Cornish Geothermal Distillery

BEIS Green Distilleries Competition - Phase 1

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Final Submission

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Glossary

Term	Definition
CGDC	Cornish Geothermal Distillery Company
COP	Coefficient of Performance (efficiency)
DHN	District Heating Network
EV	Electric Vehicle
HFO	HydroFluoroOlefin
HP	Heat Pump
HTHP	Hight Temperature Heat Pump
LCOH	Levelized Cost of Heat
LPA	Litres of Pure Alcohol
MVR	Mechanical Vapor Recompression
UDDGP	United Downs Deep Geothermal Power Project

Executive Summary

The Celsius project by the Cornish Geothermal Distillery Company aims to be the UK's first zero-carbon distillery with onsite maturation facilities.

The proposed demonstrator system aims to utilise waste hot water from a geothermal power production process for use within the CGDC site. The hot water will enter the site at 80℃ via a plate heat exchanger interface located at the geothermal site boundary and be distributed through a piped heating network. This geothermal heat supply will then be increased to 120℃ steam with an industrial high temperature steam heat pump.

Ultimately heat return water from the evaporator side of the heat pump will then be returned to the geothermal wells via the plate heat exchanger interface. However, the goal is to utilise the return water (60-70℃) around the rest of the site for heating and humidification before the heat is transferred back to the geothermal plant. For the demonstrator project the waste energy will be used to provide heating to the maturation pods, warehouse, R&D facility and offices. For later phases of the project, the waste heat will serve the whole site, including the visitor centre, hospitality facilities and a spa.

Power to site will be supplied by a zero-carbon private wire network from the geothermal site. This will be delivered to an electrical substation within the CGDC site and used across all building and for onsite visitor and commercial EV charging.

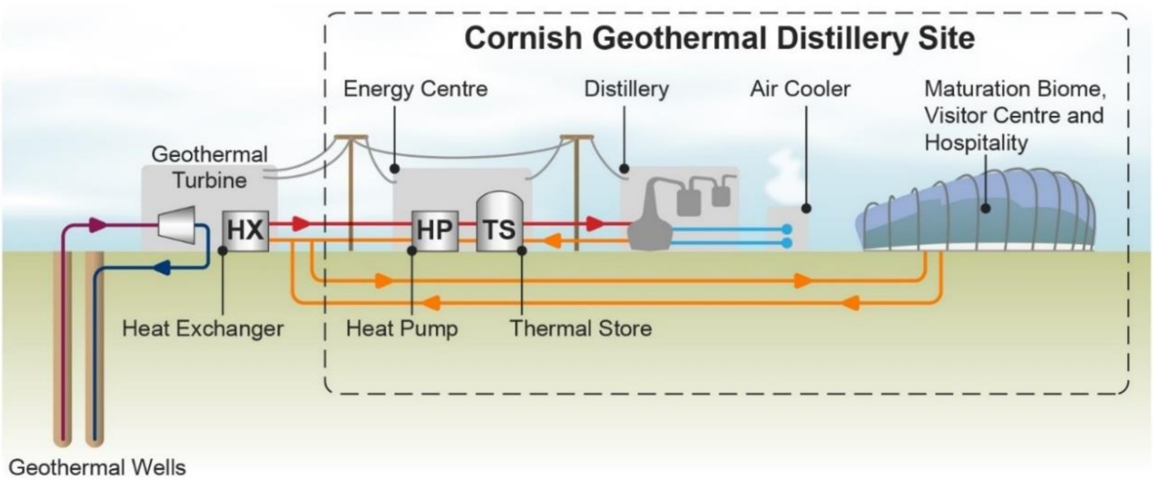


Figure 0—1 Proposed system for full build out

Having performed market research on heat pump technologies, it was decided to progress with a steam heat pump arrangement from Ochsner based on the technology readiness, efficiency and roll out potential (steam generation rather than hot water). With estimated demand calculation it was then possible to justify this decision with techno-economic modelling to determine the CAPEX and OPEX costs for a steam heat pump.

The investigation shows that the demonstrator system will cost ~£2.7M and will be zero-carbon from day one. This technology can be used throughout the industry wherever there is a requirement for steam generation. By implementing similar systems for other UK based distilleries, it may be possible to reduce their carbon outputs by 89% for heat generation.

1 Introduction

1.1 Cornish Geothermal Distillery Company

The Cornish Geothermal Distillery Company (CGDC) is developing 'Celsius', a dedicated state-of-the-art Sustainable Distillery Research Centre, directly connected to the UK's first geothermal power plant at United Downs, Cornwall. CGDC's Celsius project will develop pioneering patent-pending technologies aimed at decarbonising the distillery sector, from malting and fermentation, to distillation and maturation, using waste geothermal heat and resources.

The Celsius project aims to create the world's first geothermal cask maturation biome, capable of precisely recreating the temperature and humidity profiles found around the world, be it tropical or from the colder northern hemisphere. At full build-out, the project will include a visitor centre, cooperage, geothermal energy centre and a capacity of 1.2 Million LPA (Litres of Pure Alcohol) per year.

Celsius will use the 100% sustainable geothermal "hot rocks" power and waste heat, the latter a by-product of the electricity generation process, produced by the United Downs Deep Geothermal Power project operated by Geothermal Engineering Ltd. By utilising heat pumps alongside waste heat from the geothermal plant, the project aims to demonstrate how low carbon technologies can be implemented into existing, well established industries.

The project also has the overarching goal of creating the UK's first zero-carbon distillery and related processes. Future projects will investigate the opportunities for becoming carbon negative with onsite renewable generation, CO2 capture and hydrogen production.

Figure 1—1 Demonstrator Site

1.2 Geothermal Power Production Process

The United Downs Deep Geothermal Power Project (UDDGP) is the first geothermal electricity project in the UK. It is funded by a mixture of public and private funds, including the European Regional Development Fund, Cornwall Council and Thrive Renewables plc. The aim of the project is to produce power and heat from the hot granite rocks beneath Cornwall at the United Downs Industrial Site, adjacent to the Celsius project site. Two deep, directional wells have successfully been drilled; the production well is the UK's deepest onshore well at a depth of 5,275m, with the injection well reaching 2,393m. Both wells have intersected the target Porthtowan Fault Zone located approximately 800m to the west of the site, providing sufficient permeability for successful production.

Water at approximately 180°C will be brought to the surface through the production well and put through an Organic Rankine Cycle turbine to produce electricity. This process will then create 'waste' heat at approximately 80°C, which can be diverted to local heat projects before reinjection into the deep well.

The CGDC Celsius project aims to use both the diverted hot water and renewable power via a private wire network from the UDDGP project.

1.3 Scope of Study

This study will primarily concentrate on technologies capable of producing high temperature water or steam from waste heat sources.

Although many renewable and low carbon technologies are available for heat production, very few systems exist for high temperature duties above 120ºC. This investigation will focus on industrial Heat Pumps (HPs) as the electrification of high temperature heating is not reliant on specific, potentially unsustainable supply chains (such as biomass), is not location-specific and is a technology currently available at commercial scale, unlike the combustion of green hydrogen.

This study will provide a general overview of the technologies investigated, summary of the finding and reasoning for the chosen technology. The technology will be taken forward through the rest of the study and used within the proposals for the demonstrator plant. The study will also provide information on the rollout potential for the chosen technology and how it may benefit the industry.

