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Highly efficient innovative shallow-water based Sea Water Air Conditioning solution for the Channel Area

EUROSWAC

216-T4.2-UNE-001

The analysis and refining of the replicability requirements for the SWAC in the Channel Area

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EXECUTIVE SUMMARY

This report summarises the key outputs from WP4.2 of the Interreg-funded EuroSWAC project to provide a comprehensive analysis of technical replicability requirements for the employment of the SWAC systems in the Channel Area and in other regions within temperate climate zones located at the relatively shallow waters.

This analysis contributes to the design and validation of an innovative, highly competitive, cost-effective, environmentally friendly, sustainable and replicable solution for cooling and heating within the Channel Area. The SWAC technology uses ambient sea water to provide air conditioning for facilities in many agglomerations, which require controlled temperature throughout a year.

Evaluation of the potential of the innovative shallow-water-based SWAC system was essential to define the requirements and conditions needed to envisage replicability. This analysis contributes to the identification of 609 short-term replication sites (307 in England and 302 in France). The identified sites are divided into market segments, each with a similar air conditioning demand. These include 221 hotels, 103 retail sites (including supermarkets), 78 leisure centres, 52 tourist attractions, 49 ports and transport sites, 29 schools and research centres, 26 industrial and nuclear sites, 24 governmental and event venues, 23 hospitals and care homes, and 4 data centres.

The main output of this analysis is a visual indication for potential SWACs locations within the eligible area. This provides a first insight into SWACs employability for interested customers. Six types of maps were generated showing a prospect of using sea water for renewable air conditioning. Maps showing temperature difference of minimum 4°C between air and sea water at different depths indicate locations in the Channel where waters have optimum thermal properties for cooling and/or heating. The surface temperature waters could be extracted along the whole English coast, and throughout the coastline of Nord, Seine-Maritime, Manche, Côtes d'Armour, Finistère and Morbihan in France. These maps were further used to create plots with the length of pipeline system to reach the optimum water temperatures. There are sixteen locations in England and two in France where the required pipeline is less than 1 km. Nine sites in England and seven in France need pipeline between 1 and 2km long. Having the pipeline length, the maps of SWAC cost were created. In many places in England (40 locations) and France (15 locations) the cost of SWAC installation may not exceed €500k. Additional maps show energy savings and carbon footprint reduction using the SWAC technology. By installing the SWAC system 50-60% energy can be saved in England (10-30% in France), and carbon footprint can be reduced by 30-40% in England and 10-30% in France. Having the energy usage and the SWAC cost, the payback time maps were also generated. Assuming the current energy prices, the cost of SWAC installation can be returned in 10 years in nineteen locations in England. The cost of SWAC and payback time is less favourable along the French coast. It results from less favourable ambient temperatures, lower energy prices and less fossil fuels currently used for heating and cooling. Additional outputs of the analysis comprise of the tools to apply when investigating SWAC potential in the other regions, detailed bathymetry map of the Channel area, and identification of main technical parameters for analysis of individual sites. The main technical components which can be optimised for a specific location comprise of piping system, pumping system, heat exchange area and a customer.

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1.SWAC potential in the Channel

The Euroswac project is partly funded by the Interreg France-Channel-England. The eligible regions for the projects are shown on the map (Figure 1), along with the project partners and location of the SWAC demonstrators. Taken that the potential SWAC sites must have access to the sea the counties of Wiltshire, Surrey, Cambridgeshire in England, and administrative departments of Oise, Eure, Orne in France are not considered suitable for this project.

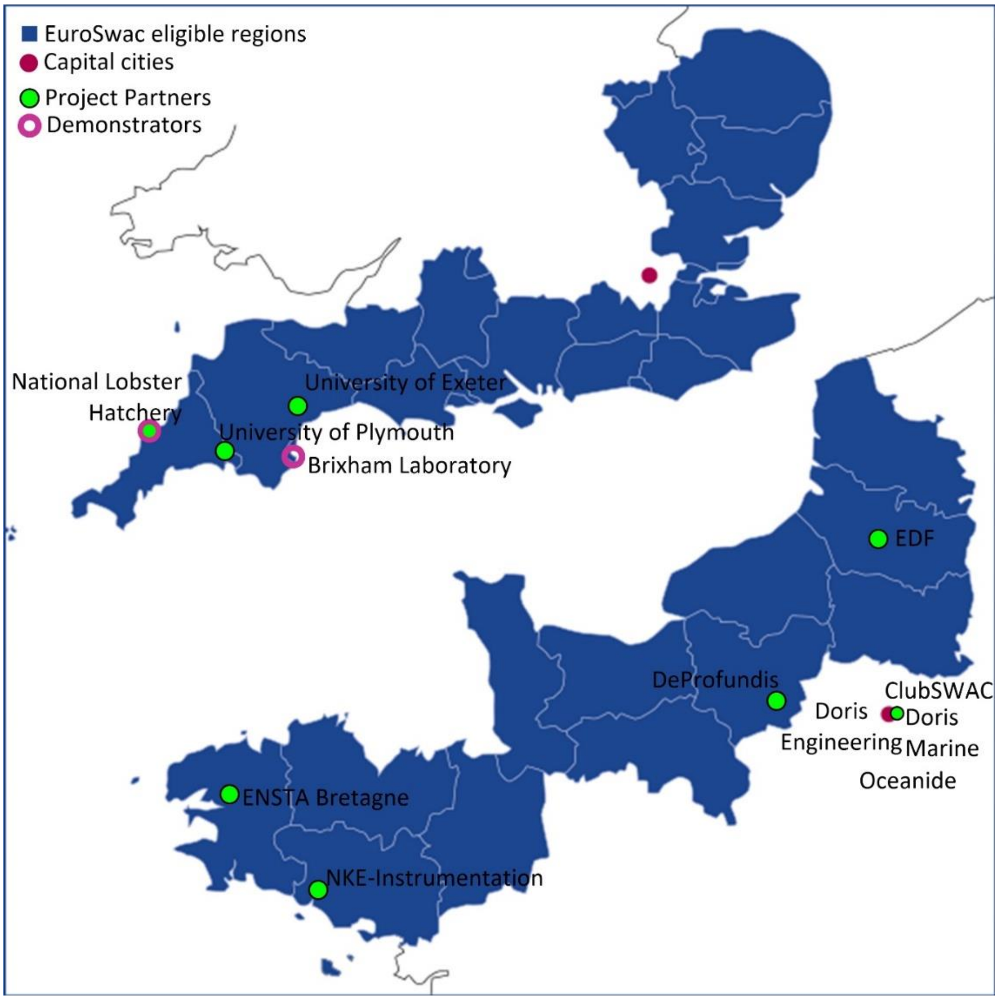

Figure 1 Euroswac Eligible Regions and locations of the project's partners and demonstration sites.

One of the outputs of the project was to identify the potential replication sites suitable for employment of the SWAC technologies (Figure 2). In total 610 end users across eleven market sectors have been identified. These were selected based on the specific criteria for each site: (1) an access to the sea, max 2km from the shore, (2) significant cooling and/or heating demand, (3) business development scope to reduce the carbon footprint impact. Each site can be considered individually. However, for the efficiency of the SWAC, agglomerations should be targeted with a several potential end-users with the similar air conditioning demand. From the selected end-users some require seasonal heating and cooling (e.g., hotels, hospitals, retail centres, education and governmental buildings, events venues) and some need a constant cooling throughout a year (e.g., ports, transport, data centres, research laboratories, industries, nuclear power facilities). When selecting hotels as potential SWAC customers, the size and the location was considered. The hotel chains like Premier

Inn, Holiday Inn, Best Western, Hilton and Travel Lodge were searched as the SWAC technology may be a desired way to reduce the carbon footprint in several location in one investment. Hospitals can be important end users due to their constant cooling and heating demand, and the size of their amenities. The nursing homes were also included under the hospitals category. Retail centres include supermarkets and their requirement for cooling all year around make them right candidate for SWAC. During this project several supermarkets showed interests in the technology. Education and research include all university and school buildings but also all research centres and laboratories. The latter are particularly important as the regulated constant temperature is often required. Governmental building and event venues occupy large spaces with a constant cooling/heating demand. The event centres often are surrounded by hospitality amenities which create multiple user space for a SWAC system in one investment. The amenities selected as tourism cover all tourist attraction from aquarium, zoos, museums, galleries etc. Leisure includes casinos, spas, theatres, cinemas and sport centres. Ports and harbours usually include office spaces, restaurants etc, but also fish markets and sea food processing areas. The latter will require cooling spaces where SWAC may be installed. Transport covers mostly terminals with the offices and accommodation around. Industry market segment include nuclear plant stations and nuclear waste services. These are significant customer due to their constant cooling demands. Industry also covers factories, renewable services parks, docks and shipyards. Data centres are interesting candidate for SWAC technology as they require a controlled temperature and a constant cooling. The conventional AC for these is expensive considering current energy price, and the cost of SWAC installation could be returned in a relatively short time.

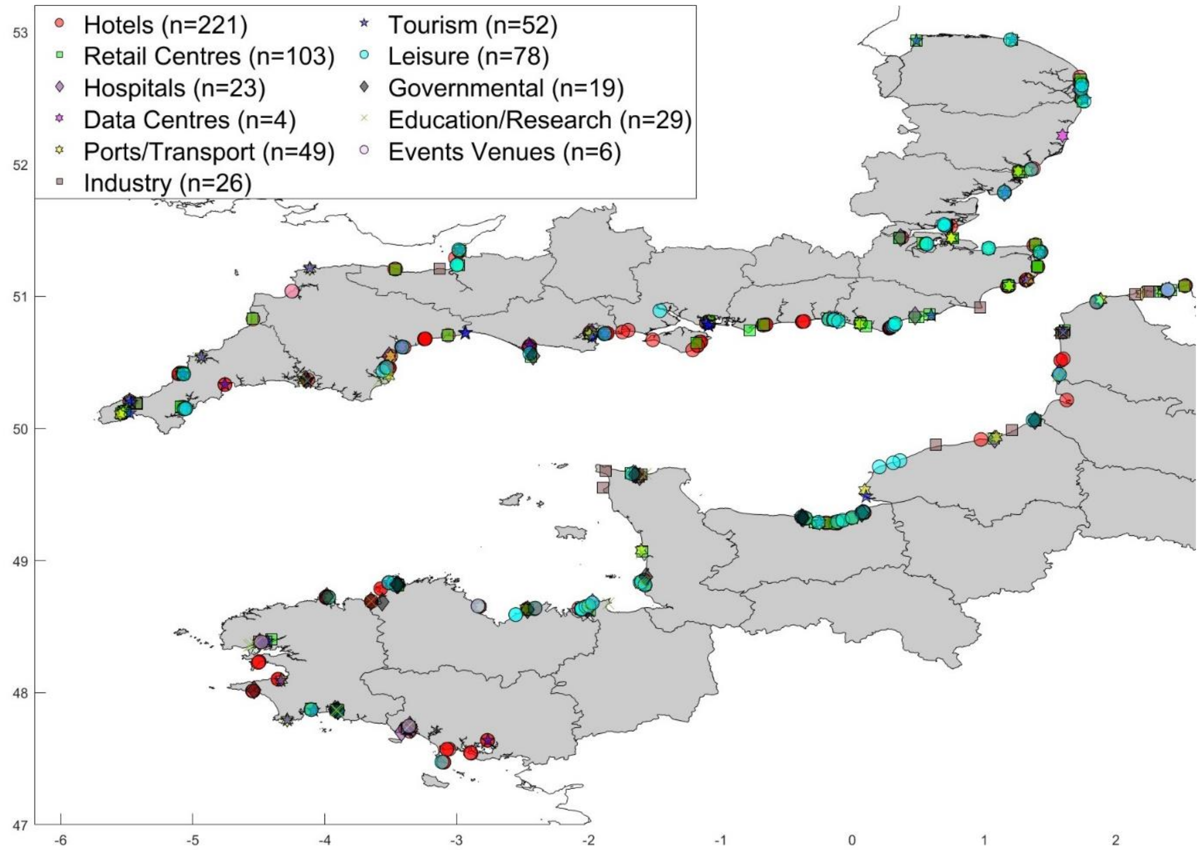

Figure 2 Identified market segments for the potential SWACs in the Channel Area.

