SEADRION

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

Case study report - Croatia

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

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Purpose of this document

This document is a pre-feasibility study for Croatia and is one of altogether 6 pre-feasibility studies that will be done in the scope of the SEADRION project.

1 Introduction

The subject of this document is a case study for the utilisation of the seawater heat pump on an existing public building, i.e. the city administration building in Kaštel Sućurac.

The city administration building was built in 1988 according to all the regulations, knowledge and materials available, and has been intensively used and maintained since then. Minor adaptations and changes have been made on the building since then, but 8 years ago, the energy renovation of the building was done.

Today, the total available building area of about 2,692 m^2 is used for the needs of city services of Kaštela city.

2 Characterisation of the site

2.1 Location

The city administration building in Kaštel Sućurac is located in South Dalmatia, Croatia, between cities of Trogir and Split. Figure 1 shows the situation of the building on particle cadastre (left) and the satellite map (right). The building is about 50 m away from the sea making the building ideal for the utilisation of the seawater heat pump system.

Figure 1 Situation of the building on particle cadastre (left) and the satellite map (right) [1]

2.2 Building

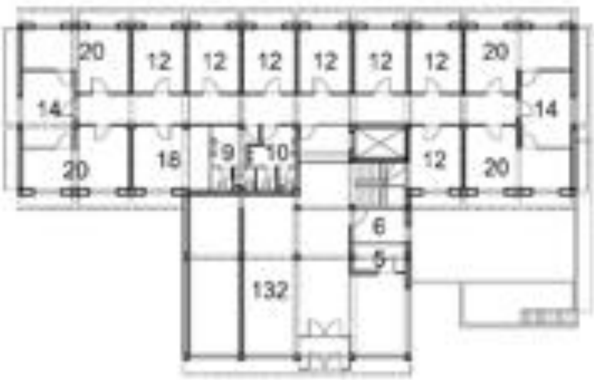
2.2.1 The existing state of the building

The subject of the case study is the application of the seawater heat pump in the city administration building in Kaštel Sućurac. The building was built in 1988 and is designed and constructed as a non-residential, free-standing building, twenty to fifty meters from the sea, with seven floors: basement, ground floor and five floors [2]. Figure 2 shows facades, windows and the shape of the building.

Figure 2 Existing state of the city administration building in Kaštel Sućurac (December 2018)

In the basement, there are facilities for great user gatherings with separate outdoor entrances, archive space and boiler room while on the ground floor there are working counters and offices. On the other floors, there are working spaces of expert services and institutions while on the last floor, there are the mayor and the city administration working spaces [2]. Figure 3 shows the layouts of each city administration building floor.

BASEMENT



GROUND FLOOR

1st TO 4th

FLOOR

5th FLOOR

Figure 3 Floor layouts [2]

The building structure consists of belted foundation, reinforced-concrete external and internal walls as well as reinforced-concrete slabs. The facade walls are built as a three-layer sandwich made of the reinforced concrete slab and a block wall from the inside, with the interlayer of thermal insulation between. In 2015, the energy renovation of the outer shell of the building was carried out where all the exterior walls and flat roofs were insulated with mineral wool and all the façade joinery was replaced by a double-glazed PVC joinery. The staircase glass wall was replaced by a continuous façade made of aluminium profile. On the fifth floor of the building, fixed bristles are built-in as protection from the sun, while on the south side of the building, internal bright protective devices are used [2].

The number of employees in the building is 135. In the heated part of the building are all the rooms except the boiler room and the lifts.

The values of the outer shell and floor parameters of the building are given in tables 1 and 2.

Table 1 Parameter values of the outer shell of the building [3]

Parameter	Value
Area of the heated part of the building, A [m^2]	2729.19
Useful area of the building, A_K [m^2]	2,692.00
Volume of the heated part of the building, V_e [m^3]	8,525.93
Total area of the facade, $A_{proč}$ [m^2]	2,037.55
Total window area, A_{proz} [m^2]	422.51
Share of window area in the total area of the facade, f [-]	0.21

Table 2 Data on the floors of the city administration building in Kaštel Sućurac [3]

Floor	Floor area, [m^2]	Floor height, [m]	Floor volume, [m^3]
-1 BASEMENT	478	3.34; 3.85	1,769.96
0 GROUND FLOOR	372	2.80; 3.31	1,111.94
1 FIRST FLOOR	374	2.80	1,047.20
2 SECOND FLOOR	374	2.80	1,047.20
3 THIRD FLOOR	374	2.80	1,047.20
4 FOURTH FLOOR	374	2.80	1,047.20
5 FIFTH FLOOR	346	2.80	968.80

2.2.2 Technical characteristics of the outer shell of the heated part of the building

Technical characteristics of the building parts and the external openings of the heated part of the building are given in tables 3 and 4:

Table 3 Technical characteristics of the building parts of the heated part of the building

Building part	A, [m^2]	U, [W/(m^{2}K)]
Z1 - basement wall to the ground	150.61	0.89
Z2 - basement and ground floor wall to the environment	318.09	0.25
Z3 - siporex wall to the environment	732.17	0.28
Z4 - siporex wall reinforcements	183.03	0.32
Z5 - 5th-floor siporex wall to the environment	109.24	0.22
Z6 - 5th-floor wall reinforcements	27.30	0.25
Z7 - wall to the elevator	215.09	2.88
Z8 - a wall against boiler room	61.90	0.83
P - floors on the ground	424.85	0.73
K - flat roof	506.91	0.21

Table 4 Technical characteristics of the external openings of the heated part of the building

External opening	n, [-]	A_w, [m^2]	U_w, [W/(m^{2}K)]
P1 - 160/140	97	2.24	1.40
P3 - 100/60	1	0.60	1.40
P4 - 300/235	3	7.05	1.40
P5 - 400/235	1	9.40	1.40
P6 - 60/60	21	0.36	1.40
P7 - 360/160	2	5.76	1.40
P8 - 570/160	2	9.12	1.40
P9 - 200/160	1	3.20	1.40
P10 - 300/160	15	4.80	1.40
P11 - 312/1300	1	34.50	1.40
Entrance to the halls- south 160/295	3	4.72	1.40
Entry door - 300/210	1	6.30	3.50
Boiler room window - 140/185	2	3.30	3.50

2.3 The heating/ Cooling system

The heating system of the city administration building in Kaštel Sućurac consists of a central hot water boiler which is fully functional with all necessary working and safety armatures. The Thermocrat type Th35TV, a capacity of 400 kW, is equipped with a thermostat and an oil burner from Venterm, type 31 LVDP (Figure 4). The projected heating system temperature of the building is 90/70 °C with hot water distributed to the heating elements via heat energy distribution system.

