Network Innovation Competition

20 October 2020

H100 Fife

SGN

Your gas. Our network.

Network Innovation Competition: Full Submission Application

1. Project Summary

1.1 Project Title	H100 Fife
1.2 Project Explanation	H100 Fife aims to deliver a 'first of a kind' 100% hydrogen demonstration of an end to end energy system, to evidence the role that hydrogen can play in decarbonising heat, using the gas network.
1.3 Funding Licensee	Scotland Gas Networks plc and Southern Gas Networks plc
1.4 Project Description	1.4.1. The Problem(s) it is exploring There is currently no fully formed or evidenced single solution for the decarbonisation of heat, and therefore it is critical that the UK explores credible options for delivery if it is to meet its net zero ambitions. It is widely recognised that hydrogen could offer a lower cost and lower disruption option for customers when compared to other technologies. Decarbonisation of the gas network offers a credible and exciting opportunity to support the transition to net zero, but requires an energy system transformation in order to succeed. A safe, reliable demonstration of hydrogen from renewable sources to customers' homes is essential to evidence the role hydrogen can play in the net zero solution. 1.4.2. The Method(s) that it will use to solve the Problem(s) H100 Fife will demonstrate a 'first of a kind' end to end system that delivers 100% hydrogen to customers as an alternative to natural gas. The project seeks to combine the extensive research, technological development to test and validate the regulatory, technical, social and operational viability of transitioning to 100% hydrogen. 1.4.3. The Solution(s) it is looking to reach by applying the Method(s) The project aims to provide critical understanding of the construction and operation of a hydrogen system, which is replicable and scalable. The learning and outcomes of this project will provide a blueprint for future hydrogen systems and critical technical, commercial, regulatory and social evidence of hydrogen's role in the pathway to decarbonisation collectively set out by network operators, industry and stakeholders in the Gas Goes Green movement. 1.4.4. The Benefit(s) of the project. This project will advance the hydrogen economy sharing evidence widely to support and inform the spectrum of interested stakeholders, from customers and markets to UK and Scottish governments.

1.5. Funding			
1.5.1. NIC Funding Request (£k)	18,101	1.5.2. Network Licensee Compulsory Contribution (£k)	2,043
1.5.3. Network Licensee Extra Contribution (£k)	500	1.5.4. External Funding – excluding from NICs (£k)	6,855
1.5.5. Total Project Costs (£k)	27,786		
1.6. List of Project Partners, External Funders and Project Supporters (and value of contribution)	**Project Partners (Network Licensees):** Cadent, Northern Gas Networks (NGN), Wales & West Utilities (WWU) (£2,043k). **Project Partners (Non-Network Licensees):** Baxi, Bosch, HyCookers, HyFires. **External Funders:** Scottish Government (£6,855k). **Project Suppliers:** Offshore Renewable Energy (ORE) Catapult, Scottish Enterprise, Fife Council, Scottish Power Energy Networks (SPEN), Scottish Water, HSE Science Division, Kiwa, Arup, DNV-GL, Environmental Resources Management (ERM). **Project Supporters:** National Grid Gas Transmission (NGGT), GTC, Energy Utilities Alliance (EUA), Energy Skills Partnership (ESP), Diageo, Scottish Hydrogen Fuel Cell Association (SHFCA), Energy Networks Association (ENA), Hy4Heat, National Physics Laboratory (NPL), University of Edinburgh, Enertek International Ltd.		

1.7. Timescale			
1.7.1. Project Start Date	1 April 2021	1.7.2. Project End Date	31 March 2027

1.8. Project Manager Contact Details			
1.8.1. Contact Name and Job Title	Angus McIntosh, *SGN Director of Energy Futures* Stephen Tomlinson, *SGN Project Manager*	1.8.2. Email and Telephone Number	Angus.McIntosh@sgn.co.uk 07966105362 Stephen.Tomlinson@sgn.co.uk 07815500204
1.8.3. Contact Address	SGN, Axis House, 5 Lonehead Drive, Newbridge, Edinburgh, EH28 8TG		

1.9. Cross Sector Projects (only complete this section if your project is a Cross Sector Project, ie involves both the Gas and Electricity NICs).	
1.9.1. Funding requested the from the [Gas/Electricity] NIC (£k, please state which other competition)	N/A
1.9.2. Please confirm whether or not this [Gas/Electricity] NIC Project could proceed in the absence of funding being awarded for the other Project.	N/A

1.10. Technology Readiness Level (TRL)			
1.10.1. TRL at Project Start Date	4	1.10.2. TRL at Project End Date	8

2. Project Description

2.1. Aims and objectives

2.1.1 The Problem to be resolved;

The global fight against climate change is a movement that affects everyone and all sectors, including industry, the energy networks, government, decision makers, regulatory bodies and customers. Hydrogen is an exciting and credible energy carrier that is recognised as an essential component of a net zero Britain[1]. There is an urgent need to evidence the role that hydrogen can play across sectors. While much focus has been on 'bulk hydrogen supply', production and transport, where hydrogen is seen as essential to decarbonisation efforts, its role in domestic heat has yet to be evidenced.

The UK Government has committed to substantial reductions in greenhouse gas emissions in order to achieve net zero by 2050[2]. Decarbonising heat is a key strand of the policy which is required to meet these targets. The Scottish Government has set out ambitions to become a net zero economy by 2045[3], this includes a new target to reduce emissions by 75% by 2030[2]. The UK Government Department of Business, Energy and Industrial Strategy (BEIS) has stated that heat policy decisions will be made in the first half of the 2020s[4], which is widely expected in 2023/24. A live demonstration of the role hydrogen can play in delivering low carbon heat to customers has not been evidenced. This is a gap in the knowledge and understanding of future energy systems that needs addressed and validated prior to any heat policy decisions on the energy transition.

Customer protection is sacrosanct to us. We have a duty to ensure a transition to a low carbon future is inclusive so that customers and stakeholders are brought along on the decarbonisation journey without unfair disadvantage.

2.1.2 The Methods being trialled to solve the Problem

To date, previous H100 NIA and wider industry hydrogen projects have followed good scientific methods through recognised technology readiness levels. We are now at the critical stage in development where all this research is pulled together to deliver an end to end hydrogen system demonstration. There are several individual subcomponents that combine to form the overarching Problem that this project seeks to answer by evidencing hydrogen for heat. The NIC funded project elements listed in Section 2.3 with their accompanying descriptions, demonstrate how they deliver information, understanding, know-how and validation on different areas of the Problem. These are as follows:

- Proving the technical viability of a 100% hydrogen network (Element 5)
- Establishing a permanent Hydrogen Demonstration Facility with multiple functions as a customer engagement tool, education, learning and training (Element 6)
- Contributing to the overall safety case for hydrogen through the project's Safety Management Framework (Element 7)
- Facilitating hydrogen market development, testing industry participation and activeness in the hydrogen economy (Element 8)
- Integration of an end to end system to include an all in one hydrogen supply, storage, distribution and customer solution (Element 9)
- Demonstrating the customer acceptance, interest and appetite for hydrogen heat (Element 10)

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[1] Net Zero Technical Report, Committee on Climate Change, May 2019
[2] The Climate Change Act 2008 (2050 Target Amendment) Order 2019
[3] Climate Change (Emissions Reduction Targets) (Scotland) Act 2019
[4] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/766109/decarbonising-heating.pdf

- Validating the operational strategy for running a hydrogen network, highlighting any differences from operation a natural gas network (Element 11)
- Exploring the process and requirements for implementing an enduring solution for a hydrogen demonstration (Element 12)
- Generating a blueprint on a local, regional and national level to secure support for hydrogen, sharing the hydrogen evidence base for further roll out of demonstration and moving towards strategic investment for transition and conversion (Element 13)

2.1.3 The Demonstration being undertaken

H100 Fife is seeking to deliver a 'first of a kind' 100% hydrogen network, supplying around 300 domestic properties initially, via an opt-in process. This number has been assessed to ensure statistical representativeness of the project for the UK, particularly the demand profile[5]. H100 Fife will be a purpose-built generation and storage solution, supplying a new distribution network, comprising of fully tested common natural gas components and fittings, laid in parallel to the existing gas network delivering an end-to-end hydrogen system. This method allows the demonstration to be undertaken without derogation from GS(M)R, affording gas customers the ability to refuse to take part in the project, while still enabling customer choice.

The hydrogen production method proposed for the project is electrolysis. The main components of the H100 Fife end to end system are:

- 7MW offshore wind turbine directly supplying the electrolyser for hydrogen production.
- Six above ground storage tanks, operating at 30bar with additional connectivity.
- Pressure reduction.
- Flow metering.
- Hydrogen quality and odorisation.
- Control system.
- A Hydrogen Demonstration Facility.
- A polyethylene pipe distribution network passing 1000 homes.
- Target of 300 domestic customers and associated service pipes and meters.
- Domestic boilers, fires, cookers and hobs for up to 300 customers.
- Various sensing technologies for network validation.
- A manned site for maintenance and emergency service provision.
- Bespoke billing arrangements supported by commodity balancing.
- Local operating procedures and training.

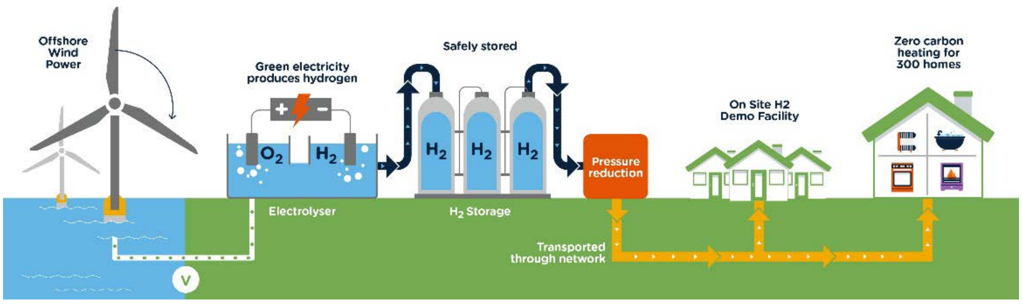

Figure 1: An end to end illustration of the H100 Fife system.

The demonstration of an end to end system in inexorably linked to the project success and learning. The technical validation of a hydrogen network could not be achieved without the inclusion of the upstream generation solution and downstream customer participation for the necessary period set out. Our approach ensures end to end control of the safety and technical management of the system, reducing cross chain risks for a 'first of a kind' demonstration and supporting the delivery of our customer commitments.

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[5] SGN/DNV-GL, Levenmouth Statistical Representativeness Report, October 2020

H100 Fife can produce learning across the whole system, offering insight into end to end interface management and transferable knowledge to facilitate hydrogen project and roll out.

Levenmouth in Fife, home to the town of Methil, offers a location that is unique for demonstrating hydrogen as an energy carrier. It provides access to an existing 7MW offshore wind turbine (owned by ORE Catapult), and a vacant plot owned by Scottish Enterprise that is development land for energy activities. This site, identified for the hydrogen production and storage facility as well as the demonstration facility, is located adjacent to the potential domestic end users. We have already engaged with Fife Council Planning and Scottish Enterprise as the landowners for the H100 Fife Site development at Energy Park Fife, therefore discussions are underway at an advanced stage to deliver the agreements and consents necessary for the construction of H100 Fife at Levenmouth. An aerial image showing Energy Park Fife in Levenmouth, with the 7MW wind turbine is in Appendix L.

2.1.4 The Solutions which will be enabled by solving the Problem

Ensuring the timely delivery of a 100% hydrogen network, with a dedicated hydrogen supply and storage solution, to customer homes will allow for informed choices to be made on future energy systems. This project integrates with the national programme, co-ordinated with the Gas Goes Green initiative, and the Hydrogen Programme Development Group, chaired by BEIS. This supports the development of policy and frameworks to deliver strategic energy system change and identify areas of required research, evidence and trailing to roll out a hydrogen economy by addressing a myriad of safety and technical, social, regulatory and operational challenges (Appendix N). Achieving net zero emissions by 2045 in Scotland and 2050 across the UK will contribute to the worldwide effort to limit average global temperature increases to 1.5°C.

2.2. Technical description of Project

The technical development and system design of H100 Fife has been informed by a number of previous projects; Project Methilltoune[6] undertook a feasibility study funded through the BEIS Hydrogen Supply Competition 2019 for a green hydrogen production and storage solution. The H100 Levenmouth Feasibility & FEED study, under the H100 NIA programme, ran in parallel to Project Methilltoune and drew on the information to complete an end to end assessment to include the distribution network and the preliminary design and development of a hydrogen system in Levenmouth. These have both been used to inform the proposal for H100 Fife. All equipment and components of the H100 Fife system will be designed in accordance with appropriate methodology to ensure compliance with relevant safety legislation and suitability for the transportation of hydrogen. H100 NIA and the BEIS Hy4Heat programme[7] informs the downstream aspects of the H100 Fife end to end system. The H100 NIA Workstream A programme that focused on testing and building the evidence base for hydrogen covered the projects listed in Appendix F. Within this submission distinct sections of the H100 Fife end to end system are referred to as follows;

- **H100 Fife Site** – to encompass all the components within the boundary of Energy Park Fife site, including the assets for power generation, hydrogen production, storage, pressure reduction, odorisation and the Hydrogen Demonstration Facility.
- **H100 Fife Network** - the low pressure distribution network.
- **H100 Fife Homes** - all works required with customer homes.

[6] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/866382/Phase_1_-_SGN_-_Methilltoune.pdf
[7] See Section 2.2.7

2.2.1 Power Generation

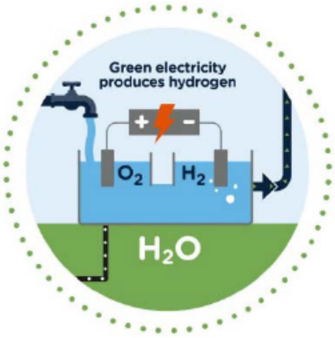
The Offshore Renewable Energy Catapult (ORE Catapult) is the owner and operator of the 7MW offshore wind turbine at Energy Park Fife, referred to as the Levenmouth Demonstration Turbine (LDT). H100 Fife is seeking to demonstrate a world-first cross-sector integration solution by using offshore wind to produce hydrogen for heating. We have agreed with ORE Catapult that a Power Purchase Agreement (PPA) will be in place between the parties to provide preferential access to the turbine for hydrogen production. This commitment is reflected in a signed agreement in principle on the pricing terms and is addressed in further detail in Figure 4. We will seek to validate the reliability of the wind turbine to provide the primary power input to the system, but in order to ensure security of supply for the overall project, an electricity grid connection will also be in place to provide a back-up power supply to the project. The renewable energy capacity of the wind turbine was evaluated and reported the average annual electricity generation as 16.0GWh over six years of modelling (2013-2018), with a range of 15.1GWh to 17.1GWh. To verify sufficient power capacity from the turbine, a longer timeframe of a 20-year period was examined to identify the lowest wind generation year, which was found to be 13.6GWh. Despite the 7MW rated power of the turbine, the maximum power output is 6.5MW.

The power curve for the wind turbine was found to be typical, with no power generation until a kick-in wind speed of 3.5m/s is reached. A cubic relationship between the wind speed and power generated continue beyond this speed until it reaches a rated wind speed of 12.5m/s, at which point the blades of the turbine feather to maintain a steady generation of 6.5MW. Between wind speeds of 12.5m/s and 25m/s, the turbine will maintain a power output of 6.5MW, however at 25m/s and higher the turbine meets its cut-off wind speed to safeguard the operation of the turbine.

[redacted]

[redacted] The power demand (import) required to power hydrogen production for 900 properties is estimated at 4.6MVA. This has been modelled for 900 properties to build in capacity for future increased hydrogen production opportunities [redacted] In engagement with SPEN, we intend to provide profile data for both the turbine and the electrolysis plant to support their future understanding of hydrogen production and the associated heat profile derived from a power supply. This offers an opportunity for joined up knowledge transfer between the gas and electricity networks.

2.2.2 Hydrogen Production



Electrolysis is a hydrogen production method which uses electricity (direct current) to split water molecules into hydrogen and oxygen. The overall reaction is:

$$2H_2O \rightarrow 2H_2 + O_2$$

When supplied by renewable electricity, this process is free of carbon, and is widely referred to as 'green' hydrogen, which can be used to describe hydrogen production for H100 Fife. In the early stages of the preparatory work for the project, we assessed alternative production methods and costs with Kiwa[8]. Figure 2 and Figure 4 illustrates that electrolysis from the grid offers the lowest cost solution:

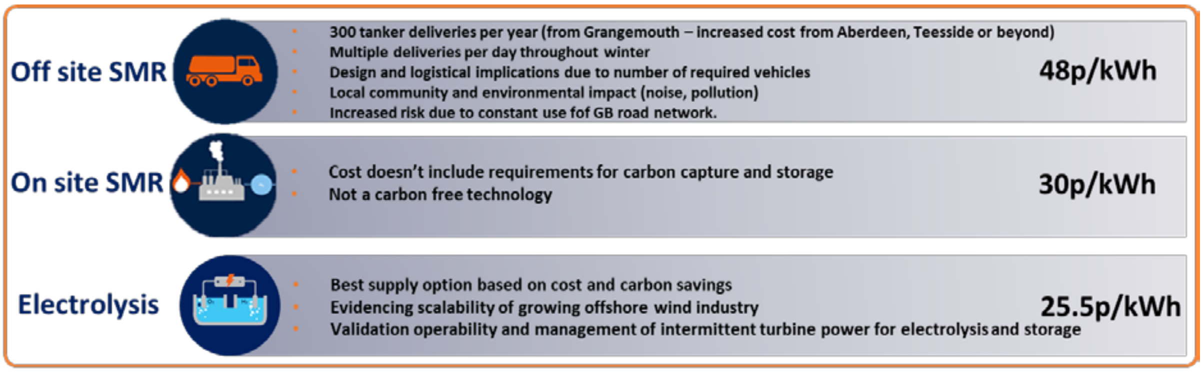


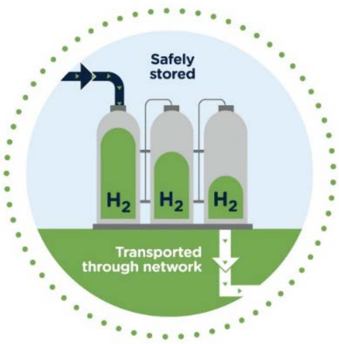
Figure 2: A summary of the cost of hydrogen production.

The cost of the electrolytic hydrogen production method can be further improved through innovative generation optimisation utilising the offshore wind turbine and its preferential electricity rate. The generation of hydrogen direct from offshore wind is a 'first of a kind' demonstration that we will seek to validate under the project and the project has been structured to ensure security of supply through the grid connection, but allow outperformance if direct generation from the turbine is successful. The hydrogen production capacity for H100 Fife has been assessed using current natural gas demand and is sized to circa 4MW to provide sufficient hydrogen for 900 homes to account for expansion opportunities, while maintaining N(100%) +1 redundancy philosophy. Several suitable technology and model options were identified in a preliminary electrolyser review under Project Methilltoune, that met the technical and commercial requirements of the project. The key selection criteria that will remain paramount in the procurement phase will be reliability and downtime turnaround guarantees to safeguard security of supply to protect customers from loss of supply beyond the 5 days of hydrogen storage built into the project design. A procurement process will be undertaken as part of Element 4 to conclude the electrolyser selection and place an order ahead of the beginning of NIC to account for the long lead time (c. 12 months) as advised by manufacturers. The Network Entry Point is expected to be at the outlet of the hydrogen production system, therefore the hydrogen will be metered upon entry to the storage system to the accuracy required to facilitate commercial arrangements.

We are engaged with Scottish Water to share the demand profile of the electrolyser, which will be fed from the mains water supply. This system data and understanding of supply requirements could prove useful in managing water supply management, store capacity and the impact on abstractions for future system rollout.

2.2.3 Hydrogen Storage

Under Project Methilltoune, the postcodes within the proposed network area were obtained from Open Source Geospatial



[8] H100 NIA Hydrogen Logistics Report

Foundation[9]. These were then used to extract the most recent gas consumption data (2017) from BEIS's sub-national consumption statistics[10]. The peak gas demand was during winter 2010 with a per property demand of 374.32 kWh of natural gas over the 5 days. This was used to determine the possible gas storage requirement for the plant to permit us to ensure security of supply through a robust system with no single point of failure and allow sufficient onsite gas storage to make sure that any potential production system downtime does not lead to a supply outage. In turn, this will allow us to continue to meet the daily demand profile of the network and to mirror licence conditions as a gas transporter.

Table 1: A summary of the above analysis for scenarios ranging from 1-900 properties.

Number of Properties	1	300	900
Average annual gas consumption (kWh)	12,624	3,787,200	11,361,600
Peak year gas consumption (kWh)	13,712	4,113,721	12,341,164
Peak week consumption (kWh)	374	112,297	336,890

This 5-day supply equates to 2850kg (112,303kWh) of hydrogen, which will be stored in 6 tanks. These storage tanks are steel cylinders of approximate dimensions of 4,000mm (id) x 25,000mm, providing a hydrogen capacity of 692 kg (27,296 kWh) at 30 bar.

Regarding alternative forms of storage, hydrogen is available commercially in Multi-Cylinder Packs (MCPs) at an approximate cost equivalent of £15,000 per home. The limited amount of gas contained within each MCP would require continuous connection and emptying at an unachievable rate. Storage of hydrogen in tanks to provide a buffer of a number of days of demand does not depend on the production method. Tanks contain over twice as much gas per quantity of capital cost compared to tube trailers, therefore storage on site using trailers would be less attractive than using fixed tanks as proposed. Furthermore, trailers or tankered hydrogen brings with it further disadvantages of logistics, disruption, risk of accidents, noise, pollution, site spatial constraints and road impact.

2.2.4 Pressure Reduction and Odorisation

From the 30bar storage system, the hydrogen will pass through the on-site pressure reduction station (PRS) with an outlet pressure of 75mb for entry into the low pressure (LP) distribution network. As hydrogen is odourless in its primary form, an odorant is required for its safe detection in the event of a gas escape. Accordingly, the H100 NIA programme researched and tested this aspect with the National Physics Laboratory (NPL) and concluded that the current odorant NB (80% tertiary butyl mercaptan, 20% dimethyl sulphide) used in the majority of the UK gas network is suitable for use in 100% hydrogen.

2.2.5 Hydrogen Demonstration Facility

The Hydrogen Demonstration Facility will be a two storey build of typical proportions to that of 3 terraced houses located on the H100 Fife Site, with safety distances taken into consideration of the hydrogen production and storage plant. This will be a permanent structure, with two buildings resembling show homes on either end of a larger central building, that will provide an area for reception, presentations and a meeting space. This will be a vital component of the customer engagement plan and will also offer education, awareness and training opportunities. Further information on the key role of the Hydrogen Demonstration Facility is provided in Section 8.3. The preliminary interior floorplans for this component are shown in Appendix L. We will be working with key

[9] https://qgis.org/en/site/about/index.html
[10] https://www.gov.uk/government/collections/sub-national-gas-consumption-data

appliance manufacturers under the Hy4Heat programme to provide appliances for the Hydrogen Demonstration Facility. This arrangement is discussion in more detail in Section 4.4.2.

Figure 3: An indicative 3D render showing the Hydrogen Demonstration Facility.

2.2.6 Distribution Network

H100 Fife Network will be a new network laid in parallel to the existing natural gas network, using PE materials commonly used by gas distribution networks today. This is an intentional approach in being able to validate 100% hydrogen operation in a network at this time and providing critical operating evidence prior to committing to natural gas network conversion to hydrogen. No derogation under The Gas Safety and Management Regulations (GS(M)R) is required. In addition, the new network protects and promotes customer choice, allowing those that wish to participate in the project to opt-in, and those that would prefer to remain with their existing natural gas supply to do so. This is a key design feature of the project that will allow the customer acceptance and interest in hydrogen to be tested in a real-time demonstration, while ensuring there is no disadvantage or mandatory involvement for customers that do not want to participate. The information obtained from H100 Fife will reciprocally complement the work being undertaken by H21 which seeks to understand the interventions required to convert the existing network by testing existing assets, including those that are not found on H100 Fife's new system.

Polyethylene 80 (PE80), the material used today in the LP natural gas network for construction projects and as part of the Iron Mains Replacement Programme, is suitable for use in hydrogen networks as evidenced in the H100 NIA programme (NIA_SGN0105) – 'PE Materials, Fittings and Jointing Techniques'. H100 Fife will be a valuable validation of this study, demonstrating the network materials and methods that are currently employed today are suitable with 100% hydrogen in the GB distribution network, which will form >90% of the entire GB gas network upon completion of the Iron mains replacement programme. The project provides critical evidence to prove the suitability of the PE pipe that makes up around 80% of the 280,000km distribution network in every city and street in GB, and support or otherwise the acceleration of the replacement programme. Pipes that were fully permeated with hydrogen were assessed against industry benchmark and passed the relevant benchmark performance requirement for electrofusion, butt fusion and flow stopping techniques. In addition, no premature/early life failure mode has been evidenced as a consequence of the activity. Currently used natural gas Excess Flow Valves and the industry standard (GIS/EFV1) are not suitable for hydrogen flow rates. A new hydrogen Excess Flow Valve and standard is being developed under the H100 NIA programme (NIA_SGN0154).

The distribution build will take place in two stages:

- **Stage 1 – 2022:** The mains build which is sized for the full demonstration area and will be laid past 1000 homes. It is anticipated this will be laid open cut to allow full quality assurance. Standard construction techniques will be applied for distribution

lay and all joints will be supervised by an SGN Competent Person. See proposed distribution network plan in Appendix L.
- **Stage 2 – 2022/23:** The installation of 300 services from within the 1000 property boundary. The plan is for all 300 properties to be identified prior to the commissioning of the mains allowing all 300 to be installed within the network area, however this will be determined by customer uptake rate. The service install programme will interface with the appliance install programme within the selected properties. The aim is to have as many of the 300 services installed towards the start of this stage as possible. Standard construction methods will apply with exception of an additional Excess Flow Valve.

Table 2: Proposed network design parameters. An indicative network plan is shown in Appendix L.

Pipe Diameter	Length (m)
250mm	150
180mm	673
125mm	2,609
90mm	3,321
63mm	1,742
Total	8,495

2.2.7 Customer Homes

The project aligns with the Hy4Heat programme funded by BEIS that is developing hydrogen appliances, include those for domestic properties. This covers hydrogen boilers, hydrogen gas fires and hydrogen freestanding cookers, hobs and ovens. It aims to provide critical evidence of end use application, safety, in-use emissions, and functionality. A number of organisations are developing appliance prototypes under WP4a that are on track for completion and demonstration in early 2021. We have agreed partnership prices with Baxi and Bosch, to provide hydrogen boilers, and with the HyFires and HyCookers consortiums. We will liaise with these partners to determine and develop the maintenance programme for the hydrogen appliances in customer homes. The provision of hydrogen appliances to customers and the associated install and maintenance is a cost borne out of the project so that the customer is not disadvantaged, which could otherwise bias the project's ability to understand customer attitudes towards hydrogen. In addition, domestic hydrogen smart meters that are in development under the Hy4Heat programme, will be procured for use in H100 Fife.

Property eligibility checks and pre-installation assessments for customers who opt-in to the project will be carried out to determine property upgrade requirements and hydrogen appliance requirements on a like-for-like basis. No hydrogen supply installations will take place prior to the adjacent mains pipe being commissioned enabling the disconnection of the existing natural gas service pipe and the installation and commissioning of the new hydrogen service pipe to occur during the same day, minimising the time gas consumers are without a gas supply.

2.2.8 Summary

The H100 Fife proposal offers an end to end hydrogen system that can validate the use of hydrogen in the gas network as a solution to decarbonising a major part of the UK's energy systems. It is evidencing the opportunity for grid integration systems between renewables and hydrogen production, and demonstrates the business case that offshore wind can offer for production of hydrogen at scale. The technical and experimental testing programme for 100% hydrogen has been completed under H100 NIA plus other projects. H100 Fife is now in a position to demonstrate the real-world operation.

2.3. Description of design of trials

2.3.1 Project Elements

The H100 Fife project structure is phased with 13 elements, all of which are packaged to deliver key stages of the project to enable its successful delivery. Of these elements, 9 are proposed for NIC funding. The detailed project element scopes are in Appendix I. In order the define the cost lines for the project, the project elements above have been categorised into four cost elements. These are further defined in Section 4.2.

Table 3: H100 Fife project elements defining distinct phases of the project.

