# UTILIZATION OF GEOTHERMAL ENERGY IN PRODUCTION SYSTEMS BASED ON TIMBER PRODUCTION EXAMPLE

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**Abstract:** Traditional energy resources like fossil fuels (coal, oil and natural gas) are depleting. Due to that their prices are unstable and increase rapidly. In addition fossil fuels results enormous damage on the environment with harmful emissions into the atmosphere, lithosphere and hydrosphere. Taking to the account the expectation of European Commission regarding sustainable development and reduction of negative environmental impact in all economics activities, utilization of different energy resources became more significant in last few years. For this reason, they are still looking for new sources of energy that will be more efficient economically and to a lesser extent negatively affect the environment. Among them deserves a special attention the geothermal energy. This paper is focused on the example of utilization of this kind of energy resources in production processes. The basis of analysis was the timber drying system.

**Keywords:** production systems, alternative energy, geothermal energy, sustainable development, timber production

## 1. The importance of renewable energy in global economics

Despite the international economic crisis, ongoing trade disputes, global demand for renewable energy continues to rise. Renewable energy sources have become a vital part of the global energy mix. Year by year the majority of worldwide policies to support the development and deployment of renewable energy technologies increases. Many countries are focused on adapting to rapidly changing market conditions for renewable energy implementation. Beyond environmental efficiency renewable energy improves social, political and economic growth. Nowadays renewable targets have been identified in more than 127 countries and continue to develop. The top countries, which are active in renewable energy policies, are: India, China, Italy (National Energy Strategy), USA (Property Assessed Clean Energy), Portugal, Philippines, United Kingdom, South Korea, Netherlands, Canada (Neighbourhood Energy Strategy) and Germany (Energiewend) [8].

Most renewable energy technologies continued to see utilization in production and global demand. The top countries for renewable power capacity at the beginning of 2013 were China, the United States, Brazil, Canada, and Germany. Germany has become one of the world's green power leaders. Its market grew from 0.8 million residential customers in 2006 to 4.3 million in 2011, or 10% of all private households in the country purchasing 13.1 TWh of renewable electricity; including commercial customers, purchases exceeded 21 TWh [13]. Other major European green power markets include Austria, Belgium (Flanders), Finland, Italy, the Netherlands, Sweden, Switzerland, and the United Kingdom, although the market share in these countries remains below German levels [13].

In 2013, a total of 25.4 GW of renewable power capacity installations were installed. Over 72% of all new installed capacity in the EU was renewable. It was, furthermore, the sixth year running that over 55% of all new power capacity in the EU was renewable [13].

The number of policies and targets continue to rise worldwide every year. For example, during 2013, renewable energy support policies were identified in 127 countries. Among them (beginning from more renewable) [8]:

- the Middle East (Qatar, Iraq, Saudi Arabia);
- the Eastern Europe (new renewable energy targets were adopted for Bosnia and Herzegovina, Croatia, Macedonia, Montenegro, Albania, Moldova, Serbia and Ukraine).

Many Organization for Economic Cooperation and Development (OECD) countries, particularly those in Europe, have government policies (including feed-in tariffs, tax incentives, and market share quotas) that encourage the construction of renewable electricity facilities.

Technological efficiency of renewable energy sources. Technological description can examine the energy efficiency. Technological efficiency indicates the least possible quantity of energy input, to the point where it is no longer possible to increase output without also increasing energy input. Measurement of technological efficiency requires segregated data for the required energy input and industrial production, in physical quantities at product level.

Comparing technologies applied for energy production allows comparing the efficiency of energy sources. According to the world technology statistics geothermal has the highest degree (60-90%) of capacity factor comparing with the rest of sources of renewable energy (bioenergy – 60%, wind – 40%, ocean and solar – 25% [8].

Economic efficiency, on the other hand, implies that the quantity of required energy per unit of output may not be decreased, whereas the costs can be reduced in various ways. Hence, whatever proves techno-logically efficient will always be economically efficient; which demonstrates rationality when aiming for economic efficiency of energy use in industrial production processes [13].

