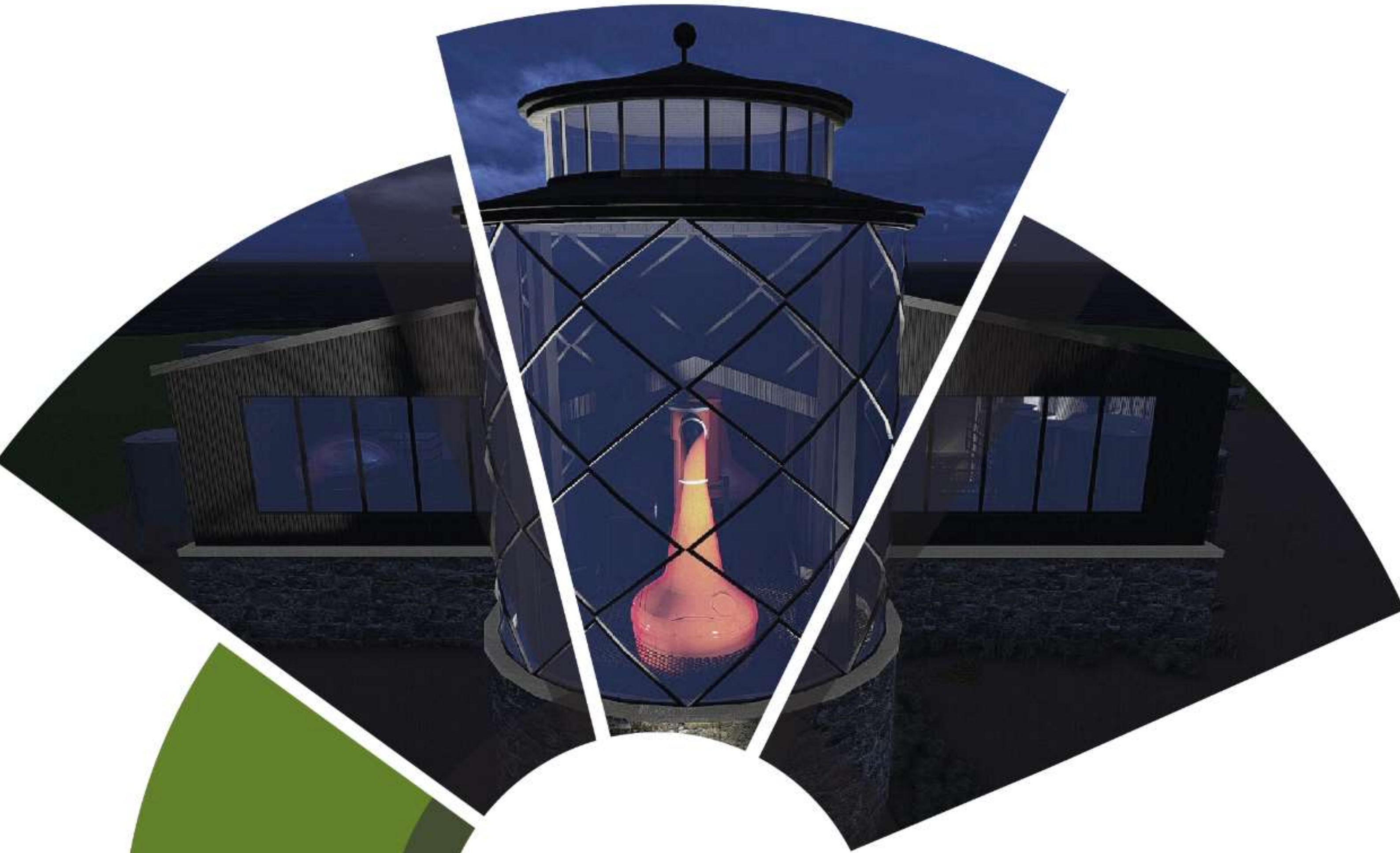

USING HYDROGEN TO HEAT THERMAL OIL TO REPLACE STEAM IN THE DISTILLATION PROCESS

BEIS GREEN DISTILLERIES PHASE 1 – GD141

THE UIST DISTILLING COMPANY LTD

Locogen | The Uist Distilling Company Ltd | Logan Energy

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Executive Summary

Locogen Ltd have partnered with Logan Energy Ltd to deliver a BEIS green distilleries Phase 1 project investigating the techno-economic feasibility of creating a new build distillery that uses hydrogen as the fuel for distillation with a thermal oil heating system, as opposed to a business as usual approach of burning oil to raise steam. The Uist Distilling Company have received planning permission for the development of Benbecula Distillery, North Uist and are committed to finding a low carbon distilling solution from inception. Benbecula Distillery was therefore used as a real world test case with which to conduct the feasibility study.

The technical solution found that will supply Benbecula Distillery with a zero carbon fuel is to produce hydrogen offsite, purchasing power from existing operational wind farms. There is sufficient renewable energy generated by single wind farms to supply adequate hydrogen for the distillery's fuel. The final design comprises the following elements:

- Babcock-Wanson TPC-1250LN thermal oil heater;
- 1,307 kW electrolyser;
- Compression skid; and
- 3 x 500 kg hydrogen trailer storage vessels.

Creating hydrogen by installing new wind generation was investigated but was found to be too high risk and cost. Creating hydrogen in the Western Isles for industrial use can be a catalyst for opening up of a wider hydrogen economy, which Comhairle nan Eilean Siar have investigated previously. Promising routes to market for hydrogen exist for large road and ferry transport and for other distilleries. The Western Isles can act as a blueprint for the hydrogen economy that can be applied to the UK as a whole and realise the Hydrogen Pathway to decarbonisation.

A thermal oil heating system, using mineral oil as the fluid, offers significant advantages over steam based systems and is an appropriate choice for integrating with renewable energy systems given the lower energy demands and heat storage capabilities of the fluid and more control over temperature and duration of heat dispatch. The use of a thermal oil distillation system is therefore recommended over steam for new build distilleries.

Combining hydrogen, created from renewable sources, with a thermal oil heating systems offers a wider application across other process heat industries such as chemical and pharmaceuticals. The principal barrier to offering this as low carbon solution is the availability of green hydrogen at a competitive price. Where renewable energy development can be situated close to site, there is a positive business case for creating hydrogen to fuel process heat and to sell excess to the expanding hydrogen market. As the UK dramatically expands its installed capacity of wind, particularly offshore, up to 2030 and beyond, the opportunity to create green hydrogen at a competitive price will become greater.

The purchase price of electricity to produce hydrogen is greater per kg than the price of fuel oil and therefore the overall running cost for the project was found to be greater than the business as usual case of using fuel oil in a steam system. Government policy is required to offer monetary reward for installation of low carbon heating solutions and a carbon emissions tax, or equivalent, to force cost parity and incentivise the increased take up of a low carbon heating solution, such as that which the project provides.

The project is calculated to save 874 tCO_2 per year and over **26,500 tCO_2** through a project operation of 25 years. There is a carbon emissions saving of **8.9 $kgCO_2$/£** of BEIS money spent and a saving in carbon emissions of **2.4 kgCO2/LOA** produced at Benbecula Distillery.

Glossary

AEM	Anion Exchange Membrane
BEIS	UK government Department for Business, Energy & Industrial Strategy
Capex	Capital expenditure
CCS	Carbon capture & storage
DNO	Distribution Network Operator
FECV	Fuel cell electric vehicle
FiT	Feed-in Tariff
GIS	Geographic information system
GSP	Grid Supply Point
HES	Historic Environment Scotland
HGV	Heavy good vehicle
HH	Half-hourly
HIAL	Highlands and Islands Airports Ltd
IRR	Internal Rate of Return
ISO	International Organization for Standardization
KPI	Key Performance Indicators
LEL	Lower explosive limit
LOA	Litres of alcohol
LPG	Liquified petroleum gas
MCB	Miniature circuit breaker
MCP	Medium Combustion Plant
MOD	Ministry of Defence
NATS	National Air Traffic Services
NPV	Net Present Value
OHLEH	Outer Hebrides Local Energy Hub
Opex	Operational expenditure
P&ID	Piping and instrumentation diagram
PEM	Proton Exchange Membrane
PSV	Public service vehicle
PV	Photovoltaic
ROC	Renewables Obligation Certificate
SAC	Special Area of Conservation
SHEPD	Scottish Hydro Electric Power Distribution

SPA	Special Protected Area
SPEN	Scottish Power Energy Networks
SNH	Scottish Natural Heritage
SSEN	Scottish and Southern Energy Networks
SSI	Site of Special Scientific Interest
SWA	Scotch Whisky Association
TUDC	The Uist Distilling Company Ltd
WTG	Wind turbine generator

Table of Contents

1. Project overview

The distillation process for most operational distilleries is fuelled by the raising of steam through burning of fuel oil or natural gas. This project will consider the opportunity for a new distillery to be designed as low carbon from the outset by providing heat for the distillation through a combination of a hydrogen burner and indirect heating of a thermal oil rather than a conventional steam system. Thermal oil heating systems offer many advantages over steam based systems and the combustion of hydrogen creates only heat and water as a by-product. There are therefore no carbon emissions associated with the burning of hydrogen. Hydrogen can be produced via electrolysis and the electricity for this can be sourced from renewable energy systems thereby making the hydrogen zero carbon, which is termed as 'green hydrogen'.

