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D.1.2: Catalogue of technologies for Maritime and Coastal Communities and Ports

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TABLE OF CONTENTS

1.	Introduction	9
1.1	Purpose of the document	9
1.2	Structure of the document	9
1.3	Relation to other project deliverables	10
2.	Catalogue of technologies for Maritime and Coastal Communities and Ports	11
2.1	Context	11
2.2	Structure	12
2.2.1	Vessels' electricity	12
2.2.2	ICE and Fuel Cell	13
2.2.3	CHE	15
2.2.4	Trucks	16
2.2.5	Other mobile vehicles	17
2.2.6	Fuel producers	18
2.2.7	Fuel production technology	19
2.2.8	Carbon capture	20
2.2.9	Electricity production	21
2.2.10	Energy efficiency	22
3.	Final remarks	23
	Annex I. Technologies	25
	Annex II. Website	42



List of Tables

Table 1: Vessels' electricity subsections	13
Table 2: ICE and fuel cell subsections.....	14
Table 3: CHE subsections.....	15
Table 4: Trucks subsections.....	17
Table 5: Other mobile vehicles subsections.....	18
Table 6: Fuel producers subsections	19
Table 7: Fuel production technology subsections.....	20
Table 8: Carbon capture subsections	21
Table 9: Electricity production subsections	21
Table 10: Energy efficiency subsections.....	22
Table 11: Vessels' electricity technologies.....	25
Table 12: ICE fuel cell technologies.....	26
Table 13: CHE technologies	29
Table 14: Truck technologies.....	33
Table 15: Other mobile vehicles technologies	35
Table 16: Fuel producers technologies	36
Table 17: Fuel production technologies.....	37
Table 18: Carbon capture technologies	38
Table 19: Electricity production technologies.....	39
Table 20: Energy efficiency technologies.....	40



List of Figures

Figure 1: SEANERGY website catalogue interface..... 42

Figure 2: Sample of vessels' electricity section 43



List of Acronyms

Abbreviation / Acronym	Description
AGV	Automated Guided Vehicles
CHE	Cargo Handling Equipment
ETS	Emissions Trading System
EU	European Union
GHG	Greenhouse gas
ICE	Internal Combustion Engine
PEM	Polymer Electrolyte Membrane
Ro-pax	Roll-on/roll-off passenger
Ro-ro	Roll on-roll off
RTG	Rubber Tyred Gantry crane
SEANERGY	Sustainability Educational Programme for Greener Fuels and Energy on ports
SOFC	Solid Oxide Fuel Cell



Executive Summary

The purpose of this report is to provide an overview of the available technologies to implement sustainable best practices and decarbonize the maritime sector within the port boundaries. This report provides the guidelines followed to review the available technological options and develop a catalogue with best practices, state-of-the-art solutions and future trends in the form of pilot solutions.

The methodology followed was based on brainstorming to identify the structure of the catalogue, followed by a literature review, analyzing the key technologies in ports decarbonization as well as future trends, after which SEANERGY partners contributed to building the list of technologies.

The catalogue is structured into ten subsections that encompass the main equipment used within the maritime sector. In total, over 90 available technologies (both commercial and pilot) have been included in the catalogue. These technologies, along with their main characteristics, have been included at the end of the deliverable in the annexes section, and will later be uploaded to the SEANERGY project's website. When going over the catalogue, it is worth noting that some technologies might not work for all ports/maritime companies due to their own specificities. For this reason, within the catalogue, each equipment subsection is structured with filters, aiming to provide a wide variety of technological solutions for different ports, and facilitating the search process.

The final remarks of the report offer insight into choosing the right technology as well as into the future of the catalogue, while the annex illustrates how the catalogue will look like on the SEANERGY webpage.



1. Introduction

The Sustainability Educational Programme for Greener Fuels and Energy on ports (SEANERGY) project aims to go towards zero-emission ports, becoming clean energy hubs for integrated electricity systems, hydrogen, and other low-carbon fuels, as much as testbeds for waste reuse and the circular economy through the creation of the SEANERGY Master Plan. Involving both public and private agents of the industry, the goal is to set the basis for green port transitioning through trainings and awareness spreading. Divided into six work packages, the first one “Understanding the current EU ports’ situation and stakeholders” develops the existing framework under which stakeholders operate, analyzing the aspects that constrain current efforts towards the clean energy and fuel port transition.