2 Technology

2.1 Technology Options Overview

Within a heat pump unit or system, lower grade heat from the geothermal system is absorbed by the refrigerant in the evaporator. As the refrigerant heats up, it turns from a liquid into a gas. Once the refrigerant has become a gas, it is compressed through an electricity input to increase the temperature to a more useful level and passed into a heat exchanger (condenser). In the condenser, the heat can be released and used within the distillery process. Three main heat pump typologies were uncovered from the market research undertakings:

Refrigerant vapour (mechanical) compression – mechanical compression of a refrigerant fluid achieves the desired temperature lift between the heat sink and heat source. This is the dominant heat pump technology in the residential and commercial markets, where supply temperatures are below 90ºC; however, suitable refrigerants, such as hydrofluorocarbons (HFC), hydrofluoroolefin (HFO) and ammonia, enable it to be applicable in an industrial setting, delivering higher supply temperatures. These units are also simply called “high temperature heat pumps” (HTHP) if their output medium is hot water; if they are able to produce directly steam, they can be referred to as “steam heat pumps.”

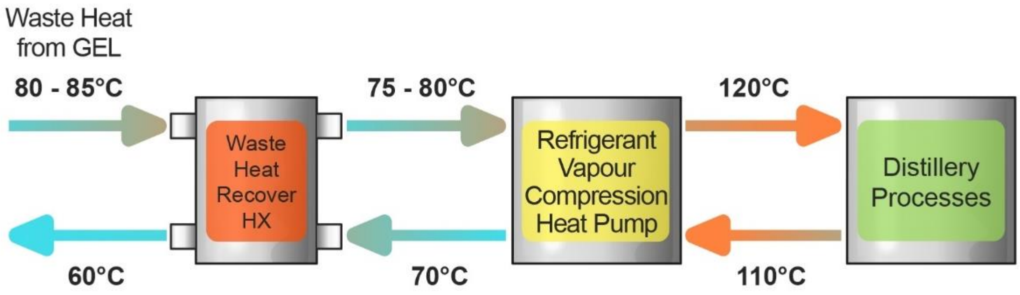


Figure 2—1 Refrigerant vapour compression heat pump overview

Hybrid absorption / mechanical compression – the use of a two-component working fluid (e.g. 50% ammonia / 50% water) allows to exploit the heat of absorption and condensation to exchange heat at the condenser/absorber setup. Gliding temperatures at the heat exchange units enables the technology to achieve higher temperature lifts between the heat sink and heat source (even up to 150 ºC) and reduce the duty of the compressor, ultimately delivering heat at higher more efficiently.

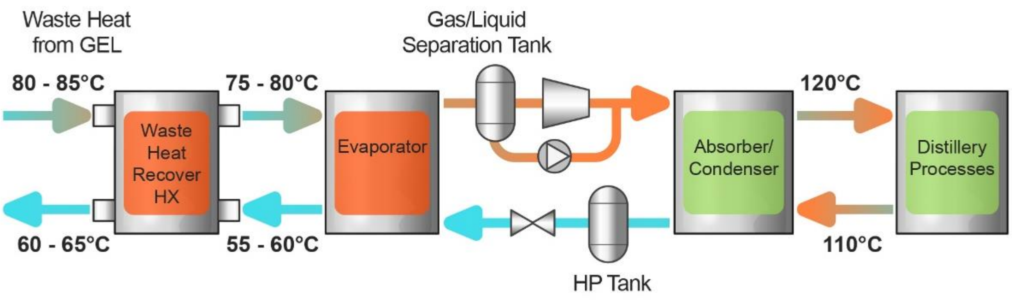


Figure 2—2 Hybrid absorption heat pump overview

Mechanical vapour recompression (MVR) – this technology is equivalent to the refrigerant vapour compression cycle, except that it relies on the increase in pressure of water vapour through multiple compression stages performed by a series of radial fans to achieve the supply temperature desired. It is already commonly employed in the industry to upgrade process waste heat, usually using the process stream directly as the medium. These installations tend to be bespoke and tailored to the specific needs of the industrial process, usually requiring a significant design and engineering input.

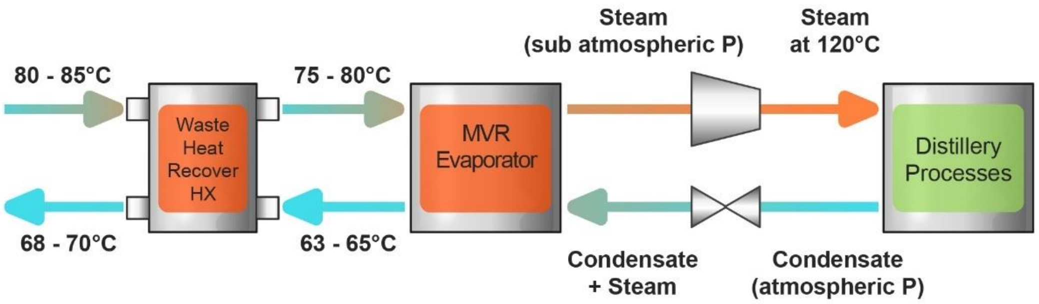


Figure 2—3 Mechanical vapour recompression heat pump overview

Table 2—1 below provides a more exhaustive list of pros and cons of each technology presented above.

Table 2—1 Industrial heat pump technology pros and cons

	Pros	Cons
Refrigerant Vapour Compression	• Packaged, compact models already available in the market, able to generate hot water or steam. Bespoke designs available at supply temperatures in excess of 120 °C. • Medium range CAPEX investment for supply temperatures below 130ºC. • Able to deliver COPs above 4 for temperature lifts below 50ºC. • HFO refrigerants with zero global warming potential available.	• Several compression stages needed to achieve temperature lifts above 50ºC, decreasing overall COP. • Virtually no packaged units able to deliver supply temperatures above 130ºC.
Hybrid Absorption	• Yields high COPs at significant temperature lifts (above 60 °C up to 150 °C), even with a low-temperature heat source. • Energy performance does not decline with increasing temperature lift. • Enhanced system flexibility to accommodate varying temperature levels. • Compact design available.	• Very limited current market offering (only 1 European commercial supplier found). • Additional tank components and equipment items required as a result of two-component working fluid. • Greater physical footprint than refrigerant-based heat pump. • Needs additional heat exchanger interface to generate steam.

Mechanical Vapour Recompression	• Can achieve a significant temperature lift of the water vapour medium through multiple compression stages. • It can achieve the highest COPs. • Well proven in an industrial process setting, with several projects implemented on the field. • The heating medium is water, non-toxic, non-flammable and environmentally friendly.	• Typically requires a minimum heat source temperature of 50 ºC, suitable mostly for industrial waste heat opportunities. • No packaged solution needs to be designed specifically from the process conditions and might require more than one supplier. • Biggest footprint requirement. • Most expensive CAPEX and maintenance estimate.

2.2 Market Research

As part of this study, a literature review of the commercially available industrial heat pump technologies was conducted. Enquiries were sent to 21 UK and European manufacturers (3 MVR specialists, 17 suppliers of refrigerant vapour compression systems and 1 hybrid absorption manufacturer) to establish their ability to provide systems capable of delivering 120 ºC hot water or low-pressure steam from 80 ºC incoming water.

Less than one third of the manufacturers approached are able or will be in a position to provide high temperature hot water or steam solutions. 24% of those manufacturers did not provide a direct response, however, based on research of the manufacturer's websites, it is not believed that any of them would have had compatible products.

Figure 2—4 below provides additional details of the maximum supply temperature, capacity range and technology typology of the companies investigated.

