Interreg - IPA CBC
Bulgaria - Serbia

Renewable Energy for Smart Growth and protected Environment

Geothermal energy

A practical guide to using geothermal energy

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R·A·R·I·S
Regionalna agencija za razvoj Istočne Srbije
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THE CONTENT

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A practical guide to using the energy of earth

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ABBREVIATIONS

OIE - Renewable energy sources

ROI - Return on investment time

ICT - Information and communication technologies

TP – Heat pump

COP – Coefficient of Performance

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INTRODUCTION

1. IMPORTANCE OF ENERGY IN CONTEMPORARY WORLD AND TRENDS

Along with water, energy is one of the two most important resources that are crucial for the current and future survival of the human community. It may sound a bit scary, almost cataclysmic, but everyday life confirms that without one of these two resources, there can hardly be any sustainable development of society or even preserving of the existing state of the art. Energy has always been a significant factor that ensured progress, starting with very basic use for food preparation, light and heating, until today where there is NO activity that is feasible without more or less energy. The consumption of this key resource began to grow exponentially with technological development in the 17th and 19th centuries, especially after the First Industrial Revolution, where energy began to be used extensively in the mass production of goods for an increasingly demanding and growing human society. Consumption is proportional to the level of industrial development, but also to the level of living standards of individual countries. From 1965 to 2021, consumption in some countries increased up to 500 times (Oman), in a number of developing Asian countries ten or more times, while in a number of very poor countries it even fell by 50%, due to reduced industrial activity (Syria, Gabon, North Korea...) or the reductions are the result of the introduction of more efficient technologies and strict energy efficiency programs (Great Britain, Denmark, Luxembourg...).

During the last twenty years, the demand for electricity has been growing rapidly due to efforts to reduce the impact on climate change, i.e. because of increasingly strict measures for the introduction of decarbonisation, i.e. industries that do not emit or have a significantly lower emission of CO_2, as the main cause of the global warming. The consequences are already clear to everyone, because the increment average temperatures cause a change in the movement of air masses and water flows, which results in extreme climatic phenomena, large droughts throughout the year, and on the other hand, huge amounts of precipitation in a short time, even at the time of the year when it has never been such climate turmoil. Electricity is perceived as the cleanest form of energy that is not polluting the environment, although this is must not always be the case. Take, for example, the production of electricity from thermal power plants, where large amounts of polluting gases, especially CO_2 and PMs are emitted, even when the installations have very complex and very expensive air purification systems. At the same time, the use of hydro or nuclear energy are driving controversies because large hydroelectric plants do not emit CO_2, but have a great impact on the microclimate, conditions on groundwater, on habitat and biotope and also at the social level when entire settlements and infrastructure are moved from areas where reservoirs are formed. Nuclear power plants are potentially at very high risk due to the even the lowest possibility of a nuclear accident or as well as due to the demanding storing of nuclear waste.

The events from recent years have only brought up all these issues to the fore front, particularly the conflict in Ukraine, which resulted with massive displacements and huge disruptions to the food and energy supply chains, therefore some almost forgotten capacities for dirty fuels, primarily coal, are resurrected by force of circumstances and returned to production.

For all these reasons, the whole world, and especially the European Union, has been trying for a number of years to introduce programs aimed at producing clean energy in sufficient quantities, aiming at sustainable development goals (RIO process, Kyoto Protocol, Green Agenda, Fit for 55).

2. WHAT ARE RENEWABLE ENERGY SOURCES

Renewable energy sources (RES) are sources that are renewed at least the same rate at which they are exploited. Everything in nature what could be renewed is done spontaneously and without side effects, thus RES are considered to be clean energy and the right choice for solving energy needs without polluting the environment and have no, or very little, impact on climate change. Unlike RES, non-renewable resources are depleted over time and cannot be renewed, at least not on timescales comparable to our understanding of time. Non-renewable energy sources are all fossil fuels (coal, oil, natural gas), for example, because they cannot be renewed even during the time that was sufficient for the creation of human civilization.

Renewable energy sources include:

The energy of water is the energy of rivers, the energy of waves and tides. It has been used to run mills or any other installations that require mechanical energy, threshing machines, saw mills, weaving mills... Since the 19th century, the production of electricity has emerged and since then, water is one of the most common way of using energy sources that are constantly renewed.

The energy of the sun is the energy that our star radiates to the earth's surface and is of both heat and light nature (although they are of the same, electromagnetic origin, but in different spectrums of radiation). This is also a form of energy that has always been available. In the beginning, the sun was only used as a thermal source, for heating homes, for boiling water and in very early stage to dry and preserve the food because, in addition to heat, the sun also radiates ultraviolet rays, which are excellent disinfectants, thus very good for preserving the food. For this reason, the sun is used to dry meat, plants and plant products. It was only in the 20th century when it was discovered that, when crystallized silicon is exposed to the sun, it causes electric voltage on its ends. This phenomenon is widely used today to make photoelectric panels that generate electricity.

Geothermal energy is the energy of the earth which is a huge heat reservoir. The earth radiates its own energy and the miners know this best because the temperature in the pits is much higher than on the surface. The earth is a great generator and this feature was used, above all, for balneological and health purposes. Each spa uses warm water from depth. Thermal waters, however, can be used for the production of electricity, for heating swimming pools, residential areas, for heating roads and streets (Iceland, which is all resting on geothermal springs, uses them abundantly for exactly these purposes), greenhouses and fish ponds. However, geothermal energy is not used only for heating, but for also electricity production and can be put to work with the help of heat pump technology for both heating and cooling, as well.

Biomass - Energy obtained by burning plant residues, using bio gas as a product of decomposition of plant mass and from bio fuel (fuel obtained from processing high oil content plants). Biomass is the oldest form of renewable energy since the humans used wood for heating, to prepare food and as a source of light ever since. Woods grow, so if used carefully, it will always be there. Biomass is both plants and residues from agricultural production and in general, all biological material that can be used as fuel. This is the primary way of using biomass (straw, residues from harvests, residues from vegetable crops, dry branches and plants, etc...). Biomass could be collected from special energy plants that are grown only for this purpose (fast-growing willows, for example). Today, biomass is commonly available as pellets, compressed plant residues that provide uniformity and easy way to use it as a fuel.

Wind energy - Wind is a result of the movement of large air masses in the earth's atmosphere, due to climatic, thermodynamic phenomena, differences in temperature and air pressure above the earth's surface. Wind occurs occasionally and we cannot precisely nor predict with certainty when it shall blow, albeit it was also used as a source of energy. In the beginning, it was a driving force for ships with sails which were energy "catchers", and later on, as a driver for mills and everything that could be powered by external energy (mills, water pumps, saw mills...). The energy that was initially used to propel vessels is now largely used to generate electricity with the help of wind generators.

3. WHICH ARE THE ADVANTAGES OF USING RENEWABLE ENERGY SOURCES

Renewable energy sources are available in some form everywhere and can be exploited in any place, immediately and without the need to transport energy sources. This means that the infrastructure for exploiting energy from renewable sources is more compact, simpler and less demanding. Large facilities such as large storage and/or reversible hydropower plants or facilities for the massive use of geothermal water, such as exist in Iceland, for example, are not considered in this publication.

The energy security status is much more favourable when it comes to dispersion of energy sources on smaller units, rather than large energy sources, with the capacity to overwhelm significant consumption. Failure of a small plant shall not jeopardize the power system, while failure of a large power installation leads to very serious problems in the production and distribution of energy.

From purely technical perspective, the generation of energy in small plants provides distribution throughout the electrical grid at a lower voltage, which reduces losses in the grid and makes it more efficient.

The price of energy production from renewable sources has a downward trend and on the other hand, the market price of energy has a tendency to increase, which justifies investments in RES.

The green economy, and therefore the industry of renewable energy sources, is, in addition to ICT, the fastest growing industry, since the transition to RES requires development of new technologies and considerably greater production of equipment and services in this particular niche, so the benefit is twofold, on the one hand energy is significantly cleaner and safer to use than the one from conventional sources and on the other hand, the level of energy security is increased and the dependence on other sources and/or energy providers has been reduced. Finally, the price of energy production from renewable sources is falling down because of the number of equipment manufacturers increases, thus the equipment becomes cheaper.

4. WHICH ARE THE CHALLENGES IN USING RENEWABLE ENERGY SOURCES

The biggest challenge in using energy from renewable sources is the fact that the two most popular and easiest to exploit, wind and solar energy, are of such a nature that they are not produced continuously. Energy from those two sources is generated when it is available, that is, when there is sun or wind, which is predictable only to a certain extent. The electric power system, roughly speaking, rests on three key pillars: the producer, the distributor and the consumer. Energy distribution is carried out through the electrical distribution grid, which, in order to operate in an optimal mode, must have a constant load. An analogy could be made with water pipes where also must be water all the time. Otherwise, air can enter the pipe and reduce the flow, or impurities can accumulate in the pipe due to stagnant water, which reduces flow rates.

In order to ensure the optimal load of the grid, more or less the same amount of energy must flow through it, for which we need to have uniform or harmonized consumption and production. This requires energy contingency that will be introduced to the grid when lacking sun or no wind. That additional energy is the so-called "balance energy" and must be provided in whatever way. So far, the grid operator is required to provide balanced energy, in accordance with the regulations both in Serbia and Bulgaria. However, in the future, most likely part or all of the obligation will be transferred to energy producers from renewable sources, which will make investments more expensive and less attractive, at least for large systems because small ones shall be exempted from it in whole or in part.

It is also necessary to secure environmental safety with no impact on the environment (this especially applies to small, run-off hydroelectric power plants and large scale installations on biomass)

Although the energy from renewable sources is cheap, the system must be regularly maintained (cleaning the panels, pruning trees so that they do not cast a shadow on the panels, checking the fluid in the solar collectors, checking the fluid in the heat pump system, maintaining the channels and catchment at the hydroelectric power plants, cleaning the stoves and chimneys in the case of biomass stoves...) and replacing parts that have passed their term (accumulators, for example).

GEOTERMAL ENERGY

5. WHAT IS GEOTHERMAL ENERGY, ITS FORMS AND POTENTIALS

Geothermal energy is the energy of the Earth that generated in its inner layers, primarily in the core whose temperature is around 6000-7000°C, which is approximately the temperature on the surface of the Sun. The name comes from the Greek words *geo*, meaning Earth, and *therme*, meaning heat.

