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

Seawater heat pump potential

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Purpose of this document

The purpose of this report is to determine the total energy potential of seawater used for heat pumps in public/private buildings. Various factors determine the potential of seawater used for heat pumps, from the distance of the buildings from the seawater to the depth of the sea, and the soil characteristics. As the Adriatic-Ionian region has different coastal characteristics, it is important to study the area in order to find where the seawater heat pumps would have the biggest potential and where a different option should be considered.

1 Introduction

The main objective of the SEADRION is to identify benefits and barriers associated with the use of seawater heat pumps and to find a system solution designed to improve the use of the seawater heat pump technology and to make the building's energy self-sufficient and independent of fossil fuels.

One of the activities that aim to determine the benefits of the seawater heat pumps are the pre-feasibility studies which will be done for all partner countries (Slovenia, Croatia, Albania and Greece). In order to start with the work regarding pre-feasibility studies, and to choose the best possible locations for pre-feasibility studies, it is important to determine the potential of seawater used for heat pumps in the Adriatic-Ionian area.

As seawater heat pumps use seawater as a heat sink or heat source the buildings where they are used need to be in close proximity to the sea, and not more than 1000 m away. Furthermore, the temperature of the seawater is one of the most important factors while considering its exploitation. If the temperature of the seawater isn't constant during the whole year, and especially if it is too warm in the summer and too cold in the winter, the efficiency of the seawater heat pump won't be high.

2 Seawater heat pump potential in Adriatic – Ionian region

The study of seawater heat pump potential begins with the study of seawater temperatures in the Adriatic-Ionian region. It is important to study the temperatures of the seawater at various locations to determine what places are suitable for the installation of seawater heat pumps and what are not, which was done detailly per country. Seawater temperatures are studied to determine the economic benefits of installing seawater heat pumps. The temperatures of the heat source determine the coefficient of performance (COP). Because of that, in case of similar air and seawater temperatures, COPs of air and seawater heat pumps would be similar, meaning that the air heat pumps would be a better option from the economic point of view.

The analysis of seawater temperatures showed that in most countries, the differences between air and seawater temperatures are higher during winter than during summer. All countries show the difference in air and seawater temperatures during winter, even on a monthly basis, raising the potential for seawater heat pumps. Some countries show a difference in air and seawater temperatures also during winter periods, but some countries have similar monthly seawater and air temperatures during summer. This would initially suggest that that the economic benefits of installing seawater heat pumps would fall. Still, if going deeper into the temperature data, on the Slovenian example, it can be seen that on the hourly basis, air temperatures rise during the day up to 4 °C higher than the seawater temperatures and that is if the sea temperatures are measured on the surface. The deeper the seawater intake is, the more constant the sea temperature. Nevertheless, since the potential is higher for the heating period, further analysis was done for the heating regime.

The data gathered for buildings where the seawater heat pumps can be installed show that altogether heating demand is 4736.08 GWh/year for hotels and 496.73 GWh/year for public buildings. Exact heating demand per country can be seen in Figure 1, while heating demand per month can be seen in Figure 2.

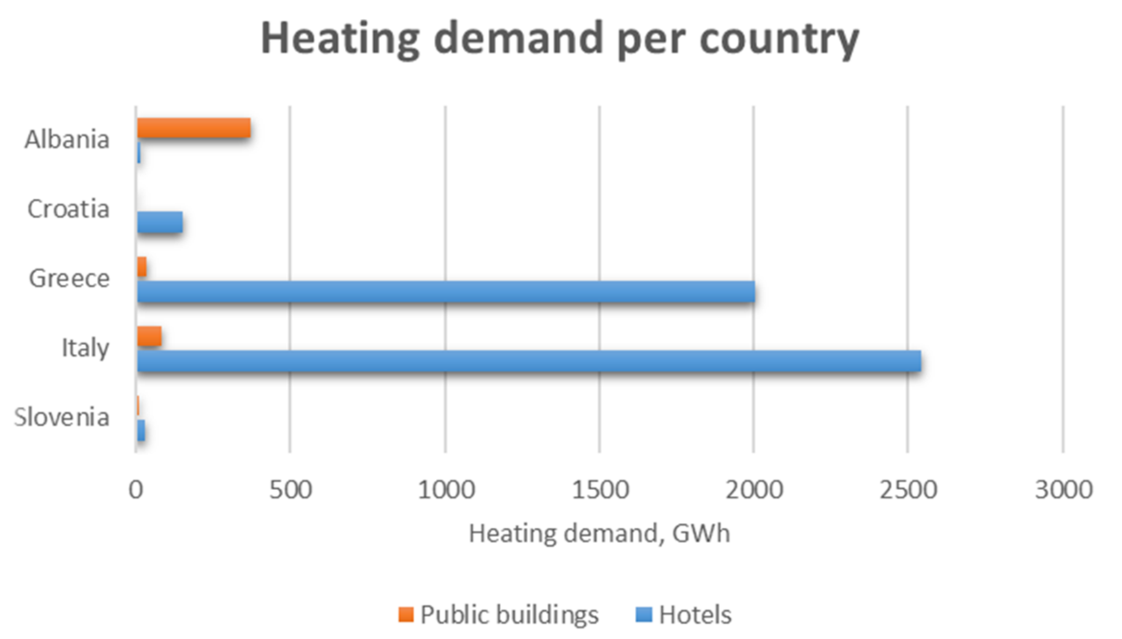


Figure 1. Heating demand per country

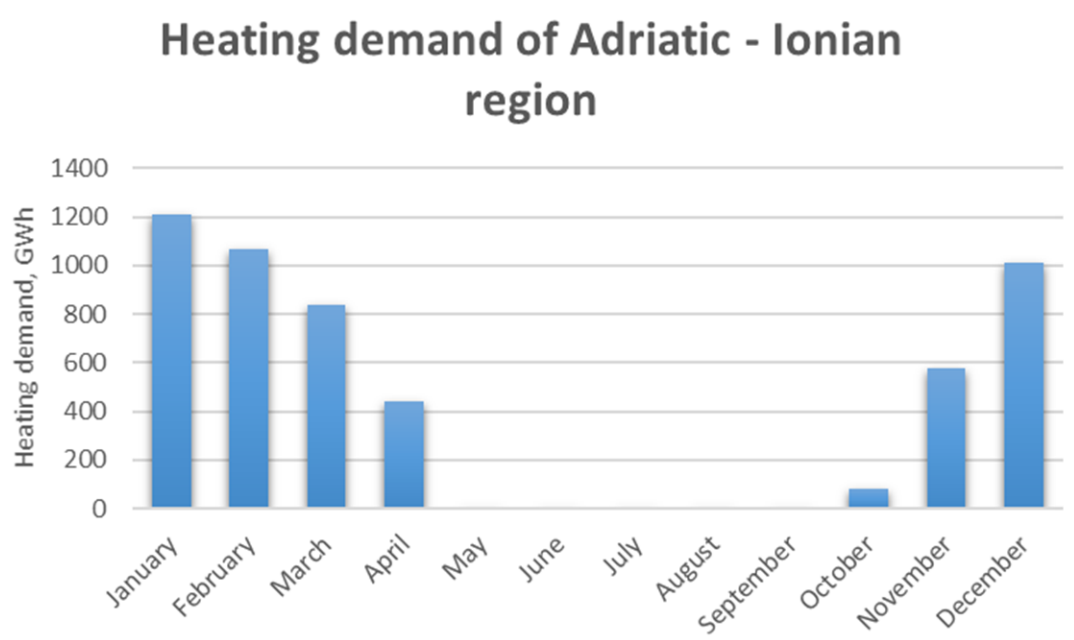


Figure 2. Heating demand of Adriatic – Ionian region per month

Further benefits of using seawater heat pumps for heating purposes is that thanks to their high efficiency, they can lead to primary energy reduction and CO_2 emission savings

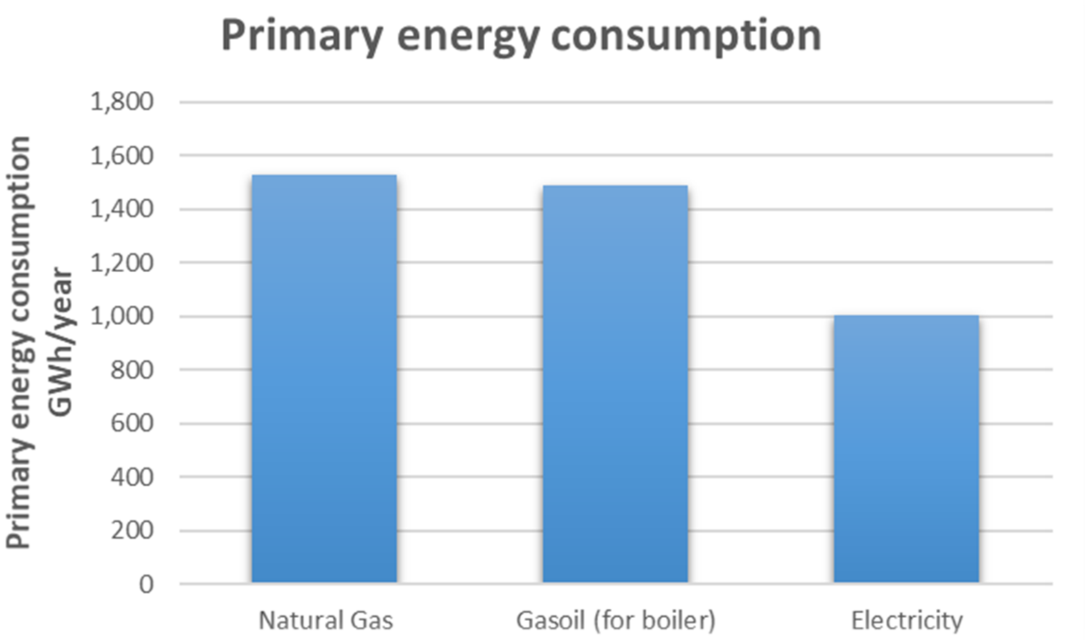


Figure 3. Primary energy consumption of public buildings close to the sea in Adriatic – Ionian Region if they would use natural gas boilers, fuel oil boiler or heat pumps for heating

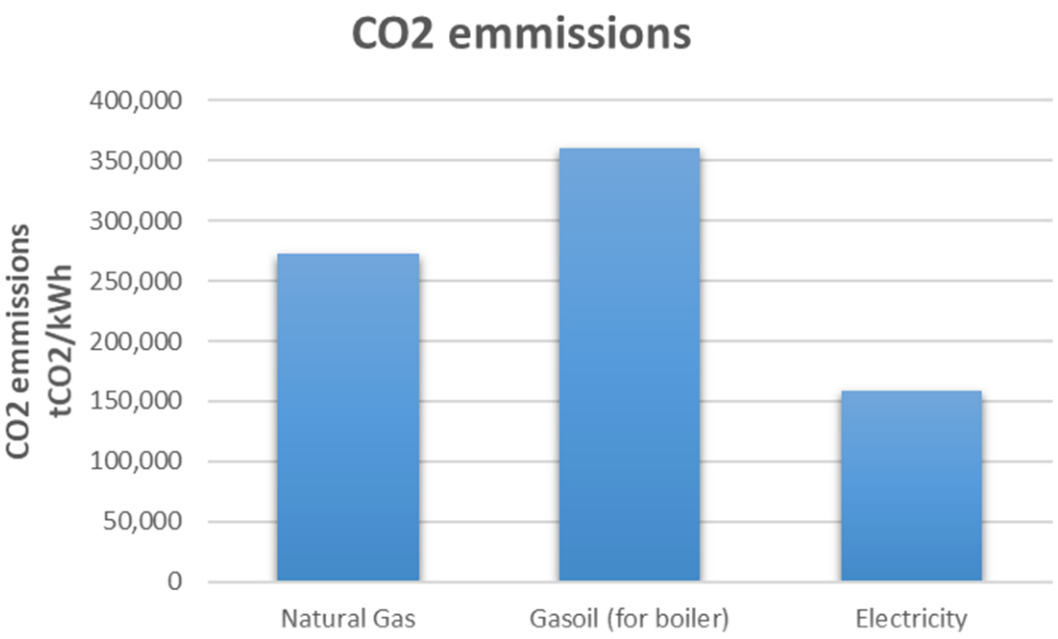


Figure 4. CO_2 emissions of public buildings close to the sea in Adriatic – Ionian Region if they would use natural gas boilers, fuel oil boiler or heat pumps for heating

3 Buildings

There are two mostly used methods of seawater exploitation. One is direct seawater intake from the sea, and the other is seawater intake from the well. For both cases, it is preferable that the building is close to the sea to reduce the length of the pipes that will need to be installed from the point of seawater intake to the heat pump, and the best would be if the building isn't more than 1000 m away from the sea.

Buildings that will be considered in this document are hotels, which are mostly very close to the sea and have high cooling demands. Furthermore, public buildings that are in close proximity to the sea will also be taken into account.

3.1 Slovenia

Near the Slovenian coast, there are 37 hotels for which data were obtained (6 hotels in the municipality of Ankaran, 4 in the municipality of Koper, 4 in the municipality of Izola and 23 in the municipality of Piran). Hotels have between 16 and 276 rooms.

Table 1 Hotels data in Slovenia

Hotels	
Number of hotels	37
Minimum number of rooms in the hotels	16
Average number of rooms in the hotels	146
Maximum number of rooms in the hotels	276
Maximum number of rooms in the hotels	78%
Percentage of hotels with a maximum number of rooms than average	22%

Figure 5. Hotels near the coast, Slovenia

Figure 6. Hotels in the Municipality of Ankaran, Slovenia

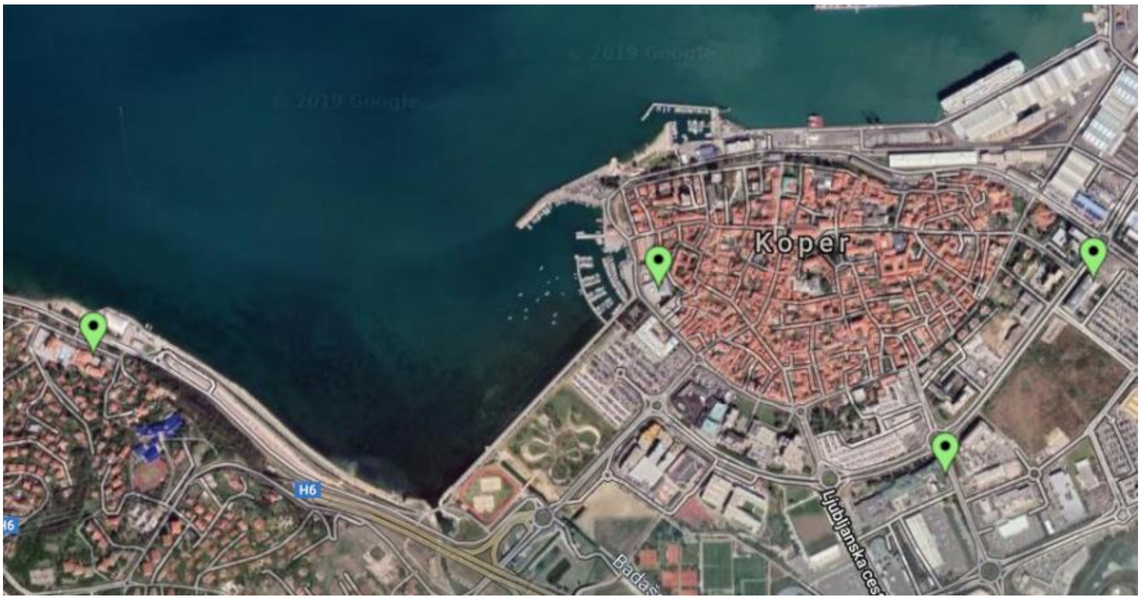


Figure 7. Hotels in the Municipality of Koper, Slovenia

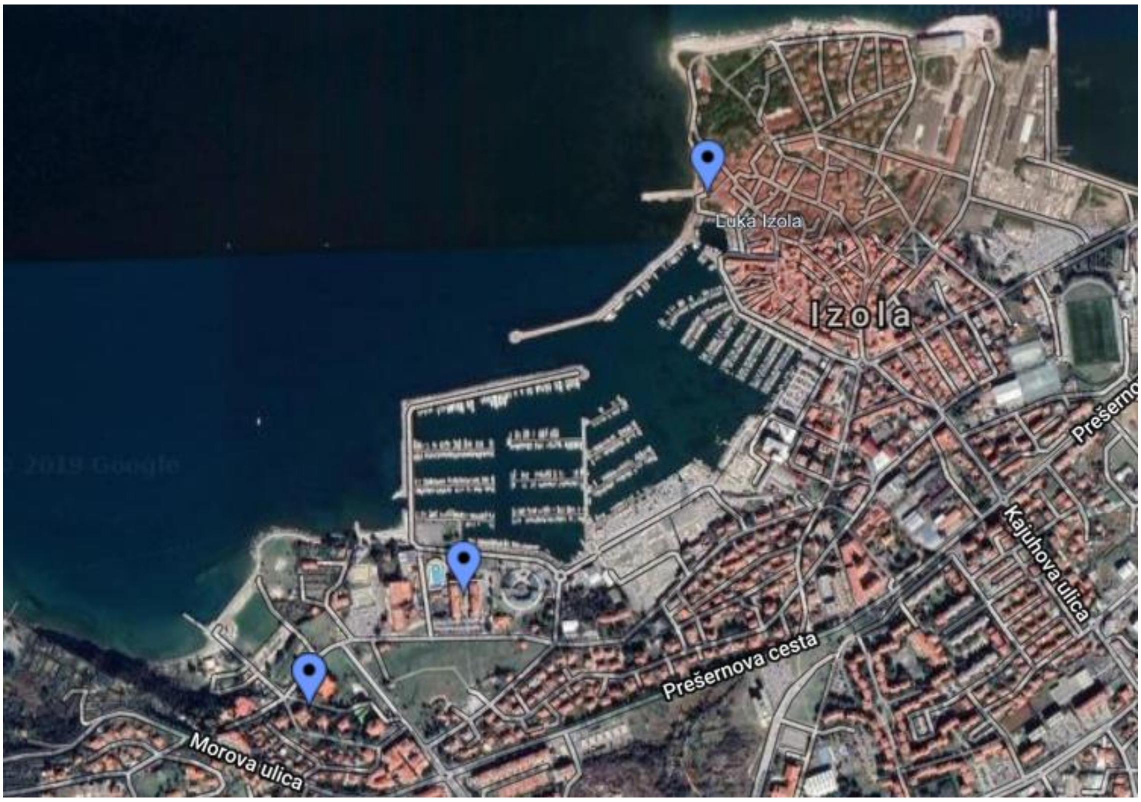


Figure 8. Hotels in the Municipality of Izola, Slovenia

In the vicinity of the coast, there are also 41 public buildings. Data on their heating energy needs has been obtained for 23 of them. The useful area of each public building is between 180 m^2 and 16.800 m^2. The heating energy needs for each building is between 7.400 kWh and 4.526.000 kWh for each building and the specific heat consumption is between 20 and 270 kWh / m2 per year.

