ELEMENT: D12.3
FRENCH ESTUARY SITE ASSESSMENT

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Contents

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 815180.

1. EXECUTIVE SUMMARY

This work was realized to satisfy deliverable D12.3 as part of the work package 12 of the ELEMENT project (Grant agreement 815180). It aims to assess French estuary and river sites' potential for tidal stream energy projects.

To achieve this work a multicriteria analysis was performed, including evaluation of technical criteria (such as current velocity, potential, and water depth), socio-economic criteria (such as employment and gross added value created), regulation applicable to France (coastline regulation, Natura2000), human activities (including fishery or recreational boating) and environmental parameters (migratory fishes). Two specific methodologies, presented in this study, were applied to assess the site potential for tidal stream energy projects, and evaluate local benefits (gross added value and jobs). In addition, stakeholders were interviewed to collect their opinion on the attractivity of France regarding tidal energy.

This study underlined the lack of information freely available regarding parameters of interest, particularly for estuaries and rivers. Consequently, some nearshore locations, for which more data are available, have been included in the study.

Multicriteria analysis showed that most of the potential is concentrated in nearshore locations such as in the Alderney Race, The Raz-de-Sein or Fromveur Passage. However, it revealed interest of smaller locations in estuaries and rivers such as the Gironde Estuary and Gulf of Morbihan. Interviews have identified other locations such as isolated sites (islands) or industrial sites. Some sites appeared to be less interesting for project development as underlined by some stakeholders such as Arcachon bay and Adour River. The final grades are 72.4 (Raz de Sein), 71.9 (Paimpol-Bréhat), 69.4 (Alderney Race), 68.9 (Fromveur passage), 67.3 (Raz-Barfleur), 59.7 (Passage de la Jument and Pont de Pierre Garonne), 58.2 (Etel river), 46.9 (Adour) and 42.3 (Arcachon Bay).

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2. ABBREVIATIONS

GVA	Gross Value Added
ORE	Offshore Renewables
RCFS	*Réserve de Chasse et de Faune Sauvage* (Hunt and wildlife reserve)
R&D	Research and Development
SEA	Social Economic Account
SHOM	*Service Hydrographique et Océanographique de la Marine* (French Naval Hydrographic and Oceanographic Department)
SME	Small and Medium Enterprises
UXO	UneXploded Ordonance
ZNIEFF	*Zone Naturelle d'Intérêt Ecologique, Faunistique et Floristique* (Natural zone of ecological interest, fauna and flora)

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3. INTRODUCTION

A Funding Grant was awarded from the European Union's Horizon 2020 research and innovation program to develop and validate an innovative tidal turbine control system, using the tidal turbine itself as a sensor, to deliver a step change improvement in the performance. This will demonstrate Effective Lifetime Extension in the Marine Environment for Tidal Energy (ELEMENT), driving the EU tidal energy sector to commercial reality. This was in response to the call LC-SC3-RES-11-2018: Developing solutions to reduce the cost and increase performance of renewable technologies.

This document relates to design work undertaken as part of work package (WP) 12 focusing on socioeconomic impact assessment and is submitted to satisfy deliverable D12.3 of the ELEMENT project. WP12 is more particularly focused on the analysis of the socio-economic regional impact of tidal energy. A first task aims at performing a case study on socio-economic impact of a tidal energy project on the local and regional economy around Étel (D12.2). A second part aims at assessing French estuaries and run of river sites, which is the purpose of this document (D12.3). Eventually a task is focused on assessing the potential impact of tidal energy on the wider European economy (D12.4).

Site characterization is a key point of project development to assess theoretical energy generation potential and also environmental, social and economic impacts. Developing multicriteria analyses, considering technical, socio-economic and environmental parameters, could help stakeholders to select a suitable zone for tidal energy project. This document summarizes such a methodology, which has been applied to 10 sites in the ELEMENT project.

This document is structured as follows:

- Section 4 summarizing task description
- Section 5 presenting the applied methodology
- Section 6 listing the data gathering process
- Section 7 summarizing interviews performed with some tidal energy stakeholders
- Section 8 presenting results
- Section 9 drawing conclusions
- Section 10 Annex: maps of target sites

References used within this report are identified using [#] and listed in section 11.

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4. TASK DESCRIPTION

4.1. Objectives

The objective of task T12.3 was initially to undertake a mapping of estuaries/river sites in France, as described in D1.1 (Grant agreement) that may be suitable for tidal energy deployment. A pre-screening was realized, focusing on both major estuaries (Garonne, Loire, Seine, Rhône) and smaller ones (Ételriver, Adour, Abers regions in Brittany, Somme, Pertuis Charentais, etc.). It quickly became apparent that appropriate public data were missing for many of these sites. It was therefore decided with partners to expand the scope of work to include also nearshore locations (Alderney Race, Fromveur Passage, etc.) to have a larger overview of French potential. Estuaries correspond to areas where rivers meet the sea, composed of brackish water (a mixture of fresh and salty seawater). Tidal currents influence the flow pattern of estuaries. Nearshore locations correspond here to open sea sites.

4.2. Sub-tasks

Task 12.3 is divided into three tasks presented in this section.

Task 12.3.1 Suitability criteria

In this subtask a multicriteria analysis matrix was developed to assess the suitability of a site for tidal stream energy implementation, based on various criteria. These criteria cover different aspects such as technical, socio-economical and environmental factors. These are presented in section 5.1.

Task 12.3.2 Data gathering, formatting and analysis

In this subtask the data needed to perform the analysis defined within subtask 12.3.1 was collected, based on data freely available, as a typical use case. Indeed, we consider that at the site screening phase, a tidal energy project developer has not yet the finance to acquire high-resolution site-specific data. In addition, this data was formatted to extract value of interest and analyzed to attribute a grade to the site and assess accuracy of the data. Relevant stakeholders were also interviewed to confirm findings from the multicriteria analysis.

Task 12.3.3 Potential for local content

This subtask focused on the criterion “potential local content”. Within this subtask, a methodology was developed to assess potential benefits of a tidal project at a national level in terms of job creation and Gross Value Added (GVA), which is an economic indicator evaluating net output of goods and services produced (mathematically corresponding to the difference between gross output and intermediate consumption).

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5. METHODOLOGY

To identify suitable areas for a tidal energy project, this study focused on various categories of parameters: technical criteria (current speed, depth, etc.), socio-economic criteria (employment creation, GVA, supply chain, etc), regulation applicable to France, covering environmental criteria, human activities and ecological diagnostics. More details are given on these parameters in section 5.1. Collected data come from public sources only or are freely given by public collectives, industrial partners or companies. Details on data sources are given in section 6.

5.1. Site Suitability criteria table

Site selection

To identify locations suitable for tidal energy deployment in Metropolitan France, various sources were used. First, a pre-screening analysis based on depth and minimal current velocity was performed. Based on initial discussions with Nova, the threshold was set to a maximal sea surface current velocity of 2m/s for a mean spring tide. In addition, a 3m minimum depth was used. Industrials and the French "*Syndicat des Energies Renouvelables*" plan that the minimal current velocity required for tidal turbines installation will be a maximum current velocity of 1.5 m/s at sea surface for a mean spring tide [1]. This value of 1.5 m/s was then considered, in order to increase the diversity of locations considered during this study.

For nearshore locations, maximal current velocity was obtained from *Service Hydrographique et océanographique de la Marine* (SHOM) data [2]. The SHOM, is a French public establishment of an administrative nature which provides a public service in hydrography and maritime cartography. These data give maximal current velocity at the surface for a mean spring tide. For smaller locations not covered by SHOM models, or where resolution is not high enough to capture local flow acceleration, the maximum current velocity was obtained using scientific publications. This approach is a limitation of the method, as only the most powerful locations and sites for which current speed has already been assessed are available for consideration.

Water depth was estimated based on data from SHOM and nautical charts from Navionics [3].

This pre-screening analysis allowed to identify the following locations Table 5.1-1.

Site	Type of site (nearshore, river/estuary)	Ocean/Sea/Estuary/River	Département[1]
Royan	Estuary	Gironde	Gironde
Saint-Estèphe	Estuary	Gironde	Gironde
Saint-Nazaire	Estuary	Loire	Loire-Atlantique
Paimboeuf	Estuary	Loire	Loire-Atlantique
Honfleur	Estuary	Seine	Calvados
Tancarville	Estuary	Seine	Seine-Maritime
Lyon	River	Rhône	Rhône
Ria d'Etel	Estuary *(Aber)*	Etel	Morbihan
Fromveur Passage	Nearshore	Atlantique	Finistère
Aber Wrac'h	Estuary *(Aber)*	Wrac'h	Finistère
Aber Ildut	Estuary *(Aber)*	Ildut	Finistère
Aber d'Elorn	Estuary *(Aber)*	Elorn	Finistère
La roche Jagu	Estuary *(Aber)*	Trieux	Côtes d'Armor
Rance	Estuary *(Aber)*	Rance	Côtes d'Armor
Alderney Race (Raz-Blanchard)	Nearshore	British Channel	Manche
Raz-barfleur	Nearshore	British Channel	Manche

[1] French administrative division

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Site	Type of site (nearshore, river/estuary)	Ocean/Sea/Estuary/River	Département[1]
Pertuis de Maumusson	Estuary *(Aber)*	Seudre	Charente-Maritime
Pont de Pierre (Bordeaux)	Estuary	Garonne (Gironde)	Gironde
Adour (Bayonne)	Estuary	Adour	Pyrénées-Atlantiques
Paimpol-Bréhat	Nearshore	British Channel	Côtes d'Armor
Raz-de-Sein	Nearshore	Atlantique	Finistère
Passage de la Jument	Estuary *(Gulf)*	Golfe du Morbihan	Morbihan
Arcachon Bay	Estuary	Bassin d'Arcachon	Gironde

Table 5.1-1 Sites considered during pre-screening phase

To reduce this list to a shortlist of 10 locations, the availability of the most critical data was assessed for each location. Several sites were not considered due to lack of data. Some of the sites for which the current speed has never been assessed may be missed opportunities or simply sites that are not suitable for tidal energy.

