Applications of Geothermal Direct Use Heating in the Beer Making Industry

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ABSTRACT

The process of brewing beer at an industrial scale is very energy intensive, and although there are numerous forms of electrical demand, the main energy input is heating and cooling. The heating demands begin at the malting stage and are required through many of the processes within the brewery itself such as mashing, lautering, wort boiling, pasteurization and temperature regulation during fermentation and conditioning.

Most of these heat demands require temperatures between 50-80ºC (122-176ºF) with some such as wort boiling, kilning and cleaning in process requiring higher temperatures that can reach 100ºC (212ºF) and above. This puts the brewing industry in the perfect position to take advantage of direct use geothermal energy which, depending on the resource available on site, has the potential to deliver hot water or low pressure steam at the temperatures specified above. Lower temperature resources can also be combined with heat pump units to raise the output temperatures to those required while allowing a greater use of low temperature resources by reducing the injection temperature.

This paper will discuss the opportunities for implementing direct use geothermal heating systems in the brewing process, through the examination of a case study for a large brewing factory in Europe. The case study focuses on the technical feasibility of geothermal heating systems based on the resource available at a specific site. The feasibility work is commercially sensitive and specific details that could allow the case study to be identified have been purposedly omitted at the request of the developer. The results from the case study are then used to describe the engineering parameters of a suitable geothermal direct-use heating system, including expected outputs, benefits, likely challenges and construction costs. By demonstrating the effectiveness of geothermal direct use heating systems in beer making, this paper provides a roadmap for the beer industry to reduce their energy costs and emissions.

1. Introduction

Owners and operators in the beer industry are increasingly reviewing opportunities to reduce energy usage and decarbonize their operations.

Beyond greenhouse gas (GHG) reductions, candidate renewable energy solutions must:

1. Be able to be rapidly deployed on existing industrial sites with only limited land area available
2. Be able to utilize local energy sources
3. Diversify the energy mix
4. Provide insurance against future rise of the cost to provide process heat (15 years and beyond)

Geothermal direct-use heating is ideally placed to meet the needs of the beer industry given its low surface area requirements (up to 5,000 m^2 required during the drilling phase but only about 800 m^2 exclusion zone around the wellheads once the wells have been drilled). Geothermal direct-use is not relocatable and is arguably one of the most local forms of energy. It can be used as a base load and in combination with conventional source of energy or lower cost, higher GHG peaking technology. Most importantly it has low operating costs that are decorrelated from electric and gas tariffs.

Direct-use geothermal has already contributed to decarbonize other hard to abate sectors in Europe such as the horticulture industry. In 2021, geothermal direct-use heating of greenhouses contributed to generating about 60 trillion Btu displacing 181 million m^3 of natural gas per year. Given process heat in the beer industry is also typically provided by natural gas and some of the temperature requirements are similar, there are opportunities for the beer industry to replicate world-beer leaders such as Heineken Brewing company, which operates large facilities all over the world including in areas that are endowed with favourable geothermal conditions.

Areas with potential include traditional geothermal countries with volcanic geothermal systems that are already being exploited for generating electricity but could benefit from cascading use of the heat (low pressure steam and separated brines). Given the relatively modest temperature requirements of the industry, areas that are underlain by productive sedimentary basins can also be favourable where they contain sufficiently thick and permeable reservoirs. Such settings are much more widespread and can be developed rather quickly.

2. Energy Usage in the Beer Industry

Energy used in the beer industry can be divided in two primary categories.

- A natural gas-, biomass- or even coal-fired boiler is commonly used for generating hot water and steam which is used in malting, brewing, packaging and general building heating.
- Electrical energy is used to power all equipment, with the largest utilization being refrigeration.

Process heat requirements typically represent >50% of the energy consumed in the brewery; however, it usually only accounts for <50% of the actual energy cost in regions with a low gas

price environment. Recent geopolitical events in Ukraine and a sharp rise in natural gas tariffs in many countries around the world are changing this situation.

Data from the US Environmental Protection Agency (EPA) for breweries of all size (Figure 1) show that refrigeration, packaging and compressed air consume 70% of US breweries electricity use (A in Figure below), whereas the brewhouse dominates process heat requirements (natural gas, biomass and coal uses) at 45 percent.

