 01/05/14**	**Wed 20/08/14**		**Toshiba**
137	**Gas Injection**	**80 days**	**Thu 01/05/14**	**Wed 20/08/14**		**ITM**
142	**Community and stakeholder engagement**	**196 days**	**Tue 01/07/14**	**Tue 31/03/15**		**WREN**
147	**Generation project**	**196 days**	**Tue 01/07/14**	**Tue 31/03/15**		**WREN**
153	**Commercial CHP**	**196 days**	**Tue 01/07/14**	**Tue 31/03/15**		**WREN**
156	**Domestic CHP**	**196 days**	**Tue 01/07/14**	**Tue 31/03/15**		**WREN**
160	**Electroliser and gas engine**	**196 days**	**Tue 01/07/14**	**Tue 31/03/15**		**WREN**
162	**ITM Scope**	**239 days**	**Thu 01/05/14**	**Tue 31/03/15**		
170	**TRL Scope**	**197 days**	**Tue 01/07/14**	**Wed 01/04/15**		
187	**CGI Scope**	**197 days**	**Mon 30/06/14**	**Tue 31/03/15**		**CGI**
200	**Toshiba Scope**	**196 days**	**Tue 01/07/14**	**Tue 31/03/15**		**Toshiba**
208	**WWU Scope**	**196 days**	**Tue 01/07/14**	**Tue 31/03/15**		**WWU**
212	**WPD Scope**	**0 days**	**Wed 24/12/14**	**Wed 24/12/14**		**WPD**
214	**Programme Management**	**192 days**	**Mon 07/07/14**	**Tue 31/03/15**	**85**	**CDC**
223	**SDRC's for Design Phase**	**0 days**	**Tue 31/03/15**	**Tue 31/03/15**		
224	Trial Design	0 days	Tue 31/03/15	Tue 31/03/15		TRL
225	Complete logical control design	0 days	Tue 31/03/15	Tue 31/03/15		Toshiba
226	IT architecture and System Design	0 days	Tue 31/03/15	Tue 31/03/15		CGI
227	Report on application of business best practice to the D&B of site infrastructure electrolys	0 days	Tue 31/03/15	Tue 31/03/15		ITM
228						
229	**Build Phase**	**502 days**	**Wed 30/04/14**	**Thu 31/03/16**		
230	**Community and stakeholder engagement**	**262 days**	**Wed 01/04/15**	**Thu 31/03/16**		**WREN**
235	**Generation project**	**502 days**	**Wed 30/04/14**	**Thu 31/03/16**		**WREN**
243	**Commercial CHP**	**262 days**	**Wed 01/04/15**	**Thu 31/03/16**		**WREN**
245	**Domestic CHP**	**262 days**	**Wed 01/04/15**	**Thu 31/03/16**		**WREN**
248	**ITM Scope**	**196 days**	**Wed 01/04/15**	**Wed 30/12/15**		**ITM**
254	**TRL Scope**	**262 days**	**Wed 01/04/15**	**Thu 31/03/16**		**TRL**
267	**Toshiba Scope**	**262 days**	**Wed 01/04/15**	**Thu 31/03/16**		**Toshiba**
276	**WWU Scope**	**131 days**	**Wed 24/06/15**	**Thu 24/12/15**		**WWU**

