WP2 Industrial Applications of Geothermal Energy

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1.Executive summary

There are several industrial applications for geothermal energy. The temperature of geothermal heat energy for industrial use lies in the range of 0-200°C. This can be split into hot water (0-100°C) and pressurized water/steam (100-200°C). These both have a wide range of uses, outlined in this report.

The Client has identified the temperature range 30 - 85°C to be of particular interest and understand geothermal applications in this range. There are three main sectors which have demand for decarbonised heat in the temperature range 30 - 85°C. The main sectors, with projected continued expansion in market size are:

- **Agricultural sector**; including soil warming, fermentation, mushroom cultivation, batch drying agricultural products (including crop drying), animal husbandry, pasteurising, aquaculture and greenhouse heating.
- **Leisure sector**; including spa and swimming pool heating.
- **Domestic Housing**; including domestic heating and space heating and cooling.

These sectors have high levels of carbon emissions and high demand for direct use of geothermal energy. Geothermal energy has substantial potential to help these sectors to achieve net-zero. Chapter 4 outlines case studies for where all three of these sectors have monopolised on the use of geothermal energy around the world.

Process heat for industrial use, such as chemical processing, the heavy industrial sector generally requires high temperature (c. >100°C) geothermal waters/brine or steam. Current industrial cluster decarbonisation projects focus on areas of high geothermal potential (New Zealand, Iceland) and outwith these areas tend to focus on hydrogen and CCUS at present and into the near to medium term.

There may be innovative industrial applications of geothermal heat at 35 – 85°C, but to evaluate the efficacy and demand a collaborative R&D project with one or more relevant industry partners is recommended. Selection of industry partners can be advised by TownRock Energy, and should be centred around specific areas of interest for 85 Degrees geothermal resource development.

This Report has also outlined heat consumers/customers in areas of interest in Germany, supplied by the client, and ranked them depending on heat demand. These areas have potential to either retrofit current operational industries and domestic heating networks or could acknowledge areas which could benefit from industry development, especially in industrial/urban areas.

2. Introduction

Geothermal Energy produces a range of temperatures which can be used for different direct industrial heating applications. Industry has a wide range of temperature requirements.

The Netherlands main geothermal resource is in hot sedimentary aquifers (HSAs). Geothermal energy will most likely be targeted at a depth between 500 – 4,000 m producing temperatures of up to 100°C. However Ultra-Deep Geothermal (UDG, more than 4,000 m) is also being considered, which could produce considerably higher temperatures[1]. Therefore electricity production has also been included as a use of direct heating.

This report details the industrial uses for direct geothermal energy, for both hot water and steam, spanning temperatures of >0 to 200°C. It will also provide case studies of where direct geothermal heat is already being used for commercial purposes.

3.Industrial Uses for Geothermal Energy

There are a number of direct industrial uses for geothermal energy. The requirements for heat energy can be split into two categories: 1) uses for steam, and 2) uses for hot water. This standard categorization of direct use is defined by the boiling point of water at 100°C. Geothermal production temperatures below 100°C are limited to heat energy produced from hot water, and production temperatures above 100°C are capable of producing heat energy from steam.

These definitions are meant to create useful categorisations of potential energy production; however, there is overlap between each of these systems. If the produced fluid is pressurised, which is often the case with abstracted fluids below the earth's crust, hot water can be produced at temperatures above 100°C - with some examples of industrial uses of geothermal brines/hot water at 160°C. In cases where steam is the primary energy carrier, condensated fluids can be recycled and used in hot water applications. These two geothermal energy categories: Hot Water and Steam, can feed into one another and there may be more than one direct use application for a single site.

3.1. Hot Water (c. 0 →100°C)

The direct use of geothermal heat in industry utilises low to moderate-temperature heat energy available from warm groundwater or geothermal brines as an inexpensive and clean alternative to burning fossil fuels. A functional separation of low and medium groundwater temperatures occurs between systems requiring a heat pump to condense and circulate heat (production temperatures of c. 4°C to 60°C), and direct use heat and binary power generation (production temperatures of c. 60°C to 160°C) [2,3].

[1] Schoof, F., van der Hout, M., van Zanten, J. and van Hoogstraten, J.W., 2018. Master Plan Geothermal Energy in the Netherlands. Stichting Platform Geothermie: Delft, The Netherlands.

[2] Lund, J. W. (1997). Direct heat utilization of geothermal resources. Renewable Energy, 10(No. 2/3), 403–408. https://doi.org/0960-1481/97

[3] Fridleifsson IB. (1998) Direct use of geothermal energy around the world. p. 7.

