

# Increasing Opportunity for Geothermal Direct Use in New Zealand, Indonesia, and the Caribbean

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## Keywords

*Direct use, geothermal process heat, geoheat, New Zealand, Indonesia, Caribbean*

## ABSTRACT

Geothermal direct use has an increasing role in the decarbonization of energy, especially in process heat through direct heat uses. This paper provides recent updates on New Zealand's industrial geothermal direct use and recent studies for potential direct heat use in Indonesia and the Caribbean. Geothermal process heat in New Zealand is now used to process woody biomass (the main decarbonization fuel in New Zealand), used more in dairy processing plants, increasingly used in process industries converting from gas-fired boilers, and is expected to be used more in food production/horticulture, among others. Recent studies indicate that there is potential for an increased uptake of geothermal direct heat use in Indonesia and the Caribbean. These opportunities so far have primarily included using geothermal direct heat for industrial processes in New Zealand and having wider application on processing of agricultural produce in Indonesia, offering higher quality, less wastage and better market access due to low carbon input. Although the CO<sub>2</sub> emitted from direct use is lower per unit of energy than for power generation, the testing/deployment of technologies available to reinject the low levels of geothermal CO<sub>2</sub> is needed to be competitive against other decarbonization options.

## 1. Introduction

Geothermal direct heat use is the use of geothermal energy for non-power generation purposes. It spans the traditional use of geothermal springs and hot pools for bathing, cooking, and heating homes to the use of geothermal process heat from geothermal bores for use in industrial processes and to the use of geothermal heat pumps to heat and cool large buildings and campuses. The range of geothermal direct heat uses are shown in Figure 1.

Geothermal direct heat use development generally requires development at scale or a co-located power plant development to off-set the cost of drilling wells and installing surface facilities.

However, geothermal direct heat use is also a more efficient use of geothermal energy as opposed to electricity generation because it can be used directly as process heat in heat exchangers or as direct process steam in drying kilns for example. In contrast, geothermal energy to electricity has a 12% energy conversion efficiency (Zarrouk and Moon, 2012). The increasing demand for low-carbon, renewable and reliable process heat is resulting in an increased interest in geothermal direct use opportunities alongside electrification of industries.

Globally, 88 countries utilize approximately 107,000 MW thermal of geothermal direct use energy (as of 2020), and direct use applications tend to create an order of magnitude more jobs/livelihoods compared to power generation (Lund and Toth, 2020). In the next sections, we provide updates on geothermal direct heat use opportunities in New Zealand, Indonesia, and the Caribbean.