Earth energy has four forms:

- thermal energy that is accumulated in the earth's core,

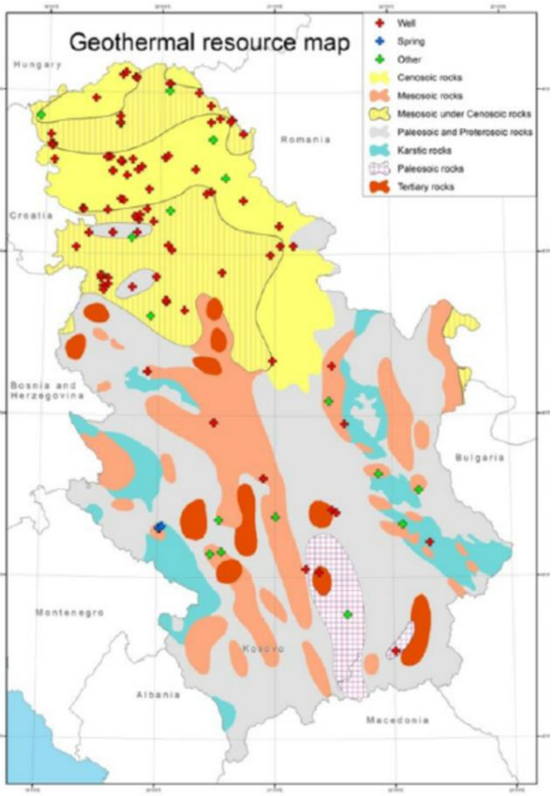
- hot gas energy,

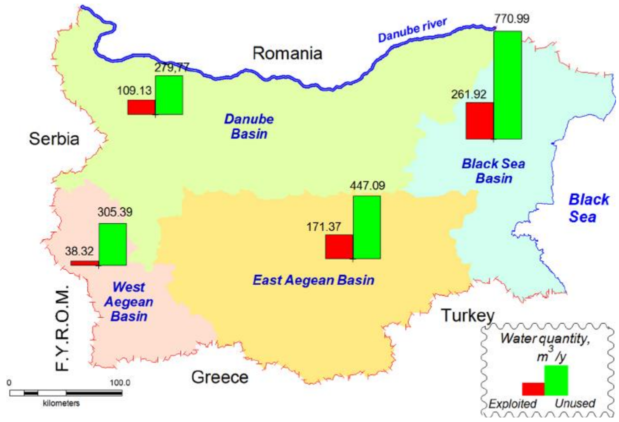
- energy accumulated in thermal groundwater

- energy of superheated water vapour.

The energy of thermal waters is most often used, but in the last twenty years, the use of geothermal energy of the surface ground has become more common because it has multiple advantages: it is affordable, it can be used directly so the exploitation costs are low, it is quickly renewed, it is not aggressive to environment and is not a threaten to human and animal health.

Geothermal energy is present everywhere, not in the same quantity though, but it is certainly profitable, reliable, sustainable and environmentally friendly. Historically, it was used mainly in areas located above the edges of tectonic plates, where warm water penetrated through cracks in the Earth's crust. Technological progress has enabled more intensive and efficient use of this natural resource, from energy production to wide exploitation in industry and households. Today, we can use only a small part of geothermal energy from the surface layer of the Earth's crust, up to several kilometres in depth.





Geothermal energy is created from the radioactive decay of elements (minerals), which constantly generates heat in the Earth's core and then heats the entire body of the Earth, all the way up to the surface. Understanding the nature of its origin, geothermal energy is considered a renewable source of energy because it is inexhaustible, measured in time frames that we can rationally comprehend, i.e. the source of the Earth's heat in its womb will be consumed in several tens of billions of years, which is even longer than predicted duration of the sun (about 5 billion years).

At the same time, the Earth absorbs almost 50 percent of the solar energy that hits its surface, thus additionally heating it. The earth is a huge thermodynamic system, and its ability to accumulate heat energy mitigates the oscillations of the air temperature close to the surface. During the night, the Earth releases part of the collected thermal energy and heats the surrounding air, which would be much colder if the Earth itself did not radiate heat, which is the case on cold celestial bodies, the Moon, for example. There, the temperature differences on the surface during the day and night are extreme (from -130°C to 120°C). The amplitudes of temperature fluctuations decrease with the depth of the earth. On the surface itself, they are proportional to the air temperature, while at a greater depth (6-10 m) the temperature of the earth is almost unchanged (10-15 °C), so it is colder in summer and warmer in winter than the surface layer. Most often, the heat exchanger for the use of geothermal energy is not buried more than two meters, except in the case of probes. The soil temperature at that depth varies with the season, but not more than in the range of 7-13oC. The temperature of underground water, depending on the depth, is within similar values. The temperature of the earth depends on the structure of the type and structure of its layers with increments of 10 to 30 °C for every kilometre of depth.

The potential of Serbia and Bulgaria for the exploitation of geothermal energy is significant, especially considering the geothermal waters that spring to the surface.

The illustrations show geothermal basins in Serbia and the degree of utilization of geothermal energy in Bulgaria.

Advantages of geothermal energy

Geothermal energy is considered extremely clean because there is no combustion, waste ash, air pollution or of the environment, in general. The impact of using geothermal heat on the environment is quite small and rather easy to control. Geothermal energy produces minimal air emissions. Emissions of nitrogen oxides, hydrogen sulphide, sulphur dioxide, ammonia, methane, particulate matter and carbon dioxide are extremely low, especially compared to fossil fuel emissions. However, both water and condensed steam from geothermal power plants also contain various chemical elements, including arsenic, mercury, lead, zinc, boron and sulphur, with toxicity which depends on their concentration. However, most of such elements remain dissolved in the water, which is returned and injected back to the same rock reservoir from which it was extracted as hot water or steam.

Geothermal power plants work constantly, considering that the earth's energy is constantly available, they occupy a relatively small space at the very source of geothermal water and do not depend on external weather conditions at the location. Opposite to this, wind and solar power plants depend on the amount and speed of the wind or the number of hours of sunshine.

Low-temperature systems of using geothermal energy are accessible, literally in every location, although in some places the exploitation is somewhat easier than in other ones, but the earth is heated everywhere and there is energy everywhere.

The capacities of the Earth in geothermal energy, besides being infinite from our perspective, are sufficient to supply the entire humanity with all the necessary energy for at least the next 17 billion years. This is only a theoretical quantity because we cannot use all the geothermal energy, but even such a lump sum estimate illustrates the energy capacity of the Earth's womb.

Of course, the future of the geothermal energy use will depend on the efficiency of the technologies, the price of energy that is inexorably rising, and the needs of industries and the final consumption of the population.

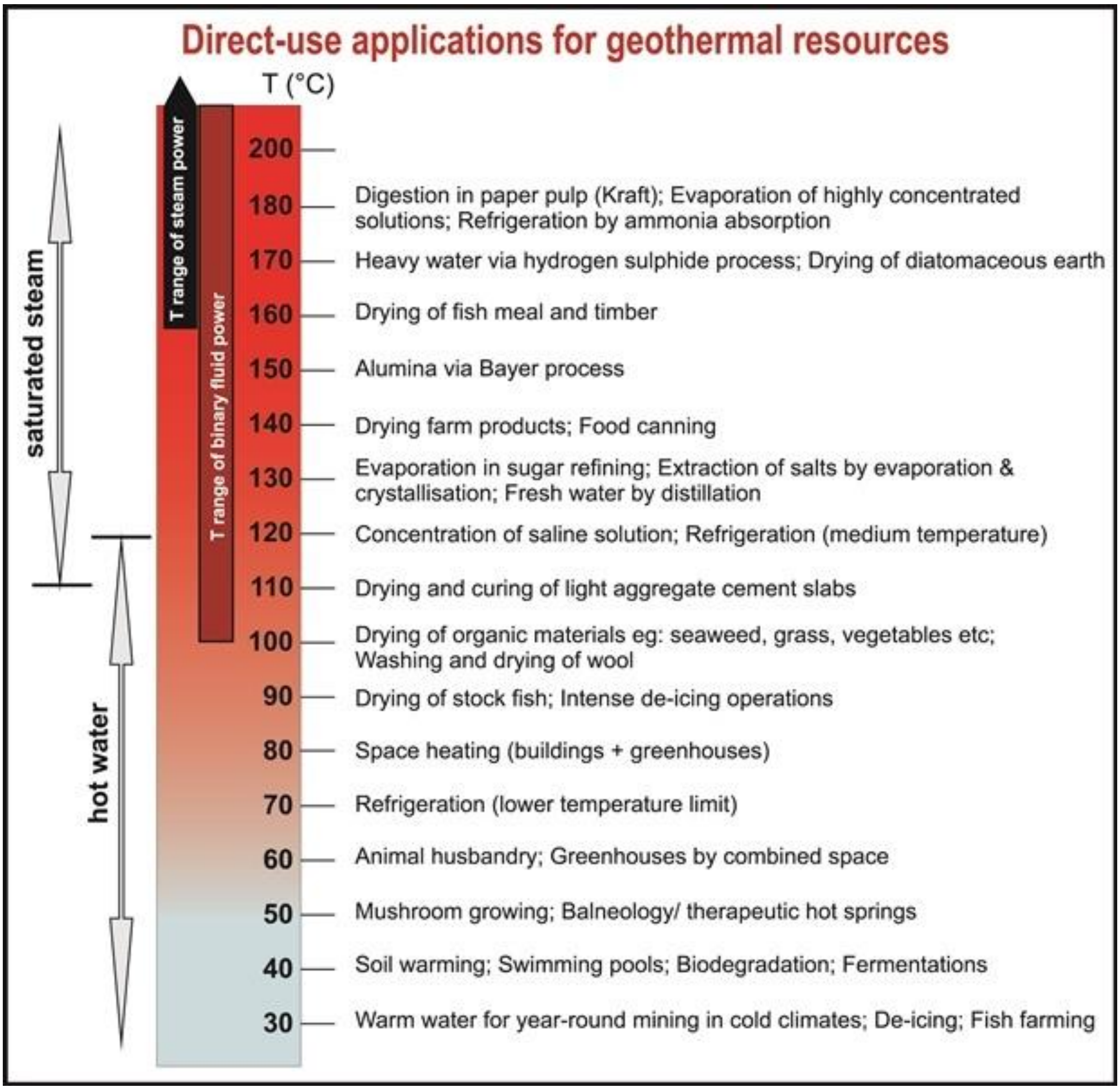
Flaws of geothermal energy

Problems in the exploitation of geothermal energy occur mainly with large electrical energy systems that cannot be installed everywhere. The reason lies in the fact that tapping into layers of earth that have the right temperature can be complicated due to the difficulty of drilling, the required depth of the wells and the risk of dangerous gasses.

