Project Code/Version No:
WPD T2 05 v1

Low Carbon Networks Fund
Full Submission Pro-forma
Section 1: Project Summary

1.1 Project Title:
Clean Energy Balance – Circumventing Electricity Network Constraints

1.2 Funding DNO:
Western Power Distribution (WPD) (South West)

1.3 Project Summary:
The Problem Clean Energy Balance (CEB) is addressing:
The DECC Carbon Plan's aim to decarbonise heating and transport and increase renewable generation will necessitate significant electricity network reinforcement unless alternative approaches can be found to store and/or transport the energy and bypass electricity network constraints. 'The Future of Heating' (DECC, 2013) envisages a 40% reduction in gas consumption by 2050 from 2011 levels. This will potentially release significant capacity in the natural gas network. The report recognises that hydrogen injection represents a key opportunity to exploit this released capacity.

The Solution which the CEB programme will test:
Building on the above, the CEB programme will provide benefits to electricity and gas Distribution Network Operators (DNO/GDN) and their customers by using the gas network to bypass electricity system constraints. This will entail the conversion of constrained generation into hydrogen gas via electrolysis and either the storage of hydrogen until either it can be converted back to electricity and returned to the grid or injected into the gas network for transportation beyond the constraint for local use including electricity generation.

The Methods which CEB will utilise:
The CEB Methods include a basic Constraint Scheme, Gas Enabled Peak Shifting, a method for Constraint Circumvention via the Gas Network, A Network Arbitrage Model for cross-network utilisation, a Method that uses CHP for Reinforcement Avoidance, and an End-to End Method that combines the above. If successful, these Methods will minimise renewable energy curtailment, exploit potential spare capacity in the gas network, support decarbonisation of heat and reduce the overarching need for reinforcement and central balancing by maximising local generation for local use. CEB aims to define a commercial framework that makes the Methods commercially viable.

CEB extends beyond the basic trial of alterative technical DNO/GDN solutions to look at the potential exploitation of commercially funded services/solutions and the overarching commercial models needed to make them viable. The end-to-end model is complex, unproven, heavily dependent on DNO/GDN cooperation and hence will not happen without industry support. Given the scale of potential DNO/GDN benefits, LCNF/NIC funding is needed to prove the Methods and, in doing so, stimulate the development of solutions to key DNO and GDN challenges.

1.4 Funding

1.4.2 LCN Funding Request (£k): 13,430 (£13,430, 440)

1.4.3 DNO Contribution (£k): 1,492 (£1,492, 270)

1.4.4 External Funding - excluding from NICs (£k): 1,180 (£1,179, 890)

1.4.5 Total Project cost (£k): 16,103 (£16,102,600)

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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 Low Carbon Networks (LCN) Fund and the other Project(s) applying for funding from the Electricity Network Innovation Competition (NIC) and/or Gas NIC.

1.5.1 Funding requested from the Electricity NIC or Gas NIC (£k, please state which other competition): Gas NIC 4,019 (£4,019,040)

1.5.2 Please confirm if the LCN Fund Project could proceed in absence of funding being awarded for the Electricity NIC or Gas 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. (£35,000 contribution)
ITM Power Plc. (£41,000 contribution)
Toshiba International (Europe) Ltd. (£187,760 contribution) will provide the energy management systems and overall programme management via Cornwall Development Company (£24,000 contribution) and learning via Toshiba's research facility, Telecommunications Research Laboratory (TRL), (£38,570 contribution)
Wadebridge Renewable Energy Network Ltd. (WREN) (£22,500 contribution)
Wales & West Utilities Ltd. (see related NIC bid for contribution details)
Western Power Distribution Plc. (contribution as detailed in 1.4.3)
External Funding: £10m WREN privately sourced funding into wind farm.
Note: 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:	**1.8.3 Contact Address:**
Stephen Stead Smart Community Director	Toshiba International (Europe) Ltd, 3 Furzeground Way, Stockley Park, Uxbridge, UB11 1EZ
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Section 2: Project Description

This section should be between 8 and 10 pages.

2.1 Aims/Objectives of the Project

The Carbon Plan's aim to decarbonise heating and transport and increase renewable generation will necessitate significant network reinforcement and/or generation curtailment unless alternative approaches can be found. DECC's report, 'The Future of Heating' (2013), envisaged a 40% reduction in gas consumption by 2050 from 2011 levels. This will release significant capacity in the natural gas network.

This programme will test methods in which the potential future capacity in the gas network can be exploited to address challenges faced by the electricity distribution networks. It will test discrete methods which form part of an integrated energy system that translates electricity to/from gaseous form for ease of transportation and/or storage. Specifically, CEB will involve the conversion of electrical energy into hydrogen gas via electrolysis and either:

- The storage of hydrogen gas until the local Distribution Network Operator (DNO) network is less constrained and it can be converted back to electricity and return to the grid, or

- The transportation of hydrogen via the natural gas network to an area where the DNO network is less constrained allowing it to be converted back to electricity for local use.

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

Clean Energy Balance has been developed as an overarching programme of work with three funding strands (LCNF, NIC and NIA), associated activities and their delivery projects. Henceforth, this bid refers to the CEB Programme, funding strands and component projects.

The Problem:
The Carbon Plan's projected increase in renewable generation will require significant network reinforcement and/or generation curtailment unless cost-effective alternatives can be found. A recent study by Imperial College, for DECC, 'Understanding the Balancing Challenge' (2012), forecasts that surplus renewable power could reach 50 TWh pa by 2030, with 60-100 TWh pa curtailment possible by 2040-2050 (i.e. 20-30% of total renewable output). However, practical energy storage technologies are few and far between and are generally expensive and/or limited in their capacity/duration and/or location.

A further complication of existing energy storage solutions is that the energy is put into them and taken out of them at the same physical point. Although this allows a level of time-based smoothing, it ignores the fact that, in the main, certain network areas will be generation dominant while others will be demand dominant. Therefore, the constraint that needs to be overcome is not only time-specific but also location-specific.

The transition to electrical heating will impact on the take-up of heat pumps and electrical transport, and its exponential impact on peak demand, will also necessitate significant additional lower voltage level reinforcement, unless local low carbon energy sources and/or methods of load smoothing can be found.

Consequently, an innovative solution is required to:

- Minimise renewable energy curtailment and reinforcement costs
- Provide a solution to both time and location-based constraints
- Provide a method of injecting local generation to support peak load
- Provide a method of smoothing intermittent generation
- Provide a solution that supports the decarbonisation of heat
- Provide a commercial framework to adequately recompense all parties.

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Project Description continued

The specific problem in the trial host community of Wadebridge is representative of the situation faced by many other communities. The Wadebridge area already hosts sufficient large-scale wind and solar generation to meet a substantial share of its electricity demand. The bulk of this generation is owned by commercial developers, with little economic benefit being retained in the local economy and no impact on local energy prices. The amount of generation in the area means the grid is now very constrained, which is preventing the development of medium to large-scale community-owned generation which could deliver substantial local economic benefit and the potential to help stabilise energy bills. 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 has ambitions to develop a large-scale community wind or solar project but has not been able to do so due to grid constraints. The connection charges associated with conventional reinforcement schemes have been prohibitive for them. This situation will be replicated in other areas and communities are at risk of 'missing the boat' where existing grid generation capacity is taken up by existing developments.

The Solution:
CEB will explore an interaction between electrical and gas systems that could lead to a cost effective alternative for accommodating renewable generation. In the trial location, the 33kV network is at capacity. Any new generation will require expensive reinforcement. Conversely, the gas grid is predicted to experience a reduction in customers, which could potentially lead to significant spare capacity. To exploit this, electrolyser technology (Appendix B) is proposed to convert excess electrical energy into hydrogen gas. The hydrogen is stored and subsequently injected into the gas network for transport from this *Generation Zone* to Wadebridge town, the *Demand Zone*, where it will be used in commercial and domestic CHP (Combined Heat and Power) units for heating/hot water and backing off local electrical demand.

Gas injection will be achieved by working in partnership with Wales & West Utilities (WWU). WWU will investigate effective mixing and injection technologies and monitor the hydrogen once it is injected into the gas network. This will be undertaken as part of a programme of work aimed at ensuring there are no detrimental effects to gas customers in the trial area as a consequence of the injected hydrogen.

The stored hydrogen will also be fed into a gas engine in the *Generation Zone* to covert back into electrical energy at a time when the electricity network is less constrained. The gas engine will be managed as part of a constraint scheme that unlocks capacity from the electrical network, allowing new generation to connect.

In this programme, the plan is to connect a 6MW community wind farm at a location considered commercially non-viable due to scale of connection cost. This cost will be avoided by removing the need for costly reinforcement by utilising the above solution set. This system will be controlled by Toshiba's Micro Energy Management System, µEMS.

There will be two instances in total, one controlling the *Generation Zone* and one controlling the CHP in the *Demand Zone*. Given the trial nature of this solution, redundant systems are not proposed. However, safety will be ensured by built-in fail safes in the core trial system components (electrolyser, gas inject, gas engine, wind farm, CHP) and the underlying electricity and gas networks.

The composite solution described above will be trialled via discrete Methods. It is the premise of this programme that together these will maximise the utilisation of renewable energy whilst limiting reinforcement cost and/or generation curtailment and optimising utilisation of the existing gas distribution network. The overarching solution will form a loosely-coupled energy storage system comprising two distinct zones:

<u>The *Generation Zone*</u>
This zone will comprise a constrained renewable generation set (the 6MW community wind farm constrained to 3MW), a 1MW electrolyser, a hydrogen store, a gas injection module and a 1.4MW_e gas engine.

The *Generation Zone* will be operated by a micro grid control system that will integrate the zone's components and network sensors. This system will use weather data to forecast future generation. This information will be coupled with gas and electricity network headroom data and available storage capacity in the hydrogen store to control the electrolyser, gas engine and gas injection operation as well as drive any constraints required on the generation. Specifically, it will look for opportunities to increase available hydrogen capacity ahead of renewable generation peaks through gas injection and/or gas engine operation, curtailing generation as a last resort.

<u>The *Demand Zone*</u>
This zone will comprise two commercial (200kW+) CHP systems and 50 micro CHP units. The domestic micro CHP installations will be trialled with a thermal store in order to determine the implications for customer take-up, generation potential and generation availability. The *Demand Zone* will be operated by its own discrete control system. This system's primary function will be to use local demand forecast data to schedule and control CHP generation operation and closely match it to local load. Local CHP generation will effectively displace local demand and the system will ensure that this does not impact on higher voltage levels or high voltage generation connections.

In support of the above, commercial arrangements will be explored that optimise the risks and returns for all parties, whilst maximising overall solution benefits, including:

- The balance between wind, electrolyser and gas engine utilisation including loss allocation
- The optimal ownership of assets and associated contracting arrangements

The Discrete Methods and Trials:
The discrete methods within the solution that will be tested by the programme are:

<u>A Constraint Scheme (Method 1)</u>
This trial will look to connect multiple generating sources above the available unconstrained capacity and maintain the net export across these sources within available network capacity.

In this way, it is anticipated that, by combining different generating forms, such as solar and wind, the generating diversity will naturally provide a degree of export smoothing and therefore allow more generation to be connected sooner.

Project Description continued

The method will be trialled in the following way:

- The constraint scheme will be implemented across the existing generation in the trial network segment, the proposed 6MW community wind farm and the gas engine. The existing generating sets will continue to export up to the levels permitted within their connection agreements. The community wind farm and gas engine export will be managed within the remaining capacity
- The impact of the scheme on different sizes of generating sets (wind and solar) will then be assessed
- The wider opportunities for deploying the scheme across WPD's network will be evaluated, including the potential for the scheme to help connect multiple constrained generation sources across a grid area, and subsequently the opportunities for deployment across all DNO networks
- The longer-term development of the method will be assessed in terms of the economies of scale of a wider rollout, the associated technical implications and the resultant cost/benefit for both WPD and GB as a whole.

<u>Gas-Enabled Peak Shifting (Method 2)</u>

This method will utilise the constraint scheme in conjunction with the electrolyser that is used as a controllable demand-side load, hence allowing the wind farm to increase export in line with electrolyser size. The hydrogen generated will be stored and then subsequently blended with natural gas and burned in a gas engine at a later date/time when the available network capacity allows. In this way, the gas sub-system will provide a mechanism for generation peak shifting.

The Gas-Enabled Peak Shifting will be trialled in the following way:

- The gas sub-system will be installed and the operational efficiency of the key components evaluated. Specifically, the electrolyser will be evaluated in terms of conversion efficiency at different power levels and the gas engine in terms of power generated with different hydrogen/natural gas mixes
- The electrolyser operation will be aligned with the wind farm export/constraint scheme to assess its utilisation levels. A reduction in the unconstrained wind farm's unconstrained connection will subsequently be simulated by a corresponding increase in electrolyser utilisation and the impact on electrolyser performance monitored. The potential impact of larger electrolyser units on the network will also be evaluated
- The impact of electrolyser operation at different levels on the available storage will be evaluated. The potential benefit of different storage sizes will be assessed, both in terms of optimised electrolyser operation and flexibility for scheduling gas engine generation
- Current and future opportunities to optimise the economic model will be assessed. This will include options for ownership (including community ownership), additional revenue sources (e.g. electrolyser and gas engine as balancing units), impact of a potential future hydrogen injection RHI tariff, scheduling generation for peak price and the impact of future energy price rises
- The future evolution of the underlying technologies will be assessed and the impact of this on price, performance and hence the overall cost/benefit for both WPD and the UK as a whole.

Constraint Circumvention via the Gas Network (Method 3)

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 (GS(M)R) will be sought, to allow the injection of hydrogen at higher levels. This will be delivered by the NIA and NIC strands.

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 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 (including community ownership), impact of a potential hydrogen injection RHI tariff, scheduling injection for peak pricing and the impact of future energy price rises
- 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 DNO and GDN perspective and also the wider benefit of decarbonising the UK gas network.

A Network Arbitrage Model (Desktop Study) (Method 4)

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.

The method will be trialled in the following way:

- 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 versus 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 will be assessed
- The opportunity to maximise energy throughput by exploiting available capacity across both networks will be evaluated.

CHP as a Means of Reinforcement Avoidance (Method 5)

This method will explore the ability of CHP systems to support local load and hence minimise the need for urban reinforcement.

The method will be trialled in the following way:

- The ability to stimulate demand for micro CHP will be assessed through the inclusion of

additional incentives: unit discounts and/or enhanced generation tariffs
- Concerns over remote operation of the CHP units will be assessed by direct customer liaison with both domestic and commercial customers. WREN will play a key role in this
- The degree to which CHP generation can be aligned to electrical demand will be assessed by remote management of the unit's generation. The ability to maximise CHP export by actively managing thermal store headroom ahead of peak electricity demand will be evaluated
- 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
- Current and future opportunities to optimise the economic model will be assessed. This will include options for ownership (including community ownership) impact of any RHI tariff changes, future increases in energy prices with the optimal balance between level of CHP incentive costs and reinforcement costs being assessed
- The future evolution of the underlying technologies will be assessed and the impact of this on price, performance and hence the overall cost/benefit for both WPD customers and GB as a whole.

All of these learning pieces will be part of the overall Knowledge Capture and Dissemination work stream and will form the backbone of outputs to the industry.

<u>The End to End Value Chain (Methods 6 and 7)</u>

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.

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 potential, reinforcement avoidance, renewable energy connections, energy lost/curtailed)
- 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 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
- Commercial arrangements will be explored that optimise the risks and returns for all parties whilst maximising overall solution benefits, including the balance between wind, electrolyser and gas engine including loss allocation.

2.2 Technical Description

This programme is very novel in its approach. It marries together two energy systems which are not typically used in tandem. The use of electrolyser and gas inject technology as an interface between the two systems has not been used in this way before within the UK.

From a WPD perspective, there are number of components which are more conventional, such as the generator connection for the wind farm and the load/generator connection for the electrolyser and gas engine. Although the physical connections to the electrical network system are straightforward, the control system and implications of connecting in the constrained network are more challenging. The 33kV ring that connects Wadebridge to Polzeath and St Tudy is already very close to its maximise voltage limit on all busbars, made worse in outage or fault conditions. The limits are reached when there is maximum generation output and minimum load and systems are designed and built to accommodate these scenarios. The natural variation between generation types and load gives the systems latent capacity which can be utilised by actively monitoring constraints and actively controlling generators and load to optimise this capacity.

An additional benefit of this approach is having direct control of a load on the system which can convert the excess electricity into a storable, useful form. This energy would otherwise be curtailed. The load can be used simply to act as ‘negative generation’, essentially giving the generator another 1MW of export, however the implication for use of this ‘excess’ energy is its versatility acting as a buffer between gas engine operation and/or gas injection.

A key part of optimising the various devices in this complex arrangement is to have a real-time control system which monitors the state of each device (for example: export, capacity, predicted load) and makes informed decisions in a predetermined hierarchy of priorities around a number of economically viable energy use scenarios. For this to be carried out successfully, integration with WPD’s Network Management System (NMS), as well as with WWU’s control systems, is critical. This ensures that WPD can supervise the automated control system without needing to intervene directly; but in the case of an unexpected fault, a control engineer can take control. Details of a Power Network Analysis are at Appendix C.

The CEB project will enable the connection of a new megawatt-scale community owned generation project. WREN is currently prevented from developing such a project due to grid constraints in the area. The core plan is to develop a wind project consisting of 3 turbines each of 2 – 2.5MW capacity, giving a total project installed capacity of 6 – 7.5MW. The project should generate around 15,000MWh per year, around 50% of the Wadebridge area’s domestic and commercial annual electricity consumption.

A connection offer has been received for 3MW of conventional export capacity at 33kV. However in certain circumstances, unconstrained capacity will potentially be as low as 0MW. The remaining 3 – 4.5MW of required connection capacity will be provided through the CEB programme. The project would not be viable without the additional constrained capacity provided by the CEB programme.

Although a potential site has been identified and basic feasibility work carried out, the community wind project is at an early stage and there is a risk that planning permission will not be obtained. Should, for any reason, the community wind project not go ahead, the contingency plan is to develop a new community solar project in the area, which would then be constrained against the existing St Breock wind farm and/or to operate the constraint model with other wind generators in the area. WREN has identified potential sites for a solar project.

2.3 Description of design of the trials

This programme's structure is fundamentally based around use case scenarios, which will explore system solutions from both technical feasibility and economic perspectives. WREN is a key partner in the programme and is able to give the CEB team a significantly better insight into the local community to ensure that the partners are responding to feedback and addressing any concerns.

Scalability is a key driver for the programme; it is forward-looking with a relatively long event horizon, however, Cornwall does have a significant number of renewable generators, and the fact that there is less interconnectivity due to its peninsula geography, means that significant constraints are apparent there before many other places in the UK. To hit the carbon targets set out in the UK Carbon Plan the propagation of intermittent renewable generation will need to increase to comparable levels in other parts of the UK, giving rise to similar constraint issues. A workable solution is sought, which uses the overall networks more effectively. In addition, as the number of constraints on the electrical network increases, in contrast, the potential demand on the gas network is predicted to reduce. With the vast majority of properties being gas mains connected and medium pressure gas mains feeding almost all main urban centres, the ability to bring energy from relatively local sources via this ready-made asset, supplying high density population areas, without concern about the electrical constraints, is a reliable and powerful proposition.

The broad and diverse backgrounds of the CEB partners bring a wide range of expertise to the table. This diversity allows varied views and a range of solutions to be tabled, with only the strongest being taken through to implementation. Every use case and idea can be moulded by the multiple parties to ensure it is the most robust solution. Once each scenario is being trialled, the effectiveness is again viewed from multiple angles, giving the wide visibility necessary to ensure a proposed solution could be adapted and scaled so as to be suitable in a business as usual situation.

2.4 Changes since ISP submission

Attention should be drawn to the following changes since ISP:

- Although the deliverables and Methods have been refined since the ISP, the learning we expect to be gained from the programme remains the same
- In order to improve VFM, an alternative approach has been proposed for the µCHP trial which no longer requires the expertise of Energy Saving Trust (EST), hence EST will no longer be part of this programme
- Due to product maturity issues with specific µCHP units, CEB will no longer evaluate those without thermal stores and will focus only on models with them
- Based on experiences of organisations such as British Gas in attracting µCHP customers and a re-evaluation of the inconvenience caused by boiler replacement and thermal store installation; the customer inconvenience payment has been increased from £500 to £1000 and the anticipated number of domestic sites is 50
- The target level of hydrogen injection sought has been reduced from 20% to 2% since this is seen as more likely to be achieved in the timescales and does not unduly impact the programme. This is based on the approach taken in Germany, where 9% is permitted but a 2% limit is used.

Furthermore, in response to Ofgem's comments following the ISP, the allocation of costs between the NIC and 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.

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In summary cost allocation has been undertaken based on the following principles: Gas Inject is the core technology required by the NIC project 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 primarily allocated in line with the ratio of estimated project complexities, learning and associated customer benefits.

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Section 3: Project Business Case

This section should be between 3 and 6 pages.

3.1 Business Case Context

The approach to be validated by the CEB Methods extends beyond the basic trial of alterative technical solutions that the DNO/GDN can apply. It looks at the potential exploitation of commercially funded services/solutions and the overarching commercial models needed to make them viable. The end-to-end model is complex, unproven, heavily dependent on close DNO/GDN cooperation and, as such, will not happen without industry support. However, the benefits to the DNO/GDN are considerable and hence the need for LCNF/NIC funding to prove the models. In doing so, this will provide the catalyst required to stimulate the development of these potentially self-funded solutions to key DNO and GDN challenges.

A comprehensive investment model has been devised to evaluate these Methods, the key assumptions and outputs of which are summarised below, in conjunction with the forecast benefits of each Method from a commercial view point. The implications of this on the networks and their customers are explained in more detail within this section.