Phase	Funder	Timeline
Element 1 - Planning Application Services	SGN	Q3 2020 – Q1 2021
Element 2 - Third Party Agreements & Project Support	SGN	Q3 2020 – Q1 2021
Element 3 - Land Acquisition	Scot Gov	Q4 2020 - Q1 2021
Element 4 - Long Lead Items Acquisition	Scot Gov	Q4 2020 – Q4 2021
Element 5 - Technical & Engineering Support	NIC	Q2 2021 – Q4 2022
Element 6 – Hydrogen Demonstration Facility	NIC	Q2 2021 – Q1 2022
Element 7 - Pre Construction	NIC	Q2 2021 – Q4 2021
Element 8 - Procurement	NIC[11]	Q4 2020 – Q3 2022
Element 9 - Construction	NIC	Q4 2021 – Q4 2022
Element 10 - Customer Works	NIC	Q4 2022 – 2023[12]
Element 11 - Operational Phase	NIC	Q4 2022 – 2027
Element 12 - Project Exit Strategy	NIC	2027
Element 13 – Stakeholder & Comms	NIC	Q4 2020 - 2027

2.3.2 Project Element Timeline

The timing of the above elements is dictated by several factors, including funding, equipment lead times, engagement periods and policy drivers. We are marrying together various funding mechanisms in order to deliver the project. The detail on this is covered in 4.4.1. Subject to a successful outcome at NIC, Elements 5-13 will be delivered under NIC funding. This funding combination allows for an operational system to be in place by the end of 2022, allowing sufficient time for the validation of 100% hydrogen ahead of heat policy decisions. In addition, this ambitious programme accounts for a dedicated and robust customer engagement period prior to the customer decision to participation. The operational period proposed provides essential understanding to the gas networks, appliance manufactures, gas customers and interfacing networks such as power and water, of a future energy system. Project components require evidenced operational history to maximise the learning in support of further trials, subsequent pilots through to full rollout. Statistical analysis undertaken evidences that representativeness more than doubles if operated over the period proposed vs a shorter period. Most importantly, the trial period proposed is more attractive to participating customers and reduces the risk of low uptake based on the disruption trade off.

2.3.3 Project Element Deliverables and Outcomes

The project elements are designed to satisfy the Deliverables in Section 9 and represent the Methods used to solve the Problem as outlined in *2.1.2.* H100 Fife will deliver a myriad of outcomes and learnings that are further detailed in Appendix N. These outcomes are essential for demonstrating the customer appetite for, and interest in

[11] Procurement of long lead items commences in November 2020 under Scottish Government Grant, remaining elements commence Q2 2021 under NIC.
[12] Following on from the project's customer engagement the aspiration is to have 300 homes signed up to the demonstration in advance of this phase, therefore we hope to have all customers connected within the first half of 2023.

hydrogen as an in home decarbonisation solution and the potential for hydrogen networks to play a role in the future energy systems.

2.4. Changes since Initial Screening Process (ISP)

#	Change Details	Justification
1	Scottish Government funding available this financial year only (2020/21) subject to Ofgem NIC award.	The Scottish Government Grant for H100 Fife will be spent in this current financial year, subject to NIC award. This will allow long lead items to be procured and land to be purchased, facilitating access to site April 2021.
2	SGN [redacted] funding of £500K acquired.	Contribution from SGN to support the ongoing development and momentum of the project and to ensure continuity with key stakeholders, third parties and contractors.
3	Element 1 funded by SGN rather than NIC.	Require planning permission to be granted ahead of NIC funding drawdown to be operational in 2022. This also provides the longest customer engagement period possible.
4	Element 2 funded by SGN rather than NIC and name change.	Allows key third party discussions to continue and have agreement in principle.
5	Element 3 to cover land acquisition only and funded by Scottish Government.	Planning scope has been moved into Element 1.
6	Element 4 (now renamed Element 5) funded by NIC rather than Scottish Government. Scope refined to detailed design and project management support.	Scottish Government funding allocated to front end critical works in current financial year.
7	Element 5 (now renamed Element 4) to include all identified long lead items, not just electrolyser.	Storage tanks also identified as a long lead item.
8	Element 6 funded by NIC not Scottish Government.	Hydrogen Demonstration Facility design and build works to begin in April 2021.
9	Elements 7-13 timeline refined.	As a result of programme development and refinement.
10	Element 14 cost now accounted for in Element 7 and Element 8. Element 14 removed as a result.	Ongoing project development refined the elements.
11	Cost certainty and refinement exercise undertaken since ISP.	It was advised at point of ISP that this exercise would be undertaken. Details of methodology in Section 6.
12	Further work and refinement of spectrum of regulatory options undertaken.	Progress to arriving at regulatory solution for the project. Details in Section 7.
13	The proposed Project Board to govern the project is now referred to at the Technical Group.	Name is more applicable to group function.
15	[redacted]	[redacted]
16	Hydrogen appliance partnerships sought and agreed in principle with Baxi, Bosch, HyFires and HyCookers.	Partnership approach pursued for hydrogen appliances to agree an arrangement between the parties to ensure mutual benefit to both sides, where the project would receive direct benefits.

3. Project Business Case

Natural gas is currently the main source of energy in the UK economy, supplying 37.7% of primary energy demand in 2018[13]. 509.24 TWh of natural gas was demanded by the UK economy in 2018 at the point of final use for the heat of its combustion (for uses such as space heating and industrial processes), compared to 299.64 TWh of electricity (of which 37.36% was produced by gas generation).

The use of natural gas, delivered through the gas networks for heat (and industry) has for decades provided a low cost and low disruption heating solution for over 23 million customers across the UK. This system is not compatible with net zero and a widespread system change to low carbon energy is required.

The decarbonisation of energy delivered through the gas networks via the transition to hydrogen presents to policy makers and the wider industry a practical, low cost and low disruption strategy to enable the decarbonisation of heat which retains the use and benefits of the UK's extensive gas networks.

Our H100 Fife project, will build the world's first 100% hydrogen network, derived from offshore wind, supplying 300 homes in Fife. H100 Fife ultimately aspires (through its expansion opportunities), to develop a fully established hydrogen economy in Fife by 2045.

The development of H100 Fife and its expansion opportunities has the potential, by 2045, to deliver around 1.5 Mt CO_2e savings per year across heat, transport and industry, and deliver around £1.6bn of cumulative NVP through the avoided electrification costs of all gas customers in Fife.

3.1 Accelerates the development of a low carbon energy sector and/or delivers environmental benefits whilst having the potential to deliver net financial benefits to future and/or existing Customers

3.1.1. Context – The role of hydrogen in achieving net zero

Net carbon dioxide emissions (the main greenhouse gas produced by the UK and World economies – accounting for 81% of UK emissions in 2018) from the UK economy in 2018 were 38.6%[14] less than levels seen in 1990. This progress, whilst significant, is not proportionate across all sectors of the economy and has been delivered primarily through major decarbonisation in power generation through successful incentives and reduction in heavy industry. CO_2 emissions from domestic heating (UK wide) in 2018 were 15.2% lower than in 1990 (5.2% of overall progress). This relatively modest reduction has been achieved mainly through demand side measures (home thermal and boiler efficiency improvements) with some supply side decarbonisation (2% of SGN's throughput was met by biomethane in 2018/2019).

For the UK economy to achieve net zero, all sectors must demand and be supplied by low carbon and ultimately, renewable energy. In the current energy system, renewable generated electricity is the only fully established energy source capable of producing net zero energy and therefore capable of decarbonising the UK economy.

As is illustrated in Appendix E[15], transport and electricity energy demand exhibit relatively flat profiles, with little variance between seasons and no significant peaks (compared to gas demand). Conversely, gas demand is characterised by a significant intraseasonal mismatch, where demand in winter is significantly greater than summer

[13] All data in this paragraph is sourced from Digest of UK Energy Statistics 2019 (BEIS)
[14] Statistics derived from Dataset from UK Government – BEIS - https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-to-2018
[15] Data from Scottish Government - https://scotland.shinyapps.io/sg-scottish-energy-statistics/

demand, and significant within-day peaks (morning and evening peaks). Electricity is a form of kinetic energy and must be used instantly unless converted to another energy form (potential energy) for storage. It is therefore best matched to supply flatter demand profiles, such as the current electricity demand and transport demand shown in Appendix E, thereby minimising the requirement for energy storage.

Heat, however, requires a highly flexible, reactive and easily stored energy source to supply its complex and unpredictable demand profile. Supplying the current heat demand profile with electricity would result in significant redundant generation capacity in periods of low heating demand (summer months), mitigated only by the build out of significant energy storage (the majority of the UK's energy storage and flexibility provision is provided by gas storage and line pack in the NTS).

Heat demand is most practically supplied by chemical potential energy. Natural gas, biomethane and hydrogen gas are all forms of chemical potential energy. Gas boilers provide the majority of space heating in the UK. The high temperature output of the combustion of natural gas (due to its high energy density) provides a low disruption and low cost heating solution to over 23 million customers across the UK.

The long-term continued use of natural gas for space heating is not compatible with achieving net zero. To decarbonise heat, a major system transformation must take place to enable low carbon energy to supply heat demand. Transitioning the nation's heat energy supply away from gas to electricity would potentially enable the decarbonisation of heat. Electricity's characteristics, however, are not best suited to the complex requirements of heating demand. As such, the blanket electrification of heat is seen as a high cost, high disruption and generally impractical option.

The installation of heat pump technologies (for example) can yield significant efficiency savings in some property types and new builds. But the lower temperature output of their operation does require larger radiators and can require underfloor heating. Retrofitting heat pump technology to existing properties currently running on gas would be a highly disruptive and costly solution to decarbonising heat. This cost is compounded by the additional investment required to reinforce the power networks to deliver energy to this significant additional demand (this is exacerbated by increased transport demand from the electricity networks as electric vehicle ownership increases).

Whilst heat pump technologies can perform at efficiencies in excess of 300%, at peak times the efficiency can drop below 100%[16]. To fully electrify heat, the UK would require energy storage technologies (batteries etc.) capable of matching the energy capacity and discharge times provided by gas storage, particularly to handle the severe ramp ups seen in current heat demand profiles

Heat demand is clearly better matched with a chemical energy supply. This requires the decarbonisation of the energy delivered through the UK's extensive gas infrastructure. Biomethane is currently the only low carbon gas delivered through the gas networks and should be maximised in its use in the networks. Due to feedstock limitations however, biomethane cannot practically supply 100% of gas demand.

The development and rollout of hydrogen as an energy vector offers an alternative means of supplying low carbon energy as a form of chemical energy through the gas networks. Hydrogen is a highly reactive element, and as such exists naturally on earth within compounds such as water and hydrocarbons. Producing hydrogen requires splitting these compounds into their constituent parts. Hydrogen is a form of energy storage and when combusted, does not produce carbon. Blue hydrogen is produced through the reformation of natural gas into hydrogen and CO_2 (which is permanently stored using carbon capture and storage (CCS) technologies).

[16] Evidenced in downstream renewables laboratory testing conducted as part of the NIC funded Real-Time Networks Project

H100 Fife will focus on green hydrogen, which is often viewed as the future end state. An electrolyser is powered by a supply of electricity. Therefore, green hydrogen can be produced directly using renewable energy. Hydrogen gas, a form of chemical energy (like natural gas), can theoretically be stored and transported through the gas networks (new or repurposed existing) to supply heat and industrial demand in the same way as natural gas (with appropriate appliance changes).

Transitioning the gas industry to hydrogen offers a pathway to policy makers to fully decarbonise the energy delivered through the UK's gas networks, providing a low cost and low disruption heat decarbonisation option, safeguarding the future of the gas industry and its supply chains, and stimulating the hydrogen economy in the UK, however this requires to be demonstrated.

A gas network reliably supplied by 100% green hydrogen represents the ultimate net zero energy supply in terms of reliability, customer impact and energy security (green hydrogen is not reliant on natural gas reserves nor the success of CCS technologies). The decarbonisation of the gas networks using hydrogen is fully compliant with the energy trilemma.

3.1.2 Environmental benefits

In 2019/2020, SGN (Scotland and Southern combined) delivered 141.2 TWh of energy to supply heat and industrial demand, 98% of this energy was natural gas. The combustion of this natural gas resulted in 25.45 Mt CO_2e of GHG emissions. In 2018, the UK economy overall demanded 877.55 TWh of natural gas (primary energy). The combustion of this energy resulted in emissions of 161.47 Mt CO_2.

This is a strategic project, which would not be undertaken under business as usual investment processes. Therefore, the direct environmental and cost benefit of H100 Fife is insignificant in the context of the decarbonisation of heat. The future expansion opportunities of the project however ultimately may lead to the total decarbonisation of heat in Fife (and more widely Scotland) through the development of a hydrogen economy in Fife and the development of a hydrogen coast (linked to offshore wind and the wider whole energy system).

H100 Fife will enable the decarbonisation of 300 homes (an average UK domestic property uses 12,000 kWh of natural gas per year, at 0.184 kg CO_2/kwh), saving 662 t CO_2/annum. The projection of environmental benefits from this project are further realised through the future expansion opportunities of the project, as outlined in Appendix M.

The work proposed in this bid and Phase 2 of the project will be completed before 2030, Expansion Opportunities 3 and 4 are projected to be complete before 2040. A hydrogen economy in Fife (Expansion Opportunity 5), catalysed by this project, is expected to be fully established in advance of 2045 (with half of the rollout of hydrogen to gas customers (around 70,000 customers) in in place by 2040 (430,000 t CO_2).

Table 4: Carbon savings and associated value.

	To 2030	To 2040	To 2050
t CO_2 saved	2,208	454,000	1,500,000*
CO_2 value	£201,811	£76,726,000	£300,150,000*

The total carbon value[17] of this reduction (assuming a carbon price of £91.4/tCO_2e, £169/tCO_2e and £200.1/tCO_2e in 2030, 2040 and 2045 respectively) is £201,811.2 by 2030, £76,726,000 by 2040 and £300,150,000 by 2045 (*achieved in 2045 but presented as 2050 in the table).

[17] Carbon values derived from Treasury Green Book 2019 (base year non-traded CO_2 price)

3.2 Provides value for money for gas customers

3.2.1. Financial benefits

There are a multitude of financial and practical benefits to customer in decarbonising heat through repurposing the gas networks to hydrogen.

At a high level, the gas networks would be transitioned to transport hydrogen through the construction of new networks or the conversion of existing networks, the only demand side change required would be appliance changes. Hydrogen production would be required at scale and gas storage would be required to be repurposed.

If the technical viability of a hydrogen economy is not demonstrated at a GB scale, the only option available to policy makers to decarbonise heat would be to electrify it. In practice, this would require the widespread installation and retrofit of heat pump and/or resistive heating technologies across all 23.2 million properties currently connected to the gas networks, the reinforcement of the power networks, significant measures to improve the thermal efficiency of the GB housing stock and the significant build out of renewable energy generation and non-gas storage technologies.

The main financial benefit to customers and the UK taxpayer of H100 Fife is the tangible saving afforded by evolving the gas networks to low carbon energy and avoiding widespread electrification.

Appendix E, through the analysis of previously published scenario modelling, estimates the cost saving to each customer through the conversion to hydrogen thereby avoiding the costs of electrification. The cost saving per customer is estimated to range between £8,000 and £17,000; a midpoint of £12,500 has therefore been taken. It has been assumed that by 2030, 1000 customer will have been converted to hydrogen, by 2040, a further 69,000 have been converted and by 2045 (2050 in the table), the remaining 74,100 have been converted. It must be acknowledged that the application of scenario modelling is based on a range of assumptions and long term projections. H100 Fife will seek to firm up the costs of the development of the hydrogen economy in Fife through the learnings of the project.

Table 5: NPV Calculation

	2030	2040	2050
Cumulative NPV (£m)	12.11	797.969	1,599.906

H100 Fife will demonstrate the full hydrogen supply chain of green hydrogen and the use of hydrogen appliances in the home. As expected from a 'first of a kind' demonstrator, the cost of the energy produced by H100 Fife in its first phase will not be cost competitive with the price of natural gas, and as such will be subsidised by the project.

The main cost barrier in developing a hydrogen economy is the fuel cost. The cost of green hydrogen is expected to reduce as production is scaled up and as the electrolyser technology matures, much like wind generation and solar generation has[18] (all hydrogen production is expected to become cost competitive with natural gas with CCS by 2040[19]). Similarly, the test bed provided by the project for hydrogen appliances will enable cost learning benefits of those appliances. The cost of a hydrogen boiler is expected to reduce by 45% between 2020 and 2030[19]. Mandating hydrogen boilers during or at the end of the trial period would expedite the industrialisation of manufacturing, resulting in a similar replacement cost to customers now, while significant reducing in-home interventions later. Approximately 1.5m boilers are replaced each year.

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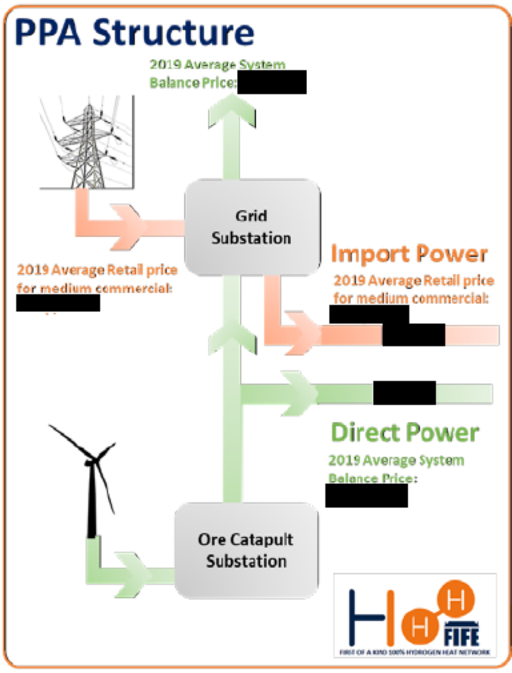
[18] Hydrogen Council – Path to hydrogen competitiveness, A cost perspective – 20th January 2020

[19]Gas Goes Green – Hydrogen: Cost to Customer – May 2020

3.2.2 Commodity Balancing

As explored above electrolytic hydrogen production is not currently cost comparable with natural gas. This is largely defined by the efficiency of the electrolyser and the electricity cost for the input power supply. We will purchase grid and turbine electricity from ORE Catapult. This electricity input will be governed under a Power Purchase Agreement between the parties. [redacted]. As a result, and based on some assumptions around efficiency[21] and cost which will be later defined in the procurement process, the cost of hydrogen production for H100 Fife is likely to range between [redacted]. The technology selection for hydrogen supply with respective calculations illustrating the spectrum of cost are set out below in Figure 4. The PPA Structure diagram below demonstrates the opportunity to achieve best price for grid import based on the increased capacity that the H100 Fife system will require ('import power'). The 'direct power' presents a system optimisation to innovate the generation aspects to maximise electricity input from the offshore wind turbine. The actual operation will be a combination of both to optimise supply. This 'first of a kind' offshore wind to hydrogen demonstration is explained in more detail below. To mitigate the risk from this innovative feature without undermining security of supply and certainty of delivery of the overall project, we have proposed a best price from grid provision, but will ensure that customers can benefit from its success by returning any outperformance that leads to cost savings to the GB gas consumer.



	Current Arrangement	Import Power	Direct Power
Cost for electricity	[redacted]	[redacted]rom grid due to renegotiated capacity	[redacted]
Cost of H2 production	[redacted] range due to electrolyser efficiency	[redacted]range due to electrolyser efficiency	[redacted]ange due to electrolyser efficiency
Natural gas wholesale	0.9p/kWh to 2.6 p/kWh		
Calculation Criteria	300 homes over 4.5 years		
Commodity Balancing	[redacted]	[redacted]	[redacted]
Justification	This does not offer best value for money and lack innovation	This improves on existing cost of grid import agreement but lacks innovation	Seek to optimise innovation of offshore wind to hydrogen to reduce cost

*Any unspent monies left over from commodity balancing will be returned to the GB gas consumer.

Figure 4: Power Purchase and Commodity Balancing

[redacted]

In order to keep the shipper whole and protect the customer from the increased cost of hydrogen compared to natural gas for the duration of H100 Fife, the commodity balancing cost provision is proposed to cover the difference between the cost of hydrogen production and the tariff at which SGN Futures ltd sell it to the shipper, expected to be linked to the wholesale natural gas price[23] or a similar index. Across the life of the project and due to the number of variables described that affect it, the commodity balancing value can potentially range between [redacted].

Currently, there are no installations where electrolysers are directly connected to offshore wind renewable electricity generating systems [redacted]. There are two key challenges for delivering this 'first of a kind' innovative solution. The first is turbine drop out, the second is following the demand profile (load following capability). Turbine drop out occurs when wind energy is not available or due to fault and this can cause loss of production and potential damage to the electrolyser. Load following capability is determined by ability of the electrolyser to respond to input power and production level. If an electrolyser is forced to respond outwith its specification, there is the potential to cause damage to the electrolyser stack and this can significantly reduce the asset lifespan. We want to understand how to apply direct electrolysis solutions to offshore wind generators, and will therefore be capturing and monitoring in real-time the symbiotic performance of the turbine and the electrolyser. This insight will inform future investments in direct production of hydrogen from offshore wind at scale. However for the purposes of this demonstration, we will require the grid connection not only as a back up in the event that the wind doesn't blow, but also by providing a critical balancing load to ensure that the electrolyser has continuity of supply. Due to the inherent uncertainty of this innovative approach and its potential to undermine the overall objective to demonstrate the distribution and within home solution, we have proposed funding at best grid import price that we can achieve (the cheapest hydrogen production method exclusive of innovation), yet commit to making as much use of the turbine energy as we can, returning any outperformance or under unspent funds as a result of this innovation's success.

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

The innovative nature of H100 Fife in terms of the project business case has been fully considered in Section 4.3.

3.4 Relevance and timing

The relevance and timing of H100 Fife in terms of the project business case has been fully considered in Section 4.5.

3.5 Demonstration of a robust methodology and that the Project is ready to implement

Through our H100 NIA project, we have carried out a significant programme of work investigating the safety and technical case for transitioning the gas networks to 100% hydrogen. H100 Fife is the culmination of the findings of that work. Since 2018, we have carried out a rigorous process of preparation for this bid to ensure the works proposed here are shovel ready and follow a robust methodology to minimise risk to the GB gas customer. The risk management and methodology of H100 Fife has been detailed in Section 6.

[23] https://www.ofgem.gov.uk/data-portal/wholesale-market-indicators

4. Benefits, Timeliness, and Partners

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

This element has been covered extensively in Section 3.1.

Decarbonisation progress in the UK economy has been limited mainly to the deep decarbonisation of the UK's electricity generation and supply, which with significant incentive has developed a widescale and efficient supply chain of low carbon kinetic energy, particularly in Scotland. However, sectors of the UK economy reliant on and designed around the high temperature output of the combustion of natural gas (potential energy) are very difficult to convert to kinetic energy and have experienced very little decarbonisation progress due to the lack of an energy vector capable of delivering low carbon and renewable energy. Hydrogen is the ideal energy vector to carry low carbon potential energy to sectors demanding affordable, easily stored and highly energy dense fuels.

The completion and success of H100 Fife is essential in accelerating the development of a low carbon energy sector enabling the hydrogen economy in Fife (and more widely in the UK) and unlocking the multiple financial and practical benefits of using a decarbonised gas supply to decarbonise the more challenging areas of the UK economy (heat, industry and transport). These benefits include:

- The environmental benefit of decarbonising the energy delivered through the UK's extensive gas network infrastructure. Emissions from the use of natural gas demanded at final point of use in the UK economy in 2018 were 98.7 Mt CO_2[24].
- The financial benefit to customers of avoiding the installation of electric heating technologies, such as heat pumps, which in the current market incur significant installation and running costs compared to gas boilers. Appendix E estimates the saving per customer to be £12,500 in decarbonising through a decarbonised gas network compared to switching to electrical heating technologies.
- The decarbonisation of the energy supplied through the gas networks (through the rollout of hydrogen) is a supply driven approach and is therefore the least disruptive credible option available to policy makers (requiring appliance changes only on the demand side). Conversely, the electrification of heat through the installation of heat pump technologies (for example), demands significant demand side changes through thermal efficiency and heat pump retrofit measures.

[24] Source Data from Digest of UK Energy Statistics 2019 (DUKES 2019) – BEIS

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

Table 6: Summary Costs Table

[redacted]

4.2.1 SGN Customer Support for Decarbonisation

Our research and engagement consistently shows that pursuing decarbonised energy solutions and minimising environmental impact are the two highest investment priorities for our customers. Following earlier qualitative research which showed that customers strongly supported investment to minimise environmental impact and the decarbonisation of heat, the willingness from customers to pay for environmental initiatives was assessed. This research showed that customers strongly support investment to minimise environmental impact and the decarbonisation of heat, to the extent that these two questions were each awarded the highest value in our willingness to pay research[25].

We have also conducted a consumer pilot in the Levenmouth area which surveyed one hundred representative households over three months, to measure how much the local community understands about heating technologies, and the barriers that could have an impact on a customer's willingness to consider green heating technologies. Overwhelmingly, households in the Levenmouth area are most familiar with gas for heating. Households also said they were most comfortable and confident with gas and this was their preferred heating technology, with 81% ranking it their top preference. Affordability was a dominant factor in the survey, with 60 out of 84 comments saying energy costs were a concern. Reducing carbon emissions was mentioned by 46% of respondents. The survey responses illustrated a concern and reluctance to move to away from gas to another heating technology.

4.2.2 Procurement & Commercial (P&C)

A comprehensive, fair and competitive strategy is essential to drive innovation, improve efficiency and ensure we provide value for money in all its activities. P&C have been involved since the very early stages of the project in establishing the sourcing strategy for all key workstreams which require third party engagement and, working with the project team, have established timelines and high-level approach to market for each.

Our procurement activities are driven by the use of competition, and by compliance with Utilities Contract Regulations 2016 (UCR) and Internal Governance Processes. This approach is geared towards ensuring value for the end consumer and interested parties, in addition, to ensuring we act responsibly and ethically in our procurement activities.

[25] https://www.sgnfuture.co.uk/wp-content/uploads/2019/12/SGN-RIIO-GD2-Business-Plan.pdf

P&C activity relating to all third party workstreams of the H100 Fife project are closely aligned with SGN's Procurement Mandate, which follows six best practice principles:

- **Comprehensive Procurement**: Utilisation of competitive processes for all projects and procurements. Processes to deal with any necessary deviation from this;
- **Robust Competition**: The competitive process must be robust, transparent and ensure equal treatment for potential bidders and protect information appropriately;
- **Efficient Operating Model**: The complexity of the competitive process used should be proportionate to the value and technical complexity of the works, goods or services in question;
- **Transparency:** All information must be provided equally to all parties and any conflicts of interest must be appropriately managed. Licencees should be agnostic to technology and bidder type;
- **Fairness**: We seek to ensure that the supply chain does the right thing through fair and reasonable processes, along with mandated evaluation criteria where appropriate; and
- **Customer Outcomes**: Competitions should be structured to generate outcomes in the interests of existing and future customers.

As a furtherance to what is planned and being developed in terms of strategy for the procurement of goods, works and services for the project, P&C and the project team have engaged current framework contractors/providers to establish high-confidence in proposed costs by obtaining budgetary quotations for the high-level scopes developed to date for key goods, works and services – ensuring that costs submitted in the bid are not historical, but indeed forward-facing and based on anticipated build/supply windows.

Go-no-go stage gates will be utilised to ensure the project is structured to manage risk and uncertainty of success as far as practicable. This allows the project to manage investment risk and ensure valuable learning is achieved throughout. Any unspent monies under the NIC funding award will be returned to Ofgem at the end of the project. The project has been set up to continue operation under SGN after 2027 if an enduring solution is secured, or implement the project exit strategy, which will include restoring the natural gas supply to customers involved in the H100 Fife demonstration.

Throughout the H100 NIA and Methilltoune phases, research was undertaken to gain an overview of the scale of the market. The selected site at Levenmouth itself, is the outcome of a national procurement event that ran to determine the optimal site to deliver a 100% hydrogen system. This initially investigated the suitability of five UK demonstration trial locations, of which three progressed to the feasibility study phase. Levenmouth in Fife was assessed alongside Machrihanish in Argyll and Bute as well as a site in Bridge of Don, Aberdeen. Both Levenmouth and Machrihanish were deemed viable to progress to the FEED stage of the selection process. Aberdeen presented itself as a strong contender in the hydrogen economy for large-scale low carbon activity but not suitable for the first 100% hydrogen demonstration based on challenging timescale alignment with site specific housing development. Ultimately, Levenmouth was selected as the optimal demonstrator for a number of reasons, including opportunities for:

- Existing gas customers to change to zero carbon hydrogen for heating through phased hydrogen ready boiler installations.
- Primary power input for electrolysis from offshore wind, evidencing the potential to maximise UK offshore wind through hydrogen production and facilitate market growth of dedicated and curtailed offshore wind.
- An accessible and flagship site for cross-sector hydrogen demonstration.
- An extensive pool of manufacturing/industrial businesses to connect to a hydrogen network.
- A case study for decarbonising heat for the distilling industry through linkages

with Diageo.