In contrast, when it comes to geothermal water at lower temperatures (around 30oC), which can be used with the help of heat pumps, the only difficulties may be in the price and scope of the investment, but it is definitely worth it and it is wise to install a heating and cooling system with the use of geothermal energy. After the period in which all invested funds are returned, it is necessary to pay only for the consumption of the heat pump, which is many times smaller than any other way of heating and cooling the room.

6. METHODS OF USING GEOTHERMAL ENERGY

Thermal waters were used in ancient China, Greece, India and ancient Rome for heating and healing. Later, the use of warm underground waters was very intensive in Italy, where they were used to separate mineral salts, sulphates, borates and others. Today, hydro-geothermal energy is used for various purposes:



The most usual way of using geothermal waters is for balneological purposes. It has been noticed since ancient times that warm waters from the bowels of the Earth have a beneficial effect on health, due to the content of various mineral salts. Spas and hot baths were most often built at the very sources of geothermal water and were very popular. Geothermal sources are most often found in areas where there is volcanic activity, at the cross cuts of tectonic plates or they can be exploited from wells.

The picture above shows different applications of thermal energy depending on its temperature, which confirm the universality of using energy of the earth for practically all purposes.

Warm geothermal water can be and is used to heat spaces. - the first heating system of this type was built in 1930 in Reykjavik, Iceland, where apartments, theatre and cinema halls, swimming pools, sports halls, and open spaces are now heated with hot water.

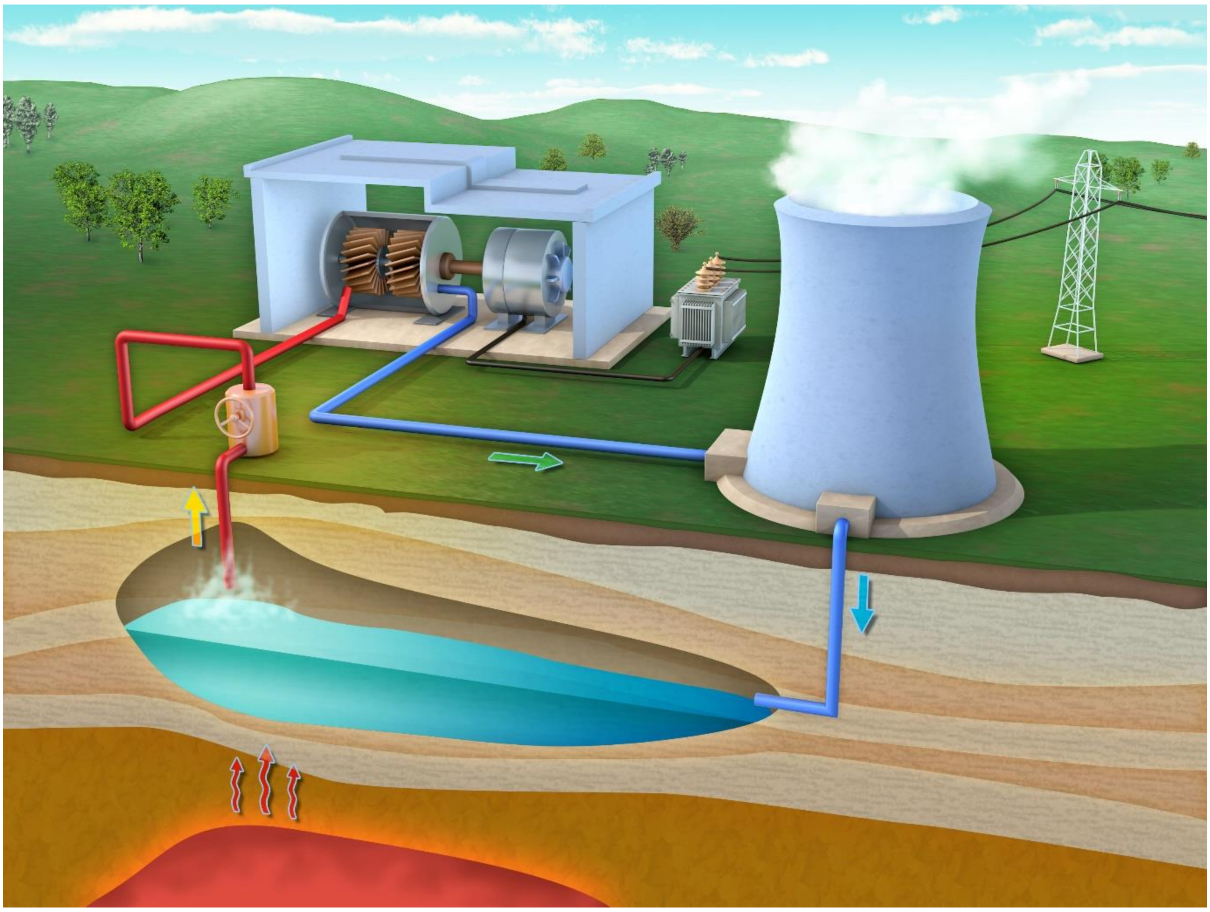
Agriculture is convenient to use the geothermal energy for hot beds, in floriculture, farming, in greenhouses for early fruits and vegetables. Later on, the warm geothermal waters started to be used in poultry farming, fishing, to grow mushrooms, for the fermentation process in the dairy industry, etc. Wherever thermal energy is needed, it can be used directly or with support of heat pumps that exploit it from the ground. water or air.

The most sophisticated way to use geothermal energy is its conversion into electricity. Such power plants use either hot water or superheated steam to drive steam turbines. The first electric power station that worked on superheated steam from a geothermal source was built in 1904 in Larderello, Italy and had a power of only 10kW, a bit more than moderate home stove.

The simplest way to obtain superheated steam is when cold water is brought to the hot rocks in the earth's depth, which creates water steam with temperatures higher than 200°C and which then comes out under high pressure to the earth's surface from where it is introduced into steam generators for the electricity production. There are currently three technologies for generating electricity from geothermal steam: dry steam technology, flash steam and binary process.

Installation for dry steam (Dry Steam) - with temperature above 235°C is directly used to run the generator turbine. This principle, although the oldest, is still in use, given that it is the cheapest way to produce electricity from geothermal sources.

Plants operating at principle of steam extraction (Flash steam) use hot water under high pressure from depth of the earth and turn it into steam to drive generator turbines. After cooling the steam, it condensates and the water returns to the ground for reuse. Most modern geothermal power plants use exactly this principle of operation.



The binary process is applied in the case of medium-temperature geothermal sources where the large amounts of accompanying and undesirable gases are present. Binary cycle power plants transfer heat from geothermal hot water to a secondary (binary) fluid that has a significantly lower boiling temperature than water. The applied heat makes the secondary fluid a steam, which is then used to drive turbines and generators. Geothermal power plants with a binary cycle differ from dry steam and flash steam systems since the water or steam from the geothermal source does not come into direct contact with the turbines and generators and, in this regards, the production of electricity is safer and does not require system maintenance measures such as required in case of dry steam plants or flash plants. However, it is necessary to pay attention to the high concentration of mineral salts in the geothermal water.

Binary cycle power plants are closed loop systems and emit virtually nothing (except water vapour) into the atmosphere. Since deep ground water springs with temperatures below 150 °C represent the most common geothermal resource, a significant part of electricity from geothermal sources in the future will come from binary cycle plants.

Heat pumps

There has been a sharp increase of using the heat pumps for the utilization of low-temperature groundwater energy during the last twenty years. These systems are frequently used for air conditioning in residential and commercial spaces, but also in agriculture and industry, due to their simplicity, relatively small dimensions and modularity, as they can be expanded as needed. A heat pump is a device that transfers thermal energy from one environment to another with the help of an intermediary, that is, gas in a closed circuit driven by a compressor. The principle of operation provides the system is reversible and always transfers heat from an environment with a higher temperature to an environment with a lower temperature.

According to the heat energy transfer technology, pumps are divided into four types: water-to-water, earth-to-water, air-to-water and air-air. The factor showing the efficiency of the pump is called COP - coefficient of performance - and represents the ratio between the energy input and the heat obtained. The higher the coefficient, the more efficient the heat pump. In the case of heat water-to-water pumps, the COP can get values between 5.2 and 6.2, in the case of earth-to-water pumps, the COP is between 4.4 and 5, for air-to-water pumps, the COP can be somewhere between 3.4 and 4, while for the air-air system it is up to 3.6.

7. HEAT PUMPS

A heat pump is a device that transfers heat energy from one medium to another.

There are several types of heat pumps depending on the environment from which the heat energy is taken and the environment to which it is transferred.

The most common types of heat pumps are: air - air, air - water, water - water and earth - water, where the first word means the source of heat, and the second means the medium to which the heat is transferred.

a) Water-to-water heat pump
   Water-to-water pumps are the most efficient and if there is a water source available, then this is definitely the best choice. COP is from 5.2 to 6.2.