Table 1 Selected market segments and for SWAC system and their numbers in individual locations. Note: H – hospitals (and nursing homes), R – retail (and supermarkets), T – tourism, L- leisure, I/N – industry (inc. nuclear), P/T – port and transport, E/R – education and research, G – governmental, DC -data centres, H/C – hospitals and care homes, E – event venues

Town/City	Region	Country	H	R	T	L	I/N	P/T	E/R	G	DC	H/C	E	#
Bude	Cornwall	England	1	1										2
Carbis Bay	Cornwall	England	1		1									2
Falmouth	Cornwall	England	4	2	1	2	1	1						11
Hayle	Cornwall	England		1			1							2
Marazion	Cornwall	England			1									1
Newlyn	Cornwall	England						1						1
Newquay	Cornwall	England	6	3	2	1								12
Padstow	Cornwall	England			1			1						2
Penzance	Cornwall	England	4	4				1						9
St Austell Bay	Cornwall	England	2		1									3
St Ives	Cornwall	England	1		1			1						3
Brixham	Devon	England						1	1					2
Dartmouth	Devon	England							1					1
Exmouth	Devon	England	4			1					1			6
Ilfracombe	Devon	England			1			1						2
Paignton	Devon	England				1								1
Plymouth	Devon	England	1		1			1	1	1				5
Seaton	Devon	England	1	1										2
Sidmouth	Devon	England	5											5
Teignmouth	Devon	England	1					1				1		3
Torquay	Devon	England	6			1								7
Westward-Ho	Devon	England	1									1		2
Bournemouth	Dorset	England	10		1	1					1			13
Christchurch	Dorset	England	1											1
Highcliffe&Walkford	Dorset	England	1											1
Lyme Regis	Dorset	England			2									2
Poole	Dorset	England	2	2	1			1				1		7
Portland	Dorset	England		1	1	1		1		1				5
Swanage	Dorset	England										1		1
Weymouth	Dorset	England	5		1							1		7
Clacton-on-Sea	Essex	England	1		1	1						1		4
Harwich	Essex	England	1	2				1						4
Southend-on-Sea	Essex	England	3	3	1	3								10
Bognor Regis	Hampshire	England	4	1										5
Isle of Wight	Hampshire	England	7	1										8
Portsmouth	Hampshire	England	2	4	4			2			1			13
Selsey	Hampshire	England		1										1
Southampton	Hampshire	England				1								1
Deal	Kent	England	4	2										6
Dover	Kent	England	3		1		1	2						7
Folkestone&Hythe	Kent	England	3	3				1						7
Gillingham	Kent	England	1	2		2								5
Gravesend	Kent	England	1	2								1		4
Herne Bay&Whitstable	Kent	England	1	1		2		1						5
Margate	Kent	England	2	1										3
Ramsgate	Kent	England	2	2	1	1		1						7
Sheerness	Kent	England		2				2						4
Whitstable	Kent	England	1	1		2		1						5
Caister-on-Sea	Norfolk	England	1	1										2
Gorleston-on-Sea	Norfolk	England		2		1						1		4
Great Yarmouth	Norfolk	England	2	2	1	1								6
Hunstanton	Norfolk	England		1	1									2
Sheringham	Norfolk	England		1	1	1								3
Brean	Somerset	England	1											1
Bridgewater	Somerset	England					1							1
Burnham-on-Sea	Somerset	England		2		2								4
Minehead	Somerset	England	2	1										3
Weston-super-Mare	Somerset	England	3	1	1	1								6
Felixstove	Suffolk	England	2			1		1						4

Leiston	Suffolk	England									1			1
Lowestoft	Suffolk	England	1	2	1	1								5
Bexhill	Sussex	England		2								1		3
Brighton&Hove	Sussex	England	4	5	1	4			1			2		17
Eastbourne	Sussex	England	8	3	1	3								15
Hastings	Sussex	England		1	1									2
Little Hampton	Sussex	England		1										1
Newhaven	Sussex	England	1	2				1						4
Seaford	Sussex	England		1										1
Worthing	Sussex	England	3											3
Cabourg	Calvados	France	5	1		1								7
Colleville Montgomery	Calvados	France		1										1
Deauville	Calvados	France	4	1		2				1				8
Dives sur Mer	Calvados	France	1											1
Houlgate	Calvados	France		1		1								2
Langrune sur Mer	Calvados	France	1							1				2
Luc-sur-Mer	Calvados	France	1	1		1								3
Merville-Franceville-Plage	Calvados	France	2	1										3
Ouistreham	Calvados	France		1	1	1		1						4
Saint aubin sur Mer	Calvados	France	1		1	1				1				4
Trouville sur Mer	Calvados	France	4			1								5
Villers sur Mer	Calvados	France	3	1		1								5
Erquy	Côtes-D'Armor	France	1	1				1		1				4
Fréhel	Côtes-D'Armor	France	1			1								2
Perros-Guirec	Côtes-D'Armor	France	4	2		3				2				11
Pléneuf Val André	Côtes-D'Armor	France				2								2
Plurien	Côtes-D'Armor	France	2											2
Saint-Quay-Portieux&St Michel	Côtes-D'Armor	France	3			1		1		1			1	7
Tréburden	Côtes-D'Armor	France	2											2
Tregastel	Côtes-D'Armor	France	1		1	1								3
Audierne	Finistère	France	2							1				3
Bénodet	Finistère	France	2	1	1	1								5
Brest	Finistère	France	1	1	3		3	2	1	1			1	13
Concerneau	Finistère	France	1	2		3	1	1	5	2		1		16
Crozon	Finistère	France	3											3
Douarnenez	Finistère	France	3		1			1						5
Guilvinec	Finistère	France			1			2						3
Locquirec	Finistère	France	2						1	1				4
Plouzané	Finistère	France							2					2
Roscoff	Finistère	France	6			1		1		1				9
Cancale	Illes-&-Vilaine	France							1					1
Dinard	Illes-&-Vilaine	France	3	2		4								9
Saint-Malo	Illes-&-Vilaine	France	12	2	1	3		1	3			3		25
Agon Coutainville	Manche	France					2		1					3
Blainville sur Mer	Manche	France		1				1						2
Bréville sur Mer	Manche	France								1				1
Cherbourg	Manche	France	1	3		1	2	1	1	1		2		12
Donville les bains	Manche	France	1											1
Flamanville	Manche	France					1							1
Granville	Manche	France	4		1	3	1	1	3					13
La Hague	Manche	France					1							1
Saint Pair	Manche	France	1	1		1								3
Arzon	Morbihan	France	2											2
Carnac	Morbihan	France	3											3
Locmiquélic	Morbihan	France										1		1
Lorient	Morbihan	France	1	2	1		2	1	2	1		1	1	12
Ploemer	Morbihan	France										1		1
Port Louis	Morbihan	France	1		1									2
Quiberon	Morbihan	France	2			1								3
Vannes	Morbihan	France	2		1									3
Bray Dunes	Nord	France	2	1										3
Dunkerque	Nord	France	1	3	4	1		2				1	2	14
Gravelines	Nord	France					3							3
Berck&Le Touquet	Pas-de-Calais	France	3			1			2			2		8

Boulogne-sur-Mer	Pas-de-Calais	France		1	1		3	2	1					8
Calais	Pas-de-Calais	France	3			1		4						8
Contenville	Seine-Maritime	France					1							1
Dieppe	Seine-Maritime	France		1				1	2			1		5
Etretat	Seine-Maritime	France				1								1
Fecamp	Seine-Maritime	France				1								1
La Havre	Seine-Maritime	France			1			1						2
Le Treport	Seine-Maritime	France				2	1			1				4
Penly	Seine-Maritime	France					1							1
Yport	Seine-Maritime	France				1								1
Fort Mahon Plage	Somme	France	1											1
Le Cotroy	Somme	France	1											1
			221	**103**	**52**	**78**	**26**	**49**	**29**	**19**	**4**	**23**	**6**	**610**

2.SWAC replicability components

There are three components to consider when assessing the replicability of the SWAC system (Figure 3). These are dependent on each other for the full assessment of the SWAC applicability. Technical requirements are important for the design, optimisation and installation of the SWAC at individual location. It also feeds and influences the environmental study and provide parameters for the financial analysis. The SWAC system evolves in a given environment which applies external stresses on it. These stresses can be directly applied on the SWAC such as thermal stress (the pumped water is warmed as it flows towards the surface) or hydrodynamic stress (the sea current and waves are generating efforts on the immerged pipe and require an appropriate anchoring system). Technical assessment is considered when reviewing environmental regulations and policies. Environmental components like bathymetry and thermal gradient affect pipeline sizing and installation procedures. Financial analysis requires all technical components for the full cost of SWAC at a specified location. It also takes to consideration LCA and Circular economy modelling to lesser impact on environment.

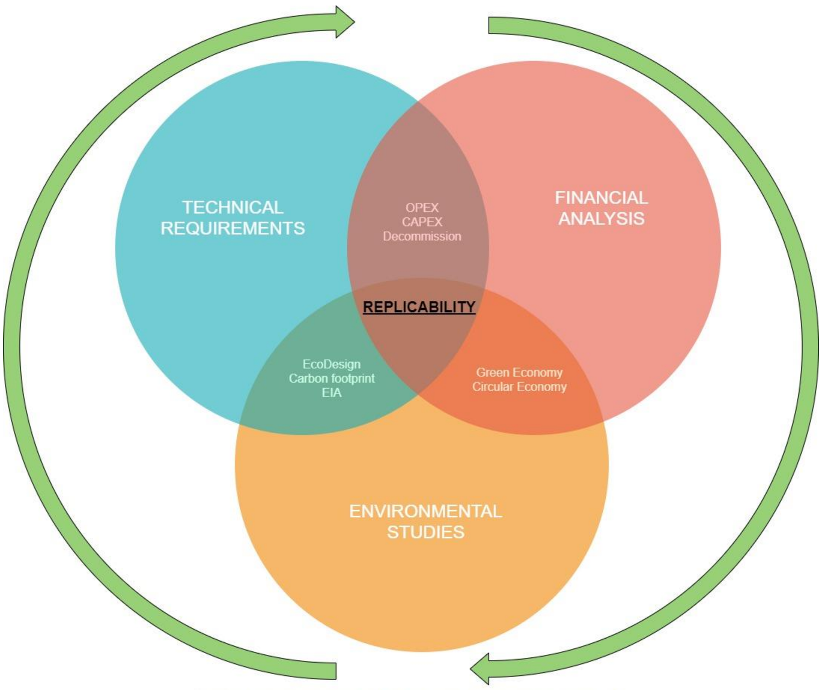

Figure 3 Components to consider for SWAC's replicability.

The simplified steps to the SWAC replicability are presented in Figure 4. The assessment process considers mainly a potential site, its location, market segment and requirements for air conditioning. Environmental studies include regulations and policies for installation and operation of SWAC, as well as environmental impact assessment and cost of environmental studies. Environmental studies and analysis have been completed in the Work Package T1 under the supervision of the University of Plymouth (*Report 216-T1.1-UNP-001 Environmental Constraints*). The financial analysis takes into the account CAPEX and OPEX and comparison of the linear vs. circular economic model (*216-T4.3-UNE-101-EUROSWAC market and replication analysis report**).

Four components have been identified for the technical SWAC design (Figure 4).

1. Piping system is influenced by intake and outtake depths. Intake depth has to be assessed to reach the desirable temperature. The outtake depth has to be chosen where the released water will not change ambient waters by more than 3°C. The difference in temperature between intake waters and released waters should not exceed 8°C and the released water should not exceed 23°C. In next step the flow rate is estimated as it will impact the pipe size and will allow to calculate the head loss. Knowing the pipe size, the weight of the pipe can be determined as the pipes are sold by diameter and weight in kg. The head loss is important for the pumping system.
2. The pumping system is used to: (1) move the sea water in the pipes, from the intake to the heat exchange station, (2) move the water from heat exchanger/heat pumps to a customer. The pumping system is defined by flow rate and manometric height. When choosing the pumping system, the location, type, number, and power are also considered.
3. Heat exchangers component is important part of the SWAC systems as it transfers the cooling power from the sea water to the secondary loop. The heat exchangers cannot be located too far from the sea to reduce changes in water temperature. The position should be the closest site from the shoreline with sufficient surface area to host a drilling operation (around 800m²) is a suggested minimum value from drilling operators). The heat exchangers number, size and type depend on the customer's size, its thermal demands, and the sea water flow rate. Heat exchangers are usually plate heat exchangers with titanium plates to resist corrosion. However, this technology implies pressure losses and can't work with high flowrates, which requires several heat exchangers to be placed in parallel. Thanks to the suppliers' data, a first estimate of the appropriate configuration can be calculated by dividing the maximum operating flowrate by the maximum flowrate that a heat exchanger can take (around 300 m^3/h). The heat exchanger ΔT_{HE} needs to be more than 0.5°C, otherwise costs are too high, and performances cannot be checked as temperature measurements are not accurate enough to ensure the HE's compliance with the need.
4. The customer is the final user of the cool or heat provided by the system. The customer component defines the minimum performance requirements for the expected SWAC system: the cooling/heating need. It is determined by the customer only and holds substantial importance regarding SWAC design. The entire SWAC system relies on the identified maximum customer cooling/heating need (in MWth).