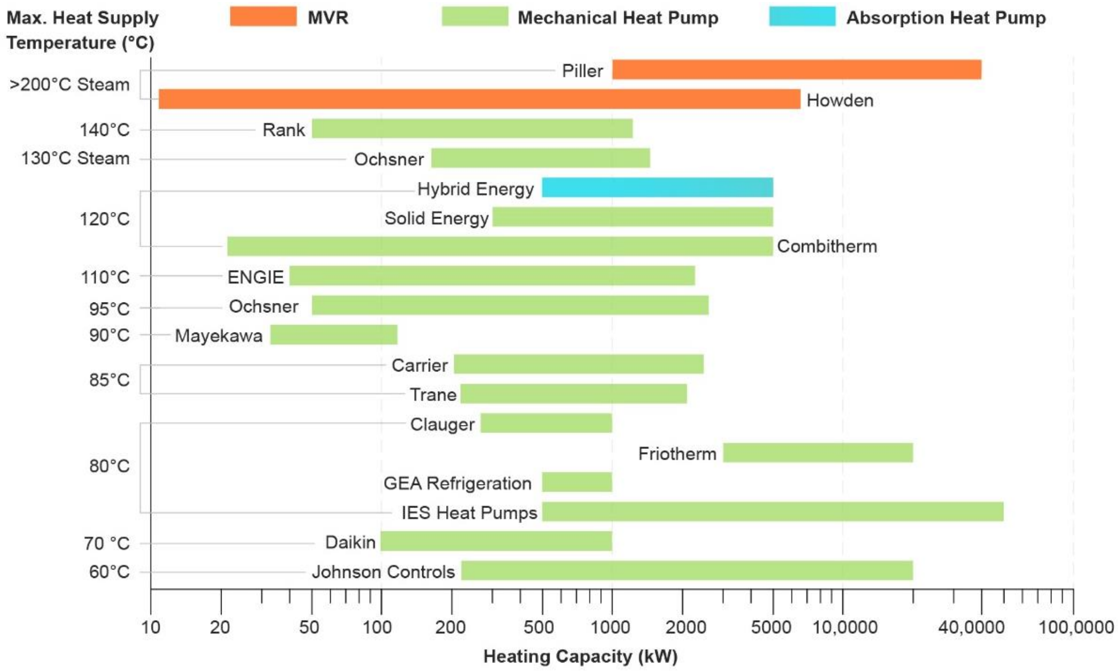


Figure 2—4 Market research summary

3 Techno-Economic Review

3.1 Thermal Energy Demands

Figure 3—1 and Figure 3—2 below illustrate respectively the daily energy flows and a sample daily heat profile of the full scale distillation facility with a target production rate of 1.2Million LPA per year. Following receipt of previous project information from Forsyths, it was possible to determine the heat demands required by the distillation process. These are divided in two temperature levels:

1. A minimum of 120ºC for the distillation processes delivered by low pressure steam at 2 – 3.5 Bar(a). The peak heat requirement is 1,200kWth which occurs three times over a 24-hour period.
2. 80ºC for the molasses dilution process provided by hot water, either sourced from the geothermal heat source or from in-process waste heat recycling.

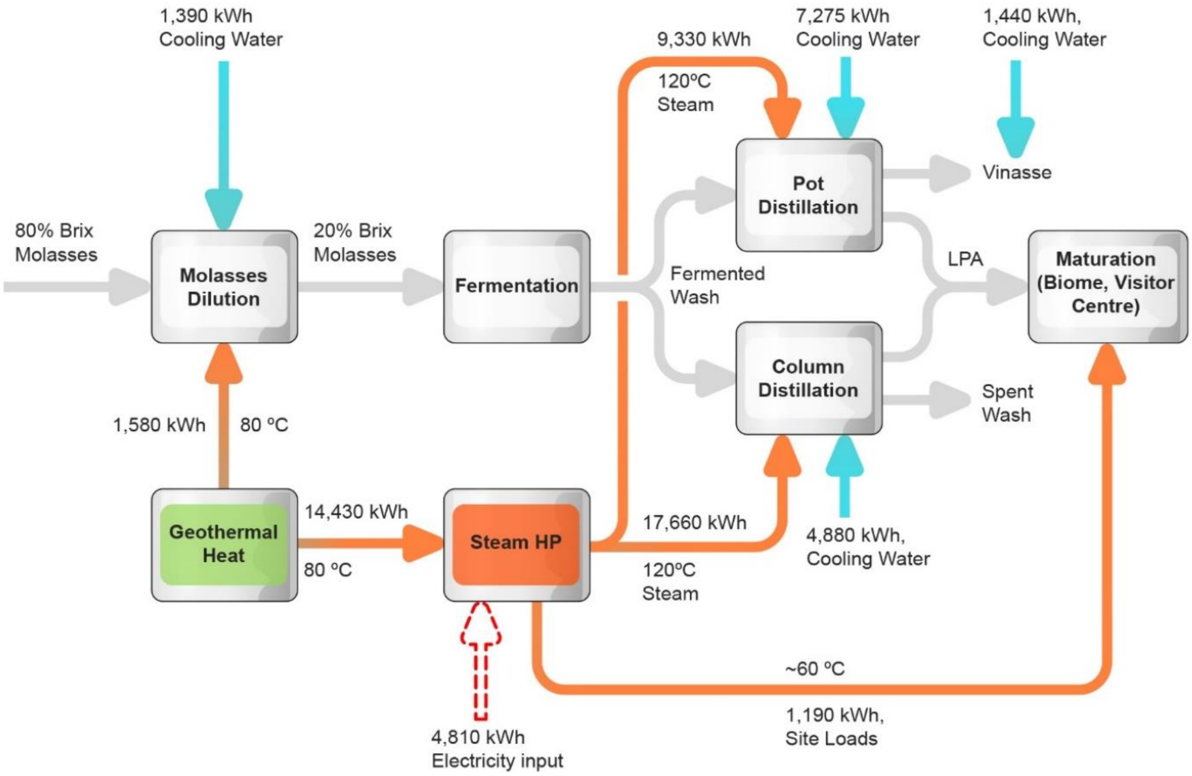


Figure 3—1 Full build out energy flow (kWh/day)

The waste geothermal energy returning from the distillery process (~60 ºC) will also be used to provide heat to the maturation facilities, visitor centre, warehouses, office, hospitality and spa. Within the maturation facilities this will also be used for variable humidification to mirror hourly weather changes that you would typically see in warmer climates.

The cooling supply to the process will remain unchanged from traditional methods (typically dry air coolers). For this project it may be necessary to utilise hybrid air coolers due to the warmer climate in Cornwall compared to Scotland.

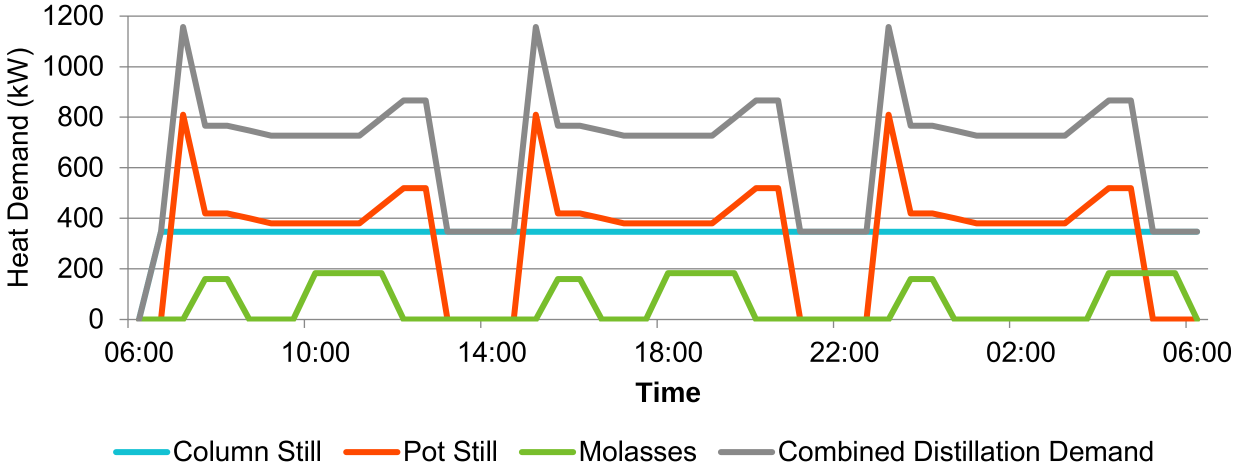


Figure 3—2 Daily full build out heat profile for all distillery heat demand

Peak heating demand for the full build out will be ~1.2MW and ~510MWh per year.

