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Introduction

The will to use renewable energy sources, as well as to find new water sources is nowadays practically global. The same could be said for the will to protect the environment via the use of green energy sources.

Our project aims at exactly these areas. In the installation that took place in the building of Hydraulics and Environmental Engineering (in the following pages, building of Hydraulics), located inside the campus area of the Aristotle University of Thessaloniki (A.U.Th.), main objectives were to make use of a renewable energy source, namely geothermal energy, and moreover to use water from an aquifer below and around the area of A.U.Th., water from which is not currently in use anywhere else.

Although the prerequisites for such a system to work were present in A.U.Th., the same is true for several locations in cities and areas around the world. Thus, the installation that took place in the building of Hydraulics can serve as a guide for the installation of such systems in several other buildings.

In the following pages it is shown which indications led to the thinking that the area around the building of Hydraulics was suitable for a system, like the pilot installation which took place, to work. Following that, case studies present the case of creating a system similar to that in A.U.Th. in other places in Thessaloniki.

Lastly, with having the experience of installing such a system comes the knowledge gained from the difficulties that occurred during the process. As it is the case currently, a part of those difficulties in our country came from the process of obtaining the necessary permits and other issues related to bureaucracy. Thus, a report was created describing them and suggesting possible solutions to them. This can be found at the last part of this broader document.

Freshwater sources

General information

Freshwater is the water which contains low levels of dissolved salts. It is totally vital to both, sustaining human life and to the land ecosystems in general. Freshwater is a finite resource, contrary to saline water, and it can be found in rivers, lakes and underground aquifers.

Lakes and rivers are the main freshwater sources on the surface of the Earth and the ones that receive the most attention by the general public. However, the lesser talked about underground aquifers are not only an important source of freshwater, but also a vital one for many areas around the world.



Figure 1. The McKenzie River, in western Oregon, U.S.A. (Source: pixabay.com)

Underground aquifers

An underground aquifer is a geological formation which stores water and allows water to move through it. This formation can consist of permeable rocks, gravel, sand and other materials capable of holding water. Water coming from rain events or the melting of the snow can infiltrate in the ground. As it (usually) slowly moves in it, it fills the pores of the ground creating an underground reservoir.

The water in underground aquifers can be an important source of freshwater for human consumption, irrigation, and industrial uses. The aquifers can be found all over the world and vary in size and capacity. Some aquifers are small and local, while others are massive and can span across entire regions or countries. The water in them is typically replenished by precipitation or surface water that percolates down into the ground and fills the spaces within the porous material.

Within the aquifers water will naturally flow from areas of high pressure to areas of low pressure. The structure and composition of the aquifer is going to affect how quickly the water flows and how easily it can be extracted. The water stored within an aquifer is usually extracted by the means of drilling and pumping, when needed to be used.

It is worth noticing that the water within these aquifers, although it is located underground, is also susceptible to contamination from human activities such as industrial practices, agriculture, and urban development. Pollutants can infiltrate into the groundwater and affect its quality, making it unsafe for consumption or other uses. Therefore, proper management and conservation of aquifers is crucial to ensure their long-term sustainability.

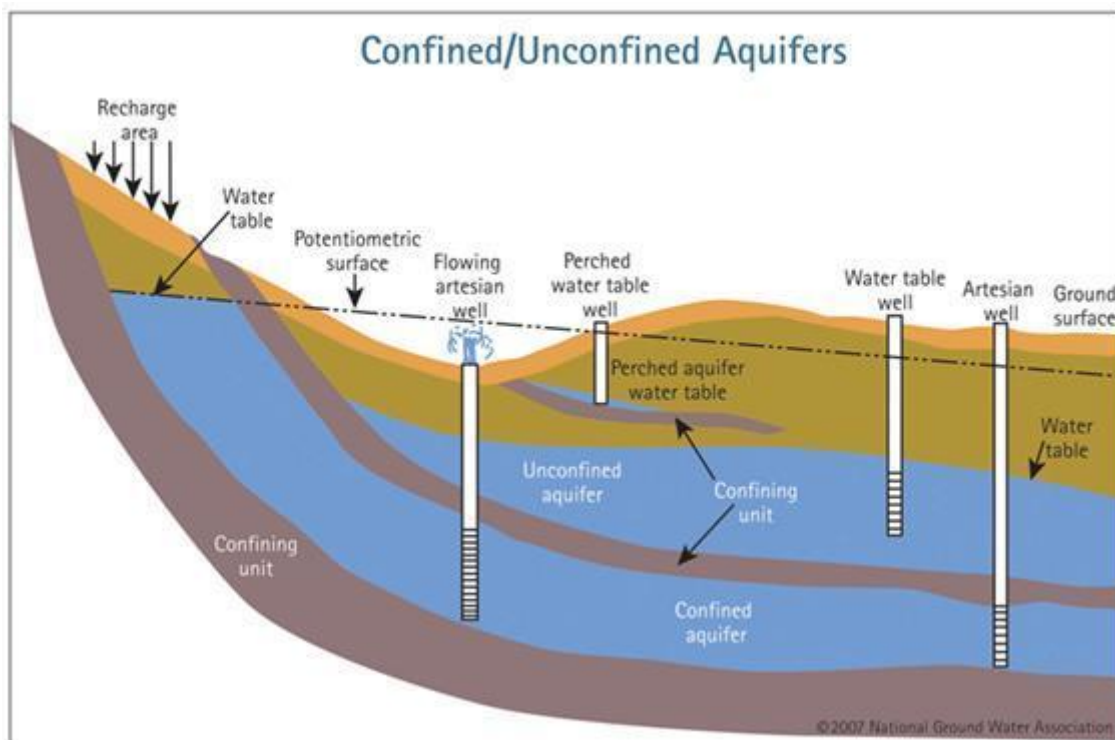


Figure 2. Underground aquifers (Source: A. Kersting, 2018)

Renewable energy sources

General information

As an increasing number of people seek to reduce their reliance on fossil fuels, as well as to protect the environment, renewable energy sources are becoming more and more important. Renewable energy sources can be considered those which provide energy from a natural source that is practically not able to be depleted or that can be replenished or renewed. Examples of renewable energy sources are solar, wind, hydroelectric and geothermal energy, as well as biomass.

The use of renewable energy sources comes with several advantages. One of the most significant ones is the fact they can not be depleted, unlike fossil fuels. Additionally, their use can be more environmentally friendly and lead to less pollution of the environment, compared to the use of fossil fuels.

Solar energy is likely the most widely used out of all the renewable energy sources. Solar energy is usually harnessed via panels which convert it to electricity (photovoltaic panels). Their application can be either domestic, with photovoltaic panels placed on rooftops, or industrial, with smaller or larger areas of land getting covered with photovoltaic panels and forming solar farms.



Figure 3. Photovoltaic panels, as part of a solar farm (Source: pixabay.com)



Figure 3. Photovoltaic panels on the roof of a house (Source: pixabay.com)

Wind energy is one more widely used renewable energy source. It is usually harnessed via the use of specialized turbines. These turbines use the kinetic energy of the wind and can convert it to electricity. Wind energy is not commonly used domestically. It is mostly harnessed through large scale constructions. These usually include multiple large turbines and are called wind farms. These farms can be located on land, as well as offshore.

Additionally, when harnessing hydroelectric energy, it is again kinetic energy that is being used. In this case, the kinetic energy comes from water falling or flowing. The usual modern practice is to have a dam created, blocking the natural flow of water in a river or stream. As the water is being released from the dam in a controlled fashion, the power plant of the dam uses its energy to produce electricity.

Finally, biomass comes from plants, plant-based materials and in general organic matter. The organic matter gets burned in specialized power plants and the heat produced can be turned into electricity.

It is worth mentioning that as renewable energy sources are being used in an even larger scale and as more and more funding and research gets dedicated towards improving the available ways to use them, the cost of using them is expected to decrease, leading to them gaining further popularity and an even more increased usage rate. However, they also come with a few disadvantages, each of them with specific ones, that should not be neglected and should be taken into account in an appropriate manner.

Geothermal energy

Geothermal energy is a renewable energy source and it comes from the thermal energy that is stored within the Earth. This thermal energy is primarily generated by the decay of naturally occurring radioactive isotopes in the Earth's mantle and crust, as well as by the residual heat from the planet's formation. In countries that receive a lot of sunlight, the heat coming from the Sun is also an important factor contributing to the amount of heat stored in the soil, and especially in the more shallow layers of it.

In order for geothermal energy to be used, a number of different technologies and practices have been employed. These have resulted in the creation of geothermal power plants, ground-source heat pumps (or simply, heat pumps) and more. Geothermal power plants generate electricity by exploiting underground reservoirs of hot water and steam. These reservoirs contain vast amounts of thermal energy, which is used to drive turbines and generate electricity. Ground-source heat pumps, in contrast, utilize the relatively constant temperature of the soil, even only a few meters below the surface, to heat and cool buildings.

The use of geothermal energy, since it is a renewable energy source, is advantageous in a number of ways. It has a low environmental impact, it produces negligible greenhouse gas emissions, and it can provide a reliable, steady source of energy.

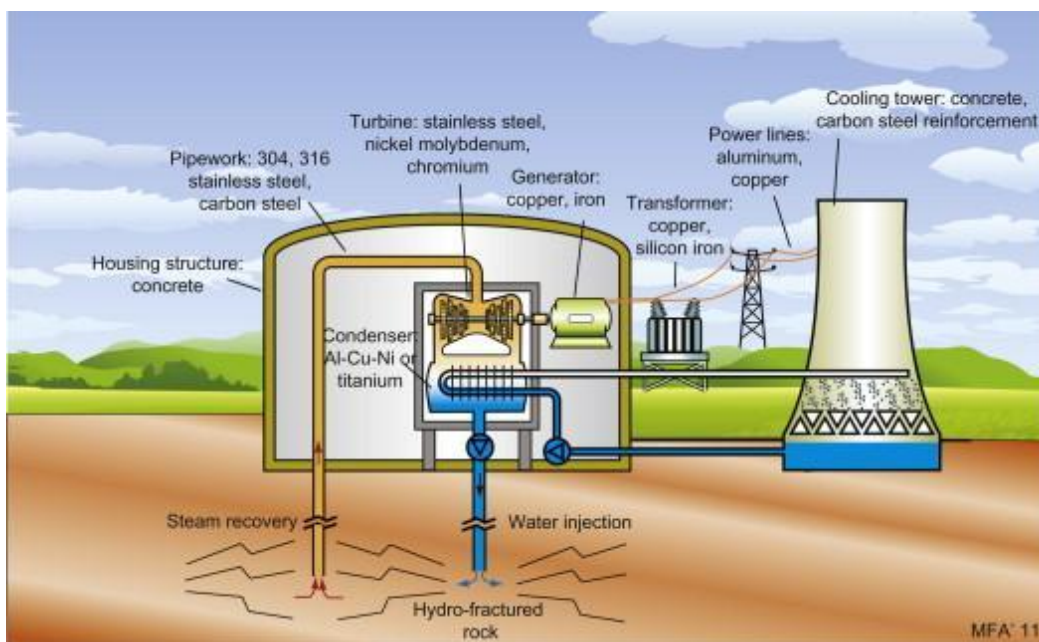


Figure 5. An overview of geothermal power plant (Source: M. F. Ashby, 2013)

Geothermal energy from shallow depths and the case in the Mediterranean countries

The soil temperature is not equal to this of the air above it. This is true due to the fact that the soil has a much greater capacity to store heat. Consequently, even in relevantly small depth, its temperature can differ drastically from this of the air above.

