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Pre-Feasibility Study of a Swimming Pool Complex for a University Campus

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ABSTRACT

Izmir Institute of Technology has a geothermal production well (32°C) in its Campus area. To conduct research and demonstrative projects in the Campus and the Region, "Center for Geothermal Research" was established in 2005. One of the projects planned for the Campus is to design and construct an indoor and outdoor swimming pool complex for recreational purposes for the students and staff by using the geothermal water with 65 m^3/h flow rate. In the complex three swimming pools are considered with the total area of 1013 m^2 and volume of 1393 m^3. Total heating and cooling load is calculated as 244 kW and 149 kW, respectively. Water source heat pumps are considered as heating and cooling system. The results of the study show that the existing flow rate of the geothermal well is not enough for the whole complex to be able to use the outdoor pools during the winter season. Therefore, the geothermal flow rate should be increased to 2-4 times depending on the outdoor air temperature or the outdoor pools should be used at above 10°C of the outdoor air temperature.

1. INTRODUCTION

Nowadays, two of main problems in the world are depletion of fossil fuels and environmental pollution. The main energy source in the world is fossil fuels and depletion of fossil fuels is a risk for energy poverty in the future. On the other hand, consumption of fossil fuels causes another problem which is environmental pollution. Investigations are focused on solving these two problems by two ways: (i) developing alternative energy sources (especially renewable energy sources) and its applications and (ii) improving energy efficiency of equipment that use fossil fuels (Hepbasli et al, 2009). Due to availability, economic and environmental issues it is expected that the worldwide use of oil, natural gas and coal is going to decline in the future and that geothermal energy will play an important role in the replacement of those fossil fuels (Fridleifsson, 2001).

Turkey has a place among the first seven countries in the world with the abundance of geothermal resources, but only about 4% of its potential has been used. It is estimated that geothermal heating potential of Turkey corresponds to 5 million residence equivalent and 48 million ton/year CO_2 emission reduction and as a result, releases of 48 million ton/year CO_2 emissions into the atmosphere will be prevented. Therefore, it is expected that geothermal energy development will significantly speed up in the future (Kömürcü and Akpınar, 2009). The rise of oil and gas prices during last 3 years has made the development of the geothermal resources of Turkey more economically feasible (Serpen et al., 2009).

Low-temperature geothermal resources have been used cost-effectively in a number of countries where appropriate geological, hydrological and geophysical conditions are present such as in sedimentary strata. Examples of this are found in European countries like Romania, Slovakia, Serbia, France, Poland and Hungary. In these countries geothermal water is successfully used for fish farming, in heat pump applications, horticulture for greenhouse heating, for space heating, for animal husbandry, in industry for drying products, in balneological and recreational applications such as swimming pools, health spas etc. (Skapare, 2001).

There are relatively few researches on the energy utilization in indoor and outdoor swimming pools. Johansson and Westerlund (2001) compared the energy performance between adsorption heat recovery system and heat pump for indoor swimming pools. Lam and Chan (2001) calculated the heating load by applying heat transfer method and analyzed the energy utilization of a hotel swimming pool with heat pump by using life cycle energy cost method. The optimum heat pump design was discussed by Lee and Kung (2008) for swimming pool heating. Asdrubali (2009) was worked on the evaluation of water evaporation from indoor swimming pools. Because evaporation may cause the highest energy consumption of the pool plant and it is a topic of considerable practical interest. Skapare (2001) and Nasrabadi (2004) studied about designing on geothermal swimming pools.

The aim of the study is to design an indoor and outdoor swimming pool complex for recreational purposes for the students and staff in the Campus area of Izmir Institute of Technology. Therefore, size and the water flow rate of the swimming pools are determined, heating and cooling load of the complex are calculated. Capability of the existing geothermal well for the considered complex is investigated according to the geothermal water properties (temperature, flow rate, etc.). Finally, possible heating and cooling systems are analysed by considering the energy consumption and CO_2 emission.

