2014 - 2020 Interreg V-A
Italy - Croatia CBC Programme
Call for proposal 2017 Standard – COASTENERGY

COASTENERGY – Blue Energy in ports and coastal urban areas

Priority Axis: Blue innovation
Specific objective: 1.1 - Enhance the framework conditions for innovation in the relevant sectors of the blue economy within the cooperation area

WP3 Analysis of the potential of integrated Blue Energy production in the Programme area's coasts
Activity 3.2 Regulatory framework and background analysis

D3.2.3 Review of case studies on integrated Blue Energy and RES systems

December 2020

Coordinator:

PP2 – THE INTERNATIONAL CENTRE FOR SUSTAINABLE DEVELOPMENT OF ENERGY, WATER AND ENVIRONMENT SYSTEMS (SDEWES CENTRE)

Partners involved:

LP – IRENA – Istrian Regional Energy Agency

PP1 – CITY OF DUBROVNIK DEVELOPMENT AGENCY DURA

PP3 – UNIVERSITY OF CAMERINO

PP4 – UNIVERSITY OF UDINE

PP5 – COMMUNITY OF MEDITERRANEAN UNIVERSITIES

PP6 – CHAMBER OF COMMERCE INDUSTRY AGRICULTURE AND CRAFT CHIETI PESCARA

PP7 – CITY OF PLOČE

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Project ID Number	10045844
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Work Package Number	3
Work Package Title	Analysis of the potential of integrated Blue Energy production in the Programme area's coasts
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Wave, current and tidal energy

GENERMA	
Group:	Wave energy
Name of project/plant	GENERMA
Location	Z 33 T – 501669.74 E, 4649547.14 N. Termoli, Molise Z 33 T – 404250.92 E, 4780338.64 N. Porto San Giorgio, Marche
Year of commissioning	2015
Name of used technology	Linear alternator
Type of energy source	Wave energy oscillation
Type of energy output	Electricity
Type of project	Implementation of technology and commercialization of the product
Plant status	The prototype is not under continuous operating conditions because it is being moved to collect data in different locations
Involved actors	Generma - Umbria Cuscinetti - Costruzioni meccaniche San Marco - CNM&Co - Quadri Umberto Siderurgia – Guidotti Ships
Nominal power	200 kW – 350 kW – 800 kW
Size	Length 80, width 2.1, height 1.6 m Length 140, width 2.1, height 1.6 m Length 160, width 3.3, height 1.75 m
Annual productivity	471866 kWh
Implementation cost	For 1 MWh plant (4000 MWh/year): procurement and installation 2,500,000 € grid connection 125,000 € authorizations 87,500 €
Payback period	5 years
Operating cost	Maintenance cost 75,000 €/year
Sources of financing	Not available
Reason for interest for COASTENERGY	GENERMA prototype is a wave energy converter device able to be competitively applied in every sea typology. With a lightweight and

	semi-submerged structure, GENERMA floats harmoniously, replicating the movements of the waves. It is a solution for wave energy exploitation based on an innovative and patented converter. The modular system is structured as follow: a semi-submerged unsinkable floating structure, composed by closed profiles manufactured with expanded polystyrene and customizable for each specific site with a standardized production process; linear alternators fitted on the converter and connected to the circuit in a parallel configuration: a break or malfunction of one segment does not cause damage to the others, which remain under normal operating conditions; a self-protection system for extreme sea conditions (beyond a certain sea power threshold): 1) the alternators are automatically disconnected; 2) the auto-driving system is activated with pumps that fill the buoys with water, submerging the whole system; 3) at the end of the storm, the buoys are filled again with air, and the system reacquires its position.
Problems and obstacles	The problems that the system could encounter are closely linked to the positioning of the module and the operation time. The problem related to possible damages caused by extreme sea conditions is solved thanks to the self-protection system (see above). The plant, depending on its position, can interfere with fishing activities. Another problem is seaweeds growing on the module.
Assessment tools and methods	Currently, the assessment tools and methods have not been fully studied because the tests, although started in 2015, were not always done in the same place and the module was removed from the sea and then repositioned.
Environmental and landscape impacts	GENERMA does not affect wave conditions (greatly reducing the environmental impact). Its visual effect is negligible since only the levelling buoys are on the sea surface.

	Under these conditions, it is conceivable that GENERMA will not bring any damage to either the environment or landscape. Furthermore, the deep mooring does not interact with the zone where the waves have effects on the seabed.
Socio-economic impacts	Assessment is not available
Success factors	GENERMA combines excellent production and low installation and maintenance costs, leading to the best economic returns and the lowest LCOE. The modular GENERMA configuration allows an easy installation of small, medium and large plants, also in small and irregular waves environment. GENERMA is applicable everywhere, also in the Mediterranean Sea, where there are scarce conditions for the installation of other technologies.
Transferability in the COASTENERGY area	GENERMA technology could be available in large part of the Adriatic Sea: the minimum wave height suitable for energy production is 0.6 meters, and the modules are not direction dependent. These features make GENERMA a great solution for energy production in most parts of the Adriatic coast.
Keywords	Floating module, wave energy converter, wave power.
Weblink	https://www.generma.com/
Year of data collection	2015-2019
Sources	https://www.estra.it/ef-magazine/notizia/generma-e-l-energia-del-mare/101 https://www.youtube.com/watch?v=rmNrkL36xig

Case study summary

A full validation test phase on GENERMA prototype was performed at sea in Termoli and Porto San Giorgio.

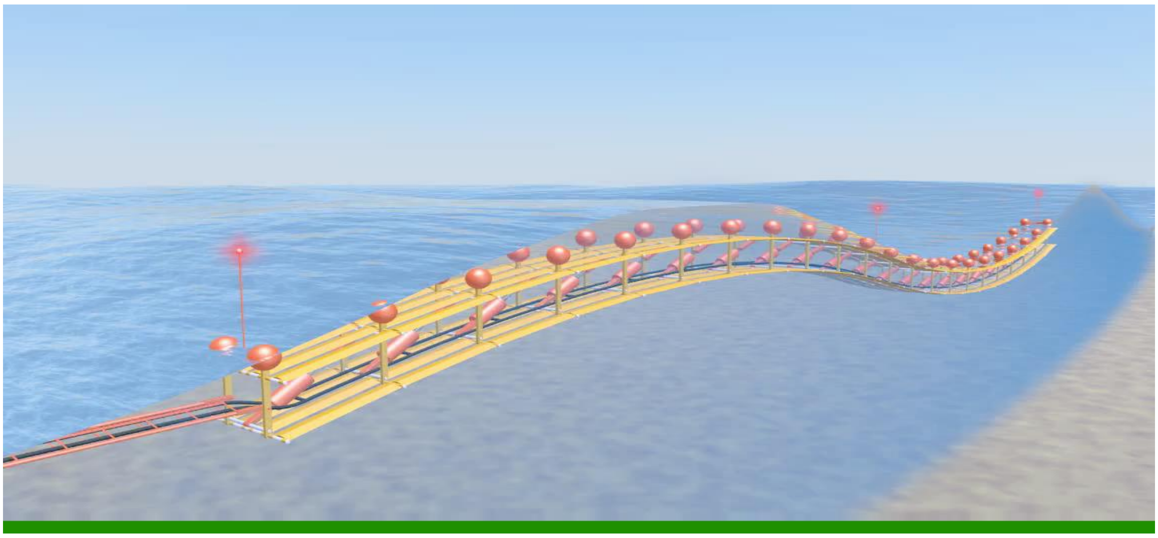

Figure 1 - Prototype scheme

GENERMA summarize their team knowledge in 5 achieved milestone from the discovery in 2013 to present.

Milestone 1 – Discovery (2013, TRL2): GENERMA concept was developed. Fluid-dynamics models of the innovative design for the exploitation of wave energy have been formulated, confirming the converter profile performance potentiality.

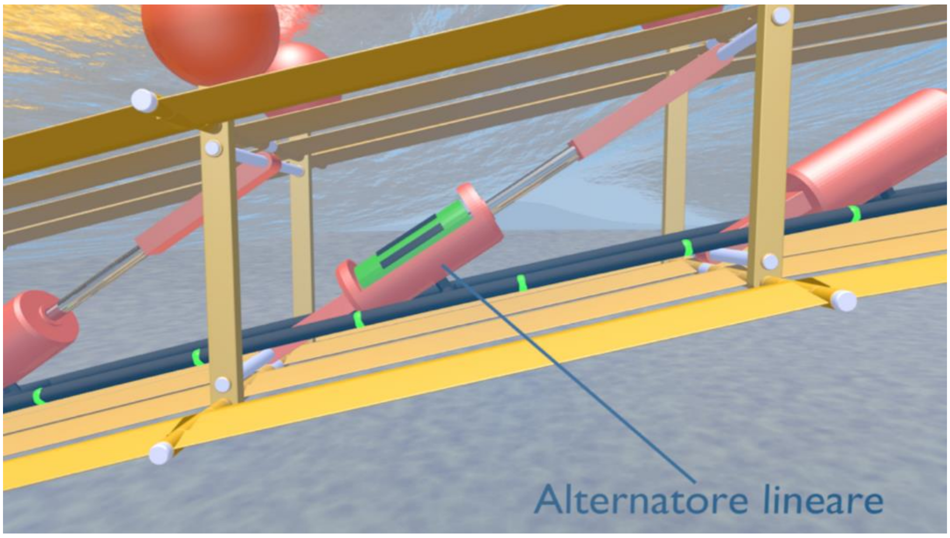

Figure 2 - Linear alternator

Milestone 2 – Lab-scale validation (2014 - 2015, TRL4):

1. first tests on small prototypes performed in the pool with the collaboration of the University of Ancona;
2. technical verification of mechanical components;
3. selection of materials;
4. executive design of the first fully equipped pilot plant (capacity = 5 kW).

Milestone 3 – 5 kW Prototype Manufacturing (2016 - 2017): 1:20 scale prototype manufactured. A partnership agreement was defined with Umbra Group (a 200 M€ yearly turnover company leader in mechanical components design and production) for the development of the linear alternator.

Milestone 4 – Validation at sea (2018, TRL6):

5. a full validation test phase was performed at sea in Termoli and Porto San Giorgio for more than one year;
6. the average power coefficient of 0.5 (0.7 peaks) was confirmed, together with the reliability of the self-protection system;
7. linear alternator performance was optimized;
8. the fluid-dynamics model has validated thanks to the testing results, and the Minimum Viable Product (MVP) generator (100 kW) behaviour was simulated to optimize the floating structure profile.

Milestone 5 – Scale-up (2019):

9. selection of 100 kW module as MVP;
10. definition of the strategy for the modular series production
11. the schematization of the purchase of components, processing, assembly and installation work phases;
12. approaches to the market with direct contacts to customers and renewable energy operators. First agreement with Edison, one of the largest players in the Italian energy sector (10 bln € turnover, 6.3 GW of power generation plants installed in Italy).

Table 1 - Technical specification of the model

Model	G-200	G-350	G-800
Power	200 kW	350 kW	800 kW
Wave condition	0.6 – 4 m	0.7 – 5 m	0.9 – 6 m
Weight	12 tons	22 tons	38 tons

Surface	168 sq. m	294 sq. m	528 sq. m
Working area	150-meter radius circle	210-meter radius circle	230-meter radius circle
Estimated lifetime	25 years with maintenance	25 years with maintenance	25 years with maintenance

Resonant Wave Energy Converters (REWEC3)	
Group:	Wave energy onshore
Name of project/plant	POSEIDONE project – DIMA-FP TW1.5 turbine
Location	Z 32 T – 728252.88 E, 4665333.32 N. Civitavecchia, Lazio
Year of commissioning	2015-2016
Name of used technology	DIMA-FP TW1.5 turbine
Type of energy source	Wave energy Oscillating Water Columns
Type of energy output	Electricity
Type of project	Implementation of technology
Plant status	The plant is operating in Civitavecchia Port
Involved actors	Faggiolati Pumps, Wavenergy.it, Università Mediterranea di Reggio Calabria, CRAS La Sapienza
Nominal power	16-25 MWh/km
Size	For a 1 MWh plant: length 200 m, width 6 m, height variable
Annual productivity	6000-9000 MWh/km/y
Implementation cost	For a 1 MWh plant: Turbines 4,000,000 € Structures 832,000 € Grid connection 125,000 €
Payback period	3 years
Operating cost	Maintenance cost 32,000 €/year