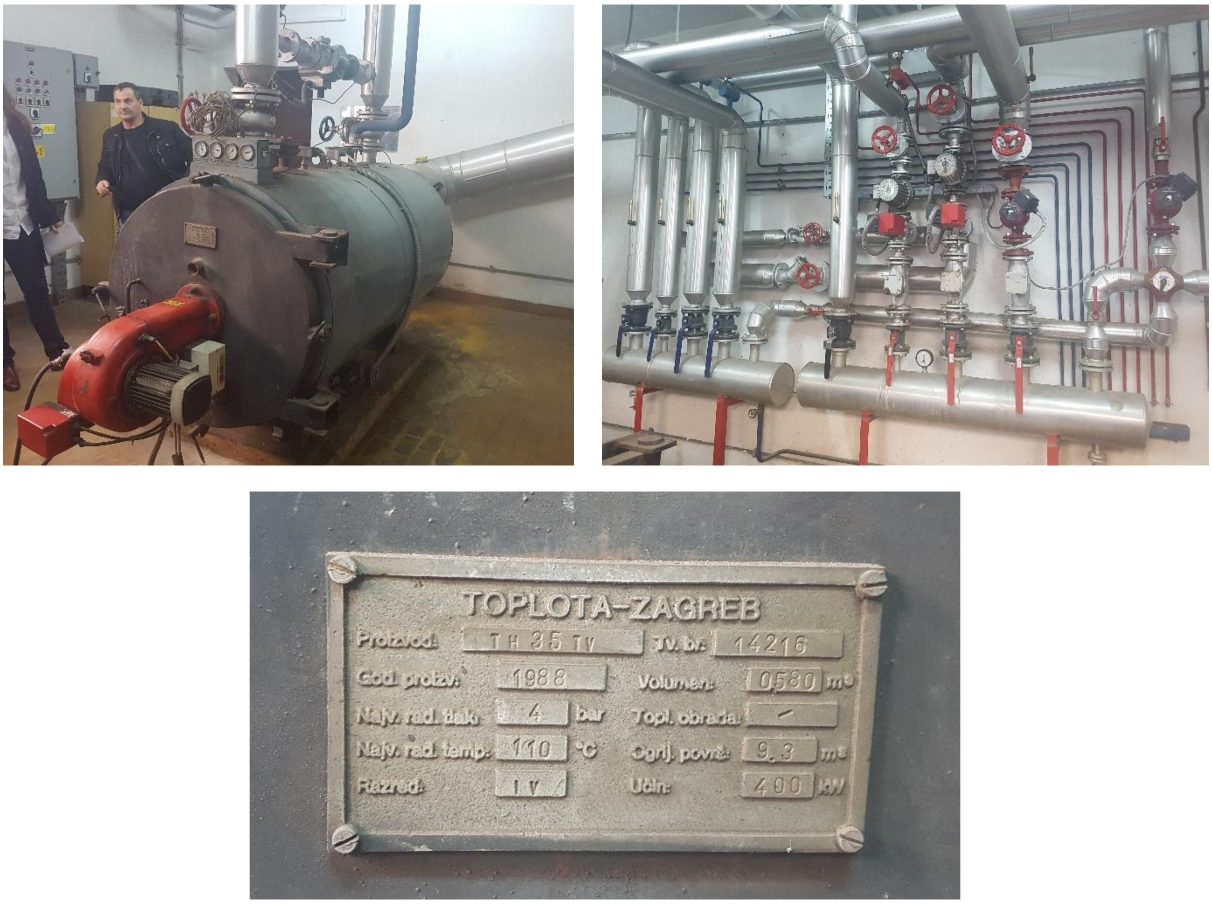


Figure 4 Boiler room of the city administration building of the City of Kaštela (December 2018)

Aluminium radiators (Figure 5) of the Lipovica manufacturer, according to Table 5, are used as heating elements within certain areas of the city administration building of the City of Kaštela.

The heating system has no regulation, but thermostatic valves are installed on all radiators (Figure 5). Since the building is located in the coastal part of Croatia and on the seashore, the heating season starts at the beginning of December and lasts until March. The boiler runs from 6:00 until 13:00 h when it turns of. The building is heated from Monday to Friday. The greatest need for heat energy occurs during the morning due to the appearance of the strong wind bora, while later during the day, due to large solar gains, the boiler goes off.

Table 5 Data on the number and power of the installed heating elements in the city administration building in Kaštel Sućurac

Radiator type	Total number of articles	Single article power, [W]	Total number of radiators	Total installed heat output, [kW]
Ekonomik SE 690	1346	168	142	226.13
Ekonomik SE 285	80	105	4	8.40
TOTAL:			146	234.53

The measured room temperature during the energy inspection of the building (December 2018) was 23 to 24 ° C. After the energy renovation of the outer building shell in 2015, the annual consumption of extra light fuel oil is 15,000 to 18,000 litres, while before it was about 27,000 litres.

