Feasibility studies for Coastal Energy projects in pilot areas

Feasibility study for Cres-Lošinj archipelago

30/12/2021

Deliverable Number D.4.3.1

SDEWES Centre

Project Acronym	COASTENERGY
Project ID Number	10045844
Project Title	Blue Energy in ports and coastal urban areas
Priority Axis	1
Specific objective	1.1
Work Package Number	4
Work Package Title	Creating multi-level Hubs to define joint strategies & local actions supporting coastal Blue Energy
Activity Number	4.3.
Activity Title	Defining pilot projects
Partner in Charge	DURA
Partners involved	SDEWES
Status	Final
Distribution	Public

Content

Current situation..4
Proposed project...9
Energy savings...20
Economic assessment..22
Local coastal energy hub 25
Conclusion 26

List of figures

Figure 1. Location of the townhall (Gmaps)...4
Figure 2. Existing radiators..5
Figure 3. Existing boiler with the torch and regulation (left); boiler specification (right) 5
Figure 4. Electrical heaters 6
Figure 5. Specification of heat pumps used for cooling 7
Figure 6. Heat pumps in the attic 7
Figure 7. Existing fan coils 8
Figure 8. Monosplit devices...8
Figure 9. The layout of the machine room with the new heat pump 10
Figure 10. DAIKIN EWHQ150G-SS heat pump 11
Figure 11. Scheme of the heat pump installation together with the intake (red) and outlet (blue) well...12
Figure 12. Sensitivity analysis of yearly savings and simple return of investment 24

List of tables

Table 1. Electricity consumption in the Mali Lošinj Townhall 8
Table 2. Pros and cons of a seawater heat pump with indirect water intake 13
Table 3. Heating and cooling demand 20
Table 4. Comparison of current and SWHP system 21
Table 5. Comparison of yearly emissions..22
Table 6. Comparison of yearly operating costs 22
Table 7. Investment costs for SWHP, acceptable for funding from EU sources.....................23
Table 8. Investment costs, not covered by EU funding sources 23
Table 9. Savings with increased energy prices (100% electricity, 200% heating oil)............24
Table 10. Comparison of SWHP and air-water heat pump 25

This feasibility study will be shown the socioeconomic influences of the installation of seawater heat pumps in the Townhall of Mali Lošinj.

Current situation

The Townhall is in the Cres-Lošinj Archipelago that was analysed in previous project deliverables from activity 3.4 - Blue Energy potential analysis. The exact location is shown below. The building is next to the sea and the side that is looking towards the sea is under architectural conservation. The building has 3 floors, with the attic partly used as an archive and partly for thermotechnical equipment. The building is mostly used between 7:70 and 15:30 on the weekdays by 45 employees working there. The total area of the building is 504 m^2. Heating oil is used for space heating and air-air heat pumps are used for cooling. There are 58 horizontal radiators in the building that have a heating power of 151,35 kW. Each radiator has a manual regulation valve. The heating power of radiators is sufficient, but the heating system is old and has a problem with regulation and balancing, why there is a problem with heating of some rooms in the buildings.

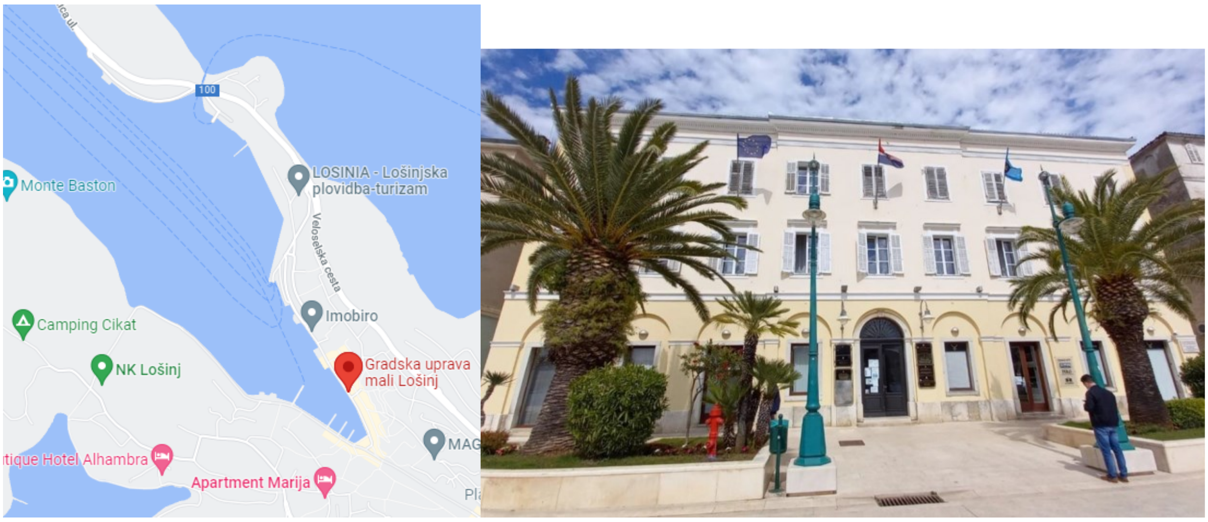


Figure 1. Location of the townhall (Gmaps)

Current devices for heating and cooling in the building are:

- 12 different electric air heaters – total power 23.8 kW
- Heating oil boiler TKT-TOPLOTA – TK 40 with the power of 400 kW from 1999. Efficiency is η=0,83. This boiler is oversized, due to the total heating demand being 100 kW

Figure 2. Existing radiators

Figure 3. Existing boiler with the torch and regulation (left); boiler specification (right)

Figure 4. Electrical heaters

The heating boiler is in the machine room in the basement together with a large oil tank. The heating boiler is oversized because previously it was used to heat the neighbouring building, which is not connected anymore. Due to problems with the balancing of heating system, in the buildings are used 12 electric heaters.

