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DIRECT USE OF GEOTHERMAL RESOURCES

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ABSTRACT

This paper presents an overview of direct use of geothermal resources and key considerations for their development.

1. INTRODUCTION

Although electricity production is nowadays under the lights because of the highly praised value of electricity, direct use of geothermal resources should not be neglected. Direct heat use is actually one of the oldest and most common form of geothermal utilization.

In 2010, direct use applications installed capacity was about 50 GW_{th} with a total annual use of about 438 PJ/year (according to the International Geothermal Association database; without GSHP).

The most spread forms of direct use are space heating, balneology, horticulture, aquaculture and some industrial uses. Geothermal heat pumps are furthermore currently the most widespread type of direct utilization of low temperature energy.

2. DIRECT USE

1.1 Definition

The direct use of geothermal resources is the use of the heat energy or the fluid from geothermal resources without intervening medium as opposed to its conversion to other forms of energy such as electrical energy.

Most direct use applications can be applied for geothermal fluids in the low to moderate temperature range 20 - 120°C. Low to medium temperature geothermal resources have been used for ages especially in a first time for bathing and later on for space heating and farming applications.

Low and medium temperature geothermal fields can be found in many places around the world. Such fields can hardly be utilized for power generation in steam turbines nor binary plants, mainly due to economic reasons. These fields might however fit perfectly for direct use applications.

In addition to being more common than high temperature fields, low and medium temperature fields are often more accessible and/or closer to potential end-users, which makes direct use of geothermal resources an interesting option.

3. MARKET PROSPECTS

3.1 Direct use of geothermal resources worldwide

It is rather difficult to obtain an accurate picture of the actual amount of heat used for direct use overall and per application. It is partly due to the broad range of applications concerned and to the fact that such use is somehow more difficult to monitor at local or national level as it may be used for individual decentralized units or applications. The International Geothermal Association holds an inventory every 5 years. Figure 1 shows an overview of the countries with the highest direct use yearly energy consumption as of 2011.

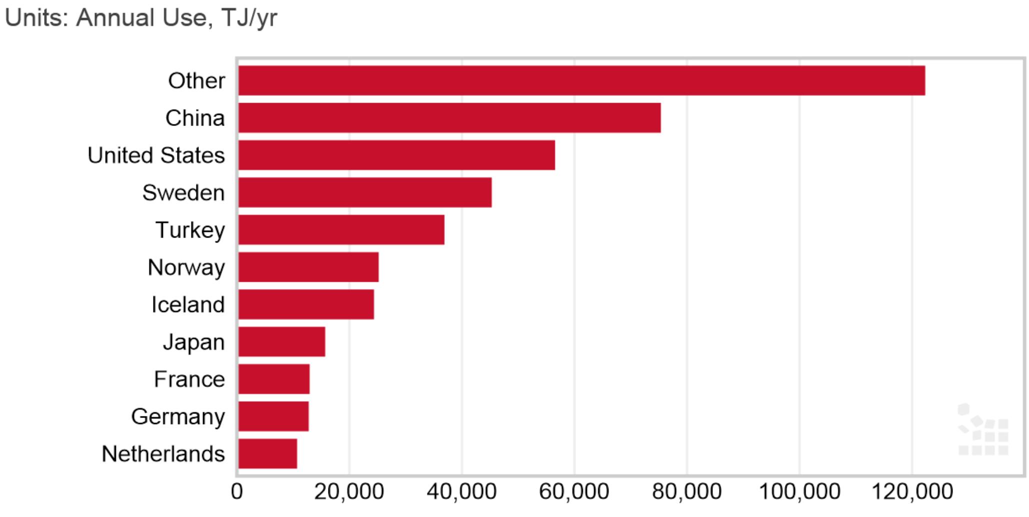

FIGURE 1: Direct use – Top 10 countries in 2011 (Íslandsbanki, 2011)

The total heat used for direct use of geothermal, excluding the ground source heat pumps amounted to nearly 26,000 GWh per annum in 2010 in the member countries of the International Energy Agency Geothermal Implementing Agreement (IEA-GIA). According to the same source, the heat used for ground source heat pumps in these countries amounted to approximately 30,000 GWh/a in 2010. On a world scale, the heat used in such applications was estimated to be about 60,000 GWh/a.

