DESCRIPTION

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Low Energy Cooling Systems Based On The Cold Energy Sources Of The Ground

Abstract

Nowadays a lot of attention is paid to low energy systems all over the world as includes low energy cooling system. In many places on the earth the building is necessary for some additional cooling. A lot of energy to cool the whole building was required. Therefore alternative systems of cooling of a building, for example use of cold energy sources of the ground have started to be developed. Ground is a very good cool storage because the depth of the earth in a warm season is usually colder than on a surface, also there are a lot of ground waters in the earth which usually have got low temperature. On the earth surface there are many the rivers, lakes and the seas which water also can be used for cooling of buildings.

Nowadays engineers are using quite extensively cold energy sources of the ground. There are four types of cooling systems based on these sources: ground coupled air system, sea / lake / river cooling, aquifer cooling, ground cooling with heat pump in reversible mode

All these systems are quite new. The first system was built about twenty years ago. In my bachelor thesis I have to review all these systems and show their advantages over typical cooling systems.

Capital cost of such systems can be bigger than conventional system in any case because besides equipment installation in the building, these systems need a lot of earthworks and research works. But the annual operating cost of systems which based on the cold energy sources of the ground will be about two times less than operating cost of conventional system. Also advance cooling systems are much more ecological than conventional cooling systems. Unfortunately it’s impossible to use all low energy cooling systems based on the cold energy sources of the ground in hot climate and in temporary buildings.

But in spite of disadvantages low energy systems began more popular from year to year. Such systems compare with low energy heating systems, lighting and good building envelope can help to make very low energy buildings.

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LOW ENERGY COOLING SYSTEMS BASED ON THE COLD ENERGY SOURCES OF THE GROUND

Preliminary study

Bachelor's thesis

Double degree programme

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CONTENTS

1. INTRODUCTION

Nowadays a lot of attention is paid to low energy systems. It occurs because of the great technological progress which mankind has made for last century. New heating systems, cooling systems, ventilating systems etc. has been invented. Thus it turns out that one building supply much heat and energy in environment. There are millions of such buildings worldwide. All of they together with planes, cars, etc. do huge harm to environment. Such obvious negative influence of technological progress has forced people to think of preservation of the environment seriously. Great attention is given to preservation of non renewable natural resources, struggle against a greenhouse effect etc. The modern multi-storey building supplied by set of systems for convenience of people, therefore it demands the big quantity of energy. Because of it engineers and scientists start thinking about buildings which have low energy demands. As the result of their work low-energy buildings are appearing.

Low-energy building is a building which have smaller energy demands then ordinary buildings. The parameters of low-energy buildings are changing with a time. When this type of building is designed a lot of attention is paid to building construction, especially to building envelope as walls, windows, doors and roof. Such buildings must be well-insulated to have small heat transfer with environment. Also all buildings systems must be projected very carefully and be reviewed in association with all materials and components to achieve best result.

In many places on the earth the building is necessary for some additional cooling. Cooling systems are developed for this purpose. They must remove heat surpluses from the building. Early cooling system worked by the principle of refrigerators by the electricity consumption. A lot of energy to cool the whole building was required. Therefore alternative systems of cooling of a building, for example use of cold energy sources of the ground have started to be developed.

There are a lot of ways to use ground as a cooler. For example the temperature in the depth of the earth in a warm season is usually colder than on a surface. Also there are a lot of ground waters in the earth which usually have got low temperature. On the earth surface there are many the rivers, lakes and the seas which water also can be used for cooling of buildings.

Nowadays engineers are using quite extensively cold energy sources of the ground. There are four types of cooling systems based on these sources:

- Ground coupled air system
- Sea / lake / river cooling
- Aquifer cooling
- Ground cooling with heat pump /1/

All these systems are quite new. The first system was built about twenty years ago. In my bachelor thesis I will review all these systems and show their advantages over typical cooling systems.

2. GROUND COUPLED AIR SYSTEMS

Ground coupled of the ventilation system is one of the alternative methods to provide passive cooling. This system may be use not only for the cooling supply air in summer, but also for the preheating supply air in winter. The preheating will remove risk of freezing heat exchanger.

2.1. Basic idea

The main idea of the ground coupled cooling system is to create piping system underground and flow through it air. There is a layer in the earth, which situated from 6 to 12 meters under the land surface, where the temperature is almost constant during the year (for example in Zurich, Germany t^o=11^{o}C on 8m depth). In the coupling pipes warm air is cooled down to 18-22 ^{o}C. Then chilled air goes to the building ventilation system (Figure 1).