In this context, task 1.2 “Mapping of Technologies” aims to develop a catalogue of technologies for maritime and coastal communities and ports, including available technologies for sustainable energy generation and the use/production of alternative fuels. Though the catalogue itself has been developed in tables to facilitate the compilation and update of data, the present document serves as a guide to the work performed as well as a complement to the catalogue.

1.1 Purpose of the document

The purpose of this document is to map the available technologies for sustainable energy generation and for the use/production of alternative fuels on the maritime sector, identifying best practices, state-of-the-art solutions and future trends.

1.2 Structure of the document

Whereas this first section of the document is related to contextualizing the deliverable within the scope of the project, the rest of the report focuses on the catalogue of technologies to decarbonize maritime and coastal communities and ports. The structure of the document is divided into the following sections:

- Context



- Structure of the catalogue
- Final remarks
- Annex. Technologies

1.3 Relation to other project deliverables

This report is directly related to Work Package one, pertaining to Task 1.2 SEANERGY's Mapping of Technologies. In addition, this report is related to Work package two, particularly, Task 2.2 Regional policy and business model development workshops, and Task 2.3 Recommendations on tech uptake. Specifically, this report will set the basis for the Work Packages that will conduct workshops and analyze the possibilities to implement decarbonization technologies in the sector. This deliverable will also contribute to the Master Plan and the Handbook.



2. Catalogue of technologies for Maritime and Coastal Communities and Ports

2.1 Context

The EU's maritime transport is one of the most energy-efficient modes of transport. However, it is a considerable source of increasing GHG emissions representing 3-4% of the EU's total carbon footprint. Even though currently there are no concrete obligations set in place to scale down maritime transport emissions, reducing them is part of the EU economy-wide reduction commitment under the Paris Agreement, and it also plays a role in the EU's goal of achieving climate neutrality by 2050. Thus, efforts are being made within the EU to decarbonize all sectors, and further commitments are being set in place with the European Green Deal (Fit for 55 package).

In this context, the maritime sector is set to increase its climate ambition with the imminent inclusion of the shipping sector in the EU ETS, increasing the demand for the use of renewable low-carbon fuels as well as alternative fuel infrastructure, in efforts to undergo an energy transition. For this reason, ports and maritime companies are called to pursue climate action and promote the use of efficient and clean energy by implementing innovative technologies to increase electrification of equipment, consumption of alternative fuels, etc.

In light of this, it is important to find sustainable alternatives for the technologies used within the maritime sector, that provide available options to help companies undergo a smooth transition and lower their GHG emissions. The purpose of this catalogue is to map available technologies that allow for the generation/use of sustainable energy sources and decarbonization, identifying best practices, state-of-the-art solutions and future trends.



2.2 Structure

The catalogue is structured into the main type of solutions that could be used in the maritime sector:

- Vessels' electricity
- Internal Combustion Engines (ICE) and Fuel Cells
- Cargo Handling Equipment (CHE)
- Trucks
- Other mobile vehicles
- Fuel producers
- Fuel production technology
- Carbon capture
- Electricity production
- Energy efficiency

Each section is further divided in specific subsections using filters, to facilitate the search of technologies. The following sections of the report expand on the specificities used for each equipment.

2.2.1 Vessels' electricity

Vessel's electricity is related to providing sustainable and green electricity options for vessels.

The fields included in the catalogue are the following:

- Type of solution: equipment where the sustainable, low emissions technology alternative applies to.
- Type of vessel: type of vessel that uses the sustainable technology.
- Manufacturer: developer of the technology, and brand.
- Model: commercial name of the technology.
- Availability: whether it refers to a product already in the market or to a pilot.
- Comments: any other relevant information, detail or description.
- Source: reference providing information about the product, such as web address.