2. CASE STUDY

2.1 Introduction to Izmir Institute of Technology

The Izmir Institute of Technology (IZTECH) is a state institution established in 1992 as the third university in the city of Izmir. The campus, which has a total area of 3500 ha, is located in Urla, about 40 km west of Izmir with a highway connection. Location of the Campus is shown in Figure 1.

In the Campus, a geothermal resource exists and exploration studies in the field started in 1995. In 2002, five gradient wells were drilled and one of which is assigned as production well having a 32°C temperature and 65 m^3/h flow rate. Using this production well, a swimming pool complex was designed and the panoramic view of the complex is given in Figure 2.

Figure 1: Location of IZTECH Campus (CIA, 2009).

Figure 2: Panoramic view of the considered swimming pool complex.

Izmir city has Mediterranean Climate. Figure 3 shows the annual outdoor air temperature duration curve for Izmir city. As it can be seen from Figure 3, the temperature range is (-3) - 40°C. The swimming pool complex is designed by considering the cooling requirements besides heating. 0°C is the design outdoor air temperature for heating.

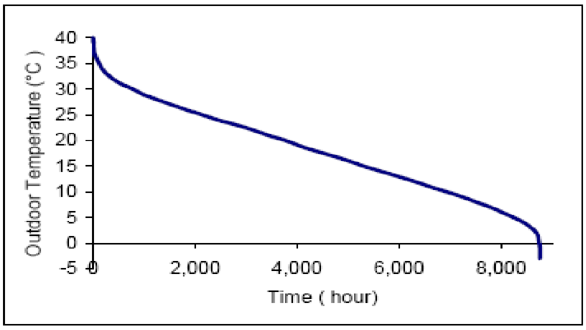

Figure 3: Outdoor air temperature curve for Izmir city (Yildirim, 2003).

The schematic diagram of the complex is given in Figure 4. As it can be seen from the figure, the swimming pool complex is divided in two parts, swimming pools (Unit I) and heating and cooling system of the whole complex (Unit II).

2.2 Swimming Pools

Three swimming pools are considered for recreational purposes for the students and staff of the university. The swimming pools are designed according to Turkish Standard, TSE 11899 "Swimming pool- General rules for preparation of water, technical construction, control, maintenance and management", and the related publications of Chamber of Mechanical Engineers. The complex is located 750 m from the geothermal well. For the complex the geothermal water temperature and flow rate are 32°C and 65 m^3/h, respectively. The geothermal water is filtered and sent to the swimming pools directly. In another words, the swimming pools are considered as a thermal pool.

2.2.1 Size of the Swimming Pool

The size of a swimming pool is one of the important items for design of the pool; it is a basic factor for determining the pool's service, water value, selection of equipment etc.