- An existing customer base with opportunity for expansion beyond the initial 300 properties, with the capacity to facilitate town conversion to hydrogen.
- Aligning with the political agenda for a hydrogen coast in the east of Scotland.
- Expanding the network to integrate surrounding key assets such as underground storage, offshore wind development, strategic gas infrastructure and clusters and central transport linkages including rail.
- Developing a dedicated Energy Park, that is located next to a port, to continue their participation in the low carbon and renewables sector.

While Machrihanish will not be progressed as the first 100% hydrogen demonstrator, the site presents an opportunity for;

- Off gas customers to be connected to the gas grid through a hydrogen network, since properties are currently supplied by electricity and oil.
- Delivery of a cheaper energy source, with the stimulation of the hydrogen economy possibly providing a cheaper low carbon heat source than renewable grid electricity, once the market has become established.
- Testing hybrid solutions such as heat pumps and Combined Heat & Power.
- Scalability by connecting the neighbouring area of Campbeltown via a hydrogen pipeline.
- Exploring industrial heat demand with onsite industrial users.
- Connection to transport links such as haulage and marine.

This comprehensive selection process concluded that Levenmouth, with its key strategic advantages associated with its location and characteristics, was the most suitable site for the initial H100 Fife demonstration with the greatest value and learning opportunity potential.

Prior to the H100 Feasibility studies across these three sites, Project HyGen, funded through the Low Carbon Infrastructure Transition Programme (LCITP) and run by Scottish Government, conducted a desktop study on the hydrogen generation and storage options across the three sites. One of the key conclusions of this study was that Levenmouth should be prioritised as the most suitable site for the demonstration of an electrolytic hydrogen generation and storage solution that could supply a 100% hydrogen network. This initial recommendation from the desktop work under Project HyGen in 2019, was then later validated through the H100 Feasibility and FEED studies across the three sites.

European Union
The Scottish Government
Riaghaltas na h-Alba
EUROPE & SCOTLAND
European Regional Development Fund
Investing in a Smart, Sustainable and Inclusive Future

Figure 5: LCITP programme funders.

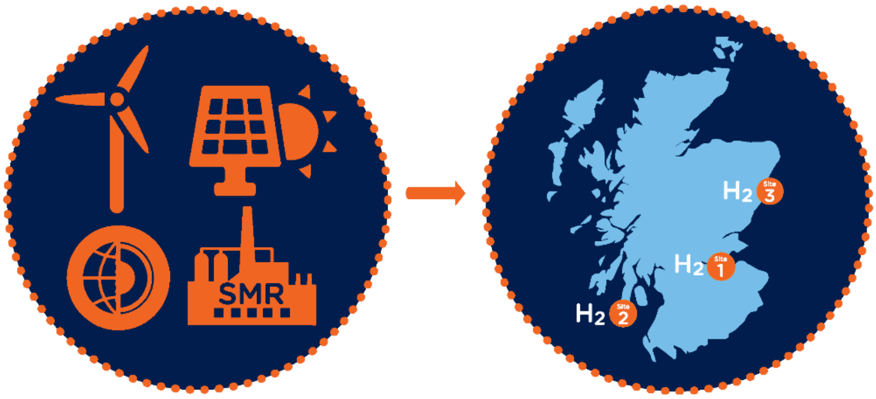


Figure 6: Project HyGen, assessing the hydrogen generation and storage options across the three proposed H100 sites, conducted by SGN and ERM.

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

H100 Fife is both technically and commercially innovative. Electrolyser technologies are not new but have never before been used to supply 100% hydrogen for heating. The gas network infrastructure to be constructed as part of H100 Fife will be the world's first 100% hydrogen gas network. Hydrogen boilers and appliances operate in the same way as natural gas equivalents but have not been offered or available to customers before. This project will provide the first test bed for hydrogen appliances and network operation.

H100 Fife is also innovative at the consumer level. Gas customers have for decades, relied upon the gas networks for their heat supply in a low disruption, affordable and reliable way. Transitioning to hydrogen potentially enables these benefits to be retained with only the fuel changing and appliances being replaced.

H100 Fife will enable customers to experience hydrogen appliances and the process of conversion in the home. By laying a new network parallel to the existing network, the process of transferring customers to hydrogen will be refined and less disruptive than transitioning the existing network. As a first trial, this is critical in ensuring a positive customer experience and gaining wider support from customers to convert to hydrogen across the gas networks. The importance of customer acceptance is second only to safety in developing a hydrogen economy; this project will demonstrate both.

In addition, there is also innovation merit in the cross-sector integration solutions of the H100 Fife system. Using offshore wind to generate hydrogen for heat and distributing it to end users is a 'first of a kind' demonstration. Harnessing offshore wind for the production of gas to heat customer homes will provide heat profile data that can be shared with the electricity networks.

This demonstration delivers a system in line with the move decentralised energy systems by utilising local renewables to provide a heat solution for the immediate community situated adjacent to Energy Park Fife, where the turbine is situated. The H100 Fife project is proposing a step further in the whole system innovation solution to also provide a heat source, derived from the same turbine.

A local heat solution derived from power that integrates the electricity and gas networks in a combined solution paves the way for transformation towards a whole system energy innovation, the delivery of which is proposed under H100 Fife Expansion Opportunity 5.

H100 Fife validates the concept of offshore wind to heat, and consequently stimulates a market creation platform by proving the technology innovation concept. The UK's and particularly Scotland's geographical positioning lends itself to an abundance of natural renewables resources. With a target of 30GW installed capacity by 2030[26], the new Offshore Wind Sector Deal ambitions lends itself to the grid integration solutions between the electricity and gas networks, where hydrogen generation could be a secondary function of offshore wind energy in order to alleviate grid capacity barriers. The transfer of hydrogen offshore to onshore through pipelines could deliver higher volumes of energy more efficiently and then integrate with the existing gas network to transport zero carbon energy to customers.

Hydrogen affords the stimulation and transformation of the supply chain and the opportunity for skills transfer from the natural gas sector. H100 Fife is a first step to future-proofing the participation of renewables combined with the gas network in Scotland and UK's net zero future.

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[26] https://www.gov.uk/government/publications/offshore-wind-sector-deal/offshore-wind-sector-deal

4.4 - (e) Involvement of other partners and external funding

4.4.1 External Funding

The complexity of the H100 Fife system, the timeline for delivery and regulatory intricacies means that there is not one funding solution that can fund the entirety of H100 Fife, and with each individual funding offer comes with it the separate terms and requirement obligations. We are supporting the project with a Licensee Extra Contribution to the value of £500k. This is in place currently to continue the project momentum and deliver critical works to ensure project readiness prior to external funding becoming available. These works are defined in Elements 1 and 2 to cover planning application services and third-party agreements & project support. The continuation of these works allows for continuity to be maintained from work previously carried out under H100 Feasibility and FEED at Levenmouth and Project Methilltoune. In addition to SGN funding, the project has secured a Grant for up to £6.9m from Scottish Government, that is subject to the success at NIC, which will be available for drawdown following a successful NIC outcome until the end of this financial year (2020/21). This will be used to procure key long lead items to align with the optimal programme delivery and be attributed to the land acquisition in line with the planning process. These activities are defined under Element 4 and 3 respectively. [redacted]

The Grant award is conditional to the requested NIC award, and committed network funds. [redacted]

4.4.2 Project Partners

The Project Partners under H100 Fife are split into the Network Licensees and the Non-Network Licensees who are financially contributing to the project cost. The Network Licensees Partners are Cadent, NGN and WWU. NGGT and GTC are defined as non-funding Project Supporters under this bid. We recognise and actively respond to opportunities for collaboration between the UK Network Licensees and as such embrace the opportunity to share knowledge and outcomes of H100 Fife with the other networks as Project Partners and Supporters, as we have done in previous projects.

The Non-Network Licensees who are also contributing to the project as Partners includes Baxi, Bosch, HyCookers Consortium and HyFires Consortium as the key developers and suppliers of hydrogen appliances under the Hy4Heat programme. We are encouraging the appliance manufacturers to play an active role in the engagement and marketing activities of the Hydrogen Demonstration Facility so that customers will have the ability to meet with appliance experts. We have agreed partnerships in principle with Baxi and Bosch as the hydrogen boiler manufacturers. As part of the Hydrogen Demonstration Facility, have each been dedicated a show home space to complete the interior design for. This is gifting a space to both manufacturers to demonstrate and market their hydrogen appliances to potential customers of H100 Fife and to their wider cliental, global markets and industry. Both Baxi and Bosch have agreed to dress and design the interior of these spaces at their own cost as a contribution to the project. We have also agreed partnerships in principle with the HyCookers and HyFires consortiums and will be equipping each show home with the relevant hydrogen gas fires and cooking appliances. The HyCookers Consortium will unlock participation in the project from the UK's primary cooking appliance manufacturer, GDHA, who will use their marketing departments to promote customer engagement and bring publicity to the H100 Fife project to both their domestic and international clients, thereby showing that the UK and SGN are at the forefront of decarbonising domestic cooking and heating. Similarly, the HyFires Consortium will bring participation from the UK's three leading gas fire manufacturers in terms of publicity, customer awareness, marketing benefits and promotion via the marketing networks of all three manufacturers. HyFires involvement will also promote the future of the gas fire industry and provide customer with differing model types. This enables flexibility of installation in addition to personal preference, providing a range of solutions for participating customers.

4.4.3 Project Suppliers

All Project Suppliers are yet to be defined. However, there are various key suppliers involved in the project that are already identified based on their previous project participation or through their direct connection to the proposed site at Levenmouth. ORE Catapult are a key Participant and Supplier as the owner and operator of the offshore wind turbine dedicated to the project for the primary power supply. ORE Catapult were initially identified as potential contributor to the project in the H100 Feasibility study at Levenmouth and were later incorporated into the Project Methilltoune (refer to Section 2.2) Consortium led by SGN, which sought to assess the feasibility of the hydrogen supply solution derived from the 7MW wind turbine belonging to them. This Consortium also included Kiwa and Arup, who in parallel were contracted through commercial process by SGN under the H100 Feasibility & FEED study for Levenmouth. Accordingly, the continuity in these Suppliers for the benefit of design, asset ownership, momentum, expertise, knowledge and understanding transfer has been maintained for the delivery of H100 Fife. The HSE Science Division are also continuing the independent review of the H100 Fife Safety Management Framework as a furtherance to its work under H100 NIA, as are ERM for the continuation of the QRA.

DNV-GL have been appointed to provide preliminary designs for the Hydrogen Demonstration Facility in order for the facility, that was initially not included in the H100 Feasibility and FEED study at Levenmouth, to be integrated into the ongoing pre-application planning works. This is timeline driven and on the basis that DNV-GL has helped deliver a similar facility at their laboratory and test site at Spadeadam as part of the H21 NIC Phase 1b. The early delivery of this project component will allow for customer engagement time to be maximised prior to opt-in decisions being made. It will also potentially offer a demonstration zone for COP26 if completed in time.

The remaining Project Suppliers that have been identified is due to their locality. Fife Council are the Local Authority for the area and have social housing properties within the proposed network area. In addition, the Energy Park Fife, in which the proposed project falls within the boundary of, is owned by Scottish Enterprise through a joint venture with Fife Council. With Scottish Enterprise, we have negotiated and agreed the Heads of Terms for the lease of the land to SGN [redacted]

[redacted] Scottish Water will supply the water input for the electrolyser and the general water supply to facilities on site.

4.4.4 Participants Summary

H100 Fife has been recognised as a project of national strategic importance and benefit for delivering the outcomes of a real-life demonstration that presents a solution to the decarbonisation of heat. The project has received extensive support across the energy networks, industry, the public sector and academia. The Project Participants are listed with their inputs to the project in Appendix K. Those marked with '*' have provided letters of support for the project, which are available on request.

4.5 - (f) Relevance and timing

Enabling the energy system transition to a hydrogen economy and the realisation of all its benefits to customers, stakeholders and the wider UK economy will require the collaborative completion of the full technical and safety case by the UK gas industry and the successful execution of various demonstrations including that of a fully operational 100% hydrogen gas network and supply chain from turbine blade to appliance.

H100 Fife aims to build the world's first 100% (green) hydrogen network derived from offshore wind and is therefore a key enabler in unlocking the hydrogen economy. Construction of a new hydrogen network in parallel with the existing gas network, allows full customer choice and control in this 'first of a kind' trial which if successfully completed, will be the world's very first customer use of 100% hydrogen gas for heating and cooking in the home.

Britain has one of the most advanced and efficient gas infrastructure networks in the world with 23.2 million customers connected to 284,000km of pipeline, including 83% of homes. Significant sums have already been invested to replace old metallic gas mains with 'hydrogen ready' polyethylene (PE) pipes. The majority of the gas distribution networks will be made up of PE pipes by 2032.

Our future decarbonisation direction and strategy aims to deliver the widespread system transition to 100% hydrogen. Our RIIO-GD2 high level objectives include the construction and operation of a 300 home, 100% hydrogen network by 2022/2023 and to collaboratively provide evidence for the gas quality decarbonisation pathway. H100 Fife will be our flagship hydrogen project and will influence the future direction of the gas networks in RIIO-GD3 and beyond. We, and the Gas Goes Green (described in detail below) members, aim by the end of RIIO-GD2, to be in a position to (subject to heat policy decisions and appropriate investment) commence the strategic rollout of hydrogen across our networks and also into new sectors, such as transport.

Our strategic direction in RIIO-GD2 and beyond is to enable the transportation of up to 100% hydrogen through our networks, thereby stimulating hydrogen production and the market for hydrogen appliances. H100 Fife will demonstrate the full system required to safely and efficiently produce and store hydrogen from offshore wind (a high potential renewable energy resource in the UK), deliver it to customers and enable its safe and practical use in the home using new hydrogen appliances. This project will demonstrate our vision for many of our networks in the future and enable each aspect of this future system to be optimised and maintained.

The Committee on Climate Change (CCC), recently published net zero technical report[27] identified hydrogen as a key enabler to reach net zero. Key policy recommendations put forward to government included the continued support and innovation funding for large-

[27] Net Zero Technical Report, Committee on Climate Change, May 2019

scale demonstrations of hydrogen production and support for the development of hydrogen ready boilers, capable of running on natural gas and hydrogen (following minor modifications). H100 Fife aligns with both of these key policy recommendations from the CCC.

Similarly, the International Energy Authority (IEA) recently stated that "developing low carbon hydrogen production routes is critical for hydrogen aid in clean energy transition"[28], citing the development of green hydrogen production from electrolysis as a key technology in enabling the hydrogen economy and unlocking its benefits. Lastly, the German National Hydrogen Strategy, released in June 2020, outlined the importance and usefulness of hydrogen as an energy source (particularly for industry) and storage medium, highlighted its role in whole system sector coupling[29]. The importance and potential of hydrogen is well recognised globally and H100 Fife's role in demonstrating the world's first 100% hydrogen network will be key in developing the hydrogen economy in the UK and also internationally.

H100 Fife is shovel ready and is a critical step and requirement in the national hydrogen programme and evidence base feeding into heat policy decisions by BEIS anticipated in the mid-2020s. The commencement and success of H100 Fife is therefore time critical in evidencing a 100% hydrogen network in time to provide decarbonisation options for heat policy decisions.

In collaboration and agreement with the other gas distribution networks, we devised 'The Gas Quality Decarbonisation Pathway' to set out the strategic changes required to achieve decarbonisation in the gas network, the key steps required and the project evidence that supports each step. This was later adopted by all networks and taken forward with the Energy Networks Association (ENA) to deliver the project 'Pathways to Net Zero: Decarbonising the Gas Networks in Great Britain' with Navigant. This demonstrates the collaborative, coordinated and industry approach towards solving the Problem, and H100 Fife is no exception to this approach. It will provide critical evidence on this pathway that will benefit the gas industry and the energy sector as a whole.

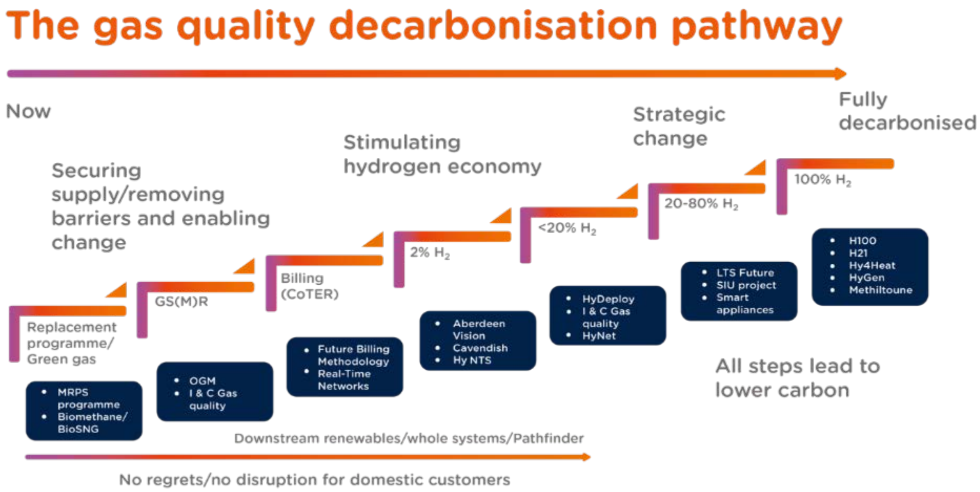

Figure 7: The Gas Quality Decarbonisation Pathway, setting out the strategic steps and evidence base required to achieve decarbonisation of the gas network.

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[28] https://www.iea.org/reports/hydrogen

[29] The National Hydrogen Strategy – German Federal Ministry for Economic Affairs and Energy, June 2020

H100 Fife advances the credible evidence already gathered under the H100 NIA, the H21 series of collaborative projects and the Hy4Heat programme of works for hydrogen appliances. There is clear alignment between H100 Fife and the work being undertaken from the outputs realised through the ENA 'Pathways to Net-Zero: Decarbonising the Gas Networks in Great Britain' report. This provided policy makers and networks with a set of deliverables and recommendations as to the optimal approach in the decarbonisation of the gas networks and the nation's heat. Overall, the report found a balanced scenario to be the most affordable, with potential savings in the region of £13 billion a year. It was also determined to be the most deliverable and of least disruption to customers compared to an electrification scenario[30].

Stemming from the recommendations made in the Pathways to Net-Zero report, the Gas Goes Green initiative, is the world's first comprehensive programme to decarbonise the gas grid and transform our networks to deliver net zero emissions gas to consumers across the UK. This programme brings together the engineering expertise from the UK's five gas network operators, building on the foundations of our existing grid infrastructure, research and innovation work.

The H100 Fife project forms a key component of this wider programme to meet the challenges and opportunities of climate change in the most cost effective and least disruptive way possible.

Delay in the commencement of this project would materially impact the evidence base for an energy system transition to hydrogen as a means of decarbonising heat and industry. This would leave electrification as the only fully evidenced option, which as discussed, is not necessarily in the best interests of the GB gas customer, in terms of cost and disruption.

The earliest possible commencement of this project is also in the best interests of the wider UK economy commercially and macroeconomically. In the face of the need to decarbonise away from fossil fuels, the creation of a hydrogen economy provides a possible route for the UK oil and gas sector to transition its highly capable and advanced workforce and skillset to low carbon energy production. Furthermore, the immaturity of hydrogen technologies provides a commercial opportunity for GB manufacturers to develop IP in what will hopefully be a highly competitive and lucrative global hydrogen market.

[30] https://www.energynetworks.org/assets/files/gas/Navigant%20Pathways%20to%20Net-Zero.pdf

5. Knowledge Dissemination

H100 Fife will conform with the default IPR arrangement as defined in the NIC governance. See Section 5.3 for details.

5.1. Learning generated

Understanding the suitability of the gas distribution system and customer in-home aspects is a priority for any hydrogen transformation. Other aspects of the system, such as the future of the local transmission, system operation and the national transmission system are also very important, and form part of the national programme. However, any solution for these aspects will be determined by what we need to do at a distribution and customer level.

If successful, this project will validate the technical, social and operational ability to deliver 100% hydrogen to homes, offering a route for decarbonisation of the gas network. Constructed using materials currently deployed in the natural gas networks today, the H100 Fife Network will demonstrate the role the gas networks can play in the future of heat. With the project programme offering a fully operational system by 2023, vital learning and validation of the hydrogen evidence base will be available to support both Scottish and UK Government decarbonisation policy, including UK Government heat policy decisions.

The project will evidence critical understanding of network management and operation. For example, to understand how to scale hydrogen production and storage requirements, we need to understand how to match supply and demand. This will help determine interventions required for the networks, such as additional storage requirements for within day and intra-seasonal. This evidence is needed not only for GDN’s, but for a range of stakeholders, from water companies and power system operators to renewables investors and operators. The project will also provide full visibility of the regulatory aspects, from turbine tip to burner. This insight will support future regulatory models.

The business model developed by H100 Fife supports investment in hydrogen generation and appliances, creating a market for renewable hydrogen systems for use in domestic, commercial and transportation applications. For appliances, it is possible to link heat policy decisions, such as the mandating of hydrogen ready boilers to the success of the project, which would significantly reduce conversion costs in the early 2030’s.

Given the significance of this project in proving the viability of 100% hydrogen networks and a pathway to decarbonisation for gas networks, the project has been shaped to deliver multiple key outcomes that will be widely beneficial. This project aims to generate learning for industry, government, regulatory bodies, stakeholders and the public, on both a national and international level to help inform the energy transition. An example list of the outcomes from H100 Fife is in Appendix N of this document. While this is not an exhaustive list, the hydrogen system that H100 Fife delivers, covers an extensive end to end scope of works that will be transformational in validating the evidence base for hydrogen for heat. As such, it is paramount that the dissemination of this learning is effective and timely.5.2 Learning dissemination

5.2.1 Internal

As a complex, high value and multi-discipline project, we have set up an internal Advisory Group prior to the Ofgem NIC submission to draw on the expertise and guidance from across the key business areas within SGN. This has been depicted in the organogram provided in Appendix I, which lists the various teams involved. The intention is to apply the knowledge of this group to the initial submission and then mobilise the group for supporting the project as it moves into the delivery phase, subject to funding award. As the project develops, different business areas will be invited to join the Advisory Group. This regular engagement will help to ensure that all of the key departments are up to date and aware of the project progress, which will subsequently facilitate the smooth and coordinated roll out of H100 Fife. This will subsequently allow our stakeholders and customers to be informed and prepared for the necessary transition to net zero, contributing to the overall public acceptance of hydrogen.

H100 Fife is supported at all levels within SGN, as indicated in the organogram in Appendix I, where there has been full support demonstrated from the SGN Investment Committee, the SGN Executive and the SGN Board, which will continue throughout the life of the project.

In addition to the Advisory Group, the H100 Fife project will be communicated internally across various channels and platforms such as internal reporting, SGN intranet updates through 'Digital Hub' blogs and news stories, as well as a dedicated H100 Fife page.

The project will benefit throughout from our wider business, who will support the project delivery through to operation. This will build on the hydrogen awareness component that is already being integrated into internal training programme across the business, ensuring that the appropriate resources and training are provided to upskill critical teams such as SGN Operations and Emergency Response.

5.2.1 External

We recognise the importance of collaboration and effective learning dissemination. The project has been designed to provide transparent critical evidence for the decarbonisation of heat, but also detailed validation of the safety and technical aspects specific to network operation. All Network Licensees have been invited to support the H100 Fife bid. This commitment is demonstrated in the letters of support received and in Appendix P. We also recognise the important contribution the H100 Fife project can make to future industry skills diversification and future STEM career opportunities. We will lead an external Technical Group, with representatives from the other Network Licensees, External Funders, Project Partners, Project Suppliers and other Industry, Consumer and Skills bodies. There will also be a complementary Stakeholder Group to ensure the project stakeholders are kept well informed on the project progression, to share emerging outcomes and next steps. The positioning of these groups within the project is shown in the organogram in Appendix I. The groups will meet quarterly to be updated on the project's progress and ensure coordination with related projects on the integrated hydrogen trial pathway as well as any other relevant projects in the hydrogen space.

The H100 Fife project and potential expansion opportunities form a key part of the national hydrogen programme and is recognised under the Gas Goes Green programme. We already have key members updating and participating in the following groups:

- ENA Gas Futures Group
- ENA Gas Strategy Group
- ENA Open Networks Work Stream 4 – Whole Systems
- ENA Energy Data Group
- ENA HPDG Network Safety and Integrity
- ENA HPDG System Transformation
- ENA HPDG Integrated Hydrogen Trials
- ENA Gas Environment Group
- IGEM Gas Quality Working Group
- HyDeploy Advisory Board
- H21 Steering Group
- HyStorPor Advisory Board
- BEIS Hydrogen Programme Development Group
- IGEM Hydrogen Working Group
- CEN/CENELEC – Sector Forum Hydrogen
- Marcogaz – Work Group Gas Quality/Renewable Gases
- NECCUS
- Northern Ireland Energy Policy
- Spatial GB Clean Heat Pathway Model - Advisory Group
- Stornoway LCITP Steering Group
- Scottish Energy Advisory Board

- Scottish Government Heat Decarbonisation External Advisory Group
- Scottish Government 2024 New Build Zero Emissions (from heat) Working Group
- Scottish Government Energy Networks Leadership Group

We will continue to participate proactively and commit to sharing the project learning effectively to inform the wider strategy for decarbonisation.

As the project will supply a 100% live hydrogen network to occupied homes, a carefully developed and managed stakeholder, customer and communication plan for the project will be vital for the project. Engagement will be on a local, regional and national scale to support targeted customer participation through the opt-in process. At a high level, and facilitated in part by the Hydrogen Demonstration Facility (see Section 8), the activities and resources that this plan will seek to deliver includes:

- Public information and community events
- Best practice visits
- Industry workshops
- Educational resources and workshops
- H100 Fife launch event
- Project video
- Promotional materials
- Hydrogen awareness tool
- Website platform
- Social media
- Publicity and advertising
- Dissemination of project information and learning at external events
- Attendance and participation at cross-industry/sector conferences

Further detail on the customer engagement plan is set out in Section 8.

We will deliver the NIC governance reporting requirements, including the Project Progress Report (PPR), a Close Down Report, peer review and support an Annual Conference.

5.2.2 Project Linkages and Interfaces

Market Creation

Under Project Methilltoune, the route to commercialisation of hydrogen was assessed at a local, regional and national scale to correspond with short-term, long-term and beyond 10TWh. The short-term developments look at current small-scale demonstrations such as H100 Fife to evidence the case for hydrogen. Demonstrations like H100 Fife are critical for mobilising a hydrogen economy and facilitating a starting platform for a transition to green energy. The long-term developments is building on the blueprints from the local demonstrations that have validated security of supply on a local scale, and applying it to a regional and national formula for roll out to deliver larger capacity hydrogen networks. Growth in scale attract investment once public sector funding has supported the delivery of demonstrations to validate the business case.

This ‘first of a kind’ demonstration project will deliver an end to end system blueprint that can be replicated and used to mobilise hydrogen market growth, consequently driving down the cost of equipment, such as electrolysers. With capital expenditure reduction, the cost of hydrogen production can become more competitive, particularly when derived from offshore wind which is currently at its lowest recorded cost of approx. £39.65/MWh. The project will deliver evidence that supports the use of hydrogen as a viable decarbonised energy carrier for heat and aims to demonstrate that the costs associated with rolling this out compare favourably to the electricity network upgrade costs required for electrification of heat.

Hy4Heat

We have worked closed with Hy4Heat, a programme funded by BEIS and managed by Arup+ (Arup, Kiwa Gastec, Progressive Energy, Embers and Yo Energy), to develop the appliance market and use of hydrogen in residential and commercial buildings. This programme brings together partners across industry, academia, research and development. It is scheduled to conclude in 2021 and produce fully certified hydrogen appliance prototypes as an output. We have been working closely with the Hy4heat team and the H21 team, sharing knowledge and learning as our project progresses, particularly in relation to safety. We're pleased to partner with the appliance manufacturers in the H100 Fife project.

There are two QRA's for H100 Fife (see Appendix J), the upstream system and the distribution and downstream system that are being compiled by SGN and ERM. These are site specific to Levenmouth and have been informed by the testing programme carried out under various hydrogen projects such as H100 NIA Workstream A, HyHouse, H21 and Hy4Heat.

We have also supported the development of Hy4Heat programme through provision of supporting data across SGN led initiatives, such as outlet pipe failure data from Opening Up the Gas Market, Public Reported Escapes data and operational insight.