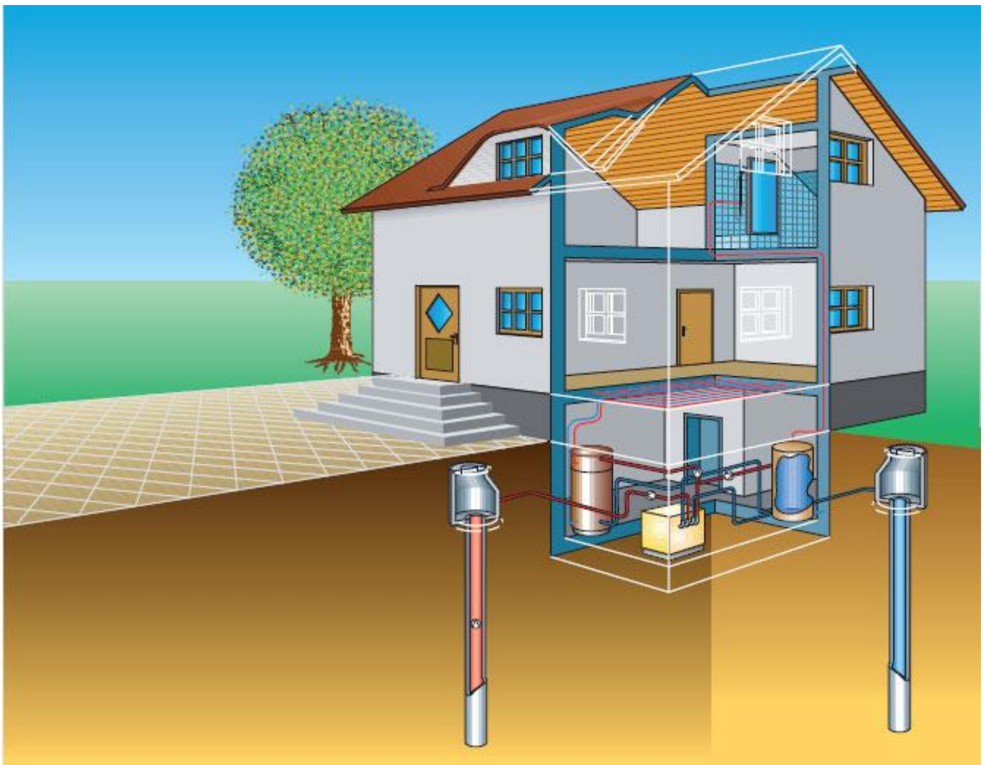
b) Ground-to-water heat pump
The second ranking are earth-to-water pumps, but one has to keep in mind that for the installation of horizontal collectors, a large enough area of land is necessary for the distribution of pipes, which must be about 2 times larger than the heated area of the building. On the other hand, if probes are introduced, their depth is close to 100 m. The COP of these pumps has a value between 4.4 and 5.

c) Air-to-water heat pump
However, the most common choice is the air-to-water heat pump, since it does not require any special access to the resource or a large area. However, these heat pumps have a COP that depends on the outdoor temperature and ranges from 3.4 to 4 at an outdoor temperature ranging from -20°C to +35°C.

d) Air-to-air heat pump
Air-to-air heat pumps are, in essence, modern split air conditioners with ability to cool and heat the air. The heat pump drains the heat from the air and its big advantage is that it can work at temperatures down to -25°C. The flaw is that this system cannot provide hot sanitary water or hot water for any other purpose while their COP is lower than other types of heat pumps (about 3.2-3.4), thus they are less energy efficient.

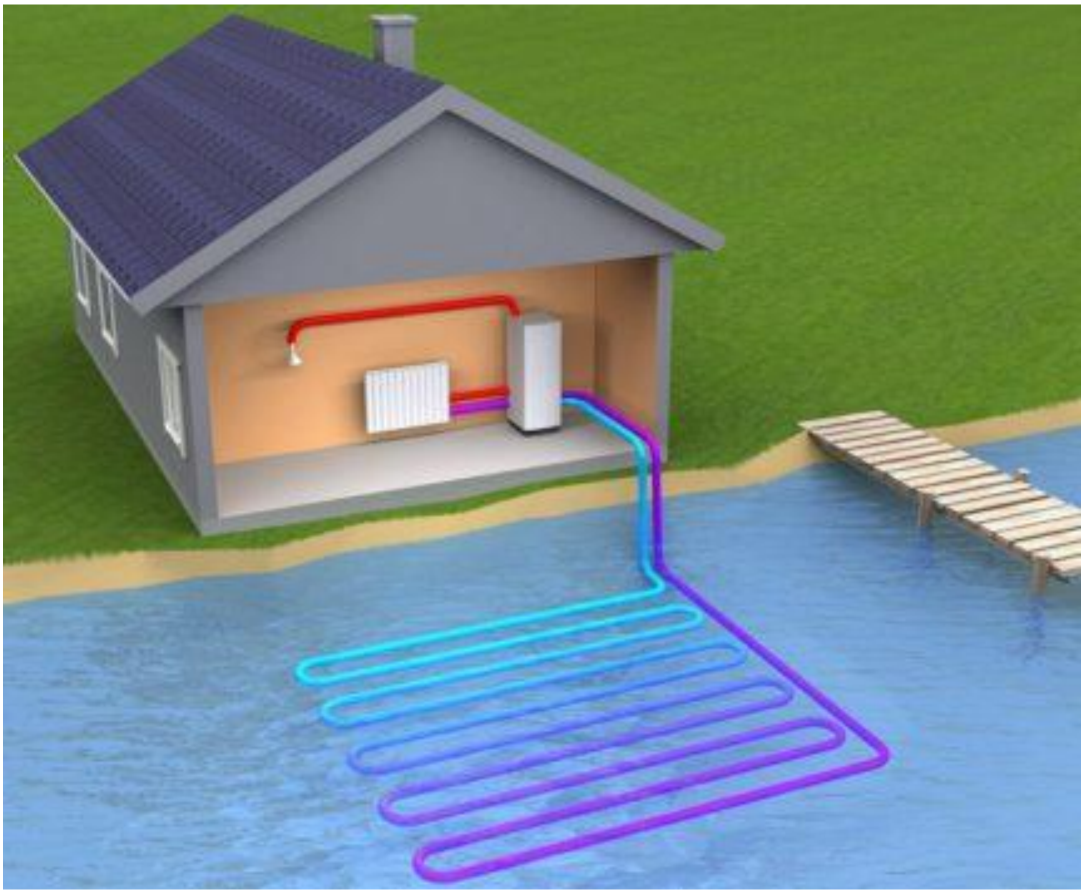
Strictly speaking, air-to-water and air-air systems are not heat pumps for the use of geothermal energy, but the heat of the air above the ground comes from the energy it radiates either from its core or from absorbed sun energy in which regards they might be considered as technologies that indirectly use geothermal.

Water-to-water heat pump



Heat pumps water-to-water use underground water or surface stagnant water for energy exchange. Thermal energy is taken directly from underground water whose temperature is constant throughout the year and usually from 10 to 15°C (depending on the depth of the source). The water flows through the heat pump system where part of the energy is transferred. The process takes place by pumping underground water from the first (exploitation) well and using a submersible pump to deliver it to the heat pump, where it cools down by about 5°C, and then returns to the second, so-called return (absorption) well where it is heated again, and the process continues from the beginning.

The distance between one well and another is a minimum of 12 m and is very important how they are oriented with regard to the direction of the groundwater flow, in order not to disturb the groundwater flows. It is an open-type borehole or geothermal well and the most efficient system for exploiting renewable energy sources using a heat pump. The water-to-water heat pump is suitable for heating residential and commercial buildings and for heating sanitary water. These systems can be attached on existing central installations for wood, coal or gas heating, but it should be adjusted to low-temperature heat distribution. Radiators and fan-coilers require a higher water temperature, thus it should be necessary to provide a system with higher compression of intermediate medium, most often Freon. The Freon is compressed by a compressor and then releases the latent heat transferred to the water that circulates through the condenser and heating system in the building. Water is exploited as a vehicle for the accumulated heat of the earth and, with the help of electricity, turns it into thermal energy for the heating or cooling system, depending on the needs.



Cooling is most often provided by a passive method, introducing underground water into the heat exchanger without an intermediary, i.e. Freon. The underground water has a temperature that is lower than the summer air temperature, and without the use of a compressor, cooling of the rooms is achieved at almost no energy rate.

Advantages

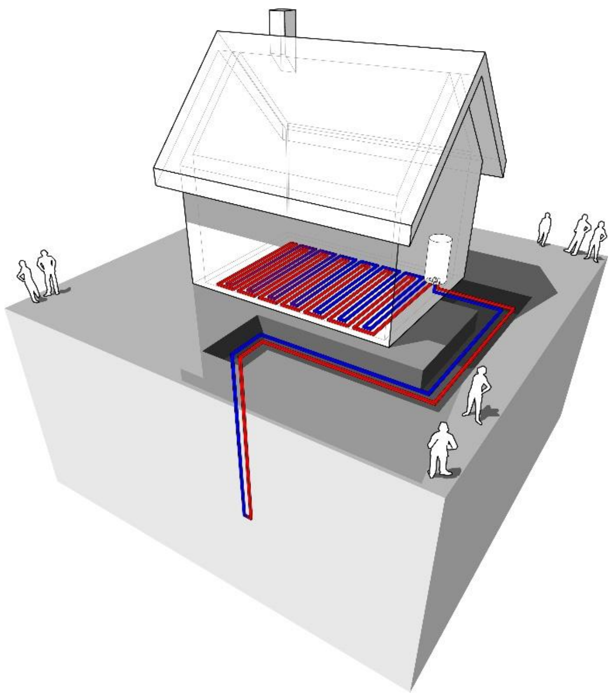
Water-to-water heat pumps have the highest COP (coefficient of performance) that ranges between 5.2 and 6.2, which means that with 1kWh of electricity used to operate the heat pump, between 5.2 kWh and 6.2 kWh of heat energy is released, thus, with only 16% of electricity consumption, the same effect is achieved as if used a conventional electrical heating system. This speaks for itself. It isn't even compare with the cooling capability, with virtually no energy consumption needed just to drive the water pump. Classic heating systems do not provide cooling, so it is necessary to introduce additional systems for this purpose.

Flaws

Water-to-water systems can only be installed where we have access to groundwater that is relatively close to the surface, since drilling holes for the probe is a significant expense. Another option is to have surface water nearby where the probes can be immersed, so even though the heat of the water is used indirectly, through the exchanger, the COP is high considering that the heat transfer from the water mass to the pipe is very intense.

Another challenge are geothermal waters, often highly mineralized and they cannot be directly introduced into the system, but only through a heat exchanger which somehow reduces the efficiency of the system. The maintenance of the system can be a considerable challenge in order to regularly prevent salt and mineral deposition.

Heat pump soil-to-water



The heat pump is using water that circulates through a system of buried pipes at a depth of 1.2 - 1.5 meters or through deep probes, which takes away heat in the winter and transfers heat to the earth in the summer. One should know that the temperature at that depth is stable throughout the year and ranges between 10-15 degrees Celsius. The pipes can be placed horizontally and then the distance between the pipes should be from 0.5 to 0.8 m. The width of the pipe is determined based on the project. Pipes can also be installed spirally, which saves space. The heat pump, through the heat exchanger transfers energy to or from the building. If it is not possible to install geothermal collectors due to lack of space or a system with a higher performance is needed, then geothermal probes are used. In this case, holes are drilled in the ground several hundreds of meters deep or, if the calculation is such that it requires a longer pipe length, in several wells that are usually up to 100 meters deep. For an average house of about 150m^2, the depth of the geo-probe should not be greater than 100m. Polyethylene pipes, in "U" shape or as a coaxial pipe so that water can flow through them in both directions and to exchange heat with the ground. High efficiency is achieved with heat pumps, and if installing horizontal collectors under the manure, one can get even better heating efficiency.

