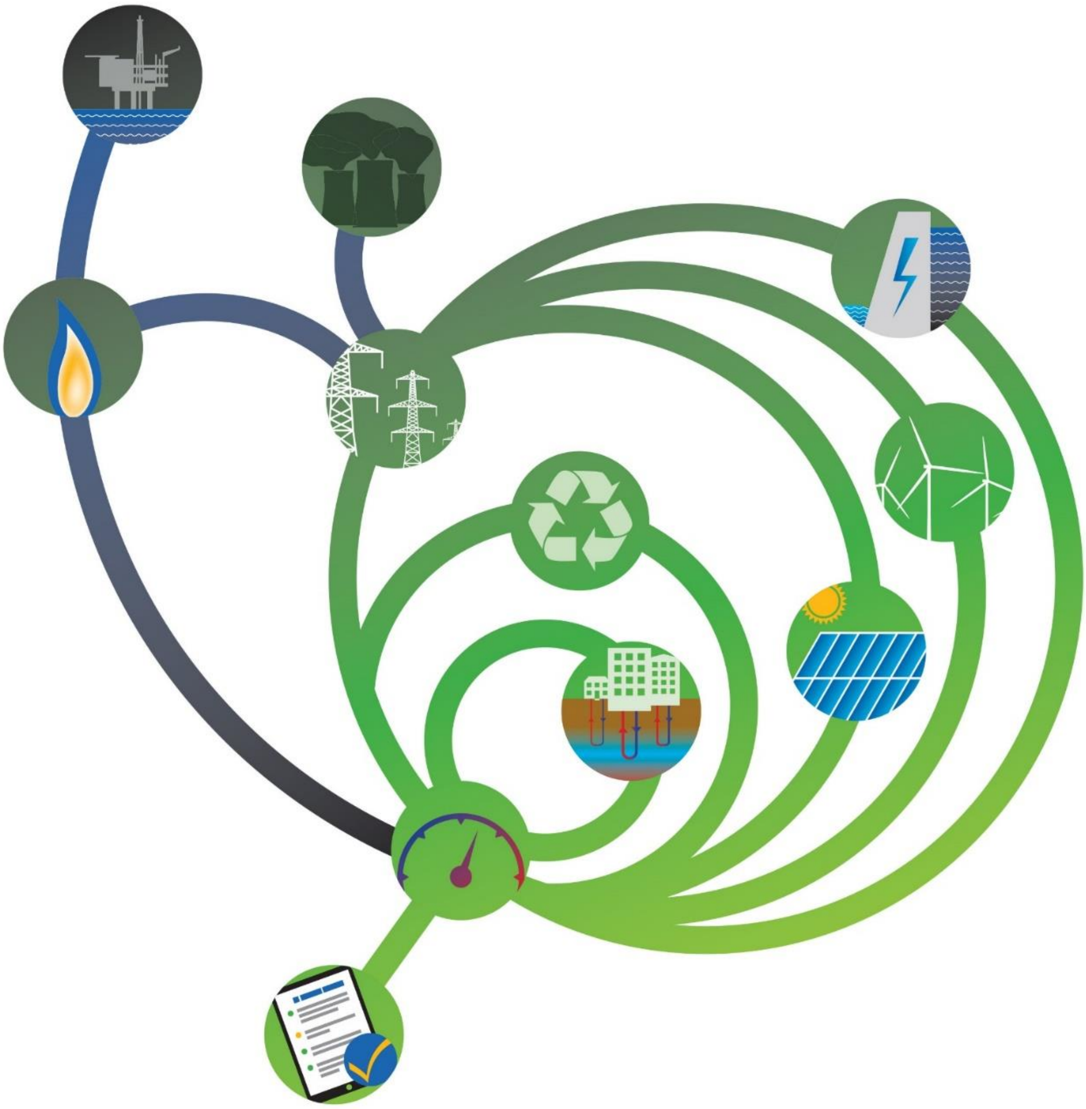

# BEIS Green Distilleries Competition
# St Andrews Brewers Ltd

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## Contents Amendment Record

This report has been issued and amended as follows:

| Revision | Description | Date | Signed |
|---|---|---|---|
| 1.0 | Initial Draft | 01 March 2021 | A Lee |
| 2.0 | Second Issue | 15 March 2021 | A Lee |
| 3.0 | Third Issue | 18 March 2021 | A Lee |

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# Glossary

| Term | Meaning |
|---|---|
| kW | kilowatt |
| kWh | kilowatt-hour |
| kJ | kilojoule |
| kg | kilogram |
| CoP | coefficient of performance |
| $tCO_2e$ | tonnes of carbon dioxide equivalent |
| Solar PV | solar photovoltaics |
| PFD | process flow diagram |
| bar | unit of pressure |
| $m^3$ | metres cubed (1,000 litres) |
| v/v | volume per volume |
| mJ | millijoule |
| DSEAR | The Dangerous Substances and Explosive Atmospheres Regulations 2002 |
| PVSOL | solar modelling software |
| $m^2$ | unit of area |
| TIC | total installed capacity |
| kWp | kilowatt peak |
| Te | metric tonne (refers to size of mash in distillery terms) |
| SSSI | site of special scientific interest |
| SPA | special protection area |
| SAC | special area of conservation |
| LCT | landscape character type |
| AARI | archaeological regional importance |
| SEPA | Scottish Environment Protection Agency |
| IRR | internal rate of return |
| l | litre |
| BEIS | Department for Business, Energy & Industrial Strategy |
| HAZOP | hazard and operability study |
| LOPA | layer of protection analysis |
| KPI | key performance indicator |
| Vital Energi | Energy centre operator for St Andrews University |

# Executive Summary

Eden Mill became Scotland's first single site distillery and brewery (making gin, whisky and beer) and are aiming to build Scotland's first carbon neutral distillery located within the University of St Andrews' Eden Campus. The campus, located in Guardbridge, is a hub where university and private companies conduct innovative energy research. Since its opening in 2018 it has reduced the university's carbon footprint by 20% through solar power and biomass heat. The centralised biomass plant (energy centre), which serves a district heating network, is located directly adjacent to the proposed distillery location.

Working alongside the University of St Andrews and Mabbett, a leading environmental, engineering, safety, planning/development and sustainability consultancy, Eden Mill were provided support by BEIS to investigate a range of innovative low carbon solutions for their new site. These generally focused on the use of high temperature hot water to provide the heat for distillation, whilst using the return loop of the district heating network as a heat sink to facilitate high levels of heat recovery.

The following options were assessed:

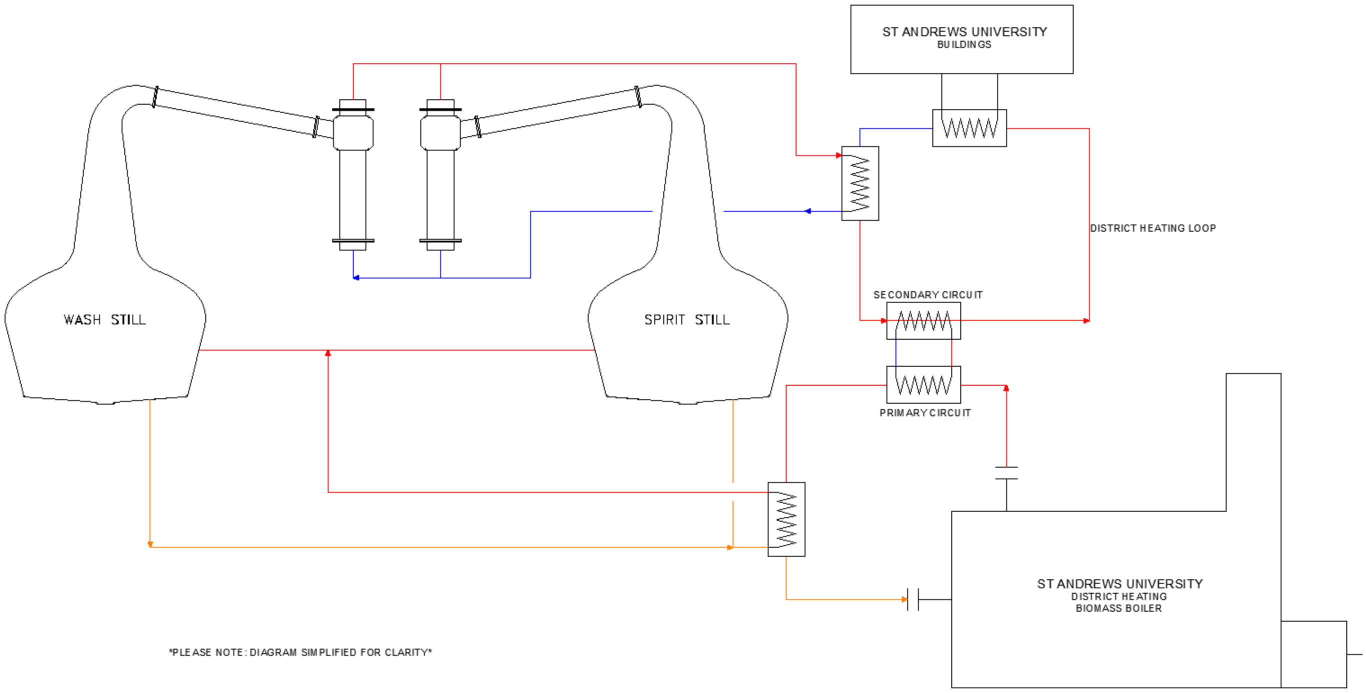
a) Integration with the energy centre, with supply via the primary circuit of the biomass plant
b) Integration with the energy centre, with supply via the secondary circuit of the biomass plant, in conjunction with a high temperature heat pump powered by roof mounted solar panels