The temperature of the soil, especially in small depths, can be affected by solar radiation, which is the primary source of energy that heats it. The Mediterranean region is characterized by a hot and dry climate, which has a significant influence on the temperature of the soil. The high levels of solar radiation it receives lead to it having an elevated temperature. Thus, even at a depth of about 5 to 10 meters from the surface, the temperature of the soil can be around 15°C all year long.

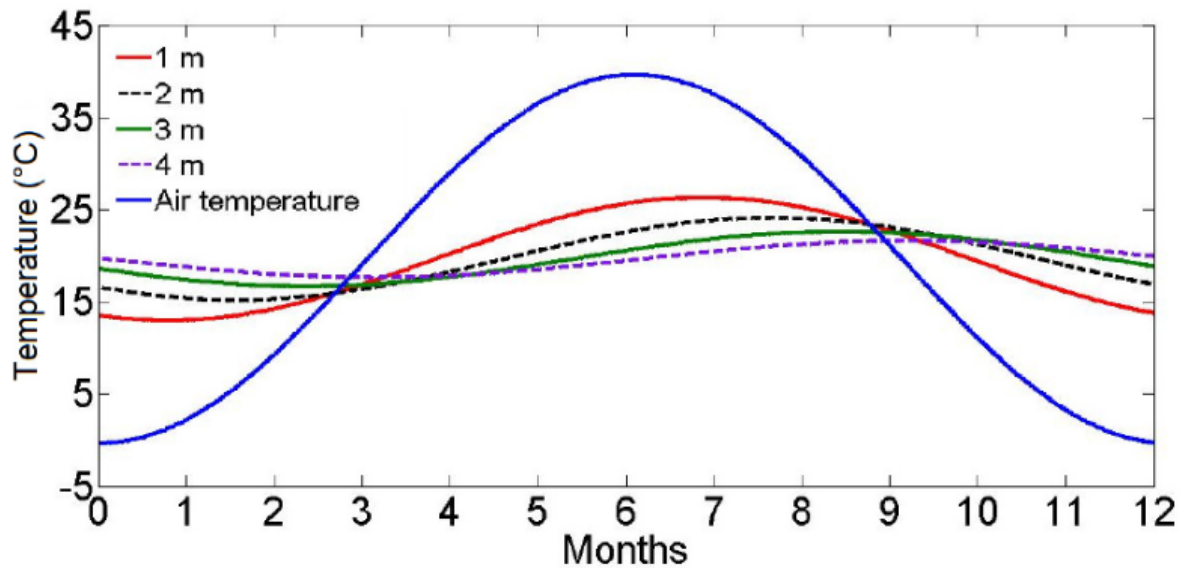


Figure 6. Annual variation in the temperature of the ambient air and the soil at different depths at a location on the same geographic latitude as areas of the Mediterranean (Source: R. Vidhi, 2018)

Geothermal systems

The use of the geothermal energy in buildings, in order for their demands for heating to be covered, can happen via one of two main types of systems. A closed-loop system or an open-loop system. Both systems make use of the fact that the temperature of the ground at a certain depth below the surface is higher than that of the air, and in certain cases significantly so. Consequently, what these systems do is make use of this energy that is stored inside the ground.

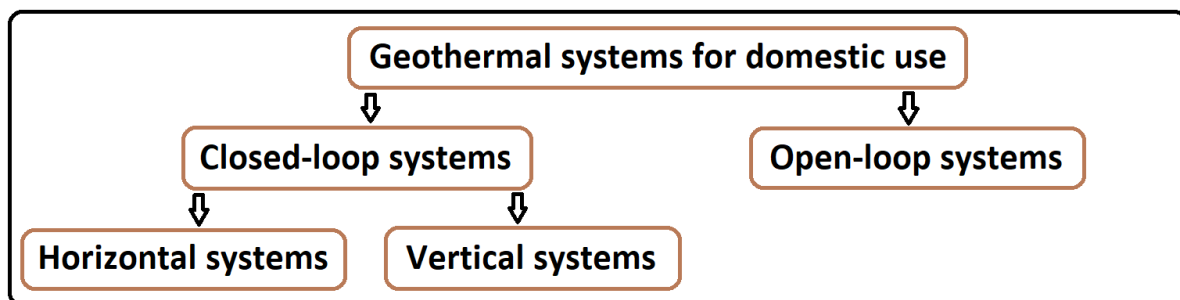


Figure 7. Classification of the common geothermal systems for domestic use

The closed-loop geothermal systems

In order for a closed-loop system to work, a network of pipes needs to be constructed at an appropriate depth inside the ground, and usually not too far away from the building where the rest of the system will be installed. One or more pumps get connected to the pipe network and one or more heat pumps get placed in the building and get connected to the network, as well. The heat pumps get connected to the heating system of the building too. The part of the system in contact with the ground is called a “geo-heat exchanger”.

The pipes get filled with a fluid, for example water. The water travels in the geo-heat exchanger in which its temperature raises and gets closer to that of the ground. Then it travels back to the building and inside the heat pump. The heat pump extracts heat from the water in this pipe network and transfers it to the water traveling inside the heating system of the building. This water in the heating system gets heated and as it travels into the system brings the heat inside the building. This cycle of heat transfer continues as the whole system continues functioning.

Based on how the pipes of the geo-heat exchanger are placed, horizontally or vertically, the whole system can be referred to as a horizontal or a vertical one, respectively.

The main components of the closed-loop geothermal systems

The main components of the closed-loop geothermal systems are the water pump, the pipe network and the heat pump.

The water pump keeps the system functioning by cycling the water inside the geo-heat exchanger and making sure enough heat is being provided to the heat pump.

The pipe network allows for the water to travel from the heat pump to the ground, where it can retrieve heat for the building, and then back to the heat pump.

The heat pump is perhaps the most important part of the system. It is this piece that is able to extract amounts of heat from the ground (via the fluid in the geo-heat exchanger) and provide it to the heating system of the building. It is most likely the most expensive of the parts of the system, as well.

Difference between a horizontal and a vertical closed-loop geothermal system

The main difference between a horizontal and a vertical closed-loop geothermal system is the way in which the pipe network is placed in the ground.

In a horizontal closed-loop system, trenches are created that can be several tenths of meters long and several meters deep. The trenches are horizontal and the pipes get placed in them either in a serpentine-like or a loop-like manner. In areas where there is a lot of available space it is typical to have a horizontal closed-loop system created.

In a vertical closed-loop system the pipes are placed vertically in the ground, inside boreholes that can be tenths to hundreds of meters deep. These systems are more common in urban areas and other locations where there is not much available space.

When choosing between a horizontal or a vertical system, one needs to take into account parameters like the available space and the characteristics of the soil in the area, as well as the heating requirements of the building. The vertical systems take advantage of the fact that in greater depths the temperature of the earth is generally more stable. However, these systems can be more expensive too. In contrast to them, the horizontal systems require more space and can be affected to a greater extent by seasonal changes in the temperature of the soil. However they are, in general, more inexpensive.

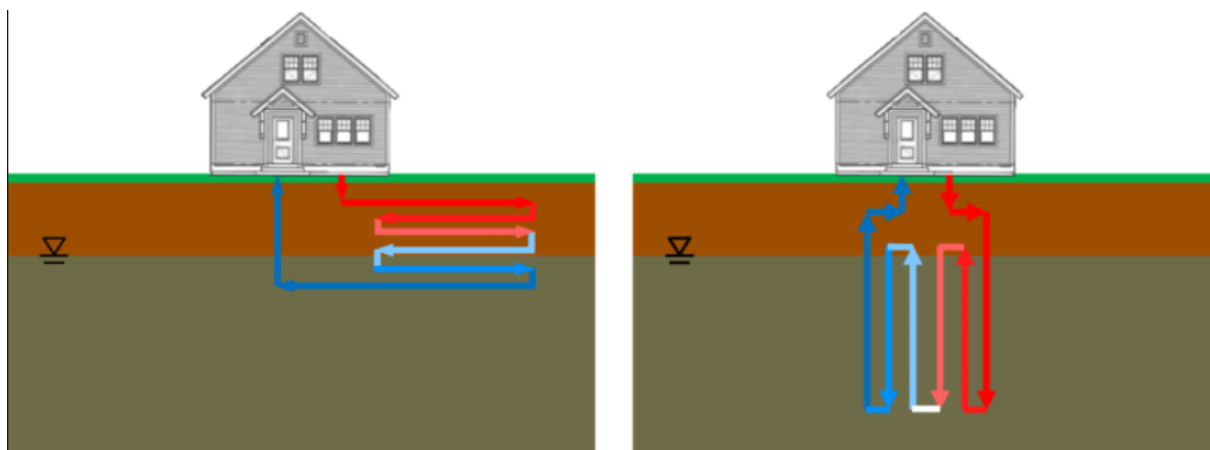


Figure 8. The typical design of a closed-loop system: Of a horizontal one on the left and a vertical one on the right (Source: C. A. Kramer, 2013)

The open-loop geothermal systems

In order for an open-loop system to work, one or more wells need to be constructed, and at an appropriate distance from the building where the rest of the system will be installed. Inside each well, a water pump can be placed and pipes will connect it with the building and the heat pump or the heat pumps in it.

What is more, pipes that connect the heat pump with the sewer network are installed. Alternatively, one or more extra wells are created, all of which get also linked to a water pump. In the second scenario, the heat pump gets connected to such a well, instead of the sewer network.

The system works in this way. The wells get filled with geothermal water from the ground. This water is then transferred to the heat pump. There, heat gets extracted from the geothermal water and gets transferred to the water traveling in the heating system of the building. The heating system can, thus, work properly and heat the building.

Depending on the setting, the used geothermal water is either discarded in the sewer network or gets transferred to a well, through which it gets re-injected to the ground.

In many cases, the quality of the geothermal water is such that it can lead to a faster erosion of the heat pump. In these cases, one more piece is added to the system, the heat exchanger, which is very resilient to erosion and serves as a barrier between the geothermal water and the heat pump.

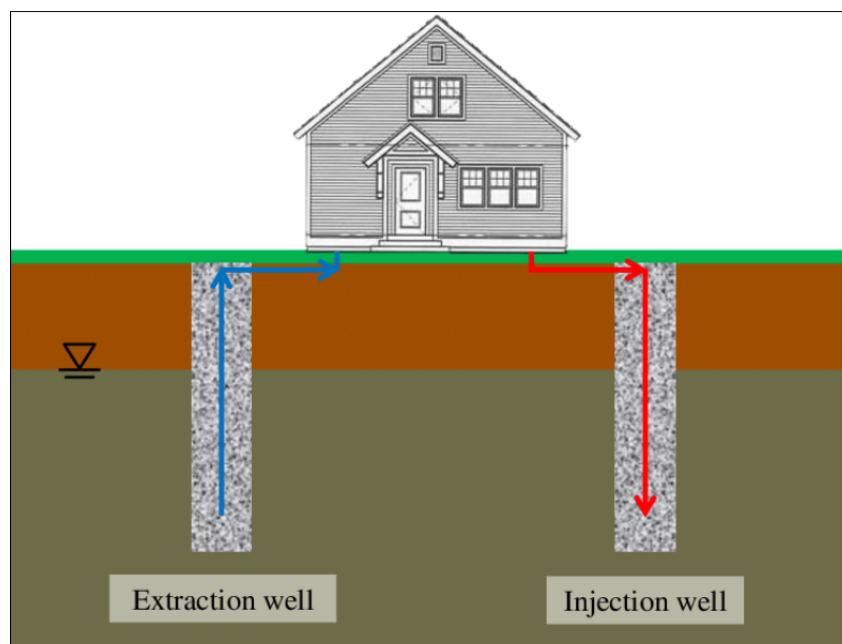


Figure 9. The typical design of an open-loop geothermal system in which the used water gets re-injected in the ground (Source: C. A. Kramer, 2013)

The main components of the open-loop geothermal systems

The main components of an open-loop geothermal system are the water pumps, the pipes, the heat pumps and, if needed, the heat exchanger.