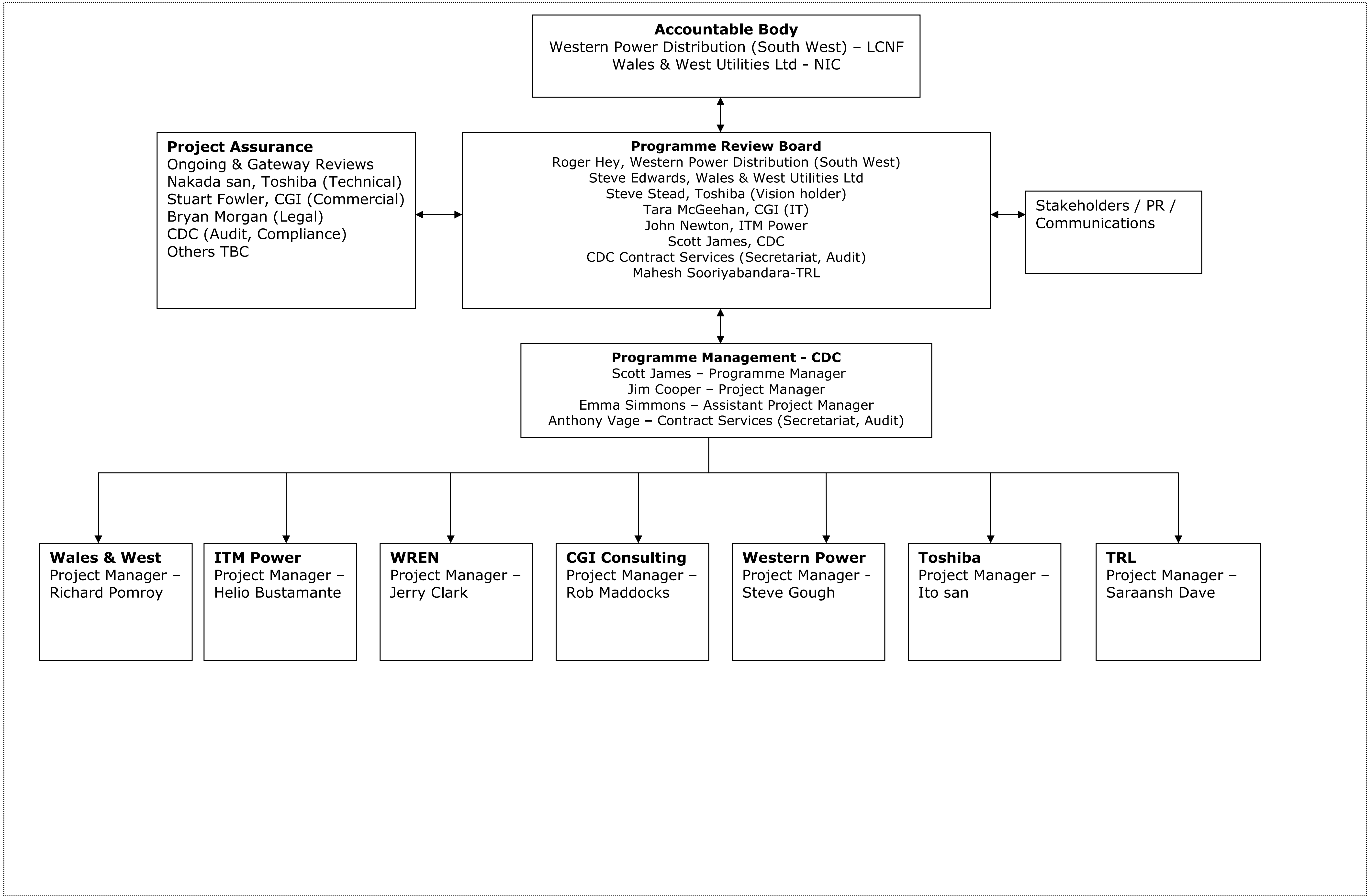


Project: NIC Appendix M CEB Delivery
Date: Thu 10/10/13

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
279	**WPD Scope**	**131 days**	**Wed 24/06/15**	**Thu 24/12/15**		**WPD**
282	**Programme Management**	**262 days**	**Wed 01/04/15**	**Thu 31/03/16**		**CDC**
293	**SDRC's for Build Phase**	**0 days**	**Thu 31/03/16**	**Thu 31/03/16**		
294	Acquire compound	0 days	Thu 31/03/16	Thu 31/03/16		WPD
295	Gas Engine passes Factory Acceptance Test	0 days	Thu 31/03/16	Thu 31/03/16		ITM
296	Electrolyser passes FAT	0 days	Thu 31/03/16	Thu 31/03/16		ITM
297	Gas Mixing & Injection passes FAT	0 days	Thu 31/03/16	Thu 31/03/16		ITM
298	Local Comms / PR Event on deliverables / benefits	0 days	Thu 31/03/16	Thu 31/03/16		WREN
299	Sign Network Entry Agreement	0 days	Thu 31/03/16	Thu 31/03/16		WWU
300	Report on readiness to commence trials	0 days	Thu 31/03/16	Thu 31/03/16		CDC
301						
302	**Trials**	**391 days**	**Fri 01/04/16**	**Fri 29/09/17**		
303	**Community and stakeholder engagement**	**391 days**	**Fri 01/04/16**	**Fri 29/09/17**		**WREN**
308	**Generation project**	**65 days**	**Fri 30/06/17**	**Fri 29/09/17**		**WREN**
311	**Commercial CHP**	**391 days**	**Fri 01/04/16**	**Fri 29/09/17**		**WREN**
313	**Domestic CHP**	**391 days**	**Fri 01/04/16**	**Fri 29/09/17**		**WREN**
315	**TRL Scope**	**391 days**	**Fri 01/04/16**	**Fri 29/09/17**		**TRL**
334	**Toshiba Scope**	**391 days**	**Fri 01/04/16**	**Fri 29/09/17**		**Toshiba**
336	**WWU Scope**	**391 days**	**Fri 01/04/16**	**Fri 29/09/17**		**WWU**
347	**WPD Scope**	**261 days**	**Fri 24/06/16**	**Mon 26/06/17**		**WPD**
351	**Programme Management**	**391 days**	**Fri 01/04/16**	**Fri 29/09/17**		**CDC**
362	**SDRC's for Trials Phase**	**0 days**	**Fri 30/12/16**	**Fri 30/12/16**		
363	Mid trial dissemination event - local event	0 days	Fri 30/12/16	Fri 30/12/16		WREN
364						
365	**Consolidate and Share**	**66 days**	**Fri 29/09/17**	**Fri 29/12/17**		
366	**Community and stakeholder engagement**	**65 days**	**Mon 02/10/17**	**Fri 29/12/17**		**WREN**
371	**Generation project**	**65 days**	**Mon 02/10/17**	**Fri 29/12/17**		**WREN**
373	**Commercial CHP**	**65 days**	**Mon 02/10/17**	**Fri 29/12/17**		**WREN**
376	**Domestic CHP**	**65 days**	**Mon 02/10/17**	**Fri 29/12/17**		**WREN**
379	**ITM Scope**	**65 days**	**Mon 02/10/17**	**Fri 29/12/17**		**WREN**
381	**TRL Scope**	**66 days**	**Fri 29/09/17**	**Fri 29/12/17**		**TRL**
398	**Toshiba Scope**	**65 days**	**Mon 02/10/17**	**Fri 29/12/17**		**Toshiba**
400	**WWU Scope**	**0 days**	**Wed 27/12/17**	**Wed 27/12/17**		**WWU**
402	**Decommission network modifications**	**65 days**	**Mon 02/10/17**	**Fri 29/12/17**		**WWU**
405	**WPD Scope**	**0 days**	**Wed 27/12/17**	**Wed 27/12/17**		**WPD**
407	**Programme Management**	**65 days**	**Mon 02/10/17**	**Fri 29/12/17**		**CDC**
419	**SDRC's for Consolidate & Share Phase**	**0 days**	**Fri 29/12/17**	**Fri 29/12/17**		
420	Report on the Commercial Models	0 days	Fri 29/12/17	Fri 29/12/17		TRL
421	Report on the community engagement approach	0 days	Fri 29/12/17	Fri 29/12/17		WREN
422	Agree ongoing commercial arrangements	0 days	Fri 29/12/17	Fri 29/12/17		Toshiba




Accountable Body
Western Power Distribution (South West) – LCNF
Wales & West Utilities Ltd - NIC
Project Assurance
Ongoing & Gateway Reviews
Nakada san, Toshiba (Technical)
Stuart Fowler, CGI (Commercial)
Bryan Morgan (Legal)
CDC (Audit, Compliance)
Others TBC
Programme Review Board
Roger Hey, Western Power Distribution (South West)
Steve Edwards, Wales & West Utilities Ltd
Steve Stead, Toshiba (Vision holder)
Tara McGeehan, CGI (IT)
John Newton, ITM Power
Scott James, CDC
CDC Contract Services (Secretariat, Audit)
Mahesh Sooriyabandara-TRL
Stakeholders / PR / Communications
Programme Management - CDC
Scott James – Programme Manager
Jim Cooper – Project Manager
Emma Simmons – Assistant Project Manager
Anthony Vage – Contract Services (Secretariat, Audit)
Wales & West
Project Manager – Richard Pomroy
ITM Power
Project Manager – Helio Bustamante
WREN
Project Manager – Jerry Clark
CGI Consulting
Project Manager – Rob Maddocks
Western Power
Project Manager - Steve Gough
Toshiba
Project Manager – Ito san
TRL
Project Manager – Saraansh Dave

Programme Name: Clean Energy Balance Bid									Programme Manager: CDC								
					High Level Definition										Cause	Effect	
Workstream	Risk Ref. No.	Risk Status	Owner	"There is a risk that..."	Impact	Probability	Proximity	Rating	Movement	Raised by	Raised on	Target Date	Last Updated	"...because of..."	"...leading to..."	Mitigation Action Plan	Issue ID
Dropdown list	Next No.	Dropdown list	Responsible for mgmnt	Details of the Risk	See Table below Score 1-5	See Table below Score 1-5	See Table below Score 1-5	Auto Calculated	If risk has changed to a higher / lower priority	Who raised the Risk?	when was it raised?	Target Date for Resolution	Last date the risk was updated	What will Trigger the Risk?	What will happen if it occurs?	How will this Risk be avoided?	ID of Issue Risk has transferred to
	R001	Closed	CDC	Governance arrangements unclear or inappropriate to deliver the bid to a high standard.	4	3	4	**48**		CDC	16/05/2013	07/06/2013		Partners not formally committed to the process in agreed timescales.	Potential to undermine the bid.	Clear legal partnership formalised with all parties.	
	R002	Closed	CDC	Failure to engage community in the project.	5	3	4	**60**		CDC	16/05/2013	07/06/2013		Partnership not adequately addressing tangible community buy-in to the process.	Potential to undermine the bid, as per the previous submission.	Ensure adequate community buy-in to the process, through the partnership agreement.	
	R003		CDC	Failure to hit deadlines set by CDC for bid submission, due to late contributions of material from partners.	4	3	5	**60**		CDC	16/05/2013	21/06/2013		Deadline missed.	Delaying the pre-submission review. Potential to reduce quality and viability of the bid.	Adherence to programme and ongoing liaison with bid management team.	
	R004	Closed	CDC	Ensuring that all parties are clear of the nessary responabilties required in the develary phase.	5	4	3	**60**		WPD	22/05/2013	07/06/2013		Unclearly defined responsabilties in contracts and poor comincation between partners	Re-neogatioan of contracts and inopriprate input to the bid	Clear and stingent contractual framework	
	R005		CDC	Stakeholders' perceptions of the programme change	5	1	4	**20**		JC	09/07/2013	12/07/2013		Change in stakeholders' views	Potential to undermine the programme and delivery	Constant communication by team and confirmation of targets and SDRC throughout the programme delivery phase.	
	R006		CDC	Overal programme cost and/or scope could creep	4	1	3	**12**		JC	09/07/2013	17/07/2013		unexpected hike in capital item cost	Impact on budget will be negative; requre re-appraisal possible virement. Refinement?	Contant review of market prices and communication with potential suppliers.	
	R007		CDC	Stakeholder may withdraw from programme or have oversold their project solution	5	1	5	**25**		JC	09/07/2013	12/07/2013		It becomes apparent to programme partners that one stakeholder is withdrawing or is failing to deliver on target deliverables and SDRC.	Significant impact on deliverables, key components or link in chain could be missing and required to be re-procured with consequential delays.	Constant communication by team and confirmation of targets, SDRC and resourcing throughout the programme delivery phase. Early contracutal tie in of all parties.	
	R008		CDC	Programme delivery team does not have the required knowledge and skills to deliver the programme	5	1	5	**25**		JC	09/07/2013	12/07/2013		CDC is failing to deliver on its target deliverables and SDRC.	Significant impact on deliverables, key components may be undeliverable or delayed whilst skills are reinstated.	Constant communication by team and confirmation of available personnel and their skill sets throughout the programme delivery phase.	
	R009		CDC	Insufficient CDC resource for programme management delivery	5	2	5	**50**		JC	09/07/2013	12/07/2013		CDC is failing to deliver on its target deliverables and SDRC.	Inputs from this stakeholder will be inadequate, jeopardising programme delivery.	Constant communication by team and confirmation of available personnel and their skill sets throughout the programme delivery phase.	
	R010		CGI	IT Costs are too high	5	2	5	**50**		SS	07/05/2013	01/06/2013		Insufficient detail on requirements. Over specified solution.	Lose both LCNF and NIC bids	Provide full detail on interfaces to be supported. Provide as much info as possible on data requirements. Provide as much detail as possible on level of support required. Retain a pragmatic approach to solution. This is a four year trial.	
	R011		CGI	Insufficient CGI resource for IT support delivery	5	1	5	**25**		JC	09/07/2013	12/07/2013		CGI is failing to deliver on its target deliverables and SDRC.	Inputs from this stakeholder will be inadequate, jeopardising programme delivery.	Constant communication by team and confirmation of available personnel and their skill sets throughout the programme delivery phase.	
	R012		ITM Power	Insufficient ITM Power resource for programme delivery	5	1	5	**25**		JC	09/07/2013	12/07/2013		ITM is failing to deliver on its target deliverables and SDRC.	Inputs from this stakeholder will be inadequate, jeopardising programme delivery.	Constant communication by team and confirmation of available personnel and their skill sets throughout the programme delivery phase.	
	R013	Closed	ITM Power	Determining specification of gas engine based on availablity of sufficient fuel (hydrogen)	4	3	5	**60**		JN	07/06/2013	30/06/2013		Findings of constraint modelling and commercial model work to be completed (underway)	We will need to find alternative constrained generation or buy in non-constrained electricity necessary to produce sufficient fuel	Complete constraint modelling and commercial model work as soon as possible. Identify alternative generators and/or agree business case to buy non-constrained electricity	
	R014	Closed	ITM Power	Agreeing specification and cost of gas mixing/injection equipment	3	3	5	**45**		JN	07/06/2013	12/07/2013		Lack of technical input from W&WU re: Wadebridge MP network plus any unknown technical/regulatory issues with Wadebridge MP network at proposed injection site	Uncertainty around technical solution to gas mixing/injection	Complete analysis of MP infrastructure in proximity to proposed gas injection site	
	R015		ITM Power	NIC business case doesn't stack up	5	3	5	**75**		JN	07/062013	30/06/2013		Insufficient timeline considered.	Lose NIC bid; LCNF alone becomes non-viable.	A longer-term view on the business case needs to be adopted given that without a low-carbon gas substitute, current predictions show 40% of gas customers migrating to electricity by 2050. Short-term planning horizons will only include the start of this migration. However actions are required now to protect this asset investment, hence a longer-term business case horizon is required to make this case	
	R016		ITM Power	Proposed payment sechedule in CA	4	3	5	**60**		JN	07/06/2013	30/06/2013		Impact the build timetable for electrolyser & storage hardware during delivery phase	Affect build of hardware during delivery phase	Review proposed payment schedule from Ofgem and how this is refelcted in CA	

