

Work Package 4: Elaboration of studies

Deliverable 4.7.4 (former 4.3.4): Cost estimation study for third party use (partner contribution)

Beneficiary: IHU (former TEICM)

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About this document:

The present Deliverable summarizes the cost estimation report of the studies concerning the conjunctive water and energy conservation system for third party use. The studies concern a carefully selected representative building of IHU campus in Serres (International Hellenic University, former Technological Educational Institute of Central Macedonia).

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1. Scope of Deliverable 4.7.4 (former 4.3.4) – IHU (former TEICM) contribution

The present Deliverable 4.7.3 (former 4.3.3) is the contribution of IHU (International Hellenic University) and represents the part of the former TEICM partner (Technological Educational Institute of Central Macedonia). This Deliverable summarizes the cost estimation report of the studies concerning the conjunctive water and energy conservation system for third party use. The studies concern a carefully selected representative building of the IHU campus in Serres, with large requirements in terms of water quantities for secondary uses (toilets) and heating of the numerous teaching rooms.

The cost estimation study of the water conservation system records the required construction and modification cost of the water distribution system for secondary uses, including the purchase and installation of the necessary auxiliary equipment (water tank, insulated piping etc).

The cost estimation study of the heating system based on shallow geothermal energy is also presented and includes the required equipment and services for the construction of the production and rejection wells, the electromechanical installation, the geothermal heat pump etc. Moreover, to help cost estimates of third party applications, the additional cost of replacing the heating distribution system inside the building as well as the cost of thermal insulation of the building shell are also estimated. The examined scenario is presented in detail in the following sections.

2. Cost estimation of the water distribution system for secondary uses

2.1 Brief description of the required construction

As reported in Deliverable 4.7.2 (former 4.3.2), a significant number of water pumps are installed in the basements of the Institution buildings as shown in Figure 1, aiming at the protection of the buildings from flooding. Monitoring of the pumped water amount, as performed in the framework of the project for the pumps installed in the basements of Building B and the neighboring Building C (no. 6 and 8 respectively in Figure 1), can provide feedback on the feasibility of utilizing the pumped water for secondary uses (i.e. toilet, irrigation etc.).

As mentioned in the study of the geothermal system (Deliverable 4.7.3-former 4.3.3) The water conservation system is based on the usage of water quantities which are extracted with the existing water pumps installed at the building basement. In case the pumped quantities are not adequate, the secondary water distribution system will be complemented by water supply from the wells accompanying the geothermal heating system of the building, whereas, connection to the conventional water network will also exist for failsafe reasons. The schematic layout of the proposed system, as presented in the respective study of Deliverable 4.7.3 (former 4.3.3), is depicted in Figure 2 and a plan view of the basement level with the proposed water tank position is given in Figure 3.

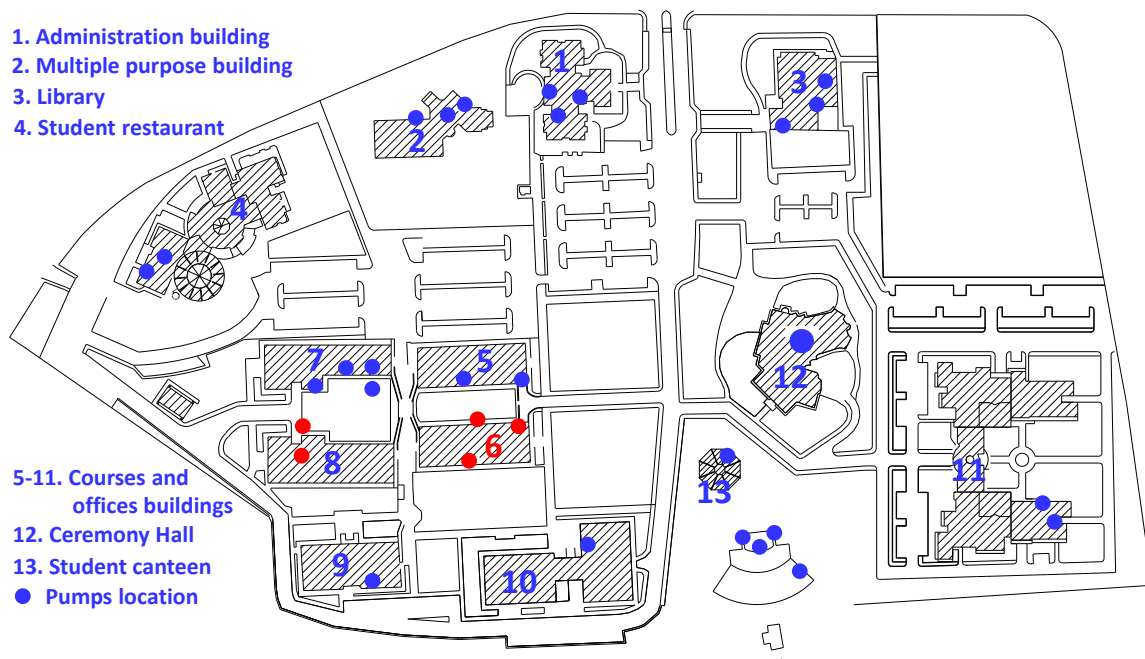


Figure 1. Location of the existing water pumps at the basement level of the building for flooding protection (pumps of buildings B-no.6 and C-no.8 are monitored in the framework of the project)

The layout of Figure 2 depicts the basic part of the system along with the additional equipment and installations required for the proper function of the secondary water distribution network.