Figure 2 shows the heat used for direct use among the IEA-GIA countries in 2010 combining the ground source heat pumps with other applications. Disregarding ground source heat pumps that may be applied for various uses (space heating, swimming pools etc.), district heating and space heating accounted for the most current direct uses of geothermal resources in the IEA-GIA countries in 2010.

3.2 Potential market

About 25% of US energy use occurs at temperatures < 120°C and most of it comes from burning natural gas and oil.

Figure 3 shows the spectrum of U.S. thermal energy use and may be extrapolated to some extent to other parts of the world. In any case, the potential for utilizing low and medium temperature geothermal resources is huge. Direct use of geothermal resources should always be in the picture when considering potential applications for a given field.

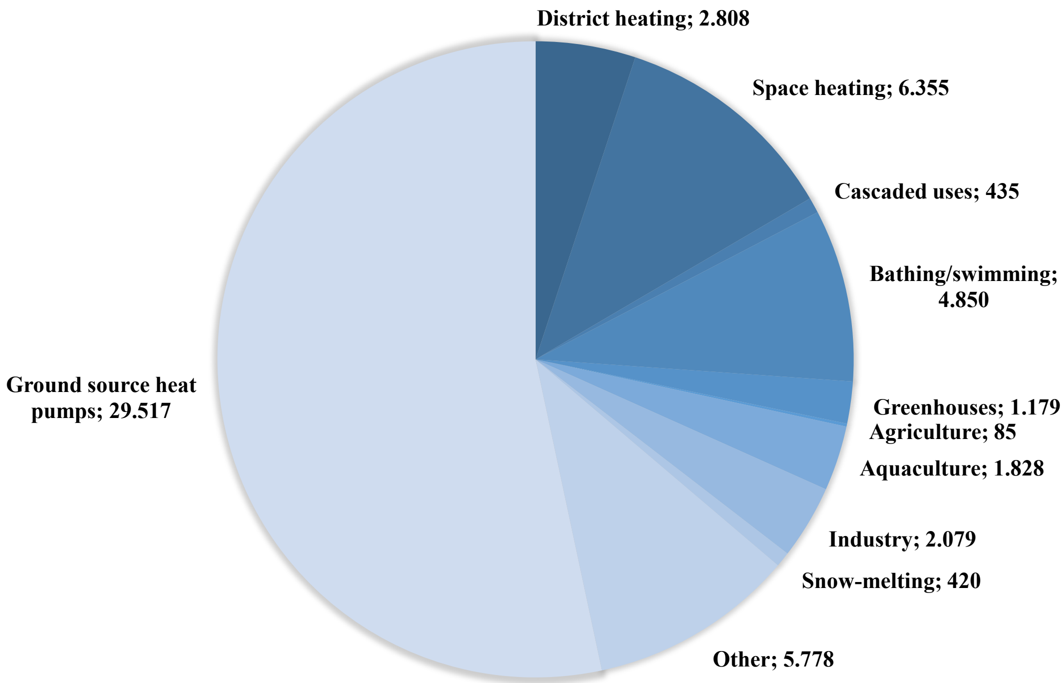

FIGURE 2: Direct use of geothermal heat in 2010 among the IEA-GIA countries (GWh/a) (Ganz, 2012)