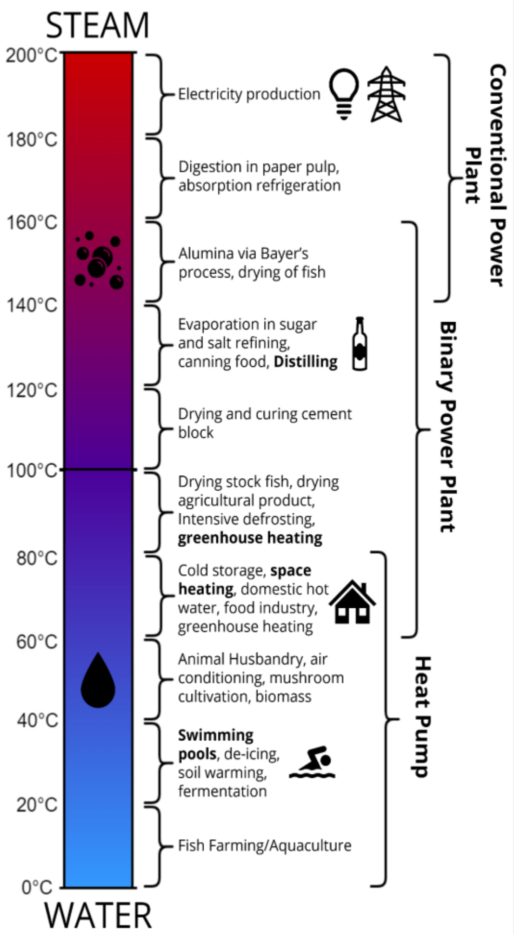

Figure 1 An adapted Lindal's Diagram of geothermal production temperatures and direct uses (modified from Kurnai et al. 2022 and GeoScience 2022).

A review of the worldwide direct use of geothermal heat[4] showed eight main categories of commercial heat use excluding domestic use of ground source heat pumps for individual homeowners. Those categories are: *space heating, greenhouse heating, aquacultural pond heating, agricultural drying, industrial uses, bathing and swimming, cooling/snow melting*, and *other*. Suitable temperature ranges vary for each sector of heat application (table 1) and have been shown in figure 1. The following section describes these eight categories in more detail.

3.1.1. Space Heating and District Heating

Hot water is produced from a central location and is circulated through individual buildings or a community-wide water system using a network of pipes to replace a traditional gas boiler or other heating system. This can be used to heat communities, office buildings, industrial estates, and large warehouses, and can also be used for domestic water heating and industrial process heat[2,4].

3.1.2. Bathing, Swimming, Leisure, Spas and Balneology

Heat is used indirectly to warm swimming pools and leisure centres and directly in geothermal spas and bathhouses. Balneology is a subset of this application where therapeutic use of thermal and mineral (acidic and basic) waters and muds are used to treat symptoms of high blood pressure, rheumatism, skin disease, diseases of the nervous system, ulcers, cerebral palsy, and generally for physical therapy and recuperation after surgery[2,5].

3.1.3. Greenhouse Heating

Greenhouse heating allows farmers to control soil and ambient temperature ranges. This improves crop growth in locations with cold climates and short growing seasons, or creating an ideal growing environment in places with warm climates. Examples of crops that have been developed in geothermally heated greenhouses are cucumbers, tomatoes, flowers, house plants, tree seedlings, berries, bananas, asparagus, and cacti[2,6].

3.1.4. Aquaculture and Pond Heating

Farmers can use geothermal heat to control pond temperatures to improve the growing conditions for various aquatic species. Examples of animals that have been raised in geothermally heated ponds are tilapia, bass, salmon, lobster, shrimp, prawn, catfish, eels, crocodiles, and tropical fish[2,4,5,5].

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[4] Lund, J. W., & Toth, A. (2020). Direct Utilization of Geothermal Energy 2020 Worldwide Review. 39. https://doi.org/10.1016/j.geothermics.2020.101915

[5] Green, B. D. (2004). *Geothermal Technologies Program: Direct Use* (DOE/GO-102004-1957; p. 16). U.S. Department of Energy: National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy04osti/36316.pdf

3.1.5. Agricultural Drying

This sector uses geothermal heat to dehydrate grains, vegetables, and fruit crops to improve storage life. Examples of dehydrated crops are alfalfa, onions, pears, apples, seaweed, wheat, cereals, lucerne, coconut meat, and timber[2,4].

3.1.6. Industrial Uses

There are several industrial and process applications of geothermal heat such as: concrete curing, bottling of water and carbonated drinks, wool washing, milk pasteurisation, leather industry, chemical extraction, CO_2 extraction, pulp and paper processing, iodine and salt extraction, distillation, borate and boric acid production[4], evaporation of highly concentrated solutions[6], and absorption refrigeration. The industrial sector represents a relatively small amount of the world's use of geothermal heat[2] and generally requires high temperature (c. >100°C) geothermal waters/brine or steam. A few of these industrial uses are discussed in more detail in the following section (3.2) within the context of high temperature geothermal heat use.

3.1.7. Cooling and Snow Melting

Coupled with space heating is the option to use space cooling systems to recycle reinjected geothermal fluids. Common cooling applications may be for industrial process cooling or data centre cooling. In cold climates, excess heat from these applications may be sent to sidewalk heaters and parking or driving pavement to melt snow and ice[2,4,5].