The exact position of the installed pumps, as presented in Figure 3 with respect to the main installation of the secondary water distribution network at the basement, i.e. the tank and expansion vessel position, is required for the design and cost estimation of the whole system.

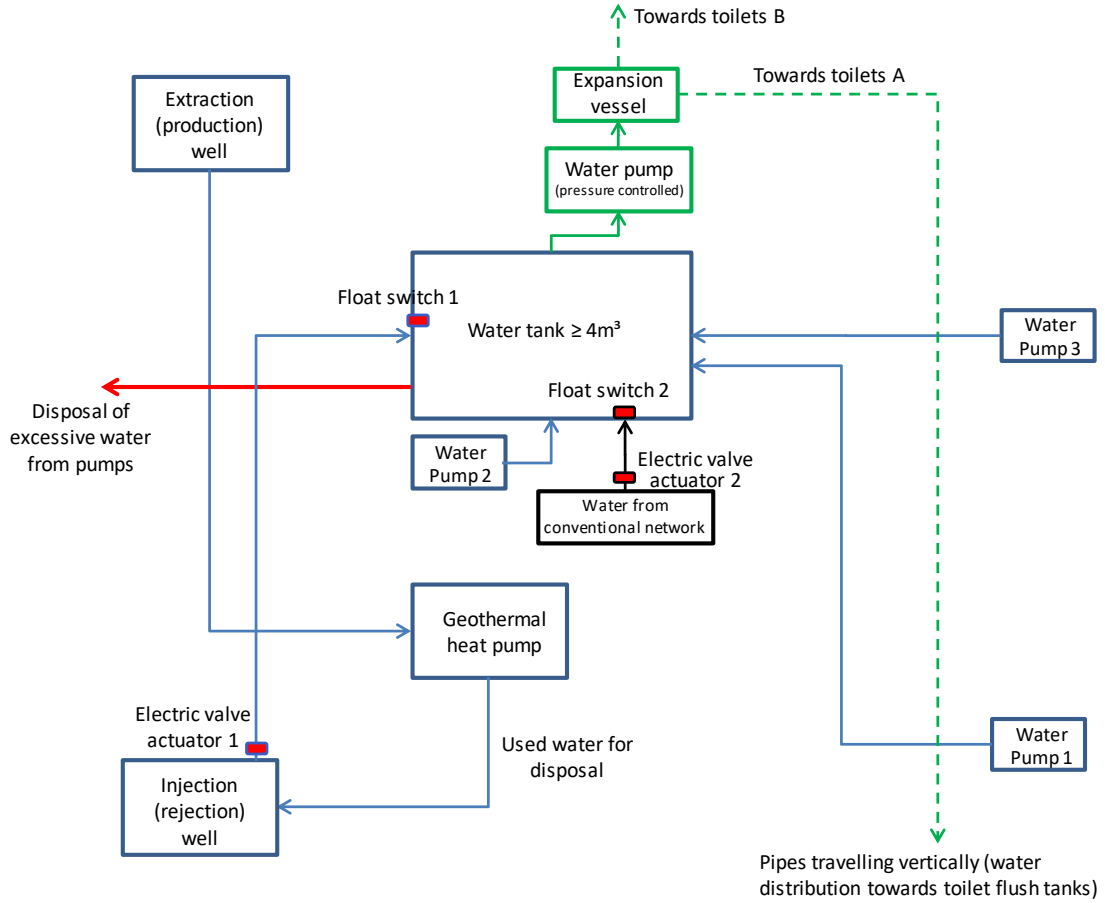


Figure 2. Schematic layout of the secondary water system

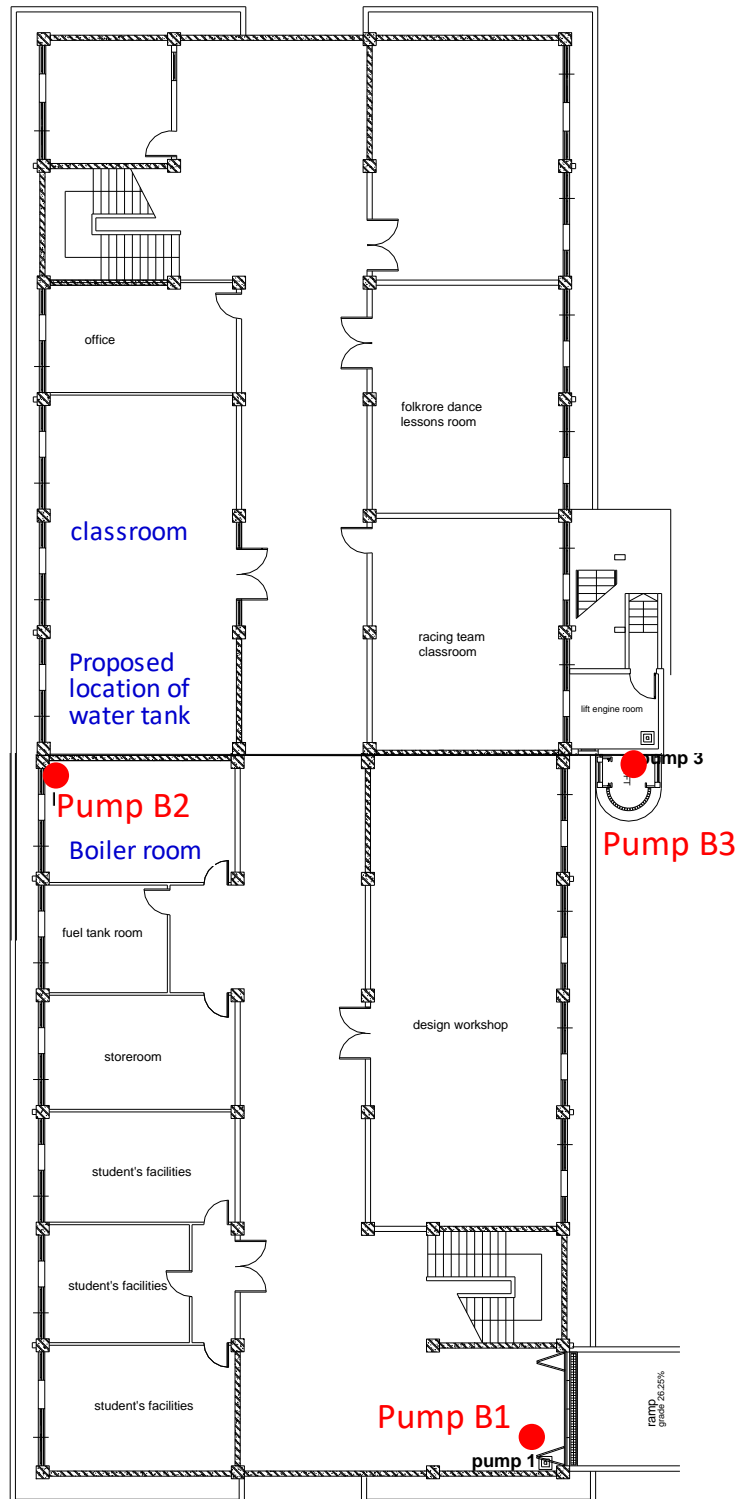


Figure 3. Basement of Building B (position of existing pumps along with the proposed water tank location)

2.2 Basis of cost calculation

The cost calculation of the constructions and installations regarding the secondary water distribution system involves the purchase of the required equipment as well as the related labor cost.

The costs that will be presented in the following paragraphs refer to market values, after proper investigation at the time of the deliverable finalization (year 2020). It should be mentioned that in case of public tender to assign a contract for the construction of the secondary water distribution network, the involved prices on behalf of the public service would be clearly increased taking into account specific procurement procedures and relevant articles described in Greek legislation. On the other hand, the expected discount on the proposed construction cost is likely to reach levels corresponding to the increased prices included in the tender process. Therefore, the cost that will be estimated in the ensuing is not expected to be far from the actual cost required for the installation.

During the study and the cost estimation of the system, all the toilet facilities are considered to belong to the type depicted in Figure 4, with visible cistern (flush tank) where the external connection joint with the water distribution network can be easily modified. It should be mentioned that a small number of “indian” toilets existing only in the 3rd floor of Building B is scheduled to be replaced during a renovation in the near future, thus the respective replacement cost is not considered herein. Most toilets are separated with light partitions instead of masonry, thus, construction of an additional horizontal pipe to supply water from the secondary system is feasible.



Figure 4. Typical toilet facility of Building B

2.3 Cost of required equipment

The required equipment that will be installed to serve the secondary water distribution system using water from the existing pumps is divided into sub-categories to facilitate the calculation of the related costs, each one relating to a specific part or function of the system. The following categories/parts are considered (indicatively presented in the basement plan of Figure 5):

- Part 1: Equipment from existing pumps (Pump1, Pump2, Pump3) to the water tank
- Part 2: Equipment from rejection well and from conventional water network to the water tank
- Part 3: Tank overflow equipment
- Part 4: Equipment for installation of water tank – water pump – expansion vessel system at the basement
- Part 5: Equipment of water distribution network from water tank to WC units
- Part 6: Electrical equipment