Eventually, the following 10 locations from pre-screening analysis were chosen for the full analysis. A picture of each site obtained using Google Earth [4] is available in appendix.

Site	Type of site (nearshore, river/estuary)	Ocean/Sea/Estuary/River (département[2])	Index
Ria d'Etel	Estuary *(Aber)*	Etel (Morbihan)	1
Fromveur Passage	Nearshore	Atlantique (Finistère)	2
Alderney Race (Raz-Blanchard)	Nearshore	British Channel (La Manche)	3
Raz-Barfleur	Nearshore	British Channel (La Manche)	4
Pont de Pierre	Estuary	La Garonne (Gironde)	5
Adour	Estuary	L'Adour (Pyrénées-Atlantiques)	6
Paimpol-Bréhat	Nearshore	British Channel (Côtes d'Armor)	7
Raz-de-Sein	Nearshore	Atlantique (Finistère)	8
Passage de la Jument	Estuary *(Gulf)*	Golfe du Morbihan (Morbihan)	9
Arcachon Bay	Estuary	Bassin d'Arcachon (Gironde)	10

Table 5.1-2 10 Sites considered for the study

[2] French administrative division

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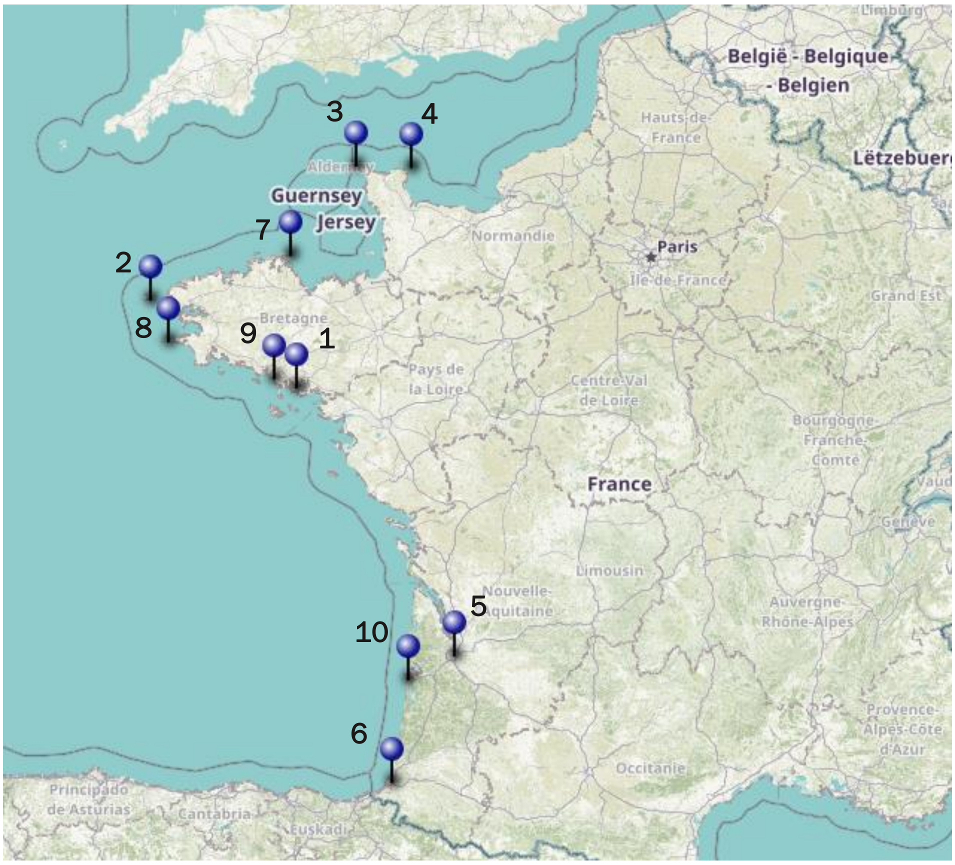

Figure 5.1.1 10 Sites selected for the analysis

Suitability criteria

Once the 10 sites were chosen, they were graded based on a specific criteria system. Those criteria are detailed below.

Table 5.1-3 summarizes the different criteria used to perform the site assessment and gives a description of each.

Technical criteria	Description
High speed current	Maximal sea surface current velocity at mean spring tide (coef.95 - see section 5.2)
Technical potential (MW installed)	Technical potential (MW) calculated following methodology described in section 5.2
Turbulence	Turbulence intensity (%) estimated based on site configuration
Depth	Minimum depth for a mean spring tide
Tidal range	Maximum tidal range at the specified location
Soil conditions	Type of soil at the specified location (sand, mud, rocks, etc.)
Navigation area	Presence of a navigation route. This criterion is tricky to assess, impact being different depending on conditions (high water depth, fixed bottom tidal turbines or floating ones). But as discussed later, cross-conditionality is not considered.
Servitude (vicinity of gas pipeline, etc.)	Distance to a servitude such as gas pipeline or power cable
Accessibility	Evaluation of site accessibility by road or boat
Access to electrical connection (distribution network)	Distance to a connection point (without power restriction)

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Socio-economic criteria	Description
Local content	Project Economic impact (jobs created and GVA[3])
Regional strategy for offshore renewables	Regional help to support offshore renewables (R&D[4] projects, subsidies, etc.)
Active SME[5]: start-ups in the sector	Existing companies with capacities for offshore renewables in the region
Possible synergies with current offshore renewable activities	Other offshore renewables activities or projects close to the studied location. "Possible synergies" means potential cost reductions by sharing infrastructures, workers, etc.
Relevant academic stakeholders	Presence of academic stakeholders in the region of the studied location. They could create synergies with industrial partners, develop R&D projects, revenues, etc.
Regulation applicable to France	Description
Natura 2000	Special European protection areas for fauna and flora that would require further authorizations before installation
Listed site	Protected area (zone of interest for architecture, arts, etc.) that would require further authorizations for tidal farm construction
ZNIEFF[6] I and II (birds)	Special protection areas for fauna and flora that would require further authorizations before installation. Type II refers to bigger areas, while Type I is more restrictive.
Loi littoral (coastline regulation)	Coastline regulation aiming at protecting the coastline to avoid erosion and coastal flooding.
RCFS[7]	Special protection areas for animals that would require further authorizations for tidal farm construction
Human activities	Description
Fishery	Evaluation of fishery activities in the studied area
Port activity	Evaluation of port activities in the studied area
Shipwrecks	Presence of shipwrecks in the studied area
UXO[8]	Presence of UXO in the studied area
Tourism - recreational boating	Level of recreational boating in the studied area
Military zone	Presence of a military zone in the studied area
Ecological diagnostics	Description
Migratory fish	Presence of migratory fishes in the studied area
Habitats (mudflats, seabed) & Inventory zone - *roselières, vasières*	Presence of habitats or inventory zone in the studied area. Habitats refer to areas important for fauna and flora preservation, while inventory zone are areas used to assess environmental state of a site

Table 5.1-3 Suitability criteria used to perform site assessment

Further criteria could have been considered such as "Water usage" (water pumping, hydroelectric dam), "Existing infrastructure on site" (floating platform, export cable) or "Relevant local supply chain". These criteria, initially listed in D12.1, appeared to be not relevant (no water usage on nearshore locations) and were therefore disregarded. In addition, some criteria appear to be not discriminating (i.e all sites had the same grade because they are equivalent or because data are not sufficiently accurate to discriminate) and were disregarded, such as "Sediment and suspended objects". These changes have led to a refinement of the categories initially stated in D12.1.

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[3] GVA: Gross value added

[4] R&D: Research and Development

[5] SME: Small and Medium Enterprise. Only SME were considered because they represent most of companies involved in this sector today.

[6] ZNIEFF : Zone naturelle d'intérêt écologique, faunistique et floristique (Natural zone of ecological interest, fauna and flora)

[7] RCFS: Réserve de Chasse et de Faune Sauvage (Hunt and wildlife reserve)

[8] UXO: UneXploded Ordnance

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Criteria weight

Criteria presented above do not have the same importance regarding project development. To underline this importance each criterion is weighted. Definition of these weight factors are given in Table 5.1-4.

Categories	Weight
Possible exclusion criterion	5
Primary criteria for site selection	4
Criterion with impact on project but not a main site selection driver	3
Criterion that should be considered but does not significantly impact the project	2
Criterion that can be overlooked	1

Table 5.1-4 Weight factor system

The weight allocated to a criterion was reviewed with WP12 partners. It must be underlined that the table does not account for cross-conditionality. For instance, if water depth is low, navigation area could be an exclusion criterion, but it is covered here. A percentage is also given, corresponding to the weight of the final grade.

Table 5.1-5 gives weight factor for each criterion. A grade of 5 has a contribution of 5.1% to the final grade, 4 of 4.1%, 3 of 3.1%, 2 of 2.1% and 1 of 1%.

Technical crtieria	Weight
High speed current	5
Technical/Practical potential (MW installed/Energy Yield GWh)	4
Turbulence	3
Depth	5
Tidal range	3
Soil conditions	4
Navigation area	3
Servitude (vicinity of gas pipeline, etc.)	4
Accessibility	3
Access to Enedis electrical connection (distribution network)	4
Socio-economic criteria	**Weight**
Local content	5
Regional strategy for offshore renewables	3
Active SME:startups in the sector	1
Possible synergies with current offshore renewable activities	3
Relevant academic stakeholders	3
Regulation applicable to France	**Weight**
Natura 2000	3
Listed site	4
ZNIEFF I and II (birds)	4
Loi littoral (coastline regulation)	4
RCFS (Hunt and wildlife reserve)	2
Human activities	**Weight**
Fishery	3
Port activity	5
Ship wrecks	3
UXO	4
Tourism - recreational boating	2
Military zone	5
Ecological diagnostics	**Weight**
Migratory fish	3
Habitats (mudflats, seabed) & Inventory zone - *roselières, vasières*	3

Table 5.1-5 Weight factor allocated to criteria

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Criteria grading system

For each criterion, a grade is given. It was decided to use a grading system between 1 and 3 for each criterion. 3 corresponds to the most favorable case while 1 is the worst. A grade of 1 combined with a weight factor of 5 corresponds to a potential exclusion criterion (i.e tidal turbine cannot be installed at the selected site) and would thus be the least favourable combination. Table 5.1-6 gives the grading system for each criterion as well as a justification.

