Fostering diffusion of Heating & Cooling technologies using the seawater pump in the Adriatic-Ionian Region

Case study report - Greece

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Purpose of this document

This document refers to the pre-feasibility study of a public building in Greece and is one of altogether 6 pre-feasibility studies that will be done in the scope of the SEADRION project.

Feasibility studies for the design and implementation of innovative systems that use heat pumps with seawater as an energy source will be carried out, in order to meet the cooling requirements and to ensure their contribution to heating requirements in the winter period and for domestic hot water production.

A report on technical and economic feasibility studies and a sensitivity analysis regarding the installation of a seawater heat pump will be carried out. Each one of the case studies reports will consist of an **economic, energetic and environmental** analysis.

1 Introduction

The subject of this document is to elaborate a seawater heat pump utilization case study on an existing public building, which thermal needs are currently covered by other means. To this end, the indoor swimming pool in Kavala was selected, which distance from the sea is approximately 300m.

The mode of operation of the building mentioned above is similar to one of the other buildings. One such example is the newly constructed open Olympic swimming pool of Ilida (Western Peloponnese) of 1.050 m^2 surfaces and 2.205 m^3 volume. The heating needs of the swimming pool and for the sanitary water at the swimmers' baths are covered by two ground source heat pumps of 400 kW_{th} capacity each. Both heat pumps are placed in series, fed by an open-loop doublet comprising two 100m deep wells, supplying 70m^3/h of groundwater with a temperature of 18°C through a heat exchanger. The water is re-injected at 10°C. The capital costs of the GSHP system were around 500,000 €, and the estimated payback time was approximately 1 year.[1]

2 Characterization of the site[2]

2.1 Location – Characteristics

The indoor swimming pool (natatorium) in Kavala was built in 2008 and started operation in 2009. In 2010, its roof was badly damaged as severe weather conditions (storms) decomposed the PVC sealant as well as the existing layer of the roof's insulation. The mechanical equipment remained however in excellent condition.

Its main building includes two swimming pools (the main pool and a children's pool). It can accommodate up to 324 athletes and 2000 spectators. It operates daily from 9:00-10:00 and Saturdays 9:00-13:30. It is used by the public and by sports clubs for leisure, training and competition activities.

The two pools of the natatorium are heated. The large swimming pool has 8 swimming lanes, measuring 21m x 50m, with a total area of 1050 m^2 and a total volume of 2320 m^3. The children's pool is 11m x 10m, with a total area of 110m^2 and a volume of 85m^3.

[1] Papachristou M, Mendrinos D, Dalampakis P, Arvanitis A, Karytsas C, Andritsos N, Geothermal Energy Use, Country Update for Greece, European Geothermal Congress, Strasbourg, France, 19-24 Sept 2016

[2] VASILIKOPOULOU A, PLANT DESIGN PARAMETERS AND PROPOSALS FOR ENERGY UPGRADING OF THE KAVALA MUNICIPAL SWIMMING POOL, DIPLOMA THESIS, AUTH, GREECE, 2014

Figure 1: Location of the building

2.2 Building envelope

The building is rectangular with gradients on the west side and a sloping roof, which starts at 11.15 m height and reaches 16.5 m.

The floor area of the two swimming pools is 3528.7 m^2 and 1160 m^2 respectively. The area of the roof is 3724 m^2. The envelope consists of a series of glazed units covering a total area of 786.64 m^2. Specifically, the four sides of the envelope are summarized in Table 1.

Table 1: Structural elements [m^2]

	South side [m^2]	**North side** [m^2]	**East side** [m^2]	**West side** [m^2]	**Total** [m^2]
Masonry in contact with unheated indoor air	0	33.7	138.18	50.76	222.64
Glass facades in contact with outside air	179.78	175	214.2	177.1	746.08
Masonry in contact with outdoor air	489.63	501.27	469.4	1000	2460.3
Masonry in contact with heated indoor air	0	0	0	149.55	149.55
Glass facades in contact with unheated indoor air	40.56	0	0	0	40.56
Total	**709.97**	**709.97**	**821.78**	**1377.41**	

The masonry of the building is constructed of reinforced concrete and brick with integrated insulation. The floor is in full contact with the ground, except for the stands' surfaces that are insulated with a base substrate.