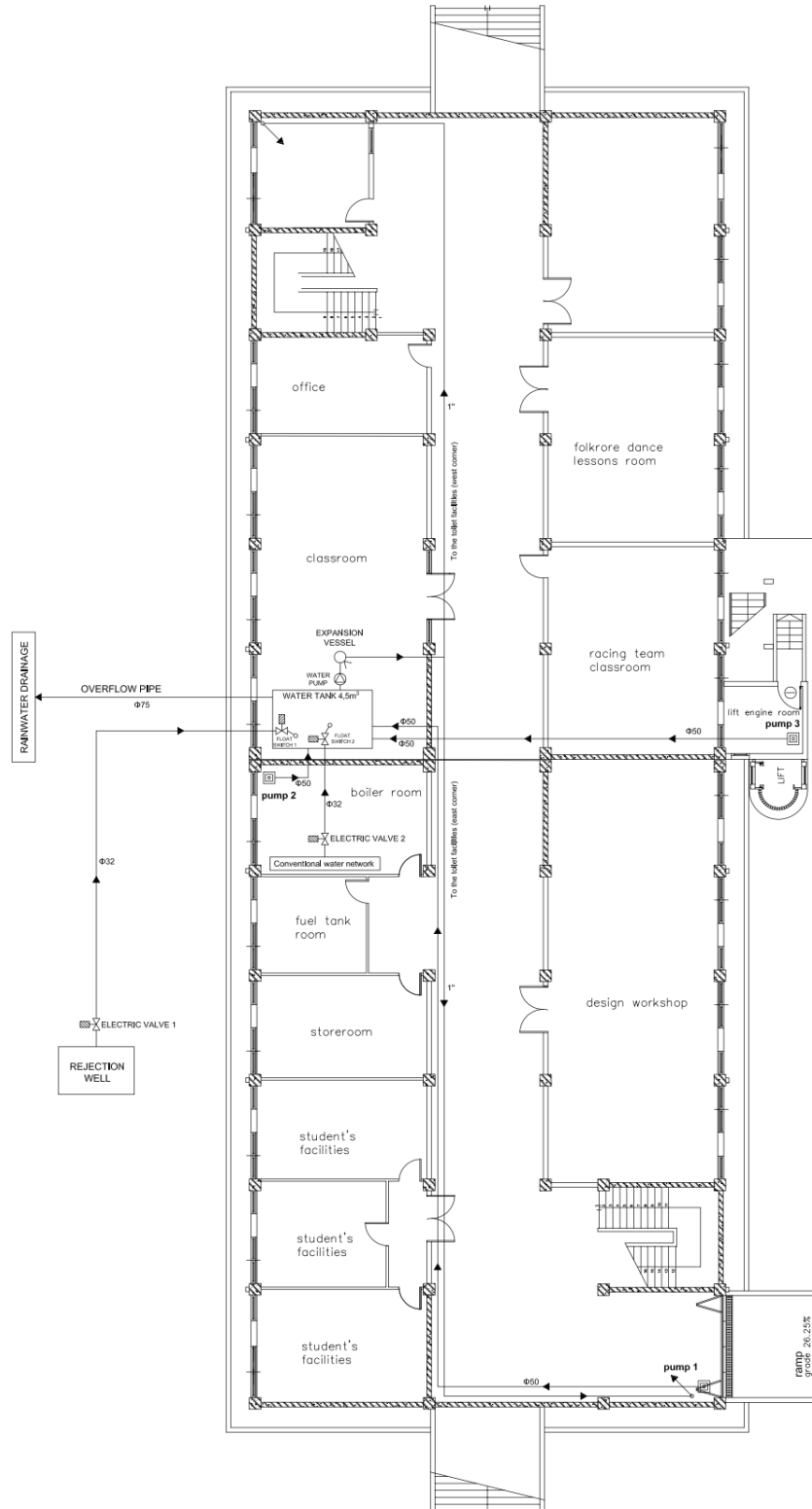


Figure 5. Plan view of secondary water distribution system at basement level

Table 1 summarizes the total cost in each part/category, including a brief description of the considered parts and specific reference to the main installation equipment of the system. A detailed presentation of all involved parts and equipment is presented in Annex A of Deliverable 4.7.4-former 4.3.4 (in Greek).

Table 1. Summary of equipment cost estimation per category/part of the installation

Item description	Cost	Mean Discount*	VAT (24%)	Total cost
Part 1: Equipment from existing pumps (Pump1, Pump2, Pump3) to the water tank (pipes Φ 50, pipe angles, fittings/joints, check valve, supports and related parts etc.)	628.00 €	-94.20 €	+128.11 €	661.91 €
Part 2: Equipment from rejection well and from conventional water network to the water tank (pipes, pipe angles and fittings/joints, pipe insulation, valves, water hammer arrestor etc.)	450.47 €	-67.57 €	+91.90 €	474.80 €
Part 3: Tank overflow equipment (pipes, supports, pipe angles, etc.)	211.40 €	-31.71 €	+43.13 €	222.82 €
Part 4: Equipment for installation of water tank – water pump – expansion vessel system at the basement (water tank 4.5m ³ , water pump, expansion vessel, pipes, valves, pipe angles/joints/fittings, etc.)	1006.12 €	-150.92 €	+205.25 €	1060.45 €
Part 5: Equipment of water distribution network from water tank to WC units (pipes, valves, pipe angles/joints/fittings, shutoff switch, equipment for supports etc.)	1080.93 €	-162.14 €	+220.51 €	1139.30 €
Part 6: Electrical equipment (liquid water level detection relays and related equipment)	229.17 €	-34.38 €	+46.75 €	241.54 €
Total equipment cost				3800.82 €