The project seeks to assess the feasibility of creating hydrogen offsite using pre-existing operational wind farms and transport to site. Creating of hydrogen onsite through installation of renewable energy generation will also be investigated. This project will explore the technical and financial feasibility for decarbonising the distillation process via the combustion of hydrogen combined with a thermal oil heating system, using the pre-construction Benbecula Distillery as a project demonstration site.

Benbecula Distillery is a new build distillery in Benbecula, North Uist at the pre-construction stage. Comhairle nan Eilean Siar have ambitions to develop the Western Isles into a region with extensive capabilities in hydrogen production, storage and distribution. How the new distillery could integrate with a wider regional hydrogen hub will be investigated. The techno-economic feasibility of such energy systems will be assessed and discussed in the context of national energy strategy and the transition towards a hydrogen economy.

The project is a Phase 1 project funded through the UK government Department for Business, Energy & Industrial Strategy (BEIS) green distilleries competition.

1.1. Project team

The Uist Distilling Company Ltd ('TUDC') are a special purpose vehicle set up to develop Benbecula Distillery. The owners of TUDC own the development land proposed for the distillery, which is on the island of Benbecula, North Uist. The owners are local and have operated in other business ventures in the area and within the drinks industry over many years. The distillery has received planning permission and initial architectural design has been completed. TUDC are eager to explore possibilities for supplying the distillery with a renewable energy solution so that the counterfactual usage of fuel oil can be avoided. TUDC are aware that low carbon and renewable options can be cost prohibitive and are therefore actively seeking grant funding opportunities to finance a low carbon option.

Locogen Ltd ('Locogen') are Project Manager for the project and have been responsible for overall delivery as well as technical and financial feasibility. Locogen is an independent renewable energy consultancy and developer with over a decade of experience in development, implementation and monitoring of renewable technologies. Locogen designs and delivers hydrogen, district heating, low carbon heat solutions, wind, solar and hydro projects and therefore has the understanding of challenges in developing and operating low carbon projects which enables managing the inter-dependency of multiple low carbon technologies that may comprise an optimal energy system.

Locogen have partnered with Logan Energy Ltd ('Logan Energy') for exploring the feasibility of hydrogen system design. Logan Energy specialise in delivery of integrated hydrogen engineering solutions including production, refuelling, storage, distribution, fuel cells and heat generation. They offer turnkey service from project inception and feasibility to design, development, manufacturing, installation, operation and maintenance. Logan Energy are manufacturer independent and are able to analyse and select any appropriate equipment based on proven experience in delivering hydrogen energy projects. A team of expert engineers and commercial professionals deliver optimally sized hydrogen systems to maximise future return on investment and have developed economic models that capture the evolution of hydrogen technology.

1.2. Aims and objectives

The project aims to design a green hydrogen energy system appropriate for a new build distillery. To do this, the following objectives were identified:

- Define Benbecula Distillery's expected energy use and distillation infrastructure for a thermal oil system rather than steam;
- Conduct a constraints mapping exercise for deployment of renewable energy technologies;
- Create costed engineering design for hydrogen based energy system;
- Undertake a route to market assessment for excess hydrogen production in the Western Isles;
- Conduct financial feasibility assessment;
- Identify risks to the project; and
- Create dissemination strategy.

1.3. Technology options appraisal

Prior to the undertaking of the Phase 1 project, a comparison of different low carbon technologies and energy systems was conducted that were applicable to a new build distillery. It was found that a hydrogen-based distillation process offers a novel technological solution to decarbonising distilleries that offers greater simplicity and replicability in comparison to other technology options as well as providing an opportunity to generate additional revenue through the selling of hydrogen as a by-product and tying into a wider hydrogen economy. The rationale for proposing hydrogen as a low carbon fuel is provided below in Section 1.3.1 with a discussion of alternatives in Section 1.3.2.

1.3.1. Technology proposed

This project is innovative in the technological solution proposed and unique in that it will be applied to a test case of a new distillery still at the pre-construction phase but with planning permission consented. The innovative engineering design utilises burning of hydrogen to heat a thermal oil which replaces the conventional raising of steam for distillation. The hydrogen burner will transfer heat to a thermal oil via a thermal fluid heater. The thermal oil will be pumped from the boiler house through the distillery to deliver the required heat for distillation. Indirect combustion of hydrogen and heating of thermal oil enables the hydrogen burner to be housed outside the distillery, making the installation highly flexible and not constrained by space.

Hydrogen

The use of hydrogen as a fuel source is well understood and has been proven in many industrial settings, however not in an operational distillery. The use of hydrogen at distilleries has been previously investigated, such as at Kirkjuvagr Distillery in Orkney through BEIS' HySPIRITS project (EMEC, 2019), but no commercialisation of a hydrogen fuelled distillery has been advanced.

Commercial hydrogen burners, boilers and storage vessel products are all readily available for using hydrogen as a fuel source. The creation of green hydrogen via an electrolyser is also an established process with readily available items on the market. The different components required to construct the engineering solution are off-the-shelf products and can be procured, constructed and installed with relative ease. This factor is a key advantage over other possible technological solutions to decarbonising the distilling sector.

Hydrogen can be burned either directly or indirectly to fuel distillation. The indirect process would be to burn hydrogen to either heat a thermal oil, as is the case being proposed, or to raise steam in a boiler. Combustion of hydrogen creates steam directly therefore this can be used for distillation rather than having the intermediate step of the boiler. The use of hydrogen burners, either direct or indirectly fuelling the distillation process, is extremely adaptable and scalable and can therefore be applied across the country to distilleries of differing sizes and geographies. The engineering design can also be applied to other industries using process heat.

Hydrogen is stored at pressure in vessels and can be readily dispatched as easily as current fossil fuel burners. The process for distillation is therefore unchanged with no disruption to operation or existing infrastructure. There will therefore be no impact on the quality of the end product. The combustion of hydrogen creates only heat and water as a by-product. There are therefore no carbon emissions associated with the burning of hydrogen.

Renewable energy can be used to produce hydrogen through electrolysis. The switching from fossil fuels to hydrogen offers the exciting opportunity for integration of renewable power into the distillation process to fully decarbonise the distillery. Renewable sources of power can be obtained through development of onsite renewables, through potential private wire arrangement from nearby operational assets or importing via transported containers from production elsewhere.

Thermal oil

The heat transfer medium for the distillation process is proposed to be a thermal oil rather than conventional steam. Steam systems have been commonplace in the distilling industry for many decades, however these systems are far from optimal in comparison to thermal fluid heaters. Thermal fluid heating systems are very similar to conventional wet heating systems that use water, for example in domestic central heating systems. Thermal fluid burners are used in a number of industrial applications that require high temperature process heat, such as pharmaceutical and petrochemical industries but have yet to be utilised in a commercial distillery setting. One of the main differences between the thermal fluid heat distribution system and a steam one is the requirement for a pump to transfer the fluid around the system, whereas a steam system uses valves and compressors to alter the pressure of the steam to transport around the piping circuit.

Mineral oil would be used as the thermal oil in a closed-loop heating system. Unlike with pressurised steam systems, no phase change takes place with mineral oil as it can be heated up to 350°C and can be cooled to minus 20°C. Mineral oil has a lower specific heat capacity than water and it therefore takes less energy to raise the mineral oil a given temperature. The energy input into the heating system, to deliver the required heat for distillation is therefore less than with steam systems. Additionally, the thermal conductivity of mineral oils is higher than steam, given that it remains in liquid form rather than transforming to a gaseous state. Heat is therefore transferred to the stills more efficiently. Less energy requirements offers savings in associated carbon emissions, with the same fuel used in both systems, and financially.

The pump system means that the system is easily controllable and operable. Heat supplied to the distillation system can therefore be controlled more effectively, meaning that the desired temperatures and durations are applied at the required sections of the process. Steam systems' heat is often wasted through continual raising and condensing to alter the temperature. The thermal oil heating system is compact and requires less space than equivalent steam systems in the majority of cases.

1.3.2. Alternative technologies

Heat pumps also present a low carbon option for distilleries, and potentially have smaller energy demands due to the compressor efficiencies. Systems have been developed which are able to raise steam, but at lower pressures than the design of most currently utilised stills, which therefore require refurbishment or replacement of the still. Where high temperature systems are available, they are also not able to operate with rapid ramp rates utilised on most current distillery processes, and therefore require either large steam accumulators or modifications to the process methodology. Depending on the type of heat pump to be used, site specific conditions may limit the utilisation of industrial heat pumps across the industry.

Biomass and biofuel systems have also been utilised on other distilleries to reduce carbon emissions in replacement of oil-fired steam systems. Fuel supply and transport is a key limiting factor in the feasibility of these schemes, and both still have considerations related to local air quality. The low carbon credentials of these fuels are also questionable as they must be sourced from sustainable plantations. Though such a system may work for a single distillery, the scale up would demand excessive quantities of land and would have the potential to create significant land use conflicts. Lack of available land within the UK to support wide adoption of biomass and/or biofuels in the distilling sector would lead to sourcing offshore which would result in increased carbon emissions from transport and would not add any value into the UK economy.