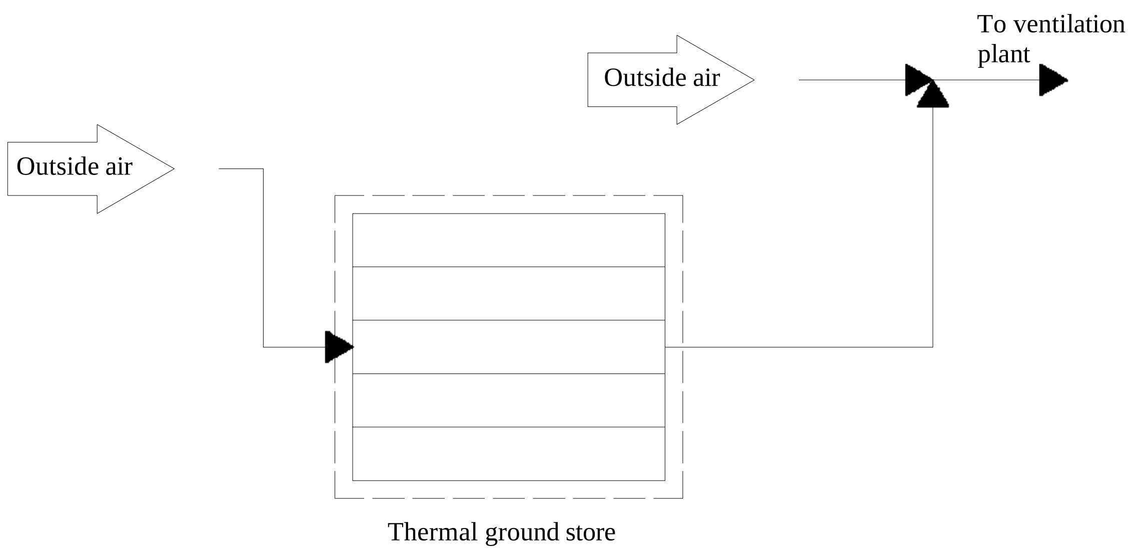


Figure 1. Schematic of the ground coupled system /1/

2.2. The overall scheme

The attention must be given to air-intake device. It must be situated quite far from source of radon gas and busy roads, because usually temperature is higher in such places. In the same reason air intake must be covered from strong sunshine. Better is to put such devices in the place with a lot of odorless plants, because the intake temperature is lower in such spots. Air-intake device must be protected from the entering dirt, small animals, birds etc., it may be achieved using tight-fitting grille, filters or by restricting access. Of course the better result getting with filters, because they effectively remove bacteria, pollen, fungal spores etc., but their using possible only with regular professional service.

Ground coupling piping system is making using round pipes from plastic, cement and cement fibre. It's impossible to use thin-walled pipes, because system is situated quite deep in the ground and the repair of it will be very difficult. So the pipes must have the life-cycle more than 50 years. Generally the material of the pipe depends on the cost. Based on PVC or HDPE plastic pipes are better for pipes with diameters up to 30 cm, but for larger diameters cement pipes are cheaper. (Figure 2)

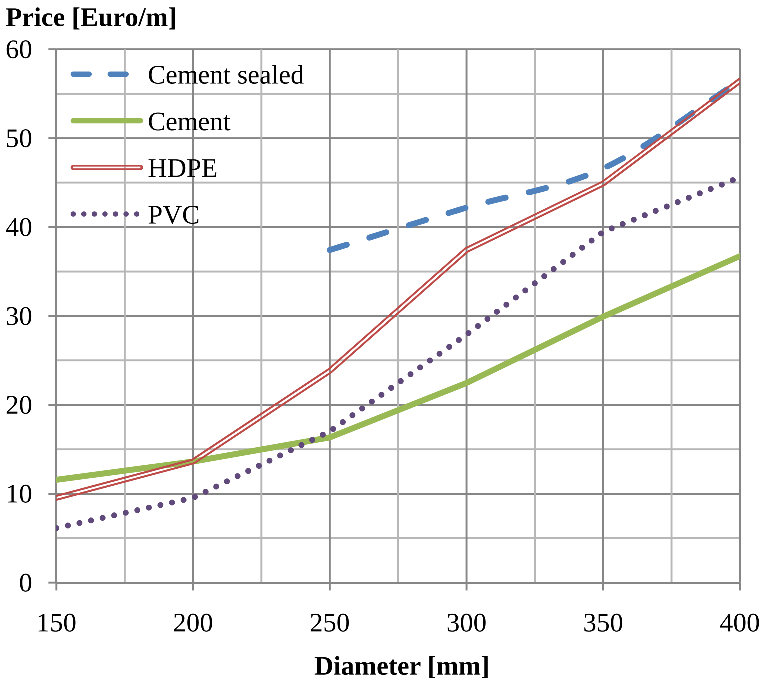


Figure 2. Prices for different pipe materials /3/

The distance between pipes must be about one meter. If the distance will be smaller, the influence pipes for each other will be too big. The size of the pipes must be choosing in such way that the air velocity in the pipe will be about 2.0 m/s. The velocity restriction is necessary for limit the pressure drops in the piping system.

Better place for installation pipes is layer of the earth with sand or/and gravel below water level. If it system will be situated under the building the cellar of this building must be unheated or be very good insulated. That the condensate, any ground water or the remained clearing water can be dried up, pipes should have an inclination about 1 percent, against movement of a stream of air. It is usually enough to lay pipes on sand in pure tranches though short pipes from cement can be laid on small quantity of thin concrete.

2.3. Field of application

Usually ground coupling piping system is using in public buildings as schools, office buildings, shopping centers etc. because normally residential buildings don't required in the mechanical ventilation system. It can be used combined with displacement ventilation to reduce temperatures in the occupied zone. For provision space cooling ground coupling systems are using in combination with natural night-time air cooling, with mechanical night-time air cooling, with slab cooling – cooled ceiling, with chilled ceiling or chilled beams. This system must to be used in climate which has quite big temperature difference between day and night and summer and winter. Wet and heavy soils are better for thermal performance (Table 1)

Table 1. Properties of different soil qualities /1/

Ground type	Thermal conductivity (W/mK)	Density (kg/m^3)	Heat capacity (J/kgK)	Cooling (%)
Wet soil	1.5	1400	1400	100
Dry sand	0.7	1500	920	90
Wet sand	1.88	1500	1200	98
Damp clay	1.45	1800	1340	104
Wet clay	2.9	1800	1590	105

2.4. A case study

Nowadays there are not very many buildings with such type of cooling system. The better example of it is “The Schwerzenbacherhof” office and industrial building in Schwerzenbacher, Switzerland.

Table 2. “The Schwerzenbacherhof” Office and Industrial Building Schwarzenbach, Switzerland. Project data. /2/

Altitude	440 m
Year of Construction	1989/90
Number of Working Spaces	190
Heated Floor Area	8050 m^2
Heated Volume	27060 m^3
Cooling Degree Days	198 Kd
Heating Degree Days	3616 Kd
Heating Capacity	240 kW

Ground coupled system was chosen in this place because by Swiss requirements active cooling can be used in extraordinary cases and this system was proposed as alternative passive cooling technology. The building envelope consists of aluminum and glass and is very airtight and well insulated. “The Schwerzenbacherhof” has very good solar and overheating protection.