*The considered discount is a mean estimated market discount for all involved equipment

2.4 Cost of construction process-labor

The construction process of the secondary water distribution system involves labor costs in two distinct categories, i.e. plumbing and electrical related work. The estimated cost per category and as a total is presented in Table 2. It is quite clear, as expected, that the most significant cost concerns the plumbing related work during the installation construction. It should be mentioned that the existing configuration of the building toilets (light partitions, visible pipes etc) require only small-scale interventions such as drilling floors or walls to install the secondary water distribution network. Thus, the related costs are including in the plumbing labor cost of the table.

Table 2. Summary of labor cost estimation per category

Item description	Cost	VAT (24%)	Total cost
Plumbing labor cost	4000.00 €	+960.00 €	4960.00 €
Electrical labor cost	250.00 €	+60.60 €	310.00 €
Total equipment cost			5270.00 €

2.5 Total cost of secondary water distribution network

Based on the calculations presented in the previous paragraphs, the total construction cost of the secondary water distribution system is presented in Table 2.

Table 3. Total cost of secondary water distribution network

Item description	Cost	VAT (24%)	Total cost
Equipment and installations	3065.18 €	+735.64 €	3800.82 €
Labor cost of construction	4250.00 €	+1020.00 €	5270.00 €
Total equipment cost			9070.82 €

3. Cost estimation of the geothermal heating system

3.1 Brief description of the required construction

The cost estimation of the geothermal heating system concerns the study of the system that is described in Deliverable 4.7.3 (former 4.3.3). The geothermal heating system comprises of the following:

- One (1) water extraction (production) well one for the extraction of the required underground water quantities.
- Two (2) injection (rejection) wells, for the rejection of the utilized water.
- A heat exchanger (placed between the wells and the heat pump)
- The geothermal heat pump and the closed network for heat transfer between the heat exchanger and the heat pump
- The buffer tank (contains a volume of heated water to limit cycling of the heat pump)
- Internal heating distribution network to the heating units inside the building

In the following sections, the cost of the aforementioned equipment, services and the associated labor cost will be estimated for the examined Building B. As mentioned in previous Deliverables, approximate dimensions of the building in plan are 55m length and 20m width, resulting in a floor plan area equal to 1100m². Considering that the building comprises of 3 functional floors and a basement, the total building area is equal to 4400m², whereas the building volume, given a 3.4m height of each storey, is estimated close to 15000m³.

It should be mentioned that this building is representative of several buildings in Greek Universities, thus those estimates can be used as indicative of several other cases. In the Serres campus alone, 3 other buildings are similar to Building B, one of which is actually identical as depicted in aerial photos of Deliverable 4.7.1 (former 4.3.1).

As mentioned in Deliverable 4.7.3 (former 4.3.3), in addition to the above, the internal heating distribution network to the heating units inside the building should be appropriate for use of geothermal energy, i.e. include pipes of proper diameter suitable for the -relatively- lower obtained water temperatures compared to a system that uses an oil boiler. Moreover, heating should be achieved using fan coil units instead of conventional radiator units, to ensure maximum efficiency of the designed system. Finally, the building should be properly insulated in order to comply with current regulations. The additional cost related with those requirements will be also indicatively estimated in the following sections, yet it

should not be directly linked to the installation of the geothermal heating system. Indeed, the above requirements either pre-exist in the buildings where such modifications occur, or they are covered from other sources using state or EU funds. Such programmes are currently running in Greece and should be employed to minimize the overall cost and maximize the results of the geothermal heating system.

3.2 Basis of cost calculation

The cost calculation of the constructions and installations regarding the geothermal heating system involves the purchase of the required equipment as well as the related labor cost.

The costs that will be presented in the following paragraphs refer to market values, after proper investigation at the time of the deliverable finalization (initial study year 2020, costs updated for 2021). It should be mentioned that in case of public tender to assign a contract for the construction of the secondary water distribution network, the involved prices on behalf of the public service would be clearly increased taking into account specific procurement procedures and relevant articles described in Greek legislation. On the other hand, the expected discount on the proposed construction cost is likely to reach levels corresponding to the increased prices included in the tender process. Therefore, the cost that will be estimated in the ensuing is not expected to be far from the actual cost required for the installation. Moreover, the costs considered in the ensuing were updated for year 2021 and refer to the post-covid increased prices that have been reported worldwide, sometimes of the order of 20-30% or more in specialized equipment. This should also be taken into account when reviewing the final results of the cost estimation study.