The table below shows the filters used in the catalogue for vessels' electricity, including the different options for each subsection:

Table 1: Vessels' electricity subsections

VESSELS' ELECTRICITY							
Type of solution	Cable management		Electronics		Batteries	Chargers	Others
Type of vessel	Cruise	Containership	Ro-ro	Ro-pax	Pilot boats /tugboats	Other/all	
Manufacturer							
Model							
Availability	Commercial			Pilot			
Comments							
Source							

The main solutions included in this section are related to cable management, electronics, batteries, chargers and other. A subsection has also been added to account for the type of vessel for which the solution is intended, such as cruise, containership, ro-ro, ro-pax, pilot boats/tugboats or other/all vessels.

Several technologies have been found in the market from different manufacturers, and future trends in the form of pilots have been identified, such as submerged electric motors or hydrogen bromine flow battery technology.

2.2.2 ICE and Fuel Cell

This section includes any sustainable green option to generate mechanical energy or electricity from the energy content of a fuel, including only those that could be used for applications within the maritime sector that carry out most of its activity in a port environment (i.e., technical-nautical services). The fields included in the catalogue are the following:

- Type of solution: equipment where the sustainable, low emissions technology alternative applies to.
- Subclass: category within the solution.
- Application: equipment where this technology can be used.
- Fuel: type of sustainable, green fuel used by the technology.



- Power range: combustion range.
- Manufacturer: developer of the technology, brand.
- Model: commercial name of the technology.
- Availability: whether it refers to a product already in the market or to a pilot.
- Price range: CAPEX estimated for the technology.
- Comments: any other relevant information, detail or description.
- Source: reference providing information about the product, such as web address.

The table below shows the filters used in the catalogue for powerplants, including the different options for each subsection:

Table 2: ICE and fuel cell subsections

ICE AND FUEL CELL					
Type of solution	Internal combustion engine (ICE)	Fuel cell	Turbines	Battery	Other
Subclass	Engine - 4 strokes	Fuel cells - PEM	Fuel cells - SOFC	Fuel cells - Other	Turbines - gas
Application	Domestic vessels	Cargo Handling Equipment	Trucks	Locomotives	Other
Fuel					
Power range					
Manufacturer					
Model					
Availability	Commercial		Pilot		
Price range					
Comments					
Source					

The main solutions included in this section are related to internal combustion engines (4 strokes), fuel cell (PEM, SOFC, other), turbines (gas), batteries and other. A subsection has also been added to account for the application for which the solution is intended, such as domestic vessels, CHE, trucks, locomotives or other.



Several technologies have been found in the market from different manufacturers, especially with the use of fuel hydrogen, and future trends in the form of pilots have been identified in terms of compact systems and the use of alternative fuels such as ammonia, methanol etc.

2.2.3 CHE

CHE encompasses any sustainable, low emissions options for Cargo Handling Equipment. The fields included in the catalogue are the following:

- **Type of terminal:** description of port terminals where the technology can be used.
- **Type of equipment:** type of CHE that uses the sustainable technology.
- **Technology:** sustainable, low emissions alternative.
- **Fuel:** type of sustainable, green fuel used by the technology.
- **Power range:** range of power output from the ICE or the electric motor/s used in the CHE.
- **Fuel storage:** fuel capacity of the equipment (i.e., size of the tanks or battery capacity).
- **Manufacturer:** developer of the technology, brand.
- **Model:** commercial name of the technology.
- **Availability:** whether it refers to a product already in the market or to a pilot.
- **Price range:** CAPEX estimated for the technology.
- **Comments:** any other relevant information, detail or description.
- **Source:** reference providing information about the product, such as web address.

The table below shows the filters used in the catalogue for CHE, including the different options for each subsection:

Table 3: CHE subsections

CHE							
Type of terminal	Container		Ro-ro		Liquid bulk	Solid Bulk	Other
Type of equipment	RTG	Straddle carrier	Terminal tractors	AGV	Empty container handlers	Other	
Technology	Fuel cell		Pure electric		Hybrid	Other	
Fuel							



CHE	
Power range	
Fuel storage	
Manufacturer	
Model	
Availability	Commercial Pilot
Price range	
Comments	
Source	

The technologies in this section are divided according to the type of terminal they are intended for (container, ro-ro, liquid bulk, solid bulk, other), and the type of equipment they refer to (RTG, straddle carrier, terminal tractors, AGV, empty container handlers, other). A subsection has also been added to account for the technology (fuel cell, pure electric, hybrid or other).