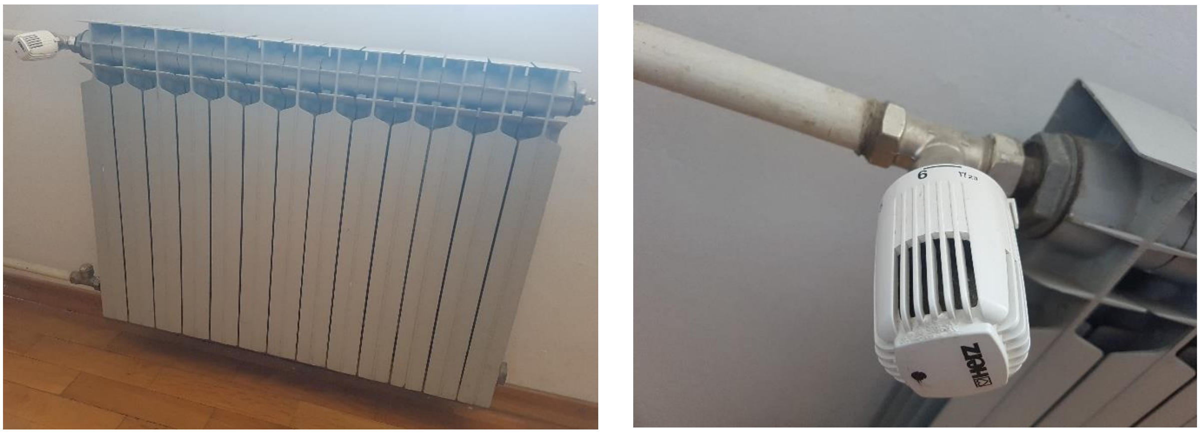


Figure 5 Heating elements (left) and built-in thermostatic valves (right) (December 2018)

The cooling of the town administration building of the City of Kaštela is centralised in 2016 by installing a VRV system consisting of six exterior units and twenty-seven new interior units of the GREE producer, while for the needs of the other rooms the internal units of the former local split systems have been used to heat the building (Figure 6). The type and performances of cooling VRV outdoor units are shown in Table 6.

Table 6 Type and performances of the outdoor units of the VRV cooling system in the city administration building in Kaštel Sućurac

Type	Amount	Φ_{hl}, [kW]	Φ_{gr}, [kW]
Gree GWHD(56S)NM3CO	3	15.50	17.50
Gree GWHD(42)NK3AO	3	12.10	13.00
TOTAL:	6	82.80	91.5

Figure 6 VRV cooling system in the city administration building in Kaštel Sućurac (December 2018)

The cooling season begins in April and lasts until October. During the cooling season, the VRV system operates throughout the working hours of the city administration building of the City of Kaštela (07:00 - 15:00 h).

The conference halls, located in the basement of the building, have a separate heating and cooling system which consists of two LTH Škofja Loka air conditioning units, type 155 Z (Figure 7), of which only one is in operation. Air conditioning unit operation is almost negligible since it works only ten days for only five hours throughout the year.

Figure 7 Air conditioning unit in the city administration building in Kaštel Sućurac (December 2018)

2.4 Domestic Hot Water system

Since the building is public and non-residential, there is no system for the preparation of domestic hot water.

2.5 Energy consumption

2.5.1 Thermal load of the city administration building in Kaštel Sućurac according to HRN EN 12831

Calculation of the thermal load of the city administration building of the City of Kaštela was conducted according to HRN EN 12831. Internal and external design temperature of the thermal load calculation for the location of Split, Marjan are given in Table 7.

Table 7 Design temperatures for thermal load calculation

Description	Symbol	Value	Unit
External design temperature for Split, Marjan	ϑ_e	-4	[°C]
Internal design temperature	ϑ_{int}	20	[°C]

Table 8 shows the values of transmission, ventilation and total thermal losses of the city administration building of the City of Kaštela. The values are shown for each floor of the building, and are the largest for the basement of the building since the floor and wall of the cellar to the ground are not thermally insulated which is why the transmission heat losses are large. The total thermal load of the City of Kaštela city administration building is $\Phi_{Gr} = 88.87\ \mathrm{kW}$. This data will be used for selecting heat pumps in economic analysis.

Table 8 Thermal load calculation results

Floor	Φ_T, [W]	Φ_V, [W]	Φ_{Gr}, [W]	Φ_{Gr}, [kW]	Φ_{Gr}, [W/m^2]
Basement	11,365.00	6,335.00	17,700.00	17.70	6.81
Ground floor	9,863.00	5,936.00	15,259.00	15.26	5.88
1st floor	7,083.00	4,531.00	11,614.00	11.61	4.47
2nd floor	7,083.00	4,531.00	11,614.00	11.61	4.47
3rd floor	7,083.00	4,531.00	11,614.00	11.61	4.47
4th floor	7,083.00	4,531.00	11,614.00	11.61	4.47
5th floor	4,960.00	4,380.00	9,340.00	9.34	3.60
Total	54,520.00	34,347.00	88,867.00	88.87	34.22

Figure 8 graphically illustrates the thermal losses of the city administration building in Kaštel Sućurac.

