REPORT

Brewing Global Technology Scan

EECA

13 February 2023

Prepared by Beca Ltd.

Executive Summary

EECA want to support small to medium businesses in the Brewing sector to align with New Zealand's climate change vision and targets. Adopting New Zealand's target would mean cutting greenhouse gas GHG emissions in half by 2030 (from a 2005 baseline).

To do so EECA has created the Sector Decarbonisation Programme which is designed to accelerate decarbonisation by driving transformational change at a sector level. This Global Technology Scan of the Brewing Sector provides recommendations to small & medium breweries on decarbonisation and fuel switching opportunities and innovations.

The top technologies recommend from the findings of this report were high temperature CO_2 heat pumps, MVR, and convert direct-fired brewhouse equipment to electric element.

This study focuses on process innovation and fuel switching opportunities

Emphasis was put on relative benefit to highlight the best value projects

Cost per tonne of GHG emissions abated was the primary evaluation criteria

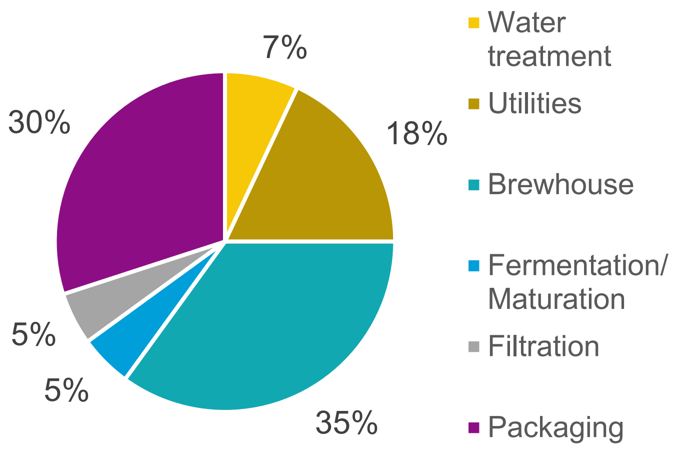
Supply of natural gas

There is a risk associated with the supply and operational cost of relying on natural gas. MBIE predicts NZ's domestic natural gas production will drop by 25% between now and 2026, and by a further 50% by 2032.

Cost of carbon

The highest cost projects will become increasingly cost effective, as the Climate Change Commission's 'GHG emissions values' used in their modelling, increase the carbon price from around \$80/tCO_2 today, to \$170/tCO_2 by 2030.

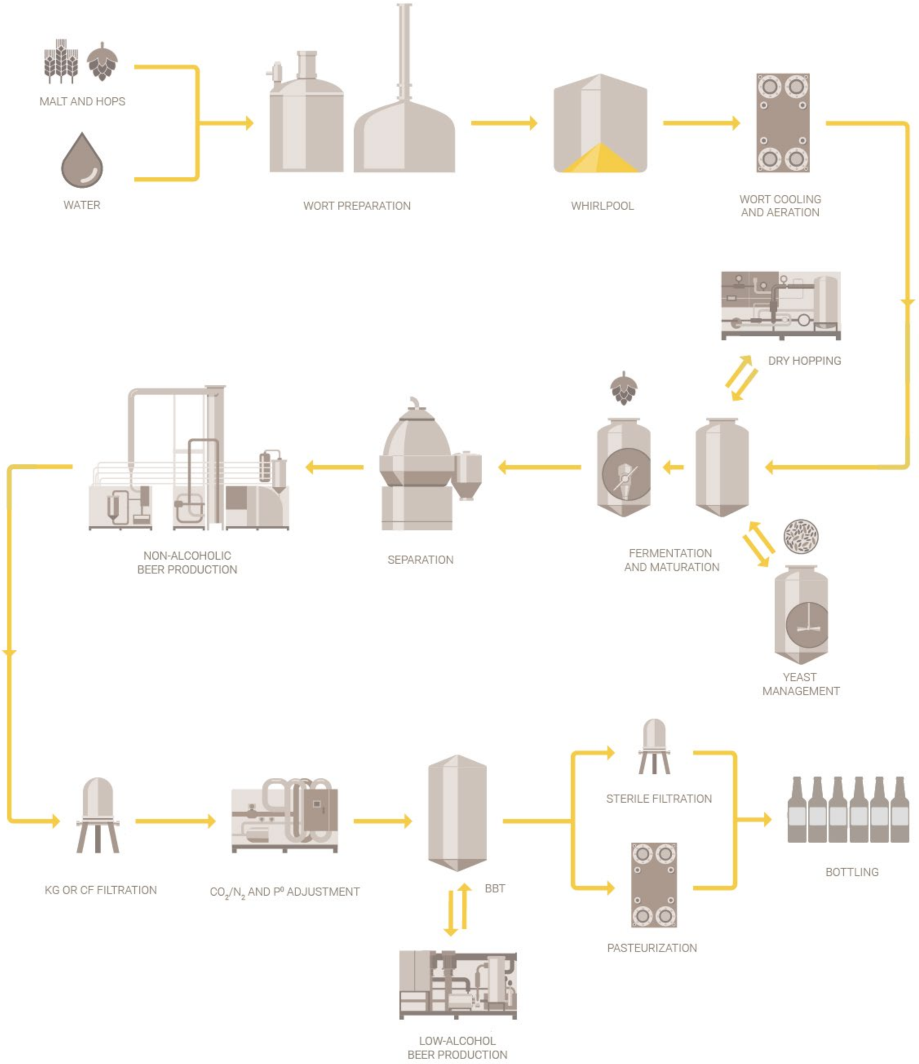
Representative breakdown of thermal energy use by plant area – Brewery



Relative GHG emissions factors for various fuel sources

Energy source	Relative GHG emissions Factor to purchased electricity (MfE)
Coal – Sub-bituminous	2.55
Natural gas	1.48
Purchased electricity - annual average (2020)	1.00
Biomass (wood - industrial)	0.04

Process Overview – The Craft Brewing Process



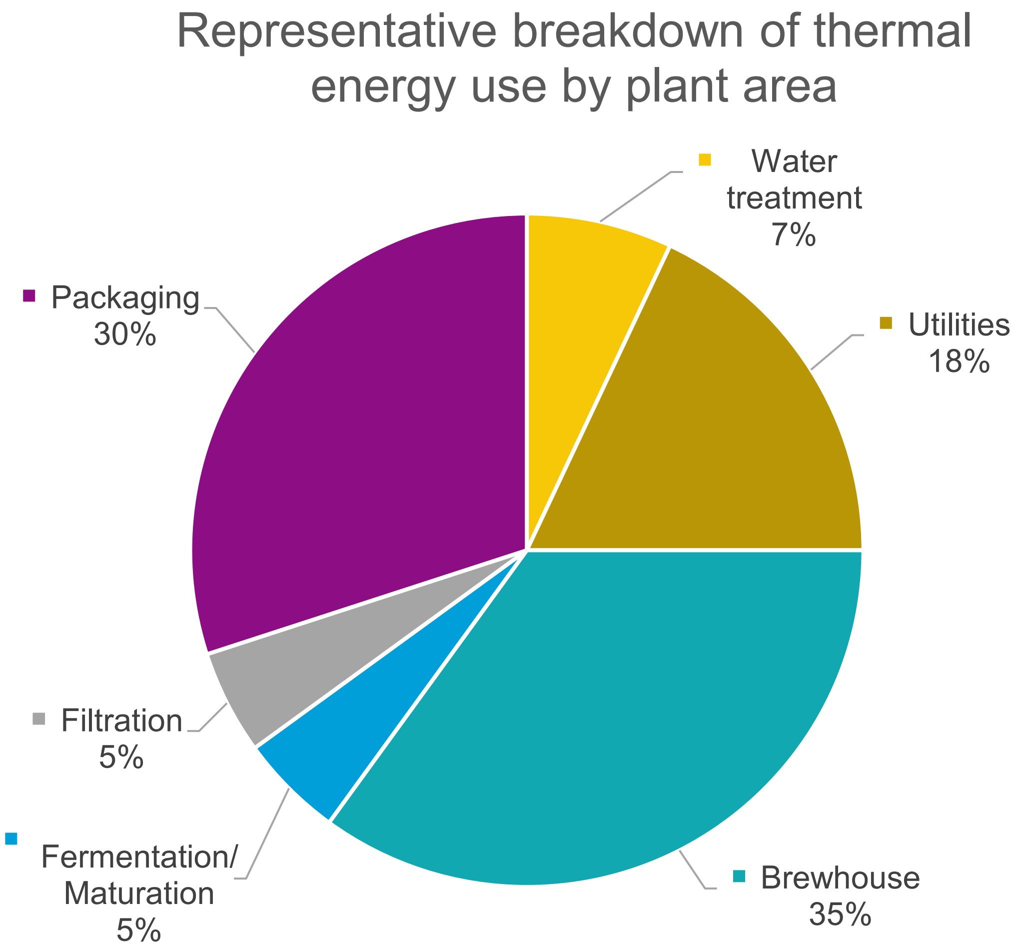


Image retrieved from: https://www.alfalaval.co.nz/industries/food-dairy-and-beverage/beverage-processing/beer-production/craft-brewing/

For further details on the brewing process reference Appendix A

Process Overview – Global Best Practice

Energy Efficiency and Decarbonisation Strategies

Opportunities which are current best practice in the wider brewing sector, including large scale producers.