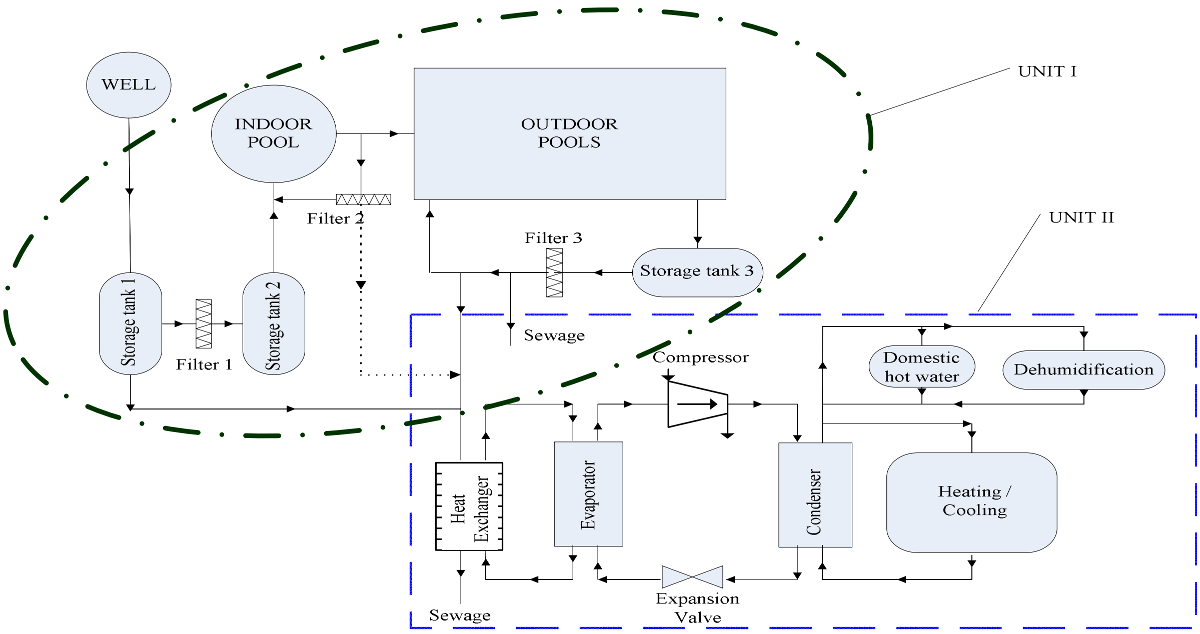

Figure 4: Schematic diagram of the complex.

In the literature the swimming area of a pool should be based on 3.5 m^2 per swimmer. For proper swimming, a lane at least 2.0 m wide and 5.0 m long is required. The designer feels that in a pool which is intended only for swimming, and not for diving and water polo, the maximum depth of water need not to exceed about 1.5 m. For the teaching part of a swimming pool, the amateur swimming association recommends a minimum length of 12.0 m and a minimum width of 7.0 m. The depth generally varies from 0.8 m to 1.0 m. The maximum depth should not exceed 1.2 m (Perkins, 1988; Nasrabadi, 2004).

According to the literature and TSE 11899 standards, one of the swimming pools is considered as an indoor swimming pool with the area of 240 m^2 and 1.4 m height. The other one is semi-Olympic outdoor swimming pool. The area of the outdoor swimming pool is 745 m^2 and the depth is 1.5 m. The third one is children swimming pool with the area of 28 m^2 and 0.5 m height and it is located to outside. The total area and volume of the swimming pools is 1013 m^2 and 1393 m^3, respectively.

<u>2.2.2 Preparation of Swimming Pool Water</u>

As it can be seen from Figure 4, the swimming pools are fed by geothermal fluid. The geothermal fluid is not pure, includes corrosive elements, such as Fe, NH_4, NO_x and salt, Therefore, pipe material polypropylene (PP) is selected. The geothermal fluid is transferred to the first storage tank by polypropylene pipes. To remove these corrosive elements and sand from the geothermal fluid, the filters (Filter 1) are used. Filtered geothermal fluid is collected in the second storage tank and sent to the swimming pools. Turnover period, which shows the refill of the swimming pool, is another important parameter to design a swimming pool, is selected as 3 hours according to TSE 11899. Total required water volume for the swimming pools is 1393 m^3, but the geothermal water flow rate is 65 m^3/h. Therefore, 395 m^3/h of swimming pool water should be re-circulated to the pools to meet the turnover period of the pools. But waste swimming pool water includes some biological remains, chemicals and sand. Other filters (Filter 2, 3, zeolit) are used to clean the waste water of the swimming pools. The remaining filtered swimming pool water is passed to heat exchanger of the heating system.

2.3 Heating and Cooling System

The complex is considered to be operated between 8 and 24 for 365 days. Water source heat pump is selected as heating and cooling system (Figure 4). Filtered geothermal water flooded from the pools is used as heat source of heat pumps. Heating of the swimming pool complex is designed in two different heating types as floor heating and duck fan-coil system. While the area of the indoor swimming pool is heated by floor heating, the other places are heated by fan-coil system. For cooling duck fan-coil system is used.

Since domestic hot water and dehumidification is required throughout the year, two heat pump units are considered. One is to meet the domestic hot water and dehumidification requirements; the other one is used for heating or cooling demand according to the season.