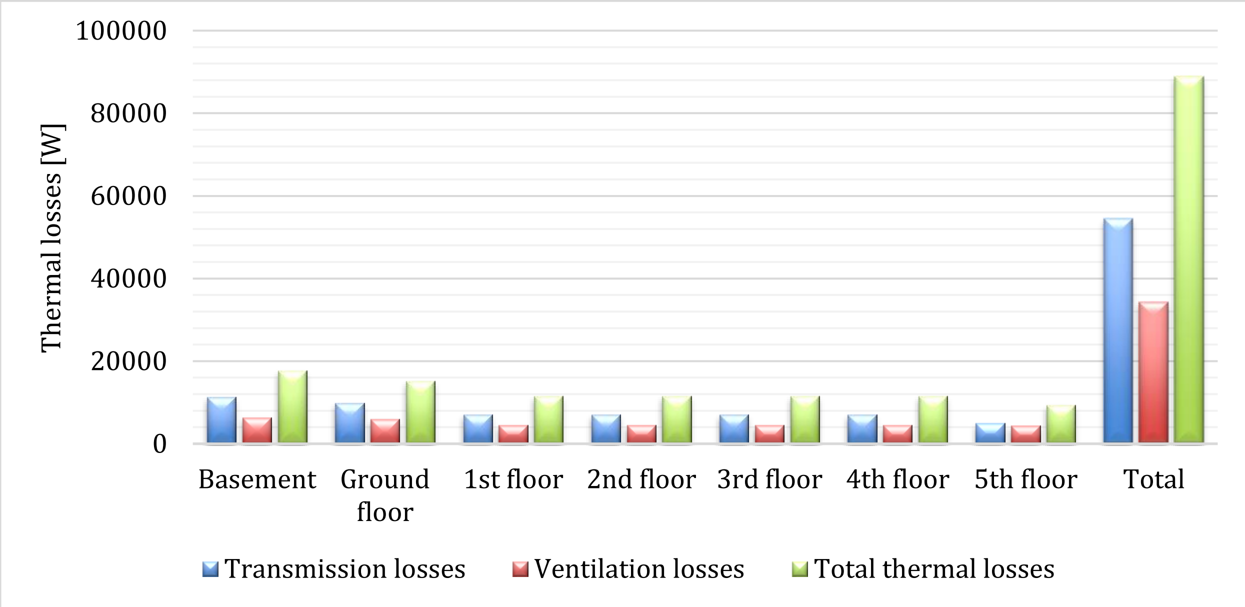


Figure 8 Graphical illustration of thermal loses in the city administration building in Kaštel Sućurac

2.5.2 Cooling load of the city administration building in Kaštel Sućurac according to VDI 2078

Calculation of the cooling load of the city administration building of the City of Kaštela was conducted according to VDI 2078. Internal and external design temperature of the cooling load calculation for the location of Split, Marjan are given in Table 9.

Table 9 Design temperatures for cooling load calculation

Description	Symbol	Value	Unit
External design temperature for Split, Marjan	ϑ_e	34	[°C]
Internal design temperature	ϑ_{int}	24	[°C]

Table 10 presents the values of the internal, external and total thermal gains of the city administration building of the City of Kaštela. The values are shown for each floor of the building and are the largest for the basement of the building where the conference halls are located. It is assumed that the accumulation of the people on these premises is greatest, so therefore the internal heat gains are high. Floors on which the offices are located also have high heat gains since on these floors the accumulation of people and appliances is large and there are a large number of transparent elements facing south. The total cooling load of the city administration building of the City of Kaštela is $\Phi_{Hl} = 152.71$ kW. This data will be used for selecting heat pumps in economic analysis.

Table 10 Cooling load calculation results

Floor	Φ_i, [W]	Φ_A, [W]	Φ_{HI}, [W]	Φ_{HI}, [kW]	Φ_{HI}, [W/m^2]
Basement	12,452.00	8,813.00	21,265.00	21.27	8.19
Ground floor	6,124.00	10,921.00	17,045.00	17.05	6.56
1st floor	6,174.00	16,819.00	22,993.00	22.99	8.85
2nd floor	6,174.00	16,819.00	22,993.00	22.99	8.85
3rd floor	6,174.00	16,819.00	22,993.00	22.99	8.85
4th floor	6,174.00	16,819.00	22,993.00	22.99	8.85
5th floor	3,926.00	18,500.00	22,426.00	22.43	8.63
Total	47,198.00	105,510.00	152,708.00	152.71	58.80

Figure 9 graphically illustrates the thermal gains of the city administration building in Kaštel Sućurac.

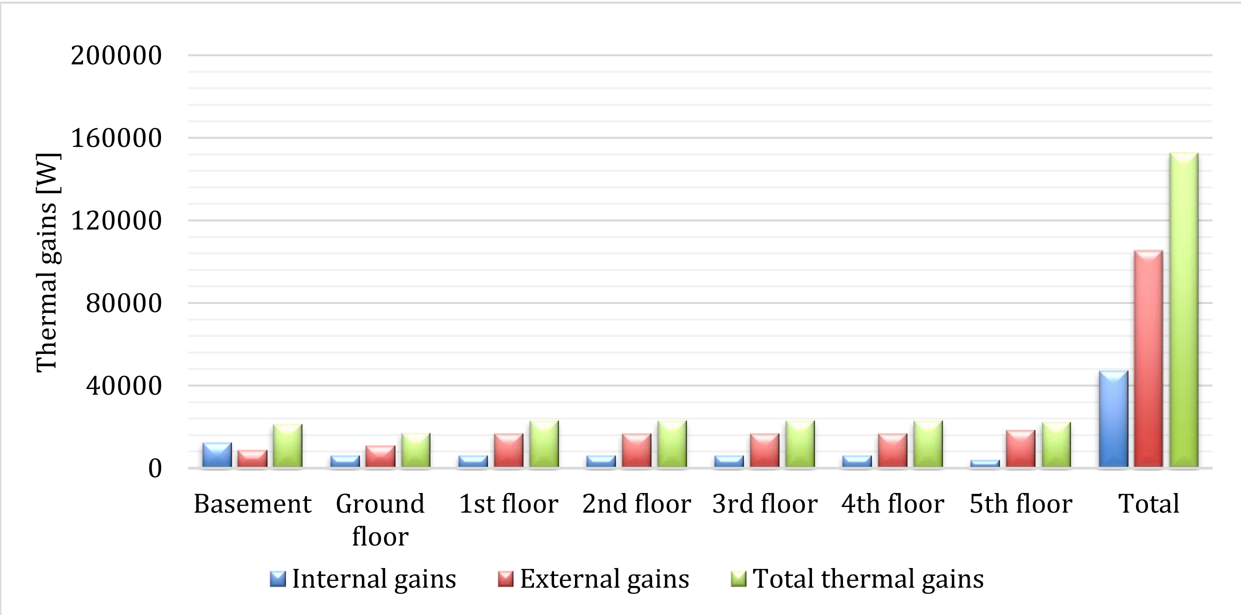


Figure 9 Graphical illustration of thermal gains in the city administration building in Kaštel Sućurac

2.5.3 Calculation of the annual heat energy required for heating and cooling

The annual heat energy required for heating and cooling, $Q_{H,nd}$ and $Q_{C,nd}$, is the calculated amount of heating/cooling energy that a heating/cooling system needs during a year to be brought into a building to maintain its internal design temperature during the building heating/cooling period and is calculated according to HRN EN ISO 13790.