Energy Systems (Fuel Switching Opportunities)

- Local energy generation (boiler alternatives, wind, solar)
    - Electrification of process heat (electric boilers and heat pumps)
    - Biomass boilers using wood chip and/or waste material

Operational Processes

- High temperature heat pumps
- Flash pasteurisation / pasteurisation alternatives
- MVR/TVR systems
- Wort kettle upgrades

Waste Utilisation

- Heat recovery
- Anaerobic digestion

Key global markets

New Zealand

- Electrification of process heat, utilising the relatively clean renewable energy sources supplying the national electricity grid
- Biomass and anaerobic digestion combinations for improved circular economy and GHG emissions

Australia

- Utilisation of local energy generation via solar and biomass, advantageous due to carbon intensity of the Australian electricity grid
- Brewers often 'greening ' their electricity supply through Power Purchase Agreements (PPA's)

Europe & UK

- High level of technology and automation, especially in Germany. Energy efficiency is improving as more craft suppliers come to market with more standard solutions – Braukon & Rolec, DME (Ziemann) brewhouses more targeted to craft market & high quality equipment to recover more energy and/or operate more efficiently

General Industry

- Modern goal - Carbon negative brewing
    - Asahi's planned greenfield brewery in Japan aiming for net negative carbon production

For further details on the brewing process reference Appendix A

Methodology: Emission Reduction Options Development

Solution Generation → Initial evaluation of relative cost of implementation and CO_2e reduction → Prioritisation / shortlisting → Development of recommendations

Solution Generation: Beca researched and generated ideas to reduce energy and fossil fuel use in small to medium breweries in New Zealand, ***generating over 48 energy/fossil fuel reduction ideas***

Initial evaluation of relative cost of implementation and CO_2e reduction: A preliminary evaluation and multi-criteria analysis was conducted, evaluating each of the ideas based on their:

- ***Capital cost***
- ***Operational cost*** *(including energy costs)*
- ***Greenhouse Gas (GHG) emission reduction potential***

Other project criteria considered throughout the evaluation were:

- ***Project Complexity***
- ***Technical Readiness***

Prioritisation / shortlisting: The top 30 ideas were shortlisted to **14 Ideas** based on their rankings in the multi-criteria analysis and consultation with industry experts

Development of recommendations: Beca provided recommendations detailing **relationships between options** and applicable business scenarios. These are applicable for a range of **process scales and budgets.**

Capital and operational costs, and GHG emissions rankings are sufficient for the purpose of comparing options only. Relativity between options is emphasised rather than absolute actual cost, and all options have been developed to a similar level of accuracy. CAPEX/OPEX investment will depend heavily on the brewery size, and the existing equipment/technologies installed. Additionally, only operational GHG emissions have been considered, with embedded carbon in equipment and construction is omitted.

Supporting information from **leading global experts, case studies and potential suppliers** are referenced throughout.

Potential suppliers listed are for example only. There are other suppliers who provide similar services who are not mentioned in this report.

For further details on Assumptions and clarifications reference Appendix B and evaluation methodology Appendix C

Methodology

Methodology Quick-Points

- Each long list option was given a 1-5 score for relative CAPEX, OPEX, and GHG emissions, from 1 being relatively poor (high CAPEX/OPEX and GHG emissions) to 5 being relatively good (low CAPEX/OPEX/GHG emissions).
- Option evaluations were informed by a representative breakdown of thermal energy demand by plant area and relative emission factors where applicable

Exclusions

- Efficiency studies on existing equipment and plant optimisation are not in the scope of this report – covered by other EECA resources
- WWTP digestion: Small-medium breweries will often not have sufficient spare land for this to be viable, and these are complex processes that require engineering management for operation.
- Decarbonisation relating to pasteurisation: Many small-medium breweries do not pasteurise.
- Condensate return decarbonisation opportunities: Many small-medium breweries do not have steam reticulation.

Outcomes

- Each long list option was given a score from 2 – 50 indicating the relative value of GHG emissions savings potential against cost
- These relative value scores were used to categorise and compare potential options

Relative Cost of Investment				Relative GHG emissions cost		Relative Value	
Description	**Score (CAPEX)**	**Score (OPEX)**	**Score (Total relative Cost)**	**Description**	**Score**	**Description**	**Score**
The relative costs of the option	1-5	1-5	2-10	The relative GHG emissions savings in tCO_2e	1-5	The multiplication of total relative cost and GHG emissions savings	2-50

Energy Source	Relative GHG emissions factor to purchased electricity (MfE)
Coal – Sub-bituminous	**2.55**
Natural gas	**1.48**
Purchased electricity - annual average (2020)	**1.00**
Biomass (wood - industrial)	**0.04**

Relative Value Categorisation	Score Limits
Very poor	0-7
Poor	8-14
Neutral	15-21
Good	22-30
Very good	31-50

For further details on Assumptions and clarifications reference Appendix B and evaluation methodology Appendix C

Beca

GHG Emissions Reduction Options

Solution generation

By Beca, through:
- Internal desktop review
- External research
- GHS emissions reduction workshop (45 ideas generated)

Initial evaluation of relative cost of implementation and CO_2e reduction

An initial evaluation was conducted to consider:
- The carbon reduction potential
- Commercial readiness of technology
- Applicability & suitability to small-medium breweries

Prioritisation / shortlisting

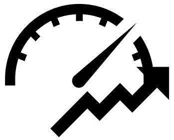
14 initiatives shortlisted
- 2 x Heat recovery
- 10 x Technology Change
- 2 x Fuel Switching

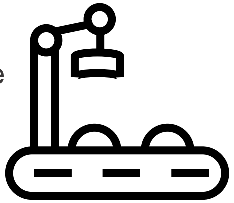
Development of recommendations

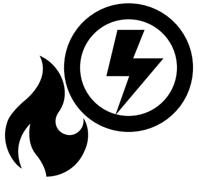
- Initiatives ranked according to relative value
- Option applicability across small-medium breweries
- Recommendations detailing relationships between options and applicable business scenarios

#	Options	#	Options
1	*High temperature CO_2 heat pump*	8	*Retrofittable Vapour Condensers*
2	*MVR on wort kettle*	9	*Electric Element boiler*
3	*Direct fired brewhouse equipment > Electric element*	10	*Dry de-husking*
4	*3 stage wort cooling*	11	*Warm Filling*
5	*Simmer and strip technology for wort kettle*	12	*Wort boil via High Temperature Hot Water*
6	*TVR on wort kettle*	13	*Carbon Dioxide Recovery*
7	*External Stripping Column for Wort*	14	*Tank Purging with Nitrogen*

Ideas recorded in order as ranked during the Beca internal workshop based on their perceived "Greatest value against cost and potential impact". Each solution is categorised as either:

Heat Recovery 

Technology Change 

Fuel Switch 

For the long list of options reference Appendix D

1 – High Temperature CO_2 Heat Pump

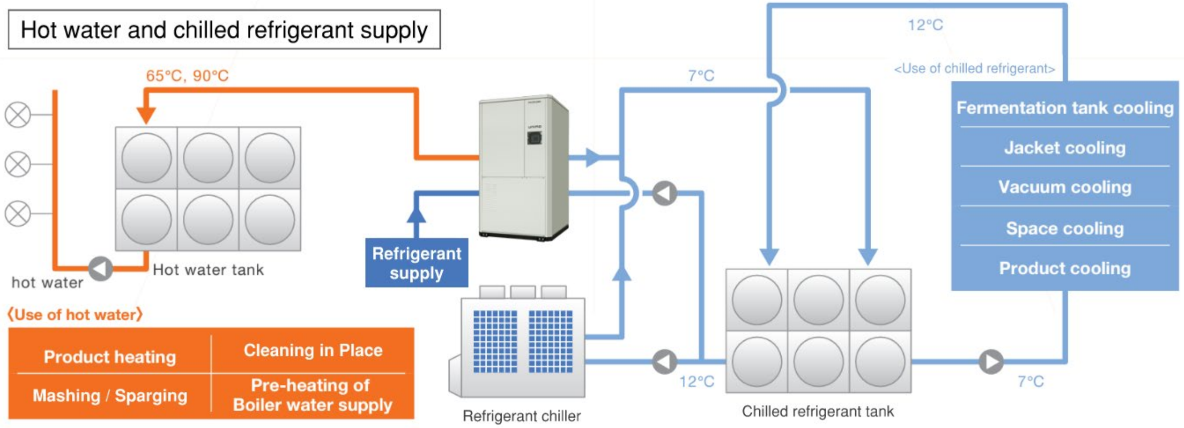
AREA: SITE UTILITIES
OPPORTUNITY: RETROFIT

Summary

A high temperature CO_2 heat pump can be installed to generating both process heating and cooling loads. For instance, heat pumps can remove energy from a cold source (e.g. chilled water or glycol refrigerant), and efficiently heat a hot water source such as ~90°C hot water for mash pre-heating/hot liquor, and CIP/utilities hot water.

Small package heat pump units are available for this purpose, running on CO_2 refrigerant.

When installing a heat pump, consider electrical supply infrastructure, and scheduling of process loads. Tank storage is necessary for both heating and cooling fluids, plus additional heater (e.g. electric) and dry cooler for when system loads are unbalanced.