Key Sizing Assumptions			Key Equipment Costs		Key O&M Costs		Financial Outcomes			
								IRR	Pay Back Year	20 Year NPV
Wind (MW):	6		Electrolyser/MW:	0.80	Electrolyser Ops:	0.05				
PV (MW):	3		Gas Inject:	0.60	Gas Engine Ops:	0.05	Method 0	4.12%	17	3.31
ELY (MW):	*1*		Gas Engine/MW:	0.65	Gas Inject Ops:	0.05	Method 1	10.45%	11	8.75
Firm Connection (MW):	6	*	uEMS Gas:	0.60	Gas Price:	34	Method 2	6.77%	14	5.27
Gas Engine	1.4		uEMS Wind:	0.40	Electricity Price:	55	Method 3	7.33%	13	5.86
uCHP Numbers (K)	1		uEMS CHP:	0.30	uCHP 1st 10:	0.0045	Method 4	4.99%	16	3.29
			Wind Farm/MW:	1.49	uCHP 2nd 10:	0.0020	Method 5	17.72%	6	4.11
			Wind Ops:	0.37	Discount 1st 10:	50%	Method 6	10.35%	10	10.85
					Discount 2nd 10:	30%	Method 7	10.35%	10	8.28
* the firm conection figure is for 3MW PV AND the new wind farm										

3.2 Benefits of the Project

There are benefits to the renewable generators in enabling them to connect to constrained networks where previously connection would have been financially prohibitive. This benefits the UK by increasing the penetration of low carbon generation. There are also key benefits through decarbonising the gas network alongside the electrical network. If the technical system designed for this programme is widely replicated, the overall impact on the volume of CO2 saved would be significant, potentially in the region of 0.3 terra tonnes of CO2 per annum.

The commercial models evaluated will seek to optimise contracting relationships and clarify benefits for involved parties across what may otherwise be considered prohibitively complex contracting models. The learning will enable the take-up of the Methods, once proven, to be maximised and the removal of any restrictive industry practices and regulation. This will have particular benefit to the commercial model that underpins the end-to-end solution as, if successful, it will allow communities to invest in and consume locally-generated energy in order to reduce, stabilise and localise their energy spend and become more energy independent. As such, it will provide a stepping stone for the development of future local energy market arrangements.

If rolled out on a wider scale, the benefits to the electrical network are considerable and include significant reductions in the requirement for local and higher level network reinforcement and central balancing reserve.

Generation Zone

The *Generation Zone* Methods will demonstrate how a significant increase in the amount of renewable generation connected to the electricity network can be achieved without the need for network reinforcement. This will accelerate the deployment of renewable generation, significantly reduce its associated costs and maximise the potential for carbon reduction. Methods that will be considered within this zone include:

Method 1 – A basic constraint model

Method 2 – Gas enabled peak shifting

Method 3 – Constraint circumvention via the gas network

Method 4 – A network arbitrage model

Demand Zone

In the *Demand Zone*, the Methods will demonstrate how CHP generation can be best aligned to the electricity demand peak to ensure CHP unit generation is maximised at times of peak electricity demand. In doing so, the programme will demonstrate how low carbon energy can be delivered to the hearts of those urban areas most likely to feel the impact of the planned higher levels of EV transport and electric heating penetration. These are, by nature, the areas where the costs of reinforcement and the associated impact on customers are likely to be most severe. In doing so, the Method will demonstrate how the cost of the transition to low carbon technologies can be reduced and a faster deployment enabled.

In addition to the above, the *Demand Zone* Method will also ensure that the increased local generation and the subsequent reduction in demand on the constrained higher network levels doesn't lead to over-generation. This will provide an additional programme benefit, since the local Wadebridge LV network is also becoming constrained. The programme will therefore demonstrate a Method by which both domestic and commercial generation can continue to grow within existing network constraints. Methods that will be considered within this zone include:

Method 5 – CHP as a means of reinforcement avoidance

Community Based Model

By working with WREN to develop a model that has the potential to evolve into a comprehensive community energy management scheme, the programme will seek to demonstrate the potential for communities to generate and consume high levels of renewable energy locally.

This will also help to inform how localised smart grids using the gas network could work effectively and how CEB could be used as a legacy for the future of Cornwall. It is believed that this legacy is an important factor in evaluating the success of this programme and one of the key learning outcomes will be how the programme can provide a platform for the future, should it be successful. Methods that will be considered within this zone include:

Method 6 – The end to end value chain (inject only)

Method 7 – The end to end value chain

3.3 Overall Financial Benefits

Business As Usual Cost

Due to the network constraints in the Wadebridge area, connecting the proposed community wind farm would require reinforcement at the 132kV level, the majority of which will be borne by the generator. The cost attributed to the generator of connecting a 6MW wind farm has been estimated at £7.4m.

CEB

The CEB solution will remove the need for reinforcement and hence the size of the associated connection cost by reducing the unconstrained connection offer to that permitted by current constraints. The need to curtail excess generation will be minimised by the use of a controllable electrolyser load and a constraint scheme. Energy translated to hydrogen by the electrolyser will be recovered via a Gas Engine and local decentralised CHP units.

In order to prove that this Method is viable, it is not sufficient to demonstrate that the solution is cheaper than the alternative £7.4m connection cost, given the fact that, at this cost, the community wind farm simply would not go ahead and an opportunity for low carbon generation would be lost. Consequently, the viability of the CEB solution needs to be proven in its own right. In doing so, the cost of replicating the model in a commercial environment needs to be assessed. Specifically, it is expected that, on rollout, the solution cost would be considerably lower than the initial LCNF cost, with each scheme allowing multiple generators to connect to the network and each deployment servicing multiple distribution substations. In addition, an increase in production batch sizes for key components, such as the electrolyser, would see their costs reduce significantly. Following these assumptions, each of the CEB Methods has been looked at in turn, as detailed in section 4.

Analysis has demonstrated the potential for each Method to deliver a positive IRR once the programme has delivered as a demonstration and moves into business as usual. These range from 4.99% to 17.72% over a twenty year period (ten for micro CHP) based on technology prices reflective of a large scale rollout. The analysis of the end-to-end solution (wind farm through to CHP) shows an IRR of 10.35% over the same period, assuming no increase in energy costs, whilst allowing for a 50% micro CHP unit discount for customers in return for the electrical generation and FIT. These returns are despite the operator of the scheme being responsible for all costs including connection, control systems and gas inject. Were the GDN to bear gas injection costs, for example, IRR would increase to 11.59%. This compares with a 10.45% IRR for a basic constraint scheme under the same assumptions and excludes wider solution benefits. For example, the *Demand Zone* control scheme will demonstrate how additional local generation can be integrated into a heavily constrained system. Such a model would benefit areas where penetration of PV and other local generation is causing significant local issues. In addition, the CEB system will provide an enabling infrastructure for local community energy cooperatives, such as WREN, to increase community generation and maximise benefits to local consumers. If these IRRs can be proven and a commercial model found that enables their effective delivery, they are sufficient to enable community ownership of the scheme. The objective of the programme is to demonstrate this viability and find a workable commercial solution which will enable market forces to drive the Method forward and, in doing so, provide a self-funding alternative to DNO reinforcement.

3.4 Benefits of Wider Rollout

When the benefits from the *Generation Zone* and *Demand Zone* are scaled up to all GB network licences, the investment by customers and shareholders in the initial demonstration is well justified.

Assuming the above analysis will be substantiated during the trial, the benefits of the rollout of this solution are considerable. GB peak demand is expected to grow ~60GW to ~75GW in 2030 (Work stream 3 Phase 2 Report, SMART Grid Forum, 2012). During this time, an additional cumulative Business-As-Usual investment of circa £7 billion will be required to support the low carbon technologies necessary to deliver this.

The Carbon Trust estimated that micro CHP units may be viable in up to 8m UK houses. With 2kW generation each, this would provide an additional 16GW of peak generation at the point of consumption. The micro CHP subsidy that has been modelled, which it is believed will be enabled by this Method, will provide a significant stimulus to the adoption of these units. Consequently, micro CHP should have the ability to offset a significant proportion of the £7 billion investment required by 2030 and the far larger figures predicted thereafter.

Imperial College's 2012 research, 'Understanding the Balancing Challenge' states that the distribution network investment required could reach £35bn by 2040 and more than £90bn by 2050. If successful, the Method used within the *Demand Zone* will offset this future network reinforcement. It is estimated that about 20% of distribution substations will need reinforcement by 2030, at a cost of approximately £20,000 per substation. WPD South West has roughly 13,000 distribution substations. Deployment of the solution could therefore avoid this reinforcement in many situations. Across the UK, where there are estimated to be over 400,000 substations, the opportunity, at £8bn, is obviously far greater. Overall, the combination of measures demonstrated by CEB will provide significant support to GB's ability to deliver the Carbon Plan and the associated carbon reduction targets.

3.5 Customer Benefits

Generation Customers

If proven successful, implementation of the trialled Methods will allow a substantial increase in the number of viable renewable generation schemes and enable these to connect to the grid far more quickly and cheaply than is currently possible. This has the potential to radically change renewable generation into the future, and thereby give longer term benefits to customers through a far more flexible and creative generation mix.

All Customers

The benefits to customers can be summarised as follows:

- The carbon reductions that are achieved as a result of greater renewable generation connection will benefit all customers, helping GB towards its CO2 emission targets
- The ability to maximise renewable generation without the need for network reinforcement will provide considerable benefit to customers in terms of security of supply and reduced charges apportioned to them based on the reinforcement needs two or more levels above the point of generation connection
- The community ethos that underpins this programme and the aim of using renewable generation locally will reduce the load on network assets, reduce losses and consequently lead to a reduction in the Distribution Use of System (DUoS) charges for both generation and demand customers
- The community ownership models being explored have the potential to reduce community energy prices.

By proving the viability of low-carbon gas generation through this Method and its transportation through the existing gas network, the scale of the electrification of households required to de-carbonise heating will be reduced. This will subsequently reduce the associated levels of DNO-funded network reinforcement required across the county.

Additional learning benefits of this scheme to DNOs are that it will:

- Demonstrate an optimal solution to enable renewable energy connection
- Demonstrate the viability of utilising the gas network where costs of reinforcing electricity networks are inhibitive

- Build upon other projects to demonstrate how a constraint scheme can be enhanced by the use of a controllable load to provide an optimal solution for renewable connection
- Investigate the degree to which micro CHP can help alleviate peak demand in constrained areas, enabling joined-up strategies with communities and CHP providers, which offset the need for reinforcement
- Understand how best to manage local renewable generation to reduce peak demand while avoiding consequent problems at higher network levels
- Evaluate the pros and cons of working with community and/or other third-party organisations to deliver solutions to what are inherently network problems.

3.6 Carbon Benefits

Onshore wind is predicted to rise by 5-8GW by 2020 (Renewable Energy Roadmap, DECC, 2012). A 2010 study on Wind Farm Power Output by Cardiff University estimated that mean GB onshore wind farm power output was 25.5% of capacity with a standard deviation of 15.5%. Connecting wind farms with an unconstrained connection equating to 30% of capacity with an additional 20% of capacity via electrolysers would therefore result in curtailment in less than circa 7% of occasions (assuming no constraint scheme) with the electrolyser having at worse a 30% utilisation. Assuming this minimum operation and a conservative 5GW rise in onshore wind, if the generated hydrogen is injected into the gas network it would displace 306,371 tonnes of CO_2 per annum. Similarly, connecting the wind farm at 20% of capacity would result in electrolyser utilisation of circa 58% and would displace 901,439 tonnes of carbon per annum. The programme will also demonstrate the viability of even lower connection which will result in far greater electrolyser utilisation and hence CO_2 displaced.

The above figure ignores the carbon savings of the wind farms enabled by this scheme which would not otherwise have been built and simply focuses on the additional carbon savings enabled by the electrolyser.

3.7 DNO learning benefits and alignment with business objectives

The benefit of this programme to DNOs is that it will identify a community-based solution to managing excess renewable generation that can be repeated across networks.

Nowhere is the problem of excess renewable generation more pronounced than in Cornwall's numerous relatively-isolated communities. Cornwall Council's Smart Cornwall Strategy will look to roll out this community concept. WPD will actively support the Council in this rollout hence the learning benefits of this programme are critical.

Additional learning benefits of this scheme to DNOs are that it will:

- Demonstrate an optimal solution to enable renewable energy connection
- Demonstrate the viability of utilising the gas network where costs of reinforcing electricity networks are inhibitive
- Build upon other projects to demonstrate how a constraint scheme can be enhanced by the use of a controllable load to provide an optimal solution for renewable connection
- Investigate the degree to which micro-CHPs can help alleviate peak demand in constrained areas enabling joint up strategies with communities, and CHP providers which offset the need for reinforcement
- Understand how best to manage local renewable generation to reduce peak demand while avoiding consequent problems at higher network levels, essential in an area of the country that is rich in renewable resources.

3.8 Industry Benefits

The problems faced by Wadebridge and Cornwall are by no means unique. Much of the British south coast is facing similar issues due, at least in part, to the levels of PV generation, whilst the north of the UK is seeing an increasing challenge through wind generation.

Each of the Methods tested within this programme will increase the ability to cost-effectively connect renewable generation and, as a result, will benefit all DNOs.

The electrification of heating will similarly impact all network operators. Methods which offset the need for this and generate learning on how to manage any consequential impact of the resultant CHP generation will also be of considerable benefit to the industry as a whole.

The wider knowledge generated around commercial arrangements will prove the viability of the various Methods in their own right. Based on this, there is the potential for specific Methods to be adopted by the industry as a whole, with minimal impact on the DNO, hence providing a self-financing method of addressing network constraints that would benefit all DNOs.

This is the first GB programme to explore the full potential of optimising across both gas and electricity networks. Given the considerable investment in both these networks, the learning developed from this activity, and its ability to minimise the need for additional investment whilst protecting existing investment, will be invaluable across both distribution industries.

3.9 Direct Benefits

There will be no direct benefits for WPD from this programme.

Low Carbon Networks Fund
Full Submission Pro-forma
Section 4: Evaluation Criteria

This section should be between 8 and 10 pages.

4.1 (i) Accelerates the development of a low carbon energy sector - Supporting the Carbon Plan

Drive deployment of renewable energy 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. This challenge needs to be considered in the context of the increasing community resistance to renewable deployment. This has influenced DECC and DCLG's decisions to implement new measures that will see communities and local authorities have a greater say in the siting of onshore wind farms as well as a range of policy and funding measures to support community renewable energy development.

In addition, the CEB approach is built around a community model. Through this direct community engagement, CEB will demonstrate how communities can directly benefit from renewable generation, consequently making wind and PV farms more palatable and hence increasing still further opportunities for their deployment.

Encourage local communities to host renewable energy projects

Ed Davey, Secretary of State for Energy and Climate Change, 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.' (DECC, 2013, *Putting local communities at the heart of energy use* [online] https://www.gov.uk/government/news/putting-local-communities-at-the-heart-of-energy-use Retrieved 31 July 2013).

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 the first LCNF scheme 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. It will also provide a repeatable template to support the Smart Cornwall programme and wider UK rollout.

Through this model, CEB will demonstrate the ability to deliver significant benefits to the DNO in terms of reinforcement and energy loss avoidance and to the energy industry as a whole via reduced need for costly central balancing reserve.

Increase the flexibility of the electricity grid to ensure sufficient capacity and access to connect new forms of energy generation

CEB provides an approach which adds dynamic operation to the electricity grid, albeit perhaps not in the way initially intended. The CEB Methods will demonstrate how the electricity grid can be managed through coordination with the gas grid in order to maximise return on existing investment while reducing the need for further investment. By reducing the need for reinforcement in many instances, the CEB Methods will ensure sufficient capacity and access to connect new forms of energy generation.

Increase business and investor confidence in the low carbon transition

CEB will demonstrate the viability of a range of commercial models relating to the ownership and operation of different elements of low carbon infrastructure and generating plant. These range from basic constraint schemes, which will validate the benefit of connecting a generating set without an unconstrained connection, to the end-to-end Method, which in the future may see a community potentially own and operate a range of equipment, including a wind farm, a gas engine, an electrolyser and CHP units.

Improve the energy efficiency of residential and commercial buildings

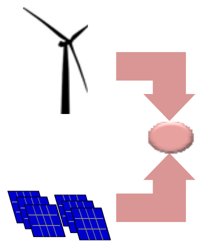
CEB will increase energy efficiency in homes and buildings by deploying CHP units and exploring control schemes which will enable both the heat and electrical energy generation from these units to be aligned to demand.

4.1 (ii) Has the potential to deliver net financial benefits to existing and/or future customers

As detailed below, CEB will evaluate the seven discrete Methods that make up an end-to-end solution for the energy value chain, from wind farm through to CHP. Within this modelling, we have assumed costs conversant with mass rollout as opposed to those employed in the proposed one-off trial.

The end-to-end trial demonstrates benefits greater than those of both basic reinforcement and of the Constraint Scheme, Method 1, alone. One of the objectives of the trials is to seek ways in which each of the discrete Methods can be optimised in order to ensure their viability while also improving the benefits of the end-to-end solution covered by Methods 6 and 7.

Method 1 – Constraint Scheme



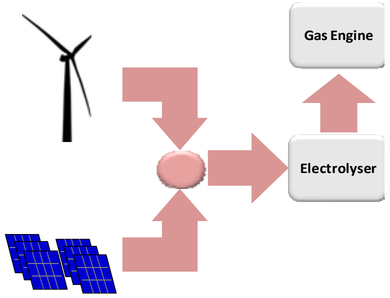
The Constraint Scheme will operate the 6MW wind farm with a 0MW unconstrained connection working alongside a 3MW PV farm to release up to 3MW of constrained capacity. There is also an existing 12MW wind farm in close proximity to the new wind farm. However, due to the expected similarity in generation profile, this has been omitted from the modelling. Our initial modelling indicates that, even with a £600k connection cost and a £400k control system, the combined solution has an IRR over twenty years of 10.45% with eleven year payback, assuming no increase in energy prices.

CEB would look to explore the financial viability of lower levels of unconstrained connection and changes in energy prices during the course of the programme and the implications on curtailed energy and Method payback.

Under this Method, an additional 4GWh of generation will be released per annum, reducing the level of curtailed generation by 23%. It is envisaged that the control system costs would reduce further and it would be possible to readily replicate this model. The only requirement to implementation would be access to appropriate measurements and to the SCADA control system of the wind farm (which should be a condition of connection). Assuming these are available, the scheme can be commissioned and operational within weeks, compared to the many months or years required by reinforcement on this scale. Assuming one system operates 10+ schemes, connecting 5MW of wind against 5MW of PV with only 5MW unconstrained capacity would release 50MW of additional capacity with negligible curtailment.

Method 2 – Gas-Enabled Peak Shifting

This Method will utilise the constraint scheme in conjunction with an electrolyser that is used as a controllable load, hence allowing the wind farm to increase export in line with electrolyser size. The gas generated will be stored and then subsequently blended with natural gas and burned in a 1.4MW gas engine at a later date/time when the available network capacity allows. In this way, the gas sub-system will provide a mechanism for generation peak shifting.



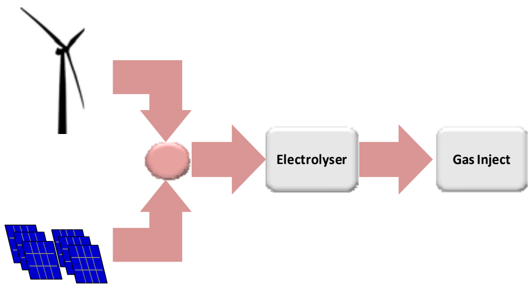
Initial modelling indicates that, with a reduced electrolyser cost of £0.8m, enabled by larger production volumes, and a control scheme encompassing the constraint scheme and additional gas equipment, the combined solution has an IRR over twenty years of 6.77% at current energy prices, rising to 7.53% assuming a 3% annual increase in energy prices. The low returns on this model are as a result of the low spark spread caused by the high gas wholesale prices currently being experienced and, to a degree, the relatively high unconstrained connection in respect to connected generation. If wholesale prices were to reduce to £20/MWh, prices more common during 2012, the IRR increases to 9.64% with an eleven year payback. In addition, the Method reduces the level of curtailed renewable generation from 28% to 1% of total potential generation.

Under this Method, an additional 15GWh of generation would be released per annum. In terms of ease of implementation, although the electrolyser and gas engine are self-contained units designed for easy install, they would both require an appropriately sized compound with adequate connectivity. The core lead time of this Method will relate to site preparation, equipment installation and network connection.

It should be noted that with a 50% unconstrained connection, despite the positive payback, the electrolyser utilisation is very low. During the trials, we will evaluate the cost/benefit of reducing the level of unconstrained connection to zero. Preliminary analysis shows that even with an unconstrained wind farm connection of zero, 11GWh of additional generation can be supported per annum. In addition to the 50MW of Method 1, a 1MW electrolyser would release 3.3MW of additional effective capacity based on a 30% load factor.

Method 3 – Constraint Circumvention via the Gas Network

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 acceptable levels at a time when there is available gas network capacity to accommodate it.



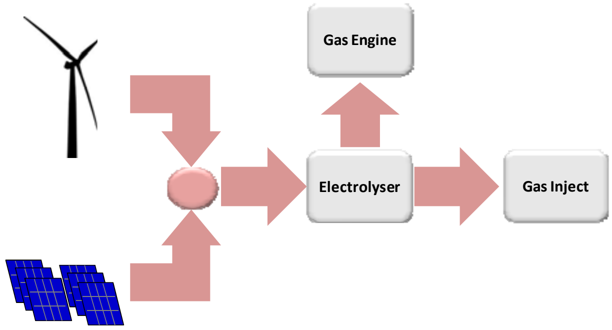
In support of this, an exemption to the GS(M)R will be sought to allow the injection of hydrogen at higher levels.

Our initial modelling indicates that this Method will have an IRR over twenty years of 7.33%. It should be noted that the Method is bearing the full cost of gas injection. Given hydrogen gas injection provides a tangible Method of increasing the life of the gas network and protecting existing investment in network assets, there is a strong argument that these costs should be, at the very least, part-subsidised by the GDN. If the gas inject costs were transferred to the GDN and a wholesale gas price of 20£/MWh used, the Method would have a return of 8.57% with a twelve year payback.