Tab. 1. Technological status of renewable energy sources (not including hydropower). Source:[13].

| **Technology** | **Typical Characteristics** | **Capital Costs(USD/kW)** | **Typical Energy Costs(USD/kWh)** |
|---|---|---|---|
| Bioenergy combustion | Plant size: 25-200 MW<br>Conversion:25-35%<br>Capacity factor:50-90% | 800-4,500 | 5,5-20 |
| Bioenergy gasification | Plant size:1-10 MW<br>Conversion:30-40%<br>Capacity factor:40-80% | 2,050-5,500 | 6-24 |
| Bioenergy anaerobic digestion | Plant size:1-20 MW<br>Conversion:25-40%<br>Capacity factor:50-90% | Biogas 500-6,500<br>Landfill gas 1,900-2,200 | Biogas 6-19<br>Landfill gas 4-6,5 |
| Geothermal power | Plant size:1-100MW<br>Capacity factor:60-90% | Condensing flash: 2,100-4,200<br>Binary: 2,470-6,100 | Condensing flash: 6-13<br>Binary:7-14 |
| Hydropower | Plant size:1-18,000MW<br>Capacity factor:30-60% | projects>300MW:2,000-4,000 | 2-12 |
| Ocean power (tidal range) | Plant size:<1 to>250MW<br>Capacity factor:23-29% | 5,290-5,870 | 21-28 |
| Solar PV | Peak capacity:2,5-250 | 1,300-1,950 | 14-34 (Europe) |

| Technology | Typical Characteristics | Capital Costs(USD/kW) | Typical Energy Costs(USD/kWh) |
|---|---|---|---|
| (ground-mounted utility scale) | MW<br>Capacity factor:10-25 % | Averages:2,270 (USA), 2,760 (Japan), 2,200 (China), 1,700 (India) | 20-46 (OECD)<br>28-55 (non-OECD) |
| Concentrating solar thermal power | Plant size: 50-250 MW<br>Capacity factor: 20-40% (no storage)<br>35-75% (with storage) | No storage: 4,000-7,300<br>With storage: 7,100-10,500 | No storage: 19-38<br>With storage: 12-37 |
| Wind (onshore) | Turbine size: 1,5-3,5 MW<br>Capacity factor: 25-40% | 1,750-1,770<br>925-1,470 (China, India) | 5-16 (OECD)<br>4-16 (non-OECD) |
| Wind (offshore) | Turbine size: 1,5-7,5 MW | 3,000-4,500 | 15-23 |
| Wind (small-scale) | Turbine size: up to 100 MW | 3,000-6,000 | 15-20 |

## 2. The wood production process specificity

Wood is an important and valuable manufacturing raw material. Nowadays forest recourses are used more efficiently, wood utilization is improved and the quality of manufactured products increase. One of the most important wooden-based raw materials is a timber, which could be defined as wood material obtained in sawmill by longitudinal sawing of the wooden logs [17]. Timber sawed into boards, planks, or other structural members of standard or specified length (called lumber) is required to further processing into products such as firewood, furniture, building materials, flooring, cladding joinery, pulp and paper.

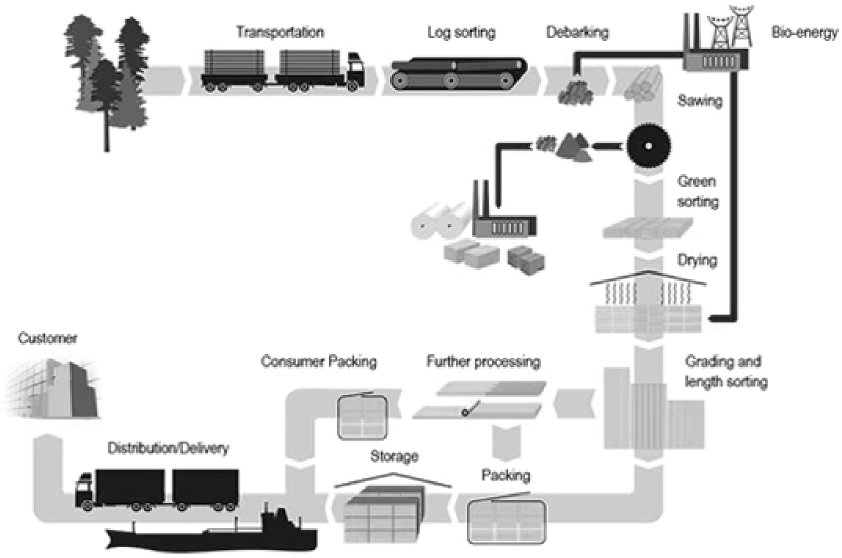


Fig. 1. Lumber production process.
Source:[18].