Programme Name: Clean Energy Balance Bid | **Programme Manager: CDC**

					High Level Definition										Cause	Effect	
Workstream	**Risk Ref. No.**	**Risk Status**	**Owner**	**"There is a risk that..."**	**Impact**	**Probability**	**Proximity**	**Rating**	**Movement**	**Raised by**	**Raised on**	**Target Date**	**Last Updated**	**"...because of..."**	**"...leading to..."**	**Mitigation Action Plan**	**Issue ID**
	R017		ITM Power	Current constraint on electricity network is insufficient to justify capital cost of electrolyser system - see assessor feedback re: costs from 2012 PATHS proposal	5	3	5	**75**		JN	07/06/2013	12/07/2013		Findings of constraint modelling and commercial model work to be completed (underway)	We will need to find alternative constrained generation or buy in non-constrained electricity	Given the financial risks associated with connecting a constrained generator with commercial funding it is not possible to connect a fully constrained generator for the trial. However the trial will simulate more severe constraint levels and demonstrate the viability of commercially connecting generation under these conditions, hence providing the pathway for future commercial projects.	
	R018		ITM Power	Gas Engine fails to pass Factory Acceptance Test	2	1	3	**6**		JN	12/07/2013	31/03/2016		Engine failes FAT	Repeat FAT	Follow established processes including QA and QC procudures during build phase	
	R019		ITM Power	Electrolyser fails to pass FAT	2	2	3	**12**		JN	12/07/2013	31/03/2016		Electrolyser fails FAT	Repeat FAT	Follow established processes including QA and QC procedures during build phase	
	R020		ITM Power	Gas Mixing & Injection fails to pass FAT	2	2	3	**12**		JN	12/07/2013	31/03/2016		Gas mixing/injection fails FAT	Repeat FAT	Follow established processes including QA and QC procudures during build phase	
	R021		ITM Power	Commodity price increases in electrolyser stack components (SS, Ni, Ti, Pt, Ir)	3	2	3	**18**		JN	12/07/2013	15/07/2013		Commodity price volatility	Price increase	Forward price increases factored into electrolyser costs at bid stage	
	R022		ITM Power	Report on application of business best practice to the D&B of site infrastructure electrolyser / hydrogen injection	3	2	3	**18**		JN	12/07/2013	31/03/2015		Planning application	Delay to receiveing necessary consents	Utilise knowledge gained from other UK and European projects	
	R023		Toshiba	Risk that programme financial position is not clear for the bid, or misrepresents the scheme to one or all partners making the programme undeliverable or confusing for partners / funders	4	5	5	**100**		CDC	16/05/2013	21/06/2013		Poor presentation of programme costs and funding.	Potential to impact on funding application.	Appoint dedicated lead programme accountant / finance role to support bid process. Preferably from the lead body.	
	R024		Toshiba	There is a risk that the commercial position of the programme is not agreed between all parties, thereby impacting on an agreed scope and financial position which will in turn impede the development of the bid and funding opportunities	5	3	5	**75**		CDC	16/05/2013	07/06/2013		No agreement on the commercial position. One or more parties not supporting the structure of the programme.	Programme will not progress at this point for the immediate funding deadlines.	Dedicated workshops with a nominated member of each team to develop and agree the commercial structure. To be led by Toshiba as lead partner.	
	R025	Closed	Toshiba	There is a risk that we do not procure the right resources or they are inappropriately procured against relevant legislation.	4	2	4	**32**		CDC	16/05/2013	07/06/2013		Insufficient analysis of compliance required. Inappropriate procurement process deployed.	Non-appproval or clawback of funding. Sub-optimal input from IT Partner.	Clear interpretation and understanding of legislation and robust procurement process implemented.	
	R026		Toshiba	Clear understanding of what the exisiting systems are capable of currently and what needs to be developed further	3	3	4	**36**		WPD	22/05/2013	07/06/2013		Poor comunication between programme bid team and deilvery team	The use cases and intial design scoping will not be approiate	Continual commuication between technical delivery teams and bid preparation team. Clear definition of scope of work within contracts at outset.	
	R027		Toshiba	LCNF Business Case doesn't stack up	5	3	5	**75**		SS	07/05/2013	01/06/2013		Insufficient commercial options considered	Lose whole bid	To address this, the strand has been broken down into a number of discrete Methods, each of which may be viable in its own right. Hence the strand is not simply dependent on the viability of the end to end solution but may be justified upon the success of one or more of the Methods being trialled. Initially modelling has demonstrated the viability of each of these AND the full end-to-end solution.	
	R028		Toshiba	Insufficient Toshiba resource for programme delivery	5	1	5	**25**		SCP3	24/05/2013	12/07/2013		Toshiba is failing to deliver on its target deliverables and SDRC.	Inputs from this stakeholder will be inadequate, jeopardising programme delivery.	Constant communication by team and confirmation of available personnel and their skill sets throughout the programme delivery phase. Key resources identified and allocated as part of the bid process.	
	R029	Closed	TRL	The curtailment model is not ready in time for WREN to make a commitment to the windfarm	4	3	4	**48**		WPD	22/05/2013	07/06/2013		TRL/Cardiff Uni not completing the analsys in time	WREN will not be able to to comfirm investment for the wind farm extending the connection data	TRL to manage Cardiff Uni closely and WPD to support both with data required	
	R030		TRL	System does not support required learning	4	2	4	**32**		SS	07/05/2013	01/06/2013		Lack of clarity at the outset of what learning is required	SDRC and targets around dissemination of learning and embedding good practice will be lost with consequential impacts on stage payments.	Develop detail use cases at the outset and map to system requirements	
	R031		TRL	Insufficient TRL resource for capture of programme learning & dissemination	4	1	3	**12**		JC	09/07/2013	12/07/2013		TRL is failing to deliver on its target deliverables and SDRC.	Inputs from this stakeholder will be inadequate, jeopardising programme delivery.	Constant communication by team and confirmation of available personnel and their skill sets throughout the programme delivery phase.	
	R032	Closed	WPD	Lack of resource to support bid preperation	4	4	4	**64**		WPD	22/05/2013	07/06/2013		Too many ongoing programmes of key WPD representaives	Late summison of critcal feedback	Bringing in extra resoure	
	R033		WPD/Toshiba	Cost of high cost items are significantly higher than anticipated	5	2	5	**50**		JC	09/07/2013	12/07/2013		Quotations received as a response to procurement activity.	Budget lines will be inadequate for high cost items, jeopardising programme unless re-procured or re-negotiated.	Contant review of market prices and communication with potential suppliers.	
	R034		WPD	Insufficient WPD resource for programme delivery	5	1	5	**25**		SCP3	24/05/2013	12/07/2013		WPD is failing to deliver on its target deliverables and SDRC.	Inputs from this stakeholder will be inadequate, jeopardising programme delivery.	Constant communication by team and confirmation of available personnel and their skill sets throughout the programme delivery phase.	