3.1.8. Other

These are various other uses of heat that fall outside of the other sectors of direct heat use. Examples of other heat uses include fermentation, biomass, mushroom cultivation, animal husbandry, domestic hot water, spirulina cultivation, desalination and sterilisation of bottles, cooking, and boiling water[2,4,5]. A full table summarising the uses of hot water can be seen in table 1.

3.1.9 Summary

These eight categories provide a thermal capacity of 30,180 MWt and annual energy use of 420,906 TJ/year (8,383 GWh/year) of clean renewable heat around the world. This marks a 68% increase in industrial direct use heat development since 2015[4.]. These activities have created a diverse array of direct use geothermal heat applications modulated to fit each country's individual industrial and cultural needs.

3.1.10 Table of Direct Uses of Geothermal Heat (c. 0 - 100°C)

Direct Use of Geothermal Heat (c. 0-100°C)		
Temperature Range (°C)	Use	Binary Power (BP) (60°-177°C, min - Kurnia et al. 2022, max - Hernández Ochoa et al. 2021) Direct-use Heat (DH) (60°-100°C, Lund 1997) Space Heating with Heat Pumps (HP)(4-60°C, Lund 1997)
0-20	Aquaculture	HP
20-40	Swimming pools	HP
20-40	De-icing	HP
20-40	Soil warming	HP
40	Fermentation	HP
30-50	Balneology	HP
50	Biomass	HP
50	Mushroom cultivation	HP
40-100	Batch Drying Agricultural products	HP, DH, BP
40-100	Industrial Processes	HP, DH, BP
40-100	Other (desalination, sterilisation, cooking, and boiling water)	HP, DH, BP
40-60	Air conditioning	HP
40-60	Animal husbandry	HP
70	Domestic hot water	DH, BP
70	Food industry	DH, BP
70	Pasteurising	DH, BP
60-80	Cold storage	DH, BP
60-80	Space heating and district heating	DH, BP
60-100	Seawater desalination by thermal distillation[6]	DH, BP
80	Greenhouse heating and Horticulture	DH, BP
80-90	Enhanced Heap Leaching of Gold[6]	DH, BP
90	Intensive defrosting	DH, BP
90	House heating	DH, BP
80 - 100	Dry stock fish	DH, BP
40 - 100	Wool Washing (50°C) and Drying (40°C)	DH, BP

Table 1 : Direct uses of geothermal heat with production temperatures and level of energy production (from Lund 1997[2], Kurnai et al. 2022[4], and GeoScience Ltd 2022[5])

[6] Patsa, E., Zarrouk, S. J., & Zyl, D. V. (2015). The Lindal Diagram for Mining Engineering. *GRC Transactions*, *39*, 151–156.

3.2 Pressurised Hot Water and Steam (>100°C)

Once groundwater temperatures reach 100°C the boiling point of water is exceeded, and steam, or pressurised hot water/geothermal brine (>100°C), becomes the carrier fluid for thermal energy at high temperature loads. The temperature increase in production fluids diversifies the use of geothermal energy to those industries that have high energy and temperature demands. The application of high geothermal heat and energy can be placed into three main categories: *Industrial Drying and Evaporating, Other Industrial Uses* (e.g. mineral production, canning and sterilisation, paper making, and distilling), and *Conventional Power Generation*. Suitable temperature ranges vary for each sector of heat and energy application (table 2) and have been shown in figure 2. These three categories, along with critical industrial uses within them, are described in the following section.

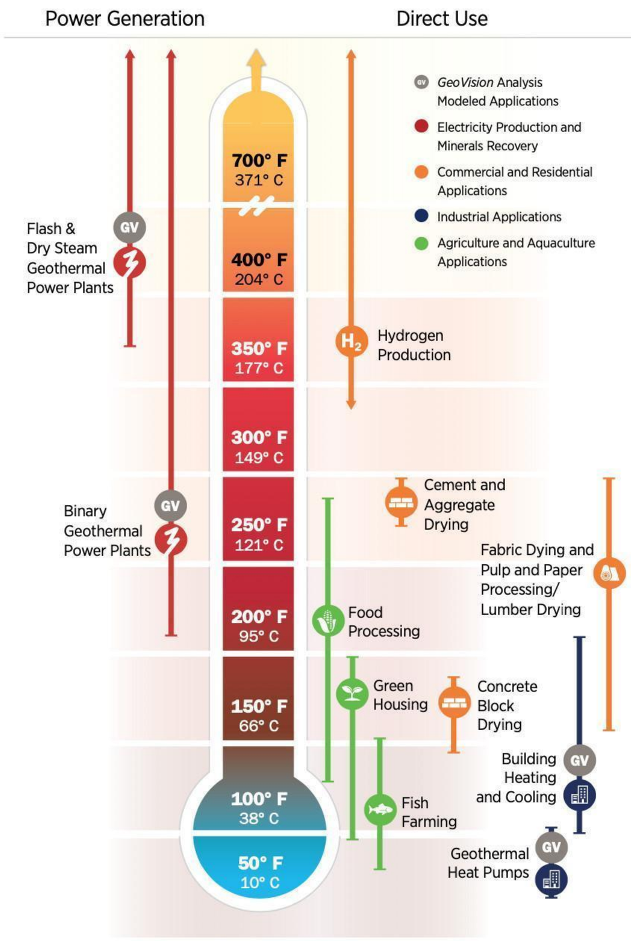

Figure 2 Adapted lindal diagram of production temperatures in a geothermal field required for various uses with a focus on >100°C including electrical power generation[9] .