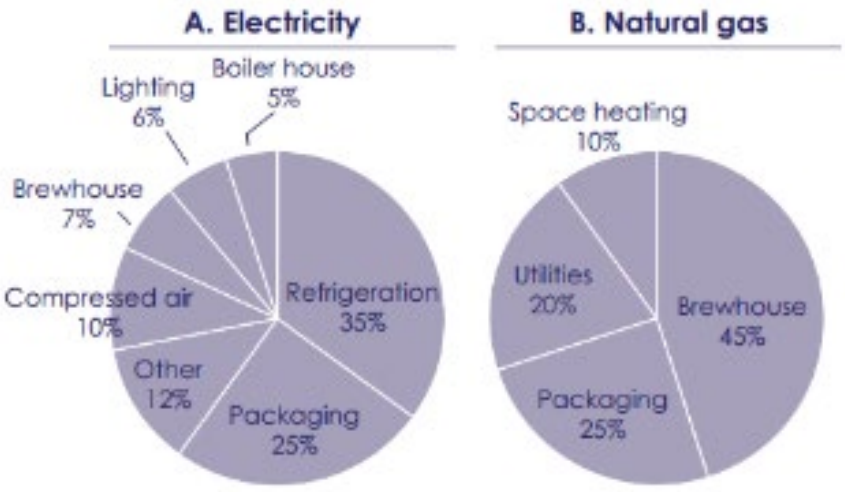

Figure 1: Data from the US Environmental Protection Agency (EPA) for breweries of all size

According to EPA, in 2020 alone the United States beverage industry consumed about 70 trillion Btu of energy:

- 32 trillion Btu in process uses (e.g., process heat, refrigeration, mechanical drives)
- 25 trillion Btu in boiler fuel
- 11 trillion Btu in non-process use (e.g., heating, ventilation, air conditioning, lighting, onsite transportation)

The main opportunity for direct-use geothermal is to displace boiler fuel particularly for the lower temperature requirements of the beer making process such as malting, mashing ground malts and other hot water heating in the brewhouse. Alternative technologies (Figure 2) to conventional gas-fired boiler providing process heat include:

- Solar technology (flat plate collector for the lower temperature requirements and evacuated tube for wort boiling, kilning and cleaning requirements) – however this generally require space requirements that are not available at industrial sites where real estate is at a premium
- Biomass technology – however this may not be considered renewable in some areas where a sustainable source of woody biomass is not available and cannot be sourced locally
- Geothermal direct-use and cascading use of deep geothermal and conventional volcanic geothermal resources

