Feasibility study of the implementation of renewable energy sources at the marine sports port in Ploče

WP4 Creating multi-level Hubs to define joint strategies & local actions supporting coastal Blue Energy

D 4.3.1. Feasibility studies for Coastal Energy projects in pilot areas

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City of Ploče

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ABSTRACT

The task is being implemented as part of the COASTENERGY project with the aim of determining the potential for the use of marine energy in ports and urban coastal areas, and the City of Ploče has selected the future building of the Sports Port in Ploče for this task. According to the conceptual design for the building of the sports port in Ploče, for the first phase of construction, the optimal technical system for the production of the required energy has been determined.

Two variant solutions for the building were analyzed. Variant A is a sports building with accommodation capacity (hostel) with a total gross area of 1,523 m^2.

For variant A, six combinations of technical systems were analyzed, seawater-water heat pump in combination with photovoltaic system (1), LPG condensing boiler in combination with photovoltaic system (2) and in combination with solar thermal collectors for different collector surfaces (3 and 3a), and an air-to-water heat pump in combination with solar thermal collectors (4) and a photovoltaic system (4a). In the financial cost-optimal analysis for variant A, the most favorable solution is A3a (condensing boiler 151 kWth on LPG, compression chiller 80 kW, air conditioning chamber (1,500 m^3/h) with heat recovery 80%, solar thermal collectors 382 m^2). The global cost is 5,671 kn/m^2, and the primary energy is 119 kWh/m^2.

Variant B is a sports building with a cafe with a total gross area of 1,211 m^2.

For variant B, five combinations of technical systems were analyzed, seawater-water heat pump in combination with photovoltaic system (1), LPG condensing boiler in combination with photovoltaic system (2) and in combination with solar thermal collectors (3), and heat pump air - water in combination with solar thermal collectors (4) and photovoltaic system (4a). In the financial analysis for variant B, the most favorable solution is B2 (Condensing boiler 90 kWth on LPG, compression chiller 70 kW, air conditioning chamber (1500 m^3/h) with heat recovery 80%, photovoltaic system 13.9 kWp). The global cost is 4,078 kn/m^2, and the primary energy is 68 kWh/m^2. Combinations with a gas boiler room and the use of liquefied petroleum gas are only

feasible if the position of the boiler room is changed to have an exit to the field and be located next to the outer wall.

In the financial analysis for variant B, the most favorable solution is B2 (Condensing boiler 90 kWth on LPG, compression chiller 70 kW, air conditioning chamber (1500 m3 / h) with heat recovery 80%, photovoltaic system 13.9 kWp). The global cost is 4,078 kn/m^2, and the primary energy is 68 kWh/m^2.

According to the multicriteria analysis, the optimal technical solution for both variants is the seawater / water heat pump system, ie solution A1 and B1. These combinations do not have the lowest global cost compared to other combinations, but achieve significantly lower primary energy, CO2 emissions, operating costs and have a higher share of renewable energy sources. Variant A1 is a seawater / water heat pump (151 kWth (10 ° C / 45 ° C)) with waste heat recovery, an air conditioning chamber (1500 m3 / h) with 80% heat recovery and a 13.9 kWp photovoltaic system. The global cost is HRK 6,521 / m2 or a total of HRK 5,627,903, and the primary energy is 98 kWh / m^2 and the annual emission is 0 tCO2. Variant B1 is a combination of seawater / water heat pump 104.7 kWth (10 ° C / 45 ° C)) with waste heat recovery, air conditioning chamber (1500 m3 / h) with 80% heat recovery and 13.9 kWp photovoltaic system. The global cost is HRK 4,681 / m^2 or a total of HRK 2,565,188, and the primary energy is 14 kWh/m^2 and the annual emission is 1 tCO_2.

The construction of the sports and tourist complex Ploče is financially demanding and that EU funds are desirable to co-finance its construction. Option A, where the total estimated investment is HRK 13.46 million, is more financially viable, as it has a positive net present value (HRK 6.7m) and an internal rate of return (6.7%) higher than the discount rate used (4%). Option B, where the total estimated investment is HRK 9.32 million, is not financially viable and has a negative cumulative cash flow (HRK -2.3 million) and a rate of return (2.3%) lower than the discount rate used (4%). In addition to the financial cost-benefit analysis, there is a positive impact on reducing CO2 emissions that can be expressed in money. The result is similar, as the economic analysis applies an economic discount rate of 5% which is higher than the financial discount rate of 4%. Economic NPV in variant A is HRK 3.9 million with an IRR of 6.8% and in variant B is NPV - HRK 3.2 million with an IRR of 2.4%.

1. Description of the task

The task is carried out within the COASTENERGY project with the aim of determining the potential for the use of marine energy in ports and urban coastal areas by examining possible conflicts and opportunities through the involvement of local and transnational stakeholders on both sides of the Adriatic Sea.

The City of Ploče has chosen the future building of the sport marine port in Ploče for this task. According to the conceptual design for the building of the sport marine port in Ploče, for the first phase of construction, a model will be made for the required energy for heating, cooling, ventilation, and lighting according to the conditions for nearly zero energy buildings. Energy simulations will be performed for different combinations of energy supply systems and the investment cost will be determined for:

- application of conventional heating/cooling sources;
- implementation of seawater heat pumps independently and in combination with solar panels;
- in a small part, the possibilities of implementing wave converters in the breakwater will be considered, with consideration of the preconditions for the implementation of wave energy technologies and possible next steps.

Through multicriteria analysis, the optimal technical solution will be selected that has the lowest total global cost (HRK/m^2) and the lowest primary energy (kWh/m^2), produces on-site energy from available renewable sources and achieves satisfactory internal thermal comfort.

2. Description of the Sports Port in Ploče

2.1. Project context

The city of Ploče has a strong tradition of water sports. The first sailing club was founded in Ploče in the mid-1950s, and it is generally known that the kayak national team members of the former state came to this area on their own initiative for sports preparations. So in the 1960s came the idea of building a sailing club and later a home of water sports, a building that would contain more sports: sailing, rowing, water polo, sport fishing, diving in one place. Initially, the space was planned in the city center along the coast where small auxiliary sports facilities were once located. As time passed and the city expanded more and more, the coast became a new waterfront with public and residential facilities, and the new planned sports complex was never realized. With the abolition of the military port zone, a new space was opened for the development of the long-awaited home of water sports - Sports port. The center of the city of Ploče is located south of the scope of the project and currently there is no mutual pedestrian contact along the coast. The previous purpose of this zone dictated the closed and isolated location and there was no need for any connection with other parts of the city.

2.2. Location description

The new sport marine port area is situated in the NW end of Ploče city area (43°03'28.0"N, 17°25'42.7"E), in the area previously used as military technical workshop. The area is located in the cadastral municipality of Ploče and includes parts cadastral parcels no. 418/1, 418/2, 806/1, 807, 797/1 and 797/2. The building is located on part of cadastral parcel no. 418/1, while other parts of the project (coast and promenade) are located on the other listed parcels. In order to perform the project, it will be necessary to carry out parcelling, which will harmonize the scope of the project with the situation in the cadastre.

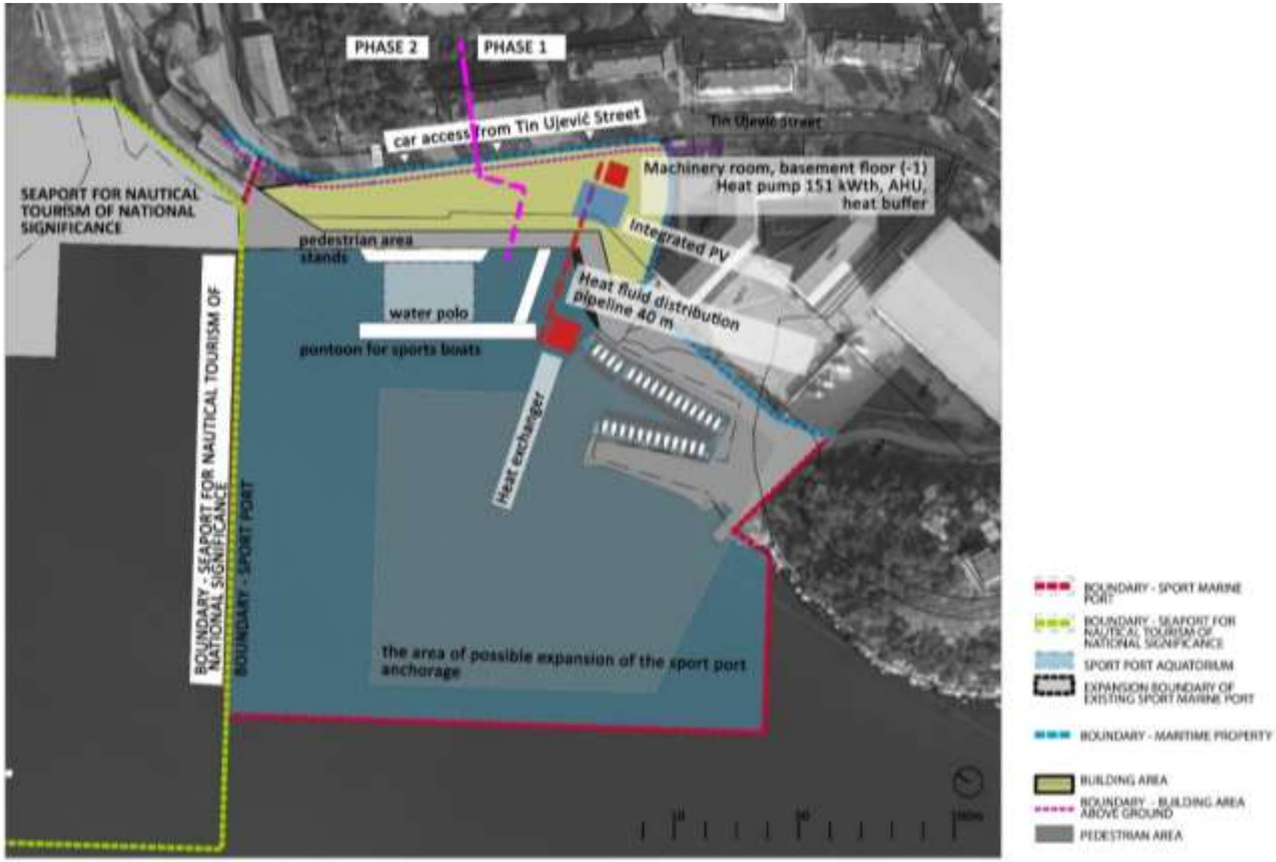

Figure 2-1 Site map

2.3. Building design

The building is set as a basement volume that fully meets the height of the non-level between the access street Tina Ujevića (elevation approx. +5 m to +3 m) and the coast (elevation +0 m). Within this volume are located all the main and ancillary facilities of sports clubs, primarily rowers and sailors, as well as locker rooms for water polo players, a gym, a small gym and a lecture hall. The spaces are dimensioned in such a way that the content overlaps in order to obtain a high concurrency of use and the team to maximize the potential of the building. Recreationalists are also planned as users of the building.

The roof of the designed building is shaped like a public square. The empty and hard-to-reach area of the new sports port thus becomes the extension of Tin Ujević Street and the accessible public square, which with its levels enables a series of connections between the coast level and the street on the east side of the perimeter. In this way, the project enables the continuation of the existing hiking and biking trail that would stretch from the city center to the newly planned nautical tourism port. In addition to the area for pedestrians and cyclists, there are several parking spaces on the square, and in terms of construction, a cube within which there is a catering space on the lower floor, and on the first floor there is accommodation for visiting athletes in the form of hostels.

2.4. Description of the building

The construction of the building will be divided into two phases. This Study will analyse Phase 1, which is located in the southern part of the site and includes sports facilities, a snack bar and hostel as indoor spaces, and a square along Tina Ujevića Street and a promenade along the coast as open spaces. At the basement level (coast level) there is a rowing pool, changing rooms and common areas of sports clubs as well as accompanying facilities (sports boat storage and technical areas). The snack bar and hostel are located on the three upper levels. The total net area of the building is 1,327 m^2, the gross area is 1,523 m^2, while the total area of heated space is 863 m^2. In energy simulations, this solution will be variant A.

2.5. Description of analysed variants

The conceptual solution is currently in the initial phase of research into the possibilities of development and potential of the space. In the existing variant, the number of storeys and purpose is not harmonized with the new spatial plan, so it will be analysed with a solution in a reduced scope, without hostels, while all other facilities remain the same. For variant B, the total heated space is 548 m^2.

3. Legal-regulatory framework

For the implementation of the project, it is necessary to meet the conditions in the field of construction, environmental protection and use of maritime property. The use of sea thermal energy does not have special treatment in Croatian legislation (special regulation, chapter or provision of law) nor special or simpler approval procedures are provided for such projects. Also, there is no single point in charge of issuing all relevant information and performing or coordinating administrative procedures related to the use of marine energy. Therefore, it can be said that the use of sea thermal energy is subject to general regulations relating to other renewable energy projects (which includes sea energy), and the administrative procedure for issuing permits for energy use should include a number of institutions at state and local level. Nevertheless, the peculiarity of arranging these projects stems from the fact that they are planned and implemented on the maritime demesne, which in the Croatian legal system enjoys a special ownership status and emphasized environmental protection.

The permitting process can be divided into interrelated, intertwined and agreed phases such as project planning and environmental assessment of the project, determining the spatial acceptability of the project and special conditions for connecting infrastructure, obtaining a concession for the use of maritime demesne, approval of construction and construction, issuing permits for performing energy activities, etc. Each of these phases will be described below with a brief overview of the relevant regulations, the necessary acts and the actions required to obtain them.

3.1. Acceptability of the environmental procedure

The area of the environmental and nature protection in the Republic of Croatia is regulated by the Environmental Protection Act (Official Gazette no. 80/13, 78/15, 12/18, 118/18) and the Nature Protection Act (Official Gazette no. 80/13, 15/18, 14/19, 127/19). The Environmental Protection Act specifically recognizes and elaborates the protection of the sea and the coastal area. The Nature Protection Act regulates the assessment of the acceptability of a plan, program or intervention for an ecological network.

According to Regulation on Environmental Impact Assessment (Official Gazette no. 61/14, 3/17), the implementation of environmental impact assessment is mandatory for power plants greater than 100 MW, while for plants for the production of electricity, steam and hot water with a capacity of more than 10 MW, it is necessary to conduct an assessment of the need for environmental impact assessment for which the Ministry of Economy and Sustainable Development (MESD) is responsible.

Conclusion: The seawater intake for the Sports Port of Ploče has a heat pump system whose power is lower than those specified in the Regulation, so it is not mandatory to carry out procedures in the field of environmental and nature protection.

3.2. Spatial planning documentation

The following spatial planning documents are valid for the spatial coverage of the project in the city of Ploče:

- Spatial plan of the Dubrovnik-Neretva County (Official Gazette of the DNC, No. 6/03, 3/05.-harmonized, 3/06.*, 7/10., 4/12.-corrected., 9/13. , 2/15.-harmonized, 7/16, 2/19, 6/19.-consolidated text, 03/20 and 12/20.-consolidated text)
- Spatial plan of the City of Ploče (Official Gazette of the City of Ploče No. 3/17, 1/18, 6/21)

The Spatial plan of the City of Ploče defines in more detail the elements important for the implementation of the project in Articles 239, 239.a. and 239 b.

Article 239

paragraph (2)

The length of the operational shore of the sports port is about 65 m, and the total area of the sports port is approximately 2.94 ha, of which the land part is 0.65 ha, and the sea part 2.29 ha. 4 piers are planned, but not less than 2 and a total of 175 berths for boats up to 11m long. The total length of the piers can be up to a maximum of 220 m, and the width of an individual pier cannot be less than 2.4 m. The maximum allowed width of the pier is a maximum of 3.5 m. Exceptionally, the pier can be wider if it proves necessary for technical reasons .

paragraph (3)

1. It is possible to expand the coast in the part where it is necessary (stretch or travel lift) by building a coastal wall - operational shore and embankment, and in the part between the piers by embankment and fortification of the shore with stone cover.
2. the construction of piers must not be carried out by embankment but on pillars (pylons) or as floating piers (pontoons), so as to ensure the greatest possible circulation of the sea
3. The pontoon piers referred to in subparagraph 2 may be anchor systems designed as a classic chain system or anchor system based on rubber inserts
4. The shoreline can be performed as a low-reflective sloping shore with a stone lining
5. It is possible to set up floating stands for the needs of the water polo court in the port, separate from the location of the berths of the sports port vessel
6. The spatial unit of the sports port must have adequate access to the public transport area and within it the corresponding number of parking spaces
7. The construction of a sports port is possible only after ensuring an adequate water supply
8. Wastewater drainage must be solved by a closed sewage system with treatment
9. It is possible to connect the wastewater drainage of the sports port to the public drainage system of the City of Ploče, in accordance with the conditions of the competent authority.

paragraph (4)

Within the scope of the land part of the sports port (including the part that is on the land part of the maritime domain), reconstruction and conversion of following facilities into facilities necessary for the activities of the sports port, i..e for landscaping, is planned:

1. Club premises of sports clubs (rowing, diving, sailing, water polo, fishing and other sports and recreational activities intended for the local population),
2. Dry berths on an area of approximately 4000 m^2,
3. Boat maintenance service and workshop;

4. Trade, storage and accompanying catering, sports, recreational and other facilities
5. The buildings referred to in this paragraph may have a flat roof
6. The flat roof of the buildings referred to in this paragraph may be designed as a passable terrace, which may in part serve as a public footpath which will connect the coastal strip (lungomare) of the sports port with the urban area forming an uninterrupted pedestrian flow.
7. at the level of the city street, at the level of the flat roof of the building referred to in subparagraph 6 of this paragraph, it is possible to realize traffic at rest in accordance with the provisions of this Plan
8. for the realization of the public pedestrian road referred to in subparagraph 6, buildings may be located on the regulation direction of the city street that passes directly above the sports port, provided that the constructive and property-legal relations between the city street and the planned building are not disturbed.

paragraph (5)

conditions and method of construction within the mainland part of the sports port:

1. The area of the mainland part of the sports port is 0.65 ha
2. Deviation from the area defined in subparagraph 1 of this paragraph is possible on the basis of precise geodetic measurements and according to the conditions in the court
3. The maximum coefficient of construction (kig) is 0.5
4. The maximum utilization coefficient (kis) is 1.0
5. The coefficients referred to in subparagraphs 3 and 4 shall be calculated on the surface of the land part of the sports port
6. The maximum permitted number of storeys is two above-ground floors
7. The height of the hangar for sailboats is a maximum of 12 m
8. It is possible to build a basement floor as a completely buried underground floor
9. The underground part of the building referred to in subparagraph 8 may be built up to the edge of the building plot and the regulation line, if the same is technically feasible

10. Within the mainland part of the port, spaces for the contents referred to in paragraph (4) of this Article, accommodation of ships of sports associations, service spaces, catering spaces shall be provided

11. The service areas referred to in subparagraph 10 must be located on the lower floors of the building

12. When designing buildings, it is necessary to keep the views from the level of the city street towards the sea as much as possible

13. It is necessary to provide the required number of parking spaces in accordance with the norms of this Plan

14. It is possible to arrange a pedestrian and bicycle path by the sea in order to connect the city and the port of nautical tourism

15. Access to emergency and service vehicles and access to coastal transport vehicles shall be provided.

paragraph (7)

It is allowed to issue acts for construction and granting concessions for the sports port „Pod cestom“ on the basis of this spatial plan.