A back-up source of heat would be required to protect against any potential issues in the supply from the energy centre. This would most likely be via steam produced on site, via a two-stage external heat exchanger. A third option considered in this study was:

c) A hydrogen electrolyser and steam boiler, powered by roof mounted solar panels

Following the outline design of each option and preparation of associated business cases, using a traditional approach (generating steam via the combustion of natural gas) as a base case for comparison, it was concluded that Option C was not viable. One of the main reasons for this is that the solar panels can only generate a relatively small percentage of the necessary electricity, meaning significant grid electricity consumption would be necessary.

Comparing Option A and Option B, it was concluded that Option A was preferred. The simplified diagram below shows the principles of the solution, taking heat form the high temperature side of the biomass system to provide the heat for the distillery, and then recovering the waste distillery heat to feed in to the lower temperature district heating network:



*PLEASE NOTE: DIAGRAM SIMPLIFIED FOR CLARITY*

It provides the greatest level of carbon and cost savings for the lowest level of investment, and is the only option to provide a positive IRR based on a 15 year profile. A high level business case, based on this 15 year profile, for each option is summarised below.

| | Base Case | Option A | Option B | Option C |
|---|---|---|---|---|
| **Net Energy Consumption (kWh)** | 51,355,618 | 7,665,325 | 25,354,553 | 96,035,010 |
| **Carbon Emissions ($tCO_2e$)** | 9,442.8 | 118.4 | 1,729.4 | 21,931.4 |
| **Additional Investment** | - | £754,220 | £1,400,000 | £4,449,003 |
| **Cost Savings** | - | £1,245,116 | -£651,034 | -£11,259,002 |
| **Carbon Savings ($tCO_2e$)** | - | 9,324.3 | 7,713.3 | -21,813.0 |
| **Internal Rate of Return (IRR)** | - | 7% | - | - |

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# Section 1.0 Project Team Overview

## 1.1 Eden Mill

Setting out to revive the lost art of distilling and brewing in St Andrews, Eden Mill became Scotland's first single site distillery and brewery, making gin, whisky and beer. The Eden Mill spirit is created by their distillers in copper pot-stills and exhibit a wide range of flavours from botanicals sourced from the local area, as well as from around the world. The distillery team is tasked with applying modern techniques and understanding time honoured traditional methods. Eden Mill are aiming to build Scotland's first carbon neutral distillery.

## 1.2 Eden Campus

University of St Andrews' Eden Campus, located in Guardbridge, is a hub where university and private companies conduct innovative energy research. Since its opening in 2018 the Eden Campus has reduced the university's carbon footprint by 20% through solar power and biomass heat. Biomass heat generated on campus heats 400 student rooms through a district heating network with capacity to heat an additional 6,000 homes for local residents.

## 1.3 Mabbett

Mabbett is a leading environmental, engineering, safety, planning and development and sustainability consultancy. We were established in 1996 and today are recognised as a leading sustainability consultancy in the U.K., Ireland and Europe. At Mabbett we are committed to the provision of tailored, leading-edge technical professional services to assist our clients manage risk, reduce costs, enable compliance, and increase commercial strength, profitability and competitiveness.

Our founding principles are underpinned by four cornerstones:

- **Persistence**: we are enthusiastic and dedicated professionals committed to long-term business success with a determination to succeed, whatever the challenge*;*
- **Integrity**: treating our clients with honesty; applying rigour and attention to detail in all we do for our clients;
- **Passion**: putting the needs of our clients first, communicating with others in a clear and concise manner; listening to our clients to clearly understand their issues and challenges, and delivering bespoke solutions; our conviction that what we do will provide real value-added results for our clients; and
- **Sustainability:** designing, implementing and managing cost-effective strategies that deliver sustainable solutions and improvements, and developing sustainable long-term and repeat business relationships.

Working with Mabbett, our clients See a difference®. For more information, please see our website for details www.mabbett.eu.

# Section 2.0 Project Overview

## 2.1 Project Summary

Malt whisky production is an energy intensive process, with distillation accounting for most of the heat demand within a distillery. At the Eden Mill distillery, distillation accounts for approximately 70% of the heat demand.

Eden Mill are in the process of relocating their distillery to the University of St Andrews Eden Campus. In the building with which they share a common internal wall, there is a biomass-fired energy centre which provides district heating to the main St Andrews University campus and Eden Campus. This presents a large source of hot water which can potentially be used by the distillery.

The hot water on the secondary (district heating) circuit of the biomass plant is sufficiently warm for mashing and cleaning within the distillery. The distillation process requires higher temperatures, and this is to be obtained using either:

a) Supply via the higher temperature primary circuit of the biomass plant
b) A high temperature heat pump operating in conjunction with a supply via the secondary circuit of the biomass plant

A back-up source of heat will be required to protect against any potential issues in the supply from the energy centre. This would most likely be via steam produced on site, via a two-stage external heat exchanger.

A third option considered in this study is:
c) A hydrogen electrolyser powered by roof mounted solar panels feeding a hydrogen boiler to produce steam.

## 2.2 Project Objectives

The objectives of this feasibility study are to:

- Determine whether heat from the energy centre alone is sufficient to provide the heat demand of the distillery;
- Assess the balancing and potential storage requirements of energy and gases to provide the distillery with continuous energy;
- Undertake a comparison of the capital and operational costs of the proposed technologies versus current fuel sources and alternative low carbon technologies;
- Evaluate the environmental impact (positive or negative) on land, air and water, both locally and nationally, including reductions in carbon emissions;
- Assess the safety implications of using the technologies at a distillery, particularly around consideration of explosive atmospheres; and
- Select the preferred technology/ies.

The key deliverables are the design for a 300kW (heat) pilot plant and outline business case.

The key to this low carbon option is the use of high temperature hot water in place of steam. This is discussed in section 2.3.

## 2.3 High Temperature Hot Water

Heat demand in a whisky distillery comes primarily from mashing, cleaning and distillation. Demand from mashing and cleaning can be met by hot water at 80°C – 90°C, while distillation requires an elevated heat source with temperatures in excess of 105°C. Currently heat for scotch whisky distillation is almost exclusively generated through combustion of hydrocarbons with either direct fired stills or stills heated indirectly through steam. If distillation powered by high temperature hot water was successfully demonstrated this would facilitate the use of low carbon technologies to generate high temperature hot water and power distillation.

Currently distillation in the pilot distillery is powered by steam via steam coils present within the stills and heating tanks throughout the distillery. As the energy density of steam is significantly larger than that of high temperature hot water, a larger flowrate of water will be required to heat the process. Along with the increased flow rate of water required, a much greater heat transfer area will also be necessary i.e. the existing coils are not adequate.

As the existing coils do not provide an adequate heating surface area, it is proposed that they are replaced with an external plate and frame heat exchanger and recirculation pump. Due to the small size of the stills, it is not possible to accommodate the size of heating coil required for the high temperature hot water. A plate and frame heat exchanger provides the most economical solution for the large heating surface required whilst also allowing the reuse of the stills. Due to the construction of the plate and frame exchanger, the increase in cost between the unit for steam heating and water heating is not as large as anticipated. The price is approximately double the price of a standard steam / water plate and frame heat exchanger which is used throughout industry to externally heat the distillation process. Whilst this results in a larger capital cost, it does not impact the technical feasibility of the project.

As previously stated, distillation accounts for approximately 70% of the heat demand at Eden Mill – a figure which is typical for most distilleries which do not house a maltings. Scotch whisky distillation is almost exclusively powered by the combustion of hydrocarbons. Most of this heat is not recovered as it is not of suitable quality to be recovered into the distillation process, and is too large a heat source to be economically recovered in other parts of the process. Therefore, while some heat recovery is commonplace in distilleries (e.g. pot ale to pre-heat the wash, wort to pre-heat mashing waters) the largest waste heat streams are typically dumped in the cooling system.