The water pumps make the system able to function and transfer the water from the wells to the heat pumps. In the cases in which the used geothermal water gets re-injected to the ground, the pumps are needed to perform this task, as well.

The pipes are what allows the geothermal and the used geothermal water to travel from and to the wells, or, if this is the case, the used geothermal water to the sewer network.

The heat pumps are the main and most important parts of the system. They extract heat from the geothermal water and transfer it to the water moving inside the heating system of the building.

The heat exchanger is an optional part of the system, however a very important one in several cases. Its parts that come in contact with the geothermal water are built by such materials that are able to resist erosion from the water and any chemical stress that this could threaten to impose on the system. This way they protect the more expensive heat pump. However, when they are used, one more heat transfer needs to take place, thus the efficacy of the whole system is lower (to a small extent usually).

Requirements of a geothermal system

In order for any technical system to be constructed and to function, certain conditions need to be met. For the geothermal systems there are certain requirements, as well. These requirements are not exactly the same for all the types of systems, closed-loop and open-loop ones, as well as for the vertical and horizontal ones.

For the closed-loop systems, the requirements are the following:

- a) The ground must not be forming an extremely high slope
- b) The materials the soil consists of must be appropriate for the construction to take place
- c) There must be enough available space for the machinery to reach the site of interest and to be deployed
- d) The temperature of the soil that is in contact with the geo-heat exchanger must be appropriate
- e) (For the horizontal systems) There must be enough space available in the area of interest for the system.

For the open-loop systems, the requirements are the following:

- a) The ground must not be forming an extremely high slope
- b) The materials the soil consists of must be appropriate for the construction to take place
- c) There must be enough available space for the machinery to reach the site of interest and to be deployed
- d) There needs to be enough water available for the heat pump to function properly
- e) The available water needs to be of high enough temperature.

The first three requirements are common for both the open-loop and the closed-loop systems. They have to do with the construction phase of the system. Regarding the slope of the ground, in certain areas the ground is forming slopes so great that it could hinder the ability of the machinery to be deployed at the area of interest, let alone function properly and perform the tasks that are required of them. Thus, in such areas a geothermal system could not be constructed, with the commonly available means at least.

The soil materials could also lead to the construction of a geothermal system being impossible in a certain area. A too soft, or an extremely hard and rocky ground could lead to the machinery not being able to be deployed there, or to it not being able to construct the wells needed or the ditches needed for the system to be created.

Lastly, the requirement regarding the available space at the area of interest for the machinery can be proven to be a really important issue in urban areas. Several vehicles are quite large and need big enough roads to move on. They also need enough space to maneuver and be deployed. These

requirements are not always met in areas where streets were designed for much smaller vehicles and / or the buildings are built very close to each other.

Regarding especially the horizontal closed-loop systems, there is an extra requirement that has to be met for the construction process to be able to be completed. There needs to be enough space available, since these systems require a pipe network to be constructed over a large enough area.

One requirement that is common in all systems and has to do with their ability to function is this. High enough amounts of heat need to be able to be provided from the ground to the heat pump, or the heat pumps, of the system.

However, especially for the open-loop systems there is an extra one. In these systems, the means by which heat is being provided to the heat pumps is water coming from the ground. Consequently, not only this water needs to be of the right temperature, it needs to be available in adequate quantity, as well. The closed-loop systems do not have this requirement since they do not depend on new water getting pumped from the ground, but rather the same water being recycled and moved around the pipe network in the ground.

On site measurements

When constructing a geothermal system like the one installed in the building of Hydraulics certain measurements can be performed on site in order for it to be shown if the system can function properly. Such a system has a dual role. To provide heating to a building, as well as water for secondary uses. Due to this, measurements regarding both of its aspects should be performed.

Measurements about the quality of the water

Although the water used for secondary uses does not need to be of such high standards as the drinking water needs to be, it still should be of at least adequate quality. Since what is typically being provided in most areas of the world, is water that (at least theoretically) should be of drinking quality, it is this water that it has mostly been studied. Thus, it is typical for a country to have a set of rules regarding its quality and regarding which parameters in it should be tested and monitored.

Regarding water exclusively for secondary uses, not an equal amount of research has been dedicated to. Moreover, typically there is not a set of rules that determines which parameters of it need to be monitored. In our case, we were able to have the water tested for several parameters. As a point of reference to others willing to use underground water to cover secondary needs, we name here several such parameters, methods by which they can be tested, as well as limits to be tested against.

Table 1. Suggestion for parameters to be tested in water for secondary uses, methods for the analysis to be performed and limit values for each parameter

PARAMETER	METHOD OF ANALYSIS	LIMITS
pH	ISO 10523:2012	> 6.5 and < 9.5
Electrical conductivity, 25 °C (µS/cm)	ISO 7888	2500 µS/cm
Ammonium (mg/L)	USEPA 350.1	0.50 mg/lit
Total hardness (°d)	2340-C. APHA-AWWA-WEF	There are no specifications for the hardness value
Calcium (mg/L)	3400-Ca B. APHA-AWWA-WEF	There are no specifications for the hardness value
Magnesium (mg/L)	3500-Mg B. APHA-AWWA-WEF	There are no specifications for the hardness value
Phosphates (mg/L)	4500-P. APHA-AWWA-WEF	5 mg/lit
Chloride (mg/L)	4500-Cl ⁻ B. APHA-AWWA-WEF	250 mg/lit
Nitrites (mg/L)	US EPA 354.1	50 mg/lit
Nitrates (mg/L)No ₂ -N	Dimethylphenol	0,5 mg/lit

Turbidity (NTU)	2130-B. APHA-AWWA-WEF	
Total Dissolved Solids (mg/L)	2540 B.APHA-AWWA-WEF	1500 mg/lt
Iron (mg/L)	ICP-AES	200 µg/lt
Manganese(mg/L)	ICP-AES	50 µg/lt
Chromium (mg/L)	ICP-AES	50 µg/lt
Total Organic Carbon (mg/L)	5310 B. APHA-AWWA-WEF	
DO (mg/L)		4mg/lt
Toxicity (mg/lt)	DaphniaMagna	0 mg/lt
Enterococci (CFU/100 mL)	ISO 7899-2: 2000	0/100 ml
E-coli (CFU/100mL)	ISO 7899-2: 2000	0/100 ml

Geophysical research

In order for the properties of the soil at the area of interest to be determined exactly, as well as information to be collected about water in the ground, at which depth it can be found and how easily it could move in it, a geophysical research needs to be conducted. This typically includes a special drilling procedure by which samples of the ground are getting collected at the area of interest. The procedure is common around the world and in general it can be thought of as inexpensive.

The drilling and the process of taking samples from the ground should be conducted until a desired depth. The depth is not standard for every case. It does depend on the type of the system that is being planned to be constructed. For example a horizontal system will require pipes getting placed at a much greater depth than a horizontal system, thus sufficient knowledge of the ground layers until that (greater) depth can be quite useful.

By having the samples taken from the ground a quality estimation can be made about the different materials in it and the depth of every different layer of material. Moreover, since the properties of each material are well studied, an estimation can be made about the properties of the ground in the area as a whole.

Site selection

For an open-loop geothermal system in a building to function properly, sufficient amounts of water need to be present in the ground. The heat pump of the system is going to need to extract sufficient amounts of heat to provide to the building, and the medium from which it is going to do so is going to be geothermal water from an underground aquifer. Thus, if such a geothermal system is being considered, a geophysical research at the area around the building can be proven to be significantly useful.

A geophysical research is this in which samples of the soil at a specific point are being taken and examined. The samples can be extracted from several different depths.

By performing certain tests in the samples it can be shown, first of all, what types of soils are present in the ground, at least until the depth from which the samples were taken. Moreover, the different layers of the ground can be shown, as well as indications of the depth of each layer (again until the depth from which the samples were taken). Additionally, the presence of water in the soil can be shown, as well as the depths in which it is present.

From all of the above useful conclusions can be drawn about the properties of the ground, like its strength etc, as well as those regarding how easily water can move in it and be extracted from it. This is due to the fact that the properties of each specific material that will be found are already known and documented.

Geophysical research is not a complicated or rare process. Moreover, it can be said that it is an inexpensive one too. However, it has a serious disadvantage. It can be challenging, or very challenging, to be performed in densely built urban areas, due to the procedure getting hindered by adjacent buildings.

Although the Aristotle University of Thessaloniki is the largest University in the Balkans, the main part of the campus is located at the center of Thessaloniki where free space is not available. What is more, the presence of so many different Faculties and Schools in the main campus has led to some parts of it being densely built. This is the case also for the area where the building of Hydraulics is located. There are several other structures around it.

When investigating this area, it became obvious that the available open space was not enough to get a ground cross-section at the required depth. Thus, a geophysical research was not feasible to be conducted.

Criteria for site selection

As mentioned in the previous part, a geophysical research was not able to be conducted, in order for it to confirm the presence of groundwater and show the depth in which it can be found. This can be common in urban areas, so a way had to be found to indicate the presence of an underground aquifer in an indirect way. This, then, could be a blueprint for people interested in geothermal energy in cities, as many of them would have to deal with the inability to have a geophysical research done, as well.

In order for the problem to be tackled, the so-called “soft” information had to be used. These pieces of information could be collected by a local survey or a literature review. The set of criteria which indicate the presence of groundwater in an indirect way are the following:

a) The flooding of the basement of the building in which a geothermal system is being examined to be installed. The flooding of adjacent buildings is an important indication, as well.

Certain events, like a pipe getting damaged or a heavy rainfall in the area, can lead to a basement getting flooded. Such events, though, are both uncommon and typically not repeated often. It is not a common phenomenon, for example, to have in Greece such rain events that will lead to the same area getting flooded repeatedly year after year.

However, there is a great number of buildings which suffer from moisture, especially in their basements. In some of them, the basements are even at risk of flooding. This is not something uncommon, but rather it is something happening on an often or consistent basis. What is more, around some buildings pumps are operating, so as to protect them from the aforementioned phenomena.

In the cases mentioned above it is clear that the water does not come from a damaged pipe or heavy rain. It has to be coming from somewhere though. Its source can be said with great certainty to be exactly that, water present in the ground. Actually, not only that, it is located at shallow enough depth to be interacting with the basement of the building, causing problems in it.

In the case of the Aristotle University of Thessaloniki, flooded basements are known to be a common problem.

b) Existence of traditional wells.

The wells, in general, are based exactly on that, water being present in the ground. Nowadays, the means are available for shallow or deep wells to be constructed, since specialized machinery is available. This was not the case, though, in previous eras. During those times, people relied mostly on their physical abilities and the limited equipment that was available to them, in order to have a well constructed. Consequently, traditional wells are most likely not very deep ones, compared to modern day standards. So, although such wells have been abandoned in modern urban areas, where potable water is provided by the pertinent authorities, they can serve as indicators of local shallow aquifers.

