Green Distilleries Competition: HySpirits 2 Public Report

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Contents

List of Tables

List of Figures

List of Abbreviations

Abbreviation	Meaning
ALARP	As Low As Reasonably Practical
ATEX	Explosive Atmosphere (Atmosphères Explosives)
BEIS	Department for Business, Energy, and Industrial Strategy
EMEC	European Marine Energy Centre
ENU	Edinburgh Napier University
tCO_2e	Tonnes of carbon dioxide equivalent
GHG	Green House Gas
DSEAR	Dangerous Systems and Explosive Atmospheres Regulations
HAZID	Hazard Identification
MW	Megawatt
kW	Kilowatt
kWh	Kilowatt Hour
LPA	Litres of Pure Alcohol
LPG	Liquid Petroleum Gas
MCP	Manifold Cylinder Pallets
ODL	Orkney Distilling Limited
RAM	Risk Assessment Method
SCDA	Scottish Craft Distillers Association
SWA	Scotch Whisky Association

1 Executive Summary

The HySpirits 2 project was awarded funding under the Green Distilleries Competition: Phase 1 run by the Department for Business, Energy & Industrial Strategy. In this project, the project partners have conducted a feasibility study intended to identify the best possible means of deploying ‘green’ hydrogen to decarbonise distilling. The project consortium is led by the European Marine Energy Centre (EMEC), partnered with Edinburgh Napier University, Edrington and Orkney Distilling Ltd. This public report summarises all project feasibility findings, as well as narrating design work undertaken to develop plans for a demonstration project aimed at testing the proposed solution.

The project team’s first task was to shortlist the main technologies available to facilitate the use of hydrogen in distilling. Through a technology selection process, dual fuelling burner systems were identified as the most appropriate solution, in that they can be run solely on hydrogen where supply allows but can also be used to provide heat using conventional fuels if required. This flexibility is a very important aspect for any manufacturing application, where energy availability is integral to process and operational integrity. The project team subsequently designed a pilot-scale dual fuelling demonstration system for application at Orkney Distilling’s Kirkwall distillery site. Subsequently, the project team evaluated benefits, barriers and routes to market for the proposed solution, with a view to defining a clear roadmap for applying this solution to other distilleries, in other locations and at bigger scales.

Hydrogen supply constraints and process disruption concerns were identified as key barriers to the progress of any demonstration project in this area. The project team have proposed mitigations for these challenges, largely focusing on the merits of utilising EMEC’s existing hydrogen supply infrastructure and expertise. Furthermore, from a practical perspective, due to having access to clear space for project development, as well as reduced exposure to regulatory barriers by virtue of its relative small scale, Orkney Distilling’s site offers an ideal location for testing and demonstrating the proposed system. The project team is bolstered by working with Edrington and Highland Park to leverage their knowledge and experience in identifying the best route forward to scale the solution up for further application.

It is widely understood that large scale change needs to occur in our energy system in order to deliver upon ‘Net Zero’ ambitions. Distilling is a key industrial sector in Scotland and elsewhere and makes for an excellent test case in demonstrating the opportunities associated with fuel switching technologies and systems.

2 Introduction

2.1 Project and consortium context

The Green Distilleries Competition was launched in August 2020 by the Department for Business, Energy & Industrial Strategy (BEIS). The programme aims to support the development of innovative fuel switching or fuel-switch enabling technologies that could be transferred to the distilleries sector. This report describes feasibility study activity undertaken during the HySpirits 2 project. HySpirits 2 brings together The European Marine Energy Centre Ltd (EMEC), Edinburgh Napier University (ENU), Orkney Distilling Limited (ODL), and Edrington (including Highland Park). HySpirits 2 seeks to build upon work undertaken by EMEC, ENU and ODL in HySpirits 1, which was funded under the BEIS Industrial Fuel Switching programme. With the addition of Edrington to the project team we propose to develop a fuel switching demonstration project that can prove replicability and scalability for the broad application of the solution within the wider distillery sector.

The distilling sector holds a huge amount of historical significance and contributes strongly to a narrative in our cultural heritage, not only in the product but also the buildings that house the distilleries themselves. Distilling is also a sector of immense economic importance; the Scotch whisky industry contributed £5.5 billion of gross value added to the UK economy in 2018, and the industry employs 40,000 people across the country (Scotch Whisky Association, 2019). These factors suggest that the distilling sector has an opportunity to take up a position of leadership in showcasing pathways towards the decarbonisation of industry and manufacturing sectors with the introduction of renewable energy and innovative technology as we all move towards delivering our 'Net Zero' future.

The project partners worked together to assess and select technology in order to design, plan and develop a pilot-scale demonstration project based upon the most optimal hydrogen-fuelled technology for use in decarbonising the distilling process. Within the project the partners also considered the most appropriate routes to market for scaling the proposed solution for application in other distilling segments and in other food and drink manufacture sectors. As well as laying out our developed demonstration project plan, this report narrates the broader findings of the project team.

2.2 Project aims and objectives

This project first evaluated possible technological routes towards using hydrogen to decarbonise the supply of energy (and in particular, heat) for the distilling process. This evaluation has informed the design of a proposed pilot-scale demonstration project. This demonstration project aims to provide a blueprint for the wider distilling sector to better understand the opportunities and implications associated with hydrogen-based fuel switching, in order to reduce the cost and risk arising from future deployments.

2.3 Background to the project

EMEC, ODL and Highland Park are all based in Orkney. Orkney has played host to an energy system revolution over the past few years, as a result of widespread deployment of renewable energy technologies. Indeed, since 2013, renewable generators in Orkney have consistently generated supplies of power exceeding 100% of local demand from the islands (ReFLEX Orkney, 2020). Power network constraints limit the capacity for further renewable generation capacity which can be deployed in Orkney, despite substantial untapped wind, wave and tidal energy resources, as the infrastructure was designed to bring electricity *to* the islands, rather than to facilitate export of power *away* from the islands. In response to the high rates of curtailment experienced by renewable generators in the area, EMEC and others have pursued a number of research, development and demonstration projects which have explored the role that hydrogen might play as an integrating vector in future energy systems. These projects have demonstrated the opportunity to store renewably produced power as hydrogen, using electrolysis, and have explored applications for that hydrogen in decarbonising energy-consuming activities in the community, including in transport and industry. These activities through Scottish Government and European Commission-supported projects including ‘Surf ‘n’ Turf’ and ‘BIG HIT’ have contributed to the development of infrastructure, skills, and experience in handling hydrogen in Orkney. Demonstration activities in the area have taken in the full future hydrogen value chain, including demonstrating production (via electrolysis), distribution (using mobile trailers aboard ferries for inter-island transport) and consumption (industrial process, vans, stationary fuel cells). These activities are depicted in Figure 1.

Figure 1. The Orkney hydrogen ecosystem showing production of hydrogen on the island of Eday, and its transport via ferry to the Orkney mainland. (Image from (BIG HIT, 2018)).