Sources of financing	Not available
Reason for interest for COASTENERGY	The REWEC3 device is composed of a chamber containing a water column in its lower part and an air pocket in its upper part. The air pocket is connected to the atmosphere via a small duct hosting a self-rectifying turbine. In addition to that, REWEC3 includes a small vertical U-shaped duct for connecting the water column to the open sea. The working principle of the system is quite simple: by the action of the incident waves, the water inside the U-shaped duct is subject to a reciprocating motion. This motion induces alternately a compression and an expansion of the air pocket, which generates airflow in the air duct. A turbine coupled to an electric generator, installed into the air duct, is driven in this way to produce electric energy. From a design perspective, the main feature of the REWEC3 is the fact that the natural period of the water column inside the plant is determined at the preliminary design stage to match the desired period.
Problems and obstacles	The technical and administrative problems of the REWEC3 system are the same as those of a port defence; also, as the turbine is fixed to the dam, it could be difficult to reach and therefore to perform extraordinary maintenance in case of breakdowns. Another problem is that the system depends on the wave direction: it correctly works only with waves directing towards the coast.
Assessment tools and methods	Although the plant is operational, there is still no data allowing to derive a cost/benefit analysis.
Environmental and landscape impacts	The REWEC3 system was designed to replace traditional port and coastal defence works, for this reason, its installation would not cause further discomfort concerning the environment and landscape because it would not change the current conditions.
Socio-economic impacts	The REWEC3 technology is very promising in terms of competitiveness in the renewable energy market and the possibilities of application on a commercial scale. The new devices are an advancement of the Oscillating Water Column (OWC), already used internationally for full-

	scale applications. REWEC3 guarantees higher energy efficiency compared to the classic OWCs. At the same time, its construction technique is very close to that of the cellular harbour containers in reinforced concrete. It is expected, therefore, that the economic coefficients of the new REWEC3 technology will surely be better than those of similar systems, such as the OWC.
Success factors	There are many port defences which work along the Italian coasts. Currently, these defences work to serve the sole function of delimiting artificial basins to protect boats and structures. With the inclusion of turbines into traditional, reinforced concrete cellular harbour containers, the port defence will also have an active function of producing electricity without affecting the landscape or the environment. For this reason, the REWEC3 system has a good chance of success because it could exploit existing infrastructure without new specific developments.
Transferability in the COASTENERGY area	The REWEC3 system can be applied in all port defences and parallel coastal defence works, for this reason, it is a valid solution for the COASTENERGY project. The only limitation of this system is its dependence on the direction of waves.
Keywords	Oscillating Water Column, wave energy converter, wave direction.
Weblink	https://www.wavenergy.it/
Year of data collection	2014-2019
Sources	http://www.faggiolatipumps.it/Turbina_conversione_energia.pdf https://www.wavenergy.it/projects/gre-ene-log/ https://www.enea.it/it/seguici/events/energia-dal-mare/Arena1.pdf https://maestrale.interreg-med.eu/news-events/news/detail/actualites/the-rewec3-device-in-civitavecchia-port/

Case study summary:

The first REWEC3 prototype docked in October 2015 in the port of Civitavecchia, and other two project projects will soon sail to the ports of Salerno and Roccella Jonica.

Figure 3 - Work in progress

The project for the port of Salerno consists in the construction of a 200 m breakwater structure, made by five caissons, three of which will be developed as a REWEC3 device. The technology of these devices allows the absorption and the conversion of the incident wave energy into electric energy through an optimized air turbine. Thanks to the REWEC3 implementation, the port of Salerno can become one of the most advanced and efficient ports in Europe.
The project for Roccella Jonica will include, at first, the construction of two caissons for a total

length of 30 m, which can be extended in the future by adding new caissons to increase the energy production and make the port totally "green".

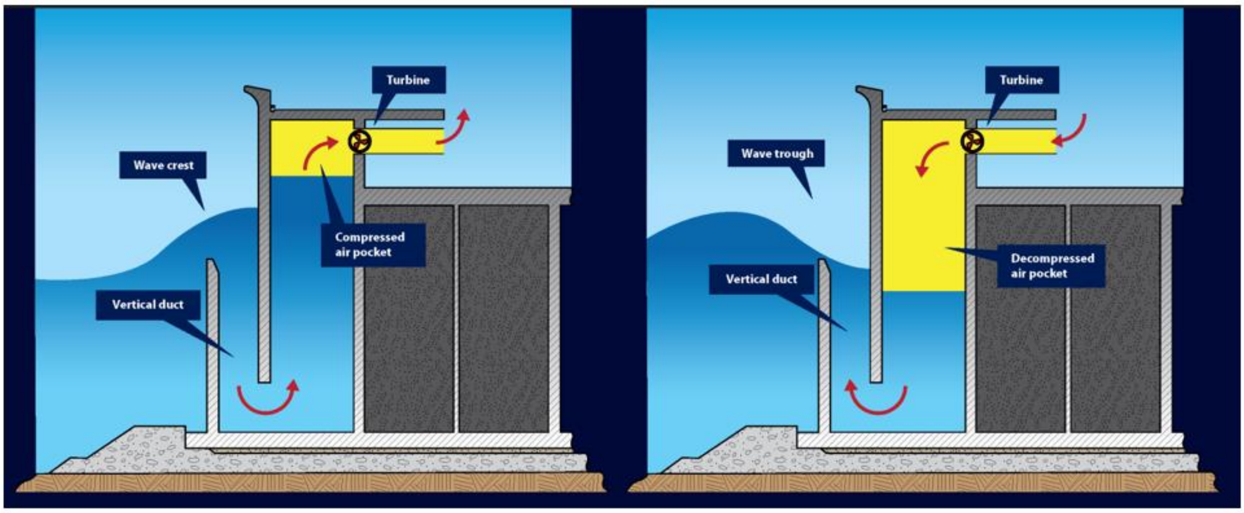

Figure 4 - System scheme

From an engineering perspective, the REWEC3, compared with a conventional OWC, introduces substantial improvements, useful in the perspective of wave energy exploitation. Specifically:

13. the opening is closer to the sea surface. This feature induces less attenuation in the wave pressure exciting the device;
14. the REWEC3 cross-section, compared to a classical OWC, is U-shaped. This new configuration does not introduce significant modifications in the structural feature, but radically changes the physics of the plant with respect to classical OWCs. Sea waves do not propagate to the inner pneumatic chamber. Still, the oscillations of the water surface inside the chamber are induced by the wave pressure fluctuation at the opening of the vertical duct.
15. Further, an additional mass is provided to the system. This fundamental property allows for the achievement of the natural resonance without the use of any phase control devices required in the conventional OWC;
16. the natural resonance significantly enhances wave energy absorption in comparison with conventional OWC. That is related to the facts that:
    a) the resonance could also be achieved at high frequency (low period) useful for the exploitation of the wave energy resource even in the Mediterranean Sea, characterized by low incident mean wave power (in deep water in

Civitavecchia it has a yearly average of about 2.25 kW/m, whereas in the Atlantic coasts of Spain and Portugal it is between 30 and 60 kW/m);

b) the natural period of oscillation of the water column inside the pneumatic chamber can be tuned, during the design stage, to the desired period (to which the greatest amount of available wave energy resource is associated), allowing for maximizing the energy harvested by the REWEC3 collector at the considered location. In Civitavecchia, wave height between 2 m and 3.5 m is the design sea states used for tuning the Eigen period of the water column oscillations.

WaveStar	
Group:	Wave energy
Name of project/plant	Wave Star
Location	56.69673 8.344315 Nissum Brednind Sea at Helligsø Teglværk Danimarca
Year of commissioning	Test machine at Aalborg University • Deployment: 2004-2005 • Scale: 1/40 • Float diameter: 0.25 m Test machine at Nissum Bredning • Deployment: 2006-2010 • Scale: 1/10 • Float diameter: 1.0 m Test section at Roshage • Deployment: 2009-2016 • Scale: 1/2 • Float diameter: 5.0 m
Name of used technology	WaveStar machine
Type of energy source	Wave energy oscillators
Type of energy output	Electricity
Type of project	Implementation of technology and commercialization of the product
Plant status	The Wavestar machine is under rebuilding and will be extended with two more floats and updated with a new state-of-the-art power take-off system (PTO). The machine is consequently out of operation, and live data are temporarily unavailable.

Involved actors	Wave Star A/S: Developer and designer Aalborg University: scientific partner EnergiNet.dk: commercial partner Currently, Wavestar has formed an industrial consortium with the purpose to produce the first full-scale 1 MW Wavestar WEC to be tested commercially. The consortium behind the EU application consists among others of STX, IFP EN, DNV and Aalborg, Gent and Cantabria Universities.
Nominal power	600 kW – 1200 kW
Size	Scale 1/40 Scale 1/10 Scale 1/2
Annual productivity	1.41 GWh
Implementation cost	Information not available
Payback period	Information not available
Operating cost	Information not available
Sources of financing	Wavestar is requesting EU for support through Horizon 2020.
Reason for interest for COASTENERGY	The Wave Star project is sustainable and efficient. It is a simple, reliable design, which can be storm protected. It sits on piles, just like an offshore structure. All moving parts are above water and are well protected from the sea environment. It is only based on standard components, standard offshore and wind turbine technology. It is scalable into multi MW converters. Energy production with wave energy is more predictable than wind because waves come and go slowly and can be forecast 24 hours. The challenge is to create a regular output of energy from waves. This is achieved with a row of half-submerged buoys, which rise and fall in turn as the wave passes. This allows energy to be continually produced despite waves being periodic. Wave energy is the largest unused renewable source in the world, with extremely high energy density, high predictability and low variability, and will

	play a crucial role in securing our energy future, ensuring a continuous supply of clean energy. The Wavestar machine could also be installed together with a wind turbine which would further increase efficiency and reduce set-up costs.
Problems and obstacles	The problems that the system could encounter are closely linked to the positioning of the module and the operation time. The machine's unique storm protection system, one of the many patented aspects of the design, guarantees the machine's sea survivability and represents a real milestone in the development of wave energy machines. Still, this technology must deal with a particularly aggressive environment such as the sea. The waves energy potential along the Italian coasts is very varied and has its highest values along the west coast of Sardinia (12 kW/m) and along the north-western coast of Sicily (7 kW/m). The Tyrrhenian and Ligurian coasts also have an interesting energy potential (3-4 kW/m), while Adriatic coast potential is lower, generally less than 2 kW/m. This factor could limit the applicability of this technology in this area. Other limits of wave energy are represented by installation and maintenance costs. The technological innovation is aimed at both increasing the efficiency of energy conversion and decreasing construction, maintenance and installation costs. By optimizing the executive design phases of the production units and exploiting the economies of scale, this will be achievable, also thanks to scientific and industrial partners.
Assessment tools and methods	Extensive tests were performed on different scale models installed in different places. Currently, Wavestar is testing new promising PTO system. Wavestar is in the process of documenting the results of the new PTO (power take-off) system. The system will increase the efficiency of the wave energy machine significantly. This is a crucial factor in making wave energy a competitive source of renewable energy in line with offshore wind. Wave motion between 0-3 meters is simulated on a full-scale test apparatus at Aalborg University and measure the power effect of our newly developed digital hydraulic system. The test results can be transferred directly to the real full-scale machine.

Environmental and landscape impacts	The wave energy technology has the advantage of minimally interfering with other production activities insisting on the coastal strip, such as the fishing industry and tourism. The Wavestar machine is less visible and quieter than wind turbines, and it also has a positive impact on wildlife below the machine, creating a sanctuary enhanced by the limits on nearby fishing. It is characterized by a little use of soil and a limited visual and environmental impact, being delocalised into the sea and half-submerged; it doesn't contain dangerous liquids, electromagnetic radiation; maintenance is easy thanks to direct access to the equipment, and the mooring system has an almost zero impact on the seabed. The visual impact is reduced to a minimum thanks to the buoyancy on the water surface.
Socio-economic impacts	From the economic/employment point of view, this technology can have a strong impact on various industrial sectors, among which: • mechanics, for the construction of the mechanisms of conversion of wave energy into mechanical energy, for the systems of stabilization and mooring; • electrical, for the components of conversion systems from mechanical energy to electrical energy and for connection to the national electricity grid; • electronic, for control systems of energy flow between the device and the electricity grid. In these sectors, many small and medium-sized companies can benefit from the nascent energy sector from the sea. The availability of clean and renewable energy from marine sources can have a noticeable effect on the development of local economies, with the creation of new jobs for the installation and maintenance of the systems.
Success factors	- Simple installation - Easy and low-cost maintenance system The Wavestar machine could also be installed together with a wind turbine, further increasing efficiency and reducing set-up costs, ensuring a continuous supply of clean energy.
Transferability in the COASTENERGY area	The potential energy along the Adriatic coast is lower. This factor could limit the applicability of this technology in the area.

Keywords	Wave energy, Wave energy converters, SSG, Wave Star, Real sea testing, Wave overtopping, Low head turbines float, renewable and clean sources
Weblink	http://wavestarenergy.com
Year of data collection	2015
Sources	http://wavestarenergy.com https://en.wikipedia.org/wiki/List_of_wave_power_projects https://www.green.it/moto-ondoso-wave-star http://fondazionesvilupposostenibile.org/f/tecnomac/Wave_Star_System.pdf

Case study summary:

The concept was invented by sailing enthusiasts Niels and Keld Hansen in 2000 when they were sailing near their parents' summer house. They began to talk about how they could harness the powerful forces beneath them. The challenge was to create a regular output of energy from ocean swells and waves that are 5-10 seconds apart. This was achieved with a row of half-submerged buoys, which rise and fall in turn as the wave passes. This allows energy to be continually produced despite waves being periodic.

The Wavestar machine draws energy from wave power with floats that rise and fall with the up and down motion of waves. The floats are attached by arms to a platform that stands on legs secured to the seafloor. The motion of the floats is transferred via hydraulics into the rotation of a generator, producing electricity.

Waves run the length of the machine, lifting 20 floats in turn. Powering the motor and generator in this way enables continuous energy production and a smooth output. This is a radical new standard and a unique concept in wave energy; it's one of the few ways to convert fluctuating wave power into the high-speed rotation necessary to generate electricity.

The machine's unique storm protection system, one of the many patented aspects of the design, guarantees the machine's sea survivability and represents a real milestone in the development of wave energy machines.