“The entire building is equipped with automatically controlled external shading devices that are operated separately for each façade. The blinds at every second building frame location can be operated directly by the occupants. In addition, fixed horizontal blinds are mounted on the façade. With this system, since the automatic blinds are activated only if the fixed blinds give insufficient shading, the view remains mostly unobstructed. Furthermore, should the individual blinds be incorrectly operated, the fixed blinds will prevent extensive overheating of the rooms. The design of the façades and the use of light interior colors ensure good daylight quality. To minimize internal loads, artificial lighting has been reduced to a minimum. To minimize air temperature variations, the room air has direct contact with the massive building structure as the concrete ceiling is not covered.” /2/

There are heating and ventilation systems in this building. In winter heating system provide necessary temperature inside. Ventilation system is used for supply of fresh air and removed used air. It is connected with ground coupled system (Figure 3).

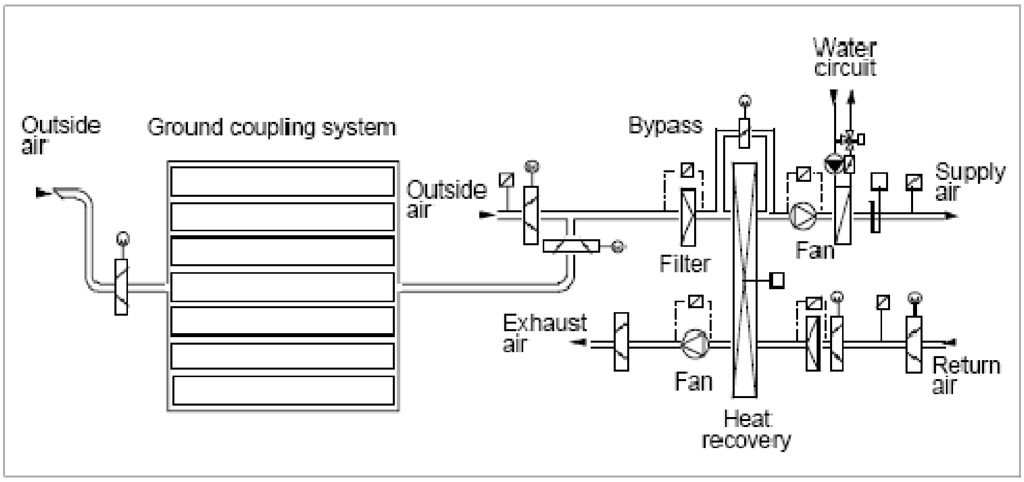


Figure 3. Schematic of the ground coupled and ventilation systems /2/

In this project the ground coupled system consist of nearly 1000 meters of plastic pipes. Pipes are made from High Density Polyethylene (HDPE) and have a diameter of 23 cm and length of 23 m. They are situated under the foundation. For guarantee good heat exchange characteristics pipes situated approximately 6 m below the groundwater table (Figure 4). This system is used when the outside air temperatures is higher than 22 °C in summer and lower than 7 °C in winter.

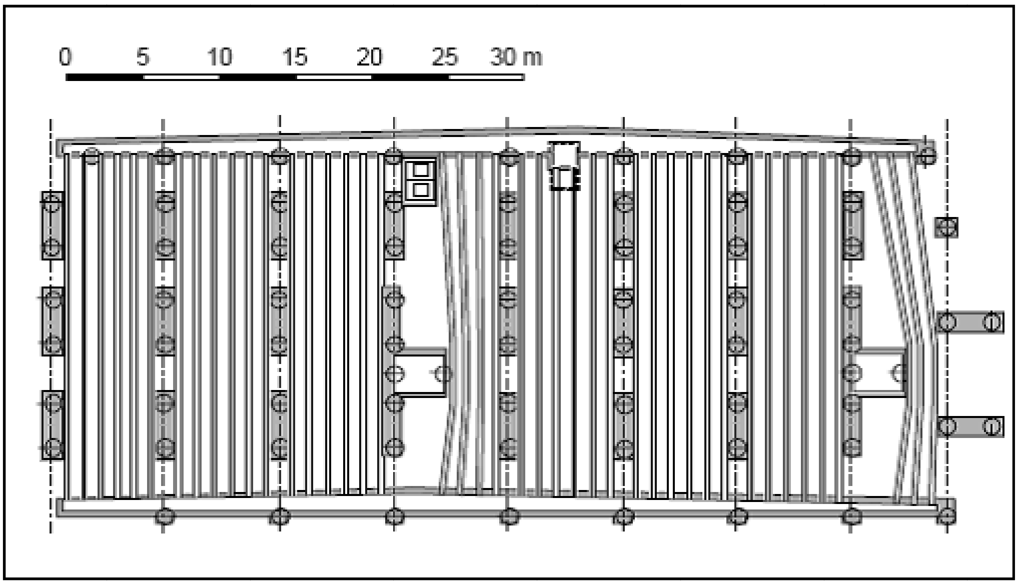


Figure 4. Ground plan of ground coupled system /2/

In this project cooling system provides 54 kW of cooling. The air flow rate for the ground coupling mode was about 1.15 m^3/h during the winter and 1.60 m^3/h during the summer.

Table 3. Energy performance (per square meter of ground coupling area) /1/

Cooling	Heating	
Ambient air at 35^{o}C	Ambient air at -5^{o}C	Ambient air at -15^{o}C
45 W/m^2	45 W/m^2	65 W/m^2

In this building the total amount of annually electricity consumption by ventilation was about 2 kWh/m^2 of floor area for the ground coupling mode in the summer for cooling and in the winter for heating.

3. AQUIFER COOLING

The aquifer is sedimentary rock which situated underground and consists of one or more interlaid layers of pervious materials as gravel, sand, slit or clay and of about 25% water. It can produce usefully quantity of groundwater using water wells and has very high heat storage capacity. The volume of aquifers usually is measured in millions of m^3.

3.1. Basic idea

Groundwater is quite cold because it is protected from direct sun rays. Overall depth of aquifer is from 10 to 15 meters, overall temperature is from 4 to 8 ^oC, but everything depends from the place. The main idea of aquifer cooling system is to create wells as energy storage and using water from them as a refrigerant.

3.2. The overall scheme

The aquifer cooling system consist of two or more wells drilled in the sand bed, one heat exchanger and water loop which round through the building. For the cooling the water is pumped from cold well to heat exchanger, cools a water loop and then goes to warm well (Figure 5).