Lumber production is broken down into many elementary processes (Fig. 1). The most important for efficiency of whole production process are:

- **Log yard activities** – after arriving at the storage yard, logs are sorted and stored according to species, diameter, length and end-use, etc. Transportation and handling depend on the capacity of the sawmill operation and the size of the loss received. Manual, overhead cranes or other handling equipment are usually used. Separation of logs from barks, using debarkers, is be-coming a generally adopted practice. Debarking is to safeguard saws and other equipment from over wear and damage that would otherwise result from stones, metal and other such contraries embedded in the bark. Log washers may also be used to remove any remaining sand or dirt that may cling to the logs [4].
- **Sawing (green lumber production)** – before the log is presented to the sawing, it is cut to the longest allowable straight length with a cut-off saw, whereupon it is loaded on the carriage and positioned in such a manner as to allow the operator to achieve a sawing sample, which will result in the optimum production of lumber with the minimum of waste. Sawing of the log is achieved by the use of a circular saw with a second saw mounted vertically above the first in the event of sawing large diameter logs. After further breakdown of slabs, flitches and cants takes place in the resawing. It allows the wood to be upgraded into planks and boards. The lumber is cut to standardized lengths, edges squared and defects removed by the use of one or more fixed or moveable trimming saws, where the lumber proceeds to be sorted and graded [11].
- **Sorting and stacking** – the sawn timber is sorted according to thickness, length, quality, width and species depending on the market requirements. For these purposes mechanized sorters and labor work are in use. They separate the lumber according to the overall quality, direction of grain, presence of knots and defects, as well as general appearance, etc. [12].
- **Drying (including wood and natural gas boilers)** – Timber drying means the main process of moisture removal from the wood through the shrinkage procedures. The drier the air, the more water it can take from the wood. If the air is stationary over the wood surface then it will quickly become full of water. If this air is replaced then the wood will continue to dry. Thus, the rate of drying of the wood is also affected by the air speed and humidity [10].

## 3. Importance of drying process in the lumber production

A growing tree, as any living organism, contains a lot of moisture, which plays a negative role in deteriorating the technical properties of the wood material. Wet wood is exposed to decay, caused by different diseases which destroy its structure. Producing a large number of items the moisture can be a serious hindrance and it must be removed from the timber in advance of its usage.

For finger jointing and laminating to produce building components it is crucial to have timber dried accurately with moisture content no more than 1%. Wood for furniture should be dried to low moisture content (6 – 10%) and for the cladding boards 16 – 18% is enough [14]. Softwood lumber planned for framing in construction is usually targeted for drying to moisture content around 15%, and not to exceed 19%. Softwood lumber for many other uses is dried to a low moisture content (10 – 12%) for many appearance grades to as low as 7 – 9% for furniture, cabinets and millwork. Hardwood lumber for framing in construction, although not in common use, should also be dried to moisture content around 15%, and not to exceed 19%. Hardwood lumber for furniture, cabinets and millwork is usually dried to 6 – 8% of moisture [15].

A particular solution of the problem is the obligatory drying in the process of each woodworking industry. Drying the wood from natural raw timber turns it into the material according to manufactured requirements. That's why timely application of optimum or at least appropriate temperature, relative humidity, and air circulation conditions is critical. Controlling systems can prevent defects of the process that can adversely affect the serviceability and economics of the product.

The simples and easy to use drying method is air drying. It involves the stacking of sawn timber in piles in the open or under sheds on suitably prepared ground, in such a manner that they are exposed to a good flow of air until such time that the required moisture content is attained. Wax or paint is applied to the end-grain of lumber to be air-dried, either by brush or spraying, so as to act as a sealant in order to bring about a slower drying of the extremities and hence, give rise to a more uniform drying of the lumber. It is cheap, but long process, and it depends from the weather and a large amount of land is also required. However the time of drying is important, because slow drying, depending on species and thick-ness, can introduce the risk of the timber damage. Due to that in many cases utilization of drying kilns seems to be more efficient than air drying. Kiln drying is quick and simple method of adding value to sawn products from the primary wood processing industries. It can reduce the moisture content to less than 12%. Although this method requires high level of technical skills and capital investment, it allows high value timber and its further processing. The process includes loading raw stacked lumber into kilns, drying and unloading rough-dry stacked lumber from the kilns. Geothermal waters can be used as energy inputs into the kiln drying process. After drying the lumber is controlled of moisture content and is graded again [11].