Programme Name: Clean Energy Balance Bid						Programme Manager: CDC											
					High Level Definition										Cause	Effect	
Workstream	Risk Ref. No.	Risk Status	Owner	"There is a risk that..."	Impact	Probability	Proximity	Rating	Movement	Raised by	Raised on	Target Date	Last Updated	"...because of..."	"...leading to..."	Mitigation Action Plan	Issue ID
	R035		WREN	Insufficient WREN resource for programme delivery	5	3	5	**75**		JC	09/07/2013	12/07/2013		WREN is failing to deliver on its target deliverables and SDRC.	Inputs from this stakeholder will be inadequate, jeopardising programme delivery.	Constant communication by team and confirmation of available personnel and their skill sets throughout the programme delivery phase. WREN to employ additional project management capacity if needed	
	R036		WREN	Technical / planning issue identified which kills wind project during bid approval process	4	3	4	**48**		WREN	Project inception	31/10/2013		Findings of feasibility work to be completed	We will need to find alternative constrained generation	Complete feasibility work as soon as possible. Identify alternative generators (e.g. new community solar project in area of wind project) and develop initial trial based on St Breock data, expanding out into generator control once project generator is in place.	
	R037		WREN/All	Wind project and/or details of CEB go public prior to planned release leading to backlash against project and/or programme (because of potentially controversial nature of both the wind and hydrogen elements)	5	2	5	**50**		WREN	16/05/2013	31/10/2013		Failure to keep project details confidential until planned release by CEB programme team member, colleague or sub-contractor	CEB will be put in the position of having to deal reactively with opposition, which could undermine public support for CEB and WREN and create a PR problem for other companies involved in the programme	All team members and sub-contractors need to be aware of risk Develop and maintain up to date reactive statement WREN to be consulted on any information going public CDC to be responsible for control of information going public	
	R038		WREN	Community consultation outcomes negative	4	2	4	**32**		JC	09/07/2013	31/10/2013		Insufficient resource to cover in-house and 3rd party costs for additional to BAU work involved	Wind, CHP and community engagement elements of the bid will be poor which could impact on viability of programme	WREN will lead early and comprehensive consultations with the local community to explain the design, scope and benefits of the programme.	
	R039		WREN	Constraints modelling reveals wind project will not be economically viable or financiable with constraint	4	2	5	**40**		WREN	Project inception	12/07/2013		Findings of constraint modelling and commercial model work to be completed (underway)	We will need to find alternative constrained generation	Preliminary modelling already undertaken which indicates viability. Complete detailed constraint modelling and commercial model work as soon as possible. Identify alternative generators (e.g. new community solar project in area of wind project and/or co-operation with REG to create false constraint around St Breock wind repower)	
	R040		WREN	Source and type of generation unresolved (Wind, solar, installed capacity, location)	5	2	5	**50**		JC	10/07/2013	31/10/2013		Lack of agreement on generation type, scale and location.	Generation capacity will be a critical missing link an the programme will require modification through simulation.	Feasibility work on key issues for the wind project is being carried out now. If an unresolvable issue is identified, WREN will seek to develop similar scale solar project in the area. If no feasible site can be secured, WREN will approach other generators in the area to be involved in the programme.	
	R041		WREN	Inability to obtain required commercial-CHP in programme area	4	3	4	**48**		JC	10/07/2013	12/07/2013		Failure to sign up sufficient candidate properties	Demand Zone trial will not have statistically significant number of CHP units and hence will be at risk	WREN is engaging a number of potential commercial CHP hosts in the town already, and will continue to do so until agreements have been secured which will provide sufficient capacity for the programme. Inconvenience allowance included in bid. Spread risk of failure across both commercial and domestic CHP units.	
	R042		WREN?	Inability to obtain required micro-CHP in programme area	4	3	4	**48**		JC	10/07/2013	12/07/2013		Failure to sign up sufficient candidate properties	Demand Zone trial will not have statistically significant number of CHP units and hence will be at risk	WREN will lead discussions and negotiations with RSLs, local owner occupiers and programme partners to secure sufficient numbers of units to achieve SDRC and programme viability. Provider discounts agreed for micro CHP and inconvenience allowance included in bid. Spread risk of failure across both commercial and domestic CHP units.	
	R043		WWU	Gas system connection problems occur	5	2	5	**50**		JC	10/06/2013	31/07/2013		Inability to find connection solution	Failure to connect system components, inability to disperse hydrogen	Appraisal of the local infrastructure, inter-connectivity requirements and close liaison between WWU and ITM Power.	
	R044a		WWU	Inability to achieve required exemption for hydrogen injection	4	1	4	**16**		JC	10/06/2013	31/03/2016		Confirmation from regulator that propsed level of injection is disallowed	Injection of Hydrogen at the level required for project viability will be dis-allowed leaving only the option of conversion back to electricity.	Early discussions and detailed proposals with regulator by WWU with support from ITM Power. Inclusion of HS Labs in the project to have an early indication of problems. Inclusion of Gas Engine in Generation Zone to ensure LCNF project is not reliant on gas inject.	
	R044b		WWU	Requirement to conduct appliance inspections	1	4	2	**8**		RP	07/10/2013	30/09/2016		Risk assessment demonstrates that inspections are requried to mitigate risk	Risk of non compliant appliances	Appliance inspection programme required (requirement in project plan with costings so low impact)	
	R044c		WWU	Not able to gain access to required premises to conduct appliance inspections if required	4	3	2	**24**		RP	07/10/2013	30/09/2016		Unresolved access problems	Inability to inspect appliances and hence unable to inject more than 0.1% hydrogen	Short term limit project to 0.1% hydrogen; longer term initiate programme to do further work to eliminate need to inspect appliances	
	R045		WWU	Insufficient WWU resource for programme delivery	5	2	5	**50**		JC	09/07/2013	12/07/2013		WWU is failing to deliver on its target deliverables and SDRC.	Inputs from this stakeholder will be inadequate, jeopardising programme delivery.	Constant communication by team and confirmation of available personnel and their skill sets throughout the programme delivery phase.	
	R046		WPD & WWU	Inability and/or delay in securing necessary consents for building compounds for electrolyser/hydrogen store, gas engine & gas mixing/injection	5	3	4	**60**		JN	12/07/2013	01/06/2014		Planning application	Delay to building compound(s)	Identify multiple/alternative sites for compound(s), earliest possible engagement with landowner(s) and appropriate planning authorities and local stakeholders who might raise objections to application(s)	
	R047		WPD & WWU	Access to site for delivery and installation of electrolyser/hydrogen store, gas engine & gas mixing/injection	4	2	3	**24**		JN	12/07/2013	01/12/2014		Access to site	Access to site will require upgrading (widening roads and access points to accept large vehicles)	Include any necessary upgrades into the planning application	

Programme Name: Clean Energy Balance Bid						Programme Manager: CDC											
					High Level Definition										Cause	Effect	
Workstream	Risk Ref. No.	Risk Status	Owner	"There is a risk that..."	Impact	Probability	Proximity	Rating	Movement	Raised by	Raised on	Target Date	Last Updated	"...because of..."	"...leading to..."	Mitigation Action Plan	Issue ID
	R048		WPD & WWU	Ownership of equipment bought/built under the programme	2	3	4	**24**		JN	12/07/2013	01/10/2013		Failure to agree which party takes title to equipment	Potential impact on what happens to assets having 'residual' value post-programme	WPD and WWU decide who owns (take title and benefit) for the duration of the programme. Ownership post programme subject of a seperate discussion based on programme outcome.	
	R049		WREN	WREN Wind Farm does not get planning permission/complete on time	5	3	5	**75**		SF	16/07/2013	01/10/2013		Wind farm fails to get planning permission	Alternative generation solution	The programme will begin working with data from the St Breock wind farm while the WREN wind farm is under development. This will allow many of the trials to commence without the need/ability to physically constrain the wind farm output. Once the WREN wind farm is completed then this will be transferred into the trial allowing the full range of trial operations to be undertaken.If the WREN wind farm fails planning, then an alternative solar farm will be pursued. This can complete in a much shorter time horizon and would allow the constraint model to work in reverse, i.e. controllable PV balancing against St Breock wind.	

COPY ABOVE LINE TO INSERT MORE ENTRIES

IMPACT	PROBABILITY	PROXIMITY	Movement
5 – Inability to deliver, business case/objective not viable **4 –** Substantial Delay, key deliverables not met, significant increase in time/cost **3 –** Delay, increased cost in excess of tolerance **2 –** Small Delay, small increased cost but absorbable **1 –** Insignificant changes, re-planning may be required	**5** – Certain **4** – More likely to occur than not **3** – 50/50 chance of occuring **2** – Less likely to occur **1** – Very unlikely to occur	**5 –** Imminent (Award - Mobilisation) **4 –** Likely to be near future (<1year) **3 –** Mid to short term (1-2 years) **2 –** Mid to long term (2-3 years) **1 –** Far in the future (4 years)	⇧ ⇩ ⇔

Appendix L   CEB Contingency Plan

With programmes of this size there are always risks and issues, and it is those risks and issues which manifest themselves in the need for contingency. Based on our experience of managing Low Carbon Projects as well as CDC's significant expertise in managing infrastructure programmes of this size, we have adopted a robust, but pragmatic approach to managing risk and therefore our approach to contingency as part of the wider governance arrangements.

From the outset we have worked to ensure that there is an agreed governance structure in place and this structure will support the proactive management of the risks within this programme, thereby giving our stakeholders confidence that the programme is under control and that we are working to ensure that contingency is only used when it is necessary and that it is at the level most appropriate for the project being delivered.

Our contingencies are self-contained within each partner's budgetary costs for their projects and are based on their individual skill and expertise to derive the most appropriate level of contingency.

There are the following key risk & contingency areas for this programme:

Area	***Risk Level***	***%***
Labour	Low to Medium	7.5-10%
IT integration	Medium to High	10-15%
Equipment/commodity risk	Medium to High	10-15%
Commercial model	Medium	10%
Regulatory	Low	5%
Partner withdrawal	Low	5%

It is important though to recognise the ones that have the potential to place the programme most at risk

This contingency plan has been written for the 8 most significant risks on the Risk Register. All risks will be continually monitored and appropriate high risk information will be referred to the Programme Review Board. Below are details of how we will mitigate against significant risks becoming an issue and the contingency plans.

R015:
NIC business case doesn't justify the expenditure
Mitigation
A longer-term view on the business case needs to be adopted given that without a low-carbon gas substitute, current predictions show 40% of gas customers migrating to electricity by 2050. Short-term planning horizons will only include the start of this migration. However actions are required now to protect this asset investment, hence a longer-term business case horizon is required to make this case

R017:
Current constraint on electricity network is insufficient to justify capital cost of electrolyser system - see assessor feedback re: costs from 2012 PATHS proposal
Mitigation

Given the financial risks associated with connecting a constrained generator with commercial funding it is not possible to connect a fully constrained generator for the trial. However the trial will simulate more severe constraint levels and demonstrate the viability of commercially connecting generation under these conditions, hence providing the pathway for future commercial projects.