Electric steam boilers are another option for decarbonisation to switch distillery energy dependence from fuel oil to electricity. When using commercial electricity rates, the running costs for this option is however extremely expensive. The carbon savings are also modest given the equivalent carbon content associated with grid imported electricity at present, although this will reduce over time. Onsite or private wire electricity from renewable energy sources could be used to provide zero carbon electricity, however the intermittency of the resource would require an onsite electrical battery. Such a battery system would be an extremely expensive means of decarbonising the energy system. The round-trip efficiency of the best performing and cost-effective battery solutions are approximately 75% which then has to raise steam through an electric boiler leading to further inefficiencies. The overall efficiency is therefore considerably lower than for a hydrogen boiler solution. There is also the risk of extended downtime of renewable energy generators onsite or via the private wire meaning the requirement for expensive grid import and/or fossil fuel back-up generation.

2. Feasibility results and conclusions

2.1. Modelling

2.1.1. Baselining energy use and operation

Benbecula Distillery is a new build distillery and therefore a true demand profile is not available. Instead, an estimate of the energy demands based on proposed sizing of equipment and operating schedule was made. The distillation process is to be on an eight-hour cycle, which is common within the industry, and is to comprise a single mash. In the first three years of operation, new distilleries often operate at a reduced capacity in order to minimise costs before producing a product that can be sold. One of the requirements for a product to be labelled as scotch whisky is the need for the spirit to be matured for a minimum of three years in oak barrels. It is after this point that distilleries are able to sell a signature single malt scotch whisky and overall production and energy consumption increases.

The energy system must be sized to deliver the required energy for the distillery when it is at peak operation, from the design outset. Benbecula Distillery, based on a thermal oil design, is estimated to have an energy demand of approximately 4,266 MWh/a, with a peak delivered load of 538 kW.

2.1.2. Energy flow modelling

An annual primary energy demand profile was created subsequent to the above energy demand assessment. The volume of hydrogen required to supply this annual demand was then also calculated. This was compared to the volume of hydrogen that could be created from different renewable energy sources. The opportunities and development restrictions to installation of onsite renewable energy systems were identified through undertaking of a constraints mapping exercise.

The volume of hydrogen produced for different sizes of new and existing wind developments and electrolyser sizes were modelled. An optimisation process was conducted that assessed adequate storage size for maximising provision of hydrogen throughout a year but keeping within reasonable scale for site availability and risks. From this analysis, the optimal technical solution could be determined, as presented in Section 2.2.

2.1.3. Financial modelling

A financial model was created for the project which calculated financial key performance indicators (KPIs). These include internal rate of return (IRR) and net present value (NPV) against the counterfactual business as usual scenario. IRR and NPV were modelled over 10 and 25 year periods and a payback period calculated for invested capital expenditure (capex). Other KPIs included carbon emissions abated, reduction in operational costs, cost saving per litre of alcohol (LOA) produced and carbon saved for the capital invested.

The model is built on a monthly resolution over the project lifetime. Capex and opex are inputted along with other assumptions, outlined in Appendix B. The results from energy flow modelling and revenue generated through export of excess generation to the grid were also inputted into the model. The heat and power demands satisfied by different sources were defined under the project and business as usual scenarios. The month when capex is spent is defined for each of the capital elements, which also then defines what month opex costs begin to be incurred.

The running costs relative to business as usual, including revenue generated, is calculated on a monthly basis and this is combined with the capex to calculate a monthly nett cashflow profile along with a cumulative cashflow profile. From these profiles, IRR, NPV and payback years can be calculated for the project. The starting month for the IRR, NPV and payback years calculations is defined by the first month of capex spend.

2.2. Technical solution

Locogen and Logan Energy conducted an options appraisal and feasibility study for providing green hydrogen to the distillery. Following on from these works, the optimal technical solution comprises the below elements. This solution involves the installation of an electrolyser at a neighbouring wind farm site to produce hydrogen, which would then be transported to site.

- Babcock-Wanson TPC-1250LN thermal oil heater;
- 1,307 kW electrolyser;
- Compression skid; and
- 3 x 500 kg hydrogen trailer storage vessels.

2.2.1. Costs

The total estimated capex for the proposed optimal solution is £3,167,700. An electrolyser stack replacement cost will occur over approximately 10 years, which is included in the financial modelling but is not part of the project capex outlay. Opex for the additional installed components and transport requirements is estimated to be £63,354. A breakdown per capex item is provided in Table 1 below.

Cost Item	Breakdown	Cost	Total
Capex	Thermal fluid boiler system	£245,000	**£3,167,700**
	1,307 kW electrolyser	£1,307,700	
	Compression skid	£225,000	
	3 x 500 kg hydrogen trailer storage vessels	£900,000	
	Design	£255,000	
	Ancillary hydrogen infrastructure	£235,000	
	Stack replacement cost	£1,718,318	Over 10 years

Table 1: Project capex

2.3. Financial & carbon assessment

The counterfactual annual spend on energy is calculated to be £268,711. Cost of energy for the technical solution is estimated to be £415,237. Even with the capex for the project provided through grant funding, it is apparent that there will be no payback or return on investment. Financial analysis calculated that an equivalent increase in fossil fuel price of 60% (through taxation, price rises or combination with incentives for using low carbon heat) would result in running cost parity between the hydrogen and burning fuel oil scenarios.

Hydrogen offers greater fuel security over the long term than oil. This greater security will enable TUDC, and any other distillery or business owner, to more easily forecast long term expenditure and cashflow. For whisky distilleries especially, having an accurate long term forecast of running costs is extremely important given the time it takes to create a market ready products.

The project is calculated to save 874 tCO_2 per year and over **26,500 tCO_2** through a project operation of 25 years. There is a carbon emissions saving of **8.9 $kgCO_2$/£** of BEIS money spent. With the social value attributed to this carbon emissions abatement and the return on investment for BEIS over the project lifetime, this represents a positive investment for the UK government in its carbon emission targets and the green economic recovery.

3. Demonstration project description

Following on from the Phase 1 feasibility study, Phase 2 will be critical for testing the hydrogen burner and boiler infrastructure and ensuring that the storage vessel’s piping connection to the electrolyser and burner works seamlessly and integrated correctly with the site’s electrical and water infrastructure. Figure 1 below displays a schematic of the whole project energy system, which has been designed by Logan Energy and their subsidiary H2Tec. The option of expansion for a hydrogen refuelling station is shown to illustrate how low carbon transport could also be integrated into the system. Phase 2 will be conducted at the consented site for Benbecula Distillery, which is shown in Figure 2.

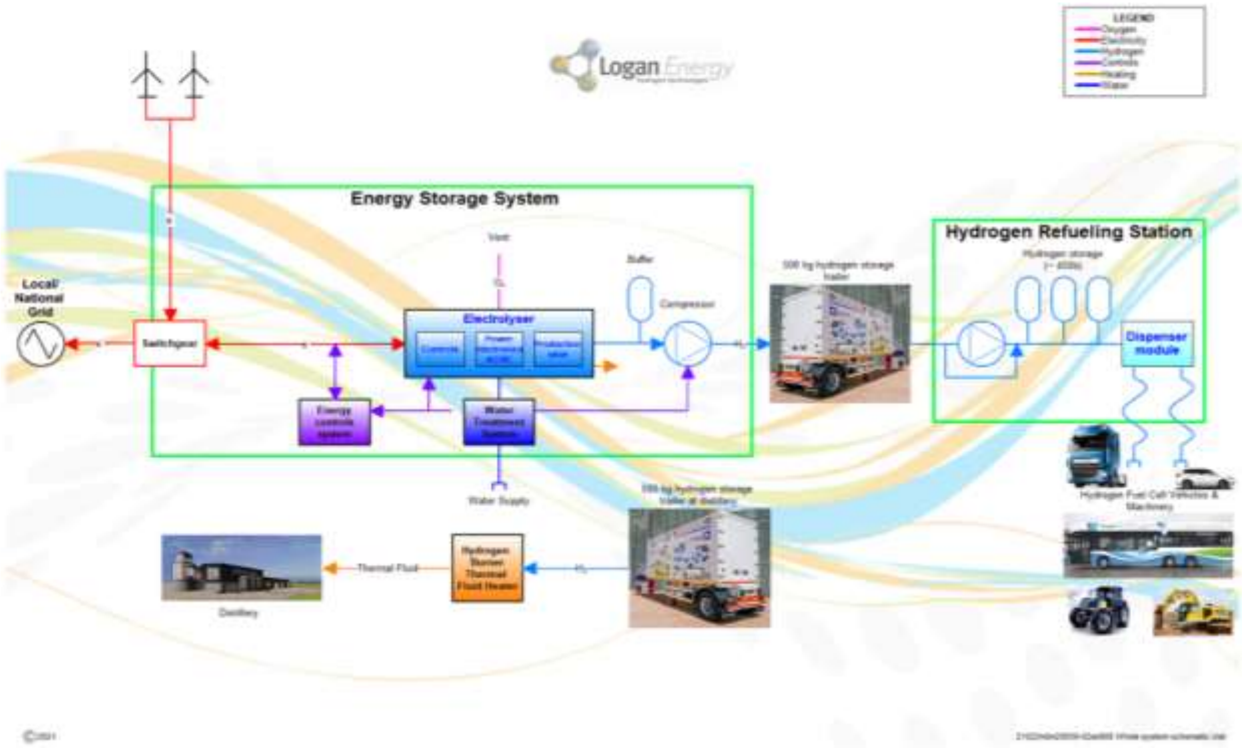

Figure 1: Project energy system schematic

Figure 2: Project site location and red line boundary of TUDC land ownership

Hydrogen will be produced via electrolysis using power from an existing operational wind farm. The electrolyser will be situated adjacent to the wind farm along with a storage trailer. The storage trailer will be transported to the distillery when full, where a second trailer will then be transported back to the electrolyser to refill. This ensures that hydrogen is being used and stored simultaneously.