The water that receives or radiates energy in the heat exchanger, circulates through the building and radiators, fan-coilers or through a flor/wall piping.

Advantages

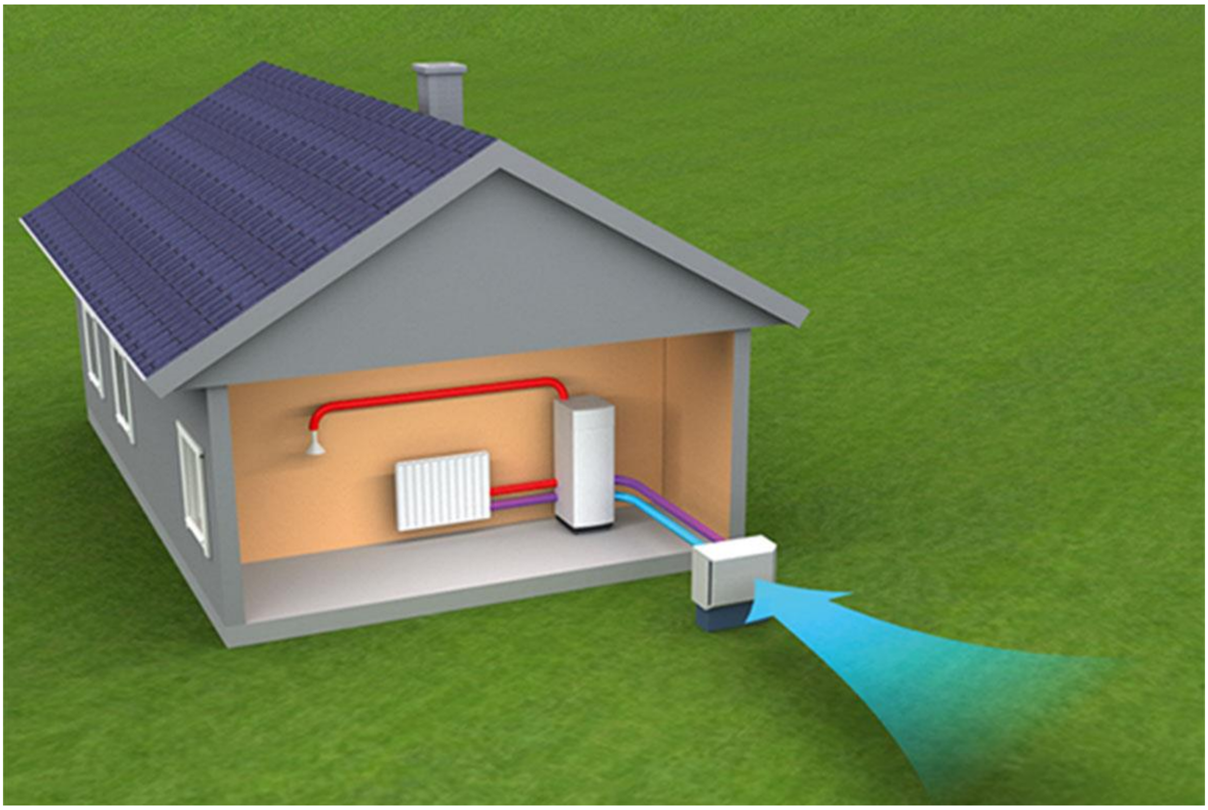
Soil-to-water heat pumps are easy to use and at the same time have a very high COP (coefficient of performance) that ranges between 4.4 and 5, which means that with 1 kWh of electricity used for the operation of the heat pump, between 4.4 kWh and 5 kWh of heat energy is obtained, thus, with only 20% of the electricity consumption, the same effect is achieved as if you were using a conventional electric heating system. This type is somewhat less efficient than using a water-to-water heat pump, but is still highly efficient. At the same time, there is a whole range of various probes that are adapted to the terrain and local conditions for using geothermal energy. Water circulates through the pipes in a closed system, so there is no special need for maintenance. Heated water for inside circulation, can be part of a high-temperature solution when it is heated to 60 or more degrees Celsius, or of a low-temperature installation that is suitable for wall and floor heating. In both cases, part of the energy can be delivered in the boiler for heating sanitary water.

<u>Flaws</u>

Soil-water systems require certain construction works in any case, which has an impact to costs of installation and exploitation of the heat pump. Digging in shallow trenches or drilling probes requires space and machinery. Calculations indicate that it is necessary to provide an area of the yard that is twice as large as the area of the building which needs conditioning. If there is not enough outdoor space, one must switch to some of the possible energy exploitation methods, spiral collectors or vertical probes. Each of these technologies has its own advantages and disadvantages, but they are proportional to the investment and larger investment ensures better quality and efficiency of the system.

Air-to-water heat pump

This is the most common form of heat pumps used (if we exclude air-to-air per unit).



The principle of operation is the same as with other types of heat pumps, only the medium from which the heat is transferred is air, and the medium that supplies or takes energy from the environment is water. As with previous technological solutions, the heat pump extracts energy from the surrounding air up to the point that is cooler than the temperature of the evaporator for the intermediate medium, usually Freon. This means that such systems can work up to -12 ^{o}C, and even down to -25^{o}C. In cooling mode, the system tolerates external temperatures up to 35^{o}C and in some cases, even higher. It is important that the device is not too exposed to external climate conditions so that it can function optimally. The device works in low-temperature water mode by default, but if the installation requires a higher temperature, a heat pump with two compressors can be used, i.e. with two compression levels.

In order to optimize the system, usually a water tank is installed as an intermediate heat storage in order to accumulate thermal energy for heating the area but also for sanitary use.

Advantages

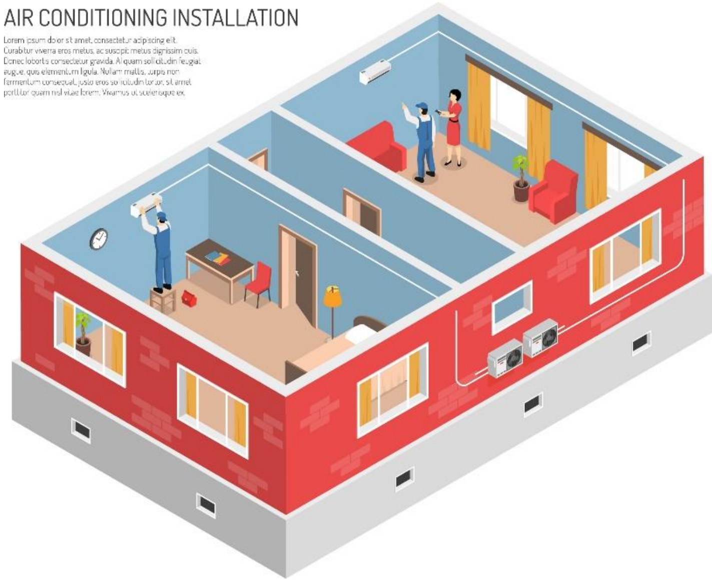
The main advantage is easy installation. Namely, as the external medium is air, these heat pumps resemble conventional split systems and the external unit is also a compressor. The only difference is that, unlike a conventional split air conditioner, the heat of the outside air is transferred into the room via water, which then circulates through the internal pipe system, whether it's floor/wall heating and cooling, whether through radiators or fan-coilers. This has an impact to relatively low price of the device and, despite the lower COP, ranging from 3.4 to 4.2, the reduced costs of installation and the system, compensate for the lower efficiency. Over 90% of all heat pumps in use are with water as an internal medium (split air conditioners are not taken into account here, which are the most used, but are different in terms of heat transfer technology). In addition, maintenance is simple because the probe is actually a heat exchanger on the device itself and there is no additional external installation.

Flaws

The main disadvantage is lower efficiency than soil-to-water and water-to-water systems. In addition, there is a drop in capacity and a change in COP when the outside temperature drops because the compressor often enters to meltdown mode, which affects overall system capacity and power consumption. These devices are particularly sensitive to increased humidity in the air, which makes the transfer of heat energy difficult. However, new generations of these heat pumps have improved technology and work in a very wide range of temperatures.

Air-to-air heat pump

The air-to-air heat pump is by far the most popular form of heat energy transfer. Although the soil does not directly appear anywhere in this thermodynamic process as its direct agent, the air is still heated by the radiation of heat from the ground, so this technology can also be seen as the exploitation of geothermal energy. Simplicity of installation and use with relatively small investments resulted that there are no urban areas without a large number of users, unless in areas where are regulations prohibiting the installation of external, compressor units



on the facades of buildings, in which case it is necessary to move them to the inside or find someone another solution. The heat is brought to the heat exchanger inside the rooms via the heat pump and intermediate medium (Freon) and is released there through the air. One external compressor usually serves one internal unit, although there are also versions with two or even three internal units or with a central heat exchanger through which air is distributed through the internal pipe system.

The devices of the new generation can work in a wide range of temperatures, although the boundaries for the tolerable efficiency of the device are within the limits of -12°C to some 30°C. Heat pumps do work at lower and higher temperatures, but their COP drops a lot.

<u>Advantages</u>

Low price, easy installation, easy maintenance. There is no need for an additional installation for heat energy distribution. The devices can heat and cool, they can be installed in residential, multi-storey buildings. The devices are autonomous and each of them can work in a special mode, as needed for a specific space.

<u>Flaws</u>

The flaws of the system are similar to those of air-to-water technology, but the main disadvantage is the low COP (about 3.2-3.4), although newer devices can achieve a coefficient of performance of almost 4, this applies to a relatively narrow temperature range. In regards with this characteristic, an air-to-air air-conditioning system would consume almost twice as much electricity as water-to-water technology to achieve the same micro climate parameters in the room. Another disadvantage is the fact that sanitary water cannot be heated with this system. The third disadvantage is that the rooms are heated with warm air and when the system is turned off, the temperature drops quickly. As mentioned, in some urban areas, the installation of outdoor units is prohibited due to bad appearance of buildings, so this technology cannot be used.