For masonry and floors, the thermal transmittance (U value) is equal to the maximum permissible threshold of the thermal insulation regulation, which is 0.7 $[W/m^2K]$. The roof after the insulation breakdown, due to a storm, is considered to consist only of metal with thermal transmittance (U value) equal to 6 $[W/m^2K]$.

Glass facades consist of a 20% metal frame with 12 mm thermal break and double glazing with a gap of 6 mm correspondings to thermal transmittance (U value) 3.6 $[W/m^2K]$.

A layer of mineral wool insulation surrounded the roof of the building during the initial construction with 10 cm thickness, which externally protected a 3 mm PVC sheet. After destruction due to a storm as aforementioned, the roof is now left without thermal insulation and consists substantially of a metal sheet.

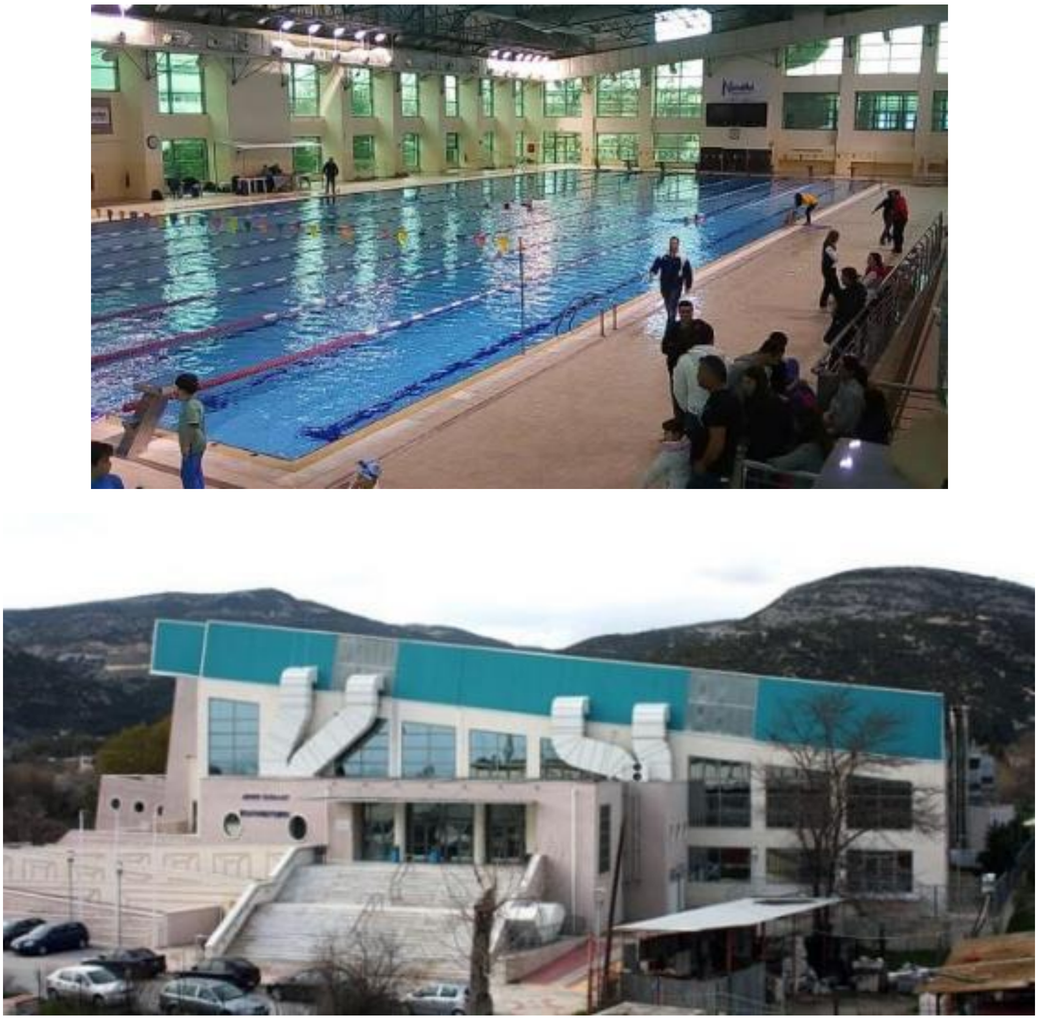

Figure 2: Internal and external view of the building

2.3 Building's technical characteristics

2.3.1 Air heating

Two steel boilers (Figure 3) with a thermal output of 800,000 kcal/h (930 kW) are used for **air heating**, with an efficiency of 90% and an operating pressure of 4 bar.