Article 239a.

For the sports port "Pod cestom", as a seaport with more than 100 berths, before obtaining the construction act, it is mandatory to conduct an assessment of the need for environmental impact assessment.

Article 239b.

(1) When obtaining construction acts for the sports port "Pod cestom", it is necessary to prepare a maritime study in accordance with the Decree on the conditions that ports must meet and determine the boundaries of the maritime domain.

(2) The maritime study referred to in paragraph (1) of this Article shall determine the optimal position in the bay, the type, coverage and acceptable number of berths and the method of anchoring, as well as protection measures.

Conclusion: The conceptual solution is currently in the initial phase of research into the possibilities of development and potential of space. In the existing variant, the number of storeys and the purpose are not harmonized with the conditions defined in

Article 239, paragraph 5 of the valid Spatial plan of the City of Ploče, and the solution will need to be adjusted to the further stage of project preparation.

3.3. Construction, location, construction and use permit

According to Building Act (Official Gazette no. 153/13, 20/17, 39/19, 125/19), the contractor may start construction based on a building permit under the responsibility of the investor even after the construction has been previously registered. The building permit for the construction of a building is published to inform the public and the interested public on an electronic bulletin board for at least 30 days.

Proof of legal interest in issuing a construction permit in respect of real estate on which the acquisition of real rights is not possible or according to a special law the right to build is acquired by concession is considered to be a concession contract by which the right to build is acquired.The building permit ceases to be valid if the investor does not start construction within 3 years from the date of validity of the permit.

The use permit is issued based on the investor's request after the performed technical inspection and trial operation if it is determined that all the prescribed

The planned scope of the project is located on the cadastral parcels as follows:

- part of cadastral parcels 418/1, 418/2, 806/1, 807, 797/1 and 797/2, where the ownership is as follows:
- 418/1 - Ministry of Defense of the Republic of Croatia, where the building is located;
- 418/2 - maritime property, where the coast and promenade in front of the building are located;
- 806/1 - City of Ploče, where the promenade is located;
- 807 - public good, sea coast, where the promenade and the coastal part of Spot port are located;
- 797/1 - City of Ploče, where the promenade and the coastal part of Spot port are located;

- 797/2 - maritime property, where the promenade and the coastal part of Spot harbor are located.

As ownership issues and re-parcelling have not been resolved, in the process of obtaining permits, it is necessary to prepare a conceptual design and obtain a location permit first. The location permit will resolve ownership issues and consents for the use of the space, where the Port Authority being responsible for the maritime domain. It is also necessary to obtain the consent of the Ministry of Defense of the Republic of Croatia, which will transfer ownership to the City of Ploče with additional contracts. Within the documentation of the conceptual design, a geodetic project is made which forms the future parcel of the sports port, and as a basis for the same is the valid spatial planning documentation. After obtaining the location permit, according to the geodetic project, a valid building parcel is formed and the ownership is resolved.

The further process includes the preparation of the main project according to the phasing of the project, which is defined by the location permit. It will be possible to obtain a building permit either simultaneously for both phases or for each phase individually as the investor decides.

Conclusion: at the current stage of project development, appropriate construction documentation is not available.

According to the Ordinance on technical standards for the design, construction, operation and maintenance of gas boilers, Art. 13., the gas boiler room should be located in a space that has one external wall, with window surface of 1/8 of the boiler room area and a door that opens to the outside (terrain level). It is also necessary to determine the position for the placement of LPG tanks. In the current conceptual design, the boiler room is in the underground part of the building, so the above stated conditions are not met. If one of the combinations of the liquefied petroleum gas heating system is chosen, it will be necessary to adjust the conceptual design.

3.4. Concession for the use of maritime property

The implementation of projects that use the sea as a source of renewable energy presupposes interventions in the sea and the seacoast, i.e., maritime demesne, which have a special status in Croatian legislation in terms of ownership regime, conditions of use and prominent environmental protection. For such interventions, it is necessary to obtain a concession for special use or economic exploitation of maritime demesne according to Concessions Act (Official Gazette, no. 69/17, 107/20), Maritime Demesne and Seaports Act (hereinafter: MDSPA) (Official Gazette, no. 158/03, 100/04, 141/06, 38/09, 123/11, 56/16, 98/19) as a special law and Regulation on granting concessions on maritime demesne (Official Gazette no. 23 / 04, 101/04, 39/06, 63/08, 125/10, 102/11, 83/12, 10/17). Annual plan for the management of maritime demesne in the Dubrovnik-Neretva County is adopted based on the Maritime Domaine and Sea Ports Act, following a previously conducted public consultation, which also determines the tasks of granting concessions on maritime property.

Concessions on maritime demesne are granted by decision, based on public bidding or at the request of the concessionaire, in accordance with the concession policy, implementation of maritime demesne,valid spatial planning documentation and regulations on environmental and nature protection.The concession for the economic use of maritime demesne and for the use or construction of buildings of importance to the county is granted by the County Assembly for a maximum period of 20 years, and the preliminary procedure is carried out by the competent administrative body in the county. The concession agreement regulates the scope and conditions of special use or economic use of the maritime domesne. Based on the authorization of the Assembly of the Dubrovnik-Neretva County, the city of Ploče independently grants concessions on maritime property in its area.

Conclusion: the project uses the maritime good for the construction of the building and for the water intake for the heat pump and it is necessary to carry out the procedure for obtaining a concession before obtaining a building permit.

4. Analysis of natural conditions of the location and technology of using sea energy

The City of Ploče is characterized by features of a Mediterranean climate with mild and rainy winters and hot and dry summers. Natural geographical features, such as the Neretva River valley, which extends deep into the interior, the proximity of the mouth of the Neretva River, the karst edge, the vicinity of the sea, the configuration of the terrain, the relative natural saturation from the sea influences have affected specific climatic local features, thus shaping the microclimate of individual areas. In the following, the natural conditions characteristic of the observed area of construction of the sports port in Ploče are analysed and presented, including wind, waves, sea currents and bathymetric data. In addition, the available technologies for the use of marine energy are described, as well as the potential for their application considering the natural potential of the site.

4.1. Natural conditions analysis of the location

4.1.1. Wind analysis

The wind analysis is based on Global Wind Atlas, which is a free, web-based application developed to help policymakers, planners, and investors identify high-wind areas for wind power generation virtually anywhere in the world, and then perform preliminary calculations. The current version of the Global Wind Atlas (GWA 3.0) is the product of a partnership between the Department of Wind Energy at the Technical University of Denmark (DTU Wind Energy) and the World Bank Group (consisting of The World Bank and the International Finance Corporation, or IFC).

The Global Wind Atlas has global onshore coverage and offshore coverage up to 200 km from the shoreline. The wind resource mapping is given at 10, 50, 100, 150 and 200 m above ground/sea with the horizontal grid spacing of 250 m. Users can assess the wind resource for a given point, over a custom area, or within a country or first administrative unit (state/province/etc.). GIS data for all layers are available for download as well as WAsP LIB files. The referent value presented by the GWA is the mean value for 10% of the windiest areas. Also, it is possible to get averages of over the whole surface (100% area) up to the 2% of the windiest areas, which can be considered asa maximum value for a chosen location. Additionally, the data obtained from GWA do not refer to a chosen point but to an area of dimensions 3 km ×3 km (9 km2), where the selected point is the centre of area.

The analysis of the wind over the described platform was performed for the city of Ploče, more precisely the area of the future sports port in Ploče. The table below (Table 4-1) shows two types of data: mean wind speed and mean wind power density for 100%, 10% and 2% of the windiest area in the range from 10 m to 100 m above sea level. It is important to note that the wind measurements that are the foundation of GWA were conducted in the period from 2008 to 2017. Therefore, GWA typically displays a inter-annual average of wind speed and wind power density.

Table 4-1 Average inter-annual wind speed and wind power density in the sports port in in the city of Ploče

Altitude [m]	Share of the windiest area [%]	Mean wind speed [m/s]	Mean power density [W/m^2]
10	2	5,48	346,76
50	2	7,28	656,23
100	2	7,86	695,87
10	10	4,73	225,32
50	10	6,58	493,12
100	10	7,40	584,20
10	100	3,25	92,99
50	100	5,10	248,15
100	100	6,05	336,12

4.1.2. Wave analysis

The wave analysis is based on a publicly available database developed within the Maestrale project (Sustainable Blue Energy in the Mediterranean). Maestrale was conducted in the period 2014-2020 as an Interreg MED 2014-2020 Programme co-financed by the European Regional Development Fund. The University of Siena (UNISI) was coordinating a consortium of 10 partners from Italy, Greece, Malta, Spain, Portugal, Croatia, Slovenia and Cyprus. At the time, the limited progress in concrete initiatives and operating plants in the Mediterranean area has been detected despite off numerous of academic and technical studies already conducted in the field of offshore renewable energy. Therefore, the Maestrale project has been launched to lay the foundation for a strategy in maritime renewable energy deployment in the Mediterranean. The project partners cooperated to analyse the maritime renewable energy potentials in their countries with regards to their physical, legal, technological, economic and social contexts. The main achievement of Maestrale is in formation of a network of local enterprises, public authorities, knowledge institutions and citizens with common goal of planning plan concrete strategies for maritime energy growth. A set of pilot projects in each participating country was envisaged as a mean for awareness raising and social acceptance to increase the feasibility of future maritime energy initiatives.

The Maestrale database gathered existing data collections provided by project partners and provides access to open geographical data on maritime renewable energy potential. The database provides a reliable and up-to-date informative support to decision-makers and investors, setting the basis for the development of maritime energy initiatives in the Mediterranean area. The database link is http://maestrale-webgis.unisi.it/.

Figure 4-1 graphically shows the inter-annual average of the wave power for the observed area. In the figure shown, it can be seen that the average wave power in the analysed area does not exceed the value of 0.1 kW/m. The inter-annual average of the wave height for the analysed area does not exceed the value of 0.3 m, which can be seen in Figure 4-2, while the inter-annual average of the wave period does not exceed the value of 3.4 s (Figure 4-3).

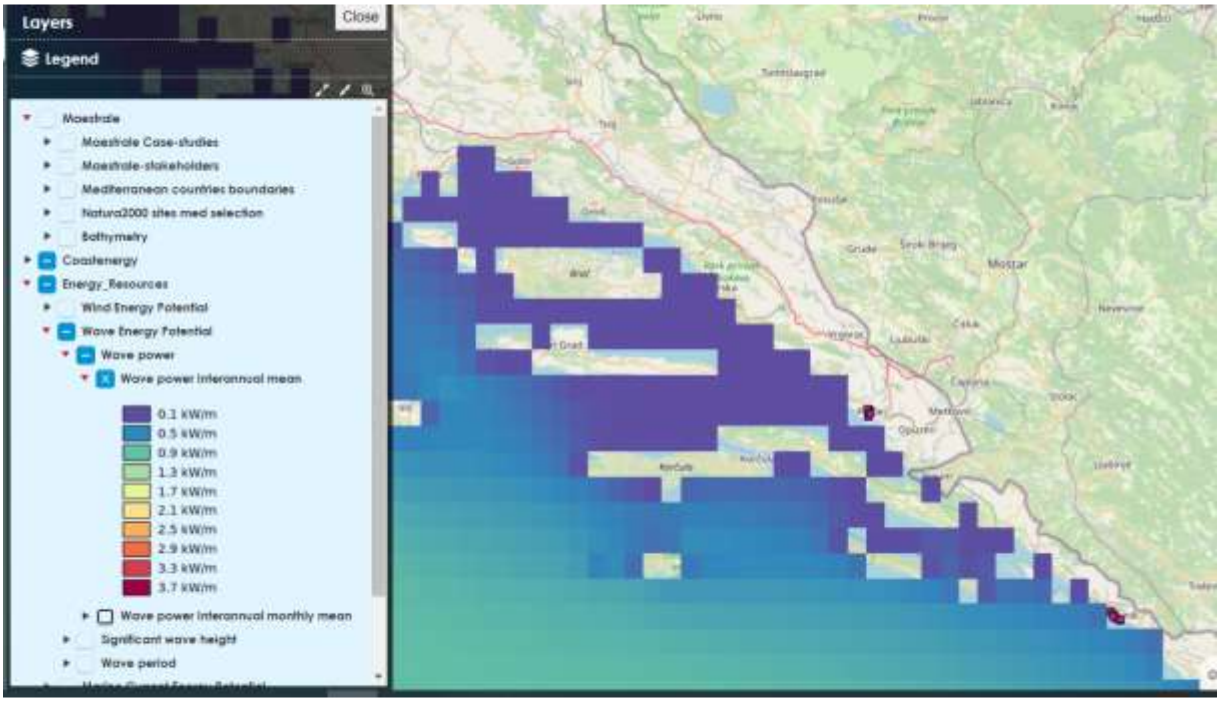

Figure 4-1 Inter-annual average of wave power in the area of the city of Ploče

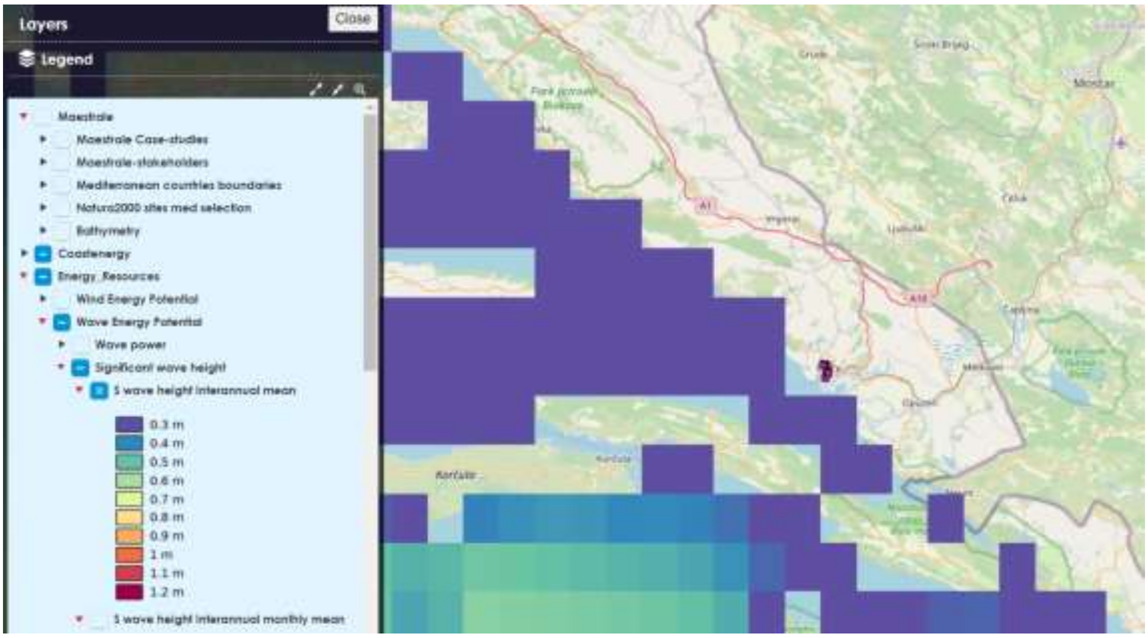

Figure 4-2 Inter-annual average of the wave height in the area of the city of Ploče

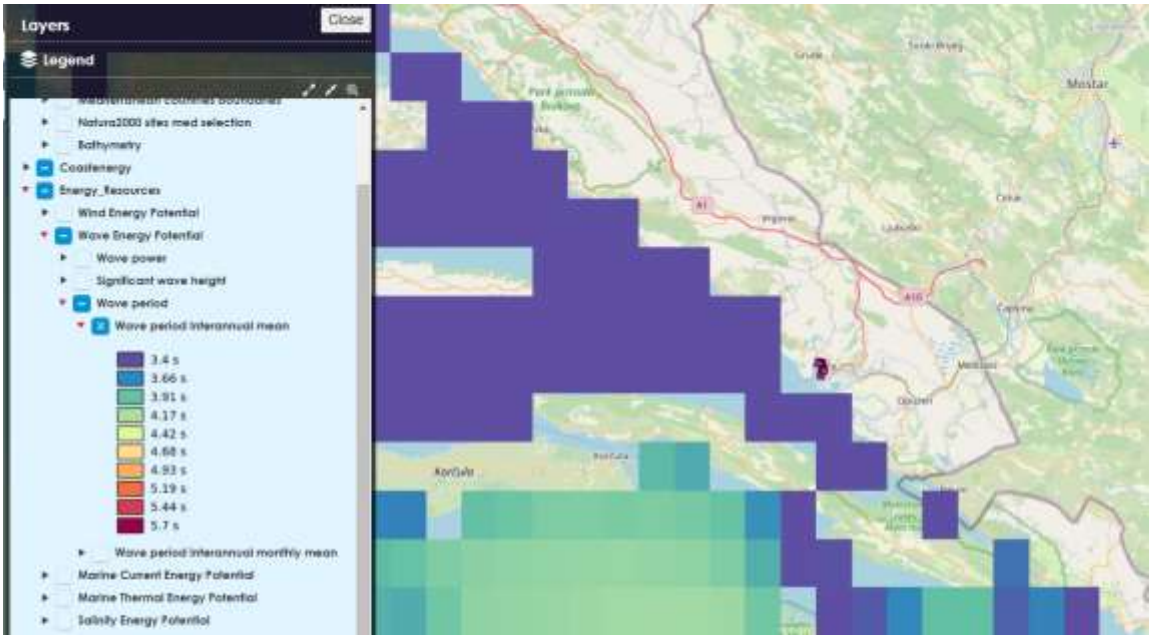

Figure 4-3 Inter-annual average of the wave period in the area of the city of Ploče

On the maps shown in the figures above, it is possible to select any place and get the average monthly values of power, height and period of the wave. Given the unavailability of data in the immediate vicinity of the sports port, the nearest location for which monthly data are available was selected, and these are shown in the table below (Table 4-2).