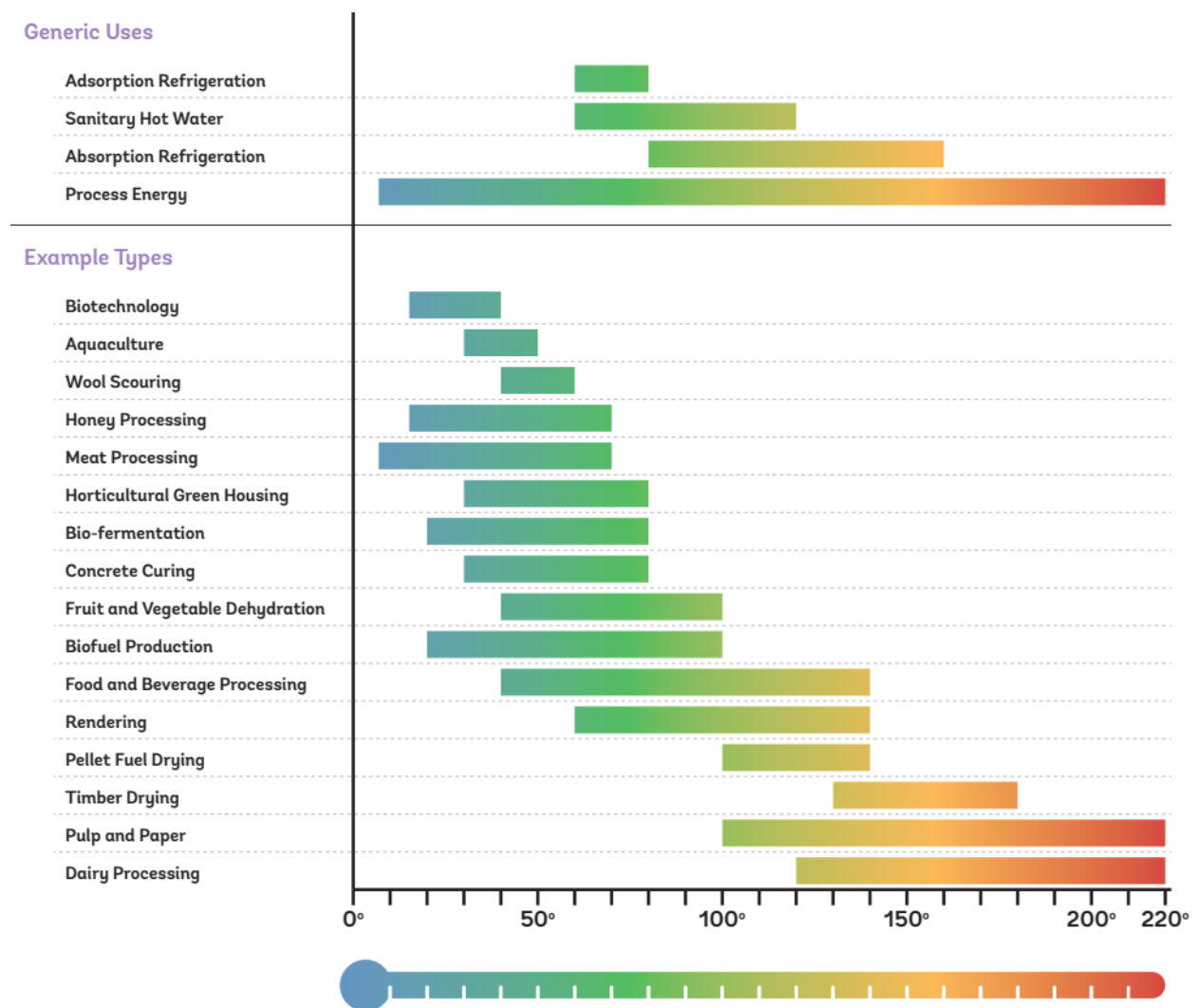


Figure 1. Geothermal heat uses (from Climo et al., 2022).

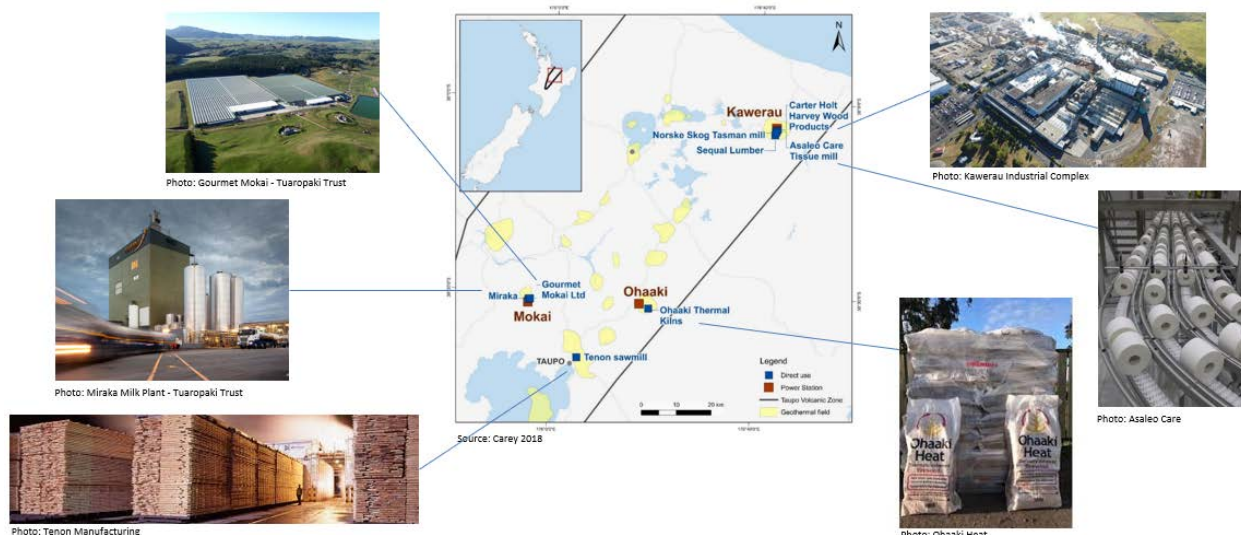
## 2. New Zealand Case Study

### 2.1 Background

In New Zealand, Māori have traditionally used geothermal energy for cooking, heating, bathing, and growing crops before any large-scale industrial uses were developed (Severne, 1995; Adlam and King, 2015). In addition, geothermal has been a tourism drawcard for towns like Rotorua since the 1880's.