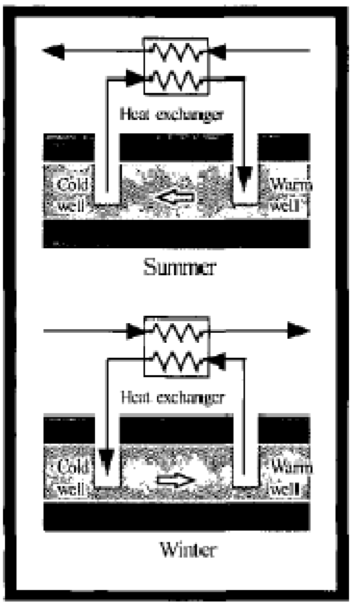
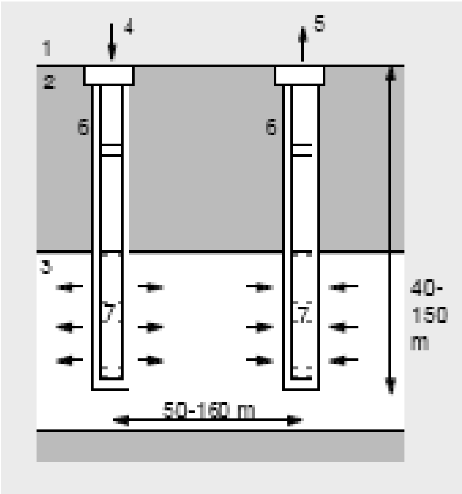


Figure 5. Schematic of ground cooling using aquifer /3/

Wells must situate with distance about 100 – 150 m between them to avoid thermal circuiting. The dimension of each well usually is 1.5 m by 1.5 m and the depth usually is from 30 to 200m. Generally the wells are lined by stainless steel. The lower part of the well contains a filter screen through which the water must be extracted or infiltrated (Figure 6). Average temperature of the water in cold well is about 6 – 10 ^{o}C and about 12 – 22 ^{o}C in warm well.



1. Ground level
2. Enclosing layer
3. Sand layer
4. Injection of cooled ground water
5. Withdrawal of ground water
6. Bore hole wall
7. Filter tube

Figure 6. Structure of the wells in the soil /2/

Better if the system will have separating heat exchanger between the building circuit and the ground water circuit than it will have combined heat exchanger. At first it is better because the ground water it’s not the closed loop, that’s mean that the pump must have much more power. It’s going because some air handling unit can be situated very high and it’s need high pumping power. And if the pump must raise ground water only to heat exchanger it needs far less power. Secondly the ground water may contend many different impurities, which may be reason of corrosion of components in the building circuit. For the avoidance of it the groundwater loop is made of plastic and metal piping parts are made of stainless steel. And in the third place the ground water usually contain the methane, which can be causes of gas bubbles, if the pressure becomes too low. Because of it the well may clog up. It’s mean than every time groundwater must be at an over pressure. This much easier if the volume of water in the loop will be as low as possible. As is evident from the foregoing the separating heat exchanger helps to economy time and money.
Capital cost of groundwater cooling system is bigger than capital cost of conventional cooling system average in 1.3 times, but annual operating cost of this system is less

than similar cost of conventional cooling system in 2 times. The payback period of these two systems is 4.5 years (Table 4) and obviously that ground water cooling system is better than conventional system in economical side because after payback period its operation cost will be two times cheaper.

Table 4. Costs and payback for a groundwater cooling system and a conventional cooling system. /1/

	Euro
Capital Costs	
Groundwater cooling	823 495
Conventional cooling	641 330
Annual operating Costs	
Conventional cooling	84 095
Groundwater cooling	43 440
Simple payback	4.5 years

3.3. Field of application

Generally aquifer cooling is using in office buildings, hospitals and shopping-centers with more than 6000 m^2 of floor area. This system can be used as direct cooling for cool building water loop, or as indirect cooling to cool the condenser of the chiller. This system can be associates with displacement ventilation to reduce temperatures in the occupied zone. For directly low quality cooling of the space aquifer cooling system may be used combine with chilled ceilings, chilled beams and slab water cooling. In mechanical cooling system the low quality cooling water may be used as condenser water. Aquifer cooling system must be situated in the region with quite big temperature differences in summer and in winter because in such way the energy input and abstraction will be approximately in balance to avoid progressive heating or cooling of groundwater.

3.4. A case study

There are many examples of aquifer cooling system all over the world. I want to review two of them. First building is The SAS Frösundavik Office in Stockholm, Sweden.

Table 5. The SAS Frösundavik Office in Stockholm, Sweden. Project data. /2/

Altitude	30m
Year of Construction	1985/88
Number of Office Rooms	1450
Heated Floor Area	64000 m^2
Heated Space	217600 m^3
Cooling Degree Days	42 Kd
Heating Degree Days	5480 Kd
Heating Capacity	3700 kW
Cooling Capacity	3300 kW

The aquifer at Frösundavik has volume about 1.5 million m^3. The mean depth of the aquifer is about 15 m and the greatest depth is about 30 m. During the year the mean temperature varies between 7^{o}C and 8^{o}C. The aquifer system consists of five wells: three for cold water (about 6 – 8 ^{o}C) and two for warm water (about 14 – 17 ^{o}C). The depth of the wells is between 8 m and 28 m. To avoid thermal circuiting the distance between two types of wells is from 150 to 300 m. For cooling the cold ground water at a temperature of +2 – 12 ^{o}C is pumped from one of three cold wells. Then it goes to heat exchanger system, where gives cold to building glycol circuits, one of these closed-circuits cools ventilation air (pre-cooling) and other used to cool the ceiling cooling convectors (Figure 7). After heat exchange the temperature of the air is reduces to about 18^{o}C and the temperature of the ground water becomes up to +17^{o}C. Heated groundwater goes to one of the two warm wells and in the winter it will be use to preheat incoming ventilation air.