Input climatic and building calculation data are given in Table 11 and 12.

Table 11 Input building calculation data

Description	Symbol	Value	Unit
Area of the walls towards the outside air	A_{zid}	1,615.04	[m^2]
Glazed openings area	A_{pr}	422.51	[m^2]
Floor area to the ground	A_{g}	428.85	[m^2]
Useful area of the building	A_{k}	2,597.23	[m^2]
Area of the heated part of the building	A	2,729.19	[m^2]
Gross volume	V_e	8,525.93	[m^3]
Net volume	V	6,820.74	[m^3]
Share of window area	f	0.21	[-]

Table 12 Input climatic calculation data

Description	Symbol	Heating	Cooling	Unit
Average annual outdoor temperature	ϑ_e	16.9	16.9	[°C]
Internal calculation temperature	ϑ_{int}	23	24	[°C]

The results of the annual heat energy calculation required for heating and cooling are shown in Table 13. The total annual heat demand for the cooling period is $Q_{C,nd,a} = 62{,}154.63\ \mathrm{kWh/a}$ and for the heating period $Q_{H,nd,a} = 107{,}058.22\ \mathrm{kWh/a}$.

Table 13 Required annual heating/cooling energy in the city administration building in Kaštel Sućurac

Description	Symbol	Heating	Cooling	Unit
Annual heating/cooling demand	$Q_{H/C,nd}$	107,058.22	62,154.63	[kWh]
Annual heating/cooling demand	$Q_{H/C,nd}/A_k$	41.22	23.93	[kWh/m^2]

Figure 10 shows the monthly distribution of the required heat energy for heating and cooling the city administration building of the City of Kaštela. The greatest need for heat energy for heating is in January and February while the needs in October and April are almost negligible. On the other side, the greatest need for heat energy for cooling is in June, July and August.

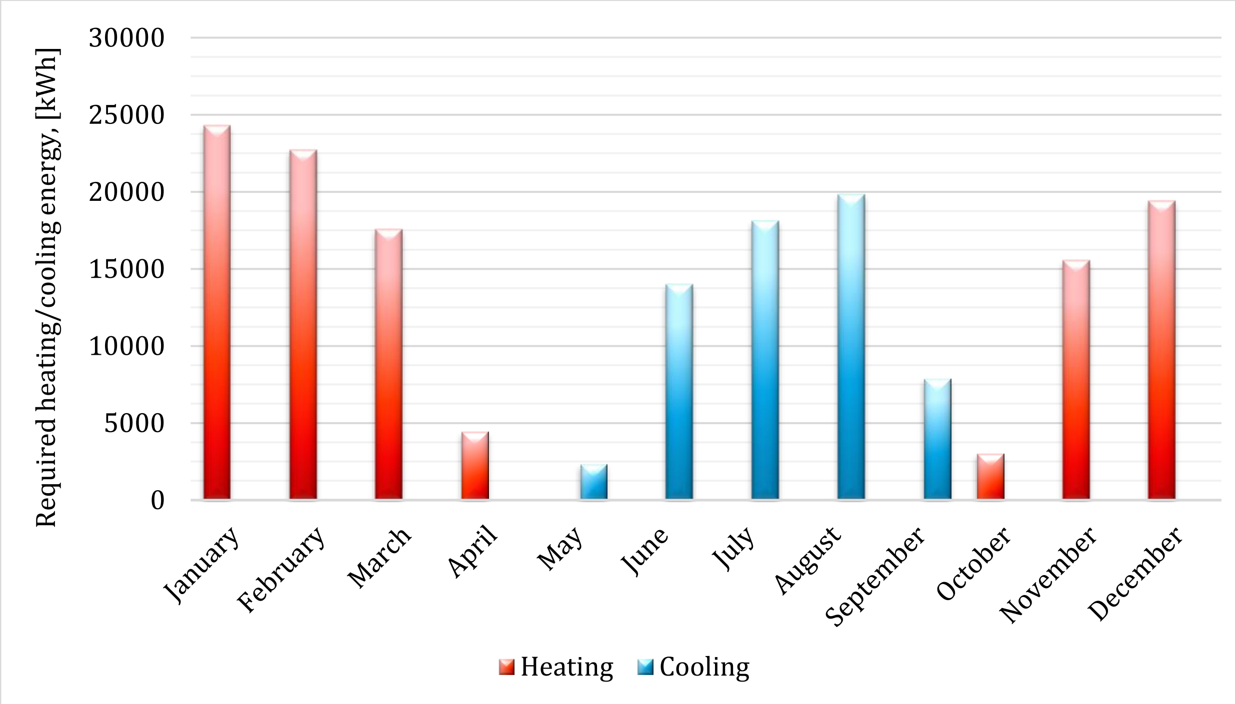


Figure 10 Monthly distribution of the required heat energy for heating and cooling the city administration building of the City of Kaštela

Calculated data will be used in the following section to carry out a techno-economic analysis.

3 Techno-economic analysis of sea water heat pump for heating and cooling of the city administration building in Kaštel Sućurac

Economic feasibility analysis of different heating and cooling source implementation was carried out in the city administration building of the City of Kaštela. The city administration building of the City of Kaštela, with a building area of 2,597.23 m^2, the thermal load of 88.81 kW and cooling load of 152.71 kW, is located in Kaštel Sućurac, a coastal part of the Republic of Croatia, near City of Split. The specific annual heat energy required for heating divided to the useful surface of the building values 41.22 kWh/(m^{2}a) while the total annual heat energy required for heating of the building values 107,058.22 kWh/a. On the other hand, the annual cooling demand of the building values 62,154.63 kWh/a, while the amount of specific annual cooling energy divided to the useful surface area of the building values 23.23 kWh/(m^{2}a).