Table 4-2 Monthly averages of wave power, wave height and wave energy period in the area of the city of Ploče

Month	Wave power [kW/m]	Wave height [m]	Wave energy period [s]
January	0,0291	0,1507	2,6087
Februray	0,0316	0,1636	2,4086
March	0,0235	0,1410	2,4053
April	0,0170	0,1187	2,4593
May	0,0131	0,1030	2,5065
June	0,0099	0,0889	2,5494
July	0,0123	0,1006	2,4859
August	0,0112	0,0959	2,4883
September	0,0096	0,0876	2,5641
October	0,0145	0,1074	2,5695

Month	Wave power [kW/m]	Wave height [m]	Wave energy period [s]
November	0,0213	0,1306	2,5562
December	0,0195	0,1262	2,5005

4.1.3. Sea temperature analysis

Sea temperature data were obtained from: https://seatemperature.info/. According to the above data, the average annual sea temperature is 18.78°C. The table below shows the average, minimum and maximum monthly sea temperature in Ploče, which were calculated based on the data over the past 10 years.

Table 4-3 Average, minimum and maximum monthly sea temperature in Ploče

Month	Average temperature [°C]	Minimum temperature [°C]	Maximum temperature [°C]
January	14,1	12,6	16,1
Februray	13,2	11,3	14,3
March	13,3	12,0	14,7
April	14,9	12,8	18,8
May	18,4	15,4	23,1
June	22,4	18,3	25,8
July	24,7	22,1	28,2
August	25,3	22,8	28,3
September	23,2	19,3	26,5
October	20,7	17,2	23,7
November	18,7	16,2	21,6
December	16,3	13,8	18,9

4.1.4. Analysis od sea currents

The kinetic energy of the moving seawater is governed by the mutual moon and sun gravitational attraction, and the earth's rotation. It is also strongly affected by their relative position as well as by the coastal geography, seabed bathymetry, and movements of large volumes of sea waters around the seas and oceans. Consequently, the tidal energy potential is distributed quite unevenly around the globe. The tidal range of the Mediterranean Sea, including the Adriatic Sea, is almost negligible as compared to the tidal ranges typical for areas like Canada, the United

Kingdom, Portugal, Chile, China, and Australia that can reach up to 17 m, resulting in seawater flow rates of up to 4 m/s. An intensive and systematic geophysical research of the Adriatic Sea as a closed system, carried out between 2002 and 2006, included extensive data collected using Automated Meteo-Oceanographic Station and Acoustic Doppler Current Profilers. It was ascertained that the sea currents reach about 0.2 m/s in the Split archipelago, 0.32 m/s at the open sea off the Dugi Otok Island, and approximately 0.1 m/s at the North Adriatic. However, a necessity for more detailed databases was recognized and a detailed analysis of the tidal currents in the Adriatic Sea as measured by surface drifters was performed. The Adriatic Sea surface was well covered, except between Croatian islands. It was concluded that the tidal forcing is strongly affected by the oscillating sea level at the Otranto Channel and that the governing tidal effects correspond to the semidiurnal lunar tide (M2), the semidiurnal solar tide (S2), and the lunisolar declination (K1) resulting with sea current flow aligned with the main axis of the Adriatic Sea. The flow strength is increasing near the Istrian Peninsula reaching the top depth-averaged velocity of about 0.066 m/s (M2) being the peak flow velocity detected by drifters, Figure 4-4.

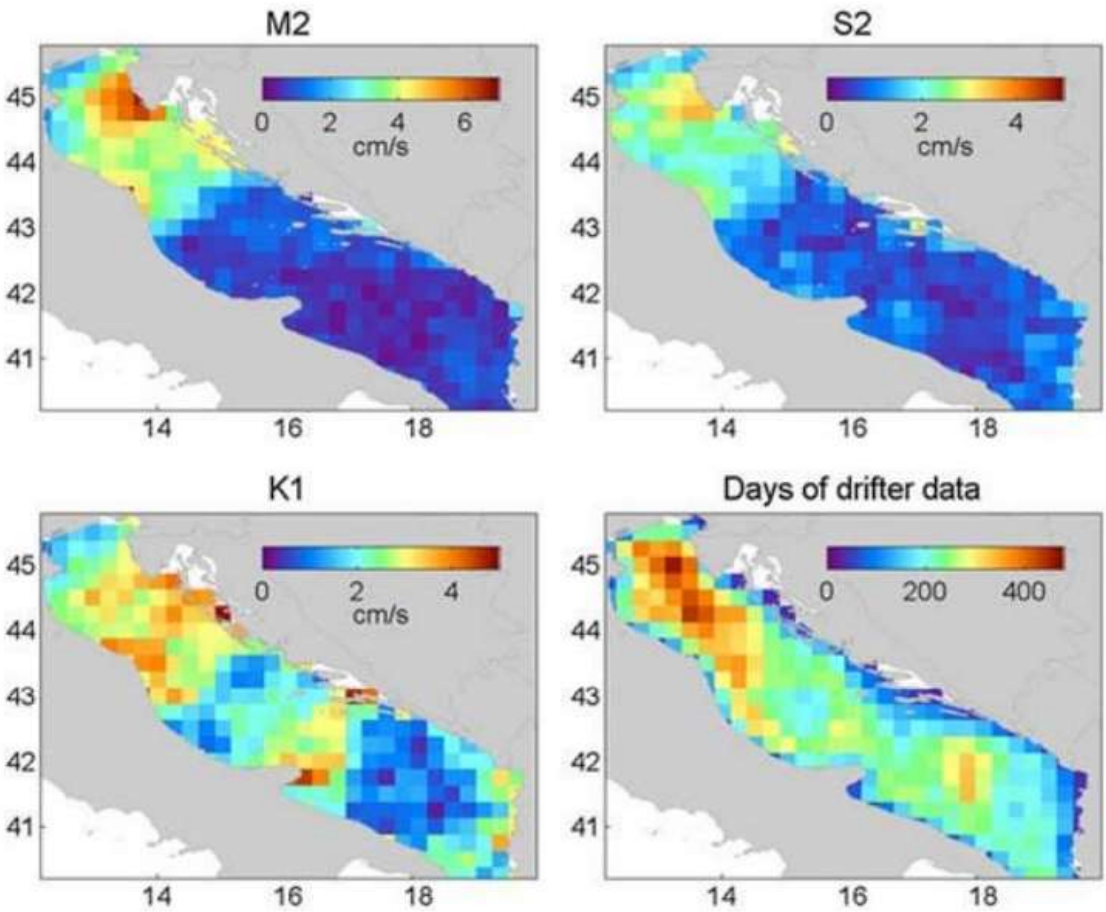

Figure 4-4 Tidal current velocity in the Adriatic Sea, M2, S2, and K2 component; days of drifter data (Poulain, PM (2013) Tidal currents in the Adriatic Sea as measured by surface drifters, Journal of Geophysical Research, 118, pp. 1434-1444.)

A more detailed view of the sea currents of the Adriatic Sea, both in territorial and data terms, is available in a prognostic format based on the application of ROMS (Regional Ocean Modeling System) numerical model which, with Boussinesqu approximation, solves Navier-Stokes equations on a given geographic network (Source: https://bora.gekom.hr/karte.php?page=more). The model, applied in the case of the Adriatic Sea, takes into account the 7 lunisolar components of tides, freshwater inflows and the influence of wind on the characteristics of surface currents. In this sense, the basic results of the model are a five-day forecast of the speed and direction of surface currents, as well as the average value of the vertical profile of sea currents. An example of prognostic data of surface current characteristics and vertical profile of sea currents is shown in figures below for the case of the southern Adriatic.

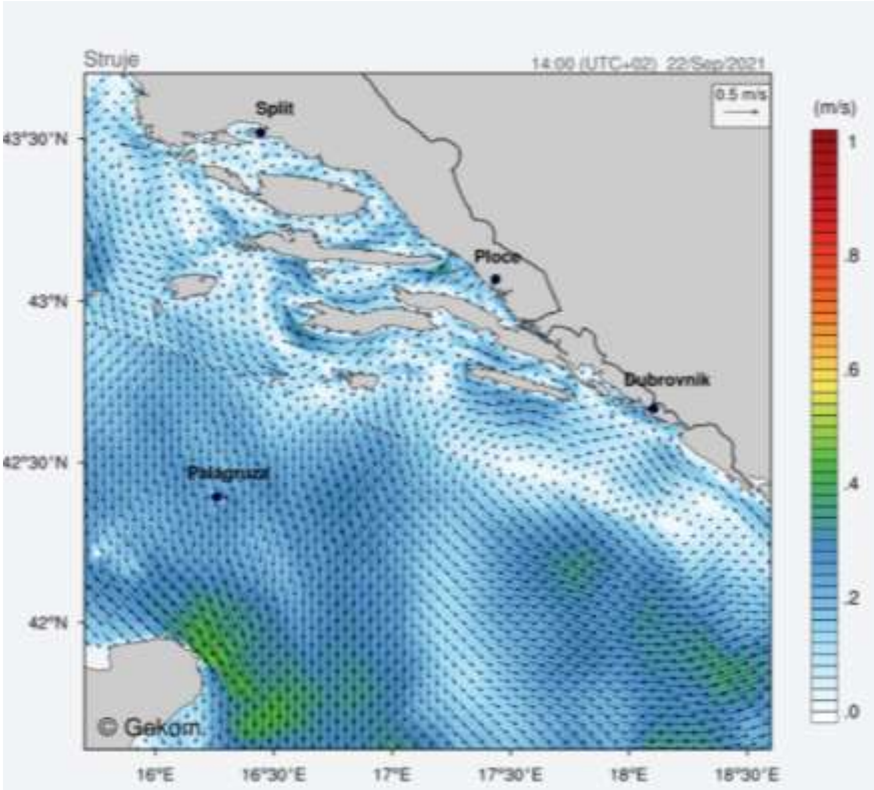

Figure 4-5 Surface velocity and direction of sea currents in the southern Adriatic

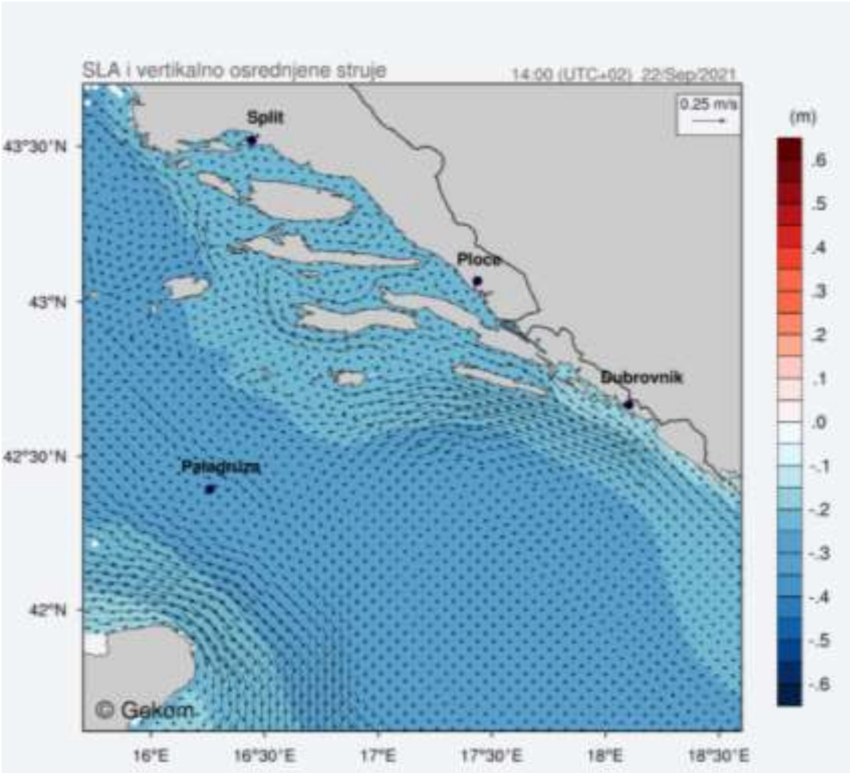

Figure 4-6 Average speed and direction of the vertical profile of sea currents in the southern Adriatic

4.1.5. Bathymetric data

The Adriatic Sea's average depth is 259.5 meters, while its maximum depth of 1,233 meters is placed at its southern part. Bathimetric data for the area of the sports port in Ploče were taken from the database of the European Marine Observation and Data Network (EMODnet) and are graphically shown in Figure 4-7. From the graphic presentation, it is possible to notice that the sea of the coastal area of the city of Ploče is quite shallow, and is approximately 5 m, while the depth of the sea at a distance of 50 m is approximately 13 m.

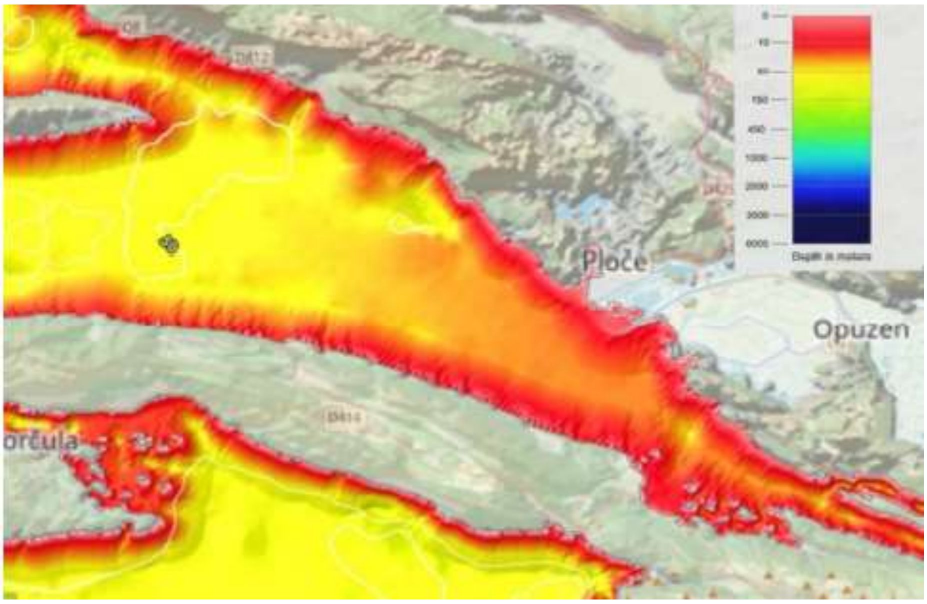

Figure 4-7 Bathymetric data for the area near the city of Ploče

4.2. Technologies for the use of marine thermal energy

The seawater thermal energy can be used for heating and cooling of facilities along / near the shore by implementing heat pump systems with seawater as a heat storage tank. Seawater heat pump systems are systems in which the heat pump uses the seawater as a heat source or sink, ie a heat storage tank - in the heating mode, the system uses the heating energy of the sea water as a renewable heat source, while in the cooling mode it transfers the heat taken from the space to the seawater as a heat sink. Due to the seawater corrosivity, seawater does not transfer heat directly via a heat pump evaporator, but previously via a corrosion-resistant intermediate exchanger to fresh water which then flows to the evaporator. The heating energy on the evaporator is then transferred to the refrigerant and rises to a higher energy level, and then transferred to the heated space. The reverse process applies to the operation of the heat pump in cooling mode.

There are two versions of the heat pump system with seawater as a heat storage tank: open and closed version (Figure 4-8). In the case of an open system, the seawater is pumped directly from a certain depth through a pipeline laid into the sea, which returns it, while in the closed version the glycol mixture exchangers are placed in the sea without seawater contact with the heat pump system. Both designs ensure equal system efficiency, but the closed version is initially more expensive because it involves more extensive installation work. On the other hand, the application of open versions is limited in areas with very cold climates as water freezing can occur, as well as the pipelines themselves laid in the sea.

Figure 4-8 Open (left) and closed (right) version of the seawater heat pump system

The target seawater intake depth for the operation of seawater heat pumps is 0 - 20 m. The higher the depth of the sea, the lower the annual water temperature changes. The considered depth of the sea is considered as the surface layer of the sea, and the temperature changes in this layer are called thermohaline properties of the sea. An example of the sea temperature profile for the Gargano - Split route in the summer and winter months is shown in the figure below. It can be observed that at a sea depth of 20 m the sea temperature varies in the range of 13 °C to 20 °C for the Split location, which is an annual temperature change of only 7 °C.