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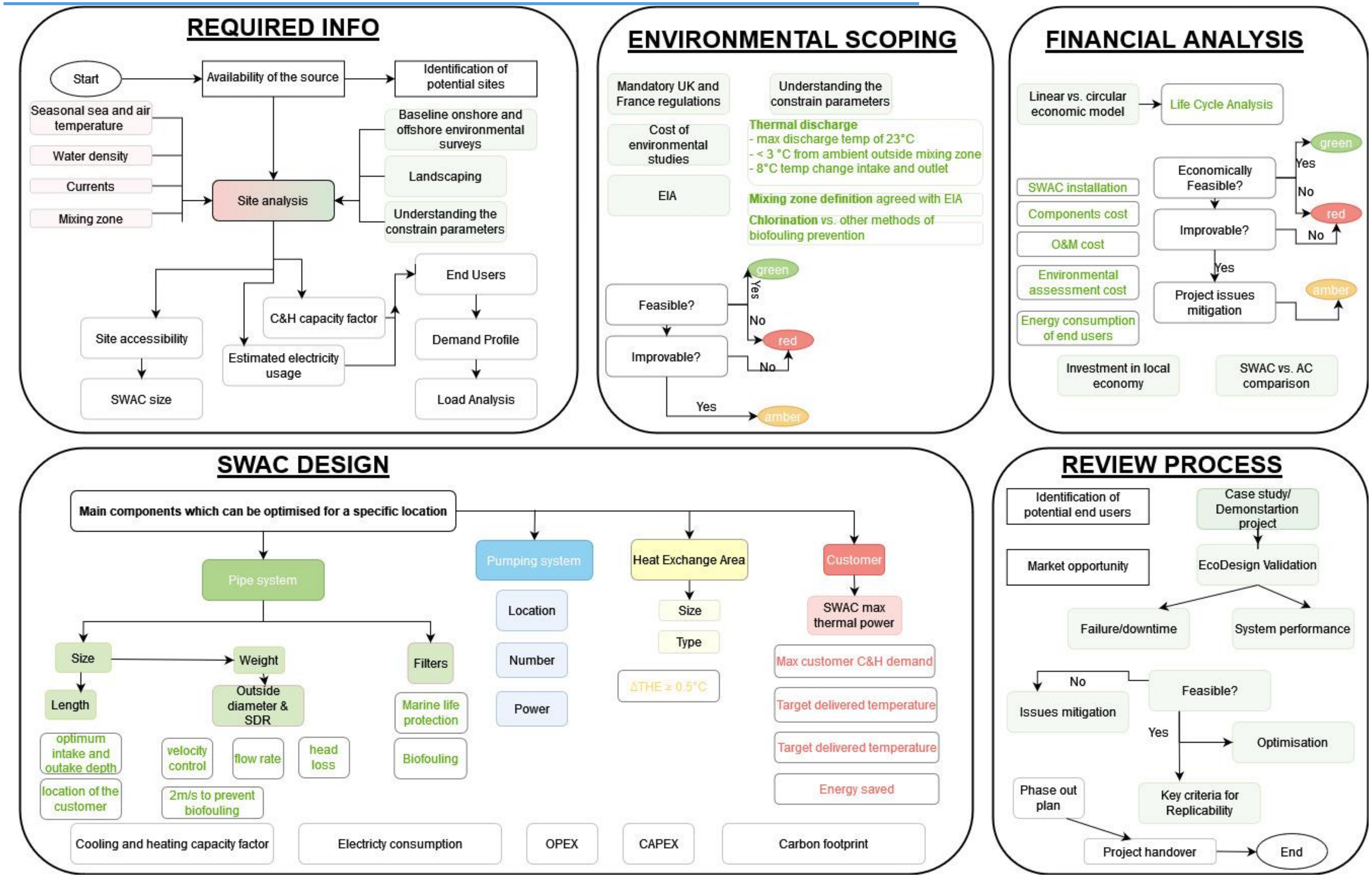

Figure 4 Replicability analysis framework.

3. A potential for SWAC in the Channel Area

Analysis of components for the SWAC design, shows that the external environment plays significant role in SWAC potential for a selected region. The majority of customers cooling/heating demand is related to the air temperature throughout a year, and the design of SWAC relies on the sea water temperature and a local bathymetry. The comprehensive analysis of pipeline length, the capacity factor for SWAC, and the depth required to reach air-sea water temperature difference of min 4°C has been performed to show the locations with the potential for employment of the SWAC systems, and to roughly estimate the cost of the investment.

3.1. Methodology and data

The model framework in

Figure 5 summarises the methods and flow for the replicability analysis. Sea water temperatures and bathymetry data are the main inputs to generate location maps where the air – sea water temperature difference is minimum 4°C. This is considered an optimum temperature difference taken that the sea water temperature may increase while travelling to the heat exchanger. Those location maps allowed to estimate the pipeline length for the identified end users locations (in Table 1). Hourly air temperatures were used to calculate cooling and heating demand, and the SWAC seasonal capacity factor. Those outputs were used to compare the optimum pipeline length with the actual thermal demand for each identified end user location. Energy usage for cooling and heating allowed to calculate the carbon footprint reduction and energy saved using the SWAC system. It also was used to assess the SWAC cost and a payback time for the potential customers. The data sources are listed in Table 2.

Table 2 Data source for the replicability analysis.

Data	Data source
Bathymetry data	GEBCO [1] https://download.gebco.net/
Sea Water temperature data at selected depths for the period July 2011 – June 2021	Copernicus Marine Service [2] https://data.marine.copernicus.eu/
Hourly Air temperature data for the period July 201 – June 2021	Weather archive at the airports at RP5 [3] https://rp5.ru/Weather_in_the_world
Energy usage 2005-2021	Subnational electricity and gas consumption summary report [4] https://www.gov.uk/government/statistics/subnational-electricity-and-gas-consumption-summary-report-2021 Consommation annuelle d'électricité et gaz par commune et par secteur d'activité [5] https://www.data.gouv.fr/en/datasets/consommation-annuelle-delectricite-et-gaz-par-commune-et-par-secteur-dactivite/
Carbon footprint emission 2022	National Statistics [6] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1064923/2021-provisional-emissions-statistics-report.pdf

	Data Lab [7] https://www.statistiques.developpement-durable.gouv.fr/edition-numerique/chiffres-cles-du-climat/10-emissions-de-ges-de-lindustrie
Cost of gas and electricity 2022	Energy Guide [8] https://energyguide.org.uk/electricity-cost-calculator/ Energy Guide [9] https://energyguide.org.uk/average-cost-gas-kwh/ Country economy [10] https://countryeconomy.com/energy-and-environment/electricity-price-household/france Global petrol prices [11] https://www.globalpetrolprices.com/France/natural_gas_prices/

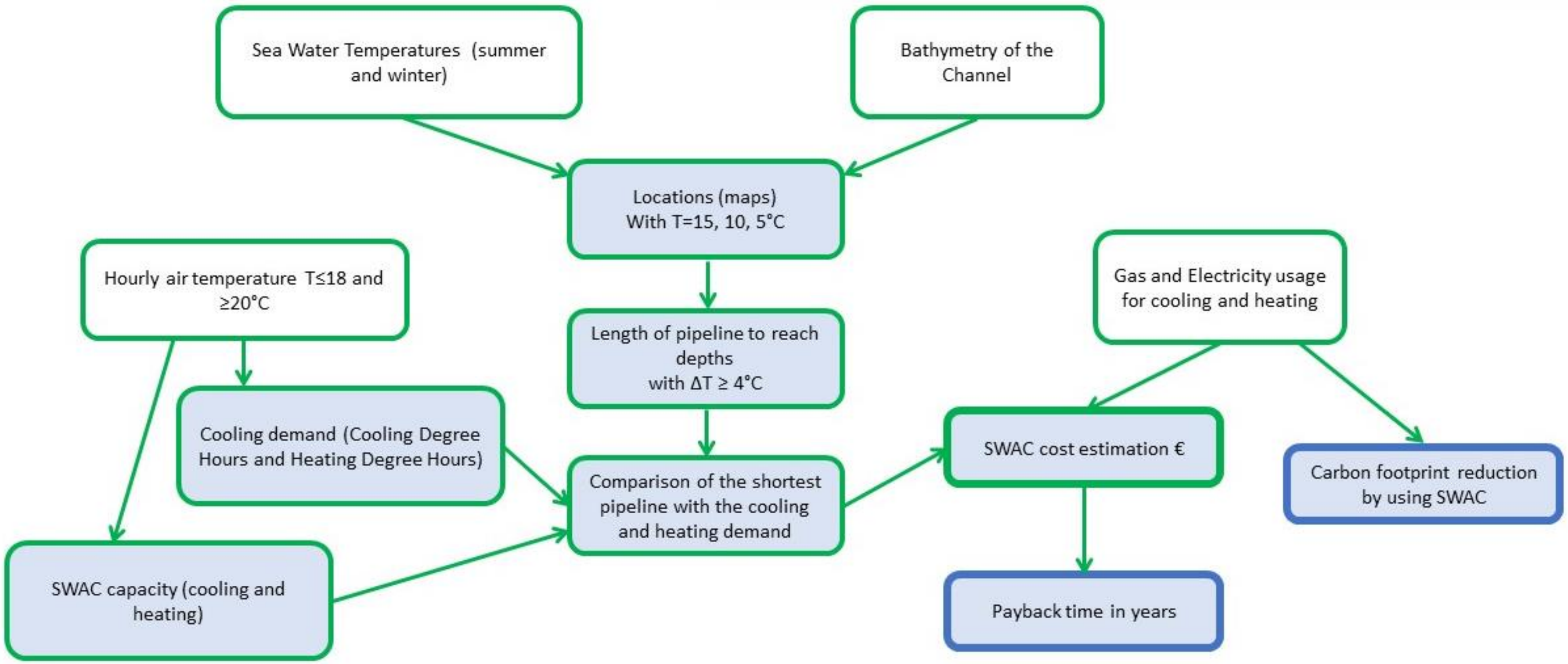

Figure 5 A model framework for analysis of replicability. Note: green frame indicates inputs, light blue fill indicates outputs.

3.2. Bathymetry map

Using the GEBCO data collection, new bathymetric maps for the Channel area were generated (Figure 6, Figure 7). The local bathymetry for each potential user is important as it influences the design and installation planning. Local bathymetry affects the water physical parameters and condition, like thermal gradient, salinity, water mixing, currents etc.

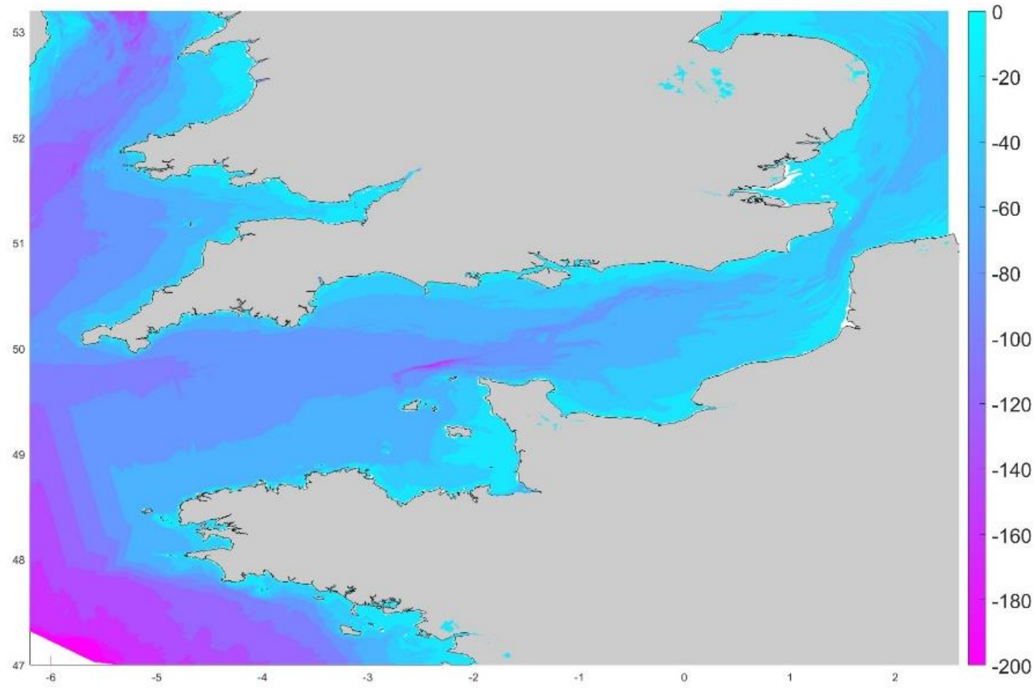

Figure 6 Bathymetric map of the Channel.