## 4. Geothermal drying process in wood production

Providing geothermal energy into the drying processes, improving and implementation of innovations, automation of the drying process and integrated mechanization of transport operations allows increase heat capacity, to minimize costs and emissions.

At the beginning of using geothermal energy for drying, timber was dried at the low temperatures for a long time. It was economically inefficient. Due to technological development geothermal drying systems are improved and atomized, which makes the process more productive, less expensive and controlled. Geothermal can be used as separated geothermal steam with heating coils or to heat pressurized water that passes through the heating coils [16]. Geothermal energy is used to heat the air (90-140˚C) circulated in the kilns, and to boil water to produce a humid atmosphere to precondition or recondition timber.

Geothermal water is pumped from the production well into the metallic pipelines (steel and ductile iron), which carry fluid to the heat exchanger. Thermal expansion of metallic pipelines heated rapidly from ambient to geothermal fluid temperatures (which could vary from 50 to 200˚C) causes stress that must be accommodated by careful engineering design. The quantity of thermal insulation of distribution network depends on many factors. Moisture can destroy the value of any thermal insulation, and cause rapid external corrosion in metallic pipes. Above ground pipeline installations are normally less expensive than buried pipes, but more affected by environment. Buried pipes prevent reduction of the heat

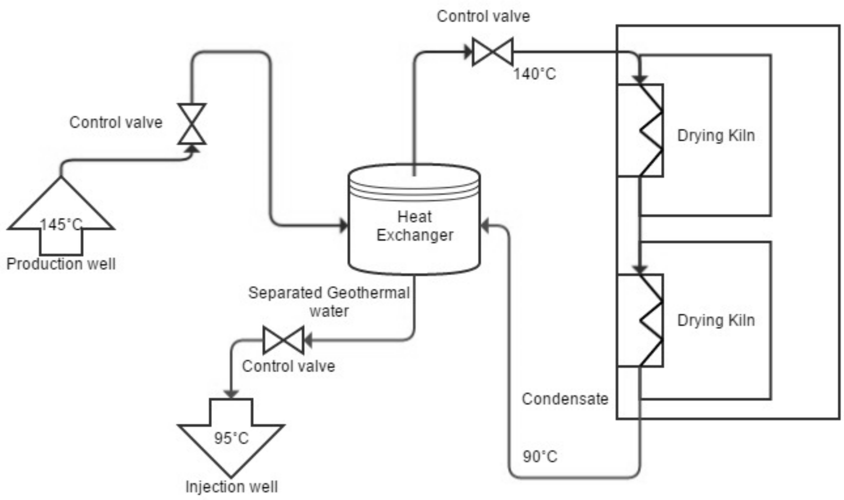


Fig. 2. Geothermal water flow diagram in geothermal drying process.
Source: own work based on [3, 16].

loss. Above ground pipes should be protected with a polyvinyl chloride (PVC) jacket, if placed below ground, or aluminum if placed above ground [2]. Temperature in every stage of the geothermal flow is regulated by control valves with temperature sensors. The design of mechanical system involving heat transfer is heavily influenced by temperature. The temperature difference between geothermal resource and required drying temperature is particularly important as it frequently determines productivity, equipment selection and flow requirements for the system. The greater the temperature difference is between these two values, the lower the cost of the heat exchange equipment, the lower geothermal flow. The waste water returns to the primary heat exchanger, which directs to the heat exchanger of the drier as a heat source [2].

## 5. Advantages of geothermal-based timber drying system

During the wood drying process the amount of air emissions is maximal (around 93% from the total air emissions released for the lumber production process) [1]. This includes emissions generated from heat exchangers and emissions released during drying of wood. Geothermal resource contains dissolved minerals and a variable quantity of gas. The range in $CO_2$ emissions from high-temperature geothermal fields is variable, but much lower than that for fossil fuels [1].

