EMEC HYDROGEN

Industrial Fuel Switching Competition - HySPIRITS Public Report

November 2019

Edinburgh Napier UNIVERSITY

ORKNEY DISTILLING LIMITED

ORKNEY'S KIRKWALL-BASED CRAFT GIN DISTILLER




Document History

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Foreword

Figure 1 - Pictured from left to right are Lord Duncan, UK Climate Change Minister; Jon Clipsham, Hydrogen Manager at EMEC and Stephen Kemp, Owner of Orkney Distilling Ltd. Photo Credit Colin Keldie courtesy of EMEC

The winners of the Industrial Fuel Switching competition were announced on Thursday 29 August by Lord Duncan, in advance of a ministerial visit to Orkney.

Lord Duncan, Climate Change Minister, said:

"Using the power of hydrogen could help cut emissions, create jobs and make industrial processes cleaner and greener, benefitting the whole economy as we work towards net zero by 2050.

This innovative project from HySPIRITS / EMEC will help our efforts to roll out hydrogen at scale by the 2030s – a crucial step towards the end of the UK's contribution to global warming."

Hydrogen has been identified as an alternative fuel for energy intensive industrial processes, such as distilleries. If the technology and business case detailed in the feasibility study proves viable, this offers a substantial decarbonisation opportunity for the wider industry and The Orkney Distillery could become the world's first hydrogen fuelled distillery.

Additionally, it is hoped that the findings of this study can be replicated across the sector with the added benefit that the technology will be designed to be retrofitted into existing infrastructure.

1 Executive summary

The HySPIRITS project was awarded funding under the Industrial Fuel Switching competition: Phase 2 run by the Department of Business, Energy & Industrial Strategy. This project has conducted a feasibility study into adapting traditional distilling processes, currently dependent on fossil fuels, to use hydrogen as a prime energy source. The HySPIRITS consortium is led by the European Marine Energy Centre partnered with Edinburgh Napier University and Orkney Distilling Ltd. Subcontractors, Risktec and Logan Energy, also had input into the project deliverables. This public report summarises the findings from confidential project reports submitted to BEIS

A world first demonstrator in the sector, such as the HySPIRITS project, can help showcase a route to distillery decarbonisation utilising green hydrogen. Sector wide adoption (noting that the HySPIRITS system could be implemented globally over the coming years) will be better understood once the technology is trialled.

Looking at the malt whisky sector alone, there is an opportunity to reduce the UK's carbon footprint by approximately 500,000 tonnes of CO_2e annually, however, greening the whole of the distilling sector, will present many obstacles to overcome.

Large scale change is required to ensure the distilling sector can meet the zero carbon targets set by the UK government. While green hydrogen offers a potential solution to this, many barriers need to be overcome to make significant impact a reality. The first step in this realisation is to have a demonstrator showing what is currently possible from existing technologies.

Abbreviations

Abbreviation	Meaning
ALARP	As Low As Reasonably Practical
ATEX	Explosive Atmosphere (Atmosphères Explosives)
BEIS	Department for Business, Energy and Industrial Strategy
CO2e	Carbon dioxide equivalent
GHG	Green House Gas
HAZID	Hazard Identification
kWh	Kilowatt Hour
LPA	Litres of Pure Alcohol
LPG	Liquid Petroleum Gas
MCP	Manifold Cylinder Pallets
ODL	Orkney Distilling Limited
RAM	Risk Assessment Method
SEPA	Scottish Environment Protection Agency

2 Introduction

The purpose of the HySPIRITS feasibility study is to investigate how green hydrogen can be used as a fuel to decarbonise a small-scale distillery, by using it as a combustion fuel for a boiler burner. HySPIRITS is a collaborative project led by the European Marine Energy Centre partnered with Edinburgh Napier University and Orkney Distilling Ltd. Subcontractors, Risktec and Logan Energy also had input into the project deliverables.

2.1 Objective of document

The objective of this document is to summarise the work completed for the HySPIRITS project. This document is intended to be released to the public and has been pitched at this level. Detailed milestone reports produced through the project have been consolidated into this report, including all information that is suitable for public release.

2.2 Background

A recent feasibility study undertaken with the Energy Technology Partnership in late 2018 (PJ0208-EUB) identified hydrogen as an alternative energy solution for local distilleries, with a potential flagship project identified on the Islands of Orkney. The proposed solution of utilising locally generated green hydrogen to displace both electric and LPG fuels in such an energy intensive environment significantly reduces the carbon impact of the processes and provides a new development sector for brewing/distilling appliance design to meet growing craft brewing and distilling demands. This also has the additional bonus of increasing the utilisation of local renewable energy and helping to alleviate local constraint in the electricity grid.

The project requires the development of a thermal fluid heater to operate with a hydrogen fuelled burner, enabling the thermal process heat requirements to be delivered from a packaged appliance, operating within a safe and controllable environment. The benefits include the ability to utilise lower cost, (predominantly) commercially available equipment; removal of direct combustion systems from a flammable environment; and labour savings gained from not having to ensure plant attendants are present, which would be required when pressurised steam systems are in operation.

The HySPIRITS system is planned to be deployed initially at a ‘craft’ distillery, which is experiencing substantial growth. The design methodology for the system is driven by the potential replicability of the technology across the sector (gin, whisky, vodka, and rum), and is potentially also applicable to breweries and creameries.

It is estimated that there are over 360 distilleries across the UK, over 200 of which have opened in the last five years. The HySPIRITS system is intended to be retrofittable into existing infrastructure and as the hydrogen economy grows, this will provide a significant carbon reduction opportunity within the industrial process sector.

3 Distilling market analysis

3.1 Energy benchmarking

Typically, the spirit production industry is a hugely energy intensive process involving successive heating and cooling processes in order to achieve a refined product. The malt whisky production process is typified by the process shown in Fig. 2 below. Energy benchmarking is used to calculate a comparative metric used across the sector in order to measure the relative energy used by a business in respect of production volume. By dividing the total annual energy usage (kWh) for the distillery by the production volume of Litre of Pure Alcohol (LPA) a specific energy consumption is derived (kWh/litre).

