Cost Efficiency Optimization Project
Enabling Heat Pump for Production Line

(proposed by TRESOT and GenAI)

Abstract

The document outlines a cost efficiency optimization project for a brewery, focusing on the integration of a large industrial heat pump to streamline energy use across several key production stages: drying, boiling, and cooling. By implementing the heat pump, the brewery aims to recover and reuse thermal energy, which significantly reduces energy costs.

The heat pump harnesses residual heat from various processes, allowing it to preheat liquids before boiling and cool them efficiently after the boiling stage, lowering overall power consumption. This optimised energy transfer system not only cuts down on fuel usage but also decreases CO_2 emissions, supporting sustainability goals. The improved thermal regulation during drying, boiling, and cooling ensures that product quality remains unaffected while reducing operational expenses. This integration is expected to result in notable long-term savings and enhance the energy consumption without compromising on output standards.

Summary

Financial Impact	pessimistically, around €1.538.000 or 36% of all energy consumption annual bill
Costs of Implementation	around €900,000
Expected period of return of investment	16 months (9 months for implementation, 7 months of exploitation)
Environmental Impact	Scope 1: -33300 kg CO_2 Scope 2: -1924 kg CO_2

Production Line

The production line is fully automated and usually works at least 97% of all time (including working hours or employees, night shifts, etc).

Stage	Details	% of electricit y	% of gas
Malting	Barley or other grains are soaked in water, allowed to germinate, and then dried in a kiln. This process converts the starches in the grain into fermentable sugars.	10%	10%
Milling	The malt is crushed to break down the grain’s outer husks and expose the starches inside, which will later be converted into sugars during mashing.	small	-
Mashing	The milled malt is mixed with hot water in a mash tun. This allows enzymes in the malt to break down the starches into sugars, creating a sugary liquid called wort.	small	-
Lautering	The wort is separated from the spent grain in a lauter tun. The spent grains are removed, and the wort is collected.	small	-

Boiling	The wort is boiled to sterilize it and to add hops. Hops provide bitterness and aroma to balance the sweetness of the malt and act as a preservative.	40%	75%
Whirlpooling	After boiling, the wort is rapidly spun to separate hop particles and other solids from the liquid.	small	-
Cooling	The hot wort is cooled down to a low temperature for filtering from unnecessary protein sediment and then heating to temperature suitable for fermentation, through heat exchangers.	15%	-
Fermentation	The cooled wort is transferred to a fermentation vessel, where yeast is added. The yeast converts the sugars in the wort into alcohol and carbon dioxide, producing beer.	small	-
Maturation	After primary fermentation, the beer is conditioned or aged to develop its flavors and allow any remaining yeast or particles to settle.	small	-
Filtration	The beer may be filtered to remove yeast, proteins, and other particles, resulting in a clearer final product.	small	-
Packaging	The finished beer is bottled, canned, or kegged, ready for distribution and consumption.	10%	-

Heat Exchange

The project only allows optimizing the processes which strongly rely upon heat exchange (heating and cooling). The criterion of selected processes for optimization:

- The production stage requires a significant amount of heat;
- The difference between heating and cooling capacity must be balanced, no more 30% shift to heating and no more 15% shift to cooling.

The list of selected processes:

Stage	Details	Thermal operation mode	% of electricity	% of gas

Malting	Drying process requires generation of dry air: cooling, condensing, and then heating back the air. Heating and cooling are equal during performance.	-5-40°C	10%	10%
Boiling	Boiling process requires the significant amount of energy. The current production line has a pre-heating stage using heat from gas combustion. Only heating capacity is consumed. This process requires accurate thermal regulation, thus must be additionally controlled by the exact production equipment (usually embedded).	70-80°C	40%	75%
Cooling	Cooling from 70-80°C to -1°C and then heating to 21°C. The balance between heating and cooling is 20/80.	-5-30°C	15%	0%

The best possible configuration with balanced heating/cooling budget:

- **INCLUDES** all electricity energy;
- **INCLUDES** gas energy for Malting and Cooling stage(s);
- **DOES NOT INCLUDE** gas energy for Boiling stage(s).

Thermal budget

The thermal budget should be calculated by real energy spends, from electricity bills, gas/oil/fuel bills, on-site sustainable generation, etc. There haven't found any signs of using any kind of sustainable generation such as solar panels, wind energy, etc.