The hydrogen trailer will be situated in a controlled zone next to a hydrogen panel and this will provide hydrogen to a thermal oil heating system. The thermal oil heating system comprises a heat, fan, controls, safety equipment and thermal fluid tank. The thermal fluid will be a mineral oil and will deliver heat for distillation via the distillery's pipework. Where insufficient levels of hydrogen are available as fuel, back-up fuel is compatible with the thermal oil heating system to ensure continuation of production.

4. Design for demonstration project

The installation consists of an electrolyser, compression skid and hydrogen trailer storage. The electrolyser and compression skid are a modular system and can be easily adjusted for site specific requirements. These are packaged units that are designed, assembled and tested off site to minimise on site operations. Trailer access and parking will be needed at the wind farm and on site at the distillery. The hydrogen storage may be provided either by a number of high pressure cylinders, tubes or bundles manifolded together or by medium pressure vessels. The storage of hydrogen will need to satisfy the minimum safety distances from other objects as recommended in BCGA CP31 (BCGA, 2015). These are shown in Figure 3, with numbers denoting the minimum required distance. A firewall can be used to reduce the recommended safety distances but there is anticipated to be adequate space onsite to ensure safe distances without such measures.

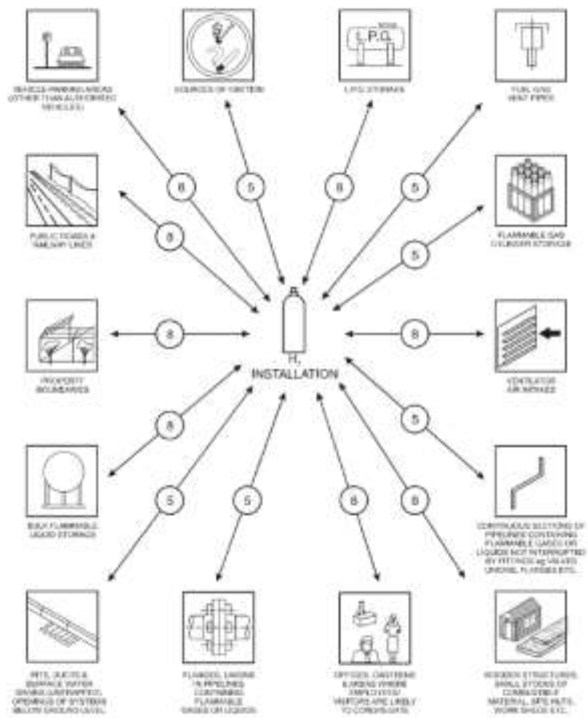

Figure 3: Minimum recommended safety distances from hydrogen (BCGA, 2015)

4.1. Electrolyser

An alkaline electrolyser, using a highly concentrated alkaline electrolyte, is the preferred option for the final design based on cost and reliability. The electrolyser will have a total installed capacity of 1,307 kW and be housed in 2 x 40ft ISO (International Organization for Standardization) containers.

4.2. Compression, storage and transport

Alkaline electrolysers produce hydrogen uncompressed at 30 bar. The compression skid will compress the hydrogen from the electrolyser from 30 bar to 300 bar allowing for high pressure hydrogen trailer storage. The compression skid will be installed in a 20 ft ISO container and the storage within will comprise of 3 x 30 ft trailers with capacity of 500 kg hydrogen. The compression skid will include the miniature circuit breaker (MCB) to control the storage.

4.3. Thermal oil heating system

The thermal oil heater will be manufactured by Babcock-Wanson, who also previously designed a thermal oil heating system for BEIS' HySPIRITS project (EMEC, 2019). To deliver the required heat load, a TPC-1250LN heater was recommended by Babcock-Wanson. The package includes a hydrogen burner, ATEX rated fan, controls and safety equipment and is designed for low NOx (nitrous oxide) emissions. A design schematic for the proposed thermal oil heater is displayed in Figure 4, with dimensions provided in Table 2. The heater will have a maximum continuous rating of 750 kW and the thermal fluid tank will have a capacity for 1,247 litres of oil. An example of a Babcock-Wanson thermal fluid heater is shown in Figure 5.

Dimension	A	ØB	C	D	E	Ø
Length (mm)	2,150	1,743	1,970	3,105	4,105	424

Table 2: TPC-1250LN dimensions

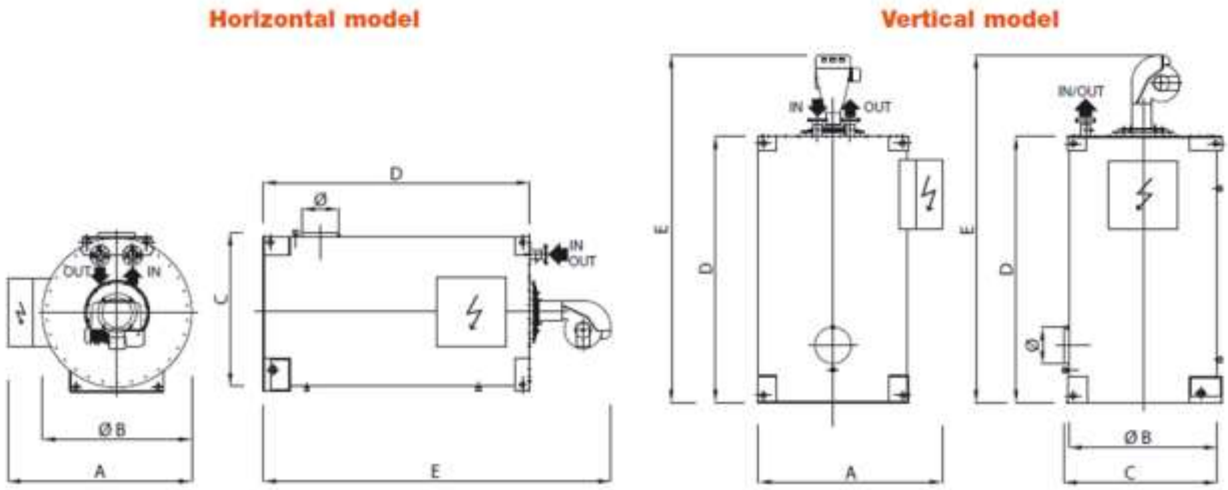

Figure 4: TPC-1250LN thermal fluid heater schematic

Figure 5: TPC-LN thermal fluid heater

4.4. Hydrogen fire and detection

Hydrogen detection and ATEX extraction fans will be installed at roof level of the room containing the thermal fluid heater to ensure there is no build-up of hydrogen. At 20% lower explosive limit (LEL) of hydrogen the system is designed to shut down and the fans will extract any build up of hydrogen. At 40% LEL of hydrogen, an emergency stop will be triggered and power will be cut to all equipment except for the ATEX extraction fans. Fire detection will be installed and in the event of fire, all systems will be shut down and the fans will not be permitted to operate.

4.5. Hydrogen piping system

The hydrogen pipework will be made of 316 stainless steel tubing, assembled with compression fittings. There will be no welded joints in the pipework. The hydrogen stored at 300 bar will be reduced to <500 mbar before entering the boiler room containing the thermal fluid heater. The piping system will include the following components:

- Hose connection to the trailer;
- Shut off valve;
- Pressure regulating valve;
- Safety relief valve;
- Pressure gauge and transmitter;
- Temperature sensor; and
- Flame arrestor.

5. Benefits and Barriers

5.1. Benefits

5.1.1. Energy reduction

The thermal oil distillation system leads to an overall reduction in required energy of 5% compared to a steam system, taking a conservative estimate. It is estimated that the thermal oil distillation system would save approximately 251,000 kWh of energy use per year.

5.1.2. Carbon reduction

If Benbecula Distillery were to install a business as usual fuel oil burner and boiler to raise steam, it is calculated that there would be approximately 1,210 tCO_2/a of carbon emissions once at full production. The plan for this hydrogen-fuelled distillery is to use hydrogen produced via electrolysis from renewable energy. By using hydrogen as the combustion fuel in place of fuel oil, there is no carbon emitted by the heating system. There are also no harmful nitrous oxides produced in the hydrogen combustion process in contrast to the combustion of hydrocarbons. Over the course of 25 years, the distillery would abate a total of 26,552 tCO_2.

5.1.3. Thermal oil heating system

As well as savings in energy, the thermal conductivity of mineral oils is higher than steam and heat is therefore transferred to the stills more efficiently. The pump system means that the system is easily controllable and operable. Heat supplied to the distillation system can therefore be controlled more effectively, meaning that the desired temperatures and durations are applied at the required sections of the process. Steam systems' heat is often wasted through continual raising and condensing to alter the temperature. The thermal oil heating system is compact and requires less space than equivalent steam systems in the majority of cases. Another benefit of heating via thermal oil is that it can enable the hydrogen burners to be sited away from the point of use for the heat, removing design constraints set by the location of the hydrogen systems.