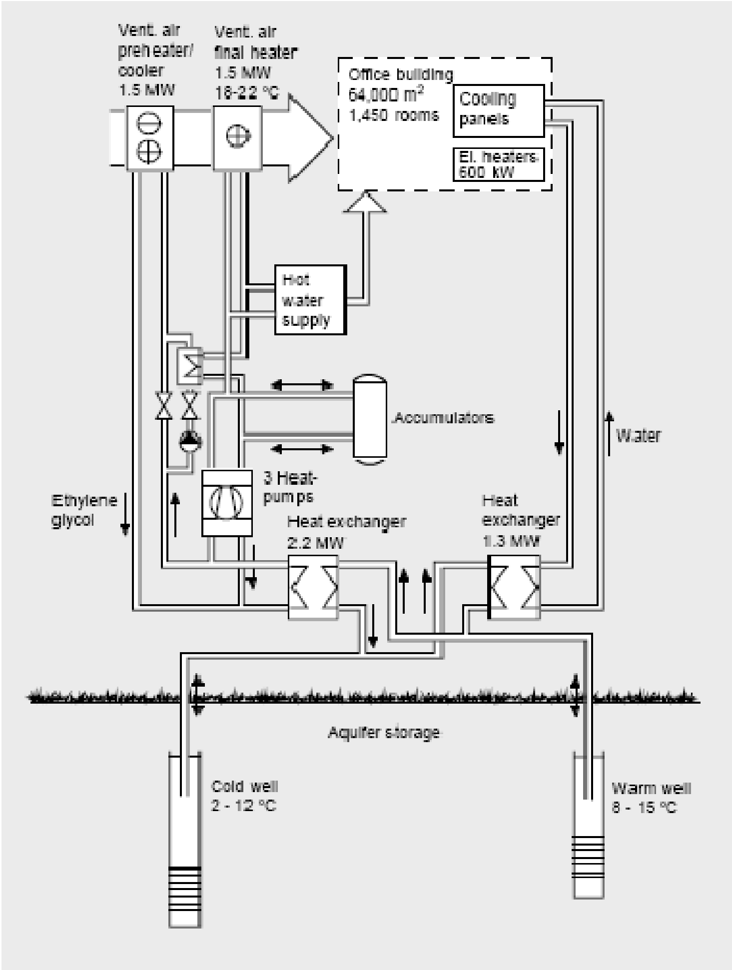


Figure 7. Schematic diagram of the system at SAS Frosundavik /2/

The energy system at SAS Frosundavik was the first such big and successful project of cooling system using groundwater. It shows that aquifer can be used for storage energy. Annual operating costs of aquifer system are much less than they would be for a corresponding conventional system, because the amount of purchase energy required is reduce by 65% compare with a conventional system.

If The SAS Frosundavik Office Building was absolutely new construction, second building - The Groene Hart Hospital in Gouda, The Netherlands – was being in operation building which used to have conventional cooling system and needs to improve their comfort.

Table 6. The Groene Hart Hospital in Gouda, The Netherlands. Project data. /2/

Altitude	2 m
Year of Construction	1992
Number of Beds	450
Heated Floor Area	5200 m^2
Degree Days	3000 Kd/a
Heating Consumption	900 MJ/m^2a
Cooling Consumption	35 MJ/m^2a
Delivered by Aquifer	23 MJ/m^2a

A soil exploration showed that the aquifer suitable for energy storage is present at a depth of 75 to 90 m. The aquifer system consists of two wells: one cold well and one warm well. The wells are situated for 150 m from each other. Each of them cans maximum produce 60 m^3/h groundwater. The cooling system consists of two chilled-water circuit, indicated as circuit 1 and circuit 2 in Figure 8 Circuit 1 is cooled by chillers and it hasn't been connect to the storage system. Circuit 2 is connected with heat exchanger and has 8 air handling units. This system as all aquifer cooling systems has two modes.

"In the summer season, when cooling is needed in the building, groundwater is pumped up from the cold well. The groundwater passes heat exchanger HE1 and cools down the return water in circuit 2. With the 4 two-way valves MV1-4, the flow direction through heat exchanger HE1 is adapted to maintain a counterflow in both the summer and winter mode. The three-way valve TWV1 controls the supply temperature at 10 ^oC and mixes in water at 6 ^oC from the chillers if the storage cannot deliver the whole cooling capacity." /2/

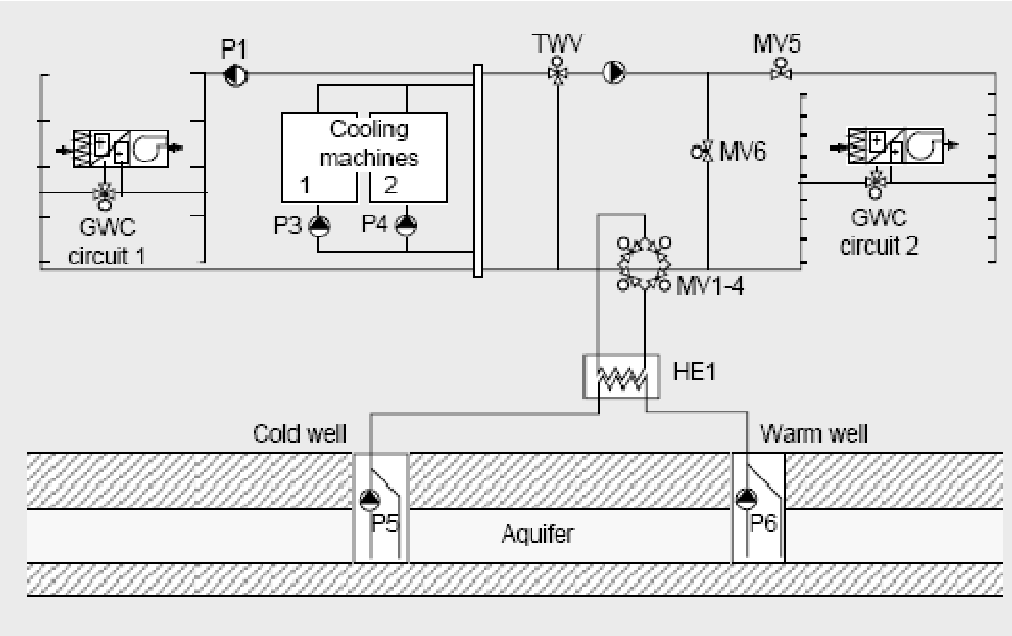


Figure 8. Schematic diagram of the system at The Groene Hart Hospital /2/

Cooling system at The Groene Hart Hospital is a very good example of collaboration of chiller system and aquifer system. This system shows how these two systems can help to each other. Generally in summer aquifer cooling system has first priority but till the cold well water is used efficiently. But sometimes after long using of the coolth storage the temperature of the cold well water increases sufficiently before the water injected into the warm well. In this case chillers began work alone or compare with aquifer system. New cooling system at The Groene Hart Hospital helps to safe money for operation and the pay-back period for this system was 4.5 years.

