Interreg
Italy - Croatia
COASTENERGY

EUROPEAN UNION

Analysis of blue energy potentials – City of Dubrovnik

Final Version of 31/12/2021

Deliverable Number D4.3.1

Project acronym	COASTENERGY
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Work Package number	4
Work Package title	Creating multi-level Hubs to define joint strategies & local actions supporting coastal Blue Energy
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Activity title	Defining pilot projects
Partner in charge	DURA
Partners involved	DURA
Status	Final
Distribution	Public

Table of content

1. GENERAL CHAPTER - Documentation

INVESTOR
DUBROVNIK DEVELOPMENT AGENCY
DURA d.o.o., DEFENDER OF DUBROVNIK 15
20000 DUBROVNIK

NAME OF THE STUDY

ANALYSIS OF BLUE ENERGY POTENTIALS

STUDY LOCATION

CITY OF DUBROVNIK

TECHNICAL MARK

TD 167-21 A

AUTHOR OF THE STUDY

DARIO HRASTOVIĆ, dipl.ing.stroj.

OIB 60311053479

S1554, P 162

DIRECTOR

DARIO HRASTOVIĆ, dipl.ing.stroj.

OIB 53321542631

In Đakovo, October 2021.

Pursuant to the Employment Contract between the client HRASTOVIĆ Inženjering d.o.o., OIB 53321542631, Petra Svačića 37a, 31400 Đakovo and the Executor of the designer Dario Hrastović, dipl.ing.stroj., S 1554

Pursuant to Article 52.st.4. The Construction Act NN 153/2013 and the Act on Amendments to the Construction Act NN 20/2017, NN 39-2019 are adopted:

SOLUTION
ON THE APPOINTMENT OF A MECHANICAL DESIGNER
NUMBER: TD 167-21 A

Which Dario Hrastović, B.Sc. authorization number S 1554 appoints a mechanical designer over the preparation of design documentation

INVESTOR
DUBROVNIK DEVELOPMENT AGENCY
DURA d.o.o., DEFENDER OF DUBROVNIK 15
20000 DUBROVNIK

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ANALYSIS OF BLUE ENERGY POTENTIALS

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EXPLANATION

Dario Hrastović, B.Sc. has the right to perform the duties of a mechanical designer in the capacity of a responsible person since he is registered in the Register of Certified Mechanical Engineers under ordinal number 1554, which is determined by inspection of the Decision of the Croatian Chamber of Mechanical Engineers. Solution:

Class: UO / I-310-01 / 04-08 / 1554
Reg. No.: 314-08-04-1

Zagreb, September 10, 2008

He was appointed responsible for performing the work of the Mechanical Designer over the preparation of project documentation

In Đakovo, December 2021.

DIREKTOR
DARIO HRASTOVIĆ, dipl.ing.stroj.

HRASTOVIĆ INŽENJERING
Petra Svačića 37 A
31400 Đakovo
OIB: 53321542631

Hrastović D

DELIVER:
1. Archives
2. Chief Designer
3. Project manager

KLASA:	035-04/21-01/331
URBROJ:	503-351-21-1
Zagreb,	18.08.2021.

Hrvatska komora inženjera strojarstva na temelju članka 159. Zakona o općem upravnom postupku ("Narodne novine", br. 47/09), po zahtjevu koji je podnio **Dario Hrastović**, dipl.ing.stroj., Đakovo, Kralja Petra Svačića 37a, izdaje

POTVRDU

1. Uvidom u službenu evidenciju koju vodi Hrvatska komora inženjera strojarstva razvidno je da je Dario Hrastović, dipl.ing.stroj., OIB 60311053479, Đakovo, upisan u Imenik ovlaštenih inženjera strojarstva, s danom upisa **08.09.2008.** godine, pod rednim brojem **1554**, te je stekao pravo na uporabu strukovnog naziva **"ovlašteni inženjer strojarstva"**, zaposlen u **HRASTOVIĆ INŽENJERING d.o.o., Đakovo.**

2. **Dario Hrastović, dipl.ing.stroj.**, upisan u Imenik ovlaštenih inženjera strojarstva, pod rednim brojem **1554** nije u statusu mirovanja članstva u Hrvatskoj komori inženjera strojarstva.

3. **Dario Hrastović, dipl.ing.stroj.**, upisan u Imenik ovlaštenih inženjera strojarstva, pod rednim brojem **1554** nije pod stegovnim postupkom te nema izrečenu mjeru privremenog ili trajnog oduzimanja prava na obavljanje stručnih poslova ovlaštenog inženjera strojarstva.

4. Ova potvrda se može koristiti samo u svrhu dokazivanja da je imenovani aktivni član Hrvatske komore inženjera strojarstva koja je pravna sljednica Hrvatske komore arhitekata i inženjera u graditeljstvu - Razreda inženjera strojarstva.

REPUBLIKA HRVATSKA HRVATSKA KOMORA INŽENJERA STROJARSTVA	Vrijeme izdavanja:	18.08.2021. 14:13:24
	Izdavatelj certifikata:	CN=HRVATSKA KOMORA INŽENJERA STROJARSTVA, L=ZAGREB, OID.2.5.4.97=VATHR-26023027358, O=HKIS, C=HR
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	Kontrolni broj:	359-637-779
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Informacije za provjeru dokumenta:	Elektronički zapisi se čuvaju najviše 3 mjeseca od trenutka generiranja te se u tom roku može izvršiti provjera elektroničkog zapisa uvidom u elektronički zapis kojem se pristupa putem broja zapisa i kontrolnog broja otisnutog u kontrolnom dijelu elektroničkog zapisa, putem Internet adrese https://egradani.hkis.hr/dokumenti-provjera.	

REPUBLIKA HRVATSKA
MINISTARSTVO KULTURE

UPRAVA ZA ZAŠTITU KULTURNE BAŠTINE
Klasa: UP/I-612-08/19-03/0018
Urbroj: 532-04-01-01-01/6-19-2
Zagreb, 8. veljače 2019.

Ministarstvo kulture rješavajući o zahtjevu Darija Hrastovića, dipl. ing. stroj. iz Đakova, na temelju članka 100. stavka 1. Zakona o zaštiti i očuvanju kulturnih dobara (Narodne novine br. 69/99, 51/03, 157/03, 87/09, 88/10, 61/11, 25/12, 136/12, 157/13, 152/14, 44/17 i 90/18) i članka 11. stavka 1. Pravilnika o uvjetima za dobivanje dopuštenja za obavljanje poslova na zaštiti i očuvanju kulturnih dobara (Narodne novine, br. 98/18), u postupku izdavanja dopuštenja za obavljanje poslova na zaštiti i očuvanju kulturnih dobara, na prijedlog Stručnog povjerenstva za utvrđivanje uvjeta za obavljanje poslova na zaštiti i očuvanju kulturnih dobara, donosi

RJEŠENJE

1. Utvrđuje se da je **Dario Hrastović, dipl. ing. stroj. iz Đakova,** OIB: 60311053479, stručno osposobljen za obavljanje poslova zaštite i očuvanja kulturnih dobara iz **članka 2. stavka 1. točke 7.** Pravilnika o uvjetima za dobivanje dopuštenja za obavljanje poslova na zaštiti i očuvanju kulturnih dobara i to za **izradu idejnog, glavnog i izvedbenog projekta za radove na strojarskim instalacijama nepokretnog kulturnog dobra** te mu se izdaje dopuštenje za obavljanje navedenih poslova.

2. Osoba iz točke 1. ovoga Rješenja dužna je o svakoj promjeni glede ispunjenja propisanih uvjeta za obavljanje poslova iz točke 1. ovoga Rješenja, pisano obavijestiti Ministarstvo kulture u roku od 8 dana od nastale promjene.

3. Rješenjem Klasa: UP/I-612-08/13-03/0274, Urbroj: 532-04-01-01-01/8-14-5 od 28. travnja 2014., Dario Hrastović, dipl. ing. stroj. iz Đakova, upisan je u Upisnik specijaliziranih pravnih i fizičkih osoba koje imaju dopuštenje za obavljanje poslova na zaštiti i očuvanju kulturnih dobara pod rednim brojem **2245**.

2. TECHNICAL CHAPTER

2.1 PROJECT DESCRIPTION

The Italy-Croatia cross-border cooperation program implements the Coastenergy project, which analyses, assesses and promotes energy potential and infrastructure in Mediterranean ports and coastal urban areas in order to facilitate business investment for companies, organizations and other stakeholders. be focused on thermal energy and sea wave energy.

The initiatives will guarantee the sustainable development and conservation of the marine and terrestrial ecosystem and be coordinated with other activities in the Mediterranean coastal area such as fishing, tourism and the maritime industry.

The project will result in the establishment of an Italian-Croatian observatory on the coastal energy system and the creation of an online database where potential investors and the public will have access to all relevant data and information related to investment opportunities.

The subject of the study is the analysis of the potential of blue energy and the development of guidelines for the integration of blue energy systems into coastal infrastructure within the project "Coastenergy".

All documentation is prepared in Croatian and English.

Project partners:

Irena - Istrian Regional Energy Agency Ltd.
Development Agency of the City of Dubrovnik - DURA
International Center for Sustainable Development of Energy, Water and Environment (SDEWES CENTER)
University of Camerino (IT)
University of Udine (IT)
Community of Mediterranean Universities (IT)
Chamber of Commerce, Agriculture and Crafts Chieti Pescara (IT)

City of Ploče

General goal of the project:

New platforms, networks and auxiliary platforms to improve knowledge transfer and exploit the results achieved in the blue economy.

Specific objective:

Analysis, assessment and promotion of energy potential and infrastructure in Mediterranean ports and coastal areas to facilitate business investment for companies, organizations and other stakeholders, focusing primarily on thermal energy and sea wave energy. The initiatives will guarantee the sustainable development and conservation of the marine and terrestrial ecosystem and be coordinated with other activities in the Mediterranean coastal area such as fishing, tourism and the maritime industry.

Project title: COASTENERGY- Blue energy in ports and coastal urban areas
Program: INTERREG V-A Italy - Croatia 2014 - 2020
Thematic area: Priority Axis 1- Blue Innovations
Main partner: IRENA- Istrian Regional Energy Agency
Implementation time: 30 months (1.1.2019.-30.6.2021.)
Total project budget: 1,827,670 EUR

2.2 ANALYSIS OF BLUE ENERGY POTENTIAL

Analysis of the potential for the use of thermal energy of the sea in the contact area (buffer zone), which mostly includes the historic urban landscape of Dubrovnik, including the historic areas of Konavle, Boninovo and Gruž west of the city centre, Ploče and Sv. Jakov to the east, and the peak zone and the southern slope of Srđ.

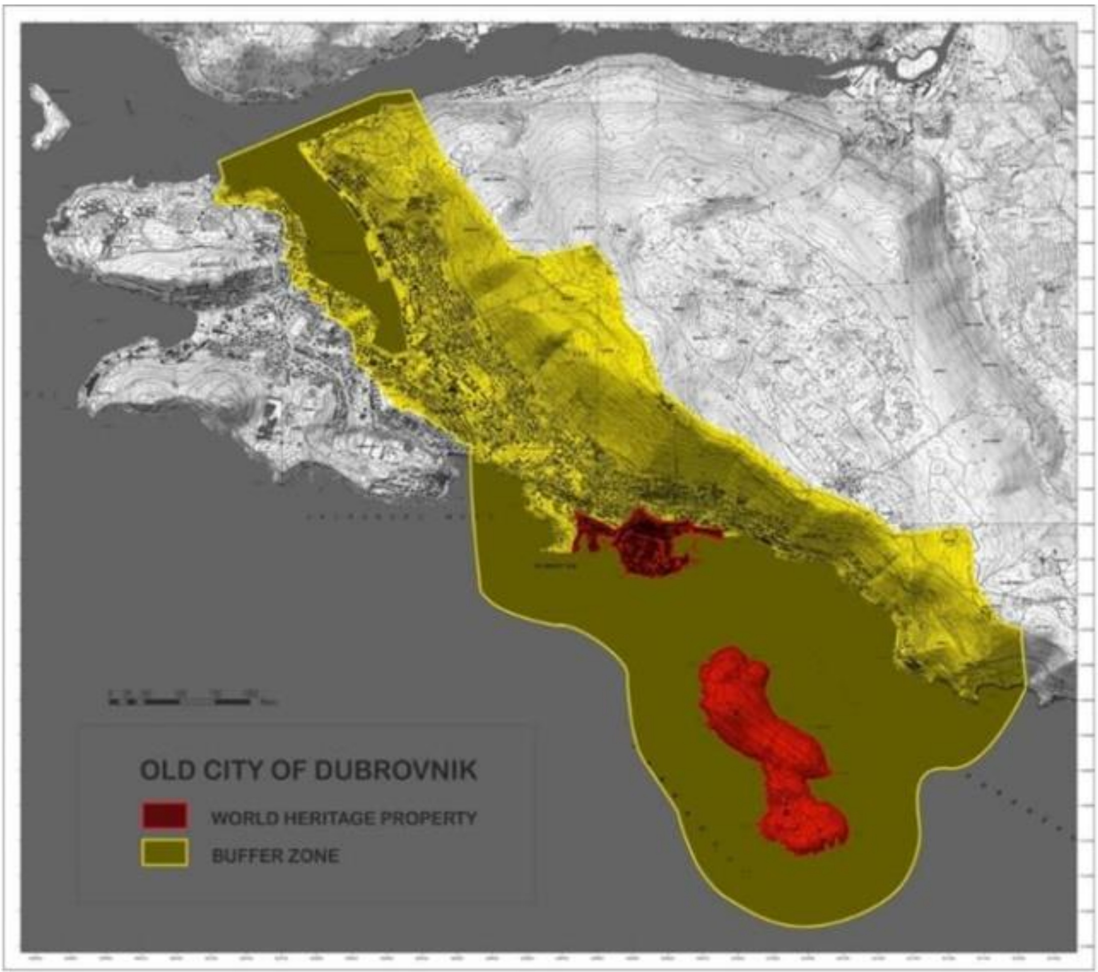


Figure 1: Urban zone of the city of Dubrovnik with the potential for the use of marine energy

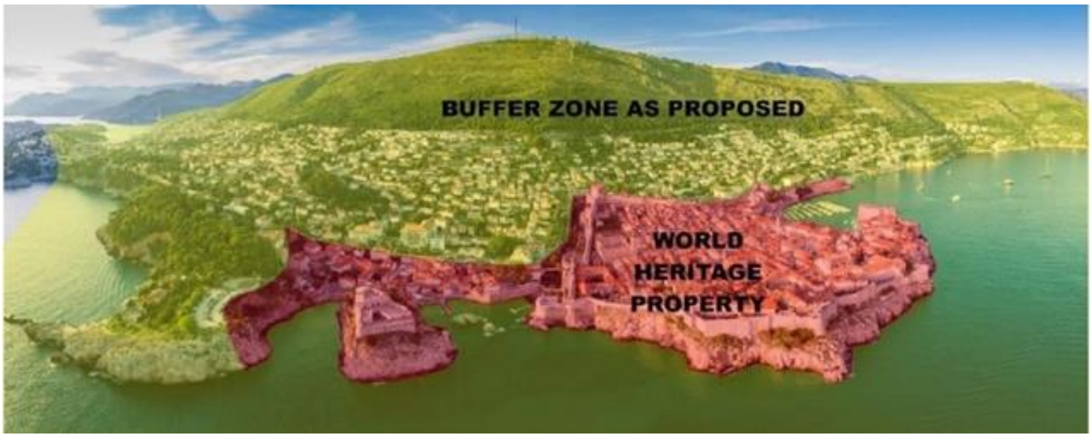


Figure 2: Urban zone of the old town of Dubrovnik

Figure 3: Satellite image of the urban zone of the city of Dubrovnik from the northwest

The study covers the possibility of using sea energy for heating and cooling buildings in a way that directs seawater to the heating system. In the heating regime, the seawater would be deprived of thermal energy and then transported to the building heating system for energy. In the cooling regime, heat energy is transferred to the sea water, and in this way the sea water is consequently heated.

The city of Dubrovnik is a coastal city located along the coast and was built in different phases over several centuries, while most of the urban ensemble is protected as a cultural urban zone that needs to be preserved in its current state. Some buildings are protected as immovable cultural property, which additionally sets the technical conditions for the selection of models and equipment for the application of marine energy.

The entire construction zone of the city of Dubrovnik is located in an earthquake area with occasional earthquakes that have significantly damaged the city centre throughout history. One of the greatest earthquakes was in 1667, which damaged most of the buildings, and an earthquake of this type can be repeated. The potential danger of stronger earthquakes further limits the possibility of applying certain technologies for the use of blue energy.

Blue energy for heating and cooling with sea water includes the capture of sea water and then the direction of sea water to the central heating and cooling engine rooms. The intention is to conduct an analysis for the possibility of using blue energy for the entire city centre. Due to the large number of different buildings and the coastal concentration of buildings, it is necessary to carry out seawater abstraction at several locations along the coast, so it will be possible to cover the entire urban zone.

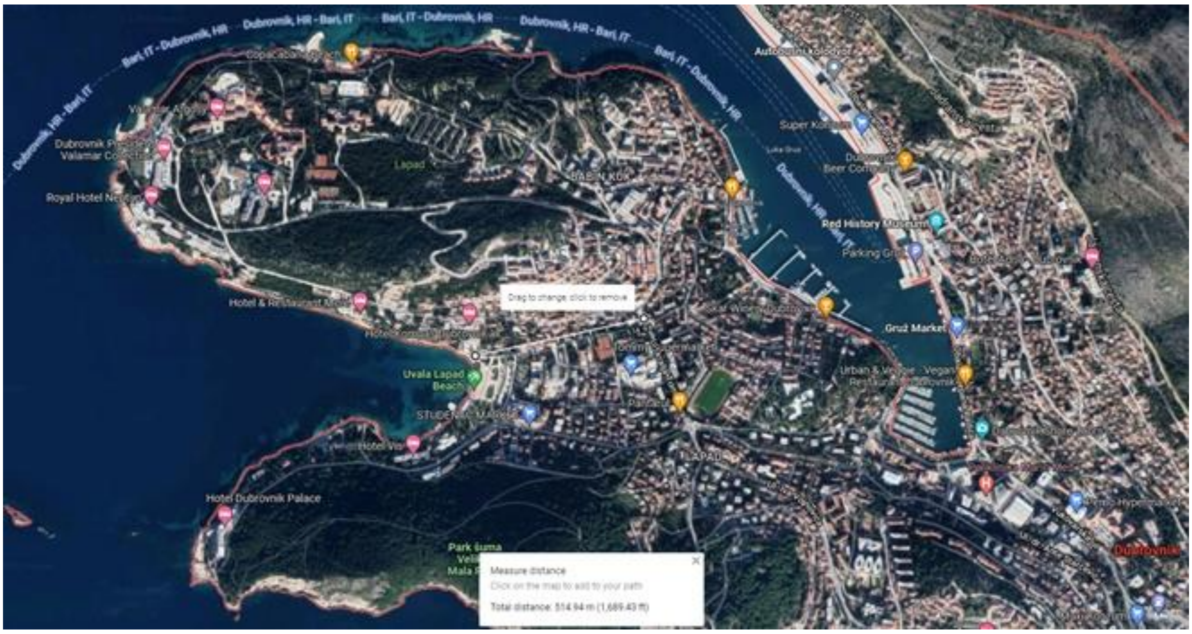


Figure 4: Satellite image of the urban zone of the old town of Dubrovnik from the south

The city of Dubrovnik is a coastal city with a small depth of construction towards the mainland, with most buildings not more than 600 m from the coast. The city was built on the slopes of the mountain Srđ, which limits the possibility of further construction of the city in depth, so the construction follows the coast with a small depth of urban construction. The specificity of the city's location greatly facilitates the possibility of using sea energy for heating and cooling because the necessary construction work will not be large to connect buildings to the system of sea energy use for heating and cooling.

The planned zone includes the historic urban landscape of Dubrovnik, including the historic areas of Konavle, Boninovo and Gruž west of the city center, Ploče and Sv. Jakov to the east, and the peak zone and the southern slope of Srđ. In all these urban zones, it is possible to build a system of using sea energy for heating and cooling.

The Coastenergy project will seek to create a common knowledge base, define common strategies and create links, cooperative patterns and synergies between companies, research centres and public authorities in order to encourage private investment in the blue energy sector. energy from marine renewable sources, can make an important contribution to the development of the new regional energy plan that is currently underway.

Coastenergy finds application in the "Clean Energy for EU Islands" initiative, which was launched after the signing of the Political Declaration on Clean Energy for EU Islands by the European Commission and 14 EU member states that have islands. The declaration says the islands face a number of energy challenges and opportunities given their specific geographical and climatic conditions. In 2018, based on the Declaration, the Commission, in cooperation with the EU Parliament, launched a Secretariat that should meet the goals of the Clean Energy for EU Islands initiative. The main goal is to ensure the energy transition of the islands, so that the inhabitants of the islands are a prerequisite for transition, and that the islands are the leading locations for innovation in the field of clean energy in the energy transition of Europe. The Secretariat should assist island institutions in transition by supporting them in developing and implementing plans for the transition to renewable energy supply.

The city of Dubrovnik is a specific urban unit that is largely protected as a culturally protected area with buildings where there are restrictions on installation, so excavations and connection with the sea surface could be significantly hampered by a large number of installations when making separate installations. The example of a seawater intake system is applicable to neighbourhood or city central heating and cooling systems in a larger scope of installation, and there is a possibility that the installation of this form will be performed in the city of Dubrovnik.

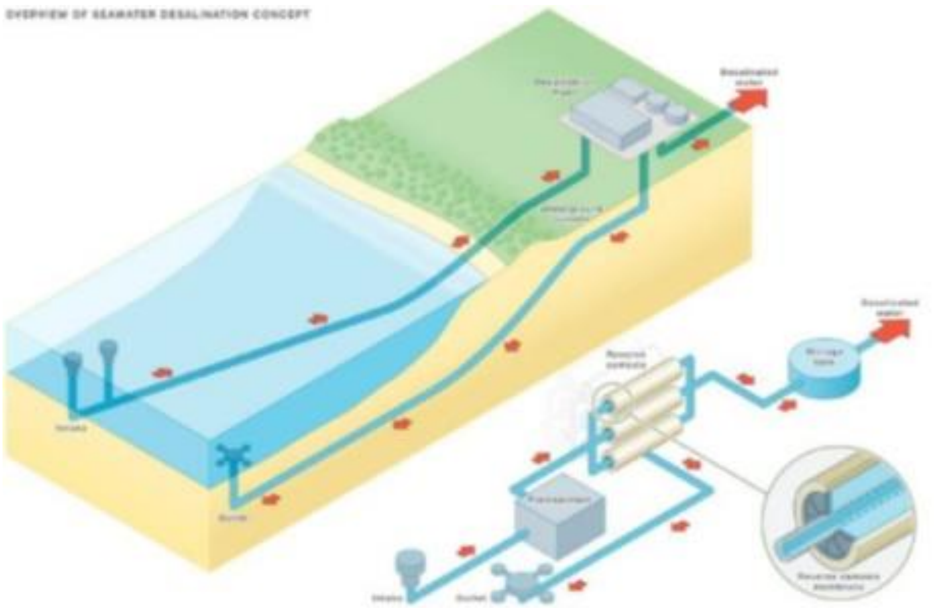


Figure 5: Illustration of a water-to-water heat pump with sea intervention

Localized installations with wells can be carried out in most of the city of Dubrovnik, primarily because the city was built along the coast with a small depth of urban construction, which ensures a connection with the sea. Terrain and soil structure is karst porous stone that leaks seawater under the influence of vacuum or seawater suction. Similar installations require specific plots on which the suction and absorption well of sea water can be built at the greatest possible distance. The great advantage of installing this form is that the water is relatively clean because it is filtered through layers of stone, but the yield is very low, so the installation is applied only to smaller buildings from the level of family houses to smaller urban villas with apartments.

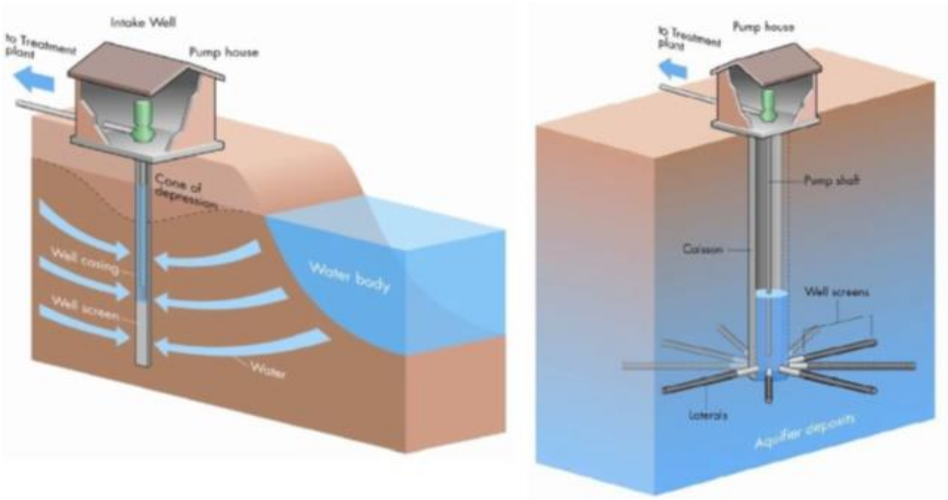


Figure 6: Illustration of a water-to-water heat pump with groundwater

Blue sea energy has a sea is a source of energy that is not used in coastal areas but there is great potential for research and development of various technological solutions.
- current technical solutions mainly convert kinetic energy of wind and water using offshore wind turbines, tidal turbines or wave energy using various converters
- the seas and oceans also represent a rich geothermal energy potential of seawater / water and it can be applied
- heat pumps have significantly higher efficiency compared to other blue energy conversion systems, so it is necessary to pay more attention to their application

The main pipes of the overall analysis of marine energy potential are:

- assess the feasibility, feasibility and economic acceptability of the use of seawater / water heat pumps in the context of available blue energy and the overall energy potential of the Adriatic Sea
- state the key milestones in the development process and an acceptable technical solution
- reduce the current financial burden related to heating / cooling energy consumption by using a system that ultimately provides lower financial costs compared to conventional heating and cooling systems
- promote the blue economy in Mediterranean countries
- reduction of greenhouse gas emissions
- identify possible financial sources that support the blue / green transition of local communities, cities, municipalities or areas

When defining the possibility of applying blue energy, the following parameters are taken into account in order to obtain the best possible vision of a potential installation that can fit into the planned area:
- analysis of locations for potential installation of renewable energy systems
- identification of available renewable sources at a particular location
- specification of technical conditions for the construction of an individual installation
- comparative analysis of energy potential and economic acceptability
- selection of a pilot site and a cost-effective renewable energy system
- feasibility study of the selected location after defining financial possibilities

The choice of applicable technology for the location depends on the geolocation parameters, urban zone and the possibility of obtaining a concession for the construction of a particular installation, and for the location of the city of Dubrovnik it is possible to use the following energy sources:
- wave energy, sea currents
- wind at sea
- salinity gradient
- geothermal energy of the Adriatic Sea
- thermal energy of the sea was selected for further evaluations

The thermal or thermal energy of the sea represents the energy potential of seawater, which can be dissipated or supplied by changing the temperature through heating and cooling systems using heat pumps.
- the thermal potential of the sea significantly exceeds all available sources
- small and predictable seasonal variations in sea temperature at lower depths of 60 m
- significant energy conversion efficiency of seawater / water heat pumps

heating efficiency coefficient COP = 4 - 5
cooling efficiency coefficient EER = 25 - 30
- it is necessary to carry out hydrogeological research works on the site to determine the soil structure before carrying out the definition of the installation
- a multidisciplinary approach is needed to properly dimension the system

Water-to-water heat pumps using seawater as a heat source are not unknown as installations, but very few installations have been carried out, but those that have been performed have shown high energy efficiency over long-term use compared to conventional heating and cooling systems.

Coastal Croatia is cooled by countless built-in air-to-water heat pumps, all of which are installed on the facades of buildings as well as on the facades of protected urban buildings that can be found in the protected zone of the city of Dubrovnik. Replacing this large number of devices would improve the vision of cities but also increase energy efficiency by greatly reducing electricity consumption of cities on the Adriatic coast, which is a big reason to consider the use of sea energy for cooling and heating. New directives on the construction of low-energy buildings NZEB impose the need to install renewable energy sources or heat pumps.

Due to the simplicity and the relationship between price and efficiency, many decide to buy and install air-to-water and air-to-air heat pumps. These models of heat pumps have relatively high efficiencies in coastal areas with a mild Mediterranean climate, but in continental areas with cold winters, the overall efficiency of the device is declining.

There are certain technical limitations for the wider application of seawater heat pumps:
- the number of skilled designers, installers and operators is limited
- A limited number of professional drilling companies with experience of similar systems
- there are no standards for the input of seawater into the systems
- surface designed oversized system based on conventional system design
- there is no certification scheme for the installers of these systems
- maintenance and long-term system performance are questionable in order to optimize performance

There are certain social constraints to the wider application of seawater heat pumps:
- Lack of public awareness of technology and sustainable energy management
- Investors continue to rely on proven conventional heating systems.
- poorly installed systems affect the reputation of seawater installations
- scepticism towards central heating and cooling systems

- one-off information on the impact on marine pollution

There are certain regulatory restrictions for the wider application of seawater heat pumps:
- Lack of laws regulating the use of seawater for heat pumps directly or with coastal wells
- Lack of a national spatial master plan for renewable energy sources as well as for the use of heat pumps
- heat pumps are only marginally mentioned in the Climate Plan of the Republic of Croatia until 2030
- it is unclear which public services should be contacted to authorize the use of such systems in the maritime area
- the development of central seawater heating and cooling projects is complex; it is long-lasting and with an uncertain outcome

There are certain economic limitations for the wider application of seawater heat pumps:
- the price-to-gas ratio is not encouraging to invest in complex installations
- Lack of incentive subsidies for large seawater use systems and heat pumps
- Lack of economic advantages and motivation for the implementation of the system of seawater installations and heat pumps in buildings

A pilot project called SEADRION was previously conducted in the Adriatic Sea, with the main goal of raising awareness and guiding the countries of the ADRION region to increase the implementation of seawater and heat pumps for heating and cooling based on findings from research and analysis conducted during the Seadrion project.