The reference scenario of the building consists of two systems: an oil boiler connected to the radiator distribution system as a heating system and a newly installed VRV cooling system. In this chapter, two scenarios will be analysed:

1. Oil boiler replacement by the seawater heat pump to heat the city administration building of the City of Kaštela, $\Phi_{Gr} = 95 \text{ kW}$
2. Oil boiler and VRV system replacement by the seawater heat pump for heating and cooling the city administration building of the City of Kaštela, $\Phi_{Hl} = 160 \text{ kW}$

3.1 Reference scenario - analysis of current consumption

Heating system

The heating system of the city administration building of the City of Kaštela consists of an oil boiler with the power of 400 kW and a radiator distribution system with an installed power of 234.53 kW. Annual required heating energy of the city administration building values $Q_{H,nd,a} = 107058{,}22 \text{ kWh/a}$. The consumption was not modelled on the reference data since the aim of the calculation was not to determine the energy class of the building but to actual needs in order to gain the value to be used in the techno-economic analysis of seawater heat pump utilisation. By the energy inspection of the building on December 5th, 2018, and by inspecting the given building documentation, the real annual consumption of the city administration building of the City of Kaštela was also obtained.

The city administration building was energy renovated in 2015 and as a result, the consumption of heat energy was significantly reduced. Before energy renovation, the consumption of extra light fuel oil in the heating season was about 27,000 l while after it the consumption fell to 15,000 - 18,000 l per year. According to that, if the calorific value of 9.96 kWh/l for extra light fuel oil is used the actual annual heat energy consumption at the entrance to the generation subsystem is:

$$Q_{H,gen,in,Re,a} = 16{,}500 \cdot 9.96 = 164{,}340 \text{ kWh/a}$$

The modelled annual heat energy consumption at the entrance to the generation subsystem values $Q_{H,gen,in,a} = 159{,}497.72 \text{ kWh}$ which is approximate to the actual consumption. Although the city administration building is facing a large number of transparent elements to the south and is at all times flooded with solar radiation, thermal losses are still higher than the solar gains of the building, which are also significant. The consequence of large solar gains is the rise in temperature in the building's premises more than desired. For workers to achieve thermal comfort in their offices, they open the windows, as shown in Figure 11, where large ventilation losses of heating energy occur. By installing movable light screens on the inside of the windows, the effect of solar gains is trying to be diminished but there is still a need to open the windows. The greatest need for heating energy is during the morning hours since in the winter season in the coastal part of Croatia frequent occurrence of bora wind is present.

In the economic analysis of the utilisation of the two scenarios mentioned above, the amount of modelled annual heat energy consumption for heating at the input of the generation subsystem will be used $Q_{H,gen,in,a} = 159{,}497.72 \text{ kWh}$.

Figure 11 View of open windows on the south facade of the city administration building (December 2018)

Cooling system

The cooling system of the city administration building consists of a VRV system which consists of six outdoor units with the power of 3 x 15.50 kW and 3 x 12.10 kW, and indoor units in the office spaces. The VRV cooling system was installed at the end of July 2016. There is no central regulation of the cooling system, but it is possible on every single indoor unit.

Annual cooling demand of the city administration building values $Q_{C,nd,a} = 62{,}154.63\ \mathrm{kWh/a}$. In conversation with building janitor, information was obtained that the cooling season begins in April and lasts until October. The energy needed to operate the cooling system is electricity.

In the economic analysis of the utilisation of the two scenarios mentioned above, the amount of modelled annual energy consumption for cooling at the input of the generation subsystem that will be used is $Q_{C,gen,in,a} = 18{,}129.90\ \mathrm{kWh}$.

3.2 Seawater heat pump implementation

Before carrying out the economic analysis of the two scenarios mentioned in the introduction of this chapter, it is necessary to define the investment costs of the seawater heat pump implementation. The economic analysis of the investment and operating costs of heating and cooling systems of the city administration building is based on the following assumptions:

- Building heating and cooling systems are independent of the source of the heating and cooling efficiency, i.e. it is assumed that all devices shown in this analysis can deliver the heating or cooling medium in the required temperature regime.
- A seawater heat pump works in monovalent mode, i.e. it can deliver the heat energy that covers the heating and cooling load of the building.

The above assumptions allow to easily determine the investment and operating costs of different thermotechnical systems and assume that there is no need to install additional auxiliary devices besides implemented thermal devices.

Investment costs for the implementation of the seawater heat pump system are:

- the costs of a seawater heat exchange system
- the cost of seawater heat pump unit
- the costs of heat energy distribution
- other costs (installation, maintenance)

The two scenarios listed at the beginning of the chapter will be analysed. The first scenario is to replace an existing oil boiler with a seawater heat pump for building heating while retaining the existing VRV cooling system. The heat pump system would be connected to the existing heating elements (radiators) with the change of the heating temperature regime from 90/70 °C to 55/45 °C. The power of installed radiators in the 55/45 °C temperature regime values 105 kW so there would be no need to install additional articles on the radiators as the thermal load of the building values $\Phi_{Gr} = 88.81\ \mathrm{kW}$. In scenario 1, the implementation of a 95 kW heat pump with all the accompanying equipment is planned, which would be used for heating the city administration building.

The second scenario is the replacement of the existing oil boiler and the VRV system with a seawater heat pump with the cooling effect of 160 kW whose purpose would be heating and cooling of the city administration building. With the implementation of the heat pump, 111 new heating elements, fan coils, and all the accompanying equipment would be installed. Scenario 2 is much more demanding than scenario 1. Table 14 lists the prices of total investment cost for each scenario.

