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A tool to select offshore renewable energy facilities. The case of study of shipyards and ports in Spain

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Abstract. The objective of this work is to create a tool that serves to know the possibilities of manufacturing, storage, assembly, and maintenance of floating marine structures trying to take advantage of the ports and shipyards of Spain. This would help reduce costs and could make this type of energy more profitable. To this end, all the Spanish ports and shipyards have been analyzed, considering the characteristics and possibilities of each of them. In the study, those that did not meet certain essential conditions for the manufacture, storage, assembly, and maintenance of power generation equipment have been discarded.

Key words.
Shipyard; port; offshore renewable energy

1. Introduction

Measures have been taken for years to prevent air pollution caused by greenhouse gases [1–3], in most cases generated using fossil fuels, both for transport and for the generation of electricity. One of the main alternatives to the use of this type of fuel comes from renewable energies and specifically marine renewable energies, since the best locations on land are already occupied [4,5]. Within marine renewable energies there are many types, such as wind (fixed and floating) [4,6–8], tidal [9–11], wave [7,12], solar [13], etc. and although some are more developed than others, all of them can have a contribution to the world energy system. Apart from not emitting greenhouse gases, these energies help not to depend on other countries for energy [14]. Another key point to achieve an increase in energy through marine renewable energies is to know the facilities associated with them, such as ports and shipyards. For this, it is necessary to know the real possibility of manufacturing this type of technology in the ports and shipyards that currently exist, since in this way the costs associated with the total process will be reduced.

Many of the shipyards that currently exist in Spain can be converted to manufacture components for this type of energy, avoiding higher costs and thus achieving greater profitability for this type of energy.

The tool proposed has the advantage of considering the main Spanish ports and shipyards and their main characteristics, which will help to plan the future of installing offshore renewable energies in Spain. It will be combined with other tools of restrictions (environmental protected areas, navigation zones, etc.) and economic issues (Levelized Cost Of Energy, Internal Rate of Return, Net Present Value, etc.) in the future in order to planning and select the best appropriate areas where install the farms and planning the maritime areas.

1. Methodology

A. PORTS

It is based on the information collected in a spreadsheet, which contains technical data of 28 Spanish ports. These data will need to be linked with geometries to implement them in a GIS project.

To obtain the geometries of ports and alphanumeric data associated with them, cartography from the National Geographic Institute (IGN) corresponding to the National Topographic Base at a scale of 1:100000, reference system: ETRS89 in the Peninsula, Balearic Islands, Ceuta and Melilla, and REGCAN95 in the Canary Islands (both systems compatible with WGS84). UTM projection in the corresponding zone.

The IGN download center allows you to obtain shapefile files compatible with GIS programs. The transport section of the BTN100 updated in 2021 is downloaded and which, among other layers, contains digitized port data with polygons and points as well as an attribute table with alphanumeric data on each port.

- BTN100_0620S_PUERTO_ZONA.shp (387 elements)
- BTN100_0620S_PUERTO.shp (515 elements)

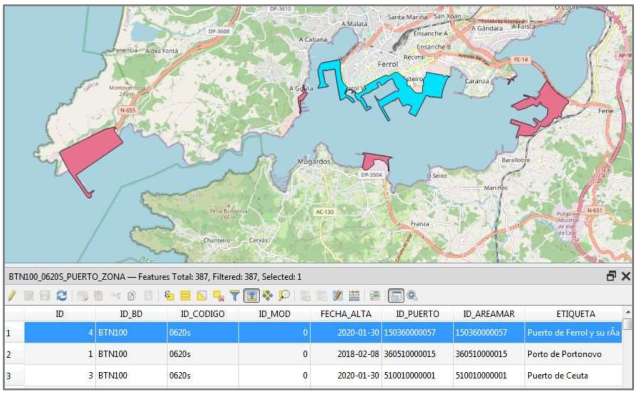

Fig. 1. BTN100 layer with geometric and alphanumeric port information

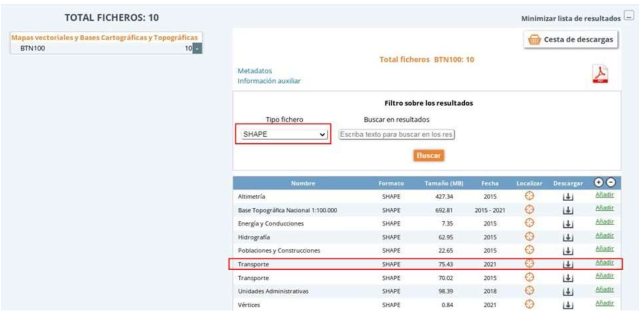

Fig. 2. Download Center of the Autonomous Organization of the National Geographic Information Center [15].