Two of the approaches being considered to supply high temperature hot water for distillation in this study, however, represent an opportunity to recover heat from distillation:

- Option A: the district heating network has a large consistent heat demand. If heat were to be recovered from distillation and input into this network it would reduce the required duty of the biomass energy centre, offsetting a significant portion of heat received from the energy centre.
- Option B: heat pumps are able to exhibit coefficients of performance (CoP) of greater than one as they utilise a “heat sink” in addition to their electrical input. In conventional heat pumps this is typically the ground/air/water however for a high temperature heat pump a higher temperature of heat sink will be required – such as the biomass district heating system or recovered heat from distillation.

Heat recovery from distillation has the potential to substantially reduce the net energy consumption of the distillery. This can be seen in the charts below which display the expected (typical day) net heat load of the pilot distillery without heat recovery, and with heat recovery, respectively.

*Figure 1 Pilot Distillery Heat Demand*

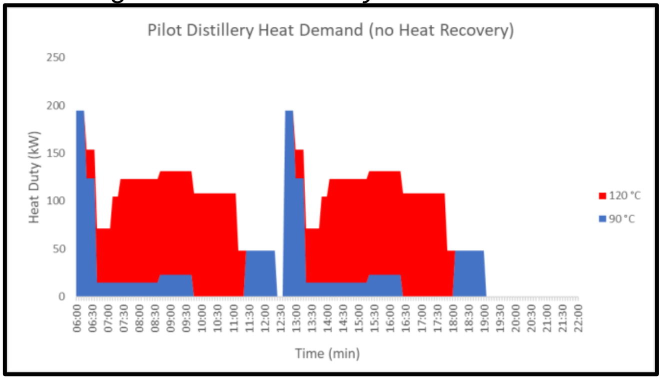


*Figure 2 Pilot Distillery Net Heat Load*

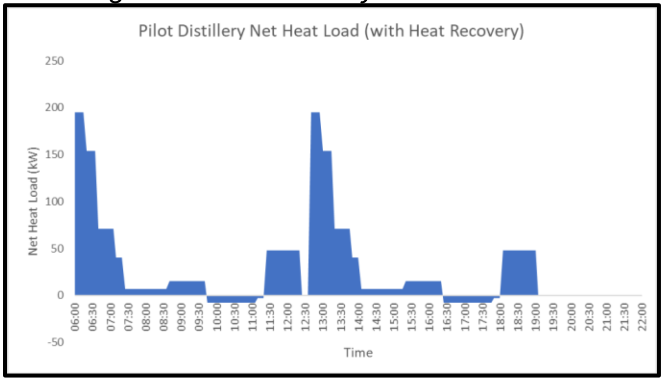
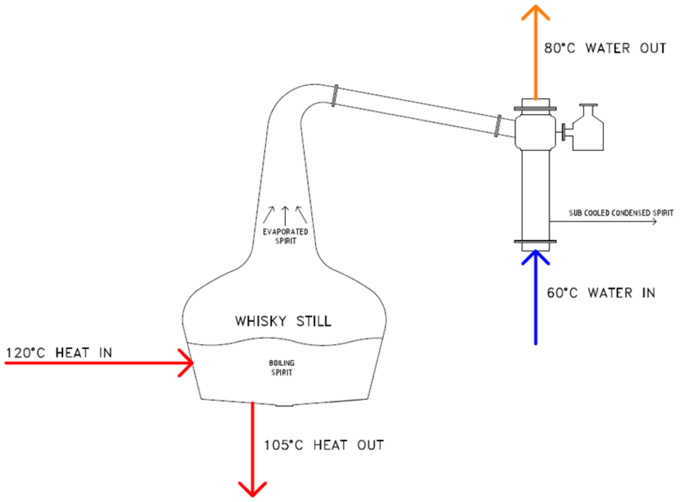


*Figure 3 Distillation Heat Input and Outputs*



Energy input to distillation vaporises spirit in the still which then travels up the body of the still, through the lye pipe until it is condensed, and sub cooled in the condenser. In the condenser the energy applied to the spirit in the still is transferred to the cooling water which is then typically sent to the cooling system at the distillery. Cooling water typically enters the condenser at around 10°C and is heated to around 40°C before it exits the condenser. For useful heat to be recovered from the condensers the cooling water supply and return temperatures would need to be increased as displayed.

An increase in the cooling water temperature within the condensers will decrease the temperature gradient in the condensers and as a result a larger heat transfer area will be required. This is displayed in Table 2-1 where it is shown that a condenser with around 3.7 times the heat transfer area would be required. While this represents increased capital expenditure for the project it is not considered to have any impact on technical feasibility.

*Table 2-1: Condenser Heat Transfer Areas*

| Condenser | Category | Cooling Water Inlet (°C) | Cooling Water Outlet (°C) | Increase in Heat Transfer Area Required (%) |
|---|---|---|---|---|
| Wash Condenser | Previous | 12 | 42 | 368% |
| | New | 55 | 85 | |
| Spirit Condenser | Previous | 12 | 42 | 365% |
| | New | 55 | 85 | |

Heat recovery and process efficiency is a key component in reducing energy consumption and associated carbon emissions in industry. Use of innovative low carbon technologies such as those described in this report, that can utilise recovered heat from the condensers, would facilitate significant reductions in net energy consumption and associated emissions within the distilling sector. At Eden Mill 70% of heat input into the process is in distillation – while not all of this heat will be recovered due to heat losses, inefficiencies etc. it highlights the potential for energy savings within the sector.

# Section 3.0 Phase 1: Feasibility Study

## 3.1 Background

At the newly relocated and expanded distillery, larger whisky stills will be put into operation to meet the bulk of production demands, while the existing stills will be operated more flexibly with a greater variation in spirit runs. Operation of this smaller scale distillery using the existing stills provides an opportunity to trial low carbon technologies to power distillation on a pilot scale, and how this could then be scaled to production size. In this feasibility study the suitability of high temperature hot water to meet the majority of heat demand of the distillery will be assessed. In addition, the feasibility of generating steam from the combustion of green hydrogen produced on site (to supplement any heat demand that hot water is not able to fulfil) will be appraised.

## 3.2 Counterfactual – Natural Gas Fired Steam Boiler

In order to provide a baseline from which to assess the three options being considered, a base case using the traditional approach to heat generation in distilleries will also be included i.e. using a hydrocarbon fired (natural gas in this instance) steam boiler, with most of the heat from distillation being rejected to atmosphere via a water cooling system. Should none of the options being considered prove viable, this is the approach that will be taken by Eden Mill.

## 3.3 Option A: Energy Centre Integration (Supply via Primary Circuit)

Within the University biomass energy centre there are two heating circuits. The primary circuit is a pressurised high temperature hot water circuit with a 125°C flow and 105°C return, which is heated directly from the biomass boiler and is used to heat the secondary circuit; the district heating network. The district heating network operates with an 85 °C flow and a 65 °C return.

It is proposed that Eden Mill would integrate heat from this system to power the distillery whilst still maintaining capacity to operate independently in the result of unscheduled downtime. To meet the high temperature hot water demand of distillation, heat from the primary hot water circuit in the energy centre would be utilised to generate high temperature hot water within the distillery. This heat demand would be significantly offset by recovering heat from the condensers, and using it to heat the return loop of the energy centre's secondary (district heating) circuit. Due to this heat recovery the net heat consumption of the distillery is low during distillation, though there is still a sizeable heat load during pre-heating and boil-up.

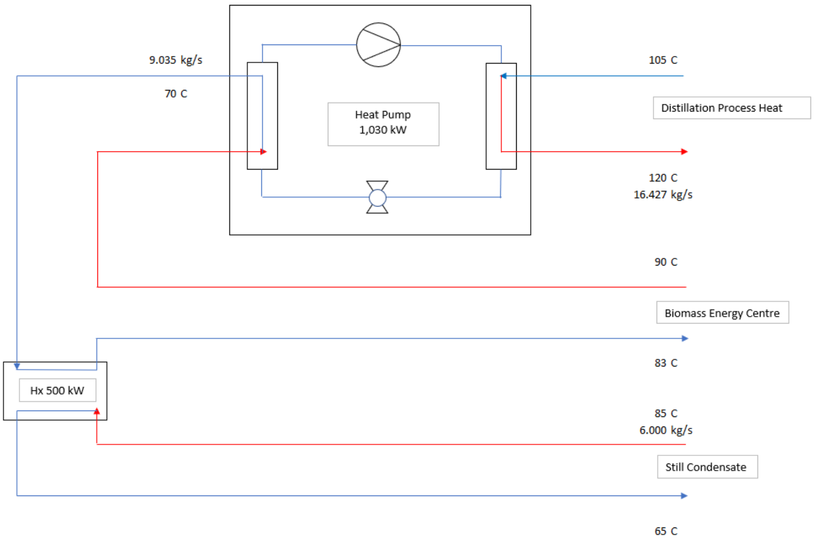
As the energy centre will prioritise meeting the heat requirements of the district heating network during periods of high demand (e.g. winter mornings), there may be limited heat supply available to the distillery on some occasions. In order to ensure continued operation of the distillery through any such periods it must have sufficient thermal storage. From analysis of heat meter data from the energy centre, and predicted heat demand of the pilot sized distillery, a thermal store volume of 20 $m^3$ should ensure a constant high temperature hot water supply for the distillery throughout the year. In addition to a thermal store, cooling capacity should also be installed within the distillery to prevent heat build-up in the condenser if there is insufficient capacity for recovered heat in the secondary (district heating) network of the energy centre for any reason. While the inclusion of a thermal store and a cooling system will add additional capital cost to the project, they are not considered to have any impact on its technical feasibility.