The proof of concept will enable the technology to be applied at other distilleries that are at the pre-construction stage which could readily install the indirect hydrogen burner solution, establishing the design as a blueprint for new distilleries. In addition to distilleries, other industrial processes that use heat such as factories, chemical plants and processing plants will be potential applications for the technology.

5.1.4. Technology readiness level

The different components that make up the engineering solution are all well established commercial products. The innovative approach to this project is combining these different components to provide a zero carbon solution to process heating in a distillery setting. This project therefore benefits from offering a novel and innovative approach to decarbonising the distilling sector whilst minimising risk due to untested and untried technology components. The hydrogen infrastructure components that will be installed at the project are all readily available from multiple different manufacturers. This includes hydrogen burners (also capable of burning fuel oil and biodiesel), boilers, storage vessels and electrolysers. The creation of green hydrogen via an electrolyser is also an established process and the use of wind power to provide the renewable energy for this is well understood.

Thermal oil heating systems are utilised in many industrial applications that require process heat such as pharmaceutical and petrochemical industries. The burners, thermal store, pump, mineral oil variants and distribution systems are all well understood commercial products and there is a well established supply chain of components from manufacturers and turn-key designers. The application of thermal oil heating systems to a distillery has been investigated at a research level but has not yet been applied at commercial scale within a distillery.

5.1.5. Future-proofing

Having an energy source created locally greatly reduces the risk of external factors determining the price and availability of supply. Fossil fuel prices are extremely volatile and uncertain. They are tied to external political influences and it can be hard for a business to financially plan for the future if they are dependent on fossil fuels. With the ever increasing pressure on governments to take further action to decarbonise and replace fossil fuel reliance there is also a future risk of increased costs of emitting carbon, purchasing fossil fuels, omission from future certifications marking carbon credentials and the possibility of an outright ban.

5.1.6. Replicability

The use of hydrogen burners for providing heat is easily replicable and scalable. Switching existing distilleries to hydrogen burners can therefore be applied at distilleries of all different sizes and geographies. Thermal oil heating systems are compact in comparison to steam systems and therefore offers a solution that will have minimal retrofit disruption for distilleries that are run using steam. Existing large industrial consumers that use thermal oil heating systems can use hydrogen to provide the heat to further displace fossil fuels across wider industrial settings.

BEIS identified industry as being the second largest contributor to annual greenhouse gas emissions (after transport) with approximately 110 tCO_2/a (BEIS, 2019). The combination of hydrogen burners with thermal oil systems presents an enormous opportunity to greatly reduce the associated emissions from industry through displacement of fossil fuels. To produce green hydrogen on this scale will require a rapid increase in offshore wind generating capacity, which is discussed further in Section 7.2.1.

5.1.7. Cornerstone development of Hydrogen Hub in Western Isles

By both generating and consuming hydrogen, this development will incentivise the roll-out of a hydrogen hub in the Western Isles which is an ambition of Comhairle nan Eilean Siar as the local authority. The Western Isles can be regarded as a microcosm for the UK, with excellent renewable energy resources but no established route to market for hydrogen production. The Hydrogen Pathway is one of the principal ways for the UK to hit its Net Zero 2050 target, which is presently touted to provide low carbon energy for industrial processes, transport and heating.

Offering a viable route to market through fuel switching distilleries to hydrogen will accelerate the transition towards a hydrogen energy economy. The Committee on Climate Change identify potential industrial opportunities for the UK from being an early mover in sectors such as engineering of low-carbon technologies with benefits of exporting knowledge, productivity and employment (CCC, 2020). The integration of the project with a hydrogen economy in the Western Isles and the wider UK is discussed further in Sections 7 and 8.

5.1.8. Economic & social

The project will provide jobs in the construction and maintenance of the technical solution. The hydrogen economy that will be instigated by the proposed solution will lead to an increase in economic activity that will be reinvested in the local economy and stand as a blueprint for the rest of the UK.

A recent survey by Scottish Renewables found that over 75% of offshore oil and gas workers would be willing to move to the renewables sector but that there are limited opportunities to do so. Additionally, 91% of respondents had not heard of the term “just transition”. A hydrogen economy would have an enormous benefit to the UK economy by finding skilled workers jobs in industries that help in achieving climate change targets, ensuring a just transition by protecting vulnerable workers.

The Arnish fabrication yard in Lewis supports approximately 50 jobs and is an important employer in the Western Isles. The yard is owned by InfraStrata after taking over from previous owners Burntisland Fabrication (BiFab) who entered administration. A similar fabrication yard, that was also previously mothballed, Port of Nigg on the Cromarty Firth is exploring the use of green hydrogen to power process machinery for assembling and constructing offshore wind farms. The North of Scotland Hydrogen Programme has also recently been announced to create a green hydrogen hub in the wider Cromarty Firth region which may eventually include the Port of Nigg. The creation of a hydrogen economy in the Western Isles could be used to mimic this project which will safeguard the future of the yard and its associated jobs.

The advancement of the hydrogen economy will have important international consequences for the UK. The Committee on Climate Change identified potential industrial opportunities for the UK from being an early mover in hydrogen engineering and technologies with benefits of creating a local supply chain and exporting product, knowledge and creating jobs.

Benbecula Distillery is committed to enhancing the local economy by providing 25 fulltime jobs including highly skilled engineering and management jobs. Many further jobs will be created in the distillery construction and 60-70 indirect jobs in the supply chain including crofters, transport, hospitality, accommodation and retail. The low carbon solution will be a key part of the distillery tours and overall story to promote sustainability to visitors and consumers. The interest that will occur as a result of this, following on from the dissemination strategy (Section 9), will have an enormous wider economic impact for the area with visitors bringing positive economic impacts for the islands in terms of accommodation, restaurants, cafes, crafts and recreation. The local tourism industry has been decimated due to ongoing lockdown restrictions imposed during the COVID-19 pandemic. The project creates an opportunity for the local area to benefit from the UK government's Green Recovery strategy to boost the local economy whilst aligning with national carbon reduction targets.

In addition to the positive economic impact, there will be an enormous wider positive social impact with greater employment opportunities leading to population retention and growth. The creation of a low carbon distillery and hydrogen economy will be a catalyst for retaining native young people on the islands and encourage them to bring up their families, thereby safeguarding the islands' culture, language and identity.

5.2. Barriers

A number of potential barriers have been identified by the project partners and these are discussed below.

5.2.1. Reliance on third-party for supply

The hydrogen will be created at the site of an existing wind farm, owned and operated by a third party. Although preliminary conversations have taken place regarding the supply of energy in principle has been welcomed, there is still a risk that a formal agreement is not reached on the supply and purchase of power. Once the project is operational, there is the additional reliance on ongoing efficient operation and maintenance of the wind farm. The wind farm is susceptible to grid outages and in this situation the windfarm would be offline. The DNO can also require the windfarm to curtail the export of electricity onto the grid network to meet operational constraints. Under these conditions the production of hydrogen may be able to continue.

5.2.2. Financial

The required infrastructure cost is outwith the finances available to TUDC and would require grant funding. Due to the production of hydrogen being offsite and needing transported, three trailers are required to ensure seamless supply which increase the costs relative to onsite production. The energy costs to produce hydrogen exceed that of using counterfactual fuel oil.

5.2.3. Planning

Benbecula Distillery itself has acquired planning permission for the development of the distillery. Planning permission for the installation of an electrolyser at the operational wind farm will have to be submitted. This is considered to present a low risk.

5.2.4. Progress to UK hydrogen economy

A longer term barrier to full commercialisation of the technical solution is the availability of a low carbon hydrogen market in the UK. There are many examples of production facilities but there is yet to be the industrial scale production that the country needs to achieve its Net Zero 2050 target via the hydrogen pathway. This project can be seen as a crucial opportunity for the UK government to invest in a scheme that creates a route to market for hydrogen which will improve the business cases for hydrogen manufacturers, be it from offshore wind or steam methane reforming with carbon capture and storage (CCS).

5.2.5. Industry confidence

The distilling sector is traditionally heavily resistant to change down to fear of jeopardising end product, quality and brand. Despite there being vocal support of transitioning to renewable energy, distilleries have been reluctant to part with their own money in a novel design. This principal barrier can be overcome by using the green distilleries grant to showcase the solution for minimal cost using a distillery at the pre-construction stage. Proving the technology works at this scale and in this setting through Phase 2 will provide the confidence the wider industry needs for widescale adoption whilst minimising risk of expenditure to BEIS by avoiding retrofitting.

5.2.6. Safety risk mitigation

Hydrogen as a fuel has characteristics that are on balance no more of a safety risk than mains gas. However, there are key differences and specific steps are required to ensure the safety of the system to workers. Hydrogen is an extremely flammable and light gas and therefore safety concerns and hazard identification form part of the feasibility study. Identified risks through the production, storage, transport and combustion of hydrogen need to be identified and risk mitigation measures implemented. This has been accounted for in the system design.

6. Costed development plan

The BEIS Phase 2 grant would be used to install a working renewable energy system that produces green hydrogen from available renewables to fuel distillation at Benbecula Distillery.