The attribute table associated with the layer has a unique ID code for each geometry and that will be used to link information from the spreadsheets to the port shapefile. The data requires filtering as it contains elements that a priori may not be relevant to the project, such as marinas or small jetties. The layers do not have the same attribute table structure, so there is information that is collected in the points layer that does not appear in the polygons layer. To solve this, a union of tables is made using the ID code of the port.

Once the geometries for ports throughout Spain are available, the data purification is carried out from the spreadsheet associated with the dbf file of the shapefile. The dbf file is copied and renamed so that it can be edited and worked without the risk of affecting the original shapefile. Thus, a spreadsheet is obtained with 387 elements identified with their unique ID that will allow links to the port geometries of the shapefile. In this spreadsheet, the input data with technical port information from the spreadsheet file are added.

In the search for information on the technical characteristics of ports, the Spanish Transport and Logistics Observatory (OTLE) has been used, which collects information in the maritime infrastructure section by port authority. Much of the available data corresponds to the total number of ports in the port authority and it is not possible to assign the value to a single port.

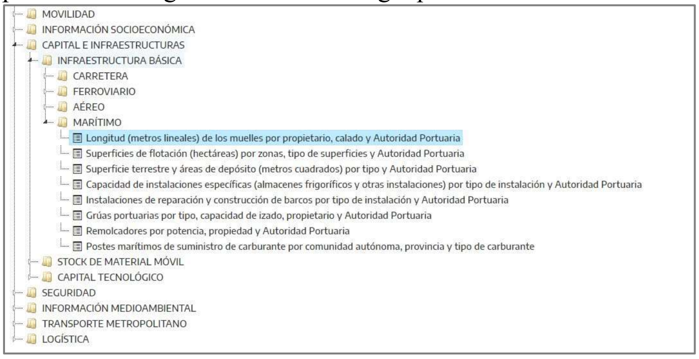

Fig. 3. Observatory of transport and logistics in Spain [16].

Information has also been searched on the state ports website with the download of annual reports of the main ports and the 2019 statistical yearbook.

Fig. 4. Annual reports of State Ports 2019 [17]

Fig. 5. Annual Statistical Report of the State-Owned Port System 2019 [18].

Section 2 of the statistical yearbook collects information on the technical characteristics of 52 ports, while the data for the other sections refer to the group of ports by port authority. The information can be downloaded in Excel format.

Table I. Data on technical characteristics of 52 ports, collected in section 2.1 of the Annual Statistical Report 2019 [18].

	Port Authorities
	Longitud
	Latitude
Wind	Prevailing winds
	Dominant
Waves	Waves máximum wave height (m)
	Maximum tidal range (m)
Channel	Width (m)
	Draft (m)
Mouth	Width (m)
	Draft (m)
	Controlled current (knots)

B. SHIPYARDS

In the geolocation of shipyards, the data collected in a shipyard data spreadsheet file with 22 shipyards and technical characteristics are taken as starting data. With the help of Google Maps, they are located and then their surface is digitized using GIS tools and taking as reference the cadastral information of parcels and orthophoto from the WMS Google Satellite server, thus creating a layer named Shipyards.shp of polygon geometry on which the it assigns an ID code to each record in order to link data from spreadsheets. The process consists of locating the shipyard, generating its surface in GIS and assigning an ID code and filling in the technical data on a spreadsheet.