3.3 Cost of required equipment and services related to the extraction and injection wells

The construction of the extraction and injection wells includes both equipment and labor and requires specialized machinery for the drilling and the development of the wells. The estimated depth of the wells is 60m each for both the extraction and the injection wells, taking of course into consideration the possibility of variation if required during the actual drilling.

Table 4. Estimation of cost related to the extraction and injection wells

Item description	Cost	VAT (24%)	Total cost
Part 1: Drilling activities (extraction and injection wells, borehole enlargement, etc)	7424.10 €	1781.78 €	9205.88 €
Part 2: Flow testing of well using different pumping procedures	881.10 €	211.46 €	1092.56 €
Part 3: Equipment related to the construction (development, casing etc) of the well (pipes, gravel, filters etc)	13681.08 €	3283.46 €	16964.54 €
Part 4: Machinery related costs (transfer, assembly and disassembly of drilling rig, flow testing machinery etc)	1942.50 €	466.20 €	2408.70 €
Total cost related to extraction/injection wells			29671.68 €

3.4 Cost of required equipment and services related to the electromechanical installations

The main part of the installation before the geothermal heating pump is responsible for the use of pumped water from the production well, extraction of thermal energy and rejection of the utilized water in the injection wells. The most important equipment of this installation part includes the submerged pump in the production well, the water circulators (circulation pumps), the heat exchanger, the buffer tank, the expansion vessel etc. The cost of the aforementioned devices, along with the associated labor and other installation works when required, is summarized in Table 5.

Table 5. Estimation of cost related to the electromechanical installations

Item description	Cost	VAT (24%)	Total cost
Part 1: Construction of water supply and rejection shafts (180x100x100 cm)	5250.00 €	1260.00 €	6510.00 €
Part 2: Submerged pumping station	6750.00 €	1620.00 €	8370.00 €
Part 3: Heat exchanger (plate type)	18000.00 €	4320.00 €	22320.00 €

Part 4: Water circulating pumps	9750.00 €	2340.00 €	12090.00 €
Part 5: Buffer tank and expansion vessels	2250.00 €	540.00 €	2790.00 €
Part 6: Polyethylene pipes (a) PE 100, PN 10atm, DN 75mm (200m), (b) PP-R (80), PN 10atm, DN90 (50m) and (c) PP-R (80), PN 10atm, DN25 (25m)	9474.38 €	2273.85 €	11748.23 €
Part 7: Electrical installation - automations	5175.00 €	1242.00 €	6417.00 €
Total cost related to electromechanical installations			70245.23 €

3.5 Cost of geothermal heat pump

The geothermal heat pump is the core and most expensive part of the whole system. The related cost, depicted in Table 6, includes the cost of both the purchase and the required labor to achieve a functional installation, along with the appropriate water circulating pumps.

Table 6. Cost related to the purchase and installation of the geothermal heat pump

Item description	Cost	VAT (24%)	Total cost
Purchase and installation of the geothermal heat pump (210/165 kW heating/cooling) and 2 water circulating pumps	52419.35 €	12580.64 €	64999.99 €
Water circulating pumps (2)	2580.64 €	619.35 €	3199.99 €
Total cost related to the geothermal heat pump			68199.98 €

3.6 Cost of fan coil units installation inside the building

Building's heating using shallow geothermal energy requires fan coil units to achieve the maximum efficiency of the system. This cost could be avoided in many cases due to one of the following reasons:

- Many public buildings or buildings of Educational Institutions have already fan coil units installed in all or part of the building areas.
- Cost of the fan coil units and internal distribution network could be funded by other sources (including programmes for environmental friendly, low energy consumption buildings).

Nevertheless, the cost associated with the replacement of the existing heating distribution network (pipes and radiator units) with fan coils and proper pipes inside the building is also estimated herein, to provide additional data for such studies.

Table 7. Cost related to the replacement of the existing internal heating distribution network with fan coils

Item description	Units	Unit Cost	Partial cost	VAT (24%)	Total cost
Fan coil unit, 4-row 1940W/2010W (Cooling/ Heating)	44	508.06 €	22354.64 €	5365.11 €	27719.75 €
Fan coil unit, 3-row 3600W/3550W (Cooling/ Heating)	28	592.74 €	16596.72 €	3983.21 €	20579.93 €
Fan coil unit, 4-row 4030W/3880W (Cooling/ Heating)	7	629.03 €	4403.21 €	1056.77 €	5459.98 €
Fan coil unit, 4-row 5670W/5720W (Cooling/ Heating)	4	870.97 €	3483.88 €	836.13 €	4320.01 €
Installation of pipes for the heating distribution system inside the building (purchase and labor cost)	1	44354.84 €	44354.84 €	10645.16 €	55000.00 €
Removal of existing pipes and radiator units	1	5483.87 €	5483.87 €	1316.13 €	6800.00 €
Total cost related to the internal heating distribution system					119879.67 €

3.7 Cost related to building thermal insulation

The efficient energy utilization scheme for heating of any building, especially when heating options such as shallow geothermal heating are concerned, requires a properly insulated structure. Although out of the scope of the present deliverable, a preliminary estimation of the insulation cost of Building B is presented in Table 8. The cost calculation approach is based on current market values (updated for year 2021). Of course, such costs should be covered by other sources such as programmes related to the decrease of energy consumption of buildings and should not be linked to the cost estimation of the geothermal heating system implementation of this study.