It is worth mentioning here, though, that the existence of traditional wells is not as a strong indication as the flooding of basements. This is due to the fact that traditional wells indicated the presence of water in past times, while the flooding of basements indicates the presence of water currently.

c) Existence of urban streams close to the site which is being investigated.

Even in the urban settings, streams can be found. Some of them can be carrying water constantly, some of them only during a part of the year and some only during or after rain events. No matter the case, all of them indicate the same. From the area around, water tends to gather towards them. Thus, the areas around the ground are more likely to be carrying water.

Regarding the topic of the urban streams, it is worth noting that when one is investigating them, he or she should even search for old stream beds, currently converted into closed conduits. Such a conduit exists in a rather small distance from the building of Hydraulics.

d) Large water masses on the surface, close to the area of interest.

Although it may not be obvious initially, when there are large water masses present, in the form of rivers, lakes or even the sea, the water can do more than evaporate or flow on the surface. What it typically does as well, is start infiltrating in the ground and moving away from the surface mass of water.

If a building is located next to such a water mass, it is more than likely that water will be available in the ground around it, and most likely in shallow depth, as well. In Greece, a large number of cities and villages are actually built next to the sea, where the presence of groundwater is practically a given.

e) Known existing underground aquifer close to the area of interest.

The underground aquifers can extend to very large areas. Consequently, if an area is known to be above an aquifer, the closely neighboring areas are likely to be located above an aquifer, as well.

f) Specific local vegetation.

Tree species (e.g. plane-trees), which require large water quantities, could also serve as indicators. In order for the trees to grow and sustain themselves, they need to obtain water from the ground through their roots. If trees that require large amounts of water are present in an area, it could be assumed that such amounts of water are present in the ground there.

The case of the building of Hydraulics

As it has been stated already, the location of the building of Hydraulics fulfilled certain of the important criteria mentioned in the previous section. There are buildings around it in which there are

known problems occurring from groundwater and moreover, an urban stream was located very close to it. In order for this second piece of information to be confirmed, a specific study was performed.

First of all, although several buildings around the building of Hydraulics suffer from the presence of groundwater, there are two which are facing the most intense challenges. These are:

a) The building of the Department of Architecture of the Aristotle University of Thessaloniki, on the NW of the building of Hydraulics, at a distance of about 100m. This building is indicated with “A” in the following figure.

b) The building of the School of Primary Education of the Aristotle University of Thessaloniki, on the SE of the building of Hydraulics, at a distance of just about 50m. This building is indicated with “B” in the following figure.



Figure 10. The buildings in the area, where groundwater is causing problems. Position in comparison to the building of Hydraulics

Secondly, regarding the streams in the area around the building. After conducting research, it was found that just south of the area where the building of Hydraulics was constructed, there used to be a stream. This stream carried water during certain time periods within the year.

The stream can be seen in the photo of the following figure. The photo is from 1962. It is worth mentioning that the building of Hydraulics was constructed in about the year 1965.



Figure 11. The site before the construction of the building of Hydraulics (1962)

In the following photo it can be seen how the site was shortly after the construction of the building of Hydraulics.



Figure 12. The site after the construction of the building of Hydraulics

In order for it to be fully verified that the aforementioned stream was located close to the building of Hydraulics, further research was conducted. The topographic plan of 1919 of Thessaloniki (E4843 in the codification system of the Cartographic Heritage Archives of the Historical Archives of Macedonia) was found and examined.

The topographic plan of 1919 was overlaid with a satellite image, in order for results to be extracted. From the examination it became obvious that the stream indeed was located very close to where the building is now and on the south and east of it (the satellite image was taken by Google Maps).

In the following figure, the overlay between the topographic map of 1919 of Thessaloniki (regarding the examined area) and the satellite image of the area are presented.

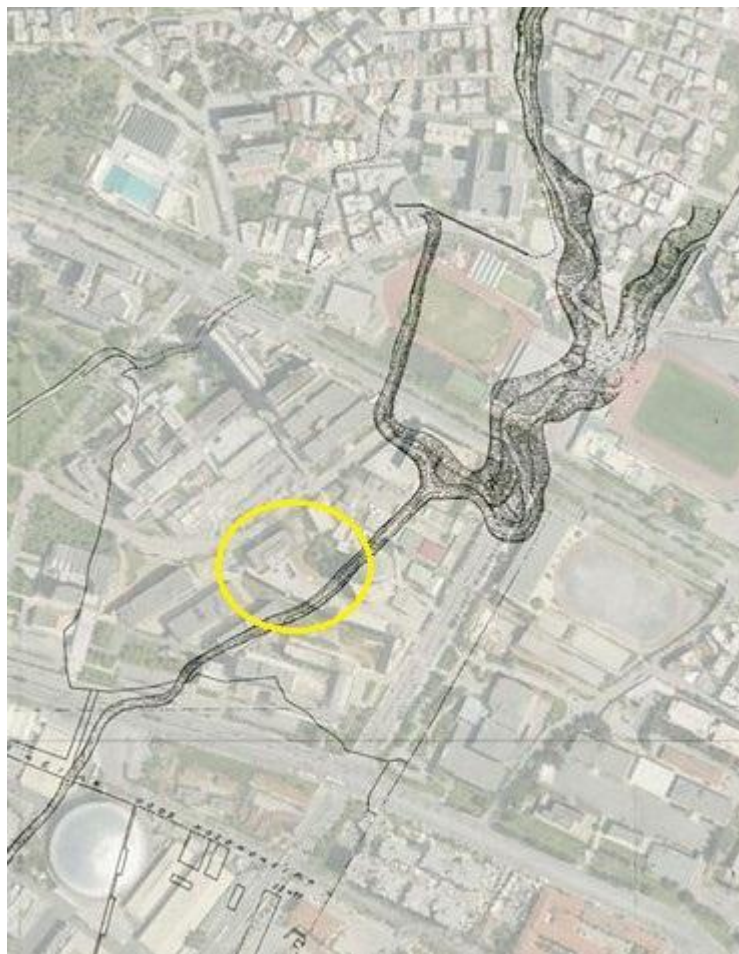


Figure 13. The overlay between the topographic plan and the satellite image. Within the yellow is the area where the building of Hydraulics is located

This stream was called “Rema Chortatzidon” and it was the combination of two secondary streams. Those two streams met about 250m upstream from where the building of Hydraulics is located, in the area where the basketball court “Ivanofeio” now stands. The secondary streams were called “Lakkos tou Chordopoiou” and “Lakkos tou Matiou” (Vasilis Dimitriadis Topography of Thessaloniki (1983) pg.218, Mplionis – Tremopoulos Thessaloniki of waters (2017) pg.171). Downstream the combined,

main, stream would find its way to the sea through the area where the International Exposition of Thessaloniki is currently located.

The aforementioned points of the research led to the belief that it is quite possible that water is still flowing in the area east and south of the building of Hydraulics, not seen on the surface, but through the ground.

The results of the research were confirmed by the previously mentioned facts about groundwater causing problems in nearby buildings. Thus, the conclusion was reached that it was quite probable that a shallow aquifer was present around the area around the building of Hydraulics.

The case study of the City Hall of Thessaloniki

The purpose of this case study is to examine the replacement of the existing heating and cooling systems of the Thessaloniki Town Hall, with an open-loop ground-source heat pump system. The source of water for the pumps will be seawater. This is due to the fact that there is only a short distance between the Town Hall from the sea and the fact that the City Hall is not elevated high above it.

Research framework

The stages of the study include:

1. Collection of information and relevant energy consumption data.
2. Data analysis.
3. Report writing.

The analysis of the data regarding the energy consumption of the building was performed with the maximum available level of detail.

Available data

The sources of data regarding the energy performance of the building were the following:

- Property details.
- Architectural designs.
- Topographic plans.
- Electromechanical designs.
- Technical reports.
- Consolidated monthly electricity consumption bills.
- Fire extinguishing and fire protection studies.
- Total annual gas consumption.

General details about the Thessaloniki City Hall

The "New Thessaloniki City Hall" was constructed on the basis of the architectural proposal, which was awarded the first prize in a Panhellenic Competition in 1987. This proposal, after a limited reform in 2002, was implemented during the period 2005-2010 (domotechniki, n.d.).

The new Thessaloniki City Hall consists of a fragmented set of building volumes with a dynamic, jagged shape and a dialectical relationship both with each other, as well as with the surrounding space and the outdoor space of the plot itself. It is located at the junction of 3rd September and Vasileos Georgiou Streets and is accompanied by an underground car park with approximately 1,000 spaces.

The execution of the project was undertaken by the "AKTOR A.T.E." Consortium. – DOMOTECHNIKI S.A. – ETETH S.A. – THEMELIODOMI S.A. – TERNA SA" (domotechniki, n.d.).

The Town Hall houses classified working office spaces, a monumental entrance-reception area, areas for movement, standing and serving the public, a multi-purpose room, the Mayor's office, the Municipal Council room, a multitude of auxiliary and storage spaces, as well as an underground parking space, extending over a semi-basement and three basement floors. The aim was to create a friendly and easily accessible building on the ground floor level, which will present the individual functions - spatial units, clearly distributed in its organization, so as to facilitate the user's perception of the space and to ensure the easiest and fastest service. The composition of the volumes also creates and highlights the outdoor space of the buildings, which incorporates the large "Town Hall Square", a thoroughfare with parking areas and a small outdoor theater. The floor of the outdoor space is formed with permeable and impermeable pavements, surfaces of high and low greenery and small water pools (domotechniki, n.d.).

As already mentioned, the town hall is not one but 8 statically independent buildings, the highest of which has 9 floors. A sketch is shown in the figure that follows. Each building has its own number of floors and its own utility (e.g. parking, meeting rooms, offices, foyer, etc.). The following table shows all the heated spaces of each floor, which are necessary for our study. The heated surfaces include the entire area with the exception of the parking and storage areas.