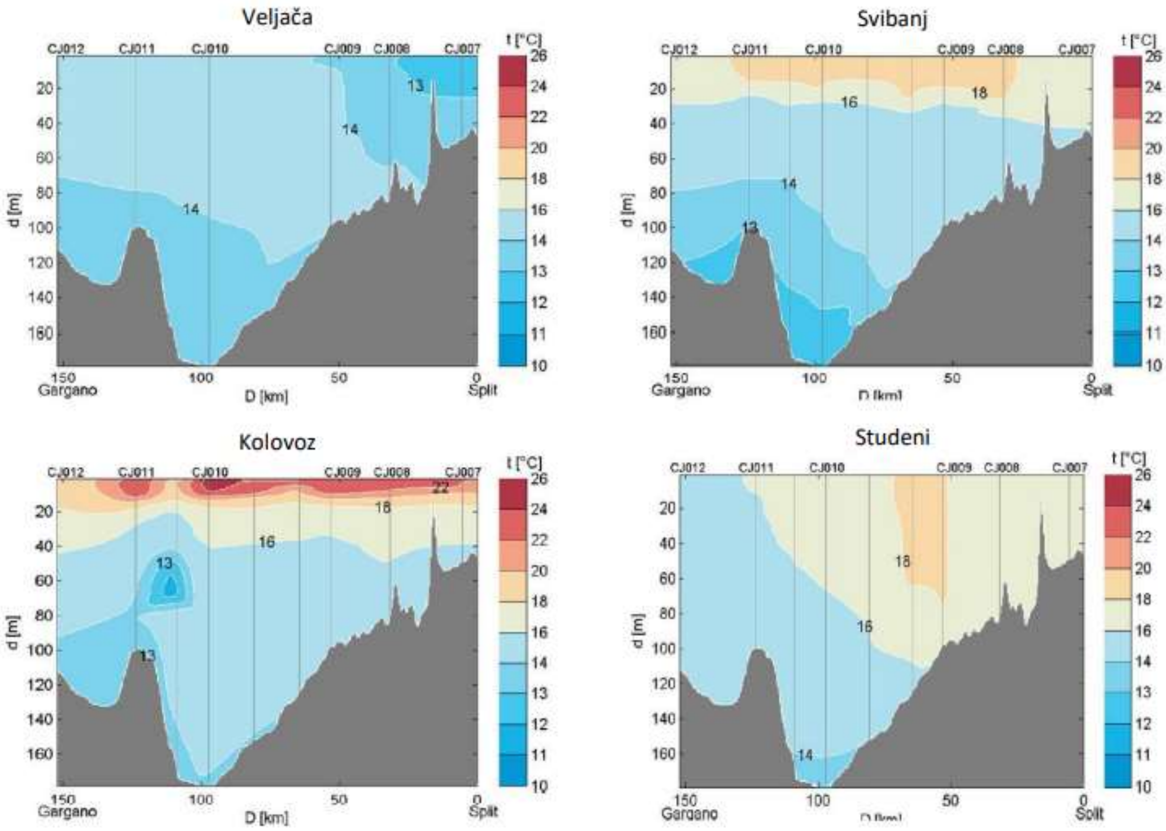

Figure 4-9 Gargano - Split sea temperature profile depending on sea depth in summer and winter

Seawater intake is one of the most important parts of a seawater heat pump system since continuous and stable operation of the heat pump depends on continuous, stable and sufficient seawater inflow. The characteristic seawater intake system consists of a suction pipeline and its associated suction port and a protective grille around it, pumps and a return pipeline. Currently, there are two ways of seawater intake for the purposes of the heat pump operation: direct seawater intake at a certain distance from the coast, and seizure of water from wells by the sea, ie on the coast itself. Direct seawater intake involves the intake of seawater directly from the sea at a certain depth and distance from the coast. It consists of a suction pipeline and its associated suction port and a protective grid around it, underwater pipelines that conduct seawater to the corrosive-resistant heat exchanger and back to the sea, pumping stations and a re-mixer of seawater, from which heat is taken over, with water in the sea. Subsurface seawater intake from wells by the sea is groundwater abstraction from aquifers only a few meters below Earth's surface on or along the coast. This groundwater may be the result of infiltration of seawater through the sandy bottom to wells by the sea or mixing of fresh, inland water and infiltrated, saline seawater. Seawater wells are constructed as vertical or horizontal, depending on the heating and cooling requirements, ie the required amount of seawater. In addition to water intake by vertical and horizontal wells, water collectors laid on the seabed, through which a sand filter layer is deposited, are applied which then prevents the entry of biological micro and macro-organisms.

4.2.1. Examples of good practice for implementing heat pumps

The increase in the implementation of seawater heat pumps has been noticed in the last ten years due to the application of low-carbon energy strategy and the recognition of seawater as a renewable energy source. But, the implementation of seawater heat pump systems began in the 1970s and 1980s worldwide. With more than 180 large systems installed, northern Europe is at the forefront of implementing seawater heat pump systems, with Sweden and Norway among the largest users. The largest seawater heat pump system is located in Ropsten, Sweden and is used for district heating and cooling in Stockholm. The 250 MW heating system covers 60% of Stockholm's thermal energy needs. It has been in operation since 1987 and can provide the flow temperature of the district heating system up to 80 °C. In addition to the above system, the following are additional examples of the implementation seawater heat pump systems (Table 4-4). Data on nominal heat and cooling capacities, efficiency coefficients, costs and payback periods are presented, for examples where data were available.

Table 4-4 Examples of seawater heat pump implementation project

Name of the building	Nominal heat/cooling capacity [kW]	COP/EER	Costs
Faculty of Maritime Studies and transport, Portorož, Slovenia	66 / 55	3.26 / 3.02	≈ 30.000 €, payback period of about 7 years
Sport hall „Fotis Kosmas Stadium“, Alexandroupolis Municipality, Greece	95 / 80	4.30 / 4,70	Heat pump 83,000 €, fan coils 20,000 €, operating costs 50,467 €, payback period around 4.7 years
Rector's Palace, Dubrovnik, Croatia	6 x 72 / 6 x 70	-	Investment costs 510,000 €, maintenance costs 20,000 €

Name of the building	Nominal heat/cooling capacity [kW]	COP/EER	Costs
Municipal building, Izola, Slovenia	79 / 67	4.40 / 4.70	Estimated costs. closed circle - 169,500 €; well - 126,400 €
District heating and cooling in Stockholm, Ropsten, Sweden	250,000 / 74,000	2.60 / 3.20	-
Rolfsbukt plant, Fornebu, Norway	2 x 16,000	-	-
Hotel Royal Blue, Dubrovnik, Croatia	2 x 417 / 333	4.90 / 3.90	-
	1 x 258 / 207	5.11 / 4.11	-
Hotel Le Meridien Lav, Split, Croatia	3 x 1,000*	4.00/ 3.00	-
Falkensteiner hotel,Croatia	3 x 1,200*	4.00 / 6.90	-
Hotel Amalia, Nafplio, Greece	740 / 566	4.77 / 3.65	-

*Data on nominal heat capacity

4.3. Wave energy technologies

Wave energy coverters (WECs) convert the kinetic energy of waves into electricity, and can be divided into several categories. Firstly, they can be divided by the design and how they extract the energy from the waves. Since the technology is still in the research and development stage, an optimal design is yet to be found. Moreover, due to the different sea characteristics over the globe, it is expected that one-design fits all may not be viable, and several concepts could finally emerge to a commercial level. The most prominent designs at the moment can be divided into the following order:

- Attenuator - a floating device that operates parallel to the wave direction and effectively rides the waves. These devices capture energy from the relative motion of the two arms as the wave passes them;
- Point absorber - a floating structure that absorbs energy from all directions through its movements at/near the water surface. It converts the motion of the buoyant top relative to the base into electrical power. The power take-off system may take many forms, depending on the configuration of displacers/reactors;
- Oscillating wave surge converter - It extracts energy from wave surges and the movement of water particles within them. The arm oscillates as a pendulum mounted on a pivoted joint in response to water movement in the waves;

- Oscillating water column (OWC) - It is a partially submerged, hollow structure. It is open to the sea below the waterline, enclosing a column of air on top of a water column. Waves cause the water column to rise and fall, which compresses and decompresses the air column. This trapped air is allowed to flow to and from the atmosphere via a Wells turbine, which can rotate regardless of the airflow direction. The rotation of the turbine is used to generate electricity;
- Overtopping/Terminator device - It captures water as waves break into a storage reservoir. The water is then returned to the sea, passing through a conventional low-head turbine which generates power. An overtopping device may use 'collectors' to concentrate the wave energy;
- Submerged pressure differential - These devices are typically located near shore and attached to the seabed. The waves' motion causes the sea level to rise and fall above the device, inducing a pressure differential in the device. The alternating pressure pumps fluid through a system to generate electricity;
- Bulge wave - This technology consists of a rubber tube filled with water, moored to the seabed heading into the waves. The water enters through the stern, and the passing wave causes pressure variations along the tube's length, creating a 'bulge'. As the bulge travels through the tube, it grows, gathering energy that can be used to drive a standard low-head turbine located at the bow, where the water then returns to the sea;
- Rotating mass - Two forms of rotation are used to capture energy by the device's movement, heaving and swaying in the waves. This motion drives either an eccentric weight or a gyroscope causes precession. In both cases, the movement is attached to an electric generator inside the device.

Furthermore, wave energy converters can be divided according to the place of use into the following: shoreline devices, near-shore devices and off-shore devices. Their advantages and disadvantages are described below:

- Shoreline devices - integrated into a natural rock face or man-made breakwater having the advantage of both being close to the utility network and contributing to the energy supply of the hosting infrastructure, and of a relative easiness of maintenance. Less likely to be damaged as energy is lost due to friction with the seabed; on the other side, the potential resource that could be captured is reduced;

- Near-shore devices- located in water shallow enough to allow the device to be fixed to the seabed via pinned pile foundations or gravity mass. This, in turn, provides a suitable stationary base against which an oscillating body can work. Disadvantages are similar to shoreline devices;
- Offshore devices - located in water tens of meters deep and tethered to the seabed using tight or slack moorings mass. Much greater potential energy resource versus near-shore but more challenging to construct, operate, and maintain. Besides, it must be designed to survive more extreme conditions. However, they present the advantage of contributing to incoming waves' attenuation, thus representing a protection measure for the coast. This potential versatility of WECs and their visual impact lower than that of offshore wind farms make them interesting for the Mediterranean environment and for small islands in particular, where the touristic fruition of the locations must also be preserved.

From the view of technology readiness for deployment, the shoreline devices have the brightest perspective to reach the commercial level in the short, mid-term. The following are examples of good practice in the implementation of wave energy converters.

4.3.1. Examples of good practice in the implementation of wave energy converters

As was already mentioned, various concepts have been developed so far, even though the vast majority still haven't been proven in an operational environment. Most notable projects or devices, which have already reached or are about to reach a commercial scale of development, are presented in the Table 4-5. The division is made by the concept design. As can be seen, at the moment, floaters that can be incorporated into coastal infrastructure are the most popular design with several projects at a high technological readiness level. The OWC concept gained significant attention, with several projects in the high stage of implementation. Finally, attenuators and point-absorbers are also very popular among R&D laboratories since they offer an opportunity to extract greater wave energy potential.

Table 4-5 The most significant projects using wave energy

Name of the project	Concept design	Short description of the project
Pelamis	Attenuators	Location: Portugal, one of the first devices developed and tested in real operating conditions; Delivery of 22.5 MWh of electricity to the grid; It is no longer in use
SWEL	Attenuators	Tests conducted in laboratory and marine conditions, and the full-size prototype is currently being tested in a French laboratory; The main advantage is the cost of energy produced around 1 p / kWh (pence per kWh), compared to the reference value of 80 p / kWh (pence per kWh) for similar devices
ISWEC	Point-absorbers	100 kW prototype; The most significant advantage is the control of the flywheel speed, which allows compliance with external wave conditions resulting in increased productivity
PEWEC	Point-absorbers	Development is still at an early stage with laboratory tests; The devices consist of two parts; the upper part is held at a smaller depth than the other
SeaRev	Point-absorbers	The capacity of the device is 250 kW (third generation SeaRev G3); the first farm with 40 devices was installed in the sea on the island of Yeu in France; high installation costs as well as equipment maintenance costs
REWEC3	OWC	The first prototype was installed in the city of Civitavecchia in the central Italian region of Lazio, Italy; The results showed that REWEC3 absorbed (on average) 50% to 70% of the incident wave power, with a maximum loads between 70%-90%
WaveSax	OWC	The concept is still under construction, but shows great prospects due to low cost and simplicity of design
OBREC	Over-topping devices	The main advantage: the possibility of installation on existing or newly planned breakwaters; Technology proven in the relevant environment, further work on capacity expansion and commercialization is expected; The prototype was installed in the port of Naples
Eco Wave Power	Floaters	It attracted a great deal of attention and was promoted as one of the most promising WEC devices for near-commercial use, with two 5 MW power plants in Gibraltar and 10 MW in the United Kingdom; Electricity generation costs are approximately 42 €//MWh, which makes it fully competitive with other renewable energy sources
Triton II	Floaters	Developed in Greece and tested in the prototype phase in laboratory and actual operating conditions; potential for further application due to low installation and operating costs and simplicity of design
GEL system	Floaters	The nominal power of one float is about 60 kW, a minimum wave height of 1.5 meters is required;

Name of the project	Concept design	Short description of the project
SINN Power	Point-absorbers	Two generations of point absorbers: rated power of 24 kW and 36 kW; The devices have been successfully tested in the port of Heraklion, and future plans are focused on increasing the rated power and testing in harsh conditions on the high seas.
ECOMar	Floaters	Details on the design and specifications of the device are not publicly available
CETO	Submerged pressure differential	It is completely submerged below sea level; can work at greater depths, thus being protected from stormy conditions and without visual impact; nominal capacity of 20 MW with the potential for future expansion to 100 MW
Wave2Water	Submerged pressure differential	Rated power between 100-150 kW; is designed to survive extreme conditions, but also to produce electricity at lower medium wave heights
Butterfly	Rotating mass	The concepts were tested on a small scale with a nominal power of 7 kW, with further prospects for a 700 kW device prototype; The device should have a capacity to use wave heights between 0.5-5 meters
The Penguin	Rotating mass	The device has been tested for several years in extreme conditions and has fully met expectations; rated power between 0.5-1 MW; the project almost reached a commercial level of readiness.

4.4. Application of technology of using wave energy and seawater thermal energy in the sports port of Ploče

In order to determine the justification and cost-effectiveness of installing a system with an energy converter in the breakwater - REWEC, a techno-economic analysis is performed for the selected pilot area, shown in Table 4-6. Analysis was carried out on the basis of the previously analysed available energy potential of waves in the area of Ploče, available data on the characteristics of the system, and the assumption of the length of the breakwater in the amount of 50 m. Taking into account the above parameters and the level of technological readiness of the device to use the potential of wave energy, it can be concluded that there is currently no economically justified potential for technology installation. . This can be supported by the fact that the average annual velocity of sea currents and the height of the wave do not meet the initial parameters required for the operation of technologies at a satisfactory level of load factors. From the above, it can be concluded that the energy produced during the lifetime of the device, cannot justify the amount of investment cost and therefore the technology of using wave energy at this time is not appropriate for the selected area. In order to achieve the necessary conditions for the economic viability of the technology, it is necessary to reduce investment costs and significantly improve working conditions from the perspective of the minimum technical requirements for starting the device.

Table 4-6 Techno-economic of justification and cost-effectiveness of installing a system with and energy converter in the breakwater in the sports port of Ploče

	Item	Amount	Unit
Available wave energy potential			
1.	Specific wave power at the annual level	0.0177	kW/m
2.	Maximum specific wave power (February)	0.0316	kW/m
3.	Minimum specific wave power (September)	0.0096	kW/m
4.	Breakwater length	50	m
System characteristics			
5.	Rated power of Wells turbine	2	kW
6.	The absorption capacity of device	0.6	-
7.	Number of devices	1	-
8.	Unit installation cost	6,000	€/kW
Actual energy conversion			
9.	Available wave energy capacity	0.89	kW
10.	Power at the REWEC output	0.53	kW
11.	Total annual energy production	4,640	kWh
Total costs			
12.	Total investment cost	90,000	HRK
13.	Simple payback period	24	years

Regarding the sea thermal energy use for heating, hot water preparation and cooling by seawater heat pump technology in the city of Ploče, there is a great potential. The seawater temperature very rarely drops below 10 °C, which provides a higher amount of heat pump heating factor compared to heat pumps that use air as a heat source, i.e. less energy is required to operate the heat pump. In addition, we are in a period of climate change and the fight against fossil fuel supplies, where the ultimate goal should be to reduce CO2 emissions and increase the use of renewable energy sources, and in particular to achieve energy independence, what the seawater heat pump system fully enables. In addition, through the presented examples of good practice, it can be noticed that seawater heat pumps in Croatia are taking an increasing share in heating, DHW preparation and cooling. More detailed technical and economic analyses for the application of this technology for heating, DHW preparation and cooling of the sports port in Ploče will be presented below.

5. Conditions for nearly zero energy buildings

The Construction Act and the Technical Regulation on the Rational Use of Energy and Thermal Protection in Buildings (Official Gazette no. 128/15, 70/18, 73/18, 86/18, 102/20) transposed the requirements of European legislation regarding energy efficiency in building, the inclusion of renewable energy sources in technical solutions of energy supply systems, as well as the construction standard according to the conditions for nearly zero energy buildings (so-called nZEB), which created a favorable legal environment for the implementation of heat pumps.

According to the Technical Regulation on the Rational Use of Energy and Thermal Protection in Buildings (Official Gazette no. 128/15, 70/18, 73/18, 86/18, 102/20), nearly zero energy buildings should meet the following requirements:

- with regard to the use of renewable energy sources, achieve at least 30% of the annual energy delivered for the operation of technical systems in the building obtained for from renewable energy sources. Also, the share of renewable energy sources can be met when at least 60% of the annual energy delivered for the operation of technical systems in the building is provided from an efficient district heating system, or an efficient district heating and cooling system, which uses: at least 50% renewable energy, 50% waste heat, 75% of the heat obtained from cogeneration or 50% of the combination of that energy and heat. Such a centralized heating and/or cooling system is not available in the city of Ploče.
- values of specific permitted annual required heat energy for heating, $Q_{H,nd}$ [kWh/(m^2·a)] and cooling energy $Q_{C,nd}$ [kWh/(m^2·a)], as well as specific permissible values of annual primary energy E_{prim} [kWh/(m^2·a)] should be below the maximum allowed, and according to the purpose of the building and the climatic area in which it is located. Below are the maximum permissible values of specific annual required heat energy and primary energy for new buildings for the purpose of a sports hall and for the purpose of hotels, which are heated

and cooled to a temperature of 18 °C or higher, and are located in coastal part of the Republic of Croatia.

Table 5-1 Maximum permissible values of annual required heat energy fot heating and primary energy for new sports halls and hotels (nZEB) heated and/or cooled to a temperature of 18 °C for the coastal part of the Republic of Croatia

Purpose of building	$Q_{H,nd}$ [kWh/(m²·a)]			E_{prim} [kWh/(m²·a)]
	$f_0 \le 0{,}20$	$0{,}20 < f_0 \le 1{,}05$	$f_0 \ge 1{,}05$	
Hotel and restaurant	11.50	$6.52 + 24.89 \cdot f_0$	32.65	70
Sport hall	37.64	$32.66 + 24.91 \cdot f_0$	58.82	150

5.1. Variants of thermal protection of the building envelope

The specific permitted annual required heat energy for heating, $Q_{H,nd}$ [kWh/(m²·a)], is achieved with the following characteristics of the building envelope structures.