This project seeks to build upon this prior experience in identifying a further application for hydrogen in Orkney. Distilling is a vital industrial sector for the local community and represents a key target in moves to deliver a ‘Net Zero’ Orkney energy system by 2030. This project offers an opportunity to demonstrate at pilot-scale the use of locally-produced hydrogen to decarbonise heat production in this vital sector, while showing a pathway to delivering this solution at greater scale within Orkney, as well as further afield.

3 Technology Selection for Decarbonisation

The first step for this project was an initial technical and feasibility assessment intended to identify the most appropriate hydrogen-fuelled process heat technology for integration in the distillery environment. This assessment leveraged accumulated knowledge and experience from a broad range of experienced professionals within the team, who are working in distilling (ODL, Edrington), in the decarbonisation of industrial processes (ENU) and in the integration of hydrogen in energy systems (EMEC). The team assessed the technical and commercial issues relating to the adoption of each of the candidate technologies in a distillery environment, noting that many distilleries are within heritage properties with specific space and infrastructural constraints.

Producing, conditioning and flavouring spirits involves energy intensive processes, most requiring heat. With this in mind, specialist heating equipment has been developed over time to control the heat supplied to distilling appliances. This heating equipment has to date typically been fuelled using fossil fuels such as fuel oils or natural gas. Feasibility work in this project sought to evaluate the typical routes used to supply process heat in a distillery context, in order to identify which technology could be most effectively replaced or retrofitted to facilitate the use of hydrogen in the process. The technologies considered were:

1. Direct combustion (as presently employed on Orkney Distillery gin stills), which utilise natural gas or liquified petroleum gas (LPG) combustion systems either directly below or within process vessels.
2. Steam heating, as employed at Highland Distillers' Highland Park distillery (where a boiler is used to generate steam which is circulated via a jacket or steam coils within the vessel or via an external heat exchanger) which is the most widely utilised media across the sector.
3. Use of an intermediate heat transfer fluid (typically oil) which is heated remotely via a range of energy sources and circulated around the distillery to provide process heating, either indirectly to vessels or via heat exchangers.
4. Use of dual fuel technology, through the replacement of hydrocarbon combustion appliances, within existing boiler plant, with combined hydrocarbon/hydrogen burners enabling seamless fuel transitioning.

The project team assessed the relative merits of each technology and made recommendations on which system could be most successfully deployed to facilitate the use of hydrogen in decarbonising distilling. A key focus for this analysis was in identifying the most appropriate solution for application at pilot scale for demonstration, but the team also prioritised considerations of future roll out of the solution to other segments of the distilling sector. This assessment was undertaken by first selecting and weighting a range of criteria, representing the most important factors influencing the operation of a typical distillery. These criteria included areas such as technical and commercial readiness of the solution or system, replicability to other distillery contexts, possible impacts upon distillery process integrity, and health and safety aspects.

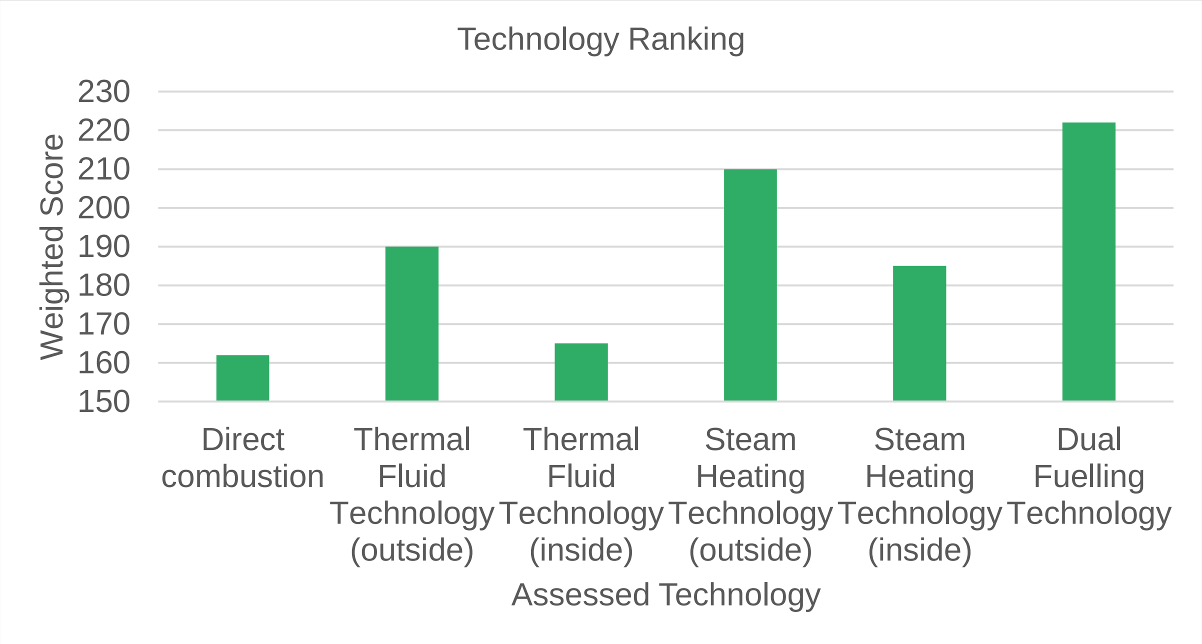
Having collated this criteria and developed a scoring methodology, the project partners undertook a scoring exercise in which each of the proposed technologies were assessed against these criteria. Noting the potential for significant disruption in attempting to retrofit the solutions described within the existing footprint of an operational distillery, the team also considered the merits of deploying the systems outside of (and adjacent to) the existing distillery plant. The results of this assessment are collated in Figure 2.

A key finding from our analysis indicates that in all of the cases considered, siting the equipment external to the facility provided clear benefits according to various perspectives. From an operational point of view, this approach was deemed to be the most practical, in that it would reduce the need for distillery down time, thus reducing the operational and financial penalty of deploying the solution. Furthermore, from a health and safety perspective this approach to delivering a 'containerised' heat decarbonisation solution was deemed to reduce the risk of exposure of staff and process equipment to experimental systems while also ensuring that safety systems could be designed optimally, rather than in a manner which would require compromise to the specifications of an existing facility.

Our assessment also sought to account for the technical and commercial maturity and practical applicability of the underpinning heat exchange systems (thermal fluid relative to direct combustion or steam) under consideration. The utilisation of steam to transfer heat from combustion equipment to the stills is relatively ubiquitous in large scale distilleries. Though thermal fluid is expected to offer advantages in terms of the control which can be exerted over heat transfer, it is not yet suitably well developed to warrant the disruption which would arise through the need to retrofit accompanying heat exchangers in existing distilleries. With these factors in mind, we concluded in our analysis that the hydrogen steam raising, and dual fuelling systems offered the most applicability, with lowest inherent risk to production, for this distillery fuel switching opportunity.