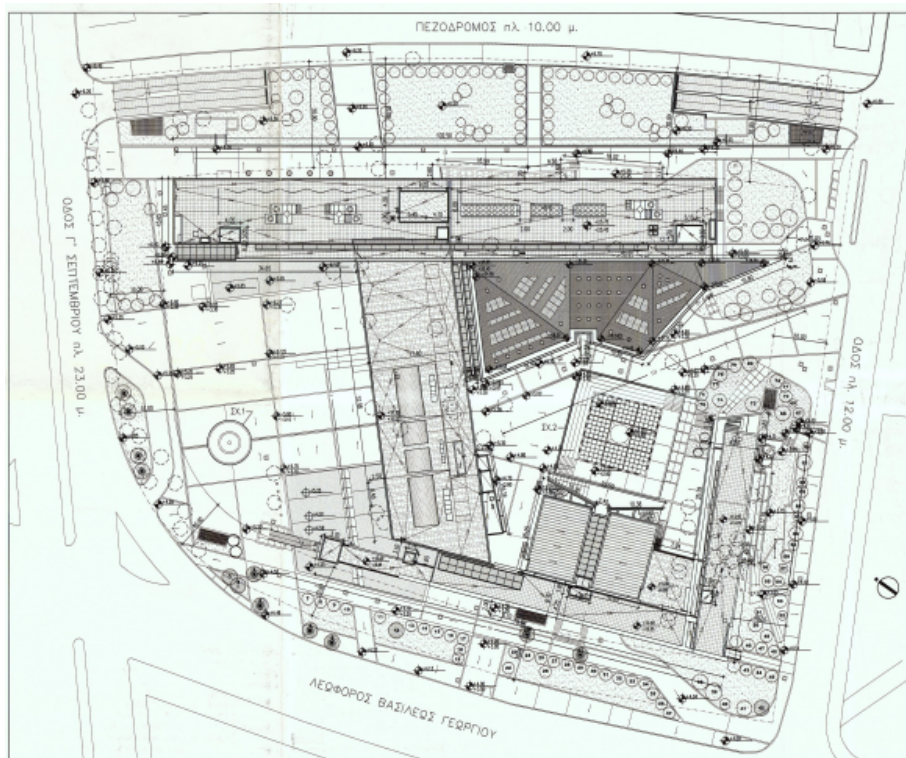


Figure 14. Design of the City Hall of Thessaloniki

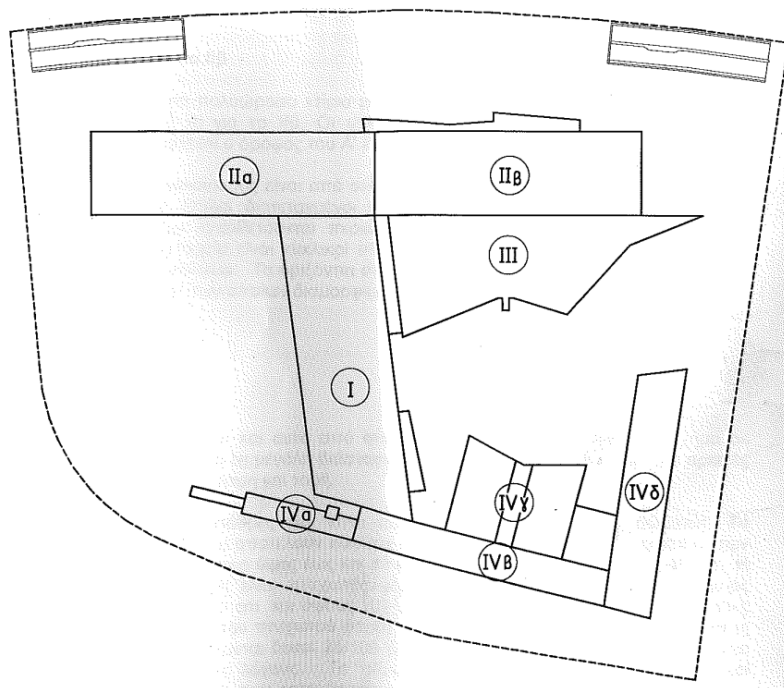


Figure 15. A sketch of the City Hall of Thessaloniki

Table 2. Total surface and surface of the heated area of each floor in all buildings combined

FLOOR	TOTAL SURFACE (M ²)	SURFACE OF THE HEATED AREA (M ²)
3 RD BASEMENT	12.248	1.330
2 ND BASEMENT	12.248	1.330
1 ST BASEMENT	12.448	1.760
1 ST GROUND FLOOR	5.621	2.545
2 ND GROUND FLOOR	3.155	3.155
1 ST FLOOR	2.484	2.484
2 ND FLOOR	2.855	2.855
3 RD FLOOR	2.280	2.280
4 TH FLOOR	1.258	1.258
SUMMARY	54.597	19.065

Consumption data regarding the existing heating and cooling systems

The City Hall is located in Thessaloniki, which belongs to the third climate zone of Greece (shown in the following figure, as well).

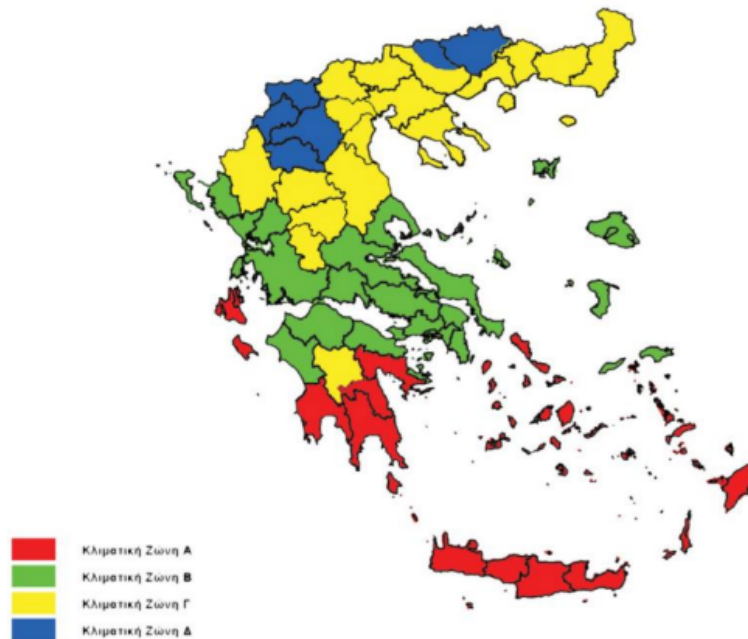


Figure 16. The climatic zones in Greece

The following table summarizes the data for the calculation of the energy efficiency of buildings (TECHNICAL CHAMBER OF GREECE, 2017) in the climate zone in which the City Hall is located.

Table 3. Data for the calculation of the energy efficiency of buildings

Climatic zone	Third Climatic zone
Type of building	Office building
Working days/ week	5
Working hours/ day	10
Working months/ year	12
Heating period	15/10-30/4
Cooling period	1/6-31/8
Desired indoor temperature summer (°C)	26
Desired indoor temperature winter (°C)	20
Desired indoor humidity summer	45%
Desired indoor humidity winter	35%

The existing heating system

The existing heating system of the Town Hall consists of three natural gas boilers (698 kW each one). For our study it was necessary to know the gas consumption on an annual basis. The following figure shows the consumption from 2013 to 2019. Based on these data, the average annual consumption is estimated at 1.374 Mwht.

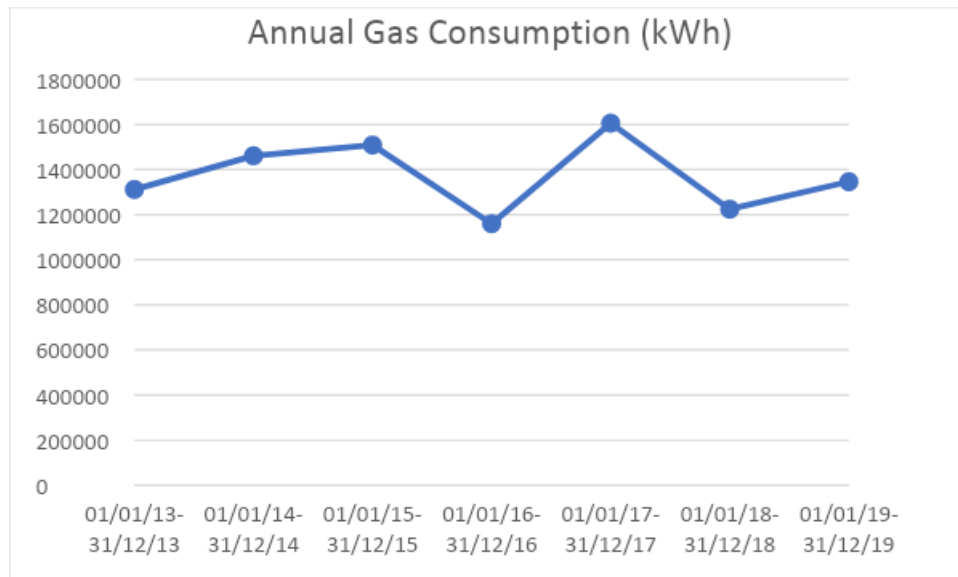


Figure 17. Total Annual Gas consumption at the City Hall of Thessaloniki in 2013-2019

The existing cooling system

The majority of spaces of the City Hall are cooled with individual cooling (air conditioning) units. Calculating the energy consumption for cooling was not an easy task, as there was no data from consumption meters. Nevertheless, the monthly electricity consumption figures from 2016 to 2019 were available and collected. From the consumption curves on kWh (figures below), it can be seen that it is almost constant, with the exception of the summer months when the air conditioners are functioning. Thus, the energy consumption for cooling of each year, the three-year average value and the predicted consumption value were roughly calculated. The estimated energy consumption for cooling reaches 264.875 kWh.

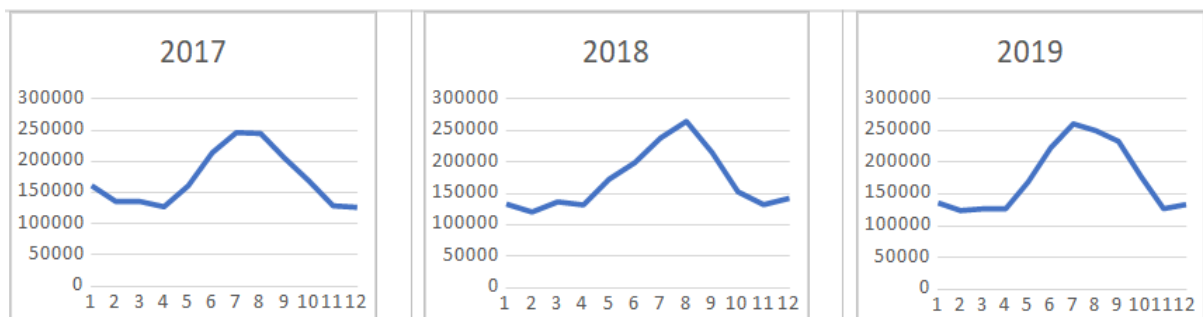


Figure 18. Monthly electricity consumption (kWh) at the City Hall of Thessaloniki in 2017-2019

The proposed heating/cooling system

For the City Hall of Thessaloniki, based on the surface of the heated area, the climatic zone in which the building is located and the thickness of the walls and frames, the required power of the heat pump was calculated. In order for the entire load to be covered, three pumps were selected, with power of 614.9 kW each. A high-efficiency pump that could be selected is the SYSCREW 570 WATER EVO HP (Systemair, 2022).



Figure 19. The heat pump SYSCREW 570 WATER EVO HP

It was estimated that the installation of the three high energy efficiency pumps could lead to a saving in the energy consumption for heating and cooling of at least 35% . Also, it could bring about an average reduction of 60% in the base loads during non-operating hours in the City Hall of Thessaloniki.

The following table of the main technical characteristics of the System-Air Syscrew 440-1550 Water EVO series is indicative of the high efficiency of modern water-cooled heat pump units.