Technical crtieria	Grading system	Justification
High speed current	$3: u \geq 2.5$ m/s $2: 2.5 > u \geq 1.5$ m/s $1: u <$ 1.5m/s	The lowest bound is based on turbines cut-in current speed which is generally between 0.5 and 1 m/s [5] (so maximum current speed below this value will not be efficient).
Technical/Practical potential (MW installed)	$3: P \geq 500MW$ $2: 500MW > P \geq 5MW$ $1: P < 5MW$	Values are chosen to split site between most powerful tidal farms intermediate, and small ones.
Turbulence	$3: low\ turbulence\ probability$ $2: medium\ turbululency\ probability$ $1: high\ turbulence\ probability$	High probability when rough soil, strong bathymetry variations, visible boil at sea surface, irregularities in seashore, medium probability for more protected area with weak features, else low probability
Depth	$3: d \geq 10m$ $2: 10 > d \geq 5m$ $1: d < 5m$	Water depth range are based on turbines technologies diameters. Below 5m, only small turbines can be used (20kW), between 10 and 5m, medium ones (20-100kW), while above 10m large turbines can be used.
Tidal range	$3: tidal\ range \leq 3m$ $2: 3 \leq tidal\ range < 10m$ $1: tidal\ range \geq\ 10m$	Arbitrary selected based on industrial criteria
Soil conditions	3: if smooth rock or other smooth seabed, 2: if rough but stable, 1: if rough or unstable	Smooth soil and rock will simplify mooring installations while difficulties will increase depending on stabilities of rough soil.
Navigation area	3: if site is out of navigation area, 1: if not	/
Servitude (vicinity of gas pipeline, etc.)	3: if no servitude, 2: if servitudes (at a distance >250m), 1: if servitude (at a distance <250m)	250m was selected as criterion because it was considered a typical distance for anchor radius or marine operations.
Accessibility	3: if high accessibility, 2: if medium, 1: if low	Low access corresponds to site where access in boat or by road is complicated due to combination of obstacles (low depth, sand bank and large currents, small roads), while medium corresponds to less detrimental combinations
Access to Enedis electrical connection (distribution network)	3: if cable is <1km, 2: if between 1km and 3km, 1: if >3km	Distances where chosen based on existing or future tidal plant locations (Fromveur, Seeneoh site and Alderney-Race)
Socio-economic criteria	**Grading system**	**Justification**
Local content	$3: P \geq 500MW$ $2: 500MW > P \geq 5MW$ $1: P < 5MW$	Jobs created and GVA are directly proportional to potential (see section 5.3). Grading system was based on potential criteria
Regional strategy for offshore renewables	3: Well-developed strategy 2: Existing but incomplete strategy 1: No or limited strategy	Strategy is roughly analysed based on local policies, funding, etc. Large strategy is assumed for Bretagne and Normandie while medium is assumed for Nouvelle-Aquitaine
Active SME:startups in the sector	3: high number of SME dedicated to ORE 2: medium number of SME dedicated to ORE 1:low number of SME dedicated to ORE	Number of SME dedicated to ORE were roughly calculated based on INNOSEA knowledge and [6] (at a regional level)

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Possible synergies with current offshore renewable activities	3: if synergies are strong 2: if synergies are small 1:if synergies are impossible	Synergies are evaluated based on number of projects, test sites, etc, at a regional level. Strong means diversity of project while small means few project
Relevant academic stakeholders	3: strong presence 2: moderate presence 1:weak presence	Presence strength is evaluated by number of teams working on subject related to ORE. Strong presence is assumed for Bretagne and Normandie while moderate is assumed for Nouvelle-Aquitaine
Regulation applicable to France	**Grading system**	**Justification**
Natura 2000	3: if site is out of zone[9], 1: if site is in zone	/
Listed site	3: if site is out of zone, 2: if equipment in zone, 1: if site is in zone	/
ZNIEFF I and II (birds)	3: if site is out of zone, 2: if site is in ZNIEFF II, 1: if site is in ZNIEFF I	ZNIEFF 1 would require further authorization so presence of ZNIEFF 1 and 2 were split
Loi littoral (coastline regulation)	3: if site is out of zone, 1: if site is in zone	/
RCFS (Hunt and wildlife reserve)	3: if site is out of zone, 1: if site is in zone	/
Human activities	**Grading system**	**Justification**
Fishery	3: if no fishery, 2: if usual fishery zone, 1: if dedicated zone	Dedicated zone means strong professional fishery zone (several professional boats, trawling, netting). "Usual" implies recreational or few professional (angling)
Port activity	3: if nearby port available for tidal project activity (<10km), 2: if nearest available port within 10-50km and/or all nearby ports lacking required capacity or fully occupied with other activities, 1: if no nearby port (<50km) and/or all nearby ports fully occupied with other activities or lacking required capacity	/
Shipwrecks	3: if absence, 1: if presence	/
UXO	3: if low risk, 2: if medium risk 2, 1: if high risk	Risk was mainly evaluated by considering bombed area during previous wars. Low risk means that there was no bombing raid, medium means few bombings raid, high risk means several bombing raid or bomb already found close to the area
Tourism - recreational boating	3: if Low, 2: if medium, 1: if high	Level was evaluated based on notoriety of the site for recreational boating
Military zone	3: if out of zone, 1: if in zone	/
Ecological diagnostics	**Grading system**	**Justification**
Migratory fish	3: if out of zone, 1: if in zone	If studied site is located on a known route for migratory fishes it is considered in zone
Habitats (mudflats, seabed) & Inventory zone - *roselières, vasières*	3: if out of zone, 1: if in zone	If studied site is known as an inventory zone or if there is a high probability of habitats, site is considered in the zone

Table 5.1-6 Grading system

[9] Zone refers to the area covered by the restriction

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5.2. Evaluation of potential

This section presents the methodology applied to calculate the potential (maximum installed capacity in MW). Potential annual energy production could not be calculated as it would require data such as current speed timeseries which were missing.

Potential calculation (MW)

As presented in section 5.1, power production potential is part of the suitability criteria. To compare locations, a methodology is applied to evaluate the potential. This section presents the methodology used.

Several potentials could be calculated depending on hypothesis considered. The instantaneous maximum fluid power [W/m²] is defined by:

$$P = \frac{1}{2}\rho U^3$$

where, ρ is the seawater density [1025 kg/m^3] and U the maximum horizontal component of the flow velocity [m/s].

The maximum theoretical power exploitable by a tidal turbine is given by:

$$P_T = \frac{1}{2}\rho \frac{\pi D^2}{4} C_{p,Betz} U^3$$

Where D is the turbine diameter (m) and $C_{p,Betz}$ the maximum power coefficient (also known as Betz limit, equal to 16/27). In reality, the power coefficient C_p is below $C_{p,Betz}$. A power coefficient of 0.4 is usually a satisfying value for current tidal technologies deployed [7] and will be used in this study.

Four virtual tidal turbines were considered (20kW, 50kW, 70kW and 100kW) in the task, and diameter associated with each turbine was provided by Nova.

To avoid wake losses due to flow disturbance downstream from the tidal turbine, a farm density is defined. Usually, two numbers are defined, one representing the lateral spacing (α) between two turbines and one representing the downstream spacing (β).

The real exploitable power within a seabed area A is then given by:

$$P_{ex} = \frac{1}{2}\rho \frac{\pi D^2}{4} C_p U^3 \left(\frac{A}{\alpha D \beta D}\right)$$

Values for α and β are respectively set to 3.5 and 11 based on Nova's recommendation.

This definition of power is the one used in this study. If the real exploitable power is above the rated power, the value is truncated to rated power to reflect control strategy.

The maximum velocity considered in this study is computed using maximum velocities during mean spring tides, defined for a coefficient between 93 and 97, following methodology used in [7].
In France, the tide coefficient is defined by:

$$C = \frac{H_h - H_b}{U} \times 100$$

where, H_h is the water depth at high tide, H_b the water depth at the low tide, and U the mean tidal range at the location.

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More details on current speeds used for this task are given in section 6. Table 5.2-1 summarizes parameters used.

Parameters	Value (Unit)
Power coefficient C_p	0.4 (-)
Lateral spacing (α)	3.5 (-)
Downstream spacing (β)	11 (-)
Turbines considered	100-75-50-20 (kW)

Table 5.2-1 Parameters used for potential estimation

Area

To apply the methodology presented above, the area considered for potential estimation must be defined. To do so, several technical criteria were listed. The considered areas must fulfill these criteria.

1. For each turbine, a criterion on a minimum water depth was set based on technical criteria recommended by Nova. The minimum water depth for a 20kW turbine is set to 6.3m, for 50kW 11m, for 70kW 14m and for a 100kW turbine 19m. A maximum water depth of 50m is considered. Beyond that limit, subsea operation become very expensive. It was however extended to 60m for Fromveur Passage to reflect real potential of this zone.

2. Only locations with a current velocity above 1.5 m/s were considered, except for Bayonne. The study [8] gives a mean current velocity above 1m/s but below 1.5 m/s for this site.

Eventually, studied areas were geometrically defined to properly calculate the potential. Figure 5.2.1 shows restricted area considered during the study. Red rectangles indicate a studied site (i.e The Alderney Race, etc). Bordeaux, Bayonne and Etel are not represented. Indeed, areas for Bayonne and Bordeaux were estimated based on a separate study [8], while no data were available for Etel. For The Alderney Race, latest maritime boundaries were included, and only French potential was considered (Channel Islands excluded). Figure 5.2.1 also give current speed compiled from MARS 2D model [9].