Under this Method, an additional 15GWh of generation has been released per annum. The ability to rollout this Method and additional capacity released will be driven by the same considerations as for Method 2.

Method 4 - A Network Arbitrage Model (Desktop Study)

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.

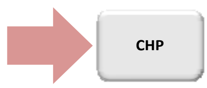


As yet, the additional revenue potential available through network arbitrage has not been modelled. However, integrating the additional gas injection costs into Method 2 demonstrates the worst case scenario. This provides an IRR of 4.99%. Decreasing gas wholesale prices to £20/MWh, as with Method 2, and transferring gas inject costs to the GDN would see IRR increase to 9.2% with a twelve year payback. Given gas and electricity price volatility, the expectation is to improve this significantly by exploiting the relative energy price peaks and troughs.

Under this Method, an additional 15GWh of generation has been released per annum. The ability to rollout this Method and additional capacity released will be driven by the same considerations as for Method 3.

Method 5 - CHP as a Means of Reinforcement Avoidance

This Method will explore the ability of CHP systems to support local load and hence minimise the need for urban reinforcement and central balancing reserve.



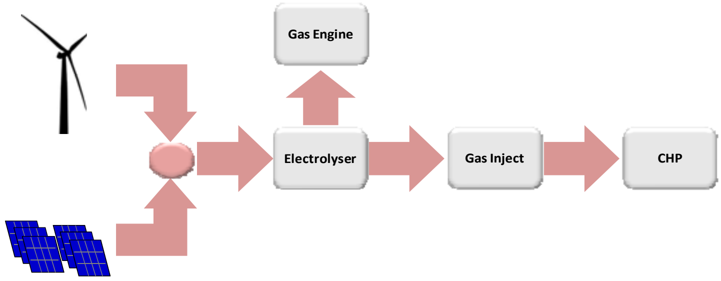
The current financial model developed focuses on micro CHP. It assumes a volume micro CHP unit discount is offered by manufacturers and is further discounted by the scheme in return for the revenues from generation and FIT. Under the model, all units are installed in year 1. The FIT tariff will apply for the next ten years, at which point, the units are replaced and, given an anticipated significant reduction in unit price, the FIT is removed.

This Method is highly sensitive to the number of CHP units within the *Demand Zone*. The Carbon Trust estimated the potential for 8m CHP units across the UK's circa 24m households. Using a similar percentage, this would equate to circa 1000 households within Wadebridge. Working with a £4.5k installed unit price for the first ten years coupled with a 50% unit discount and a £2k installed price coupled with a 30% discount for the second ten years (sufficient to undercut standard boiler prices), the IRR is 17.72% over ten years, paying back over six. The payback period for the second ten year term is two years.

The estimated network capacity released by this model equates to the total unit generation, which is 2.3GWh per annum assuming the 1kW units which will be utilised in this trial. 4.6GWh if the 2kW units perceived by the Carbon Trust are deployed. This model can be readily replicated by including the control system as part of the WPD estate, as above. In addition, the system would only require basic communications connectivity to the CHP units.

Methods 6 & 7 - The End to End Value Chain

Methods 6 and 7 are similar Methods, both looking at the optimal cost, efficiency and commercial models for the end-to-end value chain from wind farm through to CHP.



Method 6 focuses purely on gas inject, while Method 7 considers network arbitrage opportunities by deploying gas inject and a gas engine. As with Method 4, we have yet to model the network arbitrage opportunities presented by differences in gas and electricity price. Using the assumptions made above, Method 6 provides an IRR of 10.35% with a ten year payback. If gas injection costs were covered by the GDN, then the IRR would increase to 11.59% with a ten year payback.

We estimate the additional generation supported by this model within the trial scheme is circa 17.3GWh. This model can be readily replicated, as detailed above. Other factors impacting the financial performance of the above Methods include the performance of the electrolyser. ITM Power (ITM) believe this can be run at high capacity for short periods, giving operational performance of twice its actual rating. This has the potential, depending on how long it can operate in these extreme conditions, of effectively halving the unit price. Total capacity released by this method would be in the region of 56.6MW.

It should also be noted that:

- The above analysis has been undertaken on the 33kV feeder, to which the new wind farm is connected. However, the proposed control system will monitor the 33kV ring into which this feeder connects and will back off the generation and/or increase the electrolyser load in order to alleviate constraints within it caused by changes in its connected generation and load. As such, the value of this scheme is far greater than the impact it has on the feeder generation, as described above
- The control system costs have been included within the evaluation. When the scheme is rolled out, these costs will be far lower, as the control systems may be part of the DNO estate. However, they have been included in the analysis in order to demonstrate the viability and net benefit of each Method. Removing gas injection and control system costs from each option results in an IRR for the end-to-end solution, Method 6, of 12.98% with a nine year payback. This compares to 11.07% and a ten year payback of the constraint scheme alone under the same conditions
- The above analysis represents one implementation of the scheme. It is the expectation that this solution will prove a community model that can be rolled out across the UK, allowing community ownership of local generation and CHP. Over 36.5% of the UK population lives in rural communities where such a solution may be applicable. Within Cornwall, this proportion rises to 67%, making the Smart Cornwall Programme a logical focus for the initial rollout.

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Full Submission Pro-forma
Evaluation Criteria continued

4.2 Provides Value for Money to Distribution Customers

Delivering Value

The above analysis demonstrates that the solution has the potential to increase the level of renewable generation deployed and provide significant returns to local communities through generation ownership. In its wider context, the solution can provide benefit to a cross section of DNO customers. Generators and customers will benefit through the reduction in connection costs. In the 2012/13 financial year alone, the connection costs borne by all parties totalled £230m within the WPD South West area. The programme will demonstrate Methods by which these costs will be potentially reduced, thereby having a positive effect on customers, generators and DNOs alike.

Through the reduction in connection costs, it is anticipated that there will be a significant rise in viable renewable generation schemes. Given the increased powers of communities to veto these schemes, the community model supported by CEB will increase this still further, providing a net benefit to all DNO customers in terms of carbon reduction.

CEB will prove the viability of a scheme that will provide sufficient financial incentive to customers to enable the mass adoption of micro CHP. Based on an assumed future generating capacity of 2kW per unit, the 8m units anticipated by the Carbon Trust will deliver a significant level of local generation, thus reducing the need for costly urban reinforcement and therefore the DuoS charge for all customers. It will also reduce the need for central balancing reserve, hence similarly reducing TUoS charges. Due to the diverse nature of the technologies proposed within CEB and a scope that encompasses both gas and electricity distribution networks learning of this nature has not been previously generated in the UK, nor, to our knowledge, anywhere else in the world.

Minimising Programme Costs

In order to provide value for money to distribution customers associated with CEB, the following measures have been taken:

- All CEB partners have provided a financial contribution of at least 10% of contract value
- The partners will underwrite delivery of the SDRC, hence protecting the DNO from any risk of programme failure
- The programme development activity undertaken by each of the external partners has been at their own cost. This equates to over £400,000
- Toshiba has appointed CDC to provide its programme management resource. CDC has considerable experience of managing funded infrastructure projects. CDC also brings the additional benefit of providing invaluable links into Cornwall Council (CDC's sole share-holder); Cornwall Council, amongst others, will reduce the risk of recruiting CHP customers for the trial through links with its own social housing programme
- A costly, but necessary, component of programmes of this nature is the underlying IT platform and connectivity on which the control systems rely. To ensure this cost is minimised, a full IT partner selection process has been undertaken. From an initial long-list of ten potential providers, large and small, sourced from Achilles, CGI was selected based on a range of criteria including Expertise, Solution, Delivery Capability and Commercial Considerations – a key element of which was price.

Person Days and Day Rates

The person days and day rates of each partner are detailed in the Financial Spreadsheet Appendix D.

4.3 Generates knowledge that can be shared amongst all DNOs

All UK DNO long-term development statements and ED1 business plans acknowledge the challenge of connecting increasing levels of renewable generation to the distribution network. Consequently, the learning derived by CEB will directly benefit all UK DNOs.

Although the basic constraint scheme has previously been demonstrated, the end-to-end value chain, which forms the core of CEB, has not, nor has the interoperation of each of the discrete Methods proposed.

The core learning generated by CEB and shared among UK DNOs will be two-fold:

- **Technical Learning** – CEB will determine the technical issues and opportunities associated with the interoperation of the various technologies proposed by this trial. This will include the ability to time shift wind generation using a gas engine, the ability to circumvent electricity network constraints using the gas network and the ability to reduce the need for urban reinforcement using CHP units. This represents new learning for DNOs, which will complement their existing understanding of tools and techniques for connecting renewable generation, hence contributing to their delivery activities
- **Commercial Learning –** CEB will demonstrate the financial viability of each of the discrete technologies deployed both in isolation (via Methods 1-5) and as a whole (via Methods 6-7). It will explore schemes that stimulate community energy ownership whilst minimising network impact. Demonstration of the viability of such schemes will provide a catalyst to their adoption and hence have the dual benefit to DNOs of maximising the potential for renewable generation while minimising associated network investment.

4.4 Involvement of Other Partners and External Funding

Programme Selection

WPD has an ongoing activity to assess project ideas (termed “project concepts” in WPD) against identified strategic priorities. All external approaches are evaluated in a consistent manner with a standardised process and documented on a concept form. Concepts are only shortlisted if they meet the LCNF criteria, offer new learning, match WPD priorities and provide value for money.

Shortlisted concepts are then evaluated using the concept form, reviewed and approved by WPD managers and prioritised according to importance, funding and resource availability. Project concepts that can only be funded through the LCNF Tier 2 process are in the minority, with the majority of shortlisted project concepts processed through BAU, IFI, Tier1, TSB, EPSRC, ETI or EU routes as is most appropriate (and best value for customers). For the 2013 LCNF competition, four concepts reached the detailed evaluation stage. Only CEB satisfied WPD’s evaluation criteria and progressed to the ISP stage.

Partner Selection

Toshiba will provide the energy management systems, 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.

Toshiba first approached WPD with the CEB idea over a year ago and has been working to refine it ever since. WPD propose to sponsor Toshiba's idea through to LCNF. Consequently, Toshiba will be responsible for shaping and refining this strand and driving it forward. As such, Toshiba has not been put through a formal selection process.

To keep costs to a minimum Toshiba has sub-contracted:

- The trial management activity to its not-for-profit, Bristol-based subsidiary

Telecommunications Research Laboratory (TRL)

- Programme management to Cornwall Development Company (CDC). CDC is an 'arms-length' part of Cornwall Council, with considerable experience of funded infrastructure projects of this nature. Its link to Cornwall Council will prove invaluable in CHP customer recruitment and will also ensure the programme outcomes can be best exploited by the wider Smart Cornwall programme.

ITM Power (ITM) 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 all the gas-related elements of the CEB programme.

ITM first approached WWU with the gas inject proposition integral to this programme a year ago and will lead the NIC strand, sponsored by WWU. Like Toshiba, ITM has not been through a formal selection for this reason.

CGI will provide the data analytics, visualisation systems, IT integration, end-to-end testing, commissioning and operations and maintenance. In addition to its IT capabilities, it has considerable experience of DNOs and the LCNF process. CGI was procured through a competitive process via Toshiba.

Wadebridge Renewable Energy Network (WREN) is a not-for-profit community energy cooperative working to develop a local energy economy in the Wadebridge area. It will develop, finance and operate the constrained wind farm and attract local community micro CHP and commercial CHP participants. It will also help to develop a community ownership legacy model for the scheme through working with the Smart Cornwall programme and other stakeholders.

Since WREN is a not for profit organisation operating in CEB's target geography and providing commercially-funded elements of the bid, it has not been deemed necessary to put it through a formal selection process.

Wales & West Utilities Ltd (WWU) will work in conjunction with the Health and Safety Laboratory to undertake a NIA study aimed at obtaining a derogation that enables the hydrogen content within the Wadebridge gas system to be raised from the current legal limit to a level approaching 2%. WWU will also submit an NIC bid to complement this submission and will provide appropriate gas network connections and status monitoring to support the LCNF bid.

<u>External Funding</u>

The programme will exploit considerable external funding. This includes:

- **Programme 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 deployed by this programme
- **Wind farm** – WREN is funding the wind farm which is estimated to cost £8.5m. The initial development investment is being undertaken at risk since the payback model assumes the increased energy export that will be supported by CEB
- **CHP** – The CHP units will be commercially funded (although an incentive will be required for the micro CHP, to ensure customers are happy with third-party control of their units). Working on a unit price of £4,500, this equates to £225k if 50 units are installed. In addition, there is the cost of the commercial CHP units and based on two of these being sourced for this programme, this represents additional external investment of circa £640k.

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Evaluation Criteria continued

4.5 Relevance and Timing

DECC is due to launch its community energy strategy this autumn. Greg Barker, Minister of State at the Department of Energy and Climate Change, has already stated his desire to '...see even more communities taking local power production into their own hands, bringing communities together' (DECC, 2013, *Putting local communities at the heart of energy use* [online] https://www.gov.uk/government/news/putting-local-communities-at-the-heart-of-energy-use Retrieved 31 July 2013). DECC is also demonstrating increased interest in the exploitation of hydrogen. As Greg Barker 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).

Micro CHP technology has just reached its tipping point in terms of potential for wide-scale rollout. Prices are approaching levels that permit a ten year payback, making justification of investment in the technology easier, albeit still challenging. The Carbon Trust has demonstrated the huge contribution micro CHP technology can make to the generation mix with a potential for 16GW. National Grid's Accelerated Growth scenario predicts this could be achieved by 2030. However, to get anywhere close to this target, a catalyst is required to stimulate micro CHP take-up beyond the existing CHP FIT. CEB aims to identify an appropriate commercial model that will provide such a catalyst.

Given the above, this programme could not be more timely in terms of both technology maturity and government focus.

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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 is a very important aspect of this programme and, as such, requires a robust methodology and plan for delivery. In order to achieve this, there has been engagement with the senior stakeholders within WPD to ensure that that KCD approach for CEB starts by learning from previous projects.

Due to the nature of the programme, new knowledge will be produced that relates to various stakeholders; an initial exercise to identify and assemble all stakeholders into their various groups will be undertaken. These groupings will help to ensure that it is known who is generating knowledge, when and for whom. This will then be mapped onto the overall programme plan so that it can be ensured that knowledge is being disseminated in a timely manner. Knowledge will generally be of two forms; planned and unplanned. The approaches for capturing these types of learning are detailed below.

Planned learning:

I. Will be integrated into the programme plan for each part of the programme.

II. By the end of the design phase, each project team will have a framework and method in place for capturing learning. The key learning objectives will be included in the use-case document to ensure system design links to learning objectives. Each team will also have a clear method for how the key questions will be answered.

III. Outcomes of these activities will be shared through reports published on the programme website.

IV. These documents will be available to all programme partners via an online document collaboration service, such that they can be read, edited and used as required.

V. Access to data supporting the learning will available to third-parties to access and analyse independently in order to stimulate the generation of additional learning

Unplanned learning:

I. It is very difficult to anticipate the nature of these lessons learned and, as such, issuing a standard template would be counterproductive.

II. Instead, the learning lead for the programme will conduct diarised interviews with work package (and project) leads and project teams to identify all 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, can be very valuable. It is imperative that these interviews are integrated into the programme plan and take place at regular intervals. This will make it a part of normal programme activity, thus highlighting the importance of knowledge capture.

Knowledge dissemination continued

III. 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.

IV. 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.

V. This will capture issues that occur on an ongoing basis but are likely to be forgotten after a period of time. This will be shared via a lessons learned document at various stages throughout the programme.

Aspects of the planned learning objectives for this programme have already started; Appendix C provides an initial analysis of the power network in the Wadebridge area. This report analyses the thermal and voltage constraints that are impacted by introducing further distributed generation to this network. Appendix E (Use Cases) 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 ensure successful learning. Appendix E also shows functional use cases that are built below the system-level use cases. During the mobilisation phase of the programme, these system and functional 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 objectives are compatible. Note that Appendix E includes both the LCNF and NIC aspects, as this is the most appropriate way to ensure all areas of cross-sector learning are captured. Clearly, specific aspects will be more relevant for LCNF or for NIC and this 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 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. DNOs, GDNs, equipment providers). Combining this with periodic (throughout the programme) written reports collating experiences and evidence across different sub-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 and will include analysis on whether there is an impact on DNO strategy or policies.

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Knowledge dissemination continued

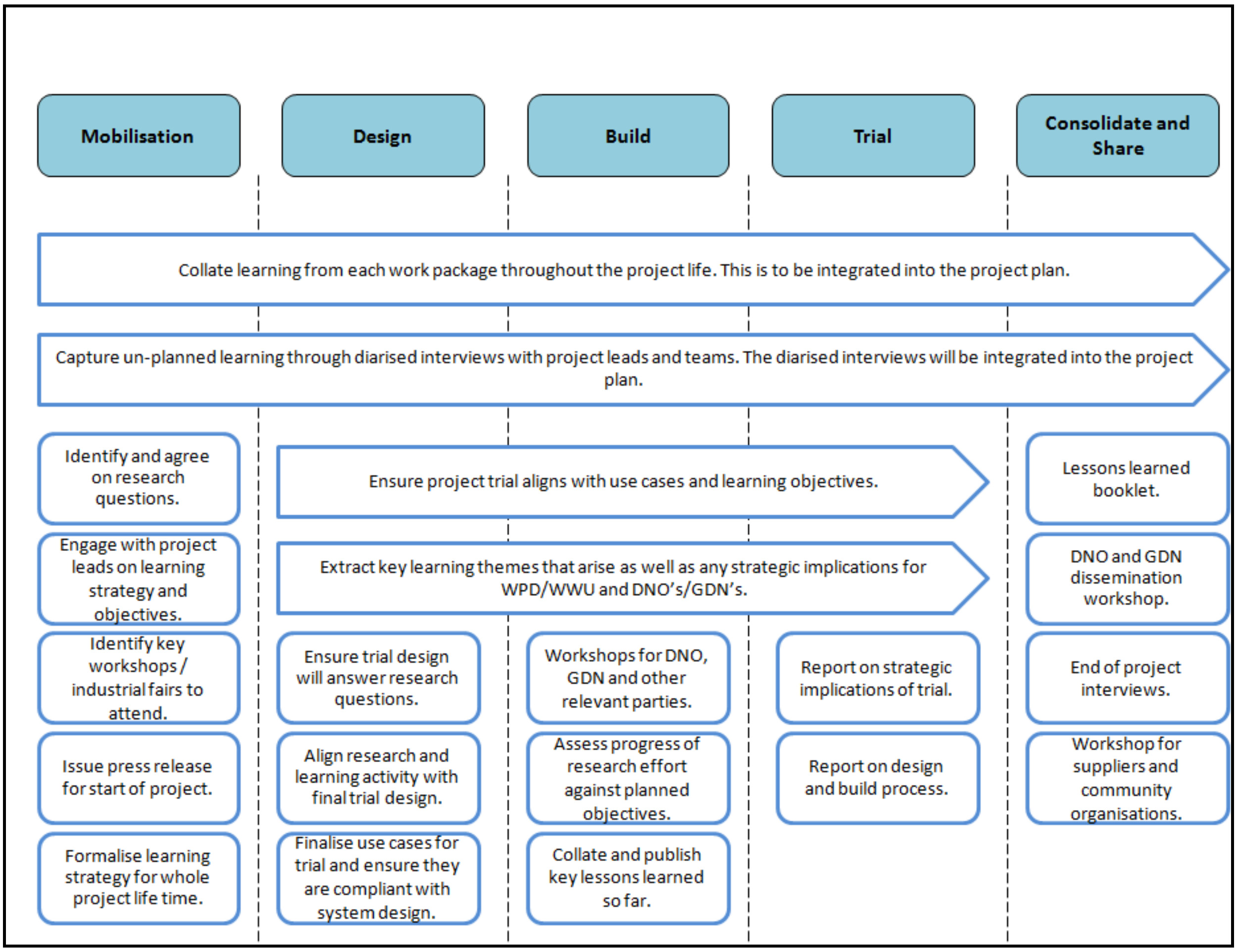

Figure 1: Overview of learning strategy for CEB

Key Learning Outcomes:

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

DNO: The programme will show to what extent future capacity in the gas network can be utilised to alleviate constraints in the distribution network. Areas of the South West are already facing severe constraints which could limit the installation of increased renewable generation. The outcomes of the programme will help find methods to reduce curtailment of low carbon energy whilst reducing connection costs for generators. Future rollout potential and impact is also a key area which will be delivered through the learning process.

GDN: The programme will investigate how the gas network can be used to provide a service for a constrained electrical network. This will have long-term impacts relating to an extended life time of the gas network, which currently anticipates a reduction in gas usage over the next 30 years. Other technical challenges also need to be investigated, such as: effects of injecting hydrogen into the network, commercial models to allow this to happen. Future rollout potential and its effects on the network will also be investigated.

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Knowledge dissemination continued

Technology vendors: This programme offers a unique opportunity for vendors to understand what technical capability is required to address future challenges within the electricity network. In addition, the commercial viability and agreements necessary for a large scale rollout will be investigated.

Consumers: Understanding how the demand side can be incorporated into future networks is key for GB's low carbon strategy. CEB will explore how µCHP units can be used to alleviate low voltage constraints whilst delivering value for money to households. This will include aspects such as subsidies for µCHP adoption in order to initiate consumer adoption of these types of technology.

Generators: Lowering connection costs through innovative solutions that utilise the gas network would make it possible for generators to connect to the grid in areas in which it would otherwise be uneconomical to do so. This would increase the amount of low carbon generation in GB and further move towards decarbonising the electricity supply. The programme will analyse the impact of rollout on connection costs, carbon emissions, and behaviour of the electrical network.

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 GB. The programme will identify the key characteristics necessary to create this community solution as well as commercial aspects necessary for its success.