Table 4. Technical Data - SYSCREW WATER EVO HP - STD / S Version R134a

Model		440	490	570	630	700	770	860	920
Cooling Capacity ¹	kW	365,0	422,5	481,8	540,0	591,2	644,1	711,7	772,0
Total Input Power ¹	kW	101,7	115,2	134,9	156,0	171,3	187,7	202,4	215,9
Heating Capacity ¹	kW	465,7	536,4	614,9	691,3	760,5	829,8	911,5	985,1
EER ¹		3,67	3,67	3,57	3,46	3,45	3,43	3,52	3,58
COP ¹		4,58	4,66	4,56	4,43	4,44	4,42	4,50	4,56
Cooling Capacity ²		413,0	474,0	539,0	604,0	663,0	721,0	804,0	869,0
Total Input Power ²		83,4	95,6	111,0	126,0	141,0	154,0	166,0	178,0
Heating Capacity ²	kW	496,0	569,0	648,0	728,0	804,0	875,0	969,0	1046,0
EER / Energy Efficiency Class ²		4,95 / B	4,96 / B	4,88 / B	4,78 / B	4,69 / B	4,68 / B	4,85 / B	4,89 / B
COP ²		5,94	5,95	5,86	5,76	5,69	5,68	5,85	5,88
SEER ³		6,43	6,43	6,48	6,45	6,38	6,65	6,43	6,40
η_{hp} ³		254	254	256	255	252	263	254	253
Number of Refrigerant Circuits		1	1	1	1	1	1	2	2
Part Load Steps	%	50-75-100						25-50-62-75-87-100	
Power Supply		400V/3/50Hz							
Start-up Type		SD	SD	SD	SD	SD	SD	SD	SD
Refrigerant		R134a							
Type		R134a							

Installation costs

The evaluation of the initial investment cost of a geothermal system is a difficult process as the cost is affected by many factors. The feasibility study is estimated to cost €700 (Michailidis, 2013), while the licensing of the investment costs €2.500 (Karagiorgas, Zacharias, & Kyrkou, 2010). The maintenance and monitoring of the system is estimated to cost €400 for the entire life of the pump (Vrahopoulos, 2015). The price of the pump together with its installation is estimated to reach 400€/kWh. The heating system inside the buildings is estimated at €100.000.

Table 5. Installation costs of the open-loop geothermal system in the City Hall of Thessaloniki

DESCRIPTION	COST
FEASIBILITY STUDY	700€
LICENSING	2.500€
INDOOR INSTALLATION	100.000€
HEAT PUMPS -UNITS	480.000€
HEAT PUMPS - APPURTENANCES, INSTALLATION WORKS	200.000€
WELL CONSTRUCTION WORKS	57.600€
IRRIGATION NETWORK	28.800€
INTERANL SECONDARY PIPE NETWORK	14.400€
TOTAL COST	884.000€

Energy expenditure

The energy crisis experienced during the past months has had a significant impact on the monthly bills for both electricity and fuel. This overwhelming rise in prices also affects the results of the economic analysis for the City Hall. In order to include all scenarios, two analyses will be performed. The first analysis takes into account the current electricity and gas prices and the second those of January 2020, which are clearly smaller.

Prices in August 2022:

Electricity price: 0,498 €/kWh (Dei, 2022)

Gas price: 0,122 €/kWh (Natural Gas Greece, 2022)

Prices January 2020:

Electricity price: 0,172 €/kWh (Aerio Attikis, 2022)

Gas price: 0,04948 €/kWh (Aerio Attikis, 2022).

The following tables show the cost and benefit, energy and economic evaluation data for a twenty-year life cycle of the proposed equipment for the two scenarios.

Table 6. Energy and Economic evaluation data of a proposed investment to replace existing systems with an open type geothermal heat pump system, 2 different scenarios

DATA	1 ST SCENARIO	2 ND SCENARIO
ANNUAL HEATING- COOLING CONSUMPTION (KWH)	1.638.739	1.638.739
COP HEATING	5,21	5,21
COP COOLING	5,26	5,26
ENERGY COST (€/KWH)	0,498	0,172
NATURAL GAS COST (€/KWH)	0,122	0,04948
SAVINGS PER YEAR (KWH)	1.303.064	1.303.064
SAVINGS PER YEAR (€)	132.676	55.804

Evaluation indicators

In this subsection, the financial indicators will be presented that show the financial performance of the investment. The following values of basic economic parameters (Table 6) are used in the calculations. The discount rate for investments of this type in Greece was assumed to be equal to 4,95% (InvestPlify, 2022). The loan interest rate is assumed to be zero as it is assumed that the cost of implementing the interventions will be covered by the own funds of the Municipality of Thessaloniki.

Table 7. The economic values for the economic analysis of the two scenarios.

	1 ST AND 2 ND SCENARIO
ANNUAL ENERGY COST INCREASE OF INFLATION	2%
LOAN RATE	-
PREPAYMENT RATE	4,95%
INITIAL INVESTMENT	884.000
INVESTMENT LIFE	25

Each scenario has been evaluated based on the following financial indicators:

- Net Present Value - Net Present Value (NPV)
- Internal Rate of Return (IRR)
- Return of Investment (ROI).

The following tables show the cost, benefit, the main economic indicators for evaluating the energy interventions, as well as the cash flows for a 25-year life cycle of the proposed equipment. The analyses have been carried out and are presented for both price scenarios, the current prices and those before the energy crisis.

Table 8. Annual investment cash flows - 1st Scenario

Year	Cash Flow	Net Cash Flow	Discounted Cash Flow	Net Discounted Cash Flow
0	- 884000.0.00	-884000	-884000	-884000
1	132,776.00	-751224	126,513.58	-757486.42
2	135,430.00	-615794	122,956.08	-634530.35
3	138,136.00	-477658	119,497.70	-515032.65
4	140,896.00	-336762	116,136.54	-398896.1
5	143,713.00	-193049	112,871.38	-286024.72
6	146,585.00	-46464	109,697.03	-176327.69
7	149,515.00	103,051.00	106,612.39	-69715.31
8	152,503.00	255,554.00	103,614.10	33898.79
9	155,551.00	411,105.00	100,700.31	134599.1
10	158,660.00	569,765.00	97,868.52	232467.62
11	161,831.00	731,596.00	95,116.28	327583.9
12	165,066.00	896,662.00	92,441.78	420025.68
13	168,365.00	1,065,027.00	89,842.13	509867.82
14	171,731.00	1,236,758.00	87,316.13	597183.95
15	175,163.00	1,411,921.00	84,860.53	682044.48
16	178,664.00	1,590,585.00	82,474.17	764518.65
17	182,236.00	1,772,821.00	80,155.37	844674.03
18	185,878.00	1,958,699.00	77,901.18	922575.2
19	189,594.00	2,148,293.00	75,710.86	998286.06
20	193,384.00	2,341,677.00	73,582.02	1071868.08
21	197,250.00	2,538,927.00	71,513.12	1143381.2
22	201,193.00	2,740,120.00	69,502.29	1212883.49
23	205,214.00	2,945,334.00	67,547.74	1280431.22
24	209,317.00	3,154,651.00	65,648.66	1346079.88
25	213,501.00	3,368,152.00	63,802.67	1409882.55

Table 9. Annual investment cash flows- 2nd Scenario

<i>Year</i>	<i>Cash Flow</i>	<i>Net Cash Flow</i>	<i>Discounted Cash Flow</i>	<i>Net Discounted Cash Flow</i>
0	-884000	-884000	-884000	-884000
1	55,904.00	-828096	53,267.27	-830732.73
2	57,020.00	-771076	51,768.11	-778.964.62
3	58,158.00	-712918	50,310.91	-728653.71
4	59,320.00	-653598	48,895.78	-679757.93
5	60,504.00	-593094	47,519.50	-632238.43
6	61,712.00	-531382	46,182.24	-586056.2
7	62,944.00	-468438	44,882.52	-541173.67
8	64,201.00	-404237	43,619.66	-497554.02
9	65,483.00	-338754	42,392.26	-455161.76
10	66,790.00	-271964	41,199.03	-413962.72
11	68,125.00	-203839	40,040.51	-373.922.21
12	69,485.00	-134534	38,913.63	-335008.58
13	70,873.00	-63481	37,818.91	-297189.67
14	72,288.00	8,807.00	36,754.63	-260435.04
15	73,732.00	82,539.00	35,720.65	-224714.39
16	75,205.00	157,744.00	34,715.84	-189998.55
17	76,707.00	234,451.00	33,739.10	-156259.45
18	78,239.00	312,690.00	32,789.84	-123469.61
19	79,802.00	392,492.00	31,867.45	-91602.16
20	81,396.00	473,888.00	30,970.93	-60631.23
21	83,022.00	556,910.00	30,099.68	-30531.55
22	84,680.00	641,590.00	29,252.78	-1278.77
23	86,372.00	727,962.00	28,430.00	27151.22
24	88,097.00	816,059.00	27,630.10	54781.32
25	89,857.00	905,916.00	26,852.88	81634.2

The above table shows the economic indicators calculated for the two price scenarios.

Table 10. The main economic indicators for the two scenarios

INDICATORS	SCENARIO 1	SCENARIO 2
NPV	1.409.883€	81.634€
IRR	16,47%	5,77%
PAYBACK PERIOD	6,311 years	13,878 years
DISCOUNTED PAYBACK PERIOD	7,673 years	22,045 years
ROI	381,01%	102.48%
ANNUALIZED ROI	6,48%	2,86%

The diagrammatic display of financial indicators helps to better visualize the results. In the following figures we can see the payback time for the two scenarios.

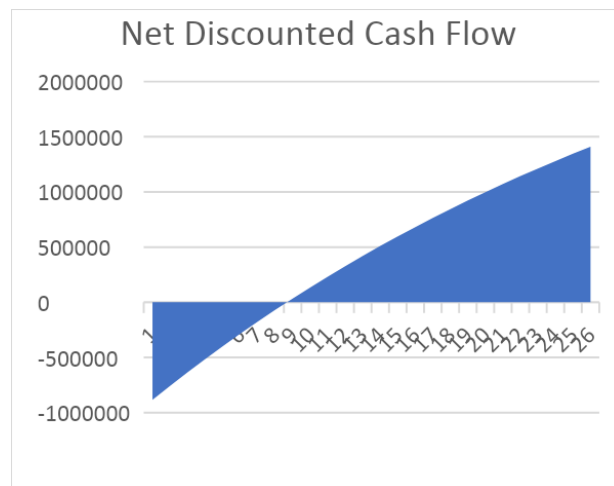


Figure 20. 1st scenario - Interest payback period of investment

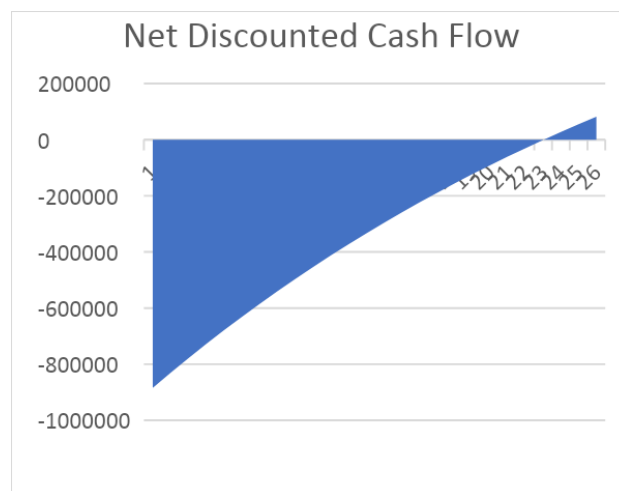


Figure 21. 2nd scenario - Interest payback period of investment

The following shows a comparison of the net present value in the two cases in terms of its various values of the discount rate.



Figure 22. NPV/ Discount Rate plot for the two price scenarios

Summary of results

In the financial analysis of the proposed investment in the Thessaloniki City Hall, two different scenarios were considered. In the first scenario, the economic indicators were calculated with the key prices of electricity and gas, while in the second with the corresponding prices before the energy crisis in the year 2020. The results of the research show that at the present stage such an investment is considered advantageous and the time to recover the initial investment of the capital is at 6.3 years, while an annual savings of 132.680 € is achieved.