- Significant reduction in site thermal energy requirements
- Utilises NZ's relatively low emission electricity
- Large capital investment, but very high GHG emissions

Global Expert Information

- Mayekawa Water Source CO_2 Heat Pump – (Figure source – edited)

Case Studies

- CO_2 heat pumps - Silver Oak Cellars
- CO_2 Chiller - South Creek Dairy

Potential Suppliers

Mayekawa Mycom, Mitsubishi Heavy Industries Air Conditioning, Clade, Carnot

CAPEX	OPEX	CARBON SAVING	RELATIVE VALUE	TECHNOLOGY CHANGE
2	5	4	28	

AREA: BREWING
OPPORTUNITY: RETROFIT

2 – MVR on Wort Kettle

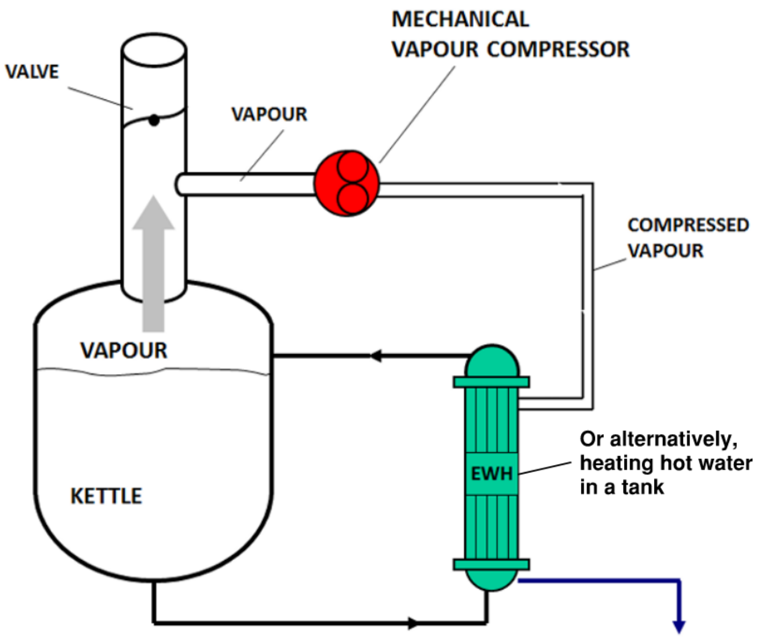
Summary

Mechanical Vapour Recompression (MVR) can be applied to wort kettles to recompress evaporated vapour. This uses electrical energy to recompress boiled kettle vapour and allows direct recovery of the boil energy to the wort boiling process.

This option is typically used in combination with an external wort heater (a large surface area tubular heat exchanger). This enables an increase in heat exchange area, lowers the required temperature of the incoming steam (increasing the efficiency of the MVR and lowering the electrical energy use for recompression), reduces cleaning frequency needed inside kettle, and can be coupled with a thermosyphon to minimise energy use. Alternatively, the energy could be recovered in a heat exchanger to heat a hot water tank

Electricity requirement is 0.1-0.7kWh/hl depending on steam pressure required.

MVR is a proven technology which has been in use in many locations worldwide over many years, although it is novel to apply this technology at craft scale. Recent advances and offerings in smaller package MVR systems makes this technology available to craft operations.



- Significant reduction in site thermal energy requirements
- Waste heat utilisation
- Large capital investment, but relatively high GHG emissions

Global Expert Information

- Brewhouse Design and its Impact on Wort Production
- Application of Screw Type Vapor Recompression to Wort Boiling Process
- Brewhouse & Heat Energy Integration – Briggs – (Figure Source – edited)
- 'Get Your Energy Back' – heat pumps in distilling
- EECA MVR

Potential Suppliers

Briggs, Mayekawa Mycom, Aerzen, Howden, Tetra Pak, Piller, Ziemann Holvrieka, GEA

CAPEX	OPEX	CARBON SAVING	RELATIVE VALUE	TECHNOLOGY CHANGE
2	5	4	28	

3 – Convert direct-fired brewhouse equipment to electric element

AREA: PROCESS SERVICES
OPPORTUNITY: RETROFIT

Summary

Direct-fired brewhouse equipment is typically inefficient, and limits breweries' ability to recover and reuse thermal energy.

Direct-fired brewhouse equipment can be upgraded to add either external wort boilers with electric heating (preferred) or adding electric heating elements directly to existing brewhouse vessels. Converting to electric can be particularly effective if MVR and/or Simmer & Strip technology has already been implemented to reduce thermal demand, as the switch from fossil fuel to electricity typically results in higher OPEX on a like for like substitution.

In addition to an external wort boiler, consider electrical supply equipment capacity (e.g. transformer).

- Individual process utilities allow for project phasing
- Utilises NZ's relatively low emission electricity
- Significant capital investment, but relatively high GHG emissions

Potential Suppliers

CERTUSS Steam Generators

CARRY BREWTECH

CAPEX	OPEX	CARBON SAVING	RELATIVE VALUE	FUEL SWITCHING
2	3	5	25	

4 – 3 Stage Wort Cooling

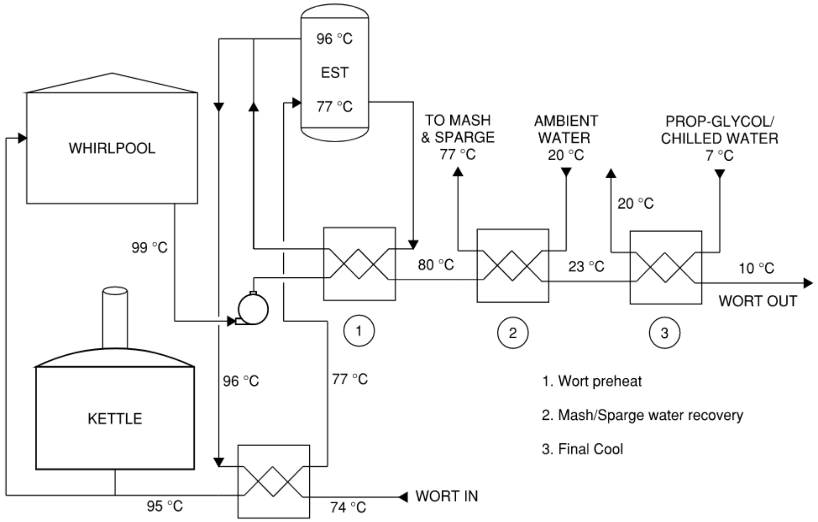
AREA: PROCESS SERVICES
OPPORTUNITY: RETROFIT

Summary

If Wort boil energy is eliminated (or recycled via MVR or TVR) further energy recovery is required to allow wort preheating.

To do this, the wort cooler can be upgraded to 3-stage, to recover hot water from wort at higher grade and allow pre-heat of wort prior to the kettle via an energy storage tank. This recycles thermal energy from other process steps which would otherwise be lost, reducing thermal energy demand.

The 1st stage consists of energy recovery from wort 98°C to 80°C using water from an energy store, The 2nd stage uses Ambient water which is recovered for mashing and sparging, then the final cooling (e.g. glycol) on the 3rd stage is applied to achieve the desired wort temperature prior to fermentation



If the kettle already has vapour heat recovery for wort preheating, the excess energy this system provides could be used to for providing mash vessel heating, removing the mash vessel steam requirement, but may require replacement of the mash vessel.

CAPEX	OPEX	CARBON SAVING	RELATIVE VALUE	HEAT RECOVERY
3	5	3	24	

Reduction in site thermal energy requirements

Waste heat utilisation

Medium CAPEX investment with minimal OPEX impact

Case Studies

ABInBev – 3 stage wort cooler

Potential Suppliers

Alfa Laval, GEA, SPX FLOW, Danfoss Sondex

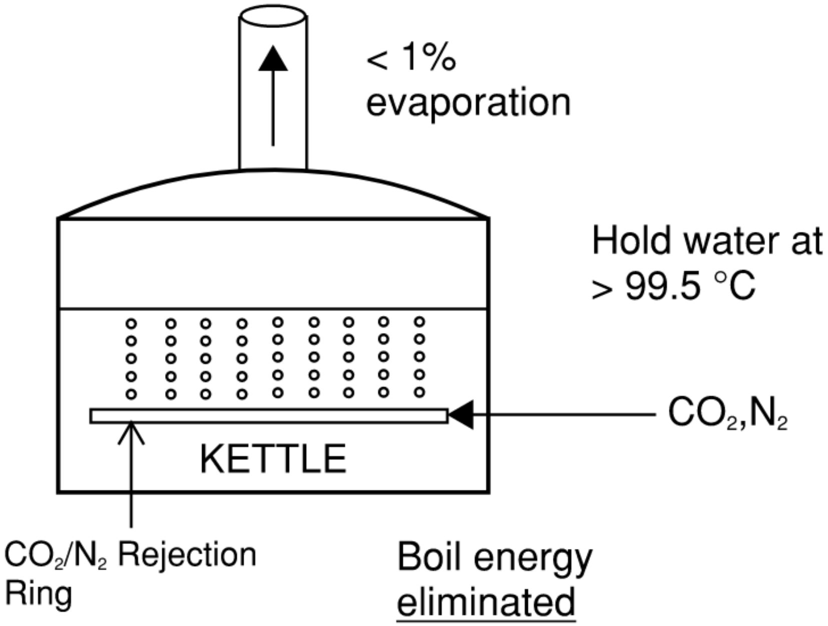
5 – Simmer and Strip Technology for Wort Kettle

AREA: BREWING
OPPORTUNITY: RETROFIT

Summary

Patented Technology by AB InBev. AB InBev often allows use of this patented process by small brewers.
With this technology, N_2 (or CO_2) is sparged through wort in the kettle to remove the volatiles, rather than boiling to remove them.

Wort boiling achieves four objectives: Hop acid isomerisation, protein coagulation, sterilisation of wort and removal of volatiles. Volatile removal is the only objective that requires boiling – hence, simmer and strip technology uses bubbles to aid volatile stripping such that evaporation can be significantly reduced from ~4% to <1%.