Dissemination Methods

Having a clear methodology and purpose for all learning activities is integral to delivering a successful programme. The approach outlined here requires close communications and contact with the project teams on a regular basis whilst ensuring that the research-based activities progress in line with the trial's objectives.

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 available via 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 DNOs, consultants and equipment vendors to understand how the 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 programme. As part of the dissemination plans, the CEB programme will utilise various routes as outlined in Figure 2.

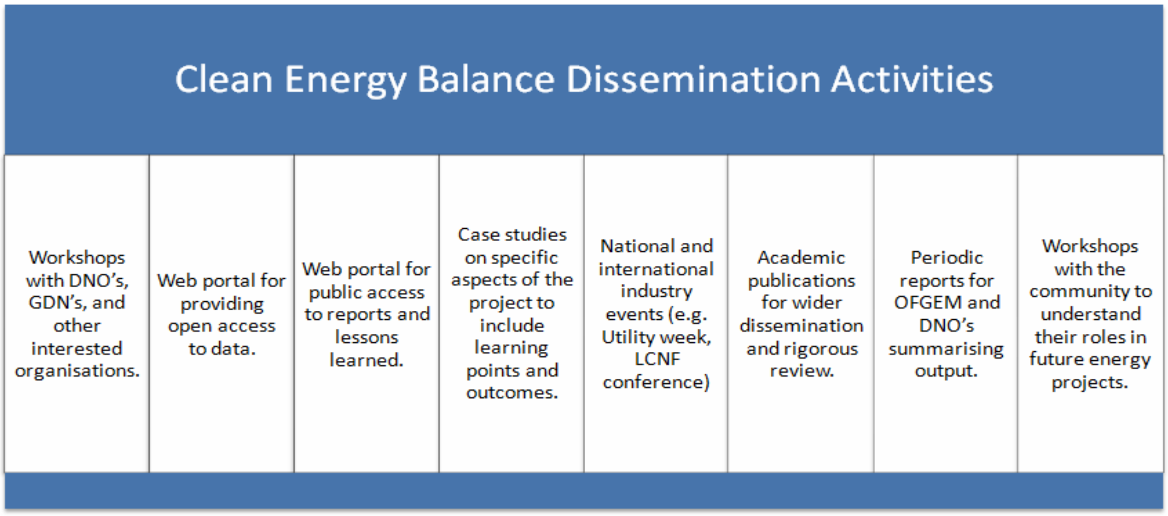

Figure 2: Dissemination activity outline for CEB.

5.2 IPR

The partners agree to the default IPR conditions.

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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 (%):N/A

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

Clean Energy Balance is one programme that comprises of two distinct strands covering two separate funding streams. For the purposes of this document, Project Readiness covers both the NIC and LCNF applications as the two applications have been treated as one from a delivery perspective.

The partners have been working on this bid for 7 months and the lead organisations for approaching two years. They have been actively engaged in agreeing the commercial and delivery structures and CEB has a Consortium Agreement prepared, which sets the scene for the programme. The partners are also well advanced in creating the supporting agreements that provide for the delivery workstreams.

In undertaking this activity, there is a commitment from all partners to ensure that mobilisation will be complete within the first five months of the programme.

The Mobilisation phase is specifically designed to finalise contracts, procure the right office space for the teams and refine project plans as appropriate. This will not be an easy task, but, by doing some of the preparatory work now and between submission and decision, partners are confident that mobilisation can be achieved in accordance with the plans.

Through in-depth engagement with the CEB partners throughout the bid development phase, it has been ensured that experience and lessons learned by all partners on previous projects (LCNF and otherwise) have been captured and borne in mind when planning the CEB programme. This integration of experience will help CEB to avoid start-up issues that partners have been experienced on other schemes and which might have affected this programme.

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, Cornwall Development Company (CDC) has been appointed to undertake the overarching Programme Management function.
- Programme Plan (Appendix F) - 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

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Project Readiness continued

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.

- Governance Structure (Appendix G) – 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.
- 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. (For more detail on the reporting structure see the Governance and Reporting Structure Appendix G.)
- Hydrogen Work - Prior to the start of the programme, ITM will have designed, built and installed three 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 by one of Germany's largest Stadtwerk (municipal utilities). The integrated containerised system, capable of generating 125kg/day of hydrogen gas, will be situated at a Mainova AG site in the Schielestraße, Frankfurt, in the state of Hessen. 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 which will conclude in October 2015. The system is designed to capture locally generated renewable energy which will be converted to hydrogen to fuel a fleet of fuel cell and modified hydrogen internal combustion engine vehicles. In addition, a third, smaller, 15kg/day unit, also powered by the local grid and connected renewable energy sources, will be installed at Ventnor, on the island, to provide fuel for a boat.
- In June 2013, ITM were awarded a contract by the Technology Strategy Board (TSB) to develop a front-end power electronics module to enable PEM electrolysers to be utilised for dynamic response energy balancing and energy storage. The ability of the electrolyser to respond dynamically to allow frequency control will enable the load presented by the electrolyser to be operated without administrative control by the grid operator and a commercial aggregator for Frequency Control by Demand Management (FCDM) services will not be required.
- 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 delivery phases. This will help mitigate the risk of losing programme knowledge and relationships that have been built with partners through the bid process.

Project Readiness continued

All of the above, which has been agreed/completed prior to bid submission, means that partners have confidence in the programme and are fully aware of how it will run post-approval. All the planning completed to date means that critical time will not be spent on these activities during the mobilisation phase. Thus, mobilisation can focus on those activities which are necessarily planned for completion post-submission.

6.2 Evidence of how the costs and benefits have been estimated

A thorough and rigorous analysis of the costs and benefits of the CEB programme has been undertaken. Further detail is provided in Appendices D and H.

Experience that partners have brought to the programme has aided the completion of thorough, realistic and appropriate cost/benefit models.

Costs

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.

Benefits

In quantifying the benefits, a number of scenarios have been considered with varying levels of low carbon generation.

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

(As per Section 3, CEB has no Direct Benefits.)

Robust modelling and analytics have been undertaken and continuous measurement, ongoing analysis and regular reporting will occur throughout the programme to ensure that costs are being monitored and managed effectively.

CDC, through its Programme Management role, will ensure close monitoring and oversight of performance versus spend profile and report back to the accountable bodies. Additionally, an experienced financial management team will be working alongside the CEB team throughout the programme delivery.

Significant work has already been undertaken to ensure that the costs presented are well set for the delivery phase, including appropriate contingencies for risk areas.

Mitigation and contingency management plans (Appendix I) have been put in place and will dictate the course of action appropriate to dealing with potential or realised risks. The 10% contingency fund will cover any minor changes to CEB's cost that emerge during the delivery.

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Project Readiness continued

A robust change request process will also be put in place with a requirement for partners to submit requests for any changes to the PRB for analysis and approval and this will include the use of contingency funds.

All partners will provide a detailed payment schedule and confirmation of outputs they will be delivering, all of which will be set out in partner contracts. CDC will then review all invoices and output records on a monthly basis and assess against Highlight Reports and the Project Assurance input to recommend payment from the fund holders.

CDC will also have responsibility for coordinating activity, preventing duplication of work, identifying different areas of tasks that together may cause overspend and ensuring that risks are escalated as appropriate and mitigating action is taken where necessary. Where there is a trend for costs to move off profile, this will be raised with the Project Manager for that project and also with the relevant senior member of the PRB. It will also form part of the monthly / quarterly reporting and discussion of the meetings.

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

- The programme proposal has been prepared by Toshiba in conjunction with WPD and CDC and information has been provided by partners and equipment suppliers.
- The bid has been prepared by a dedicated team of experts from across the partner organisations.
- The proposal has been through independent checking processes, peer review processes and sent to partners to ensure the accuracy of information.
- Information provided from partners has been reviewed by WPD to ensure accuracy.

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

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 project in any event. TRL, in their role as 'learning and dissemination partner', will ensure that learning outcomes are maximised.

If there is lower than anticipated take up of Low Carbon Technologies (LCT), CEB will still deliver learning, as the problem is not reliant on them beyond those delivered as part of the project. Moreover, a realistic approach to estimates has been taken.

In addition, if LCT take up is not as expected, there will still be learning opportunities, as any outputs can still make for more efficient solutions for networks businesses through energy management and the commercial viability of hydrogen injection. The take up of micro CHP, whilst an important ingredient of the trials, is only one element within the whole solution set; a slightly smaller sample will not invalidate the trials.

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.

As the custodians of NIC and LCNF funds, it is imperative that both WWU and WPD remain cognisant of their duties to make best use of customer funding. Given this, and given the scale of the programme, it is anticipated that the CEB team will be in contact with Ofgem about the programme. CEB already has significant interest locally and beyond and it is imperative that the governance gives a clear and transparent view of progress throughout, without being overly administrative.

A detailed governance structure and a number of review processes and checks and balances have been put in place to ensure that delivery of CEB runs smoothly.

A detailed risk register has been created (Appendix J) and all of the identified risks have been assigned an owner, who is responsible for monitoring and managing them. This, along with the overarching coordination provided by the Programme Manager, CDC, will ensure that risks are being monitored both individually, by those team members whose work is most closely linked to them, and in the context of the wider programme. Where possible, CEB has been de-risked in the current planning and development phases, with key partners contracted and a programme set to deliver all key outputs within a well developed budget. Additionally, through the detailed design phase, uncertainty will be reduced at an early stage.

Despite the above, it is possible, as with any programme, that issues will arise. Where such issues require remedial action, CDC will lead on the Exception Report process through to the Programme Review Board. Where necessary, if falling outside of the normal reporting process, an extraordinary PRB meeting will be called and action taken to ensure the programme is brought back on track and all key deliverables still achieved. This will also be undertaken in partnership with the funding bodies, through the DNO as lead accountable body for the LCNF strand.

Gateway Reviews have been scheduled for the end of each of the key programme delivery phases, as indicated in the Programme Plan (Appendix F), 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 partners that the project 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 procedures by which remedial action will be implemented to ensure the programme remains on track or, alternatively, is brought to a halt through a managed process will be as follows:

WPD senior management will review and agree the risk level associated with the programme and assign a status in the form of a Delivery Confidence Assessment. This assessment will then provide the recommended actions. Actions fall into the following categories:

- Critical (Do Now): to increase the likelihood of a successful outcome, it is of the greatest importance that the programme should take action immediately;
- Essential (Do By X): to increase the likelihood of a successful outcome, the programme should take action in the near future. Whenever possible, essential recommendations should be linked to a milestone and/or a specified timeframe;
- Recommended: the programme would benefit from the uptake of this recommendation. If possible recommended actions should be linked to a milestone and/or a specified timeframe; or…
- Halt the programme: the programme has exceeded the tolerances set and agreed at initiation and the situation is deemed to be irrecoverable. The programme is to be halted and WPD senior management will contact Ofgem to discuss and agree the way forward.

This approach will give all parties clarity and consistency from the outset.

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.

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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.

During the CEB programme, WPD will own and operate the Electrolyser, Gas Storage (joint with WWU) and Gas Engine Generator. We consider that both the flexible demand (electrolyser) and the generator arrangements are ancillary to the distribution of electricity. The devices will be despatched according to physical grid conditions, independent of any market pricing. The arrangement will be very similar to those used by WPD on the Isles of Scilly, but with flexible demand in addition to generation. Should Ofgem feel there is a need for a de minimis derogation, we would be happy to discuss the matter further.

There are a few regulatory issues on the gas side of the programme, specifically around the monitoring of customers' gas intake and the percentage of hydrogen that can be injected into the gas mains. These will be addressed within the NIC submission.

The P2/6 planning standard will be not affected, as the 33kV feeder, where the electrolyser and wind farm are going to be connected, is only feeding generator connections and thus will not impinge on the security of supply to load customers. In the event of the feeder being used as a backup through a normally open point, the control system will be disabled by the control engineer, so it will have some impact on restoration switching. In the 'demand zone', there will be no fundamental change to customers' electrical connection, so there will be no impact on their security of supply.

For post programme integration of the system, there will be a number of documents drawn up over the course of the programme (connection offers, connection agreements and operational codes of practice) to help the transition into business as usual.

Appendix L shows the electricity and gas networks across Cornwall.

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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 are two key areas where customers may be adversely affected by this programme.

First of all, there is a very small risk of additional trips and voltage excursions to connected 33kV customers, all of whom are generators. This would only happen if the µEMS failed and the WPD backup system failed to operate meaning local protection would operate. Second is the potential impact of installing CHP units in people's homes.

Trips and Voltage Excursions

The risk of trips and voltage excursions to the generators is going to be closely assessed throughout the programme. This risk will only be apparent if there are fundamental errors in the operation of the µEMS. This could be through its logic or through a communication failure alongside a failure of WPD's backup system, which will be running on BAU systems. In extreme cases, the voltage excursion may be apparent on the 11kV network, however this would be protected against through a killswitch to disable all the trial systems.

The outages due to installation will be in accordance with WPD's standard procedures, so the connection process will be business as usual. Appendix K illustrates µEMS case studies and functionality.

<u>CHP installation</u>

Some domestic and non-domestic customers may have CHP units installed. These customers will have agreed on an individual basis with the installation company to have this work done and therefore should understand the impacts on them.

To feed the µEMS system in the 'demand zone', there is a need for aggregated demand data to inform the system, however this will be anonymised. The output from the customers' CHP will be another key source of information.

Generator Connection Installation

On the generation side, the generators' export will be used to drive the µEMS' control. The intention is to get the generators' permissions to use this data. Also, these generators will be at slightly higher risk of being tripped off if the µEMS malfunctions. The fail-safe will be to trip off the entire feeder.

As part of the installation process on the 33kV network, the connections will effectively be standard ones, so they will not impact via outages any more than a standard connection. In order to minimise risk, WPD will retain control of its system, as all the units that are being dispatched directly from the µEMS are customer connected equipment. Also, the WPD control engineers will keep supervisory control, with the ability to disable the system and open the feeder breakers to each piece of equipment.

Low Carbon Networks Fund
Full Submission Pro-forma
Customer impacts continued

Customer CHP Installations
Undertaking a large domestic CHP installation programme within a close geographic proximity is not going to be easy. It requires careful planning and developing a close working relationship with the community.

CHP customer impacts will relate directly to the usual and expected disruption to be anticipated during installation of any technology that involves plumbing, electrical and building works. This will include a degree of noise and mess to be endured, as well as a curtailment of heating and electrical services during connection of the new systems. These impacts will relate equally to domestic and commercial customers, but will of course be reduced if the installations take place during a new build.

It is important to ensure that customers are aware of the implications of having CHP and hence clients will be carefully selected and it will be ensured that they have the necessary information to hand are aware of any limitations of the equipments.

There are several key benefits to the customers; domestic and commercial customers will be able to take advantage of a new and efficient CHP unit, which can reduce their electrical consumption and therefore their overall energy expenditure.

Low Carbon Networks Fund
Full Submission Pro-forma
Section 9: Successful Delivery Reward Criteria

This section should be between 2 and 5 pages.

Criterion 9.1 (LCNF 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. This is based on the robust Programme Management methodology currently in place.
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 to include:
    a. Programme – MS Project Gantt with fully detailed project component activities, milestones and deliverables.
    b. Risk Log
    c. Contingency Plan
    d. Contracts in place
    e. Logistics and IT
    f. Community Engagement Plan
    g. CHP Engagement Plan (specific)
    h. Stakeholder Management Plan
    i. Communications Plan

Criterion 9.2 (LCNF 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 (LCNF SDRC 3)
Specific: Complete logical control & IT architecture and System Design
Measureable: Logical control design document completed and IT deliverables (as below)
Achievable: The logical control design is not dependent on the finalisation of specific equipment components such as wind SCADA or commercial CHP. It is primarily dependent on the trial design. IT deliverables are industry standard.
Relevant: The logical control design is effectively the way in which the planned trials are mapped onto the underlying control system. Its production is therefore critical to ensuring the planned learning can be fulfilled as specified.

Successful Delivery Reward Criteria continued

Timely: Completed by 31st March 2015
Lead: Toshiba (inc CGI on IT lead)
Evidence 9.3

1. Logical control design document produced and signed off by the project partners
2. Solution Architecture Diagram
3. Communications Network Design document
4. Security design document for CGI solution
5. SCADA solution design document
6. Datastore and Analytics design document

Criterion 9.4 (LCNF SDRC 4)
Specific: Gas Engine & Electrolyser passes Factory Acceptance Test
Measureable: Gas Engine & Electrolyser 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 Engine & Electrolyser 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 Tests

Criterion 9.5 (LCNF SDRC 5)
Specific: Report on readiness to commence trials
Measureable: Document produced and circulated to all organisations within the programme.
Achievable: The Programme structure will see all partners contribute to this document with CDC coordination. It will ensure all core deliverables and approvals are in place to allow trials to commence.
Relevant: The statutory regulations, planning and internal checks are all required to start the trials on a firm footing.
Timely: Completed by 31st March 2016
Lead: CDC
Evidence 9.5

1. Documents to include Risk Log, Budgets and Programme
2. Reports from all partners confirming their readiness
3. All relevant statutory / regulatory approvals in place and appended

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Criterion 9.6 (LCNF SDRC 6)
Specific: Report on the Commercial Models
Measureable: Report produced summarising the evaluation of Commercial Models undertaken by the project and resultant recommendations for potential role-out of CEB to other communities and the UK as a whole
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 roll out of the full scheme, or components of it, is a core objective of the scheme.

Timely: Completed by 29th December 2017
Lead: TRL
Evidence 9.6

1. Report produced.
2. Dissemination of findings

Criterion 9.7 (LCNF SDRC 7)
Specific: Report on the community engagement approach
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.
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 SDRC and is a core strand of work throughout the scheme.
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
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 (LCNF SDRC 8)
Specific: Define ongoing commercial arrangements
Measureable: Commercial framework documented based on the findings of the project to define the optimal commercial arrangements under which the relevant legacy elements of the CEB project are owned and operated once the CEB project has completed.
Achievable: The learning of the project will provide sufficient cost and performance data to enable any viable ongoing solution and associated commercial arrangements to be identified.
Relevant: The participation of WREN with a constrained wind farm is a key element of this project. WREN is a small outfit with a lot of investment at risk. This SDRC ensures we are committed to exploring an enduring solution for their wind farm and as such is critical for ensuring their participation.
Timely: Completed by 29th December 2017
Lead: Toshiba
Evidence 9.8

1. Report produced defining the proposed commercial arrangements for the enduring trial components

Section 10: List of Appendices

Appendix A Apportionment of Costs

Appendix B Indicative Images of Electrolyser

Appendix C Power Network Analysis

Appendix D Financial Spreadsheet

Appendix E High Level Use Cases

Appendix F Programme Plan

Appendix G Governance and Reporting Structure

Appendix H Cost Benefit Analysis

Appendix I Contingency Plan

Appendix J Risk Register

Appendix K µEMS Case Studies

Appendix L Gas and Electricity Networks in Cornwall

Appendix M Base Cost Description and Value for Money

Appendix N CEB µEMS System Diagram

Appendix O CEB Demand and Generation Diagram

Appendix P Summary of Partner Roles

Appendix Q Letters of Support

Appendix R Power Network in the Wadebridge Area

Appendix S Gas 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 direct strand costs.

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, a ratio of 6:1 has been assumed

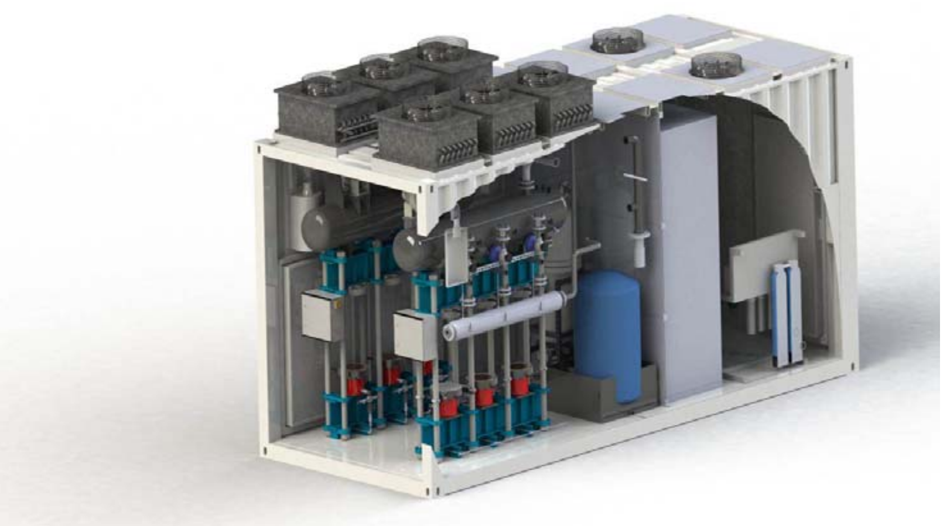
- **Knowledge Capture and Dissemination** – Learning applies across both the LCNF and NIC projects. Given learning costs have not been broken down based on specific trials at this stage but have been derived based on appropriate resourcing levels, it is difficult to accurately predict to allocation between LCNF and NIC. Consequently a pragmatic approach has been taken which assumes learning costs will be allocated based on the same assessment of project complexity and associated learning used above, i.e. 6:1 LCNF:NIC

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

- **Information Technology** –IT costs have been apportioned following the same logic as utilised above namely on a ratio of 6:1 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.

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Initial Analysis of the Electricity Distribution Network Selected for Clean Energy Balance

Toshiba Research Europe Ltd,

Telecommunications Research Laboratory

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1 SUMMARY

The objectives of this report are to present analysis of the electricity network selected for the project trial, to describe the problems of integrating further distributed generation (DG) on this network and to demonstrate the effectiveness of electrolysis to alleviate these problems. Power flow analysis was used to run half hourly simulation over the period of one year. Four case studies have been considered, with different levels of generation and control strategies for the distributed energy resources (DERs) connected to the network. This report deals with thermal limits and voltage aspects of network analysis.