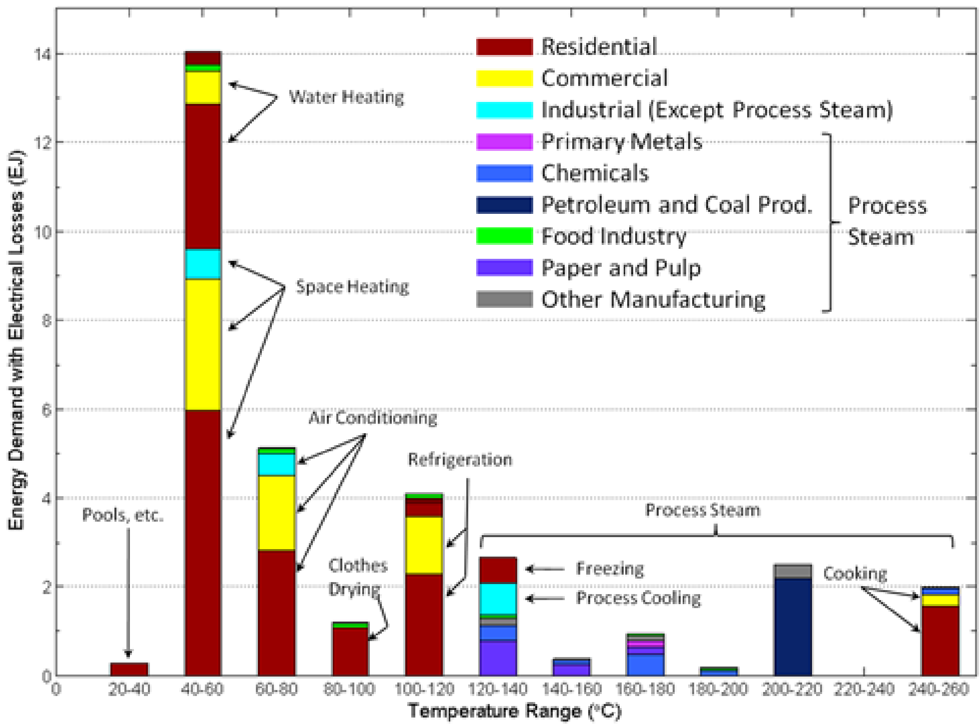

FIGURE 3: The thermal spectrum of U.S. energy use. Energy consumed as a function of utilization temperature (Tester, 2013)

4. POTENTIAL USE OF LOW TO MEDIUM TEMPERATURE GEOTHERMAL RESOURCES

Finding an adequate application for geothermal resources is not always a straight forward task as the way a geothermal resource may be utilized will be highly dependent on various factors such as:

- The characteristics of the resource: temperature, flow, chemistry and other parameters related to its sustainable utilization.
- Economic considerations related not only to the potential market for the product resulting from the resource exploitation or how easily available the resource is but also to the capability of the entity entitled to exploit the resource in terms of experience in exploiting geothermal resources and experience in the field of the application selected.

The utilization of geothermal energy depends on the resource temperature as is shown in Figure 4.