Table 2 Public buildings data

Public buildings	
Number of public buildings	23
Average area of the building [m^2]	3319
Specific Heat Consumption [kWh/m^2]	101

Figure 9. Public buildings near the coast, Slovenia

Figure 10. Public buildings in the Municipality of Ankaran, Slovenia

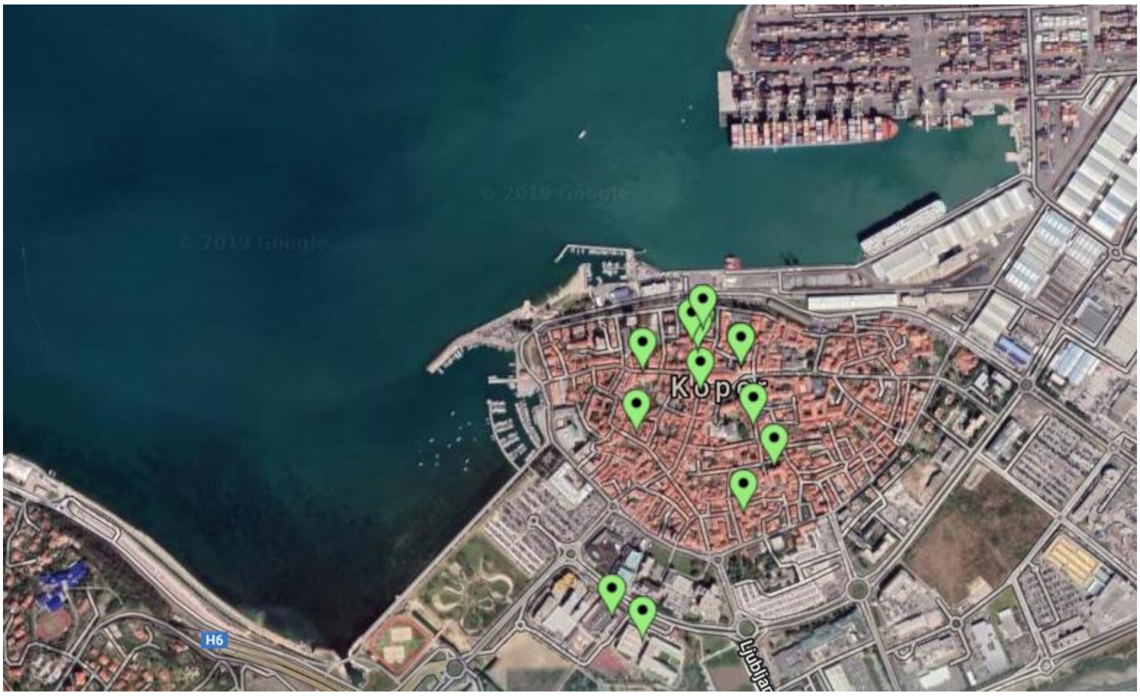


Figure 11. Public buildings in the Municipality of Koper, Slovenia

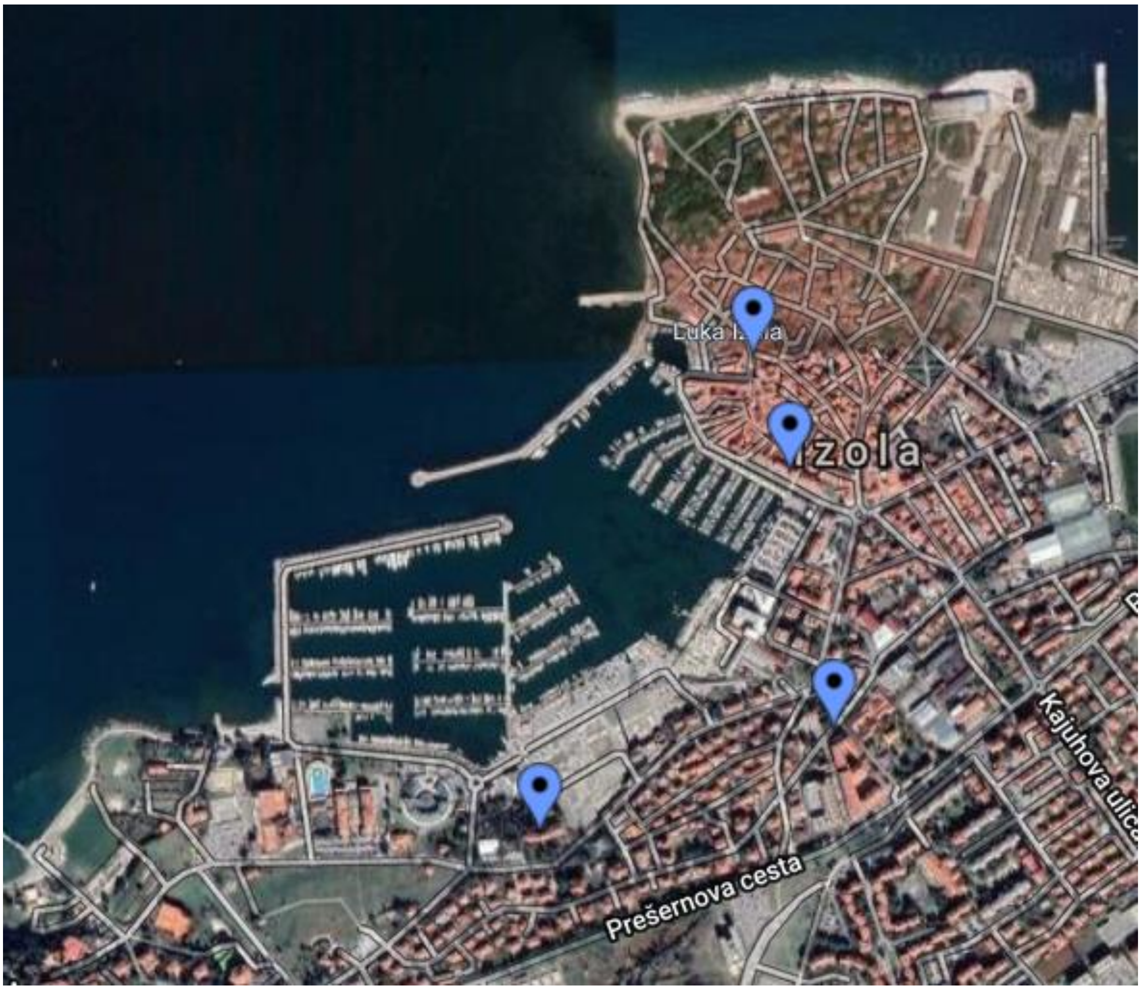


Figure 12. Public buildings in the Municipality of Izola, Slovenia

3.2 Italy

Italy accounts for the highest hotel portfolio in Europe, the third in the world. With something more than 33,200 hotels, in 2016 Italy accounted for the biggest hotel portfolio in Europe. Study for Ascoli Pieceno showed that all hotels were using natural gas or propane for heating purposes and that only a small percentage of hotels is using renewable energy sources of any kind, as can be seen on Figure 13 [1].

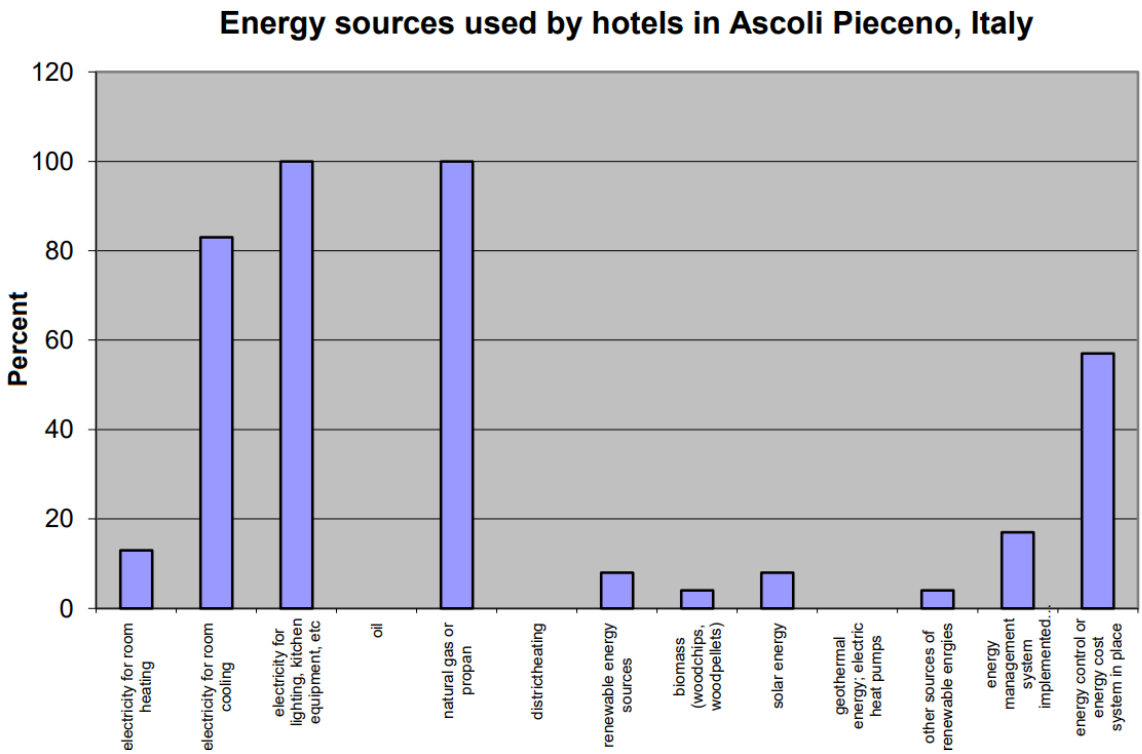


Figure 13. Energy sources used in hotels in Italy

Table 3 Hotels data

Hotels	
Number of hotels	28488
Minimum number of rooms in the hotels	15
Average number of rooms in the hotels	47
Maximum number of rooms in the hotels	180
Percentage of hotels with a minimum number of rooms than average	61%
Percentage of hotels with a maximum number of rooms than average	39%

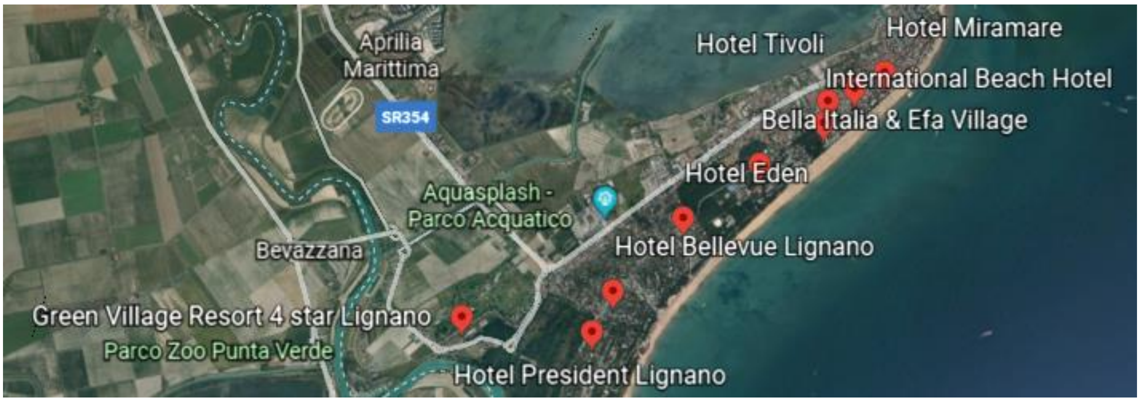


Figure 14. Hotels in Lignano Sabbiadoro, Italy

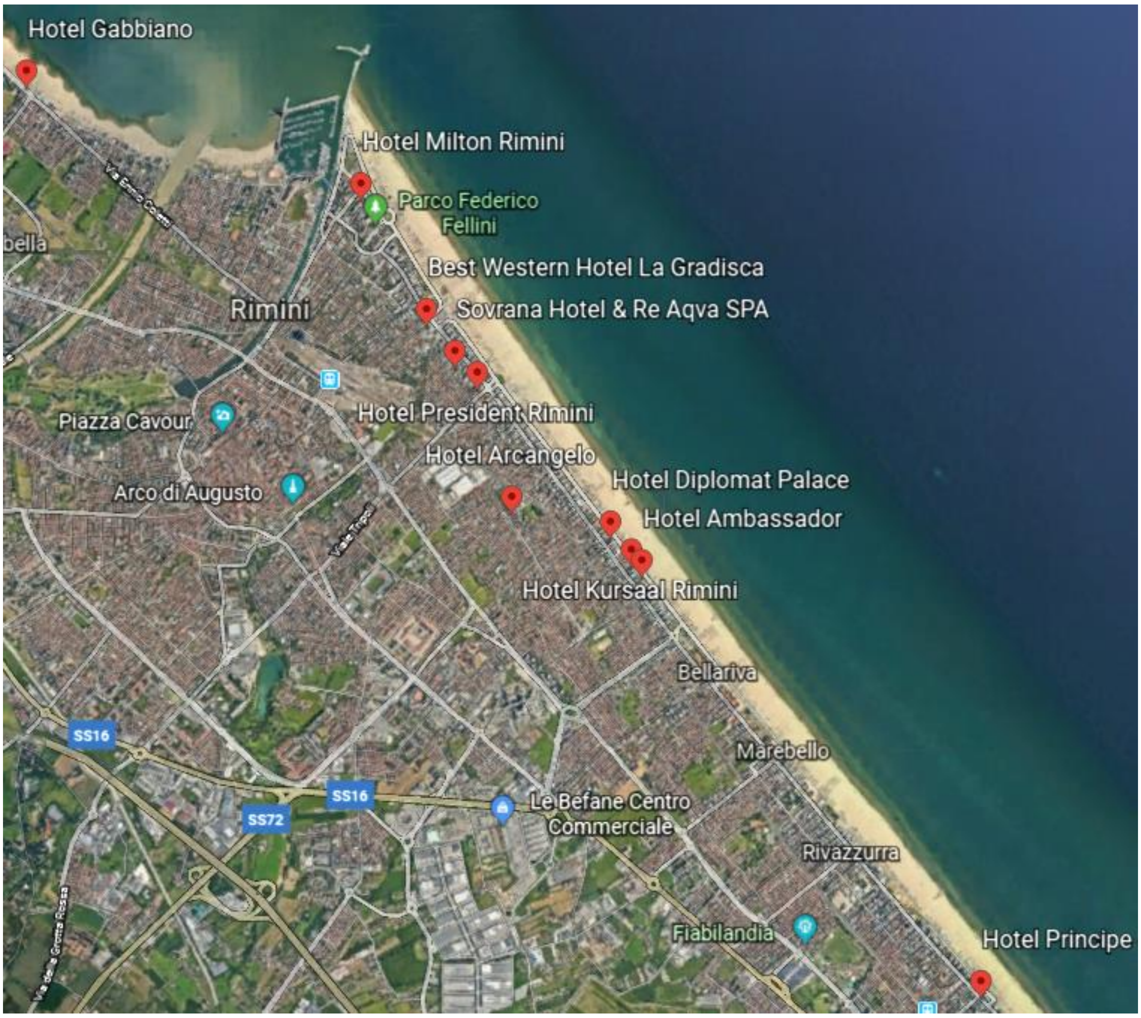


Figure 15. Hotels in the City of Rimini, Italy

Italy has 1 million public buildings, for a total of 325 million square meters. 77% of these are buildings used directly by the public administration.

The first ten municipalities for the seniority of the buildings are almost all Piedmontese, belonging to the provinces of Biella, Vercelli, Turin and Cuneo, with over 90% of the houses built before 1918 (the only exception is the municipality of Calascio in the province Aquila).

An old building also carries with it a series of problems linked to its own energy consumption: most of the times it has obsolete heating systems, subject not only to faults and malfunctions but also to heat dispersion, with a consequent increase in the cost of the bill against the required energy.

Public administrations and private entities in the oldest municipalities in Italy can learn about the real value of energy, economic and environmental savings through specific consultations on their building stock and decide to undertake a process of efficiency that, from diagnosis to maintenance and building management, bring them to a concrete improvement of their "well-being" [2].

Table 4. Public buildings data, Italy

Public buildings	
Number of public buildings	400
Average area of the building [m²]	1608
Specific Heat Consumption [kWh/m²]	126

Figure 16. Municipality building of Ancona, Italy

Figure 17. Museum of the Southern Lagoon in Chioggia, Italy

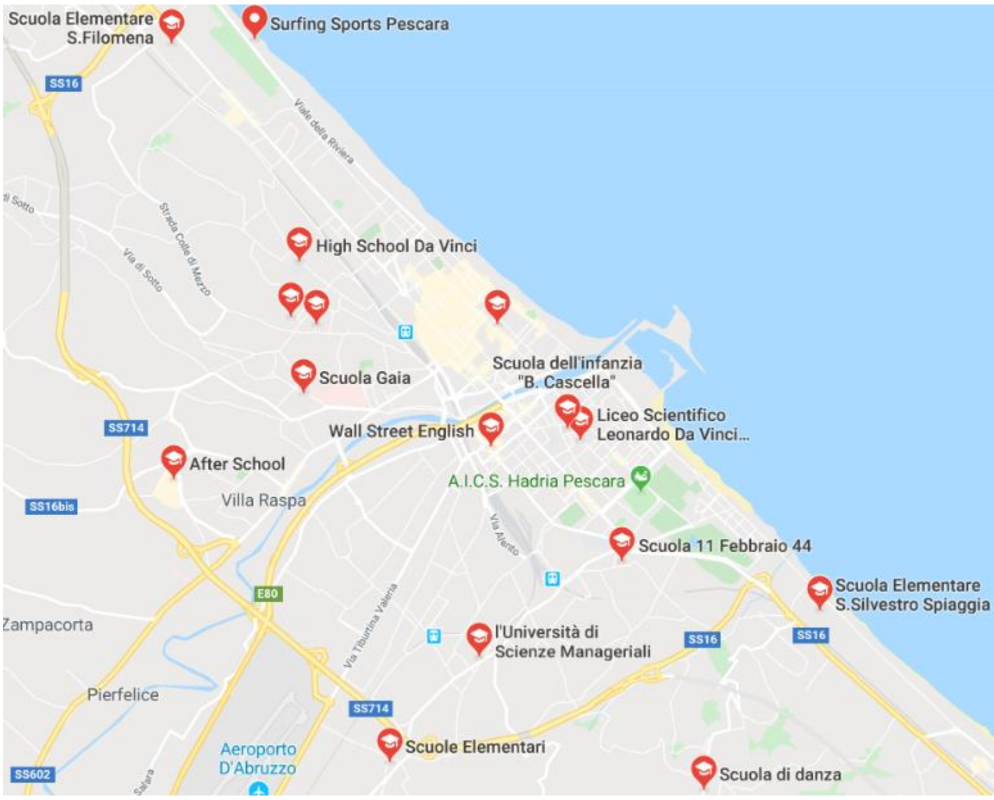


Figure 18. Educational facilities in Pescara, Italy

3.3 Greece

In Greece, due to various reasons, less than 5.500 hotel units with an average hotel size of above 21 rooms/hotel will be taken into consideration, which equals to 232.000 rooms or 450.000 beds.

From the whole country excluded were the regional units which are not suitable (having no sea or having sea, though bordering to a national park/protected area).

This way, from the 9.730 hotels, it is estimated that less than 9.604 are in regional units or municipalities bordering the sea. No data is available regarding the distance of each hotel from the sea.

It should also be noted that the statistical data are referring to **Hotels and similar accommodation,** which taxonomy includes hotels (and similar establishments, for instance operating under the name 'bed & breakfast'); resort hotels; suite/apartment hotels; motels.

It is also assumed that small, family-owned hotels are not potential followers of SWHP technology due to various reasons. Almost 43% of the hotel units in Greece are SMEs, family-centred enterprises which have no or little awareness of energy issues, due to the following reasons.

- Shortage of investment funds, including difficulties in obtaining loans, combined with concerns about the feasibility and viability of installations, and the quality of products.
- Lack of information and follow up on systems that would be suitable for a hotel and on how these could be integrated into the hotel buildings and management.
- Systems are economically most attractive where the prices for non-renewable energies are high, and economic incentives are available to offset investment costs. The benefits of low operating costs, low maintenance requirements, and long life-times of thermal installations often go unrecognised by hotel managers.

Table 5. Hotels' data in Greece (Data for 2016 according to the Hellenic Chamber of Hotels)

Hotels	
Number of hotels	9,604 hotels = 404,232 rooms, 782,463 beds
Average number of rooms in the hotels	42 rooms/hotel or 82 beds/hotel

Table 6. Distribution of hotel size in Greece, 2016 (in %)

Size of hotel	5*	4*	3*	2*	1*	Total (%)
Family owned, 1-20 rooms	1.4	11.8	23.1	41.5	22.2	42.5
Small, 21-50 rooms	2.0	9.9	24.7	50.6	12.8	37.5
Medium, 51-100 rooms	6.1	19.4	39.0	33.3	2.2	12.2
Large>101 rooms	31.7	43.5	19.8	4.7	0.3	7.8

Greece has a relatively small average number of 42 rooms per hotel compared to other countries. Also, 42.5% of the hotel capacity is family-owned, with less than 20 rooms per unit, which will be excluded from the potential hotel capacity (see reasons below).

Regarding the size of the hotel or the average number of rooms in hotels, there are 4 administrative regions which are favoured regarding the seawater heating or cooling potential, namely: Crete (57), Ionian Islands (51), Attica (49), and South Aegean (48), which are fairly above the national average (42 rooms/hotel).

Figure 19. Picture example (Grecotel Corfu Imperial)

An important factor to consider when making the decision to renovate a building and install any SWHP is inter alia the ownership of the building, which - as illustrated in the following table - the majority (96.9%) of all building stock is owned by the private sector and only 2.9% belongs to the wider public sector.

Table 7. Distribution of buildings stock correlated to the ownership [3]

Distribution of buildings stock correlated to the ownership		
Public	Private	Semi-Public
117.901	**3.980.600**	**7.136**
Total number of building stock **4.105.637**		

As regards the public buildings in Greece, which are considered to be particularly energy-intensive, it should be noted that there is insufficient data on their exact number and energy characteristics. The 2011 census valued the buildings to some 118.000, most of which are educational and school buildings usually owned by Local Authorities, as well as buildings used for hospitals and health services, with other buildings owned by the Central Government. Also, it is estimated that more than half of the public buildings are rented.

The administrative regions of Greece (Greek: περιφέρειες, peripheries) are the country's 13 first-level administrative entities, each comprising several second-level units, originally prefectures and, since 2011, regional units (74), which are further subdivided into municipalities (325) and communes (124).