On the other hand, taking into account the clearly smaller energy prices in 2020, the investment is less profitable. The payback time reaches 14 years and the annual saving of 56.000€ is not enough to cover the high installation costs in time. Nevertheless, there are additional environmental benefits, which are not included in the economic analysis.

Conclusions

The Thessaloniki City Hall is a building complex in design and construction, with a demanding operational profile, resulting inevitably in high energy consumption in order to achieve the desired conditions of thermal comfort, air quality and lighting. The energy efficiency of the buildings that make it up differs, a fact expected due to the difference in their design. With the proposed intervention, its operation will be more efficient. The proposal focuses on its air conditioning and heating system and aims to replace the gas boiler and air conditioners with an open geothermal heat pump system.

The intervention has an estimated total cost of €884.000, but it will result in a reduction in annual energy consumption of the order of 56%. With today's high electricity and gas prices, it will lead to a reduction in annual energy costs of €132.676. For a conservative estimate of an energy cost increase of 2% per year, the payback period is less than 6,5 years. On the other hand, with the older energy and gas prices of 2020, the investment is not judged advantageous, to the same extent. The proposal will result in a reduction in annual energy consumption of the order of 50% and will lead to a reduction in annual energy costs of the order of €56.000. Additionally, the payback period approaches 14 years.

Taking into account the current situation, with predictions by scientists, the already visible effects of the greenhouse phenomenon both in Greece and worldwide and wars that are lurking, the scenario of a strong reduction in prices seems utopian. Therefore, the search for green solutions such as this one for heating and cooling systems with the utilization of water bodies, where possible, will upgrade not only the City Hall of Thessaloniki but will have benefits for the entire region.

Policy report on the simplification of permits required and the elimination of bureaucratic barriers

In this report, the simplification of permits required for, and the elimination of bureaucratic barriers to the development of: a) Low and very low geothermal resources for heating purposes and b) local groundwater resources in urban environments, as foreseen in the pilot installation at the Aristotle University of Thessaloniki, Greece, are being discussed.

The initial concept of the pilot installation at the Aristotle University, was to use groundwater from the underlying shallow aquifer, first as a heat source (through a heat pump) and then as water source for secondary uses (toilet flushing, irrigation). For this reason, it has been planned and initially constructed as an open-loop system. The system also included two water tanks, as the heating demand does not coincide with demand for secondary water uses. The water surplus, if any, would be disposed of to the sewer network. Due to low water yield from the shallow aquifer, a closed-loop system has been planned and constructed at a second stage.

Required licenses

We had to obtain licenses for both systems. The procedure is more complicated for the open-loop system, for which the following licenses are required:

a) Regarding the energy use, a license needs to be issued by the General Directorate of Development Planning, Environment and Infrastructures of the Regional Unit of Thessaloniki, of the Region of Central Macedonia. The licensing process is described in the Ministerial Decision no. Δ9B,Δ/Φ166/οικ.13068/ (Government Gazette Issue 1249 B /2009). Its title is: “Licenses to install energy systems for space heating and cooling through the exploitation of the heat of geological formations and surface or groundwater, which are not characterized as geothermal potential”.

In Appendix the certificate of registration of the application that we have submitted to the aforementioned authority is included. The Ministerial Decision is included in the Appendix, as well.

Moreover, we have paid 300 EUR with the application. This fee is required, regardless of the size of the installation.

b) Regarding the use of water, a license is required from the Water Directorate of the Decentralized Administration of Macedonia and Thrace (a different administrative structure than the Region of Macedonia).

The first difficulty we met had to do with the order in which the licenses should be acquired, as the legislation was not clear at this point. The difficulty was overcome, as common sense prevailed, and the procedures advanced simultaneously. Nevertheless, this point should be clarified in the relevant legislation.

Licensing process for water use

The licensing process for water use is described in the Joint Ministerial Decision 146896 (Government Gazette Issue 2878 B / 2014), later modified by the Joint Ministerial Decision 140424 (Government Gazette Issue 814 B / 2017). Its title is: “Classes of water use licenses and of water development works. Process and conditions for issuing licenses, their content and validity duration and other relevant ordinances.” The JMD 146896 is also included in the Appendix.

The main points of this Joint Ministerial Decision, which are relevant with our installation, are the following:

In article 1, the cases in which a license is not required are mentioned. Among those are three which are related with our project:

1. The pumping wells constructed for research purposes, within the context of an approved research program, if and only if the water pumped will be used exclusively for research purposes (e.g. for water quality purposes) and no other use will take place. This provision of the law can offer a solution in different research programs, not in our case though, because a goal of the Green Pump project is exactly the utilization of the pumped water.

2. Wells of energy systems for space heating or cooling “through the utilization of the heat of geological formations and the use of surface and groundwater”. There is one very restrictive precondition, though: “The whole amount of pumped water should be reinjected to the aquifer taken from and in the quality state in which it was taken”. If taken literally, this condition can never be fulfilled, since water properties depend on its temperature. Moreover, if a reinjection system is planned a small percentage of water losses (e.g. 5-10%) should be anticipated. In any case, the aforementioned precondition forbids any use of pumped water.

In our case, water reinjection to the shallow aquifer would be, not only costly, but also damaging, due to the high underground water level and the potential problems it can cause to nearby structures. What is more, the use of pumped water was one of the goals of our project.

3. Works to pump water from the basements of buildings from the basements of buildings in order to protect their foundations and/or preserve their stability. Again, the precondition to grant the exemption is that the pumped water will not be used. Consequently, this provision could not be invoked either, although one of the goals of our project is the protection of the nearby basements and underground structures. Moreover, in this third case, a license is required from the pertinent authority, as well as licenses to allow connection to the sewer network.

By the way, these requirements to allow basement protection from flooding, are excessive. Moreover, there is no surveillance mechanism. Consequently, it comes as no surprise that a large number of relevant small installations, that do exist in many buildings in Thessaloniki, function without any license / permit.

The main problem that surfaced during the issuing of the license for our pilot installation, was due to an erroneous interpretation of the article 8 of the Joint Ministerial Decision (JMD) 146896/2014, by the licensing authority. In the first paragraph of this article it is stated that when the needs of those asking for the license are, or could be, covered by a public or a municipal water supply network, no new licenses for water use can be issued. In most urban areas of Greece there are water supply organizations, or enterprises, which aim are responsible for providing potable water. In Thessaloniki

area, for instance, the pertinent organization is Water Supply and Sewerage Company of Thessaloniki (EYATH S.A.). Consequently, according to this paragraph, the license could not be issued.

However, in paragraph 3 of the same article, it is mentioned that this provision is not applicable if the applicant (in our case the University) justifies “according to the judgement of the licensing authority” that the project will lead to “substantial savings of water resources with priority given to water refined for drinking purposes”, spent, e.g., for irrigation of green areas or industrial use”.

Saving water of high quality is an explicit goal of the GREEN PUMP project. What is more, our project aimed at the irrigation of green areas, as well as industrial water use (heat energy production in our case), which are both mentioned as examples in paragraph 3 of article 8. In addition to this, in the appendix I of the JMD 146896/2014, where water uses are classified, water use for cleaning is mentioned together with the use for the irrigation of green areas.

However, the “licensing authority” had serious doubts about issuing the required permit, perhaps because this was the first time that it considered issuing a license, based on paragraph 3 of the article 8 of the JMD, and for such a project. It took several months until the final outcome was positive. Perhaps, the rather vague provision of the JMD “according to the judgement of the licensing authority” should be supplemented with certain criteria.

The JMD 146896/2014 was modified, after the issuing of the license, by the JMD 140424/2017 (GG 814, Issue B’, 2017). In one of those modifications the exemption from the obligation of acquiring a license for research projects, as mentioned previously, has been correctly expanded to include pumping wells which are foreseen in the environmental license of projects or activities and have as a goal the monitoring of the quality and/or quantity of water bodies. No change has been made in article 8.

Additional permits

In order for one (or both) aforementioned main licenses to be issued, several different certificates are required. Among others, they include:

1. For both licenses

Confirmation of ownership of the area and the building in which the installation is going to take place. This requirement seems (and indeed is) quite reasonable. However, a large number of older public buildings do not have licenses, or the respective files are incomplete. The building of the Laboratory of Hydraulics and Hydraulic Works, in which the installation of the heating system took place, was completed before 1967 A.D., when its operation started. Fortunately, the Aristotle University of Thessaloniki as a legal entity had started the procedure of issuing the required legal documents for all the buildings of its main campus. At the time of seeking the water use permit, a certificate of non-demolition was already available for the building of the Laboratory of Hydraulics and Hydraulic Works. This certificate was adequate for the licensing procedure of the heating system installation. As far as we know, most of the legal arrangements for the buildings of the AUTH campus have been made already, and no such problem is expected to appear in the future. In other public buildings, though, this problem could potentially occur and hinder upgrading of energy efficiency of old buildings, which is necessary, in particular under climate change and high energy prices conditions. We cannot suggest omission of the aforementioned documents from the licensing process. We strongly recommend,

though, that all public entities will seek to issue all the required documents regarding ownership and proper construction of public buildings. It is a top priority, not only to facilitate energy upgrading, but for many other reasons, as well.

2. For the energy use license

a. Fire protection study, for certain types of buildings, approved by the local Fire Service. We believe that such study is redundant for any type of building, since geothermal installations do not include any type of combustion. Moreover, installations for heating and cooling do not involve high temperatures.

3. For the water use license

Permit from the Water Supply Organization which provides with water the area in which the construction is going to take place, in our case the Water Supply and Sewerage Company of Thessaloniki (EYATH S.A.).

EYATH initially gave its permission to use water for irrigation only. Later on, it gave an additional permit to use inside the building (for toilet flushing). The first permit that we received from the Water Supply Company is presented in the Appendix.

Obviously, the aim of requiring the aforementioned permit is to protect the interests of the Water Supply Organization. To our opinion, this requirement is not justified, due to the following reasons:

a) It prioritizes the financial interest of an organization over that of the environment. Substituting the use of highly processed water, which is moreover transported from a large distance, with the use of local water of inferior quality, yet high enough for the intended use, can lead to the reduction of:

- ☐ Energy consumption for water transport and treatment
- ☐ Use chemical substances, necessary to render raw water potable
- ☐ Diversion of water from its natural course towards urban centers.

b) It is likely that the financial interests of the Water Supply Organization may not be served either, if the “decentralized” use of local water resources is restricted. This case may arise, when the Organization’s ability to provide adequate water is reaching its limit. Being able to provide larger water quantities would require the construction of additional expensive works, in order to meet the demand for potable water.

Nevertheless, the Water Supply Organization should be notified by the License issuing authority for the features of the water production and use. If the Water Supply Organization has objections, e.g. small distance from its own wells, it should state them until a given deadline (e.g. one month from notification). No answer to the notification should be considered as tacit approval. Lost profits should not be considered as an objection reason, and the Water Supply Company should not have the right to demand compensation for them.

Legislation on secondary water use

There is a gap in the Greek legislation regarding adoption of lower quality water for secondary uses. This is a general and quite important issue, since the appropriate and under certain standards use of such water (for example saline water) in touristic coastal areas could lead to the reduction of the demand for high quality potable water, thus helping the touristic growth of these areas.

Regarding coastal aquifers in particular, construction of wells close to the coastline is prohibited, in order to avoid acceleration of saline water intrusion and pollution of fresh-water reserves. However, should the pumping of saline water be designed properly, it could lead to the reduction of the inland movement of the saline wedge and it would actually protect the fresh-water aquifers.