Table 14 The prices of total investment cost for each scenario

	Scenario 1	Scenario 2
Description	Seawater heat pump for building heating	Seawater heat pump for building heating and cooling
The wells + immersed pump	14,190.00 €	16,892.00 €
The pipeline to the heat exchanger	2,028.00 €	2,028.00 €
A plate titanium heat exchanger	2,298.00 €	2,298.00 €
A heat pump unit	16,892.00 €	23,650.00 €
A storage tank, 3000 l	6,082.00 €	6,082.00 €
An electric cabinet and the wiring	12,162.00 €	12,162.00 €
The fan coils	0.00 €	42,568.00 €
The pipelines and isolation	0.00 €	4,730.00 €
Installation works	13,514.00 €	30,406.00 €
Total	68,514.00 €	142,163.00 €

3.3 Economic analysis

Before carrying out an economic analysis, it is necessary to determine the cost of energy sources required for the operation of the system. The electricity price is determined according to the received electricity bills. The tariff model of the city administration building is HEP PRO and the electricity price values 0.11 €/kWh. The price of extra light fuel oil is 0.06 €/kWh [4]. The money needed to implement the heat pump system will be calculated, in both scenarios, by using loans for entrepreneurs whose interest rate is 2% [5].

Tables 15 and 16 show the results of the economic feasibility analysis starting from the presentation of investment costs, through energy analysis to economic analysis at the end.

Table 15 Economic Analysis of the Reference Scenario and Scenario 1

<table>
<tr><th colspan="2">Investment costs</th><th colspan="2">Oil boiler + VRV system</th><th colspan="2">Seawater heat pump + VRV system</th></tr>
<tr><td colspan="2">Costs of the heat exchange system with seawater, [€]</td><td colspan="2">-</td><td colspan="2">14,190.00</td></tr>
<tr><td colspan="2">Device costs. [€]</td><td colspan="2">-</td><td colspan="2">40,811.00</td></tr>
<tr><td colspan="2">Costs of heating energy distribution, [€]</td><td colspan="2">-</td><td colspan="2">-</td></tr>
<tr><td colspan="2">Installation costs, [€]</td><td colspan="2">-</td><td colspan="2">13,514.00</td></tr>
<tr><td colspan="2">Total investment costs, [€]</td><td colspan="2">-</td><td colspan="2">68,514.00</td></tr>
<tr><td colspan="2">Energy analysis</td><td colspan="4"></td></tr>
<tr><td colspan="2">Heating demand, [kWh/god]</td><td colspan="2">107,058.22</td><td colspan="2">107,058.22</td></tr>
<tr><td colspan="2">Delivered energy to the heating device, [kWh/god]</td><td colspan="2">159,497.72</td><td colspan="2">27,518.69</td></tr>
<tr><td colspan="2">Cooling demand, [kWh/god]</td><td colspan="2">62,154.63</td><td colspan="2">62,154.63</td></tr>
<tr><td colspan="2">Delivered energy to the cooling device, [kWh/god]</td><td colspan="2">18,129.90</td><td colspan="2">18,129.90</td></tr>
<tr><td colspan="2">Electricity consumption, [kWh/god]</td><td colspan="2">18,129.90</td><td colspan="2">45,648.59</td></tr>
<tr><td colspan="2">Fuel oil consumption, [kWh/god]</td><td colspan="2">159,497.72</td><td colspan="2">-</td></tr>
<tr><td colspan="2">Economic analysis</td><td colspan="4"></td></tr>
<tr><td colspan="2">Investment, [€]</td><td colspan="2">-</td><td colspan="2">68,514.00</td></tr>
<tr><td colspan="2">Interest rate, [%]</td><td colspan="2">-</td><td colspan="2">2</td></tr>
<tr><td colspan="2">Years of repayment</td><td colspan="2">-</td><td colspan="2">13</td></tr>
<tr><td colspan="2">Annual loan rate, [€/god]</td><td colspan="2">-</td><td colspan="2">6,038.00</td></tr>
<tr><td colspan="2" rowspan="2">Price of energy source, [€/kWh]</td><td>Fuel oil</td><td>0.06</td><td colspan="2" rowspan="2">0.11</td></tr>
<tr><td>Electricity</td><td>0.11</td></tr>
<tr><td rowspan="2">Operating costs, [€/god]</td><td>Heating</td><td colspan="2">9,052.57</td><td colspan="2">2,889.46</td></tr>
<tr><td>Cooling</td><td colspan="2">1,903.64</td><td colspan="2">1,903.64</td></tr>
<tr><td colspan="2">Cost of heating and cooling [€/god]</td><td colspan="2">10,956.21</td><td colspan="2">4,793.10</td></tr>
<tr><td colspan="2" rowspan="2">Maintenance, [€/god]</td><td>Boiler</td><td>67.57</td><td>DT</td><td>121.62</td></tr>
<tr><td>VRV</td><td>202.70</td><td>VRV</td><td>202.70</td></tr>
<tr><td colspan="2">Total cost after 1 year, [€]</td><td colspan="2">11,226.47</td><td colspan="2">11,154.72</td></tr>
<tr><td colspan="2">Total cost after 13 years, [€]</td><td colspan="2">145,944.28</td><td colspan="2">145,011.41</td></tr>
</table>

The table above shows that with the repayment term of 13 years the annual cost of the implemented seawater heat pump system for heating the building and the existing VRV building cooling system is less than the cost of the reference scenario. Figure 12 shows the annual relation between operating and investment costs and the maintenance costs for the reference scenario and scenario 1.

Renewable energy system implementations are often financially supported by European projects or state subsidies. With a subsidy of 40 %, the investment cost of scenario 1 decreases to 41,110.00 €

the return period of investment is reduced to 8 years which is 5 years less than the scenario without subsidies, so the possibility of subsidising should certainly be taken into account.

Table 16 shows the economic feasibility analysis of scenario 2 which from the obtained results shows that with the repayment deadline of 28 years, the annual cost of the implemented seawater heat pump system is lower than the annual cost of the reference scenario which is completely unprofitable since the investment cost is far greater than the realised annual savings. If this is the case with a grant of 40 %, the investment cost decreases to 85,300.00 €, so the repayment period is reduced to 15 years which is certainly more acceptable.