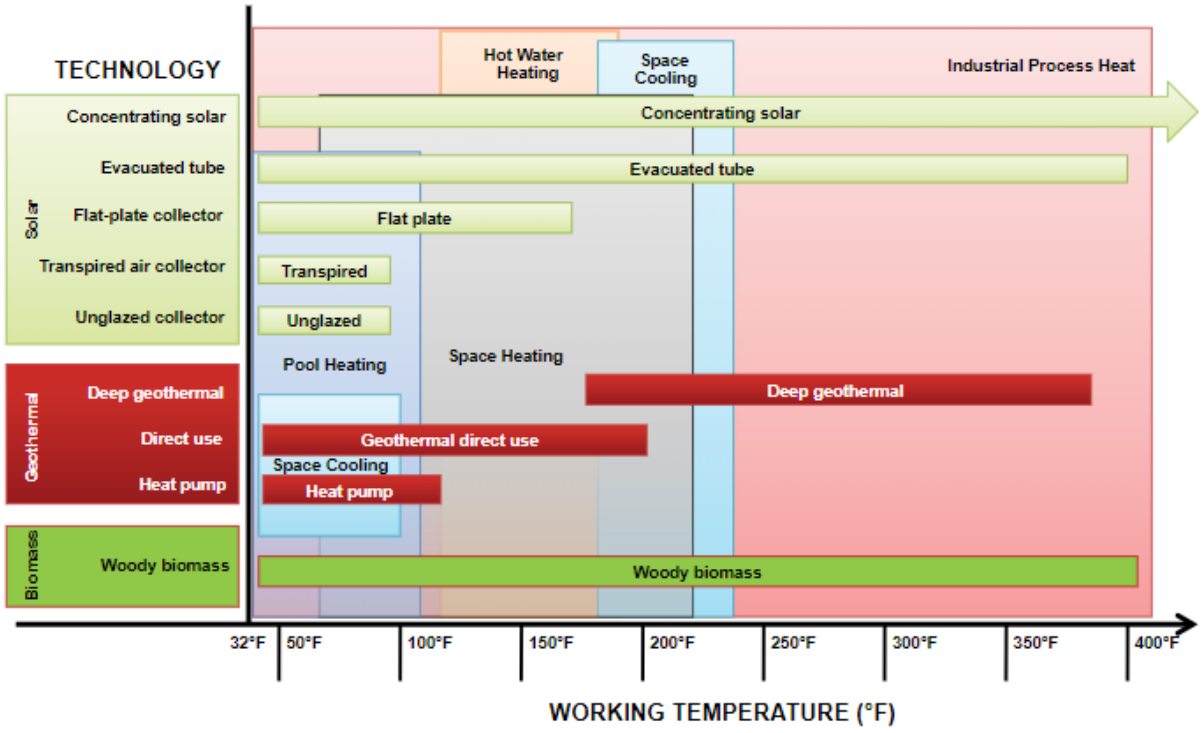

Figure 2: Working temperature of selected renewable technologies for heating (EPA)

3. Current Geothermal Applications in the Beer Industry

The concept of using geothermal heat in the beer industry is not new. A non-exhaustive list of current geothermal applications in the beer industry include:

Table 1: Examples of current geothermal applications in the beer industry

"Vapori di Birra" Brewery in Sasso Pisano, Italy	The brewery is located not far from Enel Green Power's historical Sasso 2 geothermal plant, remodeled in 2009 and equipped with 20 MW of installed power. Vapor (low pressure steam) from the plant is piped to the brewery, which uses it for all the beer production phases that require heat. The vapor gets to the brewery at about 446°F and is used to heat process water to 277°F via a heat exchanger. The process heat water is then used for various heating processes at the brewery including mashing ground malts, boiling and washing. The brewery returns the used-up vapor (condensate) to the plant, who takes care of cooling it further and returning it to the subsurface, to sustain the resource over time. Using geothermal vapor to produce beer, like the Sasso Pisano brewery does, is an economic advantage, in addition to being good for the environment. The brewery saw a 25% cost reduction compared to when it used traditional energy.

Superior Bathhouse Brewery in Hot Springs, Arkansas, USA	Sitting atop one of the natural hot springs in Arkansas' greater Hot Springs area, the Superior Bathhouse Brewery team make their beer using the springs' 143°F geothermal water.
Ölverk brew pub in Hveragerði, Iceland	Hveragerði is mostly known for the Reykjadalur "hot river" bathing spot, and the plentiful geothermal energy that helps run the heating of large greenhouses that glow brightly throughout the dark winter. The brew house, is connected to the local geothermal steam system. The steam is piped in at 302°F, and it heats up the freshwater, barley, hops and yeast.
Klamath Basin Brewing Company in Klamath Falls Oregon, USA	Geothermal water at around 190°F is used during the mashing process and for heating water for cleaning tanks and heating the building during winter.

4. Case study – process heat requirements

As part of a geothermal potential study for an industrial company in the beer industry in Europe we carried out a pre-feasibility study at the request of a developer to determine the geothermal potential of the area and the constraints.

The industrial company has a significant need for low-temperature heat (more than 50% of its requirements). Its heat production is still largely carbon-based.

The plant has a large production capacity for export. For the site, annual hot water requirements total several hundreds of billions Btu.

Two temperature levels are required to meet the hot water needs of the malt drying/clotting phase:

- 140°F (>50% of the total hot water requirement)
- 185°F (<50% of the total hot water requirements)

Overall, the results obtained at this stage suggest that the geothermal solution is technically and economically viable for this case study and well suited to the energy needs of this type of industry. The methodology can easily be duplicated elsewhere in the world.

5. Case study – subsurface assessment

5.1 Geological context

Geologically speaking, the study area lies within a large sedimentary basin in Europe.

European funded studies, such as the online "Pan-European Thermal Atlas" (Peta) have shown that there are many sedimentary basins with good geothermal potential in Europe.