Our analysis also indicates that retrofitting burners in industrial boilers with hydrogen combustion systems could offer a convenient route for fuel switching. Doing so requires the swapping-out of an existing burner appliance with a hydrogen burner and associated infrastructure, rather than necessitating the installation of a completely new heating system. Discussions with UK-based burner manufacturers also highlighted the utility of the opportunity to deploy burner systems capable of combusting both hydrogen and fuel oil within the same burner assembly. This technology is already widely adopted in industry to enable switching between hydrocarbon fuels to ensure security of energy supply and provide fuel diversity to mitigate exposure in times of supply restrictions. Indeed, the authors have experience of utilising burners with 3 fuel sources in this context. As such, the flexibility offered by the dual fuelling route appealed strongly to the assessors in the project team, who noted that this approach would mitigate risks to distillery process integrity associated with trialling any solution proposed for subsequent demonstration.

Figure 2.Technology Ranking following assessment of the four candidate heating systems. (Outside) refers to the deployment of the solution outside of or external to the existing distillery infrastructure, while (inside) refers to installing the solution alongside existing equipment. As dual fuelling is typically intended as a retrofit solution, and direct combustion systems are inherently located adjacent to the distilling equipment, no location optionality was considered for these systems.



Accounting for the full balance of these conclusions and the various priorities considered, the dual fuelling solution was deemed to be the most appropriate for widespread deployment in decarbonising distilling and was taken forward for further analysis. Subsequent project activities focused on planning for the demonstration and roll out of a dual fuelling system to facilitate the use of hydrogen to decarbonise distillery operations.

4 Phase Two Demonstration

Phase Two of the Green Distilleries programme will involve the delivery of demonstration projects which will test and prove some of the solutions evaluated through Phase One feasibility studies. The section which follows introduces the demonstration project proposed to deploy the solution explored in this study.

4.1 Description of Demonstration Project

We propose to deliver a pilot-scale demonstration of dual fuelled process heat supply at the ODL site. This system will be used to provide heat for whisky production. We will use this demonstrator to prove proof-of-concept in integrating hydrogen into the distilling process in order to give confidence for future deployments of similar systems in larger scale distilleries. Scale up and roll out plans for this solution are explored in subsequent sections. This section introduces the proposed demonstrator in more detail.

The partner distilleries within this project have widely divergent energy demands to meet their varying production needs. Highland Distillers' Highland Park distillery has a production capacity of up to 3 million litres pure alcohol (LPA) per annum, whereas ODL has a headline design capacity of 30,000 LPA. As such, the two distilleries also vary significantly in their energy demand, and in the emissions outputs associated with their energy use. These values are summarised in Table 1.

Table 1. Differential heating capacities, production rates, energy demand and energy emissions figures for the two partner distilleries in this project.

	Heating Capacity	Litres of pure alcohol per annum	Annual Energy Use (MWh)	Annual CO_2 emissions (t CO_2e)
Orkney Distillery	260 kW	30,000	404	85.6
Highland Park	2 x 4.26 MW Boilers	3,000,000	22,691	6,074

Re-fuelling Highland Park distillery with renewably-produced, zero-emission 'green' hydrogen to displace all kerosene for process heating would require **681,410 kg** of hydrogen per annum. This could result in a net reduction in CO_2e emissions of **6,074 Tonnes** per annum. At the craft sector scale, based on ODL's 30,000 LPA production output, it is anticipated a 100% transition from kerosene to 'green' hydrogen could displace **85.6 tCO_2e** per annum, with a hydrogen demand of **12,126 kg** per annum.

With existing hydrogen infrastructure at its Eday tidal energy test site, EMEC can supply between **20,000** and **60,000** kg of hydrogen annually, depending on the electrolyser operation strategy (specifically if it uses power from wind and/or tidal devices). EMEC can feasibly meet the full 100% demand for hydrogen which would arise from a demonstration at ODL without needing to invest in further hydrogen production, transportation or storage capacity. Within the project the consortium debated the merits of displacing 100% of ODL's kerosene demand relative to, for example, using 60,000 kg of hydrogen to displace 10% of Highland Park's annual kerosene use. The consortium concluded that greater impact in terms of demonstrating the transferability of the solution could be achieved through displacing a higher percentage of a distillery's energy demand.

The rationale for demonstrating a specifically dual fuelled solution at ODL despite the capacity to meet 100% of heat demand with existing hydrogen supply relates to mitigating operational risk. Although EMEC could currently supply all of ODL's hydrogen demand in a given year, relying solely on this in the short term would restrict ODL's optionality in terms of sourcing fuel and could unfortunately limit its energy security in the event of an equipment failure or similar eventuality. These factors would apply even more so to any future project seeking to roll out the solution demonstrated, which may not have a local hydrogen supply upon which to rely. As a result, dual fuelling was preferred both for the merits already described in the previous section summarising findings from our technology selection exercise, and to ensure best possible impact for the demonstrator proposed.

An additional benefit associated with demonstrating the system at ODL is the relative space afforded on the site, which will minimise the disruption associated with the demonstrator. ODL is less constrained on space than Highland Park, and thus offers a ready opportunity for pilot scale development. As a producer handling a larger volume of spirit, the Highland Park site is also subject to Control of Major Accident Hazards (COMAH) regulations. As a smaller scale distillery, there are fewer health, safety and regulatory barriers (and associated time and costs) likely to impede a demonstration project deployed at ODL. Furthermore, the operational scale of ODL offers great prospects to observe all aspects of the distillation process in order to understand with high resolution the impacts of the fuel switch solution on progress of the distillation process. A new boiler house and hydrogen fuelling infrastructure has been designed for location on land immediately adjacent to the distillery. This design work is summarised in the section which follows.