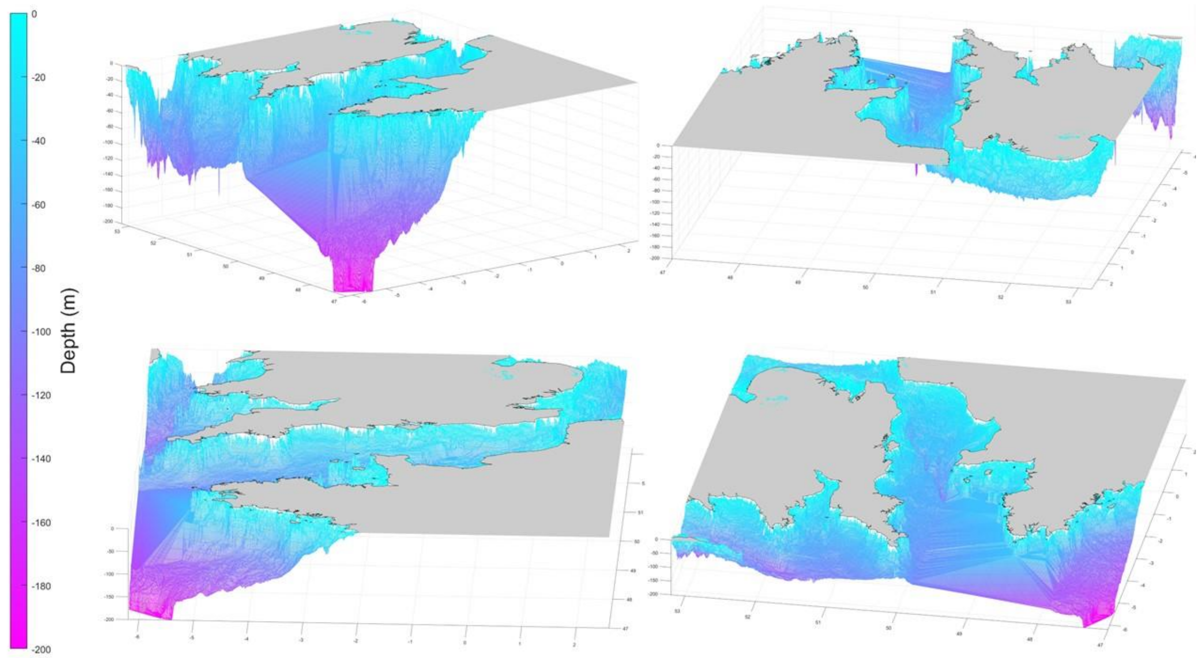

Figure 7 3D bathymetric maps of the Channel.

3.3. Air and Sea water temperature

SWAC exploits temperature differences between sea water and external air. In the deep water SWAC projects, the thermocline consists of the minimum depth for the water extraction as below it, water stays at the constant low temperature and are not subject of thermal and chemical mixing. The Channel is characterised with relatively shallow waters where thermocline cannot be formed. The Channel waters are mixed by tides, currents and waves. To investigate SWAC potential, the optimal temperature difference between sea water and air must be established. As the water temperature can increase by 1-2°C moving from the intake to the heat exchangers, the optimal difference must be minimum 4°C for SWAC to work efficiently. Using the Copernicus sea water temperature data and air temperature data recorded at the airports, temperature maps have been generated (Figure 8 and Figure 9).

3.3.1. Summer trend

In the summer the SWAC system is researched for cooling purposes. The 10 years record of averaged July temperatures were used to create the maps to compare external air temperatures with sea water temperatures at different depths (Figure 8). All the maps show that water mixing affects temperatures at all depths. There is no significant thermal gradient in the sea water. The sea water is not much colder than the air. Minimum 4°C difference between air and sea water is observed at 0m depth in the central south England (Dorset, Hampshire, Isle of Wight and Sussex) and in the north-west France (Finistère, d'Armor and Morbihan). At 20-30 m depth the min 4°C temperature difference is available of the coast of Cornwall, Devon, Dorset, Hampshire, Isle of Wight, Sussex and Kent in England, and Seine-maritime, d'Armor, Finistère, and Morbihan in France.

3.3.1. Winter trend

In the winter SWAC is considered both for heating and cooling purposes. The former is for all sectors requiring habitable conditions, e.g., hotels, hospitals, offices, schools, tourist attractions, leisure centres etc. The cooling is required for data centres, laboratories, fish markets, food processing and storage, aquariums etc. A ten years temperature data for January has been averaged and used to generate maps of air temperature and sea water temperature at selected depths (Figure 9). The maps of the winter trend for temperatures of the air and sea waters show no significant thermal gradient due to water mixing. The temperatures are influenced by continental air masses from the north-east. The coldest waters come from the east along the coast encompassing warmer waters further from the shores. This can be used for cooling where required without deep water installations. SWAC has a great potential for heating without a need of reaching deep waters. The whole south coast of England has waters min 4°C warmer than the air at 0m depth. Most of the French Channel coast is also suitable for the SWAC heating.

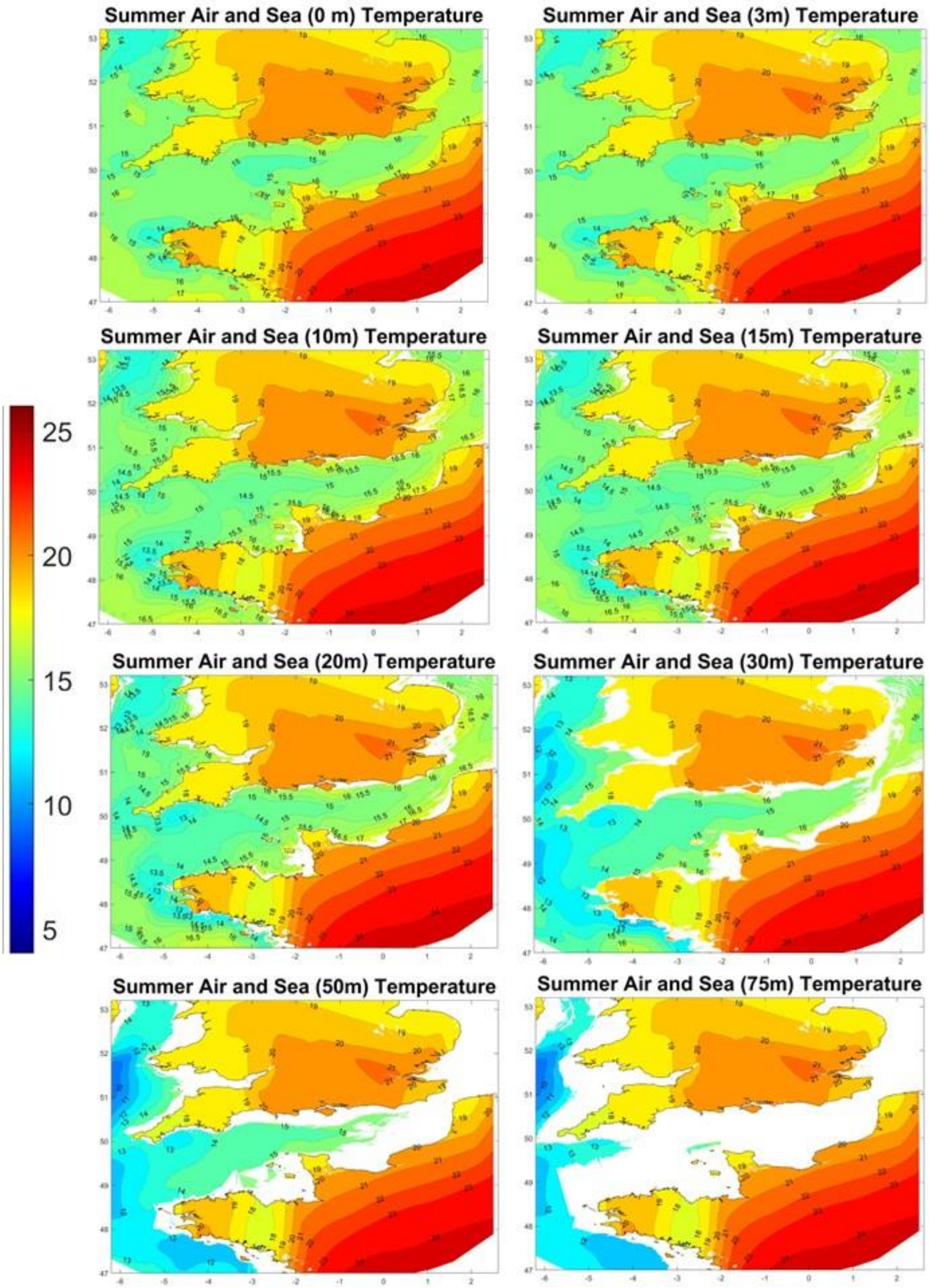

Figure 8 Average Summer Air and Sea water temperature.

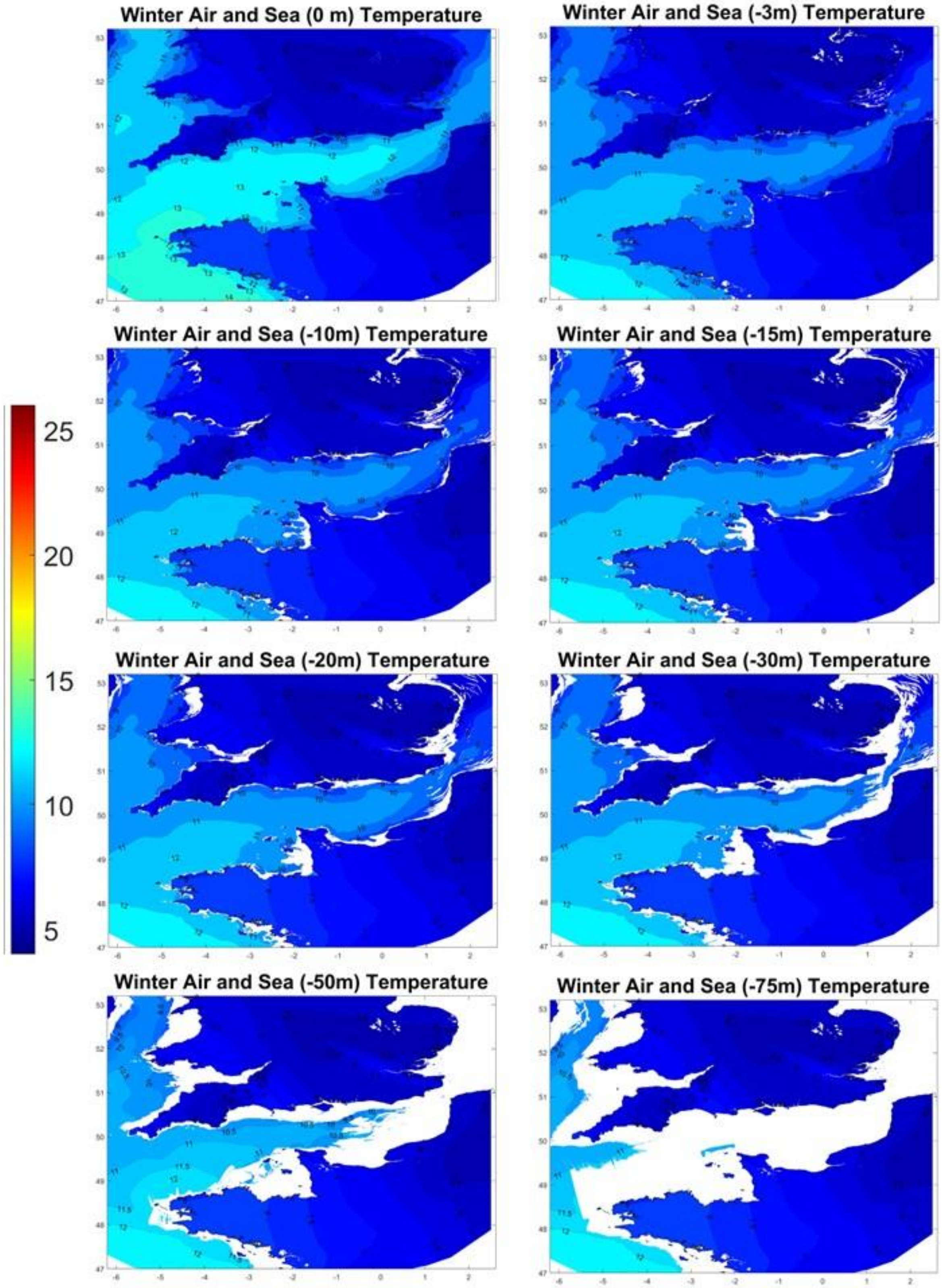

Figure 9 Average Winter Air and Sea water temperature.