## 3.4 Option B: Energy Centre Integration (Supply via Secondary Circuit) & Heat Pump

Developing a pilot scheme for the heat pump option is problematic in that the ideal thermal output for the pilot plant is in the region of 100 kW. High temperature heat pumps are in their relative infancy for process applications and none could be found at or around the desired capacity which are capable of achieving the 120°C process temperature. If this option were selected for the pilot trial it would therefore utilise steam to provide the supplementary heating. However, use of a heat pump remains an option for delivering process heat at full scale.

On this basis, this section provides an outline design for the full scale system. The distillation process load is estimated at 1,030kW. To produce 120°C water useful to the process, the heat pump evaporator would require a high energy source which in this instance is 90°C water from the secondary circuit of the energy centre. Water would leave the heat pump at circa 70°C, and pass through a heat exchanger to elevate its temperature prior to returning to the energy centre.

*Figure 4 Heat Pump Outline Design*



The most useful source of heat recovery in the still house is the condensers associated with distillation, which is estimated at 85°C with around 11 kg/s available. By rerouting the heat pump evaporator return through a heat exchanger (circa 500kW), the biomass return could be preheated to approximately 83°C and metered separately to recoup some of the purchased heat input. Based on the heat available from condensate there is a limit to this return temperature and therefore a limit to the energy returned.

The table below shows a summary of energy, cost and carbon flows associated with the installation where negative values represent paid inputs and positive values represent outputs including heat recovery. In this case equivalent carbon and energy costs have been estimated using figures for natural gas as it is the low-cost alternative.

*Table 3-1: Heat Pump Performance*

| | Energy (kWh) | Carbon ($tCO_2e$) | Energy Value (£) | |
|---|---|---|---|---|
| Biomass Energy | -2,316,356 | -35.8 | -324,290 | Heat Pump Inputs |
| Electrical Energy | -758,080 | -176.7 | -75,808 | |
| Equivalent Natural Gas | 3,423,708 | 629.5 | 102,771 | Outputs and Heat Recovery |
| Biomass Recovery | 1,384,132 | 21.4 | 193,778 | |
| **Net Savings** | **1,739,405** | **438.4** | **-111,189** | |

Based on available inputs the heat pump is expected to operate with a coefficient of performance of 3.75. Therefore, to produce the 2,842,800 kWh process requirement, 758,080 kWh will be delivered as electrical energy through the compressors whilst the remaining input is made up from the energy centre with assumed efficiency of 90%.

There is a high cost associated with purchasing biomass energy at the current contract price although around 66% of this could be recovered using condenser heat through heat exchange within the still house. With heat recovery included; the system would cost an additional £111,189 per year to operate relative to natural gas as the prime energy source. However, the heat pump solution would provide significant carbon savings in the region of 438.4 $tCO_2e$ per year.

## 3.5 Option C: Hydrogen Electrolyser & Steam Boiler

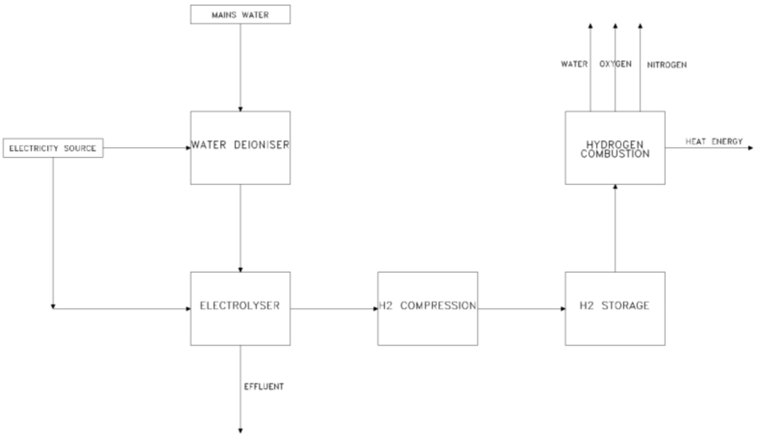
### 3.5.1 Hydrogen Technical Feasibility

As noted above a back-up source of heat will be required to protect against any potential issues in the supply from the energy centre. This would most likely be via steam produced on site, via a two-stage external heat exchanger.

The proposal being considered here is using green hydrogen to create the steam in a hydrogen powered boiler. The hydrogen would be green as it is to be produced using solar photovoltaic (PV) roof-mounted panels. A simplified process flow diagram (PFD) for such a system is shown.

Green energy generation technologies such as solar and wind power are playing an increasingly key role in the green economy.

*Figure 5 Hydrogen Electrolysis & Steam Boiler PFD*



However, in contrast to using fossil fuels, green energy generation typically fluctuates according to weather patterns. As such, they present challenges in terms of providing for a constant baseload of energy.

One means of meeting this challenge is to provide a sustainable means of energy storage. Reliable, sustainable energy storage could meet fluctuating demands by storing energy during periods of high generation, and releasing it on an as-needed basis. Hydrogen gas has the potential to provide this storage. This is typically via the following two applications:

- It can be combusted in a similar manner to natural gas, producing heat. The only significant by-product of this process is water (as opposed to the carbon dioxide, nitrogen oxides and more produced via fossil fuel combustion).
- It can be combined with oxygen to produce electrical energy, a process which is exploited by fuel cells.

It is heat required by Eden Mill, and so the first of these applications is more appropriate. The following points summarise the basis of design for the proposed pilot system:

- Electrolyser type: Alkaline water electrolysis
- Electrolyser size (electrical input): 100 kW
- Electrolyser operation factor: 100% (constant operation)
- Electrical energy source: Solar PV supplemented by grid electricity
- Hydrogen storage requirements: 3 days (to reflect uncertainties regarding the electricity supply / heat demand of the distillery)

The key components of the water alkaline water electrolysis process are as follows:

- Water deioniser: A relatively small reverse osmosis unit could be used to provide this.
- Electrolyser: An approximately 100 kW alkaline water electrolyser could be used.
- Hydrogen compression: To boost the pressure from its production level of around 12 bar, to 200 bar for storage. The required unit size is estimated at 10 kW.
- Hydrogen storage: For hydrogen at standard conditions and a 200 bar pressure, 3 day's storage would equate to a tank of approximately 8 $m^3$.
- Hydrogen combustion: A hydrogen fired steam boiler to produce steam. This unit would be sized to accommodate certain levels of fluctuation in the heat demand at the distillery, with a figure of 120 kW being estimated.

### 3.5.2 Hydrogen Safety

The potential use of hydrogen on site introduces a risk that would need to be managed, as in general it can be considered a more hazardous substance than natural gas and other fossil fuels. Some of the key hazards are summarised below.

*Table 3-2: Hydrogen Safety – Key Hazards*

| Factor | Comment |
|---|---|
| Wide flammable range | Hydrogen has a flammable range of 4% to 75% v/v in air – this is much greater than other flammable substances such as methane (4% to 15%), propane (2% to 10%), butane (2% to 8%) and petrol (1% to 8%). |
| Low ignition energy | Hydrogen has a minimum ignition energy of 0.02 mJ – this is much lower than other flammable substances such as methane (0.28 mJ), propane (0.25 mJ) and butane (0.26 mJ). Following an incident it is often difficult to determine the exact mechanism and cause of ignition when it occurs. Incidents have been recorded where released hydrogen has ignited where all obvious sources of ignition had been excluded. |
| Greater possibility of detonation | Hydrogen/air mixtures have a greater propensity to detonate than mixtures of air with other more common flammable fuels. |
| Invisible flame | A hydrogen flame radiates significantly less infrared radiation (heat) and virtually no visible radiation (light). As a result, hydrogen burns with a pale blue, almost invisible flame that is almost visually imperceptible. |
| Low viscosity | Hydrogen gas has a very low viscosity and so it is difficult to prevent hydrogen systems from developing leaks. Pipe work that was 'leak tight' when pressure-tested with nitrogen will often be found to leak when used with hydrogen. |
| High diffusivity | Hydrogen is much lighter than air and is also very diffusive. In well ventilated or open areas its diffusivity and buoyancy will help to reduce the likelihood of a flammable mixture forming. However, within poorly ventilated or enclosed areas, the concentration may rapidly reach dangerous levels and due to its lightness, hydrogen will accumulate at high levels where ignition sources (e.g. lighting) may be present. |
| Embrittlement of metals | At elevated temperatures and pressures, hydrogen attacks mild steels severely, causing decarburisation and embrittlement. |