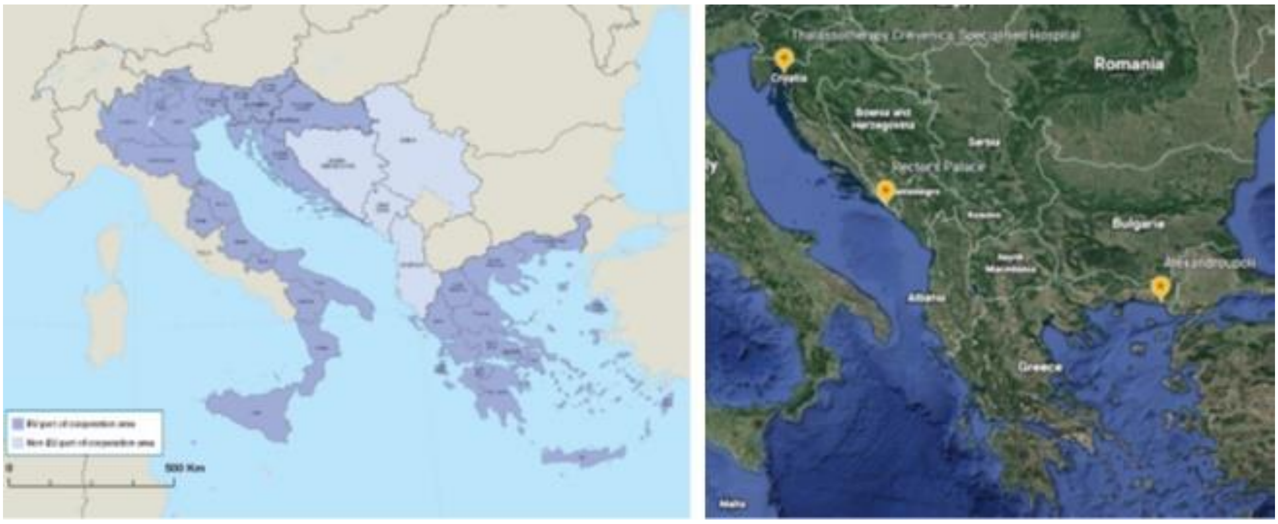


Figure 7: Seadrion project area of marine energy application

The Seadrion project was implemented with six partners from Slovenia, Croatia, Albania and Greece, all of whom participated in the project. The main goal of the project was to establish a transnational framework for the implementation of the system of sea energy use for heating and cooling. The main activities of the project were related to data collection and analysis of all information related to water-to-water heat pumps.

Through the Seadrion project, three installations using seawater and heat pumps have been built:
- In the city of Crikvenica, Croatian Thalassotherapy building
- In the city of Dubrovnik, the Croatian building of the Rector's Palace
- In the city of Alexandroupoli, Greek building Sports Hall

Policy plan for the improvement of heating and cooling technologies through innovative new technologies for the use of sea energy:
- regional / national objectives of the strategy relevant to the use of renewable technology in the heating and cooling sector, in particular focused on marine energy
- milestones for achieving the goals of the strategy
- frequent obstacles encountered by investors and designers during the implementation of new heat pump installations (environment, social and political, economic and financing, legislative and administrative framework, etc.)
- proposed measures to encourage increased implementation of new installations (industrial, social and political changes)
- target groups of stakeholders who could be involved in the implementation of the proposed measures
- international good practice applicable to each partner country

Recommendations for accelerating the development of the use of marine energy and heat pumps for heating and cooling:
- defining the current state of applicable technologies
- existing applicability of such systems (existing examples in the Adriatic-Ionian region)
- existing scientific work and innovations related to marine technology
- partner country projects related to marine technology
- research activities to promote the implementation of marine technologies

2.3 ANALYSIS OF NATURAL CONDITIONS

Analysis of natural conditions in the Dubrovnik area such as bathymetric data and analysis of sea temperature; the analysis of natural conditions is done with the aim of determining the technical and economic potential and justification of investing in technologies that use blue energy with special emphasis on the use of marine thermal energy.

SEA TEMPERATURE

The floating measuring buoy is located in the bay next to the Babin Kuk zone, and the sea temperature is read at the measuring point throughout the year. The daily current sea temperature in October 2021 was read on the website of the State Hydrometeorological Institute.

October 2021						
Station \ Measurement date [h]	07	08	11	14	15	17
Temperature [°C]	20.1	20.1	20.4	20.7	20.8	20.7

Table 1: Data on sea temperature State Hydrometeorological Institute of Croatia

Publicly available data do not show enough relevant data and therefore data on sea temperature were downloaded from the website www.seatemperature.info

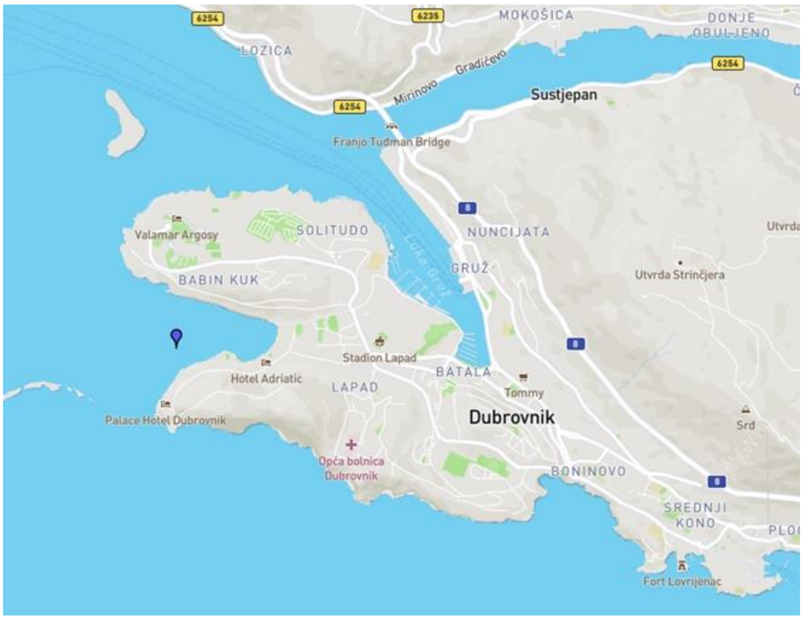
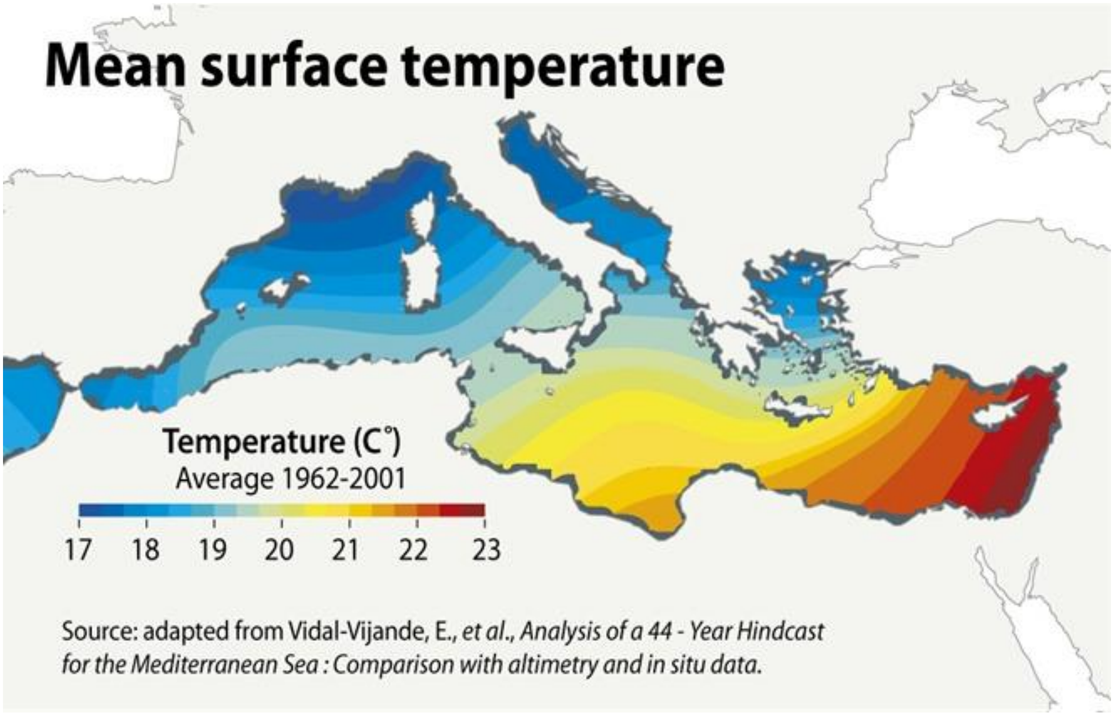


Figure 8: View of the location of the measuring sea buoy in the bay at the foot of Babin Kuk



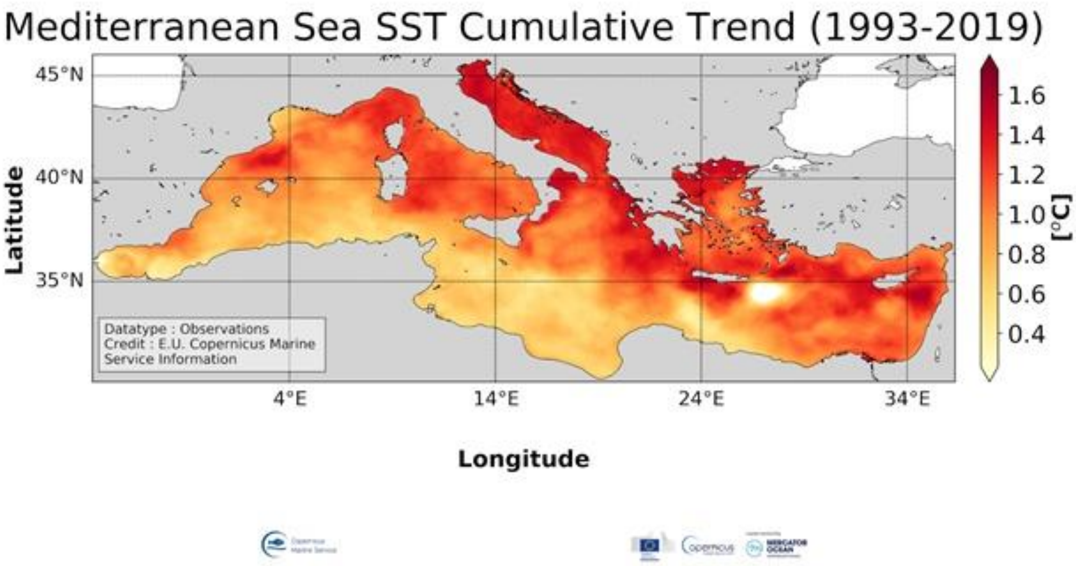


Figure 9: Surface temperatures of the Adriatic Sea

The temperature of the Adriatic Sea is not evenly distributed throughout the sea area but there is a gradient of temperature change with increasing temperature towards the southern parts where there is a constant inflow of warmer water from the Ionian Sea, the Mediterranean Sea. Hot water flows with natural currents from the warm zones of the Mediterranean Sea towards the Otra Gate and the Ionian Sea off the coast of Albania. In accordance with the Copernicus satellite monitoring, an increasing trend in the mean temperature of the Adriatic Sea was observed, given that the change in sea water is slow compared to other Mediterranean waters.

Additionally, an analysis from the website www.seatemperature.info, which monitors changes in sea temperature on a daily basis, can be accepted as an additional source of data on sea temperature.

Monthly water temperatures in Dubrovnik that show the minimum, maximum and average monthly sea temperature in Dubrovnik. Values refer to data over the last 10 years.

Month	Average [°C]	Minimum [°C]	Maximum [°C]
1	14.5	12.9	17.1
2	14	12.9	15.4

3	14.1	12.2	15.6
4	15.5	13.5	20.2
5	18.9	15.8	23.9
6	22.8	17.7	26.2
7	25.3	22.4	29.2
8	26.1	23.8	29.1
9	23.9	19.8	27.1
10	21.2	17.2	24.1
11	19	16	22.3
12	16.5	13.6	19

Table 2: Sea temperature data www.seatemperature.info

In addition to tabular values, the graph below shows changes in average sea surface temperature during the year for the city of Dubrovnik.

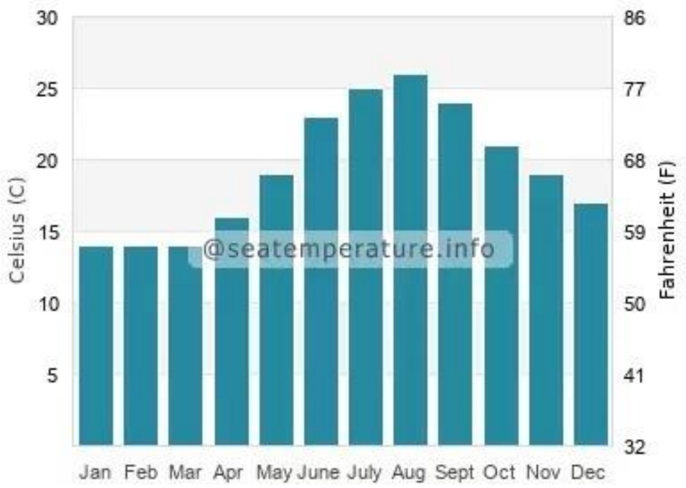


Diagram 1: Sea temperature data www.seatemperature.info

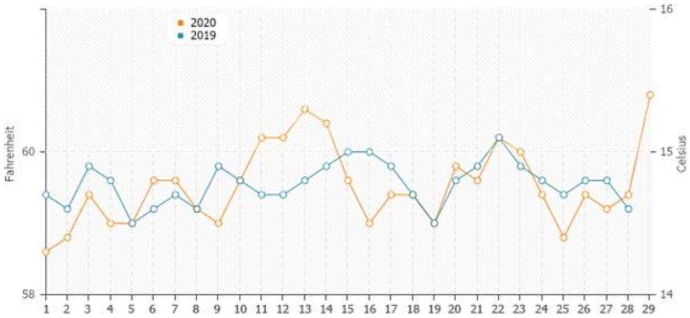
The sea temperature shall be measured at a depth of about 30 cm below the surface, with the place of measurement being as open as possible and with a depth of at least 1.8 m. The sea temperature shall be measured by automatic meteorological stations or a thermometer read by an observer.

Blue energy of the sea for heating and cooling is taken at greater depths than 30 cm from the surface and often the project is performed right at the bottom to take the water as stable as possible annual temperatures. During the winter period, the seabed temperature is slightly higher than the surface temperature, so it could be around 17-18 ° C. During the summer, the temperature of sea water at the bottom is slightly lower than at the surface, so it could be 19-20 °C.

Dan	2020	2019	Mn	Max
sij.01	16.3°C	16°C	13.4°C	17.1°C
sij.02	16°C	15.7°C	13.4°C	16.9°C
sij.03	15.9°C	15.5°C	13.6°C	16.8°C
sij.04	15.9°C	15.3°C	13.9°C	16.4°C
sij.05	15.8°C	15.3°C	13.7°C	16.3°C
sij.06	15.6°C	15.3°C	13.8°C	16.2°C
sij.07	15.5°C	15°C	13.8°C	16°C
sij.08	15.5°C	14.9°C	13.6°C	15.7°C
sij.09	15.3°C	15°C	13.6°C	15.5°C
sij.10	15.3°C	15°C	13.6°C	15.4°C
sij.11	15.3°C	14.9°C	13.8°C	15.9°C
sij.12	15°C	14.7°C	13.8°C	16.1°C
sij.13	15.1°C	14.7°C	14°C	16.2°C
sij.14	14.9°C	14.8°C	13.8°C	15.7°C
sij.15	15°C	14.7°C	13.7°C	16°C
sij.16	15°C	14.7°C	13.8°C	16°C
sij.17	15.1°C	14.5°C	13.6°C	15.8°C
sij.18	14.9°C	14.6°C	13.6°C	15.5°C
sij.19	14.8°C	14.7°C	13.6°C	15.7°C
sij.20	14.7°C	14.5°C	13.6°C	15.5°C
sij.21	14.8°C	14.4°C	13.4°C	15.4°C

sij.22	14.6°C	14.3°C	13.4°C	15.4°C
sij.23	14.6°C	14.4°C	13.3°C	15.3°C
sij.24	14.5°C	14.6°C	13.2°C	15.3°C
sij.25	14.5°C	14.6°C	13.2°C	15.5°C
sij.26	14.5°C	14.6°C	13.3°C	15.1°C
sij.27	14.2°C	14.9°C	13.3°C	15°C
sij.28	14.2°C	14.6°C	13.3°C	14.7°C
sij.29	14.1°C	14.6°C	13.6°C	15.1°C
sij.30	14.5°C	14.9°C	13.6°C	14.9°C
sij.31	14.4°C	14.8°C	13.5°C	15°C

Table 3: Sea temperature Dubrovnik January 2020 vs 2019



Dan	2020	2019	Mn	Max
vlj.01	14.3°C	14.7°C	13.3°C	15.1°C
vlj.02	14.4°C	14.6°C	13.3°C	14.8°C
vlj.03	14.7°C	14.9°C	13.4°C	14.9°C
vlj.04	14.5°C	14.8°C	13.3°C	14.8°C
vlj.05	14.5°C	14.5°C	13.3°C	14.9°C
vlj.06	14.8°C	14.6°C	13.3°C	14.8°C
vlj.07	14.8°C	14.7°C	13°C	14.8°C
vlj.08	14.6°C	14.6°C	13.3°C	14.6°C
vlj.09	14.5°C	14.9°C	13.2°C	14.9°C
vlj.10	14.8°C	14.8°C	13.3°C	14.8°C
vlj.11	15.1°C	14.7°C	13.3°C	15.1°C
vlj.12	15.1°C	14.7°C	13.3°C	15.1°C

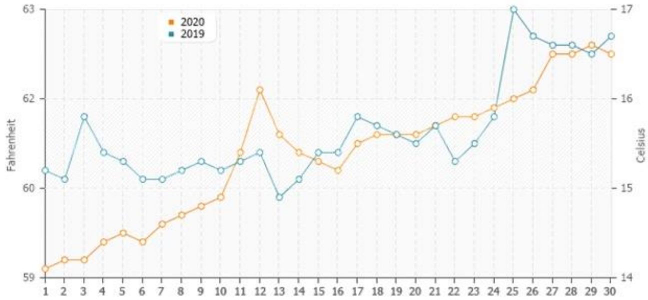
vlj.13	15.3°C	14.8°C	12.9°C	15.3°C
vlj.14	15.2°C	14.9°C	13°C	15.2°C
vlj.15	14.8°C	15°C	13.1°C	15°C
vlj.16	14.5°C	15°C	13.2°C	15°C
vlj.17	14.7°C	14.9°C	13.3°C	14.9°C
vlj.18	14.7°C	14.7°C	13.4°C	14.7°C
vlj.19	14.5°C	14.5°C	13.4°C	14.5°C
vlj.20	14.9°C	14.8°C	13.4°C	14.9°C
vlj.21	14.8°C	14.9°C	13.1°C	14.9°C
vlj.22	15.1°C	15.1°C	13.3°C	15.1°C
vlj.23	15°C	14.9°C	13.1°C	15°C
vlj.24	14.7°C	14.8°C	12.9°C	14.8°C
vlj.25	14.4°C	14.7°C	13.3°C	14.7°C
vlj.26	14.7°C	14.8°C	13.4°C	14.8°C
vlj.27	14.6°C	14.8°C	13.3°C	14.8°C
vlj.28	14.7°C	14.6°C	13.3°C	14.7°C
vlj.29	15.4°C			

Table 4: Sea temperature Dubrovnik February 2020 vs 2019

Dan	2020	2019	Mn	Max
ožu.01	15.2°C	14.6°C	13.4°C	15.2°C
ožu.02	15.1°C	14.7°C	13.4°C	15.1°C
ožu.03	15°C	14.5°C	13.4°C	15°C

ožu.04	14.2°C	14.6°C	13.5°C	14.6°C
ožu.05	14°C	14.4°C	13.4°C	14.4°C
ožu.06	14.1°C	14.4°C	12.8°C	14.4°C
ožu.07	14.1°C	14.8°C	13.1°C	14.8°C
ožu.08	14°C	14.4°C	12.2°C	14.4°C
ožu.09	13.9°C	14.4°C	12.5°C	14.5°C
ožu.10	13.8°C	14.5°C	12.5°C	14.6°C
ožu.11	13.9°C	14.7°C	12.8°C	14.7°C
ožu.12	14.2°C	14.6°C	12.9°C	14.6°C
ožu.13	14.1°C	14.2°C	12.9°C	14.5°C
ožu.14	14.3°C	14.6°C	13°C	14.6°C
ožu.15	14.4°C	14.6°C	12.9°C	14.6°C
ožu.16	14.4°C	14.7°C	12.9°C	15°C
ožu.17	14.4°C	14.9°C	12.9°C	15.1°C
ožu.18	14.6°C	14.6°C	12.8°C	15.2°C
ožu.19	14.5°C	14.9°C	13.2°C	15.2°C
ožu.20	14.5°C	15°C	13.4°C	15.3°C
ožu.21	14.9°C	14.8°C	13.6°C	15.3°C
ožu.22	14.7°C	15°C	13.7°C	15.1°C
ožu.23	14.3°C	15.3°C	13.7°C	15.3°C
ožu.24	14.4°C	15.3°C	13.7°C	15.3°C
ožu.25	14.6°C	15.4°C	13.7°C	15.4°C
ožu.26	14.5°C	15.1°C	13.6°C	15.1°C
ožu.27	14.5°C	14.9°C	13.8°C	15°C
ožu.28	14.4°C	15°C	13.8°C	15°C
ožu.29	14.3°C	15.6°C	14.1°C	15.6°C
ožu.30	14.4°C	15.3°C	14.1°C	15.3°C
ožu.31	14.4°C	14.9°C	14°C	15.4°C

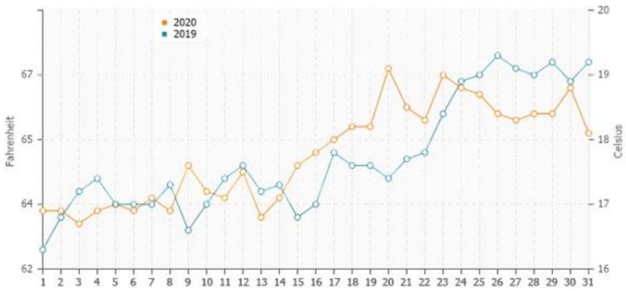
Table 5: Sea temperature Dubrovnik March 2020 vs 2019



Dan	2020	2019	Mn	Max
tra.01	14.1°C	15.2°C	14°C	15.5°C
tra.02	14.2°C	15.1°C	14°C	15.6°C
tra.03	14.2°C	15.8°C	14.1°C	15.8°C
tra.04	14.4°C	15.4°C	14°C	15.4°C
tra.05	14.5°C	15.3°C	14°C	15.6°C
tra.06	14.4°C	15.1°C	14°C	16.1°C
tra.07	14.6°C	15.1°C	13.9°C	16°C
tra.08	14.7°C	15.2°C	14°C	15.7°C
tra.09	14.8°C	15.3°C	14.3°C	15.9°C
tra.10	14.9°C	15.2°C	14.4°C	15.9°C
tra.11	15.4°C	15.3°C	14.4°C	16.2°C
tra.12	16.1°C	15.4°C	14.5°C	16.2°C
tra.13	15.6°C	14.9°C	14.7°C	16°C
tra.14	15.4°C	15.1°C	14.6°C	16.5°C
tra.15	15.3°C	15.4°C	14.7°C	16.6°C
tra.16	15.2°C	15.4°C	14.6°C	16.6°C
tra.17	15.5°C	15.8°C	14.7°C	16.6°C
tra.18	15.6°C	15.7°C	15°C	17°C
tra.19	15.6°C	15.6°C	14.7°C	17.5°C
tra.20	15.6°C	15.5°C	14.8°C	17.3°C
tra.21	15.7°C	15.7°C	14.9°C	17.3°C
tra.22	15.8°C	15.3°C	15.1°C	17.8°C
tra.23	15.8°C	15.5°C	14.3°C	18.3°C
tra.24	15.9°C	15.8°C	14.7°C	18.1°C
tra.25	16°C	17°C	14.9°C	18.5°C
tra.26	16.1°C	16.7°C	15.1°C	19.3°C
tra.27	16.5°C	16.6°C	15.3°C	19.6°C

tra.28	16.5°C	16.6°C	15.3°C	20.2°C
tra.29	16.6°C	16.5°C	15.4°C	20°C
tra.30	16.5°C	16.7°C	15.5°C	20.1°C

Table 6: Sea temperature Dubrovnik month April 2020 vs 2019



Dan	2020	2019	Mn	Max
svi.01	16.9°C	16.3°C	15.8°C	20°C
svi.02	16.9°C	16.8°C	16.2°C	20.6°C
svi.03	16.7°C	17.2°C	16.4°C	20.2°C
svi.04	16.9°C	17.4°C	16.3°C	19.4°C
svi.05	17°C	17°C	16.4°C	19.5°C
svi.06	16.9°C	17°C	16.6°C	19.8°C
svi.07	17.1°C	17°C	16.6°C	20.4°C
svi.08	16.9°C	17.3°C	16.7°C	20.8°C
svi.09	17.6°C	16.6°C	16.6°C	21°C
svi.10	17.2°C	17°C	16.7°C	21.2°C
svi.11	17.1°C	17.4°C	17°C	21.8°C
svi.12	17.5°C	17.6°C	17.2°C	21.5°C
svi.13	16.8°C	17.2°C	16.8°C	21.9°C
svi.14	17.1°C	17.3°C	17.1°C	21.3°C
svi.15	17.6°C	16.8°C	16.8°C	21.6°C
svi.16	17.8°C	17°C	17°C	21.5°C
svi.17	18°C	17.8°C	17.3°C	21.7°C
svi.18	18.2°C	17.6°C	17.4°C	21.4°C

svi.19	18.2°C	17.6°C	17.6°C	21.9°C
svi.20	19.1°C	17.4°C	17.4°C	22.1°C
svi.21	18.5°C	17.7°C	17.7°C	21.5°C
svi.22	18.3°C	17.8°C	17.8°C	22.1°C
svi.23	19°C	18.4°C	18.2°C	22.1°C
svi.24	18.8°C	18.9°C	18.3°C	22.5°C
svi.25	18.7°C	19°C	18.7°C	22.9°C
svi.26	18.4°C	19.3°C	18.4°C	22.8°C
svi.27	18.3°C	19.1°C	18.3°C	23.1°C
svi.28	18.4°C	19°C	18.4°C	23.4°C
svi.29	18.4°C	19.2°C	18.4°C	23.5°C
svi.30	18.8°C	18.9°C	18.8°C	23.8°C
svi.31	18.1°C	19.2°C	18.1°C	23.9°C

Table 7: Sea temperature Dubrovnik month May 2020 vs 2019

Dan	2020	2019	Mn	Max
lip.01	18.2°C	19.4°C	18.2°C	24.2°C
lip.02	17.7°C	19.1°C	17.7°C	24.8°C
lip.03	18.5°C	19.2°C	18.5°C	24.4°C
lip.04	17.7°C	19.5°C	17.7°C	24.2°C
lip.05	18°C	20.1°C	18°C	24.2°C
lip.06	18.6°C	20.1°C	18.6°C	24.5°C
lip.07	19.4°C	20.3°C	19.4°C	24.4°C
lip.08	19.5°C	21.2°C	19.5°C	24.2°C

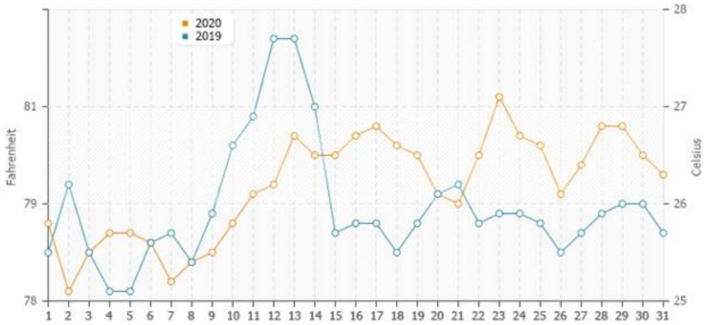
lip.09	20°C	22.6°C	20°C	23.8°C
lip.10	20.2°C	23°C	20.2°C	24°C
lip.11	20.4°C	23.8°C	20.4°C	24.3°C
lip.12	20.2°C	23.6°C	20.2°C	24.5°C
lip.13	20.5°C	23.5°C	20.5°C	24.9°C
lip.14	21.1°C	24.4°C	21°C	24.6°C
lip.15	21°C	25.1°C	19.9°C	25.1°C
lip.16	21.3°C	25.4°C	19.6°C	25.4°C
lip.17	21.4°C	24.9°C	21°C	24.9°C
lip.18	21.9°C	25°C	20.9°C	25°C
lip.19	22.1°C	24.8°C	21.7°C	25.1°C
lip.20	21.8°C	25.1°C	21.8°C	25.3°C
lip.21	21.9°C	25.2°C	21.9°C	25.7°C
lip.22	22°C	25.8°C	22°C	25.8°C
lip.23	21.8°C	24.8°C	21.8°C	26.1°C
lip.24	21.3°C	25.3°C	21.3°C	26°C
lip.25	21.3°C	24.9°C	21.3°C	26°C
lip.26	21.9°C	24.9°C	21.9°C	25.8°C
lip.27	22.5°C	24.1°C	22.3°C	25.5°C
lip.28	23°C	24.9°C	22.4°C	25.2°C
lip.29	23.7°C	24°C	22.4°C	25.6°C
lip.30	24.5°C	24°C	22.5°C	25.7°C