H21

The H21 Ph1 and Ph2 projects are a joint programme delivering hydrogen safety testing and operational preparedness. The objective of the H21 programme is to evidence that it is safe and feasible to convert the existing natural gas network to 100% hydrogen, and to identify what interventions would be required on the existing network to do so. The safety-based evidence for a conversion to 100% hydrogen transported through the existing gas distribution networks and then utilised within buildings is underway, with outputs shaping the collective understanding of risk. An example of the H100 Fife outcomes that complement the current H21 programme include:

- Validation of the safety and technical work carried out
- Operational data pertaining to the behaviour and characteristics of hydrogen in a live network
- Live community demonstration
- Project outputs will validate and enhance the H21 network conversion QRA
- Demonstration of safety devices, such as EFVs and hydrogen detection
- Local Operating plans for the network, will inform and input to the H21 Ph2 conversion operational procedures in development.
- Creation of a safe trial and operational precedent for hydrogen networks, essential for future conversion
- Commercial and regulatory model for future operation of conversion hydrogen networks

The H100 NIA programme, and associated projects, has undertaken significant research to support the safe demonstration of hydrogen and real-world operation of a hydrogen network, ensuring that learning is relevant for conversion phases too, for example odorant testing[31]. A primary focus of the H100 Fife project is to test and understand the customer acceptance and interest in hydrogen. Valuable learning can be gained from both customer participation or non-participation. Our project is designed with maximum flexibility for the customer, ensuring it is reversible and supports the social evidence for change. This information will provide vital insight into any future mandating of hydrogen conversion for customers, governments, and stakeholders. We can consider the outputs of the H21 Social Sciences report and build on survey data by delivering real data on attitudinal learning in a real-world demonstration with gas customers. In a move to transform the 'on paper' to a live demonstration, we intended to take the indicative

[31] SGN, NPL (2020) *H100 NIA: Hydrogen Odorant and Gas Detection*. Available at: https://www.sgn.co.uk/about-us/future-of-gas/hydrogen/h100-nia/hydrogen-odorant-and-gas-detection

conclusions on customer priorities and concerns reported and validate these under H100 Fife.

We are continually engaged with the H21 programme via the H21 Steering Group, but also regularly share information from the respective programmes to ensure gaps identified are captured and avoid unnecessary duplication. The gas networks have collectively set out a portfolio of work to deliver evidence for transformation of the gas network in the form of a pathway to decarbonisation. There are two key strands to this pathway; the safety, technical and practical evidence to demonstrate that the gas network and associated infrastructure can distribute hydrogen and; how the hydrogen solution would be delivered in each region. The research follows the scientific method with many connected components of research and development progressing through technology readiness level into commercial readiness, underpinning a programme of live trials as detailed in the Integrated Hydrogen Trials programme produced for BEIS through the Hydrogen Programme Development Group (HPDG).

University of Edinburgh

Under H100 NIA, we partnered with the University of Edinburgh to subject our evidence to academic challenge and jointly submit for peer-reviewed publication in academic journals. This provided a high-quality validation of the evidence and understanding determined under the H100 NIA programme and added credibility, reliability and value through their approach, investigations and measurements.

International Engagement

We understand the value in sharing knowledge and learning not only between the UK Network Licensees, but also on an international basis. H100 Fife will be no exception to this engagement openness and will continue to be transparent in its outcomes as the first 100% hydrogen network. Example of previous international engagement include:

- GRT Gaz, GRDF and Engie (France)
- Gas Network Ireland (Ireland)
- Toho Gas Co (Japan)
- Tokyo Gas (Japan)
- Tokyo Olympic Village (Japan)
- Osaka gas (Japan)
- Panasonic (Japan & Germany)
- Puget Sound Energy (Seattle, USA)
- Enbridge Gas (Canada)
- Open Grid Europe (Germany)
- ENA Gas (Spain)
- Macquarie (Global)

5.3 IPR

SGN and the relevant parties involved in delivering the project are fully committed to the default IPR position, as defined under Chapter 9 of the Network Innovation Competition Governance Document. We recognise that knowledge transfer is a key aspect of the project and are committed to the sharing learning created to a wide range of stakeholders. All parties involved will have the freedom to discuss work undertaken as part of the project in seminars or presentations, give instruction on questions related to such work and publish results obtained during the course of the work undertaken as part of the project. Under the provisions within the contracts between SGN (and/or SGN Futures) and the relevant parties to the project, we will ensure that contracts will be structured to comply with the default IPR position.

Any additional funding received by SGN will be on a separate, ring-fenced basis and will be awarded on its own Grant terms. SGN Futures anticipates that such terms may contain certain IPR provisions pertaining to the hydrogen generation and storage element of the project. The aim of the Grant funding is to advance understanding of the role of hydrogen for decarbonisation, therefore we aim to share all aspects of learning, however, as this is separate to the NIC element it is not currently considered to impact our ability to comply with the NIC IPR position. Careful consideration will be given to this area to maximise the knowledge transfer of any relevant Foreground IPR developed under the Project as a whole.

6. Project Readiness

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

Gas Goes Green, the world's first comprehensive programme to decarbonise the gas grid, seeks to coordinate evidentiary work programmes that inform the transformation of our networks to deliver net zero emissions gas to consumers across the UK. The extensive research and development under the H100 NIA, H21, Hy4heat and associated projects coupled with the detailed preparatory work carried out in the build up to the demonstration, has positioned H100 Fife as a project of national significance, recognised by industry and government.

Faced with the unprecedented circumstances of the Covid-19 pandemic, we have developed our comprehensive project plan to ensure the impact of this is being continually monitored and safety is maintained at all times. Working with our Partners and Participants, we continue to review associated risk with Covid-19 and are confident that we can deliver the project to the plan proposed. This will also be included within our project risk register and we will assign control actions and mitigation measures that will allow us to continue to progress with work in accordance with the project schedule. The key challenges anticipated should Covid-19 resurge would be events and access to the customers' premises in 2022 to facilitate hydrogen connection.

6.1.1 Previous Work

Extensive research and preparatory work has been carried out under Project HyGen, Project Methilltoune, and H100 NIA to ensure the H100 Fife project is positioned to deliver the H100 Fife demonstration.

A summary of the Workstream A programme of testing under H100 NIA[32] is provided below.

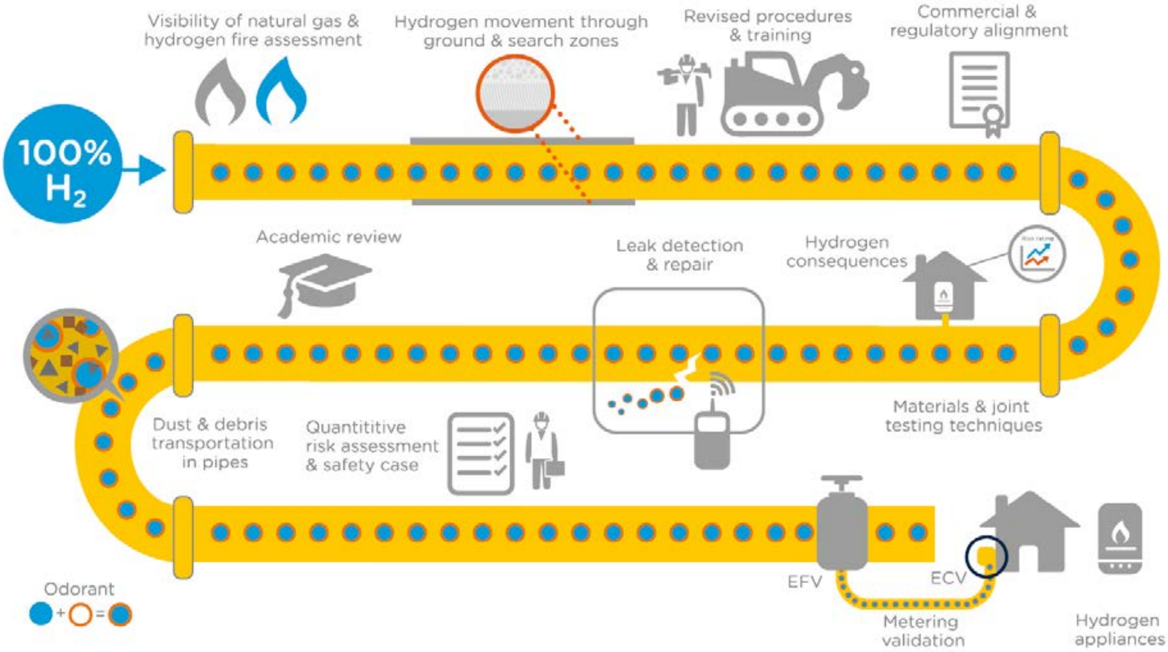

Figure 8: H100 NIA Workstream A summary of programme elements.

[32] https://www.sgn.co.uk/about-us/future-of-gas/hydrogen/hydrogen-100

Project HyGen – SGN/ERM/Scottish Government (LCITP)
Project HyGen, which is covered in Section 4.2.3, also provided evidence for the site selection process.

Project Methilltoune – SGN/BEIS/ARUP/OREC/Kiwa £500k
Project Methilltoune[33] studied the feasibility of the first ever green hydrogen production facility that utilises offshore wind for hydrogen production in order to supply the distribution network defined by H100 NIA FEED to provide domestic properties with zero carbon heat.

6.1.2 Ongoing Pre NIC work – SGN Funded

Planning Progression Works
See Appendix I, Element 1.

Third Party Agreements
Building on the preliminary work carried out under H100 NIA and Project Methilltoune, we are progressing key agreements required in advance of NIC/Scottish Government funding commencement. This includes ensuring agreements in principle with key third parties are in place, often either via MOUs, Heads of Terms or option agreements.

ORE Catapult
We have been engaging with ORE Catapult in relation to the Power Purchase Agreement (PPA) for the electrolyser input power. An agreement has been made in principle [redacted]. This agreement in principle on the pricing terms has been signed off by both parties and will be progressed to a full PPA in advance of the system becoming operational.

Land
We have engaged with the landowners of the Energy Park Fife, Scottish Enterprise and have secured Heads of Terms for an option of a seven-year lease of the land for the H100 Fife Site (subject to planning). [redacted] We plan to execute this option via the Scottish Government Grant once planning is obtained, enabling planning and land to be secured in advance the NIC funded project phase.

Fife Council
We have engaged with Fife Council in relation to an agreement in principle [redacted]. This agreement has been signed by both parties in the form of an MOU. This includes support from Fife Council in the form of:

- Communicating opportunities where hydrogen appliance installation could help support energy efficiency and low carbon targets for the Council. Including those described in Local Housing Strategy and Climate Fife.
- Supporting us on customer engagement for Council owned housing stock.
- Liaising with us during the construction period to be aware of programme of works, traffic management plans and timeline for property access and installation.
- Ensure continuity in communications between low carbon projects in the area.
- Help identify opportunities for boosting the local economic development through the project delivery.

Hydrogen Demonstration Facility Design
In recognition of the importance of the customer value proposition of hydrogen for heat

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[33] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/866382/Phase_1_-_SGN_-_Methilltoune.pdf

and the customer's want to understand what they would be signing up to, we commissioned DNV-GL to produce designs for the Hydrogen Demonstration Facility. We selected DNV-GL as a partner for this aspect to ensure that the learning from the 'in home' testing facility at Spadeadam (constructed for both H21 and Hy4Heat), could be incorporated into the facility design. A key feature of the installation is its enduring role for training of both local engineers and internationally, subject to the success of the project. These designs feed into the overall planning application works and support the planning application process.

We have received a proposal for the full detailed design and build of the demonstration facility with DNV-GL that ensures that this NIC funded element can commence as soon as funding is available in April 2021 (subject to planning).

Long Lead Item Procurement Specifications

We are preparing the tender specification for the two identified long lead items to ensure they are available for the construction phase (Element 9) of the project. These are the storage tanks and the electrolyser system. Earlier work carried out under Project Methilltoune indicates that these have a lead time of up to 12 months and we have therefore prepared the tender specification in advance of funding to allow procurement to commence in November 2020, funded via the Scottish Government Grant (subject to NIC success notification in November).

6.1.3 Project Structure

Project Plan

The H100 Fife high level timeline is provided below. This is structured to show the individual project elements alongside key work activities and associated proposed funders. The full programme can be found in Appendix B.

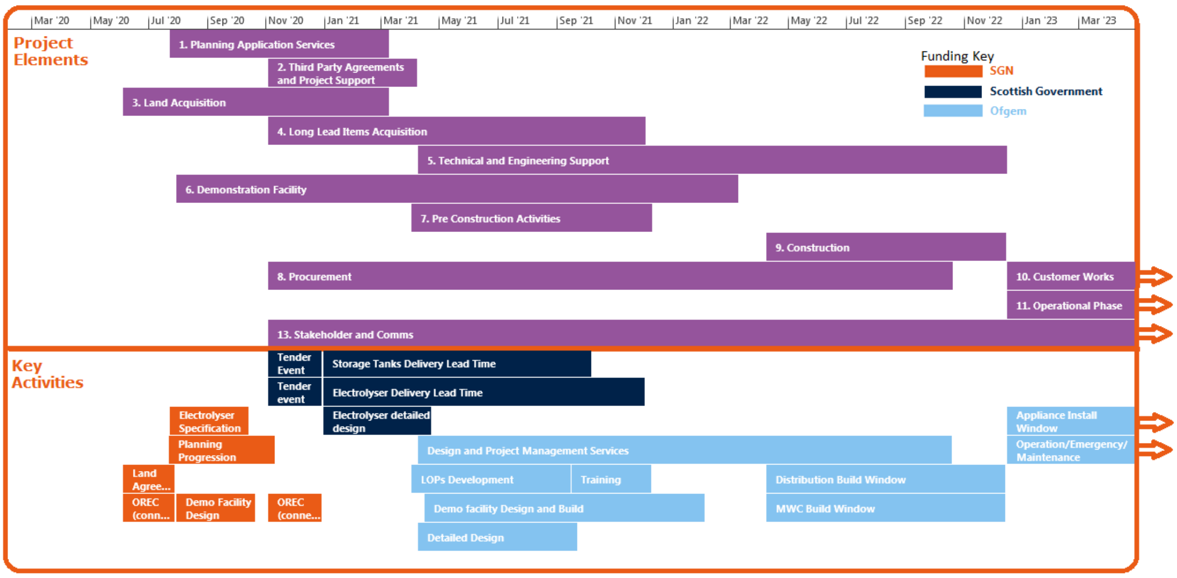

Figure 9: High level project timeline showing the project elements and key activities funded by the various parties.

Project Management

We have ensured continuity during the transition of the project from the NIA phase into the demonstration phase. On commencement of the NIC/Scottish Government funded elements of the project, the delivery team will be expanded to 7 to accommodate the expected workload and will be further supported by the internal Advisory Group as well as the external Stakeholder and Technical Groups, and contracted project support functions. See Appendix I for the H100 Fife organogram.

Project Support and Coordination

The project has been supported by a number of subject matter experts (SMEs) during previous phases of H100 NIA, both internal and external. This relevant expertise and knowledge has been retained for H100 Fife as well as bringing in new expert support in the form of partnerships, interfaces and support functions. Section 4 and Appendix K discusses the collaboration between Project Participants, to include Partners, External Funders, Suppliers and Supporters.

Contracting Structure

Across all aspects of the project and its development, we have ensured a fair, compliant and competitive approach has been followed with regards to the project contracting structure. Moving into the demonstration phase, the proposed contracting structure for H100 Fife is designed to ensure close control of the project and its success, while ensuring it is fully supported by the appropriate resources required to deliver the project safely, on time and in budget. The high-level indicative contracting structure, is provided below.

[redacted]

Figure 10: High-level proposed contracting structure across the end to end system.

CDM Structure

While H100 Fife will be delivered via 13 elements, as described in Section 2 and Appendix I, for the purposes of Construction (Design and Management) Regulations 2015 (CDM) it will be executed as four sub-projects, this approach aids the delivery and governance of the project as they are all separate, physically and/or in programme, from each other in terms of disciplines, competent persons, CDM Roles and Duty Holders.

- Sub-project 1 – Hydrogen Demonstration Facility
  The design and construction of the Hydrogen Demonstration Facility within the site at Levenmouth.
- Sub-project 2 - Production, Storage and PRS Site
  The design and build of all assets situated within the site boundary at Levenmouth (with the exception of Sub-Project 1) and the design and installation of all inputs/utilities and services that feed into the site.

Sub-project 1 and sub-project 2 together make up ‘H100 Fife Site’

- Sub-project 3 - Distribution Network
  The design and installation of the PE distribution network. ‘H100 Fife Network’.
- Sub-project 4 - Appliance Install
  The installation of appliances and associated works within customer homes. ‘H100 Fife Homes’.

Delivery Risk
H100 Fife maintains a project risk register that captures all risks in relation to the project. This allows us to oversee current risks to project delivery and ensure appropriate control actions and mitigations are in place. The full risk register can be found in Appendix G. At this time no risks have been identified that indicate the project cannot start in a timely manner or will be unable to progress to completion in line with the programme.

Safety Management Framework (SMF) and Compliance
The construction and operation of a purpose-built 100% hydrogen demonstration network is not currently covered by the Gas Safety (Management) Regulations (GS(M)R). These regulations only apply to natural gas distribution networks, where methane is a primary constituent. Following discussions with the HSE throughout the H100 NIA project phase and presently, we propose to design, construct and operate the H100 Fife demonstration within the spirit of GS(M)R and develop a gas network Safety Management Framework that supports the relevant requirements. The relevant sections of GS(M)R together with the associated SGN procedures and industry standards were reviewed under the H100 NIA and H21 projects to assess the differences and gaps between operating a natural gas and a hydrogen distribution network. H21 specifically addresses this with regards to network conversion. Where required, we have conducted evidential projects to confirm safety, through H100 NIA, H21 or Hy4heat. The BEIS Hy4Heat project is seeking to identify and address safety issues associated with the development and/or testing of hydrogen ready smart meters, pipework, appliances and their installation and use. The scope of this work extends from the Emergency Control Valve to the individual appliances such as fires boilers and cookers and will deliver a package of approved hydrogen installation products. These reviews and the evidence gathered form the framework for the H100 Fife SMF.

An end to end SMF is needed in order to evidence the interfaces between the separate sections of the SMF, which encompasses:
- Production / Storage / Gas Treatment (in spirit of lower tier COMAH requirements)
- Distribution Network (based on GS(M)R requirements)
- End user (covering downstream of the meter ECV)

An independent review of the SMF proposed is being undertaken by the HSE Science Division. The review is being conducted by a multi-disciplined team who are experienced in assessing Safety Cases, SMFs and COMAH safety assessments. The HSE does not currently have a process in place for assessing hydrogen project SMFs. It is working to develop a consistent UK wide approach for a HSE Hydrogen for Heat Safety Assurance Protocol through the appropriate advisory groups such as the HPDG run by the ENA on behalf of BEIS. In the interim, acknowledging that the HSE cannot fetter its discretion in relation to its assessment of our proposed system, hydrogen project SMF reviews will be undertaken at a local level, with the subsequent window for objection from the HSE. Regular engagement with the HSE, the local HSE representative and HSE Science Division is underway, including a project safety update on 14 October 2020, a project specific full day workshop on the 29 January 2019 and an end to end gap analysis workshop in 2019.

During Element 7, prior to construction, we will agree an approach with the duty holders of all aspects of H100 Fife Site and associated network in relation to design assurance and compliance with legislation such as PSSR. Regulation 4 of PSSR covers the design, construction, repair and modification of pressure systems and puts a duty on all concerned to ensure that the pressure system is fit for purpose. HSE guidance on PSSR advises that designs are independently verified and approved. Robust controls are therefore required to manage new works, modifications and repairs on a gas network. The purpose is to ensure that planned and executed 'design activity' is properly appraised, approved and determined as fit for purpose by fully qualified and competent people. Where possible designs will be assured against SGN existing standards and specifications via SGN's Management Procedure for managing New Works, Modifications and Repairs (SGN/PM/PS/5), when this is not possible designs will undergo an approval and appraisal process to evidence compliance with required legislation.

We will be implementing several operational measures beyond business as usual, such as the inclusion of additional safety components e.g Excess Flow Valves for network and downstream. There will be enhanced quality monitoring, a new asset database for comprehensive recording and a bespoke control system.

The H100 Fife SMF is a structured description, supported by evidence, that substantiates the safe construction and operation, in its specific operating environment and application of the H100 Fife hydrogen demonstration network. A substantial element of the SMF preparation has been the assessment of all processes, procedures and systems to identify and evaluate hazards and risks and implement the appropriate controls. This SMF will identify the safety critical aspects of the production, distribution and utilisation elements of H100 Fife both technical and managerial, and ensure that appropriate performance standards are defined and implemented. The assessment of safety is based on a risk ALARP approach and that the project can be delivered on an as safe as natural gas basis. H100 Fife seeks to deliver a safe trial, not a trial for safety. In preparation for the project we have undertaken comprehensive steps towards this. Aspects of the project, such as the electrolyser, coupled with the conclusions from the Hy4heat downstream risk assessment will continue to inform the overarching QRA until such time as the design is finalised (See Appendix J).

A roadmap has been developed with key milestones to identify hazards and risk, and effecting controls. The roadmap has 14 key milestones that cover the whole process from production through to burner tip (See Appendix H).

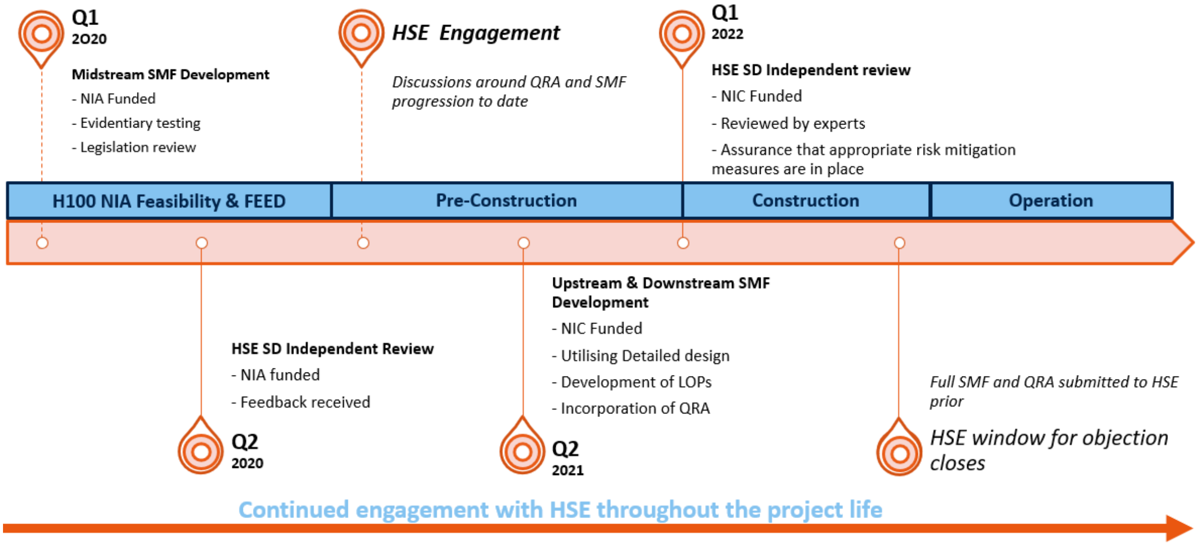

Figure 11: High level timeline for SMF and Quantified Risk Assessment (QRA) and continued HSE engagement.

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

H100 Fife aims to manage the budgetary risks by employing three main methodologies to ensure confidence in, and certainty of delivery:

Reducing Cost uncertainty

Accuracy of cost estimates ensure the risk of overspend against each individual cost line is minimised. This has been achieved through Early Contractor Involvement (ECI) and value engineering exercises at feasibility stage via workshops to identify early risks and opportunities with a view to firming up on design certainty. This approach allowed us to develop firm costs, signed agreements, written commitments where possible. Where fixed costs are not available, early market engagement, analysis of previous projects, and utilising the knowledge of internal and external subject matter experts have been used to form cost. We have also transitioned and retained expertise from within SGN and our key partners who have experience of both EPC and O&M projects.

Cost Risk Analysis

Determining low and high ranges against each cost line based on the level of uncertainty that still exists and other known variances in potential cost allows P50, P80 and P95 analyses to be undertaken. These values, combined with a reduced cost uncertainty, ensure that the risk of cost overruns can be kept as low as possible.

Robust Cost Management

Ensuring costs are managed effectively is key to the successful control of costs over runs throughout the lifetime of H100 Fife. This is achieved by the cost accuracy reduction and risk analysis activities, and via procurement and contracting strategies which can be tailored to ensure cost certainty.

6.2.1 Reducing Cost Uncertainty

Cost Estimate Development

The basis for the H100 Fife project cost estimate has been informed during previous H100 NIA phases, early market engagement and current project development work as well as drawing on internal and external expertise from similar projects. Outputs from the H100 Feasibility and FEED studies and Project Methilltoune formed certainty in design and a solid cost basis to build upon during subsequent project development phases. This initial dataset has since been refined and added to in preparation of the final cost estimates being presented in this submission by means of market engagement, securing costs via agreements in principle (such as land acquisition and MOUs for example) and discussions with various third parties that will either interface with the project or provide advise that can feed into the build-up of cost estimates.

Cost uncertainty reduction process

A full programme of work with the single aim of reducing cost uncertainty has been undertaken in the development of the cost plan. This was structured in systematic way that ensured the higher value cost items were prioritised for refinement and to ensure that key strategy and project delivery methods were mapped out in advance of refining the budget costs associated with them and their successors.

Cost Overview

The H100 Fife cost estimate is presented below by element and proposed funder, the full cost plan is provided in Appendix D.

Table 7: Cost Estimate Summary

Project Element (£k)	SGN	Scot Gov	NIC	Base Cost	Contingency	Grand Total
1. Planning Application Services	[redacted]					
2. Third Party Agreements and Project Support	[redacted]					
3. Land Acquisition	[redacted]					
4. Long Lead Items Acquisition	[redacted]					
5. Technical and Engineering Support	[redacted]					
6. Demonstration Facility	[redacted]					

7. Pre Construction Activities	[redacted]
8. Procurement	[redacted]
9. Construction	[redacted]
10. Customer Works	[redacted]
11. Operational Phase	[redacted]
12. Project Exit Strategy	[redacted]
13. Stakeholder and comms	[redacted]
Grand Total	[redacted]

6.2.2 Cost Risk Analysis

Certainty of design is important for delivering a project on time and within budget, by focusing on this through feasibility stage we are confident in our approach. Probabilistic cost risk analysis has also been applied to the base cost informed by an assessment of cost accuracy and uncertainty which has resulted in a P80 value of £27.79m. The difference between the base cost and the P80 has been accounted for in the cost plan as 'contingency' which overall accounts for 5% of the base cost, in line with industry norms for capital projects. The full cost risk analysis detail, can be found within the cost plan detailed in Appendix D.

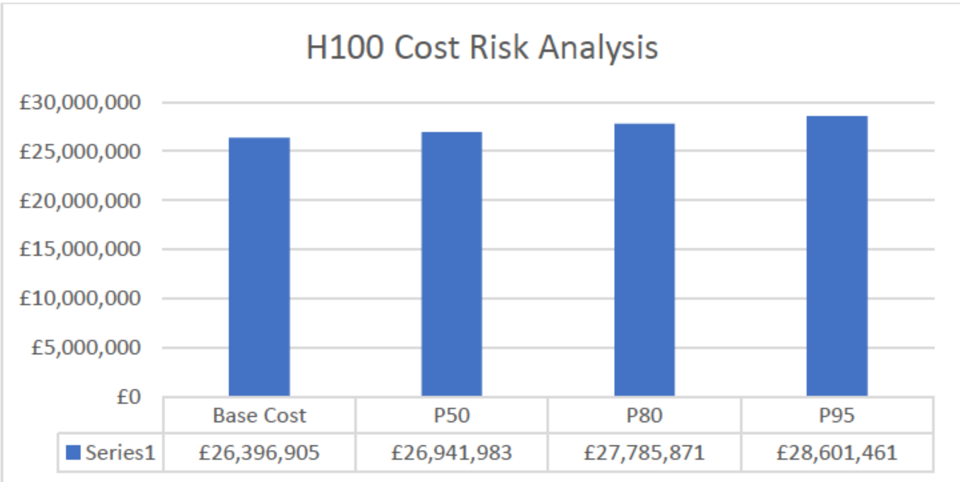

Figure 12: Cost Risk Analysis

6.2.3 Robust Cost Management

Project Management
The project will be managed by a competent project team supported where required by internal and external subject matter experts and contractors as detailed in the organogram in Appendix I. Weekly and monthly progress calls will be in place and a robust reporting structure will be implemented ensuring all information is provided to the project team from all required sources allowing comprehensive monthly progress reports to be produced and disseminated to the wider governance group. Risks will be subject to ongoing review allowing any issues to be flagged as early as possible to ensure mitigating decisions are made timeously.