2 DISTRIBUTION TEST SYSTEM

The selected distribution network is located in the Cornwall area. This area has seen an increasing number of on-shore wind farms and PV solar farms connected to the Extra High Voltage (EHV) network and High Voltage (HV) network, with many new applications being submitted each year. The area presents a high interest for developers as it has one of the highest average annual wind speed in Europe of 6.5 m/s [1] and also one of the highest average solar radiation in UK of 1300 kWh/m^2 [2].

The distribution network selected, with the layout illustrated in Figure 1, consists of two feeders from the St Tudy's 132/33 kV substation that supply the Polzeath and Wadebridge 33/11 kV substations.

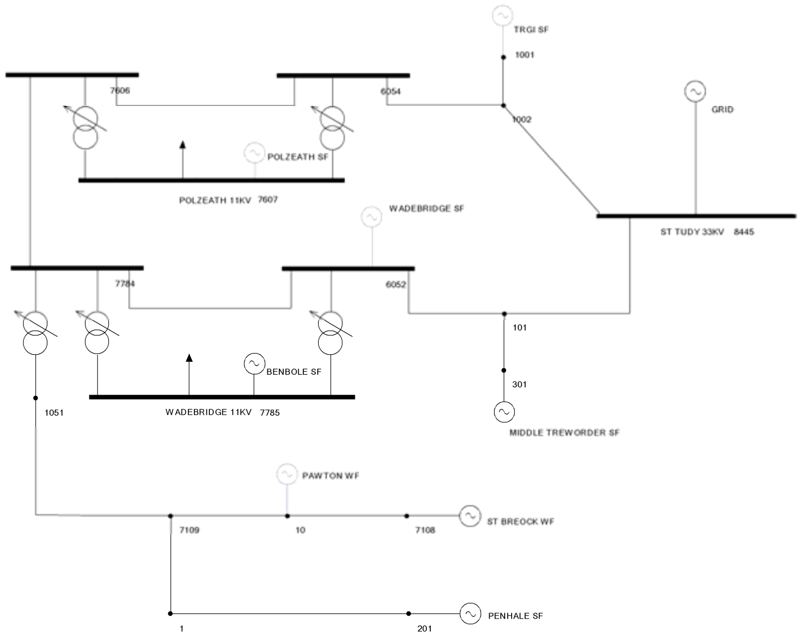

FIGURE 1. DISTRIBUTION TEST SYSTEM

The connection between the two substations is reinforced by a separate line. One of the feeders leaving Wadebridge substations connects a 5 MW wind farm and a 3 MW PV solar farm through a 33/33 ±10% voltage regulator. The regulator uses Line Drop Compensation to control the voltage at the generation connection point. There are a total of four operational renewable farms on the network and another four in the application process, represented in Figure 1 in grey.

The concerns related to the connection of new DGs on this part of the network covered by this study are the thermal ratings of the voltage regulator and the line between Wadebrige and St Tudy and the voltage rise at Wadebridge busbar and at the Pawton wind farm connection point.

The details of the line impedances values in per unit (p.u.) are given in Table 1.

From Busbar	To Busbar	Resistance (pu)	Reactance (pu)
1	201	0	0.0001
10	7108	0.07115	0.10329
301	101	0	0.0001
1002	8445	0.1172	0.23515
1002	1001	0.03325	0.03163
1051	7109	0.05605	0.10962
6052	101	0.06156	0.11999
6054	1002	0.07601	0.15344
7109	10	0.00374	0.00544
7109	1	0.06883	0.13461
7606	7784	0.17946	0.24358
7606	6054	0	0.0001
7784	6052	0	0.0001
8445	101	0.06156	0.11999

Table 1. Line records

3 CASE STUDIES

The analysis on the distribution network has been structured in four case studies according to the distributed energy resources (DERs) connected to the network, summarized in Table 2.

TABLE 2. CASE STUDIES CONSIDERING DIFFERENT LEVELS OF DG CONNECTION AND CONTROL STRATEGIES

Case study	a. Existing DERs	b. Future DERs	c. Future DERs with active power generation curtailment	d. Future DERs with active power generation curtailment and electrolyser
DER Name	**Capacity (MW)**	**Capacity (MW)**	**Capacity (MW)**	**Capacity (MW)**
ST BREOCK WF	5	12	12	12
MIDDLE TREWORDER SF	4.4	4.4	4.4	4.4
PENHALE SF	3	3	3	3
BENBOLE SF	2	2	2	2
POLZEATH SF		5	5	5
TRGI SF		5	5	5
WADEBRIDGE SF		5	5	5
PAWTON WF		6	< 6	< 6
ELECTROLYSER				1

In case study a*. Existing DERs*, recent measurements from the loads and generation are used to assess the current available headroom at the two branches.

In case study *b. Future DERs*, it is considered that all the new generators are connected with a firm access to the network.

In case study *c. Future DERS with active power generation curtailment*, the last generator connected, at Pawton site, accepts curtailment of active power to avoid payments of network reinforcements.

In case study *d. Future DERS with active power generation curtailment and electrolyser*, a large scale 1MW electrolysis element connected at Pawton site transforms the electricity into hydrogen and injects it into the gas network at times when generation exceeds the equipment rating.

To carry out this study, the network layout and parameters have been provided from Western Power Distribution’s (WPD) database. The demand and generation values used in the simulation are taken from measurements on the actual network and cover a period of one year, from the 1st of April 2012 to 31st of March 2013.

CASE STUDY A - EXISTING DERS

There are four DGs connected to the network: three PV solar farms with a total capacity of 10.4 MW and a wind farm, with eleven 450 kW wind turbines totaling 4.95 MW [3]. The solar farms are operated at unit power factor (p.f.). For the wind farms the induction generators of the wind turbines require reactive power. The wind farm has a fixed reactive compensation system; meaning that at times, when the wind farm doesn’t operate, the site exports VARs to the network. However, most of the time, the compensation is not sufficient and VARs are imported resulting in the site operating at lagging p.f.

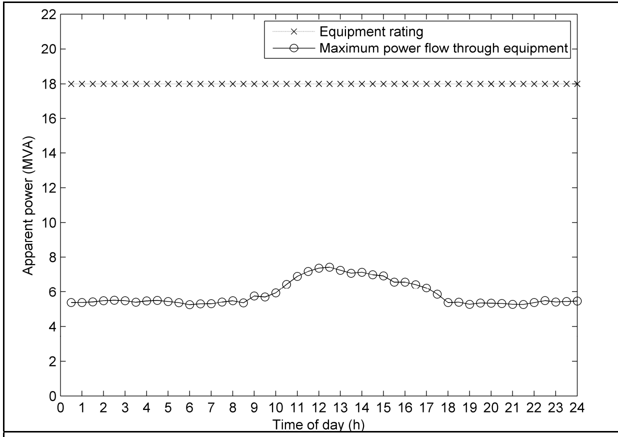

Figure 2. Maximum loading recorded at the voltage regulator

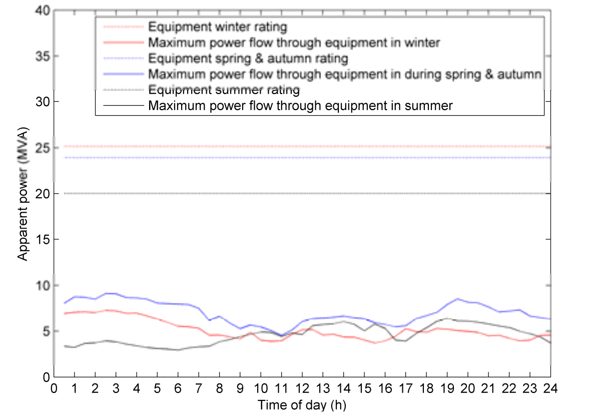

Figure 3. Maximum loading recorded at the line connecting Wadebridge and St Tudy substations

The maximum loading recorded at the voltage regulator resulted from the half hourly simulations over one year period is depicted in Figure 2. A peak is shaped in the middle of the day due to the solar farm. The minimum headroom of the voltage regulator is 10.5 MVA.

The maximum loading recorded at the line between Wadebrige and St Tudy substations resulted from the half hourly simulations over one year period is depicted in Figure 3. The minimum line headroom, of 13.6 MVA, is recorded on summer. This graph shows that the line can accept more generation sites to be connected to the network.

CASE STUDY B - FUTURE DERs

In this case study all the generators that have applied for the new connections or for increase of capacity are allowed a firm access connection policy. The output of the new generators is scaled from the existing measurements to match their capacity. A large number of small-scale embedded PVs totalling a capacity of 5MW are connected to the network in the Polzeath area. A 5MW PV solar farm is connected to the line between Polzeath and St Tudy and another solar farm with the same capacity is connected to the Wadebrige substation. A 6MW new wind farm is connected near Pawton area, while the existing wind farm at St Breock will replace its eleven 450 kW wind turbines with 5 larger turbines with a total of 12 MW [3]. We acknowledge that the new wind farms should have an improved reactive compensation system compared with the current St Breock site, or turbines which allow the control of reactive power, and therefore two scenarios have been envisioned: the two wind farms are operated at unit p.f. and the second with lagging p.f. where the reactive power from the current St Breock site is scaled to match the new capacity.

The maximum loading recorded at the voltage regulator resulted from the half hourly simulations over one year period is depicted in Figure 4 (a) for the unit p.f. scenario and Figure 4 (b) for the lagging p.f. For the unit power factor there are certain hours where the voltage regulator's rating is exceeded, especially at times of high solar radiations. For the lagging power factor, higher overloads can be expected due to the reactive power imported through the voltage regulator from the bulk supply point.

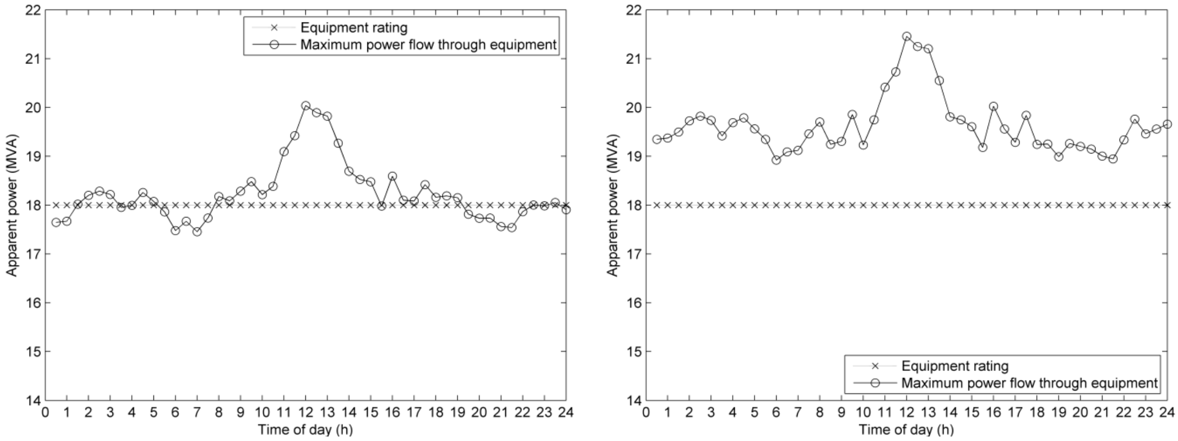

FIGURE 4. MAXIMUM LOADING RECORDED AT THE VOLTAGE REGULATOR FOR THE WIND FARMS OPERATED AT: (A) UNIT P.F (B) LAGGING P.F.

In Figure 5, the number of hours each year and the percentage of the voltage regulator's capacity by which the equipment rating is exceeded is plotted: (a) for unit p.f. and (b) for lagging p.f. For example, in Figure 5(a) the voltage regulator operates at 101% of nameplate rating for 11.5 hours during one year.

The maximum loading recorded at the line between Wadebrige and St Tudy substations resulted from the half hourly simulations over one year period is depicted in Figure 6: (a) in the scenario where the wind farms are operated at unit p.f. and (b) for lagging p.f. The maximum loading on the line is near its rating in the summer for (a) and surpasses it in (b).

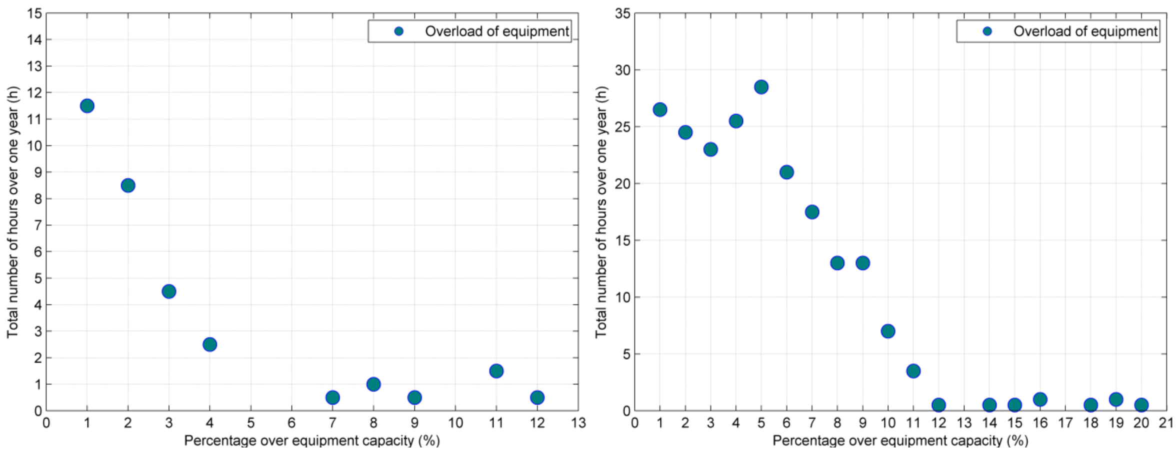

FIGURE 5. THE DURATION AND MAGNITUDE OF THE OVERLOADS RECORDED AT THE VOLTAGE REGULATOR FOR THE WIND FARMS OPERATED AT: (A) UNIT P.F. (B) LAGGING P.F. OVER A PERIOD OF ONE YEAR

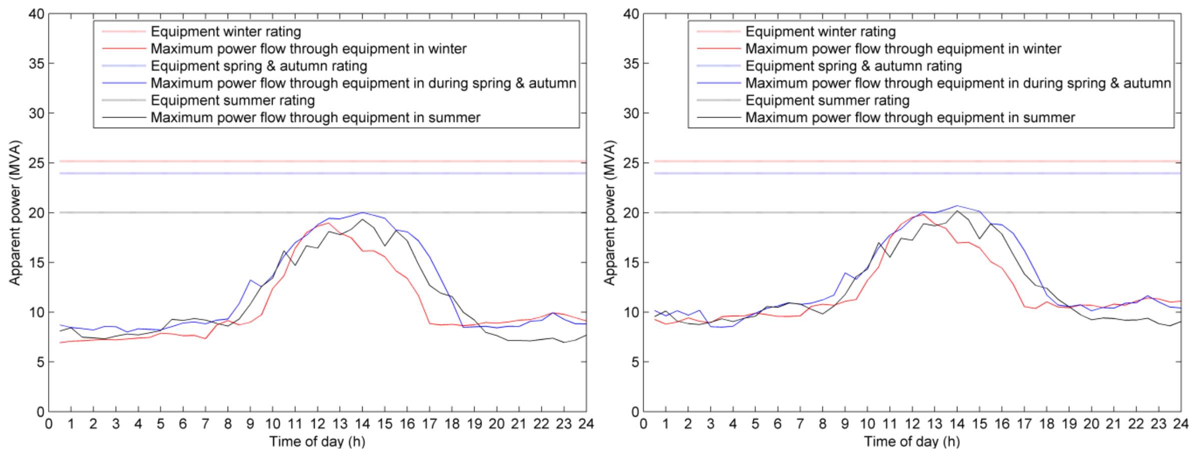

FIGURE 6. MAXIMUM LOADING RECORDED AT THE LINE CONNECTING WADEBRIDGE AND ST TUDY SUBSTATIONS FOR THE WIND FARMS OPERATED AT: (A) UNIT P.F. (B) LAGGING P.F.

VOLTAGE

The main concern related to voltage in the context of integrating large scale DGs on the distribution network is the voltage rise effect [4]. For this study only a part of the entire 33 kV network was modeled. An assumption was made on the voltage at St Tudy 33kV busbar that it is controlled by the grid supply generator (GRID in Figure 1). In reality the two 132/33 kV Grid Transformers with the On-Load Tap Changers (OLTC) will control the voltage on the 33 kV busbar. In the simulation, the voltage at St Tudy 33kV busbar is changing for each 30 minutes interval according to the measurements from WPD's database for the period 1st April 2012 to 31st of March 2013. Although different case studies are considered, the voltage value for St Tudy's busbar is held constant for the same time interval. It is reasonable to say that the voltage differences between the case studies are more relevant than the actual values for this simulation.

The maximum and minimum voltages at the Wadebridge EHV busbar are plotted in Figure 7 for the first and second case study. The second case study is chosen because it represents the worst scenario, where no curtailment or electrolysis intervenes. The integration of the new DGs will trigger an increase in the maximum voltage. However, because the voltage is kept below unit by the Grid Transformers (GT) at St Tudy (measurements indicates an average of 0.97 p.u., there are no threats of the voltage surpassing the upper limit. The voltage rise is smaller in the situation illustrated in Figure 7 (b), where the wind farms are operated at lagging p.f, due to the effects on voltage of the reactive power absorption at the wind farms sites.

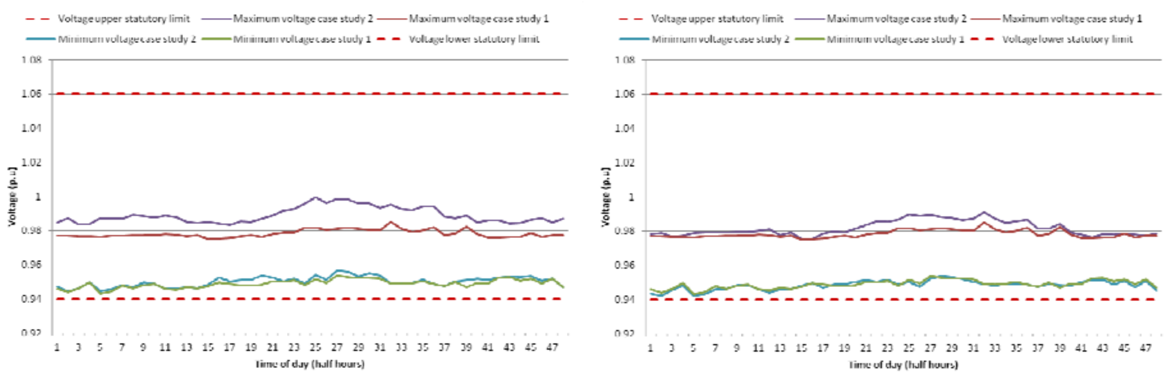

FIGURE 7. MAXIMUM AND MINIMUM VOLTAGES RECORDED AT WADEBRIDGE EHV BUSBAR FOR WIND FARMS OPERATED AT: (A) UNIT P.F (B) LAGGING P.F.

The voltage at the connection point of the new wind farm on the Pawton site is controlled by the voltage regulator, which keeps the voltage rise due to new DGs (case study 2) within moderate values. The maximum and minimum voltages are plotted in Figure 8.

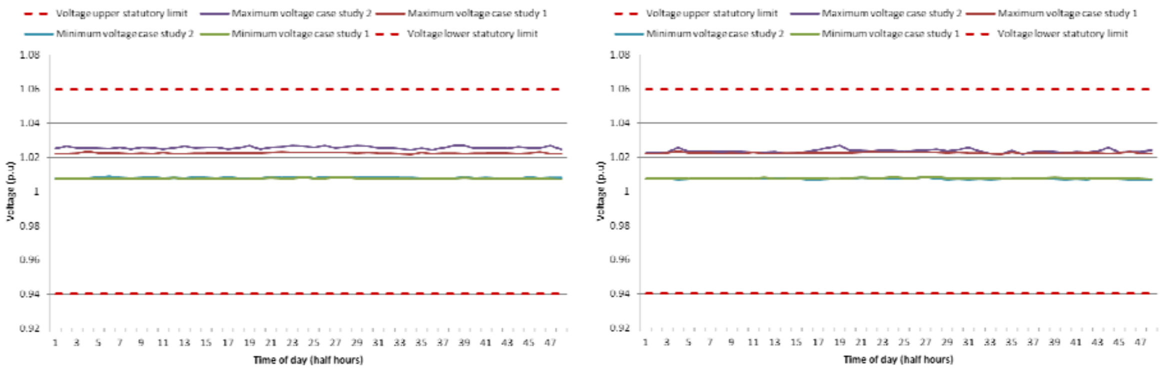

FIGURE 8. MAXIMUM AND MINIMUM VOLTAGES RECORDED AT PAWTON WIND FARM CONNECTION POINT FOR THE WIND FARMS OPERATED AT: (A) UNIT P.F. (B) LAGGING P.F.

CASE STUDY C - FUTURE DERS WITH ACTIVE POWER GENERATION CURTAILMENT

In this case study, one of the generators connected through the voltage regulator will accept curtailment of its active power output for limited periods to keep the loading on the voltage regulator below its rating. A Last in First Out (LIFO) principle of access is considered [5], therefore, the output at Pawton wind farm will be controlled to keep the loading at the voltage regulator below the rating. The control can be done by stopping one or more wind turbines in the wind farm or controlling the pitch angle in all the wind turbines.