Table 5-2 Overview of heat transfer coefficients for building envelope variant A (sport + hostel)

Construction	Type and thickness of thermal insulation/ glazing characteristics	Heat transfer coefficient accoding to TRRUETPB* U_{max} (W/(m²K)	
		On the building	Maximum allowed
Wall to floor	XPS 8 cm	0.36 0.38	0.45
Wall to the ship's storage (garage)	MV 8 cm MV 12 cm	0.27	0.30
Floor on the ground	MV 8 cm	0.40	0.50
Flat roof facing the square	MV 12 cm MV 14 cm MV 20 cm	0.29 0.28 0.17	0.30
Flat roof towards the green area	MV 20 cm	0.23	0.30
Structural glass rock in the club premises	2 x insulated glass with gas filling, 1 x low-e coating, g= 0,5, aluminum frame with interrupted thermal bridge	1.70	1.80
External wall of caffe and hostel	MV 24 cm	0.14	0.45
Flat roof over heated space	MV 32 cm	0.21	0.30

Structural glass rock in the premises of cafes and hostels	3 x insulated glass with gas filling, 2 x low-e coating, g= 0,5, aluminum frame with interrupted thermal bridge	1.40	1.80

* Technical Regulation on the Rational Use of Energy and Thermal Protection in Buildings

For variant A, the realized total annual required thermal energy for heating is 19,555 kWh or specific $Q_{H,nd}$ is 22.66 [kWh/(m^2·a)]. The building is classified in energy class A. The realized total annual required thermal energy for cooling is 36,607 kWh, or specific $Q_{C,nd}$ is 42.42 [kWh/(m^2·a)].

Table 5-3 Overview of heat transfer coefficients for building envelope variant B (sport + cafes)

Construction	Type and thickness of thermal insulation/ glazing characteristics	Heat transfer coefficient accoding to TRRUETPB* U_{max} (W/(m^{2}K)	
		On the building	Maximum allowed
Wall to floor	XPS 8 cm	0,36 0,38	0,45
Wall to the ship's storage (garage)	MV 8 cm MV 12 cm	0,27	0,30
Floor on the ground	MV 8 cm	0,40	0,50
Flat roof facing the square	MV 12 cm MV 14 cm MV 20 cm	0,29 0,28 0,17	0,30
Flat roof towards the green area	MV 20 cm	0,23	0,30
Structural glass rock in the club premises	2 x insulated glass with gas filling, 1 x low-e coating, g= 0,5, aluminum frame with interrupted thermal bridge	1,70	1,80
External wall of caffe and hostel	MV 7 cm	0,44	0,45
Flat roof over heated space	MV 12 cm	0,29	0,30
Structural glass rock in the premises of cafes and hostels	3 x insulated glass with gas filling, 2 x low-e coating, g=0,24, aluminum frame with interrupted thermal bridge	1,40	1,80

* Technical Regulation on the Rational Use of Energy and Thermal Protection in Buildings

For variant B, the realized total annual required thermal energy for heating is 15,265 kWh or specific $Q_{H,nd}$ is 27.86 [kWh/(m^2·a)]. The building is classified in energy class

B. The realized total annual required thermal energy for cooling is 19,311 kWh or specific $Q_{C,nd}$ is 35.24 [kWh/(m^2·a)].

5.2. Variants of technical solutions for heating, cooling, mechanical ventilation and domestic hot water preparation

Energy simulations were performed for the following energy supply systems according to the conditions for nearly zero energy buildings:

- Seawater source heat pump for space heating, DHW preparation and space cooling. The use of waste heat was also taken into account, as well as the photovoltaic system for electricity generation;
- Condensing boiler on LPG for space heating and DHW preparation, and compression cooler for space cooling. A photovoltaic system is also used to generate electricity;
- Condensing boiler on LPG for space heating and additional DHW preparation and solar thermal system as the basic system for domestic hot water preparation. A compression cooler was used to cool the space.
- Air / water heat pump for space heating, DHW preparation and space cooling, use of waste heat, photovoltaic system for electricity production.

All these systems must meet the requirements for the nZEB standard prescribed by the Technical Regulation on the Rational Use of Energy and Thermal Protection in Buildings (Official Gazette no. 128/15, 70/18, 73/18, 86/18, 102/20). Although the use of fossil fuels is avoided, the combination with a LPG condensing boiler was also analysed to compare the implementation of technologies on RES with respect to conventional heating/cooling sources. Fan coils were used as heating/cooling units for all combinations.

5.3. Lighting system variants

The following variants were analysed:

- Variant I - lighting is solved by high-efficiency integrated LED lamps with a minimum efficiency of 120 lm/W for a color temperature of 3,000 K. The control is solved by local switches with the possibility of central shutdown. Specific spaces such as hallways and toilets have additional control via occupancy sensors.
- Variant II - lighting is solved by high-efficiency integrated LED lamps with a minimum efficiency of 120 lm/W for a color temperature of 3,000 K. The control is solved through the occupancy sensor and the presence of daylight with the possibility of local control via contactors.

5.4. Photovoltaic system and solar collectors implementation

PV of 13.9 kWp are used as power generation system all variants (except the variant with solar collectors), with annual production of approximately 16,800 kWh. In the winter months, electricity generation is about 720 kWh/month, in the summer period about 2,300 kWh/month, while in the transition period it is about 1,600 kWh/month. The electricity produced from PV follows the demand for thermal energy (higher demand for cooling in summer than for heating in winter season) and it can be used for heat pump operation.

Solar collectors as basic DHW preparation systems are used exclusively in combination with LPG condensing boiler. For different combinations, 165,82 and 24 pieces of solar collectors were used, where each of the collectors has an absorption area of 1.8 m^2, and the total absorption area is 382.8 m^2, 148.5 m^2 and 43.2 m^2.

5.5. Results of energy simulations for combinations of technical systems

The results of the calculation of required, delivered and primary energy for different combinations of technical systems are presented. A comparison of the compliance of the combination with the conditions for the standard of nearly zero energy buildings for both variants of the conceptual design of the building was made.

For variant A, the Technical Regulation defines stricter energy efficiency requirements, where the maximum permitted primary energy is 70 [kWh/(m2·a)] for accommodation purposes, while the maximum permitted primary energy is 150 [kWh/(m2·a)] for sports purposes. There is also a greater energy need for domestic hot water preparation due to the large accommodation capacity, so this large amount of energy needs to be produced from renewable energy on site.

For variant A (sports purpose and hostel) only the combination with the seawater heat pump meets the requirements for the nearly zero energy standard. For other combinations of technical systems, a larger free area is required for the installation of renewable energy systems, which cannot be provided on site. The roof of the building is shaped like a square and only a small area of the hostel's roof of 154 m^2 is available for the installation of photovoltaic modules or solar thermal collectors.

Figure 5-1 shows the monthly consumption profile for the optimal technical solution in the version with a sea water heat pump with waste heat recovery and photovoltaic modules for variant A1. When using waste heat to heat domestic hot water, savings of about 10% are achieved on the total delivered energy, while in the case of additional use of photovoltaic modules, the total savings are about 32%.

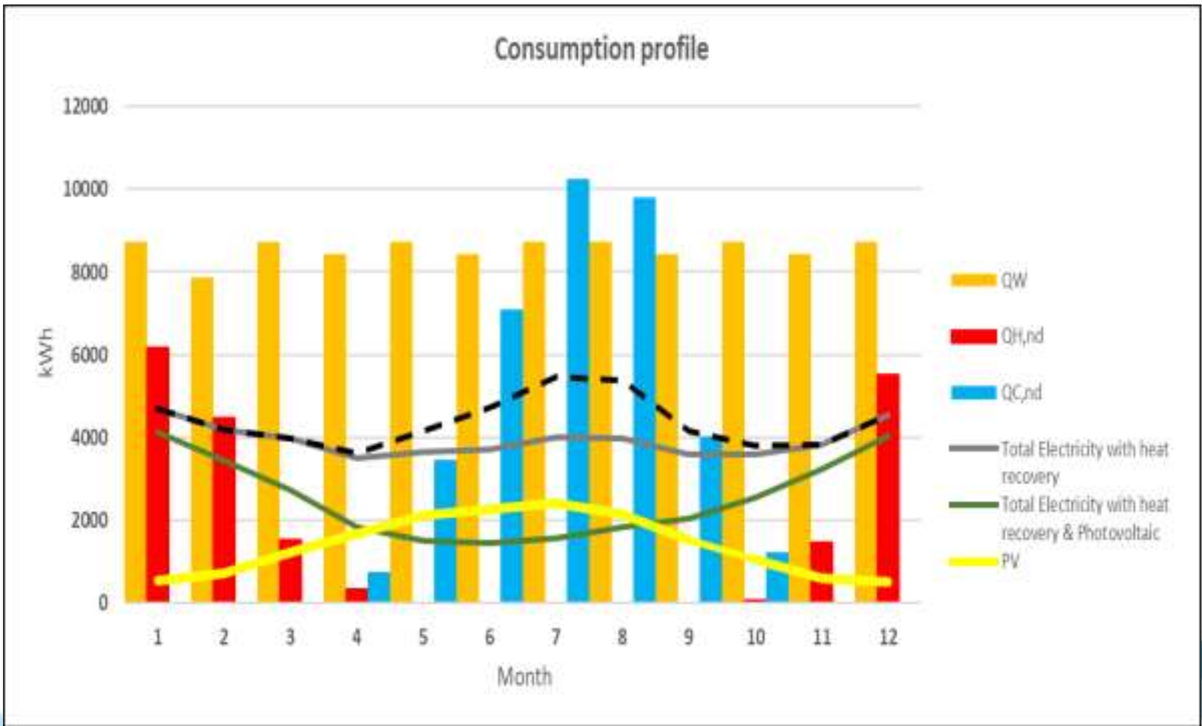

Figure 5-1 Consumption profile for variant A1

By changing the elements of the conceptual design, where another 191 m^2 of roof area (or other areas protected from damage) would be provided, variant A3a (151 kWth LPG condensing boiler, 80 kW chiller, air conditioning unit (1500 m^3/h) with 80% heat recovery, 13,9 kWp PV system, 191 m^2 of solar thermal collectors) meet the requirements for nearly zero energy standard. An additional limitation of the conceptual design for the use of LPG is the current position of the gas enclosure that is buried. According to the Ordinance on technical standards for design, construction, operation and maintenance of gas boilers, Art. 13., the gas boiler room should be located in a space that has one external wall, a window of 1/8 of the boiler room area on the external wall and a door that opens to the outside. It is also necessary to determine the position for the placement of LPG tanks. If a variant of the liquefied petroleum gas heating system is chosen, it will be necessary to adjust the location of the gas boiler room.

By changing the elements of the conceptual design, where another 382 m^2 of roof area (or other areas protected from damage) would be provided, variant A4a with air source heat pump and solar thermal collectors would meet the requirements for nearly zero energy standard.

Table 5-4 Overview of required energy and combination of technical systems for variant A (sport + hostel)

Energy needs in the building of the Sports Port Ploče – variant A	**kWh**	**kWh/m²**	**Max/min kWh/m²**	**System configuration according to the nZEB standard**
$Q_{H,nd}$	19,555	22.66	53.84	
$Q_{C,nd}$	36,606	42.42	50 (70)	
Q_W	102,649	118.94	-	
E_L	4,662	5.4	-	
(A1) 151 kW$_{th}$ (W10/W45) seawater heat pump with heat recovery, air conditioning unit (1500 m3/h) with 80% heat recovery, 13,9 kW$_p$ PV system				**In accordance with the nZEB standard**
E_{del}	42.557	49,31		
E_{del} + PV	31.048	35,98	-	
Edel + PV + waste heat from the seawater heat pump	25.745	29,83		
E_{prim}	41.551	48,15 48,90 64,35	max. accommodation 70 sport 150	
CO_2 emissions	6 t	0.007 t/m²		
RES share	75%	-	min. 30%	
(A2) 151 kW$_{th}$ LPG condensing boiler, 80 kW chiller, air conditioning unit (1500 m3/h) with 80% heat recovery, 13,9 kW$_p$ PV system				**Not in accordance with nZEB standard.**
E_{del}	146.216	169,43		The required area for installation of photovoltaic modules is 350 m², which is not available on site.
E_{del} + PV	138.740	160,77		
E_{prim}	150.845	174,79 167,16 267,55	max. accommodation 70 sport 150	
CO_2 emissions	31,5 t	0,037 t/m²		
RES share	12%	-	min. 30%	
(A3) 151 kW$_{th}$ LPG condensing boiler, 80 kW chiller, air conditioning unit (1500 m3/h) with 80% heat recovery, 382 m² of solar thermal collectors				**(A3a) 151 kW$_{th}$ LPG condensing boiler, 80 kW chiller, air conditioning unit (1500 m3/h) with 80% heat recovery, 13,9 kW$_p$ PV system, *191 m² of solar thermal collectors**
E_{del}	146.216	169,43		146,216 169.43

E_{del} + ST + (PV only in variant 3a)	96.675	96,73		117.841 kWh	112.93 kWh/m^2
E_{prim}	122.552	172,52	max. accommodation 70 sport 150	126.602	119.31 kWh/m^2 70.00 110.31
CO_2 emissions	25,80 t	0,0299 t/m^2		31,12 t	0,036 t/m^2
RES share	27%	-	min 30%	67%	min 30%
(A4) 174,4 kW_{th} (A7/W45) air source heat pump with heat recovery, air conditioning unit (1500 m^3/h) with 80% heat recovery, 43,2 m^2 of solar thermal collectors				**(A4) 174,4 kW_{th} (A7/W45) air source heat pump with heat recovery, air conditioning unit (1500 m^3/h) with 80% heat recovery, 144 m^2 of solar thermal collectors**	
E_{del}	71.378	82,71			
Edel + ST + otpadna toplina	67.649	78,39			
E_{del} + ST (only in variant 4a)				51.510	59,68
E_{prim}	109.185	126,52 125,39 127,56	Max accommodation 70 sport 150	83.137	96,33 69,55 125,39
CO_2 emissions	15,84 t	0,0184 t/m^2		12,095 t	0,0144 t/m^2
RES share	54%	-	min 30%	64%	-

** The area required for the installation of solar thermal collectors is not available on site*

For variant B (sports purpose and cafe) all combinations of technical solutions meet the requirements for the nZEB standard. Although the combination of air-to-water heat pump meets the requirements for an almost zero energy standard, the additional installation of 13.9 kW photovoltaic modules in the B4a variant achieves significant savings in delivered energy of 47%, and also a reduction in CO_2 emissions.

Figure 5-2 shows the monthly consumption profile for sea water heat pump with waste heat recovery and photovoltaic modules for variant B1. When using waste heat for heating domestic hot water, savings of about 12% on the total delivered energy are achieved, while in the case of additional installation of photovoltaic modules, the total savings are about 80%, where in the summer months the building's needs for supplied energy for heating, domestic hot water and cooling are completely met.

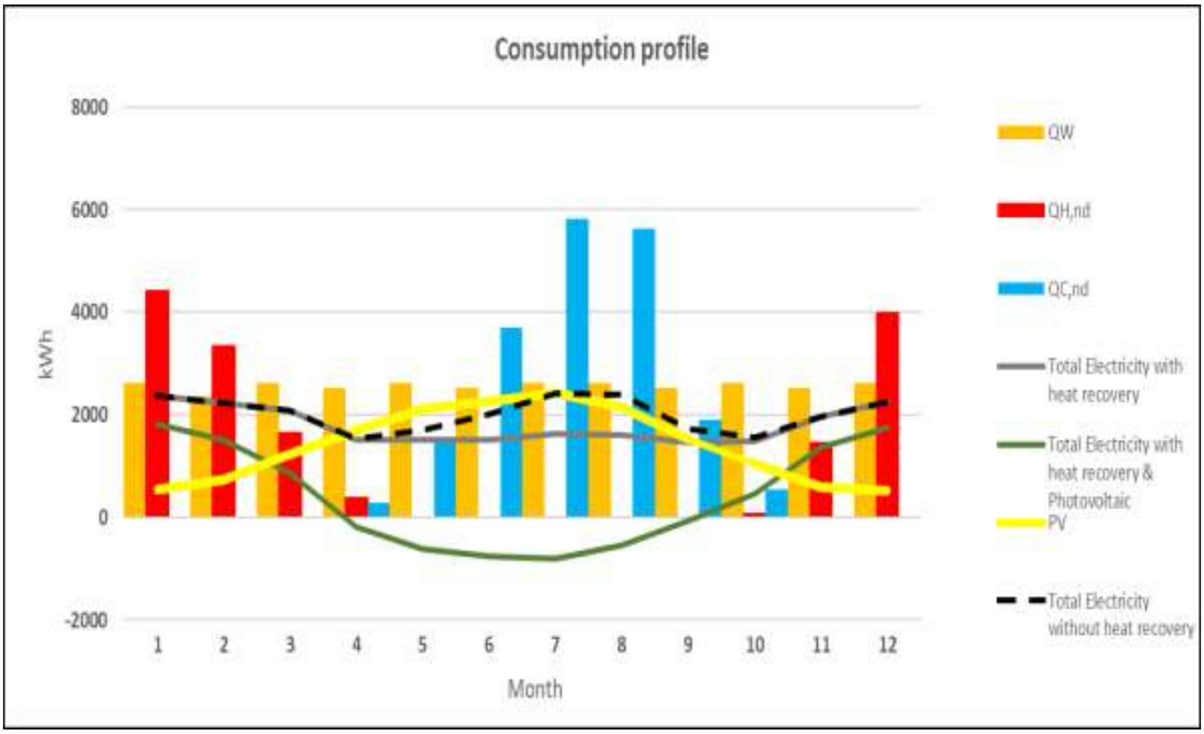

Figure 5-2 Consumption profile for variant B1

Table 5-5 Overview of required energy and combination of technical systems for variant B (sports + caffe)

Energy needs in the building of the Sports Port Ploče – variant B	**kWh**	**kWh/m^2**	**Max/min kWh/m^2**	**System configuration according to the nZEB standard**
$Q_{H,nd}$	15,265	27.86	53.84	
$Q_{C,nd}$	19,311	35.24	50 (70)	
Q_w	30,723	56.07	-	
E_L	3,900	7.11	-	
(B1) 104,7 kW_{th} (W10/W45) seawater heat pump with heat recovery, air conditioning unit (1500 m3/h) with 80% heat recovery, 13,9 kW_p PV system				**In accordance with the nZEB standard**
E_{del}	20.349	37,13	-	
E_{del} + PV	7.436	13,57	-	
Edel + PV + waste heat from the seawater heat pump	4.759	8,68	-	
E_{prim}	7.681	14,02	max 150	

CO_2 emissions	1.11 t	0,002 t/m^2			
RES share	70%	-	min 30%		
(B2) 90 kW_{th} LPG condensing boiler, 70 kW chiller, air conditioning unit (1500 m^3/h) with 80% heat recovery, 13,9 kW_p PV system				**In accordance with the nZEB standard**	
E_{del}	58.852	107,39	-		
E_{del} + PV	42.040	76,72	-		
E_{prim}	40.015	73,02	max 150		
CO_2 emissions	9,72 t	0,018 t/m^2			
RES share	31%	-	min 30%		
(B3) 90 kW_{th} LPG condensing boiler, 70 kW chiller, air conditioning unit (1500 m^3/h) with 80% heat recovery, 43.2 m^2 of solar thermal collectors				**In accordance with the nZEB standard**	
E_{del}	58.852	107,39	-		
E_{del} + ST	37.953	69,26	-		
E_{prim}	43.010	78,49	max 150		
CO_2 emissions	8.682 t	0,0158 t/m^2			
RES share	40%	-	min 30%		
(B4) 104,8 kW_{th} (A7/W45) air source heat pump with heat recovery, air conditioning unit (1500 m^3/h) with 80% heat recovery				**(B4a) 104,8 kW_{th} (A7/W45) air source heat pump with heat recovery, air conditioning unit (1500 m^3/h) with 80% heat recovery, 13,9 kW_p PV system**	
E_{del}	35.433	64,66	-	35.433	64,66
E_{del} + waste heat from the air source heat pump	32.002	58,40	-	-	-
Edel + PV	-	-	-	18.621	33,98
Edel + PV+ waste heat from the seawater heat pump	-	-	-	15.189	27,72
E_{prim}	51.651	94,25	max 150	24.516	44,74
CO_2 emissions	7.51 t	0,0137 t/m^2	-	3.57 t	0,0065 t/m^2
RES share	44%	-	min 30%	57%	-

5.6. Global cost estimate for combinations of technical solutions

Combinations of technical solutions of the building envelope and energy systems are described through:

- Total global living cost of the building (HRK/m^2) which is the sum of: net present value of the initial investment cost for technical energy systems (thermal protection of the outer envelope, technical systems for heating, cooling, ventilation, domestic hot water preparation and lighting) + operating costs for energy (HRK) + maintenance costs (HRK) + system replacement costs in the 25th year, for the observed period of 30 years. The macroeconomic and financial global cost is presented, where the financial cost represents the actual cost of investment and use of the building in the observed period, while the macroeconomic cost is increased by the cost of CO_2 emissions;
- Annual primary energy consumption (kWh/m^2) which is the energy used to produce the delivered energy for the building. It is determined according to the total amount of energy delivered to the building and national factors for primary energy for individual energy sources;
- Annual CO_2 emissions (tCO_2) from the delivered energy to the building and national emission factors for individual energy sources.