4. COASTAL COOLING

A lot of towns situated near seas, lakes or rivers all over the world. Obviously many buildings situated near water. As an earth water is quite cold in the depth, it's mean that it also can be used for cooling buildings.

4.1. Basic idea

The main idea of coastal cooling system is to pumped water from the depth by an open loop system and cooling extracted via heat exchanger.

4.2. The overall scheme

Main components in system which using water from basin are water intake, water pump and heat exchanger (Figure 9)

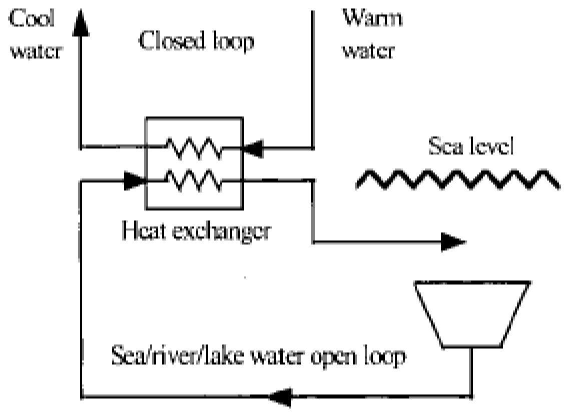


Figure 9. Schematic of coastal cooling /1/

In this way it's better to choose separating heat exchanger. Especially it's very topically with sea water, because it contains much salt and it cans make big damage to water circuit components. So the water loop components must have very good protection against corrosion /6/. In coastal cooling system pipes are better making from corrosion-resistant polyvinyl chloride.

It's better if the water will be taken great depth from the sea / lake / river because usually the water is coldest in depth. The water intake must be protected from the entering of small animals, fishes, water grass and others foreign material into the water system. Usually a grille is installed over the water intake.

4.3. Field of application

Coastal cooling systems are making for buildings which situated near the sea, river or lake. This system can be used as direct cooling for cool building water loop, or as indirect cooling to cool the condenser of the chiller, the same as aquifer cooling system.

4.4. A case study

Coastal cooling systems are quite popular nowadays. One of the best examples is Canadian project The Purdy's Wharf in Halifax.

Table 7. The Purdy's Wharf in Halifax. Project data. /2/

Altitude	Sea level
Year of Construction	1983/89
Office Area	63000 m^2
Commercial Area	2000 m^2
Cooled Floor Area	65000 m^2
Cooled Space	167000 m^3
Cooling Degree Days	59 Kd
Heating Degree Days	4254 Kd
Cooling Capacity	4.9 MW

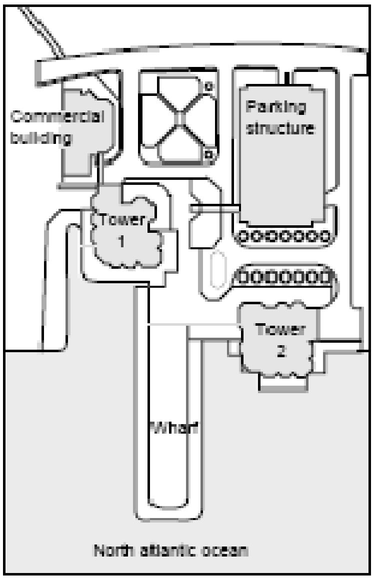


Figure 10. Purdy's Wharf complex.

The Purdy's Wharf consist from four buildings, but coastal cooling system has been using only in two towers, because they are nearest to the sea. The air conditioning system uses cold sea water from the harbor to provide cooling for Tower 1 and Tower 2 (Figure 10).

"The concept of sea water cooling is simple. As shown in Figure 11, in each tower the sea water cooling system consists of one open piping loop containing two heat exchangers in series. Two centrifugal pumps (3) draw cold sea water (2) through the intake (1) located at the ocean depth of 18 m, drive it through the two titanium heat exchangers (4) in the mechanical room, and reject warmer sea water to the harbor (5). Both heat exchangers exchange heat from closed loop water circuits to the sea water. Chilled water from the first heat exchanger goes directly to the cooling coils (8) located in the building VAV system on each floor of the building. An air circulation fan (11) blows warm air (10) through the cooling coils which provide cool air. The water (9) having been warmed up by the air, returns to the heat exchangers for another sea water cooling cycle."/2/