Table 8: Sea temperature Dubrovnik June 2020 vs 2019

Dan	2020	2019	Mn	Max

srp.01	24.9°C	23.9°C	22.4°C	25.6°C
srp.02	25.1°C	24.2°C	22.8°C	26.1°C
srp.03	25.3°C	24.6°C	22.8°C	26.3°C
srp.04	25.2°C	25.1°C	23.2°C	26.5°C
srp.05	24.2°C	25.4°C	22.9°C	26.7°C
srp.06	23.6°C	26.1°C	23.1°C	26.7°C
srp.07	22.7°C	26.2°C	22.7°C	26.9°C
srp.08	23.5°C	26.3°C	23.5°C	26.9°C
srp.09	23.8°C	26.4°C	23.4°C	27.1°C
srp.10	24.4°C	25.9°C	23.5°C	27°C
srp.11	24.7°C	24.7°C	23.8°C	27.1°C
srp.12	24°C	24.4°C	23.7°C	27.3°C
srp.13	23.8°C	24.5°C	23.8°C	27.5°C
srp.14	23.3°C	24°C	23.3°C	27.6°C
srp.15	23.6°C	24.1°C	23.6°C	27.7°C
srp.16	23.6°C	23.9°C	23.6°C	27.6°C
srp.17	23.8°C	23.4°C	23.4°C	27.2°C
srp.18	23.5°C	24.1°C	23.5°C	27.7°C
srp.19	23.1°C	23.6°C	23.1°C	28.2°C
srp.20	23.6°C	24.1°C	23.6°C	28.5°C
srp.21	23.4°C	24.2°C	23.4°C	28.5°C
srp.22	24°C	24.2°C	24°C	28.6°C
srp.23	24.1°C	24.3°C	24.1°C	28.6°C
srp.24	24.2°C	24.5°C	24.2°C	28.4°C
srp.25	23.7°C	24.6°C	23.7°C	28.5°C
srp.26	23.8°C	25.1°C	23.8°C	28.5°C
srp.27	23.6°C	25°C	23.6°C	28.5°C
srp.28	24.5°C	24.8°C	24.4°C	28.6°C
srp.29	25.2°C	24.6°C	24.5°C	29°C
srp.30	25.6°C	25.3°C	24.6°C	29.2°C
srp.31	25.4°C	25.4°C	24.3°C	28.8°C

Table 9: Sea temperature Dubrovnik month July 2020 vs 2019



Dan	2020	2019	Mn	Max
kol.01	25.8°C	25.5°C	24.3°C	28.4°C
kol.02	25.1°C	26.2°C	24.5°C	28.3°C
kol.03	25.5°C	25.5°C	24.9°C	28.1°C
kol.04	25.7°C	25.1°C	25°C	28.1°C
kol.05	25.7°C	25.1°C	25.1°C	28.5°C
kol.06	25.6°C	25.6°C	24.8°C	28.5°C
kol.07	25.2°C	25.7°C	24.8°C	28.4°C
kol.08	25.4°C	25.4°C	24.9°C	28.5°C
kol.09	25.5°C	25.9°C	24.8°C	28.5°C
kol.10	25.8°C	26.6°C	24.8°C	28.4°C
kol.11	26.1°C	26.9°C	25.1°C	28.4°C
kol.12	26.2°C	27.7°C	25.2°C	28.3°C
kol.13	26.7°C	27.7°C	24.9°C	28.6°C
kol.14	26.5°C	27°C	24.9°C	29.1°C
kol.15	26.5°C	25.7°C	25°C	28.9°C
kol.16	26.7°C	25.8°C	25.3°C	28.4°C
kol.17	26.8°C	25.8°C	25.3°C	27.8°C
kol.18	26.6°C	25.5°C	25.2°C	27.6°C
kol.19	26.5°C	25.8°C	25°C	27.5°C
kol.20	26.1°C	26.1°C	25.1°C	27.4°C
kol.21	26°C	26.2°C	24.9°C	27.3°C
kol.22	26.5°C	25.8°C	24.9°C	27.3°C
kol.23	27.1°C	25.9°C	24.5°C	27.3°C
kol.24	26.7°C	25.9°C	24.5°C	27.2°C
kol.25	26.6°C	25.8°C	24.5°C	27.4°C
kol.26	26.1°C	25.5°C	24.6°C	27.3°C

kol.27	26.4°C	25.7°C	24.7°C	27.2°C
kol.28	26.8°C	25.9°C	24.8°C	26.8°C
kol.29	26.8°C	26°C	24.9°C	26.8°C
kol.30	26.5°C	26°C	24.7°C	27°C
kol.31	26.3°C	25.7°C	23.8°C	27.1°C

Table 10: Sea temperature Dubrovnik month August 2021 vs 2020

Dan	2020	2019	Mn	Max
ruj.01	26°C	26.1°C	22.6°C	27.1°C
ruj.02	25.3°C	25.9°C	22.6°C	27.1°C
ruj.03	24.7°C	26.2°C	22.5°C	27°C
ruj.04	24.6°C	25.9°C	21.8°C	26.9°C
ruj.05	24.5°C	26.3°C	21.9°C	26.9°C
ruj.06	25°C	26.5°C	22.5°C	26.7°C
ruj.07	25.4°C	25.4°C	22.5°C	26.6°C
ruj.08	25.2°C	25.5°C	22.2°C	26.3°C
ruj.09	24.6°C	25.2°C	22.1°C	25.9°C
ruj.10	24.6°C	24.9°C	22°C	25.9°C
ruj.11	24.5°C	25.1°C	22.1°C	26°C
ruj.12	24.7°C	25.2°C	21.4°C	25.9°C
ruj.13	24.8°C	24.9°C	21.3°C	26.4°C
ruj.14	25°C	24.5°C	21.3°C	26.4°C
ruj.15	24.8°C	24.4°C	21.7°C	26.3°C
ruj.16	24.9°C	24.2°C	21.4°C	26.4°C
ruj.17	25.4°C	24.2°C	21.6°C	26.4°C

ruj.18	25.2°C	24.3°C	21.6°C	26.2°C
ruj.19	24.9°C	23.9°C	21.7°C	26°C
ruj.20	25°C	23.2°C	21.5°C	25.8°C
ruj.21	24.7°C	23.1°C	21.3°C	25.2°C
ruj.22	24.8°C	23.1°C	21.2°C	25.1°C
ruj.23	24.7°C	23.1°C	21.3°C	25.5°C
ruj.24	24.7°C	23°C	20.6°C	25.2°C
ruj.25	24.8°C	22.9°C	20.4°C	25.2°C
ruj.26	24.2°C	22.5°C	20.4°C	24.8°C
ruj.27	23.9°C	22.5°C	20°C	24.9°C
ruj.28	23.6°C	22.6°C	19.9°C	24.9°C
ruj.29	23.1°C	22.5°C	19.8°C	24.7°C
ruj.30	23.4°C	22.5°C	19.9°C	24.4°C

Table 11: Sea temperature Dubrovnik month September 2020 vs 2019

Dan	2020	2019	Mn	Max
lis.01	23.3°C	22.6°C	19.9°C	24.1°C
lis.02	23°C	22.6°C	20°C	24°C
lis.03	22.9°C	22.4°C	20.1°C	24°C
lis.04	22.7°C	22.5°C	19.9°C	23.8°C
lis.05	22.6°C	22.6°C	19.6°C	23.9°C
lis.06	22.9°C	22.9°C	19.6°C	24°C
lis.07	22.8°C	22.5°C	19.4°C	23.8°C

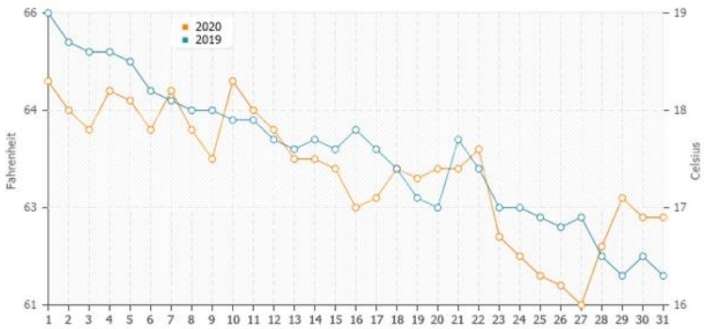
lis.08	22.8°C	22.3°C	19.5°C	23.9°C
lis.09	22.4°C	22.3°C	19.6°C	23.6°C
lis.10	22.4°C	22°C	19.6°C	22.9°C
lis.11	22.7°C	22.1°C	19.5°C	22.8°C
lis.12	22.5°C	22.3°C	19.4°C	22.8°C
lis.13	22°C	22°C	19.5°C	22.8°C
lis.14	21.8°C	22°C	19.6°C	22.6°C
lis.15	21.8°C	22.2°C	19.5°C	22.4°C
lis.16	21.9°C	22.1°C	19.4°C	22.4°C
lis.17	21.6°C	22.1°C	19.2°C	22.3°C
lis.18	21.7°C	22.1°C	19.2°C	22.1°C
lis.19	21.3°C	22.4°C	19.1°C	22.4°C
lis.20	21.5°C	22.3°C	18.8°C	22.8°C
lis.21	21.2°C	22.4°C	18.7°C	22.8°C
lis.22	21.1°C	22.3°C	18.5°C	22.9°C
lis.23	20.9°C	22.2°C	18.1°C	23.1°C
lis.24	20.9°C	22.6°C	17.3°C	23.5°C
lis.25	21.2°C	22.7°C	17.2°C	23°C
lis.26	21°C	22.4°C	17.6°C	22.7°C
lis.27	21.1°C	22.2°C	17.7°C	22.3°C
lis.28	21.3°C	22.3°C	17.8°C	22.3°C
lis.29	21°C	22.1°C	18.9°C	22.1°C
lis.30	21°C	21.9°C	18.3°C	21.9°C
lis.31	21.2°C	22.5°C	18.4°C	22.5°C

Table 12: Sea temperature Dubrovnik month October 2020 vs 2019

Dan	2020	2019	Mn	Max
stu.01	21.1°C	22.2°C	18.4°C	22.2°C
stu.02	20.7°C	22.3°C	18.4°C	22.3°C
stu.03	20.7°C	21.9°C	18.5°C	21.9°C
stu.04	20.6°C	21.8°C	18.3°C	21.8°C
stu.05	20.8°C	21.6°C	18°C	21.6°C
stu.06	20.7°C	21.2°C	17.9°C	21.2°C
stu.07	20.5°C	20.9°C	17.9°C	21.3°C
stu.08	20.2°C	21.6°C	17.9°C	21.6°C
stu.09	20.1°C	21.6°C	18°C	21.6°C
stu.10	20°C	21.6°C	17.7°C	21.6°C
stu.11	19.8°C	21°C	17.6°C	21°C
stu.12	19.7°C	20.7°C	17.4°C	20.9°C
stu.13	19.7°C	21.1°C	17.4°C	21.1°C
stu.14	20°C	20.8°C	17.3°C	20.8°C
stu.15	19.7°C	20.4°C	17°C	20.5°C
stu.16	19.5°C	20.3°C	17°C	20.6°C
stu.17	19.9°C	20.1°C	17.1°C	20.8°C
stu.18	19.9°C	20.4°C	16.9°C	20.4°C
stu.19	20.3°C	20.1°C	16.6°C	20.3°C
stu.20	20.4°C	20.2°C	16.6°C	20.4°C
stu.21	19.7°C	19.9°C	16.4°C	19.9°C
stu.22	18.9°C	20.1°C	16.4°C	20.1°C
stu.23	18.8°C	19.8°C	16.6°C	19.8°C
stu.24	18.6°C	19.9°C	16.3°C	19.9°C
stu.25	18.6°C	19.6°C	16.4°C	19.6°C
stu.26	18.1°C	19.2°C	16.5°C	19.6°C

stu.27	18.3°C	19°C	16.7°C	19.5°C
stu.28	18.2°C	19.5°C	17°C	19.5°C
stu.29	18.2°C	19.2°C	16.8°C	19.2°C
stu.30	18.3°C	19.2°C	16°C	19.2°C

Table 13: Sea temperature Dubrovnik month November 2020 vs 2019



Dan	2020	2019	Mn	Max
pro.01	18.3°C	19°C	16.1°C	19°C
pro.02	18°C	18.7°C	15.7°C	18.7°C
pro.03	17.8°C	18.6°C	15.3°C	18.6°C
pro.04	18.2°C	18.6°C	15.8°C	18.6°C
pro.05	18.1°C	18.5°C	16.1°C	18.5°C
pro.06	17.8°C	18.2°C	15.9°C	18.6°C
pro.07	18.2°C	18.1°C	16.1°C	18.3°C
pro.08	17.8°C	18°C	15.6°C	18.3°C
pro.09	17.5°C	18°C	15.5°C	18.1°C
pro.10	18.3°C	17.9°C	15.3°C	18.3°C
pro.11	18°C	17.9°C	15.1°C	18.1°C
pro.12	17.8°C	17.7°C	14.9°C	18.2°C
pro.13	17.5°C	17.6°C	15.1°C	18°C
pro.14	17.5°C	17.7°C	14.9°C	17.8°C
pro.15	17.4°C	17.6°C	14.7°C	17.7°C
pro.16	17°C	17.8°C	14.7°C	17.8°C
pro.17	17.1°C	17.6°C	14.4°C	17.6°C

pro.18	17.4°C	17.4°C	14.4°C	17.5°C
pro.19	17.3°C	17.1°C	14.1°C	17.3°C
pro.20	17.4°C	17°C	14.5°C	17.4°C
pro.21	17.4°C	17.7°C	14.9°C	17.7°C
pro.22	17.6°C	17.4°C	15.1°C	17.6°C
pro.23	16.7°C	17°C	15°C	17°C
pro.24	16.5°C	17°C	15°C	17°C
pro.25	16.3°C	16.9°C	14.9°C	16.9°C
pro.26	16.2°C	16.8°C	14.8°C	16.9°C
pro.27	16°C	16.9°C	14.5°C	16.9°C
pro.28	16.6°C	16.5°C	14.2°C	16.6°C
pro.29	17.1°C	16.3°C	13.9°C	17.1°C
pro.30	16.9°C	16.5°C	13.8°C	16.9°C
pro.31	16.9°C	16.3°C	13.6°C	16.9°C

Table 14: Sea temperature Dubrovnik month December 2020 vs 2019

Monthly water temperatures in Dubrovnik that show the minimum, maximum and average monthly sea temperature in Dubrovnik. Values refer to data over the last 10 years.

Month	Average [°C]	Minimum [°C]	Maximum [°C]
1	14.5	12.9	17.1
2	14	12.9	15.4
3	14.1	12.2	15.6
4	15.5	13.5	20.2
5	18.9	15.8	23.9
6	22.8	17.7	26.2
7	25.3	22.4	29.2
8	26.1	23.8	29.1
9	23.9	19.8	27.1
10	21.2	17.2	24.1
11	19	16	22.3
12	16.5	13.6	19

Table 15: Monthly sea temperatures Dubrovnik 2020

Available data on sea temperatures are the starting data for sizing the heating and cooling system of the city of Dubrovnik. When dimensioning the system, it should be taken into account that the change in water temperature up to 5 ° C has been empirically accepted by Hrvatske vode in order to avoid significant disturbance of the biological flora and fauna of the local marine area.

In the heating season of the local urban unit, the energy of the sea would be taken away from the sea water in a way that the water is subcooled and the energy of the sea water is directed to the city's heating systems. Thus, for the month of January, the water temperature would decrease from 12.9 ° C by a maximum of 5 ° C to 7.9 ° C and with that temperature it would be released in the planned zone.

In the cooling season, thermal energy is taken from the buildings in such a way that the buildings and the taken over energy are directed towards the central cooling system, which then directs all the taken over energy towards the sea water. Thus, for the month of July, the sea water would be heated from 29.2 ° C to a maximum of 5 ° C to a temperature higher than 34.2 ° C and with this increased temperature it would be discharged into the sea while sea currents would take hot water away from the discharge zone.

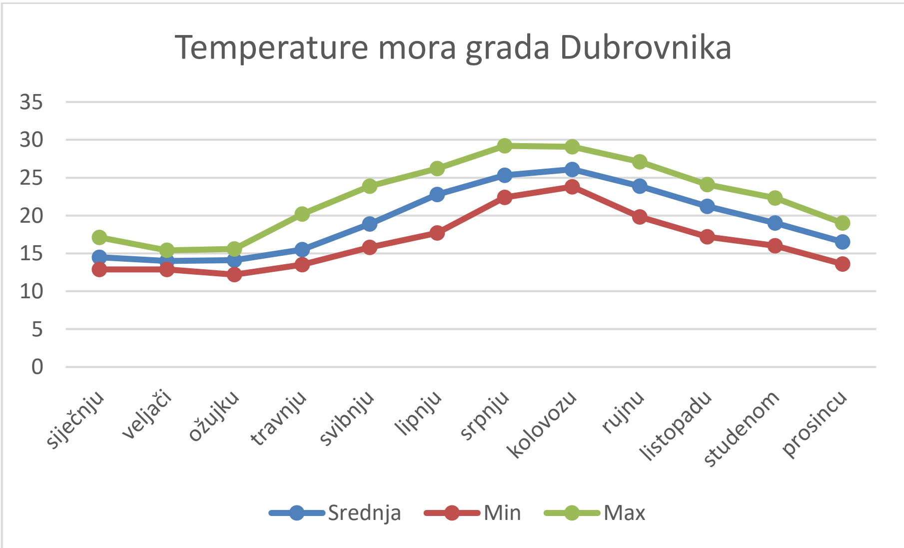


Diagram 2: Monthly sea temperatures Dubrovnik 2020

Through the Coastenergy project, digital maps have been created and are available via a web browser, so it is possible to display temperature data for individual locations in the Adriatic Sea by selecting a special filter, or to display lines of changes in the Adriatic Sea temperature.

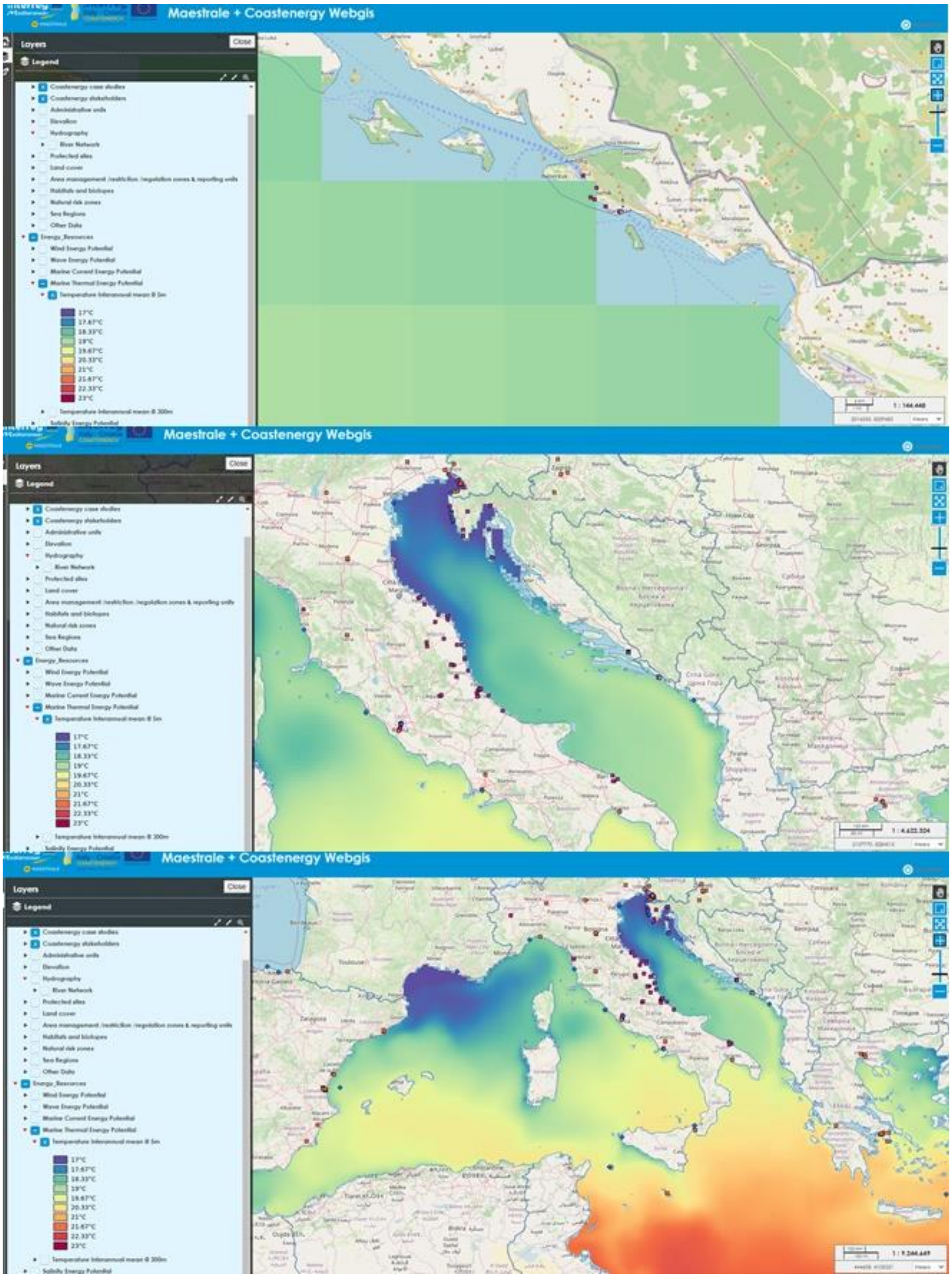


Figure 10: Coastenergy project temperature data available online

BATIMETRIC DATA

Bathymetric data are displayed in the corresponding submarine maps and show the relief of the seabed and the terrain as contour lines or isobaths. Bathymetric maps are made using an echo sonar that is placed under the ship and records the depths of the sea below the ship using a sound wave directed towards the bottom. The time required for the sound wave to bounce off the seabed and return to the sonar is equivalent to the depth of the sea.

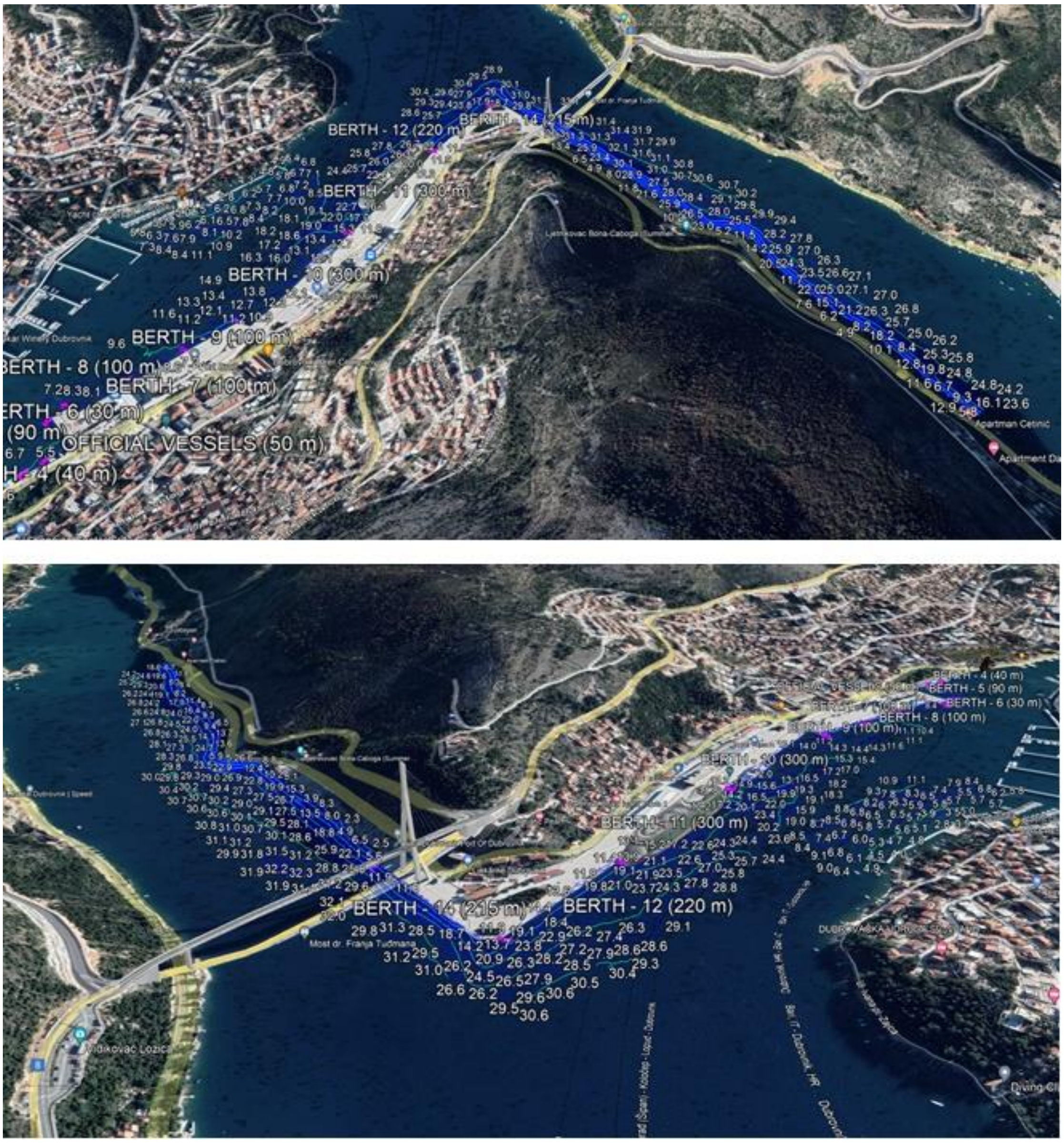


Figure 11: Bathymetric data of the sea depth of the port of Dubrovnik

The bottom of the Adriatic Sea near the city of Dubrovnik reaches the greatest depths with a constant temperature of deep water, so in this zone of the Adriatic Sea there is great potential for the use of sea energy for heating and cooling. Sea currents bring fresh water from the south-east direction and then the currents follow the coast and drain the sea water in the north-west direction.