Table 5-6 Overview of cost-optimal analysis results for combinations of technical systems

Combination	Macroeconomic global cost	Financial global cost	Primary energy	CO_2 emissions
	kn/m^2	kn/m^2	kWh/m^2	tCO_2
A1	6.918	6.521	98	0
A2	8.636	6.885	166	0
A3	8.406	8.404	142	0
A3a	**6.068**	**5.671**	**119**	**7**
A4	7.991	7.109	127	16

A4a	8.006	7.339	96	12
B1	4.681	4.681	14	1
B2	4.079	4.078	68	10
B3	**3.526**	**4.119**	**78**	**9**
B4	4.983	4.325	94	8
B4a	4.235	4.235	45	4

In the macroeconomic cost-optimal analysis (Figure 5-3) for variant A, the most favorable solution is A3a (151 kW_{th} LPG condensing boiler, 80 kW air conditioning chamber with 80% heat recovery, 382 m^2 of solar thermal collectors). The global cost is 6,068 HRK/m^2, and the primary energy is 119 kWh/m^2.

In the macroeconomic (Figure 5-3) analysis for variant B, the most favorable solution is B3 (90 kW_{th} LPG condensing boiler, 70 kW air conditioning chamber with 80% heat recovery, 43.2 m^2 of solar thermal collectors). The global cost is 3,526 HRK/m^2, and the primary energy is 78 kWh/m^2.

In the financial cost-optimal analysis (Figure 5-4) for variant A, the most favorable solution is A3a (151 kW_{th} LPG condensing boiler, 80 kW air conditioning chamber with 80% heat recovery, 382 m^2 of solar thermal collectors). The global cost is 5,671 HRK/m^2, and the primary energy is 119 kWh/m^2.

In the financial analysis (Figure 5-4) for variant B, the most favorable solution is B2 (90 kW_{th} LPG condensing boiler, 70 kW air conditioning chamber with 80% heat recovery, 382 m^2 of solar thermal collectors). The global cost is 4,101 HRK/m^2, and the primary energy is 8 kWh/m^2.

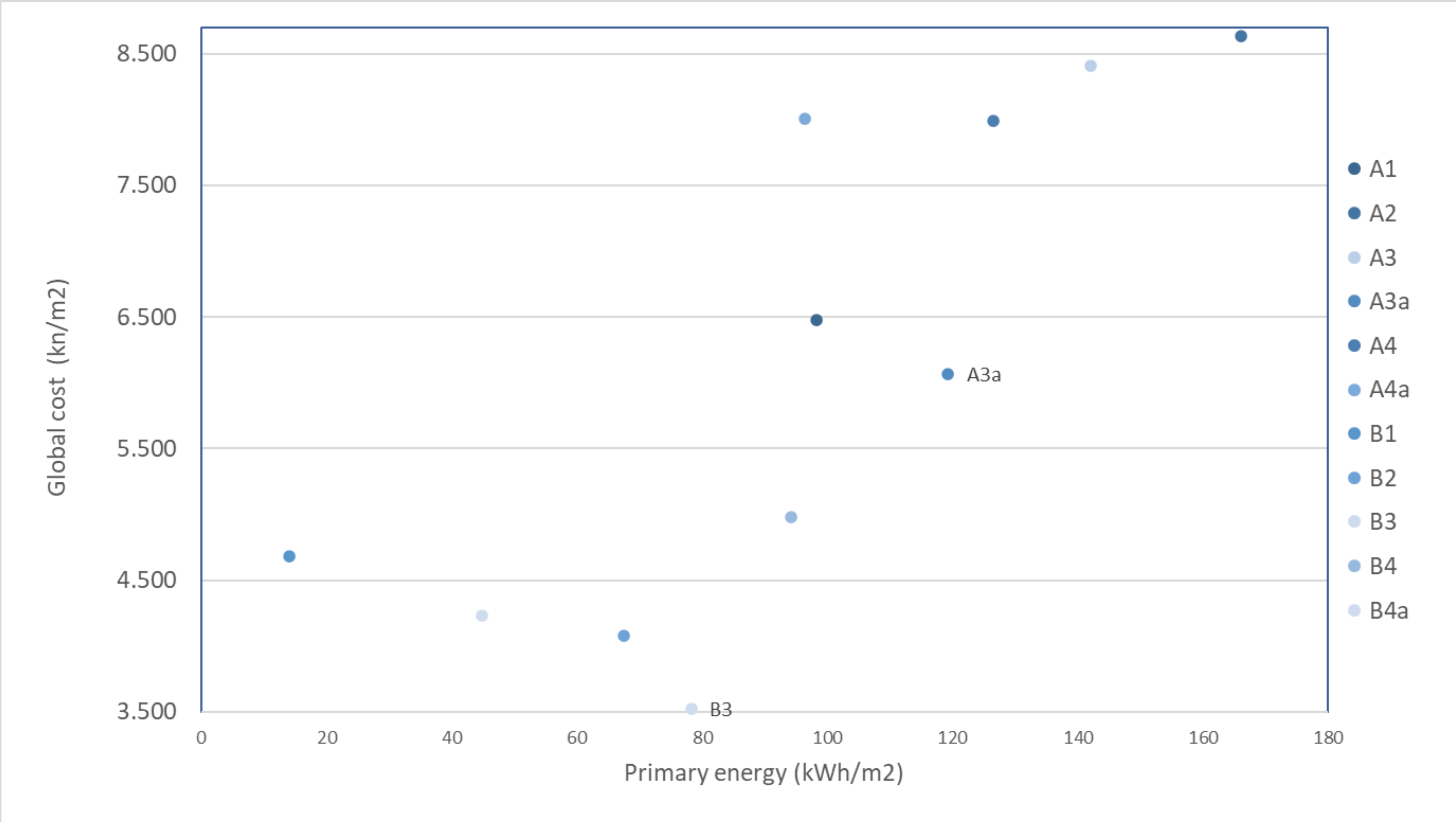

Figure 5-3 Results of macroeconomic cost-optimal analysis

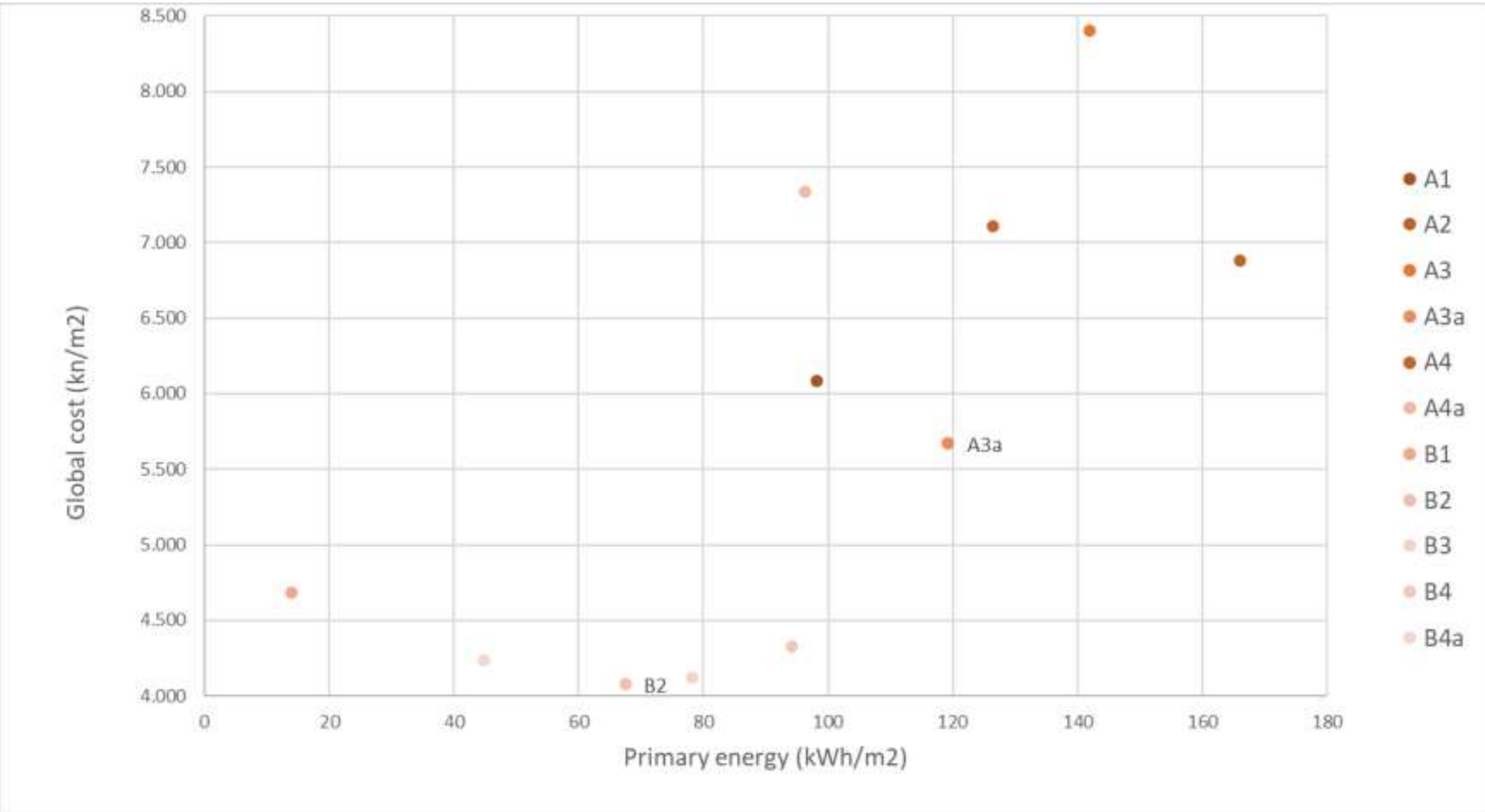

Figure 5-4 Results of financial cost-optimal analysis

6. Results of multicriteria analysis

The optimal technical solution is the one that has the lowest total global cost (HRK/m^2) and the lowest primary energy (kWh/m^2), while meeting the requirements of the Technical Regulation. In addition to the above criteria, additional criteria are used to select the optimal technical solution, either for energy efficiency, environmental protection and reducing the cost of using the building, so the following criteria were used:

- Lowest total financial global cost (HRK/m^2);
- Lowest primary energy (kWh/m^2);
- Lowest operating cost for energy (HRK/year);
- Lowest annual CO_2 emissions (tCO_2/year) from energy consumption;
- Energy produced from renewable energy sources on site (%).

Based on the selected criteria and equal weight factors for each criterion, a multi-criteria analysis was performed and the optimal technical solution for the building was selected. Table 6-1 shows the results of the analysis.

Table 6-1 Multicriteria analysis for optimal technical solution selection

	Financial global cost	Primary energy	CO_2 emissions	Operating cost	RES share	Overall rating
A1	0,870	0,981	1,000	1,000	1,000	4,850
A2	0,824	0,580	0,378	0,655	0,683	3,119
A3	0,675	0,678	0,478	0,758	0,333	2,922
A3a	1,000	0,807	0,002	0,975	0,501	3,285
A4	0,798	0,761	0,001	0,761	0,722	3,043
A4a	1,000	0,807	0,002	1,000	0,859	3,668
B1	**0,871**	**0,761**	**1,000**	**1,000**	**1,000**	**4,633**
B2	1,000	1,000	0,115	0,194	0,451	2,760

B3	0,990	1,000	0,129	0,197	0,570	2,886
B4	0,943	0,208	0,149	0,149	0,628	2,075
B4a	0,963	0,179	0,313	0,313	0,810	2,578

The optimal technical solution for both variants is a system with a seawater heat pump, i.e. solution A1 and B1 (Table 6-1, Figure 6-1).

Variant A1 is a combination of seawater / water heat pump 151 kWth (10 ° C / 45 ° C)) with waste heat recovery, air conditioning chamber (1500 m3 / h) with 80% heat recovery and 13.9 kWp photovoltaic system. The global cost is HRK 6,083 / m^2 or a total of HRK 5,249,683, and the primary energy is 98 kWh / m2 and the annual emission is 0 tCO_2.

Variant B1 is a combination of seawater / water heat pump 104.7 kWth (10 ° C / 45 ° C)) with waste heat recovery, air conditioning chamber (1500 m3 / h) with 80% heat recovery and 13.9 kWp photovoltaic system. The global cost is HRK 4,681 / m^2 or a total of HRK 2,565,312, and the primary energy is 14 kWh / m^2 and the annual emission is 1 tCO_2.

The optimal combinations have the lowest global cost compared to other combinations, and significantly lower primary energy, CO_2 emissions, operating cost and higher renewable energy share, as presented in Table 5-6.

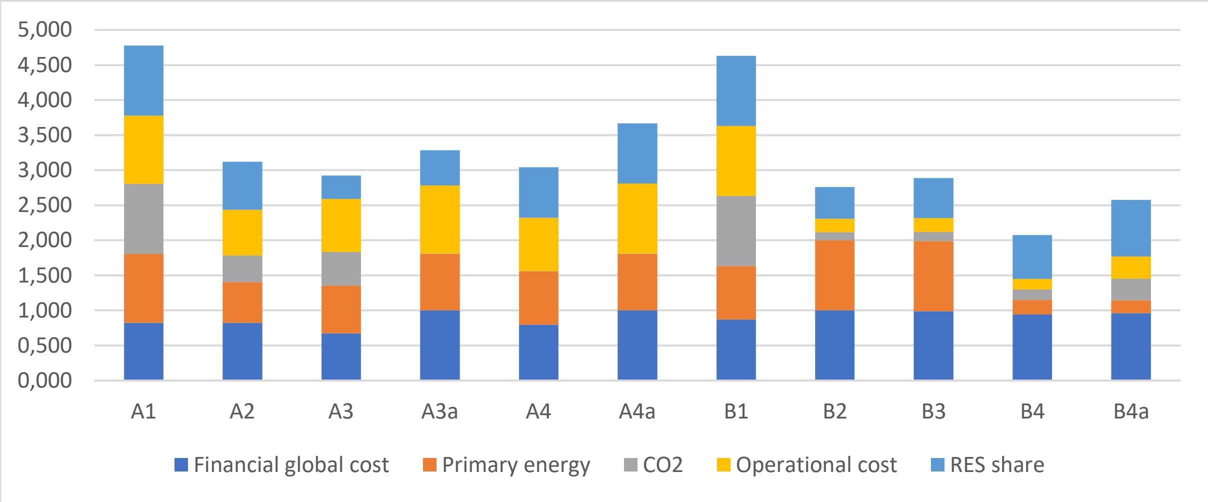

Figure 6-1 Multicriteria analysis for optimal technical solution selection

7. Socio-economic analysis

The Marine sport port Ploče is in the northwestern part of the city of Ploče and represents a very significant contribution to the quality of life of the City of Ploče due to its sports, tourist and social facilities by revitalizing the abandoned space (former military complex). There is currently an empty plot at this location that is difficult to access from the mainland. On the mainland behind the plot after Tina Ujevića Street, there are several residential buildings.

This project creates an environment that connects the community and provides additional sports and recreational facilities. The idea is to connect this complex with a promenade and bike path with the city center, which would enable a pleasant stay in the air for the city's population of all ages and reduce the environmental impact of transport by encouraging walking and cycling as environmentally friendly options.

According to the plan, in the southern part of the building there will be a rowing pool, locker rooms and other common rooms, as well as accompanying facilities (storage for ships and similar technical rooms of the building).

In the southern part there will be a rowing pool, locker rooms and other common areas, as well as accompanying facilities (storage for boats and similar technical rooms of the building).

A hostel and a coffee bar will be located on the three upper floors. The total area is net 1,327 m^2 and gross 1,523 m^2 while the total heated area is 863 m^2.

In the second phase of the project, the facilities will expand to the north: additional sports facilities, lecture hall, sports hall and gym with locker rooms, total area net 719 m^2 and gross 847 m^2.

Users of recreational and sports facilities are:

1. Rowing club: 20 students, 20 veterans, 1-2 coaches
2. Sailing club: 20 users, 1 coach
3. Water polo club: 20 younger users, 20 seniors, 1 coach
4. Diving club: 15 users

5. Sport fishing: 20 users, 20 recreational.

Club 1 and 2 are planned in the first phase, water polo is temporarily in the first phase until the second phase is built. Club 4 and 5 are planned in the second phase and water polo will be moved to that part of the building after the construction of the second phase.