Several technologies have been found in the market from different manufacturers, and future trends in the form of pilots have been identified, especially with the use of hydrogen as a fuel.

2.2.4 Trucks

This section refers to technological options for drayage trucks connecting the port with its hinterland, and includes any sustainable, low emissions technological options. The fields included in the catalogue are the following:

- Technology: sustainable, low emissions alternative.
- Type: shape of truck.
- Fuel: type of sustainable, green fuel used by the technology.
- Power range: combustion engine/electric engine power range.
- Fuel storage: fuel capacity of the truck.
- Manufacturer: developer of the technology, brand.
- Model: commercial name of the technology.
- Availability: whether it refers to a product already in the market or to a pilot.
- Price range: CAPEX estimated for the technology.
- Comments: any other relevant information, detail or description.



- **Source:** reference providing information about the product, such as web address.

The table below shows the filters used in the catalogue for trucks, including the different options for each subsection:

Table 4: Trucks subsections

TRUCKS		
Technology		
Type	Tractor	Rigid
Fuel		
Power range		
Fuel storage		
Manufacturer		
Model		
Availability	Commercial	Pilot
Price range		
Comments		
Source		

The technologies in this section are divided according to the type of truck they are intended for (tractor or rigid), and the technology and fuel they use.

Several technologies have been found in the market from different manufacturers, and future trends in the form of pilots have been identified, especially with the use of fuel cell technology.

2.2.5 Other mobile vehicles

Other mobile vehicles is related to any other sustainable technological option used for mobile applications in ports (e.g. train, forklifts, etc). The fields included in the catalogue are the following:

- **Technology providers:** developer of the technology, brand.
- **Type:** mobile technology of the project.
- **Availability:** whether it refers to a product already in the market or to a pilot.
- **Price range:** CAPEX estimated for the technology.
- **Comments:** any other relevant information, detail or description.
- **Source:** reference providing information of the product, such as web address.



The table below shows the filters used in the catalogue for other mobile vehicles, including the different options for each subsection:

Table 5: Other mobile vehicles subsections

OTHER MOBILE VEHICLES			
Technology providers			
Type	Locomotive	Vessel	Other
Fuel	Hydrogen	Electric	Other
Availability	Commercial	Pilot	
Price range			
Comments			
Source			

The technologies in this section are divided according to the type of mobile solution they are intended for (locomotive, vessel, other) and the fuel they use (hydrogen, electric, other).

The solutions found in the category are mainly pilot experiences for ships and trains.

2.2.6 Fuel producers

Fuel producers provides sustainable fuel alternatives. The fields included in the catalogue are the following:

- **Manufacturer:** developer of the technology, brand.
- **Fuel:** type of sustainable, green fuel used by the technology.
- **Availability:** whether it refers to a product already in the market or to a pilot.
- **Price range:** CAPEX estimated for the technology.
- **Comments:** any other relevant information, detail or description.
- **Source:** reference providing information about the product, such as web address.

The table below shows the filters used in the catalogue for fuel producers, including the different options for each subsection:



Table 6: Fuel producers subsections

FUEL PRODUCERS				
Manufacturer				
Fuel	HVO	Synthetic	Green ammonia	Other
Availability	Commercial		Pilot	
Price range				
Comments				
Source				

The technologies in this section are divided according to the fuel that is produced (HVO, synthetic, green ammonia, other).

Several technologies have been found in the market from different manufacturers, and future trends in the form of pilots have been identified, especially with the production of green hydrogen fuel.

2.2.7 Fuel production technology

Fuel production technology is related to products that enable on-site production of sustainable and renewable fuels by a port user (e.g. terminal operator). The fields included in the catalogue are the following:

- Type of solution: sustainable, low emissions technology alternatives.
- Fuel: type of sustainable, green fuel used by the technology.
- Capacity: amount the product can produce per day.
- Manufacturer: developer of the technology, and brand.
- Model: commercial name of the technology.
- Availability: whether it refers to a product already in the market or to a pilot.
- Price range: CAPEX estimated for the technology.
- Comments: any other relevant information, detail or description.
- Source: reference providing information about the product, such as web address.