3.2.1. Industrial Drying and Evaporating

Geothermal heat and steam are used to dry and cure goods, such as lumber[7], fish[8], and concrete in large industrial kilns (at c. 80-180°C). Drying in industrial kilns dries goods more efficiently and with greater control than traditional air-drying methods. The same processes can be used for industrial evaporation (c. 120 - 140°C). This method of industrial evaporation is used to create iodine, evaporating salt water for salt extraction or fresh water production, and sugar refining [4].

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[7] Carey, B. (2018). Using Geothermal Energy for Kiln Drying Operations. WoodTECH, Rotorua. https://www.nzgeothermal.org.nz/downloads/2018-09-19-Carey---Using-Geothermal-Energy-as-Process-Heat-for-Kiln-Drying-Operations.pdf

[8] Arason, S. (2003). The Drying of Fish and Utilization of Geothermal Energy—The Icelandic Experience. p. 7.

3.2.2 Mineral Production

At higher temperatures (c. 200°C) solutions containing metals can be further concentrated by evaporating a large portion of the solvent before the metal acquisition process[8]. Other industrial uses of geothermal energy can be applied when mining critical metals such as gold, silver, and uranium using enhanced heap leaching; lithium using co-produced geothermal brines and using brine evaporation; and alumina using a Bayer's Process[4,9]. Each of these methods have been defined in fuller detail below.

Enhanced Heat Leaching (80-110°C)

Low-grade metal ores with critical minerals such as copper, gold or uranium can be put into piles where the application of an aqueous leachate solution extracts the critical minerals from ore piles. The processed leachate solution is then collected and further purified at a refinery. This leaching process can be enhanced with the application of heat to the leachate solution, accelerating chemical reactions resulting in improved mineral extraction[8]. When this heat is applied it is called *Enhanced Heat Leaching*.

Lithium Extraction (110°C)

Lithium is used in the production of several products and industrial applications including batteries, ceramics, glass, lubricating greases, pharmaceuticals, and aluminium production. Lithium is primarily produced from hard-rock, open pit or underground mines, but may also be co-produced during some geothermal production sites through brine evaporation[8].

Alumina Extraction (150-200°C)

Alumina can be extracted using a Bayer's Process where alumina is recovered from bauxite through a complex system of milling, pressurisation, hydrating, and kilning. Each of these processes demands a high amount of energy and can utilise geothermal energy for intense leaching, evaporating, and kilning processes[12].

3.2.3 Canning food and Sterilisation

Canning involves the process of packaging food in a container and heating it (>121°C) for the purpose of destroying disease-causing bacteria and extending its useful shelf life with minimal impact on the nutritional and physical qualities of the food[10]. This same method can be used to boil and sterilise various products to make them fit for consumption[4].

3.2.4 Paper making

The paper production industry uses high heat energy to digest raw wood and recycled paper to break it down into a pulp fit for paper production. This process can use the high temperatures provided by geothermal energy to facilitate the digestion process. Excess heat can also be used for industrial drying during paper finishing and heating building spaces[11].

3.2.5 Distilling

The distilling industry requires heating in a number of its processes. The highest heat requirement is in the distilling phase (both wash distilling and spirit distilling), which makes up 80% of the energy requirement of a distillery. This uses temperatures of up to 130°C to heat and distil the alcoholic spirit. The other 20% is used in mashing and fermenting of the grain requiring much lower temperatures. Hot water is also used to flush the system after a distilling run as a cleaning mechanism. Frequency of rounds of distilling, mashing and fermentation depend on the required

[9] Chua, H. T., Sommer, H., & Regenauer-Lieb, K. (2018). Mineral Recovery Through Geothermal Desalination. Proceedings 40th New Zealand Geothermal Workshop, Taupo, New Zealand, p 5.

[10] Murano, E.A. (2014). Heat Treatment of Foods: Synergy Between Treatments, Encyclopedia of Food Microbiology, ed. 2.

[11] Carter, A. C., & Hotson, G. W. (1992). Industrial use of geothermal energy at the Tasman pulp & paper co. Ltd's mill, Kawerau, New Zealand. Geothermics, 21(5–6), 689–700. https://doi.org/10.1016/0375-6505(92)90022-2

output of the distillery, however some of the largest distilleries in Scotland operate 24 hours a day, 7 days a week[12].

3.2.6 Conventional Electricity Generation

Geothermally produced electricity is generated from steam that passes through and rotates a turbine, activating a generator which produces conventional electricity. There are six different types of geothermal power plant: Binary Power, Dry-steam, Single Flash, Double Flash, Triple Flash, Hybrid Flash and Binary Power, and Back Pressure discussed below.