The below-stated work is based on data from the national EPC (Energy Performance Certificate) electronic repository (called “buildingcert”).

The public buildings selected were the ones with a registered EPC, consequently having a total floor area of either over 500 or 250 m^2. Since 9th of July 2015 the threshold of issuing an EPC has been reduced to 250 m^2 instead of 500 m^2 which applied to public and wider public services’ buildings, which are frequently visited by the public.

Table 8. Data for public buildings in Greece [4]

Climate zone	Categories of buildings	Estimated annual average primary energy consumption of buildings (kWh/m^2), for heating	Estimated annual average primary energy consumption of buildings (kWh/m^2), for cooling	Average total floor area of a building	Number of buildings	Total floor area (m^2)
A, B and C	Commercial	40.73	115.03	425.88	2	851.77
	Hospitals	154.24	141.04	3,839.75	191	733,393.17
	Temporary Residence	269.57	113.38	2,236.02	7	15,652.15
	Educational	98.53	14.03	1,487.68	773	1,149,979.55
	Sports Halls	154.66	215.95	973.58	227	221,003.73
	Prisons and Police Stations	276.08	151.19	7,724.41	11	84,968.48
	Offices	97.36	109.89	996.68	870	867,113.12
Total					**2081**	**3,072,961.96**

As can be seen from the above table, around 2000 public buildings are selected all over the country having a total floor area of approximately 3.000.000 m^2. Almost one-third of the total floor area has been occupied by educational buildings, followed by offices of the wider public area and hospitals including retirement/nursing homes and kindergartens. These buildings are favoured in terms of their number, floor area and primary energy consumption for heating and cooling except for the cooling mode in the educational buildings, which are not fully operational during the summertime where cooling needs are the highest.

3.4 Croatia

In Croatia, a large number of hotels are located in the coastal area and most of them are within one kilometre from the sea. The data on the number of hotels and the number of rooms is easily available on the site of the Croatian Ministry of Tourism [5].

The minimal number of rooms can be found in villa hotels and is 2, while the maximum number of rooms is 743. As an average number of rooms in hotels is 98, 67% of hotels have a total number of rooms lower than average, and 33% has the number of rooms higher than average. Hotels in Croatia started implementing heat pumps for both heating and cooling purposes, but mostly the air heat pumps are installed. As most of the cities Croatian coast don't have district heating systems and natural gas was installed only recently, and not yet through the whole region, a lot of hotels, but also public buildings use fuel oil for heating purposes.

Table 9. Data for hotels in Croatia

Hotels	
Number of hotels	520
Min. number of rooms in the hotels	2
Average number of rooms in the hotels	98
Max. number of rooms in the hotels	743
Percentage of hotels with a smaller number of rooms than average	67%
Percentage of hotels with a bigger number of rooms than average	33%

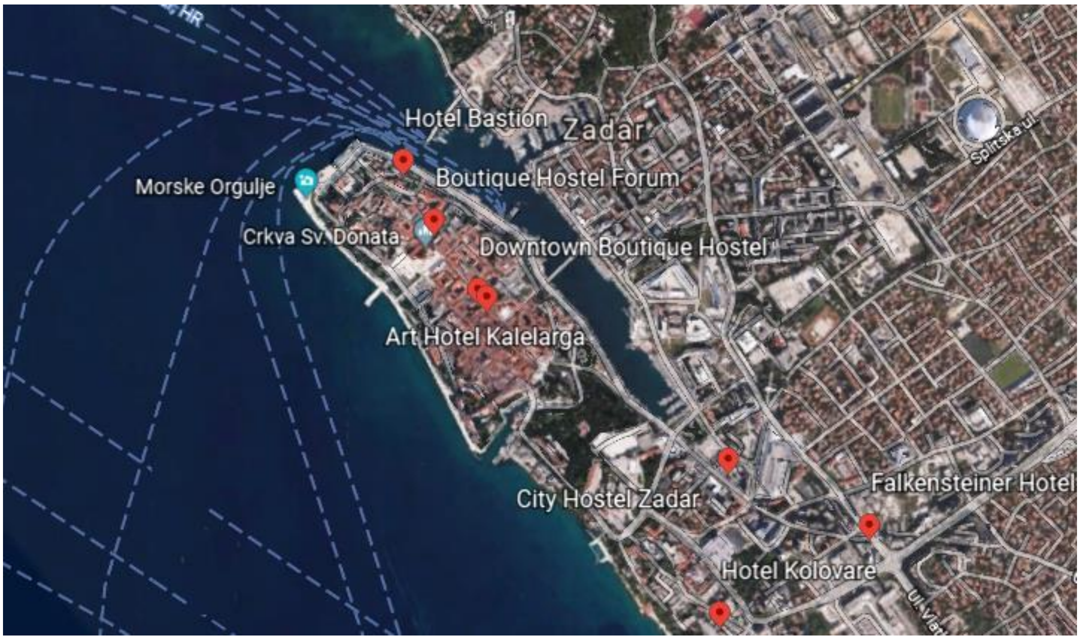


Figure 20. Hotels in the City of Zadar, Croatia

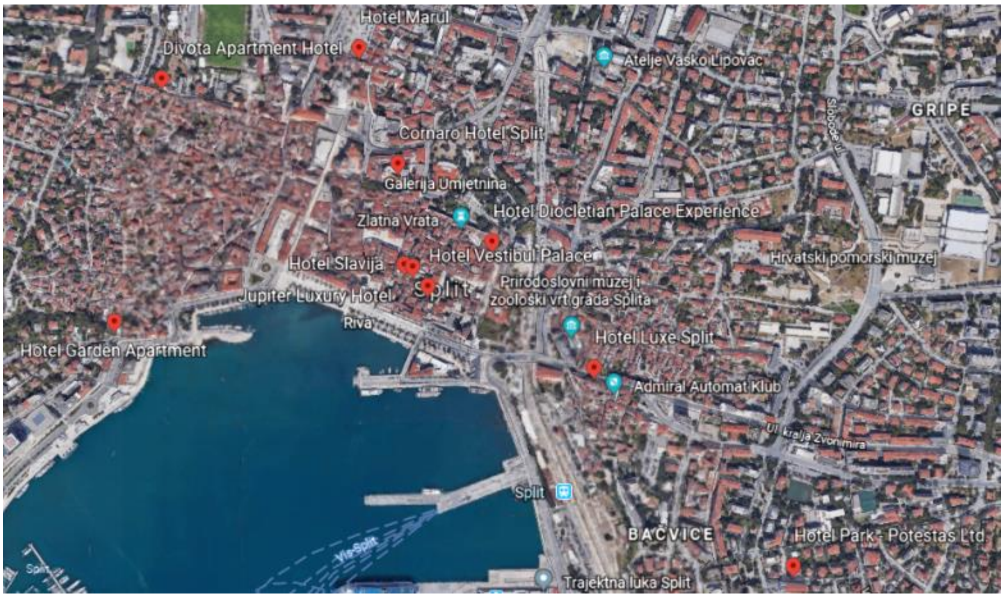


Figure 21. Hotels in the City of Split, Croatia

Figure 22. Falkensteiner Hotel in Zadar, Croatia

Figure 23. Hotel Le Meridien Lav in the City of Split, Croatia

On coastal Croatia, public buildings are most often part of old city centres, which are located near the sea. Such buildings are mostly old and need to be refurbished. As they have closely accessible seawater as a constant heat source, and currently mostly use fuel oil or gas boilers for heating, seawater heat pumps have a high potential in their refurbishment.

Croatia has 80 cities near the coast. Smaller cities have in general around 4 public buildings, while bigger cities have around 21 public buildings near the coast.

Table 10. Data for public buildings in Croatia

Public buildings	
Number of public buildings	320
Average area of the building [m²]	1,826.5
Specific Heat Consumption [kWh/m²]	107.78

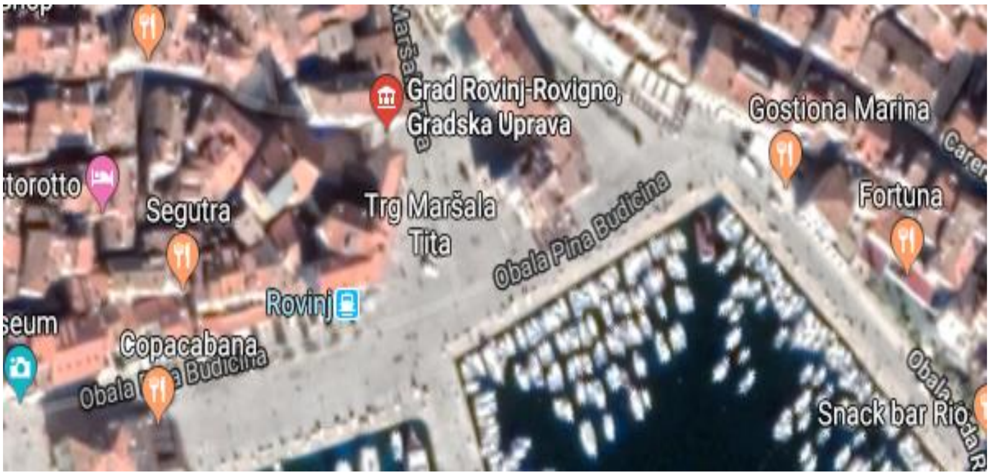


Figure 24. Public buildings in the City of Rovinj, Croatia

Figure 25. Public buildings in the City of Zadar, Croatia

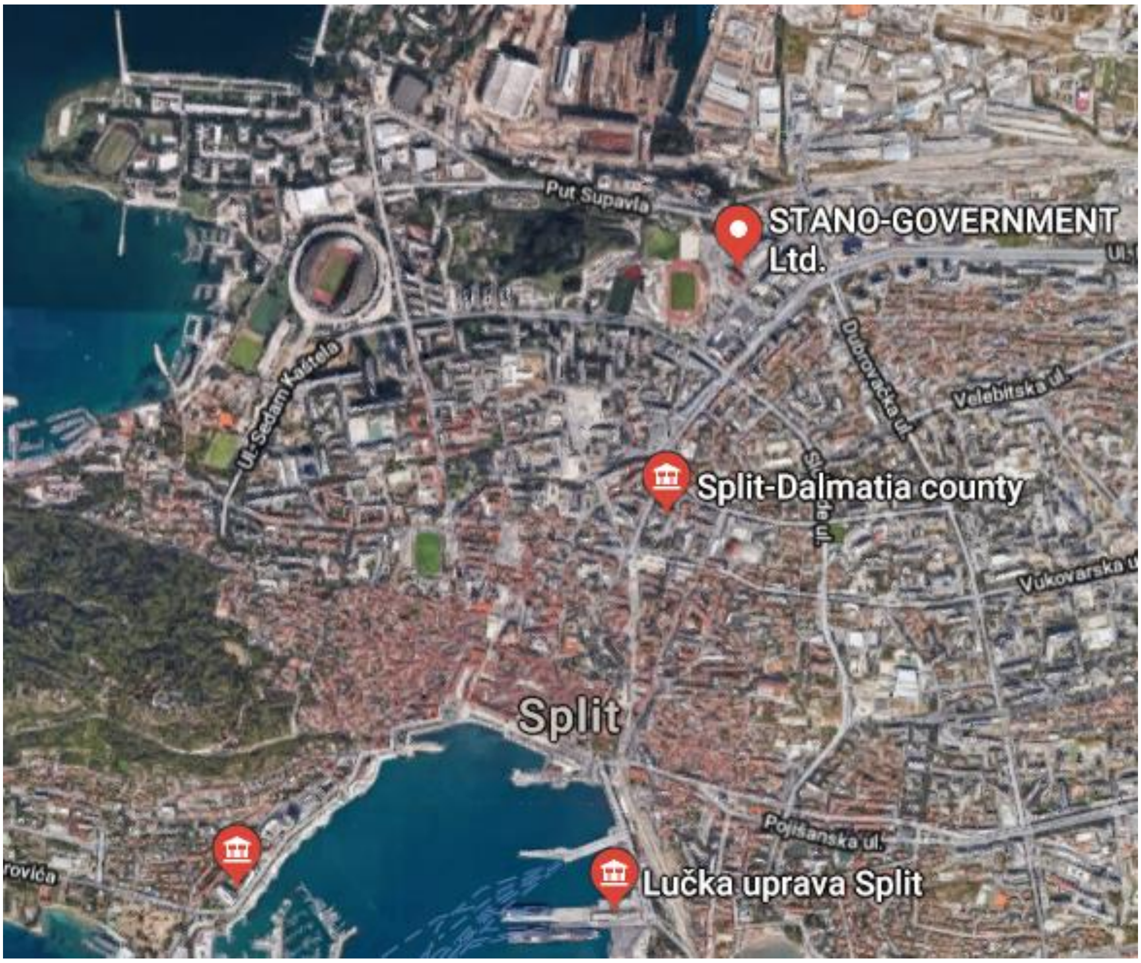


Figure 26. Public buildings in the City of Split, Croatia

Figure 27. University of Zadar, Croatia

3.5 Albania

Energy Demand in service represents a big challenge for Albania. In 2018, the sector was responsible for 30 % of the country's energy consumption and 35 % of the country's electricity consumption. Quality of energy services delivered to the service sector is low. Albanian public buildings are only heated partially, for just a few hours a day. As a contracting party to the Energy Community treaty, Albania is obliged to introduce EU energy efficiency legislation. However, achieving the related target requires more ambitious policy efforts and bigger investments in-demand site energy efficiency than is being made at present.

The total number of public buildings in Albania is 321,812, according to Albania census where 2 % belongs hotels.

The renewable energy market in Albania is developing based on the government's objective to prioritize renewable energy. This is also reflected in the revision of the legal framework and the development of a new Renewable Energy Law. Revision of this law will integrate different aspects connected with the utilisation of renewable energy. Through the integration of the various RES the RE law corresponds to the EU Directive on Renewable Energy. A core issue regulated by this law is a new tariff methodology. Private sector involvement has been identified as the key player in the development of the RE sector, the focus of the methodology was to consider the view of the private investor and consider the rate of return of an investment project.

Albania has approved an action plan of renewable energy, RES Target for Albania is 38%. This percentage will serve as the National RES Target for the year 2020. Albania has taken several steps to implement in its national energy policy the requirements of EU Directives relating to the common rules for the creation and development of the internal energy market and the promotion of the production and consumption of energy from renewable sources.

Albania is implementing Directive 2009/125/EC of the European Parliament and of the Council concerning ecodesign requirements for space heaters and combination heaters. Albania is preparing the regulation in respect of the European Directives on the use of Renewable Energy (RES) point 31.The scope of this Regulation will include boiler space heaters, cogeneration space heaters and heat pump space heaters providing heat to water-based central heating systems for space heating purposes, and boiler combination heaters and heat pump combination heaters providing heat to water-based central heating systems for space heating purposes and heat to deliver hot drinking and sanitary water.

Below we have presented several hotels in the country, near the coastline with the possibility to use seawater intake for the heat pump.

Table 11. Hotels data in Duresi area, Albania

Hotels near the sea in Durresi Area	
Number of hotels	104
Minimum number of rooms in the hotels	15
Average number of rooms in the hotels	28
Maximum number of rooms in the hotels	120
Percentage of hotels with a minimum number of rooms than average	66 %
Percentage of hotels with a maximum number of rooms than average	34 %

Figure 28. Durre's seaside, Albania

Figure 29. Hotels in Durres, Albania

Table 12. Hotels near the sea in Vlora Area, Albania

Hotels near the sea in Vlora Area	
Number of hotels	86
Minimum number of rooms in the hotels	12
Average number of rooms in the hotels	30
Maximum number of rooms in the hotels	100
Percentage of hotels with a minimum number of rooms than average	68 %
Percentage of hotels with a maximum number of rooms than average	32 %

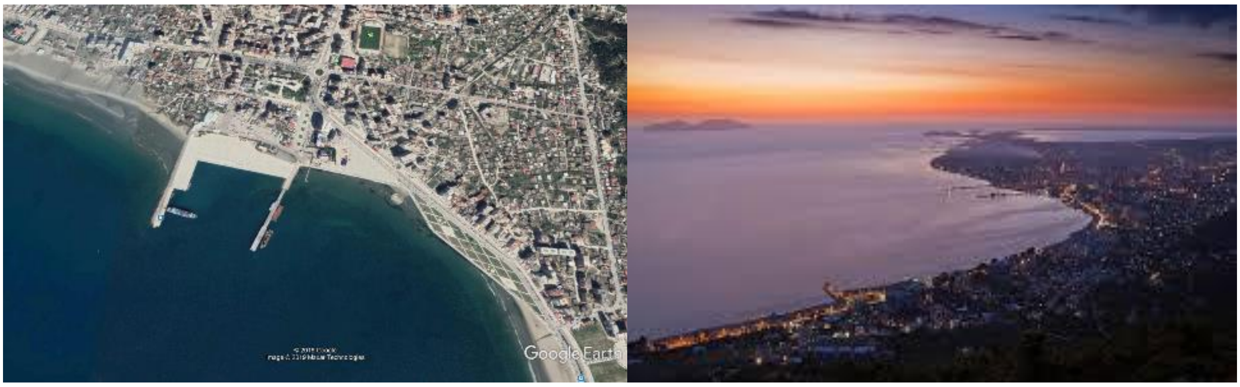


Figure 30. Vlora seaside, Albania

Figure 31. Hotels in the City of Vlora, Albania

Table 13. Hotels near the sea in Saranda Area, Albania

Hotels near the sea in Saranda Area	
Number of hotels	75
Minimum number of rooms in the hotels	14
Average number of rooms in the hotels	27
Maximum number of rooms in the hotels	90
Percentage of hotels with a minimum number of rooms than average	73 %
Percentage of hotels with a maximum number of rooms than average	27 %

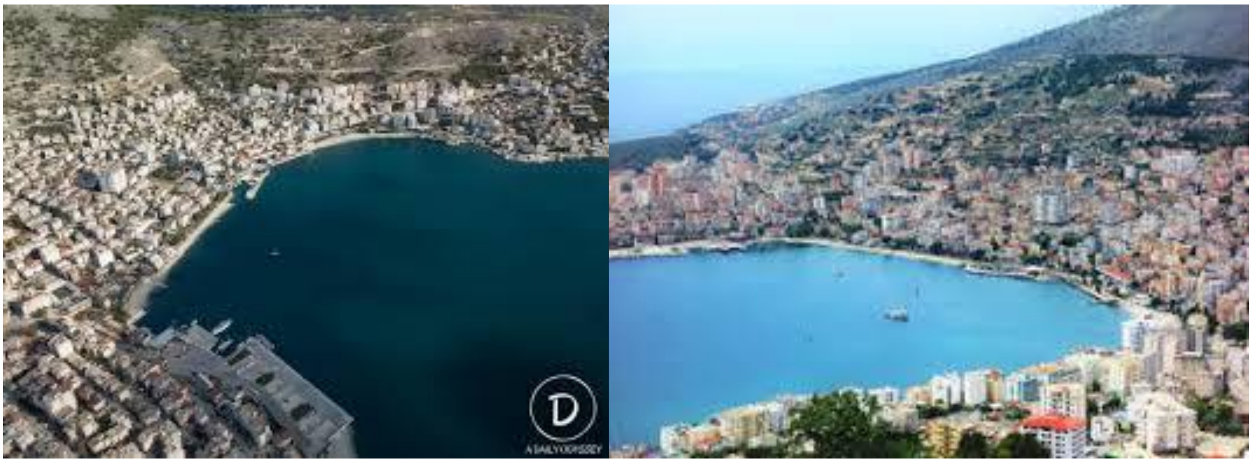


Figure 32. Saranda seaside, Albania

Figure 33. Hotels in Saranda, Albania

Table 14. Hotels near the sea in Shengjin Area, Albania

Hotels near the sea in Shengjin Area	
Number of hotels	32
Minimum number of rooms in the hotels	18
Average number of rooms in the hotels	22
Maximum number of rooms in the hotels	85
Percentage of hotels with a minimum number of rooms than average	69 %
Percentage of hotels with a maximum number of rooms than average	21 %

Figure 34. Shengjini Seaside, Albania

Figure 35. Hotels in Shengjini area, Albania

Table 15. Public buildings data in Albania

Public buildings data, Albania				
	Durres	Vlora	Saranda	Shengjini
Number of public buildings	8	3	6	2
Average area of the building [m^2]	280	320	270	160
Specific Heat Consumption [kWh/m^2]	440	440	430	450

Figure 36. Public Buildings in Durresi area, Albania

Figure 37. Vlora University, Albania

Figure 38. Building Port office in Albania

Figure 39. A public building of the local authority in Shengjin, Albania

4 Seawater characteristics

Not all locations in the Adrian-Ionian territory can be used for seawater heat pumps. Namely, at some location, Adrian and Ionian seas are too shallow, and the temperature of the seawater is too variable. Those locations would not be suitable for seawater heat pumps because their efficiency would drop significantly. Regarding the depths of the sweater, the most critical for the installation of seawater heat pumps is the north of Italy, where the sea is not deeper than 30 m, as can be seen on Figure 43.