The systems designed to cover both energy and water needs, such as the pilot system of this project, have an added benefit in coastal areas, since the water quantities used solely to cover energy needs can be disposed of straight to the final receiving water body.

Comments on the legal framework for the development of geothermal resources

Development of geothermal resources in Greece is ruled by the Law 4602/2019 (Official Gazette Issue 45/A/9-3-2019), which modified Law 3175/2003 (Government Gazette Issue 207/A/29-8-2003).

In the article 2 of Law 4602/2019 it is defined that geothermal potential includes the energy of earth fluids and ground strata, whose temperature exceeds 30oC. In the previous law (3175/2003) the limit was set to 25oC. We consider this change as positive, since the licensing procedure is simpler, when the temperature limit is not exceeded. We were allowed to follow the simpler process (through the General Directorate of Development Planning, Environment and Infrastructures of the regional unit of Thessaloniki, of the Region of Central Macedonia) since water and ground temperatures did not exceed 20oC.

The article 19 of Law 4602/2019 includes the following provision: For geothermal fluids with temperatures between 30 and 35oC, it is possible to use them as water resources, until there is interest for their use as energy resources. This provision is also positive, since it allows flexibility in the development of such natural resources.

A problem has arisen with article 15 of the Ministerial Decision ΥΠΕΝ/ΔΑΠ/42138/552 (Government Gazette Issue 1960 B / 2021), which regulates construction of geothermal works. The aforementioned article refers to the disposal of geothermal water after its use, during the exploitation phase of the geothermal potential; it is stated that disposal of all the produced water quantity is allowed only to:

- a) Geothermal aquifers.
- b) The sea or surface water bodies containing waters with salinity higher than that of the geothermal water, deemed not suitable for drinking or irrigation purposes and provided that their quality is not deteriorated by the disposal of geothermal water. Moreover, the water disposal temperature should not exceed 35oC.

This provision aims at the protection of the environment. Option b is very restrictive, though. In many cases, the quality of low enthalpy (temperature) geothermal fluids may be suitable for irrigation and even for drinking purposes. Enforcing reinjection of good quality water to the geothermal aquifer or its disposal to the sea, despite its good quality, is a direct waste of water resources. Unnecessary reinjection in particular, may hinder the development of geothermal resources, as it may render in

unsustainable, from the financial point of view. Construction of reinjection wells adds to the initial installation cost, which is the weak point of geothermal and other renewable energy resources. Moreover, it increases operation cost. In addition, operation is more complicated, since it results in the formation of a comparatively cold water body around the reinjection wells. Our conclusion is that such an excessive effort to protect the environment may, actually, harm it, since it eventually hinders the substitution of fossil fuels by renewable ones, rendering the latter even more expensive.

It should be mentioned that the aforementioned provision of the new regulation for the construction of geothermal works is stricter than that of the previous regulation, namely Ministerial Decision Δ9B/Φ166/οικ20076/ΓΔΦΠ5258/329 (Government Gazette Issue 1530 B / 2005). But even the provision of the previous regulation was interpreted, by many licensing authorities, exclusively as an obligation for reinjection of the geothermal water to the geothermal aquifer, after its use.

To our opinion, the legislation should explicitly allow different options for the disposal of geothermal fluids, based on the following criteria:

- a) the quality of the geothermal fluids, with regard to that of the proposed final recipient
- b) the hydraulic head level drawdown due to pumping from the geothermal aquifer, since drawdown might be reduced by reinjection.

General comments on licensing processes

The Greek public administration had undergone a shock after the Law 4093/2012 was implemented. This law included extremely strict and even unfair regulations for employees of the public sector. An example is the fact that they could be temporarily suspended, even after just a formal complaint, without a prior sentence by any court.

Moreover, this draconian law was somehow one-sided, as lawsuits would more probably refer to unjustified permit issues, not unfounded permit refusals.

The previously mentioned legislation was changed towards a more just and appropriate direction with the Law 4325/2015. However, during the year 2016 there was still a climate of fear, among the employees of the public sector. As a result, many employees tended to avoid actions (like issuing a license) that would go beyond what was “normal” and “ordinary”.

Our general comment is that proper functioning of the licensing process presupposes a fair general framework for the pertinent employees. As Aristotle put it more than 2300 years ago, virtue is a middle state (μεσότης), between a lack and an excess.

Conclusions

Our main suggestions on the legal framework are summarized as follows:

1. Regarding the license for energy use:

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- a) Fire protection studies should not be required for any type of building
 - b) The required fee could be lower, in particular for small installations.
 - c) When a license for construction of a well and water use is required, the issuing of it should not be a prerequisite for the energy license (nor the existence of the energy use license should be a prerequisite, in order to apply for the water use license). The legislation should clarify that the two procedures can proceed in parallel.

2. Regarding the license for water use:

- a) The statement “according to the judgement of the licensing authority”, included in paragraph 3, article 8 of the Joint Ministerial Decision 146896/2014, allows for misinterpretations. For this reason, criteria should be set, to protect both the applicants and the licensing authority employees.
- b) Permit from the Water Supply Organization, which provides with water the area in which the construction is going to take place should not be a prerequisite for the license.

3. Exploitation of local water resources of inferior quality for secondary uses should be facilitated. To this end, a legal framework should be established and appropriate standards should be set.


4. Regarding the legal framework for the development of geothermal resources, our main comment is that the legislation should explicitly allow different options for the disposal of geothermal fluids, based on their quality and quantity.

Finally, our general recommendations are the following:

- a) All public entities should seek to issue all the required documents regarding ownership and proper construction of public buildings
- b) Proper functioning of the licensing process presupposes a fair general framework for the pertinent employees. As Aristotle put it more than 2300 years ago, virtue is a middle state (μεσότης), between a lack and an excess.

Appendix

Certificate of registration of the application:

 <p>ΒΕΒΑΙΩΣΗ ΚΑΤΑΧΩΡΗΣΗΣ ΑΙΤΗΜΑΤΟΣ</p>	
Θέμα:	ΑΔΕΙΑ ΕΓΚΑΤΑΣΤΑΣΗΣ ΕΝΕΡΓΕΙΑΚΟΥ ΣΥΣΤΗΜΑΤΟΣ ΚΛΙΜΑΤΙΣΜΟΥ ΧΩΡΩΝ ΜΕΣΩ ΕΚΜΕΤΑΛΛΕΥΣΗΣ ΘΕΡΜΟΤΗΤΑΣ ΓΕΩΛΟΓΙΚΩΝ ΣΧΗΜΑΤΙΣΜΩΝ ΚΑΙ ΥΠΟΓΕΙΩΝ Ή ΕΠΙΦΑΝΕΙΑΚΩΝ ΝΕΡΩΝ ΠΟΥ ΔΕΝ ΧΑΡΑΚΤΗΡΙΖΟΝΤΑΙ ΓΕΩΘΕΡΜΙΚΟ ΔΥΝΑΜΙΚΟ
Όργανο προς το οποίο απευθύνεται:	Δ/ΝΣΗ ΑΝΑΠΤΥΞΗΣ Π.Ε. ΘΕΣΣΑΛΟΝΙΚΗΣ
Αριθ. Πρωτοκόλλου:	7127 / 2016
Ημ. Καταχώρησης:	21/04/2016
Διεκπεραίωση έως:	23/05/2016
Αρμόδιος Υπάλληλος:	ΔΗΜΗΤΡΙΟΥ ΑΝΑΣΤΑΣΙΟΣ
Αιτών:	ΑΠΘ
Στοιχεία που συνοδεύουν το έγγραφο	Ο Υπάλληλος
Αρ.Εγγράφου	ΑΙΤΗΣΗ

Initial permit from the water supply company:



ΕΤΑΙΡΙΑ ΥΔΡΕΥΣΗΣ & ΑΠΟΧΕΤΕΥΣΗΣ ΘΕΣΣΑΛΟΝΙΚΗΣ Α.Ε.

Θεσσαλονίκη 23/2/2016
Αρ. Πρωτ.: 3492

ΠΡΟΣ:

Διεύθυνση	: Ύδρευσης	Α.Π.Θ
Τμήμα	: Λειτουργ. & Επισκ Γεωτρ Αντλ. Ύδρευσης	ΠΟΛΥΤΕΧΝΙΚΗ ΣΧΟΛΗ
Πληροφορίες	: Παπαδόπουλος Κων/νος-Σπάχος Θωμάς	ΤΜ. ΠΟΛ. ΜΗΧΑΝΙΚΩΝ
Τηλέφωνο	: 2310-966753, 2310-966773	ΤΟΜΕΑΣ ΥΔΡΑΥΛΙΚΗΣ & ΤΕΧΝΙΚΗΣ ΠΕΡΙΒΑΛΛΟΝΤΟΣ
FAX	: 2310-218.051	54124 ΘΕΣΣΑΛΟΝΙΚΗ
		Καθηγητή Κ. Α. Κατσιφαράκη
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ΘΕΜΑ: Χρήση υπόγειων νερών στην Πανεπιστημιούπολη του Α.Π.Θ.
Σχετικά: Η με αρ. πρωτ. ΕΥΑΘ 3492/9-2-2016 αίτηση

Σε απάντηση της σχετικής αίτησης, σας πληροφορούμε πως η ΕΥΑΘ ΑΕ δεν έχει αντίρρηση στην κατασκευή γεώτρησης, όπως αυτή περιγράφεται στη σχετική αίτηση, με την προϋπόθεση ότι το νερό της θα χρησιμοποιείται αποκλειστικά για ενεργειακή αξιοποίηση και άρδευση χώρων πρασίνου. Για όλες τις άλλες χρήσεις ο χώρος υδροδοτείται από υφιστάμενο υδρόμετρο της ΕΥΑΘ.

Επιπλέον θα πρέπει να λάβετε μέτρα ώστε το νερό που θα λαμβάνεται από τη γεώτρηση αυτή να διοχετεύεται σε εσωτερικό δίκτυο διανομής, ανεξάρτητο από εκείνο με το οποίο τροφοδοτείστε από την ΕΥΑΘ ΑΕ (π.χ. χρήση βαλβίδων αντεπιστροφής), ώστε το αντλούμενο νερό να μην εισέρχεται σε καμία περίπτωση στο δίκτυο της ΕΥΑΘ ΑΕ. Η όλη διάταξη θα ελέγχεται από το αρμόδιο συνεργείο της ΕΥΑΘ Α.Ε. της περιοχής σας.

Η ΕΥΑΘ ΑΕ διατηρεί το δικαίωμα να κατασκευάσει γεώτρηση στην περιοχή, εάν οι συνθήκες το επιβάλλουν, χωρίς να είναι υποχρεωμένη να σας αποζημιώσει από τυχόν μείωση της αντλούμενης ποσότητας νερού από τη γεώτρησή σας.

Επίσης η ΕΥΑΘ ΑΕ βεβαιώνει ότι δεν διαθέτει ενεργή υδρευτική γεώτρηση σε ακτίνα 500μ από τον προτεινόμενο χώρο της εν λόγω γεώτρησης.

Εσωτερική διανομή
1. Διεύθυνση Ύδρευσης

Ο Διευθυντής Ύδρευσης

Λάζαρος Καμπουρίδης

The contents of the report are sole responsibility of AUTH and can in no way be taken to reflect the views of the European Union, the participating countries the Managing Authority and the Joint Secretariat.