R021:
Commodity price increases in electrolyser stack components
Mitigation
Forward price increases factored into electrolyser costs at bid stage.

R023:
Risk that programme financial position is not clear for the bid, or misrepresents the scheme to one or all partners making the programme undeliverable or confusing for partners / funders
Mitigation
Appoint dedicated lead programme accountant / finance role to support bid process, preferably from the lead body.

R024:
There is a risk that the commercial position of the programme is not agreed between all parties, thereby impacting on an agreed scope and financial position which will in turn impede the development of the bid and funding opportunities.
Mitigation
Dedicated workshops with a nominated member of each team to develop and agree the commercial structure. To be led by Toshiba as lead partner.

R027:
The LCNF Business Case doesn't justify the expenditure
Mitigation
To address this, the strand has been broken down into a number of discrete Methods, each of which may be viable in its own right. Hence the strand is not simply dependent on the viability of the end to end solution but may be justified upon the success of one or more of the Methods being trialled. Initially modelling has demonstrated the viability of each of these AND the full end-to-end solution.

R035:
Insufficient WREN resource for programme delivery
Mitigation
Constant communication by team and confirmation of available personnel and their skill sets throughout the programme delivery phase. WREN to employ additional project management capacity if needed

R049:
WREN Wind Farm does not get planning permission/complete on time
Mitigation
The programme will begin working with data from the St Breock wind farm while the WREN wind farm is under development. This will allow many of the trials to commence without the need/ability to physically constrain the wind farm output. Once the WREN wind farm is completed then this will be transferred into the trial allowing the full range of trial operations to be undertaken. If the WREN wind farm fails planning, then an alternative solar farm will be pursued. This can complete in a much shorter time horizon and would allow the constraint model to work in reverse, i.e. controllable PV balancing against St Breock wind.

Appendix M Cost Benefit Analysis

Methods	Wind (MW)	PV (MW)	ELY (MW)	Firm (MW)	Gas Price (£/ MWh)	Thrash ELY (Y/N)	ELY Util	Connection + Non-Wind Costs (£m)	GWh/ Anum	Tonnes C02 PA saved	20Year IRR	20 Year NPV (£m)	Pay Back Year	
1MW/1MW	1	0	0	1	0	N/A	0%	0.60	2.76	1,261	10.5%	1.61	12	Firm 1MW
Method 0	6	0	0	6	0	N/A	0%	7.40	18.43	8,422	8.4%	8.33	14	Firm 6MW
Method 1	6	1	0	1	22	N	34%	0.76	10.57	4,830	5.9%	1.83	17	
Method 2	6	1	3	1	22	N	34%	4.43	20.49	6,715	7.4%	4.66	15	
Method 3	6	1	3	1	22	N	34%	4.19	15.88	6,715	6.9%	3.92	16	Low Firm/
Method 4	6	1	3	1	22	N	34%	5.03	20.49	6,715	6.5%	3.47	16	Low Generation
Method 5	6	1	0	1	22	N	34%	3.01	2.28	811	24.9%	4.78	6	Diversity
Method 6	6	1	3	1	22	N	34%	7.20	18.16	6,715	9.3%	8.10	13	
Method 7	6	1	3	1	22	N	34%	8.04	22.78	6,715	10.0%	10.64	13	
Method 1	6	0	3	2	40	N	26%	0.76	11.02	5,035	6.6%	2.57	16	
Method 2	6	0	3	2	40	N	26%	4.43	21.07	6,838	3.8%	-0.17	21+	H2 RHI/
Method 3	6	0	3	2	40	N	26%	4.19	16.10	6,838	8.2%	5.82	14	Low Firm
Method 4	6	0	3	2	40	N	26%	5.03	21.07	6,838	2.9%	-1.36	21	No Diversity
Method 5	6	0	3	2	40	N	26%	3.01	2.28	811	24.9%	4.78	6	
Method 6	6	0	3	2	40	N	26%	7.20	18.38	6,838	10.3%	9.94	12	
Method 7	6	0	3	2	40	N	26%	8.04	23.35	6,838	7.5%	5.81	15	
Method 1	6	2	3	1	35	Y	18%	0.76	13.46	6,152	10.2%	6.58	12	
Method 2	6	2	3	1	35	Y	18%	3.10	24.33	7,444	7.3%	4.09	15	DECC High Gas/
Method 3	6	2	3	1	35	Y	18%	2.86	17.10	7,444	10.6%	8.55	12	Thrash Electrolyser/
Method 4	6	2	3	1	35	Y	18%	3.70	24.33	7,444	6.3%	2.89	17	Low Firm
Method 5	6	2	0	1	35	Y	18%	3.01	2.28	811	24.9%	4.78	6	
Method 6	6	2	3	1	35	Y	18%	5.87	19.38	7,444	12.5%	12.66	10	
Method 7	6	2	3	1	35	Y	18%	6.71	26.61	7,444	10.2%	10.06	12	
Method 1	6	1	0	1	40	Y	32%	0.76	10.57	4,830	5.9%	1.83	17	
Method 2	6	1	2	1	40	Y	32%	2.70	19.37	6,310	4.2%	0.23	20	DECC High Gas/
Method 3	6	1	2	1	40	Y	32%	2.46	14.74	6,310	8.7%	5.62	14	Thrash Electrolyser
Method 4	6	1	2	1	40	Y	32%	3.30	19.37	6,310	3.1%	-0.94	21	Low Firm
Method 5	6	1	0	1	40	Y	32%	3.01	2.28	811	24.9%	4.78	6	Low Diversity
Method 6	6	1	2	1	40	Y	32%	5.47	17.02	6,310	11.0%	9.80	11	
Method 7	6	1	2	1	40	Y	32%	6.31	21.65	6,310	8.1%	6.23	14	

* Figures based on pre-tax cashflows

Appendix N

Base Cost Description of Estimates and Justification of Value For Money

The programme partners are each providing a 10% discount and ITM's contribution to the LCNF and NIC strands is at cost.

ITM Power designs and manufacturers hydrogen energy systems for energy storage and clean power production and has grown from its original platform of novel polymeric electrolytes for electrolysis and fuel cells to that of a technology provider. ITM has a strong base of intellectual property and engineering expertise providing complete hydrogen solutions, CE marked and TÜV SÜD approved products. A first class team of 65 staff, including 15 with PhDs, comprising engineers and scientists account for more than 250 man-years of electrolyser, energy storage, fuel cell, polymer science, power electronics and combustion experience. ITM is accredited with ISO9001, ISO14001 and ISO18001 and has experience in leading and collaborating in numerous Technology Strategy Board and European funded projects and programs.

Prior to the start of the programme, ITM will have designed, built and installed three rapid response PEM electrolyser systems, one in Germany and two in the UK. The first unit, due to be delivered in September 2013 is a 0.3MW system for the injection of hydrogen into the gas network in Frankfurt and will be operated one of Germany's largest Stadtwerk (municipal utilities). The second integrated 0.3MW system will be delivered to the Isle of Wight in April 2014 and will be due to commence trials in November 2014 concluding in October 2015. The third is a smaller15kg/day unit, also to be located on the Isle of Wight, to provide fuel for a boat.

The costs (materials and labour) to design and build PEM electrolysers, the balance of plant and the integration of the sub-systems necessary for hydrogen storage are well known to ITM who have considerable experience of developing the UK supply chains necessary to minimise the cost of components, sub-systems and services required. This best practice approach has been extended to the suppliers of the gas engine and the gas mixing and injection equipment. UK companies were chosen in preference to overseas based suppliers although the supplier of the gas engine is the UK agent for the OEM since no UK manufactured gas engines capable of operating on high concentrations of hydrogen were available at the capacity required or of a suitable technology readiness level (TRL).