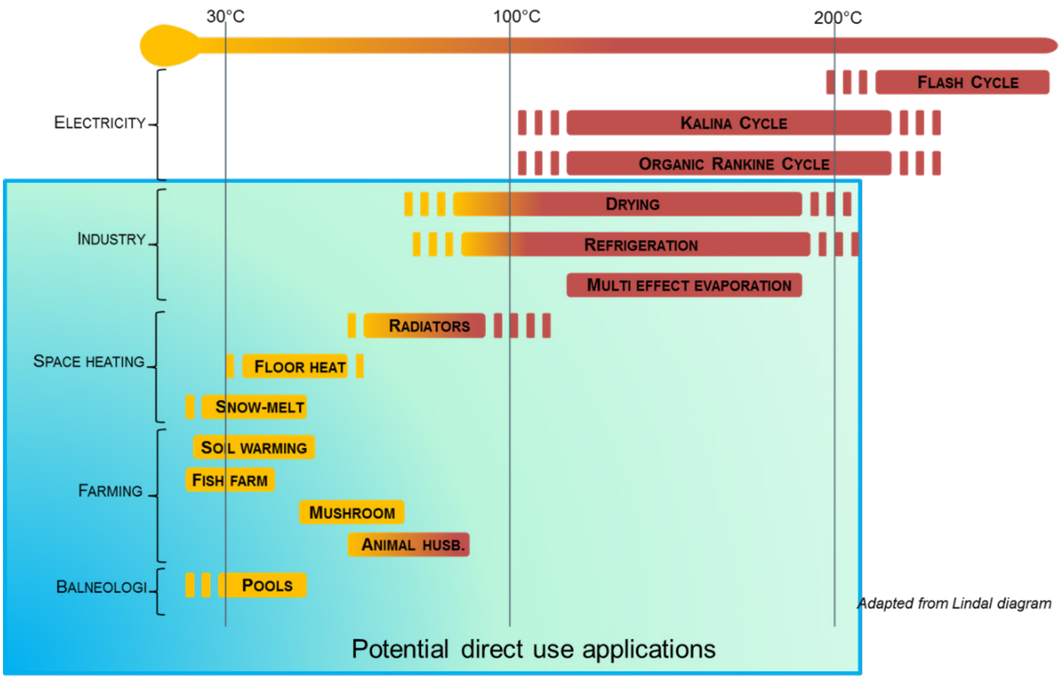

FIGURE 4: Geothermal utilization (adapted from the Líndal diagram)

The figure is mainly indicative and may contribute to narrowing down the potential uses for a given geothermal resource. The most common geothermal direct use applications are briefly presented below.

4.1 Swimming, bathing and balneology

Thermal waters have been used for centuries all around the world. Hot spring resorts are very popular places. In some cases the thermal waters are well known for their therapeutic properties and health centres have been in place for decades or centuries. Geothermal heat can also be used in swimming pools and spas. The temperature of the resource and its mineral content are important parameters

4.2 Space heating and cooling

Geothermal district heating is defined as the utilization of the earth's thermal energy for space and water heating. It can also be applied to space cooling. Space heating and cooling can either be developed for individual users or as district systems.

District systems usually combine wells, gathering and distribution systems, heat central and peak load equipment to supply heating or cooling to a group of buildings. It can also be used in co-generation cases. Iceland has been a pioneer in this field with a total installed heating power amounting to 1.4 GWth in 2011 and around 90% of homes use geothermal energy for space heating. The first house being heated with geothermal water in Iceland was as early as 1909 and the first commercial geothermal district heating system was fully developed in 1930.

Geothermal heat pumps also play an important part for individual space heating or cooling with the use of either ground or water source heat pumps. Such applications are fairly common now in Europe. Space cooling from geothermal can be successfully achieved with heat pumps.

4.3 Horticulture

Geothermal resources are ideal for horticultural applications especially when a large amount of low temperature geothermal fluid is available for heating greenhouse, soil warming and irrigation.

Geothermal horticulture was first experimented with in Iceland in naturally warm soil to grow potatoes in 1850 (Hansson, 1982). All kind of crops – tomatoes, mushrooms, cucumbers, paprika but also potted plants or flowers - can be grown thanks to the use of geothermal heat (Figure 5). Such use might contribute to significantly reduced operation cost and is seen as an interesting option for commercial operation in cold climates, with high heating requirements. In hot regions, the geothermal energy might be used for humidity control or to counteract the night cold in desert areas. It might also be a source of CO_2 for enrichment inside greenhouses.