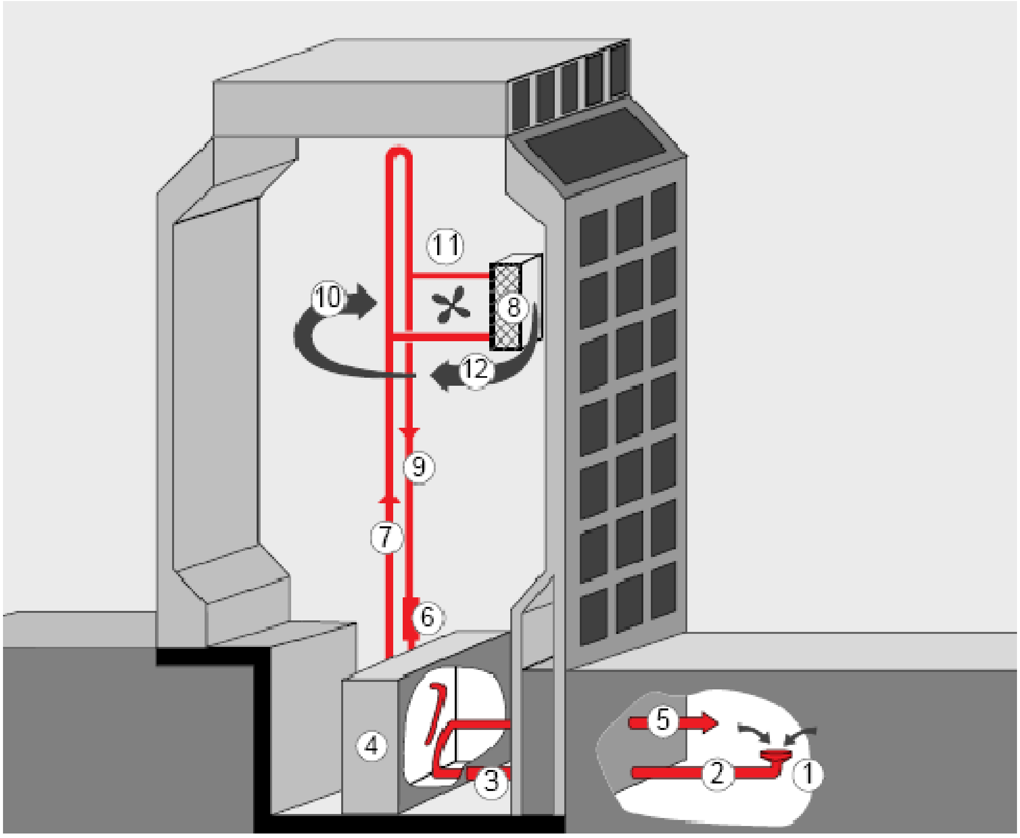


Figure 11. Schematic of the sea water cooling system /2/

The sea water intake is located 3.7 m above the harbor floor it's about 18 m deep. Over the water intake a screen is installed to prevent the entrance of foreign material and small sea animals. The temperature of the taking water remains between 5 and 7 ^{o}C.

The electricity in the coastal cooling system goes generally only for pumps and circulation fans, by this way this system allows for saving energy. Coastal cooling system at The Purdy's Wharf has proved that sea water can be used to provide more than ten month of cooling per year.

5. GROUND COOLING WITH WATER

Water has much higher thermal conductivity than air. Because of it water goes in our refrigerators. Like ground coupled air systems the ground coupled systems with water are making.

5.1. Basic idea

Thermal conductivity of water is 0.6 W/(m*K). This value means that water need quite short piping system underground to become colder. The main idea of ground cooling with water is to create closed loop which goes through cold layers in the ground.

5.2. The overall scheme

This type of ground cooling system is formed by two or more wells (Figure 12), which usually consist of one closed-loop pipe or horizontal closed loop (Figure 13). Usually water with antifreeze component mixture is circulated in this close circuit.

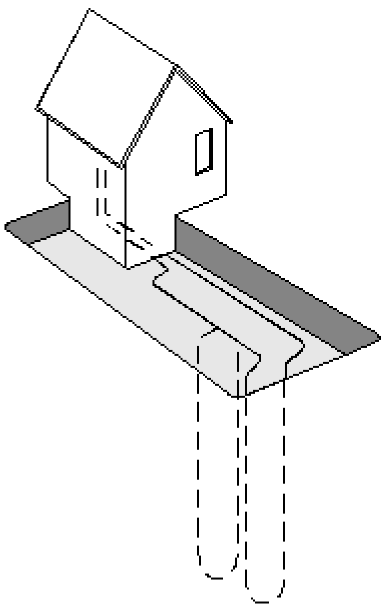


Figure 12. Vertical closed loops /5/

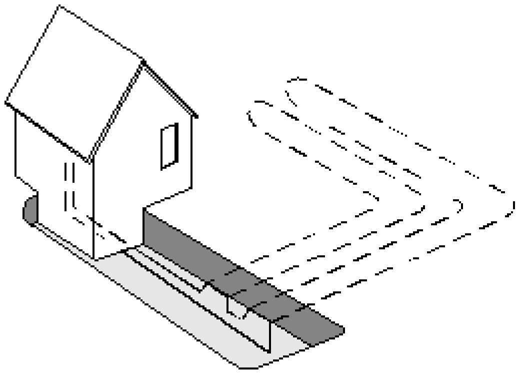


Figure 13. Horizontal closed loop /5/

For increasing efficiency of such type of cooling system the reversible heat pump can be installed.

5.3. Field of application

Ground cooling water system doesn't need big area, so it can be using in quite small family houses. This system compared with reversible heat pump can be using in very hot summer periods for cooling and in cold winter periods for heating. Ground coupled heat pumps are very popular all over the world in cold seasons for heating. But a lot of places in Earth have low temperature in winter and high temperature in summer, when additional cooling is necessary. For saving money and space the reversible heat pumps began to using. Thanks to reversible heat pump one system can be using for heating and cooling.

5.4. A case study

Under the Canadian Advanced Houses Program in 1991 ten houses were built. This program was made for develop innovative technologies which help to build low-energy buildings. One of these houses was build in Laval and called Maison Perfomante.

Table 8. The Advanced House in Laval, Canada. Project data. /2/

Altitude	17 m
Year of Construction	1993
Number of Working Spaces	190
Floor Area	132 m^2
Space	412 m^3
Cooling Degree Days	250 Kd
Heating Degree Days	4540 Kd
Energy consumption	16000 kWh/a

The Advance House in Laval has a lot of innovative technologies such as high efficiency insulation, lighting and windows, preheating of domestic hot water using evacuated-tube solar collector etc. /2/ Also it has very interesting low energy cooling system. The cooling system in Maison Perfomante consists of two rainwater storage tanks, two wells, and a reversible heat pump which operates under specific and predetermined peak temperature levels (Figure 14). When the inside temperature becomes quite high the first cooling mode which using rainwater storage tanks is activates. If the inside temperature increases till 25 ^{o}C the second mode of ground cooling began to work. But if the temperature will rise till 27 ^{o}C when first two modes is activate the free cooling stops and heat pump in reversible mode began to work.