Significant reduction in site thermal energy requirements

Reduces water use through lower evaporation

Medium capital investment, with significant OPEX benefits

Global Expert Information

- Simmer & Strip Patent

Potential Suppliers

KRONES, ZIEMANN HOLVRIEKA, BRIGGS, ALFA LAVAL, GEA

CAPEX	OPEX	CARBON SAVING	RELATIVE VALUE	TECHNOLOGY CHANGE
3	5	3	24	

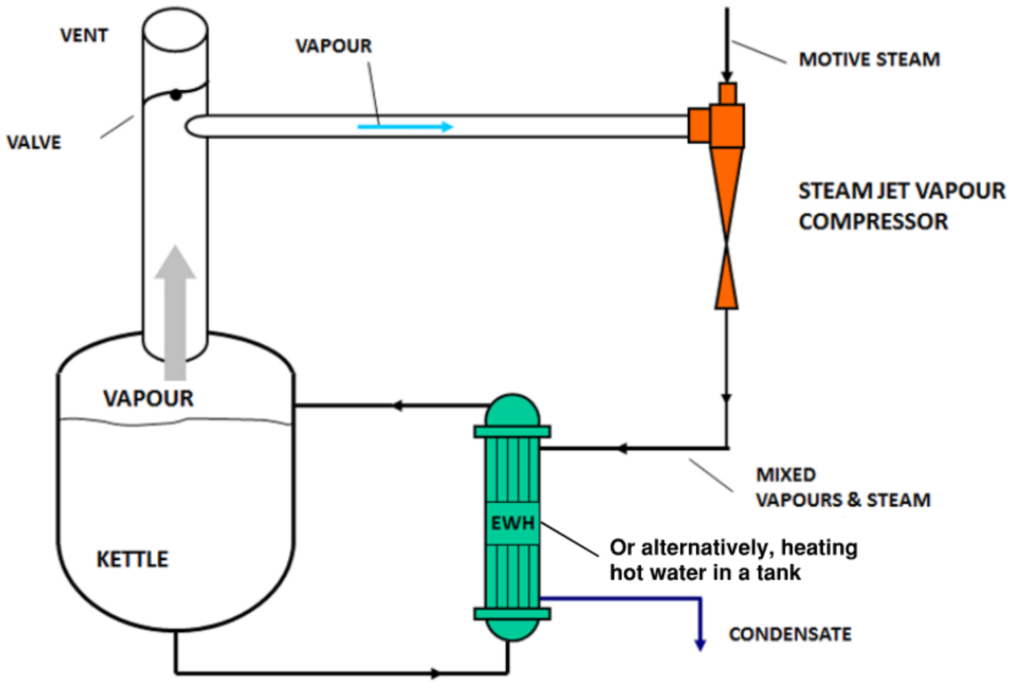
6 - TVR on Wort Kettle

AREA: BREWING
OPPORTUNITY: RETROFIT

Summary

Thermal Vapour Recompression (TVR) can be applied to wort kettles to recompress vapour from boiling. This uses high pressure motive steam to recompress the kettle vapour.

A minimum pressure of 7 bar steam is required for effective recovery. This is a cheaper alternative to MVR for implementation if the site already has 7+ bar steam available, however it only recompressed ~40-50% of the vapour, so is less effective.



Significant reduction in site thermal energy requirements

Waste heat utilisation

Only applicable to sites with an existing steam boiler

Global Expert Information

- Brewhouse & Heat Energy Integration – Briggs – (Figure Source – edited)
- EECA MVR – (includes TVR)

Potential Suppliers

Tetra Pak, Ziemann Holvrieka, Briggs, Alfa Laval, GEA

CAPEX	OPEX	CARBON SAVING	RELATIVE VALUE	TECHNOLOGY CHANGE
3	5	3	24	

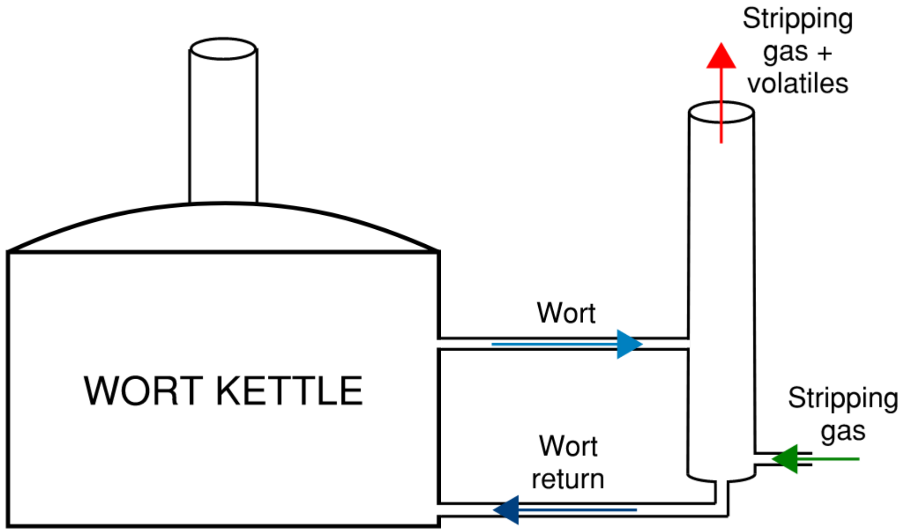
7 – External Stripping Column for Wort

AREA: BREWING
OPPORTUNITY: RETROFIT

Summary

The same principle used by the "Simmer & Strip"™ technology can be adopted in an external stripping column, with stripping gas (N_2, CO_2, air or steam) stripping volatiles such as dimethyl sulfide (DMS). This principle can achieve the same stripping of volatiles with reductions of up to half of the thermal energy traditionally needed.

Wort boiling achieves four objectives: Hop acid isomerisation, protein coagulation, sterilisation of wort and removal of volatiles. Volatile removal is the only objective that requires boiling – hence, this technology uses gas to aid volatile stripping such that evaporation can be significantly reduced from ~4% to closer to 1-2%.



- Reduction in heating load
- Emergent technology
- Good decarbonisation for investment

Global Expert Information

- Wort-Stripping: Optimised Expulsion of Off-Flavour
- Steinecker Boreas
- Meura ECOstripper

Potential Suppliers

KÖNIG BREWING SYSTEMS
KRONES
MEURA

CAPEX	OPEX	CARBON SAVING	RELATIVE VALUE	TECHNOLOGY CHANGE
3	5	3	24	

8 – Retrofittable Vapour Condensers

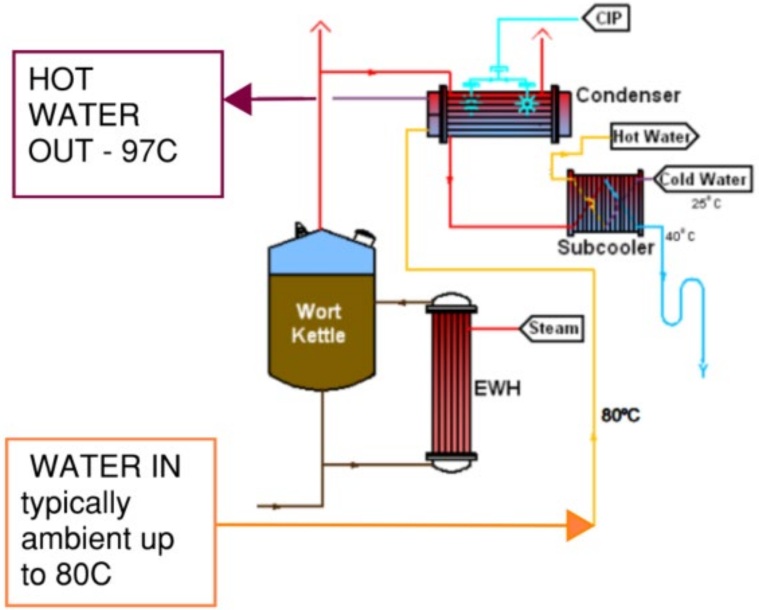
AREA: BREWING
OPPORTUNITY: RETROFIT

Summary

While vapour condensing is not new technology, there are many small to medium-sized breweries that do not currently implement this, which is an opportunity to recover a significant amount of heat if the brewery does not already generate more hot water than it can use.

The vapour from the wort kettle can be recovered and condensed in a heat exchanger, with the resultant energy used to heat hot water streams. This would commonly be installed in conjunction with an energy storage tank, to enable the energy to be utilised for mashing in or lauter pre-heat, even though the demand timing may not coincide.

It should be noted that installing this equipment prevents the implementation of MVR (or TVR), but is lower in CAPEX.



Reduction in heating load

Waste heat utilisation

Good decarbonisation for investment

Potential Suppliers

- banke
- Alfa Laval
- GEA Engineering for a better world.
- KRONES
- KÖNIG BREWING SYSTEMS

CAPEX	OPEX	CARBON SAVING	RELATIVE VALUE	HEAT RECOVERY
3	5	3	24	

9 - Electric Element Boiler

AREA: SITE UTILITIES
OPPORTUNITY: RETROFIT

Summary

Install an electric element boiler, as a like-for-like alternative to steam generation from a fossil fuel boiler. There are no flue gases produced by an electric element boiler, however. They are more efficient and have a higher turn-down compared to fossil-fuel boilers.

Seek to reduce thermal demand first to minimise CAPEX and OPEX investment needed (e.g. through MVR or Simmer & Strip in the brewhouse).

As well as the boiler, capital investment for this option will typically also include upgrading the transformer and electrical reticulation.