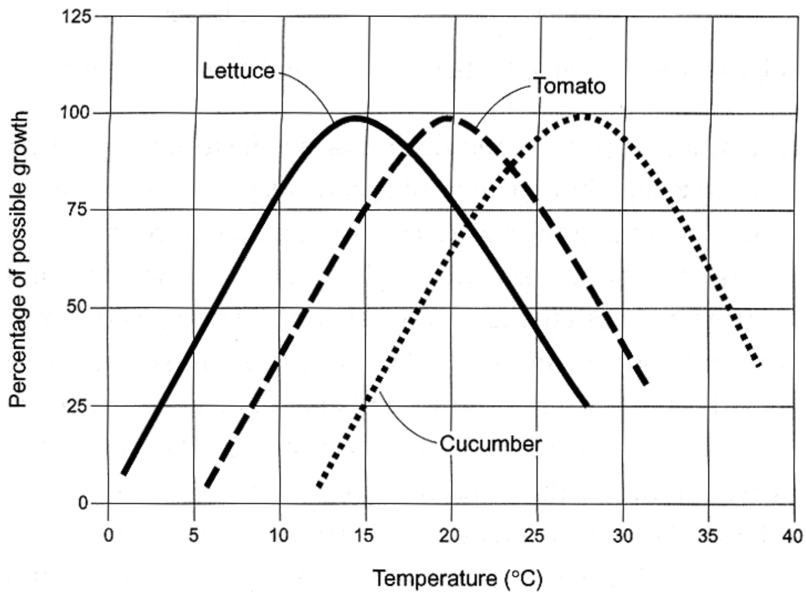

FIGURE 5: Optimum growing temperature for various species (Beall and Samuels, 1971)

4.4 Aquaculture and livestock farming

Aquaculture or aqua farming is the raising of aquatic animals such as fish, crustaceans, molluscs and aquatic plants. The farming activities are practiced under controlled conditions. The most common species raised are catfish, bass, tilapia, sturgeon, shrimp, and tropical fish. One of the purposes is to enhance the growth rate. Livestock farming is also a rather common application.

The use of geothermal resources in aquaculture depends on the type of aquatic animals raised, the quality of water and its composition. The geothermal fluid is in general used directly in the pond or pool to provide the heat required. Heat exchanger might be required if the geothermal fluid is unfit for the aquatic animals raised. Typical water temperature range is 13-30°C (Figure 6).

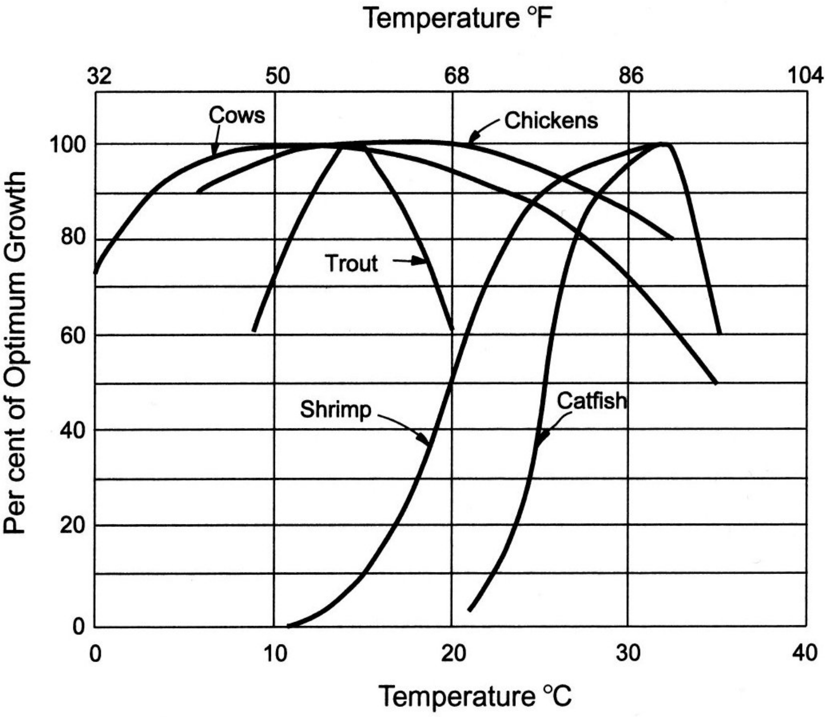

FIGURE 6: Optimum growing temperature for various species (Beall and Samuels, 1971)

4.5 Industrial applications

Industrial applications encompass a rather wide range of industrial activities requiring fluid at low to medium temperature for instance to preheat, wash, evaporate, distillate or dry. They may also be used to produce salt and other chemicals. Geothermal resources might also be used for refrigeration via heat pumps. Higher temperatures than those required for the applications described above might be required. For instance, drying and refrigeration usually require temperature above 90°C. Typical applications are presented in Figure 7.