5 Design and development

5.1 Outline design for demonstration plant

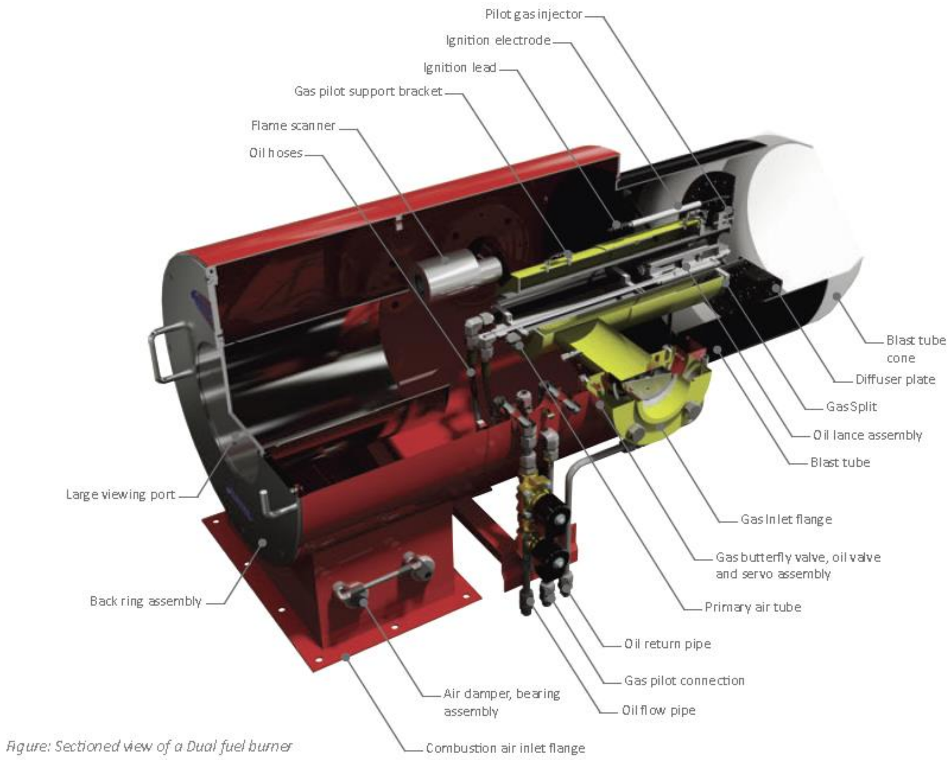
The ODL whisky distillery design features a 1650 litre still, utilising 3 m^2 of heat transfer surface. This is achieved using 10 meters of 3” nominal diameter pipework in 3 coils designed to operate at around 3 bar pressure with a saturated steam pressure of 135 ^oC.

To size the required heating equipment, the anticipated demand of ODL was used in process design load calculations. Based upon these calculations, we propose to deploy a 260 kW packaged Yorkshireman YSX1000 steam boiler from Byworth, Figure 3. This will be fitted with a dual fuel burner unit, potentially supplied and installed by Limpsfield or Babcock-Wanson. Should the hydrogen fuelling design, for any reason, fail to deliver the required primary demand, the burner train can be re-equipped to operate on LPG with oil as a ‘no-regrets’ option.

Limpsfield manufacture simultaneous firing solutions with their LP1/440 burner device, Figure 4, and Ratiotronic 6009 systems respectively, allowing a hydrogen fuel stream to be fired with kerosene/gas-oil as a base fuel.

Figure 3. Packaged Boiler House. (Image from (Byworth, 2020)).

Figure 4. Limpsfield co-firing burner unit (Image from (Limpsfield, 2020)).



In order to manage the dual fuelling itself, the control system will be designed to ensure that hydrogen fuel is burnt in preference to the base fossil fuels. An internal software algorithm controls the mix of the fuels and air to ensure combustion is optimised whilst maintaining safe combustion. Oxygen trim is achieved using zirconia oxygen probes and combustion variables are adjusted such that variations in calorific values or external environmental conditions do not compromise combustion efficiency or safety. In order to satisfy health and safety requirements, burner components rated according to 'Atmosphères Explosives' (ATEX) criteria have been included in the design.

Additional safety requirements and considerations arise in relation to the storage of hydrogen for use on site. The ODL distillery has space to the rear of the building where a car park with electric vehicle charging bays are presently located, Figure 5. The most appropriate system for storing hydrogen for distillery use will be dependent on infrastructure availability and local conditions, with EMEC experience from previous projects being used in this case to identify the most optimal solution for the ODL site. With conservative assumptions including a lower heating value of 33 kWh/kg and a boiler efficiency of 85%, the required 260 kW of concurrent heat will require an estimated 7.6 kg of hydrogen per hour when operating at maximum capacity. Table 2 shows hydrogen consumption over different timescales.

Table 2. ODL hydrogen demand over various periods.

Operation and time period	Maximum daily consumption	Average operating week	Average year
Hydrogen demand	85 kg/day	315 kg/week	12,126 kg/annum

To satisfy these requirements we propose that the most practical solution will involve twice-weekly deliveries of hydrogen using existing EMEC hydrogen storage trailers, each with 250 kg capacities. The trailer will be left in-situ to remove the requirement to purchase additional expensive hydrogen storage. A small buffer store will allow trailers to be swapped out without having to pause operations. Leaving the trailer on site is currently the best option for cost, logistics and space however further work could consider permanent storage on-site.

Figure 5. Rear of the ODL distillery building and proposed location for boiler house.

A layout diagram for the proposed boiler house, service routing and hydrogen supply infrastructure is shown in Figure 6, below. This includes safety control zones and boundary limits. The boiler unit will be installed in a pre-packaged container, pre-commissioned and then delivered to site. The boiler will be fed via two new fuel lines from the hydrogen storage and kerosene/LPG tank.

An overall design schematic for the proposed hydrogen and energy system specification is also provided below, Figure 7.

Hydrogen supply pressure will be regulated and reduced from the high pressures at the storage tanks, to the low pressure required by the burner, using pressure reducing valves installed on a dedicated panel external to the boiler container.

System integrity will be maintained through the use of high quality welded pipework, which will include pressure relief valves and pneumatic safety shut-off valves, installed at the supply end and configured to shut off the supply of hydrogen under a variety of circumstances.

To this end, pressure monitoring, fire and gas detection equipment, and emergency stop buttons will be installed in and around the equipment and continuously monitor for the presence of unsafe conditions. Should any unsafe conditions be detected, the fuel supply valve and electrical supplies to the enclosure will be isolated at the distribution boards inside the main distillery.

Flame failure devices will be fitted on the burner unit and carbon monoxide gas detection equipment installed within the boiler house and adjacent to the storage trailer. These will connect via a high integrity control panel which will actuate appropriate alarms and close the hydrogen supply shutdown valve at the storage end of the network, minimising the potential for hydrogen gas within the enclosure and any subsequent escalation.

ATEX rated fans will be installed to provide active ventilation in the boiler house and ensure sufficient air flow to prevent accumulation of dangerous quantities of hydrogen, LPG or kerosene. The system will be configured such that the supply of hydrogen is isolated in the event of fan failure. The boiler house would thus be designed to operate under Dangerous Systems and Explosive Atmospheres Regulations (DSEAR) achieving Zone 2 Negligible Extent (NE) rating. In so doing, the electrical equipment servicing the plant does not require ATEX rating.

Figure 6. Location and layout of boiler house and hydrogen trailer.