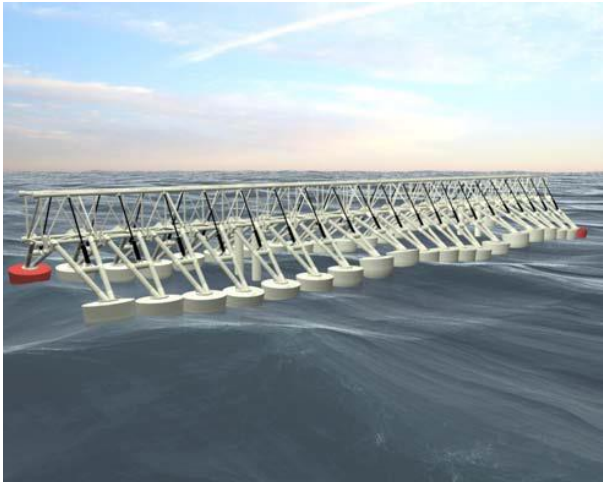

Figure 5 - Illustration of Wave Star in normal operation mode (left) and in storm safe mode (right)

The Wave Star machines

17. Test machine at Aalborg University:
    - Deployment: 2004-2005
    - Scale: 1/40
    - Float diameter: 0.25 m
18. Test machine at Nissum Bredning:
    - Deployment: 2006-2010
    - Scale: 1/10
    - Float diameter: 1.0 m
19. Prototype test section at Hanstholm:
    - Deployment: 2009-2016
    - Scale: 1/2
    - Float diameter: 5.0 m

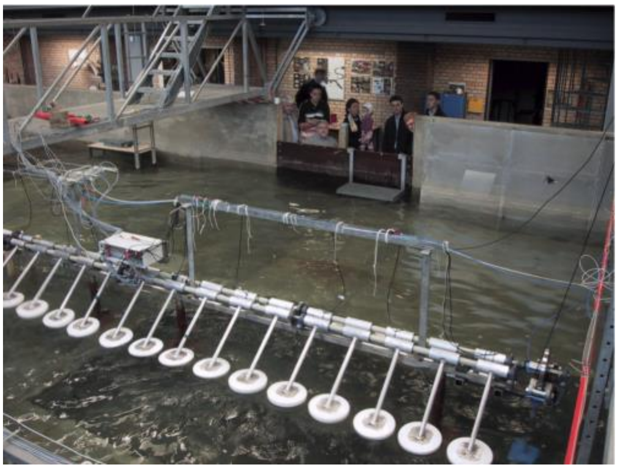

Figure 6 - Early scale 1:40 Wave Star Energy test model in the wave test tank at Aalborg University in 2004

1/40 scale

In 2004 extensive tank testing was performed on a scale 1:40 model with the sole purpose of optimising the basic configuration of the system and to document the electrical power production in typical North Sea waves. More than 1,300 different test runs were performed to optimise the concept and were used to document any technical questions about the concept as they arose from the testing.

1/10 scale

In 2005 the first grid-connected scale 1:10 model was designed and built for operation in the sea at Nissum Bredning where the waves are approximately 1:10 of North Sea waves.

It was designed as if it was a big scale machine in order to learn about the practical issues of operation in the sea. The system contained all the instrumentation and control systems necessary to work unattended round the clock. After the final dry testing, the scale 1:10 model was installed on 6 April 2006 and put into round the clock operation on 24 July 2006. Since then it has logged more than 15,000 operational hours in the sea and been through 15 storms without any damage. By international standards, it is quite an achievement because nobody has test systems in the sea which just work, without major technical problems.

Figure 7 - Nissum Bredning installation at Helligsø Teglværk

1/2 scale

The test section of the 600 kW machine has been installed at Hanstholm the 18 September 2009. The installation was performed in two days. A bridge was built to access the machine in autumn 2009, and the first guest could visit the plant during the COP15. The machine has been connected to the grid since February 2010.

Since May 2010 a monthly production report has been made and delivered to Energinet.dk. Wave Star received a payment from EnergiNet.dk every time the production was above the green curve.

The green curve had been agreed with energiNet.dk based on estimated production figures from the beginning of the test.

The reports contained both wave information (wave height, period, etc.) and information on the wind (speed, direction, etc.). EnergiNet.dk studied the data to show a correlation between wind and wave.

Figure 8 - The Wavestar prototype (above, a 2-float section of the full 20-float machine (below):

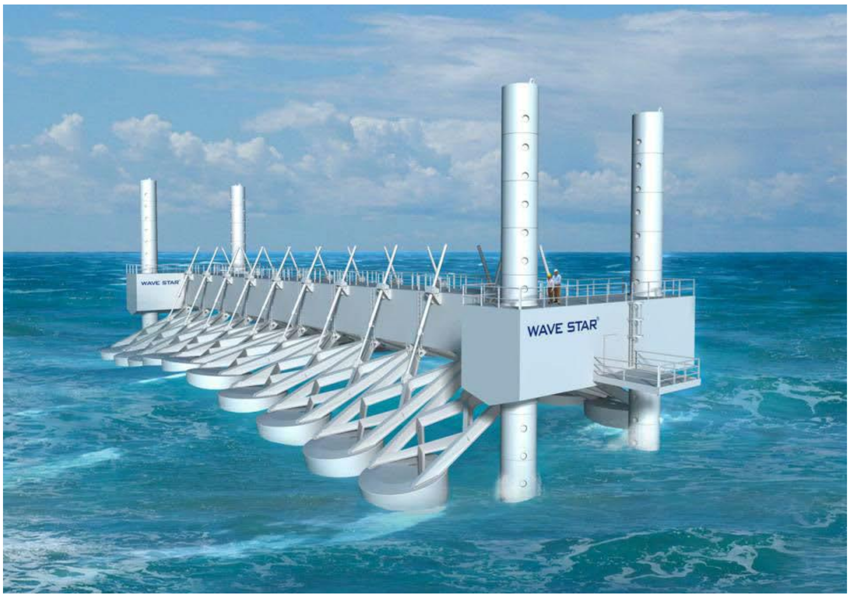

Table 2 - Technical parameters

Parameter	Hanstholm prototype	Commercial Wavestar 0.6 MW
Number of floats	2	20
Float diameter	5 m	5 m
Arm length	10 m	10 m
Weight	1000 ton	1600 ton
Nominal electrical power	110 kW	600 kW

The Wave Star Energy concept is scaled according to stringent scaling laws from scale 1:40 to 1:10 and now 1:2. Each time the system is doubled in size, in all three dimensions, the water depth and wave height are doubled accordingly. This is according to the so-called Froude´s scaling laws and is like basic physics for waves. When loads and power output are measured on a scale model, the loads and the power on the next size scale model can be accurately predicted, and later proven when the next size scale model is being built and put into operation. This consistency helps minimise scaling risks and has already proven itself in the earlier scaling stages from 1:40 and 1:10. The results obtained from the test section in Hanstholm are completely transferable to the 600 kW machine as the test section is a part of it.
In that respect, Wave Star is able to produce a power matrix for the 600 kW machine:

Wave height H_{m0} (m)	Wave period $T_{0,2}$ (s)										
	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 11	11 - 12	12 - 13
0.0 - 0.5	0	0	0	0	0	0	0	0	0	0	0
0.5 - 1.0	0	49	73	85	86	83	78	72	67	63	59
1.0 - 1.5	54	136	193	205	196	182	167	153	142	132	123
1.5 - 2.0	106	265	347	347	322	294	265	244	224	207	193
2.0 - 2.5	175	429	522	499	457	412	372	337	312	288	267
2.5 - 3.0	262	600	600	600	600	540	484	442	399	367	340
3.0 -	Storm protection										

Figure 9 - Wave parameters

Results for production in a different location are now predictable as it is based on the power matrix together with a scatter diagram for the chosen area.

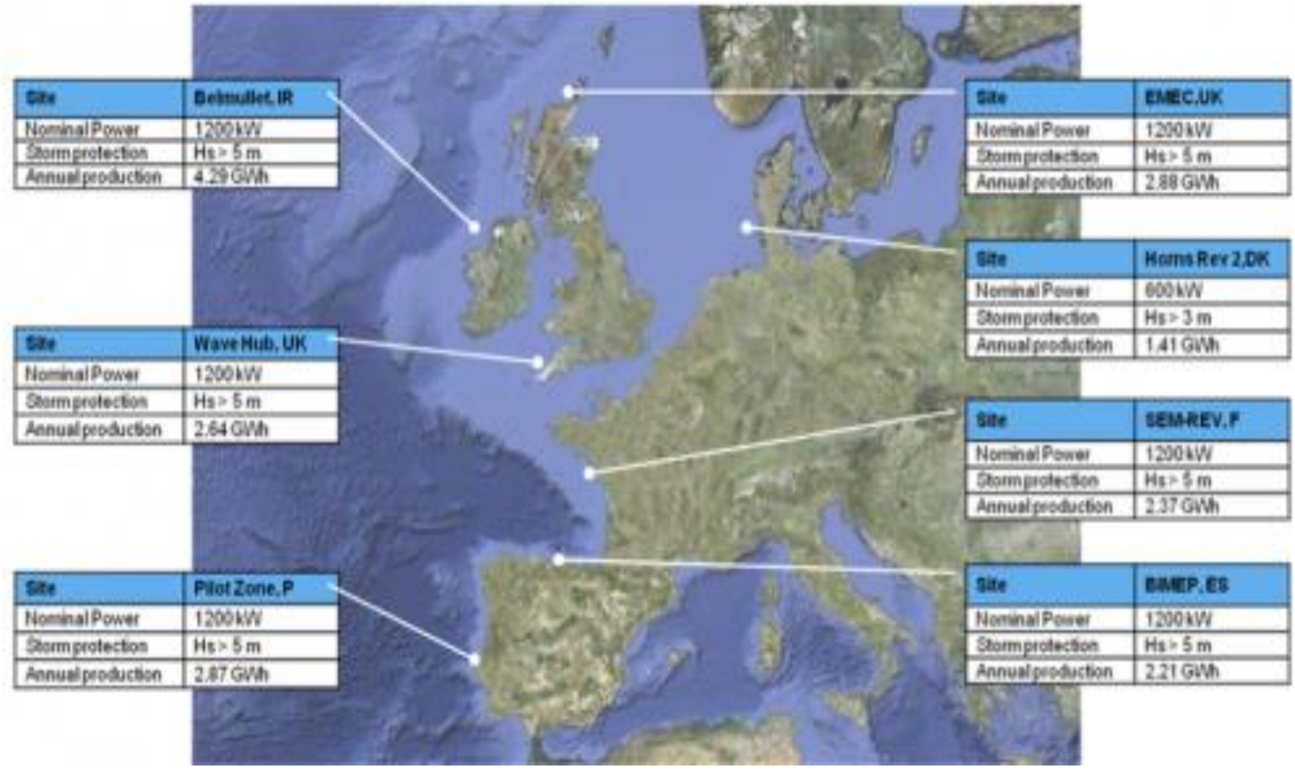

Figure 10 - Location of plants

The machine should be adaptable according to the sea conditions and to the most efficient cost of energy. The scalability of the machine (floats from 5 to 10 m in diameter) makes it very adjustable to sea conditions.

Survivability at sea is a big problem for wave energy devices. But unlike any other wave energy concept, the Wavestar's sea survivability is guaranteed, and the concept has been proved during many years of continuous operation at sea. It can continue production in strong wind and waves, and automatically raises the floats out of the sea when the conditions become too stormy.

The Wavestar machine's efficiency is being continually increased. The design was recently modified to reduce the cost by 40 per cent, while energy harvesting capacity and other aspects of the machine are being constantly improved for better efficiency.

Currently, Wavestar is testing new promising PTO (power take-off) system. The system will increase the efficiency of the wave energy machine significantly. This is a crucial factor in making wave energy a competitive source of renewable energy in line with offshore wind. Wave motion between 0-3 meters is simulated on a full-scale test apparatus at Aalborg University and measure

the power effect of the newly developed digital hydraulic system. The test results can be transferred directly to the real full-scale machine.
Wavestar is requesting EU for support through Horizon 2020 in May. Wavestar has formed an industrial consortium with the purpose to produce the first full-scale 1 MW Wavestar WEC to be tested commercially. The consortium behind the EU application consists among others of STX, IFP EN, DNV and Aalborg, Gent and Cantabria Universities.

GEM – Horizontal axis marine turbine	
Group:	Marine turbine
Name of project/plant	GEM
Location	45° 22′ 18.12″ N, 12° 20′ 17.88″ E The Mediterranean Sea, Malamocco (VE), Italy
Year of commissioning	2010
Name of used technology	Horizontal axis marine turbine
Type of energy source	Tidal stream energy
Type of energy output	Electricity
Type of project	Prototype
Plant status	Operational
Involved actors	SeaPower LLC ADAG (Aircraft Design & Aeroflight Dynamics Group) research group of the Department of Industrial Engineering – Aerospace division (DII), University of Naples "Federico II."
Nominal power	100 kW at 2.6 m/s
Size	5.2 m x 9.2 m x 10.4 m
Annual productivity	300 MWh (average annual production planned for a site with a maximum current speed of 2.5 m/s)
Implementation cost	€ 1.7 M
Payback period	4 years with Italian feed-in tariff
Operating cost	Maintenance cost 20,000 €/year
Sources of financing	Government incentive: 34 € cent/kWh
Reason for interest for COASTENERGY	The horizontal axis marine turbine GEM, "the Ocean's Kite", is a hydrokinetic turbine designed to be driven by slow-moving flows of water, namely river, tidal or water currents in general. GEM has, among other innovations, efficient blade section airfoils, self-aligning capability, shrouded rotor with three carbon blades 3 meters long, and a winch allowing: positioning at the desired depth, fast deploying, fast recovery and low-cost maintenance.