3.4. Potential for all year around SWAC

As shown in the sections 3.3.1 and 3.3.1, many places can benefit from SWAC system extracting waters at shallow depths, which decreases the cost of installations. It is also clear that SWAC can be used all year around, cooling in the summer (and winter where required) and heating in the winter. Selected locations in those areas were researched in details and results are shown in the Figure 10. During a winter there is no thermal gradient on the sea waters and the water is generally warmer than the air, a relation which can be used for heating. In the summer, the day-time air temperature is generally higher than the temperature of water even at the shallow depths. Considering that the day-time temperatures are on average 18-20°C and fall below 15°C during the night only day time cooling is required during the summer months.

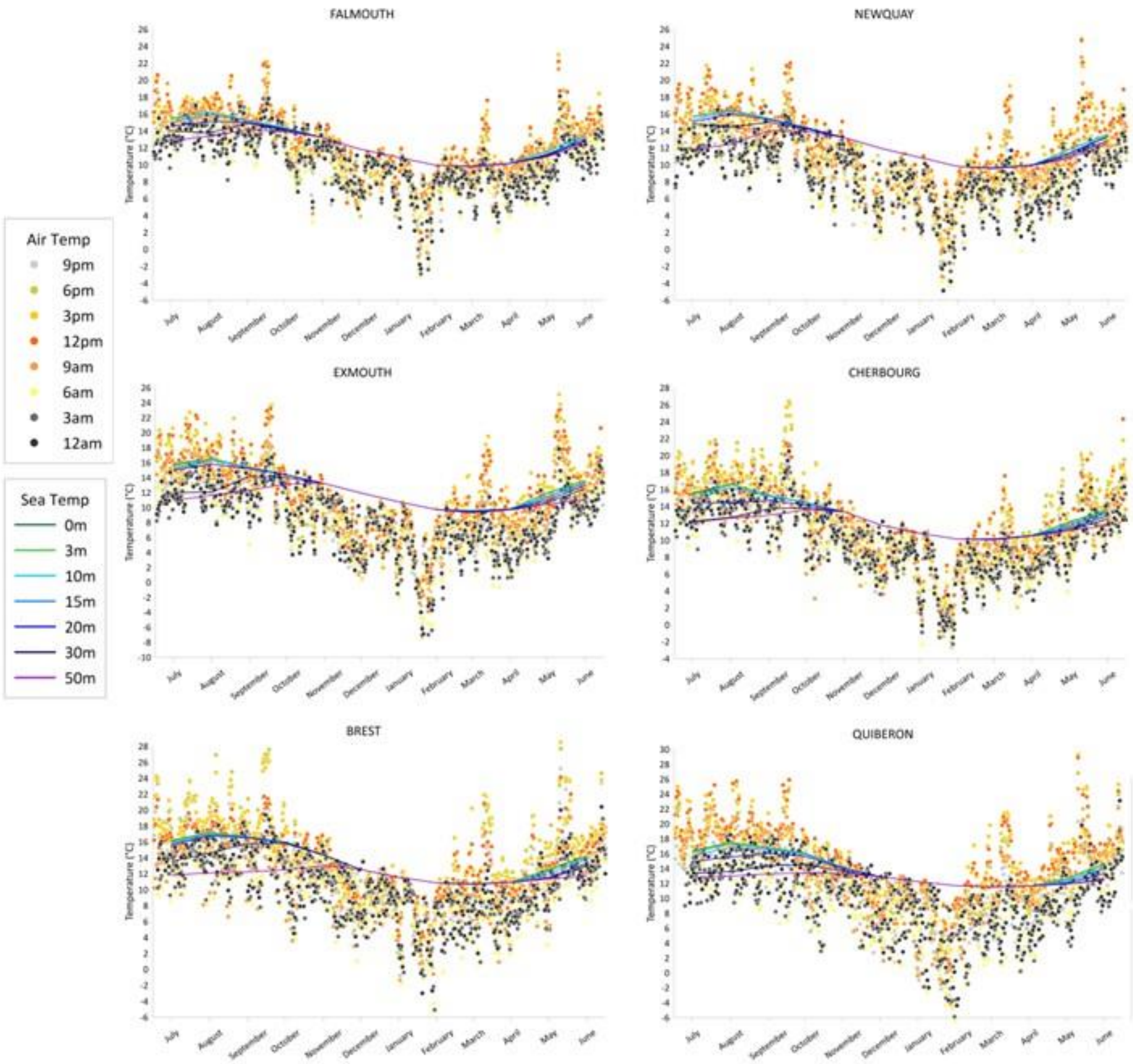

Figure 10 A comparison of sea water temperatures at selected depths to air temperature recorded every 3h throughout a year in the selected locations along the Channel coast.

As shown on the Figure 11, SWAC has an environmental capability to be employed throughout the year at many identified potential locations. It can be used for cooling and heating by extracting very shallow waters. However, cooling capabilities are greater at 20-30 m depths.

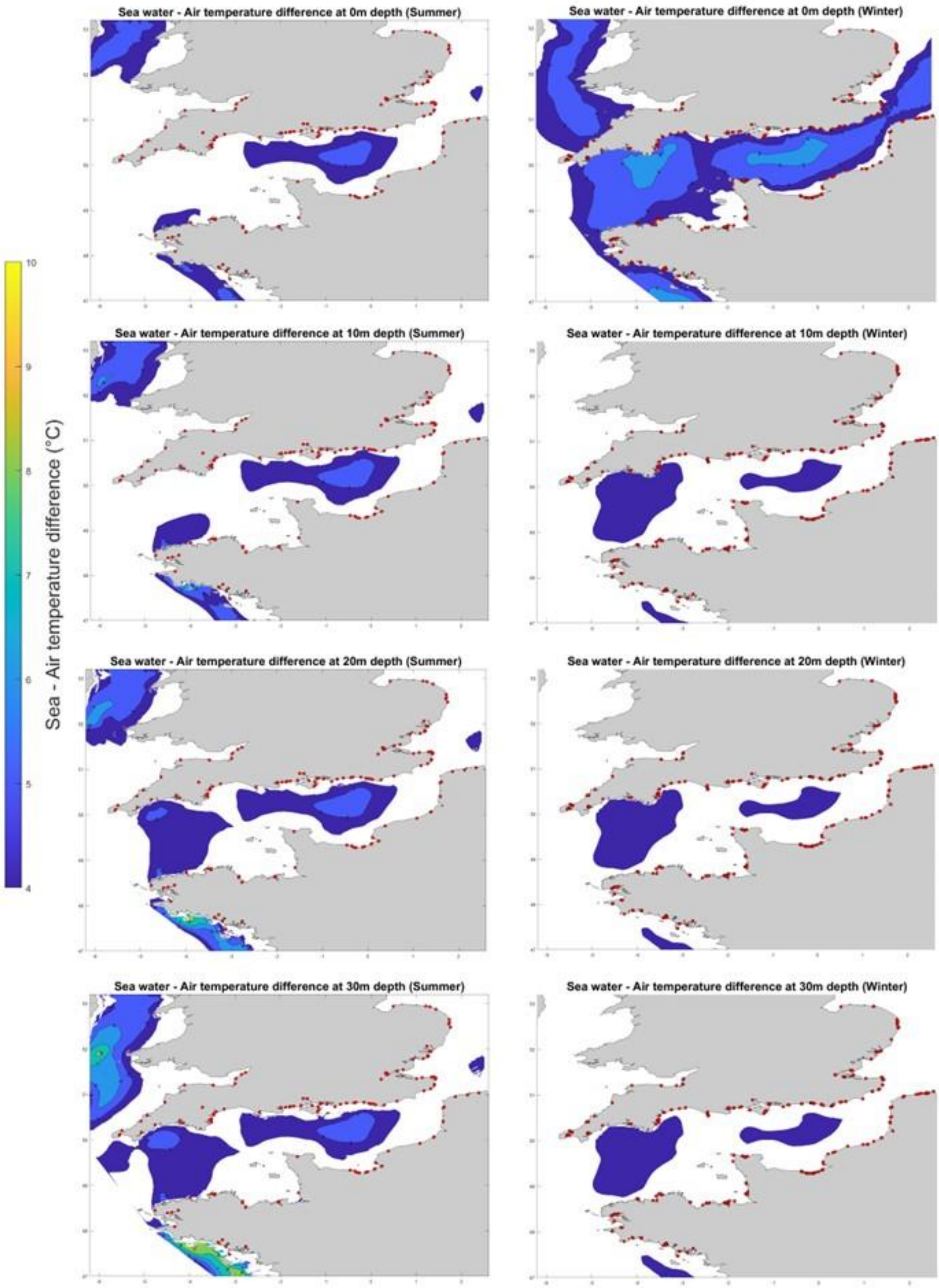

Figure 11 Seasonal temperature difference (of min 4°C) between air and sea water at different depths.

4. Pipeline length to the optimum sea water temperature

Based on the environmental parameters considered for a SWACs potential in the Channel, the length of the pipeline was calculated (considering the optimum sea water temperatures as explained in the section 3.4) (Figure 12, Table 3). The locations where the pipe length exceeds 50 km were excluded from the further analysis, because the SWAC becomes cost inefficient.

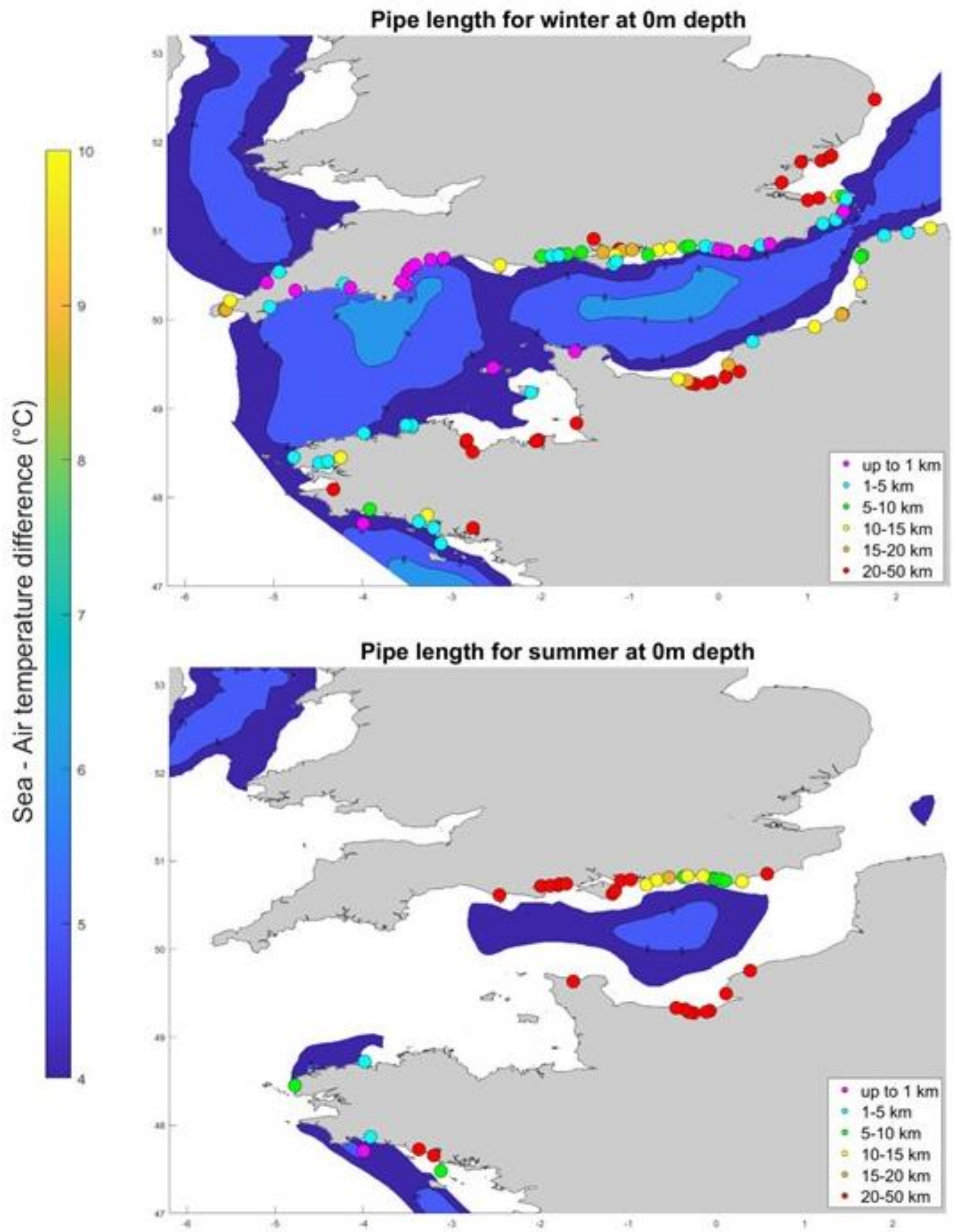

Figure 12 Pipeline length required for optimum sea water temperatures at 0m depth.