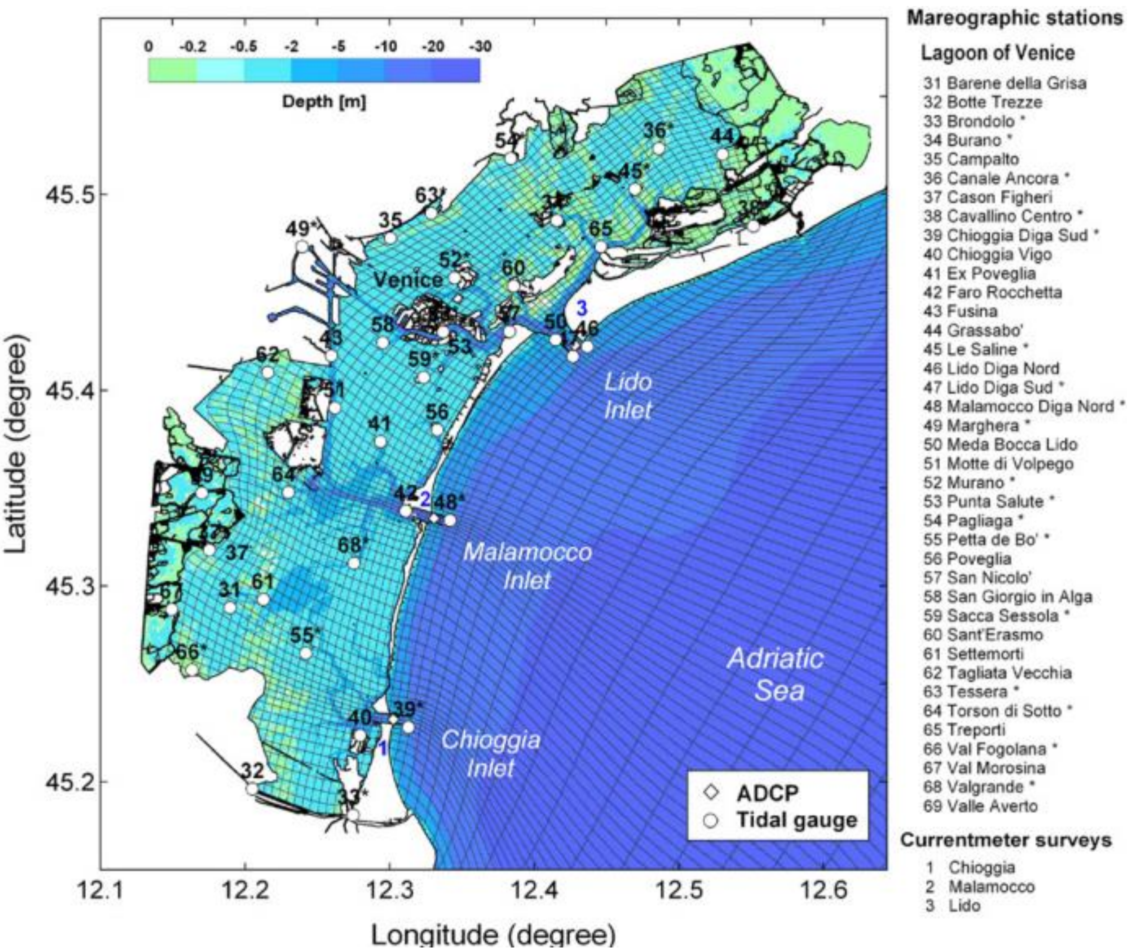


Figure 40. North Italy seawater depth [6]

The sea gets deeper on the south end of the Adriatic sea and towards the Ionian Sea, but as can be seen in Figure 44, the places close to the coastline still have a shallow water. The depth of the seawater is important because the deeper the seawater intake is, the more constant the seawater temperature is as can be seen in Figure 45.

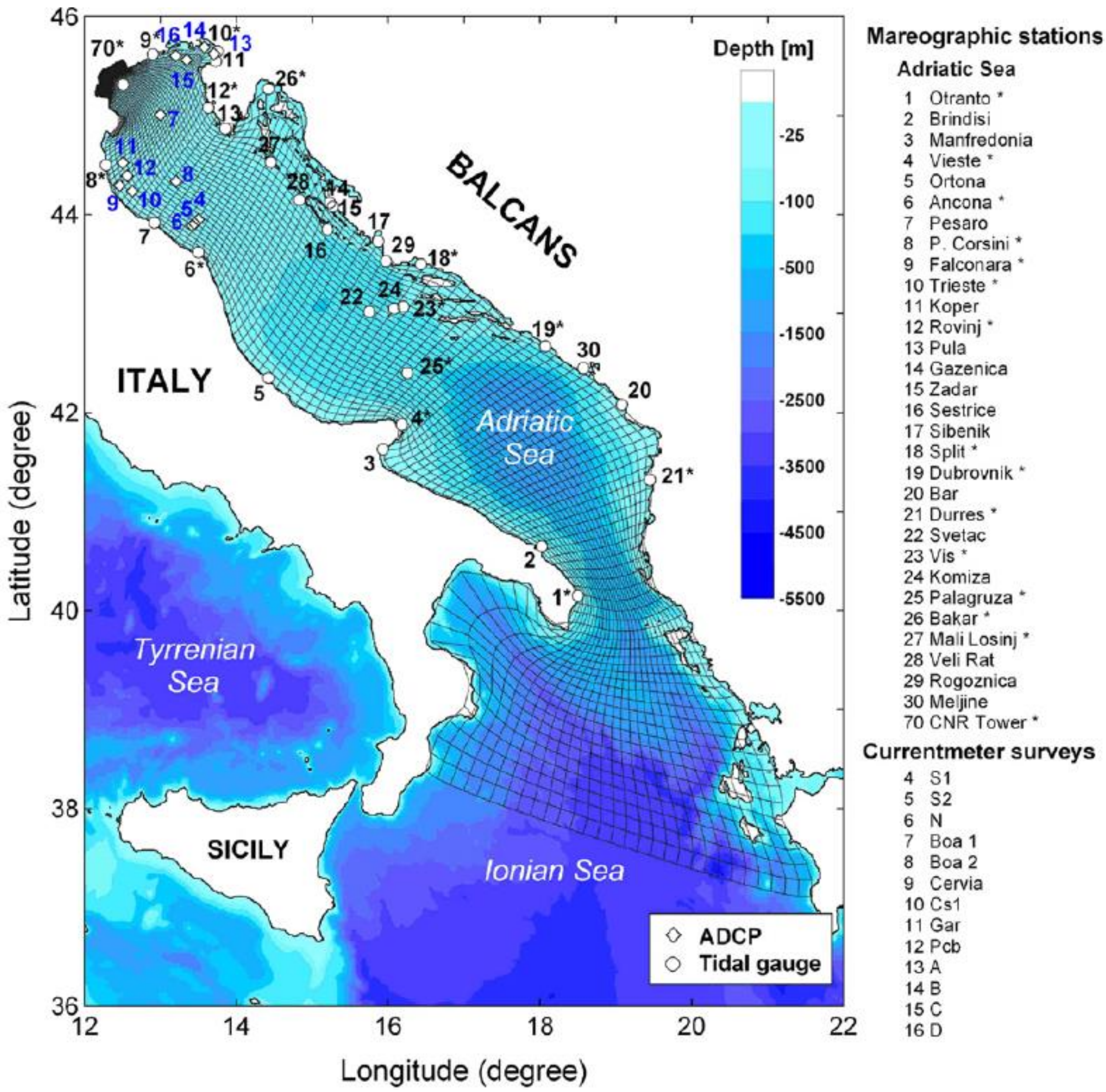


Figure 41. Adriatic-Ionian seawater depth [6]

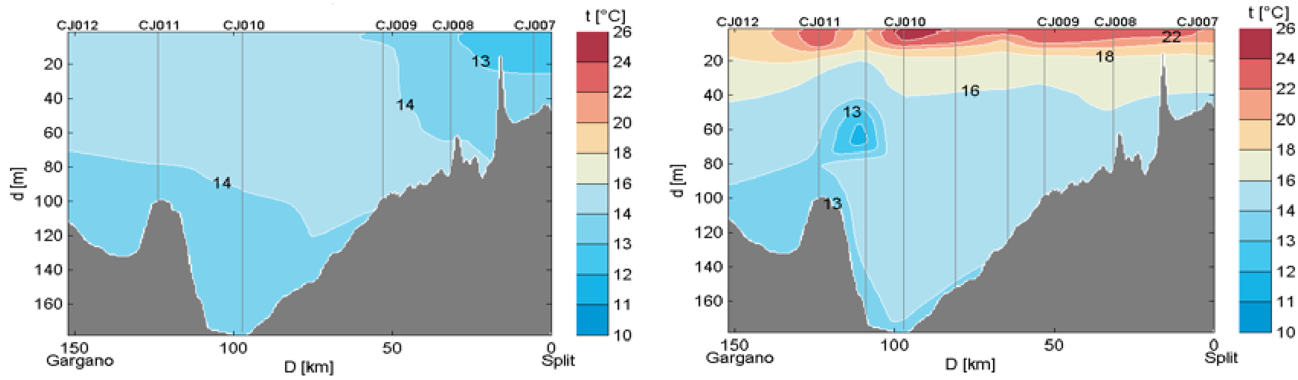


Figure 42. Profile of the seawater temperatures for February (left) and for August (right) between Gargano and Split, Croatia [7]

Because of that, it is important to study the temperatures of the seawater at various locations to determine what places are suitable for the installation of seawater heat pumps and what are not, which was done detailly per country.

4.1 Slovenia

Data on seawater and air temperatures were obtained for two measuring points.

The first measuring point is the oceanographic buoy of Vida, located in front of Piran. The diagrams show the average monthly air and sea temperature from 2014 to 2017. The comparative diagram shows the 10-year monthly average of air and sea temperature measurements.

The second measuring point is the Mareographic Station Koper, located along the coast of Koper. The diagram shows the comparison of average monthly air and sea temperatures for 2017.

The diagrams show that average monthly air temperatures during the heating season are up to 5 ° C lower than the sea temperature. Meanwhile, during the summer season, average monthly temperatures are comparable. An accurate daily level temperature analysis would show that in winter season there is an even greater difference that enables better exploitation of sea energy since the temperature of the sea is more stable compared to air and the air temperature fluctuates over the day/night. Also, in the summertime, daytime (afternoon) air temperatures are higher than the average and the sea has a lower temperature than air, which enables higher yields of cooling devices.

Furthermore, if seawater intake would be installed at the sea bottom, seawater temperatures would be much more stable, as can be seen in figure 35.

Figure 43. Location of temperature measurements – Buoy Vida

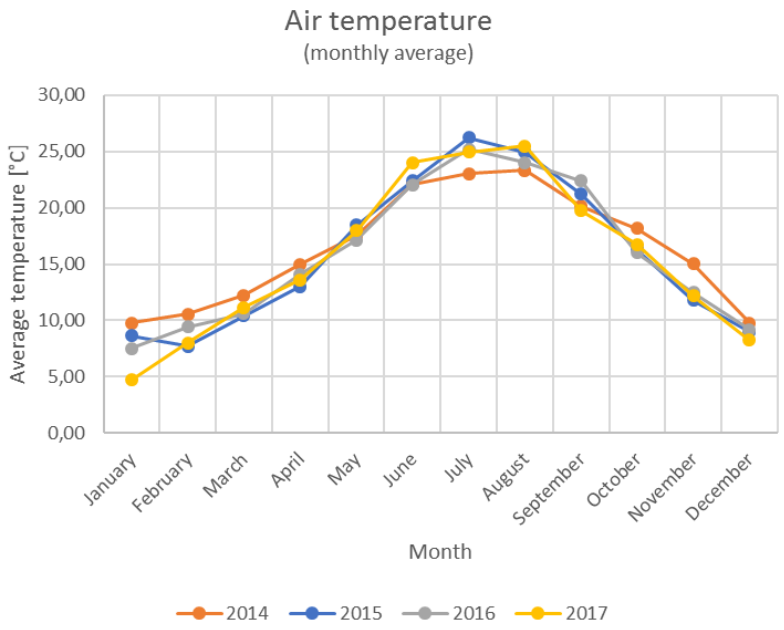


Figure 44. Average air temperature – Buoy Vida

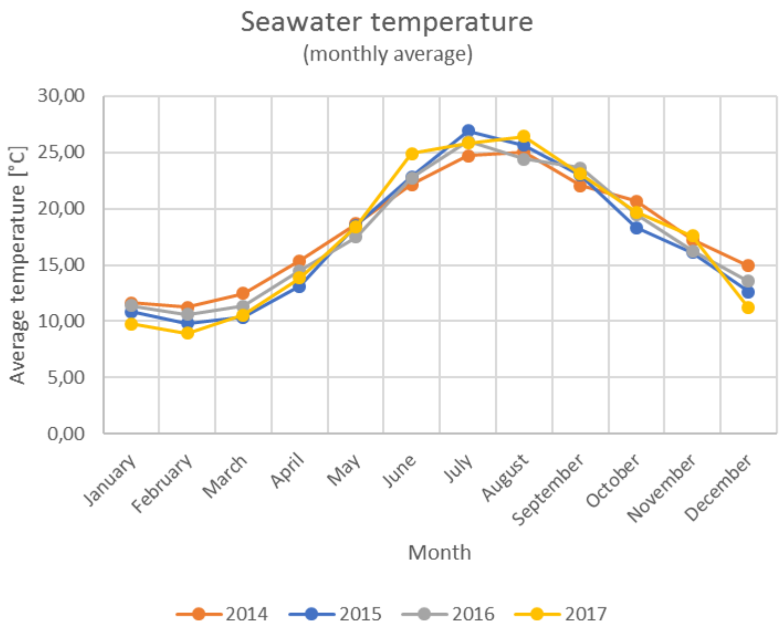


Figure 45. Average seawater temperature – Buoy Vida

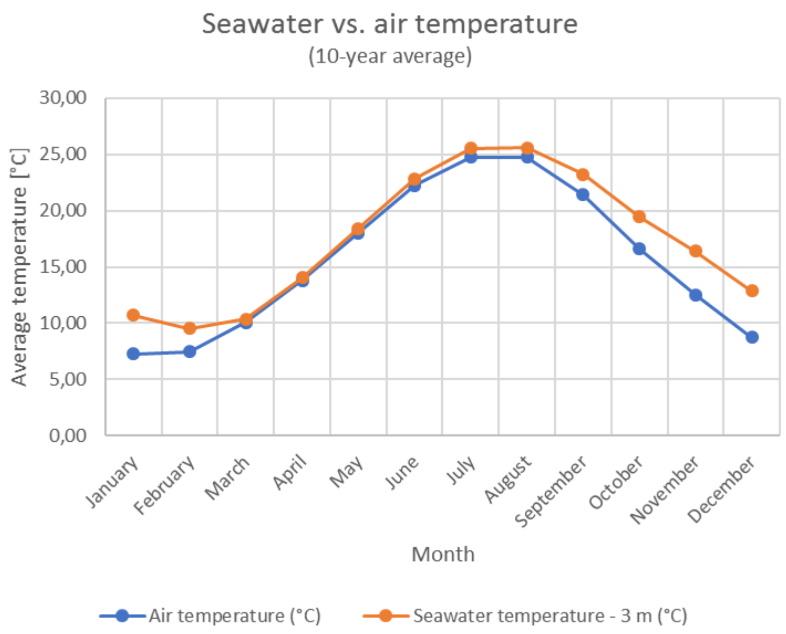


Figure 46. Comparison of seawater and air temperature – Buoy Vida

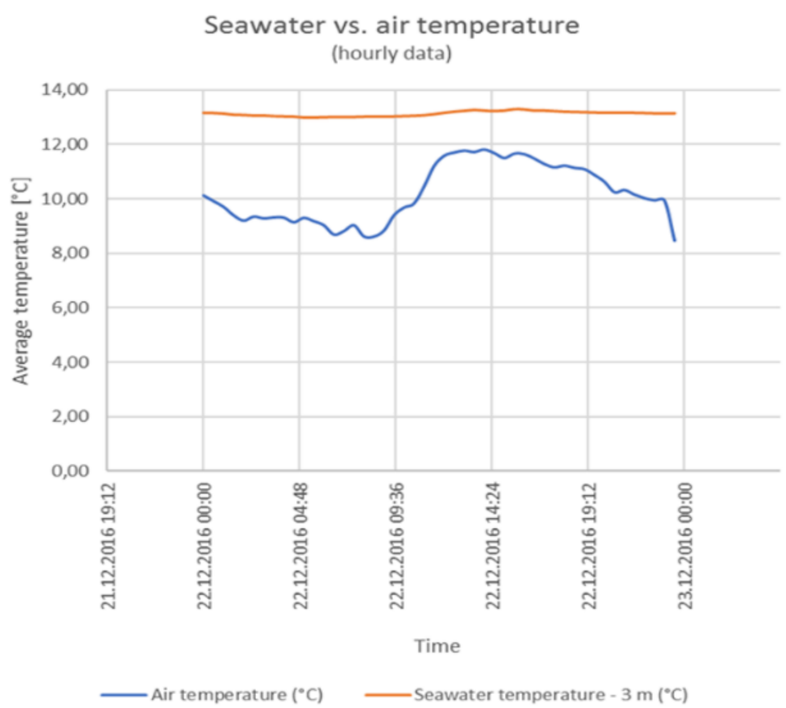


Figure 47. Daily temperatures on 22nd of December 2016 – Buoy Vida

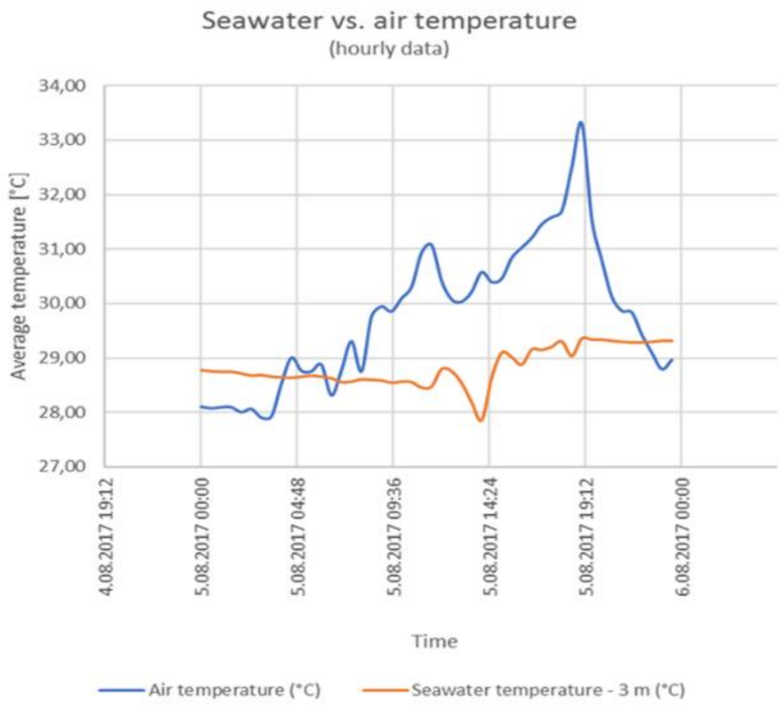


Figure 48. Daily temperatures on 8th of August 2017 – Buoy Vida

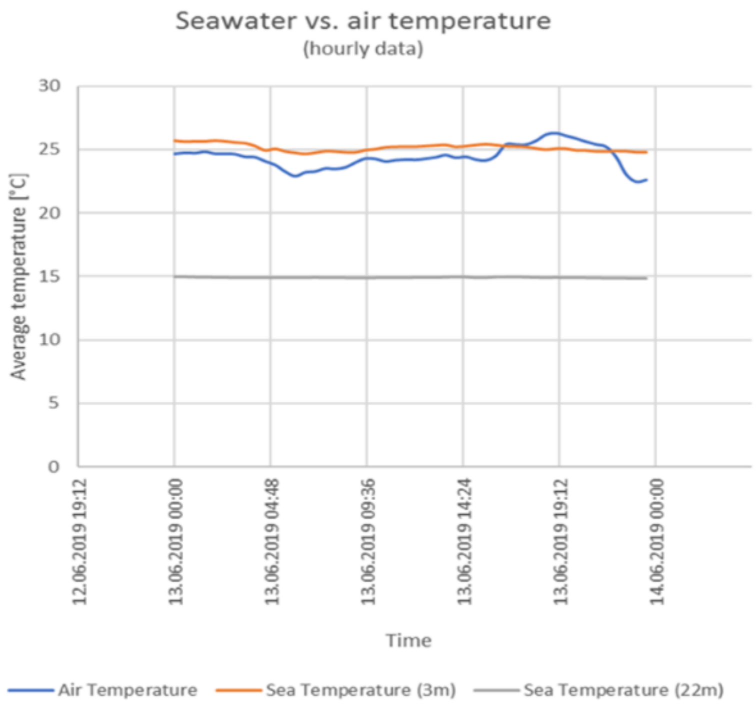


Figure 49. Daily temperatures on13th of June 2017 – Buoy Vida

Figure 50. Location of temperature measurements – Mareographic station Koper

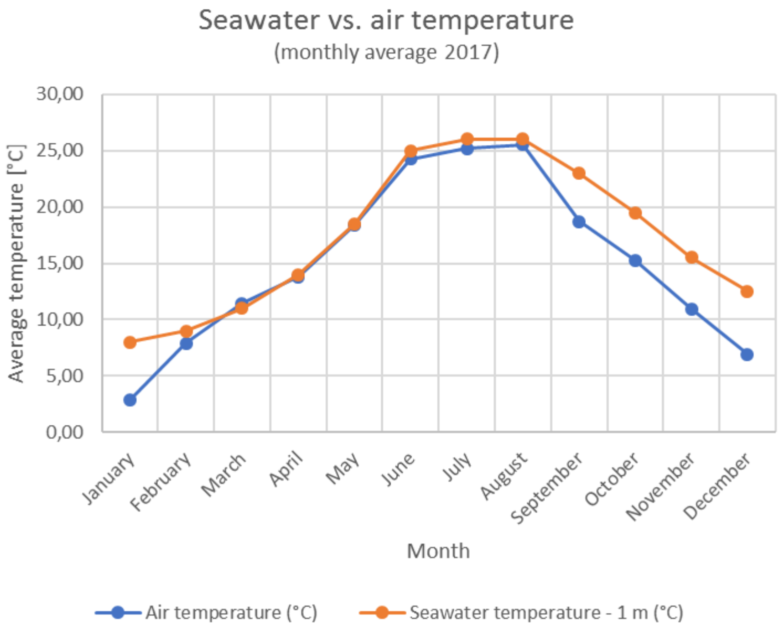


Figure 51. Comparison of seawater and air temperature – Mareographic station Koper

4.2 Italy

In the Upper Adriatic, the sea becomes warm in summer, especially in July and August, although, being a closed and shallow sea, it can undergo variations depending on weather conditions. Based on water temperature observations over the past ten years, Figure 45 shows maximal and minimal temperatures in Italy.