There is a broad range of industrial applications that may use geothermal resources. Conventional industrial processes that utilize heat can in many cases be used with minor adaptation in a technically efficient and economically feasible way.

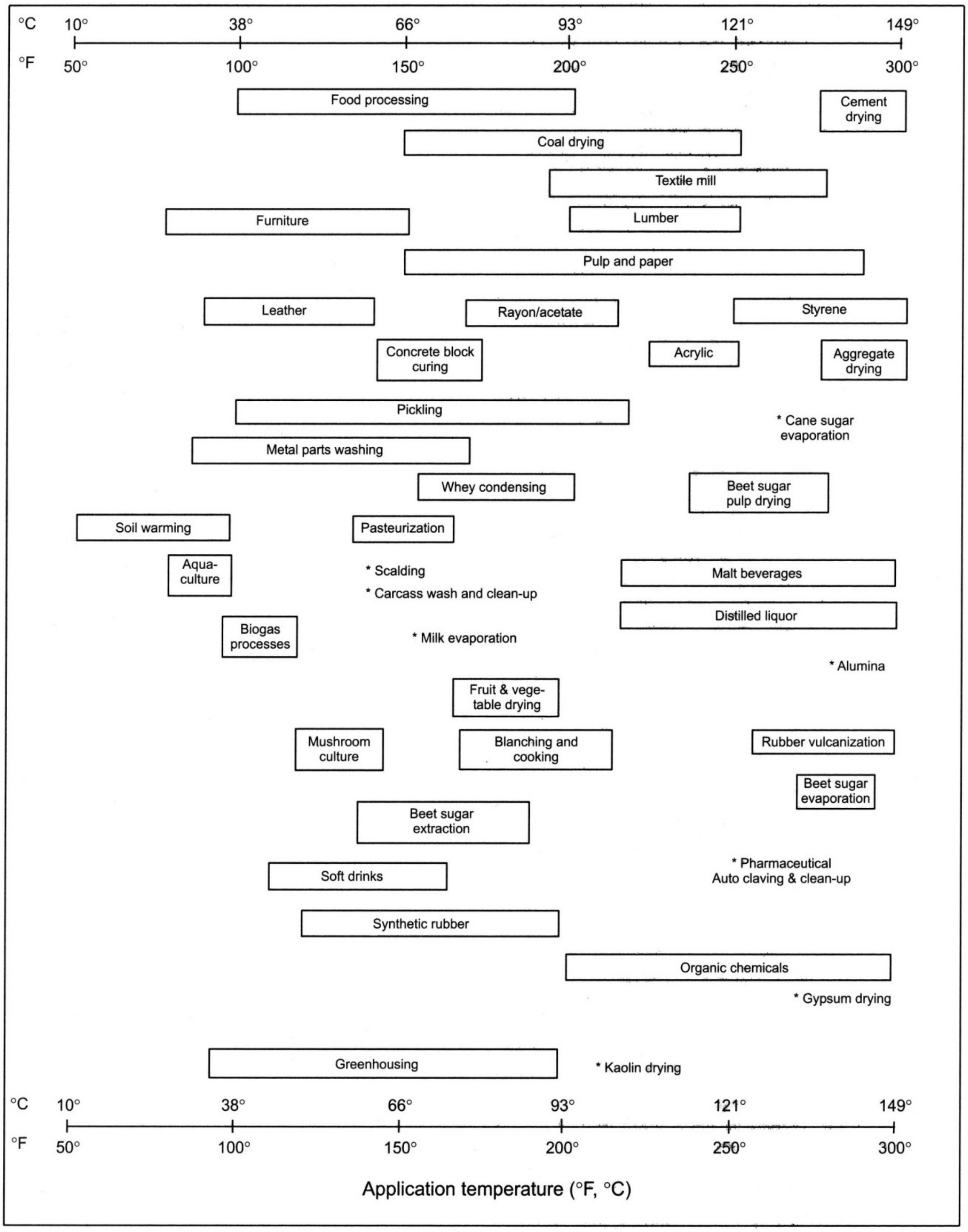

FIGURE 7: Temperature range for some industrial processes and agricultural applications