On the other hand, the cooling system is undersized, and cooling demand cannot be met during the summer. The cooling system consists of two air-to-water heat pumps in the attic (25 kW and 32 kW). Some rooms in the building use additional mono split heat pumps where the cooling system doesn't meet the demand. The current capacity of all the heat pumps used for cooling is 91.4 kW.

- The cooling system has 2 water-to-air heat pumps (R22) for indoor installation:
  - ECOCOLD, model PASRW130SB-LX cooling power: 25 kW (EER=2.3),
  - ECOCOLD, model PASRW100SB-LX cooling power: 32 kW (EER=2.7)

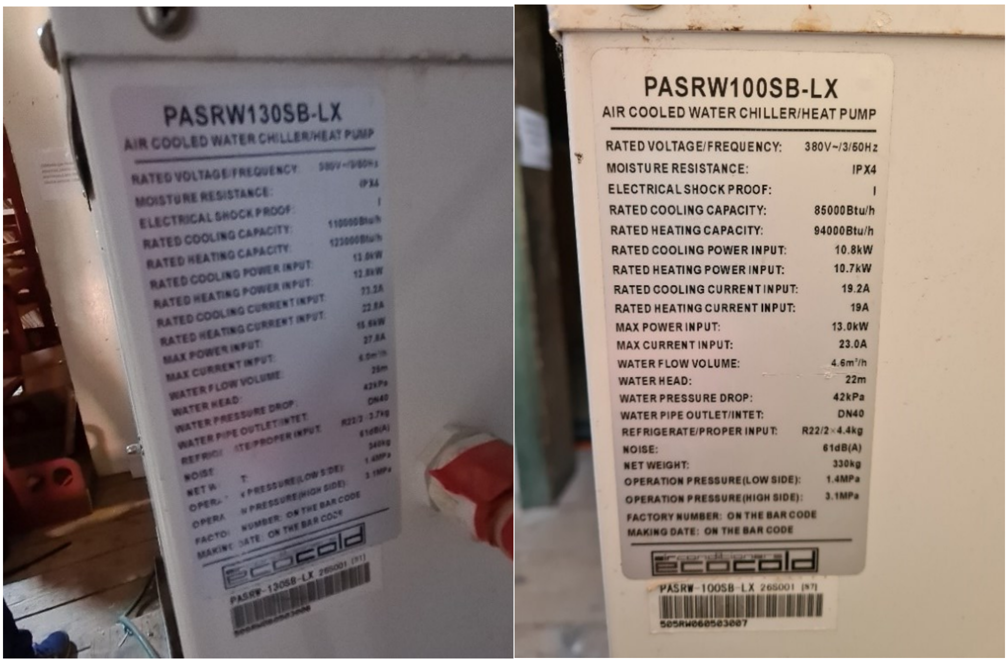


Figure 5. Specification of heat pumps used for cooling

- In the buildings are installed 3 mono split devices and 3 dual split devices using R410a as a refrigerant and mobile device using R407c.

The total cooling capacity is 91.4 kW with EER=3. According to the bills, yearly electricity consumption is 53 319 kWh.

Figure 6. Heat pumps in the attic

Figure 7. Existing fan coils

Figure 8. Monosplit devices

Table 1. Electricity consumption in the Mali Lošinj Townhall

Monthly consumption – Mali Lošinj Townhall			
Month	Consumption (kWh)	Price (HRK)	Monthly (HRK)
January	6415	0.53	3426.57
February	6612	0.53	3531.8
March	5433	0.53	2902.04
April	5543	0.53	2960.79
May	8301	0.53	4433.98
June	7303	0.53	3900.9
July	5863	0.53	3131.72
August	9180	0.53	4903.5
September	11 410	0.53	6094.65
October	4541	0.53	2425.58
November	7907	0.53	4223.52
December	6118	0.53	3267.93
Total	**84 626**		**45 202.98**

Consumption of heating oil is 13 000 litres yearly (2020).

Proposed project

For the building, there should be installed seawater to the water heat pump. The project that was made includes the installation of SWHP, with indirect water intake. That means there should be drilled wells for the water intake next to the building. The existing heating boiler would be kept as a reserve heat source. The HP will be placed in the basement room, that is currently not used, together with the heat storage tank that will have 5000 l of volume. New machine room will be equipped with:

- water-to-water compression heat pump DAIKIN EWHQ150G-SS
- heat storage for hot water, volume: 5000 l
- expansion tank for primary circle 18 l
- expansion tank for heating/cooling system: 500 l
- valves and safety armature
- pump for primary circle: WILO Stratos MAXO 65/0.5-16 PN 6/10
- pump for the second circle on the HP: MAXO 65/0.5-16 PN 6/10
- pump for the ground floor and first floor: WILO Stratos MAXO 40/0.5-16 PN 6/10
- pump for the second floor: WILO Stratos MAXO 40/0.5-12 PN 6/10
- pump for the reserve system – existing boiler using heating oil: WILO Stratos MAXO 40/0.5-16 PN 6/10

A heat pump is a device that moves the heat from the colder heat storage, heats it and moves it to the warmer heat storage. Usually, heat is absorbed from the outside air, ground, or water. In this case, the heat will be absorbed from the brackish water in the wells next to the buildings.