Procurement
As described in detail in Section 4, our procurement process is underpinned by competition, compliance and transparency. Early engagement with P&C and the project team has allowed for an initial strategy to be developed that will be refined, allowing the project to procure all goods, works and services compliantly, ensuring value for money for the consumer, is at the forefront of all awards made. Tenders will generally be evaluated on a Most Economically Advantageous basis, ensuring both quality and price

are at the forefront of appointments, ensuring H100 Fife commissions the most suitable at the best possible cost. At all times, procurement strategies, and subsequent contractual awards, aim to ensure an optimal risk profile, allowing commercial protection and maximising cost certainty through its terms and schedules. Liability levels, insurances and key risk items will be drafted to ensure that not only are vendors appointed at the lowest possible price, but the outturn price of the deliverable is value for money to the end consumer.

Programme
A series of go / no go stagegates have been built into the programme to ensure that H100 Fife has a suitable number of decision points to enable it to managed effectively. The contracting strategy also ensures that wherever possible contracts entered into for the project have suitable milestone structures and deliverables to provide the project with cost control. A summary of the go / no go stagegates associated with the NIC phase is provided below. See Appendix C for the associated success criteria required for each.

Table 8: Project Stagegates

Ref	ID (element.#)	Stagegate	Date
1	7.2	Agreed regulatory model	04/03/2021
2	5.1	Electrolyser detailed design	22/04/2021
3	5.2	Control system detailed design	12/08/2021
4	5.3	Site detailed design (tender versions)	26/08/2021
5	7.3	Regulatory model implemented	13/01/2022
6	6.1	Demonstration Facility completed	02/02/2022
7	8.1	Construction phase contracts	10/03/2022
8	7.1	HSE objection window closes	06/04/2022
9	10.1	Properties signed up	22/09/2022
10	8.2	Operational phase contracts	17/11/2022
11	9.1	H100 Fife Phase 1 system commissioned	21/12/2022
12	11.1	Six month review of operational activities	31/05/2023
13	12.1	Project exit strategy	30/04/2026

6.3 A verification of all information included in the proposal

We have detailed and documented procedures covering technical and commercial governance including a suite of major project management procedures and a project structure that ensures visibility of the project at all levels of its business, including its executive committee and board. The Local Operating Procedures (LOPs) developed under H100 Fife will mirror this principle.

6.4 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

Should H100 Fife achieve less than its targeted 300 homes connected to the hydrogen network for the demonstration, it will still produce valuable learning that can enhance and inform future demonstrations and trials and advance the knowledge base for overall hydrogen transition of the GB networks.

'First of a kind'
H100 Fife brings together a number of discrete technologies to deliver an end to end system blueprint that can be replicated and used to mobilise hydrogen market growth, consequently driving down the cost of equipment and operation of future hydrogen economies. Also being delivered is a regulatory and commercial model that can inform future trials and demonstrations and inform regulatory amendments in the future to

accommodate a hydrogen economy. These technical, regulatory and commercial learning will be generated prior to the connection of any customers onto a hydrogen network.

Customer Acceptance
As outlined in Section 2.1.3, 300 homes supports the ability for the demonstration to be statistically representative of GB across a number of datasets including demand profile, which allows key operational knowledge to be generated. Calculations carried out using the industry standard for below 16bar distribution systems (IGE/GL/1) shows that this diversity normalisation occurs between 180 and 250 properties, therefore the viability of the project remains should this number not be reached.

The customer engagement and opt-in process, as outlined in Section 8, will be iterative and we aspire to have as many customers signed up to the project following the opening of the Hydrogen Demonstration Facility. We have scheduled a 6-month engagement window to promote the project and secure customer participation. Work will also be carried out prior to 2022 to raise awareness of the project and hydrogen in the local community. While we do not envisage that insufficient customer uptake will occur or in any event impact the project deliverability, stagegates and risk management are in place to give cost and risk control, and will be continually monitored. The customer engagement under this project will also generate an understanding of customer acceptance that can feed into the wider social acceptance knowledge base by projects such as H21[34] and enhance the overall hydrogen transition methodology for GB. This facility will also support training opportunities and continue to assist and inform the hydrogen transition.

GB Hydrogen Transition QRA
The H100 Fife QRA detailed in Appendix J interfaces with QRAs being produced by other projects such as H21 and Hy4Heat, this valuable learning will still aid the future QRAs as the overall risks and mitigations are refined towards full hydrogen transition in the GB.

UK Government Heat Policy Decision
H100 Fife, in coordination with other Network Licensees, will deliver key evidence in support of repurposing the GB gas networks in advance of heat policy decisions.

Outcomes
Regardless of the level of customer uptake in H100 Fife, key knowledge will be generated as detailed in Appendix N which will inform future trials and demonstrations from technical, regulatory, commercial, and social standpoints.

6.5 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 explained in Section 6.2.3 a comprehensive project reporting structure will be implemented to monitor and control the project. We will monitor cost and time progress against the project plan and carry out assessments as each stagegate is reached. Only when we are satisfied that the acceptance tests have been met at each of these key steps will we progress through each stagegate and continue the project. Similarly, the project team can halt or terminate the project should the project cease to be able to deliver the key outcomes.

[34] https://www.h21.green/projects/downloads/

7. Regulatory Issues

7.1 Anticipated changes to regulatory arrangements

We believe that a solution for H100 Fife can be implemented that requires **no derogation, licence consent, licence exemption or changes to regulatory arrangements**. The only identified requirement would be **a letter of comfort** from Ofgem addressing the fit of the project into The Gas (Calculation of Thermal Energy) Regulations 1996 (as amended) (see detail in Section 7.3.1). We have provided an example draft letter to Ofgem.

We have previously engaged with Ofgem to set out a spectrum of regulatory options at a meeting on 10 March 2020, following an introductory call on 16 September 2019.

7.2 Options and objectives

Despite the regulatory and licensing intricacies and challenges of this project, we recognise that protection of the participating customers is sacrosanct and a solution must be sought that allows customer participation to be simple, without disadvantage and with minimal disruption.

With that in mind, our preferred approach to the project ('Option 1') involves maintaining the current regulatory structure, with only a letter of comfort required. Under Option 1, SGN Futures would deliver system activities related to the electrolyser, predominantly hydrogen gas generation from electricity, and appoint a third-party shipper to take on ownership of the gas beyond the electrolyser, allowing Scotland Gas Networks plc (**ScGN**) to deliver and operate the regulated network components of H100 Fife without the need for derogation or exemption from its gas transporter licence. Option 1 offers the opportunity to demonstrate that hydrogen gas can operate under the current industry arrangements (including the Uniform Network Code (noting our comments in the regulatory analysis on possible amendments) and Xoserve central systems) with minimal modifications. It would also allow gas consumers to remain with their current gas supplier and/or change supplier if they so desired. The roles and interfaces between each party are set out in Figure 14. Domestic hydrogen smart meters[35] and hydrogen appliances[36] are being developed and will be certified ready for use in H100 Fife through the Hy4Heat programme.

Alternative models explored by SGN were:

(a) 'Option 2': SGN Futures and ScGN carry out the project activities, but with licence requirements/ derogations. The key difference between Option 1 and Option 2 is that, under Option 2, in particular, one of them (SGN Futures or ScGN) would have to obtain a licence to act as shipper. This is a viable alternative model albeit that, considering the restrictions on ScGN acting as a shipper under the Gas Act and ScGN's licence, we would anticipate that the role would be taken by SGN Futures. However, given that this will require a shipper licence for SGN Futures and that SGN Futures should be able to source a third party shipper without difficulty, SGN considers Option 1 the more efficient approach);

(b) 'Option 3': ScGN would undertake the entirety of the project via a full derogation of its licence, including carrying out or organising shipping and production activities. SGN is conscious that, in light of the restrictions on ScGN acting as producer and/or shipper under its licence and the Gas Act, Option 3 may be less appropriate (or require a more extensive derogation) than Options 1 and 2 and that Option 1 therefore remains the most effective model.

For the purposes of the regulatory analysis, we have therefore assumed that SGN's preferred Option 1 is to be effected. However, we have also explored the implications of:

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[35] https://www.hy4heat.info/wp10
[36] https://www.hy4heat.info/wp4

(i) Option 2, for resilience purposes, in case (during the development of the project) it transpires that there are activities which it is more practical for SGN Futures or ScGN to carry out with a new licence or derogation; and (ii) Option 3, for completeness and to demonstrate why Option 1 is SGN's recommended model. The full legal analysis of the regulatory options has been provided separately to Ofgem[37] and can be shared as required.

Deviation from Option 1 to adopt either Option 2 or 3 would require a derogation. We anticipate the quickest timescale to effect a regulatory derogation is around 6 weeks, however the project plan allows an additional 3-6 months to fully implement either alternative Option. We would seek to mitigate the impact of this on project deliverability, by agreeing the regulatory approach at stagegate 1 (March 2021). If Ofgem wishes to progress under Option 2, which includes a derogation for SGN to carry out the shipper role, our intention would be to subcontract out SGN's shipper activities to avoid the cost and timescales associated with setting up a new shipper.

7.3 Regulatory analysis

In reaching the conclusion at paragraph 7.1, we have worked with Addleshaw Goddard LLP to review the relevant regulations, consider possible issues and identify a resolution which minimises the risk of any changes to the regulatory arrangements. As stated above, this analysis is available separate to this submission[39]. We intend to keep this analysis under review as we agree a regulatory model in line with stagegate 1.

7.3.1 Changes to the regulatory arrangements

Gas (Calculation of Thermal Energy) Regulations 1996
The calorific value (CV) of hydrogen gas is significantly lower than that for methane (circa 11MJ/M3 versus 39MJ/M3). This will impact the flow weighted daily CV calculation for the Scotland local distribution zone, as the CV will effectively be capped at 1 MJ/m3 above the lowest CV value for that area. This will result in gas which cannot be billed being dealt with under the National Grid shrinkage scheme.
Proposed resolution: SGN will require a letter of comfort from Ofgem excluding the hydrogen CV from the LDZ calculation. We also plan to implement bespoke billing arrangements (via suppliers, who will be billing customers directly) supported by commodity balancing. This is described in Section 3.2.2

[37] H100 Fife Full Regulatory Analysis 14 October 2020, SGN & Addleshaw Goddard LLP

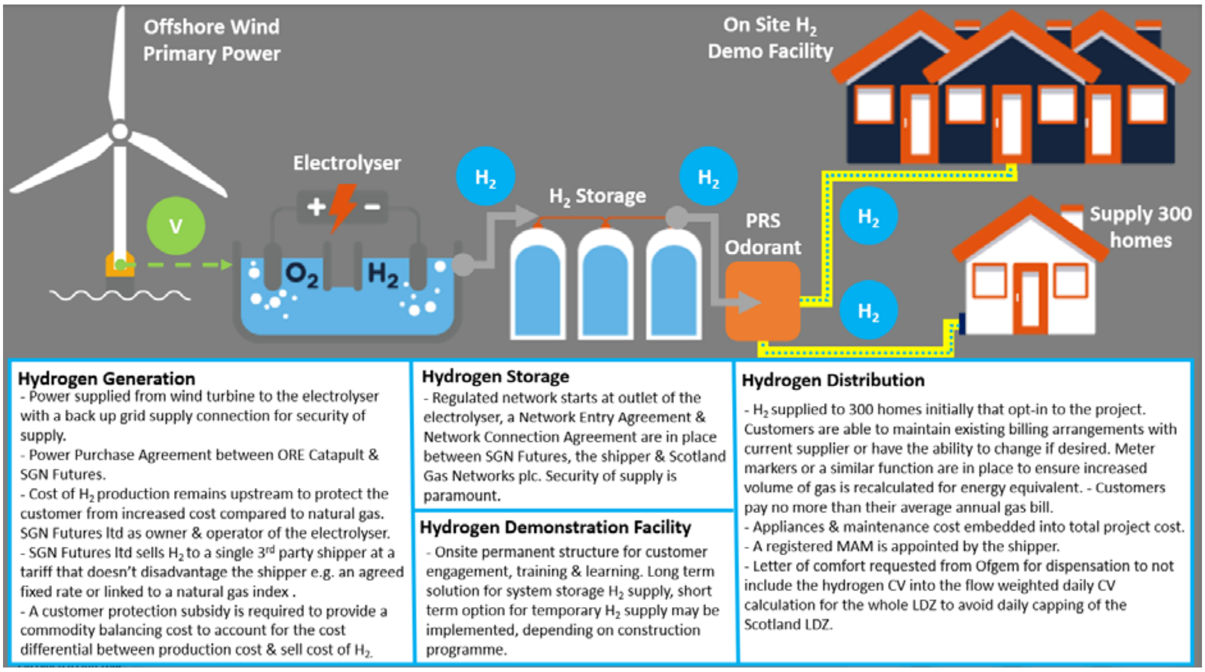


Figure 13: This illustrates the system order and the key activities for each system section.

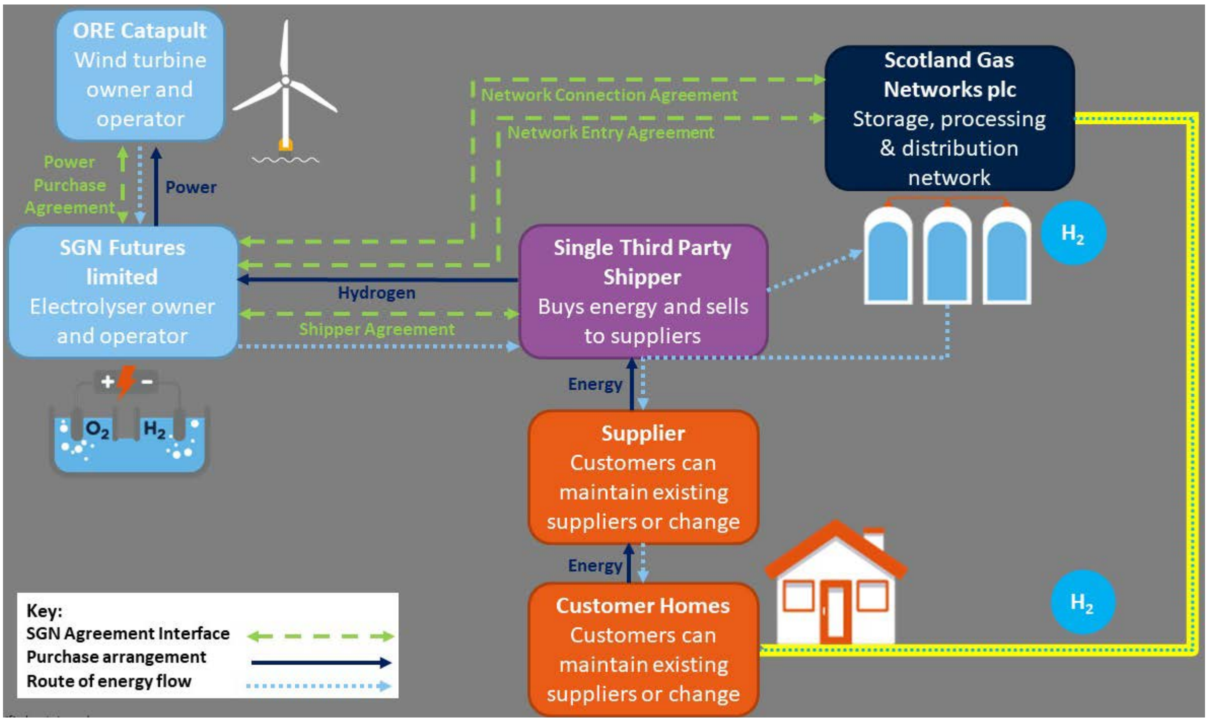


Figure 14: Key interfaces between parties, direction of energy flow & related agreements.

8. Customer Impact

8.1 Customer Value Proposition

Customers must be supported and brought along on the energy transition journey to fully address their wants and needs. Hydrogen offers a safe, reliable and green potential alternative to natural gas at lower cost and lower disruption compared to alternative decarbonisation options. The customer value proposition that hydrogen affords needs to be tested with real-world customers to inform key decisions on the future of energy in the UK. In order to understand the customer acceptance of hydrogen, eligible customers will be able to opt-in to the project, meaning the decision to connect to the hydrogen network is entirely at the customer's discretion. This approach permits the appetite, interest and confidence in hydrogen to be tested. Moreover, this method of customer choice means that any customer not wishing to participate in the project, will not be disadvantaged.

8.2 Customer Engagement Plan

Targeted customer engagement for H100 Fife is programmed to start in 2022, following a series of activities in 2021 to raise the profile of the project in the local community. A closely managed engagement period will precede the customer connection phase, which is estimated to start in Q4 of 2022. A detailed Customer Engagement Plan (CEP) will be delivered in advance of this as the project develops. At present, the key and required activities of customer engagement are known, however timing and order of delivery may change as the CEP is progressed. An example of the engagement activities identified and the indicative timeline of these is shown below:

- Customer invitations to the Hydrogen Demonstration Facility for events, workshops and sessions on hydrogen awareness as well as project information. Offers interactive experience with hydrogen appliances in a home-like setting
- Live demonstrations, such as 'Cooking with Hydrogen'
- Opportunity to ask questions of SGN, the project team and appliance manufacturers
- Multiple sources and platforms of project information e.g. leaflets, noticeboards, newsletters, posters, signage, online resources
- Encourage 'many to many' approach through word of mouth and social media
- Customer consent for home visits to verify eligible properties for those who are interested in participating, and a chance for customers to ask further questions
- A means of invitation to participate in the project via an opt-in process
- Customer support function for project information and enquiries
- Engagement with community representatives and customer surveys
- 24-hour call out support as part of the emergency response
- Free appliance inspection and maintenance for the duration of the trial

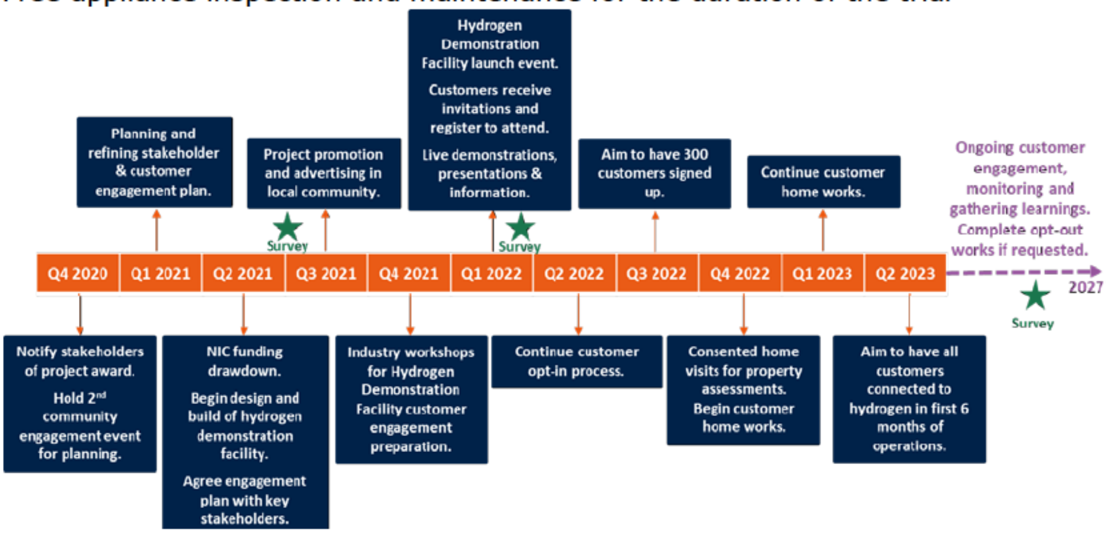


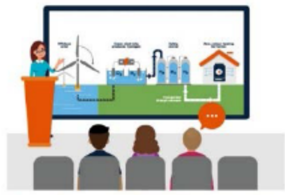
Figure 15: Example engagement activities and timeline.

8.3 Hydrogen Demonstration Facility

The Hydrogen Demonstration Facility proposed under the project is a publicly accessible centre that is located in the vicinity of the demonstration participant homes. This facility will provide a vital means of engaging with customers in a public environment, offering them the opportunity to learn about hydrogen and understand the project. This will give customers confidence through visibility of safe installation of hydrogen appliances in the home and allows customers to be informed before taking the decision on whether to opt-in. This facility will not facilitate testing in the way that H21's 'HyStreet' does, but will be designed to facilitate training, with designed features such as automated ventilation. It will be constructed in 2021, offering a venue for COP26 and allowing customer focused engagement as a priority to begin in 2022. This in-home setting will allow customers to interact with hydrogen appliances and understand the aesthetics. The facility will be a multi-functional permanent building that will serve a number of purposes during the project and as part of the enduring solution for the project, such as;

Customers will be invited into SGN's hydrogen demonstration facility on site at Levenmouth.
experience central heating, hot water, cooking and fireplaces, all supplied by hydrogen gas.

- An engagement tool for potential customers who are looking to find out more about hydrogen and the project before deciding whether to opt-in
- An event centre, delivering education, learning and awareness sessions for the public and local groups, including schools and higher education
- A centre for events and interactive demonstrations such as 'cooking with gas'
- A training centre for gas industry skills and competency
- A visitor centre for delegation groups across the energy sector, industry, academia, on both a national and international scale
- A facility for appliance manufacturers to demonstrate and market their products


There will be opportunities for customers to learn about hydrogen and the project, ask questions and meet key personnel.

8.4 Customer Protection Mechanisms

Protection of the customer is paramount, both for those participating by connecting to the hydrogen network, and those in the surrounding area who do not wish to opt-in to the project. Accordingly, we are proposing a package of incentives to ensure protection of the customer and minimise any disruption. A customer information pack will be developed to ensure the customer has an easy to follow reference point, giving them full visibility of the works to be carried out, including for example metering arrangements and appliance maintenance.

Properties able to connect to the network will be identified and invited to participate in the project.

8.4.1 Customer Billing Arrangements

It is vital that customers participating in the project are not disadvantaged through participation and that opting in is not disproportionately complex. As an emerging market, production of hydrogen via electrolysis is currently an expensive method of generating hydrogen; something that can be reduced significantly through the economies of scale and market creation. In order to offset the increased cost for hydrogen during the demonstration phase, and to validate attitudes towards hydrogen without being influenced by cost, customers participating in H100 Fife will only be charged the equivalent cost per unit of energy as they currently pay for natural gas for their hydrogen supply. It is proposed that balancing of this cost is done under the project on behalf of and to protect the customer through a commodity balancing mechanism, as mentioned in Section 3. We are engaged with Xoserve, the shipping community and retailers to manage the customer billing process as well as the key interfaces between the supply chain.

8.4.2 Security of Supply

The system critical components that ensure security of supply are the electrical input; the electrolyser and; the hydrogen storage. The supply of power to the electrolyser will aim to be supplied preferentially via the wind turbine, with a back-up grid connection in the event that wind energy is not available. The procurement process will seek to identify electrolyser solutions with built in redundancy such as multiple stacks to enable hydrogen production to continue in the event of failure. For the storage solution, the system has been sized to account for a 5 days peak hydrogen supply mirroring SGN's current licence conditions or a 1 in 20 years event. In line with this, the overall project design has adopted a spares philosophy to ensure there is adequate redundancy built into the system to mitigate any parts of component failures. As part of the procurement process, suppliers of supply critical components of kit will be required to agree to repair period obligations to ensure that in the event of an equipment failure the system downtime is minimised to ensure security of supply demand is met. The storage solution will ensure that hydrogen supply and demand remains balanced.

8.4.3 Hydrogen Appliance Provision

SGN will arrange customer home works to replace natural gas appliances with comparable hydrogen gas versions and connect to the new hydrogen gas supply.

We would not expect customers who wish to participate in the project to be financially disadvantaged. Accordingly, we aim to provide customers involved in the project with like-for-like replacements of their natural gas appliances for hydrogen equivalents. This will extend to include all works associated with installation and maintenance of their appliances for the duration of the project. The same approach has also been applied to customer meters and any internal works required in the customer property. All maintenance works will be carried out by Gas Safe Registered (GSR) engineers with sufficient hydrogen competency. Maintenance requirements of hydrogen boilers are not significantly different to that of natural gas boilers, but opportunities will be maximised for gathering operational data and customer satisfaction feedback during regular servicing visits. We will seek consent from customers for more frequent visits to support remote monitoring. Installation, commissioning, inspection, repair and maintenance of the hydrogen appliances will be carried out in partnership with the appliance manufacturers, through the partnership agreements that will be in place under H100 Fife. Only customers with an existing natural gas supply will be eligible for connection to the new hydrogen network; customers that have an electric heat supply will not be considered for the demonstration. Customers will be entitled to keep any appliances provided under the project beyond this NIC phase.

8.4.4 Return to Natural Gas

Customer support and 24 hour call out will be available through various channels and platforms for the duration of the project.

Throughout the 4.5-year operational phase of the project, customers connected to the hydrogen network will have the flexibility to revert back to their natural gas supply if they wish. Hydrogen boiler manufacturers have advised that the boilers could be back-convertible to natural gas, and arrangements will be made on behalf of the customer for new natural gas fires and cooking appliances to be installed. This will maintain the customer choice ethos of the project and help to gather vital evidence of customer acceptance, appetite and confidence towards hydrogen. For any customer wishing to revert their supply, this will be implemented at no charge. If a customer reverts back to natural gas, once the reinstatement process is complete, the subsequent costs of maintenance will return to the customer's responsibility.

8.4.5 Data Protection

A GDPR plan will be developed for the project that will compliant and committed to protecting and respecting the privacy of personal data. We have significant experience of managing customer data.

8.5 Supply Interruption Management

The construction plan for domestic works will be designed to minimise customer interruption, which is merited by the new network. The hydrogen boilers offer models that are 'hydrogen-ready', meaning they can run on natural gas initially and then undergo a minor conversion to changeover the gas supply to hydrogen. This changeover time has been quoted as less than one hour by the boiler manufacturers. In order to minimise customer disruption, it is not the intention under this project to commission the new customer boilers on natural gas and then for a second time on hydrogen. Rather, it potentially offers the flexibility and simplicity of returning any customers to natural gas that elect to do during the demonstration, and secures a contingency that avoids boiler replacement in the event that the project does not continue past 2027. The relevant licence obligations in relation to standards of service will apply to customers consenting to switch from natural gas to hydrogen, and works will be carried out to ensure minimal disruption and time off gas.

8.5.1 Emergency Response

We will provide a 24hr emergency response mirroring the current arrangements for natural gas customers. Customers and residents in the area will report emergencies in the same way as they do now under the 0800111999 emergency number. We will manage the appropriate response once it is in the system. Previous work delivered by SGN and project partners concluded that the main odorant used for natural gas can be used within the hydrogen network, therefore there will be no discernible difference for customers detecting the distinctive smell that we add to the gas.

8.6 Stakeholder Engagement

We will continue to engage with stakeholders on the project as it develops. This engagement will be delivered on a local, regional, national and a political level. Key stakeholders for the project have already been identified under the NIA phase of H100 with support from expert consultants Providence Policy. Further stakeholders may be identified as the project progresses and mapped according to their level of importance and influence, the customers being number one. A comprehensive stakeholder and community engagement plan will be developed and implemented throughout the key stages of the project and we will engage with local stakeholder on this to ensure the plan is inclusive and effective. From an early stage, we have understood the critically of gaining customer acceptance for hydrogen and the requirement to social proof hydrogen through initial learning and understanding, to acceptance and participation. This is captured in our 'Road to Social Proof'. Local awareness, acceptance and support for the project beyond the willingness for customers to connect will be important for the project's success and enduring solution. There are several characteristics of Levenmouth that we will aim to align and engage with to maximise the benefit to the local area, such as:

- Alignment with Fife Council's Sustainable Energy and Climate Action Plan (SECAP) as a Council that has declared a 'Climate Emergency'
- Decarbonisation and economic regeneration of a community categorised as deprived under the Scottish Index of Multiple Deprivation
- Partnership working with local actors in the area e.g. Levenmouth Rail Link, River Leven Programme
- Building on surveys carried out in partnership with a local environmental charity to engage customers on greening the gas
- Hydrogen awareness, competency and training courses for local workers Education opportunities e.g. Fife College, Energy Skills Partnership (ESP) Scotland
- Recognising that Levenmouth scored highest for 'unlikely to be significant opposition' in the site selection scoring criteria

9. Project Deliverables

9.1 Project Deliverable Table

The below table sets out the project's deliverables. The dates are based on the programme of works set out in Section 6 and Appendix B

H100 Fife consists of 13 elements as detailed in Appendix I. Elements 1, 2, 3, and 4 are not proposed for funding under the NIC therefore the below table includes only those deliverables for which NIC funding is being requested.