3.2 Site Wide Electricity Demands

As previously mentioned, the site will take advantage of a zero-carbon private wire network from the geothermal site. This will be supplemented with a conventional grid connection for resilience; however, the private wire connection will always take precedence. For the full build out of the site, the estimated electrical demand will be ~2MVA. In addition to these loads, twelve 44kW (528kW total) electric vehicle chargers will be provided.

3.3 Distillery Process Heat Recovery

Heat recovery opportunities are exploited within the distillation process in order to minimise the total primary energy delivered through the heat pump technology. The following energy recovery improvements are to be implemented within the process design:

- **Pot distillation effluent** – Once the batch distillation process is finished, the vinasse effluent stream (composed predominantly of ~90% water and solids - mainly salt and organic contents) is removed from the pot at a temperature of around 100 ºC. This stream can be used to preheat the wash feed from the next batch up to a temperature of 65ºC. Only a small storage tank (~7m^3) would be required to hold the vinasse stream before the next batch starts and an additional heat exchanger unit are required for this improvement. Up to 15% energy reductions can be realised within the pot still unit.
- **Pot distillation condenser** – Throughout the batch process, the alcohol-enriched vapour leaving the second retort is condensed to room temperature in order to produce the desired spirit stream. Useful heat at around 80 – 85 ºC can be recovered by passing 60 – 70 ºC cooling water through the condenser. A maximum of 80-85% energy can be recovered. The rest of the cooling to room temperature needs to be provided by an additional condenser unit interfaced with chilled water.
- **Molasses dilution heating** – the 80 ºC recovered heat from the pot distillation condenser is compatible to provide the necessary heating in the molasses dilution

unit. Again, a thermal storage unit would be needed to interface the cooling water stream from the pot still to the molasses dilution process. The energy balance indicates that there is heating energy in excess, which can potentially be used around the site for heating, humidification and R&D.

- **Distillation column** – Similar to the pot still, heating energy can be recovered from the spent wash effluent and the column condenser operating at 78 ºC. Within the column design provided by Forsyths, the wash feed is already preheated by the spent wash effluent up to a temperature of around 70 ºC and therefore this energy reduction is already included in the energy balance in Figure 3—1. Differently to the pot still, the condenser operates at a constant temperature of 78 ºC, enabling a virtually full heat recovery at 70-75 ºC. This relatively high-grade heat resource is again available to third parties or the wider Masterplan.

3.4 Sizing of Heat Supply Options

Following from the technical data received from the 7 manufacturers in a position to supply a compatible heat pump system, two distinct steam generation designs are considered for the techno-economic analysis:

1. **Steam heat pump** – specifically the unit IWWDS ER3c4, manufactured by market leader Ochsner. This Austrian manufacturer offers an extensive range of cost-effective, packaged high temperature and steam generating heat pumps, able to deliver a maximum of 130 ºC heat. Their heat exchanger units can be tailored to the characteristics of the heat source and heat sink condition. A major advantage they hold over other mechanical heat pump manufacturers is that they offer a product range able to directly generate steam from a wide range of heat source temperatures, without the need to retrofit additional equipment items through third party contractors.
2. **MVR system** – the blowers are manufactured by PILLER Blowers & Compressors, with the rest of the equipment (piping, instrumentation, pumps, vessels, evaporator) that can be designed by PILLER as well but would need to be manufactured and supplied by separate contractors. This adds to the cost and complexity of the custom-built system, in exchange for a higher performance than the steam heat pump.

The main details of each option are described in Table 3—1 below. The use of electric steam boilers is taken as the counterfactual low-carbon technology to perform against.

Table 3—1 Industrial heat pump options

	Steam Heat Pump	MVR System	Electric Steam Boilers
Heating medium	Environmentally friendly HFO	Water vapour	Water vapour
Efficiency (80ºC heat source / 120ºC supply)	400%	595%	98%
CAPEX (1.2MWth, unit only)	~£225,000	~£990,000	~£63,000

The hybrid absorption heat pump typology was not progressed for further analysis as it is predicted to perform with a similar COP as that of the steam HP and require a greater capital investment. However, this technology would be better suited in a distillation process with a lower temperature heat source and requiring a greater temperature lift.

The use of high temperature water as a heating medium is not considered as it would have a reduced rollout potential given that the majority of existing distilleries rely on the condensation of steam for their heating demands.

3.5 Cost Comparison

The CGDC site will have a private wire supply as well as a heat supply from the UDDGT. Figure 3—3 shows the final cost of heat depending on the private electricity and heat prices.

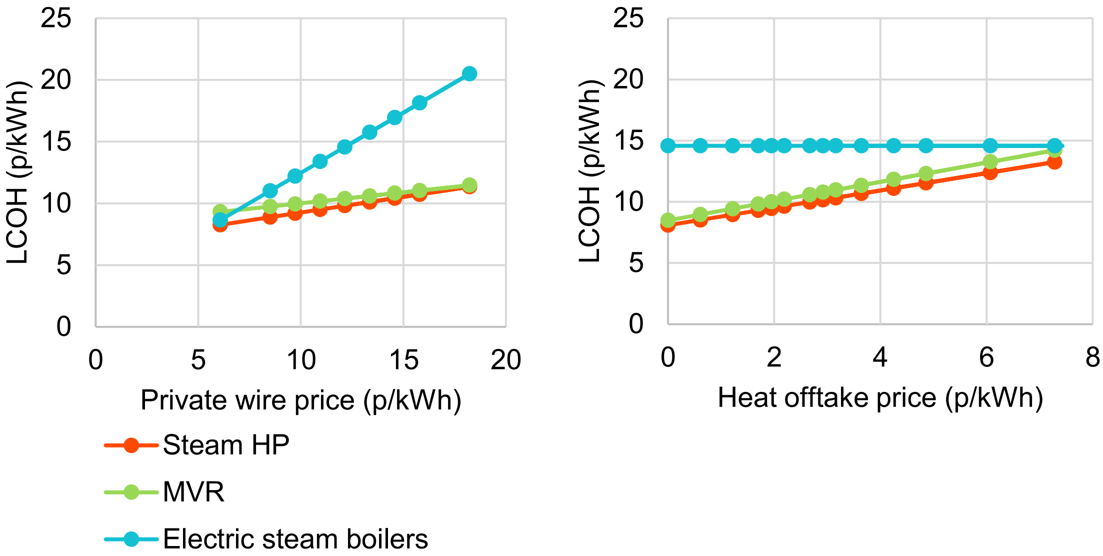


Figure 3—3 Levelized cost of heat based on electricity prices (left), levelized cost of heat from heat offtake prices (right)

3.6 Carbon Performance

Figure 3—4 shows the anticipated yearly carbon emissions for each of the technologies discussed. As a comparison, carbon emissions associated with a gas boilers system will be ~1,200 tCO_2/year.