Table 2: Air heating boiler system

	Power (kW)	Efficiency	Total (kW)
Space Heating	930	0.9	1674
	930	0.9	

Figure 3: Boiler room for air heating

2.3.2 Swimming pool water heating

The **water temperature** of the main pool is maintained at 26.2 °C and one of the children's pools at 29 °C. A 105kW air/water heat pump (Figure 4) and two boilers with a thermal output of 700,000 kcal/h or 814kW heat the water (Figure 5). A 500 litres buffer tank is used for hot water storage.

Figure 4: Heat pump and buffer tank for hot water

Figure 5: Boiler room for water heating

2.3.3 Ventilation-dehumidification

For **mechanical dehumidification** as well as for air conditioning of the space in summer, two cooling units of TRANE, type RTWB 224, double-circuit, with cooling capacity of 749kW, an efficiency factor of 3.9 and refrigerant R134a are used. One of two chillers is operating with heat recovery. Also, 2 buffer tanks of 1000 litres capacity are used to store the cold water produced by the cooling units.

Figure 6: Cooling Unit 1 & 2 (respectively)

Ventilation, as well as air intake, is made from 5 central air conditioners. These mix fresh air with recirculated air at rates that change constantly depending on the external conditions.

2.3.4 Air cooling

Mechanical cooling takes place during summer months from the two cooling units mentioned above, as well as from 2 cooling towers.

Figure 7: Cooling towers

2.3.5 Heating and cooling of auxiliary areas and production of DHW

As auxiliary areas, the entrance, offices and exercise room are included. Heating auxiliary facilities and DHW production are done by an oil boiler (250,000 kcal/h) with a buffer tank of 2000 litres capacity. Hot water circulators in central air conditioner units supplement the system. The cooling units shown in Table 3 are used to cool these spaces.

Table 3: Cooling units of auxiliary areas

Quantity	Cooling power (W)
2	60000
1	45000
1	14000
1	15000
1	18000

Figure 8: Boiler room for DHW production, 2000 litres

2.3.6 Additional Information

The system is complemented by hot water pumps in the air handling units (AHU). In addition, two three-phase motors (55 kW) are used for each AHU. The air in the swimming pool is supplied with fans. All ventilation fans are approximately 1.5 m below the roof. The fan grids are externally insulated and made of galvanized steel. The network also has several hot water expansion vessels (red) and cold water expansion vessels (blue). There is an oil tank as well as a power generator of 86 kW.

Figure 9: Piping network of AHU and Network vents on the roof of the pool

2.4 Heating oil and electricity consumption

In 2010, approximately **261,000 litres** of heating oil was consumed, which corresponds to 2700 MWh. In addition, for the same year, **2200 MWh** of electricity was used for the operation of the mechanical equipment of the natatorium, which includes heat pumps, cooling units, motors for pumps and system fans for air conditioning in the summer, cooling towers, boiler burners, room lighting and for other minor uses.

2.5 Indoor conditions

The indoor conditions of the swimming pool area for winter and summer are shown in Table 4.

Table 4: Indoor conditions

	Winter period	Summer period
Water temperature (main pool)	26.2 °C	26.2 °C
Water temperature (children's pool)	29 °C	29 °C
Internal air temperature	18 °C	26.5 °C
Relative air humidity	75 %	75 %
Absolut indoor air humidity	10 gr H_2O/kg dry air	10 gr H_2O/kg dry air

3 Scenario: Adjustment of the existing heating system with a SWHP system

According to the implementation study regarding the mechanical equipment for the natatorium of Kavala, the total thermal losses of the building are 2,065,000 kcal/h or 2400 kW and the total thermal losses of the swimming pools are 275,000 kcal/h or 320 kW.

According to the same study, the needs for maintaining the water temperature in the pools are approximately 320 kW, and the needs for the AHUs are 327,000 kcal/h or 380 kW.

As already mentioned, 2 water-cooled chillers are operating under temperatureσ of 7/12 °C at the evaporator and 50/55 °C at the condenser for heating the pool water through heat recovery and the AHU.