The Phase 2 project duration will be 18 months which will include testing and commissioning of the different components. The following six months will then be used to continue dissemination work and performance monitoring of the system will continue indefinitely. The following development costs are anticipated to deliver the Phase 2 demonstrator:

- Project management: £150,000;
- Design (including P&IDs (piping and instrumentation diagram) and layouts): £255,000;
- Ancillary hydrogen infrastructure (including installation): £235,000; and
- Dissemination activities: £20,000.

Design and installation cost, as outlined above, of the hydrogen infrastructure are accounted for in the project capex breakdown. Figure 6 displays the Phase 2 demonstrator project plan. Figure 7 shows the timeline of capex that will be spent during the project period.

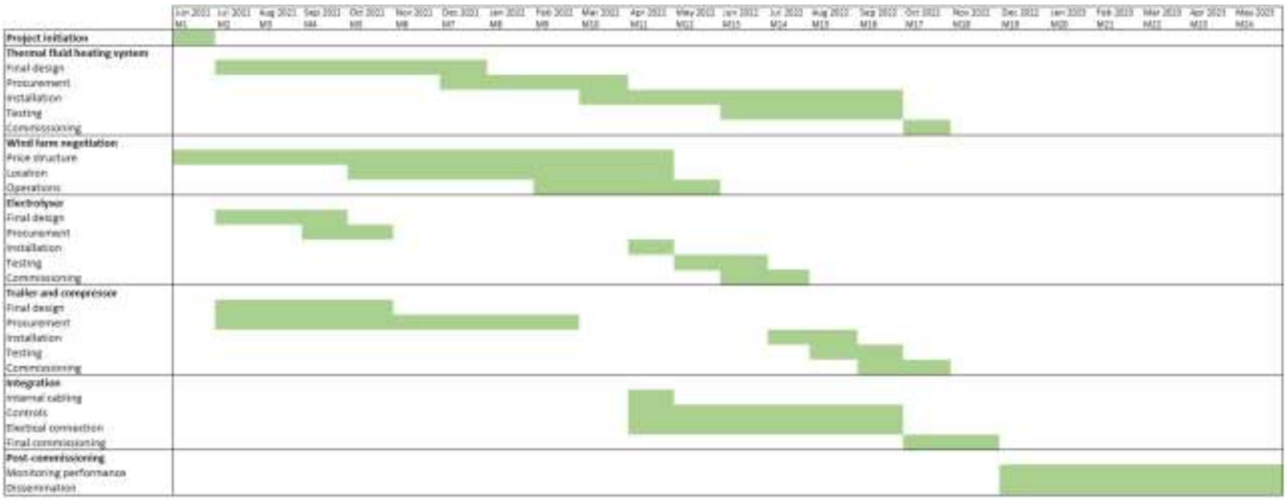

Figure 6: Phase 2 demonstrator project plan

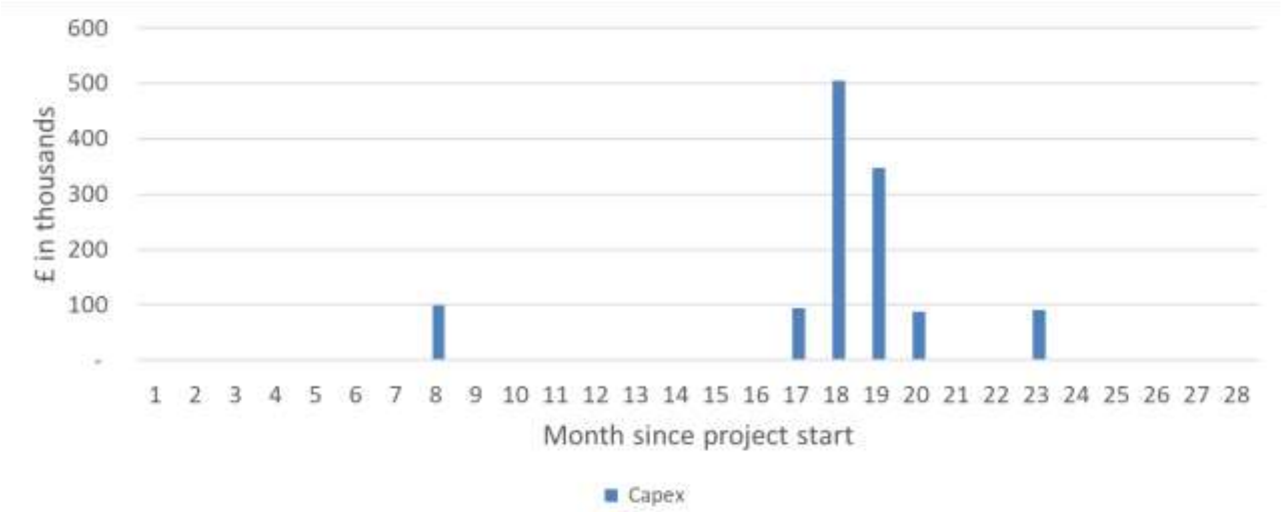

Figure 7: Capex over Phase 2 demonstrator timeline

7. Rollout potential

The rollout potential of the technical solution of thermal oil heating systems combined with green hydrogen is directly applicable to the distilling sector as well as wider industry.

7.1. Whisky industry

Under the aegis of the Scotch Whisky Association (SWA), the industry is cooperating on a Sustainability Strategy (Scotch Whisky Association, 2021) to reduce carbon emissions and promote sustainability across the sector.

A key goal within the strategy is to cut greenhouse gas emissions to achieve net zero emissions by 2040. This requires a complete move away from the use of fossil fuels as a primary heat source for the distilling process. In the latest industry report on sustainability progress to 2020 (Scotch Whisky Association, 2020) it states that the SWA has commissioned research to identify pathways to achieve net zero which will require exploration of new technologies.

Within the stated vision the 2040 status is targeted to be:

> *"Many of our distilleries are completely self sufficient in energy. Some are bio-refineries, using by-products to create new raw materials for other sectors."*

It is clear from this vision are the 2040 target that the technical solution of using hydrogen created by renewable energy sources is completely aligned with the industry’s direction and will be supported in efforts to offer a decarbonisation solution.

7.2. Hydrogen Pathway to Net Zero

Hydrogen is projected to be a crucial fuel of the future low carbon energy mix in the UK, tackling the industry, heat and transport sectors specifically.

Industry: There are processes that require high temperature heat that are presently met by fossil fuels, where hydrogen can provide an efficient alternative where it can be generated and stored on site. This is particularly the case where the high temperature heat demand is intermittent and provision of adequate electrical supply capacity to meet these peaks is problematic and / or cost prohibitive. This situation is directly applicable to distilleries but also includes welding or metal forming and major chemical and materials industries.

Hydrogen has the ability to store energy and provide generation and high temperature thermal energy when required. Through the installation of hydrolysers, storage and generation at strategic locations within the national grid network, most likely through the adaption of existing gas peaking plants, excess supply can be converted to hydrogen and stored to be used to fuel peak demands. At a more local level, this use of hydrogen can also be a route to replace diesel back-up and peaking generation on more remote or independent grid networks.

Heat: Another potential role for hydrogen in the decarbonisation of UK energy which is through its use to displace natural gas as a piped fuel to homes and businesses for use in space and water heating in conventional gas boilers. On the face of it, the conversion of electricity to hydrogen, pumping it to point of use and then burning it to generate low grade heat would appear inefficient when compared with using the electricity in an air source heat pump. However there is such a large embedded investment in gas infrastructure that this may be an expedient route to achieve the high level of take up needed to meet the UK’s necessarily ambitious carbon reduction targets.

Transport: Hydrogen offers an effective alternative to diesel fuel for large transport such as buses and road freight.

In all these instances, availability to green hydrogen as well as transport and storage to point of use and purchase for a competitive price are all barriers to uptake. The implementation of a green hydrogen energy system for provision of industrial heat gives industry and investor confidence in applying the technology in these other areas.

7.2.1. UK & Scottish hydrogen policy

The role of hydrogen as an energy vector is a key part of UK Government policy for decarbonisation as laid out in the Clean Growth Strategy updated in 2018 (BEIS, 2018). The Hydrogen pathway to decarbonisation uses the existing gas infrastructure which is adapted to hydrogen use and as a fuel for long distance transport.

BEIS currently operate a number of initiatives to support technology growth and demonstration in application of hydrogen. Of particular relevance to this project is the HySPRITS project on Orkney (EMEC, 2019) that assessed the feasibility of switching a distillery to hydrogen as a fuel and the potential for this approach across the distilling industry. Logan Energy designed the hydrogen delivery system for this project.

Within the Scottish Government energy strategy (Energy & Climate Change Directorate, Scottish Government, 2017), a similar approach has been taken to hydrogen as a part of the decarbonisation of the energy system. Much more recently, the Directorate has published two more specific reports on Scottish Hydrogen (Energy & Climate Change Directorate, Scottish Government, 2020) and the opportunity for offshore wind to green Hydrogen (Energy & Climate Change Directorate, Scottish Government, 2020). All hydrogen strategies include support for decarbonising the distillery sector using hydrogen, generated at point of use, to displace fossil fuels. This is particularly relevant to the project as “distillery sites are often remote and not connected to the gas distribution network”.

BEIS identified industry as being the second largest contributor to annual greenhouse gas emissions (after transport) with approximately 110 tCO_2/a (BEIS, 2019). The combination of hydrogen burners with thermal oil systems presents an enormous opportunity to greatly reduce the associated emissions from industry through displacement of fossil fuels. To produce green hydrogen on this scale will require a rapid increase in offshore wind generating capacity and possibly steam methane reformation with CCS.