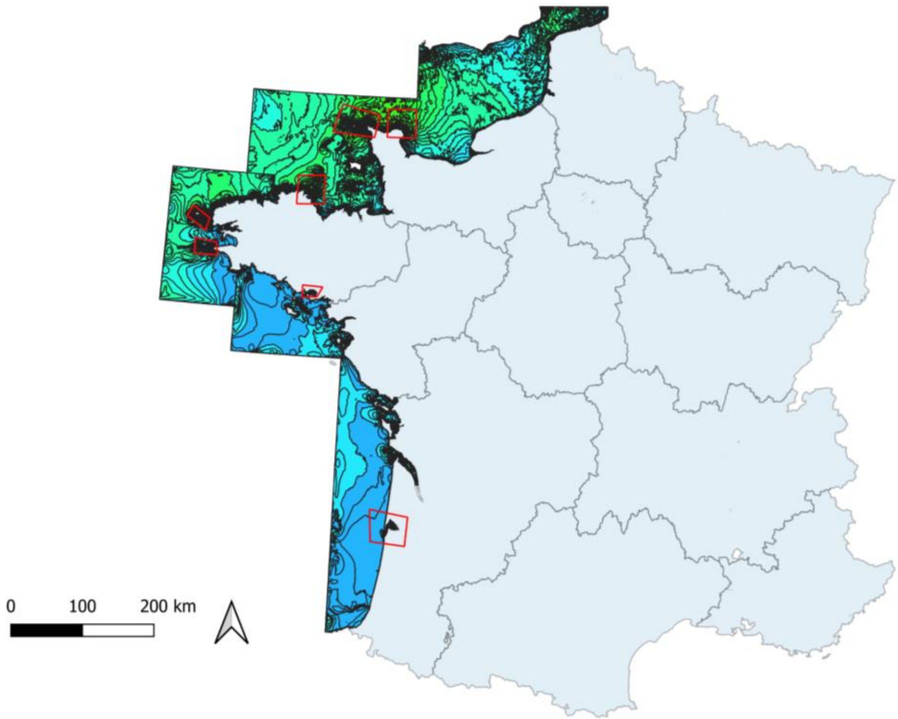

Figure 5.2.1 Restricted area considered

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Figure 5.2.2 summarizes the methodology applied to obtain the potential. A python code was developed within the project to apply this methodology.

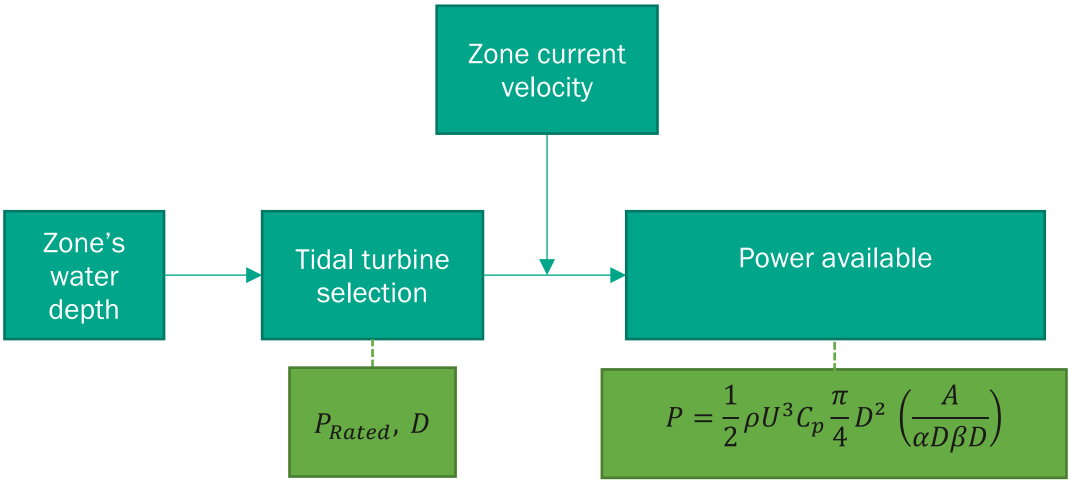

Figure 5.2.2 Methodology applies to determinate French tidal turbine potential

Results for each site are given in section 8

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5.3. Socio-economic impact evaluation

Summary

Different indicators are chosen to evaluate the socio-economic impact of a tidal energy project. The first is the gross value added (GVA) corresponding to the value of goods and services produced in a sector of economy. The second is the number of jobs expected to be created by a project.

The number of jobs is decomposed into direct, indirect, and induced jobs. Direct jobs refer to jobs created within industries directly involved in a project during the different phases. Indirect jobs come from inter-industry trades while induced jobs reflect employment created by consumer spending (from salaries). To evaluate the change induced by a project at the national level (for France), the so-called Input/Output tables [10] and socio-economic accounts (SEA) were used. This is open-source information, which gives respectively trades between economic sectors and indicators (employment, capital stocks, etc.). The following sections present the different steps to achieve these results.

CAPEX and OPEX

The methodology used in this study is based on expenditures. It requires the capital expenditure (CAPEX) and the operational expenditure (OPEX) of a tidal project. Based on [11] a CAPEX of 7580 €/kW and an OPEX of 505€/kW/year were used. These values were validated with project partners and correspond to first arrays costs in [11] and will decrease as the sector matures. In addition, CAPEX and OPEX breakdown were used, to relate tidal turbine project activity to economic sectors, as explained below. The CAPEX breakdown given in Figure 5.3.1 is used [12].

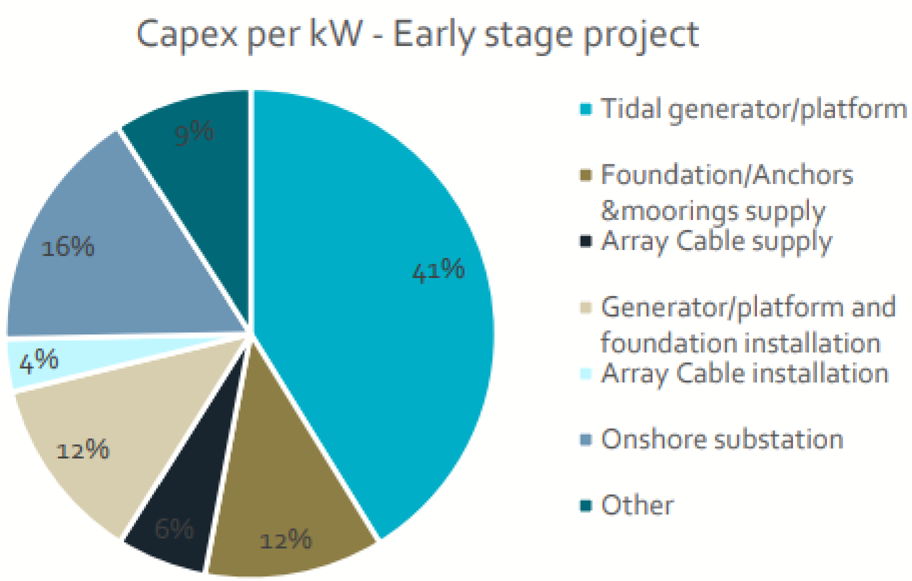

Figure 5.3.1 CAPEX breakdown for an early-stage project [12]

No reference for OPEX breakdown was found directly. Categories were decided in consultation with project partners.

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NACE identification

As shown on Figure 5.3.1, the CAPEX breakdown is split between different tidal farm elements. However, to estimate jobs created and GVA, economic sectors working on these elements must be identified. For instance, for the tidal turbine generator, the design phase would involve engineering companies, and the construction phase would involve welders. These companies are then identified by a code from the Statistical Classification of Economic Activities in the European Community, commonly referred to as NACE (*Nomenclature statistique des Activités économiques dans la Communauté Européenne*). The classification can be found here [13].

During this project, main economic sectors involved in building elements were identified and linked to their NACE codes. In addition, a part of the CAPEX (or OPEX) has been attributed to each sector. Figure 5.3.2 shows an example of this process for the tidal generator/platform element.

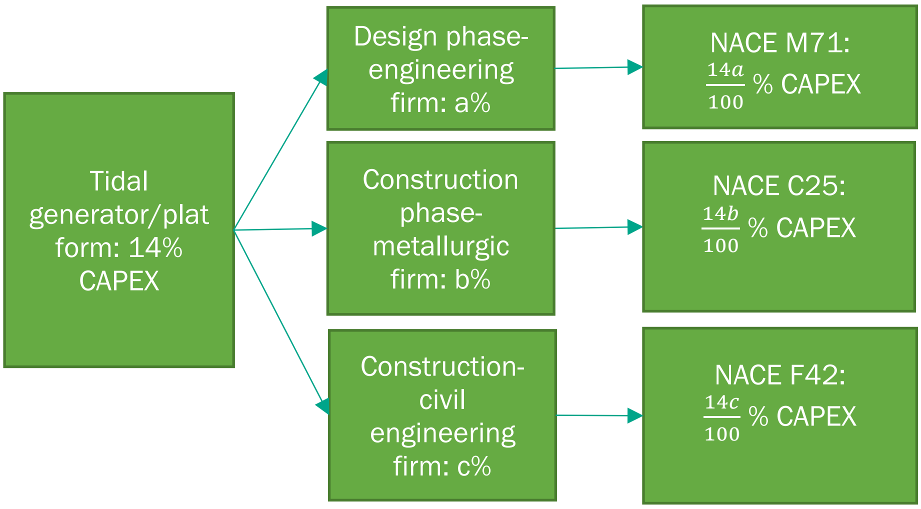

Figure 5.3.2 Example of decomposition of farm elements into NACE codes (percentages and categories given for example only)

From the CAPEX breakdown (Figure 5.3.1), the following economic sectors were retained in agreement with project partners.

NACE Code [13]	Share (%)	Economic sector
M71	14	Architectural and engineering activities; technical testing and analysis
C28	28	Manufacture of machinery and equipment n.e.c
C27	14	Manufacture of electrical equipment
C25	14	Manufacture of fabricated metal products, except machinery and equipment
H50	16	Water transport
F42	5	Civil engineering
K64	8	Final service activities, except insurance and pension funding
D35	1	Electricity, gas, steam and air conditioning supply

Table 5.3-1 CAPEX: economic sectors involved

Regarding OPEX, it was decided with project partners to retain the following categories.