In the 1950's, large-scale industrial use of geothermal process heat started in the Tasman Pulp and Paper Mill at Kawerau. Geothermal energy was used to produce electricity but was also used as process heat in the pulp and paper mill (Hotson, 1994; Hotson, 1995).

By 2018, industrial geothermal process heat use was much more widespread in the Taupō Volcanic Zone with examples shown in Figure 2. Geothermal heat was used in greenhouses (Gourmet Mokai, Plenty Flora), dairy (Miraka), honey processing (Arataki), wood products (Carter Holt Harvey, Ohaaki Heat), timber (Sequal, Tenon), and pulp and paper processing (Norkse Skog Tasman, Essity, Oji Fibre Solutions), among others.



**Figure 2. New Zealand industrial geothermal direct heat users (from NTGA, 2018).**

In addition to industrial process heat, New Zealand also uses geothermal energy for heating homes and large spaces. The towns of Rotorua and Taupō have examples of long-term geothermal direct heat use for homes and buildings.

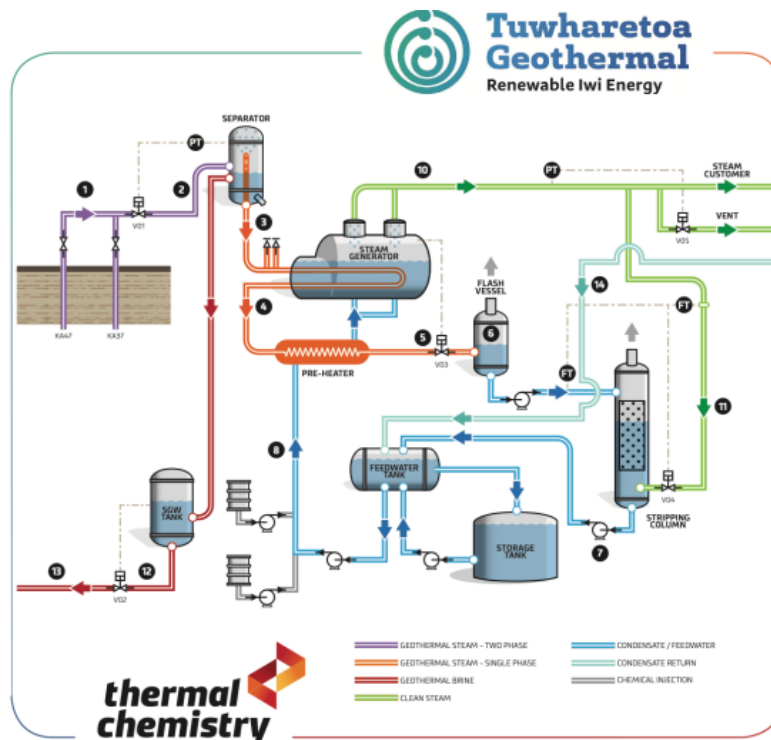
### 2.2 Recent updates

#### 2.2.1 Kawerau Industrial Complex

The Kawerau Industrial Complex in the Bay of Plenty region of New Zealand is one of the largest and longest-operating geothermal process heat users in the world. Direct heat has been used for processing pulp and paper since the 1950's with direct heat users in timber drying, wood products, and dairy processing using geothermal energy supplied by Māori-owned geothermal company Ngati Tuwharetoa Geothermal Assets Ltd (NTGA).

In the last three years, there have been significant changes to the geothermal energy use of the Kawerau Industrial Complex brought about by efforts to decarbonize process heat, the changing commodity markets, and the impact of COVID-19.

Waiū Dairy, a new dairy processing plant that focuses on high-value dairy products, started operations in Kawerau in 2019 using geothermal “clean” steam supplied by NTGA. The dairy processing plant is a joint venture between 11 Māori entities and Cedenco Dairy, a company owned by Imanaka, a Japanese company. Geothermal clean steam at 16 bar(g) (204 °C) is supplied to the dairy plant at around 4-6 t/hr. This is equivalent to a supply of 11-18 GJ/hr of process steam. NTGA’s clean steam technology is described by Moore (2011) and Addison et al. (2020) and was originally developed by the Tasman Pulp and Paper Mill (Hotson, 1994; Hotson, 1995; Climo et al., 2021). The latest schematic configuration is shown Figure 3 below. Separated geothermal steam from geothermal wells is used to boil clean water in a secondary steam generator boiler.