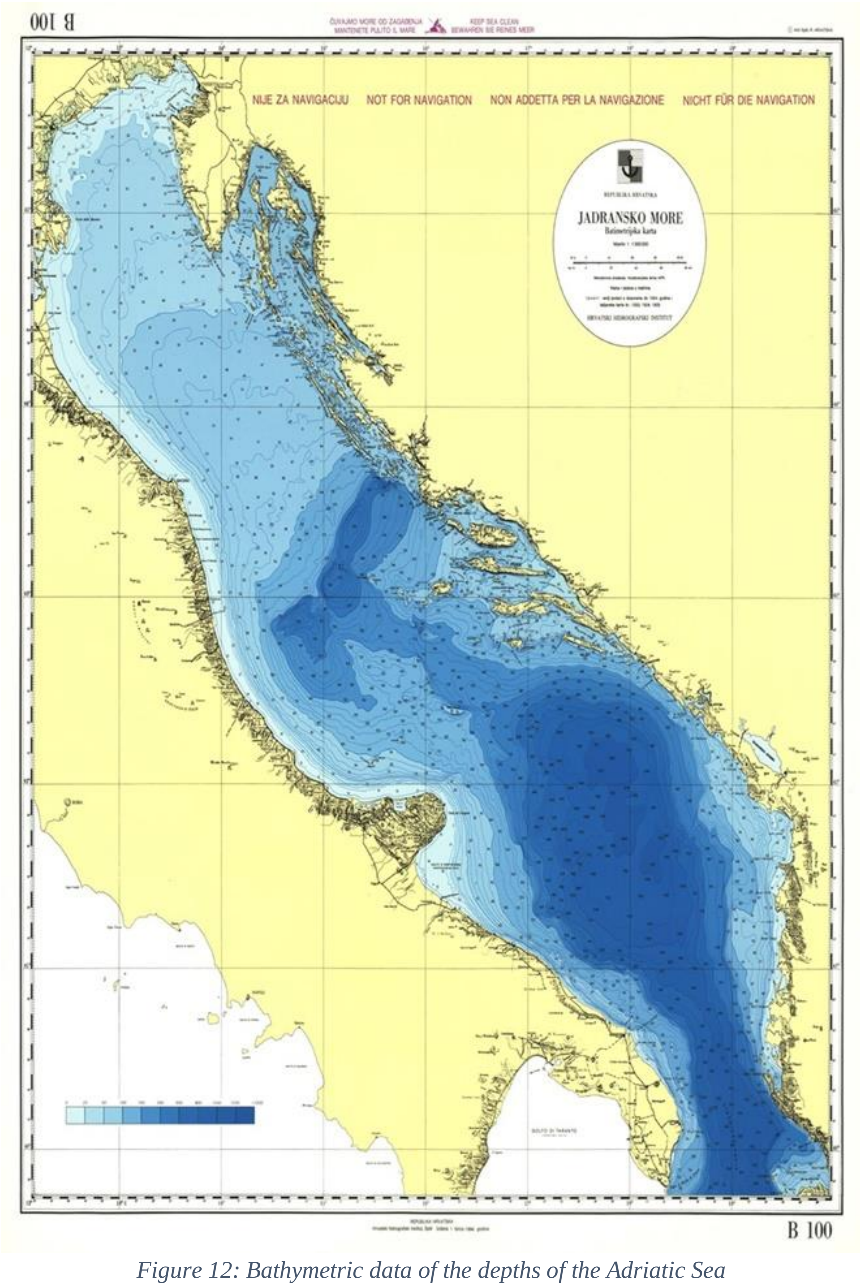


Figure 12: Bathymetric data of the depths of the Adriatic Sea

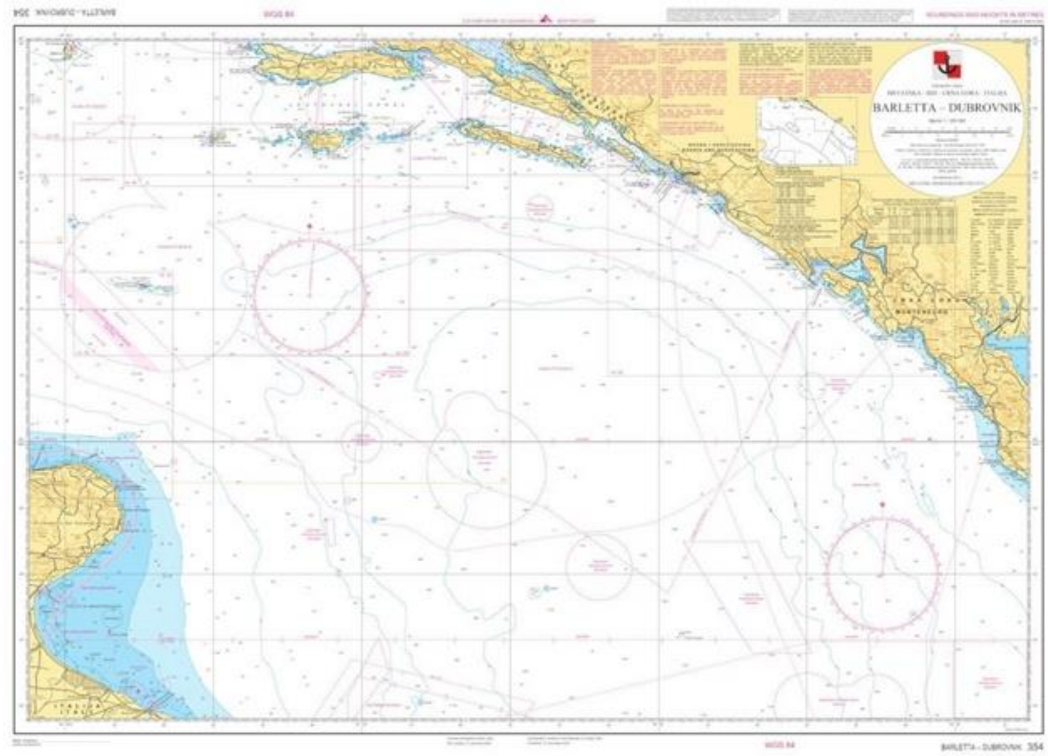


Figure 13: Bathymetric data of the depths of the Adriatic Sea near Dubrovnik

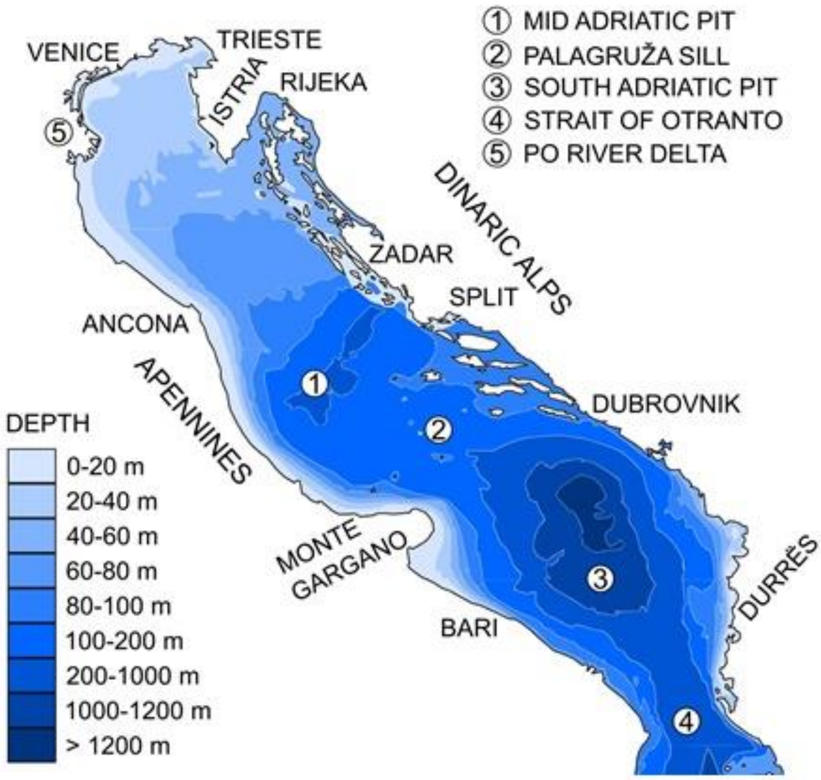


Figure 14: Bathymetric data of the depths of the Adriatic Sea

Through the Coastenergy project, digital maps have been created that are available via a web browser, and it is possible to display bathymetric data for individual locations in the Adriatic Sea by selecting a special filter, i.e., to show lines of changes in the depth of the Adriatic Sea. The digital map is easy to use and data for any location of the Mediterranean and the depths of the sea can be easily obtained.

The interactive map confirms the previously collected data that in the central part of the Adriatic Sea there is a deep-sea zone with a constant sea temperature that changes very little. This large amount of seawater is a heat accumulator that can absorb large fluctuations in seawater temperature since the temperature of deep water is almost unchanged compared to surface water whose temperature depends on the irradiated energy of the Sun.

http://192.167.120.31/lizmap-web-client-3.1.4/lizmap/www/index.php/view/map/?repository=maestrale&project=maestrale

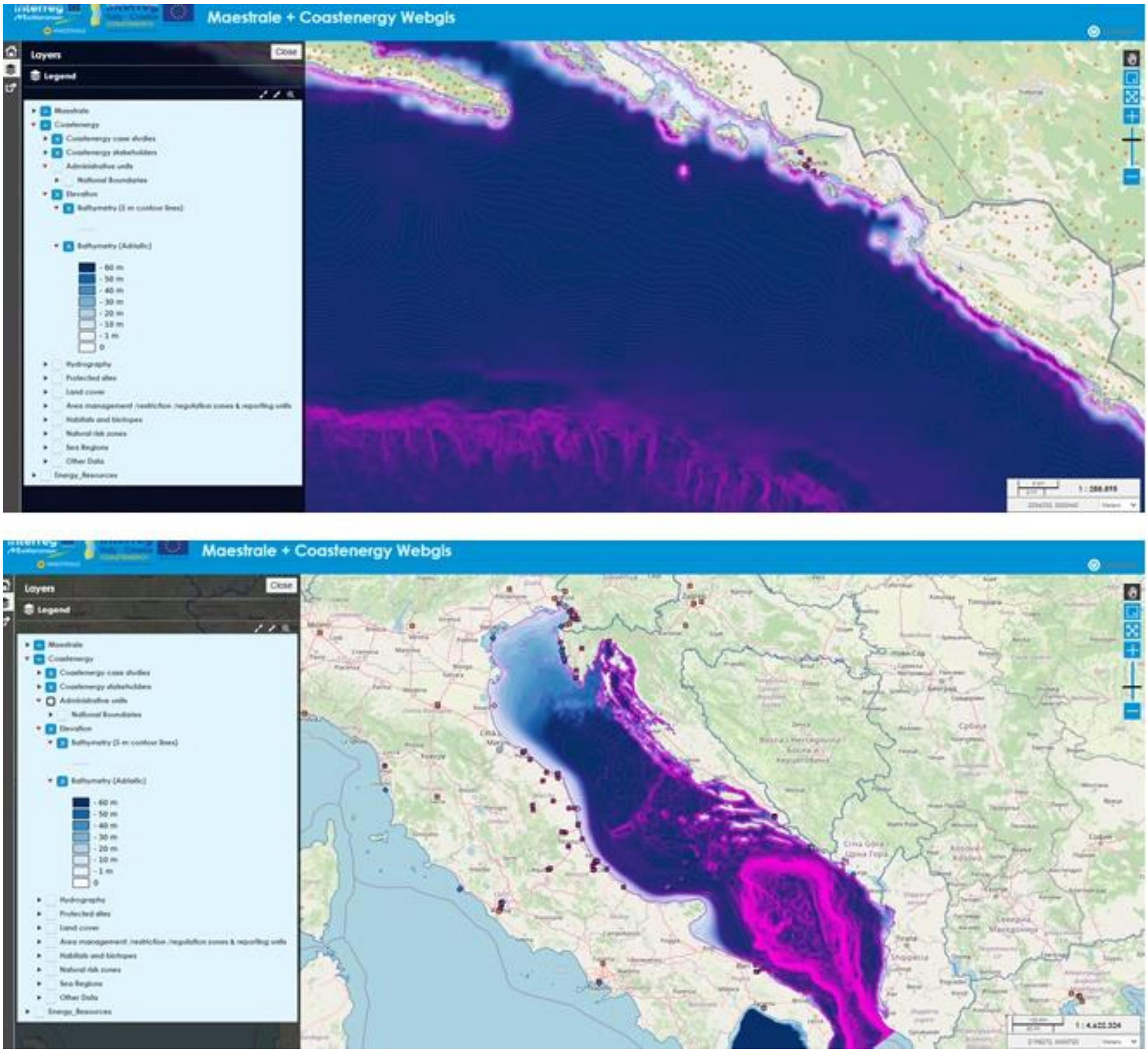


Figure 15: Coastenergy project bathymetric data available online

2.4 ANALYSIS OF AVAILABLE TECHNOLOGY

Analyse the available technologies for the use of thermal energy of the sea and the selection of technologies that have the potential to be installed in the area of Dubrovnik. The Coastenergy project is focused on the use of marine heat in the coastal area, ports and especially within existing and future infrastructure with a special analysis of the potential of heat pump technology in this way, especially taking into account future projects (infrastructure, etc.) provided by spatial plans and other relevant documents of cities and municipalities belonging to the subject area of Dubrovnik.

2.4.1 TECHNICAL DESCRIPTION OF THE CENTRAL SYSTEM

The increase in demand for heating and cooling leads to the need for more efficient cooling solutions based on renewable energy. Seawater Air Conditioning (SWAC) can provide baseload cooling services in coastal areas using deep cold seawater. Additionally, central systems can be expanded by using heat storage tanks that would stabilize the relationship between heat production and demand.

Deep seas are an almost unlimited cooler (cooling source) that creates an opportunity to develop cheaper district cooling systems near the sea. Seawater Air Conditioning (SWAC) is a district cooling technology that uses deep cold seawater for cooling, which can be cold up to 3-5 ° C at depths between 700 and 2000 m.

SWAC began to be considered in the 1970s, and gained momentum in the early 1990s. It is proposed for regions where seabed bathymetry allows for a reasonably short cold seawater intake pipeline. SWAC replaces refrigeration devices used in conventional AC systems, greatly reducing power consumption and cooling costs. The electricity cost of SWAC systems is usually 50-80% lower than conventional systems. SWAC also contributes to the reduction of heat islands due to air conditioning.

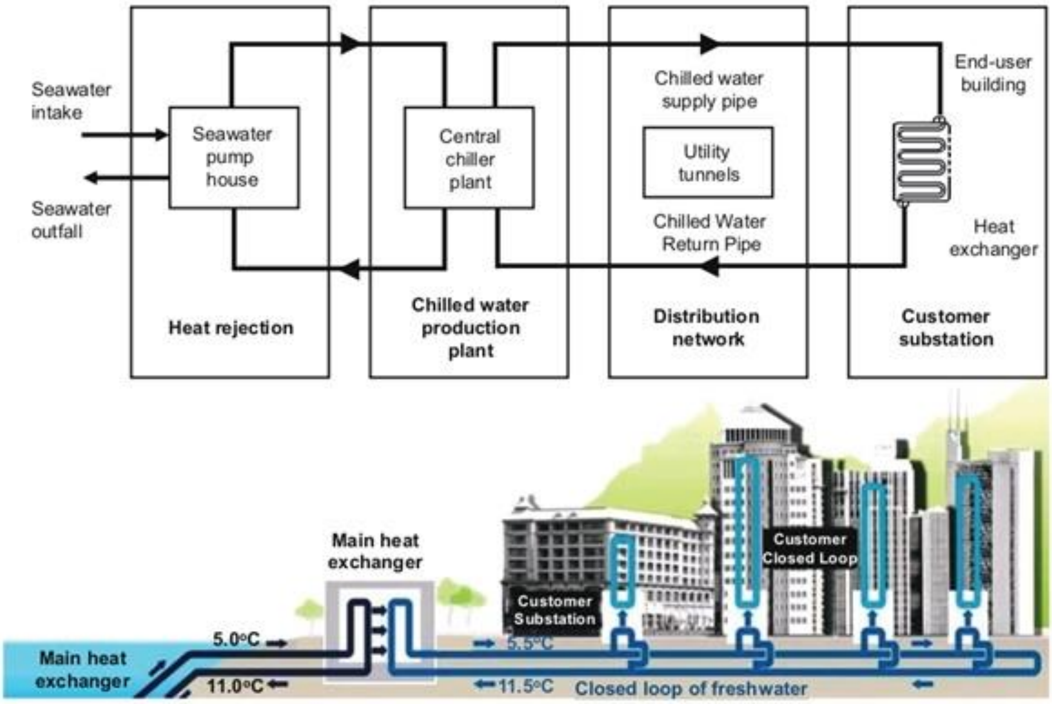


Figure 16: Central heating and cooling pipeline systems

SWAC heat storage systems can be expanded with renewable energy generation systems. Excessive production of electricity from variable renewable energy sources (VRE), i.e., wind and solar energy, can be balanced with variations in seawater flow in the SWAC plant pipeline. This cold water would then be stored in heat storage tanks to meet the need for cooling at any time.

Conventional SWAC plants consist of:
- sea water supply is a pipeline used to transport sea water to the coast
- the seawater pump delivers water from the sea via an exchanger and back to the sea
- A seawater outlet is a pipeline used to return seawater back to the ocean
- a heat exchanger or chilled water plant is used to exchange heat from seawater and district cooling or heating systems
- the distribution network distributes cold fresh water from the SWAC plant to the heating and cooling substation of the local building

The entrance of cold sea water consists of pipelines and tunnels that connect the sea at a depth of about 700 to 2000 m with a heat exchanger on the shore. The length of the pipe can vary from 1 to 20 km. The longer the inlet pipeline, the higher its capital costs, the load of electricity for pumping and energy losses in the environment. Installation costs and pipeline maintenance costs do not vary significantly with the change in pipeline diameter. The inlet pipeline usually consists of high-density polyethylene (HDPE), which has several advantages over alternative materials (strength, durability, flexibility, inertness, insulation, high pressure resistance, cost-effectiveness and mild negative cultivation). HDPE pipeline is ballast using various concrete weight constructions, most often variations of concrete anchor tightly clamped around HDPE pipeline. Flexibility of pipelines is a critical factor, as it can be exposed to stress due to sea currents, seismic activities, as well as expansion and contraction due to temperature changes. HDPE pipes also require less insulation because plastic is inherently less conductive than metal.

The hot seawater outlet should return deep seawater to approximately half the length of the inlet pipeline or to a depth of at least 50 m. This reduces the impact of cold, salt water on the marine environment. De Profundis prescribes an exit at a minimum of about 200 m to avoid algae blooms. Hawaiian coastal environmental studies have been developed to provide an understanding of pre-installation conditions at the future SWAC site and to allow a more accurate environmental assessment. An alternative use of warmer seawater discharges, which can be rich in nutrients, is for the production of algae, fish and crabs in controlled tanks or in the open ocean.

The heat exchanger allows cold seawater to cool the recirculation of fresh cooling water used for air conditioning. In a typical SWAC system, cold seawater is pumped at 5 ° C, enters 7-8 ° C into the heat exchanger, passes through the heat exchanger and exits at 12–13 ° C. The fresh water of the air conditioning system comes in at 13 ° C and comes out at 8 ° C. Titanium heat exchangers are often used because they combine corrosion resistance in salt water with high thermal conductivity. Long-term tests of the heat exchanger have reported that pollution is not a serious problem with deep seawater. After the seawater passes through the heat exchanger, it returns through the hot seawater outlet. District cooling is used to distribute the cooling load from the SWAC plant to the cooling requirements. District cooling is usually less sustainable than a district heating system. This is because steam is a better energy carrier than water, and the temperature difference between supply and return water in heating systems is usually much larger than in cooling systems. This results in a larger pipe diameter and higher power consumption in district heating pumping systems than in district heating systems. However, since cooling costs with SWAC processes can be quite low, short-distance district cooling is becoming a viable alternative. Sometimes the cost of district cooling is higher than the cost of a SWAC project. This can happen where the demand for refrigeration is very fragmented.

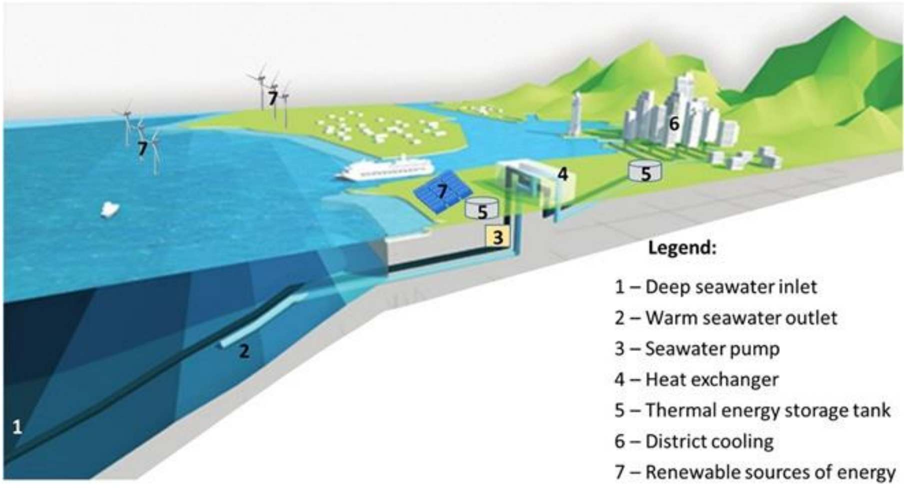


Figure 17: Hybrid heating and cooling pipeline systems

The hybrid design of a conventional SWAC plant consists of:
(1) cold seawater inlet
(2) hot sea water outlet
(3) a seawater pump, excavated at a reasonable depth to allow future increase in flow without cavitation
(4) heat exchanger
(5) heat storage tank
(6) refrigeration systems or district cooling system
(7) renewable energy sources.

High-speed SWAC is used so that the flow of the SWAC system can be increased without the need to build new seawater inlet and outlet pipelines, which have high capital costs. Instead, the seawater velocity can be increased to increase the flow and, thus, increase the cooling load of the SWAC system. However, to allow the system to be upgraded, the seawater pump must be buried to prevent cavitation with increasing flow rate in the pipeline. Cavitation is a common problem in SWAC plants, and even closed-loop systems have been proposed to reduce the impact of cavitation. The next section presents changes in the design of the seawater pump to allow for an increase in the cooling load in the SWAC plant and to avoid cavitation.

A seawater pumping station is usually designed using a wet or dry onshore pit near the shore and must be installed deep enough to calculate the total loss in the suction pipe from the shore. The deep supply pipeline and the seawater pumping station are excavated up to 2 to 5 m above sea level. Seawater in the pipeline during operation has a constant salinity equivalent to the depth of seawater in which it is located. This density is higher than the average density profile to the depth at which seawater is pumped. Another factor that contributes to the depth of excavation of the seawater pump is the loss of height due to the flow in the pipeline during the operation of the SWAC system. The main aspect that affects head loss is friction in the pipeline.

To start the pump, fresh water must be added to the seawater inlet at the end of the pump so that the seawater inlet head level can rise and reach the seawater pumping station. The pump will then operate by sucking seawater from the water pump inlet. Seawater at 7 ° C (pump temperature during normal operation) has a vapor pressure of 0.00982 bar so the maximum theoretical suction head would be about 10 m at this temperature. If the suction power increases above the setpoint cavitation will occur, which would damage the pump and piping.

High-speed SWAC plants are dimensioned with high-depth pumping station excavation projects. As the depth of the seawater pumping station increases, higher seawater speeds can be achieved in the pipeline. Increasing the speed in the pipes is useful because it proportionally increases the cooling load and reduces the retention time of water in the pipeline and can reduce heat loss to the environment. However, this could increase capital costs due to increased needs for the excavation of a seawater inlet tunnel and a seawater pumping station and increase friction head loss and thus electricity consumption. All these parameters need to be equalized in order to find the most optimal and cost-effective design of the SWAC plant.

As SWAC projects have high capital costs, pipes, pumps and heat exchangers need to work with high load factors to justify investment in technology, assuming that electricity prices are constant. However, the demand for refrigeration services can vary significantly in daily cycles; it is usually lower or non-existent during the night and high during the day, and peaks during the afternoon. Daily heat storage is important to allow the seawater inlet pipes, pumps and heat exchanger of the SWAC system to work constantly and guarantee the need for cooling during different hours of the day. During periods of low load cooling (i.e., at night), the heat storage tank is filled with cold seawater. During the day, stored chilled seawater is used to lower the temperature of the district cooling system.

Given that electricity prices can vary according to the availability of wind and solar sources and during peak and off-peak periods, the amount of electricity used for extraction may vary with electricity costs. Similar to the section above, when electricity costs are low and pumped cold seawater provides a higher cooling load than required, some of the water is stored. When electricity costs are high and pumped seawater provides less cooling load than demand, stored water is used to supplement the remaining cooling needs.

If the demand for cooling is seasonal, a large fresh water tank can be used to store heat energy by freezing water. During months when cooling is not required, cold seawater from the SWAC plant is used to increase the efficiency of the freshwater freezer refrigeration unit. During the months when the demand for cooling is high, both the SWAC system and the energy stored in the form of ice in the freshwater tank are used to supply the demand for cooling.

Currently, the electricity generation sector is undergoing fundamental changes with the intention of reducing CO_2 emissions and dependence on fossil fuels by penetrating the market of renewable energy sources such as wind and solar. However, electricity produced from these sources can be interrupted, difficult to predict and not meet demand times. Therefore, energy storage is an important aspect that enables the intermittent and unpredictable renewable energy to meet the demand for electricity and to increase the sustainability of these renewable energy sources.

Comparing pump storage, a standard technology used for energy storage, with SWAC heat storage systems, the latter has several advantages when considering cooling energy storage services. A volume of water with a temperature difference of 10 ° C stores the same amount of energy as a pump storage with 2092 m (assuming an efficiency of 80% and a refrigerant with 2.5 COP). [16]

Pump storage requires two tanks (upper and lower); a tunnel connecting both tanks; power plant with turbine, generator and auxiliary equipment; a transmission line connecting the pumping station and the demand for cooling; and a cooling system to convert electricity into cooling. The usual capital costs of pumping storage projects are in the range of 2000 USD / kWe installed, i.e., 800 USD / kWt installed (assuming a refrigerant with 2.5 COP). Due to the increase in scale, pump storage is usually sustainable with a capacity of 100 MWe or more. [16]

The pump is the only electrical component of the SWAC system. The storage of cold water pumped in moments of excess production of electricity from renewable sources is equal to the storage of electricity in the operational perspective of the network. If the SWAC project is built according to the proposals in this paper, thermal energy storage systems would require only cold sea or fresh water. Heat loss in the heat storage system is 0.5 ° C which makes the system efficient of ~ 95%, assuming a temperature difference of stored cold water of 10 ° C is used in the cooling process. [16]

The capital cost of SWAC heat storage is estimated at 585 USD / kWh which is significantly less than the cost of the pump storage system. In addition, thermal energy storage systems are sustainable with cooling requirements of as much as 20 MWh. [16]

In addition, the SWAC project with heat storage tanks and district cooling system could be improved by a heat pump that consumes electricity in periods when electricity prices are low to freeze some of the fresh water in a seasonal heat tank. This would significantly increase the energy storage capacity in the heat storage tank and increase synergies for system optimization. SWAC processes with thermal energy storage will play an important role in supporting the spread of renewable energy sources in the coming years in regions where SWAC is a sustainable alternative to cooling. [16]

The main aspects affecting the cost of the SWAC system are the distance from the coast to the depth of the ocean where the sea water temperature is 5 ° C or less (the smaller the distance, the better), the depth required to reach this temperature, which varies from 700 to 2000 m (the smaller the depth the better), the demand for cooling (the higher the demand the better), the cost of a district cooling system (the less defragmented the better) and the cost of electricity (the higher the better). The average investment required for SWAC systems is about 4000 USD / kW of air conditioning load, and the average levelled cost of thermal energy is 0.055 USD / kWh, and the payback period is between 5 and 11 years. However, these costs decrease significantly with increasing demand for refrigeration. [16]

Synergies between WPPs, such as solar and wind, and SWAC with thermal energy storage are particularly worth further analysis. This is because the performance of SWAC plants could vary depending on the availability of solar and wind generation as alternatives to demand management to reduce the impact of network interruptions. Therefore, SWAC processes with heat storage will play an important role in supporting the integration of renewables in regions where SWAC is a viable alternative to district cooling and where the share of renewables is high in the grid.

TECHNICAL DESCRIPTION OF THE LOCAL SYSTEM

Seawater energy can be used to heat and cool localized buildings by connecting the engine room of the building to the sea surface via pipelines and it is possible to use open or closed systems. In open systems, the pipelines are connected to the sea surface and the seawater is sucked in through one pipeline while the seawater is returned to the sea via the other. In closed systems, a heat exchanger made of plastic materials is placed on the seabed, while technical water passes through the pipeline, which is then introduced into a heat pump which is used to heat and cool the building.

Figure 18: View of open and closed heat pump system with lake

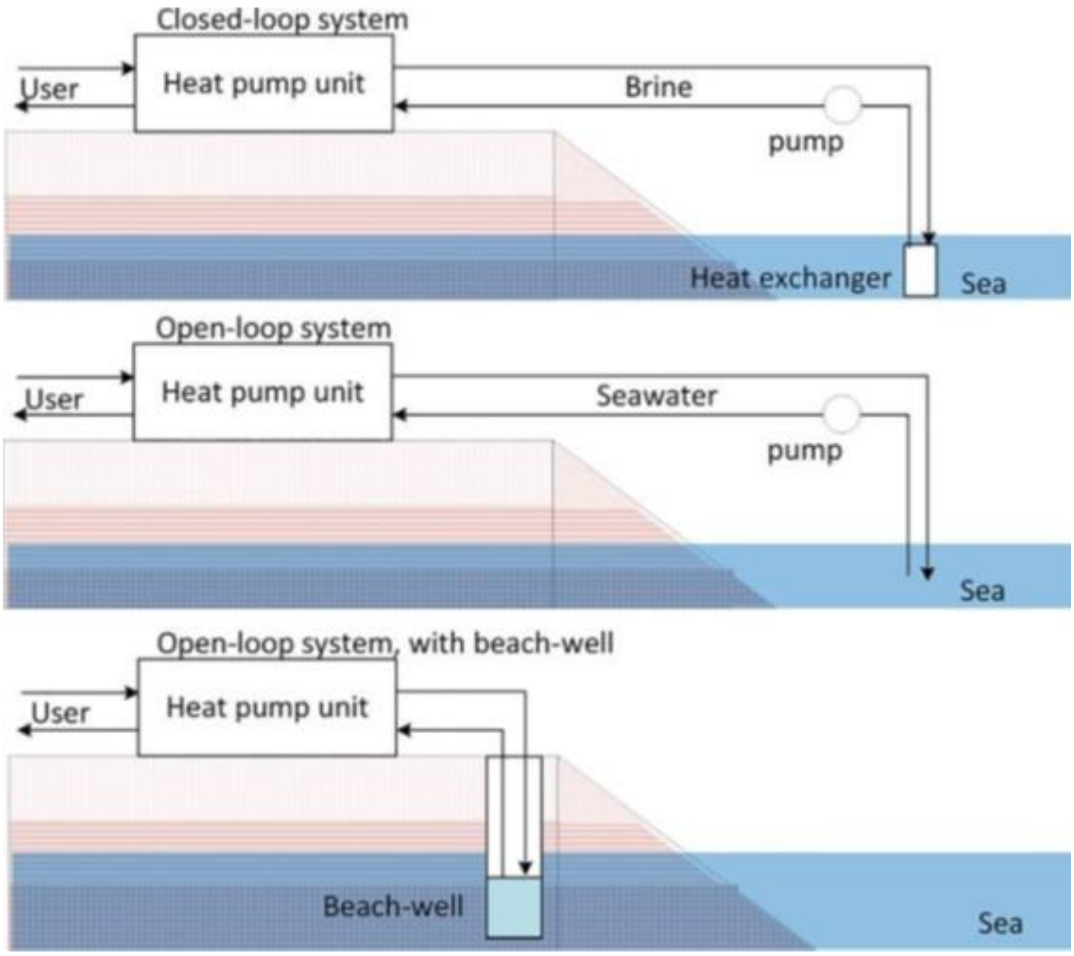


Figure 19: View of open and closed seawater heat pump system

2.4.2 TECHNICAL DESCRIPTION OF THE HEAT PIPELINE

The intention is that the thermal energy must be conducted to each individual building, and in order to achieve this, it is necessary to conduct a heating network of flow and return water throughout the city. The heating pipeline ends in the central heating station, which would house a pumping plant for cooling or heating the transmission medium with sea water and, if necessary, a central heat pump for additional heating and cooling. The heating pipeline would run through all the streets and the connections of each individual building would be connected to it. Inside the building would be a local water-to-water heat pump that heats the building itself while the heat pump draws energy from the heat pipe in heating mode or heats the heat pipe while cooling the building.

PIPELINE MONITORING SYSTEM

For pre-insulated equipment, a fault detection system is provided on the pipeline using the usual monitoring system for pre-insulated heating pipes. The Nordic monitoring system with two non-insulated copper conductors, diameter of copper wires F1.5 mm (e.g., AGFW / FUGW), all in accordance with the standard HRN EN 14419: 2009, was selected. On the routes of the hot water network, a system of control of faults that may occur due to: poor welds at the joints of the pipeline, factory errors in the manufacture of pipes, due to mechanical damage to the pipeline from the outside.

The system is made using the Nordic surveillance system of pre-insulated pipeline and connecting elements (fittings), and consists of two mutually parallel Cu conductors of standard cross-section 1.5 mm2, inserted into PUR foam inside the insulating sheath of pre-insulated pipeline. The monitoring is performed by measuring the ohmic resistance between the copper conductors and the pipe, and in the case of water penetration and wetting of the insulation, the resistance changes and thus a fault is detected in the pipeline. Locating the fault is possible with the help of reflexometry, when in the case of water penetration into the insulation, the wave resistance changes, which interferes with the propagation of the signal and the signal is reflected.