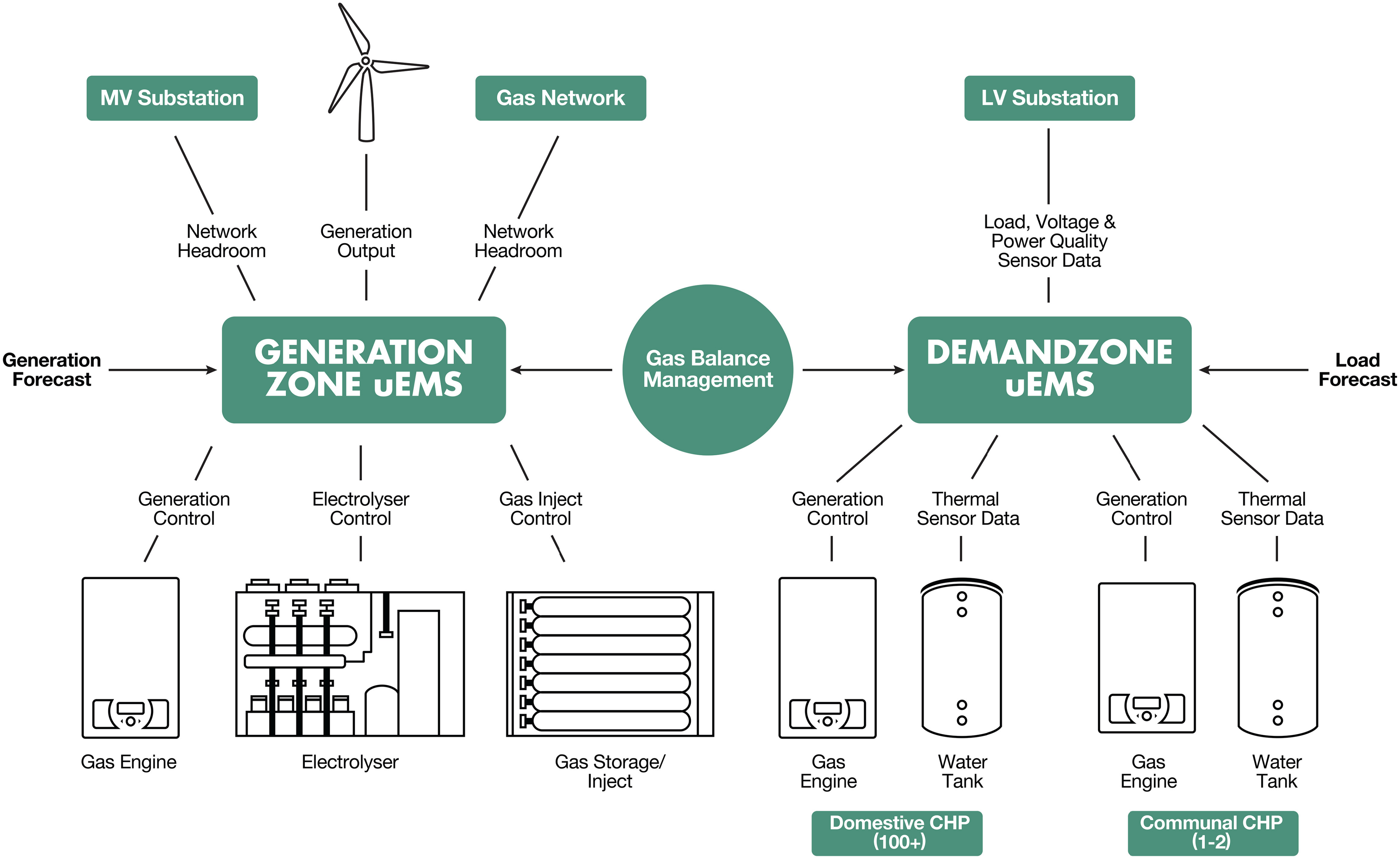
To demonstrate the full potential of the concept of hydrogen injection in the UK as a means of decarbonising the operation of gas networks and the local heat demand, it will be necessary to move to a higher hydrogen fraction. To do this it will be necessary to apply to the Health and Safety Executive for an exemption from the Gas Safety (Management) Regulations.

Working with Health and Safety Labs (HSL), part of the Health and Safety Executive, means that the Executive will help to ensure that the arguments that hydrogen injection at the proposed levels are safe and proven and are aligned to the expectations of HSE in making changes in regulation to accommodate the higher percentages of hydrogen required. This limits the need for additional work to achieve exemptions.

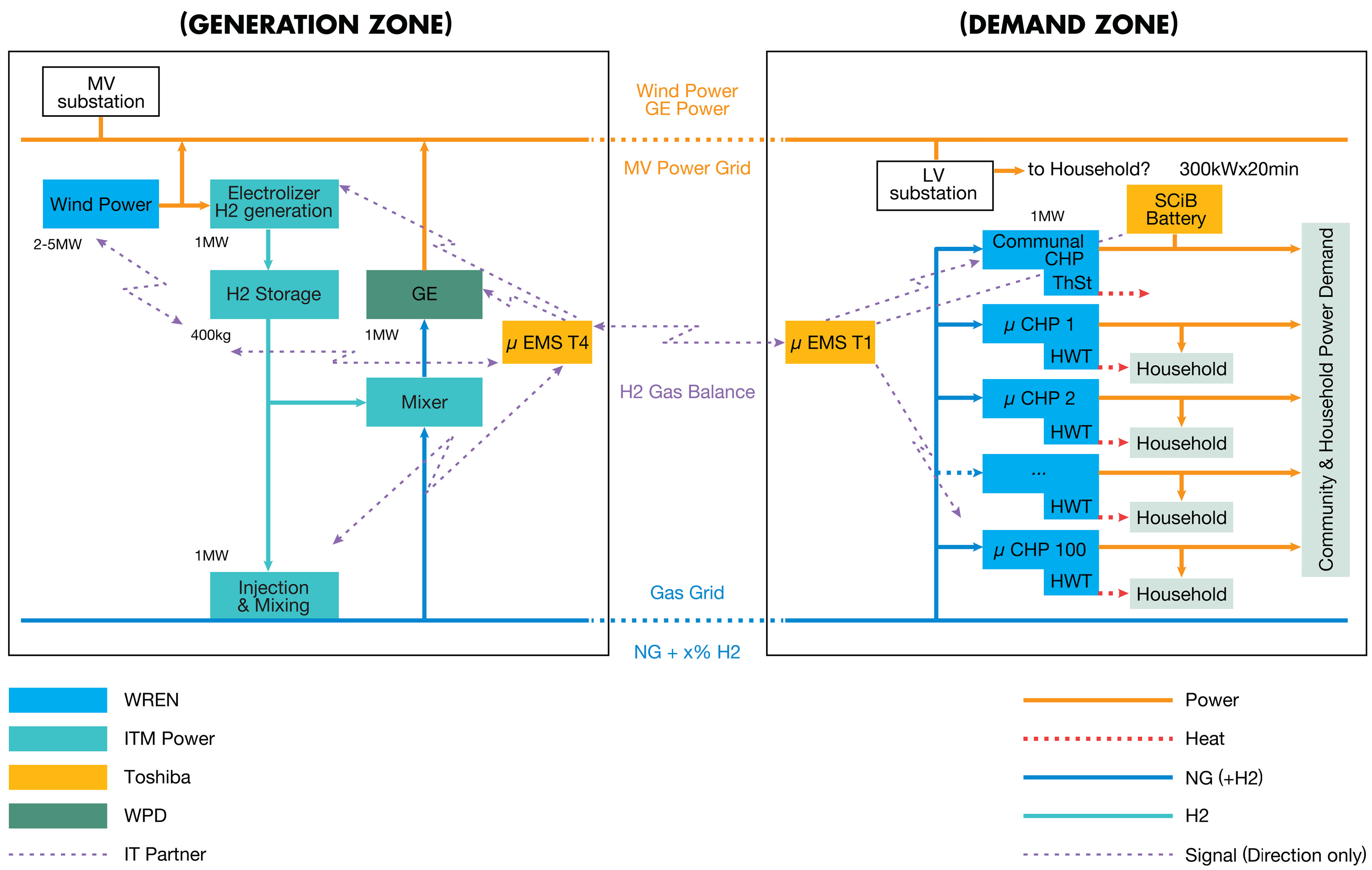
To achieve an exemption, a separate Network Innovation Allowance (NIA) strand will be undertaken. Working in partnership with the Health & Safety Laboratory, and other service providers, the NIA strand will develop the methodology necessary to demonstrate to the regulatory authority that an exemption to GS(M)R is required, how the potential hazards can be understood and demonstrate the steps necessary to assess risks and address knowledge gaps. The service providers will be selected in accordance with WWU procurement rules to ensure value for money for gas consumers.

The NIC and LCNF strands of CEB will share programme management costs, TRL led learning costs and gas storage costs. Hence, if the gas component stakeholders ran the NIC scope alone, without being part of a combined LCNF NIC programme, costs would considerably higher for those partners.

Upon completion of the detailed design, the IT costs for this project will be reassessed by the *consortium partners* and we anticipate will be reduced further based on the increased certainty about key solution areas such as wind farm and CHP control.



MV Substation
Gas Network
LV Substation
Network Headroom
Generation Output
Network Headroom
Load, Voltage & Power Quality Sensor Data
Generation Forecast
GENERATION ZONE uEMS
Gas Balance Management
DEMANDZONE uEMS
Load Forecast
Generation Control
Electrolyser Control
Gas Inject Control
Generation Control
Thermal Sensor Data
Generation Control
Thermal Sensor Data
Gas Engine
Electrolyser
Gas Storage/ Inject
Gas Engine
Water Tank
Gas Engine
Water Tank
Domestive CHP (100+)
Communal CHP (1-2)


(GENERATION ZONE)
(DEMAND ZONE)
MV substation
Wind Power
2-5MW
Electrolizer H2 generation
1MW
H2 Storage
400kg
GE
1MW
Mixer
μ EMS T4
Injection & Mixing
1MW
Wind Power
GE Power
MV Power Grid
H2 Gas Balance
Gas Grid
NG + x% H2
LV substation
to Household?
300kWx20min
SCiB Battery
1MW
Communal CHP
ThSt
μ EMS T1
μ CHP 1
HWT
Household
μ CHP 2
HWT
Household
...
HWT
Household
μ CHP 100
HWT
Household
Community & Household Power Demand
WREN
ITM Power
Toshiba
WPD
IT Partner
Power
Heat
NG (+H2)
H2
Signal (Direction only)

Appendix Q Partner Roles Summary

ITM Power is an AIM-listed company that designs and manufactures hydrogen energy systems for energy storage and clean power production and has grown from its original platform of novel polymeric electrolytes for electrolysis and fuel cells to that of a technology provider. ITM will be responsible for the hydrogen conversion and gas injection project elements.