Binary Cycle Power Plants

Binary cycle power plants operate on geothermal fluids from 77°-177°C. These systems use an Organic Rankine or Kalina cycle where the geothermal fluid is passed through a heat exchanger where it heats a "working fluid," which is usually made of an organic compound with a low boiling point such as isopentane, propane, freon, or ammonia. The vaporised working fluid passes through a turbine and generates power. Both fluids are self-contained in their own closed loop where effectively making an emission free plant[13]. Binary cycle conversion technology contributed to 14% of the world's geothermal installed electricity capacity from 2010-2014[14].

Dry-steam Cycle Power Plants

Dry-steam uses steam from the ground, requiring very high temperatures near the surface. The steam travels directly to a turbine that converts thermal energy into mechanical energy which drives an electric generator[16]. Dry steam plants contributed 23% of the worldwide installed capacity by the end of 2014[17].

Flash Steam Cycle Power Plants

Flash steam plants are using temperatures greater than 182°C[16]. Production fluids are pumped into a high separator tank at the surface which is held at a reduced pressure. The pressure changes cause some of the fluid to quickly vaporise resulting in an increase of steam fraction providing a greater proportion of steam available to drive a turbine. The liquid remaining in the tank can be reinjected into the reinjection well or flushed again in a second tank for further energy extraction before reinjection.

When production temperatures are over 210°C, a single flash setup is generally used. A double flash power plant increases the efficiency of the process by adding a second low pressure separator tank. A triple flash system uses a series of vessels for flashing the work fluid at successively lower pressures to maximise energy extraction[16].

Flash steam is the most common type of geothermal power generation with single flash conversion technology contributing to 41%, double flash contributing to 21%, and triple flash contributing to 2% of the world's geothermal power at the end of 2014[17].

Hybrid Flash-Binary Combined Cycle Power Plants

A hybrid flash-binary plant extends the life of traditional flash steam plants by adding a binary unit. This unit uses a heat exchanger to transfer the heat energy from the geothermal fluid to the "working fluid" used in a binary cycle[16]. There were only two hybrid cycle power plants in operation at the end of 2014[17].

Back Pressure Power Plants

Back pressure turbines exhaust the spent steam into the atmosphere instead of condensing steam into pressurised tanks. These plant designs have the lowest capital cost at the expense of lowest

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[12] Scotch Whisky Association., 2021. Distillery Map. [online] Scotch Whisky Association.
Available at: [Accessed 15 July 2021]

[13] Hernández Ochoa, A. F., Aragón Aguilar, A., & Franco Nava, J. M. (2021). An up-to-date perspective of geothermal power technology. In Sustainable Fuel Technologies Handbook (pp. 201–238). Elsevier. https://doi.org/10.1016/B978-0-12-822989-7.00008-1

[14] Bertani, R. (2016). Geothermal power generation in the world 2010–2014 update report. Geothermics, 60, 31–43. https://doi.org/10.1016/j.geothermics.2015.11.003

efficiency[15] and made up 1% of the world's geothermal power capacity at the end of 2014[17].

3.2.7. Efficiency Conversion of Direct Use Heat and Conventional Electricity Generation

Selling electricity can be a more attractive option to developers as revenue models can be much more favourable than direct heat sales. However, there is significant efficiency lost in converting heat energy into electric power generation. A worldwide review of average conversion efficiency of geothermal power generation is 12%[16], meaning 12% of energy from the produced geothermal fluid can be converted to electricity. However, this conversion efficiency value can vary and must be calculated for each geothermal power plant, but generally ranges between 1- 21%. This value is based on several factors such as fluid enthalpy, production temperature, geothermal plant generation (e.g., dry-steam, single flash, double flash, binary power, hybrid steam-binary and triple flash plant), non-condensable gas content, parasitic load, and turbine efficiency, to name a few[19].

In comparison, the conversion efficiency of geothermal heat is much higher because it can be applied almost directly in any industrial process. For example, the industrial use of geothermal energy in the Tasman Pulp and Paper Co. Ltd. estimates the energy it produces can be used at a high efficiency (c. 90%) when used for process heating, and at an efficiency below 20% if used for electricity generation[14]. Using steam in a direct-use industrial process maximises the efficiency of geothermal heat energy and when paired with the right industrial application can be just as profitable as electricity generation.

3.2.8. Table of Direct Uses of Geothermal Heat (>100°C)

Direct Uses of Geothermal Heat > 100°C		
Temperature Range (°C)	Use	Conventional Power (CP) (140°->200°C, Kurnia et al. 2022), Binary Power (BP) (60°-177°C, min - Kurnia et al. 2022, max - Hernández Ochoa et al. 2021) Direct-use Heat (DH) (60°-100°C, Lund 1997)
100	Vegetable drying	DH, BP
100 – 120	Drying and curing cement[8]	DH, BP
110 - 120	Lithium Extraction[8]	DH, BP
120-140	DH, BP	DH, BP
120 - 140	Evaporation in sugar and salt refining	DH, BP
120 - 130	Concentration of saline solutions[8]	DH, BP
120 - 140	Canning food	DH, BP
130	Distilling	DH, BP
140 – 160	Alumina via Bayer's process	DH, BP, CP
80 - 130	Preheating iron-ore concentrate slurry[8]	DH, BP
80 - 180	Wood drying[26]	DH, BP, CP
80 - 180	Absorption Refrigeration[8]	DH, BP, CP
140 - 160	Drying of fish meal	DH, BP, CP
160 – 180	Digestion in paper pulp	DH, BP, CP
170	Heavy water production	DH, BP, CP
190	Paper production	DH, BP, CP
190 - 200	Evaporation of highly concentrated solutions[8]	DH, BP, CP