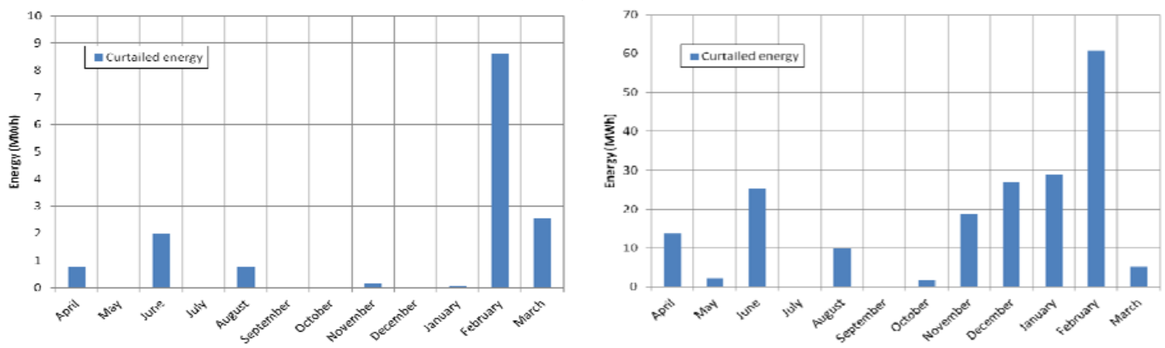

FIGURE 9. CURTAILED ENERGY DUE TO THE VOLTAGE REGULATOR RATING FOR THE WIND FARMS OPERATED AT: (A) UNIT P.F. (B) LAGGING P.F.

The curtailed energy, plotted in Figure 9, reaches a total of 14.9 MWh for unit power factor and 193.5 MWh for lagging power factor.

For this case study the maximum loadings, of both the voltage regulator and the line between the Wadebridge and St Tudy substations, don't exceed the equipments' ratings.

CASE STUDY D - FUTURE DERS WITH ACTIVE POWER GENERATION CURTAILMENT AND ELECTROLYSER

In this case study a large scale 1MW electrolysis element connected at Pawton site transforms the electricity into hydrogen and injects it into the gas network at times when generation exceeds the equipment rating.

Considering just the electrolyser, without curtailment, a comparison is made with the second case study, in Figure 10. The number of hours and the scale of the overloads seen at the voltage regulator have been reduced by using the electrolysis element.

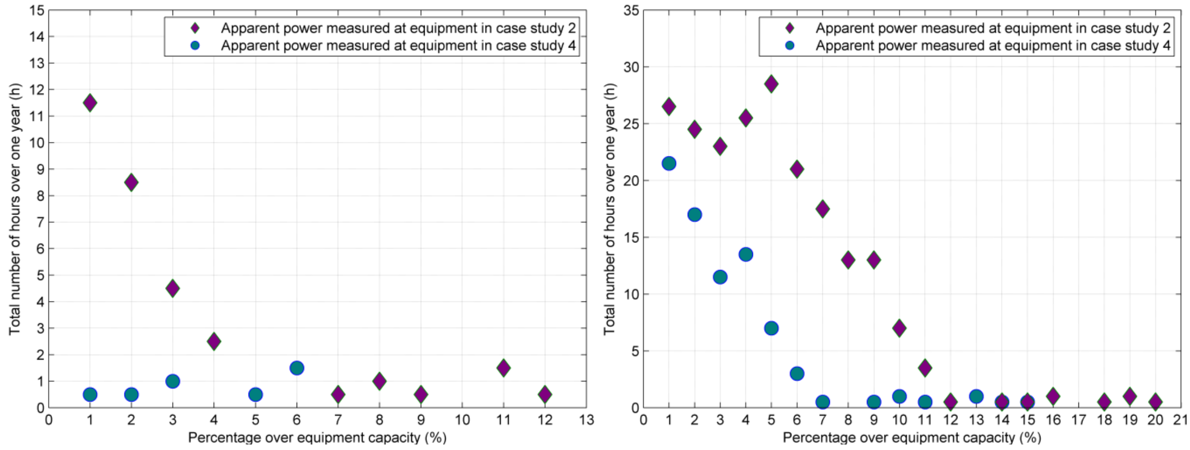

FIGURE 10. THE DURATION AND MAGNITUDE OF THE OVERLOADS RECORDED AT THE VOLTAGE REGULATOR FOR THE WIND FARMS OPERATED AT: (A) UNIT P.F. (B) LAGGING P.F.

A consequence of reducing the overload at the voltage regulator is that the maximum loading on the constrained line between the Wadebridge and St Tudy substation is kept back below its rating, as shown in Figure 11.

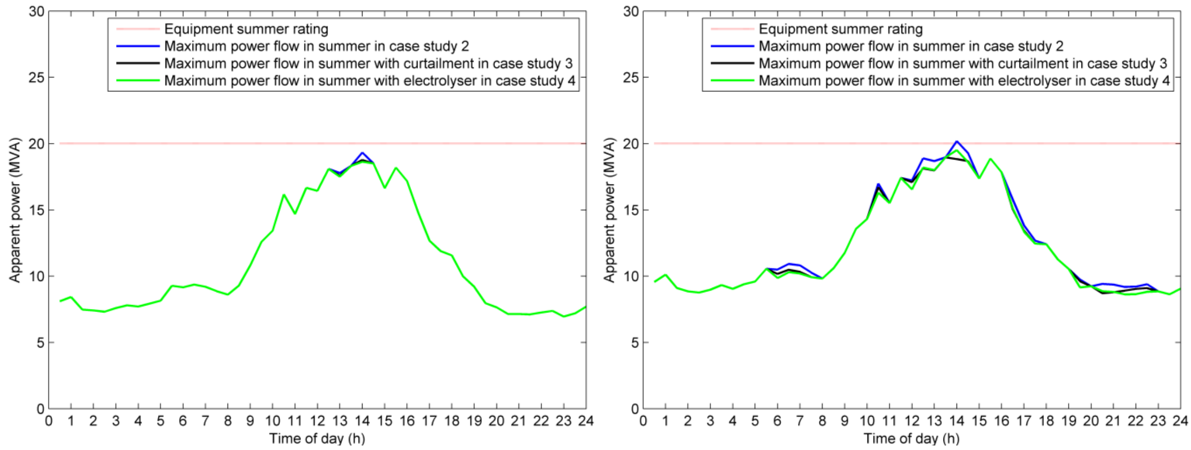

FIGURE 11. MAXIMUM LOADING RECORDED AT THE LINE CONNECTING WADEBRIDGE AND ST TUDY SUBSTATIONS FOR WIND FARMS OPERATED AT: (A) UNIT P.F. (B) LAGGING P.F.

The electrolyser has reduced the loading at the voltage regulator, however, overloads remain, as can be seen in Figure 10. The reason is that the overload exceeds the voltage regulator rating and the 1MW electrolyser capacity. Therefore, active power generation curtailment can be employed for the remaining overloads. For the scenario shown in Figure 12 (a) the energy that needs to be curtailed has reduced from 14.9 MWh to 2.75 MWh while for Figure 12 (b) from 193.5 MWh to 44.35 MWh.

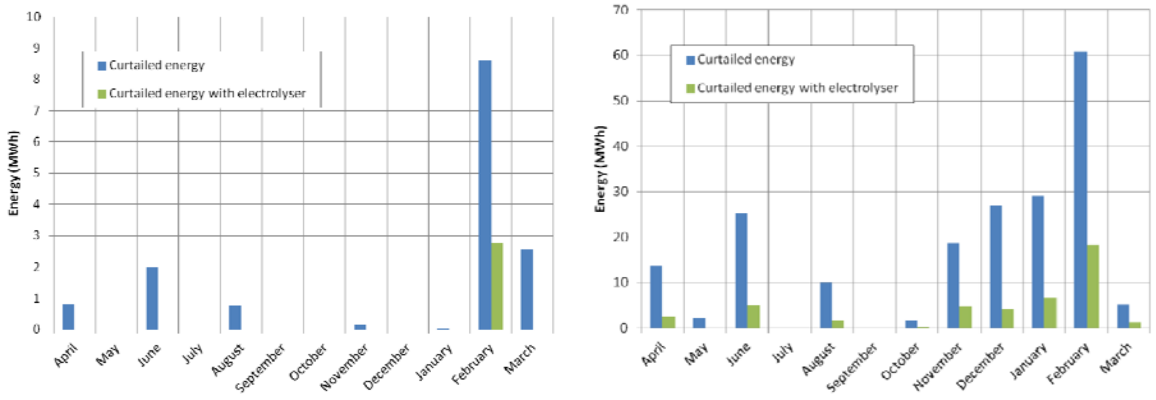

FIGURE 12. CURTAILED ENERGY DUE TO THE VOLTAGE REGULATOR RATING FOR WIND FARMS OPERATED AT: (A) UNIT P.F. (B) LAGGING P.F.

ENERGY CURTAILED AT PAWTON WINDFARM FOR DIFFERENT VALUES OF GENERATION CAPACITY

For this simulation a range of values are considered for the generation capacity at Pawton site. Figure 13 presents the values of excess energy and how many MWh are utilised by the electrolyser and how many are curtailed by active power generation curtailment.

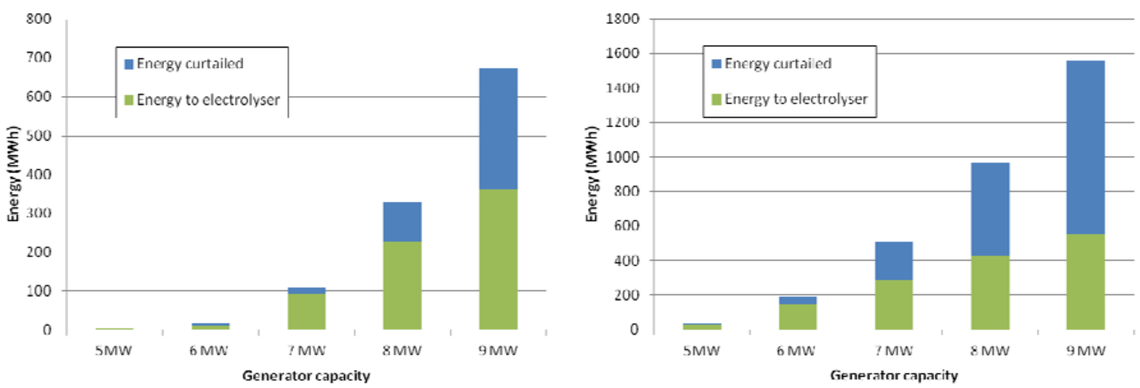

FIGURE 13. CURTAILED ENERGY DUE TO THE VOLTAGE REGULATOR RATING FOR DIFFERENT VALUES OF PAWTON GENERATOR CAPACITY FOR WIND FARMS OPERATED AT: (A) UNIT P.F. (B) LAGGING P.F.

The percentages of each of the components that cover the excess energy are shown in Figure 14.

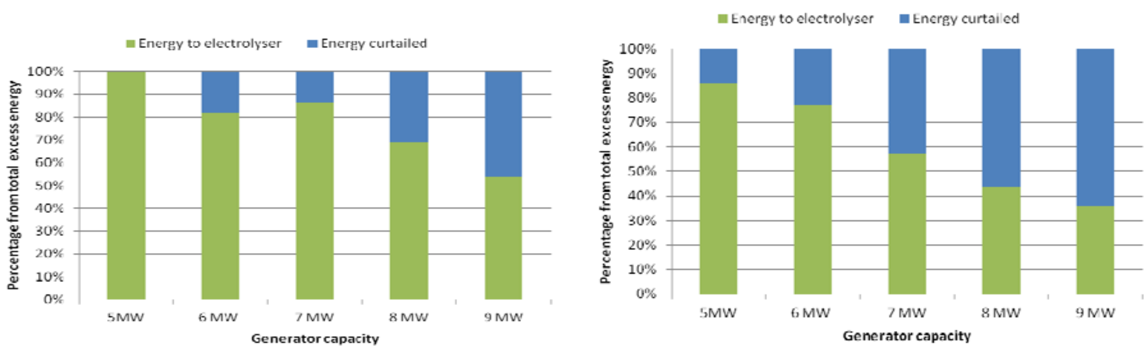

FIGURE 14. EXCESS ENERGY AND THE PERCENTAGE TAKEN BY ELECTOLYSER AND THE PERCENTAGE CURTAILED FOR WIND FARMS OPERATED AT: (A) UNIT P.F. (B) LAGGING P.F.

4 DISCUSSIONS

The first case study, which considered the DGs that are already connected, revealed significant network headroom for both the network equipments: voltage regulator and line between Wadebrige and St Tudy. The current situation permits the connection of new generation sites or an increase in the capacity of the current sites.

At the next step the future DGs are connected with a firm connection policy. The voltage regulator capacity is exceeded for 31 hours during one year for unit p.f. and 210 hours for lagging p.f. It is thus important that the reactive compensation system for future wind farms, if needed, should be placed downstream of the voltage regulator. The line's maximum loading is just below its summer rating for unit power factor and exceeds it for lagging p.f.

The above findings impose that a form of active power generation curtailment should be employed to avoid acceleration of equipment aging. The curtailed energy amounts to 14.9 MWh for unit p.f. and 193.5 MWh for lagging p.f.

A 1 MW electrolyser is introduced as an alternative to active power generation curtailment. The number of hours where the voltage regulator operates in overloading conditions is reduced from 31 to 8 for unit p.f. and from 210 to 78 for lagging power factor. Thus, curtailment still has to be employed for the remaining hours. However the electrolyser takes 12.15 MWh from the excess of 14.9 MWh for unit p.f. and 149. 15 MWh from the excess of 193.5 MWh. A sensitivity analysis was done by varying the Pawton wind farm generation capacity. At 5MW the electrolyser picks up all the excess energy for unit power factor. As the generation capacity increases both the energy to electrolyser and the one curtailed rises, with the latter at a higher rate.

An analysis on the voltage revealed a voltage rise of 0.02 per unit at Wadebridge EHV busbar due to the new DGs. The voltage rise at the Pawton wind farm connection point is smaller due to the voltage regulator. The findings on the voltage rise have considered that the two feeders don't influence the voltage at the bulk supply substation.

5 CONCLUSIONS

The connection of all the DGs that are currently in the application process can overload the voltage regulator and the line between Wadebridge and St Tudy. Connecting only the 1MW electrolyser can keep the loading on the line below its rating. For the voltage regulator, in spite of reducing the duration of operating in overload conditions, active power curtailment still has to be employed. However, the electrolyser captures most of the excess energy thus it can be a valuable asset in the integration of intermittent generation from renewable sources.

6 REFERENCES

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Appendix E Clean Energy Balance: Use Cases

Clean Energy Balance: Learning Approach

Introduction

The CEB Programme

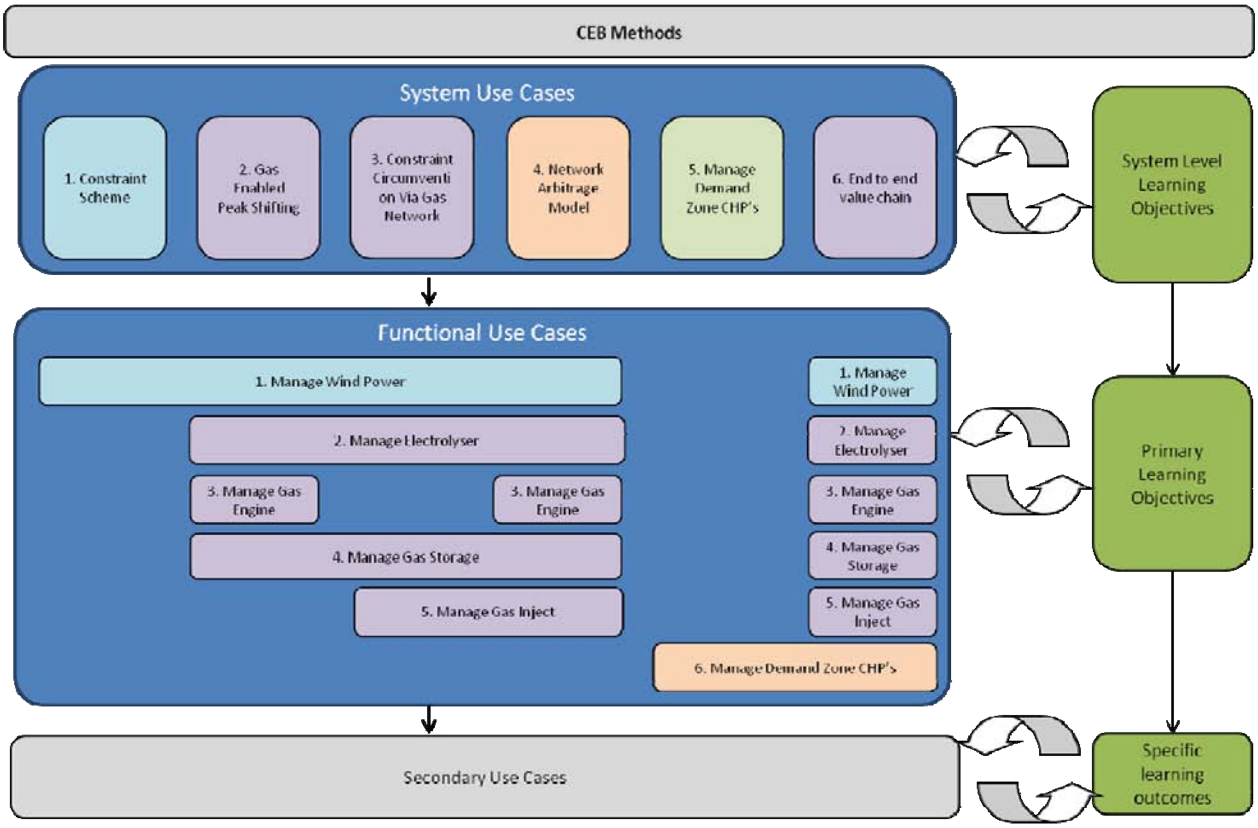
The CEB programme aims to trial a number of Methods which utilise both the gas and electricity distribution networks in order to maximise renewable generation, minimise network reinforcement and provide a mechanism for community energy engagement. To achieve this, a number of discrete technologies will 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

<table>
<tr><th>ID</th><th>Name</th><th>Description</th></tr>
<tr><td>S1</td><td>Constraint Scheme</td><td>
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

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		• 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:**

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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

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<tr><td>S5</td><td>CHP as a means of Reinforcement Avoidance</td><td>
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.
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		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