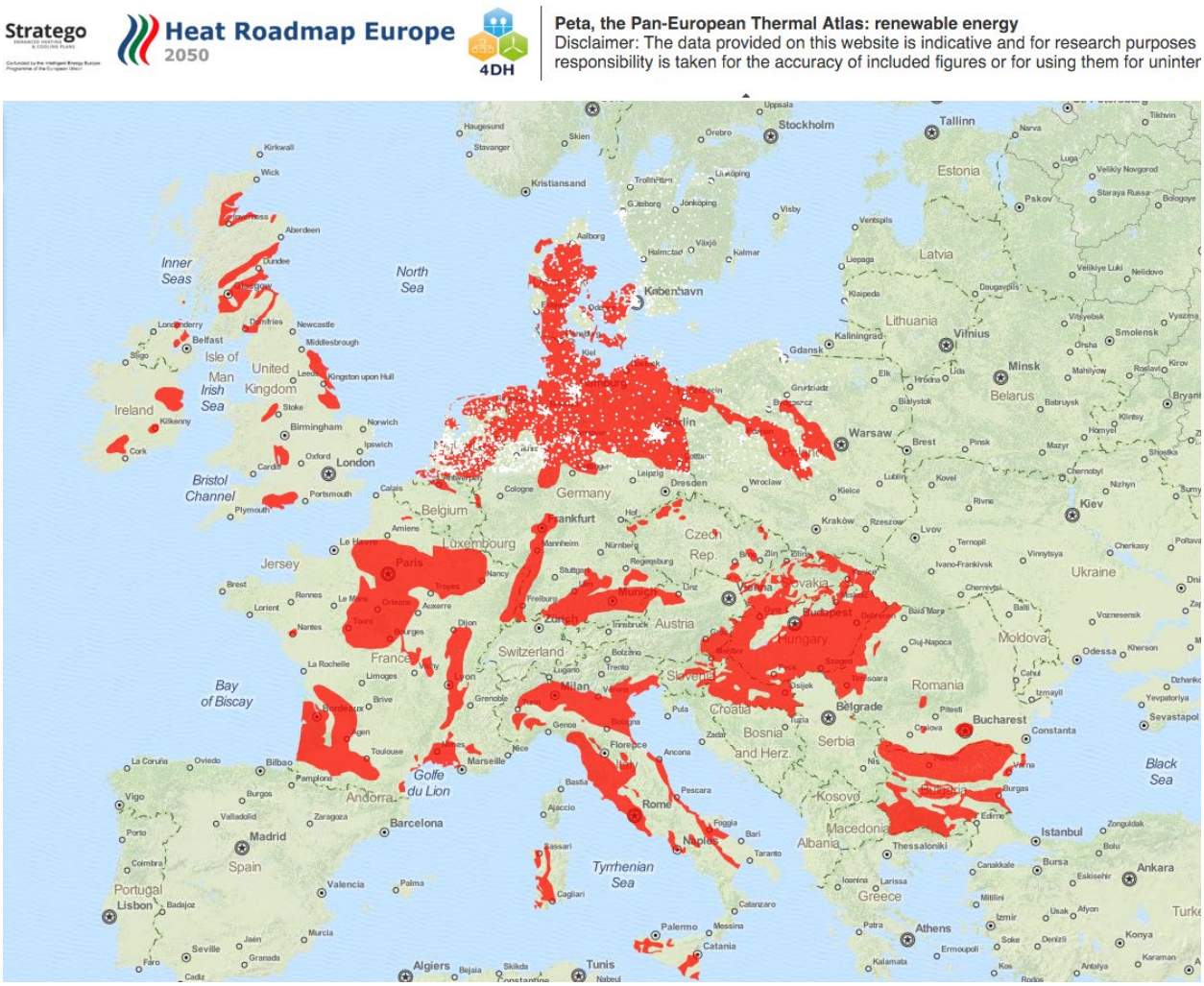

Figure 3: Pan-European Geothermal Atlas (Möller et al, 2022)

5.2 Geothermal Potential Review

To assess the geothermal potential of the project the most useful source of information was legacy oil and gas data in the vicinity of the project.

Wells that penetrated the entirety of the target reservoir were studied in priority. Since some of the wells were drilled several decades ago digitizing hard copy wireline geophysics was required for some of the wells. Cores cut by oil and gas operators in the subset of wells that penetrated primarily rocks which overlie the target reservoir and showed that these rocks did not exhibit good permeabilities despite some residual porosities (up to 10% in places).

For the deeper wells that penetrated the target reservoir, Neutron porosity, Density and Sonic logs were used to identify zones with porosity values greater than 15% that were more likely to coincide with with preserved permeability. However, no core was available from these intervals.

While reliable porosity – permeability relationships in the target reservoir remain somewhat speculative and poorly correlated. Several authors have developed relationships that were used to characterize the reservoir quality in other areas of the sedimentary basin. By applying the permeability-porosity relationship, the average permeability of the target reservoir was estimated to range from 70 to 250 mD over a thickness of 50 m.