3. ANALYSIS

For swimming pool complex, heat loss of the swimming pools, heating and cooling loads are analysed.

3.1 Heat Loss from the Pools

Heat loss of the indoor pool is not occurred, since the space of the indoor pool is designed to heat of 30°C. Consequently, heat loss of the pools is determined only for the outdoor pools.

Heat loss from outdoor pools is mainly due to (Svavarsson, 1990):

- • Convection
- • Evaporation
- • Radiation
- • Conduction
- • Rain

The main heat losses from the swimming pool occur by convection and evaporation. The obtained results from earlier research and analyses show that heat losses due to the other three factors (radiation, conduction, rain) can be estimated to be equal to 10% of total heat loss due to convection and evaporation. Heat loss due to conduction is small, because of good insulation in the pool building materials. Heat loss by means of rain and radiation is also negligible. In the following calculation, 10% of total heat loss by convection and evaporation will be assumed for these three mentioned factors.

<u>3.1.1 Heat Loss due to Convection</u>

Heat loss due to convection depends strongly on the air temperature around the pool and the wind speed. Equation 2 and 3 shows that heat loss through convection will increase with higher wind speed and lower outside temperature:

$$q_c = h_c.(T_w - T_a) \quad (1)$$

where
q_c : Amount of heat loss by convection (W/m^2);
T_w : Water temperature in the pool (°C);
T_a : Air temperature in the pool's surroundings (°C);
h_c : Convection heat transfer coefficient (W/m^2°C), is very dependent on wind speed.

The relationship between heat transfer coefficient and wind speed is shown in Equation 2 that is called the Rimsha-Doncenko formula (Svavarsson, 1990 and Nasrabadi, 2004):

$$h_c = 4.19(k + 0,45.v) \quad (2)$$

where
v : Wind speed at 2 m height from the ground surface (m/s);
k : Empirical coefficient (W/m^2°C) defined by Equation 3.

$$k = 0,93 + 0,04.(T_w - T_a) \quad (3)$$

<u>3.1.2 Heat Loss due to Evaporation</u>

Heat loss due to evaporation takes place when there is different partial pressure of water vapour at the pool's surface and in the air over the pool. This will cause evaporation of water at the pool surface, and this requires energy that is taken from the water. This kind of heat loss in the pool can be calculated with Equation 4 from Rimsha – Doncenko (Svavarsson, 1990 and Nasrabadi, 2004):

$$q_E = 4,19.(1,56.k + 0,7.v).(e_w - e_a) \quad (4)$$

where
q_E : Amount of heat loss by evaporation (W/m^2);

e_w : Partial pressure of steam at surface (mbar);
e_a : Partial pressure of steam in the air above the pool (mbar).

The total heat loss can thus be calculated as:

$$q_T = q_c + q_E + S \quad (5)$$

where
q_T : Total heat loss from the swimming pools (W/m^2)
S : Sum of heat losses due to radiation, conduction and rain = 0.1 (q_E + q_C) (W/m^2).

3.2 Re-circulated Water Temperature

The swimming pools are fed by filtered geothermal water, continuously. After filtration, geothermal water temperature is decreased to 28°C. As it is mentioned before, geothermal water flow rate is limited and not enough to meet the fresh water requirement of the pools for turnover period. Therefore, some part of the pool's water is filtered and re-circulated to the pools. But because of the heat loss of the pools, the temperature of the pool's water decreases and it has vital importance to design the complex to keep the pool temperature at the range of the standards.

The simplified flow chart of the swimming pool water is shown in Figure 5. The pool represents all pools of the complex (indoor, outdoor and children pool). During the recirculation process, it is assumed that temperature of the re-circulated pool water decreases by 1°C.

The total heat loss from the pool (Q_T) has been calculated with Eq. (5). Energy balance equation is given in Eq. (6).