8. SELECTION OF THE OPTIMAL SYSTEM AND ESTIMATION OF COSTS

1. First to determine the purpose of the heat pump system, is it for a family house or for an apartment in a residential building and on which floor it is. For a house and even for an apartment on the ground floor, all thermal energy transfer technologies are theoretically possible, while for an apartment in a residential building on the first floor, the options are limited to air-water or a conventional split air conditioning system.

2. The second step is to assess the needs, i.e. how big is the area you want to heat and cool, what is the insulation, i.e. what are the losses and whether and to what extent will you use sanitary water.

3. The third step is to choose the heat transfer technology, that is, which heat pump operating system you can and want to use.

If you have a yard or property around the house, you can consider the soil-to-water or air-to-water system, and if you have a well on the land, that is relatively accessible underground water or there is a larger body of water in the immediate vicinity (a small lake or a large pond, even still river), you can also install a water-to-water system. If the land area around the house is at least two to three times larger than the area you want to heat and your option is a soil-to-water system, you can consider the option of surface collectors, otherwise you are left with deep geo-probes.

The choice of one of these systems depends both on the previously mentioned prerequisites and on what your budget is, how you will finance the project (from your own funds or with loan), whether you have access to some incentive measures, what are the costs of regular use and maintenance of the system and in what time you expect the return of the investment, i.e. its profitability, considering the available sources of financing.

4. Based on the previous data, you determine the type of desired system.

5. When you have defined all the previous steps, you proceed to create a rough calculation of costs and check their profitability depending on the financing method. This step may require feedback adjustments in the choice of system type and its capacity, but it is the fine tuning of needs and possibilities that finally lead you to the optimal solution.

Selection of heat pump type

To present a small case study, i.e. a simple business plan, we will give the comparative costs of installing three different systems, one with water-to-water technology, the second with earth-to-water technology and the third with air-to-water technology.

The air-to-air system will not be the subject of calculations, since such systems are already deeply commercially present and a lot is known about them while they cannot provide the same ways of using heat as the previous three. For the sake of easier comparison, we will assume that two cases will use a floor installation for heating/cooling as the most efficient, which can be applied in the reconstruction of the space, whose price will be part of the calculation and one case with fan-coilers in order to see the difference in the investment and the effects of such a solution.

Likewise, for two technologies (water-to-water and earth-to-water) we looked at a small family house with a 150m^2 heating area, and for the air-to-water technology, the object of analysis was an apartment in a building with a heating area of 100m^2. A more advanced version would be a wall installation, but that requires a more massive construction work that we will not consider here.

The case study refers to individual consumption, but the principle and cost calculation is the same for larger installations, with the relative cost decreasing somewhat with the size of the heat pump. When making these calculations, it should be borne in mind that they were made with the assumption that all three cases are in building of solid construction, with normal thermal insulation and average losses of 55 W/m^2, i.e. 50W/m2 for an apartment, and with ceiling height of 2.6m.

Consumption estimation

We will take the status of the object as a parameter that does not change in all three cases, that is that the losses are the same. For a room that has concrete slab ceilings with insulation equivalent to that of 5 cm Styrofoam, solid brick walls with a layer of plaster and insulation properties as if we had a wall with 5 cm Styrofoam, with floor insulation of the same type, with PVC or wooden double-glazed windows with glass, has a calculated total loss of 8.25 kW, of which 38% are in the walls, 31% on the windows, 22% on the ceiling and 9% on the floors. Taking this into account, it is clear that we need a heat pump of at least 9kW of heat power for the house and 5.5kW of heat power for the apartment, which has slightly less losses through the floor and ceiling. It should be noted here that better insulation, especially of the walls, can achieve significant savings.

<u>Water-to-water heat pump</u>

The first important factor for making the right decision is the capacity and use of the facility that will be heated. For buildings of larger area, such as hotels, residential or business buildings, exhibition or fair spaces, warehouses, restaurants, agricultural holdings, commercial and industrial facilities, water-to-water heat pumps are certainly the best choice.

The initial costs for setting up a system with a water-water heat pump are higher compared to systems with air-to-water pumps, although a higher coefficient of performance is achieved, i.e. better consumption efficiency throughout the year. In practice, the results can be seen in a lower electricity consumption of 75 to 86% compared to conventional heating systems, which also results in greater savings.

The first condition is that there is underground water on the land next to the building and that probes for exploitation and absorption wells can be installed. We will assume that the underground water is already at a depth of 30 meters and that the wells have a sufficient capacity of 200 l/h/ per kW of pump power. In this particular case, wells with a capacity of 1800 litters per hour, or 30 l/min, are needed. The price of drilling is between 20-60 EUR/m, but we will adopt an average value of 40 EUR/m. The price of a low-temperature pump starts at around 4,000 EUR for the mentioned capacity. Fan coiler is about 400 EUR per unit and the flow compensation tank is about 500 EUR.

The price of installing underfloor heating is between 15-60 EUR/m2, but we will assume that the average price is 50 EUR/m2, which includes the floor installation and appropriate insulation as well as the finishing work of the floor.

The price of probes, distribution and additional works is about 5-10% of the total costs, so we can calculate that the water-to-water heat pump, with wells, according to the "turnkey" principle is about 15,000 EUR, i.e. about 100 EUR per m^2 for house with a size of 150 m^2, together with the installation of underfloor heating, respective installations and final work on floor coverings.

The prices of devices and installations do not differ much between Serbia and Bulgaria, but considering the higher price of electricity, in Bulgaria the systems pay off faster.

Water-to-water heat pumps have a COP between 5.4 and 6.2 and for this small case study we will choose a system with a coefficient of performance of 6. This means that the electrical power, i.e. its consumption of the heat pump is 1,500 W, thus six times less than heat power. Since the average operating time of the heat pump is 1,800 hours per year, it means that the water-to-water heat transfer technology consumes 2,700 kWh per year, together with the energy consumption for hot sanitary water. To heat this space with a classic electric heating system, 6 times more energy would be consumed, i.e. 16,200 kWh. This results with annual saving in electricity of 13,500 kWh. It should be taken into account that the heat pump has the possibility of cooling during the summer period, which the conventional heating system does not.

Ground-to-water heat pump

If a house of 150 m2 is located on a plot of land that is at least 400 m^2 and there is no underground water or access to relatively large surface water, an excellent solution is soil-to-water technology. This way of exploiting the earth's energy can also be carried out in a smaller area of at least 2.5 times larger than the area we want to heat, with the help of geothermal probes. The approximate required depth of the probe in meters is calculated by the heating power of the heat pump (kW) x 14 = depth of the probe (m), which in our case would be 126 m. In the case of very wet soil, this depth can be shortened to less than one hundred meters, since the thermal conductivity of humid such soil is higher, so heat exchange is better, but it is still a demanding job. However, here we will take the case of horizontal collectors as an example, since the example of was considered for water-to-water technology. Energy from the ground is exchanged through a buried collector that is laid at the appropriate surface, which depends on the type of soil and the heating surface of the building. For optimal performance, the surface of the collector must be approximately twice as large as the heating surface. It is important that the surface of the area under which the collector is laid is not blocked by a building, is not covered with asphalt or has not been carried out in any way that would prevent the penetration of storm water, because it maintains the humidity of the soil. The approximate calculation for the surface of the collector, which is made of PE pipes, diameter 1", buried at a depth of 1.2-1.5 m and with a distance of 70-80 cm is thermal power of the pump (kW) x 40. From it follows that in our case we would need about 350 m^2 of land, although the area can be significantly smaller if the soil moisture is high. There is also the possibility of installing the collector in a spiral manner, where care should be taken that the length of the pipe must have a heat transfer capacity in accordance with the thermal power of the pump.

We will take the same starting parameters, the heating surface of the house and insulation with losses of 55W/m^2. The prices of external installations are similar to the water-to-water system, although with a lower COP, so we will choose fan-coilers that can heat and cool the space. This is a less comfortable but therefore cheaper option. However, the amount of investment and the time of return of capital are relevant for evaluating the expediency of using these systems.

The price of excavating the soil, laying PE (polyethylene) pipes and backfilling is about 6-7 EUR/m^3, which in our case would amount to about 2,500 EUR with the need for cultivation of the excavated surface, which is roughly half the cost of drilling a 100m well, but it is very similar to the cost of shallow water wells, albeit without extensive subsequent earthworks.

The price of a high temperature pump starts at around 6,000 EUR for a heat capacity of 9kW. The fan coiler is about 400 EUR per unit and flow compensation tank is about 500 EUR EUR.

We will consider the option in which the house will require 7 fan coilers for the whole house.

The price of pipes, distribution and additional works is about 5-10% of the total costs, so we can calculate that the total expense for a heat pump system based on earth-to-water technology, with thermal power of 9kW, with horizontal ground collectors and with fan-coilers in internal rooms, for a house of 150 square meters, medium insulated, **is about 13,500 EUR**.

The cost of devices and installations do not differ much between Serbia and Bulgaria, but considering the higher price of electricity, in Bulgaria the systems pay off faster.

Ground-to-water heat pumps have a COP between 4.4 and 5 and we will choose a system with a coefficient of performance of 4.7 for this small case study. This means that we need a pump with an installed electric power of 2000W. Since the average operating time of the heat pump is 1,800 hours per year, it means that the system for using geothermal energy using earth-to-water heat transfer technology consumes 3,600 kWh of electricity per year, together with the energy consumption for hot sanitary water. To heat this space with a classic electric heating system, 16,200 kWh would be consumed. It is obvious that the annual saving in electricity is 12,600 kWh. It should take into account that the heat pump has the possibility of cooling during the summer peri9d, which the conventional heating system does not.

<u>Air-to-water heat pump</u>

The most popular technology of heat pumps is, by far the air-to-water system that enables healthy air conditioning of residential and commercial spaces with energy savings of up to 4 times compared to conventional heating and cooling system and whose installation is significantly cheaper, less technically demanding and takes up less space.

However, due to greater variations in air temperature than with the ground or geothermal water, the coefficient of performance changes during different seasons, with COP values being better in summer and worse in winter, but even then, at relatively low temperatures (up to -25^{o}C), the performance of air-to-water technology is better than other types of heating. In addition, air-to-water heat pumps can be installed separate apartments in multi-apartment buildings, while this is not the case with water-to-water or ground-to-water heat pumps that can only be used for entire individual buildings that have a specific ground area that they can use.