Problems and obstacles	Specific problems and obstacles have not been detected.
Assessment tools and methods	Assessment tools and methods have not been studied.
Environmental and landscape impacts	GEM has a low environmental impact. Investigation of environmental impact has been performed. As a result, the only special measure adopted has been the addition of a safety chain in the event of a tethering cable break.
Socio-economic impacts	GEM deployment has received relatively large attention by national and international media with local population happy about this innovative system.
Success factors	The energy from marine currents has the advantage of being predictable even in the long term with extreme precision, with practical benefits in terms of energy supply approval plans and network services. Other success factors: GEM is relatively cheap. GEM is easy to maintain. GEM has a low environmental impact. GEM does not disturb the navigation. GEM is installable almost anywhere.
Transferability in the COASTENERGY area	GEM is a technology that could be available in the Adriatic Sea. It can be easily towed to the installation site and, thanks to the self-towing winch, it can be positioned at a predetermined depth. GEM is a technology that could be useful to bring energy to remote places on the planet where even today electricity production is insufficient or is very expensive and polluting, for example in some islands of the Philippines or Indonesia, exploiting the natural resources.
Keywords	Marine turbine, tidal stream energy, wave power
Weblink	http://www.seapowerscrl.com/
Year of data collection	2010-2019
Sources	http://www.adag.unina.it/italiano/ricerca/rinnovabili/gem.html http://www.seapowerscrl.com/ocean-and-river-system/gem#slide_9

Case study summary:

The horizontal axis marine turbine GEM, "the Ocean's Kite", is a hydrokinetic turbine designed to be driven by slow-moving flows of water, namely river, tidal or water currents in general.
The patented turbine has been developed since 2005 after a research project done in collaboration with ing. Nicola Morrone, who is the patent holder together with prof. Domenico Coiro, professor at University of Naples "Federico II" (Department of Aerospace Engineering) and coordinator of the ADAG Research Group.

Figure 11 - The GEM system

How GEM Works:

The GEM system can be easily towed to the installation site, and thanks to the self-towing winch can be positioned at a predetermined depth (standard depth: 13 m). In the absence of current, the GEM assumes the position shown in Fig. 3 below. When the water current is flowing, it assumes the position as shown in Fig. 2 below. For maintenance, GEM can be easily brought to the surface by simply releasing the tension of the mooring line Fig. 1 below. The main characteristic of GEM, however, is its passive capacity of aligning itself along the current direction (as shown in Fig. 4 below) and this reminds the typical behaviour of a kite from which the name

"Ocean's Kite". In case of need, however, it is possible to control this alignment through the aid of a controlled designed system which uses the turbines as propellers.

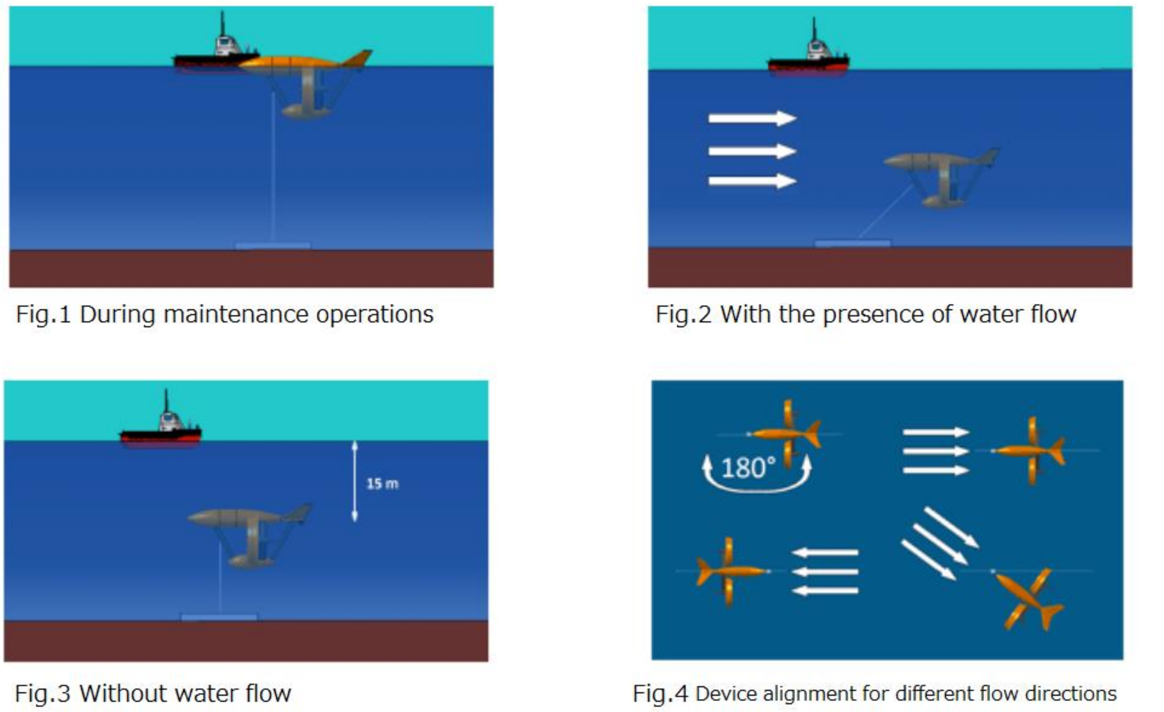

Figure 12 - Work principle animation

Performance data of 100 kW prototype

- Total weight: 10,700 kg
- Buoyancy force: 5,200 kg
- Depth (range): 15 m to 9.8 m (without current)
- Nominal power: 100 kW with a tidal current of 2.6 m/s
- Three-blade, 3 m diameter rotor
- Innovating blade section profiles
- Carbon blades – Fiberglass diffuser
- Rated rotation speed: 65 rpm
- Rotor Efficiency: 0.8
- Expected average yearly production with 2.5 m/s of maximum current speed: 300 MWh

Dimensions and components

- Length: 9.2 m
- Height: 5.2 m
- Width: 10.4 m

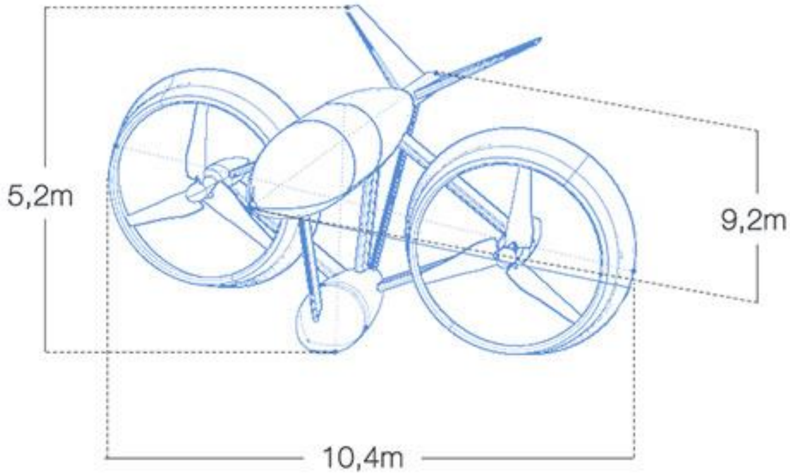

Figure 13 - Tidal turbine illustration

The GEM is basically made of the following parts:

- a buoyant unit;
- two contra-rotating turbines, with three blades, attached to two electrical generators, symmetrically positioned on the two sides of the frame;
- two diffusers, mounted around the two turbines, shaped to double the power output;
- a barrel-shaped container placed at the foot of the frame, and containing a winch;
- a mooring block laid on the seabed to which a mooring line is connected;
- an electric cable to connect the electrical generators to the grid; the electric cable running along the mooring line;
- tailplanes to provide stability;
- an automatic control system based on the differential turbine/propeller action to control orientation during current direction reversal.

ISWEC	
Group:	Wave energy
Name of project/plant	Wave for Energy (W4E)
Location	44°29'51.70"N – 12°20'52.86"E, Ravenna, Emilia-Romagna 36°49'48.67"N – 11°59'10.83"E, Pantelleria, Sicilia
Year of commissioning	2015, 2019
Name of used technology	ISWEC (Inertial Sea Wave Energy Converter)
Type of energy source	Wave and solar energy
Type of energy output	Electricity generation integrated by the wave and photovoltaic
Type of project	Transformation of the pilot project Inertial Sea Wave Energy Converter (ISWEC) into an industrial-scale project
Plant status	The first test plant is operational since March 2019 offshore Ravenna
Involved actors	Cassa depositi e prestiti (CDP) Fincantieri Terna ENI Politecnico di Torino (PoliTO) – spin off Wave for Energy LLC
Nominal power	100 kW – 130 kW
Size	8.0 x 15.0 m Height 4.5 m (drought 3.2 m, height above sea level 1.30 m)
Annual productivity	Not available
Implementation cost	Not available
Payback period	Not available
Operating cost	Not available
Sources of financing	Not available
Reason for interest for COASTENERGY	This technology has been developed by Politecnico di Torino, Wave for Energy LLC and, later, ENI. It has been specifically developed for the Mediterranean Sea. It is a structure with low environmental impact, similar in size to a small boat moored not far from the coast.

	Differently from other systems, existing or under development in Europe, it has no moving parts that can harm the sea fauna. This machine exploits wave frequency rather than height. It works thanks to an inertial system exploiting wave motion: the waves cause a movement of the hull, which is transmitted to two 10-ton metal flywheels that, thanks to a gyroscopic effect, produce a motion able to generate electricity. Another innovation consists in the possibility to tune the machine according to the variations of the sea conditions, without exposing important parts to the aggressive sea environment (which happens to most other systems exploiting wave motion), preventing corrosion and deteriorations. The main system is placed in a watertight chamber and does not come into contact with water. The raft containing the instruments has a surface of 120 sq m (8 x 15 m) and a height of 4.5 m (of which 3.2 are submerged). The plant has a nominal power of 100 kW, and the whole system weighs 300 tons. When in operation, the device is 80 % submerged, the visible part is a floating platform with boat lights, resulting in a low visual impact. It is removable, does not contain hazardous liquids, does not emit electromagnetic waves, is not noisy, and can be moored loosely. It does not need to interact with the sea system and the seabed. Moreover, little maintenance is needed. Energy efficiency is high: the maximum power peak recorded for the prototype is above 51 kW. This system is very interesting for the Coastenergy project because it is adapted to the environmental characteristics of the Mediterranean Sea, including the Adriatic, where wave motion is much lower compared to oceanic environments. Available wave power in European oceans, usually referred to the length unit of the wavefront, ranges from 25 kW/m (Canary Islands) to 75 kW/m (Irish and Scottish coasts), whereas in the Mediterranean is between 4 and 11 kW/m. In summary, what makes this case interesting for Coastenergy is:

	• the gyroscopic technology is fit for closed seas, where wave frequency is higher compared to oceans; • the low visual impact of the raft, emerging for about a metre only; • absence of environmental impacts; • low maintenance costs: only the hull is in direct contact with water; moreover, the system is easily accessible since it can be placed near the coast; • financial sustainability: this technology, as demonstrated by tests implemented so far, is intended to reach grid parity in the short period. It has been chosen by Terna, the Italian grid operator, to launch an industrial programme, with the first plant to be developed by 2020.
Problems and obstacles	All recent reports focus on the barriers that are still hindering the industrial production and marketing of marine energy technology (technological development, finance, consensus, environmental concerns, availability of grid connection). In this particular case, the problems that the system could undergo are strictly related to the location of the raft and the cable connecting it to the mainland; it is important that in the industrial development phase, the possible interferences with pleasure boating and the fishing industry are solved. Another possible problem is the necessary authorisations for the installation of the transformer tower on the coast (where necessary).
Assessment tools and methods	The research activities started in 2005 at the Department of Mechanical and Aerospace Engineering of Politecnico di Torino have led to the development of this technology, then brought to an industrial level by Wave for Energy LLC, the latter having managed the construction of the first, pre-commercial machine. After the first concept, developed in 2006, the experimental validation was implemented on a 1:8 model in the ship model basin of INSEAN (research institute on naval architecture and marine engineering within

	the National Research Council). ISWEC has been successfully tested in several lab and field campaigns. In February 2012, a full-scale version was released. The collaboration with ENEA has made it possible to identify the most proper installation site in the sea of Pantelleria and to allow the system to adapt to the variations of sea and weather conditions, optimizing productivity. In August 2015, the system was placed on-site at about 800 m from the shore, moored at a depth of about 35 m.
Environmental and landscape impacts	ISWEC has a low impact on the landscape, thanks to its small dimensions. Being just moored to the seabed, it does not alter wave conditions nor cause damage to the sea environment.
Socio-economic impacts	The high vulnerability of the Mediterranean environment requires efforts for promoting the development of innovative technologies able to foster energy independence and sustainability, especially for isolated communities such as those living in small islands, offering new solutions for mitigation of climate change and reduction of pollution. The diffusion of energy from the sea would also meet the requirements of Directive 2014/89/EU, which has established a framework for maritime spatial planning and integrated coastal management. Research, innovation and competitiveness are central in EU's strategy, which includes the objective of accelerating the transformation of the European energy system, including zero-emission energy production technologies, filling the gap between research projects, prototypes and commercial exploitation. The strategy recommends concentrating efforts towards a limited number of promising technologies for converting energy from currents and waves, aiming at a reduction of LCoE for wave converters to 20 ¢/kWh by 2025, 15 ¢/kWh by 2030, and 10 ¢/kWh by 2035. ISWEC has been developed following the directives of the Blue Energy Strategy and is suitable for having an important role within renewable sources at competitive costs.