Detection of faults in the hot water network is performed with a two-channel or four-channel stationary control device. A maximum of 2.5 km of guides can be followed per channel. With the help of a control device, it is possible to constantly monitor the laid pipeline. The signal is activated when the loop resistance value drops or the monitoring system wire breaks.

At the ends of the pipelines where the pipelines enter the thermal substations, end pieces are planned to be used to close the loop of the monitoring system. At the ends of the pipelines where the pipelines enter the engine room, end pieces are provided to be used for connection to the stationary control device.

Due to the interruption of pre-insulated pipes inside the manholes, the installation of end pieces for the connection of impedance switching cables 2x1.5 mm2 and P / F conductors 1.5 mm2 laid in PVC pipes Ø16 and appropriate connectors on the mass of the pipe is planned. Also, inside the shafts, the installation of watertight (IP65) junction boxes is planned, which will be used for switching in order to close the loop of the monitoring system.

The monitoring model can be passive or active. The passive system is based on periodic inspection of the leakage system by the boilermaker or the person in charge of monitoring and maintaining the heating system. An active monitoring system is a central monitoring system that monitors multiple variables and sends an automatic warning of a change in the resistance value of the control conductor on the pipeline.
It is planned to install an automatic device for the control of the entire length of the pipeline, which will eventually be connected to a computer with installed software for monitoring and automatic monitoring of the condition of the pipeline. An antenna will also be installed, which will send data to the exchange via the GPRS network.

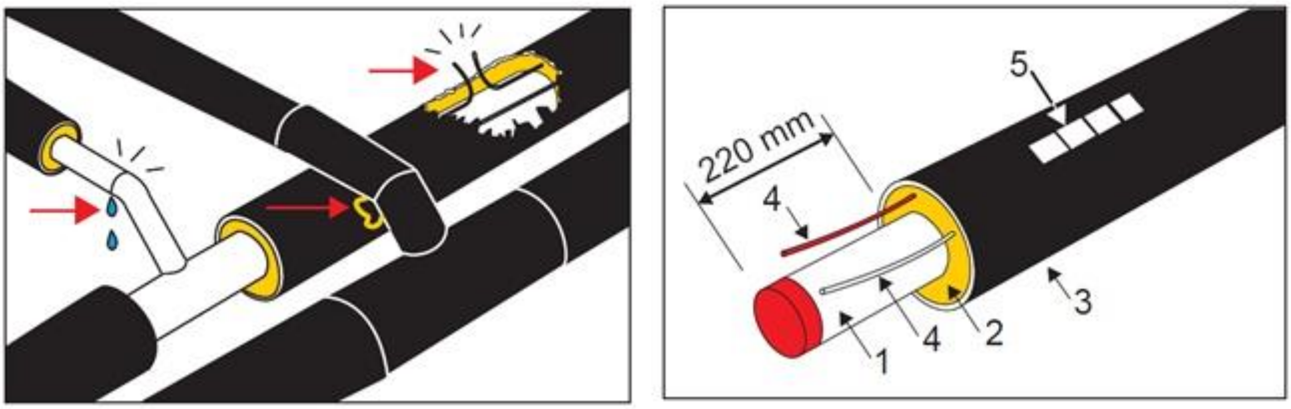


Figure 20: Detail of the heating system tightness monitoring system

PRE-INSULATED STEEL PIPELINES

The installation of pre-insulated pipes and arches for ductless laying in accordance with HRN EN 253: 2015, HRN EN 448: 2015 and HRN EN 489: 2009 is planned. It is necessary to make a construction trench in accordance with the technical detail. The pipeline is laid before welding on a base of wooden profile which is removed before filling the space with sand. Standards specify the technical condition to minimize heat losses of pipelines by using available pipelines on the market and pipelines with additional diffusion barrier coating which has the function of preventing moisture penetration into the PUR insulation layer because the insulation changes its properties in contact with water and reduces its service life.

Types of pipes	Materials			Fields of application					Operating pressure, bar	Continuous operating temperature, °C	Max. temper-ature (short -term), °C	Range of dimensions, Ø mm	Surveillance
	Service pipe	Insulation	Outer casing	District heating	District cooling	Domestic water		Oil & Gas					
						Cold	Hot						
Bonded pipe:													
Single pipe													
Series 0	Steel	PUR	PE-HD		x				25			114.3-1219	(x)*
Series 1	Steel	PUR	PE-HD	x	(x)			x	25	140	150	26.9-1219	x
Series 2	Steel	PUR	PE-HD	x	(x)			x	25	140	150	26.9-610	x
Series 3	Steel	PUR	PE-HD	x	(x)			x	25	140	150	26.9-508	x
TwinPipe Series 1	Steel	PUR	PE-HD	x	x				25	140	150	26.9-26.9/ 219.1-219.1	x
Series 2	Steel	PUR	PE-HD	x	(x)				25	140	150	26.9-26.9/ 219.1-219.1	x
Series 3	Steel	PUR	PE-HD	x	(x)				25	140	150	26.9-26.9/ 219.1-219.1	x

Table 16: Heating and cooling pipeline network materials

Pre-insulated Series 3 pipes with a steel core with PUR foam insulation have been proposed, and the outer protective membrane is made of a PE-HD layer. The pipeline has a maximum operating pressure of 25 bar and can be permanently exposed to temperatures up to 140 ° C. The pipeline can withstand a short-term temperature of a maximum of 150 ° C. In addition to the pre-insulated pipeline, a system for monitoring the penetration of water from the ground or the rupture of the pipeline with a 1.50 mm^2 conductor also comes standard.

TECHNICAL CHARACTERISTICS OF PIPELINE

The pre-insulated pipe series Model 3 has the maximum possible available thickness of the PUR foam insulation layer and is used for public heating pipelines of longer sections. It is also used to reduce heat losses of pipelines in the case of poor ratio of input price of energy and the amount of heat distributed to end users. The pipeline is available with a diffusion barrier in lengths of 12 m and 16 m.

Steel pipe			Outer casing					Pipe	Water content
ø nom. mm	ø out. mm	Wall thick. mm	ø out. mm	Wall thick. mm	6 m pipe	12 m pipe	16 m pipe	Weight kg/m	l/m
20	26.9	2.6	125	3.0	x	x		3.7	0.4
25	33.7	2.6	125	3.0	x	x		4.1	0.6
32	42.4	2.6	140	3.0	x	x		5.0	1.1
40	48.3	2.6	140	3.0	x	x		5.4	1.5
50	60.3	2.9	160	3.0	x	x		7.0	2.3
65	76.1	2.9	180	3.0	x	x		8.6	3.9
80	88.9	3.2	200	3.2	x	x		11	5.3
100	114.3	3.6	250	3.6	x	x	x	16	9.0
125	139.7	3.6	280	3.9	x	x	x	19	14
150	168.3	4.0	315	4.1	x	x	x	25	20
200	219.1	4.5	400	4.8	x	x	x	38	35
250	273	5.0	500	5.6	x	x	x	54	54
300	323.9	5.6	560	5.7		x	x	67	77
350	355.6	5.6	630	6.0		x	x	78	93
400	406.4	6.3	710	6.6		x	x	99	120
450	457	6.3	800	7.2		x	x	116	160
500	508	6.3	900	7.9		x	x	136	190

Table 17: Nominal diameters of heating and cooling network pipes

The installation of one-piece, heat-shrinkable, self-sealing and molecularly crosslinked joints without additional sleeves is envisaged in accordance with the standard HRN EN 489: 2009, HRN EN 448: 2015. Induction couplings were selected which are available in the dimension of the outer diameter of the plastic lining FI 90-1400 and are closed and self-shrinking. The coupling is connected to the electrofusion pipeline.

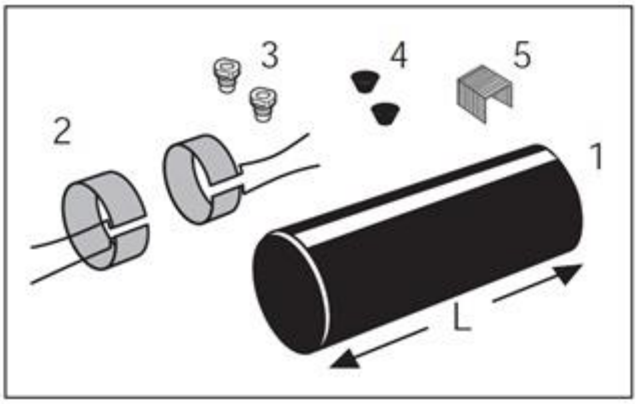


Figure 21: Nominal diameters of heating and cooling network pipe couplings

PRE-INSULATED PIPELINE FITTING ELEMENTS

The basic fitting element of the pre-insulated pipeline is the elbow, which normally comes at an angle of 45 ° or 90 °. Knee versions with a slope change of 5 ° are possible. The elbow is delivered completely pre-insulated while welding is performed on a flat part of the elbow to allow joining and lining with an additional plastic coupling. Fittings are used up to operating pressures of 25 bar. A guide for detecting pipeline leaks has been placed in the thermal insulation layer. The radius of curvature of the elbow is 1.5 or 2.5 x d where d is the outside diameter of the steel pipeline.

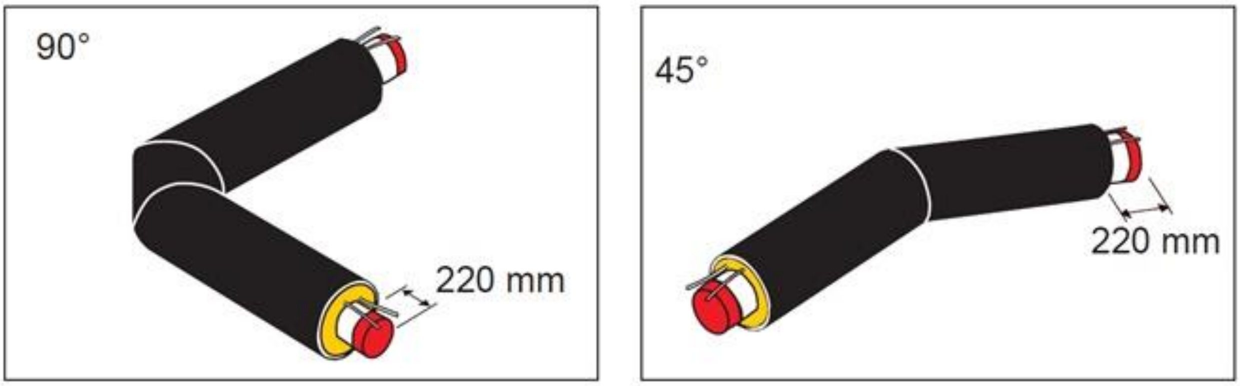


Figure 22: Nominal elbow diameters of 90 ° heating and cooling network

SOLID PIPELINE POINT

The pre-insulated pipeline must be fixed at several points by means of a specially constructed pipe element or by a solid point which prevents the pipeline from moving during the working heat load. The solid point has a welded steel sheet that is immersed in the concrete foundation, while the concrete foundation itself is an anchor or weight that holds the pipeline firmly at the intended point. The standard solid point can withstand loads of 150 MPa thermal expansion of the pipeline and has been tested for operation up to 25 bar. The solid point foundation is therefore loaded with 2 x 150 MPa max after which the load breaks the solid point welds.

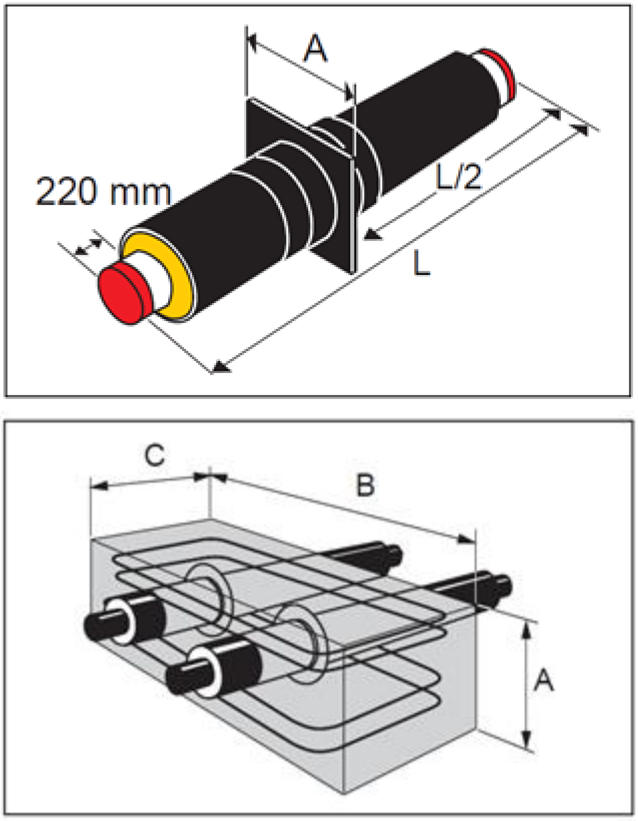


Figure 23: Nominal diameters of the solid point of the heating and cooling network

A Series 3 pipeline model with the maximum available insulation thickness and additional diffuse dam lining was selected to ensure long-term stability of the PUR foam insulation. The solid point is selected according to the outer dimension of the HDPE cladding. The solid point is performed by pouring the central part of the pipe element with concrete with a compression force of at least 25 MN / m2, while the soil itself must have a minimum compressive strength of 150 kN / m2. The concrete block is further strengthened by inserting steel profiles below and above the pipes which are secured at the required distance.

PENETRATION THROUGH CONCRETE / WALL

The pre-insulated pipe must be additionally lined with a special annular joint in the passage of the pipe through the concrete wall, foundations, shaft wall, etc. The additional ring has the function of preventing water penetration into the interior while the hole in the shaft wall is additionally filled with waterproofing compound.

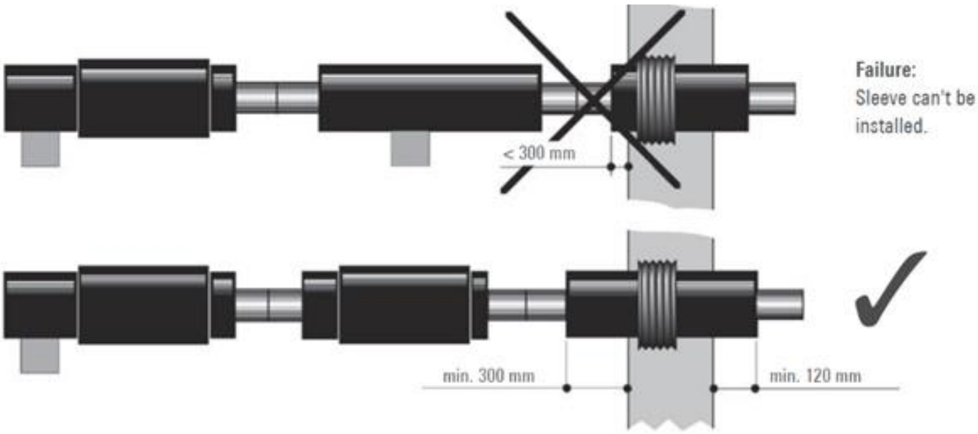


Figure 24: Fixed point connection point of the heating and cooling network of the local building

FINAL ELEMENTS OF THE PIPELINE

The pre-insulated pipeline is led through the ground and as such enters the manhole where it ends at least 120 mm in space, while the entry of 300 mm of pre-insulated pipeline into the manhole is planned. At the end of the pipeline, a final cap is placed, which has the function of preventing the penetration of moisture from the air into the insulation layer.

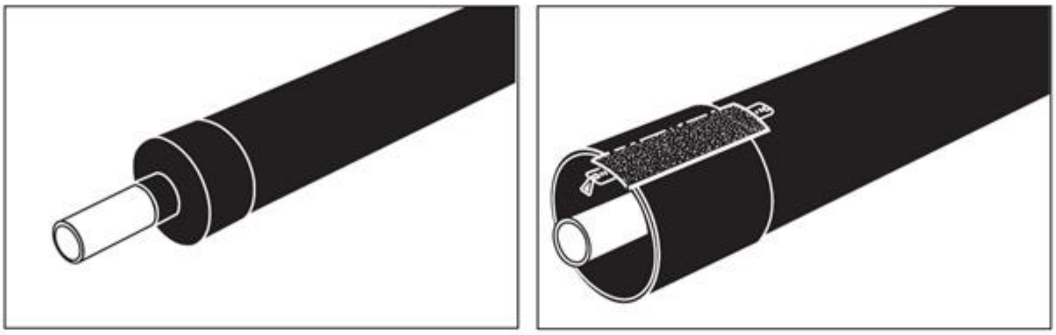


Figure 25: Finishing element of the heating and cooling network of the local building

WELDING TECHNOLOGY

The technical standard defines the class of welds and the model for testing the quality of non-destructive welded joints and is described in more detail in the quality control and maintenance program. The steel pipeline must be properly technically prepared before welding by cleaning in case of corrosion. In order to protect the ends of the pipeline, each element of the pipeline comes with a plastic cap that is removed before welding. Welders must have the appropriate certificate for welding steel pipelines. Prior to welding, it is necessary to provide a free space of 220 mm for the installation of welding equipment and the correct connection of the steel pipeline.

Around the weld zone of the pre-insulated steel pipeline it is necessary to provide enough space to expand the excavation by widening the pit below and around the pipeline by 200 mm which will all provide sufficient space for the welding process.

The pipeline must be supported on wooden beams 100x100 mm, which will be removed before burying the pipeline. Wooden pads ensure that there will be sufficient sand thickness under the pipeline, which will prevent damage to the pipeline during thermal expansion joints and expansion of the pipeline.

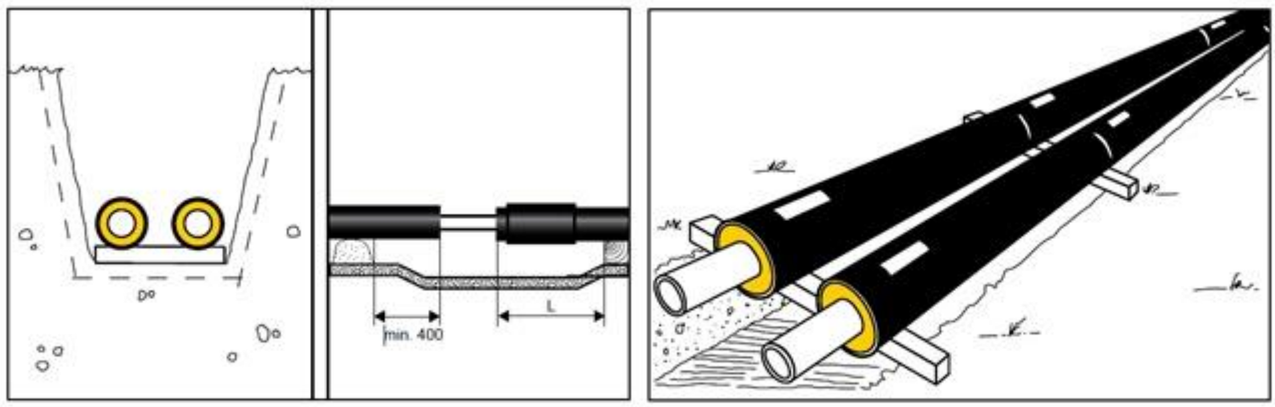


Figure 26: Connection of heating and cooling network pipelines of a local building

The polymer HDPE sheath and the associated connectors are connected by electrofusion using an automatic device consisting of two clamps and a cable connection to the generator. Welders must have a certificate from the equipment supplier that they are trained to work with the plastic lining welding system, which is a prerequisite for issuing a warranty on the delivered pipeline.

When using self-shrinking plastic coatings, a gas burner is additionally used to reheat the plastic in order to collect it on the coating. The burner is connected to a portable gas cylinder with propane-butane. The HDPE coating is heated until it collects and adheres to the substrate.

Appropriate operating conditions must be ensured to ensure proper welding of the HDPE lining. In case the outside temperature is higher than 30 ° C, it is necessary to additionally protect the coating from overheating and spreading due to heating by solar energy. The steel substrate must be sanded from dirt and rust that prevent the bonding of PUR insulation to the substrate.

PIPELINE INSULATION

The pre-insulated pipeline comes with a factory-filled layer of PUR foam that is additionally protected by a diffusion barrier that prevents moisture from penetrating the insulation layer. Water in contact with PUR foam changes the insulating properties and technical characteristics and ultimately accelerates the process of deterioration of the insulation layer.

Each end of the pipeline has a gap of 220 mm which is provided for the installation of devices for rotary welding of the pipeline or manual welding. After the completion of the welds and protection of the welds, the leakage detection wires are connected and the outer PEHD sheath is finally pulled onto the joint. After the joint is electrofusion welded, the free space is filled with a mixture that generates PUR foam in the reaction.

Liquid A isocyanate 1.0: 1 is mixed in a ratio of liquid B polyole 1.4: 1 with one compound requiring a total of 4.8 liters of direction and 2.0 liters of liquid A and 2.8 liters of liquid B, respectively, achieving complete filling of the compound. If a larger amount of mixture is required, an automatic device is used to fill the joints with PUR insulation.

PIPELINE EXCAVATIONS

The pipelines are placed in previously excavated channels, keeping the standard minimum distances between the pipelines. The smaller the distance the greater the heat exchange between the pipelines which causes the supply pipe to cool and the return pipe to heat up. To minimize this effect, a distance of 300 mm is envisaged between all pipelines, which will ensure satisfactory sand insulation between the two pipelines and will reduce the mutual heat flow.

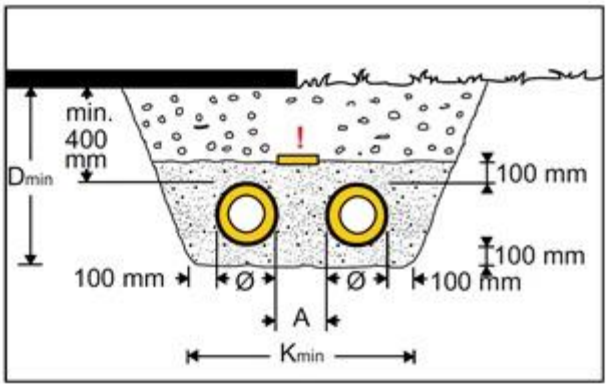


Figure 27: Dimensions of the trench excavation of the heating and cooling network of the local building

A layer of washed sand is placed under and above the pipeline, which ensures thermal expansion of the pipeline and prevents damage to the HDPE lining during the linear expansion and contraction of the pre-insulated steel pipeline. The minimum layer above the sand is 400 mm, while a layer of 900 mm is envisaged, which will provide increased thermal insulation of the pipeline with a layer of earth. There is an option to mix the soil with fine styrofoam particles which will ensure the looseness of the soil and will further increase the insulating properties of the pipeline.

PIPELINE PROTECTION

The passage of the heating pipeline under important roads should be made in a protective steel pipe (column), and on the route of the pipeline passage the
- protection of existing utility installations located near the laying of pre-insulated heating pipes
- technology of construction pit protection for excavations deeper than 1 m when constructing manholes
- technology of tunneling works,
- construction of protection of the construction pit and foundation of the pit for the accommodation of the drilling set and the acceptance pit for drilling under the installations

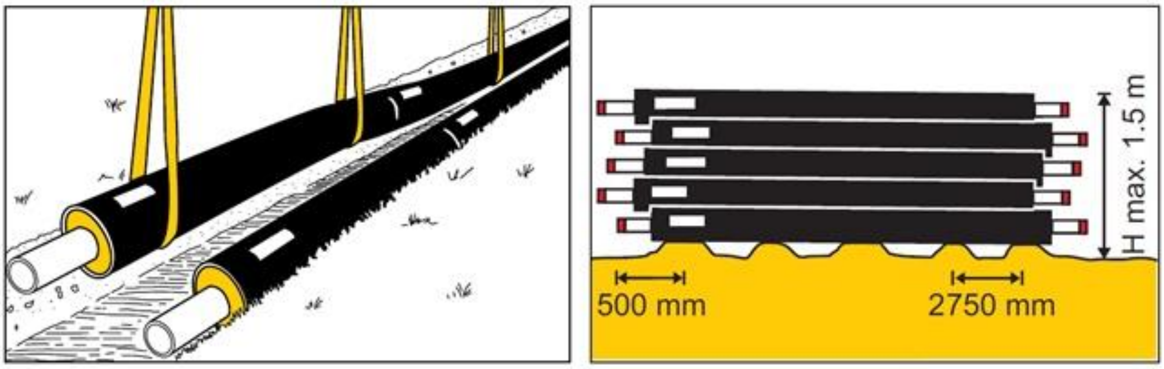


Figure 28: Laying the heating network of the local building

During the laying of the heating pipe, it is necessary to cover the heating pipe with sand in places where the height changes or changes the direction. The heating pipe must not be completely covered with sand unless a pressure test for leaks has been carried out.

When storing pipelines on the construction site, a suitable base and supports should be provided that will take on the load of the mass of pipes that are stacked on top of each other. To prevent deformation of the lining of the lower pipes, the total height of the stacked pipes should not exceed 150 cm.

PIPELINE REINFORCEMENT ELEMENTS

For all types of needs on the subject pipelines (partition, branch, discharge or vent armature) provide for the installation of flange shut-off valves. When selecting the appropriate technical characteristics of shut-off valves, take into account the following:
- all pipe fittings must be for a nominal pressure of 25 bar and at a nominal pressure for temperatures up to 60 ° C
- with regard to design, select flanged shut-off valves in all sizes

In inspection manholes, enclose the following flange reinforcement:
- partition, branch and connection fittings are shut-off valves, NP 25
- fittings for emptying and desoldering pipelines are shut-off valves, NP 25
- vent valves are shut-off valves of nominal opening DN15, NP 25

For the normal functioning of the heating pipeline, provide venting fittings and drain fittings, all installed in the inspection shafts. The fall of the pipeline is directed towards the associated shaft with a minimum slope of the pipeline of 0.25% to the left and right of the middle between the two shafts.

The pipes behind the vent armature or the discharge armature must be directed towards the floor opening of the manhole, which is further connected to the absorption well in larger manholes. It is necessary to run each DN15 steel pipe separately to the collector without connecting the pipes to each other.

Technical data

Stop valve - straight through with flanges and bellows seal - Class 150 / 300 (SA216WCB)

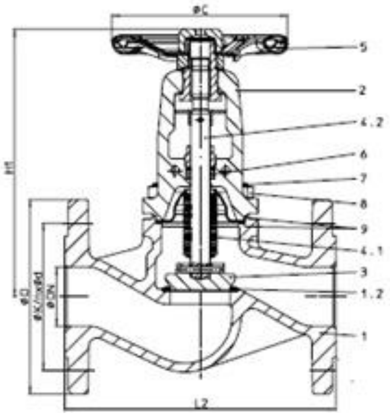


Figure-No.	Nominal pressure	Material	Nominal diameter
32.041	ANSI150	SA216WCB	DN 15-250 / NPS 1/2"-10"
35.041	ANSI300	SA216WCB	DN 15-250 / NPS 1/2"-10"

Test:	• EN ISO 15848-1 / TA - Luft TÜV-Test-No. TA 07 2016 C04
Flanges:	• acc. to ASME / ANSI B16.5
Plug design:	• Plug with marginal seat standard

At high differential pressures a balancing plug is necessary! (refer to page 8)

Figure 29: Shut-off valves of the heating and cooling network of the local building

2.4.2 TECHNICAL DESCRIPTION OF WATER-WATER HEAT PUMP

The climatic conditions prevailing in Croatia allow the use of reversible heat pumps for the purpose of heating and cooling the building. With the help of the device, it can be reliably heated even at the lowest outdoor air temperatures that can occur at the micro-location of the city of Dubrovnik and its surroundings, i.e., down to -10 ° C. For space heating and cooling, the so-called reversible heat pumps that can switch the operating mode from heating to cooling and vice versa as needed with very low time to change the operating mode of the system.

The installation is intended for use
* Water-to-water heat pump
* Installed in the engine room of the building
* Suction and absorption well located on the plot
* Or connection to a public water distribution pipeline
* Primary use of cooling and heating devices and domestic hot water heating

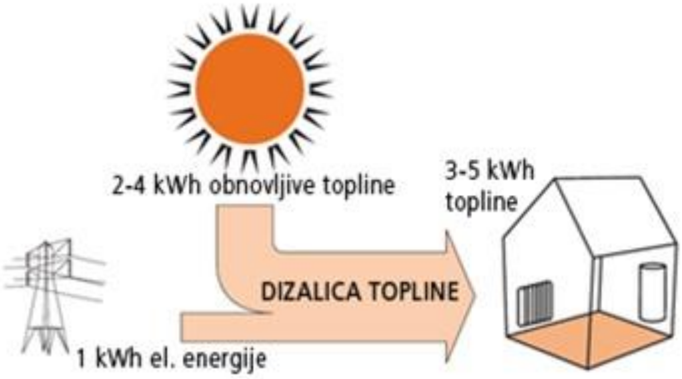


Figure 30: Heat flow of heat pump operating energies

The main energy source of a building is environmental energy, which is transformed into the required energy form by applying transformation technologies. Electricity from the grid is used to run a heat pump that simultaneously draws on energy that has accumulated in the environment. The devices are used in combination with work with renewable heat sources. Accumulated solar energy in the environment is used as a source of energy for heating buildings. The heat pump then converts the two input forms of energy into a useful form of thermal energy that accumulates in the heating system. Heat pumps convert electricity into heat or cooling energy and have an SPF system factor in the range of 2.5 - 5.5, depending on the type of heat pump that has a COP factor of 4.5 - 5.5. In cooling mode, energy is transferred from the building using a heat pump to the environment. The basic principle of operation of a heat pump is to take 1 kW of electricity from the electricity grid and 2-4 kW of renewable accumulated energy from the environment, while the sum of these energies or 3-5 kW of thermal energy is injected into the building. By using the green tariff of electricity or photovoltaic energy, the system becomes 100% renewable!

Heat pumps are devices that base their work on a compressor cycle in which heat is taken away or transferred to a certain medium. The name of the crane carries the root of transport or raising the energy level of a certain medium, which in this case is water or glycol for heating or cooling. The heat exchange process includes the environment and the water / glycol heating of the building. Depending on the location of the building, it is selected which environmental energy source will be most suitable for the required application conditions. By using natural energy sources, buildings are connected to the environment, and during the winter the energy is exchanged in the direction of the environment towards the building, while during the summer the energy flow is opposite from the building to the environment.