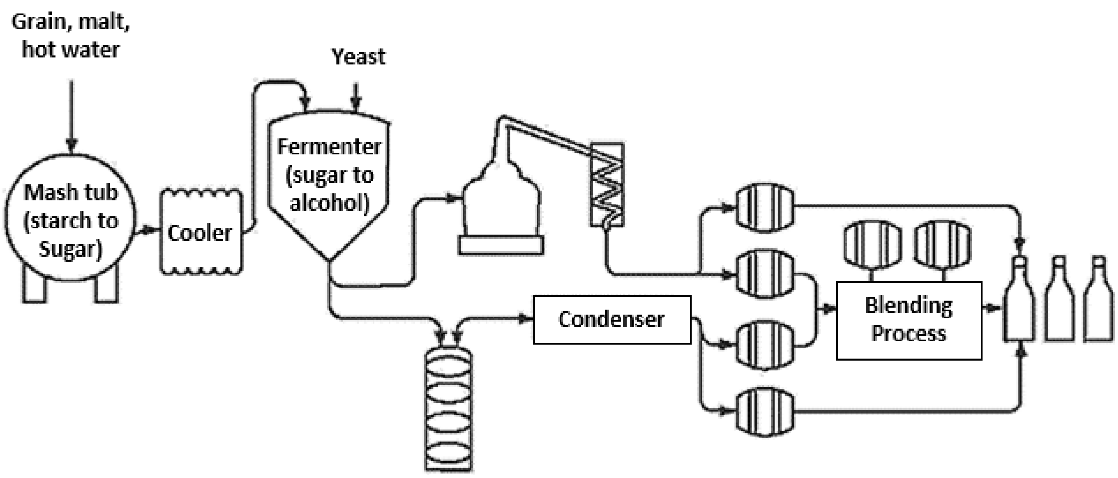

Figure 2 - Distilling Process

A survey of the Scottish Craft Distilling (SCDA) sector was undertaken in 2015 as part of an Interface Food & Drink funded study (Currie, 2015) and the collated results revealed the following specific energy consumption figures related to product shown in Table 1

Product	Specific Energy Consumption (kWh/litre)
Gin	1.7 - 2.3
Whisky	12.7 - 13.9

Table 1 - Specific Energy Consumption of the distilling process

Discussions with Orkney Distilling Ltd have identified the level of production would be in the order of 30,000 LPA per annum, once the full business scenario of whisky production has been implemented. Using the above benchmark figures, it is thus estimated that the energy requirement for meeting this level of production would be in the region of 400,000 kWh per annum. Based on these production figures several scenarios for production were then discussed with the company. The next section presents the preferred production option developed from these discussions.

4 Technology selection for decarbonisation

Having looked widely across the craft-distilling sector, a large range of approaches are taken in production models to meet expected growth in demand. Following discussions with Orkney Distillery it was agreed that the likely production configuration to meet a 30,000 LPA output of whisky, gin and possibly other spirit production (e.g. rum) would require a 2000 litre mash vessel, one 2000 litre or two 1000 litre wash stills, 1000 litre spirit still, four 2000 litre fermenting vessels, together with other supporting tankage (e.g. hot liquor and cleaning in place (CIP)).

At present the distillery uses LPG combustion sources with open flame gas burners located below the distillation vessels in the stillhouse as shown in Figure 3. The burners are fitted with flame failure devices and a flammable gas detection system is linked to mechanical extraction fans in order to ensure that flammability levels are not exceeded in the space.

Figure 3 - Current Gin Still Configuration

4.1 Technology descriptions

The HySPIRITS partners evaluated a number of options for the decarbonisation. The following describes the proposed system for deployment, shown in Figure 4.

4.1.1 Hydrogen and fire detection

Within the packaged boiler room, a hydrogen detection and fire detection system will be installed to detect any hydrogen leak or fire and cause the system to shut down and hydrogen to be isolated from entering the boiler room.

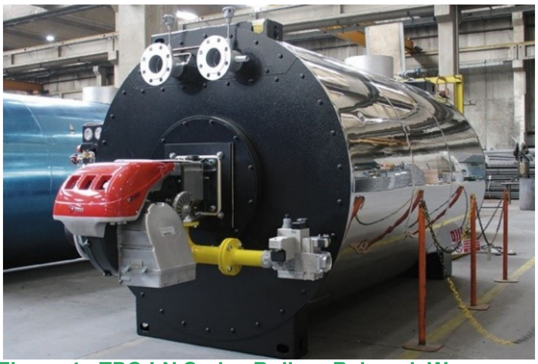

Figure 4 - TPC-LN Series Boiler - Babcock Wanson

4.1.2 Packaged boiler room

To provide a safe and retrofittable solution, a ‘packaged’ boiler room concept has been developed. This room will be a modified 20’ ISO container incorporating the boiler, oil circulating pump, hydrogen supply, control system, and hydrogen detection, with a valve cabinet mounted externally incorporating hydrogen pressure regulation and safety valve arrangement.

4.1.3 Boiler

The identified boiler for the system is a Babcock Wanson hydrogen fuelled indirect oil heater. The oil circulating system and feed & expansion cistern will be located within the boiler room.

4.1.4 Trailer / hydrogen storage

The proposed trailer would be a lightweight 20’ trailer similar to those already deployed on Orkney, transporting approximately 250 kg of hydrogen at 200 bar pressure.

4.1.5 Budget costs

The cost of the packaged plantroom excluding the cost of the boiler and oil system and site installation is estimated to cost £212,000, The trailer is estimated to cost £263,000.

4.1.6 Provision of zero regrets option

As the project is a first of its kind and is being installed in a commercial facility, there is a need to provide an option to revert to conventional solutions. This would be to use bottled LPG and the boiler manufacturers have advised that this would be achievable with a simple burner / blower change on the boiler and then re-piping of the fuel pipes to the boiler.