Success factors	All lab and field tests gave extraordinary results in terms of production, installation and maintenance costs, leading to good economic performance and low LCoE. Tests implemented on the module installed in 2015 at Pantelleria, for example, have shown that this system would allow producing energy at a more competitive cost compared to what currently necessary for producing electricity on the isle. This technology has proven to be a valid complement to the energy mix of small islands that are not directly connected to the continental electrical grid. Thanks to a design and industrial optimization process, the research group at Politecnico di Torino and Wave for Energy aims to bring energy production costs to grid parity (i.e. the point where the energy produced from renewable sources reaches the same price as traditional energy). In October 2019, ENI, CDP, Fincantieri and Terna joined forces to establish a new company for the construction of the first ISWEC industrial plant, which will be installed near the ENI „Prezios'' platform in the Strait of Sicily, off the coast of Gela. It will be operational in the second half of 2020. During the second phase, partners will formally establish the company and make a production plan, starting with minor islands in Italy and, later, abroad.
Transferability in the COASTENERGY area	The commitment of some of the major Italian companies demonstrates the validity and actual possibilities of the ISWEC system. The transferability to the Coastenergy area is already being implemented with the installation of a module off Marina di Ravenna (even if only supporting the energy needs of an ENI offshore platform). After launching the Gela offshore plant and establishing the new company, the implementation will continue in minor islands (such as Tremiti) and the Eastern coast of the Adriatic Sea.

Keywords	Wave power, gyroscope, wave energy converter, point absorber, control, modelling, wave width, wave frequency
Weblink	https://www.waveforenergy.com
Year of data collection	2006-2019
Sources	waveforenergy pantelleria-energia-blu-dalle-onde energia-dal-moto-ondoso-a-pantelleria-il-convertitore-iswec /iswec-energy-from-the-sea.page construction-of-wave-energy-power-stations-on-an-industrial-scale eni.com eni.com_2 politocomunica.polito.it iris.polito.it/ canaleenergia.com marineenergy.biz/ power-technology.com teknoring.com/ corriere.it/ https://youtu.be/1Zus7f2Klbk https://youtu.be/bvYXbdOvcmk https://youtu.be/pUmMAl0MDKE https://youtu.be/mp7oHo_kzA0

Case study summary:

Milestone 1 – Research activities started 10 years ago and were carried out by a group coordinated by Giuliana Mattiazzo and Ermanno Giorcelli of the Department of Mechanical and Aerospace Engineering of Politecnico di Torino. The technology has been industrialized by Wave for Energy LLC (an academic spin-off), which has followed the construction of the first pre-commercial machine.

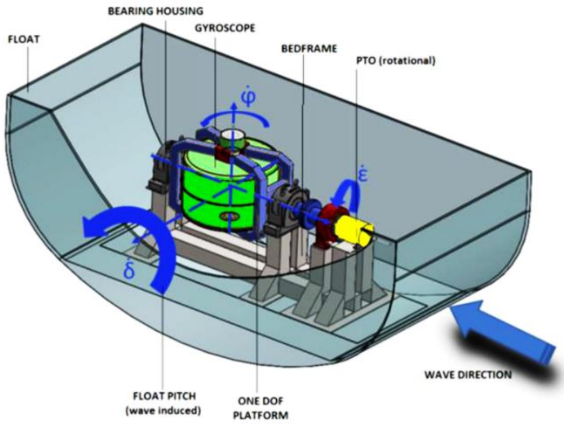

Figure 14 - Operating scheme

Figure 15 - Gyroscope

Milestone 2 – Lab-scale validation (2006-2012): after the first concept, developed in 2006, the experimental validation was carried out using a 1:8 scale model in the ship model basin of INSEAN; then, a full-scale prototype was released in February 2012.

Figure 16 - 1:8 scale models during ship model basin tests

Figure 17 - 1:8 scale model for the sea test

Milestone 3 – Validation at sea (1:1 scale model). The collaboration with ENEA has made it possible to identify the most proper installation site in the sea of Pantelleria and to allow the system to adapt to the variations of sea and weather conditions, optimizing productivity. In August 2015, the system was placed on-site at about 800 m from the shore, moored at a depth of about 35 m.

Figure 18 - Launch of the 1:1 prototype in the sea of Pantelleria

Milestone 4 – Establishment of a company for industrial production (4/2019-10/2019). Cassa Depositi e Prestiti (the Italian national savings and loan institution), Fincantieri, Terna, ENI, Politecnico di Torino and Wave for Energy LLC signed an agreement for the establishment of a company aimed at converting the ISWEC pilot project into an industrial system. According to the agreement, the first industrial plant will be installed near the ENI „Prezioso'' platform in the Strait of Sicily, off the coast of Gela. During the second phase, partners will formally establish the company and make a production plan, starting with minor islands in Italy and, later, abroad.

Figure 19 - Signing of the agreement in Ravenna in October 2019

Milestone 5 – Validation at sea (2018). A full validation test phase was performed at sea off Marina di Ravenna, close to an ENI offshore platform.

Figure 20 - Demonstration of technology

PENGUIN	
Group:	Wave energy
Name of project/plant	Clean Energy from Ocean Waves (CEFOW) Armintza (BiMEP)
Location	59°00'0.00"N – -3°00'0.00"W, Orkney, Scotland 43°27'52.2"N - 2°52'50.1"W, Armintza, Basque Country (Spain)
Year of commissioning	2012 Orkney: The Penguin 2020 Armintza: The Penguin (Armintza)
Name of used technology	The Penguin and The Penguin (Armintza)
Type of energy source	Wave energy
Type of energy output	Electricity
Type of project	Commercialization project
Plant status	Operational plant The Penguin (Armintza) scheduled for 2020
Involved actors	Wello Saipem EVE BIMEP
Nominal power	The Penguin: nominal power 500 kW The Penguin: (Armintza) nominal power 600 kW
Size	The Penguin: 30 x 16 m depth 9 m (draught 7.0 m) weight 1600t The Penguin (Armintza): 43.6 x 22 m depth 10.6 m (draught 6.8 m) weight 2251t
Annual productivity	Not available
Implementation cost	Not available
Payback period	Not available
Operating cost	Not available

Sources of financing	EU Horizon 2020 (CEFOW), Energiaren Euskal Erakundea (EVE)
Reason for interest for COASTENERGY	It is an environmentally friendly structure, similar in size to a small boat moored not far from the coast. It has no moving parts that can harm marine fauna. This machine uses the frequency of the waves instead of the height. It works thanks to an inertial system that exploits the wave motion. Another innovation consists in the possibility to fine-tune the machine according to changes in sea conditions, without exposing important parts to the aggressive marine environment, preventing corrosion and deterioration. The main system is located in a sealed chamber and does not come into contact with water. The raft containing the instruments has an area of 480 sq m (30 x 16 m). The plant has a nominal power of 500 kW and the whole system weighs 1600 tons. During operation, the visible part is a floating platform with boat lights, with a consequent reduced visual impact. It is removable, it does not contain dangerous liquids, it does not emit electromagnetic waves, it is not noisy, and it can be freely moored. It does not need to interact with the maritime system and the seabed. In addition, little maintenance is needed. In summary, what makes this case interesting for Coastenergy is: the low visual impact of the raft, which only emerges for about a meter; absence of environmental impacts; low maintenance costs: only the hull is in direct contact with water; moreover, the system is easily accessible as it can be positioned near the coast.
Problems and obstacles	The problems that the system could suffer are closely related to the position of the raft and the cable that connects it to the mainland; it is important that possible interferences with pleasure boating and the fishing industry are resolved in the industrial development phase. Another possible problem is the authorizations necessary for the installation of the transformer tower on the coast (where necessary).

Assessment tools and methods	Energy production estimation, proven scalability in tank test.
Environmental and landscape impacts	PENGUIN has a low impact on landscape. Being just docked at the bottom of the sea, it does not alter the conditions of the waves or cause damage to the marine environment.
Socio-economic impacts	
Success factors	Proven full-scale survivability, possible to build all over the world's shipyards, encapsulated design, direct drive, environmentally friendly (electromechanical design instead of hydraulic).
Transferability in the COASTENERGY area	Despite the extreme versatility of the technology, the applicability currently concerns only oceanic marine areas, therefore, only in anticipation of a possible reduction of future scale, the technology could be applicable in the Adriatic.
Keywords	Wave power, sea energy, wave energy converter, wave height, control, modelling, wave width, wave frequency
Weblink	http://www.wello.eu
Year of data collection	Since 2012
Sources	https://wello.eu/2019/07/24/the-penguin-makes-a-stop-at-orkney/ https://www.offshore-energy.biz/wello-preps-new-penguin-for-orkney/ https://www.waterpowermagazine.com/news/newswellos-wec2-penguin-ready-to-depart-for-orkney-scotland-7168426 https://tethys.pnnl.gov/project-sites/wello-penguin-emec http://www.scottishenergynews.com/finlands-full-size-1mw-penguin-wave-energy-machine-takes-to-the-see-off-orkney/ https://www.scottishrenewables.com/news/412-the-wonderful-world-of-wello-and-other-orkney-stories https://power.nridigital.com/power_technology_apr18/will_wello_turn_the_tide_for_wave_energy_technology https://www.alamy.com/wello-wave-energy-converter-penguin-orkney-isles-image327818257.html https://globalrenewablenews.com/article/energy/organisation/wello/34158/764460/wellowello-s-wec2-penguin-ready-to-depart-tallinn-shipyard-towards-orkney-scotland.html

	https://helsinkismart.fi/portfolio-items/wello/

Case study summary:

Orkney, Scotland – The Penguin WEC2 is Wello's first full-scale commercially ready wave energy converter. Wello has previously tested its prototype (Penguin WEC1) at Orkney, where it surpassed the expectations, confronting waves of over 18 meters.

The Penguin WEC2 boasts numerous improvements over its predecessor. With improved mooring design, hull shape to maximise energy capture, and other improvements, Wello is eagerly awaiting deployment.

Figure 21 - The Penguin (Armintza) starboard

Armintza, Basque Country (Spain) - The construction of the Penguin for installation in the Basque country ended in June 2019. Differently from the one installed on the Orkney islands, which had an area of 480 sq m and a nominal power of 500 kW, the Basque Penguin has an area of 952 sq m and a nominal power of 600 kW.

Figure 22 - The Penguin (Armintza) starboard and bow

It consists in an asymmetrical hull, capable of exploiting the wave movement for the production of energy, thanks to the rotation of a mass rotator placed inside the hull, which transfers the kinetic energy to the generator.

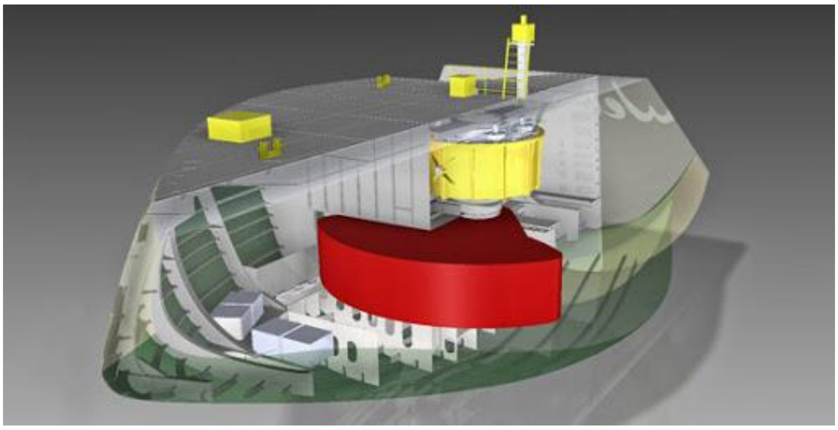

Figure 23 - The Penguin: the mass rotator in red and the generator in yellow

Figure 24 - Generator and mass rotator

Thermal energy case studies – Seawater heat pumps

Portopiccolo - ocean thermal energy	
Group:	Geothermal energy
Name of project/plant	Air-conditioning system with seawater
Location	45°45'57.6"N 13°38'04.7"E Mediterranean Sea, Sistiana, Duino-Aurisina (TS), Italy
Year of commissioning	2009
Name of used technology	Ocean thermal energy
Type of energy source	Seawater from the Portopiccolo basin, groundwater (Timavo river) and electricity.
Type of energy output	Heating, cooling, and hot water
Type of project	Implementation of technology
Plant status	Operational
Involved actors	Customer: Serenissima SGR, Rilke Real Estate Fund Management: Bovis Lendlease Responsible for authorization procedures for urban planning/landscape/environmental practices: Cesare Bulfon Architectural and landscape design: Francesco Luparelli Landscape design: Andrea Kipar Architectural and structural project development: Archest Responsible for the hydrogeological and geomorphological project: Carlo Brusca and Antonio Klingendrath Plant design: SIMM Masoli Messi Engineering Company, SGM Consulting Plant supervision, specialist planning, testing: Studio Associato Andreoli – HTW General construction management: Mauro Latino Construction company: Rizzani De Eccher Installation of mechanical systems: Fabbro Vanni, Idrotermica Buttrio, Tecnoterm Installation of electrical systems: Ranzato Impianti