Table 8. Cost related to the thermal insulation of Building B

Item description	Units (m ²)	Unit Cost	Partial cost	VAT (24%)	Total cost
Part 1: Insulation (thermal, sound and moisture) of building shell using "cool materials". Application of heat-insulating, non-combustible, anti-mold acrylic base paint with a coefficient of thermal conductivity less than 0.2W/mK	800	20.20 €	16160.00 €	3878.40 €	20038.40 €
Part 2: External thermal Insulation system (thermal façade) using extruded polystyrene (XPS) plates of 70mm thickness with thermal conductivity $\lambda=0.033\text{W/mK}$ or optimal	800	65.00 €	52000.00 €	12480.00 €	64480.00 €
Part 3: Insulation (thermal, sound and moisture) of building roof using composite thermal insulation tiles of extruded polystyrene (XPS) with protective mortar coating having a coefficient of thermal conductivity $\lambda=0.033\text{W/mK}$ or	1150	38.00 €	43700.00 €	10488.00 €	54188.00 €

optimal					
Total cost related to the building insulation					
					138706.40 €

3.8 Total cost of geothermal heating system

Based on the above calculations, the total cost of the heating system is estimated in the following Tables. More specifically:

- In Table 9 the total cost of the geothermal system is calculated, without considering the replacement cost of the existing distribution system and installation of fan coil units inside the building as well as the building thermal insulation cost.
- In Table 10 the total cost of the geothermal system is calculated, taking also into consideration the replacement cost of the existing distribution system and installation of fan coil units inside the building. The building thermal insulation cost is not taken into account.
- It should be mentioned that it is not possible to estimate the cost of the scenario where the thermal insulation cost of the building is also considered, since the geothermal heating system study and design was performed based on the building properties in its current state without any insulation.

Table 9. Total cost of geothermal heating system (without replacement of the distribution system inside the building)

Item description	Cost
Cost related to the extraction and injection wells	29671.68 €
Cost related to the electromechanical installations	70245.23 €
Cost of geothermal heat pump installation	68199.98 €
Total geothermal heating system cost (without fan coils and distribution system inside the building)	
	168116.89 €

Table 10. Total cost of geothermal heating system (with the replacement of the distribution system inside the building)

Item description	Cost
Cost related to the extraction and injection wells	29671.68 €
Cost related to the electromechanical installations	70245.23 €
Cost of geothermal heat pump installation	68199.98 €
Cost related to the replacement of the existing internal heating distribution network	119879.67 €
Total geothermal heating system cost (with fan coils and distribution system inside the building)	287996.56 €

3.9 Cost efficiency study and payback period of the investment (examined scenario)

Based on a cost efficiency study of the application of the geothermal heating system in Building B, the required payback period can be estimated.

In order to proceed to the required calculations, the building heating operation is assumed to comply with the parameters described in the recent Greek legislation (KENAK) regarding buildings of the same category, as presented in Table 11. The heated building area is considered equal to 3440m² (the basement is not considered in the heated areas for the specific building).

Table 11. Parameters of internal operating building conditions (KENAK)

Internal operating conditions of Building B (Educational Institution)		
Operating hours	8	Predefined parameters (T.O.T.E.E. 20701-2/2010 and 20701-3/2010)
Operating days	5	
Months of operation	12	
Heating period	15/10 till 30/04	
Cooling period	01/06 till 30/08	

Average internal heating temperature (°C)	20	
Average internal cooling temperature (°C)	26	
Average winter relative humidity (%)	35	
Average internal relative humidity (%)	45	
Fresh air required (m ³ /h/m ²)	11.00	
General lighting level (lux)	500	
Lighting power per unit area for reference building (W/m ²)	16.0	
Annual hot water consumption (m ³ /year)	0.00	
Average desired hot water temperature (°C)	45	
Average annual water supply water temperature (°C)	15.5	
Temperature released by users per unit area of the thermal zone (W/m ²)	40.0	
Average user presence rate	0.32	
Temperature released by devices per unit area of the thermal zone (W/m ²)	5.00	
Average factor of operating devices	0.15	

The examined scenario comprises of the following installations and respective costs:

- Cost related to the extraction and injection wells
- Cost related to the electromechanical equipment purchase and installations (including the heat exchanger)
- Cost of geothermal heat pump purchase and installation

It should be mentioned that the examined cost estimation study considers the building in its current status, i.e. without the application of any thermal insulation of the building shell, as presented in Table 9. Indeed, if the properly insulated building was to be considered during the study, the design of the geothermal heating system would have lower heating requirements, leading thus to different characteristics and parameters of the selected installations (including the geothermal heat pump and the heat exchanger, the water supply requirements, etc.). Consequently, the cost of the initial investment would have been significantly lower.