<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
2 Phase Geothermal	2 Phase Geothermal	Separated Steam	Steam/Condensate mixture	Sub-cooled Condensate
40 Bar(g) 252°C 310 tonnes/hr	22 Bar(g) 220°C 310 tonnes/hr	22 Bar(g) 220°C 35 tonnes/hr	22 Bar(g) 200°C 35 tonnes/hr	22 Bar(g) 130°C
<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>
Flashed Condensate	Stripped Condensate	Feedwater	Heated Feedwater	Clean Steam
0 Bar(g) 100°C	0 Bar(g) 100°C	16.5 Bar(g) 95°C 28.5 tonnes/hr	16.5 Bar(g) 190°C 28.5 tonnes/hr	16.5 Bar(g) 200°C 28.5 tonnes/hr
<b>11</b>	<b>12</b>	<b>13</b>	<b>14</b>	
Stripping Steam	Separated Water	Flashed SGW	Process Condensate Return	
16.5 Bar(g) 200°C 2.5 tonnes/hr	22 Bar(g) 220°C 280 tonnes/hr	12 Bar(g) 192°C	1 Bar(g) 80°C 0-25 tonnes/hr	

Figure 3. The Ngati Tuwharetoa Geothermal Assets Ltd clean steam plant (Addison et al, 2022).

Oji Fibre Solutions, a pulp, container board, packaging, and chemicals business, increased their use of geothermal process heat in their Kawerau mill through the replacement of a wood and coal-fired boiler with geothermal clean steam (Figure 3) in 2019. Oji Fibre Solutions' Kawerau mill uses between 1.5 to 2.6 PJ of geothermal process heat per year but can be supplied up to 3.7 PJ at peak processing capacities (Oji Fibre Solutions, 2019; 2021). The geothermal process heat is supplied by NTGA. The increased conversion of fossil-based process heat to geothermal process heat is estimated to have avoided around 20,000 tons per year of greenhouse gas emissions at Oji Fibre Solutions and provided around NZ\$4 million operational savings per year. Through increased geothermal process heat use in the Kawerau mill, the biomass that would otherwise be used as fuel is now able to be transported to the Oji Kinleith Mill in Tokoroa and further off-set its use of fossil fuels for process heat. Oji Fibre Solutions claims to be the largest process heat user in New Zealand (Oji Fibre Solutions, 2019).

Norske Skog Tasman mill, a newsprint paper processing plant and one of the industrial geothermal direct heat use pioneers in New Zealand, has shut down its operations in 2021 after 66 years of operations. The newsprint plant was shut down due to the global decline of the paper publication industry and the impact of COVID-19. The closure resulted in a reduction of around 2.4 PJ per year of geothermal process heat demand.

Essity (former Asaleo Care), a 60,000 tons per year tissue paper manufacturer at Kawerau and a pioneer in the use of high-pressure clean steam geothermal process heat (Moore, 2011), has won NZ\$1.65 million in government funding through the Government Investment in Decarbonizing Industry (GIDI) Fund to convert one tissue machine to run using 100% geothermal steam instead of using natural gas. The conversion from natural gas to geothermal steam reduces greenhouse gas emissions and supports the local economy. Additional details about the project are described by Essity (2021).

### 2.2.2 Taupō Industrial Direct Use

Contact Energy supplies several industrial direct heat users through its geothermal operations in the Ohaaki, Wairakei, and Tauhara geothermal fields. These include geothermal heat supply to the Ohaaki kilns, Wairakei Resort, Huka Prawn Park, Wairakei Terraces, Tenon and recently Nature's Flame.