[15] Bronicki, L. Y. (2008). Advanced power cycles for enhancing geothermal sustainability 1,000 MW deployed worldwide. 2008 IEEE Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy in the 21st Century, 1–6. https://doi.org/10.1109/PES.2008.4596118

[16] Zarrouk, S.J. and Moon, H., 2014. Efficiency of geothermal power plants: A worldwide review. *Geothermics*, *51*, pp.142-153.

190 - 200	Drying diatomaceous earth[8]	DH, BP, CP
140->200	Conventional electricity generation	DH, BP, CP
260 - 270	Zinc Extraction[8]	DH, BP, CP

Table 2 Direct uses of geothermal heat with production temperatures and level of energy production (compiled (from Lund 1997[2], Kurnai et al. 2022[4], and GeoScience Ltd 2022[5])

4. Case Studies of Direct Industrial Geothermal Heat Use

4.1. Celsius Project – Cornish Geothermal Distillery Company

The Celsius Project is a geothermal rum distillery proposed to be built using the waste hot water from the United Downs Deep Geothermal Power Project (UDDGPP) (figure 3). UDDGPP is the UKs first geothermal electricity project, located in United Downs, Cornwall[17]. It consists of two wells (doublet system) with a production well depth of 5275 m and injection well depth of 2393 m. The production well has a bottom hole temperature of 180-190°C.

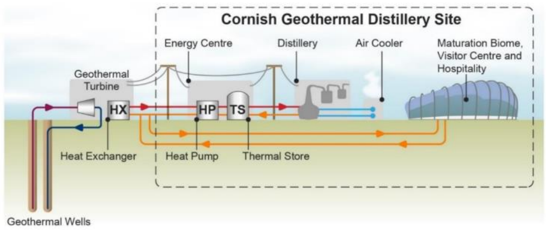

Figure 3 Model of the Cornish Geothermal Distillery Site.

The Distilling process aims to use the waste heat from the geothermal power plant. This will enter the distilling site at 80°C, and via industrial high temperature heat pumps will increase in temperature to 120°C. The waste heat from the distilling process, at a temperature of 60 – 70°C will then be used for other lower temperature heating requirements on site. There are future plans to develop site further to include a visitor centre, hospitality facility and a spa.

4.2. Jubilee Geothermal Pool, Cornwall

In Cornwall, UK, a geothermally heated open-air swimming pool has been developed to provide warm bathing waters (figure 4). During a £1.8 M upgrade of the whole swimming pool complex, a geothermal pool was also developed alongside. The geothermal aspect of the project was developed by Geothermal Engineering Limited and ARUP, with support from the European Regional Development Fund[18].

The Jubilee pool is one well system to a depth of 410 m depth. It uses a system of heat pumps to increase the temperature. The water temperature of the pool is kept at a constant temperature of 35°C [18] with a bottom hole temperature of c. 15°C, the heat has been increased by 20°C. Heat from geothermal production fluids is condensed using a heat exchanger and distributed to the pool. The used geothermal fluids are then reinjected into the subsurface.

Once the pool has been fully upgraded, the Jubilee Pool predicts a 35% increase in the 40,000 visitors it typically receives during summer months as it can now sustain increased visitor numbers during colder days / months throughout the year[21]. The project will increase tourist visits to the area and benefit the local economy.

Figure 4 Drill Rig at the Jubilee Pool Project (above) and the geothermally heated pool (left) (Photos: ARUP and Jubileepool.co.uk).

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[17] BEIS Green Distilleries Competition - Phase 1 - Cornish Geothermal Distillery – March 2021 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/978962/Cornish_Geothermal_Distillery_Company_Phase_1_Feasibility_Report.pdf

[18] https://jubileepool.co.uk/pool-info/geothermal/

4.3. Netherlands Greenhouses

4.3.1 Hoogweg Greenhouses

In the Netherlands, Greenhouses are heated using geothermal energy. This provides a sustainable and low carbon means of producing food. One example of this is the Hoogweg greenhouse which grows 160 hectares of bell peppers using geothermal heat (figure 5). Hoogweg have been growing in traditional greenhouse spaces since 1998, but in 2018, they upgraded their greenhouses by drilling geothermal wells. Geothermal energy provides the greenhouse with 70% of the heat required, combined with biomass. 95% of their required heat is supplied via renewable resources[22].

Figure 5 Hoogweg Paprikakwekerijen greenhouse operations spanning 160 hectares (www.hoogweg.nl)

In 2021, Hoogweg announced it was planning on drilling 2 more wells due to a decrease in the flow rate in the original wells. This will bring the total to 3 injection wells and 2 production wells which are planned to be operational by Summer 2022[19].