DSEAR is the overarching legislation for the use of flammable substances in UK workplaces. It sets minimum requirements for the protection of workers from fire and explosion risks related to dangerous substances and potentially explosive atmospheres. Eden Mill would be required to undertake a detailed review and update of their current DSEAR risk assessment and hazardous area classification if hydrogen were to be used. It would likely identify the need for a range of new control measures, such as:

- Minimise the quantity of hydrogen that is stored and involved in operations;
- Minimise pipeline diameter and operational pressure to satisfy technological requirements to mass flow rate where applicable;
- Isolate hydrogen from oxidisers, hazardous materials, and dangerous equipment;
- Identify and, if possible, separate or eliminate potential ignition sources;
- Separate people and facilities from the potential effects of unignited releases, fire, deflagration, or detonation originating from the failure of hydrogen equipment or storage systems;
- Elevate hydrogen systems and vent them above other facilities;
- Use of personal protective equipment;
- Prevent hydrogen/oxidiser mixtures from accumulating in confined spaces (under the eaves of roofs, in equipment shacks or cabinets, or within equipment covers or cowlings);
- Minimise personnel exposure by limiting the number of people exposed, the time that the personnel are exposed;
- Use of alarms and warning devices (including hydrogen and fire detectors), and area control around a hydrogen system;
- Practice good housekeeping, such as keeping access and evacuation routes clear and keeping weeds and other debris away from hydrogen systems; and
- Observe safe operational requirements, such as working in pairs when operating in a hazardous situation.

Hydrogen could be used safely if it is appropriately designed into the new facility, and suitable control measures are implemented and thereafter maintained. However, it does present a significant potential risk. The design upgrades and control measures will come at a financial cost to Eden Mill.

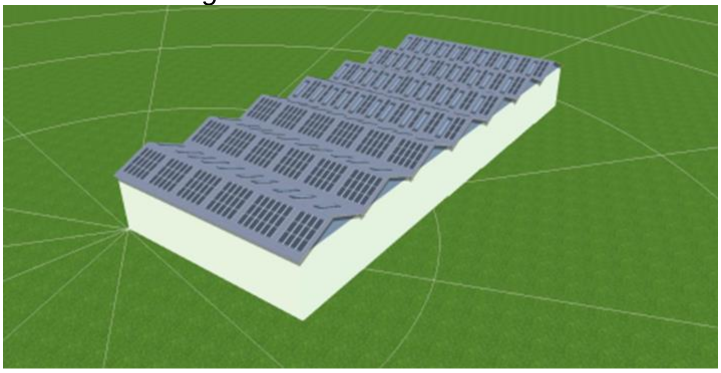
## 3.6 Solar PV

### 3.6.1 Array Design

Solar PV is being considered as part of two of three options being considered i.e. to power the heat pump of Option B, and to power the hydrogen electrolyser of Option C. An array could potentially be placed on the south facing roof aspects of the distillery buildings. The buildings are oriented at 200°, with a roof tilt of 24°. There are a total of seven roofs with an approximate area of 2,602 m$^2$. The three southernmost roof aspects are almost entirely free from obstruction allowing placement of larger arrays whereas the remaining roofs have several skylights the architect has opted to leave clear. As a result, these roof areas have potential to hold much smaller arrays.

Using PVSOL simulation software a 3D model of the distillery buildings was created. The image below shows the layout of solar modules on each of the seven roof aspects. A 3D model allows for a comprehensive shading analysis, which provides an accurate representation of system losses. As the roofs are arranged back-to-back, some shading loss is expected in modules placed closest to the roof eaves.

*Figure 6 Solar PV 3D Model*



The total roof area can support approximately 450 modules providing a total installed capacity (TIC) of 148.5 kWp. The PVSOL model was simulated to provide expected annual performance. The model uses weather data from the Meteonorm database with data set for St Andrews, Fife (1991-2010). The system would be expected to generate 138,522 kWh per year. The table below summarises the anticipated performance of the system.

*Table 3-3: PV Performance*

| **PV Performance** | |
|---|---|
| PV Generator Output | 148.5 kWp |
| Specific Annual Yield | 933 kWh/kWp |
| Yield Reduction Due to Shading | 5.1% |
| Generated Energy | 138,522 kWh |
| Offset Carbon | 34.8 $tCO_2e$ |

Assuming 100% self-consumption and a specific investment price of £900/kW, the above solar PV system has an estimated simple payback of 9.6 years.

### 3.6.2 Heat Pump

At pilot plant scale the heat pump solution would require approximately 72,400 kWh electrical energy per year to satisfy the process heat load, meaning it could potentially be served entirely by the solar array. At full scale operation (2 Te distillery) this would change – with 758,080 kWh of electrical energy per year required to satisfy the process heat load – meaning the solar array would only generate 18% of the electrical energy required for the process.

Further to this, distillation using the heat pump may not align with solar PV generation in that the estimated four hour heat up time (heat pump under maximum load) may not necessarily occur when there is peak generation from the solar PV system. Depending on other loads present in the still house or loads connected to the same electrical supply, this might result in export to grid reducing the heat pump offset potential further.

Such a situation could potentially be rectified using energy storage whereby solar generated energy would be stored locally when there is low demand rather than exporting to grid. However, as the offset potential is at best 18%, this is unlikely to be a viable solution due to the increased capital costs involved.

### 3.6.3 Hydrogen Electrolyser

The hydrogen electrolyser solution would require approximately 597,300 kWh (pilot scale) or 6,402,300 kWh (full scale) of electricity energy, meaning the array would serve only a small percentage of its demand even at pilot scale. There should be no issues with matching generation to demand, given the hydrogen can be generated at any time and stored until needed.

### 3.6.4 Summary

Solar PV could be justified to offset a hydrogen electrolyser, or distillery loads as a whole. However, using solar PV directly to power a heat pump is not considered a viable option based on the roof mounted solar option being considered.

## 3.7 Planning

### 3.7.1 Background

Eden Mill will soon be submitting a planning application to account for the site's development. The options being considered could potentially impact this application and a preliminary planning review has been undertaken. All options being considered provide a positive benefit with regards to low carbon and the natural environment, via reduced direct or indirect emissions. Therefore they should generally strengthen any planning application. No particular concerns or issues are anticipated.

### 3.7.2 Potential Impacts of Options Being Considered

The table below identifies some of the main environmental considerations for the proposed site that may need to be addressed prior to the forthcoming planning application.

*Table 3-4: General Environmental Considerations*

| Environmental Consideration | Summary |
|---|---|
| Ecology | The Firth of Tay and Eden Estuary which lies east of the proposed development, has been designated as a Natura 2000; SSSI; SPA; SAC; RAMSAR site; and Local Nature Reserve. |
| Landscape Character | In terms of landscape character, according to NatureScot, the site lies in Landscape Character Type (LCT) 196: Coastal Flats - Fife. |
| Built & Historic Environment | There are a number of Listed Buildings in proximity, including:<br>▪ Category A Listed Guardbridge (Old) Over River Eden (Grid ref: 345188, 718877);<br>▪ Category B Listed Guardbridge, Paper Mill (Former), Boiler House (Mill Building 49) and Stalk (Grid ref: 345118, 719597);<br>▪ Category B Listed Guardbridge, Paper Mill (Former), Main Street Buildings Numbers 1, 2, 3, 3a, 4, 6, 7, 8, 17 and 26 (Grid ref: 344979, 719550); and<br>▪ Category B Listed Inner Bridge (Old) Over Motray Water, Guardbridge (Grid ref: 344997, 719760). |
| Amenity | Residential receptors within close proximity include those located on the A919 to the southwest and Innerbridge Street to the northwest. |
| Recreation | The A919, which lies to the west, is used as a cycle route as part of National Cycle Network Route 1 and as part of the Fife Coastal Path: one of the Scotland Great Trails. Routes P038/04 and P038/05 (Guardbridge to Leuchars) of the core path network, also utilise the A919. There are a couple of areas of Protected Open Space north and south of the site, that should be considered through Policy 1 of the Development Plan. |
| Access | The proposed site lies within close proximity to the local highway network, with access possible from the A919 located to the west of the site. |
| Flood Risk | According to the SEPA Flood Risk Map, there are some areas at risk of surface water flooding within the site. |
| Air Quality | The site will have one or more new stacks related to combustion appliances. These must be suitably designed to ensure adequate dispersion of pollutant to control risk to local human health and the environment. |
| Environmental Noise | The site will involve the installation of plant/equipment which could result in the generation of environmental noise, and this risk must be adequately controlled, with adequate performance demonstrated via suitable noise assessment. |

| Environmental Consideration | Summary |
|---|---|
| Additional Considerations | Within approximately 1km of the proposed development, lies the Dairsie/Guardbridge (C03) Hazard Pipe, and associated Consult Zone. |

With regards to the options being considered, some of the key environmental considerations are noted below.