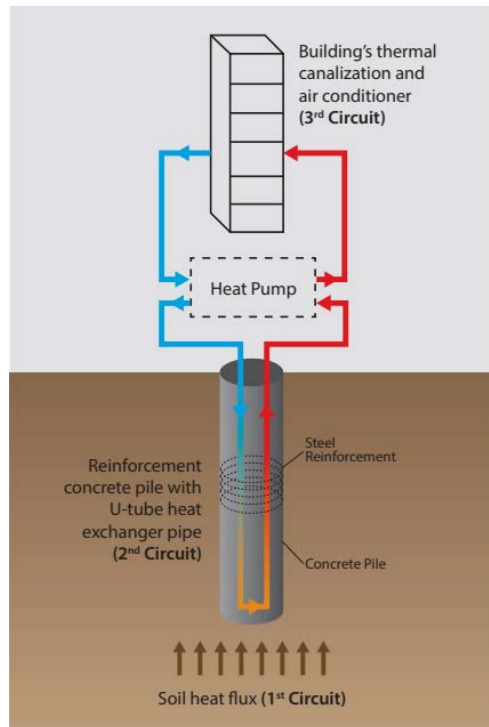
In 2019, Contact Energy started supplying geothermal process heat to Nature's Flame in Taupō to replace an existing fossil-based boiler that could not meet the plant's energy requirements at full production capacity. The process heat supply uses the remaining thermal energy of the fluid exiting another direct heat user Tenon, increasing the overall efficiency of the geothermal production well for both companies. Nature's Flame is a wood pellet manufacturer that uses wood shavings and saw dust to form an energy dense fuel that can be used as a substitute for fossil-based process heat. Geothermal energy is used to dry the wood fibers and the wood pellets allow the geothermal energy to be "transportable." Wood pellets and biomass are a key solution to decarbonizing process heat in New Zealand. In 2020, Fonterra, the largest New Zealand company, announced the conversion of their Te Awamutu Dairy Factory from coal to wood pellets, which will be exclusively supplied by Nature's Flame.

Tenon started using geothermal process heat in 2006 and has recently increased their geothermal energy use supplied through an upgraded geothermal heat plant.

### 2.2.3 Geothermal Heat Pumps and Energy Piles

Geothermal heat pump (GHP) technology has been proven successful in New Zealand, but uptake has been limited, with most of the recent examples of GHP systems being installed and operated at Christchurch in the South Island of New Zealand (Seward et al., 2014). The most famous recent example is the Christchurch International Airport which uses GHPs or ground source heat pumps (GSHPs) for heating and cooling spaces. The system uses the artesian groundwater at a stable 12°C temperature to provide geothermal energy to the heat exchangers through an open loop groundwater GHP system. Recent upgrades have resulted in the airport transitioning to 100% heating and cooling by the GHP system. The Christchurch International Airport sustainability strategy and GHP system are further described by Locke (2022).

In 2016, the Hutt City Council Administration Building in Wellington, New Zealand installed the first geothermal energy piles in the country to be used for an energy efficient geothermal heating and cooling system. The Hutt City Council building has 72 structural energy piles containing pipework for a closed-loop GHP system (Central Heating New Zealand, 2022). The schematic for the energy pile system is shown in Figure 4.



**Figure 4. Geothermal energy pile schematic (from Central Heating New Zealand, 2022).**

### 2.2.4 Rotorua direct heat use

The Rotorua geothermal heating scheme has been repeatedly studied for potential wider uptake balanced with ensuring the sustainability of the geothermal resource due to geothermal's significance to the local community and the tourism industry. Some of these reviews and studies are described by Lind (2012), and Zuquim and Doorman (2020).

A new luxury geothermal spa called Wai Ariki Hot Springs and Spa is being developed near the lakefront of Rotorua, New Zealand partly funded by the New Zealand Provincial Growth Fund (a national government grant scheme). At full capacity, the geothermal spa complex will utilize up to 800 tonnes per day of hot geothermal fluid produced from bores tapping the Rotorua Geothermal System (Bay of Plenty Regional Council, 2020a). The conceptual design assumes a cascading use of the geothermal water starting with the first heat exchanger for space heating, then the geothermal fluid itself for hot pools, before being reinjected into purposely drilled reinjection wells (Bay of Plenty Regional Council, 2020b).

### ***2.3 Opportunities***

New Zealand's geothermal energy resources have a key role to play to help decarbonize the New Zealand energy system. While the electricity grid is largely renewable, the process heat and primary energy sectors are heavily reliant on fossil fuels. According to the latest Energy in New Zealand report, only 27.9% of the country's total energy demand is met by renewable energy (Ministry of Business, Innovation & Employment, 2021).

Increasing prices for carbon emissions and government funding support for fuel conversions to decarbonize process heat have increased the opportunities for increased geothermal direct heat use in New Zealand. The New Zealand Geothermal Association, through its Geoheat action group, continue to advocate for increased uptake of geothermal heat (Climo et al., 2022).