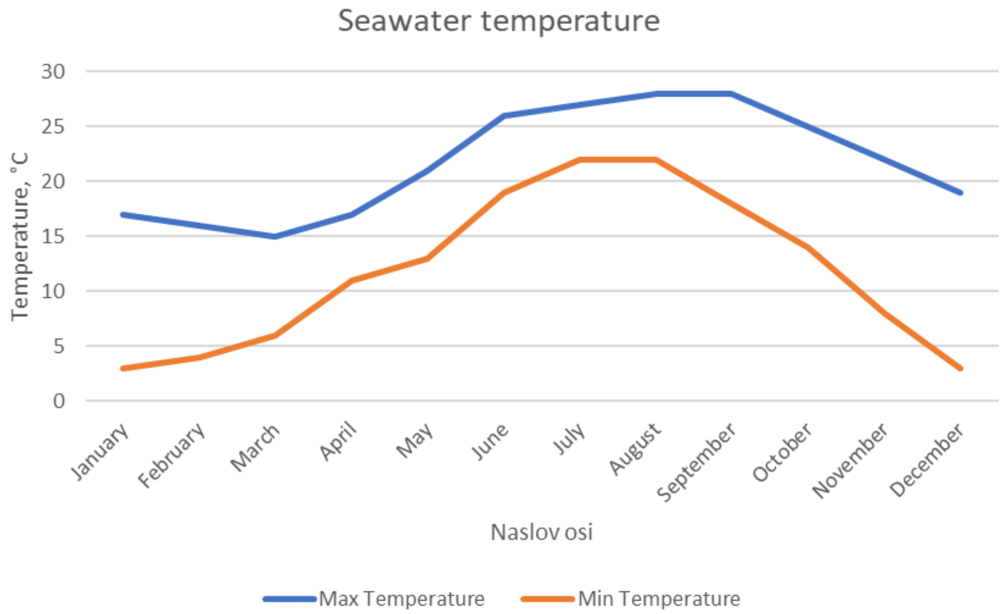


Figure 52. Maximal and minimal temperatures in Italy [8]

Temperatures in Italy were studied from the northern part of the Adriatic Sea to the southern part of the Adriatic sea, at stations that can be seen in Figure 46. The temperatures were gathered from the sea surface, meaning that there is still a possibility to get temperatures that are more constant from the deeper sea.

Figure 53. Measuring stations - Italy

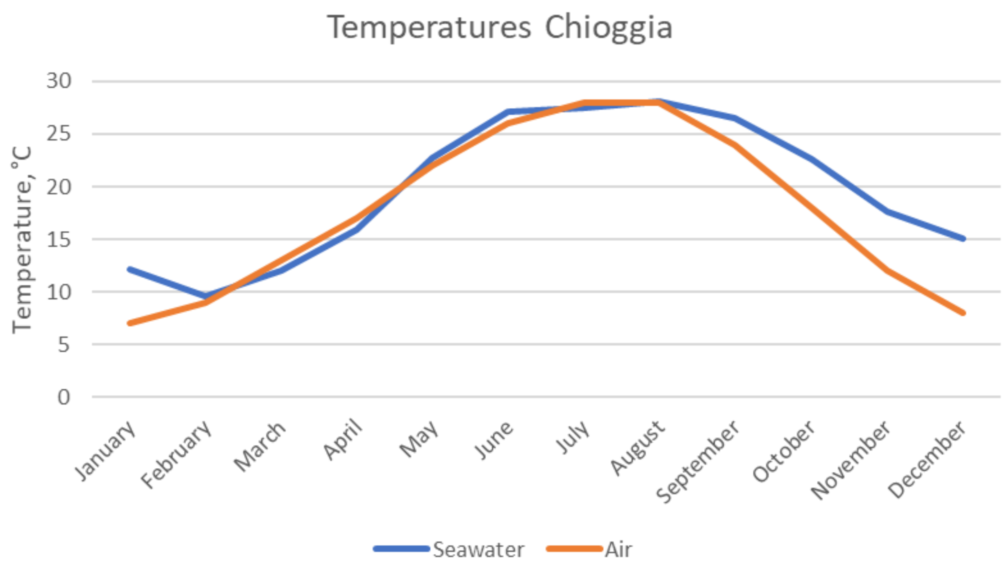


Figure 54. Comparison of maximal seawater and maximal air temperatures in Chioggia [8]

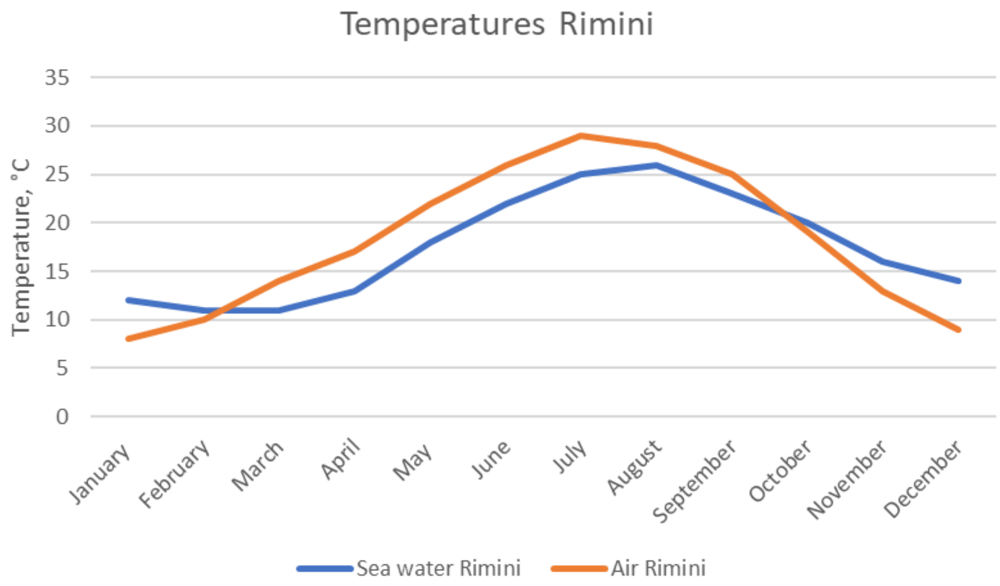


Figure 55. Comparison of maximal seawater and maximal air temperatures in Rimini [9]

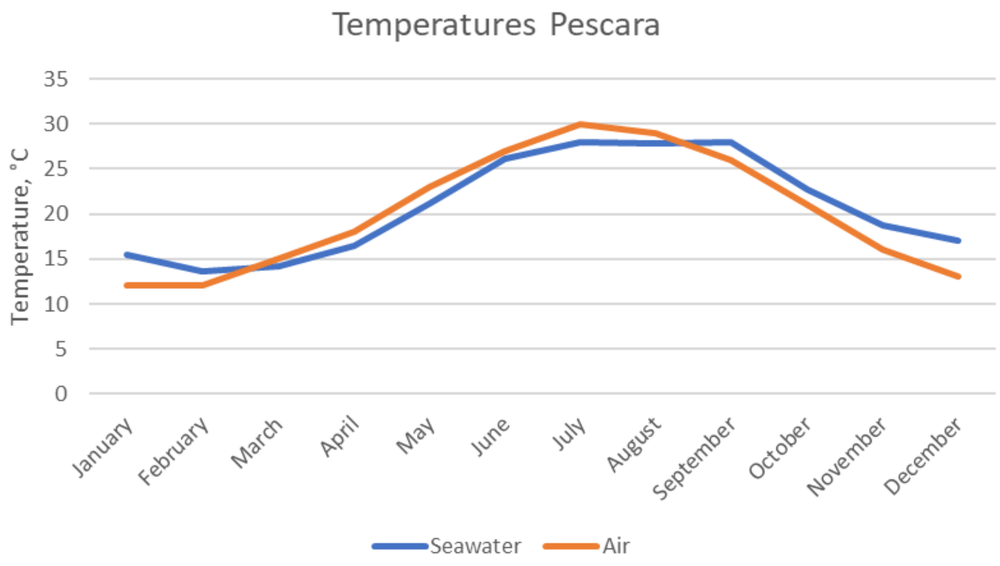


Figure 56. Comparison of maximal seawater and maximal air temperatures in Pescara [8]

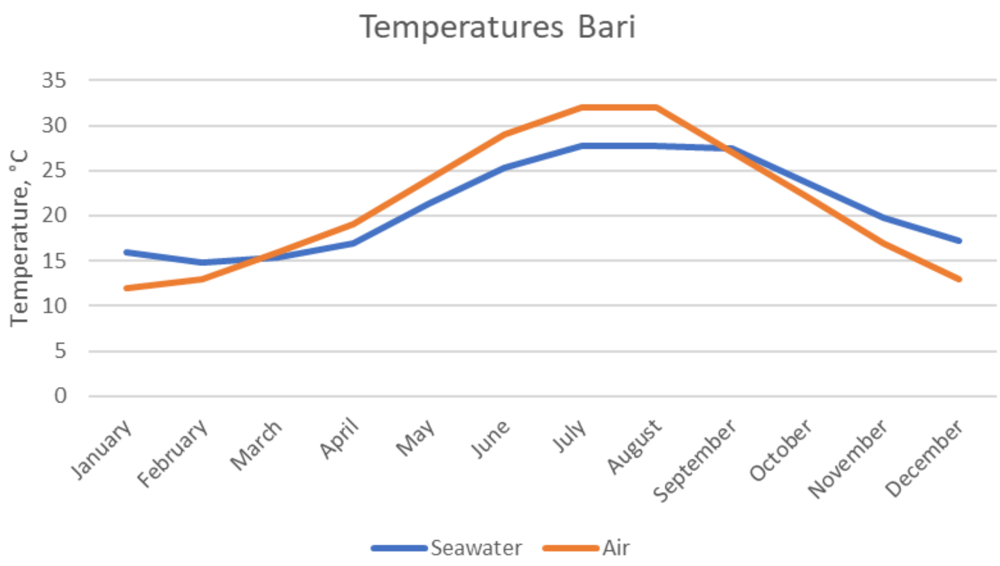


Figure 57. Comparison of maximal seawater and maximal air temperatures in Bari [8]

4.3 Greece

Below some characteristic places all over the country (mainland and insular part) are depicted, having either high population characteristics (in view of the number of public buildings) or high touristic activity (in view of the number of seaside hotels).

Figure 58. Example of the Greek Ionian and Aegean coast with the red dot marking the temperature spots

The measurements for the seawater temperature are provided by the daily satellite readings provided by the NOAA (National Oceanic and Atmospheric Administration) [10]. The temperatures given are the sea surface temperature (SST). Sea surface temperatures and air temperatures [11] were collected from different sources. As seen in the figures below, for most places in Greece, the seawater surface temperature is almost identical to the air temperature, with reference to the summer period (June-July-August). In order to increase the efficiency of SWHP in comparison to the air source heat pumps, it is proposed to take the water in from at least 20m of depth, as shown in Figure 16.