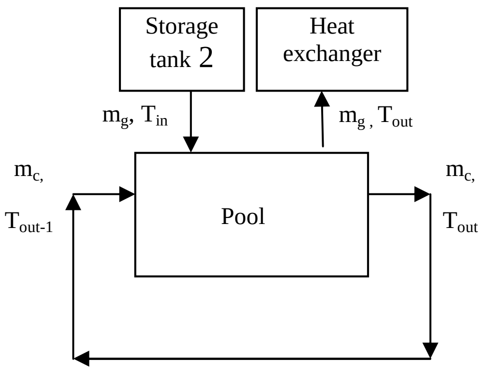

Figure 5: Flow chart of the swimming pool water.

$$\dot{Q}_T = m_g.C_p.T_{in} + m_c.C_p.(T_{out} - 1) - m_g.C_p.T_{out} - m_c.C_p.T_{out} \quad (6)$$
$$\dot{Q}_T = m_g.C_p.T_{in} - m_c.C_p - m_g.C_p.T_{out}$$

Q_T : Total heat loss from the swimming pools (kW)
T_{in} : Temperature of inlet geothermal water (°C)
T_{out} : Temperature of outlet of the re-circulated water of the pool (°C).
m_g Geothermal water flow rate (kg/s)
m_c Amount of re-circulated water in the system (kg/s)
C_p Specific heat capacity of water (kj/kg°C)

Outlet temperature of the re-circulated water is calculated with Eq. (7).

$$T_{out} = \frac{(m_g.C_p.T_{in} - m_c.C_p - \dot{Q}_T)}{m_g.C_p} \quad (7)$$

3.3 Heat Load of the Complex

The heat load of the complex can be calculated according to the following:

$$\dot{Q} = U.A.(T_i - T_o) \quad (8)$$

where

A = Heat transfer surface area (m^2);
U = Heat transfer coefficient (W/m^2°C)
T_i = Indoor temperature (°C)
T_o = Outdoor air temperature (°C)

For cooling system, fresh-air load is calculated as follows:

$$\dot{Q}_{fresh-air} = \frac{\dot{V}.(h_2 - h_1)}{\upsilon}.(\frac{1}{3.6}) \quad (9)$$

$\dot{V}$ = Amount of air as volumetric (m^3/h)
h_1, h_2 = Air enthalpy of inlet and outlet (kJ/kg dry air)
υ = Specific volume (m^3/kg dry air)
$\dot{Q}_{fresh-air}$ = Heat load for fresh air requirement (W).

4. RESULTS

Total heating and cooling loads are calculated as 244 kW and 149 kW, respectively. The heating and cooling load of the swimming pool complex is summarized in Table 1.

Table 1: Heating and cooling load of the swimming pool complex.

Place Name		Area (m^2)	Heating Load (W)	Cooling Load (W)
Z01	Management office1	15.40	852	1836
Z02	WC-woman	7.92	131	
Z03	WC-man	7.92	131	
Z04	Management office2	15.40	852	1793
Z05	Entrance hole	42.54	3214	3489
Z07	Shower for man	63.69	2808	6219
Z08	Shower for woman	63.69	2509	6219
Z09	Resting area	24.92	523	2066
Z10	Massage room	6.80	93	
Z11	Steam room	3.40	53	
Z12	Sauna	3.40	221	
Z13	Corridor	87.82	5002	13609
Z14	Cafeteria	245.00	14860	44301
Z15	Iron room	12.00	171	
Z21	Indoor swimming pool	420.00	75670	
TOTAL OF HEATING OR COOLING			**107093**	**79532**
ADDITIONAL LOAD	Domestic hot water		36831	
	Dehumidification		100030	
	Fresh air			69341
GENERAL TOTAL			243955	148873
GENERAL TOTAL (kW)			**244**	**149**

For heating system floor heating and duck fan-coil system are selected. Floor heating is applied to the indoor swimming pool area of 420 m^2. The total pipe length is 2450 m for 76 kW heating load with 50/40°C floor heating water temperature regime. Domestic hot water and dehumidification load is 137 kW. In the system two water source heat pumps are considered. One is to meet domestic hot water and dehumidification load through the year, the other one is for heating or cooling demand. Therefore, the capacity of the heat pump units is selected according to 137 kW domestic hot water and dehumidification load and 149 kW cooling load.