Table 16 Economic Analysis of the Reference Scenario and Scenario 2

<table>
<tr><th colspan="2">Investment costs</th><th colspan="2">Oil boiler + VRV system</th><th>Seawater heat pump</th></tr>
<tr><td colspan="2">Costs of the heat exchange system with seawater, [€]</td><td colspan="2">-</td><td>16,892.00</td></tr>
<tr><td colspan="2">Device costs, [€]</td><td colspan="2">-</td><td>47,568.00</td></tr>
<tr><td colspan="2">Costs of heating energy distribution, [€]</td><td colspan="2">-</td><td>-</td></tr>
<tr><td colspan="2">Installation costs, [€]</td><td colspan="2">-</td><td>30,406.00</td></tr>
<tr><td colspan="2">Total investment costs, [€]</td><td colspan="2">-</td><td>142,163.00</td></tr>
<tr><td colspan="2">Energy analysis</td><td colspan="3"></td></tr>
<tr><td colspan="2">Heating demand, [kWh/god]</td><td colspan="2">107,058.22</td><td>107,058.22</td></tr>
<tr><td colspan="2">Delivered energy to the heating device, [kWh/god]</td><td colspan="2">159,497.72</td><td>27,518.69</td></tr>
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<tr><td colspan="2">Fuel oil consumption, [kWh/god]</td><td colspan="2">159,497.72</td><td>-</td></tr>
<tr><td colspan="2">Economic analysis</td><td colspan="3"></td></tr>
<tr><td colspan="2">Investment, [€]</td><td colspan="2">-</td><td>142,163.00</td></tr>
<tr><td colspan="2">Interest rate, [%]</td><td colspan="2">-</td><td>2</td></tr>
<tr><td colspan="2">Years of repayment</td><td colspan="2">-</td><td>28</td></tr>
<tr><td colspan="2">Annual loan rate, [€/god]</td><td colspan="2">-</td><td>6,680.15</td></tr>
<tr><td colspan="2" rowspan="2">Price of energy source, [€/kWh]</td><td>Fuel oil</td><td>0.06</td><td rowspan="2">0.11</td></tr>
<tr><td>Electricity</td><td>0.11</td></tr>
<tr><td rowspan="2">Operating costs, [€/god]</td><td>Heating</td><td colspan="2">9,052.57</td><td>2,889.46</td></tr>
<tr><td>Cooling</td><td colspan="2">1,903.64</td><td>1,450.27</td></tr>
<tr><td colspan="2">Cost of heating and cooling [€/god]</td><td colspan="2">10,956.21</td><td>4,339.74</td></tr>
<tr><td colspan="2" rowspan="2">Maintenance, [€/god]</td><td>Boiler</td><td>67.57</td><td rowspan="2">121.62</td></tr>
<tr><td>VRV</td><td>202.70</td></tr>
<tr><td colspan="2">Total cost after 1 year, [€]</td><td colspan="2">11,226.47</td><td>11,141.51</td></tr>
<tr><td colspan="2">Total cost after 28 years, [€]</td><td colspan="2">314,341.53</td><td>311,962.34</td></tr>
</table>

3.4 Environmental impact

The return period of the investment has a significant impact on the decision to utilise seawater heat pumps. However, one of the most important factors is the environmental impact. By comparing the CO_2 emissions in each scenario, it is estimated that these emissions are 80% less in scenario 1 and 2 than in the reference scenario. This is a result of lower primary energy consumption in scenario 1 and 2 than in the reference scenario, which is used for generating the same amount of heating and cooling energy. Table 17 shows the values of primary energy consumption and CO_2 emissions for each scenario as well as its reductions.

Table 17 Primary energy consumption and CO_2 emissions for each scenario

	Reference scenario	Scenario 1	Scenario 2
Primary energy consumption, [kWh/a]	210,770.00	73,677.00	66,708.00
Reduction of Primary energy consumption, [%]	0%	65%	68%
CO_2 emissions, [kg CO_2/a]	52,037.92	10,718.84	9,704.93
Reduction of CO_2 emissions, [%]	0%	79%	81%

4 Conclusion

The city administration building in Kaštel Sućurac is located about fifty meters from the sea, whose winter temperature, at depths up to twenty meters does not fall below 13 °C. As the existing heating system has been in operation for 30 years, its renovation is needed. Due to the good energetic properties of the building, the thermal load of the building is considerably lower which allows the implementation of the seawater heat pump system on existing radiators with a lower heating system temperature regime while the thermal load is still covered. The return period of such an investment would be 13 years as the investment cost is high, however, with financial subsidies, the system would be more cost-effective in the shorter period. The case of the heat pump implementation for building heating and cooling has also been considered, yet because of the necessary installation of a new heat energy distribution system, the investment cost is considerably higher than the previous case and the investment return period rises to 28 years, with a subsidy of 15 years.

Heat pump systems are systems with high investment costs and it is still easier and cheaper to implement conventional heating and cooling systems, however, attention should not be put on the cost and complexity of the system's performance. The ultimate goal in the current period of climate change and the struggle for fossil fuel reserves should be to reduce CO_2 emissions and increase the use of renewable energy sources, and in particular to achieve energy independence, as systems such as seawater heat pumps and heat pumps in general provide.

5 References

[1] https://www.google.hr/maps/@43.5460185,16.4210214,185m/data=!3m1!1e3?hl=hr (Accessed July 15, 2019)

[2] Forming d.o.o.: Energy Renovation of the City Administration Building Shell, Kaštel Novi, 2013

[3] Roterm d.o.o.: Report on carried out energy inspection of the building - City Administration Building of the City of Kaštela, Split, 2012

[4] http://www.servis-perkovic.hr/financijska-usporedba-energenata (Accessed January 12, 2019)

[5] https://www.hbor.hr/kreditni_program/zastita-okolisa/ (Accessed January 12, 2019)