- As Carbon prices increase, relative OPEX will improve over time
- Utilises NZ's relatively low emission electricity
- Large capital investment, but significant carbon savings

Case Studies

- Diageo Carbon Neutral Distillery
- Steam Boiler Helps Brewery Save Energy On New Kegging Line

Potential Suppliers

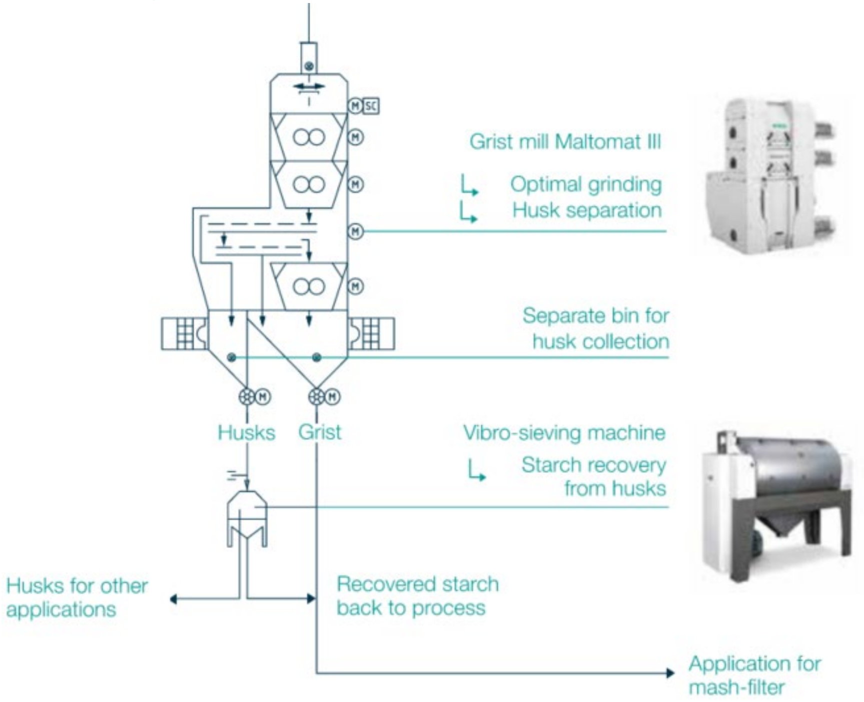
Cooke Industries, Lyttelton Engineering (Marine and Industrial Engineers), Tubman Heating (Boiler & Burner Specialists)

CAPEX	OPEX	CARBON SAVING	RELATIVE VALUE	FUEL SWITCHING
1	3	5	20	

10 - Dry De-husking

AREA: MILLING
OPPORTUNITY: RETROFIT

Summary



An emerging technology is dry de-husking (DDH) – removing husk from grist in the mill prior to mashing. Buhler offer this technology, however equipment capacities are only available from as low as 4 tonnes per hour at present. The technology offers good benefits to consider once scalability is achieved.

Use of this technology results in a 2.5% yield extract increase, and 3% reduction in the grist mass, leading to 10% more brewhouse throughput with higher quality and less explosion risk. There are added benefits of a reduction in hot water needed for mashing, a lower polymerisation index, and less fluctuation in grist quality.

While this technology can be retrofitted, we consider it is most likely suitable as a greenfield consideration. As de-husking allows higher malt load into mash tun and lauter tun, more wort can be produced, though vessels such as kettle and whirlpool would need to be larger to accommodate the volumes required, which also impacts utilities. Limited additional equipment is needed; however, consider waste removal for husks.

Increases effective wort production

Reduces water used while mashing

Emergent Technology

Global Expert Information

- Buhler DDH – Husk Separation – (Figure source)

Case Studies

- ABInBev – Husk Away

Potential Suppliers

BÜHLER

CAPEX	OPEX	CARBON SAVING	RELATIVE VALUE
3	5	2	16

TECHNOLOGY CHANGE

11 - Warm Filling

AREA: PACKAGING
OPPORTUNITY: RETROFIT

Summary

Warm filling is another emergent technology. While traditional beer fillers operate chilled (close to 5°C), the Krones Dynafill is a combined filler/capper that fills under vacuum at up to 30°C. It can significantly reduce the refrigeration load for breweries, in chilling beer to filling temperature, and also heating energy – avoiding the need for a warmer tunnel, as condensation will not generally form at that temperature. The speed of filling (0.5s per container) also helps to reduce CO_2 consumption by 20% compared to conventional systems.

At present, this technology is just available for glass bottles, and with crowns (not screw cap). Its size (up to 80,000 containers per hour maximum) will be too large for smaller breweries, however the energy benefits of this technology are worth considering as the equipment scalability develops.

Reduction in heating load and refrigeration load

Emergent technology

Large capital investment compared to emission reduction potential

Global Expert Information

- Krones Dynafill
- New energy line concepts for beer filling

Potential Suppliers

KRONES

CAPEX	OPEX	CARBON SAVING	RELATIVE VALUE
2	5	2	14

TECHNOLOGY CHANGE

12 – Wort Boil via High Temperature Hot Water

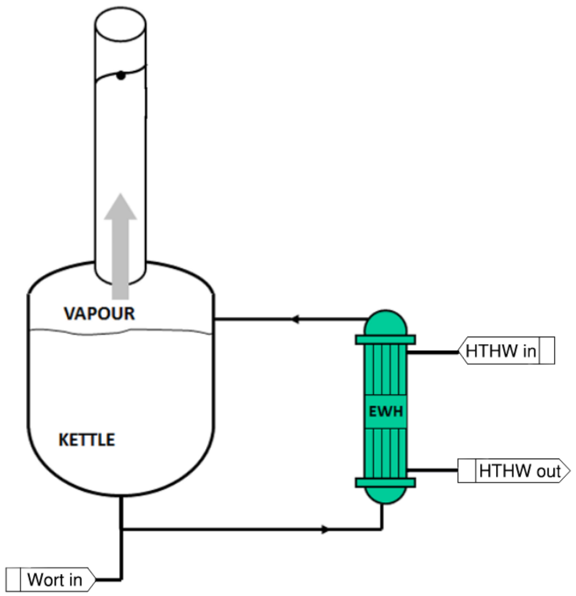
AREA: PROCESS SERVICES
OPPORTUNITY: RETROFIT

Summary

Small to medium-sized breweries that want to avoid installing steam, can do so by converting direct-fired kettles to external wort boilers, but using high temperature hot water systems as the heating medium. While steam is an effective heating medium, the installation of a steam and condensate system can increase operational complexity and introduce safety risks.

High temperature hot water (HTHW) operates by pressurising water in a closed loop, enabling it to be heated to greater than 100°C, providing enough temperature difference to boil wort. These systems may operate in the order of 5 barg. Due to the decreased efficiency of heating compared to steam condensation, it requires much larger heat exchanger surface area. HTHW systems usually operate with a stratified energy storage tank, to enable take-offs at different temperatures. It enables effective integration with current and future heat recovery circuits.

The use of external wort boilers could save approximately 30 minutes per brew, as wort boiling can commence immediately, rather than waiting for the wort kettle to be filled.



Reduces condensate losses

Emergent technology

Large capital investment, but reasonable emission reduction potential

Global Expert Information

- Low-Temperature Brewing – Krones

Potential Suppliers

ROLEC, KRONES, KÖNIG BREWING SYSTEMS

CAPEX	OPEX	CARBON SAVING	RELATIVE VALUE	TECHNOLOGY CHANGE
2	4	2	12	

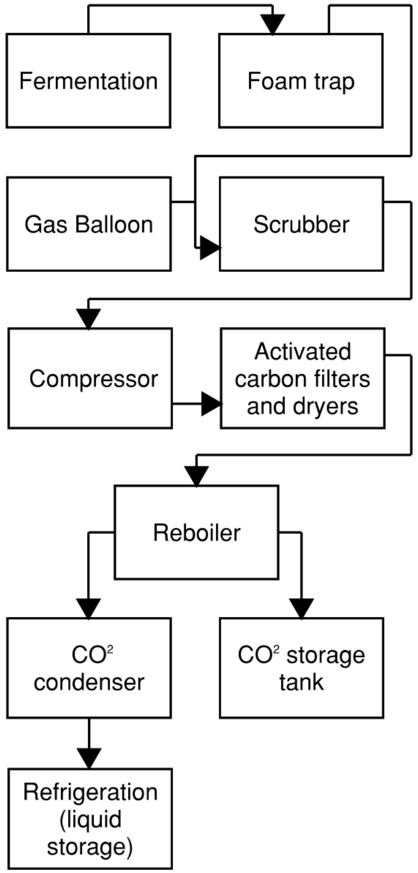
13 – Carbon Dioxide Recovery

Summary

Large breweries have for some time been recovering fermented CO_2 to reinject into product at carbonators prior to bright beer/filling. The technology is mature, but until recently, only cost-effective for larger scale.

Market CO_2 shortages in New Zealand in 2022/23 have been challenging for many small-to-medium sized breweries, who typically purchase CO_2 for carbonation. Recovering CO_2 enables breweries to become self-sufficient with high-quality CO_2, avoids some biogenic atmospheric emissions from sites (savings of approximately 3kg of CO_2/hL, depending on wort Plato), and reduces in transportation carbon emissions for CO_2 deliveries.

The recovery of CO_2 usually includes piping CO_2 from fermentation tanks via a foam trap, gas receiver (e.g. balloon), scrubber, compressor, and activated carbon filters/dryers, to CO_2 storage – CO_2 is usually liquefied for storage to make volumes manageable, and an air-cooled evaporator can deliver CO_2 gas for use.



AREA: SITE UTILITIES
OPPORTUNITY: RETROFIT

- As Carbon prices increase, relative OPEX will improve over time
- Reduction in CO_2 purchase costs
- Large capital investment, but significant carbon savings

Global Expert Information

- Eddyline Breweries CO2 Recovery Project
- European Commission Report – CO2 Recovery in Beer Production

Potential Suppliers

Hypro GROUP, Earthly Labs, PENTAIR, DALUM Beverage Equipment

CAPEX	OPEX	CARBON SAVING	RELATIVE VALUE	TECHNOLOGY CHANGE
2	5	Unrated(1)	N/A	

1. GHG Emissions not rated due to biogenic nature

14 – Tank Purging with Nitrogen

Summary

After fermentation, brewing vessels are usually purged with carbon dioxide to eliminate oxygen, and the impacts of oxidation on beer quality. As well as being an opportunity to decrease the volume of purchased carbon dioxide, some breweries have had challenges procuring food-grade CO_2 due to supply shortages in New Zealand in 2022/23.