5. RESOURCE CONSIDERATIONS AND TECHNICAL ASPECTS – BRIEF OVERVIEW

The development of a geothermal project is in most cases a rather lengthy process. A greenfield geothermal resource takes 5-10 years to come to a full development, from early exploration to the time the resource is ready to be exploited. Various factors will impact the project duration. For instance, a green-field project with little information at hand regarding the resource might take longer time in its identification and exploration phases than a field which has previously been identified.

Geothermal projects are usually developed in successive phases at the end of which the project developer decides to carry on with the project or not. The development stages can be divided into 4 major phases: 1) Identification, 2) Exploration, 3) Design and construction, 4) Operation and maintenance. Geothermal projects imply high upfront costs with assessment of the geothermal resource and above all drilling of the first successful well(s). Significant investment, and therefore financial risk, is required prior to establishing whether the resource is viable or not. A common approach to manage risks associated with geothermal projects is to have milestones and decision points included in the successive phases.

Basic factors influencing the development of a geothermal applications are the temperature and available flow rates. They determine the resource energy potential for the application under consideration. The thermal energy extraction is directly proportional to the water temperature drop that can be achieved by the application. Table 1 below gives an idea of how much energy can be extracted from geothermal fluid.

TABLE 1: Hot water required to give an equivalent of 1 MWth for various temperature drops

ΔT	**(l/s)**
40	6
30	8
20	12

Exploitation of a geothermal resource has to carefully take into consideration long term extraction to avoid unsustainable extraction rates causing serious water level drawdown in the reservoir. In any case, re-injection should always be considered as a high priority reservoir management practice to replenish the geothermal reservoir and contribute to its sustainable use.

Chemistry of fluid is also an important factor for the direct use of geothermal resources as geothermal fluids are commonly richer in mineral than cold groundwater. The chemistry of the fluid might impact the feasibility of a geothermal application as expensive material may be required for the application. The equipment selection is generally affected by components such as: silica, oxygen, chlorides, calcium, magnesium, hydrogen sulphide and the pH of the fluid. The materials selected for the equipment could be mild steel, stainless steel, fiberglass or even titanium depending on the fluid and the application under consideration. Furthermore, the water chemistry may change over time due to inflow of cold of groundwater or seawater into the geothermal system. Deposition is not expected to be a major problem in low-temperature utilization compared to high-temperature utilization (calcite, sulphides, silica). Mixing of geothermal water with cold groundwater is not desirable due to the potential magnesium silicate scaling that might result from such mix.

Finally, although low and medium temperature geothermal fields can be found in many places around the world and are often more accessible and/or closer to potential end-users, the distance from potential market might be an obstacle to the development of given applications. This is probably of most relevance for district heating system where it might be uneconomical to transport hot water over long distances. The economic radius will be dependent on the parameters affecting the investment costs, i.e. pipelines and equipment, and the operation costs, related to heat losses, pumping costs or others.

The design of direct use of geothermal resources is highly dependent on the local climate, the characteristics of the geothermal resource and on the local market. However, the efficiency of geothermal direct use applications can be quite high, especially when different forms of utilization are combined in either an integrated or cascaded arrangement.

6. CONCLUSION

There is a broad range of geothermal direct use applications, the most common being bathing and space heating either in a centralized system – district heating – or with decentralized units such as ground source heat pumps. Although most of the applications mentioned in this paper can be rather easily implemented using conventional equipment or systems with minor adaptation, their conceptual design will have to take into account a few peculiar parameters, specific to geothermal resources such as the chemistry, temperature and mass flow of the geothermal fluid or other local conditions, e.g. the weather or the market targeted for the application, impacting the feasibility of the application.

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