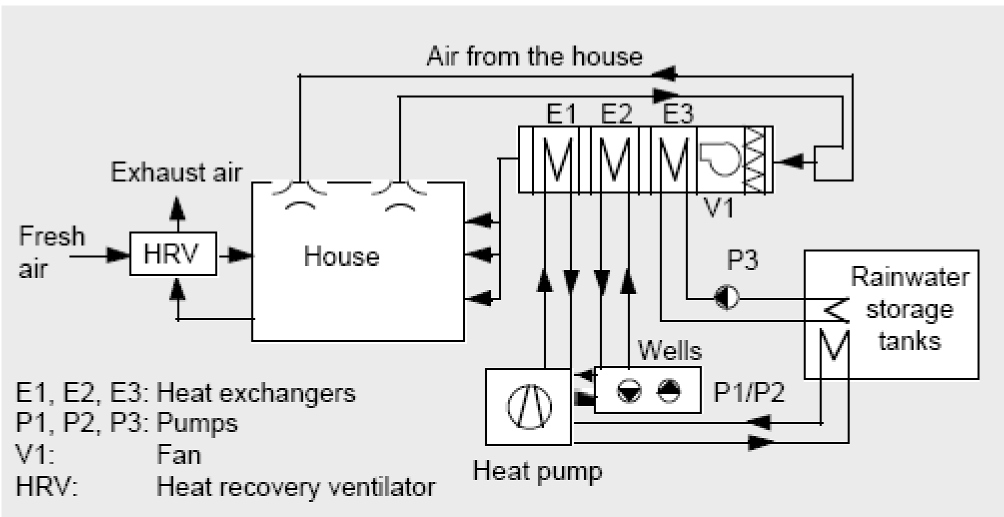


Figure 14. Advance house cooling and heating mechanical system schematic /2/

Ground cooling system in The Advance House in Laval consists of the wells, pumps and the heat exchanger. The two wells consist of the one closed loop pipe. Inside the pipe 50% water-methanol mixture circulates through the wells and heat exchanger E2 (Figure 14). Such mixture makes very good heat exchange between the house and the ground. The depth of the wells is 42 m and 78 m and the diameter is 15 cm.

The ground cooling is more reliable than the rainwater tanks because the rain temperature and occurrence depends on the weather. But during the spring rains is quite regular and rainwater cooling during this period is mostly efficiency. However rainwater is absolutely useless between the 18^{th} June and the 7^{th} July when the rain temperature is 20 ^{o}C.

6. CONCLUSION

There is review of main types of low energy cooling systems based on the cold energy sources of the ground in this bachelor thesis was made. These systems are quite different, so it’s possible to build them in many places in the world which has quite big temperature difference in summer and winter.

There is economical comparison between conventional cooling system and aquifer cooling system in this bachelor thesis (Table 4) bring. In spite of the fact that comparison is resulted particularly for groundwater storage cooling system, on the basis of it is possible to draw a conclusion concerning other low energy cooling systems based on the cold energy sources of the ground. Capital cost of such systems will be bigger than conventional system in any case because besides equipment installation in the building, these systems need a lot of earthworks as piping, well drilling, excavation or installation water intake deep in the sea or river. For another thing cold energy sources of the ground should be studied before using and research works should be paid also. But all these systems are developed for making low energy buildings, obviously that these systems must consume less energy than standard cooling systems. It means that the annual energy consumption of low energy cooling systems will be about two times less than energy consumption by chiller cooling system, therefore that annual operating cost of systems which based on the cold energy sources of the ground will be about two times less than operating cost of conventional system. This fact gives a big advantage to low energy cooling systems in economical aspect because most cooling systems are making for a long time and after payback period the standby charges will be much less than charges for conventional cooling system.

But energy consumption characterizes not only economical aspect. Also it’s characteristic of safety to environment. Most energy is make on the thermal power stations which using fossil fuels. When such fuel burns it produces carbon dioxide emissions and it makes the big harm to environment, by the way it’s one of the main cause of global warming. Obviously if requirement for energy becomes less it begins to burn less fossil fuel therefore harm to environment will be less too. In such way cooling systems based on the cold energy sources of the ground are much more ecological than conventional cooling systems.

Unfortunately all low energy cooling systems based on the cold energy sources of the ground have very big general disadvantage. It's impossible to use such systems in hot climate. It's mean that it's impossible to use these systems in places where cooling systems are necessary, for example in Africa or in South America. Also such cooling systems are absolutely non-mobile and all of them need quite a big time for installation. So low energy cooling systems based on the cold energy sources of the ground never will be use in temporary buildings.

But in spite of disadvantages low energy systems began more popular from year to year. It's impossible to choose better low energy cooling system based on the cold energy sources of the ground, because everything depends on specific case. For example aquifer cooling will be cheaper and more favorable for buildings with a floor area more than 6000 m^2 and which have suitable aquifer between 30 m and 200 m depth. But this system can't be using in a small houses. Coastal cooling system is quite expensive, but if the building situated near the basin on the solid ground this system is only one way to create low energy building. Ground water cooling system with reversible heat pump will help to make a lot of environmental friendly one family houses. And the ground coupled air system is cheapest and commonly used system but it also has unfavorable factors such as rocky ground and ground pollution.

Low energy cooling systems compare with low energy heating systems, lighting and good building envelope can help to make very low energy buildings. If people began to build more such buildings all over the word it will help to reduce total energy consumption it three times and maybe it helps to stop a global warming.

7. BIBLIOGRAPHY

Books

1995. Review if Low Energy Cooling Technologies. Canada, CANMET.

Zimmermann, Mark – Anderson, Johnny 1998. Low Energy Cooling - Case Study Buildings. UK, Building Research Establishment Ltd.

Barnard, Nick – Jaunzens, Denice 2001. Technology Selection and Early Design Guidance. UK, Building Research Establishment Ltd.

Roel, Henk 2000. Detailed design tools.

Electronic sources

Sound Geothermal Corporation
<URL:http://www.soundgt.com/ghp.htm >

Environment Canada
<URL: http://www.ec.gc.ca/default.asp?lang=En&n=FD9B0E51-1 >