For these temperature conditions, the thermal capacity of the refrigerant is 840 kW, which overlaps the energy needs for heating water and space heating (approximately 700 kW).

The proposed scenario is this cooling system to operate as a seawater/geothermal heat pump. The modifications that are necessary to be done are related to the operating temperature of the condenser. The temperature has to set at 45/40 °C instead of 55/50 °C in order to increase its performance.

Specifically, the ratio of thermal efficiency to electrical consumption will be altered yielding thus COP 4.5 instead of COP 3.23. The evaporator will be connected with a plate heat exchanger through boreholes, which have to be drilled. The temperatures will be 7/12 °C between cooler and heat exchanger and 20/15 °C from the side of the boreholes.

The system of the boreholes consists of the construction of four production drillings, 100m depth each one with a flow rate of 25m^3/h and construction of five injection drillings.

During the operation of this system, the only form of energy consumed is electricity. This replaces any other form of conventional fuel (heating oil). In order to calculate the energy benefit for this system, an operating cost analysis is performed between the specific geothermal system and the corresponding conventional one. This comparison refers to a conventional system, which may have the same energy requirements as that of the specific geothermal system.

The annual energy requirements for the geothermal system for the heating period is 2,400,000 kWh. The average cost of heating oil is 1.08 €/lt, and the average calorific value of heating oil is 10 kWh/lt, so the average cost of oil is estimated at 0.108 €/kWh.

The cost of electricity for professional use according to PPC (electricity utility) billing is 0,20 €/kWh.

According to the above data, the operating cost of the conventional existing heating system is:

	Annual energy needs (kWh_{th})	**Operating cost (€)**
Conventional system with oil boilers	2,400,000	304,941

Respectively, the operating cost for the geothermal system is:

	Annual energy needs (kWh_{th})	**Operating cost (€)**
Geothermal system	2,400,000	106,666

4 Economic analysis – Environmental impact

The total cost for converting the existing heating system into a geothermal system, as mentioned above, is presented below. The total cost of the installation includes:

- System Design
- Licensing of drillings
- Construction of nine drillings (4 productions, 5 injections)
- Supply and installation of submersible pumps
- Supply and installation of a heat exchanger
- Retrofitting

At this point has to be mentioned that all the calculations were made under the condition that the 4 production drillings will have at least a flow rate of 100 m^3/h in total. In case that the aquifer cannot produce the above amount of water, then the power output will be reduced proportionally.

Also, since all cost sizes depend on the water supply of the drillings, the best way to accurately identify the flow rate is to construct a test drill after the licensing procedure. The results of these tests will be used to finalize the sizing of the system (efficiency and costs).

According to KENAK, the Greek Energy Performance Regulation for Buildings, the CO_2 emissions from electricity are 0.989 kg CO_2/kWh whereas from fuel oil 0.264 kg CO_2/kWh.

Table 5: Summary of techno-economic analysis

	Conventional system	**Geothermal system**
Heating power (estimated)	800 kW	
Oil Boiler efficiency	0,90	-
COP geothermal system (estimated)	-	4,5
Annual heating energy demand	2,400,000 kWh_{th} / year	
Annual fuel oil consumption	266,666.67 lt/year	-
Annual electricity consumption		533,333,33 kWh_{el}
Price of electricity	-	0.20 €/ kWh_{el}
Price of fuel oil	1.08 €/lt	-
Annual cost of heating	288,000 €	106,666.67 €
Money savings (winter period)	181,333.33 €	
Money savings rate	62.96%	
Total installation cost	-	300,000€
Simple payback time	-	1,65 years (or 19 months)
CO_2 Emissions	633,600.00 kg CO_2	527,466.67 kg CO_2
Reduction CO_2 emissions	16.75%	

5 Conclusions

Due to the complete lack of roof insulation (a situation that appeared from 2010 onwards), the failure to comply with thermal comfort conditions is noticeable as it is very difficult and costly to maintain the desired indoor temperature. In addition, to the lacking comfort and wellbeing, the water evaporated from the pool is concentrated as it comes into contact with the cold surface of the roof, creating stagnant water and eventually mould.

If this situation continues, there is a risk that the building's components and the mechanical and electrical equipment of the facility may be damaged. It is, therefore, necessary to address the problem immediately.