Total heat loss of the swimming pools is calculated as 897.6 kW for 0°C outdoor air temperature. Design and calculated parameters of the swimming pools are shown in Table 2 and Table 3.

As it can be seen from Table 3, temperature of the re-circulated water outlet of the pool is calculated as 9.99°C for 0°C outdoor air temperature and 18 kg/s geothermal water flow rate. If the water at this temperature is re-circulated to the pools to meet fresh water requirement, the water temperature of the swimming pool decreases continuously.

Table 2: Design parameters of the outdoor and children swimming pools.

Design parameters		Value
Air temperature (°C)	T_a	0
Wind speed (m/s)	v	3
Humidity (%)	H	60
Specific heat capacity of water (kj/kg°C)	C_p	4.19
Geothermal water flow rate (kg/s)	m_g	18
Temperature of inlet to pool (°C)	T_{in}	28
Amount of re-circulated water in the system (kg/s)	m_c	109.7
Pool area (m^2)	A	773

Table 3: Calculated parameters of the swimming pools.

Calculated parameters		Value
Convectional heat loss (W/m^2)	q_c	398.9
Amount of heat loss by evaporation (W/m^2)	q_E	657.1
Amount of heat loss by radiation, conduction and rain (W/m^2)	S	105.6
Total heat loss from the swimming pool (W/ m^2)	q_T	1161.6
Total heat loss from the swimming pools (kW)	Q_T	897.9
Temperature of outlet of the re-circulated water of the pool (°C)	T_{out}	9.99

In Figure 6, re-circulated water temperature versus depending on geothermal water flow rate for 0°C outdoor air temperature is shown. It is clearly seen that, the re-circulated water temperature increases with increasing geothermal water flow rate. Therefore, to be able to use outdoor swimming pool during the winter season, the geothermal water flow rate should be increased if possible. If not, the outdoor and indoor swimming pools should be used separately. Re-circulated water temperature and heat loss of the swimming pools depending on outdoor air temperature for 18 kg/s geothermal water flow rate is shown in Figure 7. According to TSE 11899, the water temperature should be maximum 26-28°C for deep pools and 15°C for shock pools. Therefore, it is reasonable to use the outdoor swimming pool, when the outdoor air temperature is above 10°C during the winter season.

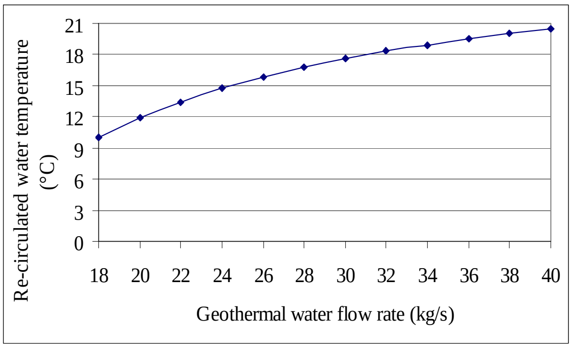

Figure 6: Re-circulated water temperature versus geothermal water flow rate for 0°C outdoor air temperature.

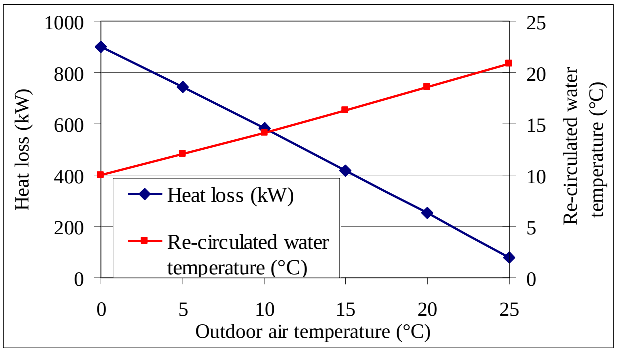

Figure 7: Re-circulated water temperature and heat loss of the swimming pools outdoor air temperature for 18 kg/s geothermal water flow rate.