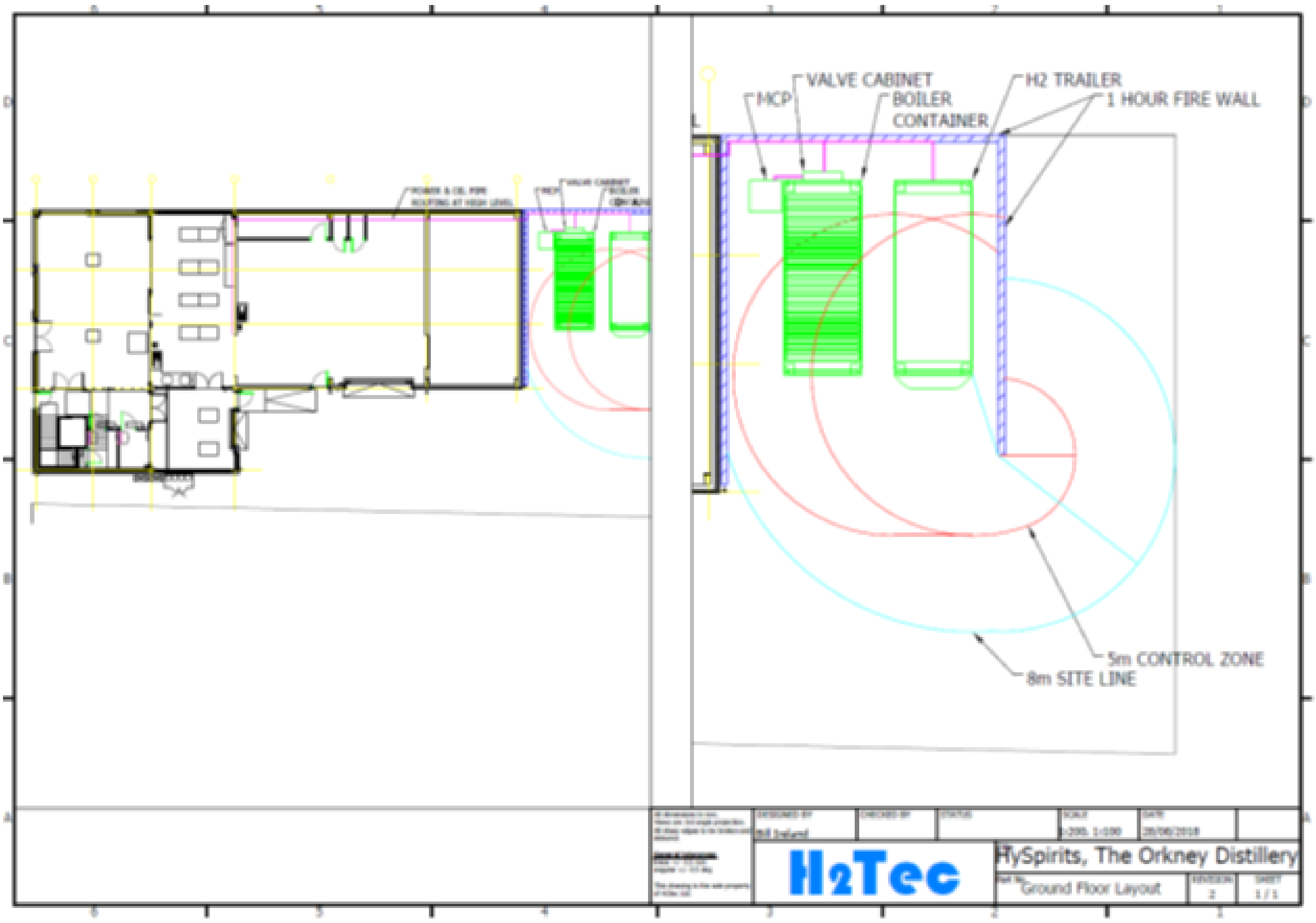
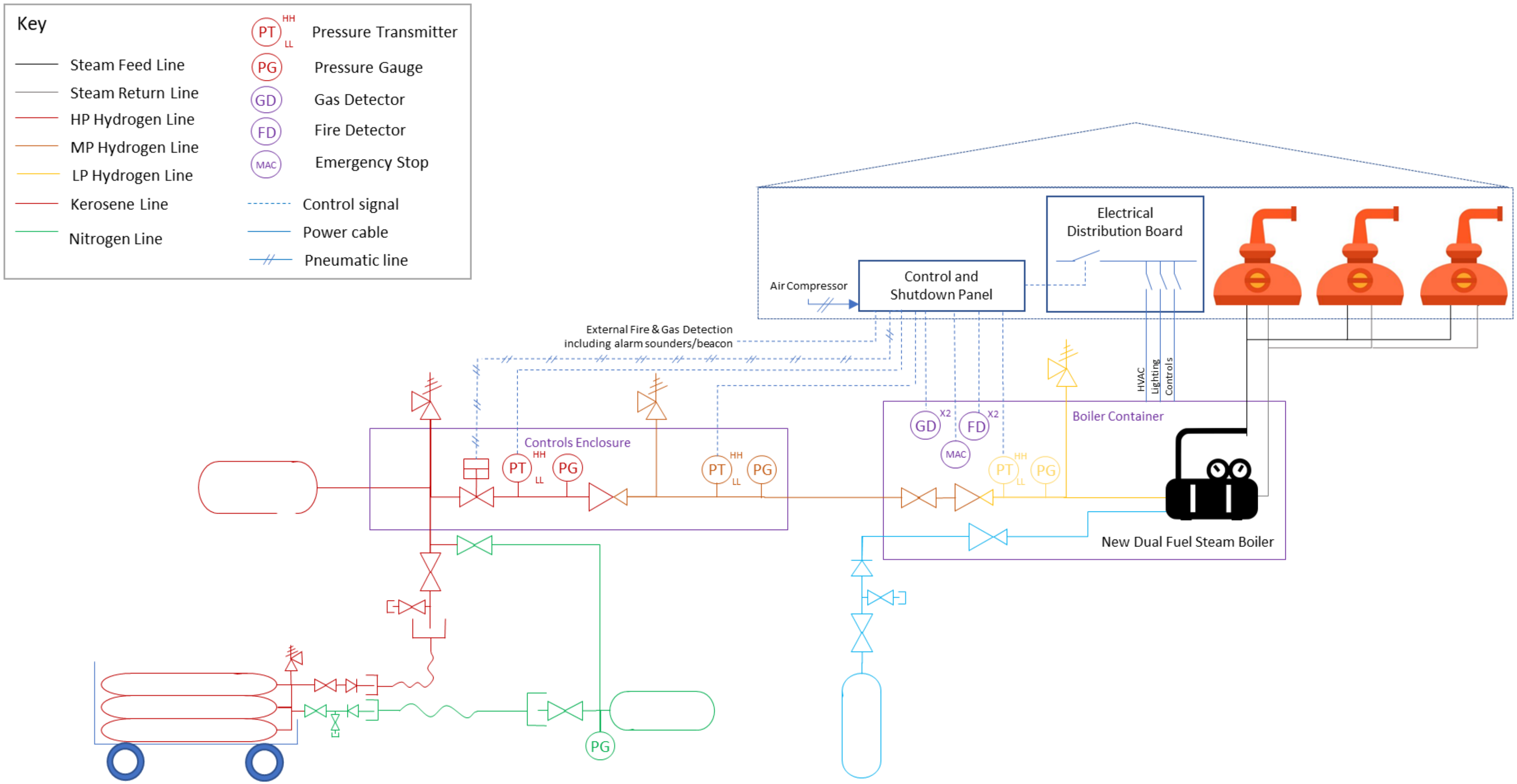


Figure 7. Outline design schematic for hydrogen and energy system.