Here we will look at the case of a 100 m^2 apartment in a residential building with slightly lower heat losses of 50W/m^2. For the heat distribution system, we shall select floor heating/cooling because it is the most comfortable and has hidden installations, thus it does not take up space and does not influence the aesthetics of the apartment. An outdoor unit with a compressor (in some models also with a water unit that is later led through the distribution system in the interior rooms), can be installed on the outside wall or on the balcony/terrace/loggia, if it exists.

The price of a low-temperature pump starts at around EUR 4,000 for a heat capacity of 5.5 kW, which is necessary for the air conditioning of this space. The price of installing underfloor heating is between 15-60 EUR/m^2, but we will assume that the average price is 50 EUR/m^2, which includes the installation of the floor installation and appropriate insulation as well as the finishing works of the floor.

The piping costs and additional works is about 5-10% of the total costs, so we can calculate that the air-to-water heat pump, on a "turnkey" basis, **is about EUR 9,500** for a 100 m^2 apartment, together with the installation of underfloor heating, respective installations and craft work on floor coverings.

The prices of devices and installations do not differ much between Serbia and Bulgaria, but considering the higher price of electricity, in Bulgaria the systems pay off faster.

Ground-to-water heat pumps have a COP between 3.4 and 4 and we will choose a system with a coefficient of performance of 3.7 for this small case study. This means that we need a pump with an installed electric power of 1,500W, which can deliver 5,500W of heat power. Since the average operating time of the heat pump is 1,800 hours per year, it means that the system for earth-to-water heat transfer technology consumes 2,700 kWh of electricity per year, together with the energy consumption for hot sanitary water. To heat this space with a direct electric heating system, 9,900 kWh would be consumed. Therefore, the annual saving in electricity is 7,200 kWh. It should take in to account that the heat pump has the possibility of cooling during the summer, which the conventional heating system does not.

Calculation of savings and investment payback time

Type of heat pump	Heat output of the system kW	System price EUR	HP consumption kWh	Total consumption of conventional system for electric power supply MWh	Savings MWh	Value of savings EUR/god.		Return of investment (ROI)-year	
						Sr	Blg	Sr	Blg
Water-water House 55W/m2	9	15.000	2,700	16,2	13,5	1.350	2.025	**11**	**7,4**
Soil-water House 55W/m2	9	13.500	3,600	16,2	12,6	1.260	1.890	**10,7**	**7,2**
Air-water Apartment 50W/m2	5,5	9.500	2,700	9,9	7,2	720	1.050	**13,2**	**9**

Note: the prices of electricity have been adopted at level of September 2022: 0.1 EUR/kWh in Serbia and 0.15 EUR/kWh in Bulgaria

If the project is financed from a loan, the investment return time is extended, and if the user has access to incentive funds, it is shortened. In addition, energy will become more expensive over time, so the return on investment will get shorter.

It should be noted that all three examples are given with options that are slightly more expensive, due to the installation of underfloor heating, however, if heat is distributed with passive radiators or fan coilers that have the possibility of both heating and cooling, the entire installation cost is significantly lower, however, since this option requires higher water temperatures, the heat pumps are also more expensive since they need a double compressor. In addition, radiators do not have the ability to cool and fan-coilers work on the principle of forced air circulation, so they are less comfortable to use. Installations are easier to carry out and it is not necessary to reconstruct the entire floor, but they are visible and this sometimes might be a problem.

The calculation for the installation of heat pumps, regardless of the technology, is always worthwhile because the life span of the equipment is 25+ years and no matter how long the repayment period is, after its expiration the cost is only the management of the system, which is at least 4 and at most 6 times lower than the costs that has equipment for conventional solutions. In addition, it is possible to combine heat pumps with other forms of renewable energy sources, especially solar energy for heating water or photoelectric panels for running heat pumps, which enables even greater degree of efficiency and almost full independence from external energy sources.

9. ENERGY STORAGE SYSTEMS

Heat storage is a particular challenge that is usually solved with materials that have a high heat capacity, water or stone for example, but for efficient use, it is necessary to provide very good insulation so that the stored heat does not "leak" over time. Depending on the technology used to store it, excess thermal energy can be stored and used hours, days or even months later for objects of different sizes, from individual housing units, houses, apartment buildings, districts, cities or regions. Thermal energy is also stored for the purpose of balancing consumption in periods when consumption is lower, and when it is needed more, the stored energy is used. For example, the distribution between day and night, summer and winter season (seasonal thermal energy storage) and can be performed for heat or cold storage. Storage media can be water or ice slurry reservoirs, large amounts of soil or salt, rock masses accessed by boreholes for heat exchangers, deep aquifers located between impermeable layers, or shallow, lined pits filled with gravel and water and insulated at the top. Thermal accumulators can store energy from combined heat and power plants (CHP) as well as heat produced from other renewable energy sources as well as waste heat from industrial processes.

Thermal reservoirs can also be used for "charging" energy with support of heat pumps in periods when the price of electricity is lower and used when it is more expensive. This application is particularly interesting for individual use of heat from geothermal systems. In these cases, a water tank is most often used, which can store thermal energy for several days.

For example, a tank of 1,000 litters ($1m^3$) with water heated to 80°C, has thermal energy that can be used to independently heat a living space of about $100m^2$ for over six hours. The exact volume is calculated by the designer, but according to practice, about 55 litters of water is sufficient for every kW of the factory-declared power of the heat pump or other heating device. There are several types of tanks: without and with a heat exchanger, with two exchangers for solar heating, with or without an additional heater.

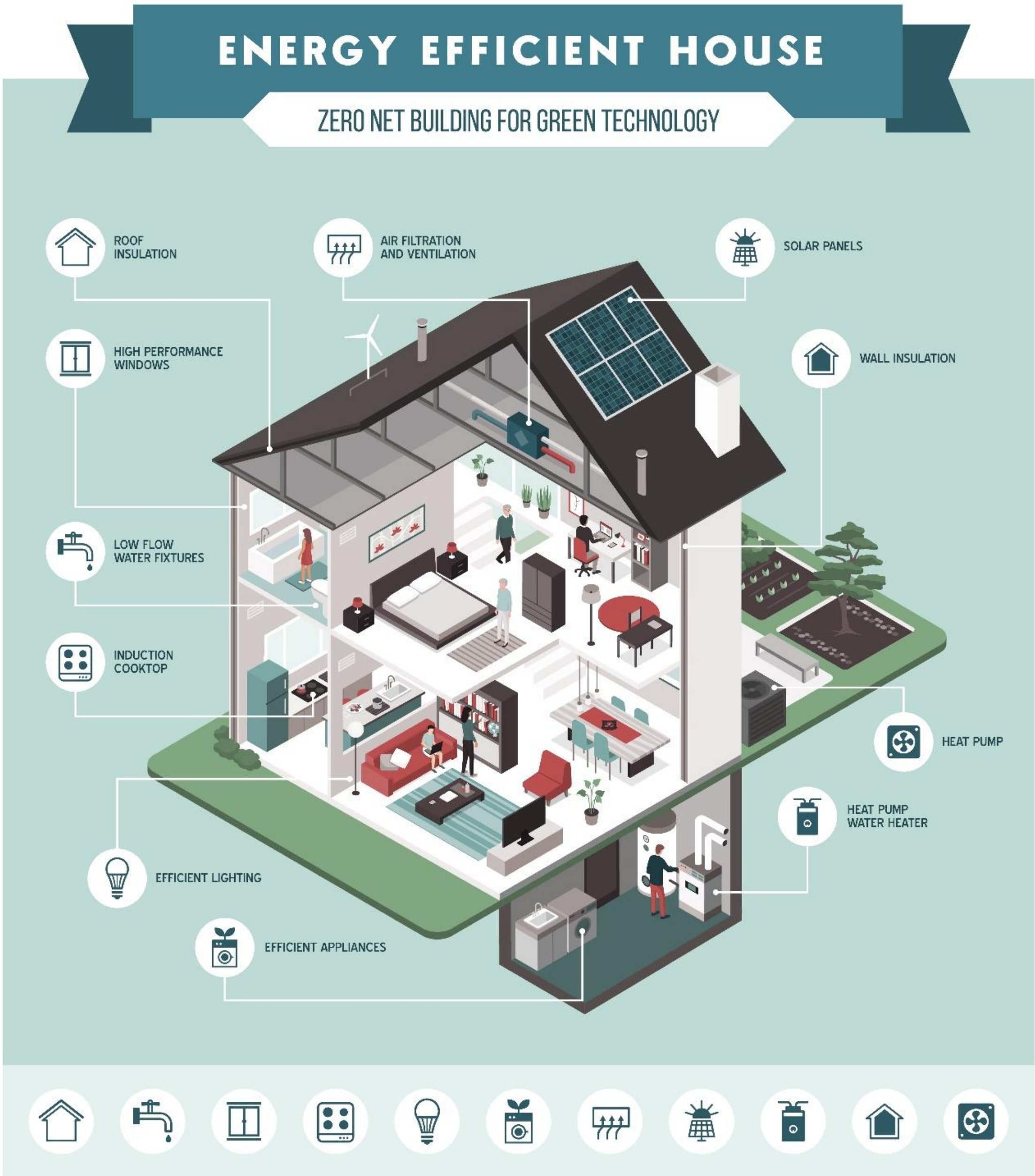
Even with all the imperfections, it is still a way to save energy instead of losing it irretrievably, with the said technology constantly improving and the process perfected.

Large tanks with gel or sand (pictured) are used as accumulators, which can store heat for several months, and can then be used for heating rooms or for industry.

Thermal storage, both seasonal and short-term, is considered an important tool for cheap balancing high shares of variable electricity generation from renewable sources and for integrating the electricity and heating sectors into energy systems that are almost or entirely powered by renewable energy.

10. SMART HOUSES

Smart houses/buildings are facilities that have monitoring and management systems which are using modern technologies, integrated for achieving maximum efficiency and self-sufficiency of all systems. Internet of Things (IoT) plays an important role in this concept.



These are homes that have autonomous energy solutions using renewable energy sources, from solar, to produce electricity and heat, to heat pumps that enable air conditioning throughout the year and with minimal energy consumption for their work. Digital systems monitor water consumption and its processing into technical water, house lighting, ventilation, and all the way to programmed watering of the yard and the use of rainwater for technical use. In addition, the security of the house can be controlled by cameras, but also by anti-fire and/or anti-flood sensors. Control systems can even support the planning of tenants' activities, with reminders and management of entertainment and leisure devices, the dynamics of charging electric devices and need to optimize their consumption by redirecting it to periods of cheaper energy. The extent of automation of current processes is only a matter of requirements, investment possibilities and the justification of such systems because there are no limitations in the technological sense. Such objects often approach the ideal model of completely self-sufficient and independent units in terms of energy as well as with a high degree of independence when it comes to water, whereby their ecological footprint, i.e. the impact on the environment and climate change through CO_2 emissions, is negligible.