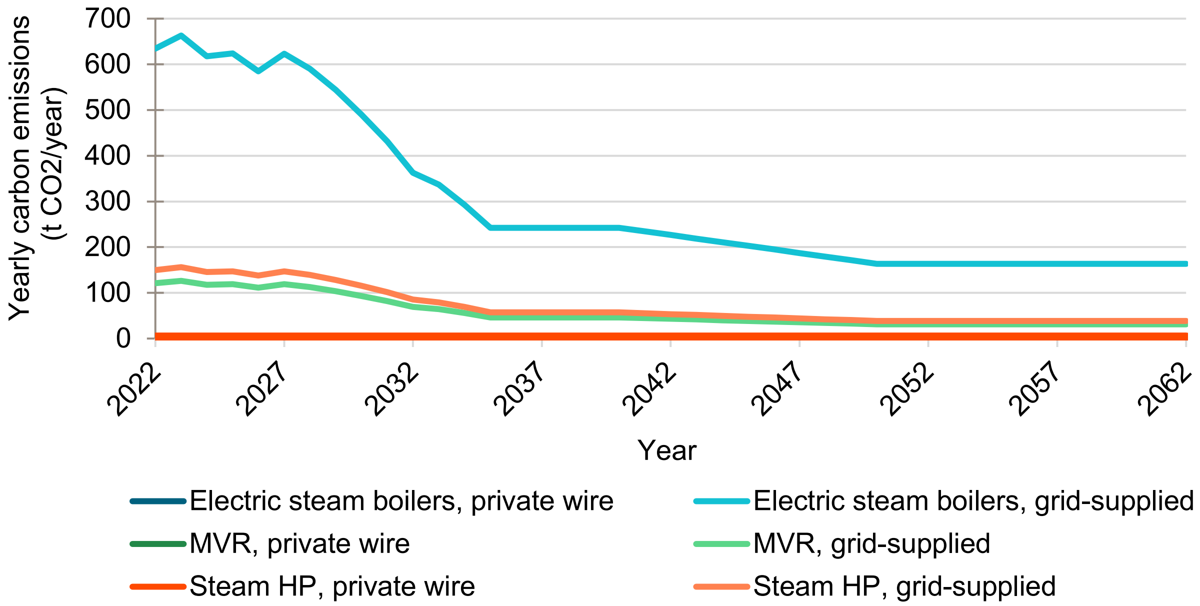


Figure 3—4 Yearly carbon emissions by technology and supply (full site build out)

The geothermal electrical supply from GEL will be a zero-carbon source of energy. Therefore, the private wire technologies shown in Figure 3—4 are shown as producing zero-carbon throughout the lifetime of the project. The same technologies have also been shown with grid supplied electricity (BEIS Grid Carbon Factors 2020) to illustrate the carbon emissions for those without access to zero-carbon energy sources.

Although the electricity supply to this site is zero-carbon, the heat pump system and distillation process has been designed to be as efficient as possible. This not only demonstrates how others can reduce carbon outputs from thermal generation changes, but how efficiencies can be improved within the distillation process.

3.7 Chosen Technology

Following a review of the manufacturer responses, the wider rollout potential of each technology and the LCOH results of the techno-economic modelling, it was decided that the Ochsner IWWDS ER3c4 heat pump unit would be taken forward. They were the only manufacturer capable of providing a compact, purpose-built steam generating heat pump unit with suitable COPs at a competitive price. At the same time, they provide a sufficient level of project customisation (e.g. heat source temperature and state, heat supply range, refrigerant type, etc.), as they can offer up to three different model lines that produce steam. They have a number of these systems in operation which removes some of the risk associated with implementing low carbon technologies into a carbon intensive industry.

The Ochsner unit will also be specified with the low global warming potential (GWP) refrigerant, ÖKO 2, providing a GWP performance equivalent to natural refrigerants.

4 Design of the Demonstration Project

The Celsius demonstrator comprises three bespoke modules; a geothermal energy centre, distillery and maturation pod which are scaled to 25% (300,000 LPA per year) of the intended full-scale build-out. This is to ensure that a practical, cost-effective and flexible solution, with a realistic load, can demonstrate the potential for scale and volume at commercial distillery levels. Production and maturation rates within the demonstrator will accurately mimic the average distillery, providing evidence-led data capable of proving the universality and potential for wider industry roll-out, especially for larger scale distilleries in remote locations without access to geothermal resources.

The demonstrator plant, housed within a purpose-built dedicated R&D facility, will enable CGDC to continually develop, test and prove pioneering sustainable technologies that can be rolled out internationally to help decarbonise the distillery sector.

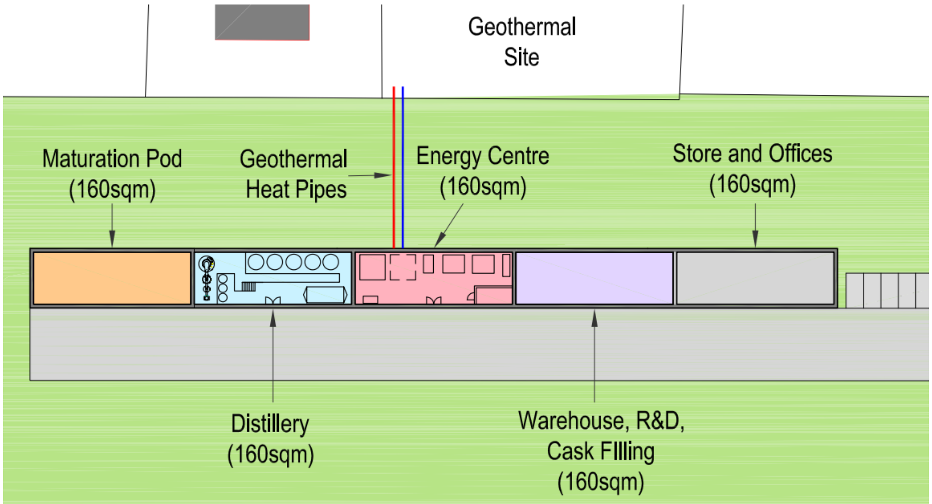


Figure 4—1 Demonstrator site layout

4.1 Demonstration Distillery Plant

The demonstrator distillery plant is a pioneering and fully functional distillery setup producing 0.3M LPA. Although focused on rum, the concept behind the modular Celsius technology solution is applicable to all distilleries (including whisky and gin) and will include:

- **Fermentation:** Reception of molasses, and molasses fermentation
- **Distillation:** Pot still and double-retort, crucially of the type usually only found at larger distilleries in the Caribbean.
- **Maturation:** Aging of spirit in a maturation pod, mimicking rare and coveted tropical conditions using geothermal technology to create truly unique and singular expression.
- **Universality:** Technology that can be reused on-site later in the project life, for continual R&D, production, and within a visitor centre for educational purposes.

The efficiency measures to be implemented will be smaller scale versions of those listed within section 3.3. These include;

- Preheat of the pot still wash feed with the vinasse effluent (~15% heat demand reduction).
- Pot distillation retort heat recovery at 85 ºC via an additional condenser, and provision of molasses dilution heating.

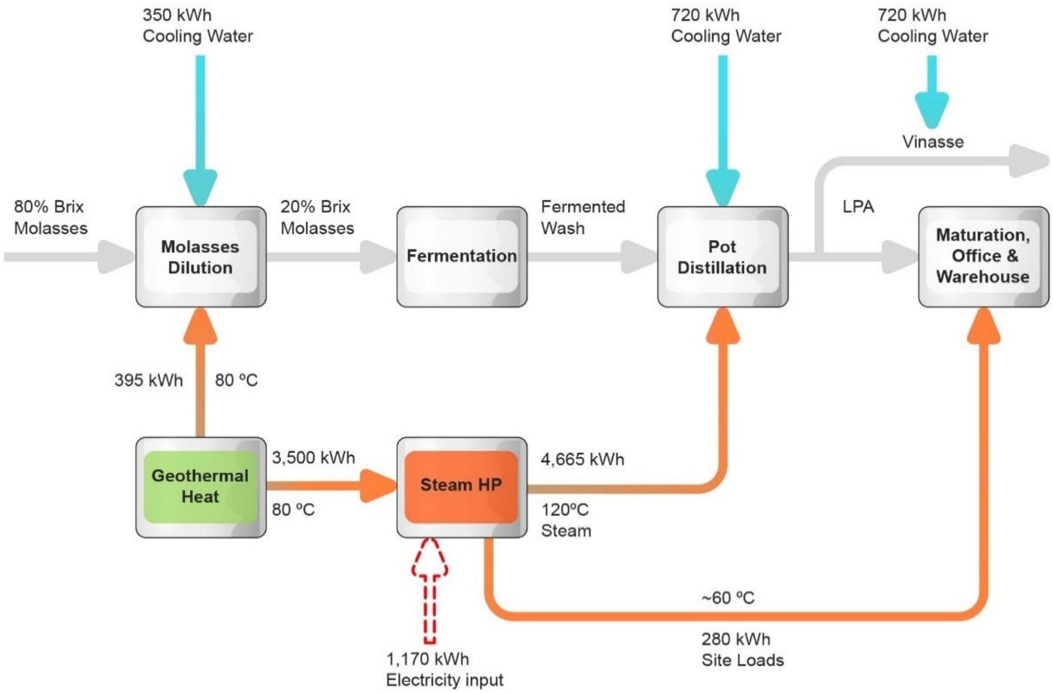


Figure 4—2 Demonstrator plant energy flow (kWh/day)