The capacity of the hostel is 48 beds.

The benefits of green building can be grouped into three categories: economic, social and environmental.

Now more than ever, resilient, green and low-carbon cities are essential for an economically healthy, socially responsible and environmentally sustainable future (Cities and Environment - OECD). The construction sector has the greatest potential to significantly reduce greenhouse gas emissions compared to other large emitting sectors. Therefore, green building projects contribute to the realization of the Green Plan adopted by the EU in order to achieve the goals of the Paris Agreement. The biggest savings are expected in reducing energy consumption for lighting and reducing the energy required for heating / cooling and domestic hot water by using non-fossil energy sources.

The construction of a sports complex and other facilities according to the standards of almost zero consumption buildings achieves:

- use of construction materials that are non-toxic, ethical and sustainable;
- environmental aspects and quality of life of project beneficiaries are considered during design, construction and maintenance;
- design that allows adaptation to changes in the environment,
- good indoor air quality;
- efficient use of energy, water and other resources and
- use of renewable energy sources such as heat pumps.

This study will present an analysis of the costs and benefits of the Ploče sports port complex, the results of which will serve decision makers to make a decision on project implementation. It is used as a systematic method for evaluating local, regional and central policies. The inputs for the analysis are capital expenditures (CAPEX) and operating costs and maintenance costs (OPEX), including replacement costs during the observation period, which are compared with the benefits arising from the construction of the project for society as a whole and its contribution to reducing the negative impact on the environment.

The analysis was performed separately for two variants:

1. Variant A: sports building with accommodation capacity (hostel) with a total gross area of 1,523 m^2;

Technical solution for variant A is a seawater / water heat pump 151 kWth (10 ° C / 45 ° C) with waste heat recovery, air conditioning chamber (1500 m3 / h) with 80% heat recovery, photovoltaic system 13.9 kWp, thermal insulation of the building envelope in energy class A, high-efficiency integrated LED luminaires with control via sensors of occupancy and the presence of daylight. Total annual energy consumption is 25,745 kWh, 75% of energy is produced by heat pump and photovoltaic modules and the total annual emission is 6 tCO_2.

2. Variant B: sports building with a cafe with a total gross area of 1,211 m^2.

The technical solution for variant B is a sea water / water heat pump 104.7 kWth (10 ° C / 45 ° C) with waste heat recovery, air conditioning chamber (1500 m3 / h) with 80% heat recovery, FN 13.9 kWp, thermal insulation of the building envelope in energy class A, high-efficiency integrated LED lamps with control via sensors of occupancy and the presence of daylight. Total annual energy consumption 4,759 kWh, 70% of energy is produced by heat pump and photovoltaic modules and total annual emission is 1.11 tCO_2.

7.1. Costs

The categories of investment (CAPEX) and operating costs (OPEX) and how to estimate them are described in more detail below.

Investment costs represent the total cost of project documentation, connections and contributions, as well as the cost of materials and labor and the necessary technical equipment for the implementation of the investment. They are presented according to the time dynamics of their occurrence.

All estimated investment costs are shown in the following table. The construction is expected to take 2 years.

Table 7-1 Investment cost for Variant A and B

	Variant A			**Variant B**		
	Construction period			Construction period		
Investment cost (kn)	*Year 1*	*Year 2*	***TOTAL***	*Year 1*	*Year 2*	***TOTAL***
a. design documentation	300,000	0	**300,000**	260,000	0	**260,000**
b. construction cost	6,140,736	2,631,744	**8,772,480**	4,882,752	2,092,608	**6,975,360**
c. energy efficiency and RES	421,102	3,789,919	**4,211,022**	193,915	1,745,237	**1,939,152**
d. grid connection, concession and communal fees	180,043	0	**180,043**	146,601	0	**146,601**
TOTAL	7,041,881	6,421,663	**13,463,544**	5,483,268	3,837,845	**9,321,113**

Source: EIHP

A detailed calculation of connections, contributions and concessions is provided in Annex 1.

Operating costs are incurred during the period of use of the facility. Their amount is estimated on the basis of technical parameters of facilities and the price or costs of similar projects that have been previously implemented and whose data are available to the developer of the study. The cost of replacement in this project occurs in the 25th year after the start of use of the facility and refers to the replacement of mechanical systems (seawater / water heat pumps, heat tanks, air chambers) and photovoltaic (PV) systems.

All estimated operating costs are shown in the following table. The amounts represent the annual amount of each cost category and are usually the same in each year during the observation period. This analysis envisages that the use of the project from 2028 to 2053 will be considered. Maintenance costs are estimated as 1% of the total investment costs for construction and energy efficiency and RES.

Table 7-2 Operational and equipment replacement costs for variants A i B

Operational costs	Variant A	Variant B
Maintenance	129,835	89,145
Annual electricity cost	43,852	3,950
Concession for use of maritime area	39,960	39,960
TOTAL	213,647	133,055
Investment in year 25	672,596	593,l252

Source: EIHP

7.2. Incomes and benefits

The benefits of green building can be grouped into three categories: economic, social and environmental.

7.2.1. Economic benefits

The direct economic benefits from the realization of the project are primarily operational cash income from:

1. catering and tourist activities (caffe-bar and hostel): income from renting space for caffe bar and hostel

These types of revenues, for the purposes of this analysis, will be estimated based on the assumption that the City of Ploče will lease the business premises in question. The area of the coffee bar is 86 m^2, and together with the accompanying areas (storage, toilets) a total of 119 m^2.

The area of the hostel is 326 m^2. For the purposes of this analysis, the rental price of business premises in the City of Ploče will be assumed to be 165 kn/m^2.

Income from renting business premises

Variant 1 = (1192 + 326 m2) * 165 kn * 12 = 881,100 kn per year

Variant 2 = 1192 * 165 kn * 12 = 235,620 kn per year

2. sports membership fees

There are a total of 155 users of sports and recreational facilities, of which 115 are younger and seniors and 20 are veterans and 20 recreational and 3-4 coaches.

For the purposes of this analysis, the amount of the monthly membership fee of HRK 100 for all ages and categories will be assumed.

Revenue from membership fees (valid for both variants):

155 * 100 kn * 12 = 186,000 kn per year

Also, the new sports facilities will enable the holding of various competitions at this location and additional income from the competition. These revenues are difficult to determine so they were not taken into account in this analysis.

3. income from new employees in the cafe bar and hostel

It is assumed that there will be 5 employees in the cafe bar (3 waiters, 1 cleaner, 1 manager) and as many in the hostel (3 receptionists and other staff, 1 cleaner, 1 manager). Therefore, surtax revenue is projected for the City of Ploče. The calculation uses the average gross salary in the Republic of Croatia, according to the latest data from the CBS, in the amount of HRK 9,671 and the amount of surtax on income of 10%, according to the Decision on surtax on income tax of the City of Ploče (OG 4/2015) from 2014. The amount of monthly income per employee is HRK 74.74 per month or HRK 896.88 per year. Option 1 envisages 10 new employees (for cafes and hostels) and option 2 envisages 5 new employees (cafes).

Income from surtax for new employees

Variant 1 = 10 * HRK 74.74 * 12 = HRK 8,969.80 per year

Variant 2 = 5 * 74.74 * 12 = HRK 4,484.40 per year

By transforming the neglected land into an attractive sports and tourist complex that is connected to the promenade with the city center, it significantly changes the look of the city and represents the sports and social potential of this area which gravitates to all surrounding settlements. A more beautiful view of the city and an increase in sports facilities can in the long run lead to a significant increase in tourism potential, including sports tourism (maintenance of preparations for other clubs and sports competitions). In this way, other economic benefits for the city, the state and the private sector could potentially be realized, such as: increase in retail turnover and revenues from catering (restaurants, cafes).

7.2.2. Social benefits

In addition to the economic costs and benefits, which are directly reflected in the economic flow of the project, there are also benefits that the project generates for society as a whole and the positive effects of the project on the environment. Some of them can be presented in monetary units. Those benefits that cannot be presented in monetary units and that are considered to be significant for the project, should be taken into account when multicriteria decision-making on project implementation.

Social and environmental benefits relate to the benefits of green building that contribute to improving the health and quality of life of the citizens of Ploče, job creation, and reducing energy consumption, which would contribute to a green recovery from COVID-19.

Construction of a sports and tourist complex according to the standards of almost zero energy buildings:

- contributes to better indoor air quality by applying ventilation with recuperation (low concentration of CO_2 and pollutants);
- enables a greater amount of daylight and views that achieve comfort for users of the space and enjoy the environment, and consequently reduce the need for energy for lighting;
- contributes to quality sound and acoustic insulation for better concentration, rest and recovery of hostel users after demanding sports activities (extended sleep time) and
- comfort of living by ensuring the appropriate temperature of the interior, the application of management and supervision of the building.

Social benefits depend on the number and structure of the population of the city of Ploče. According to the latest 'Report on the situation in the area of the City of Ploče'[1], the City of Ploče is one of 22 local self-government units in Dubrovnik-Neretva County, consisting of nine settlements, representing urban, historical, natural, economic and

[1] http://www.zzpudnz.hr/LinkClick.aspx?fileticket=fdRNiARK75g%3D&tabid=234 [29.10.2021.]

social units: Baćina, Banja , Komin, Peračko Blato, Plina Jezero, Ploče, Rogotin, Staševica and Šarić Struga. According to the 2001 Census, there were 10,834 inhabitants in the City of Ploče, and the new Census of 2011 determined 10,135 inhabitants, or 8.27% of the population of Dubrovnik-Neretva County. The largest settlement is Ploče, with 6,013 inhabitants or 59.3% of the total population of the City. They are followed by Komin (1,243), Staševica (902) and Rogotin (665). Ploče is the central and most economically important settlement, which together with neighboring settlements (Šarić Struga, Rogotin, Baćina) forms a physical (mini-conurbation) unit with a total of 7,485 inhabitants in 2011, or 73.85% of the total population. The settlement of Ploče, as the administrative center and demographically and economically the most important settlement of the City, is a traffic hub of international importance.

Table 7-3 City of Ploče inhabitant`s structure by age and sex

	Age groups						
Sex	*Youth (0-14)*		*Adult (15-64)*		*Old (>64)*		*TOTAL*
M	807	16,0%	3,532	69,9%	715	14,1%	5,054
F	792	15,6%	3,366	66,2%	923	18,2%	5,081
TOTAL	1 599	15,8%	6,898	68,1%	1 638	16,2%	10,135

Source: National Statistics Office

According to the National Statistics Office, the natural movement of the population of the City of Ploče[2], in the period from 2005 to 2013, was moving in a positive direction until 2011 when there was a sharp natural decline, with a sharp increase in deaths and a decrease in live births. culminated in 2012. Due to such trends, it is very important for infrastructure projects to improve the quality of life of the City of Ploče and contribute to changing demographic trends in the direction of increasing birth rates, reducing emigration and extending the life expectancy of the elderly population.

At least the following categories have been identified as social benefits of this project:

[2] The natural movement of the population depends on the birth and death rates of the population and can be positive (natural increase) or negative (natural decline).

- increase the quality of life due to the additional possibility of sports facilities and the promenade that connects this complex with the city center;
- improving demographic trends (which are not currently favorable) and
- increase of sports potential for the younger population.

This project could significantly contribute to increasing the number of inhabitants of the City of Ploče and surrounding settlements that gravitate to this area, less emigration of primarily young population and working population, but also increase birth rates due to the satisfaction of younger populations and increase the quality of life. . Providing a pleasant walk for the elderly population, which also provides the opportunity to socialize, can significantly affect their better mood, better immunity and consequently longer life expectancy. The construction of this sports and tourist complex would enable the achievement of significant sports results of the younger population in water sports (rowing, sailing, water polo, diving, sport fishing) and long-term positioning of the City of Ploce as a recognizable sports environment.

The previously expressed qualitative benefits that the project would generate are difficult to express in monetary terms in order to quantify and on the basis of which the net present value of the project could be calculated taking into account all benefits and costs. One of the common methods of assessing these benefits is willingness-to-pay: residents of the City of Ploče should be asked how much they are willing to pay for certain effects of this project on their lives. In this way, these categories of benefits could be included in the financial calculation of the project's cost-effectiveness.

However, this method has several drawbacks. The key disadvantage is that an individual’s response depends on his or her total income. If the responses are not properly weighed, the data used in the cost-benefit analysis give inappropriate weight to the decisions of high-income individuals. An additional disadvantage of this method is that it relies on scientific projections of categories that are difficult to estimate in the coming period, specifically on population movements that depend on many factors.

harm.

8.3. Environmental benefits

Green buildings can not only reduce or eliminate negative environmental impacts, using less water, energy or natural resources, but can, in many cases, have a positive environmental impact (on a building or city level) by creating their own energy. One of the measurable effects of green building on reducing negative environmental impact is the reduction of CO2 emissions due to reduced energy consumption for lighting, heating / cooling and domestic hot water using non-fossil energy sources.

Evaluation of CO_2 emission reductions

The annual reduction in CO_2 emissions depends on the type of fuel / energy used in the heating system.

The following technical solutions have been defined for the sports port building, and energy consumption and CO2 emissions have been achieved:

- Variant A - seawater / water heat pump 151 kWth (10 ° C / 45 ° C) with waste heat recovery, air conditioning chamber (1500 m3 / h) with 80% heat recovery, photovoltaic system 13.9 kWp, thermal insulation of the envelope energy class A buildings, high-efficiency integrated LED luminaires controlled via occupancy and daylight sensors. Total annual energy consumption is 25,745 kWh, 75% of energy is produced by heat pump and photovoltaic modules and the total annual emission is 6 tCO2.
- Variant B - sea water / water heat pump 104.7 kWth (10 ° C / 45 ° C) with waste heat recovery, air conditioning chamber (1500 m3 / h) with 80% heat recovery, PV 13.9 kWp, thermal insulation envelopes of the building in energy class A, high-efficiency integrated LED lamps with control via sensors of occupancy and the presence of daylight. The total annual energy consumption is 4,759 kWh, 70% of the energy is produced by a heat pump and photovoltaic modules and the total annual emission is 1.11 tCO2.

In order to determine the savings in CO2 emissions, the solution of energy supply with a fossil source, a condensing boiler on liquefied petroleum gas was observed:

- Variant A - condensing boiler 151 kWth on LPG, compression water cooler 80 kW, air conditioning chamber (1500 m3 / h) with heat recovery 80%, solar thermal collectors 382 m2, where the total annual energy consumption is 96,675 kWh, 27% of energy is products from solar thermal collectors and the total annual emission is 25.80 tCO2
- Variant B - condensing boiler 90 kWth on LPG, compression water cooler 70 kW, air conditioning chamber (1500 m3 / h) with heat recovery 80%, photovoltaic system 13.9 kWp, where the total annual energy consumption is 42,040 kWh, 31% energy is produced from a photovoltaic system, and the total annual emission is 9.72 tCO_2.

Formula for calculating the annual reduction of greenhouse gas emissions:

ECO2 = FES x e / 1000

where:

ECO2 [tCO_2 / year] - reduction of greenhouse gas emissions

FES [kWh / year] - total annual energy savings in direct consumption

E [$kgCO_2$ / kWh] emission factor

The emission factor for electricity is 234.81 $kgCO_2$ / MWh.

To calculate the amount of CO_2 savings, the price projections listed in the following table are used, according to available expert sources (https://www.euractiv.com/section/emissions-trading-scheme/interview/analyst-eu-carbon-price-on- track-to-reach-e90-by-2030 /). The same emission price from 2030 is used to calculate emissions after 2030, since the uncertain movement of CO_2 prices is so long-term. However, emissions prices are expected to continue to rise, depending on European climate policies and regulations and the reduction of negative environmental impacts, and the European Union's goal of making Europe a climate-neutral continent by 2050.

Table 7-4 Projection of CO_2 costs

Cost of emission unit for GHG	2026.	2027.	2028.	2029.	2030.
EUR/tCO_2e	76,67	80	83,33	86,67	90

Kn/tCO_2e	577	602	627	652	677

Source: EIHP

Table 7-5 Annual CO2 savings for variants A and B

	2026.	2027.	2028.	2029.	2030.
Variant A	11 425	11 920	12 415	12 910	13 405
Varianta B	4 968	5 183	5 398	5 614	5 829

As an additional benefit of the project to reduce the negative impact on the environment, it is necessary to emphasize the contribution to reducing the impact of transport on the environment by encouraging walking and cycling as environmentally friendly options between the sports and tourist complex to the city center.

8.3. Methodology of cost benefit analysis

A cost-benefit analysis is conducted to verify the economic viability of the project. The first step in the economic analysis is to estimate the amount by years of total costs and benefits during the construction period and during the period of use of the sports-tourist complex. All monetary costs and benefits are presented in HRK and are expressed in base year prices depending on the time of launch of the investment in order to be comparable. When calculating costs and benefits, only cash receipts and expenditures related to the construction and use of the sports and tourist complex are taken into account. Non-cash accounting items such as depreciation and reserves (eg for future replacement costs) are not taken into account in the calculation.

The methodology of economic analysis used in this study is the discounted cash flow method. The calculated cash flows are discounted by applying an appropriate discount rate over the estimation period.

To calculate the net present value of a project the cash benefits and costs should be estimated based on the same assumptions. Therefore, before starting the analysis, it is necessary to define the following parameters:

- reference period,
- the residual value of the project after the end of the observation period,

- financial and economic discount rate,
- inflation treatment (whether real or nominal prices are used in the analysis),
- tax treatment.

Reference period

Project cash flow estimates cover the period appropriate to the economic life of the project and its likely long-term effects. The length of the reference period affects the result of the analysis. The reference observation period in this study is 30 years and includes the projected two years of construction.

The residual value

Given that after the observation period, the facility continues to operate, the residual value will be calculated assuming a constant residual future cash flow (the difference between operating rental income and operating expenses). The present value of all remaining cash flows that continue indefinitely is calculated as follows:

$$present\ value = \frac{\text{cash flow continued indefinetly}}{discount\ rate}$$

The amount of fixed cash flow is reduced by the average annual amount of replacement costs assumed every 25 years.

Financial and economic discount rate (time value of money + income inflow risk in future periods)

The financial discount rate reflects the opportunity cost of capital for the investor. All estimated benefits and costs are discounted to present value using an appropriate discount rate that reflects the opportunity cost of capital. A financial discount rate of 4% is applied in this analysis (in line with EC recommendations).