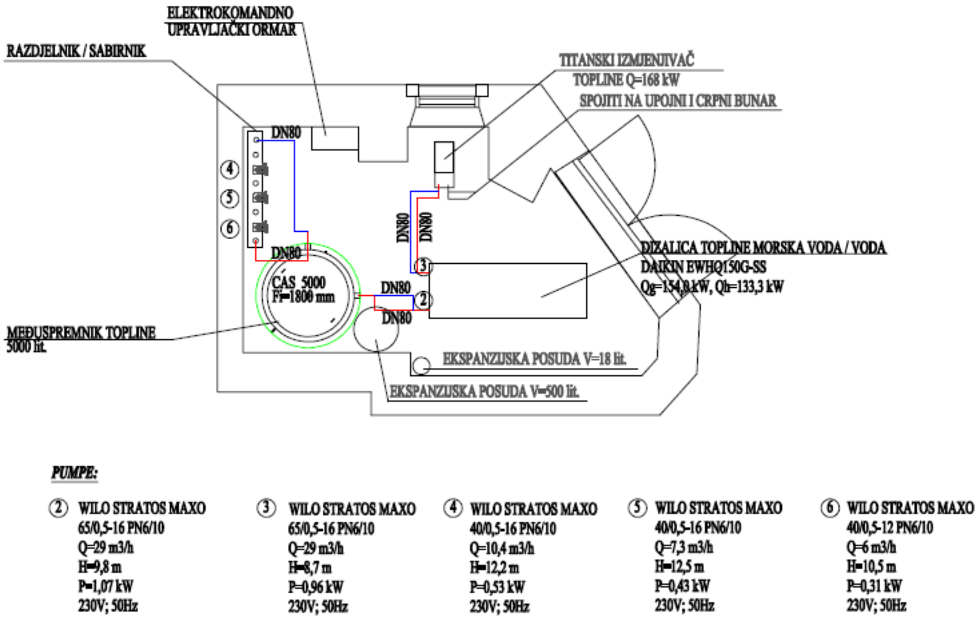


Figure 9. The layout of the machine room with the new heat pump

There will be installed water-to-water compression heat pump DAIKIN EWHQ150G-SS with the following specifications:

Cooling:

- Cooling capacity: Qc = 133 kW
- Electric power: N = 32.65 kW
- Efficiency: EER = 4.084
- Seasonal efficiency: SEER = 4.89 / hs=187.6%
- Water flow in a primary circle (well): 8.01 l/s

Heating:

- Heating capacity: Qh = 154 kW
- Electric power: N = 38.73 kW
- Efficiency: COP = 3.975
- Seasonal efficiency: SCOP = 4.24 / hs = 161.6%
- Water flow in primary circle (well): 6.91 l/s

This heat pump has two hermetically sealed compressors that allow different working stages from 44%-100%. The refrigerant fluid used in the HP is R-410a.

Figure 10. DAIKIN EWHQ150G-SS heat pump

<u>Water intake</u>

In this case, the heat source will be brackish water in the wells drilled next to the buildings. The temperature of the water in the wells is usually between 8 °C and 13 °C. Due to low fluctuations of the temperature, underground water is one of the best heat sources for heat pump installations.

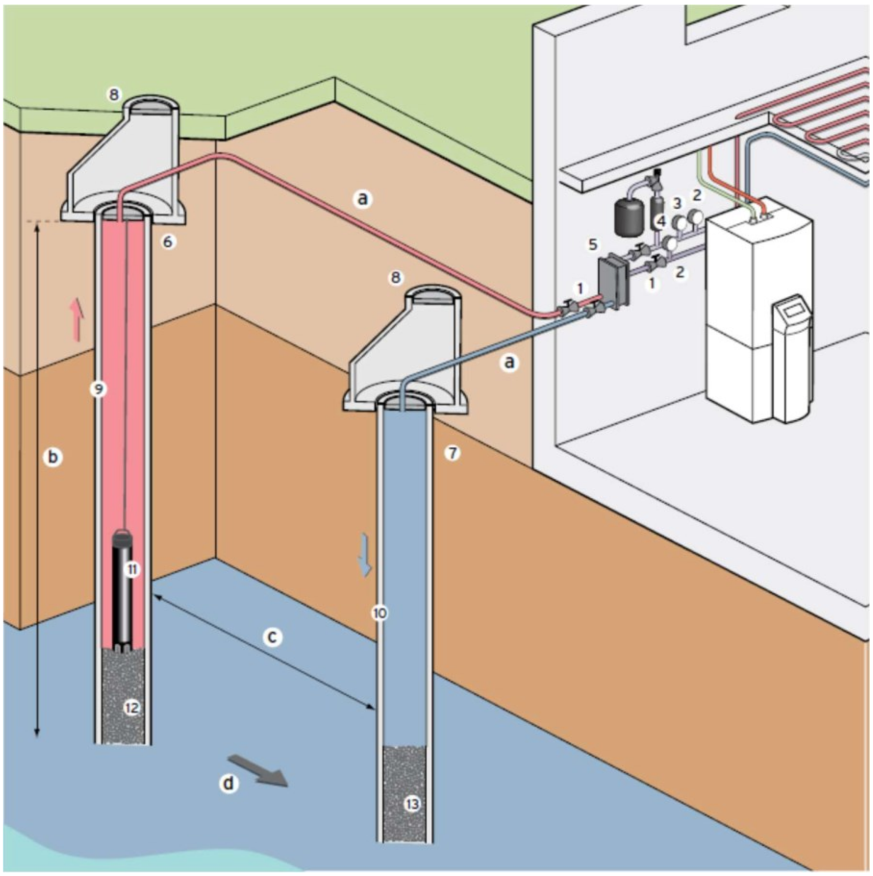


Figure 11. Scheme of the heat pump installation together with the intake (red) and outlet (blue) well.