4.2 Replicability for scale

Whilst this initial system is a demonstrator, the follow on from this will be to assess the applicability of the technology to be scaled and adapted across the industry. It was an important consideration to the HySPIRITS team to understand how the system could be deployed across the ~ 360 distilleries around the UK.

The present layout of the Orkney distillery is relatively spacious for small scale gin production; however, the addition of larger scale distillation plant and associated equipment will put pressure on the available space.

Data provided on the malt whisky sector indicates that five of the smaller distilleries, in the production range of 0-100 thousand LPA, in Scotland could be sites for replication. It is assumed that the majority of small-scale gin distillers could also be of similar size to benefit from replication and further data is being gathered to confirm this.

5 Conversion of existing distillery

5.1 Basis of design

5.1.1 Scope

This section of the report identifies the size, options, design, layout, practicalities, and any further scoping required for the installation of a hydrogen fuelled heating system for the Orkney Distillery distilling operations.

5.1.2 Brief

The brief was determined by The Scottish Energy Centre, Edinburgh Napier University in conjunction with the distillery, EMEC and Logan Energy by reviewing the requirements for the distillation process and anticipated quantities. These were as follows:

- Based on 30,000 LPA of whisky production this uses 400,000 kWh of energy and emits 85.6 tCO2e per annum.
- Output is based on 5 wash distillation and 5 spirit distillations per week i.e. 660 litres per week which works out about 8,800 kWh per week
- Boiler size was determined as 200 kW

Using the manufacturer's boiler efficiency of 85% this requires approximately 315kg of hydrogen per week. The system has been designed around the use of an indirect heating oil which will circulate from the packaged boiler house through the distillery to the various stills and is outlined in Figure 6. It is intended that the boiler house is a packaged unit designed, assembled and tested as a unit off-site to minimise disruption to onsite operations.

Figure 5 - Hydrogen Tube Trailer & Orkney Distilling Ltd Rear Car Park

Given the quantity of hydrogen required, the most practical method of delivery would be by hydrogen trailer, similar to those currently deployed in Orkney. The trailer will also be used as the onsite storage/supply method. A buffer would be provided in the form of a standard MCP allowing the replacement of the trailer without interruption to the boiler operation. An example of one of the trailers currently in use is show in Figure 5 along with the rear car park of the distillery which would be adapted for its use. An initial design layout of the system is shown in Figure 6 below.

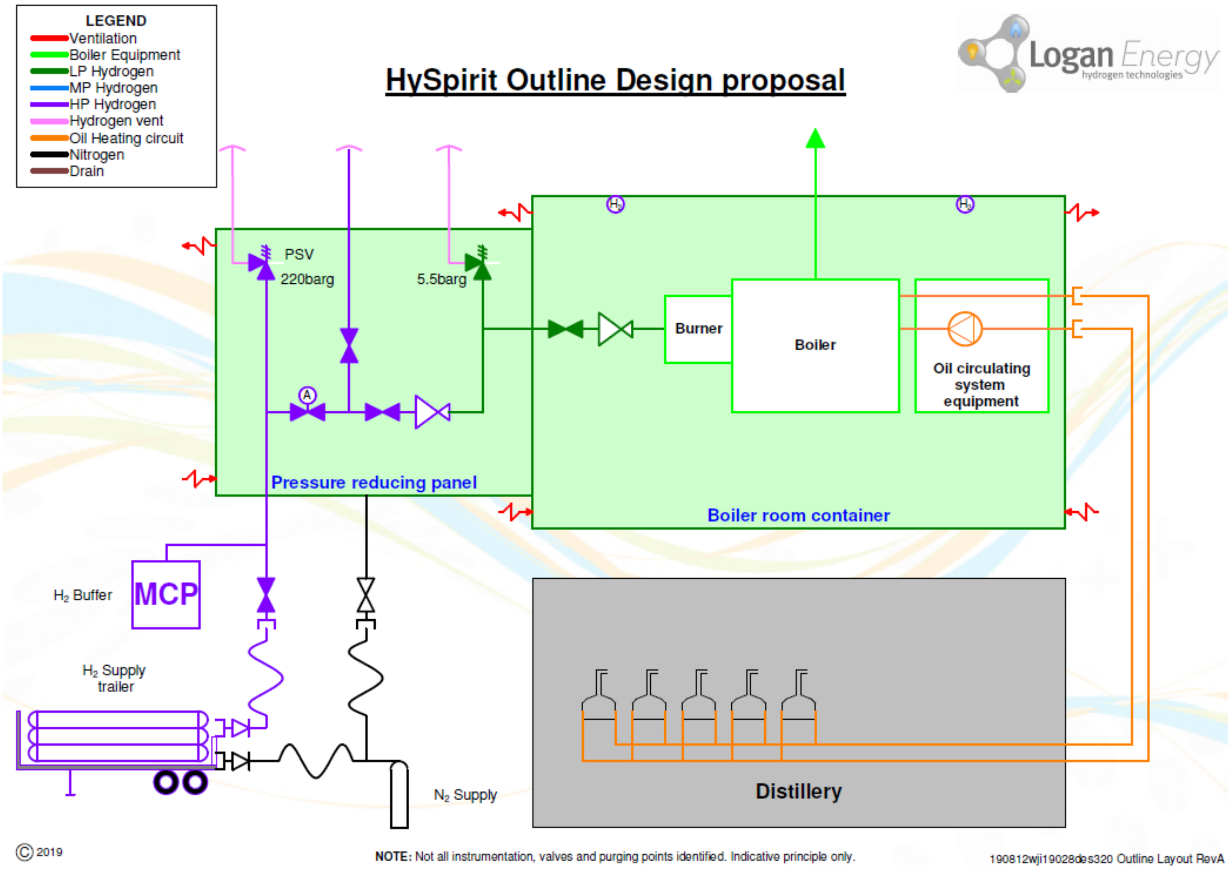

Figure 6 - Outline Design

5.2 Design considerations

The distillery is aspiring to become one of only a few craft distillers who produce their own spirit by mashing grain and fermenting the resulting wort, which is then distilled. Initial discussions with the distillery and potential distillation equipment suppliers have identified a notional 0.33 tonne (mash) plant capacity as meeting production needs. From these discussions a fuller plant specification has been arrived at and forms part of the cost modelling undertaken.