NACE Code [13]	Share (%)	Economic sector
C33	50	Repair and installation of machinery and equipment
H50	49	Water transport
D35	1	Electricity, gas, steam and air conditioning supply

Table 5.3-2 OPEX: economic sectors involved

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In this study, the CAPEX is entirely allocated to one year of the project, which would correspond to the first phase of the project (design, construction and installation), and the same OPEX is used for each year of the project lifetime (no cost reduction included).

National Share

The two first steps allow to list the different economic sectors (i.e characterized by NACE codes) involved in the project, and their shares regarding OPEX and CAPEX. In this project, the region of interest is Metropolitan France. Therefore, a difference must be made between French companies and international ones. French companies refer to companies based in France and having their employees in France. Indeed, when developing a project, different companies from the same economic sector can be involved, and part of them only are French. Hence, only a part of the costs allocated to a sector would go to French companies. This part is reflected by the national share applied. Values for these shares were chosen based on Innosea's industrial experience, and results were compared with other existing evaluations.

An example from wind industry is given here, to illustrate these national shares. Wind turbine foundations and nacelles construction would both involve companies from sector C25 (Manufacture of fabricated metal products, except machinery and equipment). For the wind farm of Saint-Nazaire, foundations are built in Belgium, while nacelles are produced in France. Therefore, the CAPEX share allocated to C25 must be split between French and Belgian companies.

Input/Output Matrices

These steps allow us to obtain for each year and each sector the economic change induced by a project. Using Input/Output tables, one can obtain gross output (GO) per sector. Introducing SEA tables to define jobs/GO and GVA/GO coefficients, employment and GVA can be calculated.

Mathematical operations should be realized on the Input/Output table before being used. The following reference, [14], is one example which introduces the Leontief inverse matrices. These matrices are mathematically derived from Input/Output matrices and are used to calculate the economic impact of the project. The difference between type 1 and 2 effects is the inclusion of householders. Therefore type 1 matrices account for direct and indirect effect, while type 2 also includes induced effects.

Summary and analysis

This methodology leads to 18 full time equivalent (FTE) direct jobs per MW in phase one (design, construction and installation), which is above values found for other offshore renewables energies or in previous studies (3 FTE/MW for tidal energy in [15]). One reason is the hypothesis of the CAPEX allocation over one single year, while development and construction would require multiple years. In addition, the OPEX and CAPEX values retained have a strong impact on the results. For instance, when using alternative values from [11], the number of direct jobs drops to 9.2 FTE/MW during construction.

During the operation phase, 2.5 FTE per MW (direct and indirect) are found while 0.65 FTE per MW are given in [15]. Once again, the methodology and values retained, could explain this difference.

Regarding GVA, the analysis gives 6.8 M€/MW (direct + indirect) during construction, and 16 M€/MW including induced effects, while 0.47 M€/MW per year are expected during operation (1.1 M€/MW including induced effects).

Applying the presented methodology gives results dependent on installed power only. In reality for a project at a specific location, the technologies deployed, and companies involved would affect the results.

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The aim of the current study being to compare sites by attributing grades, results were considered consistent and kept for the rest of the analysis. To obtain results for each site, one needs to multiply these results by the installed capacity. Results for each site are given in section 8.

Figure 5.3.3 summarizes the methodology applied to calculate employments and GVA of a project.

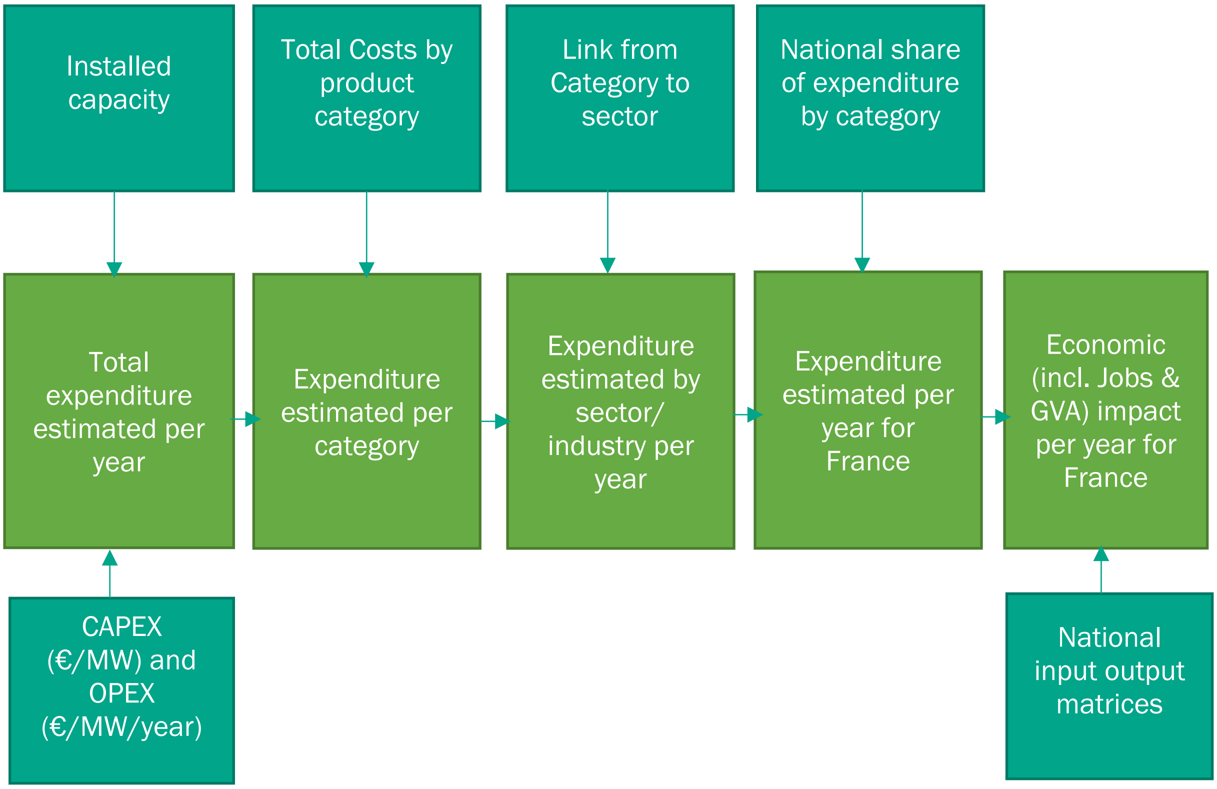

Figure 5.3.3 Jobs and GVA assessment methodology

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6. DATA GATHERING

This section describes the data sources used and level of accuracy when available.

High speed current

For nearshore locations, such as the Alderney Race or Fromveur passage, maximum surface current velocity is extracted from SHOM data [16]. Spatial resolution varies from 2 km down to few meters for some regions [16]. The SHOM underlines that some details are not represented, and some local currents generated by a local topography are not captured. The last update of this data is 2005.

For Bordeaux and Bayonne, data are not covered by the SHOM. A study gives mean speed velocity for a mean spring tide [8]. For both locations, the mesh has a cell size of 5m close to regions of interest. Mean current velocity at Pont de Pierre (Bordeaux) is above 1.5 m/s and mean current velocity is above 1 m/s at the Adour site (Bayonne). For both locations, maximum velocity was estimated based on these values. For Bordeaux, the value was compared to other existing sources [17]. Eventually, for Etel river, a maximum current speed between 2.6 m/s and 4.0 m/s for a coefficient of 120 is given in [18]. It is reasonable to consider that a maximum current of 2 m/s will be observed during mean spring tide (coefficient of 93-97). Therefore, 2m/s was kept, and internal data have been used to validate this value.

To estimate the potential, other data were used for ocean locations such as the Alderney Race or Fromveur passage. It was decided to use simulations from MARS2D model [19] [9]. MARS2D is a model developed by IFREMER, to provide predictions for current, water levels, etc. The spatial resolution of the model used here is 250m and the time resolution is 15 minutes. To follow the methodology defined in [7], year 2015 was used to extract the current velocity. This year was selected because it is representative of other years [7]. 37 days have a tidal coefficient between 93 and 97, and the average current velocity over these days was computed for each point of the model.

Figure 6.1 shows the current velocities obtained.

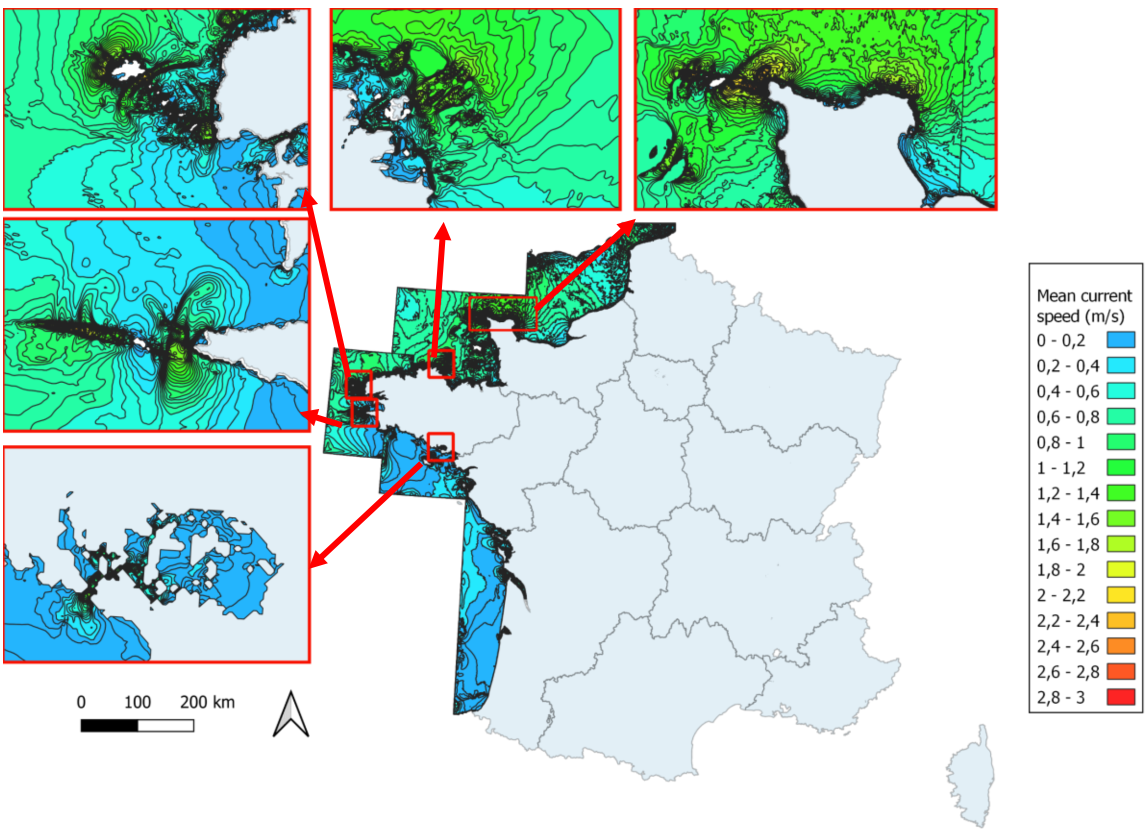

Figure 6.1 Mean current speed for mean spring tide (coef. 93-97) from Mars 2D [9]