1 – shut-off valve	2 – temperature gauge
3 – pressure gauge	4 - expansion tank
5 – Heat exchanger between the wells and the heat pump	6 – Water intake well
7 – water return well	8 – Well cover with the deaerator
9 – Transport tube	10 – Tube needs to be corrosion resistant
11 - Well pump	12 / 13 – Filtration space - residue
C – spacing between intake and return well	

2 wells will be drilled behind the building, one for water intake and one for water outlet. Outlet water could be released in the sea or sewage without drilling the well, but due to legislation, it would not be considered as water for technological purposes, and costs for its utilization would be much higher. For the usage of water, it is necessary to obtain a permit for water usage from

the national water management body (Hrvatske vode). Usage of water from the extraction well would cost 0.1 HRK/m^3. Distance between the wells needs to be at least 15 m, to avoid the mixing of warm and cold water. The wells will be 30 m deep. Pump for the water intake in the primary circle will be placed in the well at the depth of 25 m. Free depth bellow of 5 m will be left for the residues from the water and to reduce the costs of the maintenance. The water return well will be 20 m deep. Heat exchangers that are used within the heat pump need to be made of titanium or stainless steel, due to the corrosive characteristics of brackish water. For this type of water intake, it is necessary that:

- Used water is pumped back into the ground
- Creating a preliminary hydrogeological study
- Strict demands for the well and filtration system
- The well needs to have a cap and protection from surface water

Table 2. Pros and cons of a seawater heat pump with indirect water intake

Pros	Cons
• Water source heat pumps are most efficient during the whole year • Cheapest heat source • A constant temperature in the well	• Chemical characteristics of the water • The thermal capacity of one well • It is not available everywhere • Higher costs • Geological testing of underground water • A complex system of water intake and water return to the ground

Instead of drilling the well, it is physically possible to have a direct water intake. This means pipes for water intake would be placed directly into the sea. The main drawback of this solution is the need for often cleaning the pipes. In Croatia, this solution brings additional legislation problems. It is necessary to obtain the concession for the application on the maritime good, for which the procedure is not clear, and the investors are often avoiding it.

Heating and cooling system

During the winter, heating fluid will be circulating the system with a temperature range of 45/40 °C. During the summer, cooling fluid will be circulating within the range of 7/12 °C. The new system will have lower temperatures to enhance the efficiency, but that means there will be needed more efficient heating bodies. The old radiators and armature will be replaced with new fan coils. They will be wall-mounted or parapet fan coils. Wall-mounted coils will use small pumps for condensate removal.

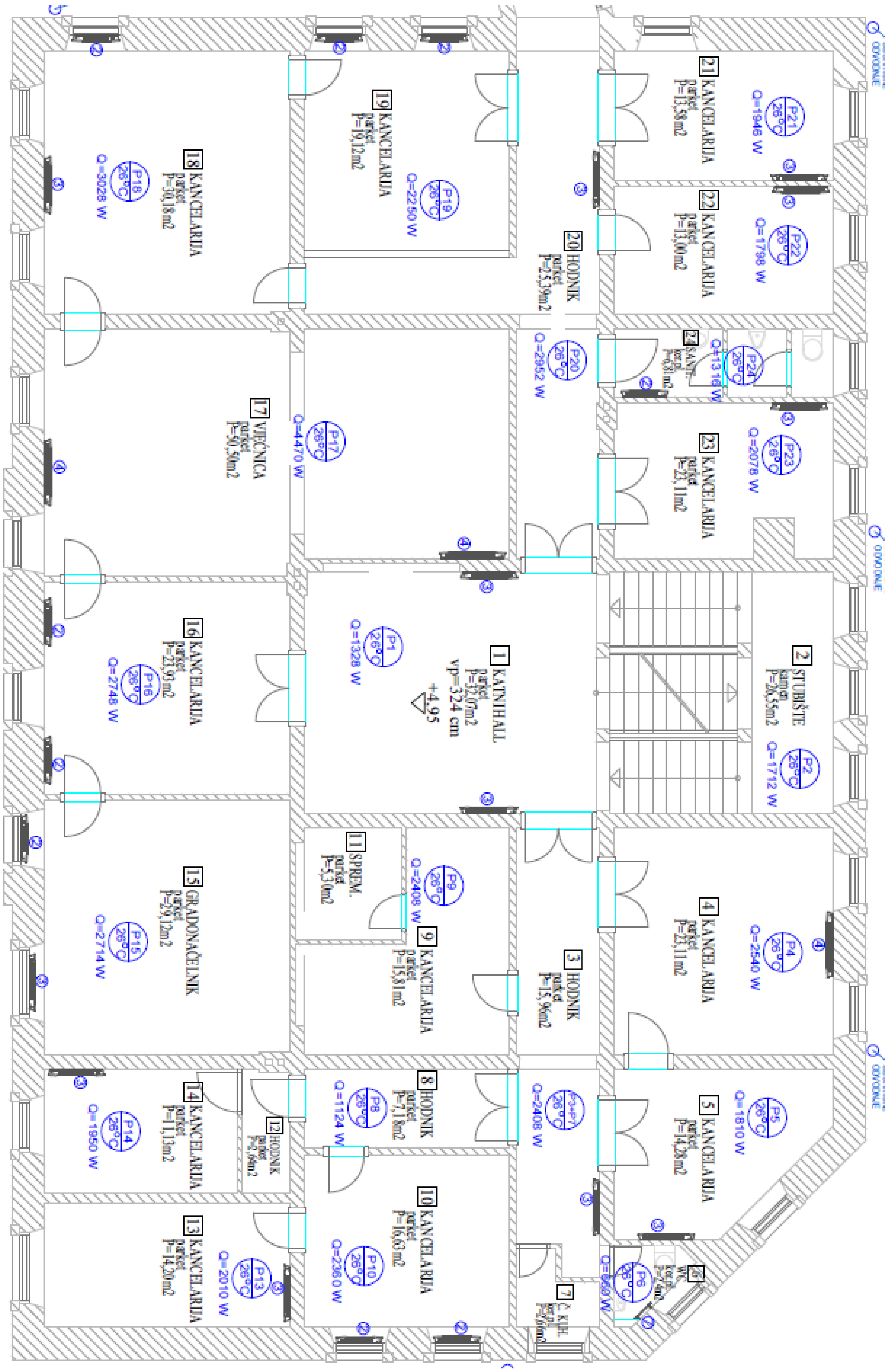
On the ground floor there will be 6 wall units and 6 parapet units:

- 5 wall – DAIKIN FWXT20ATV3 (1.35 kW cooling & 1.95 kW heating),
- 1 wall - DAIKIN FWXT15ATV3 (1.2 kW cooling & 1.51 kW heating),

- 5 parapet – DAIKIN FWXV10ATV3 (1.36 kW cooling & 1.63 kW heating)
- 1 parapet - DAIKIN FWXV20ATV3 (2.25 kW cooling & 3.05 kW heating)

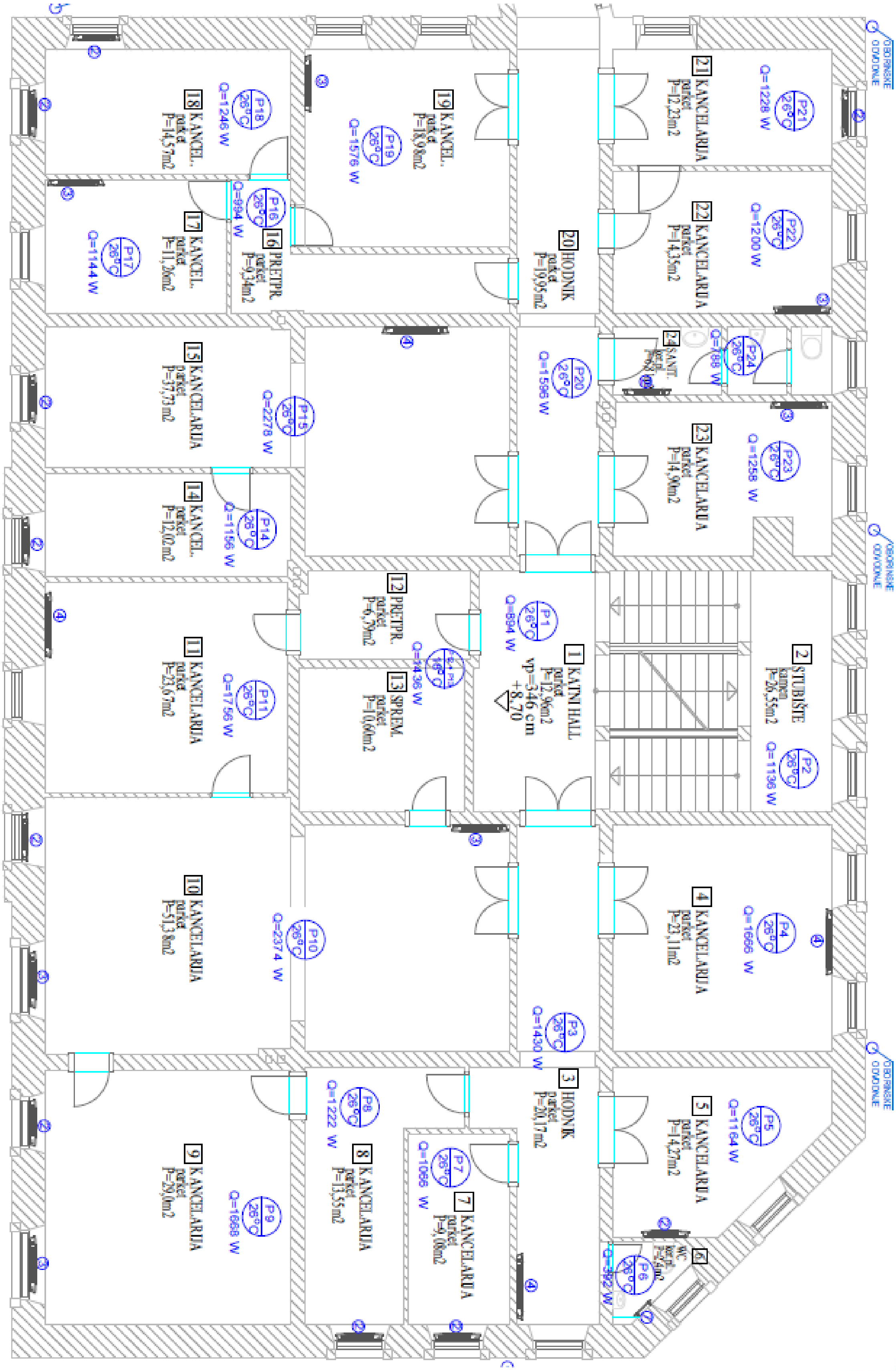
On the 1st floor there are only parapet units - 24 Pieces:

- 9 parapet – DAIKIN FWXV10ATV3 (1.36 kW cooling & 1.63 kW heating),
- 12 parapet - DAIKIN FWXV15ATV3 (2.16 kW cooling & 2.33 kW heating),
- 3 parapet - DAIKIN FWXV20ATV3 (2.25 kW cooling & 3.05 kW heating)


KANCELARIJA
VIJEĆNICA
GRADONAČELNIK
KATNI HALL
STUBIŠTE
HODNIK
SPREM.
ODVODNJE

On the 2nd floor there are only parapet units - 24 Pieces:

- 12 parapet – DAIKIN FWXV10ATV3 (1.36 kW cooling & 1.63 kW heating),
- 7 parapet - DAIKIN FWXV15ATV3 (2.16 kW cooling & 2.33 kW heating),
- 5 parapet - DAIKIN FWXV20ATV3 (2.25 kW cooling & 3.05 kW heating)



The noise level on average fan speed is between 35 and 42 dB. The whole heating and cooling system would be automated. In the machine, a room will be placed control unit that can be operated remotely.

The heat pump can work in 2 modules, so during the night when the electricity price is cheaper, the heat pump works with 44% capacity and fills the heat storage (5000 l) that is used during the day. During the periods with higher demand, the second compressor starts operating, and the heat pump works with 100% capacity. This system will be placed in the machine room, and there is no need to fulfil strict regulations on safety for gas boilers. Pipes connecting coils and heat pumps are made of steel and copper and are isolated. Pipes that are connecting the wells with heat exchangers on the heat pumps are made of PE110 material (SDR17, Ø110x6.6). Projected temperatures for heating are:

- Offices, toilets, conference hall: 22 °C
- Hallways: 18 °C
- Storage rooms, staircase: 15 °C

The projected temperature for areas with cooling is 26 °C. Total investment is estimated at 2 108 805 HRK without VAT (281 111 EUR).

Energy savings

Considering current electricity and fuel oil consumption, existing devices for heating and cooling and technical specification of a new system, and certain estimations, energy savings are calculated.

Table 3. Heating and cooling demand

Month	T [°C]		Heating days	Cooling days	Q_h [kWh]	Q_c [kWh]
January	6.6	31	21	0	25 184.86	0.00
February	7.5	28	20	0	23 985.58	0.00
March	9.9	31	15	0	17 989.18	0.00
April	13.4	30	9	0	10 793.51	880.67
May	18	31	0	14	0.00	3407.40
June	21.6	30	0	20	0.00	2900.84
July	24.5	31	0	23	0.00	2407.06
August	24	31	0	20	0.00	3768.63
September	20.5	30	0	22	0.00	4531.10
October	16.2	31	0	12	0.00	722.02
November	11.6	30	20	0	23 985.58	0.00
December	7.9	31	23	0	27 583.41	0.00
Total			**108**	**111**	**129 522.12**	**18 617.72**

The number of heating days and average air temperature can be found in the national rulebook for energy audits energy certificate [1]. Energy for heating (Q_h) and cooling (Q_c) is calculated from the bills for heating oil and electricity. The number of cooling days and energy for cooling is estimated based on electricity consumption in a specific month and installed cooling capacity. It is estimated that one-fifth of electricity is used for cooling in months with the highest cooling demand.

From energy consumption data and considering the efficiency of existing heating and cooling systems, the electric energy needed for the planned system is calculated. The heating and cooling demand will stay the same.

Table 4. Comparison of current and SWHP system

Existing system		New SWHP	
83%	250%	424%	489%
Q_h [kWh]	Q_C[kWh]	Q_h [kWh]	Q_c [kWh]
30 343.20	0.00	5939.83	0.00
28 898.29	0.00	5656.98	0.00
21 673.71	0.00	4242.73	0.00
13 004.23	352.27	2545.64	180.10
0.00	1362.96	0.00	696.81
0.00	1160.34	0.00	593.22
0.00	962.82	0.00	492.24
0.00	1507.45	0.00	770.68
0.00	1812.44	0.00	926.61
0.00	288.81	0.00	147.65
28 898.29	0.00	5656.98	0.00
33 233.02	0.00	6505.52	0.00
156 050.74	**7447.09**	**30 547.67**	**3807.31**
163 497.83 kWh		34 354.97 kWh	
		78.99%	

It is calculated that the existing system consumes 163.5 MWh yearly, with an average efficiency of 83% for boiler and 250% for air conditioning units. Using the nominal efficiency of the new system, energy savings would be 78.99%. The biggest saving is achieved by replacing inefficient and pollution heavy boilers that is using fuel oil.

Table 5. Comparison of yearly emissions

Fuel oil	0.267	$kgCO_2/kWh$
Electricity	0.33	$kgCO_2/kWh$
Current CO_2	44 123.09	$kgCO_2/a$
New CO_2	11 337.14	$kgCO_2/a$
Savings CO_2	**32.786**	**tCO_2/a**

With lower energy consumption, it is expected that CO_2 emissions will be reduced by 32.8 tonnes yearly (74.3%).