*Table 3-5: Environmental Impacts*

| Option | Comment |
|---|---|
| A | This option will provide an environmental benefit via reducing the combined heat load of the energy centre and distillery, and thus the release of less pollution to atmosphere via the combustion of fossil fuels. No negatives are noted. |
| B | As above, this option will provide an environmental benefit via reducing the combined heat load of the energy centre and distillery, and thus the release of less pollution to atmosphere via the combustion of fossil fuels. In terms of potential negatives, the heat pump will include compressors which produce noise, and this must be managed. The solar panels, located on the distillery roof, represent a potential visual impact. |
| C | As above, this option will provide an environmental benefit via reducing the combustion of fossil fuels, and thus the release of less pollution to atmosphere via the combustion of fossil fuels. The combustion of hydrogen may lead to higher $NO_x$ emissions than with natural gas. In terms of potential negatives, the solar panels, located on the distillery roof, represent a potential visual impact. |

### 3.7.3 Summary

All options being considered will likely require some adjustment to the pending planning application. However, no significant impacts are expected. Planning is not considered a major factor when assessing the feasibility of the three options being considered.

## 3.8 Comparison of Options

A detailed comparison of each option has been undertaken, which considers the technical, carbon and commercial variation between scenarios – against a base case of the traditional distiller’s approach i.e. generating steam via combustion of fossil fuel (natural gas in this instance) to produce steam. This comparison is summarised in the tables below. The cost and carbon savings noted for each option are in reference to the counterfactual base case of natural gas. Both the pilot plant and full scale system are presented.

### 3.8.1 Pilot Plant

*Table 3-6: Pilot Plant Option Comparison – Annual Performance*

| | Base Case | Option A | Option B | Option C |
|---|---|---|---|---|
| **Net Energy Consumption (kWh)** | 337,604 | 73,523 | - | 657,690 |
| **Carbon Emissions ($tCO_2e$)** | 62.1 | 1.1 | - | 121.7 |
| **Additional Investment** | - | £286,450 | - | £457,031 |
| **Cost Savings** | - | -£165 | - | -£53,803 |
| **Carbon Savings ($tCO_2e$)** | - | 60.9 | - | -59.6 |

It can be seen that at pilot plant scale none of the options appear economically favourable, with option B excluded entirely as it was found to be not viable as discussed above. However, the pilot plant is primarily geared towards proving technical viability, and economic viability is best assessed at full scale – see below.

### 3.8.2 Full Scale

*Table 3-7: Full Scale Option Comparison – Annual Performance*

| | Base Case | Option A | Option B | Option C |
|---|---|---|---|---|
| **Net Energy Consumption (kWh)** | 3,423,708 | 511,022 | 1,690,304 | 6,402,334 |
| **Carbon Emissions ($tCO_2e$)** | 629.5 | 7.9 | 191.1 | 1,461.0 |
| **Additional Investment** | - | £754,220 | £1,400,000 | 4,449,003 |
| **Cost Savings** | - | £31,168 | -£111,189 | -£593,131 |
| **Carbon Savings ($tCO_2e$)** | - | 621.6 | 438.4 | -831.5 |

*Table 3-8: Full Scale Option Comparison – 15 Year Profile*

| | Base Case | Option A | Option B | Option C |
|---|---|---|---|---|
| **Net Energy Consumption (kWh)** | 51,355,618 | 7,665,325 | 25,354,553 | 96,035,010 |
| **Carbon Emissions ($tCO_2e$)** | 9,442.8 | 118.4 | 1,729.4 | 21,931.4 |
| **Additional Investment** | - | £754,220 | £1,400,000 | £4,449,003 |
| **Cost Savings** | - | £1,245,116 | -£651,034 | -£11,259,002 |
| **Carbon Savings ($tCO_2e$)** | - | 9,324.3 | 7,713.3 | -21,813.0 |
| **Internal Rate of Return (IRR)** | - | 7% | - | - |

### 3.8.3 Conclusion

The first conclusion which can be drawn is that Option C (using a hydrogen electrolyser and boiler to produce steam, powered by roof mounted solar panels) is not viable. It involves the greatest capital expenditure, results in the greatest running cost, and has the greatest carbon footprint of all options considered. One of the main reasons for this is that the solar panels can only generate a relatively small percentage of the necessary electricity, meaning significant grid electricity consumption would be necessary. In addition, it would introduce a significant new hazard to the site (hydrogen gas), which would only be justified should the environmental and/or cost benefits also be significant. Option C is therefore discounted and is not considered further within this report.

Comparing Option A and Option B, it can be seen that Option A (integration with the Eden Campus' Biomass Energy Centre and District Heating Network, with supply via the primary circuit) is preferred. It provides the greatest level of carbon and cost savings for the lowest level of investment, and is the only option to provide a positive IRR based on a 15 year profile. It is therefore progressed to the next stage (see Section 4 below).

# Section 4.0 Phase 2 – Pilot Scale Demonstration Project

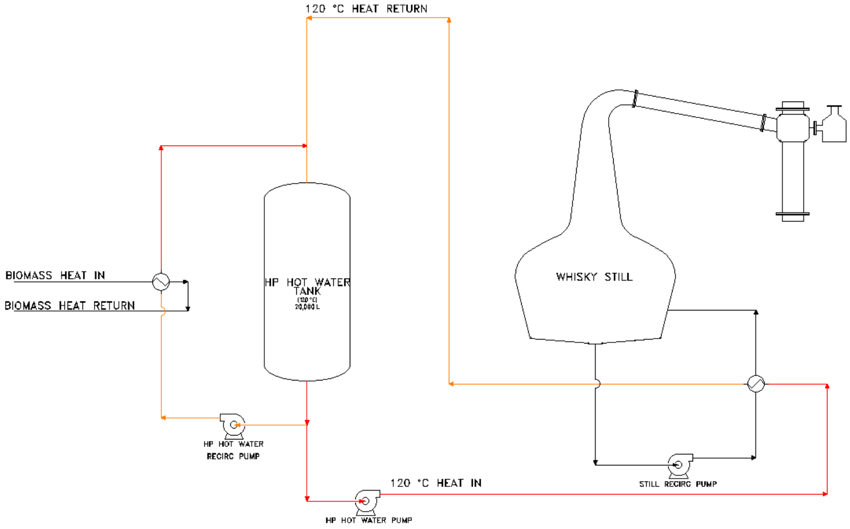
## 4.1 Project Description

The proposed demonstration project involves utilising the high temperature hot water from the primary circuit of the energy centre to power distillation at Eden Mill's pilot distillery. Multi-pass condensers will be installed on the wash and spirit stills to allow heat recovery from distillation. This heat will be fed into the district heating network which is served by the energy centre. Heat recovery from the condensers will result in an estimated 68% reduction in net heat consumption of the distillery.

### 4.1.1 High Temperature Hot Water System

The high temperature hot water system for the pilot distillery will operate with a 20 m$^3$ thermal store. Temperature will be maintained within this store through circulation through a plate heat exchanger with heat provided by the internal biomass heat circuit. Heat from this store will provide power to the distillation through an external heat exchanger. An outline of the operation of the high temperature hot water system for one of the stills is shown.

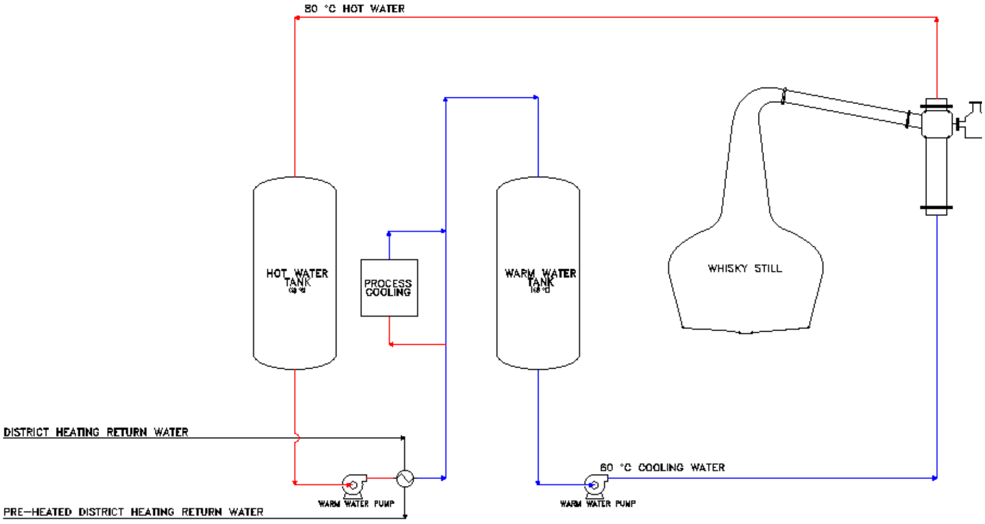
*Figure 7 High Temperature Hot Water System*



### 4.1.2 Condenser Heat Recovery

Heat recovery from the condenser on the wash and spirit stills will pre-heat the return water in the district heating network before it is heated by the internal biomass heat circuit. This will offset a significant amount of heat used from this circuit to provide high temperature hot water for the distillery.