The application of the geothermal heating system in Building B results in an upgrade of the building's energy class from D to C (Δ to Γ in Greek symbols, Figure 6).

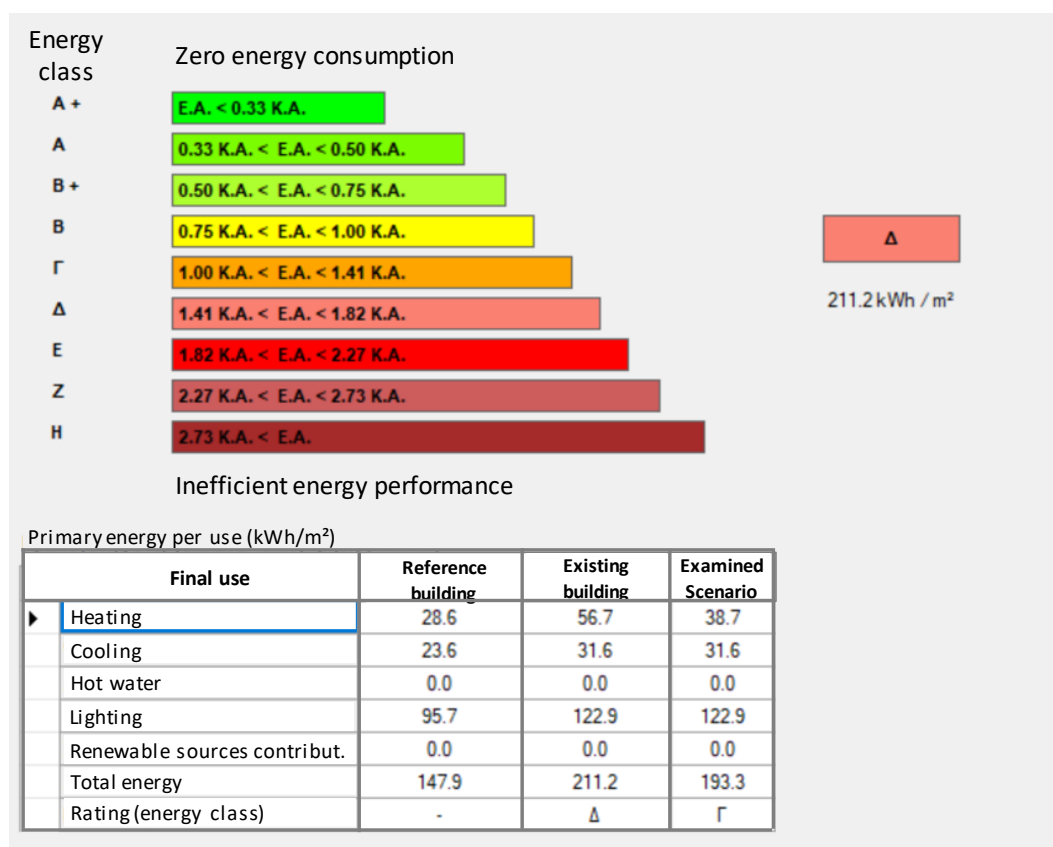


Figure 6. Energy rating of Building B (existing building vs Examined Scenario) (figure translated from TEE KENAK software)

The payback period of the system is estimated using a specialized software (TEE KENAK) that takes into consideration all energy consuming sources of the building (including heating, cooling and lighting). As presented in Figure 7, the operating cost is reduced almost 10500€ every year, whereas the full payback of the investment could be achieved in approximately 15-16 years for the examined building. Of course, if the building was already insulated, the investment cost would be much lower and the expected payback period would be also reduced.

It should be mentioned here that if the operational cost of the Building was estimated based on different parameters compared to the ones described in the respective regulations, i.e. different hours of heating compared to the KENAK values, non-uniform heating in various building areas etc, the payback period would also be different. Such a study is out of the scope of the present deliverable.

Costs and payback period				
	Savings and costs	Reference build.	Existing build.	Scenario
▶	Operating cost (€)	32.972.0	49.634.7	39.045.0
	Initial investment cost (€)			168.116.9
	Saving of primary energy (kWh/m ²)			17.9
	Saving of primary energy (%)			8.5
	Cost of saved energy (€/kWh)			2.7
	Reduction of CO ₂ emission (kg/m ²)			7.3
	Payback period (years)			15.9

Figure 7. Costs and payback period (figure translated from TEE KENAK software)

4. Acknowledgements

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The contents of the report are sole responsibility of IHU (former TEICM) 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.