As the offset oil and gas exploration wells were located several kilometres away from where the process heat requirements are needed, the next step involved the acquisition of legacy 2D seismic lines that went through the site.

The reprocessing provided signficant uplift and allowed the identification of a fault not previously mapped when the original seismic data was originally aquired. The fault displaces the reservoir.

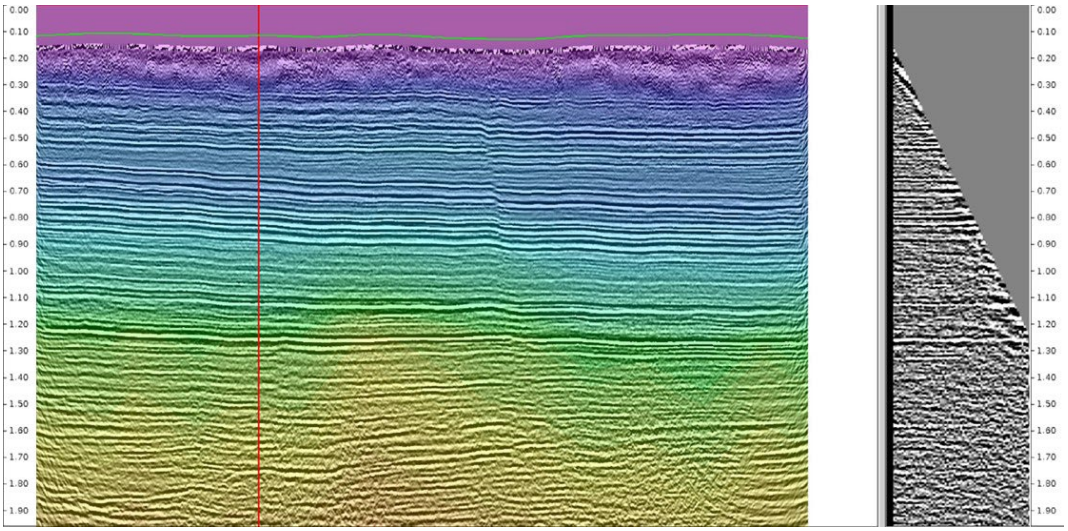

Figure 4: Example of 2D line after re-processing (west in left, east in the right)

The next step was to propose a conceptual well design that would meet the following criteria:

- Wellheads located on available land area near the factory
- Incorporate a vertical pump chamber section to accommodate an Electrical Submersible Pump (ESP) set to depths of up to 400 m
- Has a build angle of no more than 3 degrees/30 m to ensure casing can be run to depths
- Does not exceed 60 degrees stabilised angle
- Incorporate a multidrain through the reservoir at angles of at least 75 degrees through the reservoir
- Achieved an adequate distance between the producer and injector at reservoir level to avoid thermal recirculation during the life of the project
- Had an orientation such that the wells are located sufficently far from the fault, in the western fault-block to avoid hydrocarbon risk and penetrate the target reservoir where it is the thickest

One of the candidate conceptual well designs is shown in Figure 5 below along with one of the reprocessed 2D lines, the fault and top and bottom surface of the target reservoir.