6 Costed Development Plan

6.1 Project Delivery Plan

During the next phase of this project, Orkney distillery will be upgraded to utilise hydrogen as the primary fuel for process heat production. This plan details the activities proposed for a demonstration study which will seek to evaluate the impact of adopting the solution proposed, to inform future roll out activities. This will be executed through the completion of the following work packages:

WP1 – Detailed design

WP2 – Planning

WP3 – Construction and commissioning

WP4 – Performance testing

WP5 – Reporting and dissemination

6.1.1 WP1 – Detailed Design

During the earlier HySpirits 1 project, a high-level design was developed and subjected to a formal HAZID review (EMEC; Edinburgh Napier University; Orkney Distilling, 2019). However, the work focussed on a thermal oil solution which has since been superseded by a design utilising steam as the thermal transfer fluid. This change was reviewed as part of the technology selection process completed in this phase of the project, with steam deemed to be a lower risk solution due to the flammability of the alternative thermal oils. During the next phase, it will be necessary to verify this work, with the formal update of the HAZID study, taking account of all final design choices.

In addition, it will be necessary to carry out a formal HAZOP (hazard and operability), SIL (Safety integrity level) study and LOPA (layers of protection analysis), ensuring any process risks are designed out or fully mitigated through the implementation of robust safety systems.

In parallel with this work, a suite of formal design calculations, documents and drawings will be completed, covering the full suite of engineering disciplines. All systems will be designed and built in accordance with local and international standards, with a view to facilitating future scaled deployment of the solution at larger scale distilleries which are subject to more stringent requirements (e.g. COMAH legislation).

This work package covers the preparation of design documents and the subsequent tendering, issue and management of a set of contracts, which will be issued to suitably qualified engineering contractors who will be responsible for the detailed design, procurement and construction and commissioning support, and the completion of all activities stated above.

6.1.2 WP2 – Planning and consenting

Due to the location and nature of the work, a planning application will have to be submitted and approved. This work package covers the preparation and submission of a formal planning application and any associated work.

It should be noted that given the potential of the site to store up to 250 kg of hydrogen in a built-up area, it may be necessary to carry out some element of blast and escalation modelling with some risk of additional containment measures being required and a worst-case outcome of a rejection of planning to build the facility at the chosen location.

6.1.3 WP3 – Construction and commissioning

Due to the broad range of projects already completed in the hydrogen sector, Orkney and EMEC have developed strong relationships with a wide range of suppliers and companies who have a proven track record of delivering hydrogen related services and equipment.

The work package will involve preparation of tender documents which will be used to place contracts with suitably qualified contractors who will construct and fully commission the systems, with the support of the relevant design contractors and project partners where necessary.

6.1.4 WP4 – Performance Testing

EMEC was initially founded as a test site for wave and tidal energy converters. Since then, it has achieved accreditation to carry out performance testing for wave and tidal energy devices. We have also applied this experience in real world testing of 'green' hydrogen-based energy systems.

Using this experience, EMEC will develop a test plan to fully assess the performance of the hydrogen fuelled distillery. Full details of the tests to be carried out will be developed during Phase Two, and will focus on aspects such as:

- assessing the transition between conventional and hydrogen fuelling scenarios,
- the operability of fuel changeover,
- the differing real-world efficiencies of combustion on a pilot-scale boiler plant
- impact on spirit quality
- impact on production volumes
- emissions (NOx content)
- impact to operating costs and cost of product

Such work is required in order to develop an evidence base which can be leveraged in demonstrating replicability of the solution to the wider distilling sector, by proving that dual-fuelling is a viable mechanism for fuel switching.

6.1.5 WP5 – Reporting and dissemination

To date, both this project and the earlier HySpirits 1 study have garnered significant attention from the media, industry and public alike. Further engagement with a wide range of stakeholders is proposed to ensure dissemination of demonstration project findings. Results from WP4 will be disseminated through peer-reviewed academic publications, as well as direct engagement with industry stakeholders including trade groups and associations (Scotch Whisky Association (SWA) and the Scottish Craft Distillers Association (SCDA)). We will ensure wide reporting and benchmarking of our findings against those from other projects evaluating alternative solutions for the decarbonisation of distilleries, including from projects evaluating other hydrogen systems, and those systems based upon other technologies. A proposed next step for disseminating project findings would involve the formation of a working group to bring together the value chain participant groups engaged with this issue, including as broad a cross section of distillers as possible, of course, but also the energy system developers (those focused on all alternative technologies including hydrogen, heat pumps and others) and appliance manufacturers (of boilers, heat exchange specialists and others). Given the interest in scaling this solution up to provide for other food and drink applications, this working group would also engage with stakeholders in other manufacturing sectors to establish a clear pathway to replicating the project experiences.

6.2 Cost Estimates

To plan for the subsequent phases while also fully assessing the impact of the proposed use of hydrogen in a distillery environment, a number of cost estimates have been prepared during this phase of the project. These broadly fall into the following categories:

1. Project costs – the costs required to implement a robust test of hydrogen in a distillery environment as outlined in this report
2. Differential operating costs – assessing the impact of hydrogen use on the production costs per bottle, compared with kerosene use as a counterfactual

6.2.1 Project Costs

During the next phase of the project, the proposed dual fuel steam boiler will be installed at ODL and will undergo comprehensive testing to determine the real world performance, as well as to validate the outcomes of this study. To this end, a packaged steam boiler will be designed, purchased and installed on site as per the schematic shown in Figure 7.

This will include the design and installation of the associated fuelling infrastructure, safety systems and civil and electrical infrastructure. In addition, costs have been included for the supply of renewable hydrogen by EMEC and the subsequent planning, execution and reporting of a comprehensive performance test programme.

The design, construction and testing programme is expected to run for 18 months, with costs summarised in Table 3.

Table 3. Cost summary for the proposed Phase Two demonstration project.

Project Management	£41,600

Engineering and Construction	£309,699
Materials	£925,380
Fuel Supply	£48,504
Performance Testing and Reporting	£20,000
Dissemination	£10,000
Total Test Programme Cost	£1,355,183

6.2.2 Differential operational costs

In order to assess the impact on production costs associated with fuel switching, it is necessary to estimate the differential cost between the hydrogen solution and a counterfactual fossil fuelled solution, in this case using kerosene. As hydrogen is pre-commercial as a fuel, it can be difficult to make robust cost estimates. For 'green' hydrogen these range particularly with input electricity prices but are also influenced by other factors including storage and handling costs. In this analysis we have considered a range of hydrogen cost scenarios to account for likely current and future costs, as well as anticipated commercial hydrogen prices. These prices are summarised below.

£3.60/kg – the predicted future cost of hydrogen as per recent Xodus report, detailed below.

£8/kg – lower range of estimates for hydrogen supplied to the project at cost price.