There is presently approximately 13.7 GW and 10.4 GW of installed capacity of onshore and offshore wind energy in the UK. The UK government has made a target of having 40 GW of installed offshore wind capacity by 2030. There will be a demand for this power from many competing sectors but the decarbonisation of industry should be a key area of focus given the impact on the Net Zero 2050 law-binding target

Great Britain curtailed over 3.6 TWh of wind energy in 2020 (LCP, 2021). This could be used to create zero carbon hydrogen to be dispatched for industrial, heating and transport use. With the increase in offshore wind capacity by 2030, there is the potential for an expansive green hydrogen market. Purchasing zero carbon hydrogen and combining with a thermal oil heating system can therefore be adapted across UK industry.

7.2.2. Hydrogen policy in Comhairle nan Eilean Siar

At a more local level, the potential for green hydrogen to support the local energy system has been recognised by Comhairle nan Eilean Siar who have recently commissioned a detailed report on the Outer Hebrides Hydrogen Opportunities (Wood Group, 2020) in conjunction with Local Energy Scotland, the Western Isles development Trust and Greener Scotland.

This report identified that the largest volume potential came from heat and transport where there is high dependence on fossil fuels (oil and LPG) imported from the mainland. The opportunities in the power sector to displace local diesel generation as seen as less certain as upgrades to the two electricity transmission network interconnectors to the mainland may remove the need for local backup generation. It may also remove some of the generation constraint on the local wind generation, removing the opportunity for alternative consumption of constrained generation.

However, the report dismissed any industrial application and does not appear to have taken account of the growing distillery sector in the Western Isles with new distilleries operational in Uig (Abhainn Dearg), Tarbert (Isle of Harris Distillery) and Castlebay (Isle of Barra Distillers Co.) and the planned Benbecula and North Uist distilleries. Whilst these are currently at early stages, it should be expected that these will be successful ventures.

It has also made little assessment for the market hydrogen as a fuel and oxygen as a commodity for use in the farmed fish industry. The Western Isles represents almost 20% of the UK aquaculture industry and currently largely depends on diesel generation and bottled oxygen.

7.3. Available market

7.3.1. Distilling

The available market for the proposed technology can be assessed with reference to the scotch whisky industry initially but taking in the wider market for low carbon distilling across the global industry. This industry represents £4.9bn of exports, 21% of all UK food and drink exports and employs over 10,000 people directly in Scotland.

The SWA are very active in promoting carbon reduction within its membership and have recently commissioned a detailed assessment of the pathway to net zero for the industry (Ricardo EE, 2020). This provides a reliable assessment of the potential take-up of hydrogen as a fuel to displace higher carbon alternatives. The report covers 127 sites including 70 malt distilleries, 5 grain distilleries and 11 packaging sites.

The analysis states that 88% of emissions are related directly to distilling and this matches the energy use from gas, oil and LPG. The industry currently uses 19% oil fuels and LPG which can be taken to be locations off the mains gas grid. At 56% gas is the preferred energy source when available due to its significantly lower cost. The remaining is split as 17% electricity and 8% as renewable heat – biomass combustion or biogas from anaerobic digestion on site.

There is therefore 36% of the available market that uses oil fuels or electricity that can be targeted as a priority for conversion to green hydrogen as a fuel. The 19% on oil can be targeted immediately as the infrastructure to burn fuel oil is very similar to that required for hydrogen. New distilleries can be equipped with thermal oil heating systems from the outset. Taking the initial market to be the distilleries currently reliant on oil, this would comprise the approximately 50 Highlands and Islands distilleries that produce 20% of total annual scotch whisky production.

Those distilleries that use electricity can be convinced to switch to a thermal oil and hydrogen system given the large cost of energy they will be on. It is also probable that longer term, even distilleries currently using mains gas will be converting to hydrogen to decarbonise, making 92% of the entire existing distilling market potentially available to this technology.

7.3.2. Wider industry

Thermal oil heating systems are commonly used in various process industries and are an established viable alternative to water or steam heating. Thermal oil is usually favoured over steam in industrial processes that require temperatures greater than 200°C. The main advantage of using thermal oils over steam is that thermal oils do not require pressurising at temperature up to 350°C. Steam requires a high operating pressure to achieve the same temperatures that thermal oil archives at normal atmospheric pressure. High pressure systems typically require full-time specialised engineers supervising the operation of high-pressure fired steam systems.

There is a clear potential market for the use of hydrogen heated thermal oil. Some examples of industries that use thermal oils as a heat transfer fluid are the food & beverage, metal, chemical, pharmaceutical, and other manufacturing industries. All these industries represent an important part of the UK’s economy having a Gross Value Added percentage contribution of almost 10%. Regarding the energy demand, the UK’s industry used 16% of the total energy consumed in 2019. The breakdown of energy use was 35% from electricity, 39% from natural gas and 26% from other fuels (Department for Business, Energy & Industrial Strategy, 2020). There is therefore a significant opportunity for using green hydrogen to offset these energy heat demands combined with pre-existing industrial users that utilise thermal oil heating systems.

8. Route to market assessment

8.1. Technology route to market

The proof of concept will enable the technology to be applied at other distilleries that are at the pre-construction stage which could readily install the hydrogen burner and thermal oil distillation solution, establishing the design as a blueprint for new distilleries. The long term development plan will target owners of multiple distilleries. Such owners are more likely to have the capital and resources to undertake multiple installations across the country. Many of the distilleries that are owned by a wider group are also some of the largest production facilities with the largest associated carbon footprint. Distilleries that are off the gas grid and reliant on oil or electricity for their distillation energy use will be targeted given their ability to practically change supply with minimal disruption to production. Having such owners adopt the technology would accelerate the decarbonisation of the industry and further improve the supply chain and costs of the technology.

In addition to distilleries, other industrial processes that use heat such as factories, chemical plants and processing plants will be contacted to also convert them to the technology. Initial industrial users that use thermal oil process heat systems already will be targeted to convert to using hydrogen in combination with their existing system in place of fossil fuels. Many multi-national industrial organisations have committed to net zero emissions over their operations including smaller companies within their supply chain. These companies have already investigated onsite renewable energy. Those companies that use process heat and have made a commitment to net zero will be targeted to showcase the possibilities of using green hydrogen produced onsite through renewables as their fuel source. Adoption by major industrial users will have an enormous impact on carbon abatement and will increase confidence in the wider industry, causing a cascading uptake throughout industry.

8.2. Hydrogen and oxygen route to market

As the rollout of hydrogen production from wind farms increases, there will need to be a market for hydrogen production that is in excess to the requirements of the site. Oxygen is also a by-product of hydrogen production via electrolysis. The potential applications for excess hydrogen and oxygen have been assessed and provided below, with a focus on the location of the project.

8.2.1. Transport fuel

The choice of hydrogen as a transport fuel has been proposed in the Western Isles due to the distances travelled by local delivery/collection vehicles. H2Growth proposed this back in 2012 and the Outer Hebrides Local Energy Hub (OHLEH) project included hydrogen co-fuelling for diesel refuse collection trucks.

The issue of using electric vehicles for local delivery/collection is that a typical round trip of 100-120 miles for a delivery vehicle would require a recharge partway through a day. This is a particular issue for heavy good vehicle (HGV) delivery/collection (e.g. refuse) and larger public service vehicles (PSVs).

PSVs would normally operate continuously through the working day and the recharge time is an issue. Hydrogen powered buses are now available with fuel cells powering electric drive. These offer 350-400 mile range and refuelling in minutes. Colocation of a hydrogen compressor and refuelling station may be a potential outlet for excess hydrogen to fuel the Uist bus service.

Another market for Hydrogen as a transport fuel is to power ferries. The HyDIME project being run by EMEC will trial a hydrogen/diesel dual fuel conversion system on board the MV Shapinsay, providing auxiliary power only initially. Meanwhile progress is being made by Norled in Norway who plan to trial two ferries, one with compressed hydrogen and one with liquified hydrogen. In Denmark, green hydrogen produced by an offshore wind farm near Copenhagen is planned to supply a new purpose built RO-RO ferry for the Oslo-Frederikshavn-Copenhagen route. This will be powered by a 23MW Hydrogen fuel cell supplied from a 44t capacity compressed hydrogen tank. The newly announced Sea Change high speed passenger ferry in California, as a smaller example, uses a 360kW Cummins fuel cell and is designed to operate a circuit around San Franciso Bay, a circuit of over 100nm.

On the Western Isles, the Caledonian MacBrayne ferry route from Berneray to Leverburgh is a short run that would lend itself to conversion with limited hydrogen capacity. Lochmaddy-Uig and Tarbert-Uig are also relatively short runs. Ferries would require compressed hydrogen therefore the necessity for compression for transport does not lose any unwanted efficiency at the end of use. This means that the location of hydrogen relative to the ferry port has minimal impact on the viability of the business case. Fuel cell ferries using hydrogen are more practical than electric ferries, particularly for longer routes.