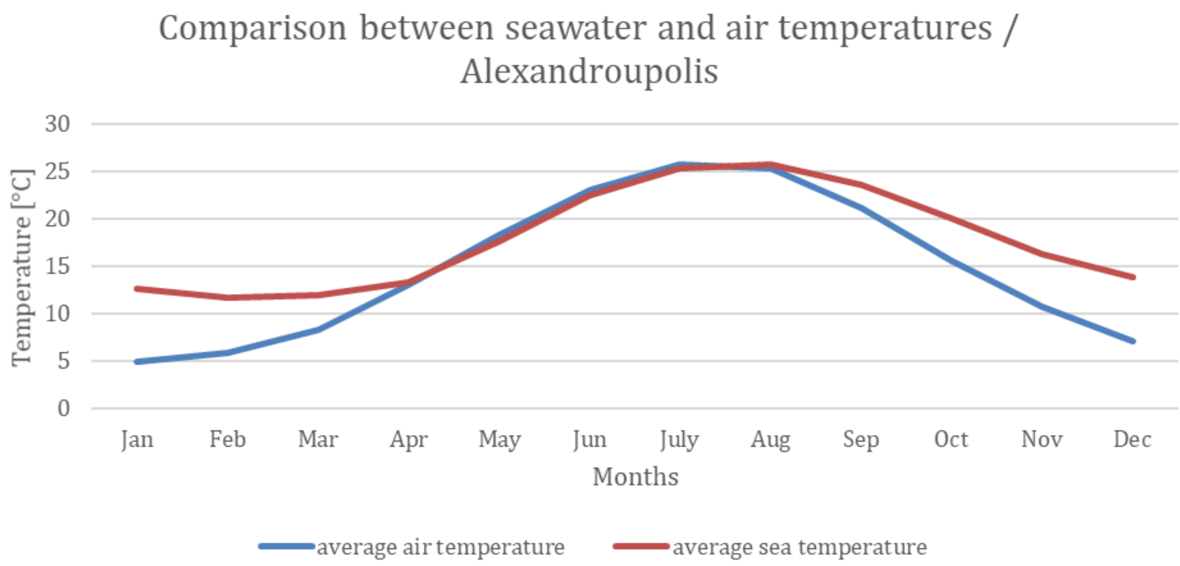


Figure 59. Seawater and air temperatures in Alexandroupolis

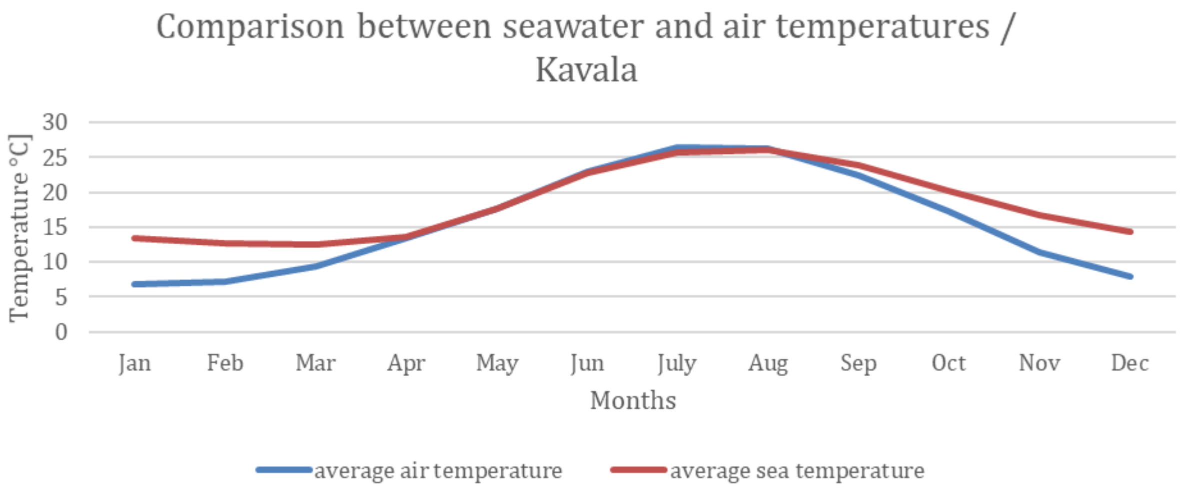


Figure 60. Seawater and air temperatures in various in Kavala

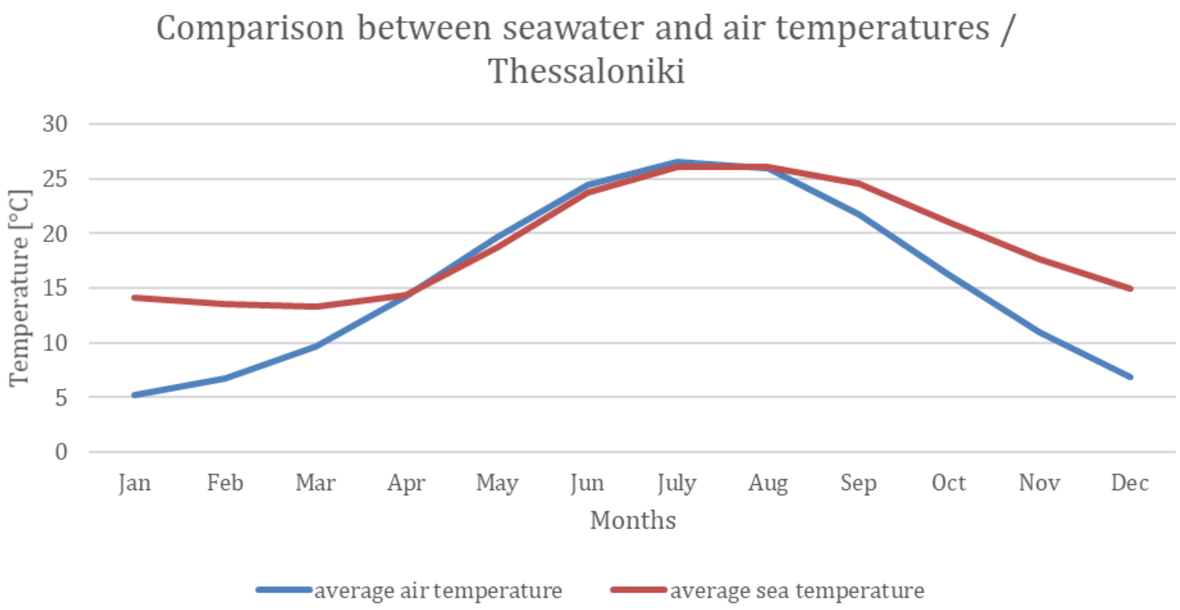


Figure 61. Seawater and air temperatures in various in Thessaloniki

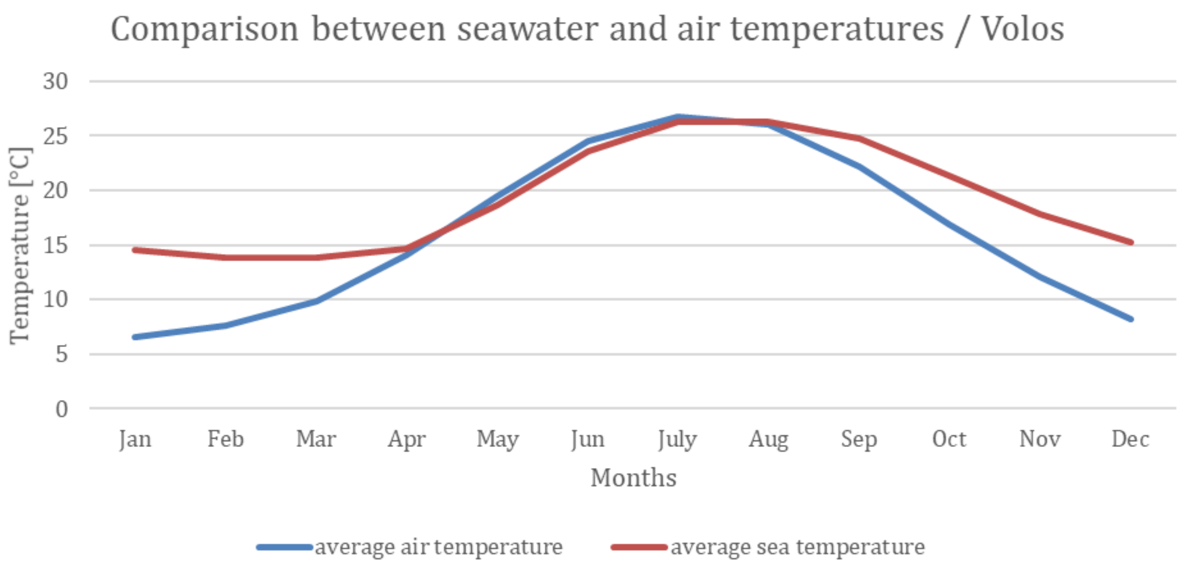


Figure 62. Seawater and air temperatures in various in Volos

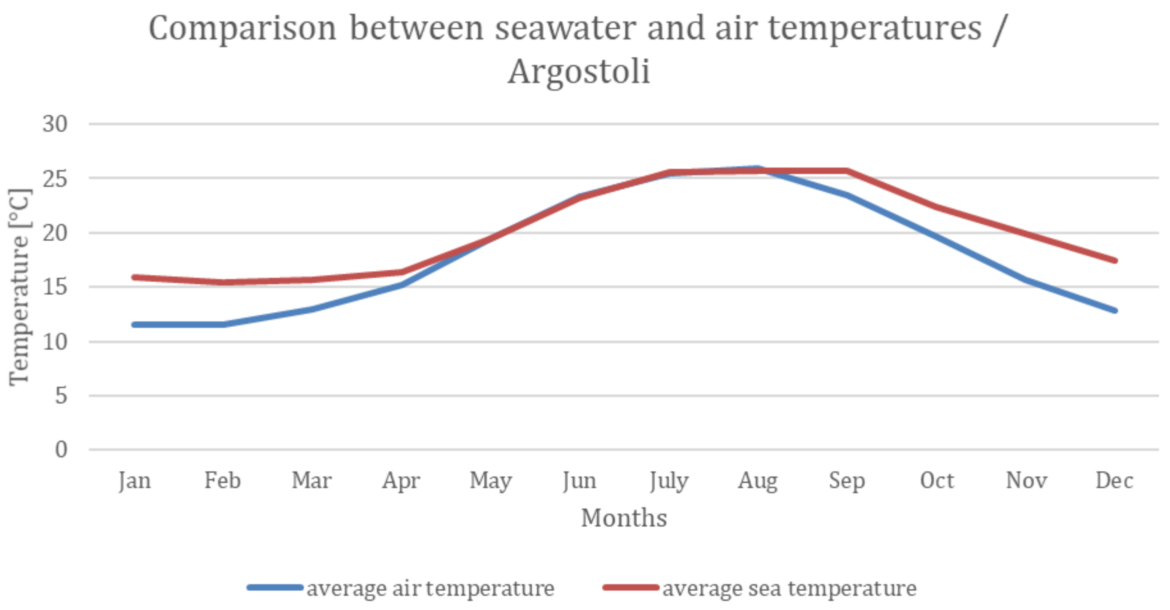


Figure 63. Seawater and air temperatures in various in Argostoli

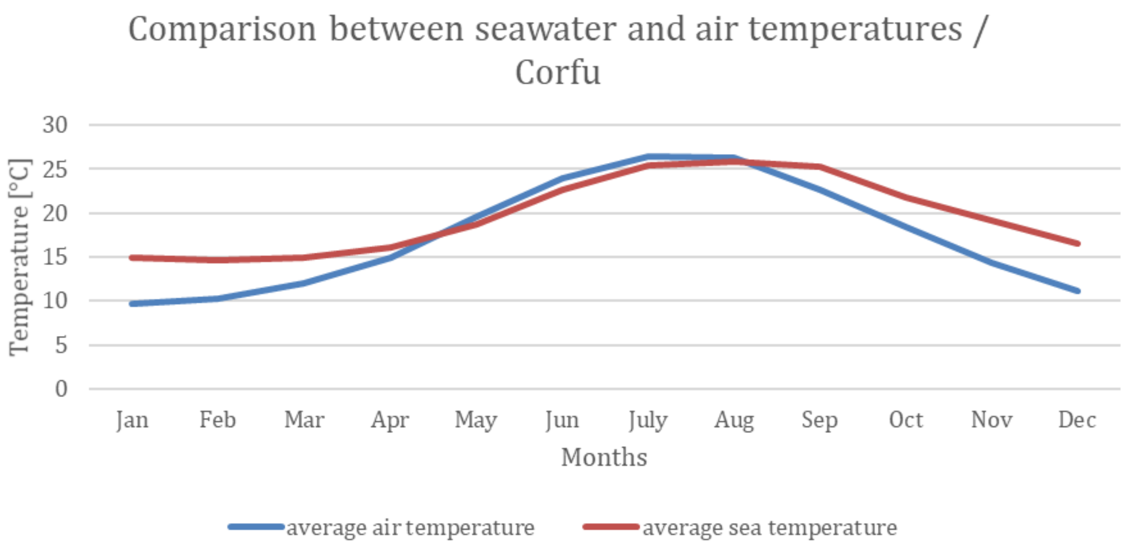


Figure 64. Seawater and air temperatures in various in Corfu

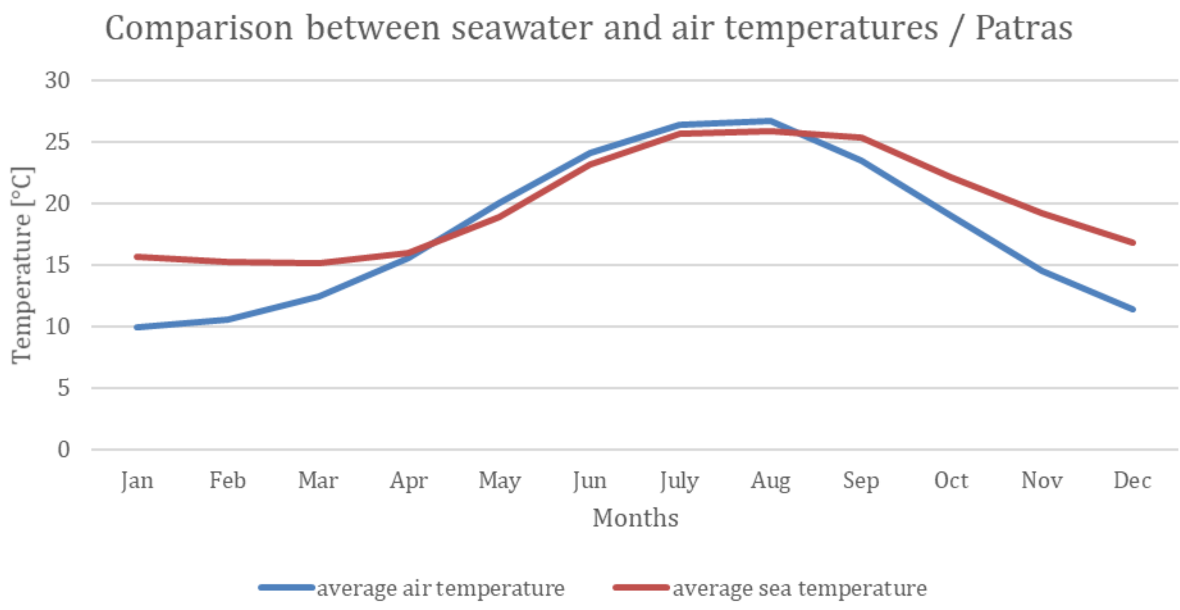


Figure 65. Seawater and air temperatures in various in Patras

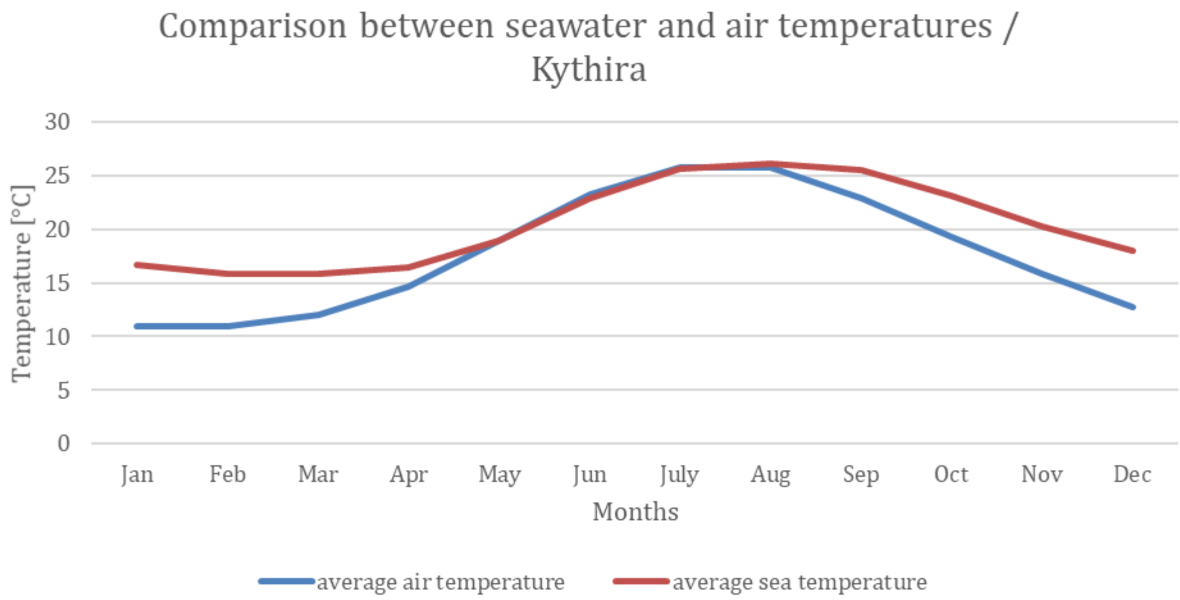


Figure 66. Seawater and air temperatures in various in Kythira

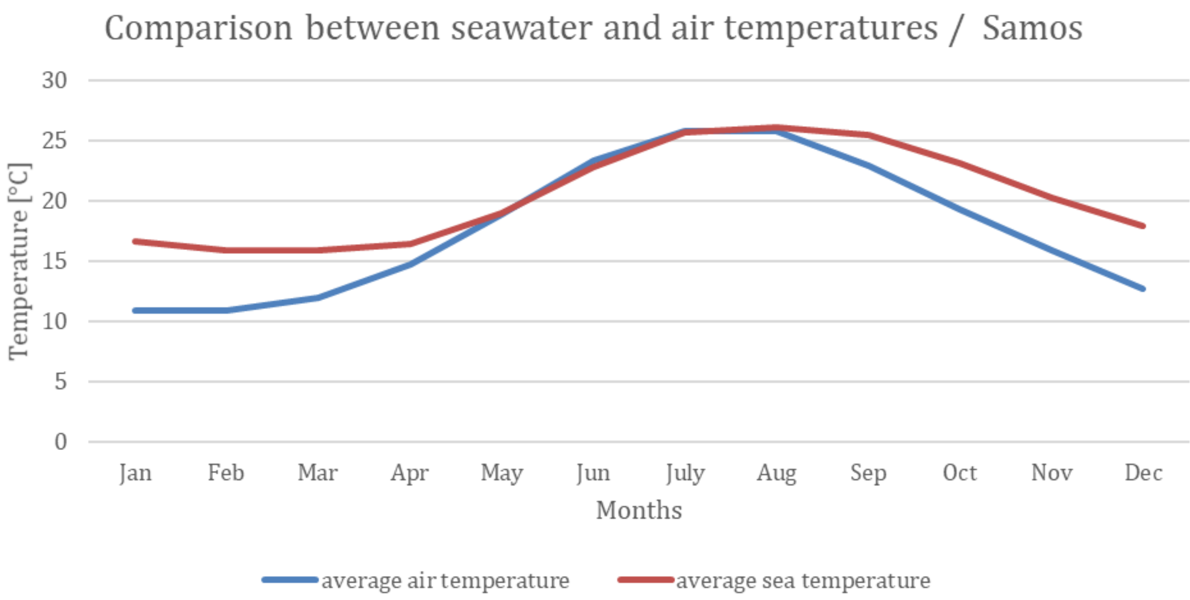


Figure 67. Seawater and air temperatures in various in Samos

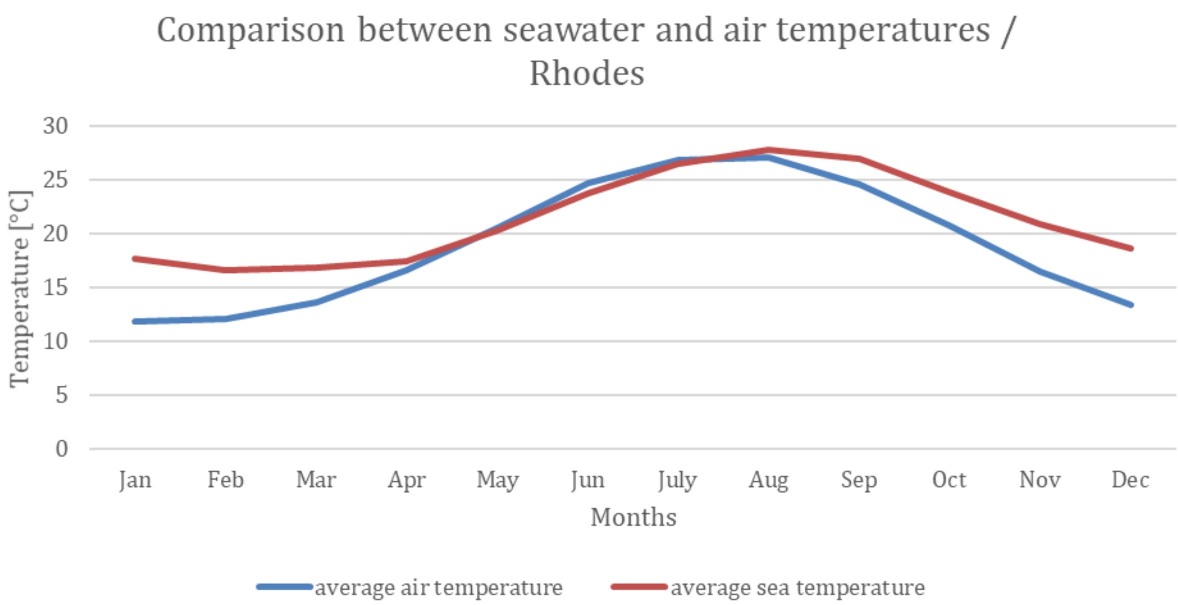


Figure 68. Seawater and air temperatures in various in Rhodos

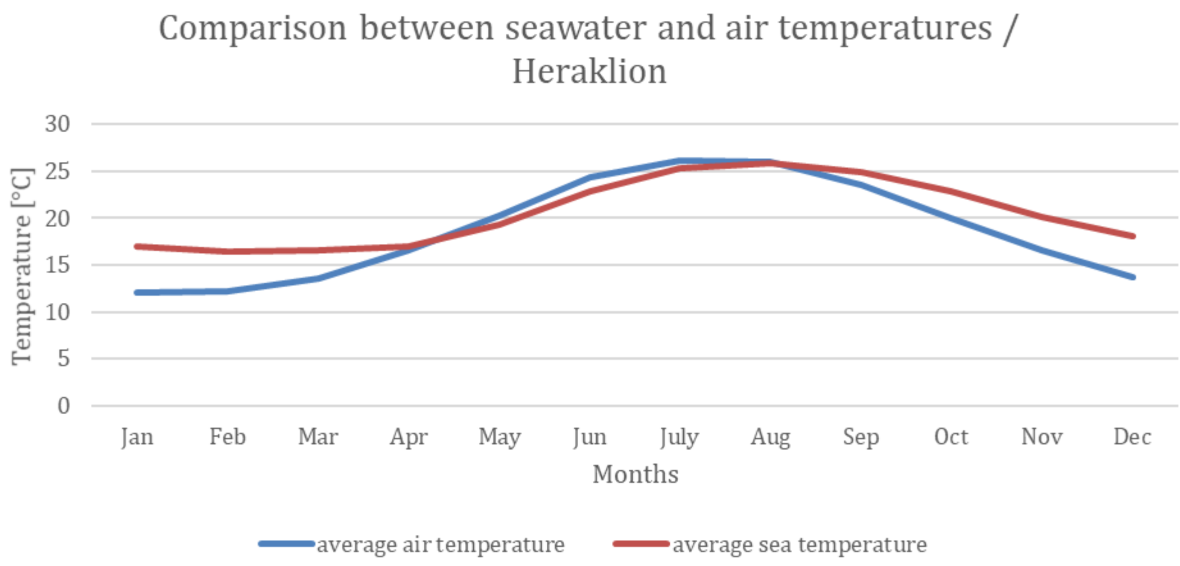


Figure 69. Seawater and air temperatures in various in Heraklion

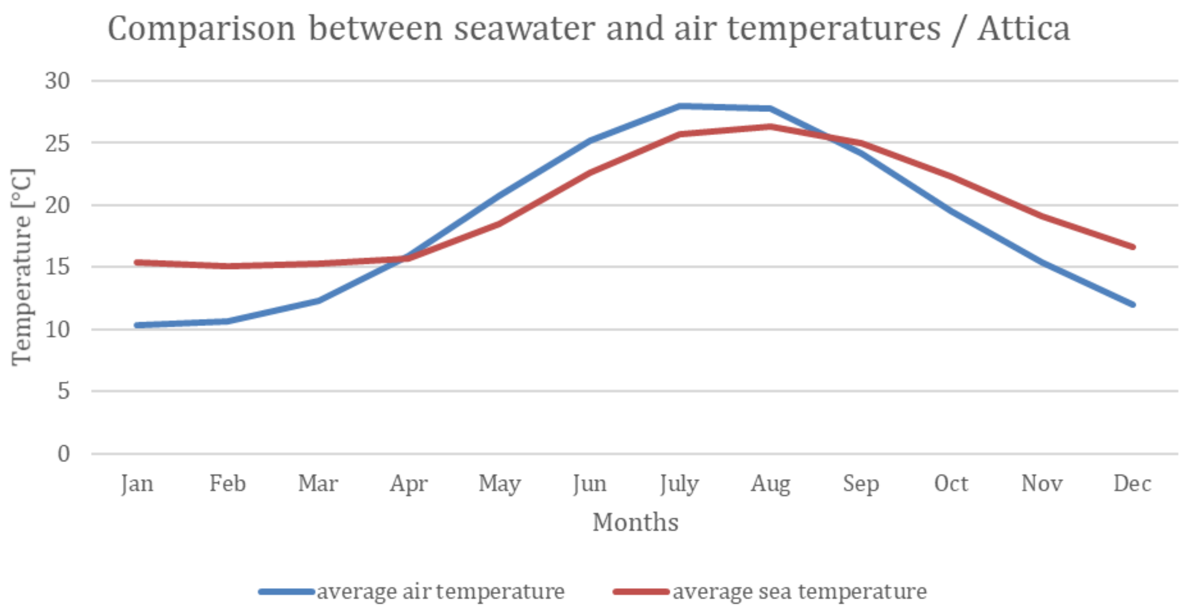


Figure 70. Seawater and air temperatures in various in Attica

For the sea around Athos (Chalkidiki), the temperature varies depending on the depth of the sea is depicted in the following figure:

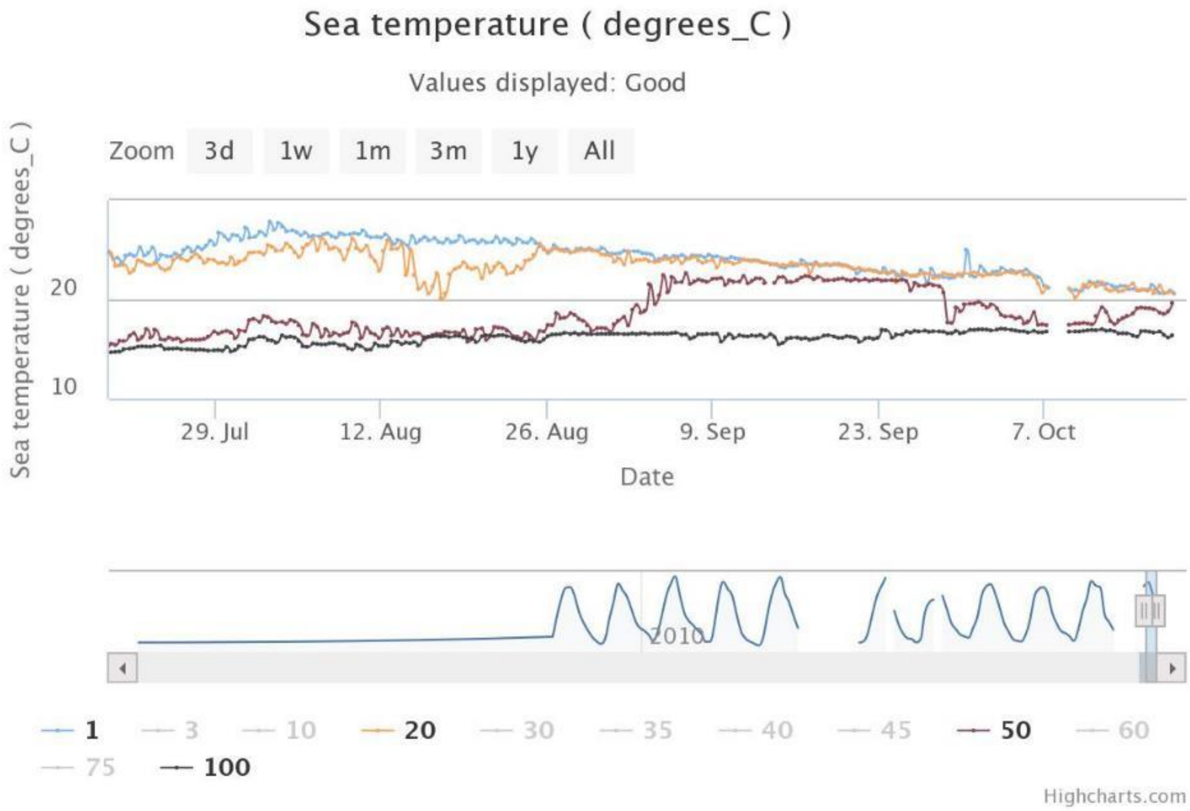


Figure 71. Seawater temperature in correlation to the depth of the sea (1, 20, 50, 100m) [12]

The figure shows that from a depth above 20 m from the water surface, the temperature is decreasing by 2 ^{o}C to 10 ^{o}C below air temperature. At a depth of 100 m, the seawater is almost constant during the summer season and well below the air temperature (10 ^{o}C).