	Providers: Heat pumps and fan coils: Clivet Heat exchangers: Clivet Electric pumps: Salmson Valves: Belimo Radiant floors: Unical Controlled mechanical ventilation: Aldes Solar Collectors: Sonnenkraft
Nominal power	6.5 MW (for 25 heat pumps)
Size	The holding tanks have dimensions 4 x 4 x 5 m the water ring has a length of about 1.2 km.
Annual productivity	Total energy produced by the thermo-cooling plants (2014-2019): 20,659 MWh. Total energy supplied by the water ring to the thermo-cooling plants (2014-2019): 11,794 MWh.
Implementation cost	Mechanical, electrical and sanitary installations: about € 25 million. Air conditioning system: 2.5-3 M€, of which 1.6 M€ for the sea power plant and technical water ring. Total investment: over 300 M€.
Payback period	Not found
Operating cost	Not found
Sources of financing	Not found
Reason for interest for COASTENERGY	From the analysis of the data recorded in over four years of constant monitoring of the plant, it is clear that the system has worked well, for now, showing excellent efficiency and without approaching the limits imposed by environmental protection laws: only once, the temperature of the wastewater was 36° C (against the maximum 35° C allowed), and the problem was solved by increasing the pump speed and therefore the water flow.
Problems and obstacles	No significant problem was found during the implementation of the project. It was necessary to pay more attention to the environmental limit according to which the water cannot be released at more than

	5° C with respect to the set temperature. Furthermore, a solution had to be sought for the enormous amount of chlorine initially used, since for the environmental legislation, it is not possible to exceed 0.2 mg/l. About 40 sacrificial nodes (initially not foreseen) were installed. The temperature of seawater (taken from the small port) reached a maximum summer peak of about 28 °C and a minimum of 9° C, on the occasion of an insistent Bora wind. The most critical conditions for the operation of the plant, initially hypothesized for the summer period, were unexpectedly encountered in the winter period. In winter, the operating temperatures of the technical water circuit are, in fact, around 10/5 °C (flow/return). It is instead necessary to guarantee the production of water at a temperature of about 40° C for heating.
Assessment tools and methods	The continuous control system allows the identification of load losses, allowing the manager to assess when maintenance is required. Unlike what is believed, this is not done annually, but it is continuous, it requires the constant presence of personnel, to ensure that the system does not stop and is fully functional.
Environmental and landscape impacts	The system has no environmental impact. The plant uses seawater, groundwater and electricity as an energy source, without making the connection to gas necessary. Induction hotplates were installed in the utilities, eliminating the use of gas or diesel. In the village, there are also 200 square meters of solar panels, placed on the roofs of modern-style buildings, which contribute to the high-efficiency heating of hot water. The entire village has an energy class A.
Socio-economic impacts	Among the characteristic features of the project, attention is focused on the contextualization of the architectural image and the reduced energy impact which, thanks to the solutions adopted, shows consumptions between 30 and 40 % lower than an equivalent intervention carried out with technologies based on fossil fuels, completely absent in Portopiccolo.

Success factors	The system has the water intake inside, by means of two tanks, placed at a depth of about five meters and a size of 4x4 meters. The choice of this position is given by three fundamental reasons: 1. conservative solution, since there is an important mussel farm just outside the port; 2. minimize costs, since inserting the water outlet outside the port would have required the use of pipes with a length of at least 100 meters; 3. to guarantee a careful and effective maintenance.
Transferability in the COASTENERGY area	The system has many advantages. First, respect for the environment. Geothermal energy is indeed a clean and renewable source. Geothermal probes do not pollute. There are no emissions of CO_2 or other greenhouse gases. There is no production of fine dust or combustion by-products. Therefore, it avoids the possible dangers of fire or gaseous emissions since there are no combustibles. The absence of combustion also eliminates the risks derived from carbon monoxide and gas leaks from the pipes. It does not pollute the soil, as completely non-toxic antifreeze refrigerants circulate inside the geothermal probes.
Keywords	air-conditioning system; seawater; heating; thermal energy
Weblink	https://www.teknoring.com/news/riqualificazione-urbana/un-sistema-oceanotermico-per-sistiana-da-cava-di-calcare-a-borgo-di-lusso/
Year of data collection	2009-2017
Sources	Transcript of the interview carried out during a survey in Portopiccolo: http://www.airu.it https://www.rcinews.it/2017/03/24/fonti-termiche-differenziate-per-residenze-di-qualita/

Case study summary:

The former limestone quarry of Sistiana, in the province of Trieste, was the subject of an important environmental restoration intervention. "Portopiccolo Sistiana" is a complex that includes 460 housing units, public and private beaches, green areas, bars and restaurants, hotels, 124 berths and a large spa. This is the case of an entire village that can boost the energy efficiency class A. It was decided to plan the settlement with a centralized air conditioning system with zero emissions: the energy sources are in fact seawater and the electricity (heat pumps), without making the connection to the gas network necessary. After the construction of the infrastructures, the laying of the networks and the construction of the buildings, the small port was excavated and opened, allowing the start-up of the air conditioning system in April 2014. For the plant, operating throughout the year and 24 hours a day, no penalizing limits were imposed by the province, which, together with the ARPA (Regional Agency for Environmental Protection), ordered the respect of the constraints of the national legislation (D.Lgs. 152/06), or the obligation to install a monitoring system capable of constantly guaranteeing:

- a threshold on the maximum discharge temperature of 35° C;
- an increase in sea temperature at 1 km from the drain less than 3° C;
- a limit to the presence of residual chlorine at the exhaust of 0.2 mg/l.

The system, shown in the figure below, is based on the water ring technology that uses seawater as the exchange source. Also, the plant is set up for the exploitation of groundwater, thanks to the precious contribution of the Timavo river, which emerges from the calcareous crushing of the quarry floor and then continues the seabed. Seawater exchanges heat with the technical water circuit, which in turn brings the energy carrier to the 25 electric pumps located in the 18 sub-stations spread throughout the village, covering the heating, cooling and hot water needs of all utilities.

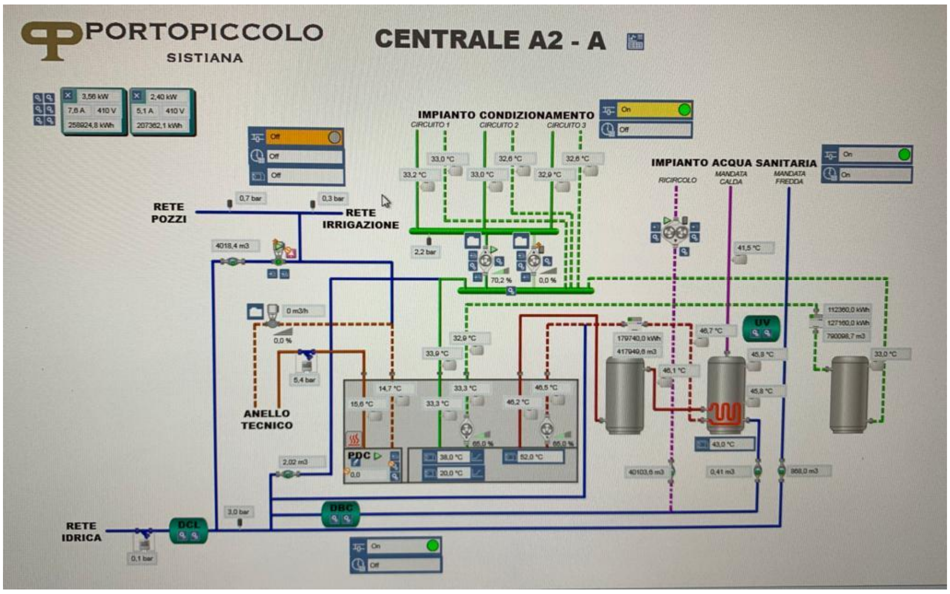

Figure 25 - Working scheme

The water circuit forms a ring that extends for about 1.5 km along the whole quarry and has been entirely made with polyethylene pipes, having dimensions DN315 in the section of the main ridge.

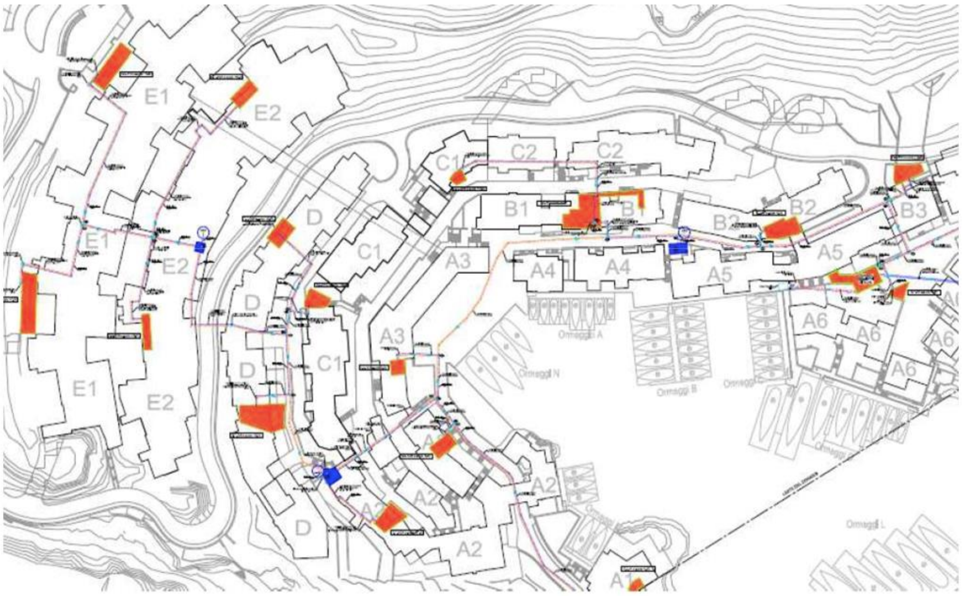

Figure 26 - System illustration

System operation:

The proper power plant is the most innovative and elaborated part of the system. There are four sea water-technical water exchangers and a regulation system that governs their activation, with a minimum of one and a maximum of three working simultaneously, since one has been designed as a reserve. Each has a nominal power of 1.45 MW and is made of titanium and insulated to avoid condensation during winter.

Each exchanger is equipped upstream with a self-cleaning filter for algae removal: the control system automatically plans the flow reversals with the dirty water by-pass to the exhaust manifold. The maximum thermal power that can be extracted from seawater is around 4.5 MW (with three circuits active out of 4). The system involves the injection of ClO_2 according to the volumetric flow rate of the seawater and its temperature, to eliminate the presence of algae and microorganisms and keep the entire pipeline clean. The amount of chlorine, however, after a trial period, was excessive, reaching a cost of 120,000 euros. The best solution is, therefore, to dose uses chlorine only when one of the two circuits is put at rest and proceed with cleaning. The alternation of the circuits is continuous: usually in summer, only two pumps are kept operational, allowing the remaining part of the circuit to be dosed manually. The rest of the maintenance is done mechanically: interesting part is identified, removed, fixed and put in place again. About 40 sacrificial anodes were installed to protect the plant from what is called galvanic currents.

Figure 27 - Pipe installation

Seawater circulation is guaranteed by four centrifugal pumps fed by stainless steel inverters (same material as the collectors and the rest of the seawater circuits), with a nominal flow rate of 183 m^3/h. The water of the technical water distribution ring is moved to the sea plant by four centrifugal pumps: two are larger with a flow rate of 274 m^3/h each, a medium and a smaller one, which is activated according to the needs. In the central unit, there are also two fan coils cooled by water from the well for the cooling of the environment, they allow to dispose of the thermal load towards the outside, without the need for noisy fans.

The Orthopaedic and Rehabilitation Hospital „Prim.dr. Martin Horvat”	
Group:	Thermal energy
Name of project/plant	The Orthopaedic and Rehabilitation Hospital „Prim.dr. Martin Horvat”
Location	13,64°; 45,10°
Year of commissioning	2016
Name of used technology	Seawater heat pump
Type of energy source	Thermal energy
Type of energy output	Thermal energy
Type of project	Fully operating plant
Plant status	Operating
Involved actors	The investor is named in the name of the project. The designer is GEO-5 d.o.o.
Nominal power	700 kW
Size	167,312 m^2
Annual productivity	800 MWh
Implementation cost	1,2 mil. €
Payback period	7 years
Operating cost	Not available
Sources of financing	EU funds and private equity
Reason for interest for COASTENERGY	The installed technology is directly related to the scope of project COASTENERGY. Thermal seawater heat pumps are the only mature and commercially viable technology for the installation in coastal and port areas. Since the COASTENERGY aims to improve and ease the procedure for deployment of blue energy (BE) devices, obtained knowledge from such project are very valuable and important for further actions.