It is anticipated that installation of a 1650 litre wash still together with a 1200 litre spirit still operating on a 5-day cycle of 1 mash/day and 5 wash/5 spirit distillations per week could achieve the predicted annual production capacity of 30,000 LPA. The basis of the initial plant sizing metrics is given below and provides a basis for scoping the demand loads. In terms of hydrogen usage, utilising the metrics developed earlier from benchmark data and production figures listed in Table 2, together with boiler specifications (85% efficiency) it is anticipated that the following hydrogen demands might be realised.

Consumption	Rating (h2 equivalent)
Maximum demand	235 kW
Daily consumption (max)	2,825 kWh (85 kg)
Average weekly Consumption	10,490 kWh (315 kg)
Average annual Consumption	403,800 kWh (12,126 kg)

Table 2 - Energy Consumption

5.2.1 Demonstrator design conclusion

The scoping work covered by the HySPIRITS consortium , evaluated the process loads and demand, matched to an innovative energy supply system, for fuelling a modern craft distillery sustainably. The team have identified a means for re-fuelling the distillery with hydrogen utilising an intermediate heat transfer fluid system linked to hydrogen storage infrastructure and safety mechanisms in order to meet distillery expansion and growth metrics. Based on the projected expansion of the distilling operation to 30,000 LPA production output, it is anticipated that this industrial fuel switching approach will displace 85.6 tCO_2e per annum.

Hydrogen has thus been identified as an alternative fuel for energy intensive industrial processes, such as distilleries. During Phase 3 of the HySPIRITS project, a demonstrator will be able to confirm the feasibility study and business case, this then offers a substantial decarbonisation opportunity for the wider industry. The Orkney Distillery would become the world's first hydrogen fuelled distillery. Additionally, it is expected that the findings of this study can be replicated across the sector with the added benefit that the technology will be designed to be retrofitted into existing infrastructure. If this system can be replicated across the five malt whisky distilleries assessed in the 1-100 thousand LPA production range, as shown in Table 3, there is the opportunity to displace an estimated 1300 tonnes of CO_2e annually produced by current fossil fuel use.

LPA Range	Distilleries	Energy Used	Green House Gas
Thousand litres	Count	MWh	Tonnes CO_2e
0 - 100	5	1,197	1,303
100 - 1000	18	210,539	51,562
1000 - 5000	71	1,418,710	347,449
5000 - 10,000	4	234,617	57,459
TOTAL	98	1,865,063	457,773

Table 3 - UK Malt Whisky Sector Breakdown

6 Safety considerations

As the hydrogen economy continues to grow, there is increased exposure to the public. Demonstration projects provide a platform to understand safety concerns around nascent technology. The Aberdeen hydrogen bus project has led to greater public acceptance of hydrogen use as a fuel on public transport, having now carried over 1 million passengers 1.6 million miles, HySPIRITS will be able to showcase to the public, hydrogen use in industry, and clearly show that it provides no more of a risk than current fuel use.

Whilst still in the feasibility stage, the project sought to review associated hazards incurred by introducing hydrogen to a distillery environment. A full HAZID (hazard identification) assessment was carried out by Risktec which reviewed the high-level design options for the system and associated risks.

Unless hazards are identified, they cannot be controlled through implementation of appropriate risk reduction measures. It is essential that all hazards associated with the entire lifecycle of hydrogen and associated equipment in the distillery process are identified. This allows for them to be 'engineered-out' or, where this is not possible, for appropriate risk reduction measures to be vested in the design to reduce the risk to As Low As Reasonably Practicable (ALARP).

6.1 HAZID

A HAZID workshop was carried out as part of the feasibility study to make initial safety assessment of the system concept available at the time.

The purpose of the HAZID workshop was to:

- Identify all reasonably foreseeable, significant hazards/threats associated with the storage and use of hydrogen in a distillery environment.
- Identify consequences of hazards/threats to people and the environment.
- Risk rank the identified hazards using the EMEC Risk Assessment Matrix (RAM).
- Identify any controls/mitigation which can be claimed to prevent/mitigate the hazard/threat.
- Raise any actions necessary to either confirm/obtain further information, carry out additional assessment or incorporate further risk reduction measures into the design.

The output from this HAZID workshop provided valuable input into the HySPIRITS project, particularly with regard to designing out risk where possible. The output from this HAZID workshop will also feed into subsequent safety studies related to the next phase.

The HAZID study considered hazards associated with:

- Transportation of hydrogen to distillery
- Delivery/storage options of hydrogen at the distillery;
- Hydrogen trailer left onsite with direct feed to boiler
- Hydrogen trailer supplies hydrogen into fixed storage solution which feeds boiler
- Delivery of hydrogen bottles/MCPs to site which feed boiler
- Location of storage i.e. distillery car park or warehouse across road from distillery, with hydrogen supplied via underground pipework to boiler
- Use of HySPIRITS equipment (this includes all equipment containing or using hydrogen, the thermal boiler, and all associated equipment containing thermal oil)
- Maintenance & service of HySPIRITS equipment

- Parallel distillery operations
- Identification of any distillery operations that could potentially impact the HySPIRITS equipment and what effect these would have e.g. deliveries, bottling, distillery tours, storage.
- Interfaces between distillery equipment and HySPIRITS equipment e.g. still coils containing thermal oil, or equipment which may interfere/come into contact with HySPIRITS equipment e.g. storage racking against pipework
- Reversibility of concept to a non-hydrogen system
- Disposal / decommissioning of hydrogen from distillery

6.1.1 Methodology

The following methodology was followed for HAZID brainstorming.