The economic analysis additionally analyzes the benefits of the project, which relate to society as a whole. In this analysis, an economic discount rate of 5% is applied (in accordance with the EC recommendations).

Inflation treatment

Financial analysis is done at constant prices (fixed prices in the base year). Since constant prices are used, a real discount rate is applied.

Tax treatment

The analysis does not include the calculation of VAT, if it is reimbursable for the investor. Direct taxes (on profits, income, etc.) are taken into account only to check financial viability and not to calculate financial profitability, which is calculated before tax deductions.

Decision criteria

In order to make a decision on the cost-effectiveness of the project for society, absolute and relative indicators are calculated. The following two criteria were used in this analysis:

1. Net present value (NPV) - obtained by the sum of discounted differences in benefits and costs in a given year during the observation period. It is calculated according to the following formula:

$$S_0 = \sum_{t=1}^{T} \frac{Vt}{(1+k)t}$$

S0 - net present value;

T - total assessment period;

Vt - cash flow in year t, (T - K) t;

k - discount rate (opportunity cost)

According to the criterion of net present value, the investment project is the better the higher the net present value of the project. This is an absolute indicator and depends on the input variables.

2. Internal rate of return (IRR) - the second basic criterion for financial decision-making. This is the discount rate that reduces the net cash flows of a project during the observation period to the value of its investment costs. It is calculated according to the following formula:

$$\sum_{t=1}^{T} \frac{Vt}{(1+r)t} = I_0$$

where R is the internal rate of return.

The criterion of project acceptance is a comparison of the internal profitability rate and the discount rate. For the project to be profitable, the internal rate of return should be at least equal to or greater than the amount of the discount rate used:

$$r \geq k$$

It is not profitable to invest in projects whose internal rate of return is lower than the applied discount rate. The internal rate of return is related to the net present value criterion: projects with a positive net present value have a higher internal rate of return than the applied discount rate, and vice versa. Projects with zero net present value have an internal rate of return equal to the applied discount rate.

This is a relative criterion that allows you to compare the cost-effectiveness of several different projects.

Based on the obtained calculation of net present value (NPV) and internal rate of return (IRR), comparing exclusively financial categories of costs and benefits, applying the financial discount rate, it can be concluded whether the project is profitable from the Investor's point of view (City of Ploče).

Applying the social discount rate, taking into account all the benefits generated by the project (financial, social, environmental), it can be concluded whether the project is profitable from a socio-economic aspect for all future beneficiaries of this project.

8.3. Methodology of cost benefit analysis

Table 7 6 and Table 7 7 show the calculation of the financial viability of the project based on the above input data and assumptions in the model.

Table 7-6 Cost-benefit analysis results for variant A for the period from 2024 to 2053, in HRK

	Construction period		Sport and tourism complex use period				
Cost and benefit category / Year	2024	2025	2026	…	2050	…	2053
Costs							
1. INVESTMENT COST (CAPEX)							
a. Design documentation	300,000	0		…		…	
b. Construction	6,140,736	2,631,744		…		…	
c. Energy efficinecy and RES systems	421,102	3,789,919		…		…	
d. Grid connection, maritime concesion and communal fees	180,043	0		…		…	
Total	7,041,881	6,421,663		…		…	
2. OPERATIONAL COSTS (OPEX)							
a. Maintenance			129,835	…	129,835	…	129,835
b. Annual electricity cost			43,852	…	43,852	…	43,852
c. Maritime Concession	39,960	39,960	39,960	…	39,960		39,960
d. Investment in year 25				…	672,596	…	
Total	39,960	39,960	213,647	…	672,596	…	213,647
TOTAL COSTS	7,081,841	6,461,623	213,647	…	886,243	…	213,647
Benefits							
Economic benefits							
a. income from renting business premises*			881,100	…	881,100	…	881,100
b. income from sports membership fees			186,000	…	186,000	…	186,000
c. increase in employment - surtax income			8,969	…	8,969	…	8,969
ECONOMIC BENEFITS TOTAL			1 076 069	…	1 076 069	…	1,076,069
REMAINING FUTURE CASH FLOW							20,887,949
Cash flow (neto benefits / costs)	-7,081,841	-6,461,623	862,422	…	189,826	…	21,750,371
Net discounted benefits / costs	-6,809,463	-5,974,134	766,690	…	65,835	…	6,706,045
Cumulative	-6 ,809,463	-12,783,596	-12,016,906	…	-560,482	…	6,709,698

NPV 2024	6,709,698
NPV 2022	6,203,493
IRR	6,71%

*caffe bar and hostel

Source: EIHP

Table 7-7 Cost-benefit analysis results for variant B for the period from 2024 to 2053, in HRK

	Construction period		Sport and tourism complex use period				
Cost and benefit category / Year	2024	2025	2026	…	2050	…	2053
Costs							
1. INVESTMENT COST (CAPEX)							
a. Design documentation	260 000	0		…		…	
b. Construction	4 882 752	2 092 608		…		…	
c. Energy efficinecy and RES systems	193 915	1 745 237		…		…	
d. Grid connection, maritime concesion and communal fees	146 601	0		…		…	
Total	5 483 268	3 837 845		…		…	
2. OPERATIONAL COSTS (OPEX)							
a. Maintenance			89 145	…	89 145	…	89 145
b. Annual electricity cost			3 950	…	3 950	…	3 950
c. Maritime Concession	39 960	39 960	39 960		39 960		39 960
d. Investment in year 25				…	593 252	…	
Total	39 960	39 960	133 055	…	726 307	…	133.055
TOTAL COSTS	5 523 228	3 877 805	133 055	…	726 307	…	133.055
Benefits							
Economic benefits							
a. income from renting business premises*			235 620	…	235 620	…	235 620
b. income from sports membership fees			186 000	…	186 000	…	186 000

c. increase in employment - surtax income			4 484	…	4 484	…	4 484
ECONOMIC BENEFITS TOTAL			426 104	…	426 104	…	426 104
REMAINING FUTURE CASH FLOW							7 286 272
Cash flow (neto benefits / costs)	-5.523.228	-3.877.805	293.049	…	-300.203	…	7.579.321
Net discounted benefits / costs	-5.310.796	-3.585.249	260.520	…	-104.115	…	2.336.846
Cumulative	-5.310.796	-8.896.045	-8.635.525	…	-4.869.140	…	-2.340.602
NPV 2024	-2.340.602						
NPV 2022	-2.122.995						
IRR	2,30%						

*caffe bar and hostel

Source: EIHP

Based on the obtained values of the NPV and IRR, it can be concluded that the construction of the sports and tourist complex Ploče is financially demanding and that EU funds are desirable to co-finance its construction. Option A is more cost-effective, with a positive net present value (HRK 6.7m) and an internal rate of return (6.7%) higher than the discount rate used (4%). Variant B is not financially viable and has a negative cumulative cash flow (HRK -2.3m) and a rate of return (2.3%) lower than the discount rate used (4%). In addition to the financial cost-benefit analysis, there is a positive impact on reducing CO2 emissions that can be expressed in money. The result is similar since the economic analysis applies an economic discount rate of 5% which is higher than the financial discount rate of 4%. Economic NPV in variant A is HRK 3.9m with an IRR of 6.8% and in variant B the NPV is negative by HRK 3.2m with an IRR of 2.4%.
However, if the financial analysis, in addition to reducing CO2 emissions, is added to all the listed social benefits of this project related to improving the quality of life and improving demographic trends, and further benefits from increasing sports and tourism potential and improving the city's vision, then justified all construction and maintenance costs. In addition, such sports and tourism infrastructure would in the long run contribute to better sports results of the younger population in this area in sports that are specific to this geographical and climatic area because it provides better conditions and greater capacity for sports of younger generations. These benefits would consequently contribute to the reduction of health care costs due to the better general condition of the elderly population, but also to the reduction of sick leave of the working population, which would reduce business costs for employers in this area.

Recognized benefits apply to all residents of the City of Ploče, and spill over to residents of surrounding settlements that gravitate to this administrative center. Therefore, it can be concluded that from the aspect of future users of this sports and tourist complex, its social and environmental profitability and justification are unquestionable. In the long run, this type of investment can attract and emphasize additional private sector investments in catering and tourism facilities that can contribute to the development of sports tourism and increase income from tourism and

related catering facilities (restaurants, bars, etc.). It can also contribute to the positioning of the City of Ploče as a sports center for water sports: water polo, sport fishing, diving, sailing and the like.

8.3. Sensitivity analysis

The sensitivity analysis was performed with respect to the possible change in investment and maintenance costs.

The results of the sensitivity analysis for possible changes in investment costs and operating costs for both variants are presented below, showing the changes in NPV and IRR as basic criteria in deciding on the cost-effectiveness of the project.

Table 7-8 NPV calculation for changes in investment and maintenance cost for Variant A, thousand kunas

Changes in OPEX \ Changes in CAPEX	90%	100%	110%	120%	130%	140%	150%
90%	8.505	7.234	5.964	4.693	3.422	2.151	880
100%	7.981	**6.710**	5.439	4.168	2.897	1.626	356
110%	7.456	6.185	4.914	3.643	2.373	1.102	-169
120%	6.931	5.660	4.390	3.119	1.848	577	-694
130%	6.406	5.136	3.865	2.594	1.323	52	-1.218
140%	5.882	4.611	3.340	2.069	798	-472	-1.743
150%	5.357	4.086	2.815	1.545	274	-997	-2.268

Source: EIHP

According to the data from the previous table, it is clear that the cost-effectiveness of the project in variant A is not significantly sensitive to changes in investment costs. With an increase in investment costs above 50%, an NPV equal to zero is achieved. The reason for this insensitivity is that the residual value of all future cash flows of the project after the observation period in this analysis was taken into account when calculating the NPV. Without taking into account the residual value, the project would be significantly sensitive to changes in investment costs (CAPEX) and an increase above 2% would result in a negative NPV.

If we observed a simultaneous increase in CAPEX and OPEX, then with a simultaneous increase in these values above 40%, the result would be negative.

Table 7-9 IRR calculation for changes in investment and maintenance cost for Variant A

		Changes in CAPEX						
		90%	**100%**	**110%**	**120%**	**130%**	**140%**	**150%**
Changes in OPEX	**90%**	7,7%	6,9%	6,2%	5,7%	5,1%	4,7%	4,3%
	100%	7,5%	**6,7%**	6,1%	5,5%	5,0%	4,5%	4,1%
	110%	7,3%	6,5%	5,9%	5,3%	4,8%	4,4%	3,9%
	120%	7,1%	6,3%	5,7%	5,1%	4,6%	4,2%	3,8%
	130%	6,9%	6,1%	5,5%	5,0%	4,5%	4,0%	3,6%
	140%	6,7%	5,9%	5,3%	4,8%	4,3%	3,8%	3,4%
	150%	6,4%	5,7%	5,1%	4,6%	4,1%	3,7%	3,3%

Source: EIHP

IRR values confirm the above about NPV movements: when NPV is less than zero then the IRR value is less than the discount rate used (4%).

Table 7-10 NPV calculation for changes in investment and maintenance cost for Variant B, thousand kunas

		Changes in CAPEX						
		50%	60%	70%	80%	90%	100%	110%
Changes in OPEX	50%	3.748	2.866	1.984	1.102	220	-662	-1.544
	60%	3.412	2.530	1.648	766	-116	-998	-1.880
	70%	3.077	2.195	1.313	430	-452	-1.334	-2.216
	80%	2.741	1.859	977	95	-787	-1.669	-2.551
	90%	2.405	1.523	641	-241	-1.123	-2.005	-2.887
	100%	2.070	1.188	306	-576	-1.459	-2.341	-3.223
	110%	1.734	852	-30	-912	-1.794	-2.676	-3.558

Source: EIHP

Since NPV is negative for variant B, a sensitivity analysis was conducted to analyze how cost reduction affects NPV. With a reduction in investment costs in variant B above 20%, an NPV equal to zero is achieved. If the residual value of cash flows after the observation period is not taken into account, then the investment costs should be reduced by more than 50% so that the NPV is at least zero.

If we observed a simultaneous increase in CAPEX and OPEX, then with a simultaneous decrease in these values of 20%, the result would be positive.

Table 7-11 IRR calculation for changes in investment and maintenance cost for Variant B

		Changes in CAPEX						
Changes in OPEX		50%	60%	70%	80%	90%	100%	110%
	50%	8,1%	6,7%	5,7%	4,9%	4,2%	3,6%	3,0%
	60%	7,8%	6,5%	5,4%	4,6%	3,9%	3,3%	2,8%
	70%	7,4%	6,2%	5,2%	4,3%	3,7%	3,1%	2,6%
	80%	7,1%	5,9%	4,9%	4,1%	3,4%	2,8%	2,3%
	90%	6,8%	5,5%	4,6%	3,8%	3,1%	2,6%	2,1%
	100%	6,4%	5,2%	4,3%	3,5%	2,9%	2,3%	1,8%
	110%	6,1%	4,9%	4,0%	3,2%	2,6%	2,0%	1,5%

Source: EIHP

IRR values confirm the above about NPV trends: when NPV is less than zero then the IRR value is less than the discount rate used (4%).

8. CONCLUSION

For variant A (sports purpose and hostel, total gross building area 1,523 m^2) the following combinations of technical systems were analyzed:

- (A1) Sea water / water heat pump 151 kWth, waste heat, air conditioning chamber 80 kW with heat recovery 80%, photovoltaic system 13.9 kWp ca heat sea water / water 151 kWth, waste heat, air conditioning chamber 80 kW with recuperation heat 80%, photovoltaic system 13.9 kWp
- (A2) Condensing boiler 151 kWth on LPG, air conditioning chamber 80 kW with heat recovery 80%, photovoltaic system 13.9 kWp
- (A3) Condensing boiler 151 kWth on LPG, air conditioning chamber 80 kW with heat recovery 80%, solar thermal collectors 382 m^2
- (A3a) Condensing boiler 151 kWth on LPG, air conditioning chamber 80 kW with heat recovery 80%, photovoltaic system 13.9 kWp, * Solar heat collectors 144 m^2
- (A4) Air-to-water heat pump 174.4 kW (7 ° C / 45 ° C) with waste heat recovery, air conditioning chamber (1500 m^3 / h) with 80% heat recovery, Solar heat collectors 43.2 m^2
- (A4a) Air-to-water heat pump 175 kW (7 ° C / 45 ° C) with waste heat recovery, air conditioning chamber (1500 m^3 / h) with 80% heat recovery, Solar heat collectors 144 m^2.

Only the combination with the seawater / water heat pump qualifies for the near-zero energy standard. For other combinations of technical systems, a larger free area is required for the installation of renewable energy systems, which cannot be provided on site. The roof of the building is shaped like a square and only a small area of the hostel's roof of 154 m^2 is available for the installation of photovoltaic modules or solar thermal collectors.

In addition to changing the elements of the conceptual design, which would provide another 191 m^2 of roof area (or other surface safe from damage), and variant A3a with condensing boiler on liquefied petroleum gas, photovoltaic modules and solar thermal collectors, meets the requirements for almost zero energy standard, and the combination would be optimal.

In the financial cost-optimal analysis for variant A, the most favorable solution is A1 (seawater / water heat pump 151 kW_{th}, waste heat, air conditioning chamber 80 kW with heat recovery 80%, solar thermal collectors of 382 m^2). The global cost is 5,671 kn/m^2, and the primary energy is 119 kWh/m^2.

For variant B (sports purpose and cafe) all combinations of technical solutions meet the requirements for the standard of almost zero energy. The following combinations of technical systems were analyzed:

- (B1) Heat pump seawater / water 110 kWth, waste heat, air conditioning chamber 80 kW with heat recovery 80%, photovoltaic system 13.9 kWp
- (B2) Condensing boiler 90 kWth on LPG, air conditioning chamber 70 kW with heat recovery 80%, photovoltaic system 13.9 kWp
- (B3) Condensing boiler 90 kWth on LPG, air conditioning chamber 70 kW with heat recovery 80%, solar heat collectors 43.2 m^2
- (B4) Air-to-water heat pump 104.8 kW (7 ° C / 45 ° C) with waste heat recovery, air conditioning chamber (1500 m^3 / h) with 80% heat recovery
- (B4a) Air-to-water heat pump 104.8 kW (7 ° C / 45 ° C) with waste heat recovery, air conditioning chamber (1500 m^3 / h) with 80% heat recovery, 13.9 kWp photovoltaic system

In the financial analysis (Figure 5 2) for variant B, the most favorable solution is B2 (Condensing boiler 90 kW_{th} on LPG, air conditioning chamber 70 kW with heat recovery 80%, photovoltaic system 13.9 kWp). The global cost is 4,681 kn / m^2, and the primary energy is 14 kWh / m^2.

Based on multicriteria analysis the optimal technical solution for both variants is a system with a heat pump, i.e. solutions A1 and B1.

Variant A1 is a combination of seawater / water heat pump 151 kWth (10 ° C / 45 ° C)) with waste heat recovery, air conditioning chamber (1500 m3 / h) with 80% heat recovery and 13.9 kWp photovoltaic system. The global cost is HRK 6,894 / m2 or a total of HRK 5,627,903, and the primary energy is 98 kWh / m2 and the annual emission is 0 tCO2.

Variant B1 is a combination of seawater / water heat pump 104.7 kWth (10 ° C / 45 ° C)) with waste heat recovery, air conditioning chamber (1500 m3 / h) with 80% heat recovery and 13.9 kWp photovoltaic system. The global cost is HRK 4,681 / m2 or a total of HRK 2,565,188, and the primary energy is 14 kWh / m2 and the annual emission is 1 tCO2.

These combinations do not have the lowest global cost compared to other combinations, but have significantly lower primary energy, CO_2 emissions and operating cost and the highest share of renewable energy generated on-site.

The construction of the sports and tourist complex Ploče is financially demanding and that EU funds are desirable to co-finance its construction. Option A, where the total estimated investment is HRK 13.46 million, is more financially viable, as it has a positive net present value (HRK 6.7m) and an internal rate of return (6.7%) higher than the discount rate used (4%). Option B, where the total estimated investment is HRK 9.32 million, is not financially viable and has a negative cumulative cash flow (HRK -2.3 million) and a rate of return (2.3%) lower than the discount rate used (4%). In addition to the financial cost-benefit analysis, there is a positive impact on reducing CO2 emissions that can be expressed in money. The result is similar, as the economic analysis applies an economic discount rate of 5% which is higher than the financial discount rate of 4%. Economic NPV in variant A is HRK 3.9 million with an IRR of 6.8% and in variant B is NPV - HRK 3.2 million with an IRR of 2.4%