Economic assessment

To assess the simple return of investment, it is necessary to consider current costs of electricity and fuel oil on yearly basis and compare them with the costs of energy for the new system and the total cost of installation. As mentioned before, for heating is mostly being used fuel oil, with the addition of electrical heaters in some periods.

From the bills for electricity and fuel oil, gotten from the Townhall, the price of energy is:

Electricity price	0.53415	HRK/kWh
Heating oil price	0.36132	HRK/kWh

Except for the energy costs, with the new system the user has an additional cost for usage of water from the well, as a renewable energy source. This costs 0.10 HRK/m^3 of pumped water. Total yearly costs are shown below:

Table 6. Comparison of yearly operating costs

[HRK/a]	Heating oil	Electricity	Water	**Total**
Current system	56 384.26	3977.86	0	**60 362.12**
New SWHP	0	18 350.71	2039.04	**20 389.75**
Saving				**39 972.37**

There are potential funding sources for this type of project. It is possible to apply for the call *Energy production from the sea* funded by the EEA grants [2]. It is possible to get funding to cover 85% of equipment and installation works. Acceptable expenses for funding are the heat pump, the system for water intake and other equipment in the machine room (heat storage, heat exchangers…).

For this project, it is necessary to change the heating bodies, since the old ones are outdated and should be replaced to get the highest level of comfort and efficiency. For this part of the project, it is not possible to get any funding in *Energy production from the sea* called. Costs for the acceptable expenses are mentioned in the following table:

Table 7. Investment costs for SWHP, acceptable for funding from EU sources

Investment cost with an acceptable funding	1 186 965.00 HRK
85% funding	1 008 920.25 HRK
Cost for investor	178 044.85 HRK

Another part of the investment, for which is not possible to get funding is 921 840 HRK. Total costs of investment are mentioned below:

Table 8. Investment costs, not covered by EU funding sources

Other investment costs	921 840.00 HRK
Total investment cost	2 108 805.00 HRK
Total cost for the investor	1 099 885.75 HRK

The mentioned costs are without VAT. Total VAT is 527 201.00 HRK.

Considering the total cost for the investor, including the exchange of heating bodies, the simple return of the investment period is **27.5 years**. If we consider only the installation of SWHP and parts that are acceptable for funding, the simple return of the investment period is 4.5 years.

In this project, it is important to consider that the current system is old and needs refurbishment. The new system would offer a higher level of comfort. Except for 27.6 tonnes of CO_2 saved, there would be no need for imports and storage of fuel oil in the building. For projects like this, there are many potentials for funding.

If we calculate the cost of CO_2 emissions by the EU Emission Trading System, there would be additional savings. In December 2021, prices are around 610 HRK/tonne. If EU ETS was implemented for this case, the current system would present an additional cost of 19 999.43 HRK annually. In this case, total savings would be 59 971.80 HRK/a, reducing the return of investment period to 18.34 years.

Assessment with different energy prices

Today we can see that energy prices of electricity, gas and oil are increasing significantly, and forecasts are showing a major increment in prices in next years. The additional assessment was made with the price of electricity being 100% greater than today, and heating oil being 200% greater:

Electricity price (100% increase):	1.068	HRK/kWh
Heating oil price (200% increase):	1.084	HRK/kWh

With higher energy prices, SWHP would be more feasible due to its higher efficiency. With higher prices, the new SWHP system would be saving 138 368 HRK yearly. With those savings, a simple return of investment would be 7.95 years.

Table 9. Savings with increased energy prices (100% electricity, 200% heating oil)

[HRK/a]	Heating oil	Electricity	Water	**Total**
Current system	169 152.8	7955.72	0	**177 108.5**
New SWHP	0	36 701.42	2039.04	**38 740.46**
Saving				**138 368**

Sensitivity analysis was made, depending on the change of heating oil price. The price of electricity is set at 1.0683 HRK/kWh (100% increase). For the analysis, we considered an increase of heating oil prices up to 300%. In the analysis, it is shown that the period for simple return of investment is significantly shortened with the higher cost of heating oil - Figure 12.