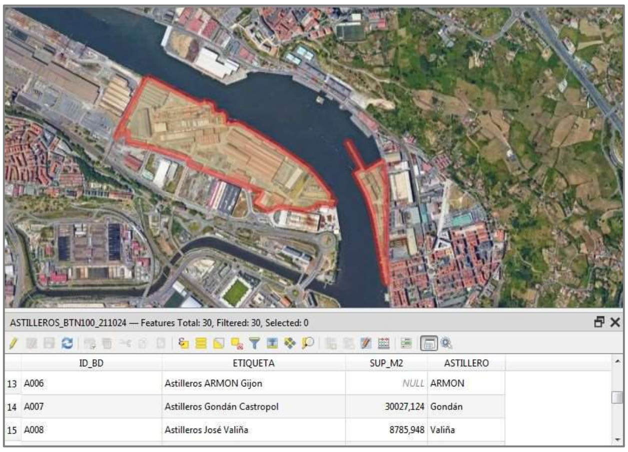

Fig. 6. Location and digitization of shipyards

Information from the OTLE database that provides data by port authorities has been used. In this way, a spreadsheet is available with the number of shipyards of each port authority.

Table II. Data on the number of shipyards by Port Authority collected in the OTLE.

Port Authority	**Type of facility**	**Shipyards**
Vigo	Shipyards	38
Marín y Ría de Pontevedra	Shipyards	10
Las Palmas	Shipyards	7
Bilbao	Shipyards	5
Ferrol-San Cibrao	Shipyards	5
Baleares	Shipyards	4
Barcelona	Shipyards	4
Valencia	Shipyards	4
Alicante	Shipyards	3
Avilés	Shipyards	3
Cartagena	Shipyards	3
Almería	Shipyards	2
Gijón	Shipyards	2
Pasaia	Shipyards	2
Bahía de Cádiz	Shipyards	1
Santander	Shipyards	1
A Coruña	Shipyards	0
Bahía de Algeciras	Shipyards	0
Castellón	Shipyards	0
Ceuta	Shipyards	0
Huelva	Shipyards	0
Málaga	Shipyards	0
Melilla	Shipyards	0
Motril	Shipyards	0
Sevilla	Shipyards	0
Sta. Cruz de Tenerife	Shipyards	0
Tarragona	Shipyards	0
Vilagarcía	Shipyards	0

Much of the information on the technical characteristics of the shipyards is obtained directly from the corresponding web page when they collect it.
Another source of input data information is a Shipyards of the World spreadsheet with data from the main shipyards in Spain collected in the book "*Large shipyards and shipbuilding facilities: technologies, current situation and prospects*" by Alfonso García Ascaso [19].

Three plans of the shipyards are also extracted from this book: Astano, Bazán and Cádiz A.E. that are incorporated into the GIS project taking as support for their georeferencing the orthophoto of the National Plan of Aerial Orthophotography (PNOA)

Table III. Characteristics of shipyards collected in the book "*Large shipyards and shipbuilding facilities: technologies, current situation and prospects*" by Alfonso García Ascaso [19].

			DIMENSIONS (m)					
Shipyard	Country	Class	Length	Width	Deep	Capacity (TPM)	Operation date	Type
Bazán-Ferrol	Spain	G	320	52		230000		Construction
A.E.S.A.-Cádiz	Spain	G	300	54		250000		Construction
Astano	Spain	G	335	49		300000		Construction
Astano	Spain	G	335	58		400000		Construction
Bazán-Ferrol	Spain		330	53	13,67	230000	In service	Repair
A.E.S.A.-Cádiz	Spain					400000	1974	Repair
Islas Canarias	Spain					500000	1975	Repair

2. Case of study

The case of study are the ports and shipyards located in Spain and their main characteristics.

They will be used in the future for analysing their technical and economic feasibility in terms of being part of the supply chain for installing offshore renewable energies in Spain.