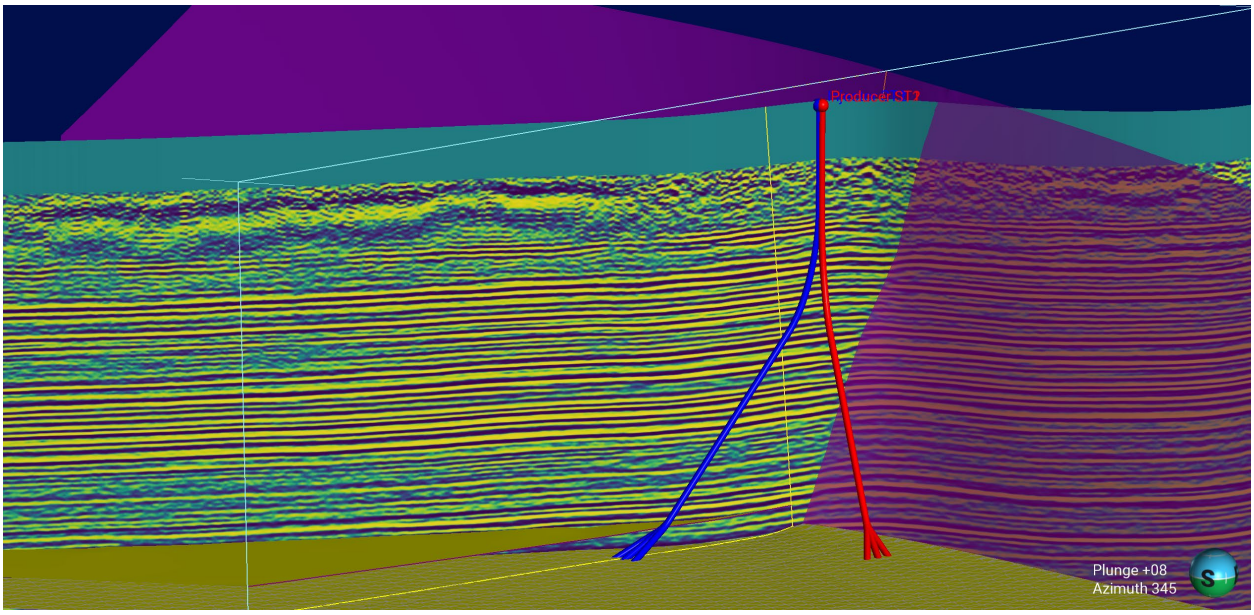

Figure 5: 3D visualization of the conceptual producer and injector well design with multi drain side-tracks through the reservoir

The target reservoir near the factory was found to be only about 20-25 m thick. By optimizing the well trajectories, the injector was predicted to likely intercept 35-40 m of reservoir thickness; however, the constraints listed previously meant the producer would likely intercept a thinner reservoir of only 25-30 m.

Given the uncertainty with the average permeability of the target reservoir, the likely Productivity Index was estimated to range from:

- High case: 8.5 m^3/h/bar
- Mid case: 6.5 m^3/h/bar
- Low case: 3.4 m^3/h/bar

Wellbore modelling was carried out to estimate the likely flowrate for a minimum dynamic water level of 300 m below ground (i.e., 100 m above the ESP to ensure that Non Condensable Gases would stay in solution).

Results shown in Figure 6 indicate that under the Mid-case scenario a mass flowrate of 270 m^3/h is achievable.

The temperature of the geothermal fluid was predicted using the temperatures collected in the wells in the vicinity of the project. The geothermal gradient of 0.0325°C/m associated with well SAU2 is consistent with indicated minimum and maximum gradients of 0.028°C/m and 0.04°C/m respectively. They are also consistent with the regional temperature map published by the regulator. Using the geothermal gradient of 0.0325°C/m resulted in a predicted temperature of 67.1°C +/- 3.5°C (i.e., 153°F) at the depth of the reservoir (1620 to 1750 m vertical).