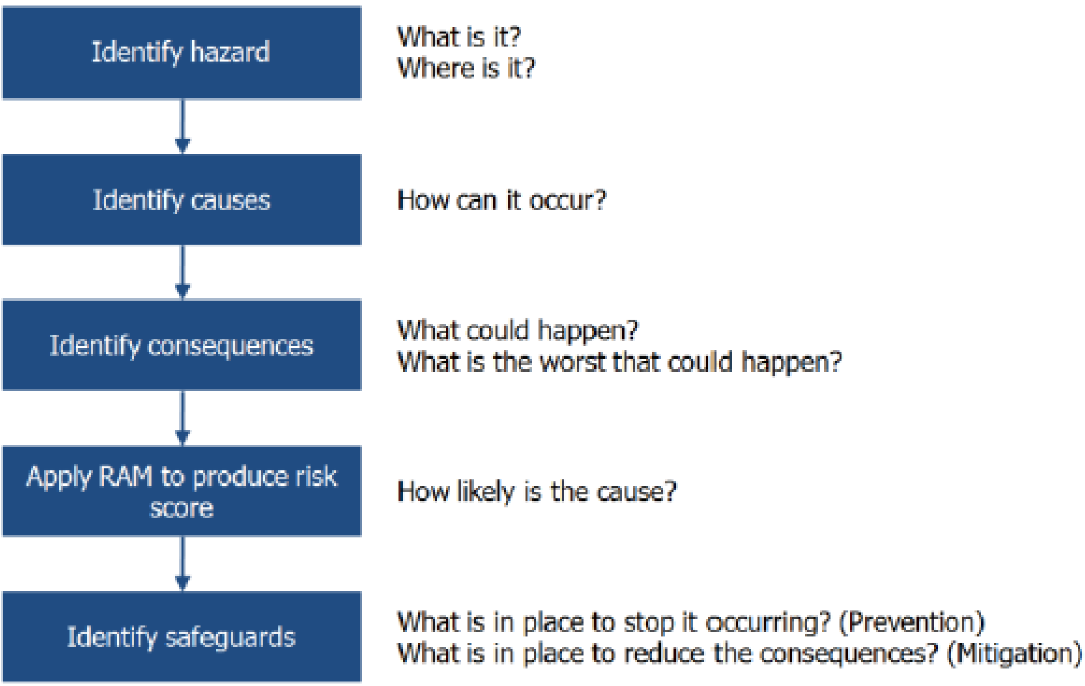

Figure 7 - Risk Assessment Methodology

6.1.2 Key issues

As this is a conceptual design, there are a lot of unknowns regarding design, layout, responsibilities and management of the hydrogen equipment to be installed at the distillery. The purpose of this workshop was to identify, at a high level, potential hazards associated with the proposed equipment. Once the design is progressed further and more information is available, the project should undertake a complete in-depth safety study for the entire facility.

- There was specific discussion during the workshop regarding the importance of verifying that the correct and appropriately rated equipment is used within areas that may be designated as being hazardous areas once the hydrogen equipment is installed. Guidance for such verification is provided in DSEAR ACOP and includes review of design records to provide assurance that equipment is correctly rated for hazardous area zone by design; visual inspections to ensure that equipment is installed correctly and damage free; and potential support to commissioning engineers to ensure that equipment is installed and commissioning correctly.

- Once the equipment design and layout are defined, there will need to be a complete review of access to the distillery carpark and security access to hydrogen equipment. Currently, there is no control of access to the carpark and the proposed location for the hydrogen equipment. Given the central location of the distillery (residences, pubs/club, restaurants), it is a busy area through the day and night and therefore sufficient access control needs to be implemented.

- During the HAZID workshop, it was assumed that the hydrogen equipment will be inspected, maintained and operated by a qualified and competent person. At this stage, it is unknown who will undertake these activities (distillery, third party contractor or otherwise) and therefore when assigning these roles and tasks, it should be ensured that the competency of that party can be assured and verified.

- Once operational, there will be several hazardous inventories stored at the distillery in varying volumes, namely; hydrogen, LPG, ethanol, thermal oil, gin/whisky product. The distillery and the HySPIRITS project will need to undertake a review of the COMAH regulations to ensure they are either below the threshold for regulation or are complying with the regulations within which the project falls.

- In general, a public engagement and awareness session on hydrogen generation and use of hydrogen as a fuel for various applications will lead to a better understanding and greater buy-in from the residents of Orkney and, in particular, Kirkwall. This is essential for successfully and safely integrating hydrogen into the community HAZID conclusion

Although the application of hydrogen in a distillery environment is a novel concept, the use of hydrogen as a fuel source is not. The hazards identified during the workshop are ones which are foreseeable for storage and use of hydrogen and can be assigned actions for mitigation. This concept-phase HAZID workshop did not identify any hazards which cannot be appropriately managed to ensure associated risks are acceptable (contingent on suitable design and managerial control provisions).

At the next phase, further assessments (e.g. HAZID and/or HAZOP workshops, design reviews and risk analysis) will need to be undertaken at appropriate stages of the HySPIRITS project to ensure risks are ALARP. EMEC and project partners should ensure that all non-procedural safeguards are shown in the drawings/documents prepared by the designers, and if not, appropriate risk control actions should be raised. The project will also need to ensure that all procedural arrangements are in place and are being managed effectively. Particular attention should be paid to the hazards shown as having a high or medium risk to ensure that the risk is reduced to a tolerable and ALARP level. Those hazards with residual medium risk should be monitored to ensure the risk level does not increase.

7 Financial cost modelling

A review of the HySPIRITS cost requirements was conducted as part of the Phase 2 Feasibility Study and provided component selection and pricing, based on the infrastructure design needs identified in the HySPIRITS – system requirements, in order to support the wider demonstration expected in the next phase of the project.

7.1 System costs

7.1.1 Distillery costs

The distillery has been sized on an anticipated full production volume of 30,000 litres pure alcohol (LPA) per annum. Initial quotations have been received from a Scottish based manufacturing company, LH Stainless, to provide this capacity of plant which would supply a 0.33 tonne configuration comprising 2000 litre mash vessel, 1650 litre copper wash still, 1200 litre spirit still, associated condensers / fermentation vessels and hot liquor tanks / spirit receivers / pumps and ancillary equipment. The total cost of this equipment is £295,380 (ex VAT).