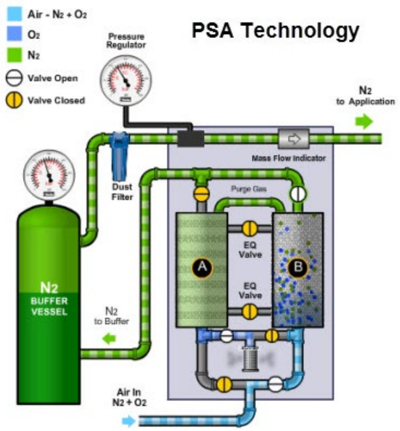
An alternative to purging tanks with CO_2 is to instead purge with nitrogen (N_2). Nitrogen can either be purchased from a compressed gas supplier, or generated on site. Air is 78% nitrogen, and can be purified by one of two techniques – either Pressure Swing Absorption (PSA) for up to 99.999% purity, or Membrane Nitrogen Generation for up to 99.5% purity. The purified nitrogen can be stored in a buffer tank to reduce the size of the nitrogen generation unit required.

Nitrogen generators can be skid-mounted, and would require dedicated nitrogen piping to be installed.

Other opportunities for replacing CO_2 with N_2 exist in the brewery, such as deaeration. For each application, changing to mixed or 100% N_2 headspace gas could have an effect on final product beer foam characteristics and should be trialled before full scale adoption of the technology.

As breweries produce more CO_2 than they use, this technology is not valuable for breweries that have a CO_2 recovery system, as unused CO_2 will be vented anyway.

CAPEX	OPEX	CARBON SAVING	RELATIVE VALUE	TECHNOLOGY CHANGE
3	4	Unrated(1)	N/A	



AREA: SITE UTILITIES
OPPORTUNITY: RETROFIT

- As Carbon prices increase, relative OPEX will improve over time
- Mature technology
- Reduces transportation costs, and reliance on 3rd party gas delivery

Global Expert Information

- How to Select an On-Site Nitrogen Generator (Parker Hannifin – Figure Source)

Potential Suppliers

Industrial Air Systems NZ, TC, Atlas Copco

1. GHG Emissions not rated due to biogenic nature

Option Recommendations

Key Points	Recommendation
Quick wins	Options which are **easy to implement** and have a **high GHG emissions saving to cost ratio** = first items to look at • Heat recovery options – **less CAPEX** compared to fuel switching, & **reduces demand** before you fuel switch, resulting in a smaller installation when a fuel switch project is investigated e.g. an electric element boiler 1. 3 stage wort cooling 2. Kettle vapour recovery (non-MVR/TVR)
Fuel sources	**Largest decarbonisation opportunity** – recommend partial switch to electricity or equipment requiring less power – heat pumps or heat recovery systems • Heat pumps – **3 factor GHG emissions reduction** 1. Utilises green electricity from the New Zealand National Grid (**less GHG emissions per kW**) 2. Reduced energy requirements with good efficiency. Coefficient Of Performance (COP) of 4-5 (**Less kW required**) 3. Combined utilisation of warming & cooling sides of the heat transfer process (**increased utilisation per kW**)
Change of process	Focus on the **Brewhouse** as generally consumes **35% of site energy use** – most energy used in kettle (Greatest opportunity for **reduction in consumption**) • Simmer and Strip, or external wort stripping column – reduction in energy • MVR or TVR – heat recovery option, or retrofit vapour condensers • Replace Direct fired brewhouse equipment with either local electric element or connect to steam boiler / heat pump
Emergent Technologies	Future for craft scale, **yet to be developed** to a practically applicable extent • Dry De-husking • Flow on effects of throughput to other equipment makes this option hard to retrofit • Warm filling • If not pasteurising, warm filling increases susceptibility to infection/ bacteria etc.

Wider Recommendations

Key Points	Recommendation

Greenfield vs Retrofit	• All options provided are technically retrofittable, however the following systems are comparatively harder to retrofit;
	1. **Warm filling:** Difficult to remain in specification at BBT, unless investment is put into the BBT as well to handle the new conditions and keep the brew in spec.
	2. **Dry de-husking** and **higher gravity brewing:** Process changes produce additional capacity requirements in other process steps e.g. mash & Lauter tun, kettle, and whirlpool
	• All options are **most efficient at greenfield**
	  • The best decarbonisation value is given when upscaling, i.e. the cost per emission saving is higher for retrofit applications
	• Simmer and strip retrofit consideration:
	  • This option **minimises vapour production** which negates the need for vapour recompression and may cause existing plant items to be obsolete.

Relationships between options	To make the most of either Simmer and Strip or a vapour recompression options you would have one or the other, **not both**. Either must be used with **wort boiling** • **Simmer and Strip utilises the same thermal energy as heat recovery options on the wort kettle**, it would be advantageous to apply simmer and strip (or external wort stripping column) first and then size wort kettle heat recovery to manage the remaining waste heat • MVR vs Simmer and Strip are similar energetically overall, however Simmer and Strip GHG emissions are Scope 3 (supply chain) for the supply of compressed gas as opposed to scope 1 when recompressing vapour
Step Change Drivers	• **Cost of carbon is expected to increase** in the short-medium term. Coupled with national availability concerns for CO_2, recovery of CO_2 or switching to nitrogen for tank purging may be considered to reduce OPEX • Consumers' transparency – Low (and high) carbon products: • There is a drive in the consumer markets for evidence of low carbon products as people become more aware of the implication of their consumption. Labelling is an opportunity for businesses to express their decarbonisation efforts

Transition Risks and Opportunities

Low Carbon Products

There is significant and growing demand for low-carbon products That contribute towards a greener industrial sector. Development of low emission beer production will allow Breweries to capitalise on the growing demand for these products as their business transitions to low carbon products.
A way to capitalise on this would be to include **the product carbon footprint on each bottle** – planetary accounting/PAN. This would allow carbon considerations to be included in consumer choice. Another consideration for practices like dry hopping, which are less sustainable in terms of waste, solid waste and loss of beer is **recipe sustainability**. As customers become more aware of product GHG emissions the demand for carbon intensive brews **may reduce**

Carbon Price Changes

Since the beginning of 2020, NZ's tradeable carbon price has almost tripled; auctions in early 2020 traded carbon for close to $25/t, and recent auctions have closed as high as $88.00/t. This upwards trajectory is anticipated to continue in the short-to-medium term which will have flow-on impacts to the price Breweries pay for their natural gas and diesel. The CCC's modelling has stated that a carbon price of $170 per tonne of CO_2 is required by the year 2030 for New Zealand to meet its carbon reduction targets.

Climate Change

Climate change risks to hops and grain with production set to reduce due to harvest conditions, soil degradation and poor growing practices (Malt price may continue to increase), water supply climate change & adaptation, CO_2 availability is also a significant issue (will become more expensive). Capture of biogenic CO_2 is an opportunity, Disruptions to international supply chains are also causing uncertainty. Grain/malt comes from south AU & US, Barley & malt from AU, distribution, malt from Belgium, Germany, UK etc. Climate change is causing areas to be warmer, wetter etc. which is changing the landscape of raw material supply.

Supply of Natural Gas

There is risk associated with the supply and operational cost of relying on natural gas. Current MBIE predictions have NZ's domestic natural gas production dropping off by 25% between today and 2026, and by a further 50% by 2032. Based on this trajectory, natural gas will almost disappear from NZ's energy sector by 2040. As available volumes decrease over time, it is likely that scarcity will increase the price of natural gas and there may not be enough to go around to all industrial users in times where industrial users will be competing with electricity generators for fuel. This could improve the financial cases for process heat reduction and fuel switching opportunities closer to the time of implementation.

Packaging

There is quick progress and plenty of opportunity in **sustainable changes of primary and secondary packaging**, with alternatives in materials and designs. Paper bottles, reduction of plastic, hot glue packs, glue-less paper packs, etc. This is an opportunity for breweries to provide a **visual impression of their sustainability intentions** to consumers.