4.3.2. Nieuwlandseweg Greenhouses

Another geothermally heated greenhouse is the Nieuwlandseweg site. At Nieuwlandsweg, they have three deep wells on site to a depth of 1850m, with production fluid temperatures at 78°C at a rate of c. 350m^3 /h, and reinjection temperatures at 15-20°C. The heat obtained from the geothermal wells is transferred through a grid of pipework that distribute heat to each greenhouse. The wells are spaced 1.5 – 2km away to avoid thermal breakthrough, and subsequent cooling, of the production wells. The geothermal scheme is expected to provide heat for the next 30 years[20].

4.4. Huka Prawn Park – Taupo, New Zealand

Due to New Zealand's geographic location, the geothermal potential varies largely from the other case studies discussed in this report. New Zealand is in a region with a high geothermal gradient where greater subsurface temperatures are witnessed at shallower depths. The UK and Netherlands are regions with lower geothermal gradients where in order to reach equivalent subsurface temperatures it is necessary to drill wells to deeper depths.

The Huka Prawn Park is one of the examples of a geothermally heated aquaculture site and tourist destination in New Zealand (figure 6). Founded in 1987, the aim of the project was to use waste heat from the neighbouring geothermal power station to breed and grow tropical prawns in captivity. The Wairakei Geothermal Power Plant which feeds the waste heat to Huka Prawn Park, is an active 210.6 MW conventional electricity project, commissioned in 1958[21]. The project contains 54 production and 9 injection wells, reaching temperatures of 130°C at a maximum depth of 660 m[22].

Figure 6, Huka Prawn Park, 2021[23] .

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[19] [Geothermie - Hoogweg Paprikakwekerijen B.V](#)

[20] Nieuwlandseweg Greenhouse citation

[21] https://www.power-technology.com/marketdata/wairakei-geothermal-power-plant-new-zealand/

[22] Clotworthy, A. (2000). Response of Wairakei Geothermal Reservoir to 40 years of production, *Proceedings World Geothermal Congress 2000*.

[23] *https://hukaprawnpark.co.nz/*

The Huka Prawn Park uses a system of heat exchangers, transferring heat from geothermal fluids and combining it with freshwater pulled from the local Waikato River. This warmed water is then circulated through the ponds at c. 26°C and passed back to the river in an open-loop system. The heated pools create an ideal environment to raise a species of Giant Malaysian River Prawn that are ready to harvest at 8 months of age.

The Park has been a success with expansions in 1988 and 2002, resulting in a total of 19 ponds. When fully stocked, it can produce 5 tons of prawns per year. In 2006, the park expanded further to maximise their interactive tour route, introduced a Geothermal Foot Bath and built their 400-person capacity alfresco restaurant[24].

4.5. Carter Holt Harvey Woodproducts – Kawerau, New Zealand

Carter Holt Harvey (CHH) Limited is a privately-owned New Zealand-based company, whose origins date back to 1872 where it started as a steam-powered sawmill. It's now one of the oldest and largest producers of timber building products across New Zealand and parts of Australia[24]. As of 2018, CHH Woodproducts had a log intake of 630,000m^3 per year and 350,000m of sawn timber per year. They have been using geothermal steam to kiln dry sawn wood product in batch kilns[25] (figure 7). Wood drying (also known as *wood seasoning*) reduces the moisture content of the freshly milled "green" wood before its use. Excessive moisture levels in wood can warp and twist dimensional lumber within wood-supported architectures, bind and kick during machining, or buckle and crown installed wood surfaces which can cost businesses millions to repair. Advantages of kiln drying also include better control of the final moisture content, higher drying efficiency, faster drying times, and equal drying throughout the processed wood pile when compared to traditional air drying methods[26].

CHH Woodproducts uses steam supplied by the local Ngati Tuwharetoa Geothermal Assets Ltd, which produces process steam at pressures of 7 to 16 bar with around 2.8 GJ of thermal energy per tonne of steam[27]. Tuwharetoa Geothermal also produces process water at 170°C (7 bar) and continuously generates 21 MW of renewable electricity in a binary-cycle power plant. The steam is pumped into batch kilns at CHH Woodproducts mill where it operates on cycles between 80 to 140°C. Advantages of the direct geothermal use for kilning includes constant load energy demand profiles throughout the kilning process and the ability to maintain lower kiln temperatures at longer cycles, ideal for drying hardwood[28].