Electrical Work including motor control centre and panels – this aspect can range from £140,000 for a basic system to £280,000 depending on the level of automation and interlinking with the hydrogen supply infrastructure required in order to comply with DSEAR.

Other costs for associated works which are not included in the above distillation equipment CAPEX are included in Table 4:

Component	Cost
Process Pipework	£65,000
Mechanical Installation	£140,000
Design and Documentation	£30,000
Commissioning and testing	£25,000
Packaging and transport	£30,000
Lacquering of wash and spirit stills	£9,000
Flame Arrestors	£20,000
CIP System	£49,000
Electrical Work (high estimate)	£280,000
Distillery Equipment	£295,380
Total	**£943,380**

Table 4 - Distillery cost breakdown

7.1.2 Thermal fluid heater

At this stage of the feasibility study a CAPEX cost in the order of £69,500 (ex. VAT) is estimated for the supply, delivery and commissioning of the heat transfer fluid heater and burner unit (excluding civil works, and process connections, electrical works and hydrogen supply infrastructure).

Additional costs associated with the site electrical and mechanical interfaces/connections in order to ensure safe operation and control are estimated in Table 5:

Component	Cost
Process, Pipework, Pumps, Valve work and Insulation	£30,000 (ex. VAT)
Electrical Installation	£140,000 (ex. VAT)
Fluid Transfer Unit and Burner	£69,500 (ex. VAT)
Total	**£239,500 (ex. VAT)**

Table 5 - Thermal fluid system costs

It should be stated that as this project is at feasibility stage and detailed design work has yet to be undertaken, several additional costs have yet to be realised. Allowance still needs to be made for civil works. Many of these costs are not directly attributable to the industrial fuel-switching element of the project.

7.1.3 Hydrogen infrastructure costs

Costs for the hydrogen supply infrastructure to the boiler have been estimated by Logan Energy Ltd, a company that specialises in the integration and installation of energy centres, energy storage, hydrogen production and refuelling stations. Their design has incorporated trailer deliveries of hydrogen to the distillery, together with a small buffer to allow trailers to be swapped out and the boiler still run; leaving the trailer on site was the best option for cost, logistics and space The costs are highlighted in Table 6 below.

Component	Cost
Hydrogen infrastructure	£211,787 (ex. VAT)
Trailer	£263,070 (ex. VAT)
Civil Works	£27,500 (ex. VAT)
Detailed P&ID & Commissioning drawings	£5,000 (ex. VAT)
Total	**£507,357(ex. VAT)**

Table 6 - Hydrogen Infrastructure Costs

7.2 Cost summary

This Phase 2 Feasibility Study has evaluated the process loads and demand, matched to an innovative clean energy supply system, for fuelling a modern craft distillery sustainably. The team have identified means for re-fuelling the distillery with hydrogen utilising an intermediate heat transfer fluid system linked to hydrogen storage infrastructure and safety mechanisms in order to meet distillery expansion and growth metrics. Based on the projected expansion of the distilling operation to 30,000 LPA production output it is anticipated that this industrial fuel switching approach will displace 85.6 tCO_2e per annum.

Total costs in the sum of £746,900 (ex. VAT) have been identified for equipment required for a demonstration scale project to use hydrogen as an alternative fuel for the distillery, against a distillery capital infrastructure cost of over £943,380. If the technology and business case detailed in the feasibility study proves viable through articulation into Phase 3, this offers a demonstrable and substantial decarbonisation opportunity for the wider industry and The Orkney Distillery could become the world's first hydrogen fuelled distillery. Additionally, it is anticipated that the findings of this study can be replicated across the sector with the added benefit that the technology will be designed to be retrofitted into existing infrastructure so will reduce overall costs for transitioning. Real world demonstration and 3rd party testing carried out in Phase 3 of the HySPIRITS project will bring greater confidence in the system's ability to produce the same high-quality products with massively reduced carbon emissions.

8 Carbon reduction

The SEPA Sector Plan for scotch whisky states "The SWA member companies have agreed a target of ensuring that by 2020, 20% of their primary energy requirements will be from non-fossil fuel sources, with a target of 80% by 2050. Table 7 shows the carbon reductions that can be met by an individual demonstrator with various fuel types for the 400,000 kWh estimated energy use for the HySPIRITS distillery.

Fuel type	Net CV CO_2e per kWh	kWh energy	CO_2e (kg)
Kerosene	0.25963	400,000	103852
LPG	0.2303	400,000	92120
Natural Gas	0.20437	400,000	81748
Green H_2	0	400,000	0

Table 7 - Carbon emissions per fuel type

Even with the use of natural gas the counter factual of replacing the 400,000kWh needed by a single demonstrator will save over 80 tonnes of CO_2e annually.

Overall an estimated 500,000 Tonnes of CO_2e, as shown previously in Table 2, is emitted by the malt whisky distilling sector in the UK annually. Specific data is still being gathered from individual distilleries, however, this value for malt whisky production alone is considerable. For a product that can take over ten years to bring to market, and with an increasingly climate aware public, the sector is keen to make transitions now, to ensure their future products will meet the demands of their market. 2019 will also see a further Scotch Whisky Industry Environmental Strategy Report. It is expected that this will further endorse the need for carbon reduction in the distilling sector. Once further industry data is gathered it is recommended that a road map to decarbonisation of the sector is developed.

8.1 Subsidy support

The commitments to reach Net Zero have to be met by appropriate measures to reduce the attractiveness of traditional fossil fuels, either by substantially increasing their current low costs or imposition of a carbon tax. Alternatively, green solutions could be encouraged by providing subsidy to industrial practice, along similar lines to the Renewable Transport Fuel Obligation or Renewable Heating Incentive. These market driven subsides offer financial incentive based on the polluter pays principle.