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Technical potential

Technical potential was calculated following the methodology established in section 5.2. Current speeds used to calculate the potential are given above.

Turbulence

Current turbulence intensity is complicated to obtain. Indeed, *in-situ* data are required to obtain accurate values. When available, data were used (see below). For other locations, turbulence was estimated based on bathymetry profile, type of soil, and observation.

For the Alderney Race, different studies exist regarding turbulence intensity. A reference document [20] was used in this study.

Depth

Water depth is evaluated using data from SHOM [2] and Navionics [3]. Spatial resolution for the SHOM is 111m [21] . For Bordeaux and Bayonne, data were compared to those used in [8].

Tidal range

Tidal range is evaluated using data from SHOM [2].

Soil conditions

Soil conditions are evaluated using data from SHOM [2]. Spatial resolution is 5 arcminutes [22]. SHOM data gives seabed conditions, which is not sufficient for mooring design, but these data were used due to lack of more precise data.

Navigation area

Navigation areas are evaluated using data from Navionics [3]. For Bordeaux data were also kindly provided by the Grand Port Maritime de Bordeaux [23].

Servitude

Servitudes are evaluated using data from SHOM [2] and from Navionics [3].

Accessibility

Accessibility is evaluated using Google Maps, Navionics [3] and SHOM data [2].

Access to Enedis electrical connection

Access to Enedis electrical connection is evaluated using their open data [24]

Natura 2000

Natura 2000 sites are identified using the geoportail [25], a tool developed by IGN [26] and BRGM [27], two French organizations. Information can also be found on the dedicated website from the European Environment Agency [28].

Listed site

Listed sites are identified using the geoportail [25], a tool developed by IGN [26] and BRGM [27], two French organizations.

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ZNIEFF I and II

ZNIEFF I and II areas are identified using the geoportail [25], a tool developed by IGN [26] and BRGM [27], two French organizations.

Loi littoral (coastline regulation)

Coastline regulation is evaluated using the tool published by the *Observatoire des Territoires*, which gives cities under regulations [29].

RCFS (Hunt and wildlife reserve)

RCFS areas are identified using the geoportail [25], a tool developed by IGN [26] and BRGM [27], two French organizations.

Fisheries

Fishing activity was analyzed using various sources. A state of the art of the professional fisheries is given in [30]. Other studies were also used [31] [8], complemented by online research on each location.

Port activity

Port activity was measured using various sources (articles [32], [33], scientific papers, port website, stakeholders' comments).

Shipwrecks

Areas with shipwrecks are evaluated using data from SHOM [2] and from Navionics [3].

UXO

UXO are evaluated using different criteria. First, a map gives WWII bombings (by Allies) in France with circle sizes proportional to the number of tons of explosive dropped [34]. In addition, human activities are used as a key indicator (fishing trawler, existing tidal site). Finally, a literature review was conducted to check if any UXO has already been found on the location [35], [36].

Tourism – recreational boating

No systematic, quantitative data exist about recreational boating. To evaluate if tourism activity is high or low, different parameters are evaluated. The number of ports is evaluated using specialized websites (example for Normandie [37]). In addition, existing studies are used [8], [31].

Military zone

Existing studies are used [8], [31] to evaluate military zones (test sites, ammunition depot). For locations not covered by these studies, zones are analyzed using Navionics [3].

Migratory fish, habitats, and inventory zones

Presence of migratory fishes, habitats or inventory zone are mainly assessed by information relative to the PLAGEPOMI (migratory fish protection plan) project [38] from DREAL. Information are also freely available on special agency websites ([39], [40], [41], [42]).

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7. STAKEHOLDER INTERVIEWS

Interviews were conducted with different tidal energy stakeholders, either academics, industrials or from administrative services, to draw a conclusion on Metropolitan France tidal energy potential. They were asked to give their opinion on the attractivity of France regarding tidal energy from different point of view, such as:

- Attractivity due to the French potential (*i.e.* Does France have an important current resource?)
- Development and strength of the supply chain
- Public supports from administrations and society

Their opinions on retained locations for this study were also sought. This section summarizes the outcomes from these interviews. The 6 following stakeholders were interviewed (Table). A total of 14 stakeholders were contacted.

Stakeholders	Company/University/Administration	Position
Marlène Kiersnowski	Énergie de la Lune/SEENEOH	Development director at Energie de la Lune
Grégory Pinon	Université du Havre	Assistant professor and researcher at Université du Havre
Grégory Germain	IFREMER	Researcher at IFREMER
Guillaume Conan	Nouvelle-Aquitaine Region	Project manager in MRE at Region Nouvelle-Aquitaine
Nicolas Ruiz	Guinard Energies	CEO at Guinard Energies
Grégory Payne	Ecole Centrale de Nantes (ECN)	Research Engineer at ECN

Table 7-1 Stakeholders interviewed

Interviews with the different stakeholders have highlighted that Metropolitan France has a real potential for tidal energy with the second-best European potential, about 3-5GW [43] after the United Kingdom (about 9GW [43]) and one of the best in the world. Everyone has underlined a strong potential in nearshore locations, commonly illustrated by the Alderney Race and the Fromveur Passage. However, they also agreed, with different enthusiasm, on the potential of tidal energy in estuary and run of river regions such as the Gironde estuary or for isolated locations (Molène Island, Chaussée de Sein).

They have also highlighted that France has already developed a strong supply chain, from developers to manufacturers, that can benefit local communities at different levels, depending on the region and the project.

Pilot projects, such as Guinard Energies test in the Etel River, tend to demonstrate a good population acceptance (no legal appeals) regarding this technology, especially when the different stakeholders are included within the early stages of the project. Particularly, it appears that both floating and fixed tidal turbines benefit from their small or inexistant visual impact. Additionally, when water depth is sufficient, bottom fixed tidal turbines are not in the way of navigation.

In addition, interviews have revealed that France benefits from a strong academic fabric, with several research center and test sites (Seeneoh site at Bordeaux, EDF and Seeneoh site at Paimpol -Bréhat, Hydrodynamics laboratory of Boulogne-sur-Mer or LHEEA-Ecole Centrale de Nantes for instance). Some stakeholders have also underlined that, European programs such as H2020 or Interreg, and regional strategies and support such as from the Normandie region, provide suitable conditions for tidal energy development.

Several stakeholders also highlighted that some events [44] in the recent years could have impacted international visibility or attractivity of the sector and reduced national support. For instance, the lack of feed-in tariff to support the development of the sector or the absence of tidal

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energy within the last multiannual energy plan might have reduced the development of tidal energy. Some stakeholders draw a comparison with the United Kingdom, which has a more dynamic environment for tidal energy.

Another common comment was the lack of studies to fully characterize tidal energy potential. Several explanations were listed to explain this lack of data: most developers are currently SMEs, which cannot deploy means to characterize resources (*i.e.* developing models with sufficient high accuracy, validating by in-situ measurements) without financial support or guarantees. Consequently, at the moment, the focus is only on most powerful locations neglecting other smaller locations. As a comparison, wind speed data is much easier to obtain, mainly because this data has several other utilizations (air transport, high rise building, etc.).

Some disparities appeared between opinions, regarding the competitiveness of the different type of sites (nearshore, estuary, river, isolated location). Some underlined that each type of site can have a key role in the energetic mix while others think that sites with lower capacity cannot be competitive except in a few cases. However, everyone agreed on the benefits of tidal energy in isolated locations.

It is also worth mentioning that most stakeholders highlighted that the tidal sector is mainly in the R&D phase and costs can significantly change in the next steps.

As a conclusion, all agreed that France is an attractive country for tidal energy and that this energy source can be part of the French energetic mix, by increasing financial support, R&D projects, and cooperation between the different stakeholders. In addition, discussions have shown that opportunities exist in regions for sites that are not yet characterized (rivers, estuaries, isolated locations). Local utilization (connection to industrial sites, hydrogen production, etc.) is also a great opportunity giving scope to various types of technologies and sizes.

Finally, ecological benefits are always listed as one of the main advantages of the technology. Firstly, it can replace fossil fuel generation in isolated locations, helping to decrease greenhouse gas emissions. Secondly, cohabitation between power production and river continuity can be improved with tidal turbines which do not require fish ladders. Thirdly, recent studies conclude that collision risk between mammals and birds and tidal turbines is low [45].

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8. RESULTS

This section presents results. Grades for each site can be found in the ELEMENT-EU-0023_Attachment spreadsheet.

8.1. Site review

The 10 sites retained for the analysis are listed in Figure 5.1.1 and Table 5.1-2. Among these sites, some are known for being locations with high current resource (Alderney Race, Raz-Barfleur, Fromveur Passage) and some are known for being test sites (Pont de Pierre-Bordeaux, Etel river, Paimpol-Bréhat). A prototype of tidal turbine was also installed at Bayonne close to the Adour site [46] and two tidal turbines should soon be installed at the Passage de la Jument [47].