The table below shows the filters used in the catalogue for fuel production technology, including the different options for each subsection:



Table 7: Fuel production technology subsections

FUEL PRODUCTION TECHNOLOGY					
Type of solution	Electrolysers		Biomass thermochemical processes		Other
Fuel	Hydrogen	Green ammonia	Biofuel		Other
Capacity					
Manufacturer					
Model					
Availability	Commercial		Pilot		
Price range					
Comments					
Source					

The main solutions included in this section are related to electrolysers, biomass thermochemical processes, gasifier and other. A subsection has also been added to account for the fuel (hydrogen, green ammonia, biofuel, other).

Several technologies have been found in the market from different manufacturers, particularly with the use of hydrogen as a fuel.

2.2.8 Carbon capture

Carbon capture is related to the technology of capturing and removing CO₂ from the atmosphere. The fields included in the catalogue are the following:

- **Developer:** participants of the project.
- **Description:** any relevant information or detail.
- **Availability:** whether it refers to a product already in the market or to a pilot.
- **Price range:** CAPEX estimated for the technology.
- **Comments:** any other relevant information, detail or description.
- **Source:** reference providing information about the product, such as web address.

The table below shows the filters used in the catalogue for carbon capture, including the different options for each subsection:



Table 8: Carbon capture subsections

CARBON CAPTURE	
Developer	
Description	
Availability	Commercial Pilot
Price range	
Source	

The solutions found in the category are pilot experiences in ports related to the carbon capture and storage.

2.2.9 Electricity production

Electricity production is related to technology used to generate or store renewable sources of electricity. The fields included in the catalogue are the following:

- **Type of solution:** type of renewable energy produced or technology.
- **Manufacturer:** developer of the technology, and brand.
- **Power:** amount of energy that can be generated or stored by the technology.
- **Availability:** whether it refers to a product already in the market or to a pilot.
- **Price range:** CAPEX estimated for the technology.
- **Comments:** any other relevant information, detail or description.
- **Source:** reference providing information of the product, such as web address.

Table 9: Electricity production subsections

ELECTRICITY PRODUCTION				
Type of solution	Solar	Wind	Storage	Other
Manufacturer				
Power				
Availability	Commercial	Pilot		
Price range				
Comments				
Source				

The main solutions included in this section are related to solar, wind, storage and other.



Several technologies have been found in the market from different manufacturers, and future trends in the form of pilots have been identified, such as offshore solar technology for ports.

2.2.10 Energy efficiency

Energy efficiency encompass any other relevant sustainable technology options for the maritime sector that help reduce energy consumption and increase efficiency. The fields included in the catalogue are the following:

- Technology providers: manufacturer, participants of the technology.
- Type: area of action of the project.
- Availability: whether it refers to a product already in the market or to a pilot.
- Price range: CAPEX estimated for the technology.
- Comments: any other relevant information, detail or description.
- Source: reference providing information about the product, such as web address.

The table below shows the filters used in the catalogue for energy efficiency, including the different options for each subsection:

Table 10: Energy efficiency subsections

ENERGY EFFICIENCY					
Technology providers					
Type	Buildings	Green planting	Industrial Symbiosis	Synchromodality	Other
Availability	Commercial			Pilot	
Price range					
Comments					
Source					

The main solutions included in this section are related to buildings, green planting, industrial symbiosis, synchromodality and other.

Several technologies have been found in the market from different manufacturers, and future trends in the form of pilots have been identified in terms of applications that aim to reduce fuel consumption and optimize runtime, and other innovative solutions.



3. Final remarks

The Sustainability Educational Programme for Greener Fuels and Energy on Ports (SEANERGY) project has aimed to support the transition of ports towards zero-emission, green energy hubs that use hydrogen, integrated electricity systems, and other low-carbon fuels.

This report has provided an overview of the technologies available to bring in sustainable best practices and decarbonize maritime (and port) sector(s), as well as the guidelines and methodology used to structure the catalogue of available technologies. The report discussed the characteristics of each section pertaining to the different equipment used within the sector.

The catalogue contains over 90 different solutions for vessels' electricity, ICE and fuel cell, CHE, trucks, other mobile vehicles, fuel producers, fuel production technology, carbon capture, and energy efficiency, with each section pertaining to the different equipment used within the sector. The catalogue is structured into ten subsections that encompass the main equipment used within the maritime sector, and filters have been placed within each subsection to allow for a quicker and more efficient search of the desired technology.