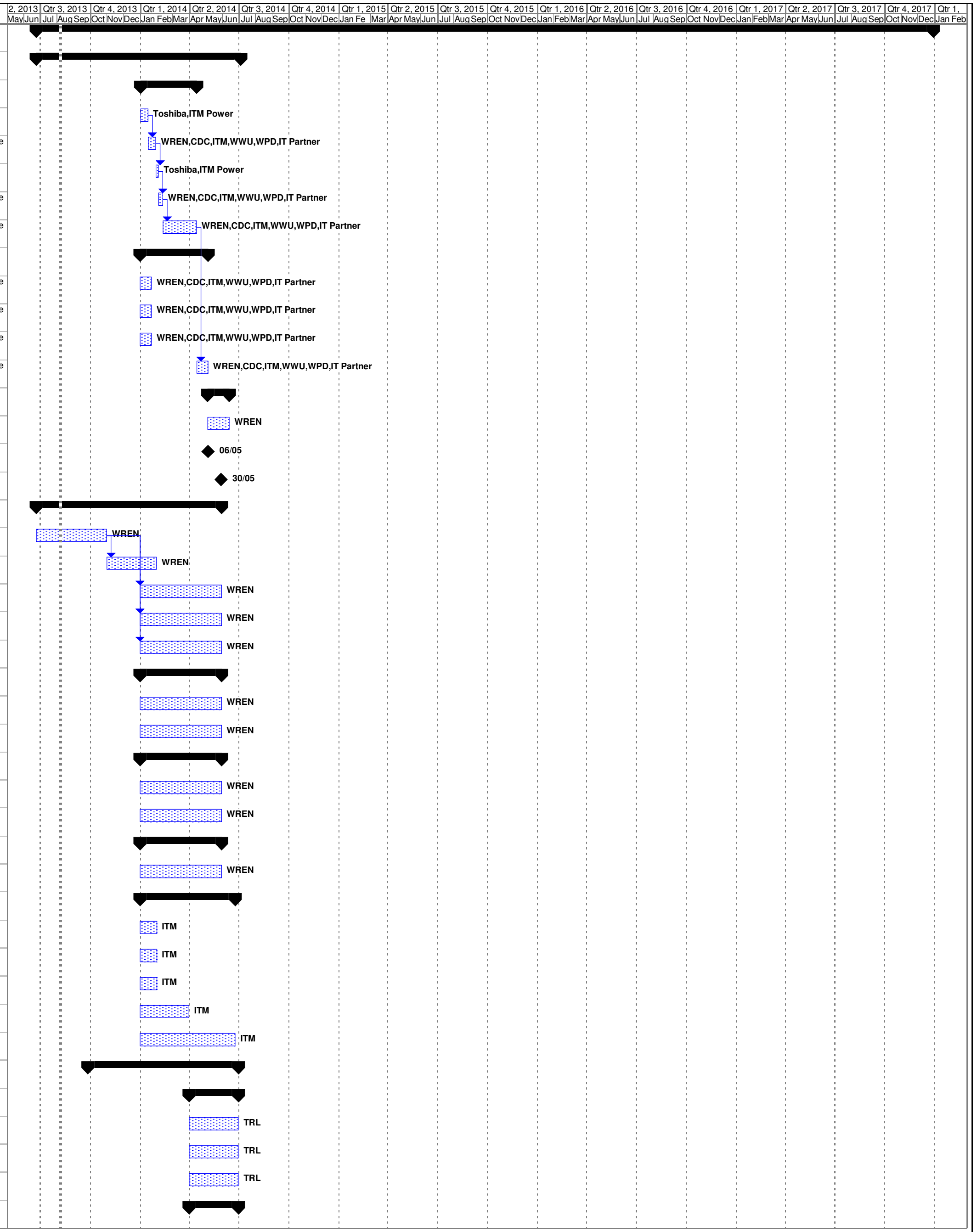
Functional-Use Cases

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

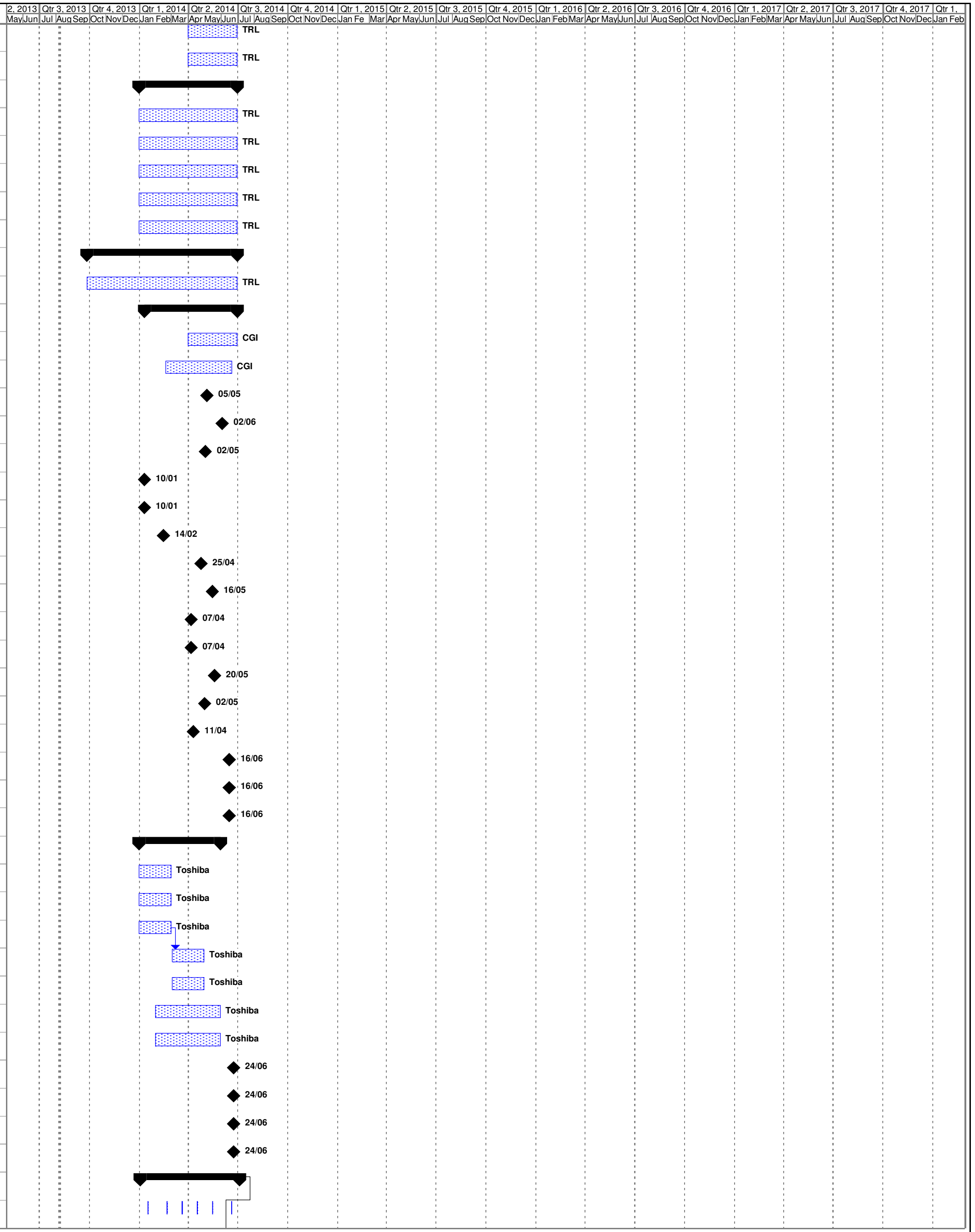
ID		Task Name	Duration	Start	Finish	Predecessors	Resource Names
1		**Clean Energy Balance - Overarching Programme**	**1180 days**	**Mon 24/06/13**	**Fri 29/12/17**		
2		**Mobilisation Phase**	**270 days**	**Mon 24/06/13**	**Fri 04/07/14**		
3		**Contracts**	**73 days**	**Thu 02/01/14**	**Mon 14/04/14**		
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: Tue 06/08/13

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

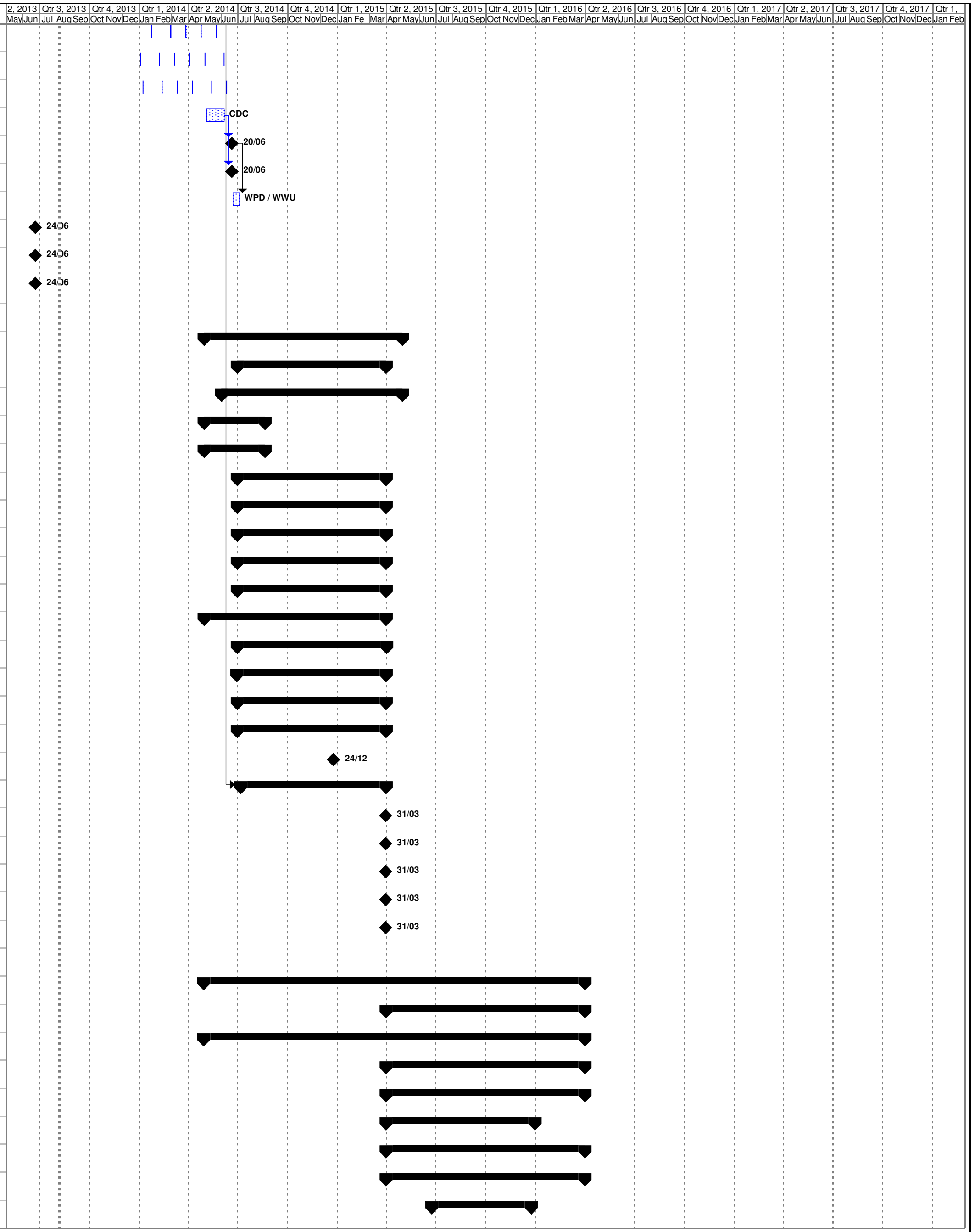
ID		Task Name	Duration	Start	Finish	Predecessors	Resource Names
44		Developing electrical network models	65 days	Tue 01/04/14	Mon 30/06/14		TRL
45		Develop gas network models	65 days	Tue 01/04/14	Mon 30/06/14		TRL
46		**Knowledge Capture, dissemination and training**	**129 days**	**Wed 01/01/14**	**Mon 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: Tue 06/08/13

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

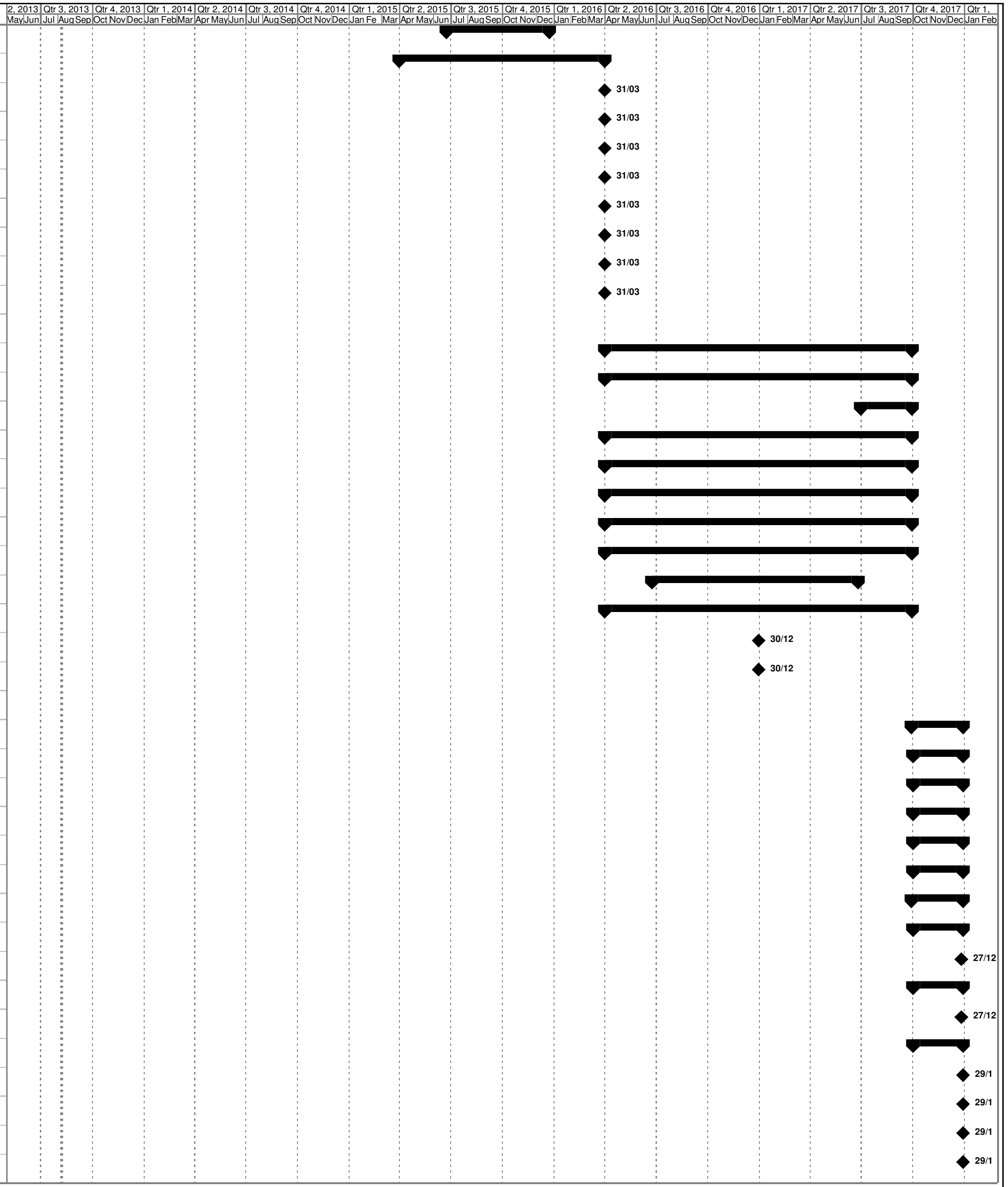
ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
93	**CDC internal review and production of overarching Highlight Report for CEB Prog**	**86 days**	**Fri 24/01/14**	**Fri 23/05/14**		**CDC**
99	**Agenda and reports - Project Mng mtg / Programme Mng Board (Quarterly)**	**111 days**	**Fri 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**



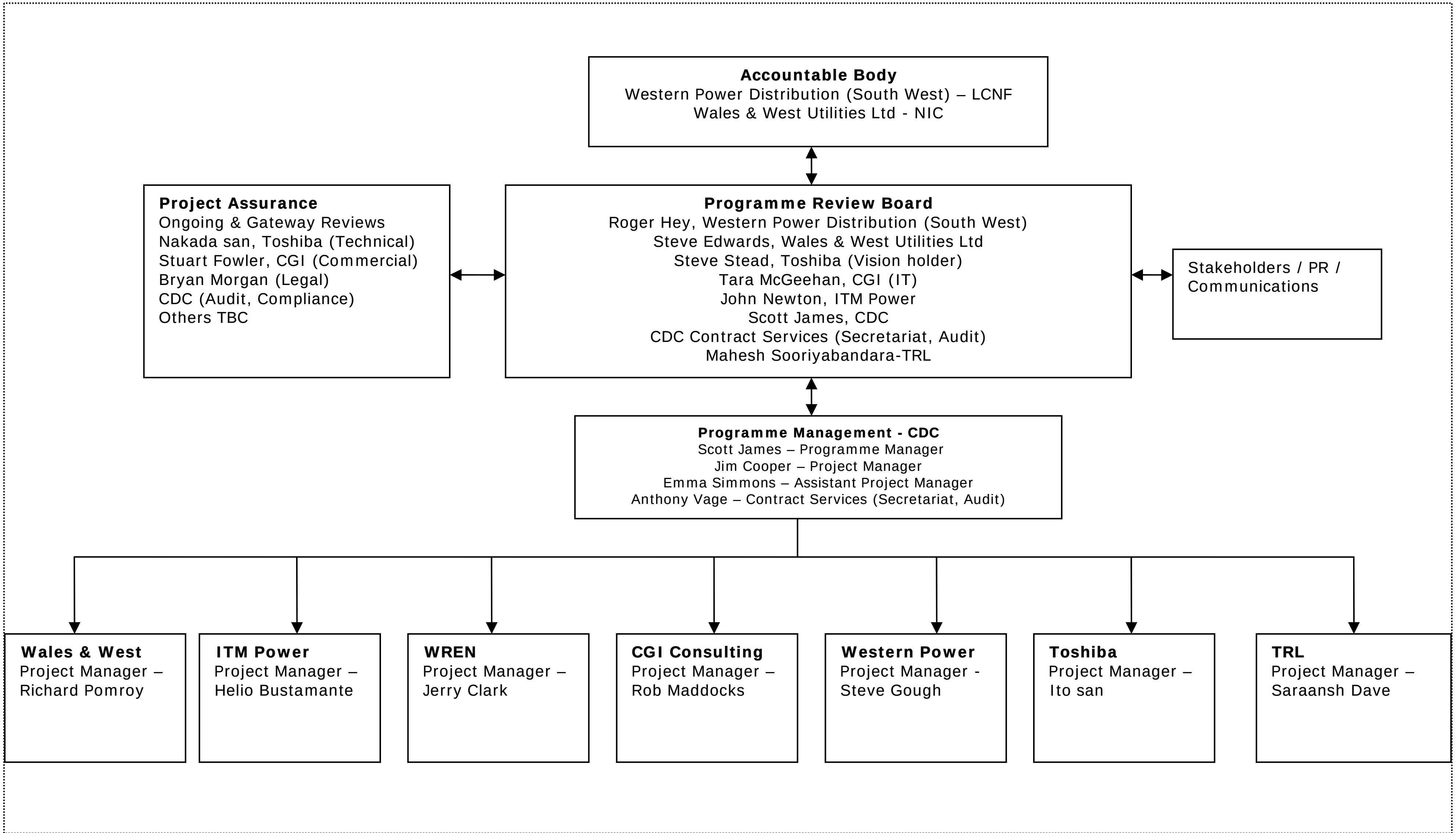
Project: NIC Appendix M CEB Delivery
Date: Tue 06/08/13

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

ID	Indicators	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



CEB Appendix G



Appendix H Cost Benefit Analysis

Scenario A – Method Performance with 50% Firm

Key Sizing Assumptions			Key Equipment Costs		Key O&M Costs		Financial Outcomes				Performance Outcomes		
								IRR	Pay Back Year	20 Year NPV			
Wind (MW):	6		Electrolyser/MW:	0.8	Electrolyser Ops:	0.05					ELY Utilisation:	6%	
PV (MW):	3		Gas Inject:	0.6	Gas Engine Ops:	0.05	Method 0	3.84%	17	2.91	% Gen Curtailed (No ELY):	5%	
ELY (MW):	*1*		Gas Engine/MW:	0.65	Gas Inject Ops:	0.05	Method 1	10.45%	11	8.75	% Gen Curtailed (ELY):	1%	
Feeder Capacity (MW):	6	*	uEMS Gas:	0.5	Gas Price:	34	Method 2	6.45%	14	4.97	Non Curtailed Wind (No ELY):	16.30	GWh
Gas Engine	1.4		uEMS Wind:	0.4	Electricity Price:	55	Method 3	7.00%	14	5.57	Non Curtailed Wind (ELY):	16.86	GWh
uCHP Numbers (K)	1		uEMS CHP:	0.3	uCHP 1st 10:	0.0045	Method 4	4.72%	16	3.00	Gas Engine Output:	11.36	GWh
			Wind Farm/MW:	1.489	uCHP 2nd 10:	0.0020	Method 5*	17.72%	6	4.11	(Add to this the additional constriant scheme ~4GWh)		
			Wind Ops:	0.37	Discount 1st 10:	50%	Method 6	10.01%	10	10.56			
					Discount 2nd 10:	30%	Method 7	10.01%	10	7.99			
* the firm conection figure is for 3MW PV AND the new wind farm													

Under the trial conditions (specifically with a 50% firm wind farm connection) the constraint scheme provides a marginally better IRR than the end-to-end solution albeit with a slightly longer payback. Under this model the level of curtailed generation is insignificant, albeit primarily supported by the constraint scheme as the electrolyser has limited utilisation.

Scenario B – Method Performance with 0% Firm

Key Sizing Assumptions			Key Equipment Costs		Key O&M Costs		Financial Outcomes				Performance Outcomes		
								IRR	Pay Back Year	20 Year NPV			
Wind (MW):	6		Electrolyser/MW:	0.8	Electrolyser Ops:	0.05					ELY Utilisation:	27%	
PV (MW):	3		Gas Inject:	0.6	Gas Engine Ops:	0.05	Method 0	0.76%	21+	-1.82	% Gen Curtailed (No ELY):	34%	
ELY (MW):	*1*		Gas Engine/MW:	0.65	Gas Inject Ops:	0.05	Method 1	3.88%	18	1.38	% Gen Curtailed (ELY):	20%	
Feeder Capacity (MW):	3	*	uEMS Gas:	0.5	Gas Price:	34	Method 2	0.93%	21+	-1.63	Non Curtailed Wind (No ELY):	11.33	GWh
Gas Engine	1.4		uEMS Wind:	0.4	Electricity Price:	55	Method 3	1.40%	21+	-1.11	Non Curtailed Wind (ELY):	13.67	GWh
uCHP Numbers (K)	1		uEMS CHP:	0.3	uCHP 1st 10:	0.0045	Method 4	-0.60%	21	-3.42	Gas Engine Output:	8.73	GWh
			Wind Farm/MW:	1.489	uCHP 2nd 10:	0.0020	Method 5*	17.72%	6	4.11	(Add to this the additional constriant scheme ~4GWh)		
			Wind Ops:	0.37	Discount 1st 10:	50%	Method 6	5.49%	15	3.88			
					Discount 2nd 10:	30%	Method 7	5.49%	15	1.57			
* the firm conection figure is for 3MW PV AND the new wind farm													

By reducing the firm wind farm capacity to zero the end-to-end solution provided a far better return that the constraint scheme alone with shorter payback. Under this model the electrolyser utilisation is increased significantly although there is a significant level of generation that still needs to be curtailed. There is clearly a trade off that needs to be explored between electrolyser size, utilisation and resultant cost/benefit.

Scenario C – Method Performance with Control System / Inject Costs Borne by the DNO/GDN

Key Sizing Assumptions			Key Equipment Costs		Key O&M Costs		Financial Outcomes				Performance Outcomes		
								IRR	Pay Back Year	20 Year NPV			
Wind (MW):	6		Electrolyser/MW:	0.8	Electrolyser Ops:	0.05					ELY Utilisation:	6%	
PV (MW):	3		Gas Inject:	0	Gas Engine Ops:	0.05	Method 0	4.12%	17	3.31	% Gen Curtailed (No ELY):	5%	
ELY (MW):	*1*		Gas Engine/MW:	0.65	Gas Inject Ops:	0	Method 1	11.07%	10	9.14	% Gen Curtailed (ELY):	1%	
Feeder Capacity (MW):	6	*	uEMS Gas:	0	Gas Price:	34	Method 2	7.44%	13	5.86	Non Curtailed Wind (No ELY):	16.30	GWh
Gas Engine	1.4		uEMS Wind:	0	Electricity Price:	55	Method 3	9.43%	11	7.81	Non Curtailed Wind (ELY):	16.86	GWh
uCHP Numbers (K)	1		uEMS CHP:	0	uCHP 1st 10:	0.0045	Method 4	6.74%	14	5.24	Gas Engine Output:	11.36	GWh
			Wind Farm/MW:	1.489	uCHP 2nd 10:	0.0020	Method 5*	22.42%	5	4.63	(Add to this the additional constriant scheme ~4GWh)		
			Wind Ops:	0.37	Discount 1st 10:	50%	Method 6	12.98%	9	13.32			
					Discount 2nd 10:	30%	Method 7	12.98%	9	10.75			
* the firm conection figure is for 3MW PV AND the new wind farm													

As one would expect, this model provides a significant increase in IRR and reduction in payback years and demonstrates the clear viability of the end-to-end solution.