Sites' potential

The following potential have been calculated. Potentials with bold font are those found using methodology described in section 5.2 using Mars2D data. For Bordeaux and Bayonne, the same methodology is applied based on area and current speed given in [8]. For Etel, data was not available. In order to attribute a grade, only a range is required for the study, it was thus considered that potential would be below 5MW. This potential was validated by project partner CHBS.

Site	Potential (MW)	Grade attributed
Ria d'Etel	≤ 5	1
Fromveur passage	**282**	**2**
Alderney Race (Raz-Blanchard)	**1830**	**3**
Raz-Barfleur	**1057**	**3**
Pont de Pierre	≤ 5	1
Adour	≤ 0.5	1
Paimpol-Bréhat	**246**	**2**
Raz-de-Sein	**266**	**2**
Passage de la Jument	**6.1**	**2**
Arcachon Bay	**2.3**	**1**

Table 8.1-1 Potential (MW) for each site

Sites' socio-economic impact

Site	Direct jobs		Indirect and induced jobs		Direct GVA (m€)	
	Construction phase	Operation phase	Construction phase	Operation phase	Construction phase	Operation phase
Ria d'Etel	94	5	219	16	8	0.5
Passage du Fromveur	5308	282	12376	925	464	29
Raz-Blanchard (Alderney Race)	34443	1,832	80320	6000	3012	189
Raz-Barfleur	19893	1058	46393	3466	1739	109
Pont de Pierre	94	5	219	16	8	0.5
Adour	9.4	0.5	22	1.6	1	0.05
Paimpol-Bréhat	4630	246	10797	807	405	25
Raz-de-Sein	5006	266	11675	872	438	28
Passage de la Jument	115	6.1	268	20	10	1
Arcachon Bay	43	2.3	101	7.5	4	0.2

Table 8.1-2 Potential local content (jobs and GVA) for each site

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Table 8.1-2 gives results regarding potential local content for each site. As explained in section 5.3, results are higher than the current values found in the literature for other energy sources. Several hypotheses can explain that result, such as:

- the CAPEX and OPEX values retained in this study which corresponds to the first arrays that were built and would decrease as the sector matures, particularly when installed capacity would reach the GW.
- national shares applied
- the CAPEX being applied on the first year instead of on several years.

This last hypothesis leads to high number (34443 direct jobs), which means that 34443 FTE would be required to accomplish the design and construction phase in one year. If 10 years of studies and construction had been retained, we would obtain 3444 FTE per year.

To compare different sites, it was necessary to define one methodology applicable to each site. More precise results could be obtained with a more precise methodology dedicated to each site, however, the methodology developed here is robust and fits the objectives.

8.2. Site comparison

This section provides results. The grade of the site is given by:

$$X = \sum_{i} x_i w_i$$

Where x_i is the grade (1, 2 or 3) of the criterion i, and w_i the weight factor of this criterion. Hence, the minimum grade is 100 and the maximum 300. To get a final grade between 0 and 100, the final grade is calculated using:

$$Y = \frac{(X - 100)}{2}$$

Table 8.2-1 gives the final grade for the 10 locations.

Table 8.2-2 gives the detail of scores for each category. Scores have been reported on a scale of 0 to 100. Details regarding grades can be found in Appendix A (attached spreadsheet).

Location	Score
Raz de Sein	72.4
Paimpol-Bréhat	71.9
Alderney Race	69.4
Passage du Fromveur	68.9
Raz-Barfleur	67.3
Passage de la jument	59.7
Pont de Pierre Garonne	59.7
Etel	58.2
Adour	46.9
Arcachon Bay	42.3

Table 8.2-1 Final grade multicriteria analysis (100 is the maximal score)

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Location	Technical criteria SCORE	Socio-economic SCORE	French Regulation SCORE	Human Activities SCORE	Ecological diagnostics SCORE
Raz de Sein	63.2	63.3	70.6	88.6	100.0
Paimpol-Bréhat	69.7	73.3	70.6	81.8	50.0
Alderney Race	68.4	76.7	70.6	70.5	50.0
Fromveur Passage	68.4	73.3	58.8	65.9	100.0
Raz-Barfleur	68.4	76.7	58.8	70.5	50.0
Passage de la jument	65.8	63.3	47.1	72.7	0.0
Pont de Pierre Garonne	56.6	23.3	82.4	88.6	0.0
Etel	60.5	46.7	58.8	77.3	0.0
Adour	44.7	23.3	35.3	88.6	0.0
Arcachon Bay	50.0	23.3	35.3	59.1	0.0

Table 8.2-2 Categories score (100 is the maximal grade)

The Raz de Sein has a particular high score in ecological diagnostics and human activities, and good grades in other categories (French regulation, technical criteria and socio-economic scores). The site is relatively energetic though the spatial extent is limited. The absence of strong constraints (UXO, military zone, shipwrecks) gives the site an advantage compared to other nearshore locations.

Technical score of Paimpol-Bréhat is particularly high because it benefits from existing infrastructure (synergy with current test site). Even if the fishery activity is high, it has a good grade in the related category. Its ecological diagnostics score is impacted by migratory fish routes near its location. Its technical score is mainly due to its grade for the electrical connection (grade 3). It was considered that connection point already exists due to the existing tidal test site. If it is considered that a new power line would be required, then Paimpol-Bréhat overall grade would drop.

The Alderney Race is particularly impacted by the human activities score (high probability of UXO). As with many nearshore locations, technical criteria are affected by the criterion on access to grid connection point (above 3km).

Fromveur Passage is mainly impacted by human activities score. Several shipwrecks are present in the zone. Part of the site is also a listed site, reducing its grade in this category.

Part of the Raz-Barfleur zone is included in a ZNIEFF type 1 site, which leads to a low score in the French regulation category.

The Passage de la Jument location is particularly impacted by its ecological diagnostic score and French regulations grades, the Gulf of Morbihan being a highly protected area. In particular, it is the only RNCFS site among those studied.

The Pont de Pierre (Bordeaux) site is particularly impacted by its grade in three categories. First, the technical category, since the potential capacity is low. Then, in the socio-economic category, Nouvelle-Aquitaine having lower grades compared to other regions and because the local content is directly related to potential. Finally, its score in the ecological diagnostic due to presence of migratory fishes in the Garonne and estuary, and rivers are particularly suitable habitats.

The Etel river potential key strengths are within the human activities' category while it is particularly impacted by ecological diagnostic category (presence of both habitats and migratory fishes).

Arcachon Bay and Adour (Bayonne) locations have similar grades except for human activities, which give an advantage to the Bayonne site. Interviews with stakeholders have revealed that these two sites are unlikely to be suitable for tidal turbines, validating the scores awarded in this

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study. For instance, the study has shown that only 5 turbines (20kW) could be installed at the Adour (Bayonne). A stakeholder also underlined that Arcachon has a high degree of tourism activity (recreational boating, Dune of Pilat) and is a protected (Marine nature reserve) site, therefore installing turbines would not be suitable.

Results obtained are relatively consistent with other studies ([15], [48]), most powerful sites (Alderney Race, Raz-Barfleur, Fromveur, Raz de Sein) being at the top of the ranking. Three blocs could be identified from this study:

- “Green sites” corresponding to nearshore locations at the top, concentrating most of the potential capacity with about 99% of the capacity found in this study (Alderney Race, Raz-Sein, Paimpol-Bréhat, Passage du Fromveur, Raz-Barfleur), that look promising
- « Yellow sites » corresponding to estuary and rivers, with a medium score (Passage de la Jument, Etel, Pont de Pierre)
- “Red sites” corresponding to estuary and rivers sites, with a low score (Adour, Arcachon bay)

Within each group, grades are relatively close, and a small change in the hypothesis, would change ranks (as explained with Paimpol-Bréhat connection point).

Grades listed here are mainly comparative grades. The aim is to give data to the decision-makers to inform a decision between the different sites, either based on a global score or by the category score if one appears to be more relevant for a stakeholder.

In addition, the methodology employed (categories considered, only three grades), influence the classification. For instance, if a grade between 0 and 10 was applied, the Alderney Race would have a higher technical grade thanks to its potential. However, sensitivity analysis has shown this would have little impact on ranked order.

A sensitivity analysis has shown that ranked order was not found to be particularly sensitive to the weighting awarded to each category.

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9. CONCLUSIONS

During this study, a multicriteria analysis was developed to assess the potential of sites for tidal stream energy project development. Two methodologies were developed to assess theorical potential (MW) and economical impacts (jobs and GVA). From this analysis, it can be concluded that nearshore locations concentrate most of the potential evaluated, with locations such as Raz-de-Sein, Paimpol-Bréhat and the Alderney Race, while lower grades sites are situated in estuary or rivers (Adour-Bayonne and Arcachon Bay). In between, a diversity of locations appears to be interesting for project development both at a national or local level (Etel river, Pont de Pierre Bordeaux, Passage de la Jument).

This study found that Metropolitan France has a strong potential for tidal energy in both nearshore and estuary/run of river locations. Additional nearshore locations could have been included in this study (for instance, Batz island, Landuvez, Molène Island).

Work undertaken to fulfill subtasks 12.3.2 “Data gathering, formatting and analysis” has also highlighted that key parameters (maximum and mean current velocities) are missing in the public open-source database for several estuary/run of river areas. Consequently, the scope of the work was changed to include nearshore locations. Also, due to lack of refined data, areas with a possible high potential for tidal energy could not be analyzed (for instance, Gironde Estuary or Abers’ region). Interviews realized with tidal energy stakeholders have confirmed this finding, several saying that studies on site characterization should be realized to clearly identify tidal energy potential.

This study also underlined, with results and across interviews, that France is attractive for international investors or developers, benefiting from various type of sites from MW to GW scale. In addition, France has various research centers that could provide support during development, a local supply chain composed of a wide variety of companies, and different installations to test technologies (test tank and test sites).