Table 9: Project Deliverables

Ref	Project Deliverable	Deadline	Evidence	NIC funding request
Element 5	Detailed designs and specifications produced.	22/09/21	- Approved and appraised design packs (tender versions) - Signed off versions of tender documentation including detailed specifications and award criteria.	[redacted]
Element 6	Demonstration facility constructed	10/03/22	- Build completion certificate - Certified hydrogen appliances installed and commissioned	[redacted]
Element 7	Pre-construction activities completed	07/04/22	- H100 Fife QRA produced - Local Operating Procedures produced and approved - Safety Management Framework completed - Training delivered and training and competency records produced - HSE window for objection closes - Regulatory model agreed - Project insurance in place and documentation available	[redacted]
Element 8	Procurement phase completed	20/10/22	- Signed contracts completed for all works, supply and service agreements	[redacted]

Ref	Project Deliverable	Deadline	Evidence	NIC funding request
Element 9	Construction phase completed	15/12/22	- Distribution network installed and commissioned - Hydrogen production system installed and commissioned - AGI including storage, PRS, control and ancillary systems and buildings constructed and commissioned - As built documentation produced - Monthly progress reports available	[redacted]
Element 10	Customer works completed	29/12/23	- Services to participating properties installed and commissioned - Appliances installed in participating properties - Any required upgrades or mitigation measures carried out in participating properties - Installation certificates available - Monthly progress reports available	[redacted]
Element 11	Operational phase completed	31/03/27	- Maintenance, emergency, and repair records available for phase. - Monthly progress reports available	[redacted]
Element 12	Project Exit Strategy Finalised	30/04/26	- Approved project exit strategy executed and complete	[redacted]
Element 13	Stakeholder Engagement and Comms complete d	31/03/27	- Stakeholder engagement final report produced - Comms final report produced	[redacted]
N/A	Comply with knowledge transfer requirements of the Governance Document.	End of Project	1. Annual Project Progress Reports which comply with the requirements of the Governance Document. 2. Completed Close Down Report which complies with the requirements of the Governance Document. 3. Evidence of attendance and participation in the Annual Conference as described in the Governance Document.	N/A

9.2 Project Cost commitments

9.2.1 Go / No Go Stagegates

[redacted]

Figure 16: Cumulative project spend against stagegates.

9.2.2 Deliverables

[redacted]

Figure 17: Cumulative project spend by deliverable.

10. Appendices List

Name	Summary
Appendix A – **Benefits Table**	Benefit tables for cumulative financial benefit and cumulative carbon benefit.
Appendix B – **Project Plan**	H100 Fife indicative project plan, subject to further refinement.
Appendix C – **Stagegate Success Criteria**	Stagegate success criteria linked to the go /no-go stagegates in Section 6.2.3.
Appendix D – **Cost Plan**	Presents the four cost elements, the project elements in each and the associated base cost, contingency and total cost.
Appendix E – **NPV Summary Analysis**	Summary of NPV analysis and supporting narrative.
Appendix F – **H100 NIA Workstream A Projects**	A description of each of the research and testing programme elements as part of H100 NIA, with the respective project partners.
Appendix G – **Risk Register, Risk Management & Mitigation**	The current project risk register with associated mitigation measures to manage risk.
Appendix H - **SMF Milestone Descriptions**	Detailed descriptions of each on the milestones on the SMF Roadmap as shown in Section 6.1.3.
Appendix I - **H100 Fife Project Element Descriptions and Organogram**	The 13 project elements that make up H100 Fife and the associated scope of works under each. The organogram for the project, indicating high level governance and team structure.
Appendix J – **QRA**	H100 Fife QRA summary.
Appendix K – **Project Participants**	A summary of the Project Participants, their specific Participant role and their input into the project.
Appendix L – **Project Maps & Diagrams**	A selection of images, design drawings and renders to provide context to the H100 Fife Site.
Appendix M - **Future Expansion Opportunities**	Background information to the possible expansion opportunities subject to the success of H100 Fife.
Appendix N – **Project Outcomes**	An example list of key project outcomes that H100 Fife aims deliver, progression the TRL of hydrogen networks.
Appendix O – **Regulatory Analysis**	This analysis is available separate to this submission.
Appendix P – **Network Licensees Contribution**	A signature page demonstrating the UK Network Licensees commitment to delivering H100 Fife in partnership.

Appendix A: Benefits Tables

Note – Capacity released in considered not applicable to H100 Fife. The lower energy density of hydrogen compared to natural gas will in fact withhold overall system capacity, requiring a higher flow rate to deliver the equivalent energy as natural gas.

Method	Method Name
Method 1	Saving of converting to hydrogen vs. electrifying heat

Gas NIC – Cumulative Financial Benefits (NPV terms: £m)								
Scale	**Method**	**Method Cost**	**Base Case Cost**	**Benefit**			**Notes**	**Cross-references**
				2030	**2040**	**2050**		
Post-trial solution *(individual deployment)*	Method 1	N/A	N/A	N/A	N/A	N/A	The deployment of hydrogen to decarbonise an individual customer is not practical. The benefits of hydrogen can only be realised under a whole system change.	N/A
Licensee scale *(If applicable, indicate the number of relevant sites on the licensees' network)*	Method 1	8,151	N/A	12.122	797.969	1,599.906	The licensee scale considers the expansion opportunities ultimately rolling hydrogen out to all 144,100 gas customers in Fife. Base case cost is not applicable as hydrogen has not yet been proven on the GB gas networks. Method cost is derived from the per customer cost of converting the entirety of the GB gas networks to hydrogen as per GGG discussed in Appendix E. (£1,301bn/23 million customers = £56,565 per customer *144,100 (number of gas customers in Fife) = £8,151bn). It should be noted that this method cost is not all	Appendix E and section 3.2

							for the GB gas customer and encapsulates the entire Gas industry supply chain, therefore requiring extensive public and private sector investment.	
GB rollout scale *(If applicable, indicate the number of relevant sites on the GB gas distribution network)*	Method 1	N/A	N/A	N/A	N/A	N/A	The rollout of a hydrogen economy to GB has not been factored into the benefits table of H100 Fife. H100 Fife however, will be critical in shaping the national hydrogen approach under GGG. The conversion of all gas customers in GB to hydrogen in dependent on the individual strategies of all GDNs in terms of timings (which have an impact on the NPV calculation outlined in appendix E)	Appendix E and section 3.2

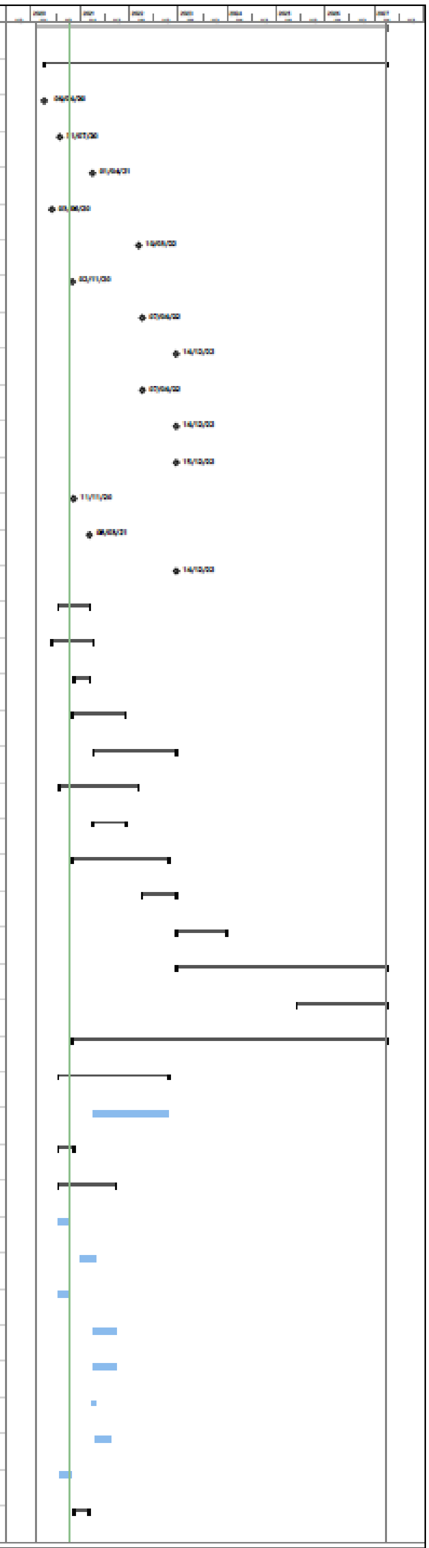
Gas NIC – Carbon and/or environmental benefits: Cumulative Carbon Benefits (Mt CO_2e)								
Scale	**Method**	**Method Cost**	**Base Case Cost**	**Benefit**			**Notes**	**Cross-references**
				2030	**2040**	**2050**		
Post-trial solution *(individual deployment)*	Method 1	N/A	N/A	N/A	N/A	N/A	The deployment of hydrogen to decarbonise an individual customer is not practical. The benefits of hydrogen can only be realised under a whole system change.	N/A
Licensee scale *(If applicable, indicate the number of relevant sites on*	Method 1	8,151	N/A	2,208	454,000	1,500,000	As per section 3.1.2. The licensee scale considers the expansion opportunities ultimately rolling hydrogen out to all 144,100 gas customers in Fife.	Section 3.1.2

the licensees' network)							Base case cost is not applicable as hydrogen has not yet been proven on the GB gas networks. Method cost is derived from the per customer cost of converting the entirety of the GB gas networks to hydrogen as per GGG discussed in Appendix E. (£1,301bn/23 million customers = £56,565 per customer *144,100 (number of gas customers in Fife) = £8,151bn). It should be noted that this method cost is not all for the GB gas customer and encapsulates the entire Gas industry supply chain, therefore requiring extensive public and private sector investment.	
GB rollout scale *(If applicable, indicate the number of relevant sites on the GB gas distribution network)*	Method 1	N/A	N/A	N/A	N/A	N/A	The rollout of a hydrogen economy to GB has not been factored into the environmental benefits table of H100 Fife. H100 Fife however, will be critical in shaping the national hydrogen approach under GGG. The conversion of all gas customers in GB to hydrogen in dependent on the individual strategies of all GDNs in terms of timings. The maximum possible environmental benefit of H100 Fife is the decarbonisation of all final gas demand in the UK (total emissions of 98.7 Mt CO_2). The direct benefit of H100 Fife has been limited however to the decarbonisation of heat, industry and (some) transport in Fife.	Section 3.1

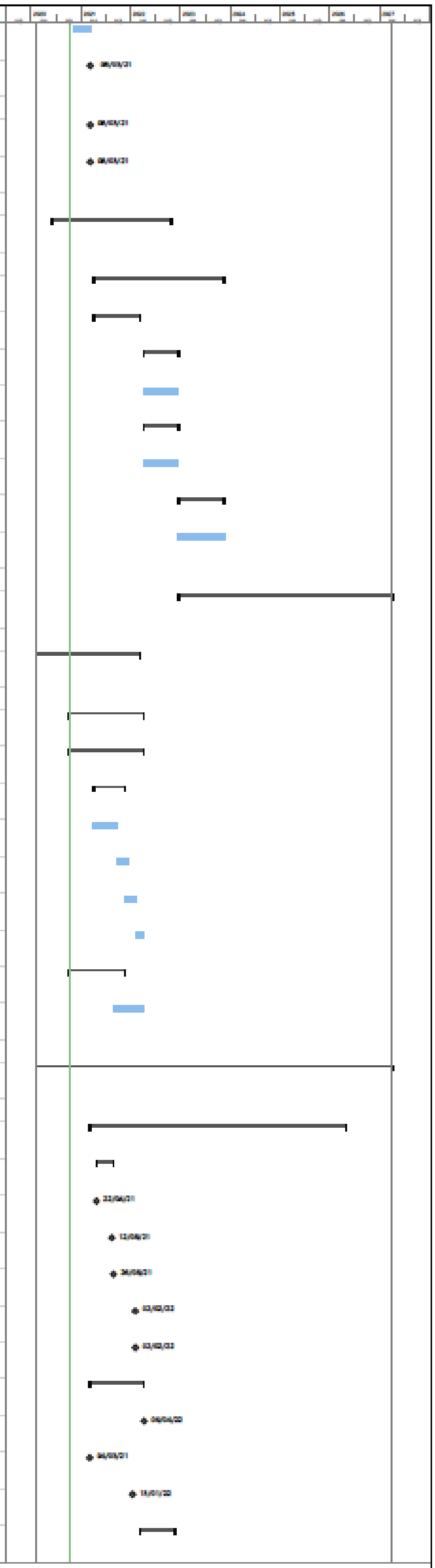
Appendix B: Project Plan

The H100 Fife project plan is provided below. This is will be developed further once the project management support services and the works contracts are in place.

Task Name	Duration	Start	Finish
Programme - H100 Fife	1864 days?	Mon 03/02/20	Wed 31/03/27
Key Dates	1819 days?	Mon 06/04/20	Wed 31/03/27
NIC ISP Submission	0 days	Mon 06/04/20	Mon 06/04/20
NIC Bid Submission	0 days	Fri 31/07/20	Fri 31/07/20
NIC Funding Available	0 days	Thu 01/04/21	Thu 01/04/21
SGN Funding Available	0 days	Wed 03/06/20	Wed 03/06/20
Demo Facility Complete	0 days	Thu 10/03/22	Thu 10/03/22
ScotGov Funding available	0 days	Mon 02/11/20	Mon 02/11/20
MWC Works Start	0 days	Thu 07/04/22	Thu 07/04/22
MWC Works End	0 days	Wed 14/12/22	Wed 14/12/22
Distribution works start	0 days	Thu 07/04/22	Thu 07/04/22
Distribution works end	0 days	Wed 14/12/22	Wed 14/12/22
Customer Installs Start	0 days	Thu 15/12/22	Thu 15/12/22
Planning Submitted	0 days	Wed 11/11/20	Wed 11/11/20
Planning Awarded	0 days	Mon 08/03/21	Mon 08/03/21
Gas On	0 days	Wed 14/12/22	Wed 14/12/22
1. Planning Application Services	161 days?	Wed 22/07/20	Tue 09/03/21
2. Third Party Agreements and Project Support	218 days?	Wed 03/06/20	Thu 08/04/21
3. Land Acquisition	76 days?	Wed 18/11/20	Tue 09/03/21
4. Long Lead Items Acquisition	281 days?	Mon 02/11/20	Fri 03/12/21
5. Technical and Engineering Support	442 days?	Thu 08/04/21	Fri 16/12/22
6. Demonstration Facility	418 days?	Wed 29/07/20	Thu 10/03/22
7. Pre Construction Activities	181 days?	Thu 01/04/21	Thu 09/12/21
8. Procurement	510 days?	Mon 02/11/20	Thu 20/10/22
9. Construction	181 days?	Thu 07/04/22	Thu 15/12/22
10. Customer Works	272 days?	Thu 15/12/22	Fri 29/12/23
11. Operational Phase	1120 days?	Thu 15/12/22	Wed 31/03/27
12. Project Exit	480 days?	Thu 29/05/25	Wed 31/03/27
13. Stakeholder and Comms	1669 days?	Mon 02/11/20	Wed 31/03/27
Design	582 days	Tue 21/07/20	Wed 19/10/22
Design and Project Management Services	20 mons	Thu 08/04/21	Wed 19/10/22
Planning Progression	80 days	Tue 21/07/20	Tue 10/11/20
Detailed Design	302 days	Wed 22/07/20	Wed 22/09/21
Electrolyser Specification	3 mons	Wed 22/07/20	Tue 13/10/20
Electrolyser detailed design	4 mons	Wed 30/12/20	Thu 22/04/21
Storage Specification	3 mons	Wed 22/07/20	Tue 13/10/20
Storage Design	6 mons	Thu 08/04/21	Wed 22/09/21
AGI Site Design	6 mons	Thu 08/04/21	Wed 22/09/21
Distribution Network Design	1 mon	Thu 01/04/21	Wed 28/04/21
Control System Design	4 mons	Fri 23/04/21	Thu 12/08/21
Demo Facility Design	3 mons	Wed 29/07/20	Tue 20/10/20
Planning	80 days	Wed 11/11/20	Mon 08/03/21



Task Name	Duration	Start	Finish
Planning Submission	4 mons	Wed 11/11/20	Mon 08/03/21
Planning Award	0 days	Mon 08/03/21	Mon 08/03/21
Land	0 days	Mon 08/03/21	Mon 08/03/21
Lease Option Executed	0 wks	Mon 08/03/21	Mon 08/03/21
Procurement	617 days	Wed 03/06/20	Thu 20/10/22
Construction	685 days	Thu 01/04/21	Wed 15/11/23
Demo Facility Build	245 days	Thu 01/04/21	Wed 09/03/22
MWC Works	180 days	Thu 07/04/22	Wed 14/12/22
MWC Build Window	9 mons	Thu 07/04/22	Wed 14/12/22
Distribution Works	180 days	Thu 07/04/22	Wed 14/12/22
Distribution Build Window	9 mons	Thu 07/04/22	Wed 14/12/22
Customer Works	240 days	Thu 15/12/22	Wed 15/11/23
Appliance Install Window	12 mons	Thu 15/12/22	Wed 15/11/23
Operation/Emergency/Maintenance	1120 days	Thu 15/12/22	Wed 31/03/27
Legal - Contracts	544 days	Mon 03/02/20	Thu 10/03/22
Pre Construction Requirements	391 days	Wed 30/09/20	Thu 07/04/22
Safety Case/QRA/LOPs/Training	391 days	Wed 30/09/20	Thu 07/04/22
Compilation of overall safety case	165 days	Thu 01/04/21	Wed 17/11/21
LOPs Development	6 mons	Thu 01/04/21	Wed 15/09/21
Training	3 mons	Thu 16/09/21	Wed 08/12/21
Third Party Review	3 mons	Thu 18/11/21	Wed 09/02/22
HSE Decision Point	2 mons	Thu 10/02/22	Wed 06/04/22
QRA	291 days	Wed 30/09/20	Wed 17/11/21
Asset management system implementation	8 mons	Thu 26/08/21	Thu 07/04/22
Stakeholder and Comms	1864 days?	Mon 03/02/20	Wed 31/03/27
Project Milestones	1345 days	Thu 04/03/21	Thu 30/04/26
5. Technical and Engineering Support	89 days	Thu 22/04/21	Thu 26/08/21
5.1 Electrolyser detailed design	0 days	Thu 22/04/21	Thu 22/04/21
5.2 Control system detailed design	0 days	Thu 12/08/21	Thu 12/08/21
5.3 Site detailed design (tender versions)	0 days	Thu 26/08/21	Thu 26/08/21
6. Demonstration Facility	0 days	Wed 02/02/22	Wed 02/02/22
6.1 Demonstration Facility completed	0 days	Wed 02/02/22	Wed 02/02/22
7. Pre Construction Activities	285 days	Thu 04/03/21	Wed 06/04/22
7.1 HSE Window for Objection Closes	0 days	Wed 06/04/22	Wed 06/04/22
7.2 Agree regulatory models	0 days	Thu 04/03/21	Thu 04/03/21
7.3 Regulatory model implemented	0 days	Thu 13/01/22	Thu 13/01/22
8. Procurement	180 days	Thu 10/03/22	Thu 17/11/22



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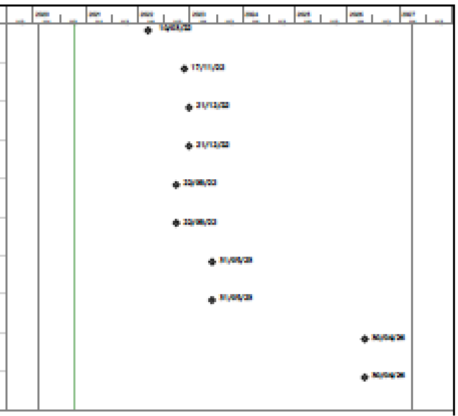
ID	Task Name	Duration	Start	Finish
[illegible]	8.1 Construction phase contracts	0 days	Thu 10/03/22	Thu 10/03/22
[illegible]	8.2 Operational phase contracts	0 days	Thu 17/11/22	Thu 17/11/22
[illegible]	9. Construction	0 days	Wed 21/12/22	Wed 21/12/22
[illegible]	9.1 H100 Fife Phase 1 system commissioned	0 days	Wed 21/12/22	Wed 21/12/22
[illegible]	10. Customer Works	0 days	Thu 22/09/22	Thu 22/09/22
[illegible]	10.1 Properties signed up	0 days	Thu 22/09/22	Thu 22/09/22
[illegible]	11. Operational Phase	0 days	Wed 31/05/23	Wed 31/05/23
250	11.1 Six month review of operational activities	0 days	Wed 31/05/23	Wed 31/05/23
251	12. Project Exit Strategy	0 days	Thu 30/04/26	Thu 30/04/26
252	12.1 Strategy executed	0 days	Thu 30/04/26	Thu 30/04/26



Appendix C: Stagegate Success Criteria

H100 Fife project stagegates listed in task order with required success criteria.

ID	Description	Success Criteria
7.2	Agreed regulatory model	Regulatory model accepted by Authority
5.1	Electrolyser detailed design	Designs completed and accepted via appropriate SGN design assurance process
5.2	Control system detailed design	Designs completed and accepted via appropriate SGN design assurance process
5.3	Site detailed design (tender versions)	Designs completed and accepted via appropriate SGN design assurance process
7.3	Regulatory model implemented	Accepted regulatory model in place and operational
6.1	Demonstration Facility completed	All works in relation to the demo facility completed. Facility available for customer engagement activities
8.1	Construction phase contracts	Agreements ready to be executed
7.1	HSE objection window closes	HSE review of safety management framework complete with no objections
10.1	Properties signed up	Required number of properties opted in
8.2	Operational phase contracts	Agreements ready to be executed
9.1	H100 Fife Phase 1 system commissioned	Production, storage and HP and LP systems commissioned
11.1	Six month review of operational activities	Validation that operational procedures in place are sufficient to meet requirements
12.1	Project exit strategy	Strategy in place and approved by relevant SGN representative

Appendix D: Cost Plan

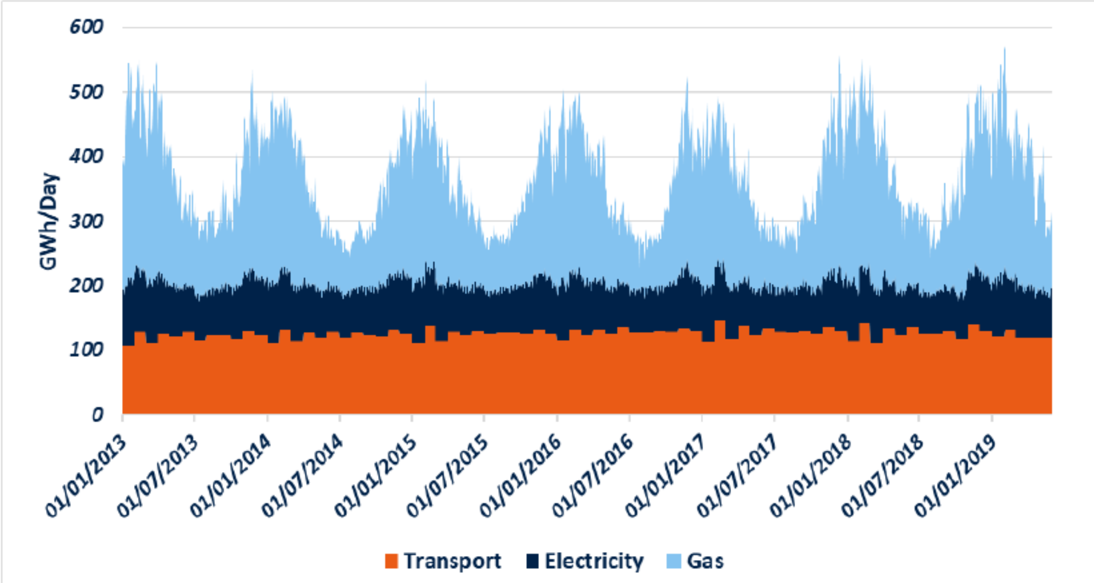
[redacted]

Making a positive difference
for energy consumers

[redacted]

Appendix E: NPV Summary Analysis

The majority of heating demand (shown in the below Figure 3[38]) in the UK is met by natural gas transported to customers through the UK's extensive gas network infrastructure and combusted in gas boilers. The use of natural gas in gas boilers has for decades, provided a reliable, low disruption and low cost heating solution to over 23 million customers



However, the long-term continued use of natural gas in the UK economy is not compatible with achieving net zero greenhouse gas emissions from the UK economy by 2050 (2045 in Scotland). The use of natural gas must be phased out and heating demand must be transitioned to low carbon and (ultimately) renewable energy.

As discussed in Section 3.1, the main source of the UK's overall decarbonisation progress has been the decarbonisation of the UK's electricity supply; driven primarily by the build out of renewable generation and the decommissioning of coal fired turbines.

At present, the only low carbon energy source permitted in the gas networks under current GS(M)R standards is biomethane. At a high level, biomethane production involves the decomposition of organic compounds (such as food waste and crops) into methane. Whilst biomethane injections to the UK gas networks must be maximised, the total decarbonisation of the UK gas networks via biomethane is not practical nor possible due to feedstock limitations. The CCC's central estimate in their 2016 Progress Report to Parliament for total biomethane availability by 2050 was 20TWh[39]. By 2025/2026, only around 3.8% of total throughout through our networks is projected to be biomethane (as per RIIO-GD2 biomethane targets).

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[38] Data from Scottish Government - https://scotland.shinyapps.io/sg-scottish-energy-statistics/

[39] CCC Technical note – Biomethane - https://www.theccc.org.uk/wp-content/uploads/2016/12/2016-PR-Biomethane-Technical-Note.pdf

The energy delivered through the gas networks is more affordable for a number of reasons, but fundamentally the higher energy density of gas compared to electricity makes it easier and therefore cheaper to transport, store and use.

Unlocking the potential of hydrogen as an energy vector of low carbon and renewable energy and developing the hydrogen economy and supply chain has the potential to enable the total decarbonisation of the energy delivered through the UK gas networks, enabling its continued use and benefits in a net-zero world.

According to Ofgem [40], as of the 1st April 2020, typical UK annual domestic energy consumption was 12,000 kWh for gas and 2,900 kWh for electricity. At present, the average unit price per kWh is 14.38p and 3.80p for electricity and gas respectively [41].

Without a deliverable and proven strategy to decarbonise the gas networks, policy makers would be left with no option other than to electrify heat. In terms of customer energy bills, the full electrification of heating demand would increase customer bills. It must be acknowledged however that in any case, including a switch to hydrogen, it is almost certain that the cost of decarbonisation will result in an increase in the unit energy cost to customers. All options must be explored, including hydrogen (which, according to the ENA, is nonetheless expected to become cost comparable with natural gas by 2040 [42])

In practice, the electrification of heat would require, at a high level, the widespread installation and retrofit of heat pump or resistive heating technologies across all 23.2 million properties currently connected to the gas networks, the reinforcement of the power networks, significant measures to improve the thermal efficiency of the GB housing stock and the significant build out of renewable energy generation and non-gas storage technologies (of which none currently exist at the capacity and discharge time of gas storage).

At a high level, the gas networks would be transitioned to transport hydrogen through the construction of new networks or the conversion of existing networks (following recommendations from the overall safety and technical programme of work), the only essential demand side changes required would be appliance changes. Significant hydrogen production would be required at scale and gas storage would be required to be repurposed.

The main financial benefit to customers and the UK taxpayer of H100 Fife is the expected saving afforded by evolving the gas networks to low carbon energy and avoiding widespread electrification, which is regarded as the more costly and disruptive option requiring significant demand side and system changes.

Accurately estimating the cost to the UK gas customer of either electrifying the energy demand currently met by natural gas (and building out the generation capacity to meet the increased demand) or transitioning the gas networks to hydrogen and developing the hydrogen economy (with all necessary supply chains and appliance changes) is a naturally uncertain calculation. All scenario modelling conducted to date by is underpinned by a number of assumptions. The business case of H100 Fife will estimate the cost differential between transitioning heating demand to hydrogen and electrifying heating demand currently met by natural gas.

A study undertaken by KPMG in 2016 for the ENA [43], investigated four possible approaches to decarbonising Britain's heat requirements (shown in Table 10). This study

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[40] https://www.ofgem.gov.uk/publications-and-updates/infographic-bills-prices-and-profits#:~:text=Figures%20based%20on%20dual%20fuel,and%202%2C900kWh%20for%20electricity).

[41] https://www.ukpower.co.uk/home_energy/tariffs-per-unit-kwh

[42] Gas Goes Green – Hydrogen: Cost to Customer, May 2020 (page 8)

[43] KPMG – 2050 Energy Scenarios, July 2016

found that maintaining the use of the gas networks with extensive use of biomethane and hydrogen – the "Evolution of Gas" option – to be the lowest cost and most easily achieved route. The cost breakdown of each scenario accounted for the incremental cost of commodities, the required investment in the electricity networks, the required investment in the gas networks and household adaption costs.

Table 10 - KPMG 2050 energy scenarios

	Evolution of Gas	Prosumer	Diversified Energy	Electric Future
Practical obstacles	Low/Medium	Very High	Medium/High	High
Incremental Costs	£104 – 122bn	£251 –289bn	£156 – 188bn	£274 – 318bn
Incremental Cost per Consumer	£4,500 – 5,000	£11,000 – 12,500	£6,800 – 8,000	£12,000 – 14,000

Achieving net zero across the UK economy is seen as a multi-trillion pound problem. The 2016 KPMG report, in light of findings and analysis carried out more recently, is seen as conservative.