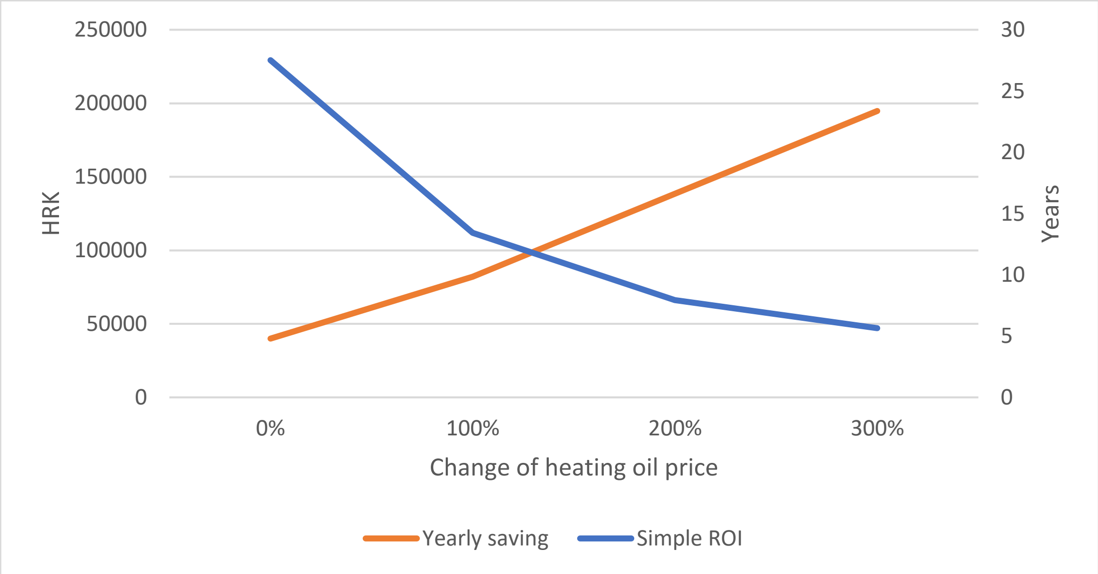


Figure 12. Sensitivity analysis of yearly savings and simple return of investment

Comparison with air source heat pump

Alternative for the seawater heat pump can be air to the water heat pump. This way there would be no need for drilling the wells and the total cost would be 260 000 HRK lower, but the efficiency would be also lower for both heating and cooling. Average seasonal COP for air source heat pumps varies between 2.6 and 2.8, depending on conditions and location. It is calculated that the air source heat pump would consume 34.4% more electric energy annually or 56 465.39 kWh/a. Specific data on energy consumption is shown in Table 10.

Table 10. Comparison of SWHP and air-water heat pump

Seawater HP		Air source HP	
424%	489%	260%	280%
Q_h [kWh]	Q_c [kWh]	Q_h [kWh]	Q_c [kWh]
5939.83	0.00	9686.48	0.00
5656.98	0.00	9225.22	0.00
4242.73	0.00	6918.92	0.00
2545.64	180.10	4151.35	314.53
0.00	696.81	0.00	1216.93
0.00	593.22	0.00	1036.02
0.00	492.24	0.00	859.66
0.00	770.68	0.00	1345.94
0.00	926.61	0.00	1618.25
0.00	147.65	0.00	257.87
5656.98	0.00	9225.22	0.00
6505.52	0.00	10 609.00	0.00
30 547.67	**3807.31**	**49 816.20**	**6649.19**
34 354.97		56 465.39	
		64.36%	

Comparing the electricity consumption, air sourced heat pump would consume 64.36% more electricity than SWHP. This is due to the lower efficiency of air sourced HP, which depends on air temperature.

Local coastal energy hub

The local coastal energy hub was formed by SDEWES Centre in Cres-Lošinj Archipelago. This hub aims to disseminate the findings and knowledge gathered during the project implementation, but also to get feedback from stakeholders about potentials for blue energy in the area.

The first meeting of the local hub took place on the 9th of September 2020 in Cres. The project was presented to the stakeholders and experts presented the analysis of the blue energy potentials in the targeted area. Stakeholders previously stated their interest to hear how SWHP compare to the air sourced heat pumps and where can they be implemented, which was presented and discussed during the meeting. The discussion went further on topics of the legal framework and necessary permits. During the meeting, we met stakeholders and got more information on the best pilot locations. Following this meeting we found out about the town hall of Mali Lošinj and that it could be a pilot location for the project. During the organization of this meeting, SDEWES collaborated with Island Development Agency (OTRA) from Cres, and an agreement was made that OTRA will help with the organization of the next meetings and the second local conference of the project.

The second meeting took place in the Mali Lošinj townhall together with city representatives and experts working on SEADRION and BLUE DEAL projects. They presented their experiences with SWHP in Croatia. City representatives sent us all necessary documentation for heating, cooling and building construction data before the meeting. They have shown great interest in the project and in the following week, they have agreed to participate in the project with their building.

For the **third meeting,** SDEWES hired a project developer to develop the whole project for the installation of the SWHP in the town hall. During the meeting, he presented the calculations and planned solutions. The meeting was attended by the representative of Energy Institute Hrvoje Požar, which presented a scheme for funding projects utilizing the energy of the sea by EEA and Norway Grants. Main stakeholders were interested in the development and the project was slightly modified according to the comments.

On the **4th and last meeting,** the project developer presented the final project, investment costs and savings. Analysis was made including the funding that would come from EEA and Norway Grants. The call for projects was published before this meeting and a representative of EIHP came to present the final call and its requirements.

Meetings of the local hub were held live in Cres (1st) and the town hall of Mali Lošinj. They had a key role in the preparation of the project and this feasibility study. They had a major role in the dissemination of knowledge and experience gathered during the COASTENERGY project, but also experiences from other similar projects. Specific barriers were lockdowns and strict measures implemented because of the COVID-19 pandemic. We had to plan the meetings in a short period according to lockdowns and we were limited on the number of attendees.

Conclusion

This project would replace old heating and cooling systems with new ones that would use a seawater heat pump. This way, the annual cost for heating would be reduced by 39.972 HRK (5.302 EUR). Still, if we consider the only financial return of investment, considering only saving on energy costs, this project wouldn’t be feasible, since the return of investment period is 27,5 years with EU funding included. Another benefit is lowering CO_2 emissions by 32,8 tonnes every year. Half of the cost would go for replacing of old heating and cooling system in the outdated building. This way comfort in the building would be raised since now some rooms don’t get enough heat. On the other hand, cooling demand is not met during the warm summer days. With the new system, there would be no need to import heating oil every season, which is more difficult since the town hall is on the island and the delivery truck needs to come via the pedestrian pathway.