The large-scale process heat users of geothermal steam and hot water would likely be based on the main industrial direct use heat complexes in Kawerau, Taupō and Mokai. These locations have geothermal energy capacity available to supply to new users, are mature operations with existing resource consents, have available industrial land, and are connected to services and co-located with power generation facilities and transportation infrastructure. Taupō's 168 MW Tauhara Power Plant development (Contact Energy Ltd.) includes plans for a direct heat use energy park that aims to expand the direct heat use operations in the area (Climo et al., 2022). Kawerau's Norske Skog Tasman area and the Putauaki Industrial Area are prime industrial-zoned land that should also attract interest, including the availability of the geothermal energy supply that used to go to Norske Skog Tasman at around 2.4 PJ per year.

The success of the modern geothermal heat pump (GHP) projects either using open loop groundwater systems in Christchurch or the closed loop geothermal energy piles used in Wellington would provide case studies to improve and further deploy the technology in future projects.

Geothermal district heating systems have the potential to improve the standard of home heating in New Zealand. According to the feasibility study and workshop for geothermal district heating in a new Taupō subdivision project carried out by Wells and others (2021), there is support for a renewable and reliable home heating and cooling system using geothermal. The feasibility study and workshop have generated an interest from property developers. However, details around the economics, technology, ownership models, and environmental effects are being further explored.

The growing Māori economy and active participation of Māori commercial organizations in geothermal development also provide opportunities for direct heat use projects. Māori organizations are currently involved in geothermal development either as landowners of areas

where geothermal systems are located, as geothermal field operators themselves, or as geothermal process heat users through Māori-owned businesses.

### **3. Indonesia Case Study**

#### ***3.1 Background***

Indonesia has one of the largest geothermal resource potentials in the world and is second only to the United States in installed geothermal power plant capacity. However, geothermal direct heat use uptake has been modest, with examples focused on geothermal heat for bathing, tourism, and a number of cascade uses from existing power plant operations.

As reported in the 2015 and 2020 World Geothermal Congress, there has been no notable addition to Indonesia's geothermal direct heat use activities (Lund & Boyd, 2015; Lund & Toth, 2020). The reports indicate that geothermal direct heat has been used for the distillation of vetiver oil, mushroom cultivation, palm sugar processing, fish farming, and copra, cocoa, coffee, and tea drying. These activities are small scale (Surana et al., 2010).

#### ***3.2 Recent updates and Opportunities***

Jacobs has recently reviewed options for direct heat use in several geothermal resource locations in Indonesia and has identified potential pilot projects to use geothermal energy for drying and processing tea. A proposed project will use excess geothermal hot water from existing operations to supply 1 MWth of geothermal process heat, with options for the system to be deployable in other locations. The geothermal hot water will be used to heat non-geothermal water, a secondary working fluid that will then be the process heat used for drying tea. This process aims to minimize the risk of contaminating the product with geothermal fluids.

The use of geothermal heat for tea drying is predicted to replace the use of wood as a fuel source which has been suspected of introducing contaminants in the dried tea and has resulted in limited access to European markets and lowered overall value of the final product. Therefore, geothermal not only can reduce existing carbon emissions, but also reduce pressure on forests as a fuel and increase product quality.

A study of the geothermal direct heat use in Mataloko, Flores Island, indicates the potential for using geothermal heat from one of the drilled exploration wells for drying agricultural products, mainly coffee (Rachmadani et al., 2021). A parallel study carried out by Jacobs indicate that if the geothermally heated coffee drying system is constructed, it will have a positive impact on the community and the economics of local coffee production (Fikha et al., 2021).

PT Geo Dipa Energi (Persero) has presented a study on the potential for geothermal direct heat use in Dieng, Indonesia (Banjarnahur, et al., 2020). The study recommends prioritizing space and water heating, hot pools, and agricultural product (carica) processing with opportunities for greenhouse and coffee drying.

## 4. Caribbean Case Study

### 4.1 Background

The Caribbean countries have geothermal resources that remain largely undeveloped but can be utilized for both power generation and geothermal direct heat uses. Viable geothermal resources have been proven to exist in Dominica, Guadeloupe, Montserrat and Nevis through drilling while deep geothermal resources have been indicated in other locations (Figure 5). Geothermal power development has been achieved in Guadeloupe while the other proven deep resources remain undeveloped.