Considering the winter temperatures at 0m depth, there are 16 locations in England and 2 in France where the required pipeline length is less than 1km (Figure 12). 17 locations in England and 13 in France require minimum pipeline length of 1 – 5km. A minimum length of 5 – 10 km is needed for another 8 locations in England and 3 in France. At least 10 – 20 km pipeline is recommended for further 12 locations in England and 10 in France. There are not as many locations with the easy access to waters of optimum temperatures for SWAC in summer months (Figure 12). However, to make the SWAC work all year around, the additional study is required to check all potential intake locations indicated for heating in the winter to assess their capability for cooling in the summer. Each potential SWAC location should be studied individually in detail for that purpose.

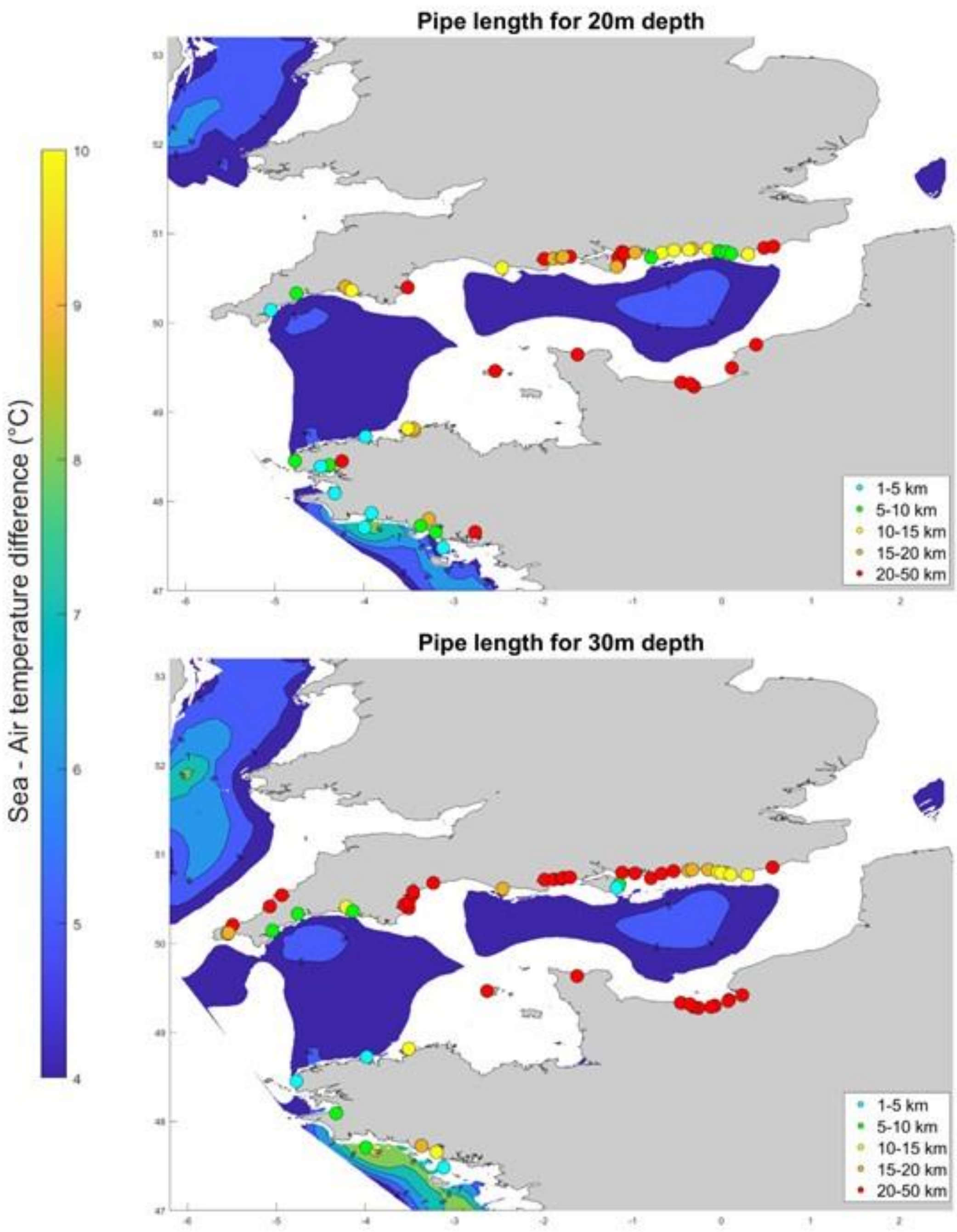

Figure 13 Pipeline length required for optimum sea water temperatures at 20 and 30m depth.

When looking for the optimum water intake temperature for cooling in the summer, the waters at 20 and 30m depths are suitable for the SWAC systems at the selected locations (Figure 13). However, the installations costs rise with the increasing depth.

5. Air conditioning demand in the Channel

SWAC systems can be eco-friendly alternative to other air conditioning technologies. To investigate the replicability and efficacy of the SWACs, the Channel area was studied to assess the demand for cooling and/or heating. This was assessed by calculating annual cooling and heating degree hours, and by estimating SWAC's cooling and heating capacity factors.

5.1. Cooling demand

Cooling degree hours (CDH) gives an indication of the cooling load of a residence along the Channel area calculated for the whole year. The Channel area is characterised with the temperate humid climate. Hence, the temperature reaches over 22°C only for limited time in a year. It is estimated that there are up to 2000 hours in a year where the cooling in the offices, hospitals, hotels, restaurants, leisure centres etc., may be required. This is also supported by the SWAC cooling capacity factor, which shows only up to 5% capacity at the selected potential locations.

This calculation is the rough estimate for all buildings and does not take in accountancy amenities with the larger cooling demands (e.g., fish markets, research laboratories, data centres). Where the cooling is required all year around and/or demanded cooling is lower than 20°C, individual SWAC assessment is required.

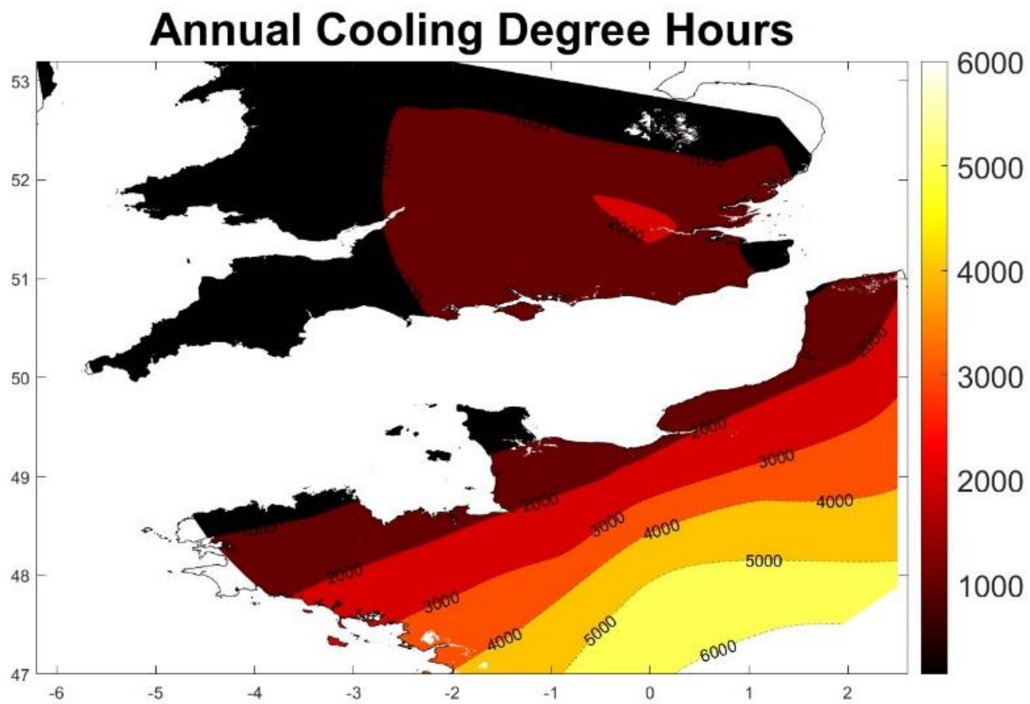

Figure 14 Annual Cooling Degree Hours.

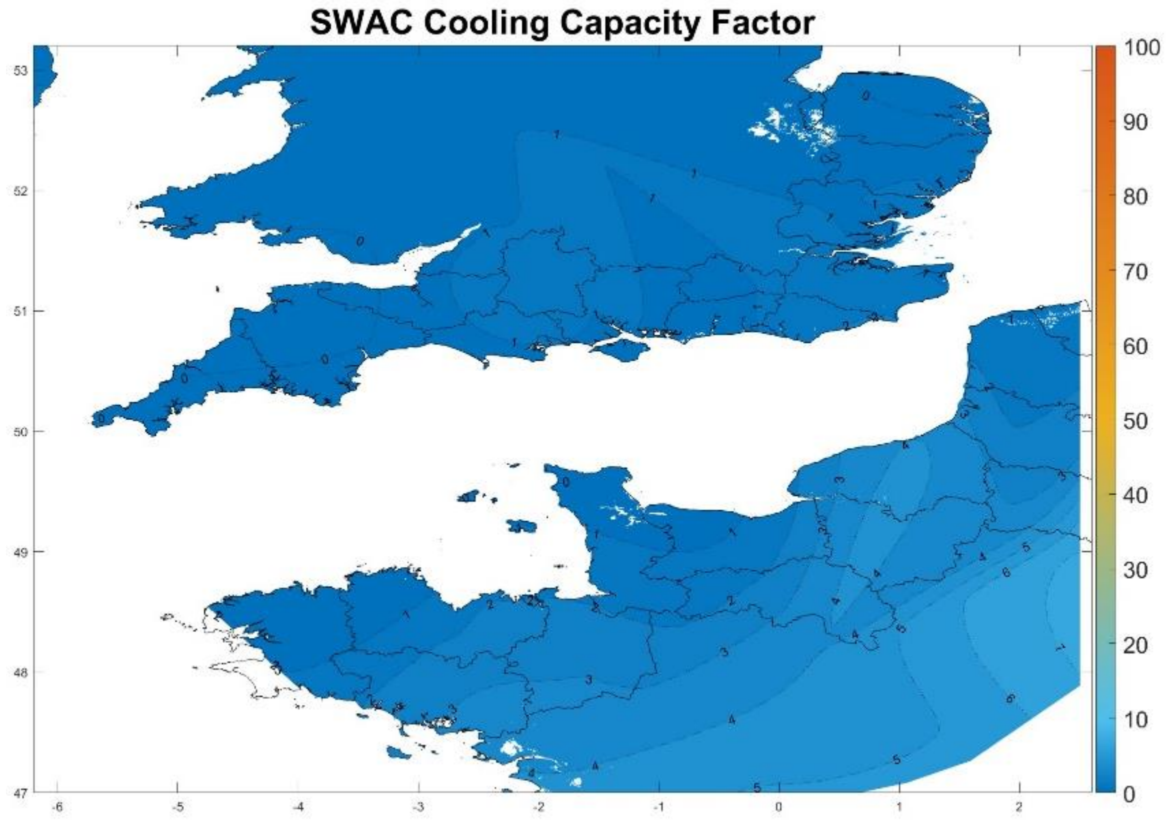

Figure 15 SWAC cooling capacity factor.