For the swimming complex annual heating requirement is calculated as 132573 kWh by assuming heating system runs 8:00-24:00 at outdoor air temperatures below 20°C.

Water source heat pump system is compared to electric and fuel-oil boiler according to annual energy consumption and CO_2 emission for only considering the heating load of the complex which is 107 kW. For water source heat pump, two different COPs are considered as 4 and 5. The results are tabulated in Table 4.

Table 4 indicates that, using the water source heat pump with COP of 5 instead of fuel-oil boiler, the annual energy consumption is reduced to 26514.6 kWh with an energy saving of 127640 kWh which corresponds to 13667 kg fuel-oil. Depending on energy saving, CO_2 emissions reduced to 4.8-6% by using heat pump.

Table 4: Annual energy consumption and CO_2 emission of different heating system alternatives.

Heating system type	Efficiency or COP	System capacity (kW)	Energy consumption (kWh)	CO_2 emission (kg/year)
Fuel-oil boiler	0.86	124.4	154154.7	46246.4
Electric boiler	0.96	111.5	138096.9	11600.1
Heat pump 1	4	26.8	33143.3	2784.0
Heat pump 2	5	21.4	26514.6	2227.2

5. CONCLUSION

Izmir Institute of Technology has a geothermal resource in its Campus area with 32°C -34°C temperature and 65 m^3/h flow rate. It is aimed that to construct a swimming pool complex for recreational purposes for the students and staff by using renewable energy sources. Therefore, water source heat pump system is selected as heating and cooling system. As a heat source, the existing geothermal water will be used and the required electricity is supplied by wind turbines. In this study, technical analysis of the swimming pool complex is given to assess the viability of the project.

In the complex three swimming pools are considered with the total area of 1013 m^2 and volume of 1393 m^3. The filtered geothermal water with the temperature of 28°C and flow rate of 65 m^3/h flow rate feeds the swimming pools. Because of the limited flow rate of the geothermal water, used swimming pool water is considered to re-circulate with 395 m^3/h flow rate to meet the turnover period of 3 hours. Total heat loss of the swimming pools is calculated as 897.6 kW for 0°C outdoor air temperature. Because of the heat loss of the outdoor pools, during the winter season the water temperature of the swimming pools decreases down to 9.99°C with the existing geothermal water flow rate. To be able to use outdoor swimming pool during the winter season, higher geothermal water flow rate is required. If higher flow rate is not possible, the indoor and outdoor swimming pools should be separated. It is concluded that the outdoor pool is suitable to use at outdoor air temperatures above 10°C.

Total heating and cooling loads are calculated as 107 kW and 149 kW, respectively. As heating and cooling system water source heat pump system is selected. While space of the indoor swimming pool is heated by floor heating, the other spaces are heated by duck fan-coil system. Domestic hot water and dehumidification load is calculated as 137 kW. For the complex, two individual heat pump units are used. One heat pump is operated to meet the domestic and dehumidification requirement, the other one is considered for heating or cooling of the complex.

The heating system of the complex runs 8:00-24:00 at outdoor air temperatures below 20°C and annual heating requirement is 132573 kWh. Water source heat pump system is compared to electric and fuel-oil boiler according to annual energy consumption and CO_2 emission. Annual energy consumption is reduced to 26514.6 kWh with an energy saving of 127640 kWh which corresponds 13667 kg oil by using the heat pump with COP of 5 instead of fuel-oil boiler. On the other hand, CO_2 emissions reduced to 4.8-6% by using heat pump system. Besides the heating requirement, if the cooling requirement of the complex is also considered the amount of the energy consumption and CO_2 emissions reduces greatly by using geothermal energy.

This study is a pre-feasibility study to design a swimming pool complex by using geothermal energy. A detailed technical and economical analysis should be conducted to select of the optimum system type for the complex.

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