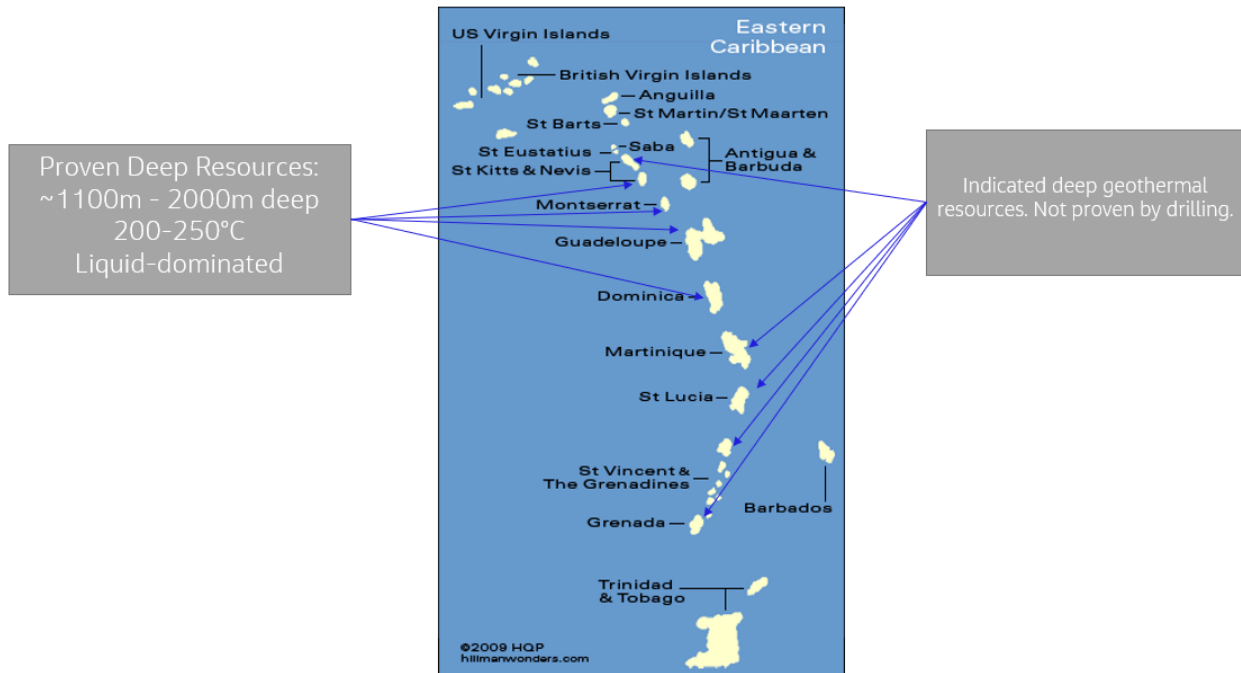


Figure 5. Geothermal resources in the Caribbean (from Jacobs, 2022).