Depending on the geological, hydrogeological and thermodynamic conditions, apart from carbon di-oxide ($CO_2$), it can usually contain hydrogen sulphide ($H_2S$), hydrogen ($H_2$), ammonia ($NH_3$), methane ($CH_4$) and nitrogen ($N_2$) [6]. Those gases are noncondensable gases that are not easily converted to liquid form via a cooling mechanism. The amount and relative proportion of noncondensable gas components can vary substantially from one geothermal resource to another [5]. Geothermal dry kiln is a closed sys-tem, which retain the noncondensable gases in the geothermal fluid and inject them back to the geothermal reservoir, emitting near-zero emissions because the geothermal resource is not exposed to the atmosphere. Reinjection the waste brine into the reservoir tends to drop bellow natural levels, resulting in a de-cline in surface emissions [7]. Due to that geothermal dry systems produce a relatively low amount of greenhouse gases in comparison to fossil fuels.

To assist in assessing the potential of the geothermal resource`s efficiency for timber drying process it is sufficient to estimate the quantity (flow tones per hour) of geothermal fluid. The 55 m$^3$ drying kiln was observed as the most commonly used. The next formula is proposed to use [16]:

$$F_{geothermal} = \frac{Q_{kiln}}{(H_{T1} - H_{T2})}, \quad (1)$$

where:

$F_{geothermal}$ – flow rate of geothermal fluid (kg/sec)
$Q_{kiln}$ – heating needs of kiln (kW)
$H_{T1}$ – enthalpy for high temperature (kJ/kg)
$H_{T2}$ – enthalpy for low temperature (kJ/kg)

When geothermal fluid is supplied at the temperature is 120˚C, kiln works at 70˚C, maximum heating rates – 1200 kW and average heating rates – 750 kW, the flow rate of geothermal fluid will be the next:

$$F_{geothermal} = \frac{1200}{(503{,}7 - 293{,}03)} = 5{,}7\ {}^{kg}/_{sec} \quad (2)$$

$$F_{geothermal} = \frac{750}{(503{,}7 - 293{,}03)} = 3{,}5\ {}^{kg}/_{sec} \quad (3)$$

When geothermal fluid is supplied at the temperature is 90˚C, kiln works at 60˚C, maximum heating rates – 500 kW, the flow rate of geothermal fluid will be the next:

$$F_{geothermal} = \frac{500}{(376{,}9 - 251{,}1)} = 4\ {}^{kg}/_{sec} \quad (4)$$

Capital costs of timber drying consists of the budget cost of development, obtaining and installation of a single 55m$^3$ drying kiln, and estimates $800,000 (110˚C) and $610,000 (140˚C). These costs include [9]:

- kiln capital repayment, plant life 15 yrs, 12% financial interest rate;
- geothermal supply, well life 15 yrs, 12% financial interest rate;
- filleting contract costs;
- labour costs;
- maintenance;
- budget drying cost/m$^3$.

The annual drying capacity of the represented kiln is 15,400 $m^3$ (110˚C) and 7,700 $m^3$(140˚C) with an average thermal loads: 1.9 MWt and 0.75 MWt [16].

## 6. Conclusions

The main advantage of geothermal energy utilization, which distinguishes it from other renewable re-sources, is the fact that the heat from the earth is inexhaustible to use for twenty four hours a day, all year round. Geothermal energy is independent on climatic conditions and its changes. Although the capacity power of geothermal resources is on the fourth place among other renewable, the awareness of its efficiency is not high. A number of new and innovative applications of geothermal energy have been developed in recent years. It is used for electricity production, for heating, as well as in production processes.

The aim of this work was to show how efficient geothermal resources (especially geothermal waters) can be used as a source of energy in production processes based on timber production example. Closed-loop circulation system, demonstrated in the lumber production process, allows providing the process of timber drying with zero direct emissions and save more heat. Moreover operating costs and resource utilization can be reduced.

Summarizing, no doubt geothermal energy plays an important role in the renewable energy share. However practical utilization of this kind of renewable resources should be optimized and improved to achieve long-term sustainability of production and protect natural thermal features. It can be innovations in well drilling, new production technologies; improvement of methods to simulate reservoirs and heat flow control systems, development of data management systems.

Additionally, world experiences were shown that the relative success of geothermal development in particular countries is closely linked to their government's policies, regulations, incentives and initiatives. Further research and successfully taking into account the benefits of geothermal energy can provide policies that support, improvement and development would benefit all geothermal technologies, especially in production processes.

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