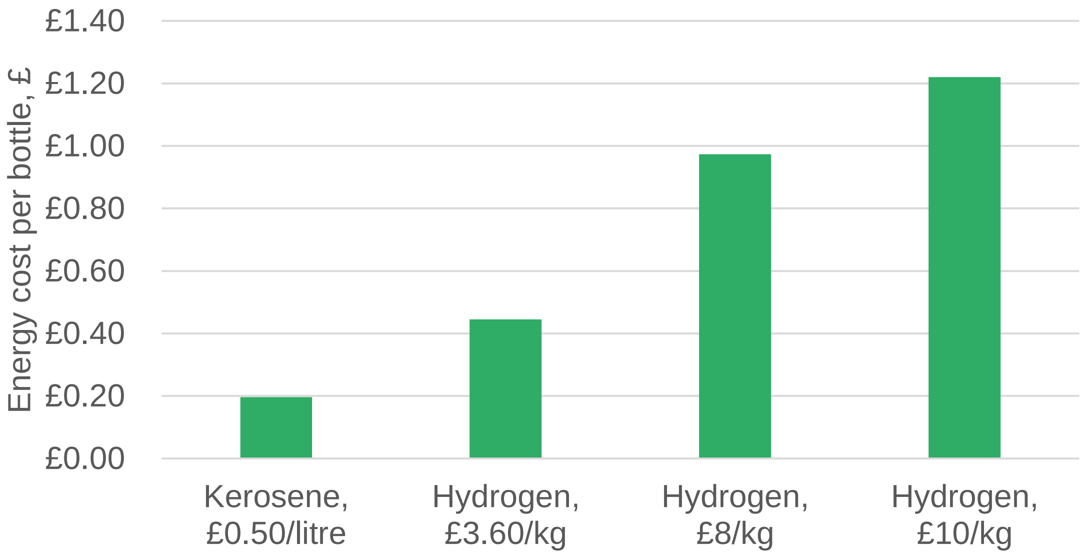
£10/kg – near term prediction for potential commercial hydrogen price in Orkney.

In future production scenarios with very high capacity factors, EMEC's hydrogen plant is expected to draw upon both curtailed and non-curtailed wind, as well as electricity from a 2 MW tidal device. In this scenario the 20-year average delivery rate was around 60,000 kg per annum and the levelised cost was about £8/kg. The costs of hydrogen in Orkney will fall as a hydrogen economy is established. Some savings will be from efficiencies in logistics e.g. avoiding hydrogen transport via ferries. Others will be from technology improvements, business models and scaling effects. Thus, in the near term, a realistic commercial supply price of £10/kg could be anticipated. Beyond Orkney and considering a national market in Scotland, costs are expected to fall further in the coming years; Xodus predicted a levelised production cost of £2.30/kg by 2032, with a levelised price, inclusive of handling and delivery costs, of £3.60/kg (Xodus Group, 2020).

Taking forward these cost values of £3.60/kg, £8/kg and £10/kg we calculated cost per unit of energy delivered. Using the hydrogen lower heating value (33.3 kWh/kg), we arrived at figures of £0.11/kWh, £0.24/kWh and £0.30/kWh, respectively. In comparison, kerosene at £0.50/litre has an energy cost of about £0.05/kWh (assuming 9.8 kWh/litre). Thus, hydrogen is associated with a significant cost premium in all scenarios. (Energy values taken from (Engineering ToolBox, 2003)).

Whisky typically requires 12.7 to 13.9 kWh of heat input per LPA produced (EMEC; Edinburgh Napier University; Orkney Distilling, 2019). Using this value alongside the energy cost values allowed us to calculate the difference in energy cost when using hydrogen, Figure 8. The difference is an uplift of between £0.25 and £1.02 per bottle, ranging with the hydrogen cost scenario.

Figure 8. Whisky energy cost comparison using kerosene and hydrogen, according to three parallel hydrogen cost scenarios.



6.3 Project legacy and business planning

Beyond the funded pilot described, assuming the demonstration proves to be successful, EMEC and ODL will likely pursue a commercial hydrogen supply arrangement in order to continue to supply the facility with hydrogen. For ODL this represents a significant opportunity to differentiate their products and to add value to their brand. The project consortium will work together to ensure that findings from these projects are shared widely with the broader industry in order to encourage uptake of the solution elsewhere in other distilling segments and in other applications. This is discussed in detail in the sections which follow.

7 Roll Out Potential

7.1 Applicability

The technology selection activity undertaken in this analysis considered as priority criteria the applicability of the proposed solutions to other distilleries, and the roll out potential of the solution in those contexts. The dual fuel solution selected was considered to offer the best possible impact in terms of possible emissions mitigation while balancing both cost and disruption to working distilleries. Energy and fuel supply security and resilience are important considerations for any manufacturing business but can be particularly difficult challenges for organisations operating in rural and islanded locations. With this in mind, given the Orkney context for this study and for the deployment of the proposed solution, we have considered enhanced resilience as a key potential outcome of the deployments envisaged. Below we have elaborated on the findings of our evaluation in identifying potential opportunities to roll the solution out.

Several distilling segments have been identified for the roll-out of the solution described. In the island setting, there are additional costs associated with importing fuel oils, and reliance on these imports can introduce additional production resilience risks. As such, the decentralised, local production of hydrogen fuel using power from equally local renewable generators would increase localised resilience while delivering economic benefits. For island distilleries this solution can therefore offer a wide range of benefits. Island distilleries are not alone in lacking access to natural gas infrastructure and networks, and so these benefits can also be transferred to these contexts for mainland distilleries in rural locations. Moving beyond distilling, too, this solution could be applied in any food or drink manufacturing setting in which heat inputs are a key energy requirement, and this is expected to provide additional markets for the solution, especially in those island and off-gas-network locations.

7.2 Scalability to other food and drink segments

Orkney-wide

From an Orkney perspective an assessment of the potential for utilising this dual fuelling technology within the food and drink sector has identified 3 distilleries (Orkney Distillery, Highland Park, and Scapa), a brewery (Swanney), a dairy (Crantit), and a cheese factory (Orkney Cheese), all of whom have a process heat demand which could be served by a variation of the solution described. All of these presently utilise off-grid hydrocarbon fuelling for heat in an estimated consumption of 34,600 MWh and carbon emissions of **8,892 tCO_2e** (EMEC; Edinburgh Napier University; Orkney Distilling, 2019). Deployment of this developed fuel switching solution at scale locally has the potential to displace significant emissions burden while also supporting resilience within the community through establishing additional markets for locally produced hydrogen fuel. An immediate next step following completion of this study will involve the project team engaging with local stakeholders to share project findings and learnings, and to explore opportunities to develop this solution locally.

Islands

When considering the issue of decarbonising islanded distilleries, hydrogen is viewed as a promising potential solution. This is in part due to the practicalities and costs associated with implementing electrification-based solutions in islanded contexts which are often subject to the already noted issues of constrained power infrastructure, as well as intermittency and curtailment of renewable generators.