### 4.2 Recent updates and opportunities

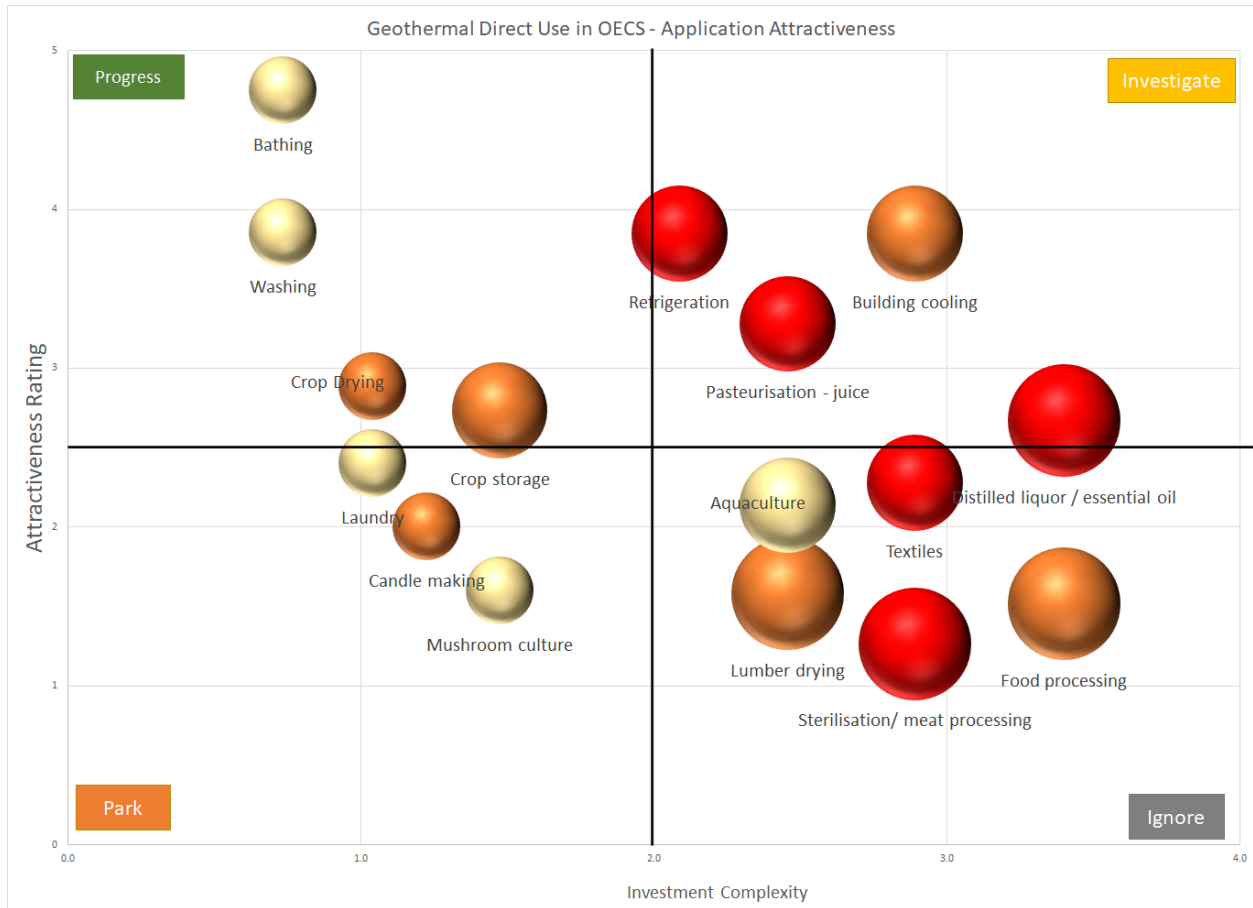
Jacobs has recently completed a study on non-electricity generating uses for geothermal resources in the member states of the Organization of Eastern Caribbean States (OECS). The relevance of potential geothermal direct heat uses was determined by understanding the energy available, the materials and inputs required, the impact of the local climate to the potential application, the level of investment required, and the market characteristics for the end-products. Examples of potential geothermal direct heat uses in the OECS is summarized in Figure 6.

#### 4.2.1 Dominica

The opportunity for geothermal direct heat use in Dominica is to use geothermal process heat for crop drying and for distillation of essential oils. Existing geothermal wells have the capacity to provide process heat that is sufficient to distill over 1,000 liters of essential oils per day, with the geothermal process hot water sufficient to dry at least 20 tonnes of fruit per day.

### 4.2.2 Montserrat

The opportunity for geothermal direct heat use in Montserrat is to use geothermal process heat for a cold storage facility to support exports, process heat for industries such as bricks/aggregate processing, and process heat for tourism activities such as spas. Capacity from an existing geothermal well is sufficient to supply process heat for a 6000 m<sup>2</sup> cool storage facility, drying of 20 tonnes of fruit per day and process heat for large pool heating.



**Figure 6. Attractiveness rating and investment complexity of the potential geothermal direct heat uses in the OECS.**

### 4.2.3 Nevis

The opportunity for geothermal direct heat use in Nevis is to use geothermal process heat for space cooling for tourism facilities and process heat for spa complexes. The direct heat application would use hot water exiting a power plant, with sufficient process heat available to cool a 30,000 m<sup>2</sup> facility and provide process heat for a spa.

## 5. Conclusions

- Geothermal direct heat use opportunities are increasing due to the decarbonization of energy and interest in expanding the use of local, renewable and reliable geothermal energy.
- Geothermal direct use allows the utilization of geothermal resources of lower energy grade than typically used for power generation (higher enthalpy / temperature) and, being more widespread, are potentially more accessible to users.
- Direct heat use is a much more efficient use of the primary energy source than producing electricity, especially at lower temperature sources where the efficiency of energy conversion to electricity can be as low as 10%.
- New Zealand's geothermal process heat use reduction due to declining newsprint market is balanced by growth in other process heat users due to social and market incentives to displace fossil-based fuels and decarbonize process heat.
- District heating, geothermal heat pumps for large buildings and spaces and geothermal energy piles have been successfully installed in New Zealand, with potential for increased deployment.
- Indonesia's geothermal direct heat use opportunities are dependent on local process heat needs and require additional successful case studies to increase uptake.
- Immediate opportunities for direct heat use in the Caribbean are mainly around process heat use in agriculture and tourism.

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