Problems and obstacles	Problems are related to marine spatial planning which indicates the need for drilling. Moreover, the obstacle might be the lack of proper funding if EU funds cannot be used.
Assessment tools and methods	Not available
Environmental and landscape impacts	Probation work was carried out in the area where the terrain is lacking primary shoots of the rock from which the substrate was constructed. It was found that this rock layer is shallow and characterized by high primary porosity. The waterfall is opened to the sea which is to 100 m away from the nearest edge of the area. Pressures are higher in this area due to the tectonic activity.
Socio-economic impacts	Socio-economic impacts are focused on exploiting locally available renewable energy sources by improving the quality of life of locals. Benefits of this project are visible from the fact that the hospital is using renewable sources to accommodate users and achieve thermal comfort.
Success factors	Appropriate funding, regulatory framework,
Transferability in the COASTENERGY area	Project is in COASTENERGY area.
Keywords	Seawater, heat pumps, heating
Weblink	Not available
Year of data collection	2019
Sources	Various

Case study summary:

Firstly, elaborate on hydrogeological water was carried out to investigate the potential of using groundwater for heat pumps from a borehole. Drilling was carried out on the previously described terrain close to the Rovinj and on the landscape owned by Hospital. Total Hospital particle area is 200 000 m^2, while it is already occupied around 167 312 m^2. Hospital buildings were built in the 19th century.

Figure 28 - Aerial view and the location of the Hospital

Installed technology:

Installed heat pumps are using seawater as an energy source, and the pump type is DYNACIAT power, model 700V. The heat output of the pump is 192 kW (50/55 °C) on the condenser outlet which leads to 120 kW (3/-1 °C) on the evaporator with the required power to operate compressor of 71 kW.

On the rooftop of the Physiotherapy there are installed flat solar collectors, oriented in the south-south/west direction. It was planned to be installed 4 groups per 10 solar collectors type Vitosol 100-F, model SH1, Viessmann. Total surface is around 92 m^2.

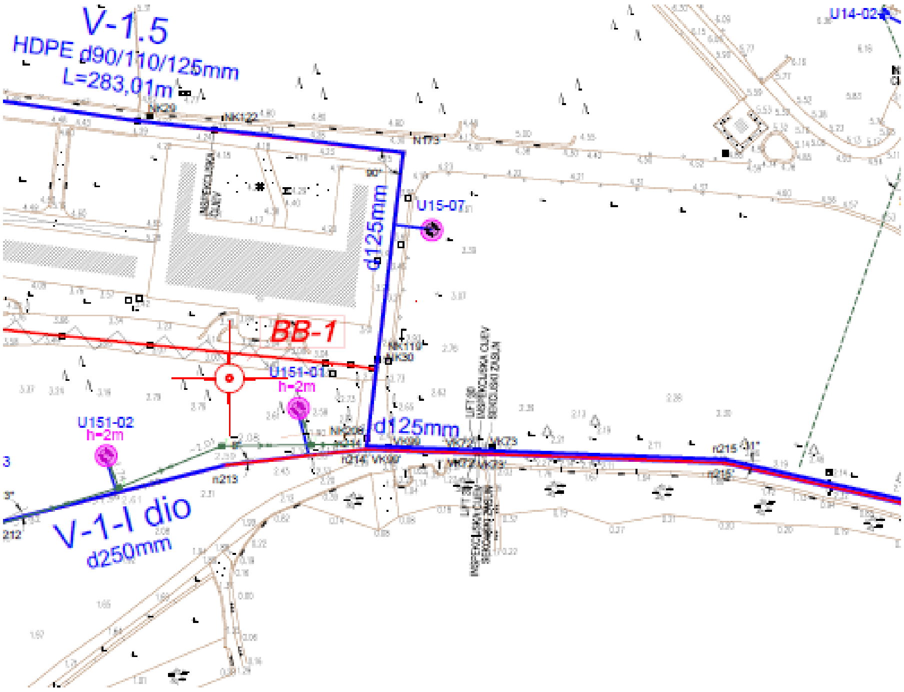

Figure 29 - Pipeline distribution system

Sources

- University of Rijeka - Faculty of Engineering (2015) . Project 958-15-S: Projekt grijanja potrošne vode korištenjem sunčeve energije i dizalice topline za bolnicu ""Prim. Dr. Martin Horvat"" Rovinj, Rijeka
- University of Rijeka - Faculty of Engineering (2015). Project 958/15-Rev.l .: Idejna tehničko rješenje i studija isplativosti sustava grijanja i hlađenja za bo l nički kompleks ""Prim. Dr. Martin Horvat"" Rovinj, Rijeka
- Geo-5 d.o.o. (2016). ELABORAT O HIDROGEOLOŠKIM VODOISTRAŽNIM RADOVIMA U KRUGU BOLNICE ZA ORTOPEDIJU I REHABILITACIJU „prim.dr. MARTIN HORVAT' te o izradi istražno-eksploatacijskog zdenca na k.č. 2495 k.o. Rovinj i zahvata podzemne vode u svrhu projekta dizalice topline. Rovinj ."

Hotel Parentium, Poreč	
Group:	Thermal energy
Name of project/plant	Hotel Parentium
Location	13°35'18'' Longitude; 45°12'12'' Latitude
Year of commissioning	2014.
Name of used technology	Seawater heat pumps
Type of energy source	Thermal energy
Type of energy output	Thermal energy (heating/cooling)
Type of project	Full operating plant
Plant status	Operating
Involved actors	Owner of the Hotel complex and equipment producer CIAT Group
Nominal power	Cooling 692 kW x 2 Heating 795 kW x 2
Size	20 582 m^2
Annual productivity	723 MWh per annum
Implementation cost	2 mil. €
Payback period	6 years
Operating cost	Not available
Sources of financing	Private funding
Reason for interest for COASTENERGY	Project is in the scope of COASTENERGY project since it is related to the exploitation of seawater thermal energy by using heat pumps technology. As an example of good practice, the project is not only relevant but extremely important for COASTENERGY project, as well as for the programme area.
Problems and obstacles	Problems are related to spatial planning which is widely missing for such technology. Need for drilling to exploit the thermal potential.
Assessment tools and methods	Not available

Environmental and landscape impacts	At the end of the chalk is almost the entire Adriatic carbonate platform, so also the area of Istria. Under the influence of the regional phenomenon of locally very different duration. The waterfall is open to the sea which is 0 to 100 m away from the nearest the widest edge of the area.
Socio-economic impacts	The hotel achieved carbon-neutral production and consumption of energy, contributing to the sustainable development of the touristic offer. Simultaneously, the hotel ensured savings in energy consumption for a longer period.
Success factors	Annual savings for heating/cooling of the system of the heat pump water is approximately 19,600.00 EUR.
Transferability in the COASTENERGY area	Project is in the programme area.
Keywords	Seawater heat pumps, heating, cooling, hotel Parentium, Istria
Weblink	http://lagunaporec.com/hotel-laguna-parentium-porec
Year of data collection	2019
Sources	http://lagunaporec.com/hotel-laguna-parentium-porec

Case study summary:
The system is in Poreč in "Zelena laguna". The owner of the implementation is Laguna Poreč Ltd. The complex extends on 41.873 m^2 and exists from 1967. The last adaptation was in 1987.

Figure 30 - Hotel Parentium Poreč

Installed technology:

There are two units, which produce energy power of 383,000 kWh of energy annually (for cooling) and 340,000 kWh (for heating). They produce an overall energy power for cooling and heating of the hotel. The heat pump consists of CIAT, 2 x HIDROCIAT LWP 2800 BX HPS, cooling capacity 2 x 692 kW (7/12, 35/30 °C), heating capacity 2x795 kW (5/10, 55/50 °C).

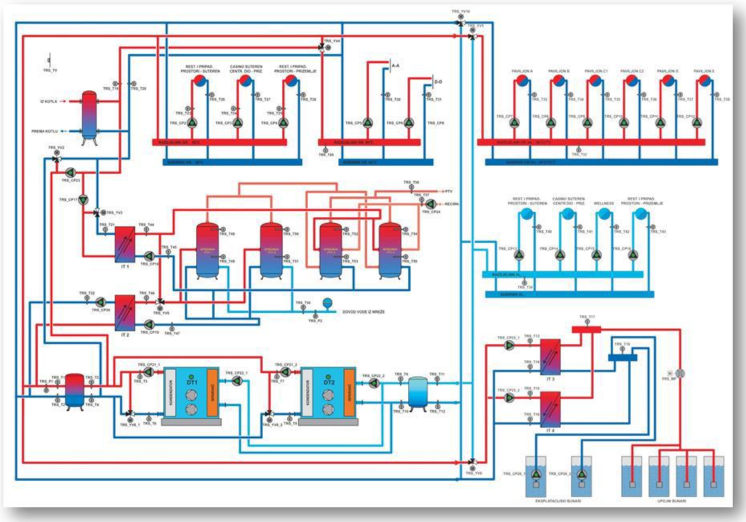

Figure 31 - Heat pump system scheme

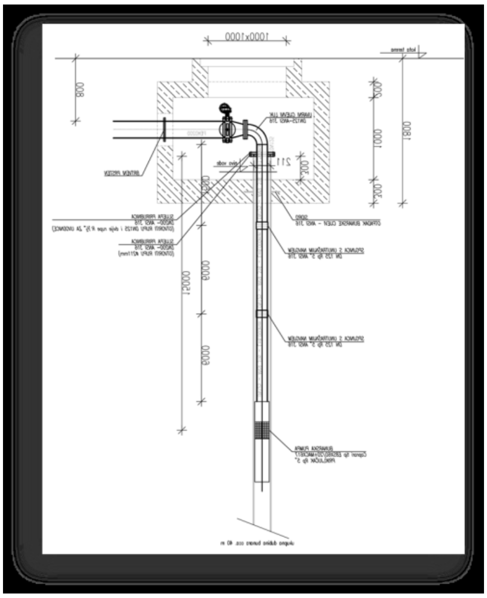

Figure 32 - Suction pipe

Sources:

- Eksperterm. I. Karačić. Primjena sustava geotermalnog grijanja i hlađenja u hotelima. kućama za odmor i agrararnim gospodarskim sustavim. (www.istra_istria.hr/fileadmin/poddomene/IRENA/Primjena_sustava_geotermalnog_grijanja_i_hladenja_u_hotelima_kucama_za_odmor_i_agrarnim_gospodarskim_sustavima.pdf (retrieved: 26.03.2017}
- Web page and telefon information from Hotel Laguna Parentium available at http://lagunaporec.com/hotel-laguna-parentium-porec (retrieved 24.03.2016.)

Faculty of Maritime Studies and Transport, Portorož, Slovenia	
Group:	Thermal energy
Name of project/plant	Faculty of Maritime Studies and Transport
Location	45°30'58"N and 3 °34'39"E
Year of commissioning	2004
Name of used technology	Heat pump
Type of energy source	Thermal energy
Type of energy output	Thermal energy
Type of project	Fully operating plant
Plant status	Operating
Involved actors	Faculty of Maritime Studies and Transport
Nominal power	Cooling 55 kW Heating 66 kW
Size	Not available
Annual productivity	Cooling 75 MWh Heating 91 MWh
Implementation cost	30 000 €
Payback period	7 years
Operating cost	Not available
Sources of financing	Private funding
Reason for interest for COASTENERGY	Installed technology is in the interest of the COASTENERGY project. Moreover, the installation site is close to the programme area, which is relevant for other similar projects, especially those related to heat pumps.
Problems and obstacles	Problems are related to the operational issues mainly to suction pipe where mud, shells and other seawater organisms might contaminate the water.
Assessment tools and methods	Absence of impact study.
Environmental and landscape impacts	When using seawater as a thermal source during the process, the temperature of seawater is changed. In heating mode, seawater is chilled. On the contrary, in cooling mode seawater is heated for a few degrees. In case of such small thermal power of the system,

	the impact on the surrounding seawater temperature is negligible. The landscape is not affected by the system.
Socio-economic impacts	While construction was carried out, due to the close location of the marine, intake and discharge system was specially designed. Benefits to wider society are in terms that oil consumption for heating is almost halved when heat pumps are installed.
Success factors	Success is significant because pumps are still operating even though the payback period passed. Operating costs are quite lower, while there were no significant issues related to the operation.
Transferability in the COASTENERGY area	Installation is close to the programme area and can be used as an example of good practice.
Keywords	Seawater heat pumps, cooling, heating
Weblink	http://primorske.si/Primorska/Istra/Morje-jih-greje-ze-deset-let.aspx
Year of data collection	2019
Sources	Project ENERCOAST

Case study summary:

The main purpose of the heat pump is heating and cooling of the building - Faculty of Maritime Studies and Transport. The System uses heat pump which benefits on seawater temperatures. Which are lower in the summer and higher in the winter in comparison with outside air temperatures. Combined heating and cooling are operated at higher efficiency. Distance between the machine room and seawater intake is about 60 m. A selected case study was one of the first water/water heat pumps in Slovenia connected to the seawater source which uses sea energy as thermal source.

Installed technology:

Seawater is pumped from the seawater inlet, through the pipelines into the saltwater/freshwater heat exchanger where it is chilled (in winter) and then discharged back to the sea. Secondary water circle is established between heat exchanger and water/water heat pump. The average flow of the seawater through the system is 15 m^3/h. The heat pump uses an electrically powered compressor to transfer heat from the secondary water circle to the heating system in the building. When transferring heat, secondary water circle is chilled, and the building is heated. In summertime heat transfer is distributed in the opposite direction.