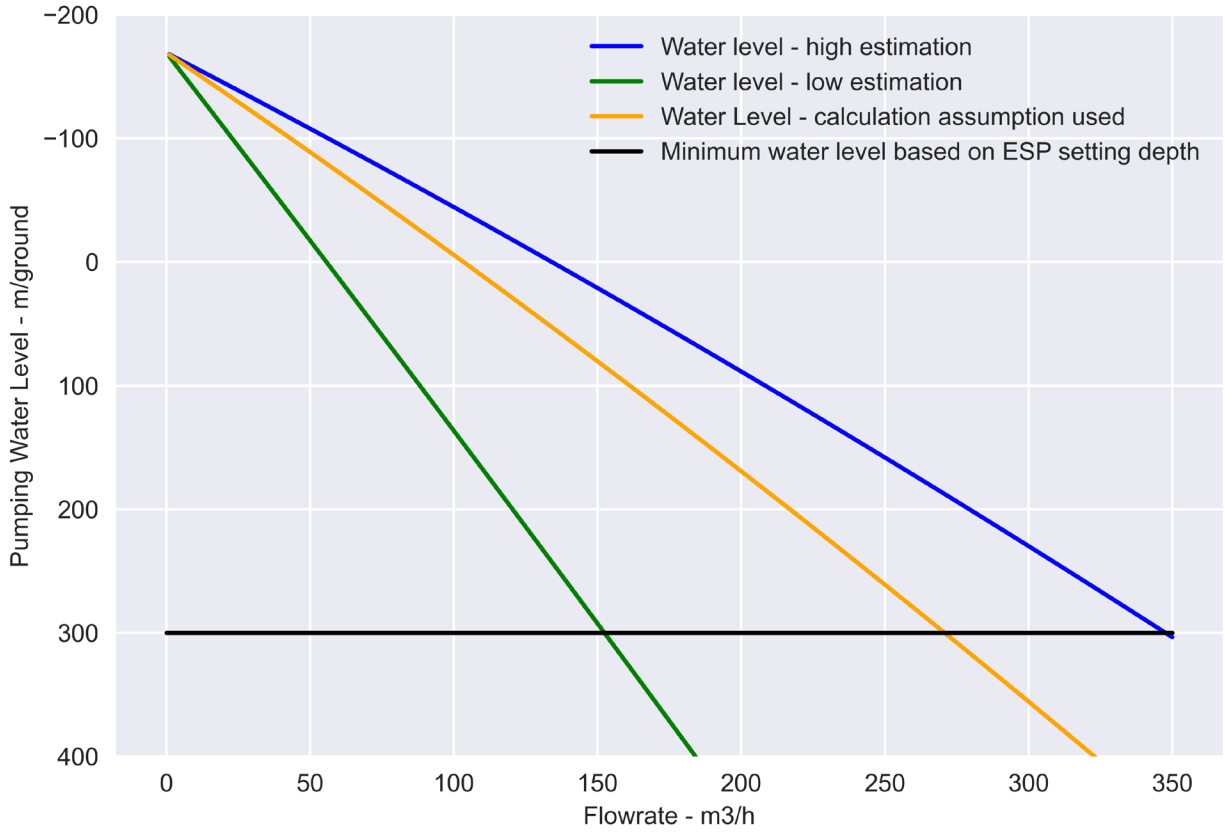

Figure 6: Producer well characteristic curve

Similar modelling was carried out to estimate the injection pressure and ensure the estimated pressure was less than 50 bar to meet the requirements set by the above-ground engineers.

The electric consumption of the ESP is primarily a function of flowrate and the equivalent total head seen by the pump, as well as pump hydraulic and motor electric efficiencies but also friction losses through surface pipelines, filter and heat exchangers.

The calculated electric power is shown in Figure 7. At the peak mass flowrate of 270 m^3/h, the Coefficient of Performance (ratio of heat power to electric power) is about 14 while it is greater than 25 at 150 m^3/h confirming the efficiency of the proposed geothermal solution for the project.

In collaboration with the developer and the above-ground engineers it was concluded that geothermal has the potential to supply up to 13.3 MW thermal for the Mid-case scenario. The average power over a year was assessed to be 10.2 MW based on the actual process heat demand requirements.

Those high power outputs are achieved because the injection temperature is lowered down to 15°C using heat pumps.

Drilling costs were estimated for the specified system. These included:

- Construction of platform and associated civil engineering,
- Mobilization/de-mobilization of the drilling rig,
- Fuel and Water,
- Management and monitoring of drilling,
- Drilling tools,
- Acidification,
- Transport and site logistics,
- Supply of casings,
- Accessories for cementing and tubing/screwing,
- Cementations,
- Sludge and sludge treatment,
- Directional drilling (multi-drain excluded),
- Mud Logging (geological monitoring),
- Wellhead equipment

The total capital costs were estimated together with all-inclusive operating costs estimated to (inclusive of electricity costs, corrosion inhibitor costs, regulatory monitoring including multifinger caliper surveys every 5-years, ESP replacements and a major workover to run a liner after 20 years).