An analysis of the whisky sector in Scotland by WhiskyInvestDirect (Whisky Invest Direct, 2020), provided an output volume for each distillery in which, summed, amounts to 390,261,000 LPA. In their report "Scotch whisky pathway to net zero" for the Scotch Whisky Association, (Ricardo, 2020) indicated that this output was responsible for a total emissions impact of **528,792 tCO_2e** per annum. Further analysis of the WhiskyInvestDirect data identified 19 distilleries which were located on islands and thus, like Orkney, off the national gas grid and utilising oil for process heating. The total volume of production from this grouping was 33,493,500 LPA, some 9% on total industry volume, and their oil heating emissions contribution amounted to **70,700 tCO_2e** (13.4%). This indicates a slightly disproportionate share of energy and specifically heat production emissions arising in this segment of the distilling sector, indicating good applicability and potentially high impact associated with rolling the solution out to these distilleries.

Off-gas-network

Utilising distillery location mapping and SGN gas infrastructure data, a total of 38 off-gas-network distilleries with a total production volume of 80,868,500 LPA, were identified as burning fossil oils with carbon emissions of **165,186 tCO_2e** (31% of the national total). This finding suggests broad possible applicability of the solution elsewhere in Scotland.

Further, we also considered the role that this solution could play in offering a route for the decarbonisation of on-gas-network distilleries. The dual fuelling solution could be equally appropriate as a hybrid hydrogen-natural gas solution in the short to medium term. In the longer term however, it is anticipated that these distilleries could benefit from the blending of hydrogen directly into gas distribution networks up to 20% and beyond. As such, the solution proposed should be prioritised for off-gas applications.

8 Route to Market Assessment

8.1 Key steps towards commercialisation

The first step in identifying a scalable route to market for the solution would concentrate on identifying the highest added value applications for other distilleries and in allied sectors. As noted already, these are expected to be in other island locations and off-gas-network locations. Engagement with potential future customers in these segments would be a natural next step in taking this work forward.

A key consideration in commercialising this solution would involve addressing the critical dependency on hydrogen supply by also evaluating the best possible locations in the vicinity of island and off-gas network distilleries for growth in electrolysis capacity. This analysis would need to consider available potential renewable electricity resource, water availability and space, aiming to identify the most realistic pilot sites for rolling the solution out.

8.2 Addressing Risks and Barriers

8.2.1 Fuel supply constraints

Fuel supply concerns and constraints will restrict the scope for using hydrogen in the distilling process, until such time as sufficient hydrogen supply capacity has been developed. This is a key challenge to rolling the proposed solution out to other sites and contexts but is also a key opportunity given the role that guaranteed demand plays in facilitating investment in fuel production capacity.

As noted already, the existing Orkney hydrogen ecosystem is sufficiently developed to address the demand arising from the Orkney Distillery scale demonstrator proposed. Demonstrating the solution at this scale will encourage the ambition to replicate the solution elsewhere, while also helping to unlock the investment required to increase production capacity locally.

8.2.2 Process disruption

Concerns regarding disruption to production are significant barriers to widespread deployment of innovative solutions in all industries. Seeking to demonstrate an untested solution within a functioning, industrial scale distillery in a heritage building would likely prove very challenging. The demonstrator proposed in this project would take advantage of comparatively good space availability at the ODL site in order to prove the concept in a more flexible environment. Investing in this proof-of-concept demonstrator is anticipated to develop the evidence base required to encourage others to pursue the solution elsewhere in the sector.

8.2.3 Health, safety and environment

Health, safety and environment concerns and challenges are also exacerbated as distillery scale increases, in line with increasing regulatory requirements which scale with production capacity (or rather with the volumes of chemicals handled). As such, testing this solution at a smaller scale with fewer regulatory barriers is anticipated to make this project more feasible from an administrative perspective. Furthermore, this demonstrator can provide the safety evidence required to evolve the health, safety and environment standards and regulatory regime to help keep pace with the emergence of new technologies.

8.3 Benefits in the wider value chain

The fuel demand associated with rolling this solution out to other distilleries and/or other manufacturers could provide the clear offtake required to justify the investment needed to facilitate the scaling up of hydrogen supply capacity. This is a key benefit of the roll out activity described. It is vital to de-risk the investment required for increased hydrogen supply capacity and infrastructure, especially in rural areas where there may be relatively few options in terms of growing hydrogen demand.

There are peripheral benefits to communities which may play host to the hydrogen supply plant and infrastructure, in that these developments could also supply hydrogen for other applications and use cases, such as in providing fuel to refuelling stations for road vehicles or for other forms of transportation (ferries or aircraft). As discussed in the previous section, a further benefit to such an approach is that bringing fuel supply into the local value chain can contribute to driving local economic development in these rural locations.

Another key element of the solution is the transferability of the solution to other sectors, which is an opportunity for developers but is also a benefit of this approach in and of itself. With distilleries providing the justification to scale up hydrogen supply in a location like Orkney, this could unlock opportunities for makers in other sectors to differentiate their products and improve their processes. This is especially true of food and drink manufacturing (cheese making, brewing, etc.) but could also be applied in broader energy system applications, for example in relation to refuelling the diesel-fired Orkney power station.

9 Conclusion

This study has evaluated the potential technologies for the most appropriate application of hydrogen in the decarbonisation of the distilling process. Dual fuelling systems were identified as the most practical solution, allowing fuel flexibility during the course of a broader energy system transition towards more widespread use of hydrogen. This feasibility study is intended to inform the design of a future applied demonstration of the system proposed. Indeed, this report has also provided an overview of a design and development costing exercise undertaken to plan for the deployment of a pilot-scale dual fuel demonstration system at Orkney Distilling Limited's Kirkwall distillery site. This demonstration project will enable the project team to evaluate the process impacts of the system, and to evaluate factors including health, safety, and environmental considerations and commercial outcomes.

This demonstration project is intended to serve as a test case which could be replicated in other, larger scale distilleries. Throughout the feasibility study the project team sought to account for industry requirements and concerns at every stage, in order to maximise potential roll out opportunities for the solution. A key finding of our study focuses on the cost uplift expected for a bottle of spirit produced using hydrogen, which we calculated to be between £0.25 and £1.02 per bottle depending upon the hydrogen price scenario considered. Possible impacts of the solution on spirit quality and production processes were discussed at length and means of attempting to minimise the potential disruption associated with the solution have been explored in this report.

This report has sought to articulate the potential for 'green' hydrogen to make a meaningful contribution to efforts to decarbonise distilling. These efforts can additionally support further widespread deployment of hydrogen supply capacity, especially in rural areas in the vicinity of distilleries. This is a key peripheral benefit of the solution described. In their primarily rural and in many cases islanded locations, distilleries inherently offer employment and development opportunities in remote locations. The proposals detailed in this report offer those distilleries the opportunity to also take up a leadership position in furthering the delivery of 'Net Zero' energy systems.

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Document History

Revision	Date	Description	Originated by	Reviewed by	Approved by
0.1	28.02.2021	First Draft	LF	RF	
0.2	09.03.2021	Second Draft	JW	LF	
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