4.4 Croatia

The temperatures of the Croatian part of the Adriatic sea depend strongly on the air temperatures, which leads to the warming of the Adriatic in the summer and its cooling in winter. The surface temperature is lowest in February and March, and the highest in August. In winter, the temperatures in the greater part of the basin decrease from more than 13 ° C in the south and east of the basin to less than 8 ° C in its northern and western parts. In summer, the surface temperature is more even and ranges between 24 and 25 ° C while at a depth of 10 to 30 m, the temperature drops sharply with depth (the so-called thermocline layer), to reach a value between 12 and 14 °C at greater depths [13].

Temperature data was obtained for 5 locations in Croatia. 3 locations have seawater temperatures gathered both on the sea surface and sea bottom, while 2 locations have temperatures gathered on the sea surface [14].

It can be seen that the for Rovinj, even though the seawater temperatures were gathered on the surface, the difference in seawater and air temperatures is enough that the seawater heat pump would be a beneficial option. Even the Rab station, which is surrounded by islands and though has poorer water circulation, shows the difference in water and air temperatures. Although that difference is too little for the seawater heat pump to be beneficial, it should be considered that that that is surface temperature and that seawater temperatures on the bottom are much more constant, as can be seen on the measurements from the rest of measuring stations.

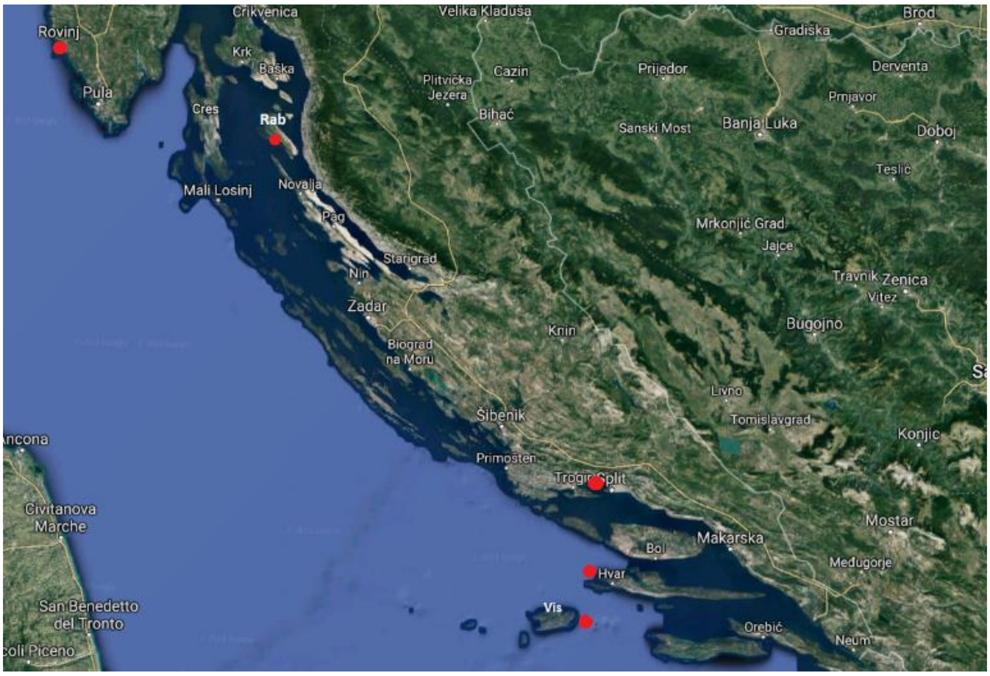


Figure 72. Measuring stations - Croatia

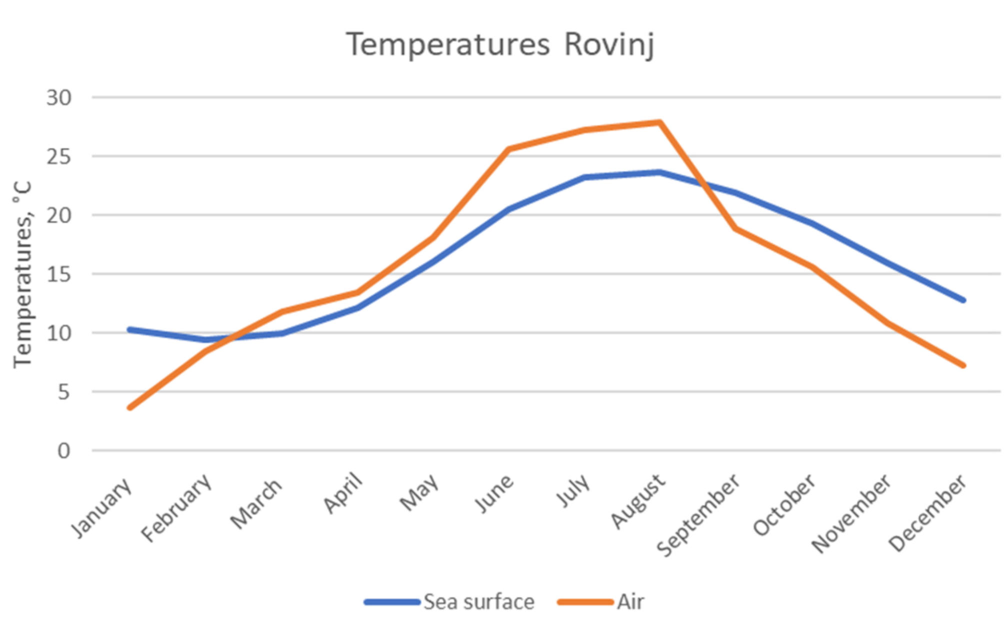


Figure 73. Average temperatures, Rovinj

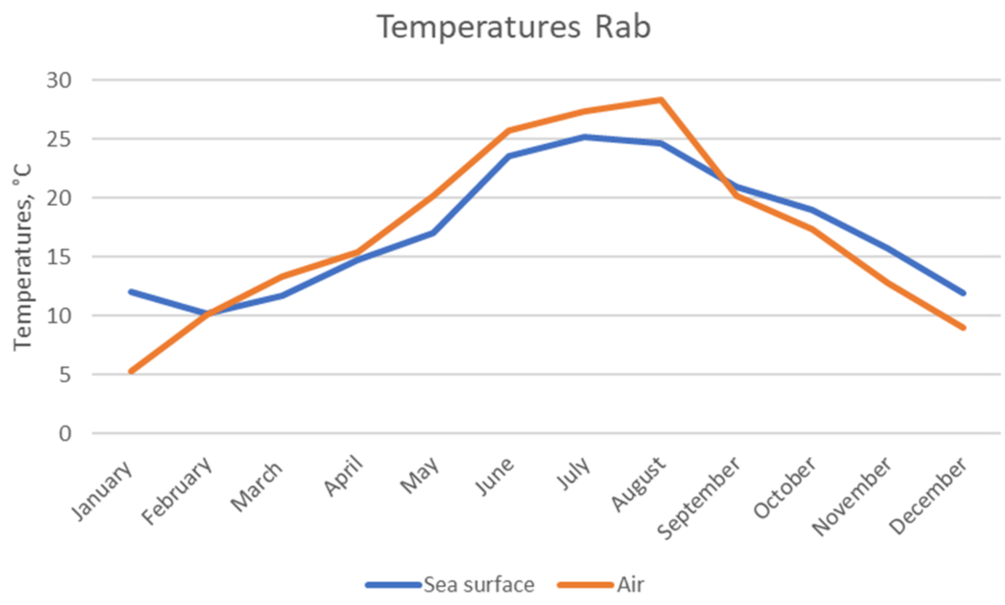


Figure 74. Average temperatures, Rab

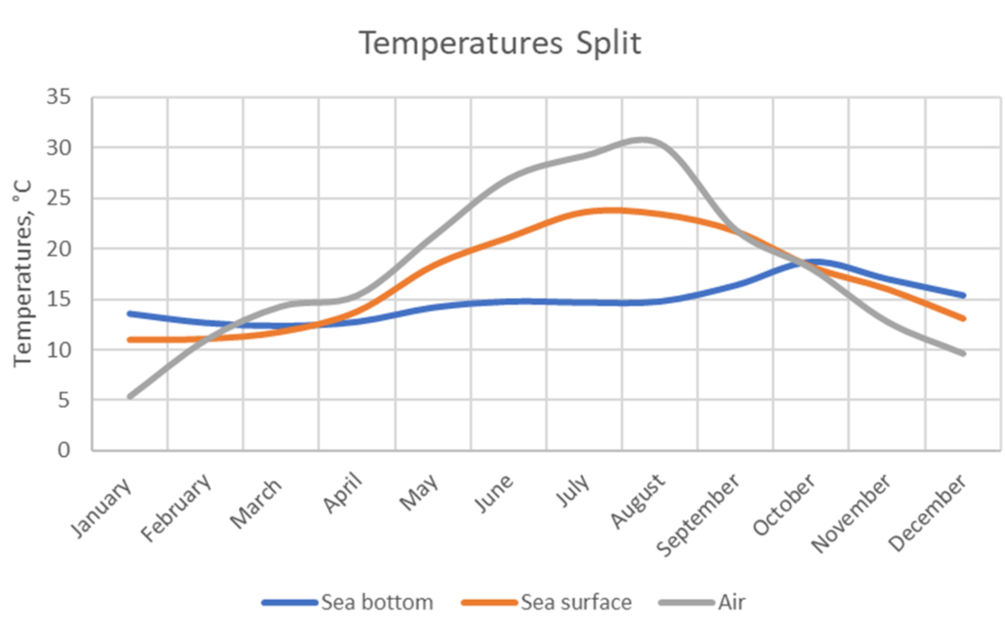


Figure 75. Average temperatures, Split

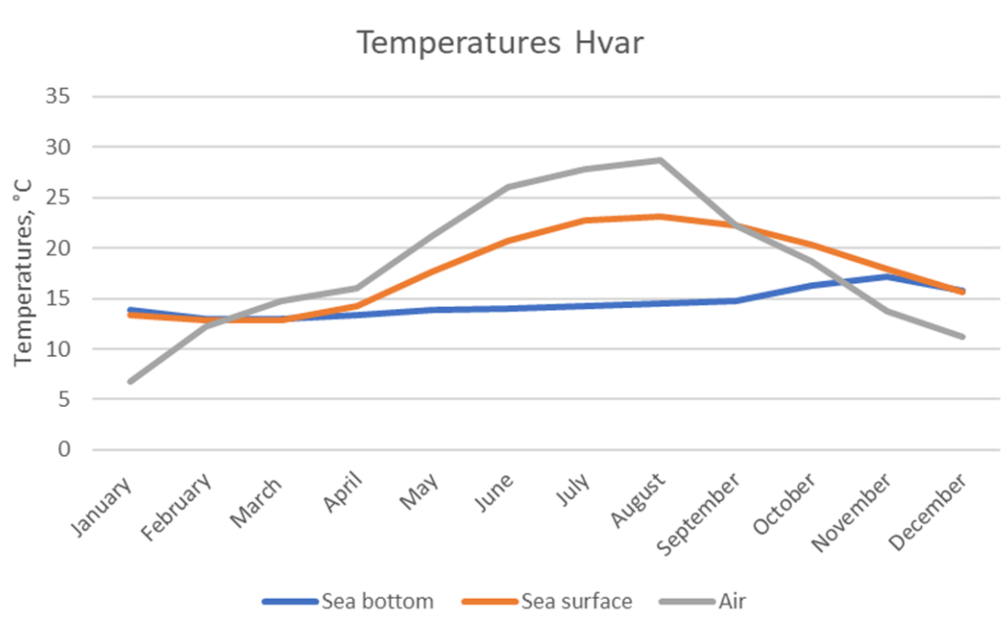


Figure 76. Average temperatures Hvar

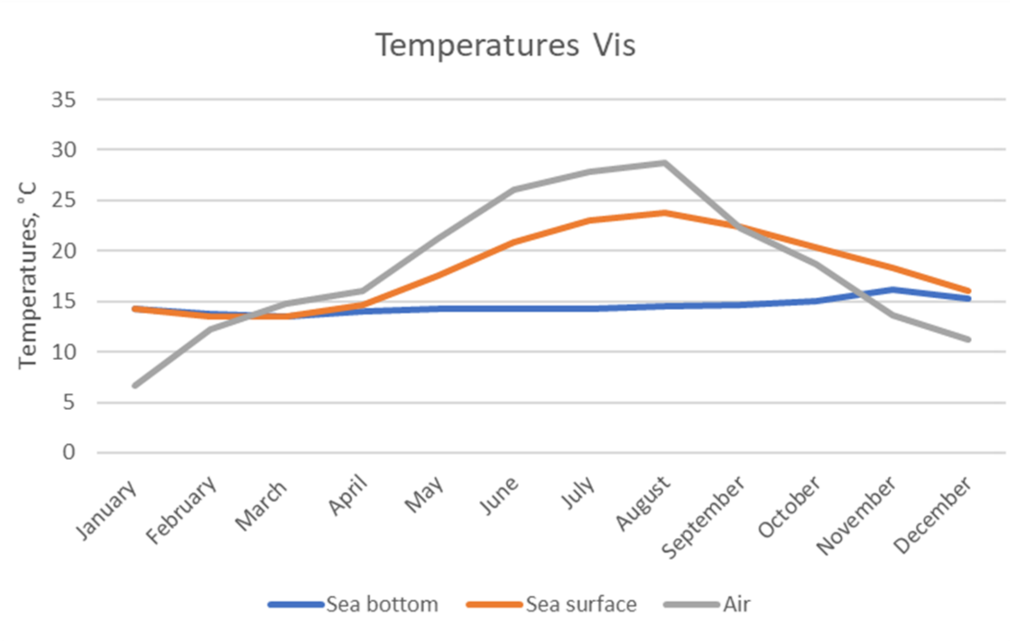
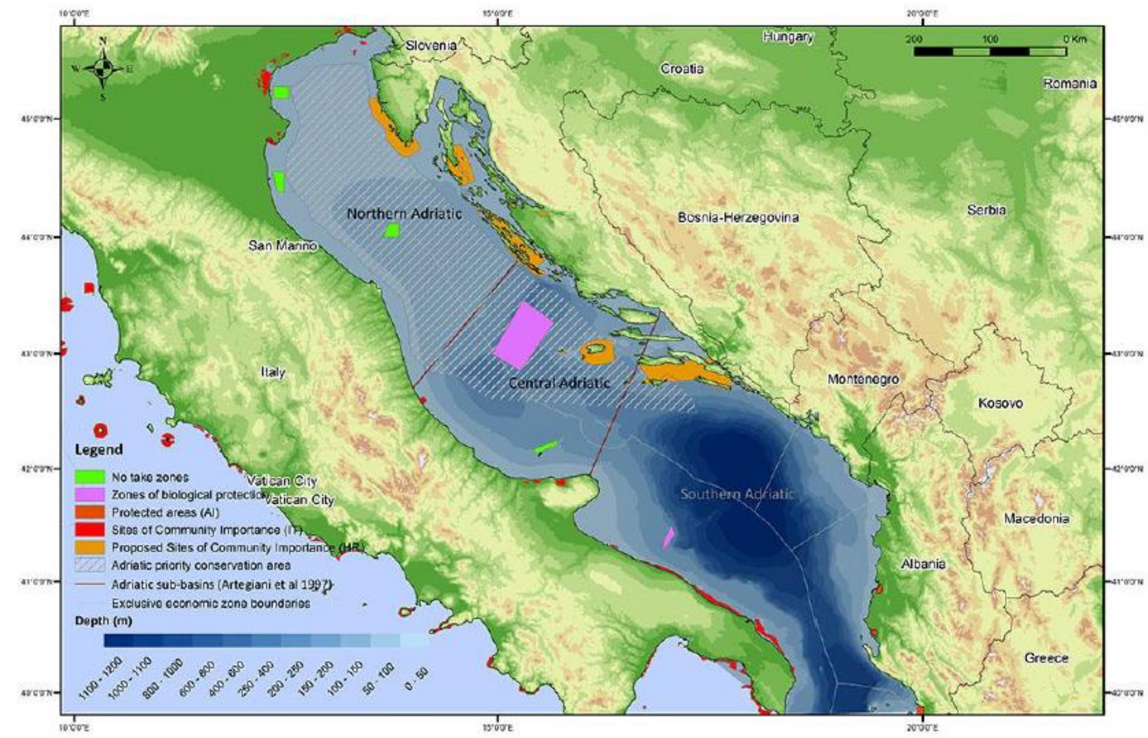


Figure 77. Average temperatures Vis

4.5 Albania

The Adriatic Sea is the northernmost arm of the Mediterranean basin. It is a semi-enclosed sea with a surface area of around 138,000 km², connected to the Mediterranean through the narrow (72 km wide) but deep (780 m) Strait of Otranto. The bathymetry of the Adriatic Sea is characterized by strong latitudinal and longitudinal asymmetries (Fig. 13).



Areas of importance for megafauna in the Adriatic Sea

Figure 78. Map of the Adriatic Sea with bathymetry and protected areas.

The northern sub-basin is shallow, with an average depth of 35 m and is strongly influenced by the Po river plumes, with low salinity, low water temperature and high productivity. The 100 m bathymetric contour line roughly separates the northern basin from the central Adriatic.

The central Adriatic is a transition zone with some open sea characteristics and the 270 m deep influenced by the inflow of Levantine Intermediate Water (LIW).

Finally, the 170 m deep Palagruža (Pelagosa) sill separates the central sub-basin from the much deeper southern Adriatic. This sub-basin, with steep slopes, higher salinity and the maximum depth of 1200 m, consists of around 55% of the surface area. Still, about 80% of the total volume of the Adriatic Sea and as such, it can be considered as a pelagic oceanic habitat.

Hydrology

The hydrological regime (thermohaline properties) of the Adriatic Sea is determined to a great extent by water exchange with the Mediterranean via the Strait of Otranto, river runoff, currents, and climatic conditions. The hydrological regime is also influenced by the sea elongation in the northwestern direction, a sharp difference of depths in its northwestern and southeastern parts, and coast irregularity. The hydrological regime is characterized by high water temperature, high salinity, insignificant water level fluctuations, weak currents, and low recurrence of high waves.

Climatology of Adriatic Sea in Albania

Apart from the considerable variation in landscape, it makes for a wide range of climate types. The Adriatic Sea in the west, the Albanian Alps in the north and Ceraunian Mountains in the south have a great influence on the climate of the area. As defined by the Köppen climate classification, the Albanian Adriatic Sea Coast experiences a Mediterranean climate with considerable maritime and subtropical influences. This means that the summers are hot, sometimes very hot and dry and the winters generally mild and wet. The coast experiences four distinct seasons. The winter is relatively humid and mild, and the summer lasts very long and is usually hot and dry. Autumn and spring are transitional seasons.