4.2 Demonstrator Thermal Generation

To align with the distillery plant, the thermal generation plant has been designed to provide 25% of the load compared to the full 1.2Million LPA per year production. The full build out thermal generation plant will follow exactly the same principals as the full site demonstrator plant.

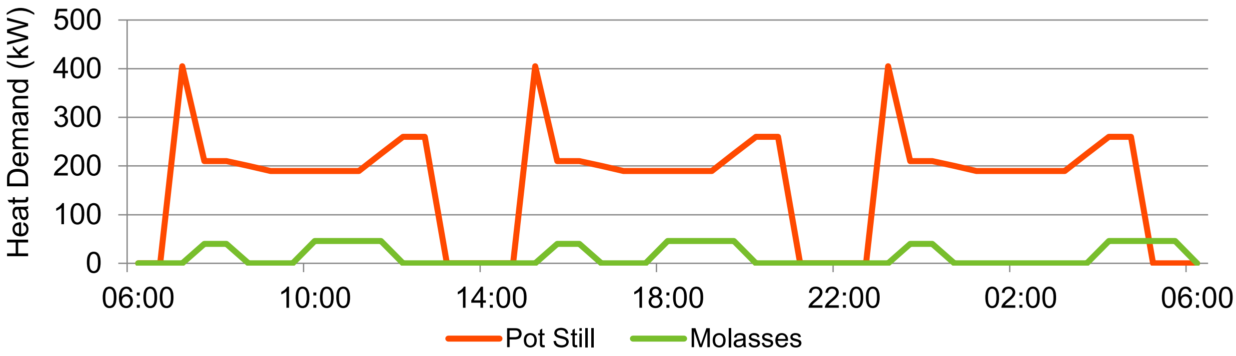


Figure 4—3 Daily demonstrator heat profile

Figure 4—4 illustrates the carbon savings which will be made by utilising a heat pump instead of using grid supplied electric steam boilers.

The demonstrator system will utilise a 400kW heat pump. When later phases of the project are constructed and the site wide load increases, it's expected that similar sized heat pumps will be added in parallel to increase the thermal capacity of the system.

Although a 400kW heat pump has been specified to deliver the peak energy requirements, the peak capacity of the unit can be reduced further by having smaller units (e.g. 2 x 200kW) or with the addition of a steam accumulator. This will be investigated in more detail at the next stage of the project.

The demonstrator site will be designed to include energy metering and local weather information with the aim of allowing external parties to gain access to the data for their own investigations.

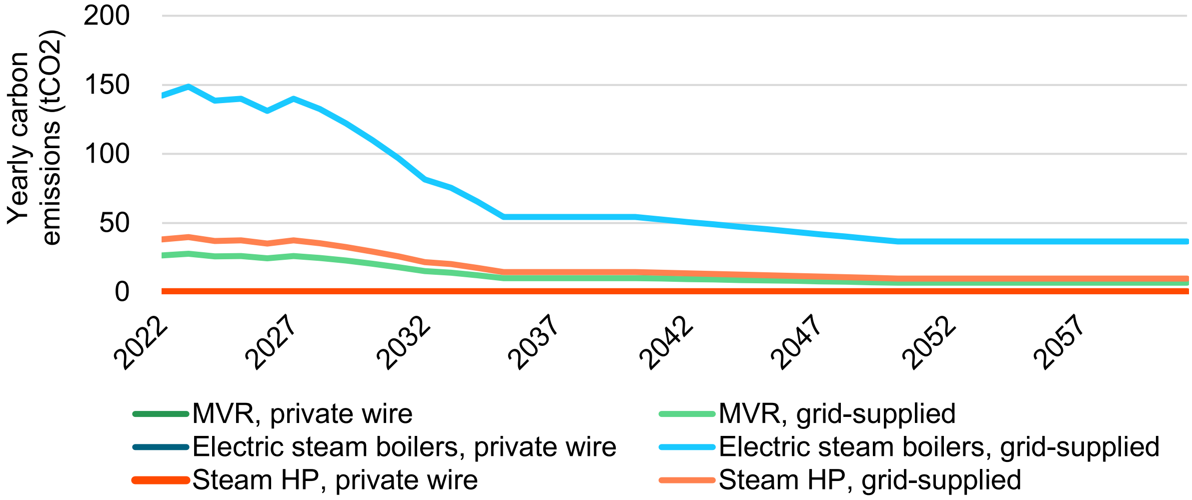


Figure 4—4 Demonstrator carbon output comparison

4.3 Demonstrator Costing

Costs for the demonstrator design have been based on supplier quotes, previous project experience and Spon's Mechanical and Electrical Services Price Book. Having conducted an initial CAPEX investigation it was found that the total demonstrator costs will be ~£2.7M.

4.4 Corporate Strategy

The Celsius demonstrator provides the unique opportunity to install a commercially scalable proof-of-concept for the first high volume rum distillery and geothermal (tropical) cask maturation facility in the UK/Europe, proving an emerging market need for tropically maturing spirits outside of tropical environments, whist providing a carbon-zero alternative to importing rum into the UK/Europe from overseas.

Once scaled, this will enable CGDC to supply carbon-zero matured rum in volume to our key partners (the largest importers and suppliers of rum to the industry) for blending and own-label supply to the on-trade and off-trade, up to 4 times faster than maturing in native continental climates, without loss of quality. The Celsius distillery and patent-pending maturation solution is modular, licensable and capable of being installed anywhere with access to renewable heat and power.

5 Benefits and Barriers

As the site and demonstrator heat generation and distillery will be a new system, the table below summarises the data between the proposed heat pump arrangement (cutting edge), electric boilers (typical decarbonisation method) and gas boilers (business as usual). In this instance Table 5—1 compares the finding between the investigated technologies for the demonstrator plant (400kW).