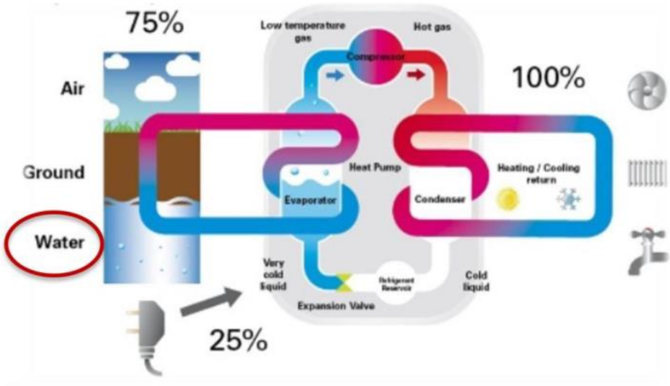

Figure 33 - Installed heating and cooling system

Figure 34 - A heat exchanger and pipeline system

Sources:

- http://primorske.si/Primorska/ Istra/Morje-jih-greje-ze-deset-let.aspx
- Project ENERCOAST

Grand Hotel Bernardin, Portorož, Slovenia	
Group:	Thermal energy
Name of project/plant	Grand Hotel Bernardin
Location	45°31'03"N 13°34'08"E
Year of commissioning	2014
Name of used technology	Seawater heat pumps
Type of energy source	Thermal energy
Type of energy output	Thermal energy
Type of project	Fully operating plant
Plant status	Operational
Involved actors	Grand Hotel Bernardin with owner ESCO partner GGE as an investor and further as an energy supplier
Nominal power	1 MW
Size	Not available
Annual productivity	3000 MWh/annum
Implementation cost	500 000 €
Payback period	Less than 10 years
Operating cost	Not available
Sources of financing	Private funding
Reason for interest for COASTENERGY	Implemented technology is the key technology for COASTENERGY project. Thermal energy used by seawater heat pumps is a type of blue energy which is getting momentum and which exploitation is rising. Therefore, this project is highly relevant for COASTENERGY.
Problems and obstacles	Regarding the Water Act, water permit is required for every intention of water use regardless it concerns groundwater-surface water, or in our case, seawater. Hotel complex already had a water permit for pumping water, but only for the purpose of swimming pool use. Additional water permit was needed to use seawater as a heat source. Issued water permit allows seawater use for extracting thermal energy with maximum seawater flow of 50 l/s and maximum yearly quantity of 542,000 m^3.
Assessment tools and methods	During acquiring water permit, impacts on water system were checked and considered as minor. With cooperation with Marine

	Biology Station impacts on the sea life were reduced to the minimum.
Environmental and landscape impacts	Seawater heat pumps were installed as a replacement for the oil-burning heater, which results in decreased CO_2 emissions. Moreover, when the intake/outlet system was installed, an artificial reef was constructed, which might be beneficial for the local marine environment.
Socio-economic impacts	Costs of heating were reduced from 300,000 € before renovation to about 200,000 € after installation of the heat pumps. As a positive impact for the hotel owner, we can also consider the ESCO model of financing.
Success factors	The main success of the case study is the fact that renovation with a seawater heat pump is possible and not only that - there is interest in private ESCO partners to carry out and finance the investment. With the renovation of the old system, expected savings of the energy costs are 33%.
Transferability in the COASTENERGY area	Project is in the programme area since it is installed on the Adriatic coast.
Keywords	Seawater heat pump, ESCO, heating, cooling
Weblink	http://www.gge.si/portfolio-posts/primer-gh-bernardin
Year of data collection	2019
Sources	http://www.gge.si/portfolio-posts/primer-gh-bernardin

Case study summary:

Hotel is in Portorož, Slovenia, and it has 240 rooms in the area of 12 000 m^2. In 2014, the old heating system with oil burners was replaced by seawater heat pumps. These pumps were selected prior to biomass, and air heat pumps due to lower operational costs, even though initial investment was higher. The ESCO model of financing was used in partnership with GGE. The GGE carried out whole financial costs and now is getting revenue by providing service for Hotel. Around 100 000 € are savings in energy costs, with the payback period of 10 years. The machine room is with pipelines connected to the seawater intake and discharge elements, which were designed as an artificial marine reef. There are two heat pumps installed in the system, each with 500 kW thermal power. Heat pumps are used as a heat source in winter as well as the cold source in summer.

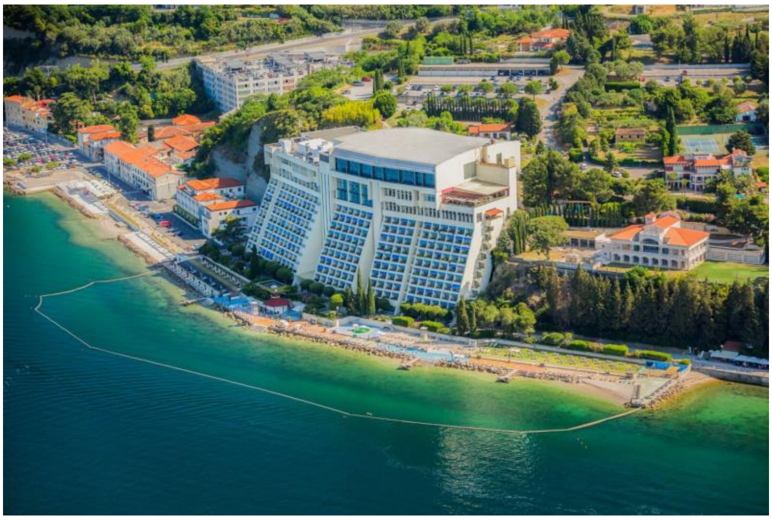

Figure 35 - Hotel Bernardin

Installed technology:

The technology used is a heating and cooling system with two reversible heat pumps installed. Seawater is sucked through the intake element to the settling tank. From settling tank, it is pumped to the seawater/water heat exchangers and then back to the sea through the discharge element. Secondary water circle flow is connecting seawater/water heat exchangers to the pair of heat pumps. Electrically powered heat pumps are producing heat (cold in the summer) which is then distributed to the existing heating system in the hotel. Two heat pumps are installed in the machine room, each with thermal power of 500 kW. Total power of the system is 1 MW. Estimated yearly energy production is 3 000 MWh. Location of intake and discharge elements is 130 m offshore. Heat and cold are supplied to the hotel area of 12,000 m^2. For selected study, thermal power, strong seawater flow is needed to overcome pressure losses through the pipeline. Therefore, intake and discharge elements must be well planned to avoid impact on sea animals.

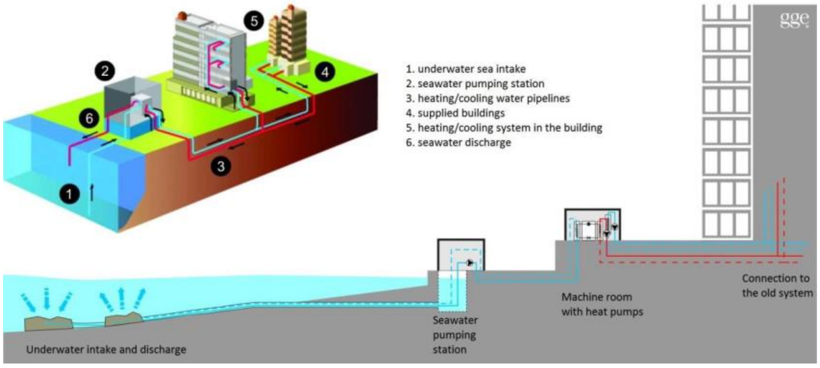

Figure 36 - The Installed heating system

Sources:

- http://www.gge.si/portfolio-posts/primer-gh-bernardin

Rectors Palace, Dubrovnik, Croatia	
Group:	Thermal Energy
Name of project/plant	SEADRION pilot plant
Location	Rectors Palace Dubrovnik
Year of commissioning	2019
Name of used technology	Seawater heat pumps
Type of energy source	Seawater
Type of energy output	Thermal, Heating and cooling
Type of project	Implementation of technology
Plant status	The plant is operating in The City of Dubrovnik
Involved actors	DURA and The City of Dubrovnik
Nominal power	• Heating and cooling of four buildings (total heat load = 430 kW) • Heating capacity: 6 x 72 kW (50/45 °C) • Cooling capacity: 6 x 70 kW (30/35 °C)
Size	Not available
Annual productivity	Not available, the Pilot plant started to work in July 2019
Implementation cost	510,000.00 EUR with VAT for equipment and installation
Payback period	Not available
Operating cost	Maintenance cost approximately 20,000.00 EUR per year
Sources of financing	SEADRION project and the City of Dubrovnik
Reason for interest for COASTENERGY	• It is using seawater as a mediator for cooling and heating • An innovation system that uses the thermal energy contained in a reservoir (sea) to achieve the cooling and thermal energy in the buildings which are close to the sea • Renewable energy in public buildings near the sea • Making the building's energy self-sufficient and independent of fossil fuels
Problems and obstacles	• The problem of placing the heat pumps in the boiler room • The considered building is a monument of cultural heritage • A larger number of smaller power units had to be selected (6)

Assessment tools and methods	Although the plant is operational, there is still no data allowing to derive a cost/benefit analysis because the pilot plant was installed in July 2019. Soon we will start with a pilot plant monitoring system.
Environmental and landscape impacts	No impact.
Socio-economic impacts	Promote the use of seawater as a renewable energy source in the Old City of Dubrovnik.
Success factors	Not available
Transferability in the COASTENERGY area	SEADRION seawater technology could be available in all buildings located near the Adriatic Sea.
Keywords	Seawater, heat pump, thermal energy
Weblink	https://seadrion.adrioninterreg.eu/
Year of data collection	2019
Sources	https://seadrion.adrioninterreg.eu/

Case study summary:

Milestone 1 – July 2018. The City of Dubrovnik has developed pilot plant tender documentation for the replacement of the existing heating and cooling system in the Rector's Palace, which meets the needs of the SEADRION project.

Milestone 2 – November 2018. DURA announced Public Procurement process "Replacement of the existing technical heating and cooling system in the Rectors Palace in the old town centre of Dubrovnik within the project "Seadrion".

Milestone 3 - February 2019. After the completion of the public procurement process, DURA signed a contract with Tehno Elektronik ltd.

Milestone 4 - March 2019. Work begins on the dismantling of the old heating and cooling system and site preparation for the installation of the new system.

Milestone 5 - July 2019. All work completed. The pilot plant started operating.

Milestone 6 - January 2020. A monitoring system is planned to be launched. Daily updates via email about seawater temperatures and energy consumption.

Figure 37 - Heat pump installation

Installed technology:

The basic elements of the engine room are:

- seawater circuit consisting of:
- two heat exchangers that supply heat / cool to the primary circuit of the heat pumps,
- MPC Grundfos seawater pump kit and alpha Laval seawater filter
- six heat pumps
- a tank of prepared water for consumers of 2000 litres
- four overflow valves that direct water to and from the tank depending on the heating/cooling mode

- transport pumps
- and a manifold and sump with consumer branches, associated pumps and mixing valves
- GRO-TS1 power cabinet equipped with U, I, P measuring instrument
- electrical control and control cabinet equipped with an engine room scheme, ridge switches to select how to control all engine room elements and a touch panel to control and read all measured sizes in the engine room, and to view all the parameters of the automation system

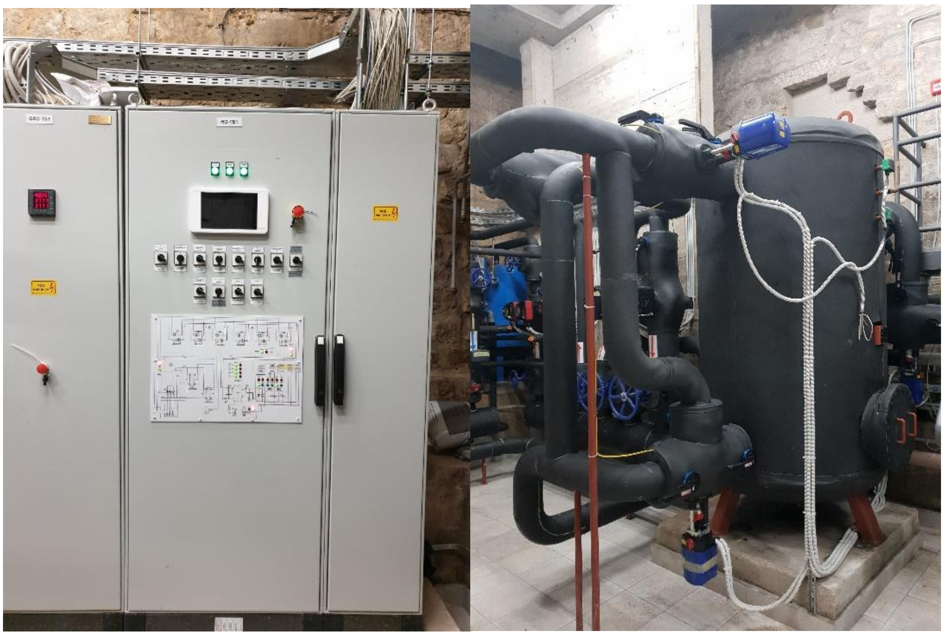

Figure 38 - Control station

There are six heat pumps from DT1 to DT6 in the engine room. The heat pumps operate in a cascade, where the DT is set as a master while the other units are set as slave. The master unit communicates with slave units via internal bus communication. DT set points are determined by the project and are entered by the service technician during commissioning.

The Grundfos seawater pump kit works as a standalone unit. The kit consists of a control cabinet RO MPC Pumps with a local Grundfos controller, three Grundfos pumps and differential temperature sensors on the outlet and return to DT. Seawater pumps operate independently driven by differential temperature.