9 Sector roll out

At a high level the 2018 Scottish Environment Protection Agency's (SEPA) Scotch Whisky Sector Plan indicates that over 40,000 jobs are supported across the UK from the sector, with 10,000 employed in the sector directly in Scotland. Information provided by the Scottish Parliament indicates that Scotland has 128 malt and grain distilleries which makes it the largest concentration of whisky production in the world. 2017 saw Scotch Whisky exports excess £4 billion and accounted for around 20% of all UK food and drink exports. By comparison in the same year tourism expenditure in Scotland was estimated around £ 2.3 billion, highlighting the significant importance of this industry. It was also highlighted that in Scotland, that gin is the primary product of over 60 distilleries, producing over 110 gin varieties.

It is estimated that over 70% of the UK gin produced by volume comes from Scotland. It is clear that the distilling sector is very import to the UK, especially so in Scotland.

It can be assumed that the need for decarbonising the sector will not be felt equally across all geographic areas. Looking at the sector distribution across Scotland gives an indication that some areas will rely on the sector for job security, such as Moray and the Scottish Highlands The following chart shows the distribution of distilleries by local authority across Scotland.

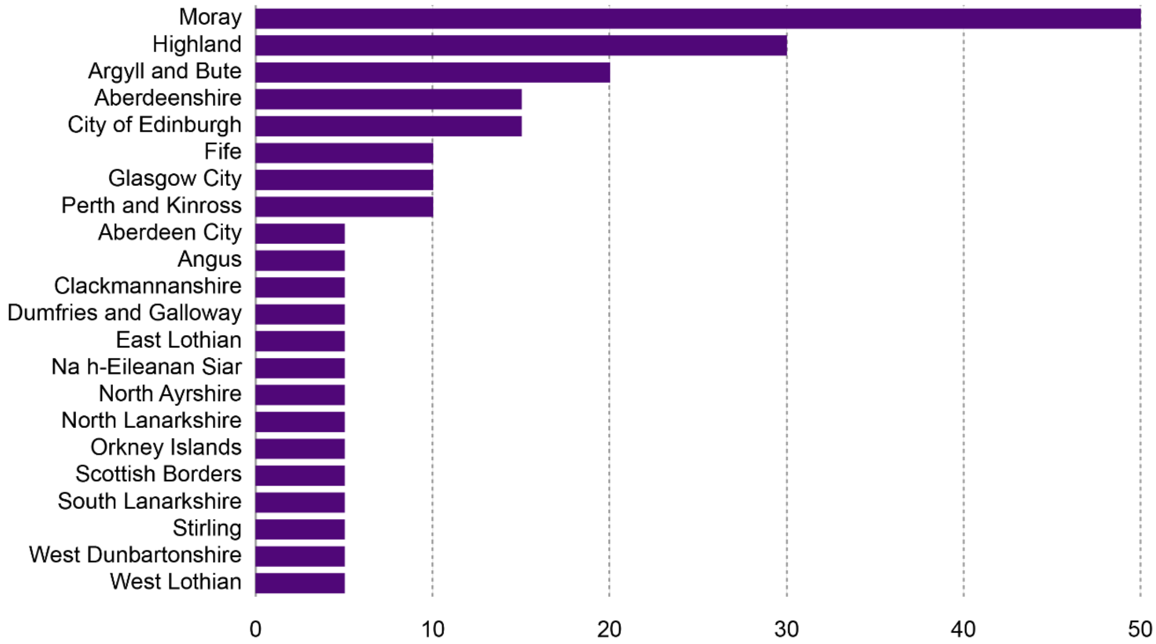

Figure 8 - Geographical Distribution Source: Office for National Statistics

The Scotch Whisky Sector Plan 2018 states a target of 20% of primary energy from non-fossil fuels by 2020, rising to 40% by 2030 on a trajectory to a target of 80% by 2050. These goals need to be achieved if the sector is to reach the legal requirements of the net zero commitments set out by government. Green hydrogen offers a solution to achieve these goals with current technology. An Industry Scale Up study assesses several potential roll-out scenarios as points of discussion.

- The HySPIRITS as a single demonstrator
- Full Orkney wide replication
- Roll out to similar size distillers
- Large scale replacement, focussed on distilleries currently connected to the gas grid
- UK wide role out

LPA Range	Distilleries	Energy Used	Green House Gas
Thousand Litres	Count	MWh	Tonnes CO_2e
0 - 100	5	1197	1303
100 - 1000	18	210539	51562
1000 - 5000	71	2999815	734670
5000 - 10,000	4	496090	121495
TOTAL	98	3707641	909029

Table 8 - UK Malt Whisky Sector Breakdown

With the available data for the malt whisky distillery sector each of the above options were considered. Assessing the data for the UK wide malt whisky industry this would equate to

GHG reductions in the region of 500 thousand tonnes of CO_2e annually. To achieve replacement of current fossil fuel use, an estimated 3.7 million MWh of clean energy in the form of heat is needed. This is not an insignificant amount of renewable power and equates to around double the annual output of Whitelee Wind Farm, the largest onshore wind farm in the UK.

It could be assumed that the largest distilleries receive the majority of their energy from the gas network. Achieving large scale roll out of the distillery sector with green hydrogen might only be possible through an overhaul of the National Gas Grid to provide bulk green hydrogen gas supply. This adaptation is being developed by Scottish Gas Networks and others, such as the H21 project, by looking into the feasibility of hydrogen introduction into the gas grid. Currently it is estimated that a 20% hydrogen blend could be introduced without large changes. To reach 100% hydrogen new appliances would need to be incorporated. The technology proposed in the HySPIRITS project could be instrumental in demonstrating such options could work for large scale industry.

9.1 Wider roll out to replicable craft distilleries

There is a clear need for an updated and in-depth data set to properly assess the sector. This has been recognized by the Scottish Government in the 2018 Brewing and Distilling in Scotland – Economic Facts and Figures stating ***"whilst the whisky sector is relatively data rich, other spirits are poorly served in terms of official data and this prevents a full understanding of current business base"*** With this in mind to make better assessment of the distilling sector beyond whisky an information request was distributed asking for detailed information. To date, response has been limited, believed to be due to the commercially sensitive nature of the information requested, developing this data set and given more time is looking to promote interest through government support and industry groups.