*Figure 8 Condenser Heat Recovery*



In order to capture useful heat from the condensers, flow and return temperatures of the cooling water have been selected as 60°C and 80°C respectively. Warm water and hot water storage tanks will be used to ensure continued operation of cooling throughout distillation and a backup cooling system will be in place in the event of unscheduled downtime of the district heating network. An outline of operation of the heat recovery network is displayed in the figure below.

## 4.2 Project Design

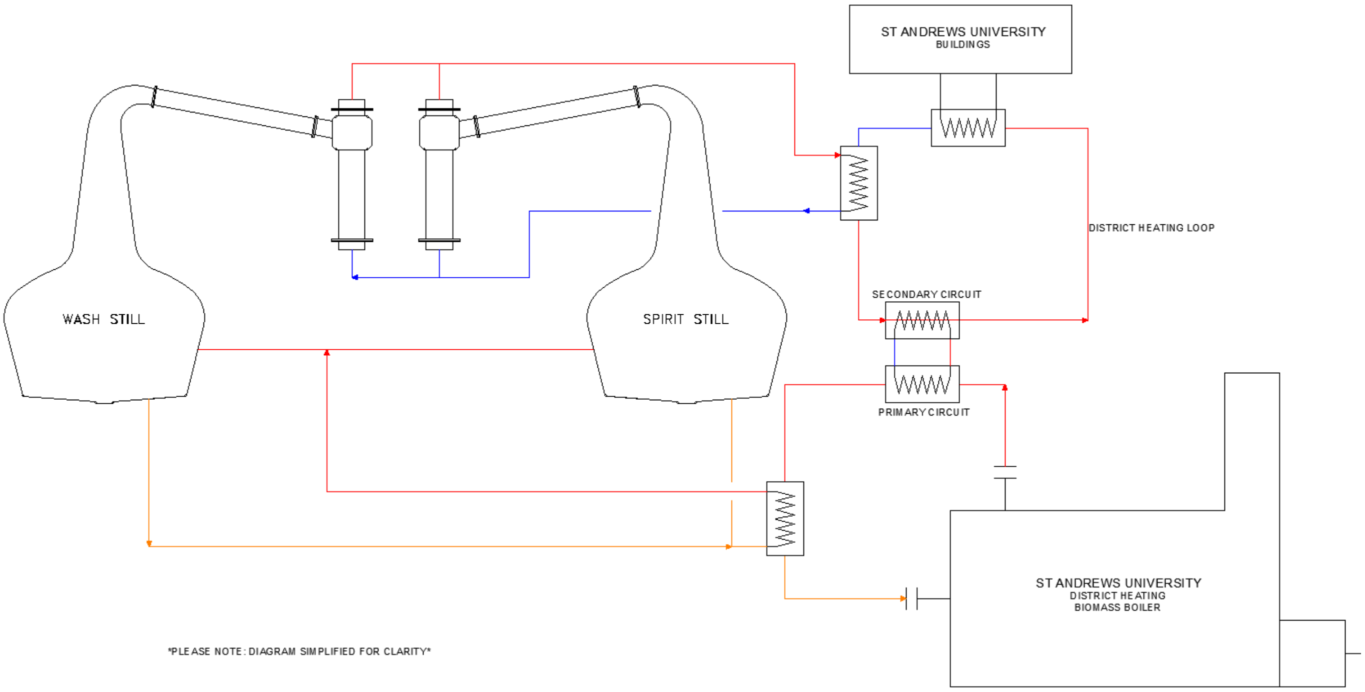
The pilot plant will utilise existing distillation and mashing equipment owned by Eden Mill, which is currently not in use during the relocation. This smaller distillery (0.6 Te mash size in comparison to a 2 Te mash size planned for the expansion) provides a cost effective solution to test the performance of a distillery primarily ran using the heat provided by high temperature hot water. During operation, the mash tun will provide 3,000 litres of wash for distillation within the 1,000 litre capacity wash still. Therefore, the mash tun will run once for every three distillation runs of the wash and spirit still.

The distillation equipment requires significant alteration to utilise the hot water for distillation, with external plate and frame exchangers required to power the distillation. This will require the removal of the current steam heating coils and the addition of several new connections on the base and side of the stills to allow for the high recirculation flow rates required within the stills.

The production of hot water is common among larger well-established distilleries; however it is not usually seen within smaller distilleries due to the large investment cost required. It requires a larger condenser which routes the cooling water through the condenser tubes several times in comparison to the straight-through condensers currently used by Eden Mill. Routing the water through the condenser a number of times makes it possible to produce hot water at a temperature exceeding 80°C.

This hot water production will enable approximately 68% of the energy used by the distillery to be returned to the secondary circuit return of the energy centre’s district heating network. A simplified diagram showing the main interaction between the distillery and the district heat network is shown below in Figure 4-3.

*Figure 9: Simplified Overview of Pilot Plant*



The distillation heat is taken from the high temperature primary circuit of the biomass boiler. The heat from condensing the vapour produced by the distillation is then recovered to the return leg of the district heat network. Whilst recovering the heat from the distillation process is key to low net energy consumption of the distillery, effectively reusing heat within the distillery is also key. There will be conventional preheating of the stills using waste effluent and hot water, the mashing waters will be further heated using hot water and all cleaning operations will be done using hot water produced by the distillery and not through heating of cold water. Whilst these practises are commonplace throughout the industry, it is key that they are included.

## 4.3 Benefits and Barriers

Some of the key benefits and barriers/risks are summarised below.

*Table 4-1: Benefits & Barriers/Risks*

| Benefit | Barrier |
|---|---|
| Effective heat recovery for the distillation process | Potentially offers less control of distillate flow rate relative to steam heating |
| Use of low carbon heat for an energy intensive process, providing significant carbon savings (60.9 $tCO_2e$/year) | The stills have not been used for around 3 years, increasing the risk of process issues |
| Large decrease in net energy consumption (73,523 kWh/year) | Reliance on a third party to provide the primary source of heat to the process, potential contractual obligations |
| Makes use of existing energy infrastructure | Dependence on a third party's heat sink to recover heat |
| Relatively simple to scale and replicate | Increased capital expenditure (~£286,450), and increased operating costs in the short term (operating cost savings of ~£3,900/year are soon achieved) |

In terms of scaling the pilot project, this is a relatively straightforward exercise. There is no change in the design philosophy, and it would simply involve the purchase and installation of large plant/equipment (e.g. heat exchangers, energy stores, etc.). A significant new risks/barriers that would require more detailed investigation is the demand on heat during peak winter months and the volume of hot water storage that would be required.

## 4.4 Development Plan

Upon commencement of Phase 2 of this project, the design of the pilot plant shall be finalised amongst the project team within a short timescale to allow for the correct safety reviews (HAZOP, LOPA, etc.) and a planning review to take place prior to submission of the design for approval by St Andrews University.

This review shall precede the tender process for the equipment manufacture and installation tender process for which 6 – 8 weeks has been allowed for. It is anticipated that equipment manufacture and alterations are to start in November 2021, with deliveries to begin in early 2022 with the aim of starting commissioning in May 2022 after an installation period of approximately 4 months.

Once commissioning has been completed a period of testing the pilot plant shall begin to allow for the proper integration with the energy centre, leading to full operation of the pilot plant in September 2022 for extended operation and testing. Operational KPIs will be monitored throughout both testing and extended operation to understand any issues that may occur during the pilot scheme which could impact the future rollout potential of such a scheme.

The pilot plant shall be used to demonstrate the potential for integrating the full-scale distillery with the energy centre. It should largely prove (or otherwise) the technical viability of proposed solution, readily allowing the business case for the full-scale project to be finalised. There are not anticipated to be any significant additional tasks required after BEIS funding for the pilot ends, necessary to finalise the business case, other than formal (detailed) assessment of the available capacity and full scale integration with the energy centre. As part of this process detailed modelling of the heat profile of the energy centre would be needed, in conjunction with the energy centre operator Vital Energi, to demonstrate it can accommodate the full Eden Mill heat demand.

Cost estimates for both pilot plant and the full-scale plant are included in the business cases outlined in Section 3.8.2.