Dual energy flow and heat source regeneration during the year are crucial for the proper operation of the system. Energy is pumped by heat pumps from the environment. Groundwater temperature fluctuates slightly during the year and groundwater is an ideal energy source in the continental as well as in the coastal climate zone. Heat pumps use environmental energy as a source of energy, i.e., a natural energy element of solar energy that has not been used in mass application for heating and cooling buildings. Solar energy accumulates as internal potential energy which is manifested through a change in the temperature of the environment or water, air or earth, which becomes a source of energy for the operation of heat pumps!

A centralized system is envisaged that maintains the required microclimatic conditions throughout the year. The water-to-water heat pump has a mean annual efficiency factor above SPF 4.5 in temperate geoclimatic areas, while the device factor itself achieves a COP of 5.5. Compared to heating with a gas system or natural gas, savings of 50-60% are achieved depending on the geoclimate of the building location. Compared to natural gas heating, carbon dioxide emissions are also reduced by 90%, which is a sufficient reason for the application of these renewable systems. The nominal operating temperature is about + 10 ° C of groundwater, while at ambient air temperatures of -20 ° C there is a small drop in the temperature of groundwater and seawater. The device itself has the ability to work at low temperatures with proper sizing and sufficient depth of groundwater. Compared to classic dual heating and cooling systems, space savings are achieved because the unit has integrated heating and cooling and facilitates system maintenance, which reduces the overall investment.

The water-to-water heat pump can be used as a heat source without icing of the unit and loss of efficiency at low temperatures compared to air-to-water heat pumps. According to the initial investment, air cranes are the most favourable, but they also have the lowest efficiency and will consume the most energy for heating and cooling the building. Water-to-water and water-to-air heat pumps use water as their heat source. The source of water can be a sea, lake, pond, river, stream, well or borehole that extends to groundwater. Groundwater is the most common source when we talk about heat pumps that use shallow geothermal energy or are directly connected to a larger source of water such as the sea.

Water-to-water heat pumps can easily use water as a medium to heat buildings. The energy obtained from the water source is raised to a higher temperature regime, and then sent to convectors or underfloor heating circuits via the building's distribution system.

The main advantage of groundwater is its constant temperature, which ranges between 7 and 12 ° C even on cold winter days. This temperature constancy means that the heat pump can successfully heat the building even during the coldest days. An air-to-water heat pump is not always capable of this or consumes huge amounts of energy to heat to the required temperature. Another great advantage of using a water source, especially groundwater, is shown in summer or hot days, when the heat pump can passively cool the building. This is also known as natural cooling. Cold groundwater leaks through the building's cooling system, causing cooling.

When installing a water-to-water heat pump, we must pay attention to which water source we choose. Surface water sources can freeze, which of course makes it difficult to operate the heat pump. Also, the water source must not be too small, because otherwise the operation of the heat pump affects its temperature too much and the system becomes energy inefficient. An interesting source is running water, such as rivers and streams and above all the sea. Their selection is less frequent because the source is limited by place and laws. They can be very energy efficient because the water is constantly changing and the outside temperature and operation of the heat pump does not affect its temperature too much. In addition, the liquid source is much harder to freeze in winter.

ENERGY FLOW SYSTEM

- external seawater passes through a plate exchanger, evaporator inside the device
- at the same time on the other side of the plate heat exchanger passes the working compressor medium which takes over the energy of the environment
- the working medium evaporates in a plate exchanger, evaporator
- the compressor sucks up the evaporated working medium

- the compressor is supplied with electricity in the ratio of 1 kW of electricity = 3-4 kW of heat energy
- the steam of the working medium is compressed to a higher temperature and pressure and the steam is injected into the condenser at the same time
- the capacitor is the second plate exchanger inside the device
- on the other side of the plate condenser there is a heating medium in this case it is water
- the water is heated and absorbs the heat of the working medium in the condenser while cooling the working medium
- the heat pump transports energy from the environment to the water of the heating system using a portable working compressor medium
- after the heat transfer has taken place, the cooled working medium reaches the expansion valve
- the expansion valve dampens the working substance to a lower pressure and at the same time the temperature of the working medium is reduced
- the subcooled refrigerant re-enters the first exchanger or evaporator and the refrigerant circuit is closed

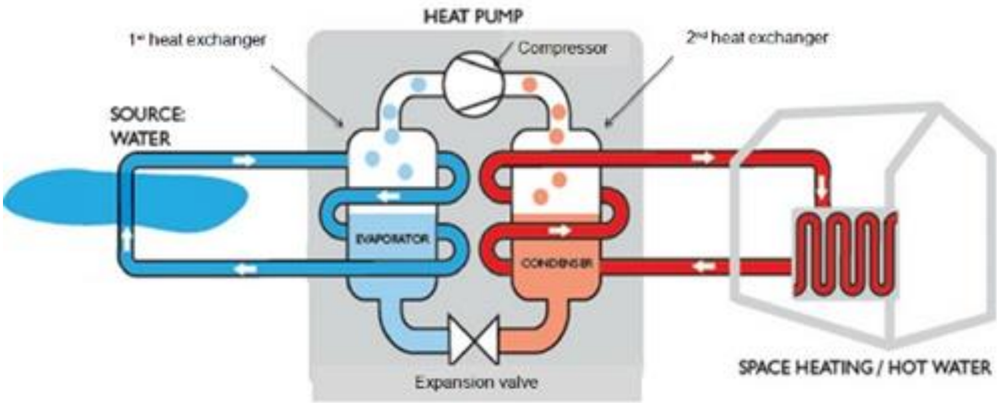


Figure 31: Heat flow of heat pump operating media

WATER-WATER COMPACT UNIT

The compressor unit is built into a compact monobloc. The device is equipped with all the necessary protective and shut-off valves, and its own automatic regulation (inverter continuous regulation) for independent operation. Capacitors are cooled by well water and are resistant to particles that can appear in well water. The units work with R410a refrigerant. The cooling circuit includes a collector, filter and oil separator. High- and low-pressure switches, coolant temperature, oil temperature, inverter temperature and outdoor temperature sensors are installed. The unit is equipped with on / off valves on the steam and liquid phase and service valves. All functions are controlled via a built-in microprocessor.

The basic microprocessor functions are continuous regulation of compressor performance, oil pressure equalization, oil return control, auto restart (after power failure or interruption). Individually adjustable functions are Low - Noise operation - work with reduced capacity for the purpose of reducing noise at a certain time, night mode (two stages); a function that allows limiting the maximum connected power for the purpose of limiting consumption in a critical period. The unit is mounted on a stand made of steel square profiles. Rubber anti-vibration pads are placed between the stand and the unit.

Example of a table with the characteristics of water-to-water heat pump equipment available in the brochures of various heating and cooling equipment manufacturers. The table contains several models of devices that differ according to the nominal heating or cooling power. Depending on the required thermal power of each building, the model with the thermal power closest to the required one is selected.

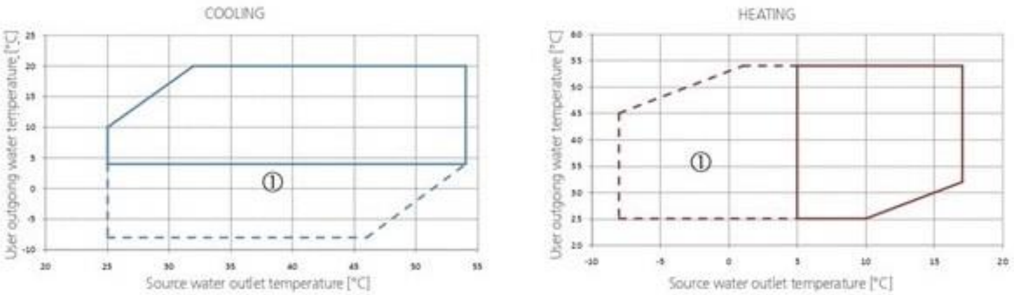
UNIT SIZE			6	8	11	16	19	22	24	28	32	35	42	48
Cooling (Gross values)														
Nominal cooling capacity (W 30°C/W 18°C)	(1)	kW	8,4	11,5	14,6	22,5	26,1	30,4	32,9	37,3	45,7	49,4	58,4	65,4
Total power input for cooling	(1)	kW	1,4	1,7	2,2	3,4	4,1	4,9	5,4	6,3	7,1	7,8	9,0	10,0
EER	(1)		6,12	6,59	6,57	6,59	6,30	6,26	6,12	5,93	6,43	6,32	6,49	6,53
Efficiency class			A	A	A	A	A	A	A	A	A	A	A	A
Cooling (EN 14511 values)														
Nominal cooling capacity (W 30°C/W 18°C)	(1),(8)	kW	8,4	11,4	14,6	22,2	25,7	29,9	32,5	36,8	45,1	48,7	57,7	64,7
EER	(1),(8)		5,24	5,75	5,78	5,33	5,18	5,20	5,16	5,04	5,41	5,37	5,55	5,62
Efficiency class			A	A	A	A	A	A	A	B	A	A	A	A
Cooling (Gross values)														
Nominal cooling capacity (W 30°C/W 7°C)	(2)	kW	5,9	8,3	10,4	15,6	18,1	21,0	23,5	26,7	32,5	35,2	41,8	46,6
Total power input for cooling	(2)	kW	1,4	1,8	2,3	3,4	4,1	4,8	5,3	6,2	7,0	7,7	8,7	9,9
EER	(2)		4,24	4,61	4,52	4,58	4,40	4,38	4,44	4,31	4,65	4,57	4,80	4,71
ESEER			4,83	5,31	5,16	5,10	4,95	4,91	4,91	4,80	5,14	5,07	5,31	5,18
Efficiency class			D	C	C	C	C	C	C	C	C	C	B	B
Cooling (EN 14511 values)														
Nominal cooling capacity (W 30°C/W 7°C)	(2),(8)	kW	5,9	8,3	10,4	15,4	17,9	20,8	23,3	26,5	32,2	34,9	41,4	46,2
EER	(2),(8)		3,90	4,27	4,21	4,09	3,96	3,96	4,03	3,93	4,22	4,17	4,39	4,33
ESEER	(8)		4,32	4,77	4,64	4,30	4,17	4,14	4,14	4,05	4,30	4,25	4,46	4,36
Efficiency class			D	C	D	D	D	D	D	D	D	D	C	C
Cooling (Gross values)														
Nominal cooling capacity (W 15°C/W 7°C)	(3)	kW	6,4	8,8	11,0	16,5	19,2	22,5	24,8	28,0	34,5	36,9	43,9	48,8
Total power input for cooling	(3)	kW	1,3	1,6	2,0	3,1	3,7	4,3	4,8	5,6	6,2	7,0	7,8	8,9
EER	(3)		4,89	5,51	5,52	5,34	5,19	5,22	5,16	4,99	5,56	5,26	5,63	5,48
Heating (Gross values)														
Nominal heating capacity (W 10°C/W 35°C)	(4)	kW	7,1	9,8	12,0	17,8	21,5	24,9	27,6	32,2	36,5	39,8	47,3	53,2
Total power input for heating	(4)	kW	1,4	1,9	2,3	3,5	4,2	4,9	5,4	6,3	7,0	7,8	8,7	9,8
COP	(4)		5,10	5,14	5,22	5,09	5,12	5,08	5,11	5,11	5,21	5,10	5,44	5,43
Efficiency class			A	A	A	A	A	A	A	A	A	A	A	A
Heating (EN 14511 values)														
Nominal heating capacity (W 10°C/W 35°C)	(4),(8)	kW	7,2	9,8	12,0	18,0	21,7	25,2	27,9	32,5	36,9	40,2	47,7	53,6
COP	(4),(8)		4,92	4,99	5,08	4,57	4,62	4,62	4,67	4,69	4,75	4,68	4,98	5,01
Efficiency class			A	A	A	A	A	A	A	A	A	A	A	A
Heating (Gross values)														
Nominal heating capacity (W 10°C/W 45°C)	(5)	kW	6,9	9,5	11,7	16,8	20,3	23,5	26,6	31,1	35,2	38,4	45,0	50,6
Total power input for heating	(5)	kW	1,8	2,5	3,0	4,4	5,3	6,1	6,7	7,8	8,7	9,6	10,6	12,1
COP	(5)		3,87	3,80	3,90	3,86	3,85	3,83	4,00	4,00	4,06	3,98	4,23	4,20
Efficiency class			C	D	C	C	D	D	C	C	C	C	B	B
Heating (EN 14511 values)														
Nominal heating capacity (W 10°C/W 45°C)	(5),(8)	kW	7,0	9,5	11,8	17,0	20,5	23,7	26,9	31,4	35,5	38,7	45,3	51,0
COP	(5),(8)		3,78	3,73	3,83	3,60	3,60	3,61	3,76	3,77	3,81	3,76	3,98	3,98
Efficiency class			D	D	D	D	D	D	D	D	D	D	C	C
Compressors														
Quantity/Refrigerant circuits		n°/n°	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1
Capacity steps		%	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
Evaporator														
Water flow rate	(1)	l/h	1.451	1.972	2.518	3.874	4.488	5.224	5.663	6.413	7.864	8.490	10.048	11.245
Pressure drop	(1)	kPa	16	11	12	117	121	115	110	111	124	118	115	106
Conderser														
Water flow rate	(1)	l/h	563	757	967	1.488	1.733	2.019	2.196	2.498	3.029	3.278	3.866	4.323
Pressure drop	(1)	kPa	22	21	17	19	25	21	19	14	26	31	25	32
Hydraulic module														
Available pump pressure		kPa	46	45	42	78	69	100	92	82	87	119	114	85
Storage tank capacity		l	35	35	35	50	50	50	100	100	100	100	100	100
Sound level														
Sound power value (standard unit)	(6)	dB(A)	61	61	62	62	62	69	69	71	71	71	72	74
Sound pressure value (standard unit)	(7)	dB(A)	47	47	48	48	48	55	55	57	57	57	58	60
Sound power value (SLN version)	(6)	dB(A)	59	59	60	60	60	67	67	69	69	69	70	72
Sound pressure value (SLN version)	(7)	dB(A)	45	45	46	46	46	53	53	55	55	55	56	58

(1)User side ingoing-outgoing water temperature 23/18°C; source side ingoing water temperature 30/35°C
(2)User side ingoing-outgoing water temperature 12/7°C; source side ingoing water temperature 30/35°C
(3)User side ingoing-outgoing water temperature 12/7°C; source side ingoing water temperature 15/30°C
(4)User side ingoing-outgoing water temperature 30/35°C; source side ingoing-outgoing water temperature 10/x°C
(5)User side ingoing-outgoing water temperature 40/45°C; source side ingoing-outgoing water temperature 10/x°C
(6)Noise power levels calculated according to ISO 3744
(7)Noise pressure levels measured at 1 meter from the unit in free field, with a directivity factor Q=4
(8)Values according to EN 14511-3:2011
This datasheet gives the characteristic data of the basic and standard versions of the series; for details refer to the specific documentation

Table 18: Thermal power data of local engine room heat pumps

The operation diagram of the heat pump in heating mode is shown in red diagram from which it can be read that the minimum recommended temperature of water entering the system is 5 ° C which is then subcooled and deprived of heat energy after which the cooled water is discharged.

CH VERSION AND HP



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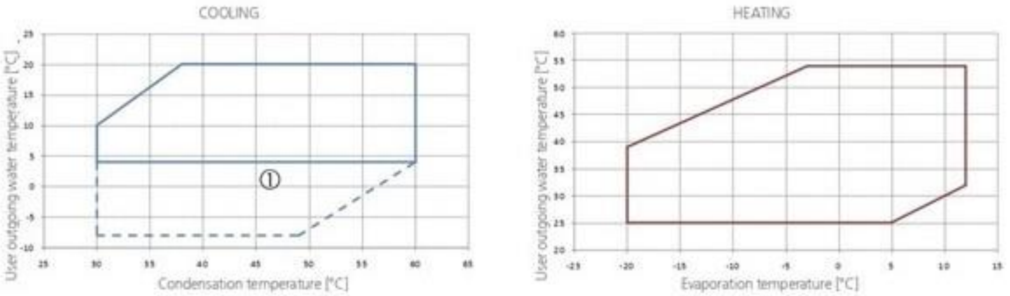

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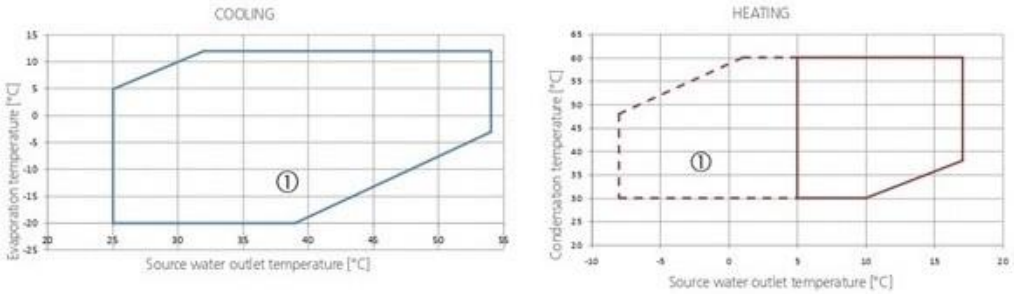


The heat exchanger temperature rise must be within 4°C e 7°C
①: within this range the unit can operate only with glycol solution on evaporator side

Diagram 3: Temperature operating range of the water-to-water heat pump

Water-water heat pump that is installed in the local engine room of the building and is connected to the public heating network or directly connected via a seawater exchanger. Similar equipment models are available at competitive prices when comparing natural gas heating.

DIMENSIONAL DRAWING

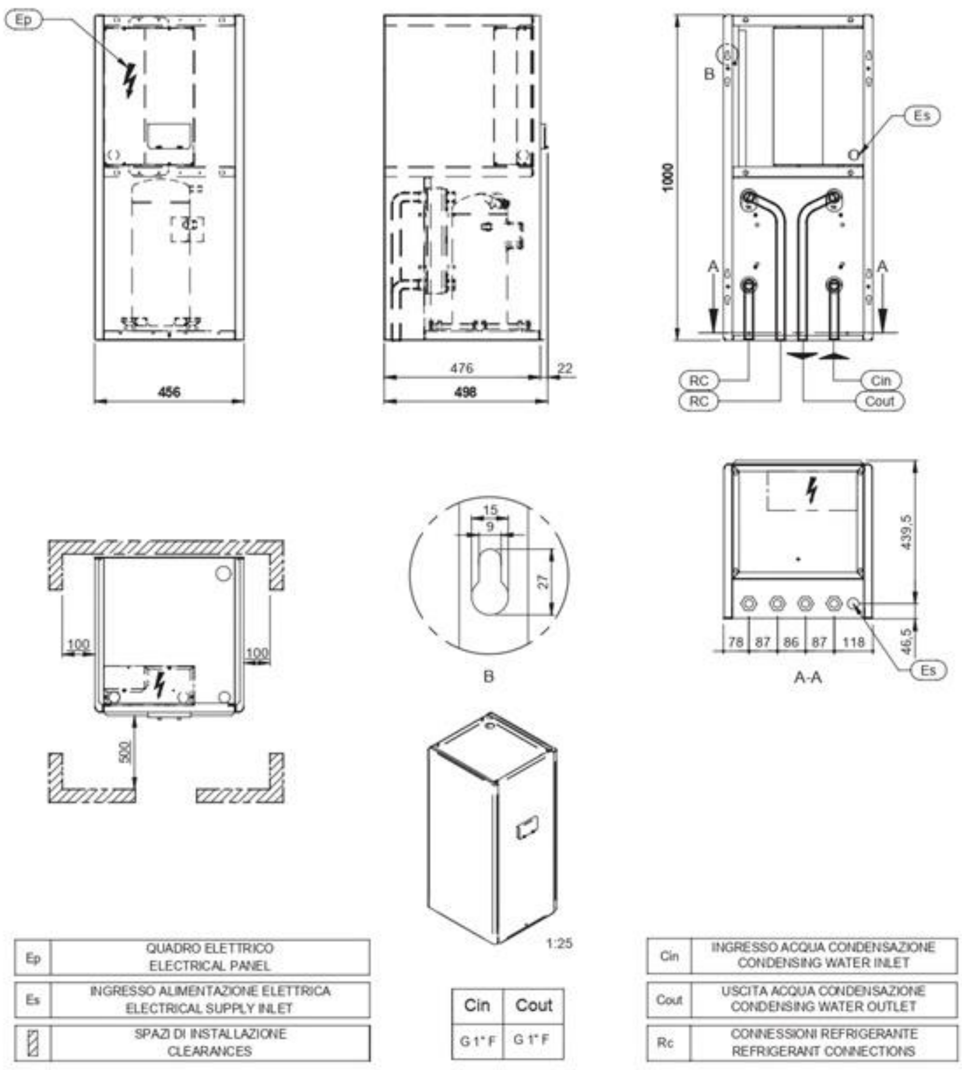
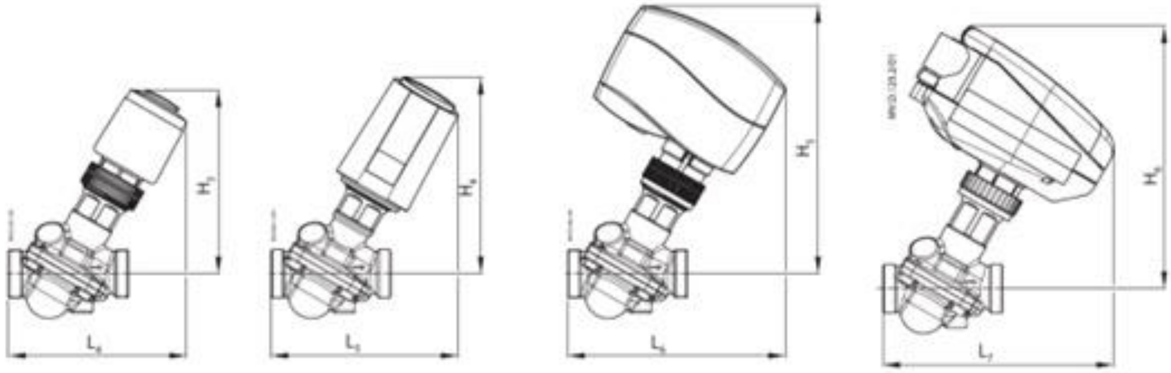


Figure 32: Dimensions and appearance of a heat pump for installation in a local engine room

NETWORK BALANCING

In order to achieve the necessary flows through individual branches and maintain the authority of the control valve, achieve the desired effects of heating / cooling bodies, and achieve flawless operation of the entire system, it is necessary to balance heating circuits on zone valves or valves of each public network connection.
* Pressure independent balance and control valve with electrothermal drive
* The valve equipped with the actuator is a control valve with full authority and automatic balancing / flow restriction function.
* Typical applications are: temperature control with permanent automatic balancing on terminal devices (refrigeration devices, air chambers, convectors, induction devices, radiation plates and heat exchangers).
* Reduced drive movement because the built-in differential pressure regulator ensures that pressure fluctuations do not affect the room temperature.
* Minimal complaints about clogging because due to the construction of the diaphragm, the valve is minimally prone to clogging as in the insert design.
* The actuating valve will automatically regulate the flow even if other parts of the installation are not completed. It is not necessary to reset the valve after finalizing the installation.
* Installation costs are halved because the valve performs two functions, balancing and regulation
* The valve is pressure independent, which means that the control characteristic does not depend on the existing pressure and is not affected by low authority. The flow limitation on the valve is achieved by limiting the stroke, and the valve drives are calibrated according to the valve stroke. This means that the valve retains a linear characteristic regardless of the value and differential pressure.
* Due to the built-in differential pressure regulator, the control valve always retains full authority and therefore always provides stable control. At part load, excessive flow does not occur unlike conventional solutions because the valve always limits the flow to the required value. By installing a valve, the entire system is divided into completely independent control circuits.
* No Kv or authority calculations required. Flow is the only parameter to consider when constructing.
* Compact design, necessary when only limited space is available. For example, in fan coils.



Tip	L_1	L_2	L_3	L_4	L_5	L_6	L_7	H_1	H_2	H_3	H_4	H_5	H_6	b	Masa ventila
	mm													ISO 228/1	(kg)
DN 10	53	36	79	92	104	109	119	69	20	100	104	138	140	G ½	0,38
DN 15	65	45	79	98	110	116	126	72	25	102	108	141	143	G ¾	0,48
DN 20	82	56	79	107	120	125	134	74	33	105	112	143	145	G 1	0,65
DN 25	104	71	79	124	142	142	149	82	42	117	124	155	153	G 1 ¼	1,45
DN 32	130	90	79	142	154	160	167	93	50	128	136	166	164	G 1 ½	2,21

Table 19: Local balancing valves of engine rooms of the heating and cooling pipeline network

2.5 ANALYSIS OF THERMAL ENERGY POTENTIAL

Estimation of the total thermal energy potential of the sea of the subject area (potential for electricity and heat production) and compare it with the current energy needs of the Dubrovnik area.

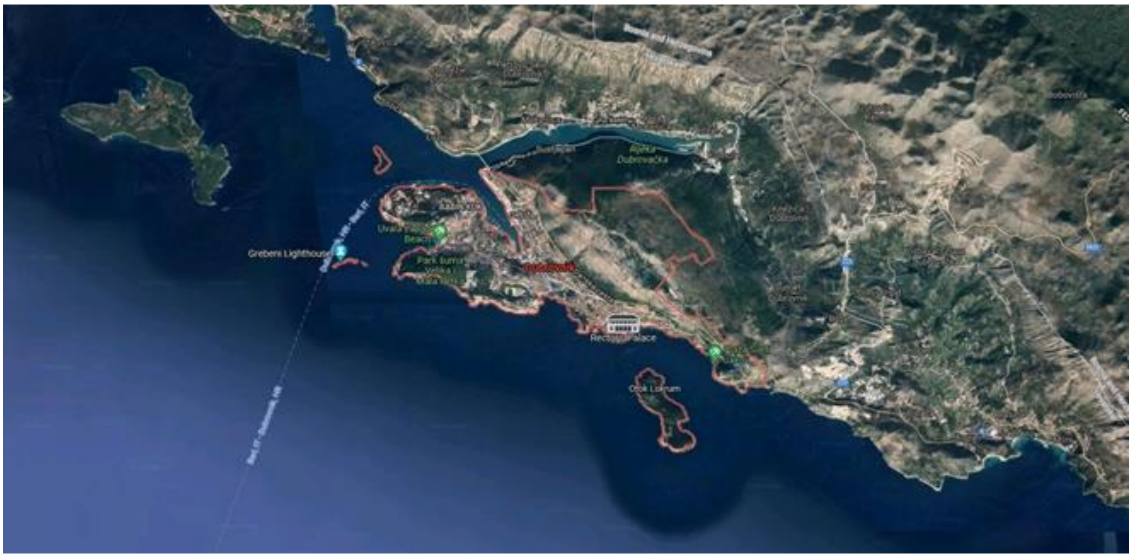


Figure 33: Coverage of the urban zone of the city of Dubrovnik

When building a central heating pipeline for heating and cooling the entire city, it is necessary to define the place of suction of marine energy into the system and the place of spillage of reheated or subcooled water. The suction site should be in a deep-water zone with a stable temperature throughout the year to facilitate the sizing of the entire system. The place of discharge of reheated or subcooled water should be in a low-use zone that is not close to the bathing area for reheating seawater during the summer season. The positions of the suction and discharge points should be harmonized with the flow of sea currents and daily changes of tides.

Deep sea heating and cooling systems are considered to be almost unlimited sources of energy, given that the heating and cooling needs of the entire city are many times less than the heat capacity of the entire sea. The thermal energy of the sea is transferred by sea and air currents to the air, which in turn flows the heat energy into the zones of colder air through the constant natural circulation of sea water and air. In the localized part of the coast, the sea can be used indefinitely as a source of heating and cooling energy.

Localized application of sea water for each individual building would be a technically difficult solution because the micro location would suck seawater and discharge seawater, which would cause a micro location change in temperature in the direction of cooling or reheating water. With localized application, it is necessary to build an engine room, seawater suction pipelines and wastewater pipelines for each building. For each micro-location, consent should be sought for connection to the public maritime domain, which would significantly complicate the process of introducing blue energy into seawater heating systems.

To define the place of fresh water intake into the system, it is crucial to know the natural movements of sea currents at the micro-location of the city of Dubrovnik. Hot waters from the Aegean Sea move along the Adriatic coast in a north-westerly direction throughout the year, as the geographical location already allows. Consequently, the fresh water suction point for the central heating and cooling system of the whole city should be in the southern part of the city while the consumed water would be discharged in the northern zone at a micro location suitable for discharging additionally heated or cooled water.

The constant natural inflow of sea water provides an unlimited source of thermal energy for heating and cooling throughout the city throughout the year. The warming seawater is directed by sea currents to the northwest and goes to the neighbouring shores. Croatian Waters should define the extent to which the heating of sea water by the cooling system is allowed and the extent to which the subcooling of sea water by the heating system of the entire city is allowed. According to experience, the temperature of sea, well and river water can be changed up to a maximum of 5 ° C from the initial value.