CHH is one of several timber drying kiln operators in the region and the technology in support of direct use geothermal is diversifying quickly. For example, another New Zealand-based power utility Contact Energy and company Nature's Flame have signed an agreement to build a geothermal heat supply system that will provide process heat to a wood pellet manufacturing plant. Where direct heat energy from Contact Energy will be used to dry wood fibre at the Nature's Flame plant. The pellets will be used to provide a sustainable alternative to burning fossil fuels as well as displacing emissions of particulate matter that occurs during the use of existing biomass boilers. Contact Energy will also provide heat to potential customers including the Huka Prawn Park aquaculture, Wairakei Resort Hotel,

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[24] *Our Business*. (n.d.). Carter Holt Harvey - About Us. Retrieved 14 April 2022, from https://chh.com/about-us/our-business/

[25] Carey, B. (2018). *Using Geothermal Energy for Kiln Drying Operations*. WoodTECH, Rotorua. https://www.nzgeothermal.org.nz/downloads/2018-09-19-Carey---Using-Geothermal-Energy-as-Process-Heat-for-Kiln-Drying-Operations.pdf

[26] Walker, J.C.F., Butterfield, B.G., Langrish, T.A.G., Harris, J.M. and Uprichard, J.M. (1993). Primary Wood Processing. Chapman and Hall, London. 595p.

[27] *Geothermal Operations: Producing renewable iwi energy from the Kawerau Geothermal Field*. (n.d.). Tuwharetoa Geothermal. https://www.tuwharetoageothermal.co.nz/geothermal-operations

Wairakei Terraces geothermal bathing and the Tenon Sawmill[28].

Figure 7: Geothermal-Kiln drying timber[28].

[28] Richter, A. (2019). *Geothermal operations in NZ to supply heat to wood pellet manufacturing plant*. Think Geoenergy. https://www.thinkgeoenergy.com/geothermal-operations-in-nz-to-supply-heat-to-wood-pellet-manufacturing-plant/

6. Discussion & Conclusion

The temperature range of 30 – 85°C of greatest interest to the client, who asked to understand the direct uses of geothermal energy at this temperature with a focus on industrial application. This temperature would provide decarbonised hot water for a number of heat intensive sectors, but industrial application is minimal with higher than 85°C temperatures generally required for industrial process heat.

The agriculture and farming sector have several uses for this temperature range for heating purposes. This includes soil warming, fermentation, mushroom cultivation, batch drying agricultural products (including crop drying), animal husbandry, pasteurising and greenhouse heating. The sector requires constant heating with little to no down time.

Food security and sustainable food systems are critical to achieve the worlds development goals. The sector is also critical to economic growth, in 2018 it accounted for 4% of global GDP (Gross Domestic Product)[29]. The market can be seen to be unstable in terms of supply of food, with climate change causing more extreme weather events, effecting crops and pests. This can affect food systems and supply causing higher food prices. Geothermal energy can create sustainable replicas of environment for crop growing. For example, by creating decarbonised green houses, a country is able to grow crops which are usually not compatible to its environment (eg peppers in northern Europe), increasing food security and supply of that country and reducing the transport related emissions of global food distribution.

The sector could also benefit from the reduction in carbon emissions. The agricultural sector (including forestry and land use change) is responsible for 25% of global gas emissions[29]. It is critical for governments to decarbonise their agricultural sector if they are to meet 2050 climate goals. Geothermal Energy could create an opportunity for a sustainable agricultural and food system, not only creating food security but also decarbonising a countries agricultural sector.

The leisure sector also requires temperatures of 30 – 85°C. Spa facilities and swimming pool warming require temperatures from 20 – 40°C. Focussed on recreation and tourism, the spa sector is a multi-billion dollar sector which continues to rapidly expand due to societies demands for 'self-care and wellness'. For example, the Blue Lagoon in Iceland is a geothermally heated spa which monopolises on being low carbon and sustainable, which was able to create increased tourist numbers to the spa. As seen in chapter 4.2, this has been moderately replicated by the Jubilee pool in Cornwall which had a 35% increase in visitors and can now be open all year round. By implementing geothermal energy, not only are you decarbonising the sector you are also able to create a tourist attraction from the sustainability aspect of the spa/swimming pool.

Housing developments could also be targeted for geothermal energy. This includes domestic hot water, district heating and cooling. The temperature required is 60 – 80°C. Ideally, new building estates should be targeted as retrofitting can be costly, however this option is not unfeasible for a geothermal installation. With global populations rapidly increasing, housing will become a major issue, with new urban developments being predicted, including housing, schools and hospitals. In the UK domestic heating and hot water accounts for 15% of national greenhouse emissions[30], and it is an incredibly important sector to decarbonise with the rapid approach of climate goals.

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[29] https://www.worldbank.org/en/topic/agriculture/overview#1

[30] https://eciu.net/analysis/briefings/low-carbon-heat/decarbonising-heat-the-basics

In conclusion, the sectors with the highest temperature demand for the range 30-85°C, is the agricultural sector, the leisure sector, and the domestic heating market. These three sectors currently have high emissions associated with heating, which could be decarbonised through the instalment of geothermal energy.

Looking forward through the rapid decarbonisation required up to 2030, it is recommended that 85 Degrees partners with several companies in these sectors to attract investment in co-located agricultural or leisure facilities, expanding 85 Degrees revenue streams beyond conventional geothermal energy use. To progress industrial process heat application at this temperature range further R&D is required to understand specific growth areas of process heat requirements and areas where existing industrial processes could be achieved at lower temperatures. Integration with high temperature heat pumps should also be considered.

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