9.1.1 Tradition

The distilling industry is steeped in tradition, which can be readily identified in the marketing / branding of final products in the whisky sector. This could potentially act as a barrier to introduction of new technologies, where distilleries use tradition as a corner stone of marketing their products. However, it is noteworthy that (particularly in large export markets such as Japan) the consumer is demonstrating an ever-increasing awareness and desire to consume ethically and sustainably produced products, and this is an awareness that is expected to grow.

9.1.2 Cost

While the hydrogen economy has been steadily growing over the last few years it is a long way from having the installed infrastructure or global acceptance that fossil fuels such as heating oil or natural gas currently experience. As such there are additional costs associated with its use. These are costs that distillers are unlikely to be able to fully pass onto their customers; however, for a premium product which can take over 10 years to reach market, a number of distilleries contacted have indicated that they would consider making the transition now, even though it is more expensive. While this is a significant barrier, it is one that must be overcome for the UK to reach its net zero commitments.

Assessing future fuel costs against the 2030 counterfactual of £77/tCO2 and £0.035/kWh of natural gas it is noteworthy that a strike price of around £1.50/kg of hydrogen would be needed to reach cost parity. Interestingly, when comparing to current fuel use for the proposed HySPIRITS distillery, LPG, a price of £4/kg for green hydrogen would make it cost competitive. The current fuel costs plus carbon tax, shown in orange and hydrogen fuel costs shown in green respectively in Table 9. These all assuming the same 400,000 kWh of heat requirement for each option.

	Fuel Type	£/kg	£/kWh	Annual Fuel Cost	CO2e/ kwh	CO2ek g	Carbon tax (2030)	Total Cost
							£77/tCO2	
Current Orkney Distillery Use	LPG	£1.77	£0.130	£52,000	0.2303	92120	£7,093	£59,093
Counterfactual (2030) estimates	Natural Gas	£-	£0.035	£14,000	0.2043	81748	£6,294	£20,295
HySPIRITS Future Roll Out	Green hydrogen	£2.20	£0.078	£31,373	0	0	£0.00	£31,373
HySPIRITS Future Roll Out	Green hydrogen	£1.50	£0.053	£21,390	0	0	£0.00	£21,390
HySPIRITS Future Roll Out	Green hydrogen	£4.00	£0.143	£57,041	0	0	£0.00	£57,041

Table 9 - Fuel Cost Comparison

9.1.3 Time scale of payback

Due to the nature of the whisky industry, products must be aged for a minimum of three years before it can be given the title of scotch whisky and many distillers will age products for much longer. With is in mind, even if sustainable products produced from the sector can charge a premium for new sustainably sourced products, the timescale until the return is seen makes borrowing prohibitive for distillers. Investments in the sector are therefore (necessarily) seen as long term and are generally strategic.

9.1.4 Skills needed

The hydrogen economy is rapidly developing as part of the global solution to decarbonise energy use. With this comes challenges of upskilling and job transitioning. Standards and training packages are still being developed. Identifying the distilling industry energy needs early and feeding into these developments will be required.

9.1.5 Scale

As indicated in the full UK roll out scenario for the malt whisky sector alone, the infrastructure and renewable power generation required is substantial. To meet the needs of the UK whisky sector an additional wind farm the size of Whitelee, the UK's largest onshore windfarm, would be needed. Given this it is unlikely that this will be a quick process, clear road maps and development plans are needed to be implemented as soon as possible. Scottish Government are developing a GIS tool which will overlay a number of different infrastructures and energy demands. This tool will be extremely helpful in identifying key locations for hydrogen production hubs, and large off takers (such as distilleries) will impact chosen locations.

10 Phase 3

The Phase 3 proposal for the Industrial Fuel Switching Competition will enable Orkney Distillery Ltd to deploy the HySPIRITS system and become the world's first hydrogen-fuelled distillery. Funding will de-risk the conversion process from fossil fuel to a zero-carbon; and support the demonstration of a highly replicable technology for wider industrial deployment to reduce UK carbon emissions.

The deployment of the technology solution developed in Phase 2 will benefit an increasing number of hydrogen system installers; UK based equipment providers; UK hydrogen manufacturers; and the distilling, brewing and wider food and drinks sector. Additionally, as the process is designed to run on 'green' hydrogen, the phase 2 study has identified that conversion of renewable energy to hydrogen has the potential to enhance revenue streams for renewable energy producers, hence the development of end-user markets for hydrogen is also of interest to the renewable energy sector.

11 Conclusions

With a world first demonstrator on the ground, the HySPIRITS project will be able to provide proof of concept evidence, while gathering valuable data on the distillery’s operation. While this work is being continued, more focus is needed to gather energy consumption data at a distillery by distillery level to allow more accurate assessment of how the transition to clean energy can be achieved.

Simply put, renewable electricity alone cannot meet the demands of high intensity heat for industry, something that the UK distilling sector relies on. Hydrogen use offers an opportunity to capture and redistribute renewable energy and help transition this vital industry to a clean and sustainable energy source.

The HySPIRITS deployment will be able to showcase the ability for hydrogen to meet the distillery demands on a small scale. This should be replicable at least across the craft distillery sector, who operate units of similar size in the UK. For this initial step to achieve the biggest impact it is proposed that replication focuses on those reliant on fuel oil, as this emits round 30% more GHG than natural gas.

While the work on the HYSPIRITS project has focused on the use of green hydrogen to meet the demands of a local distiller in Orkney, when we look at the wider picture of energy use across the UK, the variety of energy options used by a range of distillers, needs to be better understood.

For hydrogen to significantly impact the sector and provide a clean alternative to fossil fuels, further testing and adaptation of the UK gas grid is required. If this indeed becomes an option for the future, the UK distillery sector must be ready to make the transition and implement technology options such as those demonstrated in the HySPIRITS project.

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