Table 5—1 Benefits and barriers, comparison table

	Steam Heat Pumps	Electric Boilers	Gas Boilers
Unit Price	£135-500/kW	£45-75/kW	£40-70/kW
Cost of Heat	5-10p/kWh	7-15p/kWh	3-6p/kWh
Carbon Outputs in 2025 (MtCO2e/year)	Geothermal supplied: 0 MtCO2e/year Grid supplied: 38 tCO2e/year	Geothermal supplied: 0 MtCO2e/year Grid supplied: 140 tCO2e/year	287 tCO2e/year
Carbon Outputs in 2025 (tonnesCO2e / per kWh)	Geothermal supplied: 0 tCO2e/kWh Grid supplied: 0.023 tCO2e/kWh	Geothermal supplied: 0 tCO2e/kWh Grid supplied: 0.103 tCO2e/kWh	0.184 tCO2e/kWh
Infrastructure Requirements	Electrical grid capacity dependant	Less efficient than heat pumps and therefore require more additional grid capacity	Gas network capacity dependant
Space Requirements	Additional space may be required for steam accumulators. Otherwise comparable.	Steam accumulators not typically used	Steam accumulators not typically used
Scalability	Fair scalability	Fair scalability	Good scalability
Benefits	• Low operating costs • Low energy usage • Low / zero-carbon	• Lowest CAPEX cost • Easy to maintain	• Good existing gas infrastructure • Lowest OPEX costs • Easy to maintain
Disadvantage	• Highest capital cost • Highest maintenance costs • Limited turndown	• Highest operating costs due to the cost of electricity • High energy usage	• High CO2 outputs
Risks	• Performs best with low carbon electrical supply	• Reliant on a low carbon electrical supply	• Risks regarding legislation changes banning the replacement of gas boilers

6 Rollout Potential

6.1 Technology Rollout

Although this report focuses on the manufacture of rum (the 3rd largest spirits category in the world), the distillation processes and temperature requirements remain the same for the whisky and gin industry. Generating heat for distillation is the primary source of emissions and the key technical challenge, however, extensive consideration has been given to the secondary challenge of maturing spirits such as rum in the UK. A combined distilling and maturation solution can potentially reduce the high carbon footprint associated with importing rum to the UK to zero.

Research on the potential for industry-wide rollout, especially for remote and more challenging sites both within the UK and internationally, has established there are 98 medium to large-scale whisky distilleries in Scotland with output capacities of between 0.1M - 10.2M LPA per year, and 84 established small, medium to large-scale rum distilleries in the Caribbean from 10,000 – 10M LPA per year.

Research has identified that the existing infrastructure in many Caribbean rum distilleries is potentially old and operating inefficiently. Intermediate steps to decarbonising, such as upgrading existing systems to use biomass from burning distillery waste by-products, or natural gas, are being taken by some Caribbean distilleries, but many still use heavy oil boilers. Neither solutions offer a carbon zero opportunity. However, as more locally owned Caribbean distilleries evolve, and European companies buy some of these distilleries as the category premiumises, the opportunity to invest in green initiatives will rise to meet consumer demands and company goals and Government targets.

As part of this investigation the use of hydrogen was explored. With Electrolysers currently being 60-80% efficient, it was felt that hydrogen was not an effective use of energy for the site given that a heat pump will typically be 300-400% efficient.

6.1.1 Technology Scalability

The market research shows that several heat pump manufacturers have products capable of providing heat at 120 ºC from single units for loads between 170-2000kW. It is also possible to run multiple units in parallel to achieve higher demands or use thermal stores / steam accumulators to even out the peaks within the demands, thus reducing the peak capacity of the installed plant. Therefore, this technology could very easily be applied to all types of distilleries and other industries which require high temperature heat.

6.1.2 Heat Sources

Heat pumps can use several sources to produce heat including air, sea water, river water and ground water.

Figure 6—1 below shows a high-level investigation into Scottish distilleries access to viable water sources for heating, against their estimated peak load. It shows that 76% have access to a running water source or are adjacent to the sea. To do so would require an additional heat pump to raise water temperatures from 5 ºC to 30 ºC. Such inlet temperatures would be sufficient for use within a steam heat pump system like those available from Ochsner.

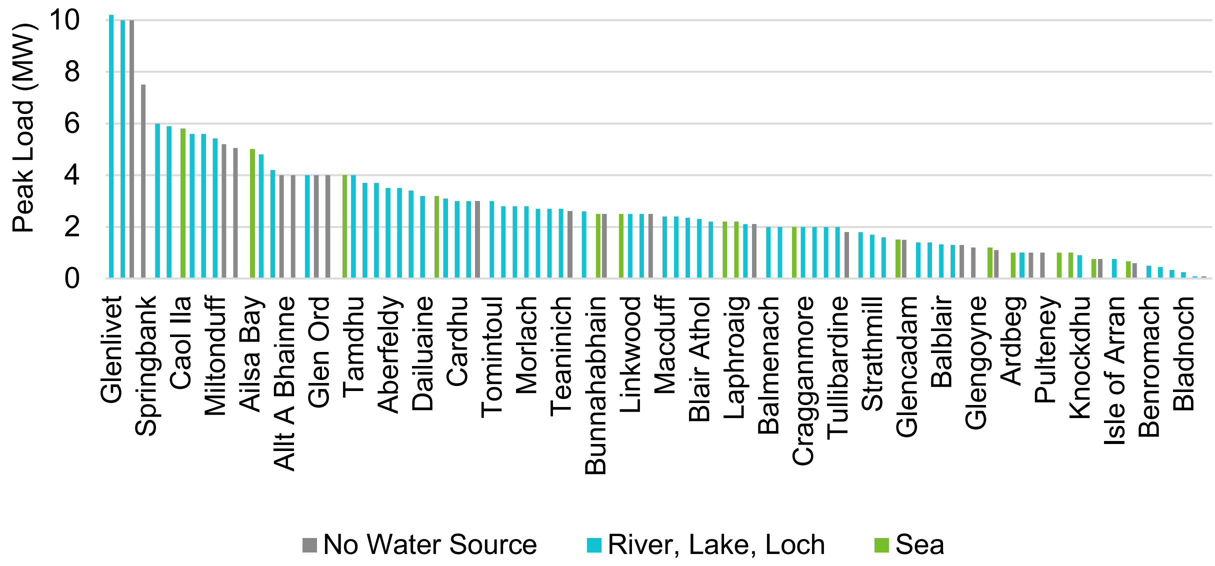


Figure 6—1 Estimated heat requirements for 96 UK distilleries and their access to water

To provide other distilleries with an idea of the cost,

Figure 6—2 shows the estimated levelised cost of heat based on the temperature of available water sources.