Toshiba will provide the energy management systems, programme management of the LCNF strand and of the overarching integration. Toshiba's Bristol-based research facility, TRL, will be responsible for trial management and information dissemination across both strands.

CGI has been selected as CEB’s IT Partner and will provide the data analytics, visualisation systems, IT integration, end-to-end testing, commissioning and operations and maintenance.

Cornwall Development Company (CDC) has been appointed as CEB’s Programme Management partner and will provide the lead specialist programme and project management resource to complement the programme, ensuring the programme vision and objectives are retained in the delivery phase with thorough processes to manage programme, budget and quality aspects of the scheme.

Wadebridge Renewable Energy Network (WREN) is a not-for-profit co-operative working with the Wadebridge community to raise income from renewable generation for local projects. It will develop and operate the constrained wind farm and the large CHP system and attract local community micro CHP participants to support the wider programme.

Western Power Distribution will submit an LCNF Tier 2 proposal to support the LCNF strand of the wider programme. It will also provide the required electricity network connections and status monitoring to support the NIC strand.

CORNWALL COUNCIL

Ofgem
9 Millbank
LONDON
SW1P 3GE

Date: 16 July 2013

To whom it may concern

Clean Energy Balance

As the Cabinet Member for Economy and Culture I am writing to you on behalf of Cornwall Council to confirm our support of the Clean Energy Balance proposal.

Through the Green Cornwall programme, Cornwall Council is committed to ensuring Cornwall maximises the opportunities for our communities and businesses by taking a leadership role in the transition to a low carbon economy. The Clean Energy Balance project has clearly recognised Cornwall's ability to lead in this field, capitalising on our strong communities and unique natural environment.

Furthermore, as a member of the Smart Cornwall steering group I understand the role this project will play within the wider programme of work. As the first major project to be delivered through this ambitious programme we are happy to provide our support.

Yours faithfully

Julian German CC
Cabinet Member for Economy and Culture
Esel an Kabinet rag Erbysiedh ha Gonisogeth

Tel: 01872 322579
Email: jgerman@cornwall.gov.uk

Cornwall Council, County Hall,
Truro, Cornwall TR1 3AY
Tel: 0300 1234 100 www.cornwall.gov.uk

CORNWALL & ISLES OF SCILLY
LOCAL ENTERPRISE PARTNERSHIP

26 July 2013

Ofgem
9 Millbank
London
SW1P 3GE

To whom it may concern

Clean Energy Balance

As the chair of the Cornwall and Isles of Scilly Local Enterprise Partnership I am writing to confirm our support for the Clean Energy Balance proposal.

The Cornwall and Isles of Scilly Local Enterprise Partnership is committed to pioneering new industries that make the most of our special environment. We will do this based on four cornerstones – Business Growth, Skills, Knowledge and the Environment. This project aligns very closely to our priorities and will support us in the delivery of our wider vision.

We understand the importance of the Clean Energy Balance project in advancing the knowledge across both the power and gas sectors in the UK through building an innovative and replicable model to address issues of grid capacity, whilst benefiting local communities. Through the UK wide network of LEP's we would commit to ensuring the learning from this project is further disseminated through our networks.

Furthermore, we understand the potential of this project to create a lasting legacy for the wider Smart Cornwall Programme and the potential to build on the innovative outcomes from this project for many years to come.

Yours Sincerely

Chris Pomfret
Chair Cornwall and Isles of Scilly Local Enterprise Partnership

Local Enterprise Partnership, 4th Floor West Wing, New County Hall, Treyew Road, Truro, TR1 9GH
www.cornwallandislesofscillylep.com
lep@cornwall.gov.uk

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tnei
enterprise with energy

Ofgem
9 Milbank
London
SW1P 3GE

17th July 2013

RE: NIC Bid: Clean Energy Balance

To whom it may concern,

We are pleased to provide this letter of support for the proposed Clean Energy Balance project put forward by Wales & West Utilities and partners as an NIC bid, which is part of a wider project requesting funding from the LCN Fund.

Managing stranded renewable generation either at a local network level or a system level is becoming an increasingly important challenge to manage. While at present there are only localised areas within the GB network that have constrained renewables, the experiences in other parts of the world such as Germany, Spain and Texas indicate that this is essential to address early.

Renewable energy once constrained is an opportunity lost as the primary energy resource cannot be stored in its natural form. Therefore technologies and applications such as this method trial will be increasing important to provide a cost effective route to energy storage and energy vector shifts to maximise the potential utilisation of renewable energy.

Therefore in this context, the Clean Energy Balance project that seeks to trial the method of using injecting hydrogen derived from electrical renewable generation into the existing natural gas network as a storage and transport vector for managing electrical distribution network constraints is a valuable contribution to the experience base. This has direct carbon benefits in the form of reducing the carbon intensity of gas users for space heating as well as power generation. A successful trial will help firm up the business case for a wider roll-out of the solution.

Regards,

Graeme Bathurst
Managing Director
Petrofac - TNEI

tnei services ltd,
2nd Floor,
Bainbridge House,
86-90 London Road,
Manchester
M1 2PW
t: +44 (0)161 233 4800
f: +44 (0)161 233 4801
w: www.tnei.co.uk

Part of the Petrofac group

VAT Reg. 553239738 Company Reg. 03891836

From: joep.huijsmans@shell.com [mailto:joep.huijsmans@shell.com]
Sent: 30 July 2013 11:58
To: John Newton
Subject: FW: Clean Energy Balance Letter of Support

Dear Sirs,

It is with pleasure that I am providing via this e-mail support for your bids in LCNF and NIC.

Shell recognises that the Clean Energy Balance projects are timely and innovative and have the potential to demonstrate solutions which will deliver customer benefits and accelerate the adoption of hydrogen technologies in the UK. The projects will serve to reduce the carbon content of not only the electricity network but also the gas network and help to de-carbonise the UK heat load in line with the targets set by DECC target.

The learning to be gained from the Clean Energy Balance projects has the potential to advance knowledge across both the power and gas sectors in the UK and will provide valuable learning to assist in furthering the move towards a low-carbon economy" .

Best regards/Met vriendelijke groeten

Joep Huijsmans
Technology Opportunity Manager – GameChanger team

Shell Global Solutions International B.V.
P.O. Box 38000, 1030 BN Amsterdam, The Netherlands

Tel: +31 20 630 2090 **Fax:** 3964
Email: joep.huijsmans@shell.com
Internet: www.shell.com/globalsolutions

Shell Global Solutions International B.V. has its statutory seat in The Hague and its registered office at Carel van Bylandtlaan 30, 2596 HR, The Hague, the Netherlands. It is registered with the Chamber of Commerce in the Netherlands under number 27155370.

Ofgem
9 Millbank
London, SW1P 3GE

19th July 2013

To whom it may concern

Re. Clean Energy Balance

As the chair of the Smart Cornwall programme I am writing to confirm the support of the Clean Energy Balance proposal.

The Smart Cornwall programme has been set up to;

"develop the U.K's first fully integrated smart energy network, providing new high value jobs, creating wealth and opportunities for future generations and leading the way into a prosperous, resource efficient future."

At the heart of the Smart Cornwall programme is the ambition to be a global leader in the development and delivery of Smart Energy technologies. We aim to achieve this through working in partnership with local, national and international stakeholders, to deliver a strategic programme with the economic and social benefits of this paradigm shift in our energy economy at its heart.

The learning to be gained from the Clean Energy Balance project has the potential to advance knowledge across both the power and gas sectors in the UK and will provide valuable learning to assist in furthering the move towards a low-carbon economy. As the first major project to be delivered within the umbrella of the Smart Cornwall programme and within the Smart Cornwall guiding principles as set out in the bid appendices, this project will be a key milestone and will become a catalyst for delivery for many years to come.

Yours Sincerely

Chris Ingram

Smart Cornwall Programme Chair

EUROPE & SCOTLAND
European Regional Development Fund
Investing in your Future

SCOTTISH Hydrogen & Fuel Cell ASSOCIATION

Ofgem
9 Millbank
London
SW1P 3GE

15th July 2013

Gas NIC: Clean Energy Balance (CEB) - Hydrogen Injection for Carbon Displacement

Dear Sirs,

I am writing to confirm that the Scottish Hydrogen and Fuel Cell Association (SHFCA) is keen to support the proposal Clean Energy Balance (CEB) – Hydrogen Injection for Carbon Displacement the Gas Network Innovation Competition for support.

The Scottish Hydrogen and Fuel Cell Association recognise that the Clean Energy Balance projects are particularly timely. There is a need for innovative thinking and solutions which will help to deliver practical benefits, and specifically those which can deliver energy across sectors, for instance between power and gas networks, and thereby enable the wider uptake of low carbon heat and power within the UK.

Electrolysers can convert electricity to hydrogen in gaseous form for ease of transportation and/or storage. The learning to be gained from the Clean Energy Balance projects has the potential to advance knowledge across both the power and gas sectors in the UK and will provide valuable learning to assist in furthering the move towards a low-carbon economy.