8.2.2. Remote electricity generation

The Wood report identified that "~33 GWh of energy is consumed annually by local industry (excluding transport and power uses) in the Outer Hebrides predominantly in the form of marine gas oil fuel. This energy is largely consumed by defence (QinetiQ), textiles, manufacturing (BiFab) and aquaculture sites". The report is unclear what of this is diesel genset use and what is for other high grade heat needs. Meeting some of this need is a potential outlet for excess hydrogen and if there is a removal of the transport fuel duty waiver would offer the opportunity to displace a relatively high cost fuel source.

Benbecula Airport is operated by Highlands and Islands Airports Ltd (HIAL) and handled 38,000 passengers in 3,649 aircraft movements in 2018/19. HIAL are pursuing an environmental strategy (HIAL, 2019) in line with meeting the Scottish Government target to achieve net zero Carbon by 2045. This is in its "baseline" phase and so the timing is appropriate to discuss hydrogen opportunities.

The HIAL SECR reporting (HIAL, 2020) shows energy use across the group at approximately 10GWh, 84% of which is electricity. If the energy use is approximately proportional to passenger movements, Benbecula comprises 2.2% of the total passenger movements and the electricity use would be expected to be approximately 180MWh. Provision of a combination of direct renewable energy and hydrogen fuelled back up may be a significant support to the airport meeting decarbonisation targets. This can act as an important project for the aviation industry as a whole to decarbonise. British Airways, for example, have committed to net zero carbon emissions by 2050.

In addition to the civil aviation operations, the MOD operating at Benbecula may be a potential partner. The MOD, together with other public sector sites, are a current target for decarbonisation. The Modern Energy Partners programme (Energy Systems Catapult, 2018) is working through many MOD sites to develop strategies to decarbonise their energy use. The Hebrides Range may be a customer for a secure green electricity supply and is estimated to use 2.5GWh of electricity which appears to be largely met by diesel generation currently. The range is now operated by QinetiQ on behalf of the MOD.

8.2.3. Fish farming

A special case relating to remote energy use is the potential for a hydrogen economy to support the fish farming industry. This has been explored in detail in a number of studies including research at Strathclyde University (Reid-McConnell, 2018). The operation of a large scale fish hatchery can require the use of gaseous oxygen to support optimum efficiency of the initial growth of smolts. With hatcheries at Langass and Clachan on the Uists and Meavaig and Geocrab Mill on Harris there is a local market for compressed oxygen. This could be supplemented with supply of compressed hydrogen for local electricity generation but is subject to the lower efficiency identified above.

This demand is currently met by purchase of commercial compressed oxygen with the lowest cost option being in the form of manifolded cylinder pallets with a value of approximately £4.30/kg.

The Scottish fishing industry is set to double in size by 2030 expanding from £1.8bn to £3.6bn and is Scotland's second largest export after whisky. Scotland is the third largest producer of farmed salmon in the world after Norway and Chile. This rapid growth has come with widely documented environmental problems and a hydrogen economy can therefore play a crucial role in improving the industries environmental credentials whilst safeguarding this important part to the UK, and fragile rural, economies.

8.2.4. Production of green hydrogen

This business model for hydrogen fuel is best suited to distilleries that can develop and own their own wind energy projects or are located close to others. Distilleries that run off fuel oil are often co-located in areas with high wind development potential and there is therefore a synergy with producing hydrogen for fuel from wind farms. If there is high curtailment of wind due to grid constraints then hydrogen can be produced at a significantly lower cost which is further advantageous for the distillery owner and the wind farm owner to make revenue from otherwise wasted energy.

If hydrogen is created by existing wind farms then the purchase price must at least match the price received for export of electricity to the grid. This is estimated to be between 4.5 – 6.5 p/kWh. The selling price to consumers will then have to be greater than this. In the case of Benbecula Distillery, they would own the hydrogen infrastructure and therefore the effective price of hydrogen fuel would be close to the export electricity price, with it being assumed the wind farm owner would seek a higher price than what is currently received.

The price for fuel oil is volatile, particularly on the Western Isles as it is dependent on transport. There is also potential for the removal of a fuel duty waiver for non-transport diesel. Over the last few years, the price for fuel oil has varied between 3.3p/kWh and 5.7p/kWh. The price for green hydrogen therefore has the potential to be competitive with that of fuel oil in the Western Isles whilst offering greater security and predictability.

As the hydrogen economy advances and as offshore wind is developed en masse up to 2030, there is a greater opportunity for green hydrogen availability. Those distilleries and other industries that were unable to benefit from green hydrogen produced locally will benefit from a fall in wholesale green hydrogen prices. This is discussed in greater detail in Section 7.2.

9. Dissemination

9.1. Completed dissemination activities

Locogen and Logan Energy have completed joint and individual press releases following the BEIS announcement of the successful Phase 1 competition projects. The joint press release was distributed across multiple platforms, websites and industry and regional press. Unprecedented traffic volume and 'hits' occurred on the Locogen website and LinkedIn pages. In the wake of the press releases, there have been numerous enquiries made from other distilleries interested in the technical solution offered and wanting a similar decarbonisation strategy implemented at their site(s). Locogen have submitted proposals for other distilleries to look at hydrogen as a fuel for decarbonisation. Logan Energy's influence in the hydrogen industry has successfully made other companies involved in hydrogen interested in this potential route to market for green hydrogen and deployment of hydrogen infrastructure.

Marketing materials have been created covering the following areas:

- Description of the green hydrogen solution and Benbecula Distillery;
- Integration of the hydrogen fuel into a distillery via thermal oil heating;
- Creation of hydrogen using renewable energy;
- Carbon savings compared to a business as usual case; and
- Business case of the creation of a zero carbon distillery.

9.2. Planned dissemination activities

Planned dissemination activities upon completion of Phase 1 and award of Phase 2 will include:

- Presentation of findings to BEIS;
- Locogen Press Release for report launch;
- Social media campaign, including LinkedIn;
- Joint public webinar with all project partners;
- Locogen webinar with distilleries – Working through members of the Scotch Whisky Association and the Institute of Brewers and Distillers. Targeting distillery owners, developers, operators and investors to attend and share the knowledge and learn how they too can benefit from the carbon and financial savings;
- Logan Energy dissemination to the UK Hydrogen & Fuel Cell Association;
- Individual conversations with distilleries and other industry operators;

- Benbecula Distillery will use their own marketing to publicise the transition to a low/zero carbon distillery and promote this in their products. The technology will be showcased on tours and website space will be dedicated to the zero carbon solution; and
- Promotion of report and findings to both technical (e.g. renewables) and industry (e.g. whisky / distilling press.

Locogen's Managing Director, Andrew Lyle, is acting chair of Scottish Renewables and Locogen are therefore excellently placed to contact the wider renewables industry to accelerate the uptake of low carbon and hydrogen solutions to the decarbonisation of the distilling sector and wider industrial processes. Logan Energy are members of the UK Hydrogen & Fuel Cell Association and will use established contacts within this membership to circulate information about hydrogen's role in decarbonising distilling and how these learnings can be applied to other industries and integrated with the Hydrogen Pathway to Net Zero. Access to these member organisations will allow for dissemination across the whole supply chain, from manufacturers to developers and industry producers of goods.

Locogen, Logan Energy and Benbecula Distillery are all active in a number of social media channels such as LinkedIn, Twitter and Facebook and will share and discuss the various findings on these platforms.

10. Conclusions

This feasibility study assessed the ability for hydrogen to act as fuel for distillation and how combination with a thermal oil heating system would offer carbon and financial savings compared to a business as usual scenario of using fuel oil in combination with a steam system. The project used Benbecula Distillery as a test case, which is at the pre-construction stage.

It was found that development of privately owned renewable energy assets to create hydrogen is presently highly constrained and not cost-effective. There are however a number of existing operational wind farms that could be used to produce hydrogen. The price to do this is greater than the price of oil but offers security of supply and protection from volatile oil pricing. There is sufficient renewable energy generated by single wind farms to supply adequate hydrogen for the distillery's fuel. This scenario is replicable across the UK and particularly in areas where distilleries use fuel oil, as these are often co-located with good potential for wind development.

Creating hydrogen in the Western Isles for industrial use can be a catalyst for a wider hydrogen economy, which Comhairle nan Eilean Siar have investigated previously. Promising routes to market for hydrogen exist for large road and ferry transport and for other distilleries. There is a significant opportunity for providing oxygen byproduct to the aquaculture sector. The Western Isles can act as a blueprint for the hydrogen economy that can be applied to the UK as a whole and realise the Hydrogen Pathway to decarbonisation.

A thermal oil heating system, using mineral oil as the fluid, offers significant advantages over steam based systems and is an appropriate choice for integrating with renewable energy systems given the lower energy demands and heat storage capabilities of the fluid and more control over temperature and duration of heat dispatch. The use of a thermal oil distillation system is therefore recommended over steam for new build distilleries.

Combining hydrogen, created from renewable sources, burners with thermal oil heating systems offers a wider application across other process heat industries such as chemical and pharmaceuticals. The principal barrier to offering this as low carbon solution is the availability of green hydrogen at a competitive price. Where renewable energy development can be situated close to site, there is a positive business case for creating hydrogen to fuel process heat and to sell excess to the expanding hydrogen market. Such circumstances are not always applicable and is dependent on the consumer's location, land availability, proximity to existing renewable energy developments and constraints to onsite development of renewable generation. As the UK dramatically expands its installed capacity of wind, particularly offshore, up to 2030 and beyond, the opportunity to create green hydrogen at a competitive price will become greater


DISTILLERY