The price differential between the midpoints of the evolution of gas scenario and the electrical future scenario is £183 billion, amounting to a cost saving per customer of £8000 (spread over 23 million customers). This will be considered as the base case saving per customer for the purposes of quantifying the financial benefit of H100 Fife.

In May 2020, Gas Goes Green through the ENA, published their "Hydrogen: Cost to Customer" report[44]. This report estimated the cost of converting the entirety of UK natural gas supply and demand to hydrogen at £1.301 trillion. This analysis carried out a more comprehensive analysis of the natural gas supply chain, considering all reasonable upstream, midstream and downstream costs. This cost of conversion split amount all 23 million GB gas customers equates to an overall cost of £56,565 per customer over 30 years (£1,885.51 per year per customer) – the entirety of this cost however, would not be borne by the GB gas customer and would require significant public and private sector investment. It is possible that the optimal approach in financing any national decarbonisation strategy and technology rollout will be a long term RAV based model (thereby sharing the cost between current and future customers

In October 2019, Navigant produced the Pathways to Net-Zero for the ENA[45]. This report considered two scenarios for decarbonising the UK gas networks; a balanced scenario, where low carbon gases are used in a balanced scenario with low carbon electricity (with the majority of heat demand met by a decarbonised gas network) and an electrified scenario, where low carbon gas use is limited to industry, where no reasonable alternative exists.

The total system costs of the balanced scenario are £109bn per year out to 2050, whilst the total system costs of the electrified scenario are £122bn per year out to 2050. This difference of £13bn per year for 30 years equates to the balanced scenario costing an estimated £390 billion less than the electrified scenario. This equates to a cost saving per customer of £17,000; this will be considered as the high case saving per customer for the financial benefit of H100 Fife. The middle case has been taken as the average of

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[44] Gas Goes Green – Hydrogen: Cost to Customer, Energy Networks Association, May 2020

[45] Navigant – Pathways to Net-Zero: Decarbonising the Gas Networks in Great Britain, prepared for the ENA, 21st October 2019. https://www.energynetworks.org/assets/files/gas/Navigant%20Pathways%20to%20Net-Zero.pdf

the base case and the high case. The middle case has been factored into the calculation for the financial benefits table found in Appendix A.

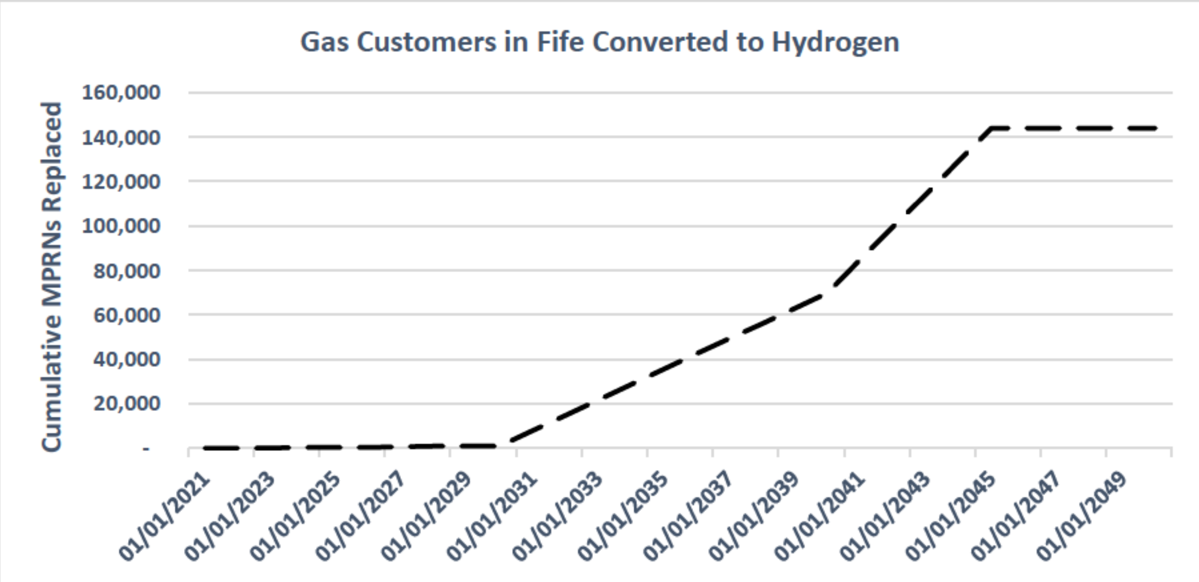
	Total cost saving for all UK gas customers	Cost saving per customer (based on 23m customers)
Base Case	£183,000,000,000	£8,000
Middle Case	£286,500,000,000	£12,500
High Case	£390,000,000,000	£17,000

The required financial benefits table has been populated in line with the price differential of the middle case between electrification and the rollout of hydrogen. H100 Fife ultimately aims to develop a scaled hydrogen economy in Fife across the heating, industry and transport sectors.

There are currently 141,100 gas customers in Fife; the potential financial benefit of this project has been aligned with the conversion of all gas customer in Fife to hydrogen as a means of decarbonising heat compared to electrifying their heating demand.

Between now and 2030, it is assumed 1000 gas customers will be converted to hydrogen through the completion of the work proposed here and the completion of Phase 2. 300 customers are projected to be transitioned to hydrogen between 2022 and 2024, with a further 700 transitioned between 2026 and 2028.

Between 2030 and 2040, it is assumed that a further 69,000 customers will be converted to hydrogen at a linear rate across the decade. Lastly between 2040 and 2045, it is assumed that the remaining 74,100 gas customers will be transitioned (again linearly) to hydrogen. Thereby achieving the decarbonisation of heat in Fife by 2045 (in line with Scotland's 2045 net zero target).



In terms of calculating the required NVP, annual inflation rates have been drawn from Treasury projections[46] and an annual discount factor of 3.5% has been assumed out to 2045.

[46] Inflation – page 18, Forecasts for the UK Economy - HM Treasury, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/886552/Forecomp_May_2020.pdf

Appendix F: H100 NIA Workstream A Projects

H100 NIA: Workstream A	Description
Polyethylene (PE) Materials and Jointing Techniques with HSL	A testing programme to evaluate PE pipe, fittings and jointing techniques specific to the construction of the H100 Fife Network and to determine their performance with hydrogen when compared to natural gas.
Characteristics of Hydrogen with ERM	An investigation into the behaviour of leaked hydrogen in the subsurface and property via physical testing and analysis.
Consequence Testing with Kiwa	A testing programme examining the possible consequences of an un-controlled hydrogen escape when it ingresses into a property. Also a review of SGN's emergency process and its suitability for hydrogen distribution.
Odorant & Gas Detection with NPL	An evaluation of natural gas odorants currently available that have the potential to be used with 100% hydrogen. A review of portable gas detection instruments for detecting hydrogen & natural gas that are suitable for use by emergency & engineering teams.
Hydrogen Logistics with Kiwa	Modelling of the demand, hydrogen generation and storage, using an average dwelling heat demand and data from commercially available technologies.
Safety Management Framework with DNV-GL	A review of GS(M)R, SGN's Safety Case, relevant procedures and standards. Then development of the Safety Management Framework for H100
Safety Management Framework Review with HSE Science Division	An independent assessment of SGN's H100 Safety Management Framework to ensure fit for purpose
Academic Partnership with University of Edinburgh	A review of reports by independent experts will be carried out. Once validated the results will be disseminated to a wider audience via peer-reviewed article and specialised press.
Stakeholder Engagement with Providence Policy	Ensure all stakeholders are aware of the project, understand its objectives and have the opportunity to contribute and collaborate.
Metering Validation with Kiwa	The development of a testing strategy of current UK gas meters to provide adequate safety and performance data to determine the fitness for purpose of the current population of UK gas meters for safe and accurate operation with hydrogen.
HyCORAL – Commercial & Regulatory with University of Edinburgh	A regulatory and commercial roadmap aimed at supporting delivery of the project's demonstration phase.
Transportation of Debris in Pipelines with Steer Energy	An investigation into the impact of increased gas velocities of hydrogen when compared to natural gas during distribution.
Risk Assessment to Compare the Visibility of Hydrogen and Natural Gas Fires with DNV-GL	An investigation providing qualitative information on the relative risks of natural gas and hydrogen fires, particularly regarding the visibility of the flames.

Appendix G: Risk Register, Risk Management & Mitigation

Definition	Explanation	Probability	Score
Almost Certain	Event is expected to occur in most circumstances	>90%	5
Likely	Event will probably occur in most circumstances	50-90%	4
Possible	Event should occur at some time	30-50%	3
Unlikely	Event could occur at some time	10-30%	2
Rare	Event may occur only in exceptional circumstances	<10%	1

Score Ranges
Impact 1-5
Likelihood 1-5

Scoring Key		
16-25	10-15	1-9

Risk Owner	Ref
SGN	SGN
Technical Services Provider (KIWA / ARUP)	TSP
Main Works Contractor	MWC

Risk ID	Risk	Business Risk	Inherent Risk: Impact	Inherent Risk: Likelihood	Inherent Risk: Pre- Risk #	Controls & Mitigation	Owner	Residual Risk: Impact	Residual Risk: Likelihood	Residual Risk: Post-Risk#
1	Hydrogen compared to natural gas risk is undefined	Safety	5	3	15	A. Develop QRA to identify risks and put in place appropriate risk mitigation measures to confirm the two gases are comparably safe	SGN	3	2	6
2	Failure to demonstrate case for safety	Time Safety	5	3	15	A. Demonstrate project Safety Case is fit for purpose B. HSE Science Division to provide an independent review of the Safety Case C. Continued engagement with HSE D. Develop QRA to identify risks and put in place appropriate risk mitigation measures	SGN	5	1	5
3	Long lead items delay programme e.g electrolyser/storage tanks	Time	4	3	12	A. Procure long lead items in advance of NIC B. Secure additional funding pre-NIC to procure long lead items	SGN TSP	4	2	8
4	Slow customer uptake in trial resulting in not enough participants to	Time	5	3	15	A. Engage with customers early, deliver customer engagement plan prior to opt-in decision	SGN	4	2	8

	demonstrate customer acceptance of hydrogen					B. Construct & operate hydrogen demonstration facility to provide a 'show home' for customers to interact with hydrogen appliances, learn about hydrogen and the project C. [redacted]				
5	Project slippage	Time Financial Reputation	4	3	12	A. Active project management B. Review project plan frequently to identify any potential delays in milestones	SGN MWC	3	2	6
6	Unable to evidence hydrogen for heat in advance of heat policy decision	Time Financial Environment Reputation	5	3	15	A. Active project management B. Review project plan frequently to identify any potential delays in milestones C. Engage with stakeholders throughout project	SGN MWC	5	1	5
7	COVID-19 interruption, delays, resource disruption	Safety Time	5	3	15	A. Engage with contractors and HSE to ensure work procedures are appropriate B. Manage work in line with latest Government guidelines C. Construction window starts Q3 2021 D. Continue to monitor impact on project, Participants, supply chain and industry E. Staff working from home, adapting flexible working hours where necessary F. Staff wellness are symptoms are being monitored and recorded	SGN TSP MWC	2	2	4
9	External funding is not obtained	Financial	5	4	20	A. Secure Grant drawdown from Scottish Government for funding, with Grant offer letter pre-bid	SGN	5	1	5
10	Poor cost accuracy	Financial	4	3	12	A. Cost uncertainty reduction process & contingency B. Market research conducted C. Estimated costs from NIA FEED studies D. Receive budget quotes E. Agreements in Principle	SGN	5	1	5
11	Power Purchase Agreement (PPA) with ORE Catapult not agreed	Time Financial	5	3	15	A. Agreement in principle on pricing terms. B. Negotiate terms of PPA with OREC C. Finalise terms of PPA with OREC	SGN TSP	3	2	6

12	Project fails to get support/commitment from Fife Council	Time	4	3	12	A. Fife Council supportive of project from regular engagement B. Fife Council part of Stakeholder Group & Technical Group C. Obtained MOU from Fife Council	SGN TSP	2	1	2
13	A regulatory solution for the project is not found	Time Regulatory	5	3	15	A. Regulatory spectrum of models mapped, preferred option reviewed by specialist legal representation B. Engaged with Ofgem on spectrum of options on 10th March 2020 C. Preferred regulatory option presented to Ofgem in bid D. Follow up engagement post-bid with Ofgem	SGN	4	2	8
13A	Preferred regulatory option not accepted by regulator	Financial Time Regulatory	5	3	15	A. Regulatory spectrum of models mapped, preferred option reviewed by specialist legal representation B. Engaged with Ofgem on spectrum of options on 10th March 2020 and throughout NIC submission process C. Regulatory options 2 and 3 implementation requirements understood (in order to be discounted) D. Additional time required to (Ofgem advised 6 weeks to 3 months) implement options 2 or 3 should not impact key milestone dates (construction and operational phases)	SGN	5	1	5
14	Planning permission for project not awarded or not achieved in current programme timelines	Time Financial	5	3	15	A. Planning process underway for H100 Site - hydrogen production and storage site B. Obtained a MOU from Fife Council whilst ongoing planning works are undertaken C. Continued engagement with Fife Council planning department	SGN TSP	5	1	5
15	Undefined scope of training and competency	Safety Time	4	3	12	A. Training and competence requirements mapped out in line with Hy4Heat's programme of training with EUSR B. Aligning training programme with SGN's training team and EUSR training programme	SGN TSP	4	1	4
16	Construction of H100 site	Safety	5	3	15	A. Specific and appropriate training and competency to contractors, follow site specific work instructions and safe control of operations processes B. Site management and CDM compliance	SGN MWC	3	2	6
17	Poor collaboration with Project Partners	Time Reputation	4	2	8	A. Active engagement with Project Partners B. Partnership Agreements to be executed C. Engagement coordinated through project Stakeholder Group & Technical Group	SGN	2	1	2

18	Poor stakeholder engagement	Reputation	4	2	8	A. Active communication and engagement with stakeholders ongoing B. Engage with stakeholders through project Stakeholder Group and other external groups C. Stakeholder and community plan to be delivered	SGN	2	1	2
19	Suitable electrolyser for the project not acquired, no hydrogen supply solution in place for the project	Time Financial	5	3	15	A. Previous work identified suitable models for project criteria and requirements B. RFQ and electrolyser design package scoped to get to tender ready point and procure optimal electrolyser C. External Funding mechanism identified for procurement of electrolyser	SGN TSP	5	1	5
20	Operational equipment and network features not suitable for hydrogen	Time Financial Safety	5	4	20	A. H100 NIA researched and tested components of network and operation for suitability with hydrogen B. Developing a hydrogen Gas Detection Instrument C. Developing a hydrogen excess flow valve for network	SGN	4	2	8
21	Risk of consequences if control system fails in unexpected manner resulting in system failure	Safety	5	3	15	A. Design to applicable codes and standards B. Site manned 24/7	SGN TSP	3	2	6
22	Risk that lack of existing standards means lack of guidance, and need to design from first principles	Safety	4	3	12	A. Review current work procedures, draw on experience from NG work practice B. Develop suite of local operating procedures specific to hydrogen networks	SGN TSP	3	2	6
23	Inadequate wind turbine generation, more expensive hydrogen production	Financial	5	4	20	A. Analysis under Project Methilltoune identified sufficient wind generation output from the turbine for hydrogen production purposes B. Grid connection as a power back-up	SGN	2	2	4
24	Site is deemed unsuitable for hydrogen production and storage	Financial Time	4	4	16	A. Site selection process under H100 and also Project HyGen determined Levenmouth as the optimal site B. Designs will be developed, approved, appraised based on information available C. Continued engagement with stakeholders relating to land	SGN	3	1	3
25	Leak on network due to interference damage	Safety Environment	4	2	8	A. Appropriate emergency procedures in place	SGN	2	2	4

26	Risk in obtaining hydrogen appliances for trial	Time	4	3	12	A. Willingness to partners on project agreed with key appliance manufacturers B. Execute partnership agreements post-bid	SGN	2	1	2
27	Risk of equipment vandalism	Time Financial Safety	5	2	10	A. Identify suitable site protection B. Install & construct site with fences, alarms, cameras C. 24/7 operatives on site	MWC SGN	3	1	3
28	IP Breach	Regulatory Financial	5	3	15	A. Following default IPR position under NIC B. Incorporate IPR position in contracts	SGN MWC	2	1	2

Appendix H: SMF Milestone Descriptions (abridged)

All aspects have either progressed and will be refined under the H100 Fife project

- Network Risk Assessment: The outputs from the QRA concluded that the risk associated with operating a new all PE hydrogen network where lower when compared the current mixed material natural gas networks operated in the UK.
- Plant and premises: Defines the location, production process, duty holder responsibilities and details the key elements of the process
- Content and Quality of hydrogen: For the purposes of H100 Fife, the purity level of the hydrogen has been defined 99.99%, this is the gas quality as it exits the electrolyser into storage. Odorant NB is added, this is the same odorant used for natural gas and will give the hydrogen the characteristic smell associated with natural gas.
- Operations Undertaken: Distribute Hydrogen through a PE Network for utilisation in domestic heating and cooking appliances.
- Continuity of Supply: The Hydrogen Production Facilities and distribution network have been designed to ensure security of supply.
- Adequate System Pressure: The hydrogen conveyance license for H100 is in place to ensure that the pipeline system security standard is met.
- Technical specifications: This element has reviewed all applicable IGEM and SGN standards. Complimentary to this review, H21 are undergoing an extensive work procedure redraft for hydrogen gas networks. Updated standards and procedures will be a key step to conversion, however for the purposes of H100 Fife, Local Operating Procedures are appropriate.
- H100 Fife SMF: This element has defined the structure and content of the project SMF, which has been independently reviewed by the HSE Science Division.
- Employee Competence: SGN will ensure that all employees involved in the construction and operation of the H100 demonstration are competent.
- Downstream Installations: Meter installations, pipework, fittings and appliances are being tested, approved and certified by the Hy4Heat project. The H100 project will only install appliances and ancillary equipment that has been certified and approved via this route for use with 100% hydrogen.
- Operations and maintenance procedures: Building on the work to date, we will incorporate into Local Operating Procedures for the H100 demonstration.
- Gas Supply Emergencies: A "supply emergency" is considered as ‘an emergency endangering persons and arising from a loss of pressure in the network or any part thereof. The H100 arrangements for managing a hydrogen supply emergency will draw on the GB best practice requirements
- Gas Escapes and Investigation: H100 NIA hydrogen characteristics and consequences projects rigorously examined the emergency process, procedures and risks associated with the switch to hydrogen.
- COMAH & Process Quantified Risk Assessment: A quantified risk assessment is underway that will quantify the risk associated with the switch to hydrogen for the end to end process, it is focused on the risk associated with the three main areas of operation so, production, distribution and utilisation. This assessment is a comparative assessment so will evaluate any change in risk associated with the switch to hydrogen.

Governance and Approvals: The H100 Fife SMF is being drafted by SGN & DNV-GL and independently reviewed by the HSE Science Division.

Timeline: SGN, SGN HS&E and HSE Science Division complete their review February 2022. The window for HSE objection is expected to close in April 2022.

Appendix I: H100 Fife Project Element Descriptions and Organogram

Element 1. Planning Application Services
Delivery of all works required to facilitate the planning application for the works at the H100 Fife Site, as well as liaison with Fife Council, and planning consultancy during the pre-application and determination periods. Works include, PAC Statement, Design and Access Statement, Planning Statement, Landscape and Visual Impact Assessment, Transportation Statement, Noise Assessment, Ecological Impact Assessment Report, Habitats Regulation Assessment, Wintering Birds Surveys, Drainage Assessment, Air Quality and Odour Assessment, Contaminated Land Assessment, Coal Mining Risk Assessment and all associated designs that affect the site layout including the electrical input and control system layout and the Hydrogen Demonstration Facility.

Element 2. Third Party Agreements and Project Support
Securing key agreements required for the successful delivery of the project including ORE Catapult PPA agreement (signed agreement in principle on pricing terms is in place) and the acquisition of the land at the H100 Fife Site (agreed Heads of Terms option in place). Continue the development of the H100 Fife SMF to ensure continuity between NIA and NIC projects.

Element 3. Land Acquisition
The securing of the land at Fife Energy Park for the H100 Fife Site. An agreed Heads of Terms option is already in place for this and will be finalised following successful award of NIC and planning award.

Element 4. Long Lead Items Acquisition
Create the tender specifications and undertake the procurement process for the purchase of the electrolyser system and the storage tanks ensuring they are delivered in time to complete construction.

Element 5. Technical and Engineering Support
The delivery of the detailed design and project management of the H100 Fife works to ensure the project is delivered on time, budget and meets its objectives.

Element 6. Hydrogen Demonstration Facility
The detailed design and build of the Hydrogen Demonstration Facility at the H100 Fife Site. Enabling potential customers to engage with hydrogen gas appliances in support of their participation.

Element 7. Pre Construction Activities
Completion of SMF including third party review, completion of QRA, development of local operating procedures and delivery of training. Ensuring all required permitry and permissions necessary for construction are in place, including HSE. Finalise development and obtain specialist tooling and equipment needed for construction and operation of the H100 Fife Site and Network.

Element 8. Procurement
All required works, supply and services contracts will be procured in line with required construction and operational timelines.

Element 9. Construction
Complete the construction and commissioning of siteworks and distribution works. These works will be completed by experienced contractors procured via a competitive tender process.

Element 10. Customer Works
Carry out the required works in participating premises in line with the procedures derived in Element 7.

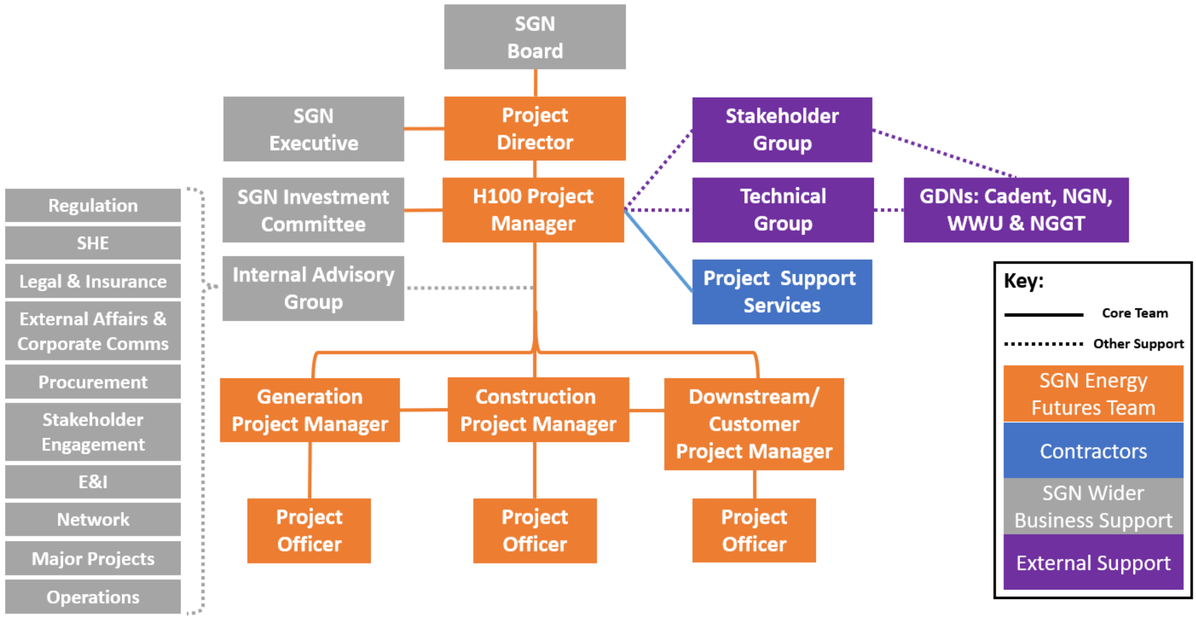
Element 11. Operational Phase
Commence operation and maintenance of the commissioned network and

implementation of developed LOPs. Validate network models. Utilise asset repository and records system. Gather data and optimise system operations.

Element 12. Project Exit Strategy
Assess project success and viability and prepare for enduring solution OR develop and implement decommissioning of the plant and network that minimises environmental and local community impact.

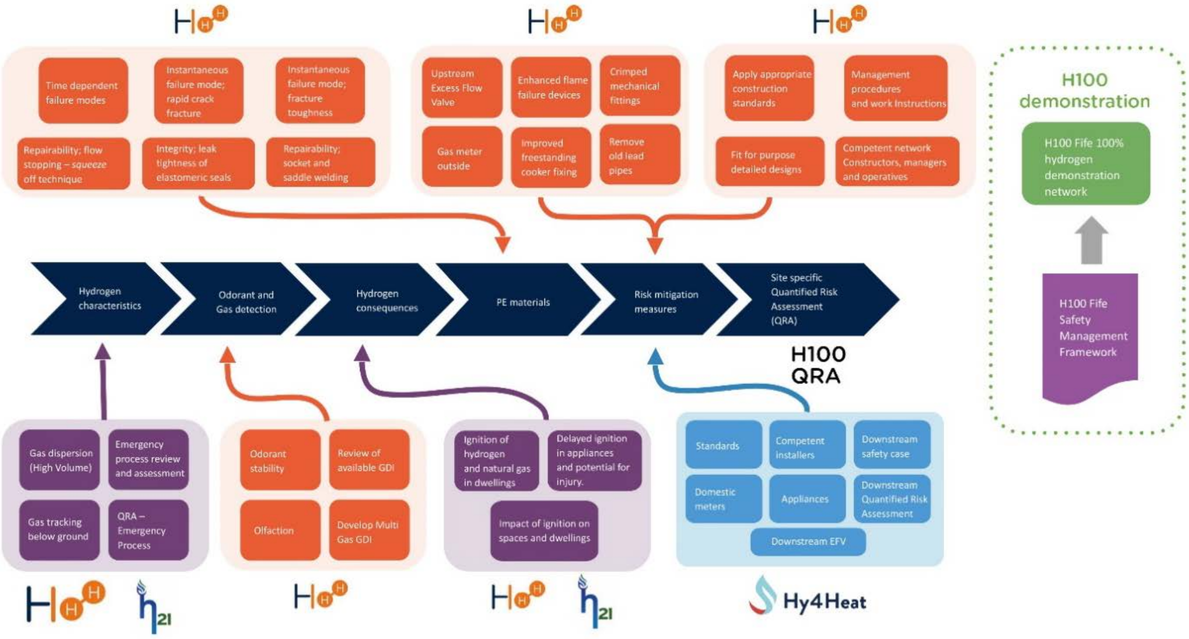
Element 13. Stakeholder and Comms
Execute the Stakeholder, Customer Engagement and Comms plans, utilising the Hydrogen Demonstration Facility to support engagement activities. Acquire customer participation in the trial via an opt-in process.

Project Organogram



H100 Fife organogram showing project governance and team structure.

Appendix J: Quantified Risk Assessment for H100 Fife



The safety testing and risk mitigation that has supported the development of the H100 Fife QRA, feeding into the overall H100 Fife Safety Management Framework.

This project is a key element of the evidential base case for deployment of hydrogen into a group of domestic properties in Levenmouth, Fife. It presents a comparative Quantified Risk Assessment (QRA) of the risks associated with a change in the gas supply for a group of domestic properties from natural gas to hydrogen, the hydrogen being supplied from a new low-pressure Polyethylene (PE) network.

This comparison of risk associated with a new hydrogen network when compared to the existing mixed material natural gas networks shows that the risks are broadly similar for both supply options, when taking into account the additional risk reduction benefits of the new PE network, an Excess Flow Valve installed on the service and the additional measures downstream of the Emergency Control Valve (ECV).