5.2. Heating demand

Heating degree hours (HDH) provides information about the heating load of a residence along the Channel area calculated for the whole year (Figure 16). It is assumed here that the base for average annual heating is 18°C. The south coast of Devon, Dorset and Sussex and Somme, Seine-maritime and Calvados have highest demand for heating, over 6000 hours in a year. That is 70% of all annual hours. Other parts of the Channel still need heating during at least half a year. The SWAC heating capacity factor is estimated for 20 to 50% along the Channel coastline (Figure 17).

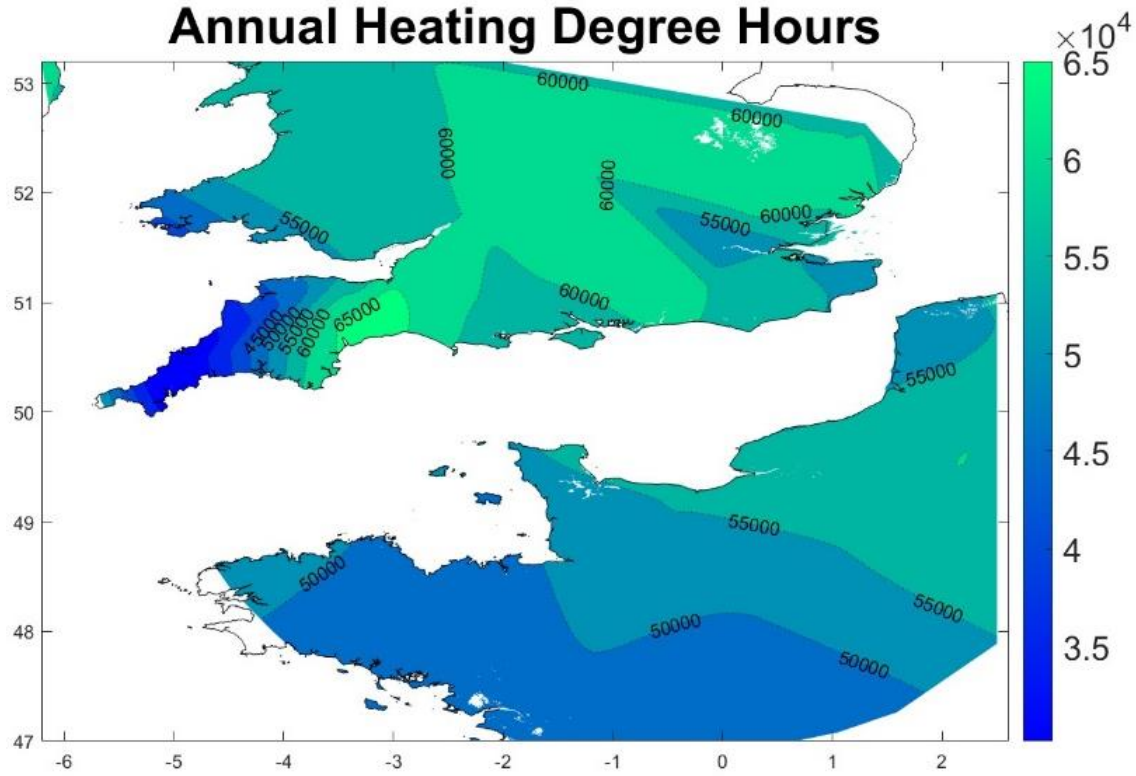

Figure 16 Annual Heating Degree Hours.

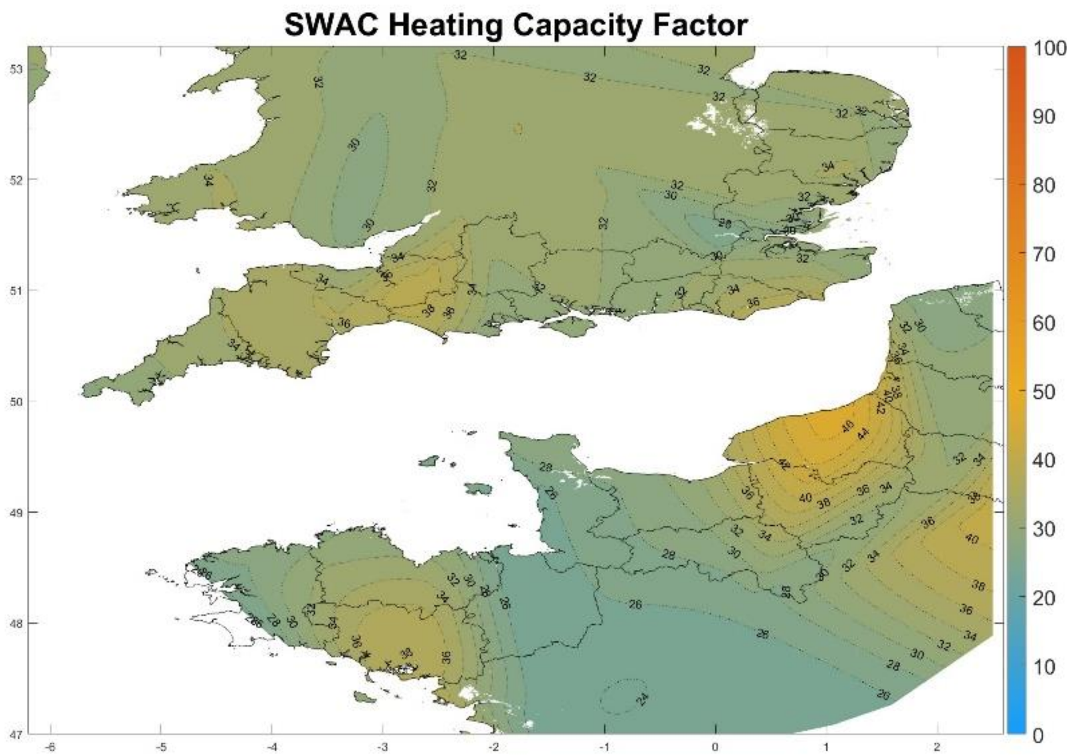

Figure 17 SWAC Heating Capacity Factor.

6. Energy saved and carbon footprint reduction by installing SWAC.

Based on the electricity and gas consumption in 2021, the energy savings and carbon footprint reduction by installing SWAC was calculated. For this, it is assumed that 40% of the whole electricity consumption and 90% of gas utilisation is used for air conditioning (cooling and heating). It is also assumed that SWAC COP is 3.5. For the carbon footprint calculation 943M tonnes CO_2 was used for England [12] and 300.5 M tonnes for France [13]. Overall, the energy used for heating and cooling in the Channel area ranges from 3 to 2,196 GWh (Figure 18). By installing SWAC, this can be lowered by 50-60% in England and 10-30% in France (Figure 18). Carbon footprint can be lowered significantly by 30-40% in England and 10-30% in France.

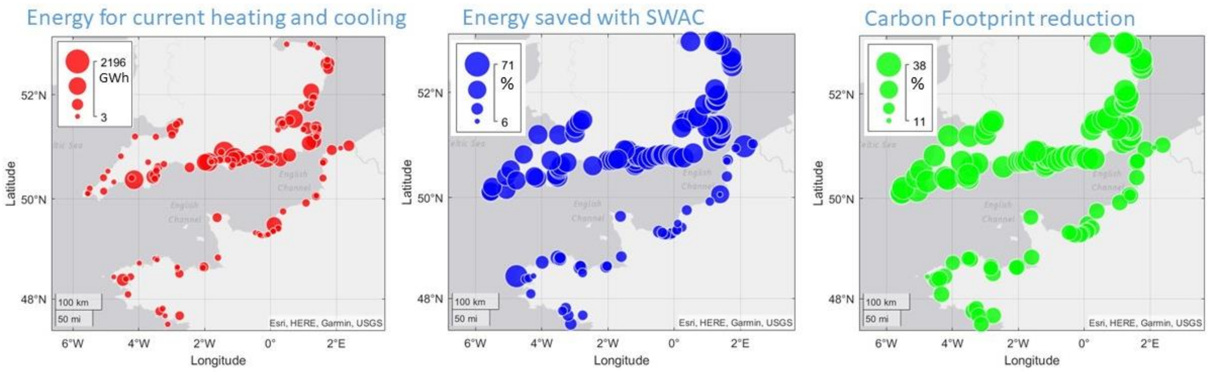

Figure 18 Energy saved and Carbon footprint reduction by installing SWAC in the Channel.

7.SWAC cost and a payback time.

Understanding the SWAC demand and environmental potential in the Channel, the OPEX and payback time was calculated for the identified SWAC potential locations (Figure 19, Figure 20, Table 3).

For the SWAC cost, following assumptions have been made:

1. The minimum pipeline length was used.
2. Pipe price - €5/kg (a quote for another DPI project)
3. 1.05kg/m is assumed for weight of the pipe SDR11, diameter of 63mm [14]. This will not always be true as the SDR and diameter of pipe will depend on the local flow rate. This estimation was used here as the same pipe are employed in the project's demonstration sites in Brixham and Newlyn which pump waters at the shallow depths.
4. Installation cost is 5 times of the pipe cost.
5. The price of the mono pump is €177,000 (a quote for another DPI project). However, the selection of the pump on the individual localisation will depend on many factors, like intake depth pump depth, pipeline length, flow rate and a head loss. The pump cost for the Channel shallow waters will be most likely lower.
6. The price of the heat exchanger is €57,000 (from another DPI project). However, the price at the individual location will depend on the type of the heat exchanger, the required heat exchanger area, how many utilities to benefit from SWAC and what is the SWAC size.

7. The price of the heat pump is €45,000 (from another DPI project). Again, it will change accordingly to the heat exchanger demands.
8. Only pipeline length up to 20km was considered.
9. The cost over €1M was excluded from the further analysis.
10. The calculations are based on the pipeline length calculated for the surface waters.

What is not included in the cost but will have to be considered at individual sites:

1. Cost of filters
2. Cost of a SWAC design
3. Cost of environmental studies
4. Cost of additional offshore pumps
5. Pipeline on shore
6. Monitoring equipment
7. Cables and electrical connections

For the Pay back calculation, the following assumption have been made:

1. Cost of electricity in England 0.23 kwh (Table 2).
2. Cost of gas in England 0.08 kwh (Table 2).
3. Cost of electricity in France 0.21 kwh (Table 2).
4. Cost of gas in France 0.12 kwh (Table 2).
5. Above rates are from 2022. With the current trend the cost may rise which will make the SWAC cost even more efficient and the payback time shorter.
6. SWAC for each location has multiple users.

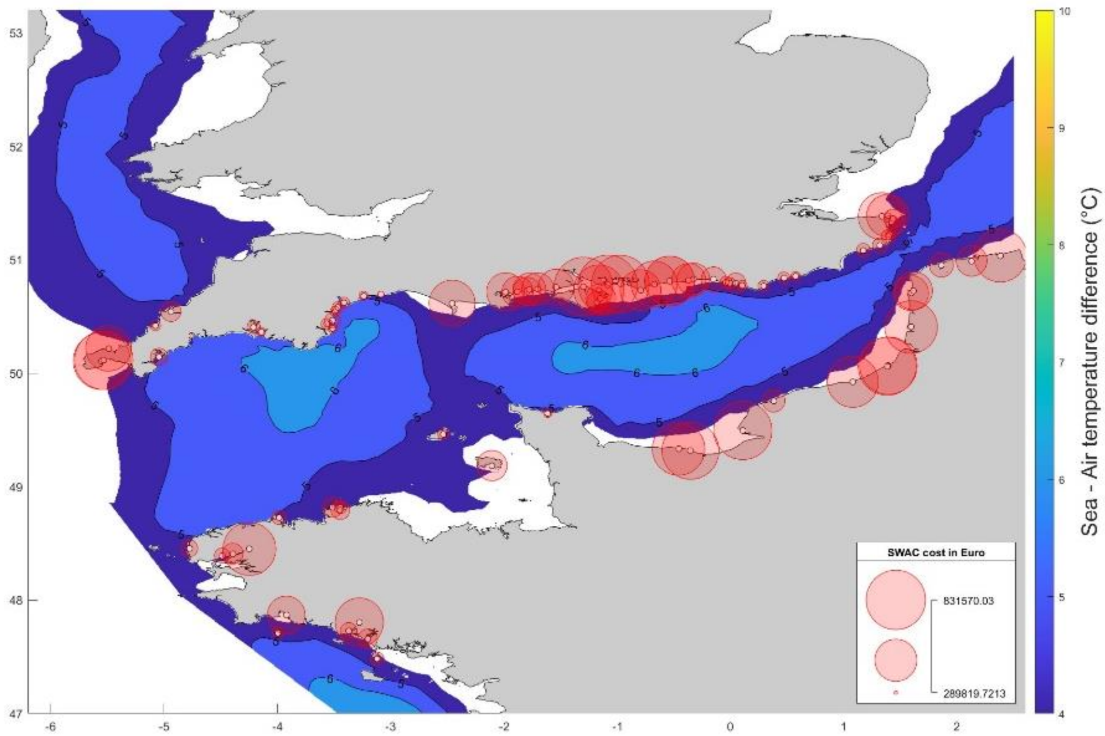

Figure 19 SWAC CAPEX along the Channel coastline.