3. Results

As a result of the work, the generated documentation is delivered organized in the following folder structure:

01_INPUT_DATA: Contains the starting information

- PORTS TABLE.xlsx
- TABLE 1.xlsx
- Ports Dossier WEB-ESP.pdf
- link state ports documents.pdf
- shipyards in the world. Garcia Ascaso.xlsx
- shipyard data.xlsx

02_DATA: Contains the information that has been downloaded or generated

- G_ASCASO: 3 plans of the Astano, Bazán and Cádiz shipyards scanned from the book of Large Shipyards and Shipbuilding Facilities
- IGN: Data in vector format downloaded from the IGN website corresponding to the BTN100 with the location of ports and port areas. Data of administrative limits at the level of provinces, municipalities and communities.
- OTLE: Data table downloaded from the OTLE database with the number of shipyards per port authority.
- PORTS: Data downloaded from the ports website with 2019 annual reports of the 28 main ports and data from the 2019 statistical yearbook

03_DOC: Text files and tables generated during the job

- Processes.docx text file to detail the processes carried out
- Annual_Statitistical_Report_2019.xls summary of data downloaded from the port website with information on 52 ports. The ID codes and ID_GIS code have been included on this table in order to link the information to the GIS port layer.
- List_Shipyards_web_Empresite.xlsx list of shipyards that has been obtained from searches on company pages by activity (unreliable information) to be able to do a search on Google Maps and locate shipbuilding companies
- OTLE_Instalac_Reparacion_Construccion_Barcos_2019.xlsx data obtained from the OTLE that allows filtering the number of shipyards by port authority to locate the companies with the help of G_maps. The data seems to include all types of shipyards or companies related to shipbuilding.
- PORTS_SHIPYARDS_211029.xls. Table resulting from the search for information on ports and shipyards. The ports tab includes all the ports that have been downloaded from the IGN BTN100 layer, discarding those that appear as marinas. The start information about ports in the PORTS_SHIPYARDS _211026.xls table of the input data has been linked. This table does not include the data downloaded from the statistical yearbook. The Shipyards tab includes the shipyard starting data from the shipyards.xlsx data file and some more localized shipyards have been added with the help of G_maps. A code has been assigned to each element in order to link the information in the table to the GIS layer.

04_SHP: Files in shapefile and raster format to add to the GIS project

- PORTS_211029.shp layer of polygons with 322 elements that contains the location of ports that is based on the BTN100 layer of the IGN. The data from the PORTS_SHIPYARDS_211026.xls table corresponding to ports have been linked to this layer.
- SHIPYARDS_211029.shp Layer of polygons with 36 elements with the location of digitized shipyards based on the satellite image of Google and Cadastre. The shipyard data from the PORTS_SHIPYARDS _211026.xls table has been linked to this layer
- PORTS_Datos_Anuario_2019.shp layer of polygons with 52 elements with the location of ports and alphanumeric data collected in the table Annual_Statitistical_Report_2019.xls
- GEORREF Folder containing 3 scanned maps from García Ascaso's book with the Bazán, Astano and Cádiz shipyards georeferenced. The georeferencing of the Astano and Cádiz shipyards does not fully adjust to the orthophoto due to distortion in the scan

The Table structure of the PORTS_211029.shp layer is the following.

Table IV. Fields of the attribute table associated with the port layer.

Field name	Gis field name (10 characters)	Description
ID	ID	Unique ID code for each geometry
Port ID	ID_PUERTO	Unique ID code for each port
Port encoding	COD_PUERTO	Acronyms for port coding (Source: BTN100 IGN)
Port name	NOMBRE	Port name (Source: BTN100 IGN)
Municipality	MUNICIPIO	Municipality where the port is located
Municipality code	COD_MUN	Municipality code
Community/Province	CCAA	Community or province of the municipality
Community or province code	COD_CCAA	Community or province code
Port Authority	AUT_PORT	Port authority to which the port belongs (Source: OTLE)
Draft (m)	CALADO_Cal	Harbor draft
Maxium pier length (m)	LONG_MUELL	Dock length
Available área (hectares)	SUP_Ha	Port area in hectares
Available área (m2)	SUP_M2_1	Port area in m2
Number of cranes	N_GRUAS	Number of port cranes
Scenario 1	ESC_1	Result of dividing the area in m2 by 5395
Scenario 2	ESC_2	Result of dividing the area in m2 by 1986
Scenario 3	ESC_3	Result of dividing the area in m2 by 4391
Scenario 4	ESC_4	Result of dividing the area in m2 by 3371
Ownership	TITULARIDA	Ownership of the port (Source: BTN100 IGN)
Bordering Sea/Ocean	MAR_OC	Sea/Ocean bordering the port (Source: BTN100 IGN)
Condition	ESTADO	State in which the port is located (Source: BTN100 IGN)

The table structure of the SHIPYARDS_211029.shp layer is the following:

Table V. Fields of the attribute table associated with the shipyards layer.