The surface current system in the Adriatic is a consequence of the distribution of thermohaline properties. Along the eastern coast of the Adriatic, there is an inlet (NW) current that transports salt Levantine water to the Adriatic, while along the western coast of the Adriatic, less salt water flows out of the Adriatic. Gradient currents are the main cause of the general cyclonic circulation, with the inlet current being more pronounced in the winter along the eastern and the outgoing current in the summer along the western coast of the Adriatic. Such a seasonal rhythm is mainly influenced by gradient currents, but also by seasonal wind changes. In summer, NW wind (maestral) prevails, which increases the outflow of sea water in the surface layer, while in winter the flow is influenced by SE wind (jugo), which increases the incoming flow of sea water. [10]

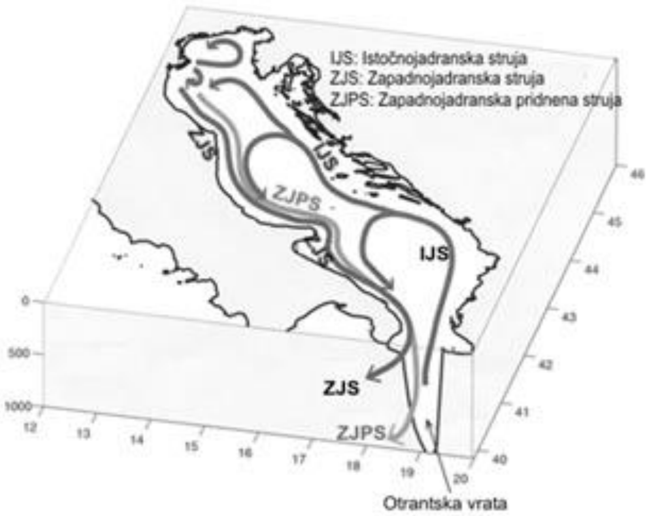


Figure 34: General flow scheme in the Adriatic

In addition to the general cyclonic circulation, several vortices occur in the Adriatic, the most pronounced of which is the South Adriatic cyclonic vortex. In addition, eddy currents occur around other topographic forms such as Jabučka kotlina, and in the northern Adriatic is characterized by wind (bora) cyclonic flow caused by the formation of high-density northern Adriatic water.

In the intermediate and deep layers of the Adriatic, the flow is influenced by thermohaline gradients. Thus, the entry of high salinity Levantine water takes place along the east coast, while the outflow of southern Adriatic water occurs in the bottom layers of the Strait of Otranto. Also, after formation in the northern Adriatic, dense northern Adriatic water flows towards the central and southern Adriatic in the bottom layer, at a speed of up to 20 cm / s, mixing and changing the thermohaline properties of the central and southern Adriatic.

When defining individual models as well as simulating possible hydrocarbon spills, it is necessary to take into account surface and depth flows, since the models of possible hydrocarbon spills themselves mainly depend on depth flows. Surface as well as depth currents vary on a daily basis and depend on various factors that need to be taken into account when designing the model.

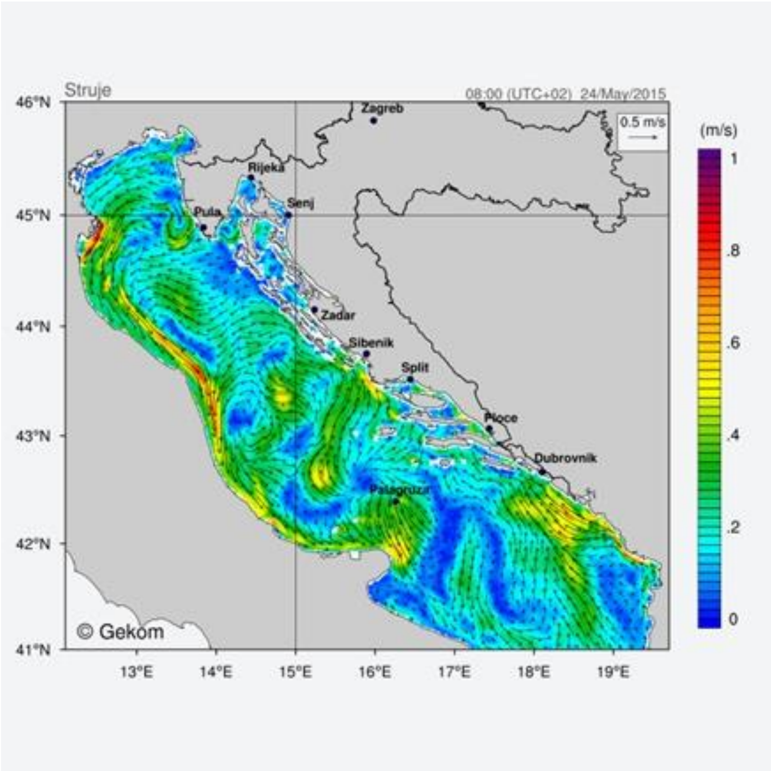


Diagram 4: Overview of surface currents on May 24, 2015

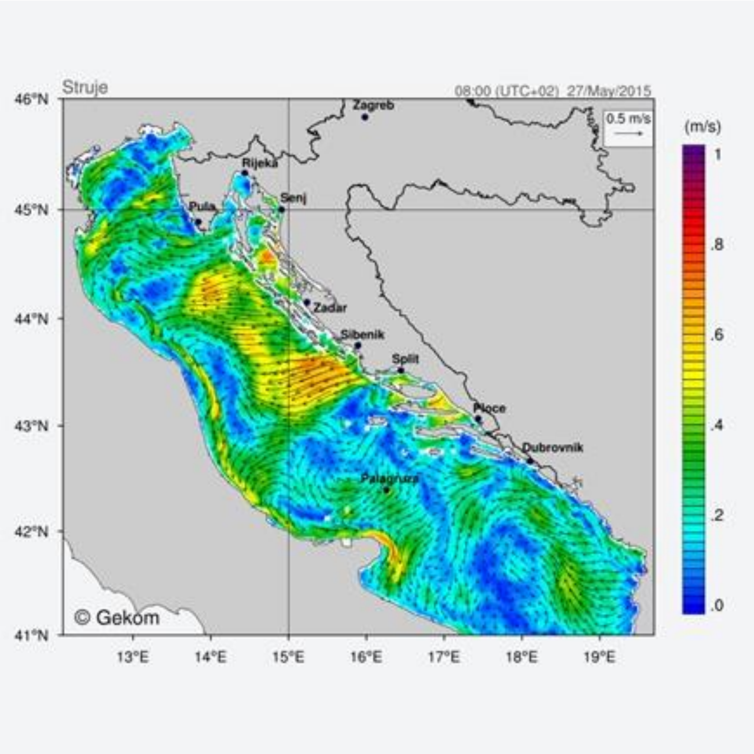


Diagram 5: Overview of surface currents on May 27, 2015

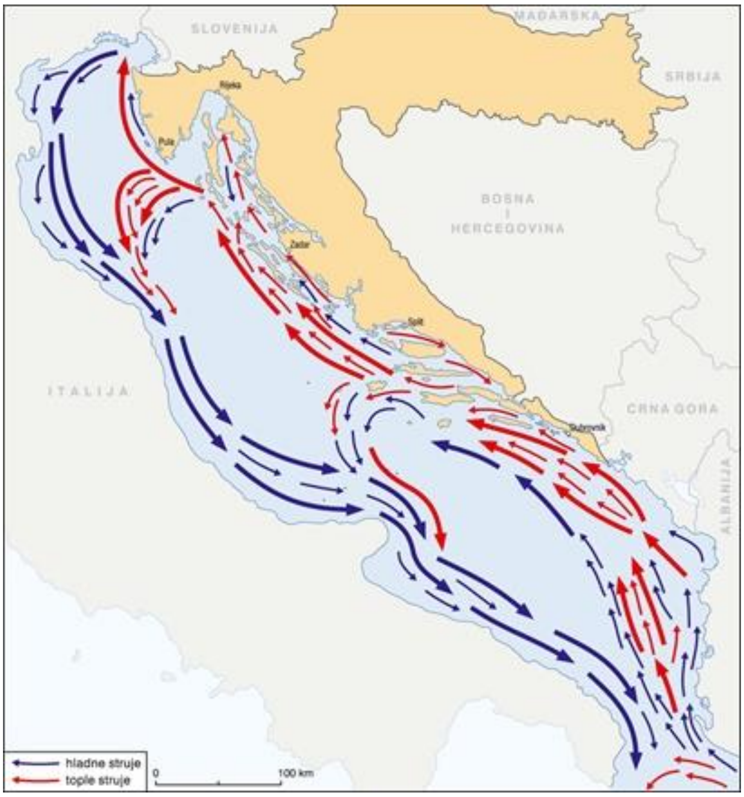


Diagram 6: Direction of constant sea currents in the Adriatic Sea

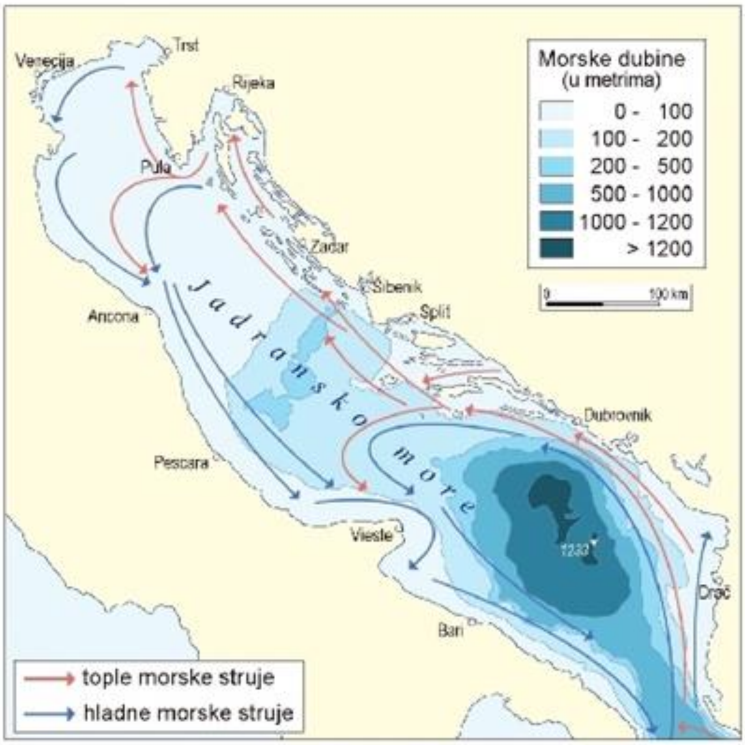


Diagram 7: Depths of the Adriatic Sea and sea currents

2.6 ANALYSIS OF ENERGY NEEDS OF BUILDINGS

Assess the energy needs of public, commercial and private buildings and compare them with the local potential of marine heat;

Figure 35: Wider urban zone of the city of Dubrovnik with the potential for the application of marine energy

Figure 36: Narrow urban zone of the city of Dubrovnik for the application of marine energy

The only available data on the built-up area of the entire city can be obtained through the website katastar.hr, where it is possible to measure the built-up area of buildings and the approximate built-up area is 5.56 km^2. If the degree of construction of 30% is assumed, then all buildings cover an area of 1.67 km^2. Assuming that all buildings have a first-floor floor, then the area is double or about 3.4 km^2 of gross heated area of all buildings.

For further analysis of the possible area of buildings in the city of Dubrovnik, the average statistical data for the Republic of Croatia and available data that are valid for any region because they are related to the time of construction of buildings were used.

From the point of view of energy consumption, the construction period is an extremely important parameter of the construction period. The division of buildings according to age and type of construction is an area to which insufficient attention has been paid and which, in the future, will need much more attention. Due to the characteristics of construction and lack of regulations on thermal protection, in the period of the largest residential construction from 1950 to 1980, a number of residential and non-residential buildings were built which are today large energy consumers, with average annual heating energy consumption over 200 kWh / m^2a.

The construction period as well as the period of possible renovation of the building are the first and basic information that is checked during the energy audit of the building. The data on age says a lot about the characteristics of construction and the types of structures that were used in a particular period of construction. It also tells us about the possible existence of thermal protection, depending on the legislative environment in the field of thermal protection in relation to the construction period.

According to the age and type of construction, and depending on the legislative environment, the existing buildings in Croatia can be divided into characteristic groups:
buildings built before 1940
buildings built between 1940 and 1970
buildings built between 1970 and 1987
buildings built in the period from 1987 to 2006
new construction harmonized with the Technical Regulation on thermal energy saving and thermal protection in buildings NN 79/05 with mandatory application from 1 July 2006, and the Technical Regulation on rational use of energy and thermal protection of buildings NN 110/08, NN 89/09.

In the analysis of the energy properties of the building and the characteristics of energy consumption, information on the purpose of the building and the specifics of energy consumption related to its purpose is important. The basic division of buildings according to purpose is into residential and non-residential buildings.

Diagram 8: Average energy consumption in Croatian buildings depending on construction time

Reduced energy consumption in the period after 2008 could be achieved by construction according to the requirements for achieving energy class A and A+; construction according to the minimum requirements of the Technical Regulation on Rational Use of Energy and Thermal Protection in Buildings maintains the level of consumption from the period 2005-2008.

Residential Buildings

The main characteristic of the existing construction in Croatia is the irrationally high consumption of all forms of energy, primarily energy for heating, but with the increase of standards more and more for cooling buildings. Energy consumption intended for heating, hot water preparation and air conditioning is the most important part of energy consumption in buildings. If the existing buildings constructed after the request for thermal protection of buildings within the standard HRN U.J5.600: Thermal engineering in construction, technical requirements for the design and construction of buildings from 1987, are accepted as conditionally satisfactory from the point of view of thermal protection and savings energy, even in this case about 83% of inhabited buildings in Croatia have unsatisfactory thermal protection, with an average energy consumption for space heating of 150 to 200 kWh / m²a.

The total number of dwellings in Croatia, according to the last census in 2001 [4.18], is 1.88 million, or 133.3 million square meters of housing construction. From this data, the energy potential of buildings in the Republic of Croatia is clearly visible. If we assume that residential buildings with one or two apartments are in fact family houses, the share of family houses in housing construction averages 65%.

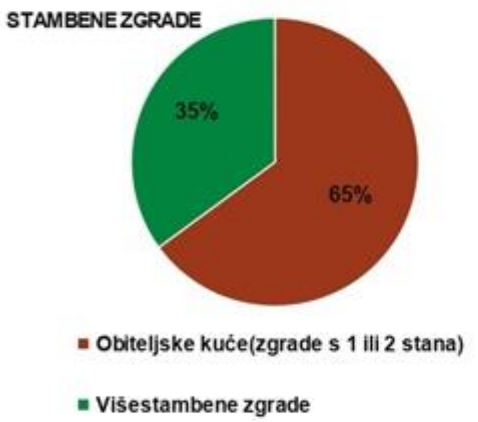


Diagram 9: Representation of family houses in total housing construction

		Number of apartments	Apartment area (thousand m2)	Average apartment area (m2)	Average apartment area per person (m2)	Average number of people per apartment
Census 1971.	**total**	1188743	62659	52,7	14,3	3,7
	urban settlements	513534	27781	54,1	15,4	3,5
Census1981.	**total**	1381434	86954	62,9	19,6	3,2
	urban settlements	727683	45035	61,9	20,1	3,1
Census1991.	**total**	1575644	110972	70,4	23,7	3,0
	urban settlements	878968	59184	67,3	23,2	2,9
Census 2001.	**total**	1877126	133307	71	27,3	2,6

Table 20: Housing stock of the Republic of Croatia according to the census

In 1971, the housing fund of the Republic of Croatia amounted to a total of 1,188,743 apartments. In 1981, the number of dwellings increased by 16.2%, to a total of 1,381,434 dwellings. In 1991, 1,575,644 dwellings were registered, an increase of 14.1%. In the period between the last two censuses, 1991-2001. In 2001, the total housing stock of Croatia increased by 301,482 dwellings, which means that in 2001 there were 19.1% more dwellings than in 1991.

Modalities of apartment use	Republic of Croatia		City of Zagreb	
	Number of apartments	Total area (m2)	Number of apartments	Total area (m2)
Total	1877126	133306758	312902	20315678
Residential housing				
Total	1660649	120973492	304163	19829752
Inhabited	1421623	105815623	271183	17958929
Temporarily inhabited	196633	12824336	31284	1791495
Abandoned	42393	2333533	1696	79328
Dwellings used temporarily				
Holiday apartments	182513	10390305	4843	201739
During seasonal work in agriculture	8418	282084	101	3755
Dwellings in which only the activity was performed	25546	1660877	3795	280432

Table 21: Division of dwellings in Croatia and Zagreb according to modalities of use

YEAR OF CONSTRUCTION	NUMBER OF HOUSING UNITS	REPRESENTATION IN THE TOTAL SECTOR OF EXISTING BUILDINGS
BEFORE 1919	129 901	9,10
1919. - 1945.	104 333	7,30
1946. - 1960.	154 672	10,90
1961. - 1970.	285 451	20,10
1971. - 1980.	329 028	23,10
1981. - 1990.	244 908	17,20
1991. - 1995.	47 911	3,40
1996. - 2001.	70 817	5,00
unknown and unfinished	54 602	3,90
in total	1 421 523	100

Table 22: Representation of occupied dwellings by year of construction in the total sector of existing buildings

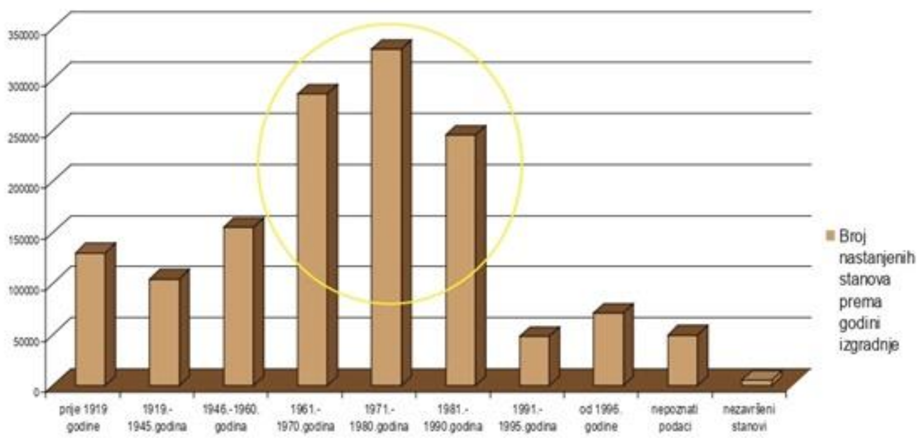


Diagram 10: Division of occupied dwellings by year of construction

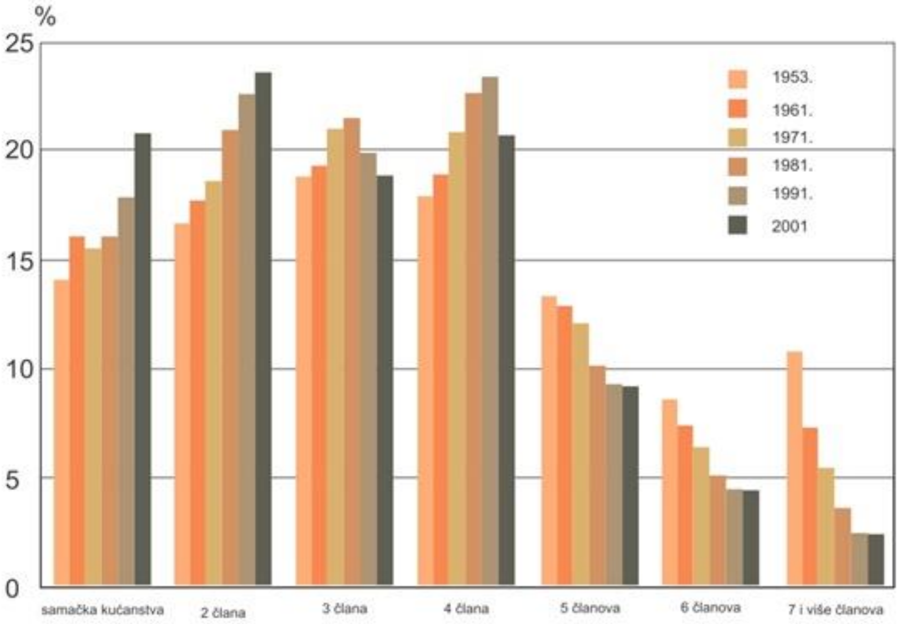


Diagram 11: Households by number of members according to the censuses from 1953 to 2001

From the conducted analyses, we can conclude that in the period of the largest construction in Croatia, from 1946 to 1990, a large number of buildings were built, which today represent large energy consumers. With the increase in living standards, and the growth of single households, the energy consumption in these buildings is additionally growing.

Today, the question is no longer about energy costs, but about costs if nothing is done about it. The potential for energy savings of the existing building sector is extremely large, and activities aimed at renovating the heating and cooling system can stimulate a number of economic activities and thus contribute to economic and industrial development, employment and greater competitiveness of the whole economy. Energy renovation of buildings and installations should be systematically planned and directed to the part of the sector that will achieve the greatest energy savings with the necessary increase in standards. Also, since a renovated building is unlikely to be renovated in the next 20-30 years, such energy renovations should be carried out in accordance with low-energy principles and with the use of renewable and alternative energy systems.

Non-residential buildings

Non-residential buildings are not as well statistically processed and recorded as residential buildings. Data on today's non-residential construction are available through issued building permits, so we can analyse the relationship between newly built residential and non-residential building stock. In the period from 1996 to 2008, there was a decrease in the number of issued permits for residential buildings and an increase in the number of issued building permits for non-residential buildings, so today the average ratio is 60% residential and 40% non-residential construction. Non-residential buildings differ greatly in energy consumption depending on age and depending on the typology and method of use buildings, i.e., the purpose of the building and to assess the energy potential is important analysis by type of energy consumption. In Croatia, a detailed specification of all non-residential buildings is not available because energy certificates have not been created for all buildings.

	BUILDINGS						
	TOTAL		RESIDENTIAL		NON-RESIDENTIAL		SURFACE RATIO %
	Surface m^2	Volume m^3	Surface m^2	Volume m^3	Surface m^2	Volume m^3	
1996.	1 463 639	4 768 048	1 032 529	2 996 941	431 111	1 771 107	71% / 29%
1997.	1 912 222	6 050 695	1 277 332	3 667 044	634 890	2 383 651	67% / 33%
1998.	1 907 048	6 339 905	1 334 851	3 916 229	572 197	2 423 676	70% / 30%
1999.	1 899 648	6 070 278	1 367 927	4 039 407	531 721	2 030 871	72% / 28%
2000.	2 182 816	7 330 076	1 476 776	4 348 993	706 040	2 981 083	68% / 32%
2001	3 191 988	10 621 828	2 153 574	6 289 905	1 038 414	4 331 923	67% / 33%
2002.	3 596 308	12 187 775	2 393 281	6 977 036	1 203 027	5 210 739	66% / 34%
2003	4 103 471	14 552 605	2 455 370	7 252 104	1 648 101	7 300 501	60% / 40%
2004	4 202 942	14 839 468	2 434 488	7 189 454	1 768 454	7 650 014	58% / 42%
2005	4 773 236	16 925 965	2 840 236	8 394 718	1 933 000	8 531 247	60% / 40%
2006	5 155 445	18 249 379	3 167 992	9 373 883	1 987 453	8 875 496	61% / 39%
2007	5 524 936	20 473 930	3 009 703	8 883 354	2 515 233	11 590 576	55% / 45%
2008	5 156 169	18 356 838	3 054 229	9 057 543	2 101 940	9 299 295	59% / 41%

Table 23: Construction sizes of residential and non-residential buildings for which building permits were issued in the period 1996-2008. years, new construction and extension

In the Republic of Croatia, detailed data on typologies and types of buildings constructed are not available, nor has a detailed database ever been created from which more detailed data on energy consumption for non-residential buildings can be read. All analyses of energy consumption are therefore carried out on the basis of possible estimates of energy consumption depending on the time of construction and depending on the technical conditions prescribed by the ordinances at the time of construction of the building.

Buildings built before 1940

The main feature of construction in this period is the construction of traditional techniques and materials, without the use of thermal protection. Thermal protection of buildings is a part of building physics which is a relatively young science. It is related to the sudden emergence of new materials in construction, the energy crisis and the development of awareness of the need to save energy and protect the environment. Insufficient thermal insulation leads to increased heat losses in winter, cold perimeter structures, damage caused by condensation (moisture), and overheating of the space in summer. The consequences are damage to the structure, and uncomfortable and unhealthy living and working. Heating such spaces requires a larger amount of energy, which leads to an increase in the cost of using and maintaining the space, but also to greater environmental pollution. Environmental pollution again has an impact on building damage and on human life and health.

In traditional construction, the protective role of the outer shell of the building was experientially transferred depending on the applied material that satisfied the load-bearing capacity and provided a certain thermal protection. Thermal protection was not the subject that guided the choice of construction, and energy savings, according to today's understanding, were unknown.

The first thoughts of theorists about the limited amount of energy raw materials appear at the beginning of the twentieth century. In 1912, Karl Schmidt spoke of limited annual energy consumption. In 1921, in the settlement of Heleran near Dresden, wooden buildings were built in the form of a double wooden structure and an interspace filled with peat. This can be considered a precursor to the installation of thermal insulation for the purpose of saving energy.

The first regulations on thermal protection in Croatia were adopted in 1970. Therefore, when analysing the thermal characteristics of existing buildings, information on the year of construction or major reconstruction of the building is important. For buildings built before 1970, no calculations of heat losses and energy savings were made. The buildings were built experientially, satisfying the statics of the construction. Older buildings were constructed as a masonry structure of solid brick or stone, wall thickness 30, 45, 60 cm in the construction of the old brick format (29/14 / 6.5-7.5 cm), and 25, 38 or 50 cm and more when building with a new brick format (25/12 / 6.5 cm).

Thermal insulation was not used. Ceilings are mostly wooden or solid made of brick, stone or concrete elements (ribbed concrete ceiling). Such older buildings with massive thick walls, due to the large thickness of the structure and the relatively low degree of space heating, did not have such large heat losses as the newer lightweight concrete structures without thermal protection. However, by introducing space heating standards to a temperature higher than 18 ° C, a significant part of heat energy is lost through such walls and the problem of moisture arises. The values of the heat transfer coefficient for such external masonry structures do not meet the requirements of today's regulations.

The walls in the ground near the old buildings were made as well as the outer walls of brick or stone. Basements were mostly auxiliary spaces of the building that were not heated. The most often ventilated basement served as a buffer space between the ground and the ground floor space. Moisture, which was inevitable, dried in the basement without harming other structures. Most often, uninsulated floor did not create problems in auxiliary unheated areas of the building. The floors were most often made on a layer of compacted earth. Wooden cubes or brick elements laid in the embankment were used as a walkway. The floors of the ground-floor rooms on the ground were performed mostly with wooden blind floors in the embankment. Ground floors in the case of heated spaces do not meet the requirements of today's regulations. Cold floors of heated spaces are often exposed and condensation appears on their upper surface.

The ceiling towards the unheated attic was most often made as a wooden ceiling with a subfloor (plaster on the board formwork), a rubble embankment and the upper board formwork as the attic floor, or brick elements laid in a layer of sand. The ceiling above the unheated space is mostly the basement ceiling and was most often constructed as a vaulted ceiling of brick or stone with an embankment and a floating wooden floor, laid in that embankment. The underlay of the vault was mostly plastered. The roof of old buildings was usually not insulated because it was built above the unheated attic space. The ceiling in traditional construction serves as an interspace between the external and internal heated space. The problem arises when converting the attic space into a heated living space.

Windows and doors in old buildings were mostly made of wood, glazed with one or two panes of glass. They were installed as single or double windows with two wings at a distance of more than 10 cm. Such windows cause large heat losses through the outer shell, both due to transmission and due to the passage of air through unsealed joints. Average heat losses in such old buildings are mostly between 180 and 250 kWh / m2 per year. Analyses show that by increasing the thermal insulation of the outer shell, primarily the outer wall, and replacing windows, heat losses are reduced to at least 60-90 kWh / m2 per year, which saves energy consumption by about 70%.

City of Dubrovnik

From the above data, the structure of buildings for the city of Dubrovnik itself can be extrapolated, and a similar analysis can be used to estimate the energy consumption of any city in the Republic of Croatia. According to available data, the city of Dubrovnik has 42,615 inhabitants.

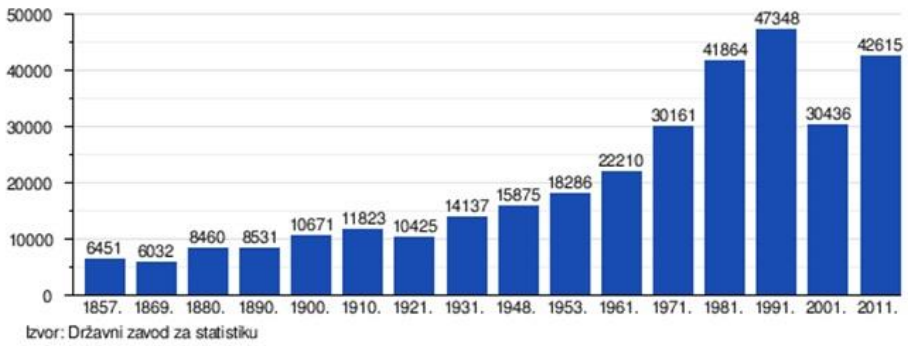


Diagram 12: Population of Dubrovnik

From 1857 to 1971 it contains data for the former settlements of Gruž-Luka and Lapad. In 2001, the settlements of Bosanka, Brašina, Župa dubrovačka municipality, Brgat Donji, Župa dubrovačka municipality, Brgat Gornji, Župa dubrovačka municipality, Buići, Župa dubrovačka municipality, Čajkovica, Čajkovići, Čelopeci, Župa dubrovačka municipality, Čibača, Župa dubjenočka municipality, , Grbavac municipality Župa dubrovačka, Knežica, Komolac, Kupari municipality Župa dubrovačka, Makoše municipality Župa dubrovačka, Martinovići municipality Župa dubrovačka, Mlini municipality Župa dubrovačka, Mokošica, Nova Mokošica, Petrača municipality Župa dubrovačka, Petrovo Selo, Plat municipality Župa dubrovačka Prijevor, Rožat, Soline Župa dubrovačka municipality, Srebreno Župa dubrovačka municipality, Sustjepan, Šumet and Zavrelje Župa dubrovačka municipality. In 1981 and 1991 it contains data for the settlements

Bosanka, Brašina municipality Župa dubrovačka, Čajkovići, Čelopeci municipality Župa dubrovačka, Čibača municipality Župa dubrovačka, Donje Obuljeno, Gornje Obuljeno, Komolac, Kupari municipality Župa dubrovačka, Mlini municipality Župa dubrovačka, Mokošica, Petrača Župa dubrovačka municipality, Petrovo Selo, Pobrežje, Prijevor, Rožat, Srebreno Župa dubrovačka municipality and Zavrelje Župa dubrovačka municipality. From 1857 to 1991 it contains data for the settlement of Nova Mokošica.