The total percentage of electrical energy converted to thermal energy:

$$a_1 + a_2 + \dots + a_n = 10\% + 40\% + 15\% = 65\% = a_{el}$$

The total percentage of gas/oil energy converted to thermal energy:

$$b_1 + b_2 + \dots + b_n = 10\% + 0\% = 10\% = b_{gas}$$

The average energy consumption is equal or close to forecast of energy consumption in the available bills. The forecast of electrical energy consumption in 2024 is about 11000 MWh. The forecast of gas/oil consumption in 2024 is about 300.000 m^3. The forecast of gas/oil energy consumption in 2024 is about 3000 MWh.

The total energy converted to thermal energy (heating and/or cooling):

$$A_{el} * a_{el} + B_{gas} * b_{gas} = 11000 * 65\% + 3000 * 10\% = 7450 \text{ MWh}$$

The electric energy optimization baseline is around 7150 MWh (by forecasts for 2024). The gas/oil energy optimization baseline is around 300 MWh (by forecasts for 2024). The total energy optimization baseline is around 7450 MWh (by forecasts for 2024).

The heating/cooling energy consumption by stages is:

$$A_{el} * a_{el} + B_{gas} * b_{gas} = 11000 * 10\% + 3000 * 10\% = 1400 \text{ MWh (Malting)}$$

$$A_{el} * a_{el} + B_{gas} * b_{gas} = 11000 * 40\% + 3000 * 0\% = 4400 \text{ MWh (Boiling)}$$

$$A_{el} * a_{el} + B_{gas} * b_{gas} = 11000 * 15\% + 3000 * 0\% = 1650 \text{ MWh (Cooling)}$$

Heating/cooling capacity

The heating/cooling balance is equal to the product of percentage of heating and percentage of the stage, divided by the same product of cooling:

$$B_{hr} = \Sigma(heat\ ratio * stage\ ratio)/all\ heating\ budget =$$
$$= (0.5 * 1400 + 1 * 4400 + 0.2 * 1650)/9700 =$$
$$= 5430/9700 = 55\% \text{ of heating}$$

$$B_{cr} = 1 - B_{hr} =$$
$$= 1 - 0.55 = 45\% \text{ of cooling}$$

The heating source usually can compensate 30% of balance shift to heating and 15% balance shift to cooling. Extra balance shift could be compensated with extra electricity costs.

The actual heating/cooling balance shift is 10% to heating. This doesn't decrease the efficiency of heat pump, or negligible.

Proposed Changes

The proposed industrial heat pump has the following technical parameters:

Heating capacity	300-800 kW_{th}
Cooling capacity	250-700 kW_{th}
Max. Coefficient of Performance	5
Power input	150-300 kW_e
Min and max temperature	-10°C and 85°C

Lifespan (90%)	18 years
Type of Source	Ground
Necessary maintenance	(1) pipes maintenance, annually; (2) refrigerant refill, semi-annually.

The operating parameters of the system: the expected extra heat losses after installation is 10-20%; the expected electric energy consumption: 290 kW or 2600 MWh annually; expected thermal energy production (both cycles): 7450 MWh annually.

The provided operating parameters MAY assume disabling and decommission of different parts of the production line related to the same or similar functions, but this part of the calculation isn't available in the preview version of the document (statistical numbers are used instead).

Costs of Implementation

Costs of main components: around €750000
Costs of support components: around €75000
Costs of installation: around €75000

The preview version of the document doesn't include the costs of decommission and utilization of old equipment, but usually it's an insignificant part of full cost.

The preview version of the document doesn't include the detailed calculation of exact necessary components and costs of installation.

Summary: around €900000 single time.

Project Timeline

Statistically, based on the heat pump capacity and the business sector, such project requires about 9 months for the implementation.

Costs of Ownership

Amortization is equal to costs of full replacement of a component (including installation) divided by lifespan:

$$A = Costs\ of\ Implementation \div Lifespan = 900000 \div 18 \approx €50000 \text{ annually}$$

The preview version of the document doesn't include inflation.

Maintenance costs consist of pipes maintenance (M_a) and refrigerant refill (M_b). Single-time maintenance of pipes maintenance (Mst_a) is average €2500 for the location. Single-time maintenance of refrigerant refill (Mst_b) is average €1800 for the location.

$$M = \Sigma(Mst * 1\,year \div period) = 2500 + 1800 * 2 = €6100 \text{ annually}$$

The full costs of ownership are the sum of amortization and maintenance costs, with inflation:

$$A + M = 50000 + 6100 = €56100 \text{ annually}$$

Summary: around €56100 annually.