Scenario D – Scenario A with Wholesale gas price of £20/MWh

Key Sizing Assumptions			Key Equipment Costs		Key O&M Costs		Financial Outcomes				Performance Outcomes		
								IRR	Pay Back Year	20 Year NPV			
Wind (MW):	6		Electrolyser/MW:	0.8	Electrolyser Ops:	0.05					ELY Utilisation:	6%	
PV (MW):	3		Gas Inject:	0.6	Gas Engine Ops:	0.05	Method 0	3.84%	17	2.91	% Gen Curtailed (No ELY):	5%	
ELY (MW):	*1*		Gas Engine/MW:	0.65	Gas Inject Ops:	0.05	Method 1	10.45%	11	8.75	% Gen Curtailed (ELY):	1%	
Feeder Capacity (MW):	6	*	uEMS Gas:	0.5	Gas Price:	20	Method 2	9.28%	11	8.96	Non Curtailed Wind (No ELY):	16.30	GWh
Gas Engine	1.4		uEMS Wind:	0.4	Electricity Price:	55	Method 3	6.93%	14	5.48	Non Curtailed Wind (ELY):	16.86	GWh
uCHP Numbers (K)	1		uEMS CHP:	0.3	uCHP 1st 10:	0.0045	Method 4	7.71%	13	7.24	Gas Engine Output:	11.36	GWh
			Wind Farm/MW:	1.489	uCHP 2nd 10:	0.0020	Method 5*	17.72%	6	4.11	(Add to this the additional constriant scheme ~4GWh)		
			Wind Ops:	0.37	Discount 1st 10:	50%	Method 6	9.95%	10	10.47			
					Discount 2nd 10:	30%	Method 7	9.95%	10	12.22			
* the firm conection figure is for 3MW PV AND the new wind farm													

The reduction in wholesale gas price has the most impact on Method 2. Under this Method Natural Gas is blended with hydrogen to utilisation available generation capacity. Hence a reduction in wholesale price improves Spark Spread and improves this Methods profitability. Utilisation of the gas engine in the way also maximises total generation export.

Scenario E – Impact of Electrolyser 'Thrashing' on Scenario A

Key Sizing Assumptions			Key Equipment Costs		Key O&M Costs		Financial Outcomes				Performance Outcomes		
								IRR	Pay Back Year	20 Year NPV			
Wind (MW):	6		Electrolyser/MW:	0.4	Electrolyser Ops:	0.025					ELY Utilisation:	6%	
PV (MW):	3		Gas Inject:	0.6	Gas Engine Ops:	0.05	Method 0	3.84%	17	2.91	% Gen Curtailed (No ELY):	5%	
ELY (MW):	*1*		Gas Engine/MW:	0.65	Gas Inject Ops:	0.05	Method 1	10.45%	11	8.75	% Gen Curtailed (ELY):	1%	
Feeder Capacity (MW):	6	*	uEMS Gas:	0.5	Gas Price:	34	Method 2	7.17%	13	5.75	Non Curtailed Wind (No ELY):	16.30	GWh
Gas Engine	1.4		uEMS Wind:	0.4	Electricity Price:	55	Method 3	7.74%	13	6.35	Non Curtailed Wind (ELY):	16.86	GWh
uCHP Numbers (K)	1		uEMS CHP:	0.3	uCHP 1st 10:	0.0045	Method 4	5.36%	15	3.78	Gas Engine Output:	11.36	GWh
			Wind Farm/MW:	1.489	uCHP 2nd 10:	0.0020	Method 5*	17.72%	6	4.11	(Add to this the additional constriant scheme ~4GWh)		
			Wind Ops:	0.37	Discount 1st 10:	50%	Method 6	10.72%	10	11.33			
					Discount 2nd 10:	30%	Method 7	10.72%	10	8.76			
* the firm conection figure is for 3MW PV AND the new wind farm													

Under this model the ability to 'thrash' the electrolyser has assumed to halve the electrolyser size and associated costs. In this way it can be seen that the IRR and payback of the end-to-end solution outperforms the standard constraint scheme.

Appendix I   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.

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
Programme Name: Clean Energy Balance Bid						Programme Manager: CDC											
					High Level Definition										Cause	Effect	
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 procedures 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 viabiity 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.	
	R044		WWU	Inability to achieve required derogation for hydrogen injection	4	1	4	**16**		JC	10/06/2013	31/07/2013		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.	
	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	
	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.	

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
	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)	⇧ ⇩ ⇔

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

Appendix M

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).

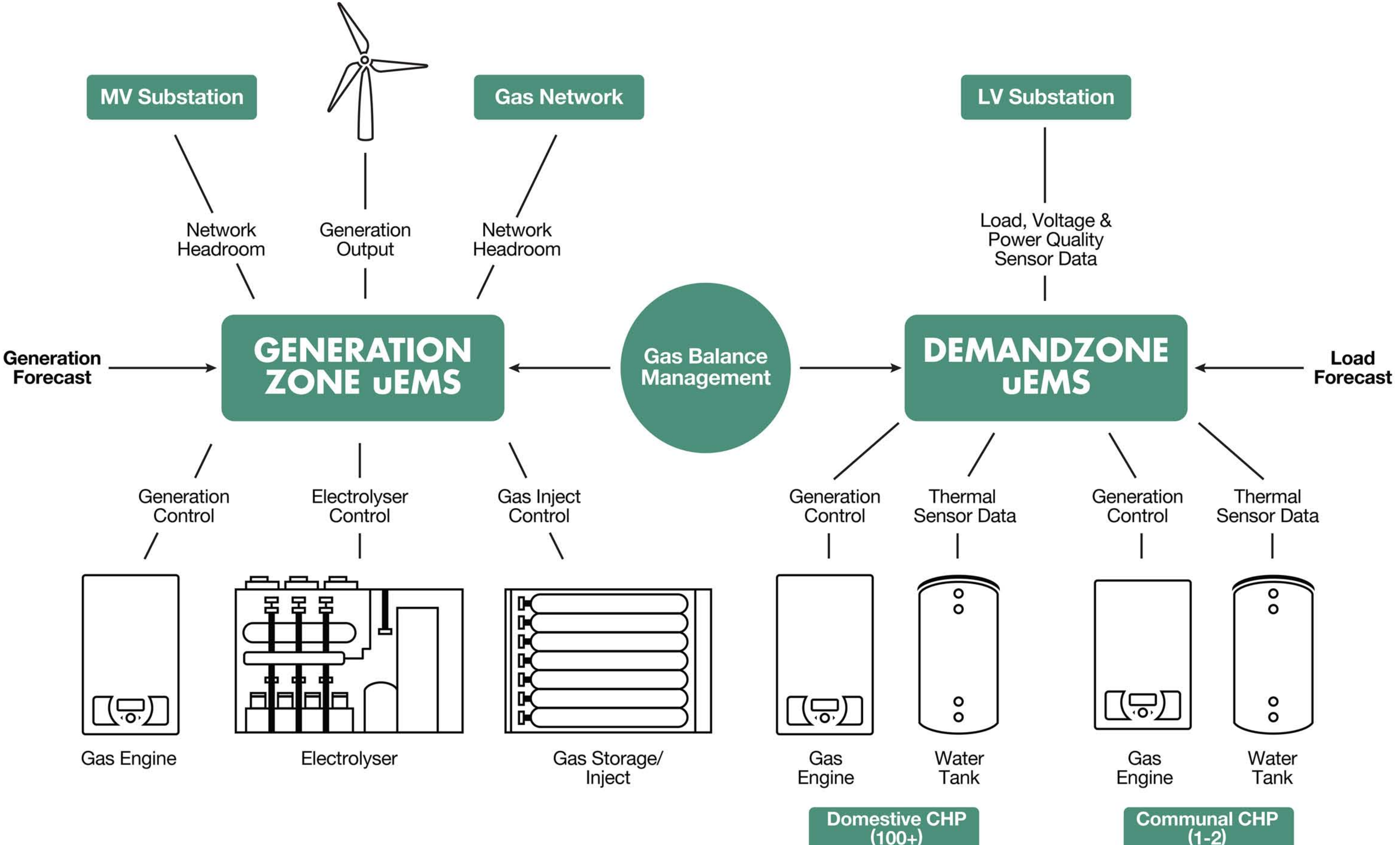
To demonstrate the full potential of the concept of hydrogen injection in the UK as a means of decarbonising the operation of gas networks and the local heat demand, it will be necessary to move to a higher hydrogen fraction. To do this it will be necessary to apply to the Health and Safety Executive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

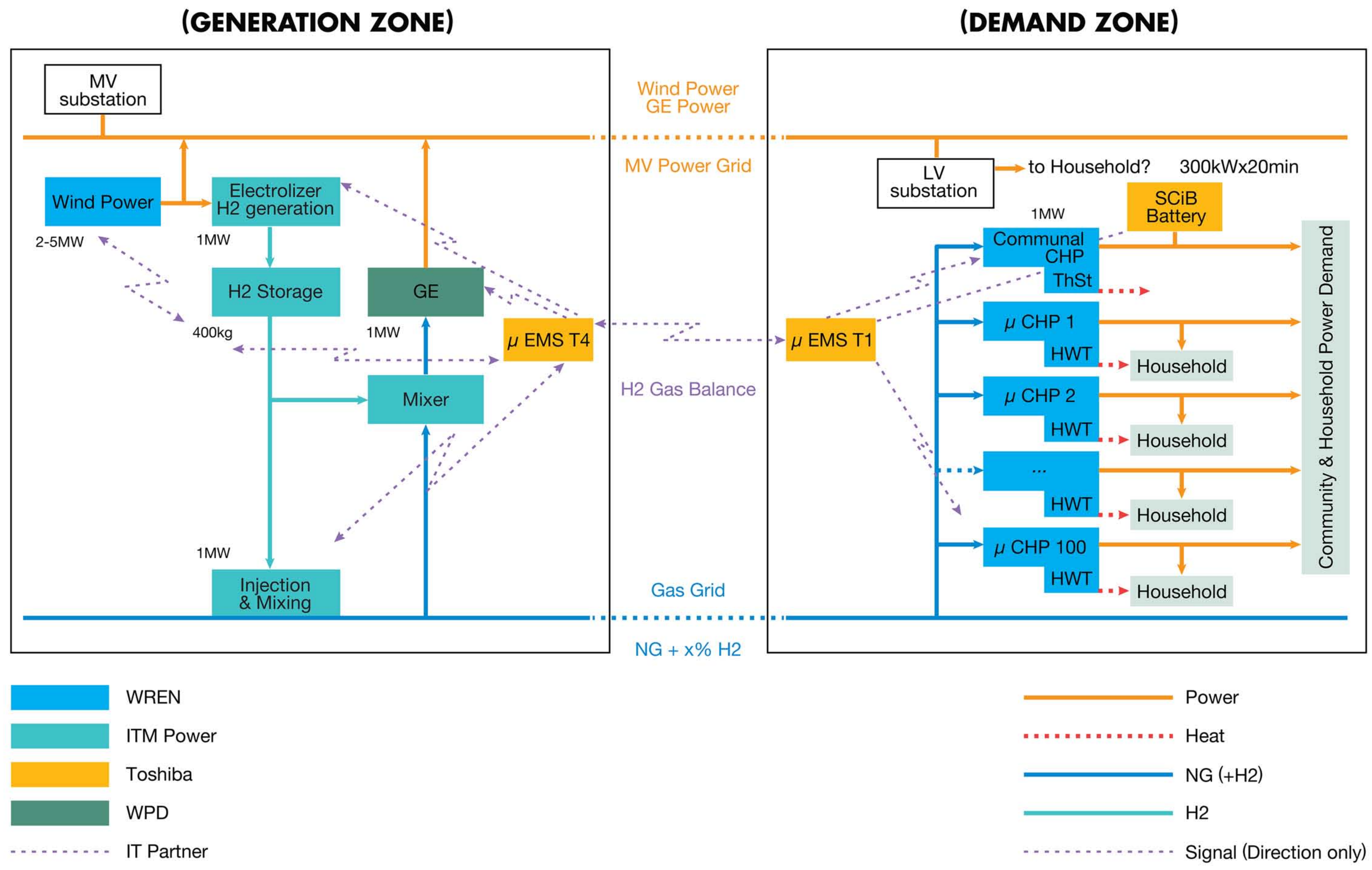
Working with Health and Safety Labs (HSL), part of the Health and Safety Executive, means that the Executive will help to ensure that the arguments that hydrogen injection at the proposed levels are safe and proven and are aligned to the expectations of HSE in making changes in regulation to accommodate 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
GE Power
MV Power Grid
Wind Power
2-5MW
Electrolizer H2 generation
1MW
H2 Storage
400kg
GE
1MW
μ EMS T4
Mixer
1MW
Injection & Mixing
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 P Partner Roles Summary

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.

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-inject project elements.

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 cooperative 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 commercial CHP systems and attract local community micro CHP participants.

Wales & West Utilities will undertake an NIA study, working in conjunction with the HSL, aimed at obtaining a derogation that enables the hydrogen content within the Wadebridge gas system to be raised from the current legal limit to a level approaching 2%. WWU will also submit an NIC bid to complement this submission and will provide appropriate gas network connections and status monitoring to support the LCNF programme.

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

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

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: LCNF 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 WPD and partners as an LCNF Tier 2 bid.

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 hydrogen as a storage and transport vector for managing electrical distribution network constraints is a valuable contribution to the experience base. 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

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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

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

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

EUROPE & SCOTLAND
European Regional Development Fund
Investing in your Future

SCOTTISH Hydrogen & Fuel Cell ASSOCIATION

Ofgem
9 Millbank
London
SW1P 3GE

15th July 2013

Low Carbon Networks Fund, Clean Energy Balance (CEB) Proposal

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) – Circumventing Electricity Network Constraints being submitted to the Low Carbon Networks Fund 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

D Pinchbeck Consultancy Limited

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T : + 44 1664 858327
F : + 44 1664 481828
M: 07798 561 535
E : davepinchbeck@hotmail.com

Ofgem
9 Millbank
London, SW1P 3GE

LCNF: Clean Energy Balance (CEB) – Circumventing Electricity Network Constraints

(submitted by Western Power Distribution)

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 "HIP" project
Secretary General GERG (retired)
Member, NATURALHY Project Executive Committee

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

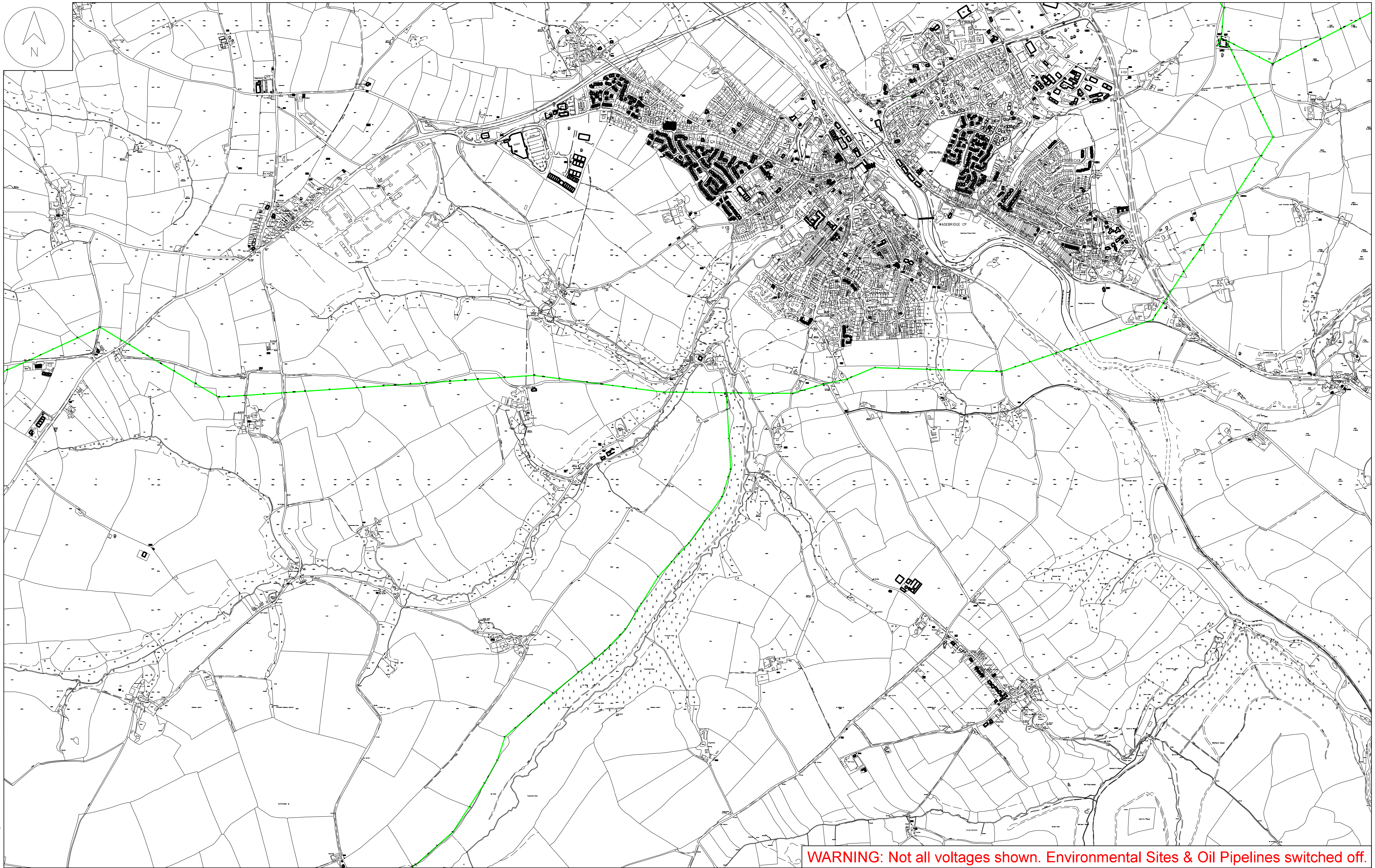
[2] European Gas Research Group (www.gerg.eu)

[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

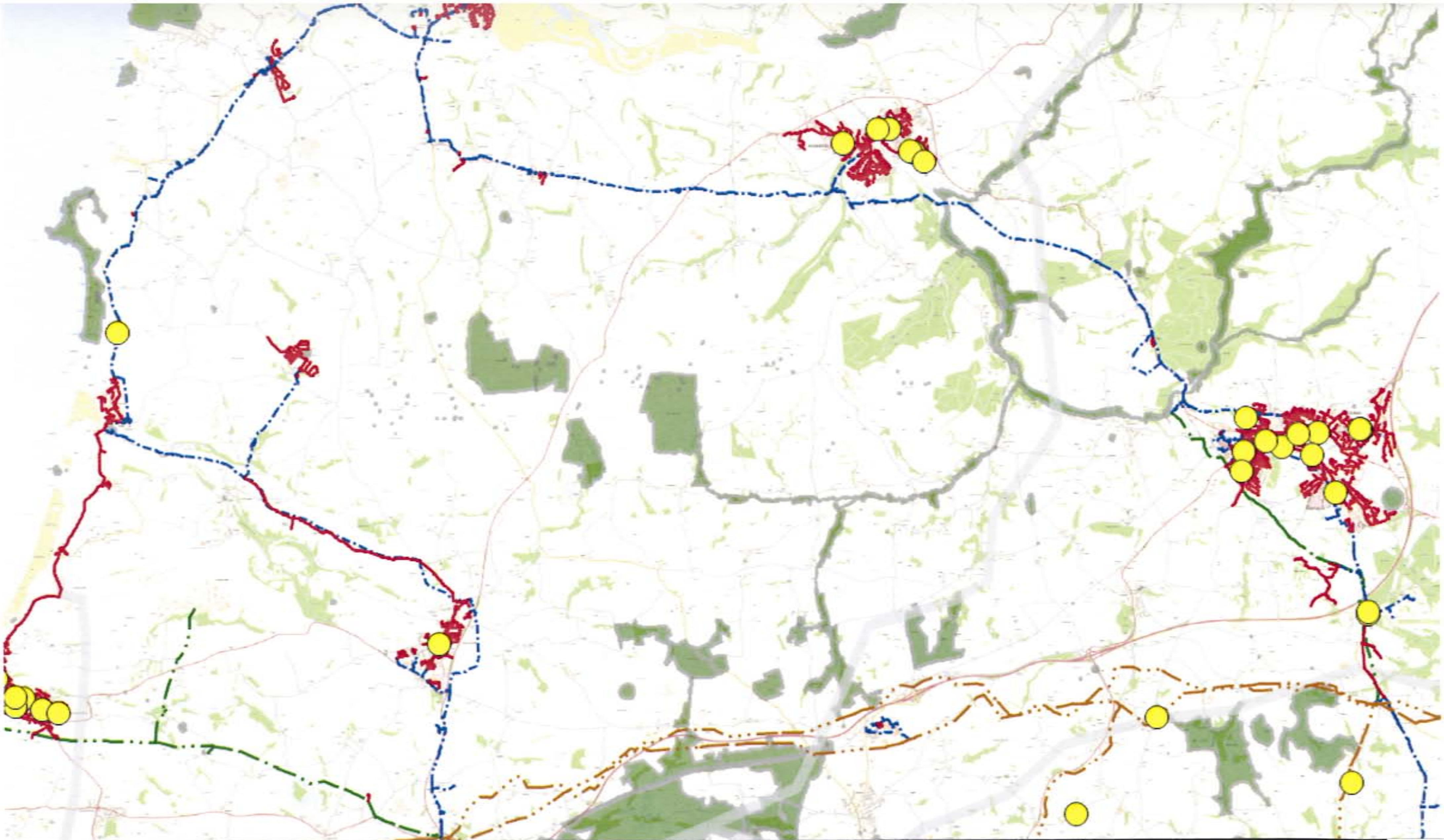
Underground Earth

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



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.