SHFCA promotes and develops expertise in fuel cells and hydrogen technologies, and supports the development of businesses and markets, bringing together the expertise and experience of specialised fuel cell companies, systems integrators, power generation companies, and energy consultants to identify key market opportunities.

The Association engages with Scottish and UK government to create the right framework for the industry to develop. SHFCA is developing relationships with other national and international hydrogen and fuel cell bodies to work together to develop a global hydrogen and fuel cell markets. Much of this work underpins the development of relevant skills, and the expertise needed to deploy our technologies in appropriate markets with safety, reliability, and performance.

The move towards low carbon solutions for our energy supply is one of the most important aims for our society, and this will require energy storage at different scales and in different forms if we are to achieve the substantial decarbonisation of our energy systems by 2050.

Yours sincerely, Nigel Holmes

Chief Executive, Scottish Hydrogen and Fuel Cell Association

Scottish Hydrogen & Fuel Cell Association Limited
Energy Technology Centre
Rankine Avenue
Scottish Enterprise Technology Park
East Kilbride G75 0QF

Tel: 01355 593570
Fax: 01355 593580
Website: www.shfca.org.uk

A company limited by guarantee
Incorporated in Scotland No. SC265209

D Pinchbeck Consultancy Limited

10 Brocklehurst Road
Melton Mowbray
Leicestershire
LE13 1RX
England
T : + 44 1664 858327
F : + 44 1664 481828
M: 07798 561 535
E : davepinchbeck@hotmail.com

Ofgem

9 Millbank

London, SW1P 3GE

NIC: Clean Energy Balance (CEB) - Hydrogen Injection for Carbon Displacement

(submitted by Wales & West Utilities Limited)

Dear Sirs,

It is becoming more widely accepted that hydrogen could become an important energy carrier in the energy mix in the quest for sustainability, because it offers several benefits related particularly to the potential for energy storage (Power to Gas.) If hydrogen in the natural gas system is to be accepted it must ensure a guaranteed technically feasible, economically viable and, crucially, safe system of storage and transportation. It's clear that the natural gas pipeline network potentially offers such a solution and there have been several studies, including the EC-supported NATURALHY[1] project which have examined the feasibility of using it as a means of widespread hydrogen storage and transportation, carrying a mixture of natural gas and small amounts of hydrogen.

However a number of crucial aspects have not been sufficiently addressed and the more recent GERG[2] study, known as "HIPS"[3], has examined these bottlenecks in the interaction between hydrogen and the wider natural gas network. If the technology is to become accepted, it's vital to consider the bottlenecks, and their possible solutions, so that we can develop a natural gas infrastructure that can support the storage and transport of hydrogen-natural gas admixtures in a move towards a low carbon economy. Beyond the studies, experimental work and demonstration projects are absolutely vital both to test proposed solutions and, at the same time, to develop confidence in the preferred technological approaches.

It's clear that the Clean Energy Balance projects are both timely and innovative and should enable solutions to be demonstrated which will deliver customer benefits and accelerate the adoption of hydrogen technologies in the UK. Crucially this will also provide opportunities for UK industry to export technology and knowledge gained to those countries with similar interests in this rapidly growing area, thus enhancing the UK economy.

There is no doubt that this project will serve to reduce the carbon content of not only the electricity network but also the gas network and help de-carbonise the UK heat load in line with the targets set by DECC. In addition, the learning to be gained from the Clean Energy Balance projects has the potential to advance knowledge across both the power and gas sectors in the UK and will provide valuable experience to assist in furthering the move towards a low-carbon economy in the UK, whilst also opening up potential export opportunities.

The UK is fortunate to have such support and encouragement available to industry and, from my UK-based European perspective, I add my strong support to this application.

Dave Pinchbeck
Manager, GERG "HIPS" project
Secretary General GERG (retired)
Member, NATURALHY Project Executive Committee

[1] http://www.naturalhy.net/

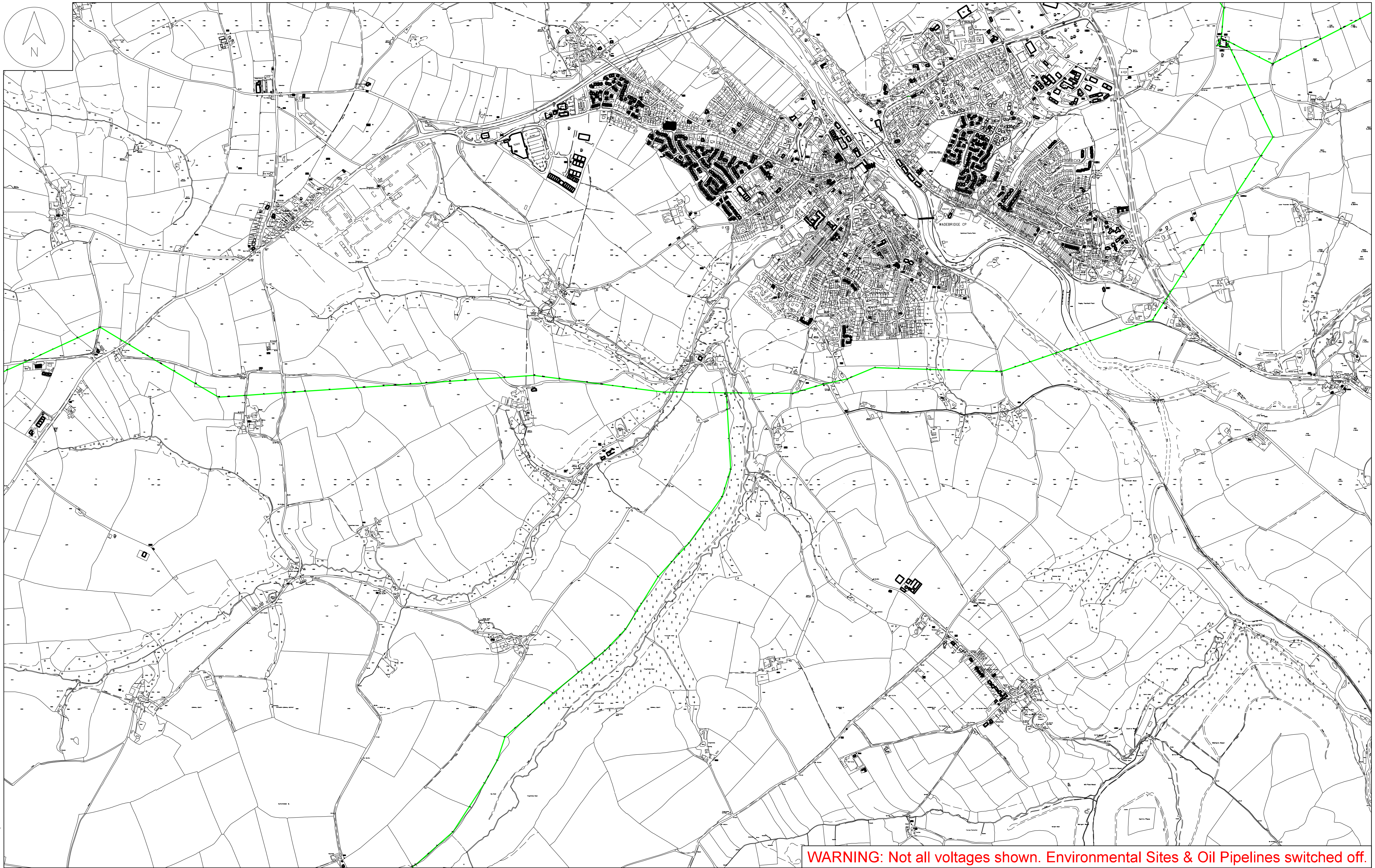
[2] European Gas Research Group (www.gerg.eu)

[3] "Hydrogen in Pipeline Systems" Not yet published.

CARE SHOULD BE EXERCISED TO ENSURE THE PRECISE POSITION OF THE WPD APPARATUS IF WORK IS TO BE EXECUTED IN ITS VICINITY.
If in doubt, contact your local WPD office.

Information is given as a guide only and it's accuracy cannot be guaranteed.

PLEASE NOTE: This plan ONLY shows assets owned by Western Power Distribution. Electricity assets owned by IDNO's (Independent Network Operators) MAY be present in this area.



WARNING: Not all voltages shown. Environmental Sites & Oil Pipelines switched off.

SURF TELECOMS APPARATUS

PILOT CABLES

	OVERHEAD LINE	UNDERGROUND CABLE
PL		
SERVICE		
LV		
HV (11kV)		
HV (33kV)		
HV (66kV)		
HV (132kV)		

PME Earth

Pole Mounted Transformer

Underground Earth

Ground Mounted Transformer

* ADVICE SHOULD BE SOUGHT FROM THE WESTERN POWER DISTRIBUTION CONTACT CENTRE S.WEST (0845 601 2989) FOR ANY WORK THAT IS TO TAKE PLACE IN PROXIMITY TO 132kV UNDERGROUND CABLES AND 132kV OVERHEAD LINES

TITLE:
DRAWN BY:
DATE: 02/08/2013
SCALE 1:16000 @ A3
PLOT CENTRE: 198249.165,071039.229

WESTERN POWER DISTRIBUTION
Serving the Midlands, South West and Wales