Change Impact

The project reduces energy consumption, because of a more effective way to produce thermal energy. The new amount of energy consists of the current consumption minus optimization baseline plus the consumption of new equipment in the selected operating parameters:

$$old\ consumption - optimisation\ baseline + consumption\ of\ new\ equipment =$$
$$= 11000 - 7450 + 2600 = 6150 \text{ MWh}$$

The project reduces gas/oil consumption, because the function is replaced by the new equipment. The new amount of energy consists of the current consumption minus optimization baseline plus the consumption of new equipment in the selected operating parameters:

$$old\ consumption - optimisation\ baseline + consumption\ of\ new\ equipment =$$
$$= 3000 - 300 + 0 = 2700 \text{ MWh}$$

And the new amount of gas consumption is equal to new amount of necessary energy divided by specific thermal impact of the gas/oil:

$$W_{th} \div 10.24 \approx 263000 \text{ m}^3$$

No significant impact to production process identified. More details are available in the full version.

Financial Impact

The forecast of costs of electric energy for 2024 **BEFORE** the project is the product of price and the forecast of amount of consumed electric energy:

$$€0.38 * 11000000 = €4180000$$

The forecast of costs of gas/oil energy for 2024 **BEFORE** the project is the product of price and the forecast of amount of consumed gas/oil energy:

$$€0.08 * 300000 = €24000$$

The forecast of costs of electric energy for 2024 **AFTER** the project is the product of price and the forecast of amount of consumed electric energy:

$$€0.38 * 6150000 = €2337000$$

The forecast of costs of gas/oil energy for 2024 **AFTER** the project is the product of price and the forecast of amount of consumed gas/oil energy:

$$€0.08 * 263000 = €21040$$

The preview version of the document doesn't include the financial impact of costs related to consumption of decommissioned equipment (the financial impact might be higher).

The financial impact is equal to the sum of the current costs of electric energy, thermal energy, and costs of ownership, minus the new costs of electric energy, thermal energy, and costs of ownership:

$$F_i = (F_e + F_{th} + CoO)_c - (F_e + F_{th} + CoO)_n =$$
$$= (4180000 + 24000 + 0) - (2337000 + 21040 + 36300) = €1809660 \text{ annually}$$

The expected costs optimization impact is roughly €1.809.660 saved annually. The statistical error of this calculation is ±15%. Pessimistically, it may save average €1538000 annually, or 31% or all energy consumption annual bill. To get the more precise calculation, please request the full version of the document.

The payback period of the project is equal to costs of implementation divided by annual financial impact (saved finances):

$$CoI \div F_i = 900000 \div 1538000 \approx 0.58\, years \approx 7 \text{ months.}$$

After the full implementation of the project, the payback period is 7 months.

Environmental Impact

CO_2 emission scope 1 covers emissions from sources that an organization owns or controls directly, including burning fuel, waste gas in chemical production, emission during recycling, etc.
The forecast of current gas consumption is 300.000 m3. The forecast of new gas consumption is 44.000 m3. The CO_2 emission reduction of scope 1 is equal to difference of gas consumption in m3 multiplied by CO_2 emission factor:

$$(GC_n - GC_c) * CO2_{ef} = (263000 - 300000) * 1.9 =- 33300 \text{ kg1 CO2}$$

CO_2 emission scope 2 covers indirect emissions from energy sources (purchased electrical energy).

Please keep in mind that this is only the preview version of the document. To make the final version of this optimization opportunity, you must apply the optimization project.

This document is the result of collaborative work of real industrial engineers and GenAI, thus may contain some inconsistent parts or misuse/misunderstanding of source data. Please ensure the correctness of all conclusions and used source data in the document.

The forecast of current electrical energy consumption in 2024 is about 11000 MWh. The forecast of new electrical energy consumption in 2024 is about 5950 MWh. The source of energy is not determined by vendor, thus the average coefficient of emission for the country (Germany) is 0.381 kg CO2 per kWh. The CO2 emission reduction of scope 2 is equal to difference of electrical energy consumption multiplied by CO2 emission factor:

$$(GC_n - GC_c) * CO2_{ef} = (5950000 - 11000000) * 0.381 =- 1924 \text{ kg CO2}$$