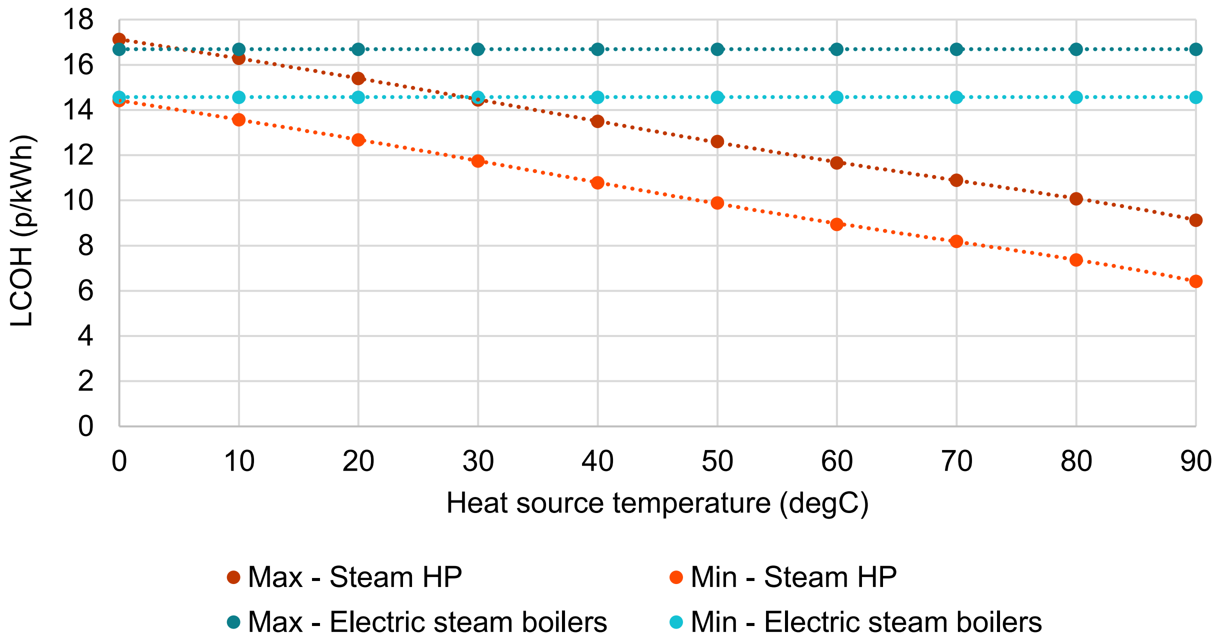


Figure 6—2 Cost of heat by heat source temperature

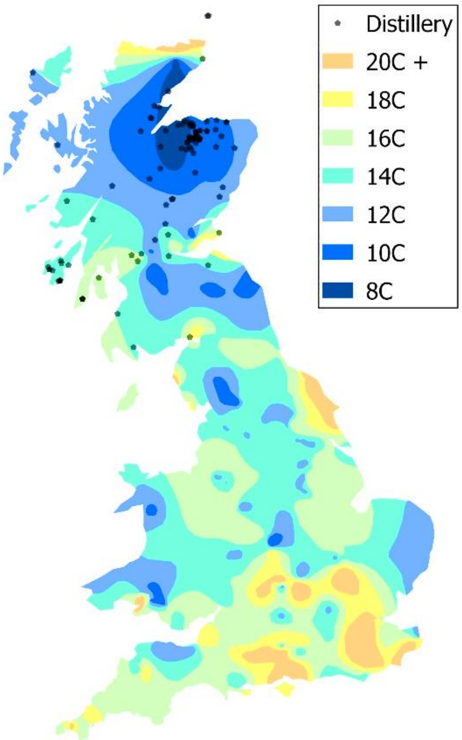
For those without access to water sources the same approach can be use with ground source heat pumps (boreholes and closed loop), air source heat pumps, solar thermal or local industrial waste heat.

It may also be possible for distilleries to recycle in-process waste heat sources (e.g. cooling water return) along the use of a heat pump to dramatically reduce the fossil fuel demands of their site.

One key aspect which should be considered for most of the distilleries in the UK is the access to additional grid electricity. Given the location of many distilleries, additional grid capacity may not be available. However, efficiency improvements within the distilling process (as discussed above) along with thermal stores / steam accumulators could dramatically reduce the additional grid capacity required.

6.2 Geothermal Availability

The future of geothermal energy in the UK is bright, with more interest than ever being placed on developing new projects. Geothermal energy is clean, sustainable, 24/7 and has a smaller surface footprint than other renewable energy sources, making it an attractive addition to the UK energy mix.



The image to the right shows the ground temperature at 200m depth alongside the location of the whisky distilleries in the UK.

There are known pockets of high heat flow across the country that could provide sufficient temperatures and permeability at depth for heat and power production. The map (to the right) shows the surface heat flow recorded across the UK, with Cornwall exhibiting the highest measurements at more than 120mWm^{-2} across the county, but higher than average heat flow also recorded in the Lake District and Weardale Granites, the Grampians, parts of eastern England and the Wessex Basin. After the successful drilling and testing of the United Downs site, GEL are currently exploring for future heat and power development sites across Cornwall and the Southwest, and with increased interest and continuously improving drilling technology, geothermal deep heat projects are anticipated in a number of other hot spots. With this anticipated increase in geothermal heat availability across the UK, the ability to co-locate industries with high heat demands is becoming increasingly attractive.

6.3 Route to Market Identification

Ageing infrastructure, unreliable power networks, and the often remote and coastal location of many distillery sites such Islay and the Caribbean (rum) to which the transportation of energy is both challenging and costly, suggest that the ultimate solution for these distilleries may be found through a steam (high temperature) heat pump system using zero-carbon electricity grid which could lead to an 89% reduction in carbon emissions. Research on potential access to viable low-grade waste industrial heat for distilling and maturation, has identified heat recovery options that may be available to rural, urban and mixed sub-urban distilleries from a range of potential sources in addition to geothermal resources, including electrical substations, heavy industry (cement, steelworks), railway and cable tunnels, cold stores, data centres, wastewater and supermarkets.

The modular distilling and maturation solution discussed in this report, powered either by geothermal heat and power, or alternative renewable zero carbon energy supply (such as tidal, solar or wind power), has the potential to provide a 100% reduction in carbon emissions. However, barriers and risks associated with the wider rollout of heat pumps to the distilling industry include;

- **Grid capacity availability**. Heat pumps are driven by electricity. Remote distilleries may struggle to gain additional capacity from the electricity grid. This can only be rectified by increasing the local grid capacity availability (costly) or by installing localised renewable energy technologies and energy storage.
- **High CAPEX costs**. Compared to gas/electric boilers, a heat pump system will have a higher CAPEX cost but should have lower operating costs. Capital investment for this sort of technology change may not be available to all.
- **Heat sources**. Heat pumps require a source of energy to extract from. These sources are not always available and may not be guaranteed in the future (river source for instance).

The key steps to commercialisation are five-fold:

1. Trial site demonstrating operational effectiveness (distillery and maturation).
2. Collection of robust data on dependability, cost (CAPEX and OPEX) and ease of use – Technical File.
3. Preparation of Document Bible, which includes the Technical File, supply chain, Intellectual Property, Legal/Licensing Agreements and Warranty obligations.
4. Identification of both Distillery and Maturation customers and delivery of Marketing Plan.
5. Product Roll-out.

CGDC will also identify other sectors where this technology may be applicable. Assuming a waste heat level of around 30ºC or higher, our technology for green distilleries could be used on a number of other sectors such as:

- Food and Drink manufacturing, including Dairy and Breweries; £100bn (UK);
- Industrial Processes – Heavy industry and Manufacturing; £186bn;
- Energy production; £95bn generated in economic supply chain activity.

It is believed that initial benefit would be centred around energy efficiency gains for these sectors with a view to further development as our technology and the market evolve.

Finally, at levels below 30ºC and assuming that electricity costs remain broadly at current levels, moving with CPI, then there may be distributed heating applications. Rarely seen in this country compared to Europe, this technology could have tremendous benefits for this sector, and recent Government policy in this regard which is very supportive of heat pump technology for the residential sector as fossil fuel boilers are phased out.

7 Dissemination and Conclusion

7.1 Conclusion

For the CGDC site a steam heat pump from Ochsner is the best technology regarding cost, efficiency and carbon savings. The investigation shows that the demonstrator system will cost £2.7M and will be zero-carbon from day one. Not only will the system be zero-carbon, but also frugal with energy usage due to the heat pumps coefficient of performance being >4.

This technology can be used throughout the industry and be very suitable for those with access to water sources. As the technology generates steam, it becomes a viable option for other distilleries to retrofit and will not require many (if any) changes to their existing distillery process. By implementing similar systems for other UK based distilleries, it may be possible to reduce their carbon outputs by 89% for heat generation.

7.2 Dissemination

The BEIS Green Distilleries Competition has provided CGDC with the opportunity to explore low carbon technologies in more detail than would typically be expected. By doing do, CGDC will have greater confidence in their technology choice whilst also providing more assurance for the future site and production costs. To summarise the works undertaken as part of the Phase 1 assessment, the following aspects have been investigated;

- Technology appraisal
- Detailed market research
- Full scale and demonstrator energy load assessment
- Detailed CAPEX estimations
- OPEX calculations and sensitivity analysis
- Carbon reduction calculations
- Evaluation of the wider market to establish rollout suitability

CGDC Ltd is a private company but recognises that this competition is partly funded by the UK Tax payer. CGDC are keen to share our technology and findings with as wide an audience as possible, subject to retaining key Intellectual Property. As such, our dissemination plan going forwards will:

- Consist of a concise report outlining what we have achieved and focusing on the Value Proposition of our project; particularly its beneficial life costs
- Include this report on our Website as a News article
- Target our supply chain and potential customers throughout the UK