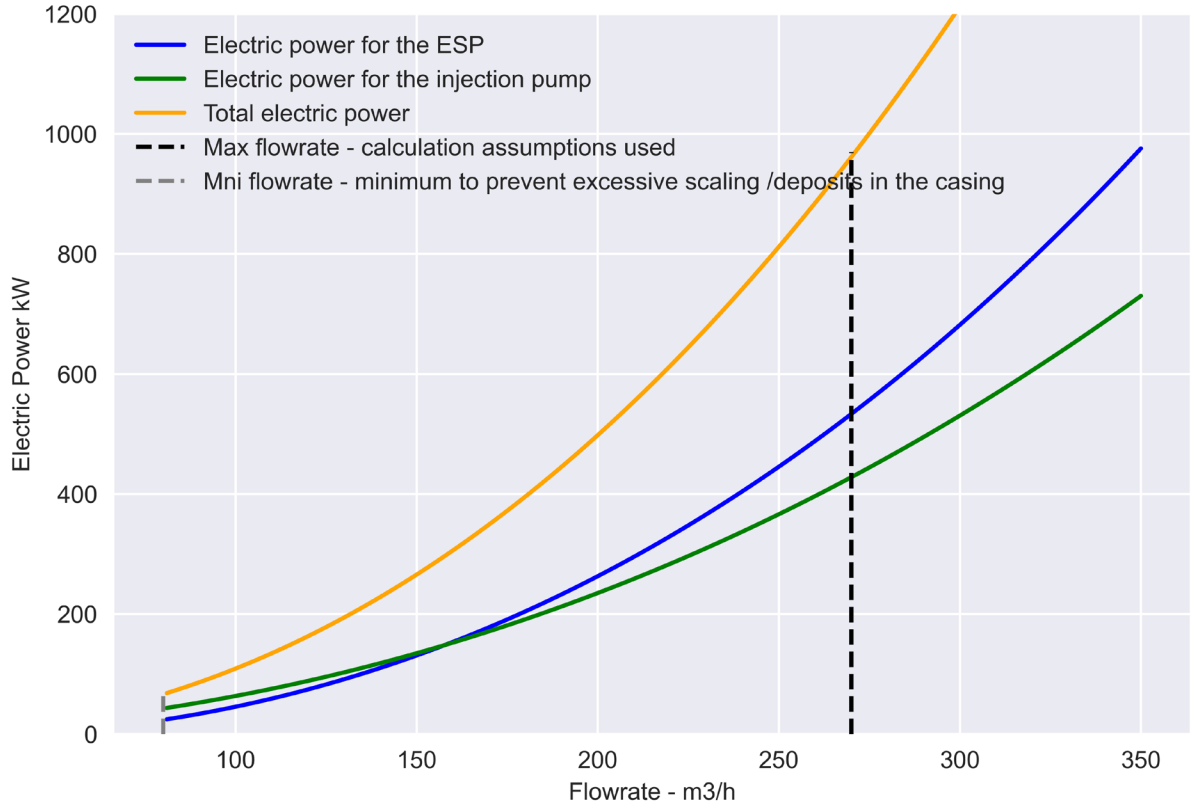

Figure 7: Electric power for Electric Submersible Pump (blue), injection pump (green) and total (orange)

6. Conclusion

The process of brewing beer at an industrial scale is very energy intensive, and although there are numerous forms of electrical demand, the main energy input is heating and cooling.

Most of these heat demands require temperatures between 50-80ºC (122-176ºF) with some such as wort boiling, kilning and cleaning in process requiring higher temperatures that can reach 100ºC (212ºF) and above. This puts the brewing industry in the perfect position to take advantage of direct use geothermal energy which, depending on the resource available on site, has the potential to deliver hot water or steam at the temperatures specified above.

There are already various geothermal applications for the beer industry around the world. A few selected applications from Italy, Iceland and the United States were discussed in this paper. However, most of the documented existing applications have been opportunistic and made use of a nearby high temperature volcanic resource or used a natural hotspring.

To demonstrate the potential for a greater utilization of geothermal energy in the beer industry, we present a case study from Europe where JRG Energy contributed to a subsurface assessment using primarily legacy oil and gas data. By reprocessing 2D seismic and analysing wireline data from offset oil and gas wells, it was identified that a permeable reservoir of up to 40 m thick was present underneath the case study site.

The geoscientific work completed by the JRG team concluded that the proposed well was capable of producing 270 m^3/h at 67.1°C +/- 3.5°C at a depth of 1.6-1.8 km vertical as long as adequate completion technology are used through the reservoir to maximise productivity. The thermal power generated is estimated to be 13.3 MW thermal.

Given that >50% of the site's hot water requirements are at 60°C the project has the potential to displace the natural-gas currently used onsite for this portion of the demand and be a major contributor to the decarbonization objective of the client. There is also potential to incorporate a high temperature heat pump into the system to meet the site's remaining hot water requirements at 85°C however this requires further investigation and collaboration with the above ground engineering team. The developer is reviewing the project economics, but given the existing support policies in Europe, which include a drilling risk insurance for developer, it is anticipated that the project could progress to detailed design subject to surface studies currently being undertaken. While the reprocessing of 2D seismic allowed significant derisking of the project, the permeability of the reservoir remains uncertain, and it is proposed to acquire new seismic data to better characterize the target reservoir and identify well targets.

This case study shows the potential for geothermal direct-use for the beer industry outside of existing conventional geothermal areas, such as in sedimentary basins of Europe and the United States where good quality legacy oil and gas data can be repurposed.

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