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10. APPENDIX

Red rectangles show potential installation sites. Rectangles are not given for nearshores locations because the zone that can be exploited for tidal energy is very large and very variable depending on the criterion chosen. Further details are given in section 5.2.

Figure 10.1 Satellite view of the Arcachon Bay from Google Earth [4]

Figure 10.2 Satellite view of the Adour site (Bayonne) from Google Earth [4]

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Figure 10.3 Satellite view of the Pont de Pierre site (Bordeaux) from Google Earth [4]

Figure 10.4 Satellite view of the Gulf of Morbihan from Google Earth [4]

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Figure 10.5 Satellite view of Paimpol-Bréhat from Google Earth [4]

Figure 10.6 Satellite view of the Alderney Race (left) and Raz-Barfleur (right) from Google Earth [4]

Figure 10.7 Satellite view of the Etel River from Google Earth [4]

Figure 10.8 Satellite view of the Fromveur Passage from Google Earth [4]

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Figure 10.9 Satellite view of the Raz-de-Sein from Google Earth [4]

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11. REFERENCES

[1] M. d. l. t. é. (FRANCE), "Énergies marines renouvelables (EMR)," [Online]. Available: http://www.geolittoral.developpement-durable.gouv.fr/l-hydrolien-a1127.html#sommaire_3. [Accessed 27 04 2021].

[2] S. h. e. o. d. l. M. (SHOM), "Courants vitesses maximales," [Online]. Available: https://data.shom.fr/donnees/legend/COURANTS2D_WMTS_VMAX_3857#001=eyJjIjpbLTY5NjMxMi40NjUzMzYwMDMxLDYyMTY3MzcuOTEwODI2ODkzNV0sInoiOjYsInIiOjAsImwiOlt7InR5cGUiOiJJTlRFUk5BTF9MQVlFUiIsImlkZW50aWZpZXIiOiJDT1VSQU5UUzJEX1dNVFNfVk1BWF8zODU3Iiwib3BhY2l0eSI6MSwid. [Accessed 27 04 2021].

[3] Navionics, "Chart viewer," [Online]. Available: https://webapp.navionics.com/?lang=fr. [Accessed 27 04 2021].

[4] Google, "Google earth," [Online]. Available: https://earth.google.com/web/. [Accessed 23 07 2021].

[5] K. Orhan and R. Mayerle, "Assessment of the tidal stream power potential and impacts of tidal current turbines in the Strait of Larantuka, Indonesia," Elservier Ldt, 2017.

[6] O. d. é. d. l. mer, "Energies renouvelables en mer: Les chantiers s'activent, les emplois en forte croissant ! Rapport #5," 2021.

[7] R. Campbell, A. Martinez, C. Letetrel and A. Rio, "Methodology for estimating the French tidal current energy resource," vol. International Journal of Marine Energy, no. 19, pp. 256-217, 2017.

[8] Artelia, "Etude regionale d'evaluation du gisement d'energies en mer de la façade aquitaine," 2012.

[9] Ifremer, "Marc Ifremer," [Online]. Available: http://marc.ifremer.fr/en/about_marc. [Accessed 06 01 2021].

[10] M. Timmer, E. Dietzenbacher, B. Los, R. Stehrer and G. de Vrues, "An illustrated User Guide to the World Input-Output Database: the Case of Global Automotive Production," Review of International Economics, 2015.

[11] OES, "International levelised cost of energy for ocean energy technologies," 2015.

[12] M. N. (ORECatapult), "Tidal stream: opportunites for collobarative action," 2019.

[13] E. Commission. [Online]. Available: https://ec.europa.eu/competition/mergers/cases/index/nace_all.html.

[14] J. D'Hernoncourt, M. Cordier and D. Hadley. [Online]. Available: http://www.coastal-saf.eu/output-step/pdf/Specification%20sheet%20I_O_final.pdf.

[15] H. Boye, E. Caquot, P. Clement, L. de La Cochetiere, J.-M. NATAF and S. Philippe, "Rapport de la mission d'étude sur les énergies marines renouvelables," 2013.

[16] S. H. e. O. d. l. M. (SHOM), "Courants de marée des côtes de France (Manche/Atlantique) - Édition 2005," 2005.

[17] Seeneoh, "Seeneoh website," [Online]. Available: https://seeneoh.com/. [Accessed 19 01 2021].

[18] S. M. d. l. R. d'Etel, "Document d'objectifs Site Natura 2000 Ria d'Etel," 2021.

[19] L. Pinneau-Guillou, "Validation des modèles hydrodynamiques 2D des côtes de la Manche et de l'Atlantiques.PREVIMER," 2013.

[20] M. Thiébaut, . J.-F. Filipot, C. Maisondieu and G. Damblans, "Characterization of the vertical evolution of the three-dimensional turbulence for fatigue design of tidal turbines".

[21] S. H. e. O. d. l. Marine, "MTN bathymétrique de façade Atlantique," [Online]. Available: https://diffusion.shom.fr/pro/risques/bathymetrie/mnt-facade-atl-homonim.html.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 815180.

[22] S. H. e. O. d. l. M. (SHOM), "Carte sédimentaire mondiale," [Online]. Available: https://services.data.shom.fr/geonetwork/srv/fre/catalog.search#/metadata/HOM_GEOL_SEDIM_MONDIALE.xml.

[23] G. P. M. d. Bordeaux. [Online]. Available: https://www.bordeaux-port.fr/en.

[24] Enedis, "Lignes et Postes," [Online]. Available: https://data.enedis.fr/pages/accueil/?id=dataviz-lignes-et-postes. [Accessed 06 05 2021].

[25] geoportail. [Online]. Available: https://www.geoportail.gouv.fr/carte. [Accessed 06 05 2021].

[26] IGN. [Online]. Available: https://www.ign.fr/. [Accessed 06 05 2021].

[27] BRGM. [Online]. Available: https://www.brgm.fr/fr. [Accessed 06 05 2021].

[28] E. E. Agency. [Online]. Available: https://natura2000.eea.europa.eu/. [Accessed 06 05 2021].

[29] O. d. territoires, "Classement des communes en loi littoral," [Online]. Available: https://www.observatoire-des-territoires.gouv.fr/classement-des-communes-en-loi-littoral. [Accessed 07 05 2021].

[30] A. Le Meur, "Rapport d'information déposé en application de l'article 145 du Règlement par la commission des affaires économiques sur la pêche".

[31] Artelia, "Determination du potentiel hydrolien en Basse-Normandie," 2012.

[32] P. d. Brest, "Mise à l'eau de l'hydrolienne DCNS/OPENHYDRO: un succès," [Online]. Available: http://www.brest.port.bzh/fr/?option=com_content&view=article&id=186:hydrolienne-openhydro-en-route-pour-paimpol-brehat&catid=39:actualite. [Accessed 08 07 2021].

[33] R. L. P. d. l. Manche, "50 hectares du port de Cherbourg seront alloués aux énergies marines renouvelables," [Online]. Available: https://actu.fr/normandie/cherbourg-en-cotentin_50129/50-hectares-du-port-de-cherbourg-seront-alloues-aux-energies-marines-renouvelables_34318820.html. [Accessed 08 07 2021].

[34] S. Genevois. [Online]. Available: http://cartonumerique.blogspot.com/2019/02/missions-aeriennes-2ndww.html.

[35] L. Ameline, "Au large du Cotentin : Un chalutier remonde une bombe dans ses filets," *La presse de la Manche.*

[36] R. d. b. association, "Inventaire des déchets de guerre régions Atlantique-Manch Janvier 2008-Décembre 2013," [Online]. Available: https://robindesbois.org/inventaire-des-dechets-de-guerre-regions-atlantique-manche/. [Accessed 07 05 2021].

[37] C. u. p. nature, "Port de plaisance et de mouillage," [Online]. Available: https://www.encotentin.fr/aventure/plaisance/port-mouillage#:~:text=Du%20port%20de%20Carentan%2C%20porte,escale%20ou%20d'un%20s%C3%A9jour.

[38] DREAL, "Plans de gestion des poissons migrateurs (PLAGEPOMI)," [Online]. Available: http://www.nouvelle-aquitaine.developpement-durable.gouv.fr/plans-de-gestion-des-poissons-migrateurs-plagepomi-a1240.html. [Accessed 07 05 2021].

[39] I. Adour, "Page d'accueil," [Online]. Available: https://www.institution-adour.fr/. [Accessed 07 05 2021].

[40] O. d. l. e. bretagne, "page d'acceuil," [Online]. Available: https://bretagne-environnement.fr/. [Accessed 07 05 2021].

[41] I. N. d. P. Naturel, "Page d'acceuil," [Online]. Available: https://inpn.mnhn.fr/accueil/index. [Accessed 07 05 2021].

[42] "Geobretagne," [Online]. Available: https://cms.geobretagne.fr/. [Accessed 07 05 2021].

[43] ADEME, "Etude stratégique de la filière hydrolien marin*".

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 815180.

[44] A. Bossard, "Naval Energies arrête l'hydrolien et ferme l'usine de Cherbourg," *France Bleu,* 2018.

[45] E. C. (. -. EnFAIT, "D8.6 – Y3 Environmental Monitoring Report," 2020.

[46] B. Technologies, "Communiqué de presse: l'hydrolienne fluviale conçue par Bertin Technologies inauguree sur l'Adour à Bayonne," [Online]. Available: https://bertin.fr/sites/default/files/2017-05/dpurabailaversion2.pdf.

[47] L. m. d. l'énergie, "Deux hydroliennes immergées dans le Golfe du Morbihan d'ici fin 2022," [Online]. Available: https://www.lemondedelenergie.com/hydroliennes-morbihan/2021/05/10/.

[48] M. d. l. t. écologique, "Energies Marines Renouvelables," [Online]. Available: http://www.geolittoral.developpement-durable.gouv.fr/l-hydrolien-a1127.html.

[49] ADEME, "Etude stratégique de la filière hydrolien marin," 2018.

[50] S. MacKenzie, "D1.1 - Project Management Plan," 2019.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 815180.

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