Assumed SWAC installation cost can be lower than €500 in many locations along the English coast (especially in Cornwall, Devon, Dorset and Kent), and in a several locations in Brittany. However, the cost may not be easily repayable if the location does not have significant demand for air conditioning. To calculate payback time, the SWAC cost has been divided by the energy used for cooling and heating considering current energy prices. This shows that in many locations, the SWAC may not be efficient (e.g., in Padstow, Cornwall the SWAC cost is estimated for €350k but repay would take 139 years). On the contrary, there are locations where the installation would be more expensive but the energy usage for heating/cooling is significant and the payback time would be very short (e.g., in Portsmouth, Hampshire, the cost would be €815k but it could be paid back within 3 years).

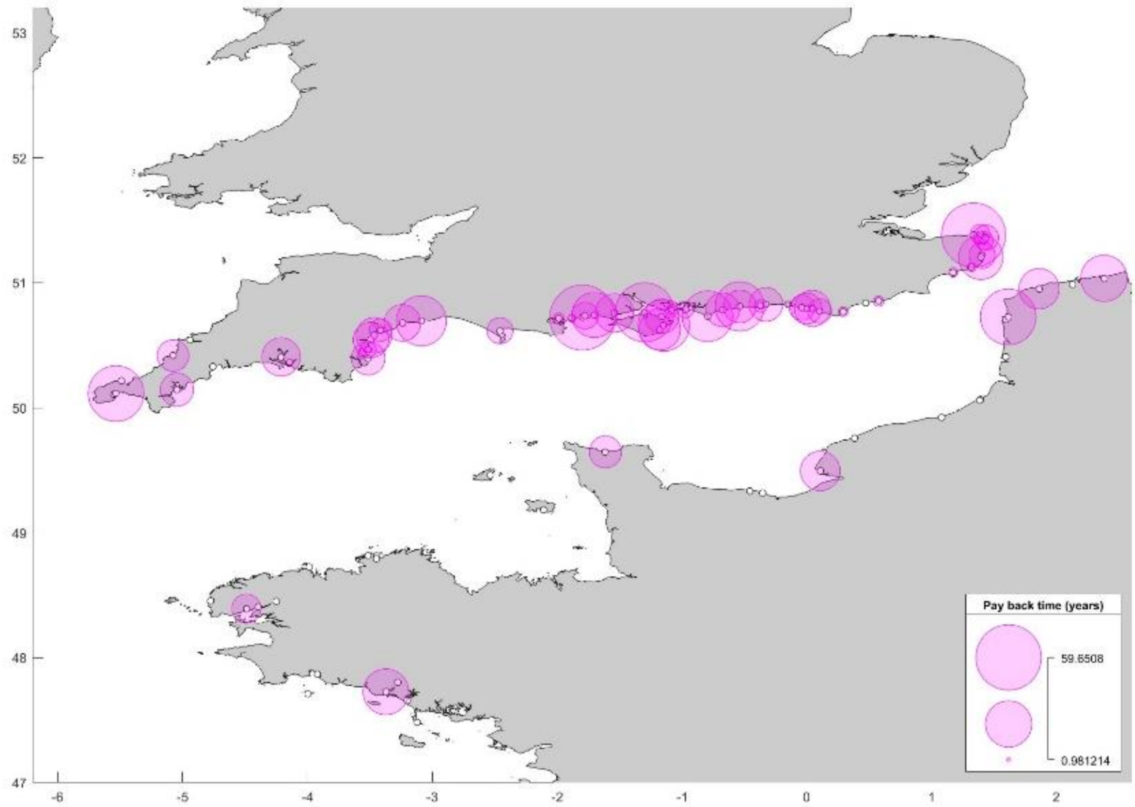

Figure 20 Time (in years) to repay SWAC's CAPEX.

Table 3 Required pipeline length, SWAC cost and payback time for the selected locations. Note: PL – Pipeline Length, PB – payback time. Note: the highlighted cells where the payback time is too long to consider the SWAC system.

Town/City	County	0m depth			20m depth			30m depth		
		PL (km)	Cost (€)	PB (yrs)	PL (km)	Cost (€)	PB (yrs)	PL (km)	Cost (€)	PB (yrs)
St Austell Bay	Cornwall	0.34	289,820	266						
Newquay	Cornwall	0.78	303,697	15						
Saltash	Cornwall	1.15	315,191	21	16.42	796,341	53	14.14	724,432	49
Falmouth	Cornwall	1.73	333,535	16	4.66	425,739	20	5.59	455,075	22
Padstow	Cornwall	2.27	350,369	139						
St Ives	Cornwall	10.42	607,174	71						
Newlyn	Cornwall	16.42	796,169	796						
Penzance	Cornwall	17.14	818,884	44				17.71	836,964	45
Seaton	Devon	0.47	293,762	35						
Plymouth	Devon	0.67	300,001	1	11.98	656,346	3	7.6	518,281	2
Brixham	Devon	0.71	301,214	16						
Sidmouth	Devon	0.72	301,624	19						
Teignmouth	Devon	0.77	303,098	18						
Exmouth	Devon	0.89	306,901	8						
Paignton	Devon	0.9	307,275	2						
Dawlish	Devon	0.91	307,705	18						

Torquay	Devon	1.51	326,550	4						
Southbourne	Dorset	4.16	410,078	60						
Bournemouth	Dorset	4.99	436,322	2	18.93	875,300	3	20.34	919,726	3
Highcliffe&Walkford	Dorset	5.37	448,051	29	22.03	973,099	62			
Christchurch	Dorset	5.61	455,817	11	19.4	890,175	21	25.98	1,097,254	25
Poole	Dorset	7.42	512,750	2	21.97	971,139	4	25.68	1,087,847	5
Weymouth	Dorset	10.68	615,380	10	12.05	658,636	11	17.63	834,212	14
Hastings	East Sussex	0.73	302,025	2	21.45	954,551	7	21.62	959,965	7
Seaford	East Sussex	0.77	303,310	9	8.35	541,979	16	13.91	717,160	21
Peacehaven	East Sussex	0.85	305,756	14	6.25	476,030	22	11.87	652,938	30
Eastbourne	East Sussex	0.9	307,253	2	12.54	674,079	5	12.52	673,337	5
Saltdean	East Sussex	1.01	310,863	10	6.54	484,929	15	13.43	702,155	22
Bexhil	East Sussex	1.02	311,071	no data						
Newhaven	East Sussex	2.25	349,780	19	9.12	566,383	30	16	783,095	42
Brighton&Hove	East Sussex	3.31	383,304	1	12.25	664,871	2	16.41	795,863	2
Lymington&Pennington	Hampshire	6.65	488,618	21						
Mengham&Havant	Hampshire	16.69	804,805	5	17.99	845,649	5	20.87	936,545	5
Portsmouth	Hampshire	17.54	831,570	3	22.24	979,667	3			
Gosport	Hampshire							25.04	1,067,696	9
Shanklin	Isle of Wight	2.41	355,067	24	19.7	899,434	62	3.92	402,591	28
Sandown	Isle of Wight	4.72	427,630	37				7.41	512,526	45
Ryde	Isle of Wight	12.63	676,847	17						
Cowes	Isle of Wight	17.13	818,464	49						
Deal	Kent	0.73	301,850	10						
Ramsgate	Kent	1.1	313,498	5						
Folkestone&Hythe	Kent	1.22	317,438	2						
Walmer	Kent	1.32	320,505	28						
Dover	Kent	1.42	323,617	2						
Broadstairs&St.Peters	Kent	2.02	342,695	9						
Margate	Kent	9.07	564,692	6						
Westgate-on-Sea	Kent	11.25	633,322	58						
Lancing	West Sussex	5.51	452,495	17	16.8	808,192	30	19.53	894,093	33
Worthing	West Sussex	5.99	467,723	3	13.23	695,872	4	19	877,579	6
Selsey	West Sussex	8.4	543,531	36	7.79	524,236	35	22.25	979,870	65
Bognor Regis	West Sussex	10.74	617,173	17	11.89	653,396	17	24.24	1,042,717	28
Rushington	West Sussex	12.49	672,522	34	13.19	694,365	35			
Little Hampton	West Sussex	12.57	675,027	16	19.78	902,044	21	21.55	957,707	22
Guernsey	Channel Islands	0.86	306,027	7						
Jersey	Channel Islands	4.8	430,173	no data						
Courseulles-sur-Mer	Calvados	13.85	715,397	430						
Luc-sur-Mer	Calvados	16.27	791,472	791						
Perros-Guirec	Côtes-d'Armor	1.04	311,830	107						
Saint-Quay-Perros	Côtes-d'Armor	1.97	341,161	838						
Tregastel	Côtes-d'Armor	2.25	349,838	319				14.12	723,924	659
Glenan Islands	Finistère	0.89	307,131	no data						
Roscoff	Finistère	1.29	319,764	264				3.53	390,177	322
Brest	Finistère	1.41	323,302	12	3.66	394,261	15			
Lampaul-Plouarzei	Finistère	1.68	331,812	462				2.61	361,285	503
Le Relecq-Kerhuon	Finistère	2.43	355,435	143						
Concarneau	Finistère	7.28	508,379	no data						
Douarnenez	Finistère							9.85	589,141	119
Landerneau	Finistère	14	720,133	720						
Cherbourg	Manche	0.64	299,156	15						
Quiberon	Morbihan	1.2	316,722	117				4.44	418,911	155
Lorient	Morbihan	1.68	332,028	30	6.88	495,747	44	18.12	849,797	76
Etel	Morbihan	2.16	347,130	500				11.7	647,607	933
Hennebont	Morbihan	11.76	649,542	176						
Gravelines	Nord	4.91	433,514	443						
Dunkirk	Nord	14.05	721,618	31						
Calais	Pas de Calais	3.14	378,001	23						
Outreau	Pas de Calais	6.31	477,672	177						
Boulogne-sur-Mer	Pas de Calais	7.4	512,040	43						
Berck&Le Touquet	Pas de Calais	13.89	716,417	716						
Fecamp	Seine-Maritime	2.79	366,841	72						
Dieppe	Seine-Maritime	13.11	691,942	94						
Le Treport	Seine-Maritime	16.76	806,864	807						
La Havre	Seine-Maritime	16.95	813,061	22						
Mers-les-Bains	Somme	16.48	798,003	798						

8.Summary

This report concludes that SWAC has significant potential in the Channel Area. The SWAC potential presented in this report focuses on four main aspects: (1) the pipeline length, (2) the estimated cooling /heating demand (capacity factor and degree hours), (3) the depth to reach water temperature which is at least 4°C higher or cooler to the air temperature, and (4) the cost estimates. The technical and financial analysis indicates that English coast is more suitable for the SWAC technology. This is due to more favourable ambient temperatures between air and sea, shorter pipe systems required, more gas-heated buildings and higher energy costs. SWAC is also applicable along the French coast of Brittany where the seafloor bathymetry is favourable to reach optimal water temperatures. The cooling capacity factor is low in the Channel Area, but with the global warming trend higher and drier weather is expected which will increase the need for air conditioning. The cost of SWAC installation in many locations is relatively low (less than €500K). However, the payback time analysis shows that the cost must be compared to the energy usage for cooling and heating to estimate the cost efficiency of the future installations. In many locations the cost must seem to be extensive but can be repaid within 10 years. Good examples of short-term CAPEX can be seen in Weymouth, Brighton, Poole, Portsmouth, Hastings, Southbourne, Gosport, Eastbourne and Worthing (Table 3). The methodology in this report can be easily applied for a detailed investigation of interested end users at individual locations.

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