Appendices

Appendix A: Process Overview – A Conventional Brewery

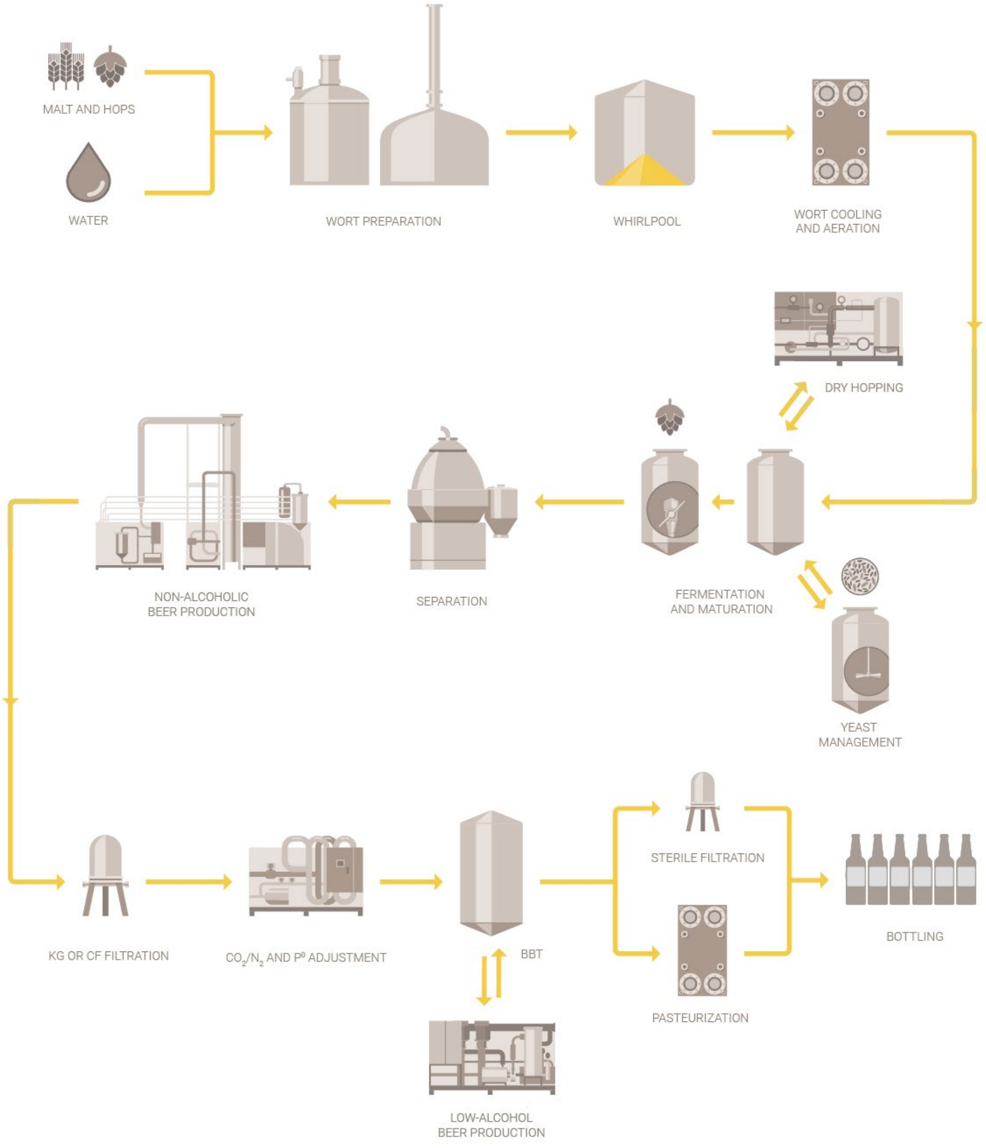


Image retrieved from: https://www.alfalaval.co.nz/industries/food-dairy-and-beverage/beverage-processing/beer-production/craft-brewing/

Process Overview

Brewing is an integrated and continuous operation, in which each main processing stage is dependent on stable operation. Main process steps may include, but are not limited to:

Area	Function
Storehouse	Collection point and storage of raw materials
Malting	Germination and activation of enzymes
Milling	De-husking and crushing to produce grist/mash
Mashing	Extraction and separation of soluble materials (Wort)
Brewing	giving stability and product characteristics (colour, flavour, type)
Separation	Removal of hot trub from the wort
Cooling	Cool wort to the yeast pitching temperature and provide aeration to aid fermentation
Fermentation	Production of alcohol and CO_2 from fermentable sugars
Maturation	Sedimentation of yeast and formation of chill haze
Filtration	Clarification, stabilisation and treatment of CO_2 and alcohol content
Pasteurisation	Eliminate pathogens and extend shelf life
Packaging	Package and label product for sale
Cool Storage	Onsite temporary storage of finished product
Distribution	Loadout of product for distribution to customers

Appendix B: Assumptions – Main Energy Users

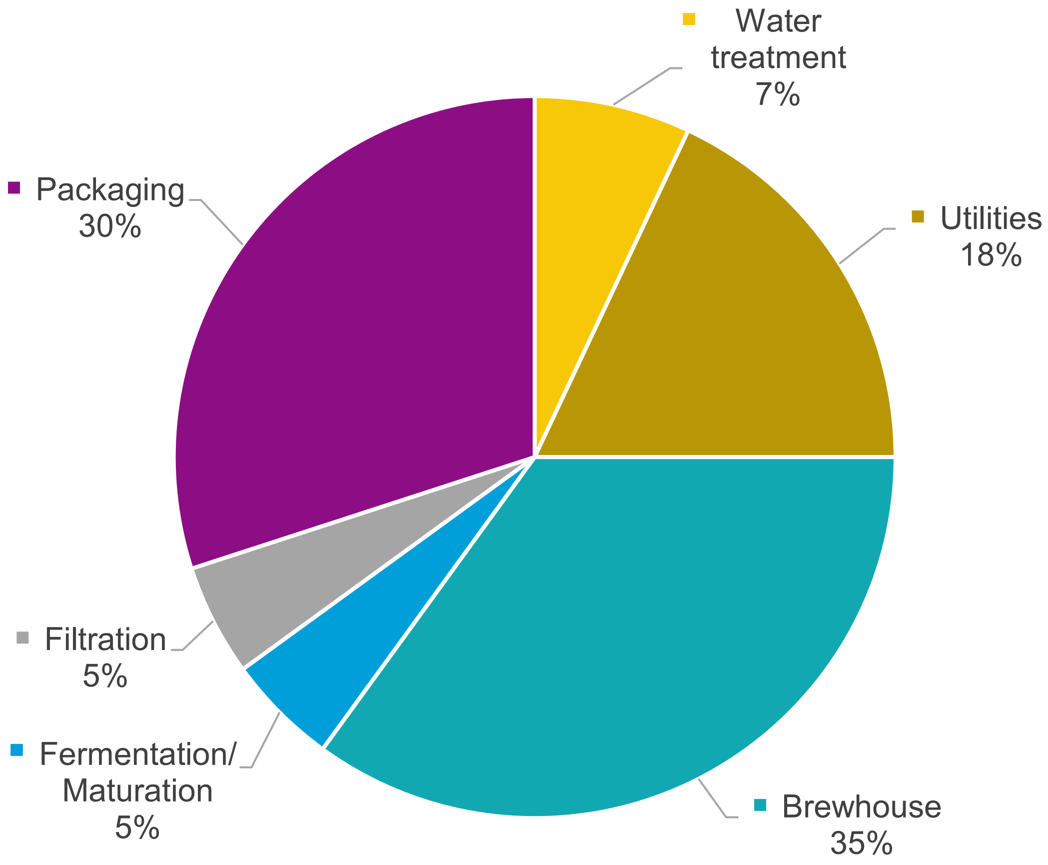
Energy Quick-Points

- Option evaluations were informed by this thermal energy demand model, this model was based on expert advice within the New Zealand and Australian brewing industry and is indicative of the current common practice.
- Total thermal energy demand will vary greatly between sites due to varying scales. However, proportions of energy use by plant area will remain consistent where similar technologies are adopted

Outcomes

- The Brewhouse and packaging are the greatest consumers of thermal energy, process improvements here will have the greatest impact
- Filtration, fermentation/ maturation and water treatment are less energy intensive, so smaller gains can be made here

Representative breakdown of thermal energy demand by plant area



Appendix B: Assumptions – GHG emissions Factors

GHG emissions Factors Quick-Points

- GHG emissions factors and Calorific values for the energy sources listed were supplied by the MfE publication:

  Measuring GHG emissions: A guide for organisations 2022 detailed guide

- Where fuel switching options are applicable, the relative GHG emissions factors demonstrate the amount of GHG emissions savings provided by less carbon intensive fuel sources. These factors informed applicable option evaluations

Outcomes

- Coal produces 2.5 times more GHG emissions per kWh of energy than electricity supplied by the nation al grid
- Biomass produces 25 times less GHG emissions per kWh of energy than the electricity supplied by the national grid

Energy Source	Unit	GHG Emissions Factor $kgCO_2e$/unit	Calorific Value kWh/unit	Normalised GHG Emissions factor $KgCO_2e$/kWh	Relative GHG Emissions Factor to Purchased Electricity
Coal – Sub-bituminous	kg	2.01	6.01	0.33	**2.55**
Natural gas	kWh	0.19	1.00	0.19	**1.48**
Purchased electricity - annual average (2020)	kWh	0.13	1.00	0.13	**1.00**
Biomass (wood - industrial)	kg	0.01	2.68	0.01	**0.04**

Beca

Appendix C: Methodology – Evaluation Criteria

Evaluation Criteria Quick-Points

- Using the previous assumptions and the knowledge of industry experts, each long list option was given a 1-5 score for relative CAPEX, OPEX, and GHG emissions.
- The scales used for these scores were derived based on what would be relatively good or poor value for a small to medium sized brewery
- The higher the score the better value for money the option is for its GHG emissions savings potential

Outcomes

- The final score (2-50) allows the comparison of all of the long list options against their relative value

Relative Cost of Investment				Relative GHG Me Emissions Cost		Relative Value	
Description	**Score (CAPEX)**	**Score (OPEX)**	**Score (Total relative Cost)**	**Description**	**Score**	**Description**	**Score**
The relative costs of the option	1-5	1-5	2-10	The relative GHG emissions savings in tCO_2e	1-5	The multiplication of total relative cost and GHG emissions	2-50

Description	Score	CAPEX (1-5 very expensive to inexpensive)	% Increase in Site OPEX	% Site Emission Savings Potential
Very high cost/low GHG emissions saving	1		30% +	1% or less
high cost/low GHG emissions saving	2		15% - 30%	1% - 5%
Neutral	3		7.5% - 15%	5% - 15%
Low cost/high GHG emissions saving	4		0% - 7.5%	15% - 30%
Very low cost/high GHG emissions saving	5		0% or less	30% +

Appendix C: Methodology – Evaluation Matrix

Evaluation Matrix Quick-Points

- Final scores for each option can be placed on the evaluation matrix for comparison, scores are categorised and colour coded to help with this comparison

Outcomes

- The comparison of relative value between long list options can be made

Relative Value Matrix	Relative Cost of Investment Score								
Energy Savings Score	2	3	4	5	6	7	8	9	10
1	2	3	4	5	6	7	8	9	10
2	4	6	8	10	12	14	16	18	20
3	6	9	12	15	18	21	24	27	30
4	8	12	16	20	24	28	32	36	40
5	10	15	20	25	30	35	40	45	50

Relative Value Categorisation	Score Limits
Very poor	0-7
Poor	8-14
Neutral	15-21
Good	22-30
Very good	31-50

Appendix D: Long List Options Register

*Note – Options for CO_2 Recovery and Nitrogen Generation for Tank Purging were originally out of scope of this study. The long list has not been updated to reflect addition of these options.