The Adriatic Sea extending meridionally between about 40 and 45, 450 N belongs to the subtropical climatic zone, while its northernmost part is characterized by moderate climate. The climate here has some Mediterranean features, but, generally, differs significantly from the climate of the Mediterranean Sea. The cyclonic and anticyclonic activity determines it over the middle and southern Europe. Cyclones usually travel from west to east over the Adriatic Sea. In summer, the spur of the Azores Anticyclone influences the formation of the Adriatic climate greatly. It creates the steadily dry and warm summer with a cloudless sky. In winter the cyclonic activity determines the mild, humid, and cloudy winter with accidental sunny periods. Winter normally lasts from December through February. The coldest month is January. The average air temperature in this month is 6–9°C in the northern regions and 10–12°C in the southern regions. Spring is not long (March–April), and its average monthly temperatures are 13–14°C nearly everywhere. In spring the air temperature may rise to 29°C and drop below zero. Summer is the longest season lasting from late April through September. The hottest month is July with the average monthly air temperatures varying from 27°C in the north to 30°C in the south. The maximum air temperature in some coastal areas may be as high as 42°C that was recorded in August. Autumn starts in October when the air temperature drops to 14°C in the north and 18°C in the south.

The cloudiness over the Adriatic coast features the clear-cut annual dynamics: it tends to increase in winter and to decrease in summer. The average monthly cloudiness is 5–6 points. The greatest cloudiness is observed in the northern part of the sea where its average monthly values vary from 6–7 points in winter to 3–5 points in summer. In spring and autumn, the cloudiness is not more than 6 points. In the other parts of the sea, the average monthly values of cloudiness fluctuate from 4–5 points in winter to 1–3 points in July and August. The average number of cloudless days in a year varies from 120–130 in the south to 100–110 in the north.

The average annual precipitations here are around 1,000 mm. The amount of precipitations over the sea decreases from the northwest to the southeast. On the coast the greatest precipitations fall in the northernmost areas; their annual amount averages 1,075–1,555 mm. Rainfalls and rainstorms usually represent precipitations. The precipitations are distributed within a year very unevenly; the greater part of their annual amount falls in autumn and winter seasons. In these months the average precipitations vary from 60–90 mm on the southwestern coast to 150–200 mm on the northeastern coast. The minimum precipitations are usually recorded in July – not more than 30–45 mm. The precipitations are especially meagre in July in the southern part of the sea where their monthly amount makes 13–15 mm. The exception is the northern coast of the sea where the minimum precipitations fall in January–February making 40–60 mm.

The average annual number of days with advective sea fogs in many regions of the sea fluctuates from 1 to 10, except the Venetian Plain with its multiple lagoons and the mouth of the Rivers which contribute to the formation of fogs that are most dense here and may last as long as 30 days. Fogs mostly occur in October through April. In the north of the sea, they are observed more frequently than in the middle and southern parts. Such a phenomenon as haze is often observed over the Adriatic Sea. It is formed by dust and fine sand brought here with the southern winds blowing from Northern Africa.

Snowfalls are quite rare here and occur only in the northwestern part of the sea. The average annual number of days with snowfalls is 4–6 in the north of the sea and 1–2 in the south of the sea. The snow forms a cover only for a very short time.

Among specific meteorological events observed here, there are thunderstorms and snowstorms. Thunderstorms may occur in any season of a year, but they happen here more frequently than anywhere else in Europe. They are most frequent in July, August, and September. In the north, they occur to 9 days in a month, on the average, while on the Dalmatian coast only 4 days per month. Strong gusts of wind usually accompany thunderstorms. Here the wind force may be as high as 6–8 points, while during “Garbina” winds – even 11 points. Many thunderstorms observed over the Adriatic cross the sea as thunder squalls from southwest to northwest. Their velocities are about 25–35 km/h. Snowstorms occur very seldom and only in winter in the northern part of the sea.

Winds in the Adriatic Sea change their direction and speed during the year as a result of the distinctive Mediterranean climate. This characteristic is mainly determined by a passing trajectory of basic systems across the Mediterranean Sea and Balkan Peninsula as well as other important factors such as morphometric characteristics of the territory.

Wind and Waves The wind regime of the Adriatic Sea is determined by the effect of such factors as a regional atmospheric activity, coast relief (orography), and local circulation provoked by temperature differences of land and sea. The most typical local winds for the Adriatic are Sirocco, Mistral, Bora, Gabrina, and Tramontane. During a year the winds blowing from the north and northeast are prevailing over the Adriatic. Their recurrence in some months is as high as 60%. The exclusion is the southwestern coast where the northwestern winds are dominating. Sirocco is the warm southern dry tropical wind from the deserts of the Arabian Peninsula and North Africa. It blows from the southwest bringing with it the dreary weather, clouds, and storms. Sometimes, mostly in winter, it can reach the hurricane magnitude. The maximum wind force of Sirocco may reach 7 points; it usually lasts for 2–3 days in succession. In the period from October through May, it blows more frequently and with greater force (to 9 points). A storm may also follow it with the waves of 3–4 m high. The signs of coming Sirocco are rough, surging sea, while in the Central and North Adriatic – tides. After long southern winds, the water level in ports may rise. Mistral is lowing mostly from the northwest in the period from June to mid-September when the low-pressure area gets established over the Balkan Peninsula. It usually starts blowing about 10 h in the morning and reaches its force of 3–5 points by the midday and calms down by the sunset. Mistral is considered to herald good weather – it brings a clear blue sky. In recent years it has been noted that Mistral has occurred more seldom. Nevertheless, it still blows quite frequently, particularly, on the coasts of remote islands. Bora is typical of the eastern Adriatic coast.

The Adriatic Sea is usually calm because more than 75% of the total number of waves is less than 0.5 m high. Moderate sea prevails most of the year (from 0 to 2 points). Resulting from the prevailing wind belt over the Adriatic the waves in the open sea are most frequently rolling from north to south. The waves generated by long Jugo, Jugo-Sirocco (southeastern) winds are higher than waves from Bora. The greatest waves 10.8 m high were recorded in the north of the Adriatic Sea. Near Palagruža Island, the maximum wave height of 8.4 m during Sirocco and 6.2 m during northeastern Bora was observed. However, it will be improper to think that the waves from the south are more dangerous than from the northeast. Quite the opposite – the period of waves generated by the northeastern winds is twice as shorter than southern winds: 50 m compared to 100 m and more, and their amplitude is very irregular. The waves from summer Tramontane (daytime northwestern wind) reach their maximum height of 4 m in the South Adriatic.

Sea Water Temperature

The **Adriatic's** surface **temperature** usually ranges from 22 to 30 °C (72 to 86 °F) in the summer, or 12 to 14 °C (54 to 57 °F) in the winter, except along the western **Adriatic coast's** northern part, where it drops to 9 °C (48 °F) in the winter.

The graph below shows the range of monthly **Durrës** water temperature derived from many years of historical sea surface temperature data.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min °C	12.9	13.5	13.5	14.2	15.8	20.4	23.5	23.2	21.6	18.4	16.6	13.9
Max °C	16	15.1	15.3	17	21.9	25.9	27.7	27.7	27	23.3	20.2	18

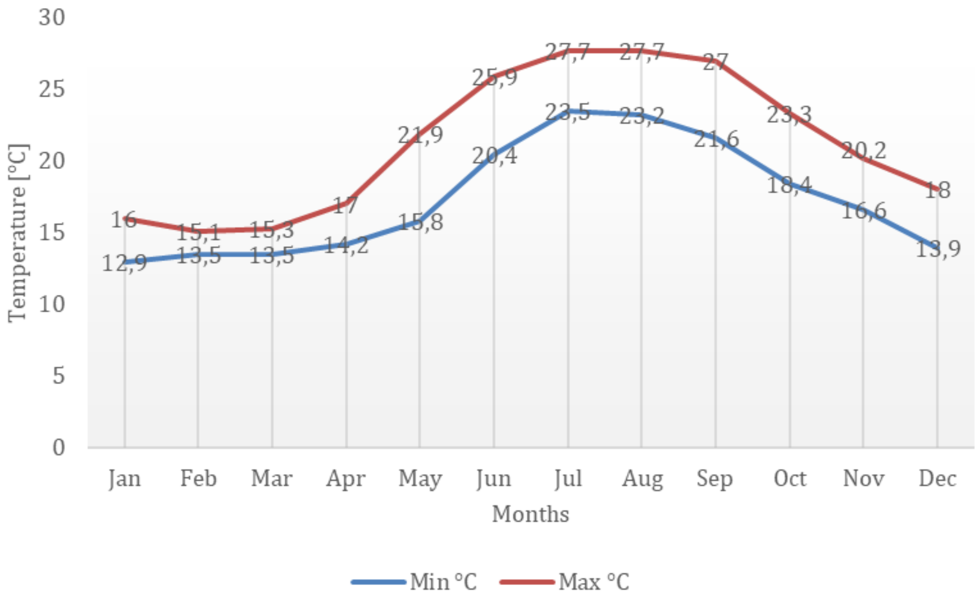


Figure 79. Durrës water temperature

The graph below shows the range of monthly **Vlore** water temperature derived from many years of historical sea surface temperature data.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min °C	13.5	14	14	14.4	16	20.4	23.1	23.3	22	18.6	16.9	14.3
Max °C	16.1	15.5	15.7	17.2	21.4	25.3	27.5	27.5	27.4	23.6	20.5	18.1

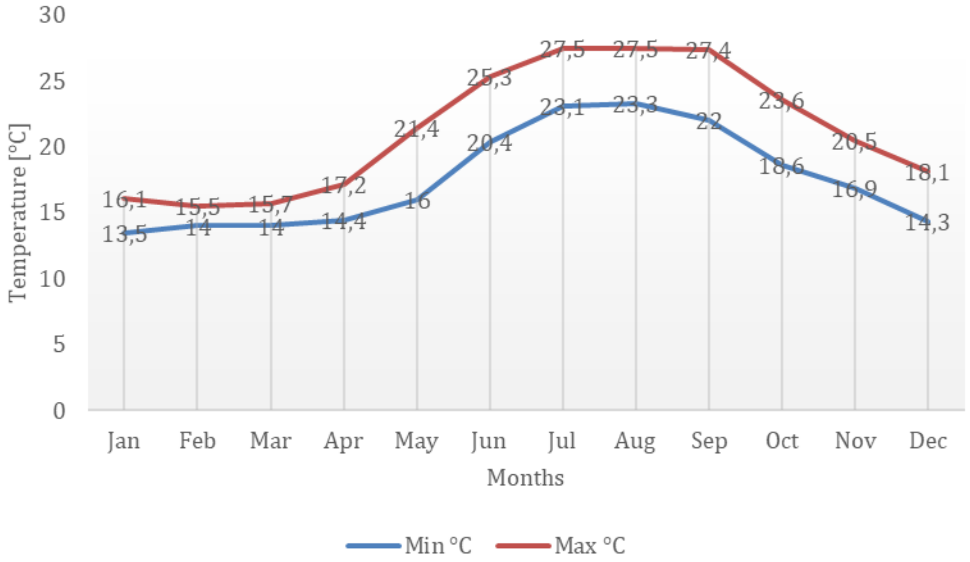


Figure 80. Vlora water temperature

The graph below shows the range of monthly **Sarande** water temperature derived from many years of historical sea surface temperature data.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min °C	14.6	14.4	14.5	14.9	16.5	20.6	23.2	23.6	23	19.8	17.9	15.1
Max °C	16.8	16.2	16.2	17.6	21.9	25.7	27.6	27.7	27.6	24.4	21.3	19.2

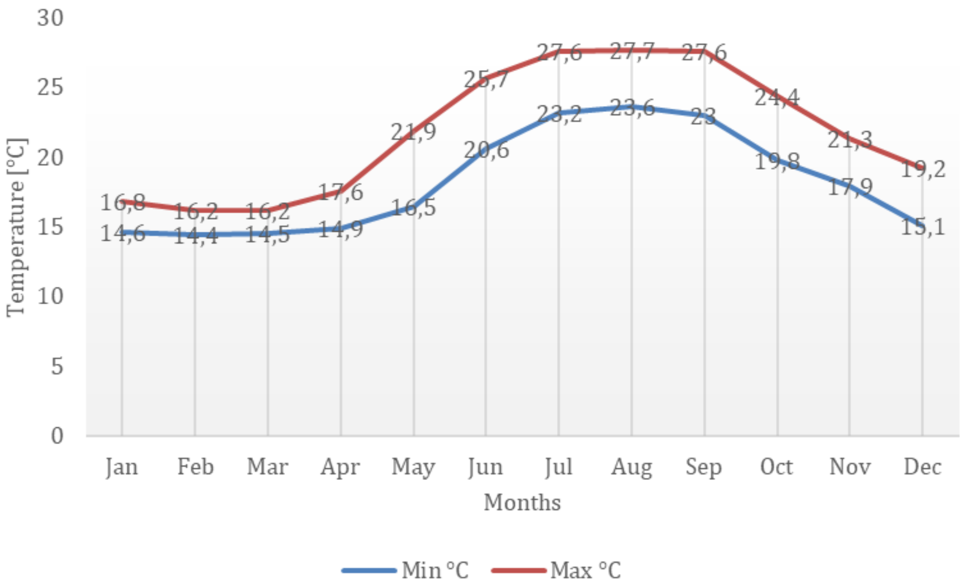


Figure 81. Saranda water temperature

The graph below shows the range of monthly **Shengjin** water temperature derived from many years of historical sea surface temperature data.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min °C	12.9	13.5	13.5	14.2	15.8	20.4	23.5	23.2	21.6	18.4	16.6	13.9
Max °C	16	15.1	15.3	17	21.9	25.9	27.7	27.7	27	23.3	20.2	18

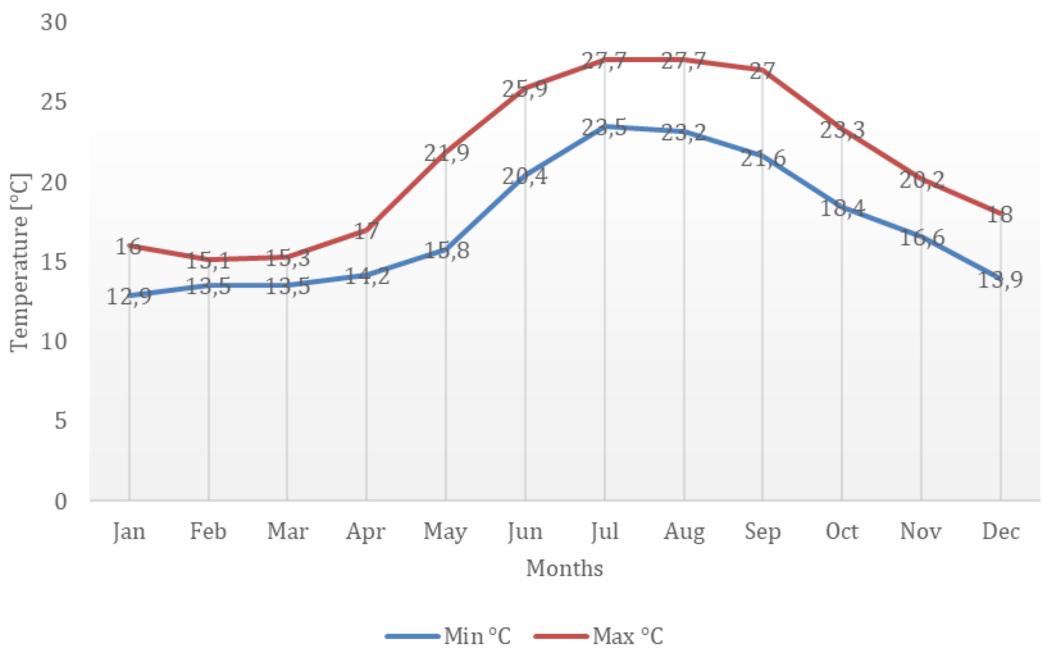


Figure 82. Shengjin water temperature

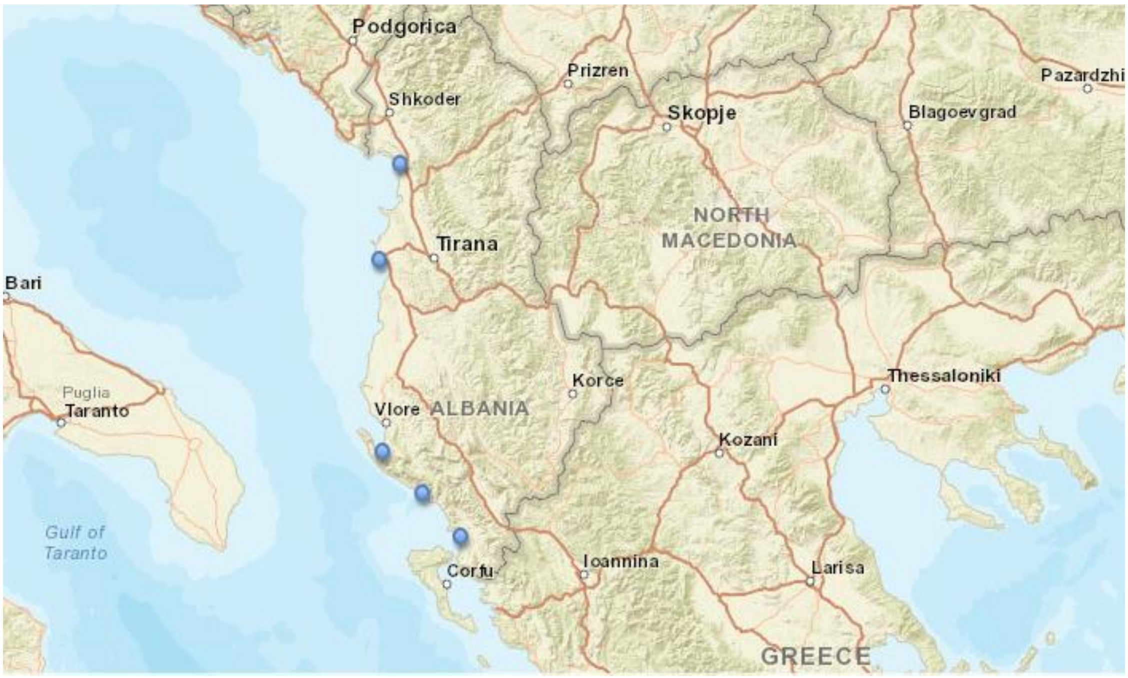


Figure 83. Albania coast with the blue dot marking the temperature spot

5 Conclusion

The analysis of seawater temperatures showed that in most countries, the differences between air and seawater temperatures are higher during winter than during summer. All countries show the difference in air and seawater temperatures during winter, even on a monthly basis, raising the potential for seawater heat pumps. Some countries show a difference in air and seawater temperatures also during winter periods, but some countries have similar monthly seawater and air temperatures during summer.

Not all locations in the Adrian-Ionian territory can be used for seawater heat pumps. Namely, at some location, Adrian and Ionian seas are too shallow, and the temperature of the seawater is too variable. Those locations would not be suitable for seawater heat pumps because their efficiency would drop significantly. Regarding the depths of the sweater, the most critical for the installation of seawater heat pumps is the north of Italy, where the sea is not deeper than 30 m

In the Upper Adriatic, the sea becomes warm in summer, especially in July and August, although, being a closed and shallow sea, it can undergo variations depending on weather conditions. Based on water temperature observations over the past ten years.

In Slovenia average monthly air temperatures during the heating season are up to 5 ° C lower than the sea temperature. Meanwhile, during the summer season, average monthly temperatures are comparable. An accurate daily level temperature analysis would show that in winter season there is an even greater difference that enables better exploitation of sea energy since the temperature of the sea is more stable compared to air and the air temperature fluctuates over the day/night.

For most places in Greece, the seawater surface temperature is almost identical to the air temperature, with reference to the summer period (June-July-August). In order to increase the efficiency of SWHP in comparison to the air source heat pumps, it is proposed to take the water in from at least 20m of depth

The temperatures of the Croatian part of the Adriatic sea depend strongly on the air temperatures, which leads to the warming of the Adriatic in the summer and its cooling in winter. The surface temperature is lowest in February and March, and the highest in August. In winter, the temperatures in the greater part of the basin decrease from more than 13 ° C in the south and east of the basin to less than 8 ° C in its northern and western parts. In summer, the surface temperature is more even and ranges between 24 and 25 ° C while at a depth of 10 to 30 m, the temperature drops sharply with depth (the so-called thermocline layer), to reach a value between 12 and 14 °C at greater depths.

In order to select the best technology for seawater intake, a detailed analysis of local micro-location is needed. In the case of shallow water, the best option is to go with boreholes for intake and discharge of the seawater and on that way, high temperatures of the seawater in the summer period can be easily solved.

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