The operation of the building is a major problem due to the high maintenance and operating costs required daily for its heating.

For this reason, it was proposed that the operation of a chiller after some temperatures adjustments along with the drilling of 9 boreholes to be converted into an open circuit geothermal system.

The total installation cost is 300,000 €, and from the operation of the new system, the municipality of Kavala will have a 63% reduction in the operating and maintenance costs of the natatorium. The simple payback period is 1.7 years, and the CO_2 reduction is about 17%.

Annexe - Financing tools

In order to finance the interventions proposed, a set of financing tools targeting public buildings is depicted as follows:

Program ELECTRA: Public buildings energy upgrade program

Funding Body	Deposits and Loans Fund / Ταμείο Παρακαταθηκών και Δανείων
Period	2019 - 2025
Objectives	The main objective of the "ELECTRA" Program is to contribute to the achievement of the national energy efficiency target and at the same time to meet the objective of the annual energy renovation of the total thermal area of central public buildings, which constitutes 3% of the total public administration.
Aim	The purpose of the Program is the energy upgrade of the building stock owned by General Government entities with interventions that are indicative of the envelope of the building, the various Electro-mechanical (E / M) systems of installations and interventions that have proven to contribute to the energy upgrading of buildings, including static reinforcement, where required.
Funded actions	Interventions at building envelope, mechanical equipment used for thermal and cooling needs, static reinforcement.

Filodimos II

Funding Body	Ministry of Interior
Period	2018 – 2022
Objectives	- Strengthening balanced, sustainable and equitable development - Improving infrastructure - Increasing employment - Enhancing the competitiveness of municipalities
Aim	Financing municipalities for: - works - supplies - services - studies
Funded actions	a) Local development and environmental protection - including interventions such as: 1. Construction, improvement and maintenance of projects - technical infrastructure - environmental protection - upgrading the quality of life 2. Financing studies of the above 3. Supply of mechanical equipment and machinery. (b) Social and cultural infrastructures and activities of municipalities - including interventions such as: 1. Construction, improvement and maintenance of administrative, social, sports and cultural infrastructures

	2. Financing studies of the above

Operational program: Transport Infrastructure, Environment and Sustainable Development (YMEPERAA)

Funding Body	Ministry of Development and Investments - NSRF 2014-2020
Period	2014 - 2020
Objectives	The goals of YMEPERAA for the environment are: - Meeting the requirements of the EU environmental acquis in the Waste and Water sectors - Adaptation to climate change - Prevention and risk management - Conservation of the natural environment and biodiversity - Sustainable urban development - Urban revitalization
Aim	The purpose of the program is: A. Environmental protection, the transition to an environmentally friendly economy, the development, modernization and completion of infrastructure for economic and social development.
Funded actions	Indicative actions of the program are: - Promoting sustainable transport and removing barriers to basic network infrastructure - Support the transition to a low carbon economy in all sectors - Promoting climate change adaptation, risk prevention and management through targeted actions to support climate change adaptation, and tackling high-risk flood events - Preserving and protecting the environment and promoting resource efficiency through actions to meet the requirements of the Union acquis in the waste and water sectors, flagship interventions to improve and revitalize the urban environment and targeted actions to reduce atmospheric pollution, and protection of biodiversity.

Regional Operational Program (ROP) Eastern Macedonia and Thrace

Funding Body	Region of Eastern Macedonia – Thrace
Period	2014 - 2020
Objectives	The Programme aims to boost economic development and create job opportunities in East Macedonia and Thrace. It contributes to achieving Europe 2020 targets for smart, sustainable and inclusive growth, also in line with the smart specialization strategy. It should create jobs and help SMEs to become more competitive and innovation-driven. EU funding will also contribute to meeting the requirements of the Union's acquis, in particular as regards greenhouse gas reduction in CO_2, solid waste and water waste management and energy efficiency.
Aim	- Enhance the competitiveness of the local economy. - Increase in employment. - Strengthening social cohesion. - Enhance the attractiveness of the region as a place to invest and live
Funded actions	- Improving the competitiveness of the local economy - Improving the attractiveness of the Region as a place of business and people - Human Resources Development and Social Cohesion Infrastructure - Human Resources Development and Social Cohesion