Brewing Global Tech Scan Preliminary Options Analysis, Rev 2

Job Number: 2932165
Status: Final
By: Patrick Bell
Reviewed: Peter Cope
Approved: Andrew Russell
Date: 13/02/2023

EECA TE TARI TIAKI PŪNGAO ENERGY EFFICIENCY & CONSERVATION AUTHORITY

Notes

1. Refer to appendix C [Methodology] for basis of scoring
2. Carbon reduction estimates do not account for multiple project interactions.

No	Option type	Process Step	Option	Reduced Consumption (production) of:	Shortlist (Y/N)	Greenfield (G) Retrofit (R)	relative CAPEX score (1-5)	Relative process OPEX increase score (1-5)	Net relative cost score (2-10)	Relative GHG emissions saving score (1-5)	Total relative value (2-50)
1	Process Technology	B. Site Services	High Temperature CO2 heat pump for generating both process heating and cooling loads	Fossil Fuel	Y	R	2	5	7	4	28
2	Process Technology	H. Brewing	Use Mechanical Vapour Recompression (MVR) on wort kettle to recompress vapour from boiling	Fossil Fuel	Y	R	2	5	7	4	28
3	Fuel Switching	A. Processing services	Replace direct fired brewhouse equipment with electric elements with external wort heating and condensate recovery (if implementing MVR & simmer and strip options already)	Fossil Fuel	Y	R	2	3	5	5	25
4	Heat Recovery	A. Processing services	Upgrade wort cooling to 3-stage, use a heat exchanger to condense wort kettle vapour and pre-heat wort via an energy storage tank	Fossil Fuel	Y	R	3	5	8	3	24
5	Process Technology	H. Brewing	Apply "Simmer & Strip"™ technology for Wort Kettle	Fossil Fuel	Y	R	3	5	8	3	24
6	Process Technology	H. Brewing	Use Thermal Vapour Recompression (TVR) on wort kettle to recompress vapour from boiling	Fossil Fuel	Y	R	3	5	8	3	24
7	Process Technology	H. Brewing	Install an external stripping column for wort boiling.	Fossil Fuel	Y	R	3	5	8	3	24
8	Process Technology	H. Brewing	Retrofittable vapour condensers	Fossil Fuel	Y	R	3	5	8	3	24
9	Fuel Switching	B. Site Services	Replace fossil fuel boiler with electric element boiler	Fossil Fuel	Y	R	1	3	4	5	20
10	Process Technology	F. Milling	Dry Dehusking - remove husk from grist in mill prior to mash.	(Waste streams)	Y	R	3	5	8	2	16
11	Heat Recovery	N. Packaging	Warm filling	Grid Electricity	Y	R	2	5	7	2	14
12	Process Technology	H. Brewing	Wort Boil via High Temperature Hot Water	Fossil Fuel	Y	R	2	4	6	2	12
13	Fuel Switching	B. Site Services	Combined Heat and Power	Fossil Fuel	N	R	1	5	6	5	30
14	Process Technology	M. Pasteurisation	Don't Pasteurise Beer	Fossil Fuel	N	R	5	5	10	3	30
15	Process Technology	B. Site Services	High Temperature heat pump for pasteurisation	Fossil Fuel	N	R	2	5	7	4	28

No	Option type	Process Step	Option	Reduced Consumption (production) of:	Shortlist (Y/N)	Greenfield (G) Retrofit (R)	relative CAPEX score (1-5)	Relative process OPEX increase score (1-5)	Net relative cost score (2-10)	Relative GHG emissions saving score (1-5)	Total relative value (2-50)
16	Process Technology	B. Site Services	Use cooling tower instead of process cooling, e.g. for tunnel pasteurisers	Grid Electricity	N	R	3	5	8	3	24
17	Heat Recovery	H. Brewing	Maximise Condensate Recovery	Fossil Fuel	N	R	3	5	8	3	24
18	Heat Recovery	H. Brewing	Pressurised condensate recovery	Fossil Fuel	N	R	3	5	8	3	24
19	Process Technology	H. Brewing	High gravity brewing	Grid Electricity	N	R	3	5	8	3	24
20	Process Technology	M. Pasteurisation	Replace tunnel pasteurisers with flash pasteurisers	Fossil Fuel	N	R	3	5	8	3	24
21	Process Technology	B. Site Services	Install a high pressure hot water system to replace some steam users (if steam reticulation is installed)	Fossil Fuel	N	G	3	4	7	3	21
22	Fuel Switching	B. Site Services	Solar PV Installation + Batteries	Grid Electricity	N	R	3	4	7	3	21
23	Process Technology	M. Pasteurisation	Use an alternative Pasteurisation Technology - Microfiltration (MF)	Fossil Fuel	N	R	2	5	7	3	21
24	Fuel Switching	B. Site Services	Biomass boiler (using wood pellets/spent grain as feedstock)	Fossil Fuel	N	R	1	3	4	5	20
25	Efficiency and Monitoring	B. Site Services	Efficient site electrical services	Grid Electricity	N	R	5	5	10	2	20
26	Fuel Switching	G. Mashing	Digest spent grain (part is landfill otherwise to farmers), wastewater and yeast (currently a cost) to produce biogas.	Fossil Fuel	N	G	1	4	5	4	20
27	Efficiency and Monitoring	A. Processing services	Invest in efficient electric motors	Grid Electricity	N	R	4	5	9	2	18
28	Heat Recovery	G. Mashing	Wort cooling optimisation	Grid Electricity	N	G	4	5	9	2	18
29	Heat Recovery	H. Brewing	Install economiser on steam boiler	Fossil Fuel	N	R	4	5	9	2	18
30	CO2 recovery	J. Fermentation	Intelligent FV CO2 recovery switching	(CO2 emissions)	N	R	4	5	9	2	18
31	Heat Recovery	M. Pasteurisation	Use high temperature hot water for pasteurisation instead of steam	Fossil Fuel	N	R	4	5	9	2	18
32	Heat Recovery	N. Packaging	Change filling technology to aseptic filling and use a bottle warmer instead of a pasteuriser	Fossil Fuel	N	R	1	5	6	3	18
33	Heat Recovery	A. Processing services	Replace ambient air CO2 evaporator with a heat exchanger to recover cooling energy for a chilled water system	Fossil Fuel	N	R	3	5	8	2	16
34	Heat Recovery	G. Mashing	External PHE wort boiling	Fossil Fuel	N	R	3	5	8	2	16
35	Heat Recovery	N. Packaging	Use heat recovery for vaporising liquid CO2 against cooling of recovered CO2	Grid Electricity	N	R	3	5	8	2	16

No	Option type	Process Step	Option	Reduced Consumption (production) of:	Shortlist (Y/N)	Greenfield (G) Retrofit (R)	relative CAPEX score (1-5)	Relative process OPEX increase score (1-5)	Net relative cost score (2-10)	Relative GHG emissions saving score (1-5)	Total relative value (2-50)
36	Heat Recovery	O. Product handling	Integrate Cool Stores refrigeration into centralised glycol network, rather than having stand-alone air conditioning systems	Grid Electricity	N	G	3	5	8	2	16
37	CO2 recovery	B. Site Services	Recover CO2 from Boiler Exhaust for allow use of recovered CO2 in carbonation or CO2 collection and storage	(CO2 emissions)	N	R	2	3	5	3	15
38	Fuel Switching	B. Site Services	Small wind turbine installation	Grid Electricity	N	G	2	5	7	2	14
39	Process Technology	G. Mashing	Replace Lauter tun with Mash filter	Fossil Fuel	N	G	3	4	7	2	14
40	Fuel Switching	B. Site Services	Anaerobic digestion	Fossil Fuel	N	G	1	3	4	3	12
41	Process Technology	M. Pasteurisation	Use an alternative Pasteurisation Technology - High Pressure Processing (HPP) or Pulsed Electric Field (PEF)	Fossil Fuel	N	R	1	4	5	2	10
42	Process Technology	C. Process handling	Cable disk conveyors (Cable way, Tubo system)	Grid Electricity	N	R	4	5	9	1	9
43	Process Technology	G. Mashing	Replace vortex pre mashers with steeles mashers	(Waste streams)	N	R	4	5	9	1	9
44	Process Technology	G. Mashing	Change spent grain blower to progressive cavity pump	Grid Electricity	N	R	4	5	9	1	9
45	Process Technology	G. Mashing	Use enzymes to increase extract from mash	(Waste streams)	N	R	5	4	9	1	9
46	Process Technology	H. Brewing	Dry Hop - Hop Gun	Grid Electricity	N	R	4	5	9	1	9
47	Process Technology	J. Fermentation	Use ambient heat to evaporate liquid CO2, rather than process heat (e.g. use air-heated evaporators, or fan-assisted)	Fossil Fuel	N	R	4	5	9	1	9
48	Process Technology	H. Brewing	Dry Hop - Decanter	(Waste streams)	N	R	3	4	7	1	7