Field name	Gis field name (10 characters)	Description
Shipyard ID	ID_BD	Shipyard ID
Shipyard name	NOMBRE	Shipyard name
Business group	ASTILLERO	Business group name
Municipality	MUNICIPIO	Municipality where the shipyard is located
Municipality code	COD_MUN	Municipality code
Province	PROVINCIA	Province to which the municipality belongs
Province code	COD_PROV	Province code
Total area m2	SUP_TOT_M2	Total area of the shipyard in m2
Total area m2 occupied	SUP_CUB_M2	Total occupied area m2
Number of cranes	GRUAS	Number of cranes
Other features	OTRAS_CARA	Other features
Location	LOCALIZACION	Location
Contact	CONTACTO	Contact

The Table structure of the PUERTOS_Datos_Anuario _2019.shp layer is the following:

	Field name	Gis field name (10 characters)	Description
	ID_GIS	ID	Geometry ID code
	ID_PORT	ID_PUERTO	Port ID code (Source: BTN100 IGN)
	Port Authorities	Aut_Port	Port authority
	Length	Longitud	Longitude coordinate
	Latitude	Latitude	Latitude coordinate
Winds	Prevailling winds	V_Rnte	Prevailling winds
	Dominant wind	V_Domnte	Dominant wind
Waves	Waves maximum wave height (m)	O_Max_m	Maximum wave height in meters
	Maximum tidal range (m)	O_max_CM_m	Maximum tidal range in meters
Channel	Width (m)	Ancho_Cana	Channel width range in meters
	Draft (m)	Calado_Can	Channel draft in meters
Mouth	Width (m)	Ancho_Boca	Manhole width in meters
	Draft (m)	Calado_Boc	Mouth draft in meters
	Controlled current (knots)	Corrnte_co	Controlled current in knots

05_PROJECTS: It contains an ArcGis-compatible *mxd file where the aforementioned layers and some wms viewer have been added as a display base.

Fig. 7. Capture of the GIS project with the location of shipyards

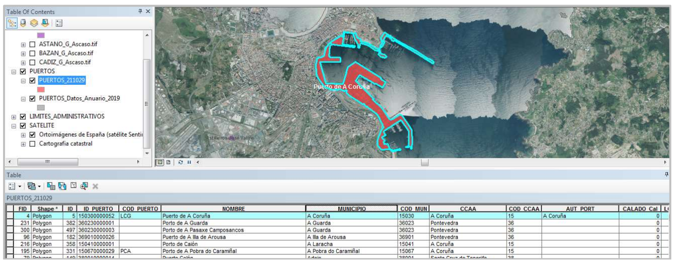

Fig. 8. Capture of the GIS project with the location and port data

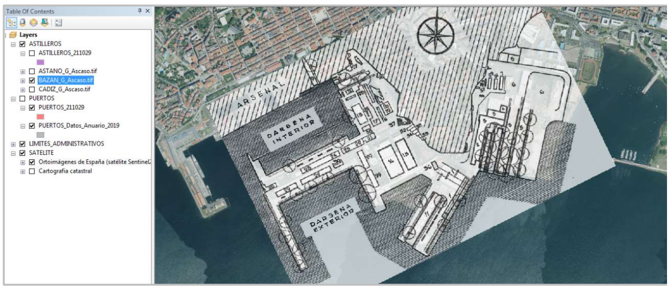

Fig. 9. Capture of the GIS project with the georeferencing of the plan of the Bazán shipyard from the book by García Ascaso.

4. Conclusions

In this paper, a tool has been created that helps to know the Spanish ports and dockyards by linking them with geometries for its implementation in a GIS project. Thus, a spreadsheet of all ports and shipyards relevant to the field of renewable energy is obtained. These elements are identified with their unique ID that will allow linking with their geometries.
This tool can be useful for the future of offshore renewable energy industry in order to develop the marine spatial planning (to be joined to the restrictions of the locations and the economic feasibility of them) of the offshore energies.

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