QRA approach:

- Assess the probability of a release from the network entering a domestic property
- Determine how a gas release (hydrogen or natural gas) will spread through a typical house
- Identify typical sources of ignition and the likelihood of them being active at any time of day
- Estimate the likelihood that each ignition source will ignite the gas release, taking account of the cloud concentration, the gas type and the likelihood of the source being active.
- Compare the overall likelihood of ignition of hydrogen and natural gas, taking into account risk reduction measures being considered for the hydrogen installation

Release probability

The key objective of the QRA is to assess the comparative risk across a range of credible release/failure cases. The first stage of this is to compare the likelihood of a release from the proposed H100 network (100% PE) with that for the currently installed NG network. To do this the following data was analysed;

- Gas Escape Data (5 year period)
- Hole Size Distribution
- Movement of gas and its ability to enter buildings
- Gas build up within buildings

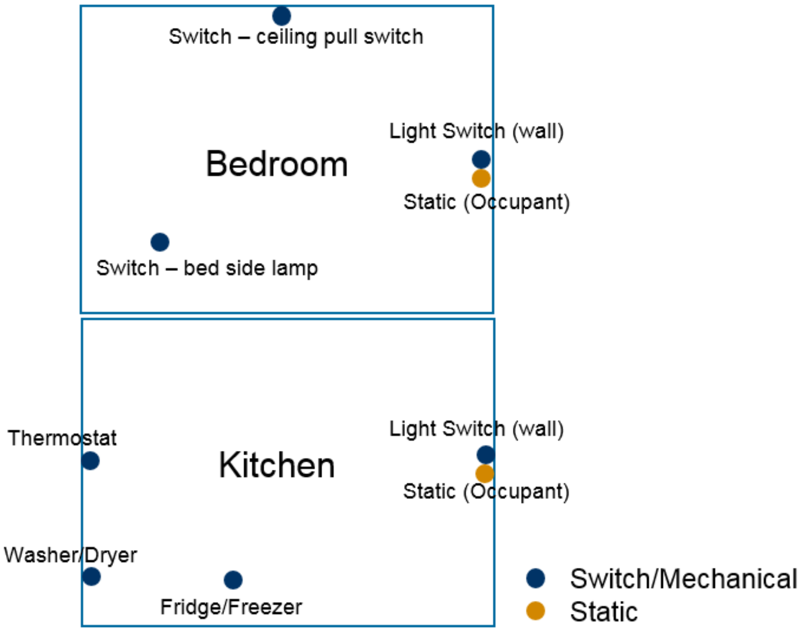
Gas Dispersion

This element utilised the results from Hy4Heat and H21 experiments carried out by DNVGL at the Spadeadam testing site in Cumbia and the KIWA HyHouse project in Scotland. These experiments at Spadeadam used purpose-built test-houses to investigate the spread of gas throughout the building from releases of both methane and Hydrogen.

Data from these experiments was reviewed to identify the concentration corresponding to significant sized clouds resulting from releases of different sizes.

Ignition Sources

Ignition sources were chosen as shown in the following figure.



It is assumed that no permanent ignition sources (e.g. naked flames or hot surfaces) are present. The likelihood of the ignition source being active has been averaged across the various time periods, assuming that a gas leak could occur at any time of day or night.

Probability of ignition

Work was carried out[47] to determine the likelihood of ignition being caused by typical domestic electrical equipment. Items were exposed to hydrogen or methane of varying concentrations to determine whether ignition would occur. These results were interpreted to give approximate ignition probabilities for varying gas concentrations.

Risk mitigation

Hydrogen deployment will necessitate the implementation of risk reduction measures on the network and in homes. Examples of risk reduction measures that will be implemented are listed below:

- Enhanced Flame Failure Device
- Crimp Fittings
- Move meter to outside
- Remove lead pipework
- Stronger flex pipe fixing

[47] "Ignition Potential Testing with Hydrogen and Methane" DNV GL Document 636105 Dated: 2020-01-20

- Rawl Bolts for cooker retaining chains
- Flow Limiting Valve – Upstream of meter
- Flow Limiting Valve – Downstream of meter

Comparison of hydrogen and natural gas

Applying the mitigation measures results in a reduction in the ignition probabilities for hydrogen and considering the measures to be 90% effective, the likelihood of an ignited release occurring is:

- Hydrogen – 4.1%
- Natural gas – 4.1%

i.e., the likelihood of ignited hydrogen events is approximately the same as ignited natural gas events.

<u>* It must be emphasised that some of these results are conservative assumptions based on dataset available and will be verified when Hy4Heat QRA is published.</u>

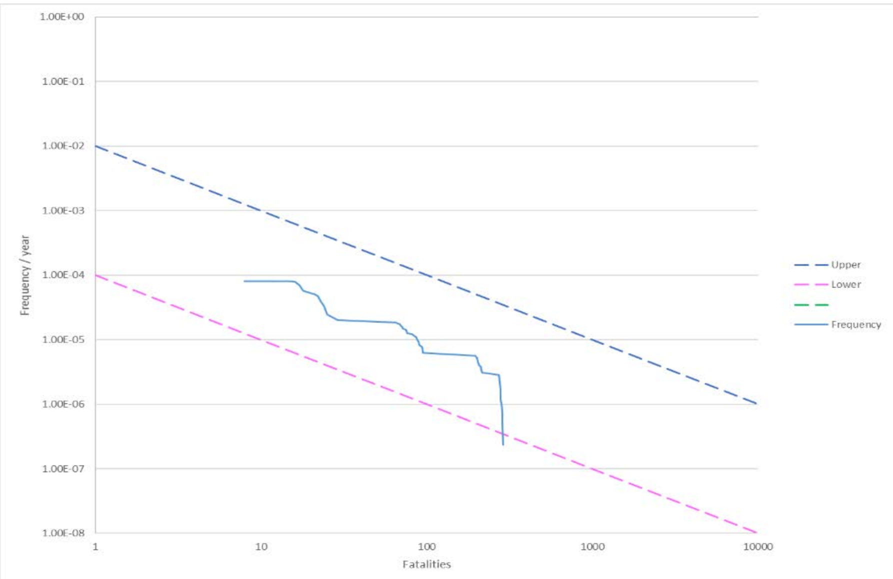
Storage and Production

The risks associated with the Hydrogen Storage and Production facility were calculated in terms of individual risk contours and societal risk (FN curve).

The consequences were modelled using Phast 8.11 software and were based on preliminary process data provided with hole sizes assumed to be no larger than 50.8mm (two inches). Consequences were modelled for jet fires, gas dispersion and explosions and the harm criteria's used were based on HSE guidance. It was conservatively estimated that there was a 50% chance that a release would be ignited, which will be refined as the project progresses.

Given the early stage of planning and design conservative estimates of part numbers and pipeline lengths have been assumed based on the proposed site layout. Generic leak frequencies used are based on OGP Data.

The LSIR contours and societal risk were calculated using RiskAnalytix software. The overall LSIR contour and the overall societal risk curve are shown below.



The LSIR contours and societal risk.

Appendix K: Project Participants Summary

Those marked with '*' have provided letters of support for the project, which can be made available separate from this submission.

Summary of H100 Fife Project Participants and their project input.

Name	Role	Input
SGN	Lead	Network Licensee Lead
Scottish Government*	External Funder	External Funder for the project (£6.9m).
Cadent*	Partner	Network Licensee, financial contribution, input into Technical Group & Stakeholder Group.
NGN*	Partner	Network Licensee, financial contribution, input into Technical Group & Stakeholder Group.
WWU*	Partner	Network Licensee, input into Technical Group & Stakeholder Group.
Baxi*	Partner	Provision of hydrogen boilers and maintenance package. Financial contribution to the interior dressing and design of one for the Hydrogen Demonstration Facility show spaces.
Bosch*	Partner	Provision of hydrogen boilers and maintenance package. Financial contribution to the interior dressing and design of one for the Hydrogen Demonstration Facility show spaces.
HyFires*	Partner	Provision of hydrogen fire appliances and maintenance package.
HyCookers*	Partner	Provision of hydrogen cooking appliances and maintenance package.
HSE Science Division	Supplier	Independent review of the Safety Management Framework.
ORE Catapult*	Supplier	Power provider, turbine operator. Inform electrical design. Input into the Technical Group & Stakeholder Group.
Scottish Enterprise*	Supplier	Landowner. Input into the Technical Group & Stakeholder Group.
Fife Council*	Supplier	Local authority. [redacted] Input into the Technical Group & Stakeholder Group.
SPEN*	Supplier	[redacted]
Scottish Water*	Supplier	Water supply for electrolyser and site utilities.
Kiwa*	Supplier	[redacted] Input into the Technical Group.
Arup	Supplier	Provider of planning, [redacted]. Input into the Technical Group & Stakeholder Group.

Name	Role	Input
DNV-GL	Supplier	Hydrogen Demonstration Facility design & build services. Safety Management Framework authorship.
ERM	Supplier	Compilation and assessment of the H100 Fife Quantified Risk Assessment
Hy4Heat	Supporter	BEIS programme for hydrogen appliance development. Alignment with downstream of H100 Fife system to include domestic hydrogen appliances, meters and ancillary equipment. QRA linkages.
NGGT*	Supporter	Network Licensee, input into Technical Group & Stakeholder Group.
GTC*	Supporter	Market leading independent utility infrastructure provider.
University of Edinburgh*	Supporter	Fulfilled Academic Partnership role under H100 NIA programme, academic review of H100 NIA reports, peer reviews & article publishing.
ENA*	Supporter	The industry body funded by UK gas and electricity transmission and distribution licence holders. Governance role for various network groups that SGN participate in.
ESP*	Supporter	Scottish body for energy, energy and construction skills collaboration across colleges and industry. Opportunities for joined up delivering of training, workshops and skills development.
EUA*	Supporter	Industry voice for future policy direction within the energy and utilities sector. Support knowledge dissemination and skills opportunity sharing with industry and political bodies.
Enertek International Ltd*	Supporter	Independent engineering research, design and development company specialising in gas, oil and electrical appliances. Consortium lead of HyFires and HyCookers under the Hy4Heat programme.
NPL*	Supporter	Delivered Odorant and Gas Detection for H100 NIA.
SHFCA*	Supporter	Project support and promotion via extensive national and international members list.
Diageo*	Supporter	A global leader in beverage alcohol, who has its largest packaging site in Leven and a distillery bordering Levenmouth, that is the largest and oldest grain distillery in Scotland. These are located 2km-3km from the H100 Fife Site. A potential future industrial demand beneficiary of future phases of H100 Fife (Phase 3).

Appendix L: Project Diagrams

[redacted]

The preliminary network design for H100 Fife.

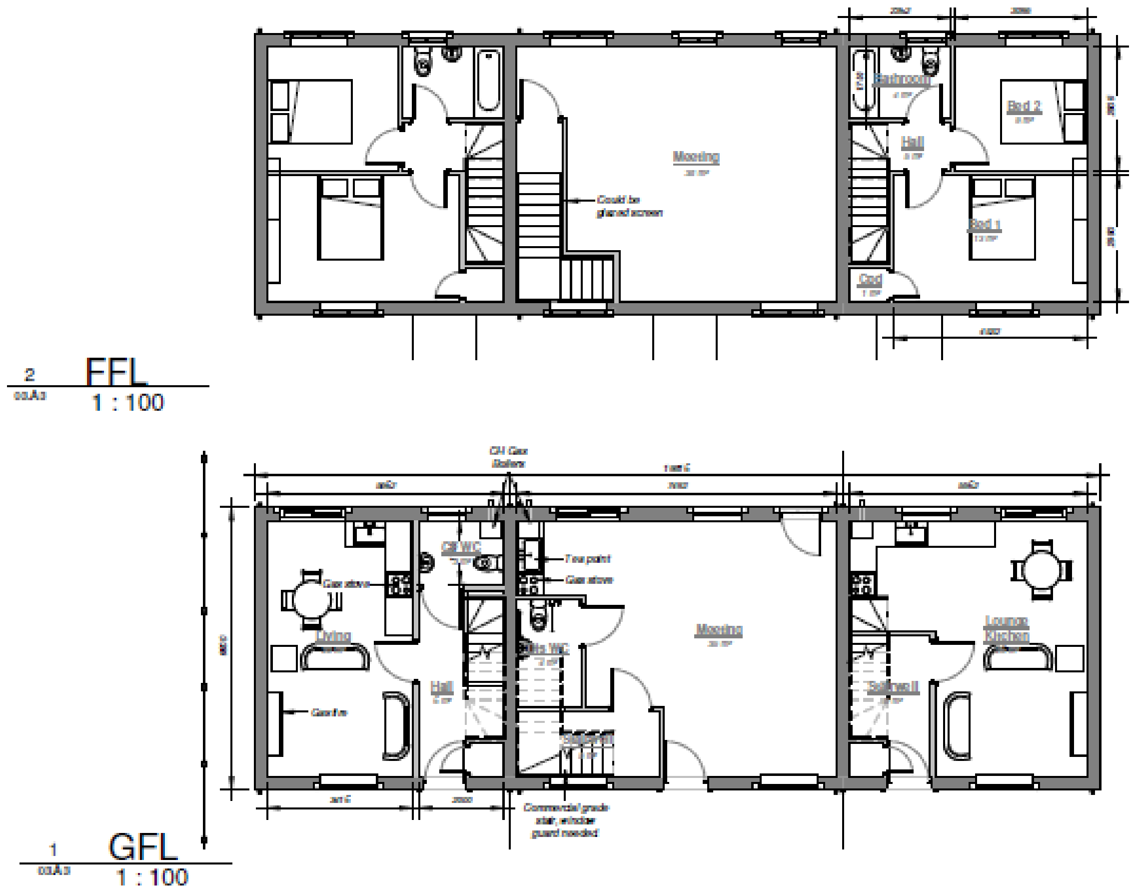
[redacted]

The H100 Fife Site boundary in red with the proposed access route in pink.

[redacted]

Indicative site layout.

[redacted]



Preliminary floorplan designs for the Hydrogen Demonstration Facility across the first floor (top) and ground floor (bottom) levels.

Appendix M: Future Expansion Opportunities

Phase 2: Expansion of Domestic Connections

- Expanding the number of customer connections to hydrogen in Phase 2. This could include a conversion of existing natural gas assets, forming one of the regional conversion demonstrations. This will provide annual emissions savings of 1,550 t CO_2, totalling 2,208 t CO_2/annum.

Expansion Opportunity 3: Industrial & Commercial

- There are currently 122 commercial and industrial MPRNs demanding 97 GWh of natural gas per annum. The decarbonisation of this gas demand will yield annual emissions savings of around 17,850 t CO_2. Total emissions savings will therefore be 20,058 t CO_2.
- Exploring integrating a hydrogen supply solution for industry through collaboration with Diageo, a global leader in beverage alcohol, who has its largest packaging site in Leven and a distillery bordering Levenmouth, that is the largest and oldest grain distillery in Scotland. These are located 2km-3km from the hydrogen production site.
- 52 manufacturing businesses operate in the Levenmouth area.
- Within Energy Park Fife is the renowned offshore jacket manufacturers BiFab, who have fabricated infrastructure for the offshore oil and gas industry as well as offshore wind turbines.
- Close to Levenmouth is the Coaltown of Balgonie anticline, that has the storage capacity to serve ~250,000 homes.
- Levenmouth Water treatment is nearby; there is future opportunity to generate hydrogen from wastewater.
- Options for utilising the oxygen for both fisheries and medical applications are also being explored.

Expansion Opportunity 4: Transport

- This phase of H100 Fife will encapsulate road, rail and marine transport over a larger area. This phase of H100 Fife is estimated on completion to save around 4,000 t CO2 per annum.
- Levenmouth was originally served by a rail link that was decommissioned decades ago. Funding has now been announced by Transport Scotland for reinstating the Levenmouth Rail Link. A hydrogen alternative to diesel or electric could be explored. This infrastructure upgrade will further improve the connectivity of Levenmouth with main routes and cities, as well as locally.
- Hydrogen powered haulage logistics also offers a possible transport opportunity, in addition to new or existing hydrogen fleet vehicles.
- As the site is located next to a marine port, there is the prospect for marine hydrogen transport or hydrogen powered vessels.

Expansion Opportunity 5: Whole Systems – Hydrogen Coast

- We deliver around 5 TWh of natural gas to Fife per annum – conversion of this demand to 100% hydrogen will reduce emissions by 860,000 t CO_2/annum. Further emissions reductions from the decarbonisation of electricity and transport through the whole energy system yields the projected Phase 5 emissions savings to be at least of the order of 1.5 Mt CO_2.
- Hydrogen could integrate with the power network, providing storage and supporting transport. There is an opportunity to expand on the 'East Neuk' project undertaken with Scottish Power Energy Networks to roll out whole system solutions.
- The roll of property connections could expand to supply an extended decarbonised east coast network.
- Mossmorran's Natural Liquid Gas and Ethylene Plant is located 25km from Levenmouth and produces industrial hydrogen as a by-product of ethylene

production. In addition, there is an existing liquid natural gas pipeline between St Fergus and Mossmorran.

- H100 Fife is proposing a fully green solution to hydrogen networks through electrolysis of hydrogen. However, in the future of heat the gas networks must adopt a technology agnostic view to the production of hydrogen. The inclusion of Grangemouth into the wider roll of hydrogen represents large scale decarbonisation through SMR production of hydrogen with carbon capture.
- With the input for electrolysis being derived from offshore wind, the hydrogen system at Levenmouth is demonstrating a world first power to gas zero carbon solution for heat.
- Hydrogen from offshore wind is a valuable process that is being demonstrated at Levenmouth opening a market solution for hydrogen production at scale.
- Neighbouring offshore wind activity off the coast of Fife is accelerating with Neart Na Gaoithe's 450MW wind farm and Cierco's 12MW-53MW development next to Energy Park Fife. Existing and future developments in the offshore wind market close to Energy Park Fife offer the opportunity for power integration for hydrogen production.
- Forth Ports are the main port owners of Fife, including those at Methil, Burntisland, Kirkcaldy, Rosyth and also neighbouring ports in Dundee and Leith (Edinburgh). Marine activity is still prominent in Fife and are key players in all tiers of the renewables sector. Marine applications are already being looked at by the hydrogen sector.

1 – H100 Fife
2 – Expansion Opportunity for Properties & Conversion
3 – Expansion Opportunity Industrial & Commercial
4 – Expansion Opportunity Transport
5 – Expansion Opportunity Whole Systems & Hydrogen Coast

Appendix N: Project Outcomes

Starting Point 2020				End Point 2027	
No 100% hydrogen distribution networks at demonstration stage.				**H100 Fife will be operational, distribution of 100% hydrogen derived from offshore wind to customer homes.**	
Subcomponent	**TRL**			**Outcome**	**TRL**
1) Commercial Framework	4	The existing commercial arrangements used for the SIU's were examined for suitability. Key gaps were identified in ownership, liability, regulatory and contractual structures. Future proof solutions were drafted for an enduring development value.	→	A commercial model in place that effectively navigates the barriers in the existing framework and operates an end to end system as required, managing interfaces with electricity networks, renewable generators, gas producers, gas transporter, shipper, suppliers and customers. Satisfying heat supply and demand with hydrogen and protecting customers from the increased demonstration cost of hydrogen. Informing future demand forecasting models by evidencing heat profile data of a hydrogen consumers with the electricity networks.	8
2) Regulatory Framework		The regulatory implications of distributing hydrogen gas as opposed to natural gas has been thoroughly mapped out with support from industry experts, legal representatives as well as academics. A regulatory solution that satisfies legislation has been identified.	→	Delivering a system that is safe, compliant and fulfils all licence obligations under a defined regulatory model. Assessment of regulatory spectrum of options provides analysis that is transferable to other networks. Sharing with Ofgem the barriers of existing legislation to delivering hydrogen for heat to customers.	8
3) Production via Electrolysis for heating purposes	6	FEED study R&D and early market engagement identified electrolyser technologies that can meet the demand requirements of the hydrogen network.	→	Electrolysis optimised to manage intermittency associated with wind turbine power generation, supported by back-up grid electricity. Matching wind data profiling to peaks in heat demand, optimising storage trends. 4.5 years reliability data of a power-to-gas electrolysis solution.	8
4) Production Facility Control systems & interfaces	4	FEED study R&D has mapped out a high-level control system, telemetry and asset repository requirements for further development in H100 Fife.	→	Control system integration developed to ensure safe operation, optimise production and storage of hydrogen, identify associated cost saving opportunities. Gather data on functionality during peak periods.	8

5) Gas Quality & Fiscal Metering	7	FEED Study R&D identified hydrogen certified gas quality equipment and fiscal meters available.		Validating hydrogen gas quality measurement on an operational distribution network. Correct energy calculations for billing customers accurately irrespective of increased volume of hydrogen compared to natural gas. Approved standard design and instrumentation.	8
6) Storage	6	FEED Study R&D identified high pressure storage vessels can be procured and built to required standards to satisfy regulations (PSSR / COMAH).		High pressure diurnal storage process proven and optimised for demand activated operation. Safety, security of supply and reliability proven over 4.5 years of operation to include 5 winters.	8
7) Odorisation	7	Odorant currently used in Natural Gas lab tested and proven to be suitable for Hydrogen gas in PE pipelines and end use.		Odorant NB validated by real-world data as suitable for a hydrogen distribution network. Providing a replicable configuration for hydrogen odorant injection.	8
8) Pressure Reduction	5	Pressure Reduction station bench tested and certified for 100% hydrogen but requires appraisal.		A hydrogen PRS functioning as required on an operational hydrogen system. Validation of design and materials specifications. Stress tested over 5 winters to prove safety and reliability. Evidencing suitability for commercial roll out.	8
9) Metering	5	Diaphragm meters recalibrated and tested which has proven the suitability of existing mechanical meters for small domestic loads as a fallback option if Hy4Heat Smart Meters are not available in time for H100 Fife. Smart meters developed under Hy4heat certified and ready in 2021.		Performance evidence of smart meters developed under the Hy4Heat programme. Meter marker scheme to identify hydrogen customers from natural gas customers. Opportunity to optimise smart functionality.	8
10) Distribution Network & Features	7	PE Materials – Pipe, jointing and repair techniques, flow stopping all lab tested and deemed suitable for hydrogen networks. Valves and connections will be hydrogen tested (as opposed to air as required in standards) before being procured.		PE materials and construction techniques validated on a live hydrogen network for at least 4.5 years. Interaction with other utilities including the existing gas network managed. Laid in parallel to the natural gas network to promote customer choice for the demonstration.	8

11) Excess Flow Valves	4	EFV's identified in the QRA as a risk mitigation measure and are currently in development. Certified EFV's will available for construction.	→	Excess flow valves fitted to all service pipes and reliability evidence over 4.5 years. Development of a new component that is market ready and a risk mitigation measure for hydrogen networks.	8
12) Hydrogen Gas Detection Equipment	5	A certified Hydrogen Detection Instrument built to industry standards is in development and will be available for construction.	→	Fully certified multi-gas detection instrument developed that is suitable for hydrogen. Extensive field validation over 4.5 years. Effective solution for operational procedures. Market ready product.	8
13) Operational Procedures	5	A review of SGN's full suite of standards & procedures complete to assess the changes required for constructing and operating a hydrogen network. National progression of operating procedures through H21 Ph2.	→	Full suite of Local Operating Procedures produced and approved through the project SMF, to include construction, emergency maintenance and repair designed specifically to ensure safe operation of H100 Fife Network. Suite can be used to inform operation of other hydrogen networks and be used to inform conversion procedures being developed in parallel.	8
14) Domestic Appliances	6	Boilers, cookers & fires developed and certified by Hy4Heat available for installation.	→	Operation of certified hydrogen appliances developed under Hy4Heat in a live demonstration. Reliability and efficiency performance monitoring data, stress tested over 5 winters, ready for full scale deployment. Customer interface and interaction information gathered.	8
15) Domestic pipe fixtures	7	Compression fittings, screw thread joints and crimped joints were tested and show a high resistance to heat and passed the joint integrity and leak tests.	→	Demonstrated domestic pipe fixtures are fit for purpose in safely delivering hydrogen to customers.	8
16) Safety Management Framework	6	Development of an all-encompassing hydrogen safety management framework from turbine tip to burner. The results from all the testing undertaken in H100 NIA will feed into the SMF, demonstrating to the HSE the risks have been identified and appropriate measures are in place to operate and maintain a	→	Delivering a 100% hydrogen network without the requirement for GS(M)R derogation by laying a new hydrogen network in parallel to the existing natural gas network. Independently assessed Safety Management Framework, risk mitigation measures in place and proven to be effective, operational techniques tested in the field without issue, site operations including maintenance deemed appropriate. Selected operational techniques, processes and procedures ready for deployment where deemed appropriate. A blueprint for HSE	8

		hydrogen gas network as safely as a natural gas network. Subsequently, an independent review of the SMF is underway to provide further assurance of the suitability of the SMF for H100 Fife.		engagement that can be used to inform the development of future hydrogen Safety Cases.	
17) Quantitative Risk Assessment	7	Extensive research and testing of the consequences & characteristics of hydrogen, Worst case scenarios of Gas in Building events and appliance failures investigated. Results feeding in to the H100 Fife Quantitative Risk Assessment which has identified appropriate risk mitigation measures to be put in place to reduce likelihood of events occurring. Testing from Hy4Heat & H21 feeding also being included in the QRA for a robust assessment.	⇨	Operational hydrogen network that validates the QRA and mitigation measures for an end to end hydrogen system in a real-world setting. Proven QRA to inform other hydrogen projects and conversion.	9
18) Competence & training	5	Development of a hydrogen competence and training framework in conjunction with the Hy4Heat programme that will guide SGN's training and competency requirements for H100 Fife.	⇨	Competent persons sufficiently trained for managing hydrogen networks. Using the Hydrogen Demonstration Facility to host hydrogen awareness and training courses. Providing a centre and legacy for hydrogen training. Upskilling Gas Safe Engineers to work with hydrogen networks and systems. Offering opportunities for the local workforce to be involved in domestic works programme. Integrating with education, industry and skills bodies to build transferable skills and embed hydrogen into learning and curriculum.	8
19) Policy Timing		Engagement with BEIS and Scottish Government to ensure the project is delivered in a suitable timeframe to allow the demonstration of hydrogen for heat to support Heat Policy Decisions.	⇨	Evidencing 100% hydrogen as a key step of the Gas Quality Decarbonisation Pathway, as part of Gas Goes Green and the UK's national hydrogen programme. Delivering an operational hydrogen network in 2022/23, providing evidence to support UK heat policy decisions for future energy solution(s).	

20) Customer Acceptance	5	Site specific customer support for decarbonisation technologies demonstrated in previous engagement studies. Commitment from Fife Council to provide social housing participation.		Promoting customer choice by offering customers the opportunity to opt-in to the project, rather than mandating a change to hydrogen in network area. A new hydrogen network in parallel to the existing natural gas network, evidencing unique information on customer appetite, acceptance and willingness to opt for a decarbonisation technology.	8
21) Social Acceptance	7	Key stakeholder engagement through H100 NIA has assisted in local government buy-in, strong stakeholder support & external funding to support H100 Fife (Scottish Government).		Engaging with a diverse group of stakeholders to deliver and inform the project, in turn providing valuable insight into social acceptance of hydrogen and willingness to support and act across a multitude of sectors.	8
22) Cross Vector knowledge	5	No proven understanding of the interfaces between networks for production of hydrogen from offshore wind directly, or through electricity network. No demonstrated understanding of electrolysis for heat or hot water requirements.		Fully evidenced impact using statistically representative customer data set (300 homes) to show impact of connection for planning.	8

There is a myriad of safety, technical, commercial, regulatory and operational aspects to this project which are being demonstrated. Due to space constraint, it is not possible to list them all here, however, we do have an extended and detailed project outcome database listing 115 project outcomes that can be shared widely, respecting and ensuring data protection of customers.

Appendix O: Regulatory Analysis

Due to space constraints, the full detailed analysis carried out by SGN & Addleshaw Goddard LLP (*H100 Fife Full Regulatory Analysis 14 October 2020, SGN & Addleshaw Goddard LLP*) for the regulatory positioning of H100 Fife is now available separately to this submission.

Appendix P: Signatory Page

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Background

A. the parties listed below ("the Parties") are Parties to the H100 Fife bid.

Acknowledgement and Agreement

The Parties have submitted this bid on the basis that they agree to provide their share of the mandatory 10% network licensees' contribution towards the NIC bid costs. If the bid is successful, the parties will sign contracting terms based on the arrangements typically adopted for collaborative Network Innovation Allowance projects.

All Parties have signed this Acknowledgement on the date set out below.

Signed by [redacted]

For and on behalf of **SCOTLAND GAS NETWORKS LIMITED** Authorised Signatory

Name John Morea

Position of Authorised Signatory CEO

Date 29-07-20 | 9:03 AM BST

Signed by [redacted]

For and on behalf of **SOUTHERN GAS NETWORKS LIMITED** Authorised Signatory

Name John Morea

Position of Authorised Signatory CEO

Date 29-07-20 | 9:03 AM BST

Signed by [redacted]

For and on behalf of **NORTHERN GAS NETWORKS LIMITED** Authorised Signatory

Name Mark Horsley

Position of Authorised Signatory CEO

Date 29-07-20 | 3:57 AM PDT

DocuSign Envelope ID: EF1CDDEB-AD44-45CE-A11E-5C60E37C8298

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Signed by [redacted]

For and on behalf of **CADENT LIMITED** Authorised Signatory

Name Steve Fraser

Position of Authorised Signatory Chief Executive

Date 29-07-20 | 11:11 AM BST

Signed by [redacted]

For and on behalf of **WALES & THE WEST UTILITIES LIMITED** Authorised Signatory

Name Graham Edwards

Position of Authorised Signatory Cheif Executive

Date 31-07-20 | 11:18 AM BST