		Number of apartments	Apartment area (thousand m^2)	Average apartment area (m^2)	Average apartment area per person (m^2)	Average number of people per apartment
2001 Census	**Total**	1877126	133307	71	27,3	2,6

Table 24: Housing stock of the Republic of Croatia according to the census

According to available data, the city of Dubrovnik with its settlements has 42,615 inhabitants. From the available data from the 2001 census, it can be read that the average number of people living in an apartment is 2.6, which would give the data that there are 16,390 functionally independent housing units in the City of Dubrovnik.

Additionally, data from the 2001 census is available that the average apartment area per person is 27.3 m2, which would then give the City of Dubrovnik and a population of 42,615 a total average living area of 1,163,389 m2 of usable heated area of residential buildings.

YEAR OF CONSTRUCTION	NUMBER OF HOUSING UNITS	REPRESENTATION IN THE TOTAL SECTOR OF EXISTING BUILDINGS
BEFORE 1919	129 901	9,10
1919. - 1945.	104 333	7,30
1946. - 1960.	154 672	10,90
1961. - 1970.	285 451	20,10
1971. - 1980.	329 028	23,10
1981. - 1990.	244 908	17,20
1991. - 1995.	47 911	3,40

1996. - 2001.	70 817	5,00
unknown and unfinished	54 602	3,90
in total	1 421 523	100

Table 25: Representation of occupied dwellings by year of construction in the total sector of existing buildings

Statistically processed data on the time of construction of buildings in the Republic of Croatia defined the percentage share of buildings in the total number of all buildings related to construction. The time of construction of an individual residential building is important to define the method of construction and materials used for construction. From all the above input data, the amount of energy required for heating the building, which is included in the Q_{hnd} energy certificate, is also defined. It should be noted that in the Republic of Croatia not all buildings are energy certified, but only a small part of buildings because there is no obligation to energy certification of all buildings. Energy certification is carried out only as mandatory for public buildings, while for other buildings it is carried out before the technical inspection of the building, before sale or rent, and an energy certificate is required in various energy renovation tenders.

YEAR OF CONSTRUCTION	SHARE	m^2	kWh/m^2*a	kWh/a
BEFORE 1919	9,1	105.868	250	26.467.100
1919. - 1945.	7,3	84.927	250	21.231.849
1946. - 1960.	10,9	126.809	250	31.702.350
1961. - 1970.	20,1	233.841	250	58.460.297
1971. - 1980.	23,1	268.743	200	53.748.572
1981. - 1990.	17,2	200.103	175	35.018.009
1991. - 1995.	3,4	39.555	150	5.933.284
1996. - 2001.	5	58.169	100	5.816.945
unknown and unfinished	3,9	45.372	250	11.343.043
in total	100	1.163.389		249.721.449

Table 26: Estimation of energy consumption of residential buildings in the city of Dubrovnik

For the city of Dubrovnik, therefore, for the estimation of the area of all residential buildings of 1,163,389 m^2 and with the application of the average annual energy for

heating 100-250 kWh / m^{2}a, data on the average annual energy for heating buildings of 249,721,449 kWh are obtained.
The energy required for domestic hot water heating can be estimated based on the provisions of the European standard HRN EN 15316-3-1: 2007 which defines those buildings with less than three apartments consume an average of 12.50 kWh / m^2 for domestic hot water needs. If we take the estimate of the living area of all residential buildings in the city of Dubrovnik of 1,163,389 m^2, then we come to the data that 14,542,363 kWh / a per year is needed for domestic hot water heating.
For the Republic of Croatia there are no statistically available data related to the required cooling energy of buildings and cooling energy was introduced only a few years ago as a provision in energy certificates, but the number of available certified buildings is not enough to extrapolate data to the whole country or city. It is experientially known that the cooling season is 1/4 of the heating season, so from the available heating energy it could be estimated that the city of Dubrovnik will need to provide 62,430,362 kWh / a of annual cooling energy. For residential buildings, the stated heating, cooling energies amount 326,694,174 kWh / a.

	Natural gas		**Heat pump water-water**	
Annual system energy required	kWh/yr	326.694.174,00	kWh/yr	326.694.174,00
Usability of the system	%	0,95	%	4,50
Heating value	kWh/m3	9,30	kWh/kWh	1,00
Annual consumption	m^3	36.977.269,27	kWh	72.598.705,33
Energy price	kn/m^3	4,20	kn/kWh	1,05
Unit price	kn/kWh	0,48	kn/kWh	0,23
Annual energy input	kWh/yr	343.888.604,21	kWh/yr	72.598.705,33
Annual energy cost	**kn**	**155.304.530,93**	**kn**	**76.228.640,60**
CO_2 emissions	kg/m^3	2,0478	kg/kWh	0,0806
Annual CO_2 emissions	**kg**	**75.722.052,01**	**kg**	**5.848.067,71**
SO_2 fuel emissions	kg/m^3		kg/kWh	0,00024
Annual SO_2 emissions	**kg**		**kg**	**17.262,36**
NOx fuel emissions	kg/m^3		kg/kWh	0,00014
Annual NOx emissions	**kg**		**kg**	**10.325,15**
Heating savings			%	50,92

Non-residential buildings are not as well statistically processed and recorded as residential buildings. Today, the average ratio is 60% residential and 40% non-residential construction. Non-residential buildings differ greatly in energy consumption depending on age and depending on the typology and use of the building, i.e., the purpose of the building, and analysis of energy potential is important to assess the types of energy consumption. There is no detailed database in the Republic of Croatia from which the value of the area of non-residential buildings could be read. From the data that the ratio of residential and non-residential 60% to 40% can then be taken to estimate that non-residential buildings have 66% of the area of residential or about 2/3. If the estimated living area of the city of Dubrovnik is 1,163,389 m^2 then the estimated area of non-residential buildings is 767,837 m^2.

YEAR OF CONSTRUCTION	SHARE	m^2	kWh/m^2*a	kWh/a
BEFORE 1919	9,1	69.873	250	17.468.286
1919. - 1945.	7,3	56.052	250	14.013.021
1946. - 1960.	10,9	83.694	250	20.923.551
1961. - 1970.	20,1	154.335	250	38.583.796
1971. - 1980.	23,1	177.370	200	35.474.057
1981. - 1990.	17,2	132.068	175	23.111.886
1991. - 1995.	3,4	26.106	150	3.915.967
1996. - 2001.	5	38.392	100	3.839.184
unknown and unfinished	3,9	29.946	250	7.486.408
in total	100	767.837		164.816.156

Table 27: Estimation of energy consumption of non-residential buildings in the city of Dubrovnik

The estimate of thermal energy consumption of non-residential buildings was obtained by a similar approach as for residential buildings in such a way that the final energy for heating of 164,816,156 kWh / a per year is obtained from the construction period estimate and the energy consumption estimate. The energy of sanitary water is 9,597,962 kWh / a, taking into account that in the city of Dubrovnik there are many hotels that have the consumption of sanitary water approximately to residential buildings. While then the cooling energy is 1/4 or about 41,204,039 kWh / a. For non-residential buildings, the stated heating and cooling energies amount to 215,618,157 kWh / a.

	Natural gas		**Heat pump water-water**	
Annual system energy required	kWh/yr.	215.618.157,00	kWh/yr.	215.618.157,00
Usability of the system	%	0,95	%	4,50
Heating value	kWh/m^3	9,30	kWh/kWh	1,00
Annual consumption	m^3	24.404.997,96	kWh	47.915.146,00

Energy price	kn/m3	4,20	kn/kWh	1,05
Unit price	kn/kWh	0,48	kn/kWh	0,23
Annual energy input	kWh/yr.	226.966.481,05	kWh/yr.	47.915.146,00
Annual energy cost	**kn**	**102.500.991,44**	**kn**	**50.310.903,30**
CO2 emissions	kg/m3	2,0478	kg/kWh	0,0806
Annual CO2 emissions	**kg**	**49.976.554,83**	**kg**	**3.859.724,73**
SO2 fuel emissions	kg/m3		kg/kWh	0,00024
Annual SO2 emissions	**kg**		**kg**	**11.393,16**
NOx fuel emissions	kg/m3		kg/kWh	0,00014
Annual NOx emissions	**kg**		**kg**	**6.814,60**
Heating savings			%	50,92

The buildings within the scope of the city of Dubrovnik were built in different time periods and include protected urban units, business buildings, mixed buildings and residential buildings. Buildings have different layers of thermal insulation from none in protected old buildings to better insulated buildings of more recent construction date. Following the above, we assume that it is necessary to provide 100-120 W / m2 of installed peak thermal power during the winter period for heating buildings.

2.0 km^2 x 1000 m x 1000 m x 100 W / m^2 = 200,000,000 W = 200,000 kW = 200 MW

2.0 km^2 x 1000 m x 1000 m x 120 W / m^2 = 240,000,000 W = 240,000 kW = 240 MW

To heat all buildings in the city of Dubrovnik, it is necessary to provide 170-240 MW of thermal energy during the coldest day of the year. When dimensioning the entire system, it is necessary to pay attention to the possibility of increasing capacity in undeveloped urban areas and accordingly select the necessary diameters of the pipeline.

Temperature 1	T1 [°C]	30
Temperature 2	T2 [°C]	20
Middle temperature	tsr [°C]	25
Temperature difference	Δ t [°C]	10

Working fluid	**water**	
Density	ρ[kg/m3]	997,6
Viscosity	v[m2/s]	1,1E-06
Spec. heat capacity	cp[kJ/kgK]	4,183

Dionica	Thermal power	Nominal diameter	Speed	The length of the section	Resistance factor	Rise / fall	Volume flow	Specific line pressure drop	Linear pressure drop	Local pressure drop	Static pressure
	Q [kW]	DN [mm]	w [m/s]	L [m]	ξ (zeta)	h [m]	qv [m3/h]	R [Pa/m]	RL [Pa]	Z [Pa]	H [Pa]
	240000						**20723**		0	0	0

Table 28: Estimation of the required thermal power of the heating system of the city of Dubrovnik

For the needs of heating the whole city, it is necessary to ensure the flow of sea water of 21,000 m^3 / h through a suction pipeline that would be installed in the southern part of the city or to create heating and cooling engine rooms in several places in the city. heating water.

For residential buildings, the stated heating and cooling energies amount to 326,694,174 kWh/a

For non-residential buildings, the stated heating and cooling energies amount to 215,618,157 kWh/a.

For all buildings, the stated heating and cooling energies amount to 542,312,331 kWh/a.

2.7 ANALYSIS OF THE PILOT PROJECT LOCATION PROPOSAL

Based on the analysed potentials, in cooperation with the Client, propose one of the locations included in the subject area of Dubrovnik for the pilot area of the Coastenergy project. The proposal is to choose one district in the city, one building or one series of public urban buildings for which a central heating system would be built using blue energy. Seawater would be introduced into a central engine room where the main distribution pipeline for running process water through the city would be heated or cooled. An underground pipeline would be brought to each building in question, while a local engine room with a built-in water-to-water heat pump would be built in each building. The building would be heated or cooled through the local engine room while the waste heat energy of the building would be transported to the return pipeline. The size of the pilot installation depends on the financial capabilities of the investor and the construction possibilities in order to define the potential of the system and research the interest of the local population to connect to the proposed central heating and cooling system.

It is proposed that fresh seawater be taken into the system in the southeaster zone, and that a cold seawater pumping station be located at this location, as well as a central heating station with pumping stations and a filter plant for seawater treatment. In addition, a system for reheating and cooling the technological water of the central heating and cooling system of the entire city would be installed. It is proposed to locate the city's central heating station at this location, given the direction of sea currents that bring fresh cold water.

All treated seawater would be drained through an underwater pipeline further from the engine room to the zone of active sea currents, which would take the heat-treated water further from the suction zone into the central system. During the summer, this wastewater would be reheated when the entire city is cooled and the system would be dimensioned to prevent uncontrolled overheating of seawater with control of the outlet temperature of seawater discharged heated into the sea. If the overheating is too high, adiabatic coolers can be provided in the central engine room to reduce the process water temperature of the entire system.

Figure 37: Concept of the heating and cooling pipe network of the city of Dubrovnik

2.8 TECHNICAL-ECONOMIC ANALYSIS OF THE PILOT PROJECT

Based on the performed analysis, a pilot area of the Coastenergy project must make a techno-economic analysis of one hypothetical project for the use of thermal energy. As previously mentioned, the total area of all buildings in the city of Dubrovnik of 2.0 km^2 is assumed. Since buildings of different energy properties have been built, the starting assumption is that 271 kWh / m^{2}a of thermal energy is needed for heating buildings, heating sanitary water and cooling.

2.0 km^2 x 1000 m x 1000 m x 271 kWh/m^{2}a = 542.312.331 kWh/a = 542.312 MWh/a = 543 GWh/a

As an initial assumption, it is accepted that it is necessary to provide 543 GWh/a of thermal energy for heating and cooling buildings. Compared to natural gas heating, using a water-to-water heat pump can save 50.9% of money while reducing CO_2 emissions by 92%.

	Natural gas		**Heat pump water-water**	
Annual system energy required	kWh/yr.	542.312.331,00	kWh/yr.	542.312.331,00
Usability of the system	%	0,95	%	4,50
Heating value	kWh/m^3	9,30	kWh/kWh	1,00
Annual consumption	m^3	61.382.267,23	kWh	120.513.851,33
Energy price	kn/m^3	4,20	kn/kWh	1,05
Unit price	kn/kWh	0,48	kn/kWh	0,23
Annual energy input	kWh/yr.	570.855.085,26	kWh/yr.	120.513.851,33
Annual energy cost	**kn**	**257.805.522,38**	**kn**	**126.539.543,90**
CO2 emissions	kg/m^3	2,0478	kg/kWh	0,0806
Annual CO_2 emissions	**kg**	**125.698.606,84**	**kg**	**9.707.792,44**
SO2 fuel emissions	kg/m^3		kg/kWh	0,00024
Annual SO_2 emissions	**kg**		**kg**	**28.655,52**
NOx fuel emissions	kg/m^3		kg/kWh	0,00014
Annual NOx emissions	**kg**		**kg**	**17.139,75**
Heating savings			%	50,92

Energy	**Natural gas**	**Emission CO_2**	**Heat pump**	**Emission CO_2**	**Savings**
kWh/yr.	**kn/yr.**	**kg/yr.**	**kn/yr.**	**kg/yr.**	**kn/yr.**
10000	4.753,82	2.317,83	2.333,33	179,01	2.420,49
20000	9.507,64	4.635,66	4.666,66	358,02	4.840,98
30000	14.261,46	6.953,49	6.999,99	537,03	7.261,47

40000	19.015,28	9.271,32	9.333,32	716,04	9.681,96
50000	23.769,10	11.589,15	11.666,65	895,05	12.102,45
60000	28.522,92	13.906,98	13.999,98	1.074,06	14.522,94
70000	33.276,74	16.224,81	16.333,31	1.253,07	16.943,43
80000	38.030,56	18.542,64	18.666,64	1.432,08	19.363,92
90000	42.784,38	20.860,47	20.999,97	1.611,09	21.784,41
100000	47.538,20	23.178,30	23.333,30	1.790,10	24.204,90
110000	52.292,02	25.496,13	25.666,63	1.969,11	26.625,39
120000	57.045,84	27.813,96	27.999,96	2.148,12	29.045,88

Table 29: Estimation of CO_2 emissions from the heating system of the city of Dubrovnik

2.9 PRELIMINARY DESIGN OF THE PILOT PROJECT

Based on the performed analysis, make a conceptual solution for one project of using a heat pump with the corresponding cost estimate; The conceptual design will serve as a basis for the preparation of a feasibility study; The conceptual design must offer a minimum of two variants of the heating / cooling system that will be analysed in parallel in the mentioned feasibility study;
The proposal is to choose one building, one district in the city or one series of public urban buildings for which a central heating system would be built using blue energy. Seawater would be introduced into a central engine room where the main distribution pipeline for running process water through the city would be heated or cooled. An underground pipeline would be brought to each building in question, while a local engine room with a built-in water-to-water heat pump would be built in each building. The building would be heated or cooled through the local engine room while the waste heat energy of the building would be transported to the return pipeline.

Activities for the construction of the first installation include:
- defining the subject project and the conceptual design
- defining the scope of installation and the number of buildings
- change of planning documentation for construction of hot water network
- production of technical documentation
- defining the economic construction of the investment
- conducting public procurement
- installation and commissioning
- monitoring the installation and preparation of periodic reports

Figure 38: Preliminary concept of the heating and cooling pipe network of the pilot project

It is proposed to build a local heating pipeline to which one building would be connected, one city district to define on a small scale the possibility of building an installation for the whole city. The heating station can be designed with the possibility of modular increase of thermal power as needed in accordance with the possible extension of the installation to more buildings that would be heated and cooled throughout the year. Seawater is taken in the zone of arrival of new water in accordance with the direction of flow of underwater sea currents. The used sea water is discharged further from the shore in the zone of outgoing sea currents by means of an underwater pipeline. Depending on the financial capabilities of the city, this installation can be increased as needed from one building to the entire city.

ONE BUILDING

The installation of a building that uses a water-water heat pump for heating and cooling throughout the year is a classic installation that has already been installed at a location in the City of Dubrovnik in the Rector's Palace and this installation was reported through the Seadrion pilot project. The installation uses seawater thermal energy for heating and cooling with a total installed cooling capacity of 430 kW. There was an older water-water heat pump in the building, which was removed and the installation was reconstructed by installing new equipment. The entire project of reconstruction of the installation cost 510,000.00 EUR, with the cost of annual maintenance of the entire installation being 20,000.00 EUR. The installation uses the existing seawater intake and existing canals to

receive fresh water and to recover used water. The installation is installed in a building that is protected as a cultural asset, which significantly complicates the application of similar installations in the old town of Dubrovnik because it is necessary to seek the opinion and conditions of the conservation institute for each project.
The installation of the seawater intake of one building can be done in the karst terrain by making an absorption and suction well on your own plot. Water is sucked in through a well connected to the sea via karst terrain, and the absorption well is located in a similar way on the same plot. The disadvantage of such a system is the possibility of local overheating or subcooling of sea water due to the relatively short distance of the two wells.
The installation of a seawater intake of a building can be performed by a direct seawater intake via a suction and absorption pipeline. With this installation, there is a problem of the installation passing through particles that are not owned by the person or building that is intended to be heated or cooled. In this installation, in reality, multiple ownership problems of the passage of the pipe to the sea surface may occur, and the procedure is much more complex for obtaining consent for the use of sea water and concession.
Considering the installed thermal power and the price of the investment, the average value of the investment is 1,186.00 EUR / kW of the installed power of the water-water crane. This is a relatively high investment cost of equipment for which the existing engine room was reconstructed. For comparison, the value of the air-to-water heat pump investment with the fan coil network for heating and cooling is 200-250 EUR / m^2 for new construction and up to 300 EUR / m^2 of building for reconstruction of installations, i.e., the price is 1000-1500 EUR / kW of installation.

MORE BUILDINGS
Preliminary installation of seawater for one building can be multiplied to several adjacent buildings, each building having its own separate engine room for heating and cooling while the water intake would be performed in a common water intake system. There must be a connecting link between the buildings and a corridor for conducting underground installations that would bring sea water to each individual building. The installation of this form can be done easily in the case when the same person owns one particle and builds an installation of heating and cooling with sea water for several buildings on his own plot. The possibility of building this combination of installations is significantly complicated when each building is on its own plot and the connecting route of the installation is on the plot of another owner or it is a public plot. In addition, the seawater catchment itself must be defined because the pipeline passes through the public good and it is necessary to obtain a concession for the use of seawater. The estimated investment value of an installation of this complexity is around 2000-2500 EUR / kW

CITY QUARTER

The previously described installation of seawater use for heating and cooling can be further multiplied to a set of buildings or to one smaller neighbourhood. The water intake would be performed at one location, so it is only necessary to define the passage of the system pipes to the sea surface for one place. One seawater suction pipe is needed and another pipe to return the treated seawater to the sea. It is necessary to build a central engine room which would be used to exchange heat energy between sea water and water from heating and cooling systems.

It is necessary to define the route that would lead the local pipes to each building and the local heating and cooling engine room. Pipes between individual particles would pass through public areas, so the spatial plan should define the zones of passage of these pipes and coordinate them with all other installations that are already passing through the street corridor or are planned to be implemented. Additionally, there is the issue of maintenance and management of the installation that would pass through public space, and therefore a special company should have a city concession for the use of urban areas for heating and cooling of buildings in the local city district. Compared to the previously described levels of complexity, this installation has a slightly higher investment value estimate of 3000 EUR / kW.

WHOLE CITY

The previously described installation of local city districts can be multiplied to the entire city through the extensive reconstruction of all city corridors to implement the new heating and cooling installation. In order to reconstruct the entire city in this way, it is necessary to change the spatial plans and maps of the city and adjust them for the installation of central heating and cooling. Since a similar installation does not already exist in the city, it is necessary to define the possibility of construction and the phasing of construction in order to secure funds and other dynamic plans. The installation would pass through the existing street corridors, so in addition to the installation works, other installations located underground would be relocated and the location would not be suitable for the implementation of the new heating and cooling installation. The complexity of the proposed installation imposes the need to establish a company that would manage and maintain this installation, and at the same time charge for the distributed heating and cooling energy. A major advantage of central seawater use systems is the reduction in the number of seawater abstractions and the smaller number of seawaters pumping stations. With a well-dimensioned system, it is possible to receive seawater with only one pumping station, while the discharge of treated water would be carried out as far as possible in the direction of sea currents. Compared to the previously described levels of complexity, this installation has a slightly higher estimated investment value of 3250 EUR / kW.

CITY AND SURROUNDINGS

Central heating and cooling systems of one city and all suburbs can be further optimized by introducing central storage tanks of hot and cold-water systems. Technical water tanks would then be heated and cooled according to user needs and habits. The energy accumulated in the tanks can be conditioned using a heat pump and electricity that has green sources. The whole area of Dalmatia has great potentials for the use of wind energy, which is quite stochastic and intermittent, so stabilization systems are needed for large oscillations of electricity production using wind turbines. The orientation of the uninhabited local slopes allows the installation of photovoltaic fields to generate renewable electricity that could be directed to the cooling system during the summer when the need for cooling increases and the production of solar electricity increases. The proposed installations with central stabilization tanks can provide a very low energy cost for heating and cooling in the long run, while CO_2 emissions from the heating and cooling system would be reduced by up to 90% compared to conventional heating and cooling systems currently in use.

The average investment required for SWAC systems is about 4000 USD / kW = 3533 EUR / kW of air conditioning load, and the average levelled cost of thermal energy is 0.055 USD / kWh, and the payback period is between 5 and 11 years. However, these costs decrease significantly with increasing demand for refrigeration. These investments are for the United States with significantly more labour, while the price of equipment is mostly the same since it is imported and could be lower in more detailed elaboration of cost items.

This installation of central heating and cooling of one urban and suburban area can be further expanded with installations that generate renewable electricity such as photovoltaic fields and wind turbines. Investment in this equipment ranges from 800-1200 EUR / kW with a tendency of constant decline with the increase of new installations.

2.10 PILOT PROJECT SWOT ANALYSIS

Based on the performed analysis, prepare a SWOT analysis of the use of marine heat in the pilot area of the Coastenergy project;

TECHNOLOGY: (STRENGTH)

It is proposed to use existing technical solutions and it is not necessary to carry out research and development procedures in order to use sea energy for heating and cooling. The use of existing technical solutions accelerates the process of building new renewable energy systems.

Hot water networks are built with existing technical solutions of pre-insulated plastic pipelines for low-temperature distribution. There is no manufacturer of this type of pipeline in Croatia, but within the European Union there are several manufacturers that can provide sufficient quantities of pipelines for the construction of hot water networks.

Water-to-water heat pumps are available in different models and sizes, so a separate heat pump model can be installed for each building. Any model of water-to-water heat pump can be built into this installation concept but it would be advisable to enter into a strategic agreement with several major suppliers to facilitate multi-year maintenance of all these installations. Public procurement for the entire settlement can provide a competitive price for ordering larger quantities of equipment.

- high energy efficiency of heat pumps that use sea water in relation to conventional heating systems or in relation to air-to-water heat pumps
- use of local energy sources, i.e., sea energy as a renewable energy source
- one device can perform several functions, i.e., it can heat, cool the space of the building, but it can also heat sanitary water
- are economic benefits for the end user due to extremely low energy bills during the use of the installation
- reduction of CO_2 emissions by using heat pumps compared to conventional heating systems
- when using heat pumps, there is greater safety in the use of equipment because there is no emission of harmful gases or combustion of conventional energy sources
- additional development is possible in technology and control management in order to optimize total energy consumption

FINANCING: (OPPORTUNITIES)

The initial investment in the new hot water heating system of the entire settlement using water-to-water heat pumps is higher compared to heating with air-to-water heat pumps. However, on the other hand, air-water devices cannot be installed anywhere, especially in protected urban areas and buildings, so the only acceptable technical solution is the use of underground hot water networks.

Most of the buildings in the zone are covered by electric resistance heaters, air conditioning units of various models and sizes, air-to-water heat pumps and conventional heating systems using fuel oil and solid biomass. The transition to water-to-water heating systems requires reconstructions of heating and cooling systems within each individual building, so the transition to a new system is technically demanding but also financially demanding. Long-term heating and cooling of sea energy is more financially advantageous, so the necessary optimization of the entire system can ensure long-term energy savings.

The proposed installation of heating and cooling of buildings using marine energy has good potential for implementation in various funds that encourage the use of renewable energy sources for heating and cooling, so it is possible to obtain subsidies from the funds for the construction of this installation. Potential subsidies facilitate the overall investment and reduce the payback time.

After construction, the energy costs of each individual building would be reduced. An additional advantage is the reduction of the peak electric load of the entire city in relation to all heating and cooling equipment, which ultimately reduces the load on the public electricity network and reduces the need to build new installations.

- it is possible to use various incentive measures for the installation of renewable energy sources
- European Union public policies aim to maximize the use of marine energy
- the development of new technologies and working media can further increase the efficiency of heat pumps
- promoting the use of locally available renewable energy sources
- new regulations impose the need to install systems that use renewable energy sources
- integration of heat pumps with other technologies that generate renewable electricity such as photovoltaic systems
- Central heating and cooling systems can be built as an example of good practice in the use of marine energy

- There is great potential in the reconstruction of existing systems that must be replaced by new heating and cooling systems
- use of public incentives for reconstruction of low-energy buildings with low energy consumption for heating and cooling

LEGAL REGULATIONS: (WEAKNESS)

Spatial plans do not envisage the construction of similar technical installations, so it is necessary to make changes and additions to all spatial plans in the area covered by the installation and plan the routes of all heating pipelines that would be conducted through the target heating and cooling zone. It is recommended that the hot water network be dimensioned for all current as well as for all possible future needs of the system to reduce the need for further reconstructions of the network in the future.

The use of sea water for heating and cooling includes the creation of a fresh water catchment zone, and ultimately the treated water is discharged into the sea with a higher or lower temperature. It is necessary to define technical conditions with the competent authorities for marine waters. For comparison, Croatian Waters allows a change in water temperature of a maximum of 5 ° C in the groundwater heating and cooling system.

Changes in sea temperature can affect organisms in the local environment, and during the summer an additional increase in sea temperature can encourage faster development of algae and plankton that prefer higher temperatures, which can have a long-term effect on marine flora and fauna. When drafting spatial plans, it is necessary to include the opinion of the competent services for the protection of the environment and the sea itself.

- the distance from the coast limits the possibility of building an individual model of heating and cooling system using marine energy
- a certain space is needed for the installation of equipment from the engine room in the building to the street corridors for the implementation of all installations
- ownership of the plot through which the distribution pipeline of the public heating and cooling system of the central system is to pass
- concessions for the use of the sea for heating and cooling and laying of pipelines to the central engine room
- the condition of existing buildings imposes the needs of medium or high temperature heating and cooling systems, which limits the need for more models of internal water-water heat pumps
- the total initial investment in central systems is higher than local heating and cooling equipment

- Reconstructions of existing buildings may incur higher costs than the construction of new installations due to extensive preparatory and construction works to bring the installation to the stage of readiness
- it is recommended to use heat pumps only in well-insulated buildings, but it is also possible to use them in older buildings, but the installed power will be higher
- specific knowledge of designers, installers and service technicians is required

POSSIBLE RESTRICTIONS: (THREATS)

During the preparation of the technical study, several pension restrictions were observed for the construction of the planned heating and cooling installation using seawater energy:
- bureaucratic problems related to the procedures for obtaining building permits
- legal restrictions on the construction of the proposed installation using seawater
- environmental protection and the possible impact of the heating and cooling installation on the sea and the environment
- financial possibilities and defining the financial construction
- technical limitations of the construction of the planned installation.
- legislative restrictions on the use of individual refrigerants for the operation of heat pumps
- the increase in the price of electricity has a negative effect on the economic balances of the use of heat pumps for heating and cooling because it increases the payback time
- the increase in the price of natural gas or some other classic energy source has a positive effect on the economic balances of the use of heat pumps for heating and cooling because it reduces the payback time
- each building is specific and, in some buildings, it may not be possible to install the proposed installation or the cost of connection to the central system would be too high
- it is necessary to educate the users of buildings on how to use the systems, so each local installation must be as simple as possible to be understandable to the end user
- restriction of locations where central or local installations can be built
- complex administrative procedures for the use of sea energy for heating and cooling
- in some locations there are probably no defined procedures for the use of marine energy because there are no previously built similar locations
- spatial plans in the Republic of Croatia do not know the use of sea energy for heating and cooling nor do they know the concept of central heating and cooling systems using sea energy

ADVANTAGES	DISADVANTEGES
the use of sea energy	high initial investment
use of renewable energy sources	technical limitations of micro location
reducing CO_2 emissions	there are no similar installations
reducing heating and cooling costs	regulations do not define this installation
modular heating and cooling technology	
possibility of hybrid heating systems	

Table 30: Advantages and disadvantages of using sea energy for heating and cooling

3. LIST OF FIGURES, TABLES AND DIAGRAMS