### 4.5 Rollout Potential & Route to Market Assessment

*The project involves implementing an innovate heat recovery approach within an established manufacturing process (distilling), and not a new product/service, and thus a conventional 'route to market' assessment is not applicable. This section therefore focuses on the rollout potential of the project.*

The rollout potential of this action, and potential benefit to the UK's net zero goals, is significant. This is highlighted by the following points:

- There are a large number of distilleries in the UK, approximately 560 at the end of 2020[1];
- It is a rapidly growing sector, with the number of distilleries in England almost tripling since 2016 – and more are expected to open in the coming years. The UK average increase in 2020 was 28%;
- Each distillery involves an energy (and typically carbon) intensive production process, and as discussed elsewhere in this report most of the energy put into the distilling process is normally rejected to atmosphere;
- Whilst there are some subtle site-specific variations, the process at each gin and whisky/whiskey distillery follows the same fundamental approach, therefore the technical viability can generally be assumed favourable; and
- Given the growth of the sector many distilleries are currently relocating their operations to larger sites.

The main limiting factors on large-scale roll out of the proposed heat recovery approach are:

- The scale of the spirit production. Many of the UK's distilleries, particularly the newer ones, are relatively small micro/craft operations. The smaller the spirit production and associated energy consumption, the less energy savings on offer – and thus the less capital expenditure which can be justified investing on heat recovery plant/equipment.
  The proximity of the distillery site to a sufficiently large heat sink capable of taking hot water at the available temperature. Potential options include: A residential/commercial district heating network; A hospital campus; An education (e.g. university) campus; Industrial parks.

Allowing for some of the micro/craft distillers being too small, there are still several hundred distillery sites with reasonable potential for distillation heat recovery – and this number will grow as more distilleries open, and currently micro/craft distillers grow in scale. Of these, the ones with the most potential are likely to be those within built-up areas – with these having greater potential for being located near to a suitable heat sink.

There may some existing heating systems which can be readily incorporated into a new distillery heat recovery system, such as is proposed for Eden Mill. Alternatively, it may be necessary to install a new energy centre close to the distillery site, to serve a newly formed heat network.

Some potential examples are discussed below. These are based on a limited review of publicly available information, for reference purposes only, and no discussion with the sites in questions has been undertaken. Further investigation would be required to confirm feasibility.

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[1] https://www.wsta.co.uk/archives/press-release/covid-19-failed-to-put-the-brakes-on-the-uks-distillery-boom

### Integration with Existing: Wick District Heating

The biomass-fuelled Wick District Heating Scheme[2] serves around 200 homes as well as providing steam to the adjacent Pulteney Distillery. Depending on its current design/configuration, it may be possible to dump heat from the condensers into the return loop of the heating circuit which serves the 200 homes.

### Implementation of New: Clydeside Distillery

The relatively new Clydeside Distillery is located on the banks of the River Clyde in the heart of Glasgow city centre. The installation of a new energy centre adjacent to the distillery, with surplus heat being used to heat one or more of the SEC Centre, hospital campus or residential/commercial premises in the area could offer significant energy and carbon savings.

The above are but two specific examples, however there are a large number of potential sites which could be considered, such as the distilleries located in or near towns like:

- Oban Distillery, Oban
- Glen Grant, Rothes
- Glencadam Distillery, Brechin
- Glen Garioch Distillery, Oldmeldrum
- Glen Scotia Distillery, Campbelltown
- Glenfiddich Distillery, Dufftown
- Auchentoshan Distillery, Glasgow
- Glenmorangie Distillery, Tain

## 4.6 Dissemination

Upon successful completion of the demonstration project, we will implement our dissemination plan, as outlined below:

1. The first stage will be to identify a list of relevant stakeholders to work with (such as Scotch Whisky Association, The Scotch Whisky Research Institute, The Wine and Spirit Trade Association, Food and Drink Federation, and Centre for Engineering Education & Development) to disseminate the learnings from the project. Our team are very well connected in the food and drink sector.
2. Thereafter we will use our tried and tested method of offering training and education to their members, covering the key findings, advantages/disadvantages, lessons learnt, risks and challenges.
3. Mabbett are heavily involved in the various professional institutions in their field (such as the Institution of Chemical Engineers, Energy Institute, The Institute of Environmental Management and Assessment). Upon request we will create an article for publishing in professional journals, website articles and newsletters of the stakeholders and professional institutions.
4. Our solution is highly replicable/scalable, given it is intended to be applied to a well-established process (distillation) and will recover heat to a well-defined heat sink (hot water heating systems). We will create an online calculator for use by anyone to allow them to undertake a first stage assessment of the opportunity for them, to include calculation of likely carbon and cost savings. This would also include links to wherever BEIS publish the results of the programme.
5. We will share the results of the study and a link to our online calculator via social media.
6. Mabbett will provide a free initial consultation to any distillery considering the implementation of the same (or a similar) solution.

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[2] http://www.ignis-energy.com/projects/

## Section 5.0 Conclusions

Working alongside the University of St Andrews and Mabbett, Eden Mill were provided support by BEIS to investigate a range of innovative low carbon solutions for their new site. These generally focused on the use of high temperature hot water to provide the heat for distillation, whilst using the return loop of the district heating network as a heat sink to facilitate high levels of heat recovery.

The following options were assessed:

a) Integration with the energy centre, with supply via the primary circuit of the biomass plant
b) Integration with the energy centre, with supply via the secondary circuit of the biomass plant, in conjunction with a high temperature heat pump powered by roof mounted solar panels

A back-up source of heat would be required to protect against any potential issues in the supply from the energy centre. This would most likely be via steam produced on site, via a two-stage external heat exchanger. A third option considered in this study was:

c) A hydrogen electrolyser and steam boiler, powered by roof mounted solar panels

Following the outline design of each option and preparation of associated business cases, using a traditional approach (generating steam via the combustion of natural gas) as a base case for comparison, it was concluded that Option C was not viable. One of the main reasons for this is that the solar panels can only generate a relatively small percentage of the necessary electricity, meaning significant grid electricity consumption would be necessary.

Comparing Option A and Option B, it was concluded that Option A was preferred. It provides the greatest level of carbon and cost savings for the lowest level of investment, and is the only option to provide a positive IRR based on a 15 year profile.

A high level business case for each option, based on this 15 year profile, is summarised below.

| | Base Case | Option A | Option B | Option C |
|---|---|---|---|---|
| **Net Energy Consumption (kWh)** | 51,355,618 | 7,665,325 | 25,354,553 | 96,035,010 |
| **Carbon Emissions (tCO2e)** | 9,442.8 | 118.4 | 1,729.4 | 21,931.4 |
| **Additional Investment** | - | £754,220 | £1,400,000 | £4,449,003 |
| **Cost Savings** | - | £1,245,116 | -£651,034 | -£11,259,002 |
| **Carbon Savings (tCO2e)** | - | 9,324.3 | 7,713.3 | -21,813.0 |
| **Internal Rate of Return (IRR)** | - | 7% | - | - |

It can be seen that there is significant potential for carbon savings from the proposed solution, at over 9,300 $tCO_2e$ across a 15 year period. Considering the high level of potential replicability across the distillation sector as a whole, the wide-ranging implementation of similar projects would make a meaningful contribution to the UK's net zero goals.

# Section 6.0 Assumptions Log

| # | Assumption | Potential impact |
|---|---|---|
| 1 | The cost of heat supplied from the energy centre is within the range which has been currently assumed | Any significant change to assumed energy price could negatively impact the viability of the project |
| 2 | The initial capital cost associated with connecting to the energy centre is met via the application of an increased unit energy cost for an initial period | Any significant initial capital expenditure of the project may deter Eden Mill from implementation |
| 3 | The proposed projects do not materially affect the pending planning application process | Any aspect of the project which reduces the likelihood of a successful planning application or adds cost to the process may deter Eden Mill from implementation |
| 4 | Any future changes to the heat demand placed on the energy centre will not affect its ability to provide heat to the distillery | The less heat able to be provided by the energy centre the less carbon and cost savings provided. The assumption is considered appropriate for the pilot scale project, based on a preliminary review of its current demand profile. If progressing to full scale, a detailed study would require to be undertaken in conjunction with Vital Energi (plant operator). |
| 5 | The distillery equipment currently owned by St Andrews Brewers Ltd is in operational condition | Any significant overhaul of equipment would greatly increase the initial capital cost of installing the equipment within the distillery space. |
| 6 | The full-scale conventional distillery is to be installed alongside the pilot plant | If this is not the case, the capital cost of installing the equipment will greatly increase to make the space suitable for a working distillery. For example, a dedicated ventilation system is required, fire partitioning within the space, new water and electrical supplies are required etc. |
| 7 | Various assumptions have been made with respect to unit electricity and gas costs, system efficiencies, likely capital and operating costs, etc. | Any notable change to one of the key parameters which feeds into the business case, now or in the future, could impact the economic viability of the project. |