11. GOOD PRACTICE EXAMPLES

Project: Barredo Colliery District Heating

When: 2019

This project transformed the old Barredo coal mine (Mieres, Asturias) into the largest geothermal district heating in Spain. Water from closed mines, such as the Barredo Colliery, had to be pumped out to prevent flooding. This entailed very high costs for Hunosa, the state-owned company that manages the facility. With the new geothermal district heating system, this problem has been turned into a renewable resource. The system uses the thermal energy of water and, thanks to the use of water-to-water heat pumps, provides heating and hot water for the citizens of Mieres.

The project created a significant environmental and social impact on its community. Mieres has traditionally been a town associated with coal mining, with several mines located along the Caudal river valley. In recent decades, the decision to stop coal mining has meant the loss of a huge number of jobs. The transformation of the mine brings new opportunities for work and diversification of economic activities in this area. Furthermore, the total estimated reduction in CO_2 emissions is significant and amounts to around 650 tons per year compared to the previous natural gas heating system. In addition, the electricity for the geothermal facility comes from 100% renewable sources. This project turned a fixed cost into an unlimited renewable resource, enabling the region's energy and economic transition.

It was awarded in 2019 by the International Energy Agency (6th Global District Energy Climate Awards) in the "Emerging Markets" category with the "Excellence Award".

Project: EBox Geoenergy Solar Hybrid Solution

When: 2020

With the motto "Engage in a carbon-free future", the Swedish company MegaWatt Solutions has developed a smart integrated heat pump solution, aiming to improve the geothermal heat pump and district heating market. MegaWatt Solutions believes in geothermal energy as an alternative solution for replacing fossil fuels in large residential and commercial buildings as well as for replacing small and medium energy sources in district heating networks. EBook (Energy-in-a-Book) was created to fulfil the growing demands for fast and reliable installations to meet national and global decarbonisation targets. The ebook integrates 3 core technologies:

1. Their own designed high efficiency and high power heat pumps,
2. Streamlined process: industrialization
3. The EBok digital control system is pre-assembled, packaged and pre-tested as an industrialized, digitalized and streamlined "plug-and-play" CO2-free solution for heating, cooling and hot water in large facilities.

The fact that it is pre-tested in the factory means that it can be quickly and conveniently installed on site by connecting the EBox to pre-drilled boreholes, saving time, transport and ensuring the safe operation and safe of the project. The installation can be increased by adding more heat pumps in a modular form or by connecting several EBoxes together. The revolutionary, modular "Lego" design of this project also allows for easy replacement of important components within minutes, even during plant operation.

EBok creates an easy-to-maintain local area network that is greatly simplified with its modular design. By using a fully integrated SCADA system within the EBok application that is connected to the company's MegaWatt Cloud server, EBok customers can optimize energy supply and increase energy performance. When combined with electricity generated by solar panels, wind energy or hydropower, the EBok becomes a complete CO2-free energy solution. Therefore, this heat pump installation is significantly more environmentally friendly than ordinary heat pumps because it generates only 3 grams of CO2 equivalent per kWh of heating.

Project: Geothermal park

When: 2019

Geothermal Park is an innovative geothermal eco-industrial park located in Iceland. It is connected to the geothermal energy plant for the use/production of heat and electricity in the Hellisheidi plant, one of the largest geothermal installation in the world. The park uses Hellisheidi's excess energy for a small hydrogen production unit and a plant to capture carbon directly from the air. In this way, the park turns the challenge of stable geothermal energy production that serves changing markets into a solution that creates value from waste, thus promoting the principle of circular economy in energy.

The multiple use of geothermal resources is not a new concept. However, every geothermal resource is different, and the multiple use opportunities can vary greatly from location to location. The originality of the Geothermal Park is related to the integration of the energy supply of the companies within the park, in parallel with the production of power plants in order to increase the flexibility of the income streams of geothermal plants. A small hydrogen installation in the Geothermal Park produces hydrogen using electricity from the Hellisheidi plant when demand for electricity is low at night or after hours. The hydrogen produced will be used to fuel hydrogen-powered vehicles in Iceland, promoting the energy transition away from fossil fuels in the transport sector.

The carbon capture facility, operated by Climeworks, uses excess high-temperature geothermal fluid at times when heat demand is low to remove carbon directly from ambient air. For this purpose, the Carbfik method is applied for the permanent mineralization and storage of CO_2 in stone, thus contributing to solving the climate crisis. This facility is the largest direct air capture and storage project in the world to date.

Both projects benefit from the extremely low carbon footprint of the Hellisheidi plant. These parallel projects have improved the overall efficiency of the use of the geothermal power plant, thereby reducing waste in terms of heat or electricity and at the same time increasing revenues and creating new values.

Residential building – Cara Dušana, Zemun

BRIEF DESCRIPTION OF THE PROJECT

In this residential building, with an area of approx. 1000 m^2, an installation for underfloor heating and cooling with a water-to-water heat pump has been installed, having the access to underground water. In the yard behind the house, 4 boreholes of 60 m each were made. The total time needed to perform all the works was 35 working days divided into 3 stages. The specificity of the residential building is the floor cooling of the entire building.

Two heat pumps have a power of 20kW, each and a COP of 5.4, so they cover all the tenants' needs for heating, cooling and hot water.

Project: mushroom growing hall

October 2013

Hall volume: 3,000 m3

Address: Novi Sad, Majke Jugovića bb

Project description:

For basic heating and cooling, a water-to-water type heat pump, with a heat output of 25 kW, was designed and built. To meet the needs of the process, automation of the air conditioning for the mushroom growing hall, fan control of the channelled FC device, circulation pumps, three-way valves and fresh air blinds was introduced. The control regulates the indoor temperature and humidity of the mushroom growing hall. In this way, the microprocessor maintains the temperature and humidity in the range of $\pm 0.5^{\circ}C$ in relation to the set temperature. The heat source is a well with underground water with a submersible pump. A unique installation with hot and cold water storage is planned for heating and cooling facility in the process of growing mushrooms. A channelled fan coil device was installed as an element for to distribute hot or cold air.

Heat pump connection to thermal storage Control panel

Family house 180 m², Niš, Srbija

Project realized in 2018. EU-reversible heat pump (ground-water). Heating power 9.5 kWth/2.2 kWel, Cooling power 8.9 kWch/2 kWel, COP 4.5.

Underfloor heating with radiators was installed during construction, so there were no subsequent interventions. Losses are projected at 50 W/m². Next to the house, two 54-meter-deep boreholes were drilled into which double U geo-probes were inserted.

Cost of the project is 14.400 EUR

Family house 200 m^2, Trnava, Srbija

For the air conditioning of the house, a floor heating system and fan-coil parapet units were installed. For use of geothermal water, the EU-reversible heat pump (water-water), heating power 10 kWth/2.5 kWel, cooling power 8.9 kWch/2 kWel and COP 4.5 was built in.

Two probes were dug at a length of 47 meters with a well capacity of 30 l/min.

12. INSTEAD OF CONCLUSION

Energy is crucial both for global development and for personal needs. Enabling stable and sustainable supply is of paramount importance.

The use of renewable energy sources provides an exceptional opportunity for energy security of the countries and its citizens, with relatively small investments.

<u>The 10 most important advantages of RES are:</u>

1) It is available everywhere

2) It is easy to use and suitable for both small and large consumers

3) Stimulates the local economy

4) Reduces dependence on energy imports and geopolitical influences

5) Low exploitation costs

6) Installations can be easily expanded.

7) Do not pollute the environment.

8) They are safe

9) Investment costs are dropping

10) They increase the living standard.

<u>The 5 most important challenges in using RES are:</u>

1) It is not there all the time

2) Relatively high initial investments

3) Lack of infrastructure

4) Insufficient knowledge, skills and practice

5) How to save the energy

This Guide aims to explain the nature and use of geothermal energy and to point out practical solutions, along with all the challenges that may arise along the way.

For all technologies using low-temperature geothermal energy that are suitable for air conditioning (water-to-water, earth-to-water, air-to-water and air-air), the investment pays off in a period of 10 to 15 years in case of the first three systems that use water for heat distribution inside the building, and for the air-to-air system even faster, with a note that the latter does not have the possibility of heating sanitary water and has lower efficiency, therefore it consumes more energy to achieve the desired effect and will be more expensive to operate. However, despite the shortcomings that each of the mentioned systems certainly has, investing in this type of air conditioning (heating and cooling) pays off many times over. The investment is sure to be returned because the life span of heat pumps is 25+ years. After the payback period, you are left with very cheap energy with relatively low maintenance costs for your geothermal energy system. If these technologies are combined with other sources of renewable energy, for example with solar, you can get an extremely efficient, independent from external influences and practically free system for healthy air conditioning of residential and business premises but also for industries.

Investing in geothermal systems for your own consumption is definitely worthwhile for several reasons:

• Geothermal systems can be installed in a relatively short time. Even in the most complex interventions, the system installation time does not exceed 30 working days.

• The level of one's own energy security increases and the dependence on external energy sources, and thus also on disruptions in the energy market, decreases.

• Energy costs are reduced because after the investment payback time, energy is obtained only with the operating costs of the system, which are significantly lower than the final energy price.

It should take into account that the price of the system itself is not negligible for the average household budget where it is important to plan the financing well ahead and to find the most suitable way. If the financing is done without loan and/or without incentives, then the geothermal air conditioning system could be considerable financial venture, although it will certainly pay off over time, especially considering that the price of energy will certainly rise over time, which will increase the profitability of the system and shorten the investment return time.

13. ABOUT THE PROJECT

Project name	Renewable energy for smart growth and protected environment
Leading partner	Vidin Chamber of Commerce, Bulgaria
Partner	RARIS, Regional Agency for the Development of Eastern Serbia, Serbia
Priority axis	Environment
Project objectives	The main objective of the project is to increase capacity and improve awareness of environmental issues such as renewable energy sources and energy efficiency among the target groups: SMEs, local authorities, environmental organizations and institutions, the general public

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