Mapping the technologies allows companies within the maritime sector to refer to it when building their decarbonization strategies and defining future investments. This can expand the knowledge and use of low-carbon technologies and reduce decision times, encouraging the use of innovative sustainable alternatives.

It is important to note that some solutions might not work for all ports depending on their specific characteristics. On the other hand, some technologies might be suitable for a wide range of companies. Therefore, it is important that ports and companies within the maritime sector analyze their concrete needs and how the technology would work with their equipment and infrastructure before implementing it.

The catalogue of technologies will be integrated on the SEANERGY project webpage in a specific section organized in the ten subsections that encompass the main equipment used within the maritime sector. Filters within each subsection will be placed to allow for a quicker and more efficient search of the desired technology.



Finally, it is worth mentioning that technologies evolve rapidly, and the field of decarbonization is advancing continuously as efforts to reduce the impact of climate change are set in place in all sectors. To maintain the catalogue's usefulness, it will be updated regularly, at least during the project's duration.



Annex I. Technologies

The tables below detail the technologies included in the Catalogue and their characteristics.

Table 11: Vessels' electricity technologies

#	Type of solution	Type of vessel	Manufacturer	Model	Availability	Price range	Comments	Source
1	Cable management	Other/all	Igus	Mobile SPO	Commercial	-	Shore power connections used to be installed permanently in sockets set into the quay	https://www.igus.eu/info/industries-echain-reel
2	Electronics	Other/all	Volterion	smartSTACK	Commercial	-	Flow-Battery-Stacks consist of multiple electrochemical cells which are stacked together	https://www.volterion.com/en/stacks-en-neu/
3	Electronics	Other/all	WATTALPS	Battery model	Commercial	-	Patented immersion cooling	https://www.wattalps.com/wp-content/uploads/2021/11/FTWA0003-UK.pdf
4	Electronics	Other/all	Zparq	OEM motor	Pilot	-	High power, high efficiency submerged electric motor system for propeller-driven watercraft	https://zparq.se/#products
5	Electronics	Other/all	Skeleton	SkelCap supercapacitor	Commercial	-	Ultracapacitors to store energy during heave-up movements, and then discharge the energy when needed	https://1188159.fs1.hubspotusercontent-na1.net/hubfs/1188159/02-DS-220909-SKELCAP-CELLS-1D-1.pdf
6	Electronics	Other/all	Elestor	Bromine flow battery	Pilot	-	Low-cost electricity storage systems with an extensive lifespan, based on hydrogen bromine flow battery	https://www.elestor.nl/
7	Batteries	Other/all	CORVUS	BOB Container	Commercial	-	Standardized modular battery room solution available in 10-foot and 20-foot ISO high-cube container sizes	https://corvusenergy.com/products/energy-storage-solutions/corvus-bob-container/
8	Electronics	Containerships	Igus	IMSPO	Commercial	-	Self-propelled and can be positioned anywhere along the berth	https://www.igus.eu/info/industries-mobile-shore-power-outlet-long-travel
9	Batteries	Other/all	Shift	Pwr-Swäp	Commercial	-	"Pay-As-You-Go" service delivering clean and reliable renewable energy with no risk	https://shift-cleanenergy.com/pwr-swap/
10	Other	Other/all	Generic	-	Commercial	-	-	-



Table 12: ICE fuel cell technologies

#	Type of solution	Subclass	Application	Fuel	Power range (kW)	Manufacturer	Model	Availability	Price range	Comments	Source
1	Fuel cell	Fuel cells - PEM	Domestic vessels	Hydrogen	200	Ballard	FCWAVE	Commercial	-	World's first DNV Type Approved Fuel Cell for marine applications	https://www.ballard.com/docs/default-source/spec-sheets/fcwavetm-specification-sheet.pdf?sfvrsn=6e44dd80_12
2	Internal combustion engine (ICE)	Engine - 4 strokes	Domestic vessels	Hydrogen	2700	Anglo Belgian Corporation	16DZD BEHYDRO	Commercial	-	Operating on 85% hydrogen gas and 15% conventional fuel	https://www.abc-engines.com/en/markets/marine-propulsion/product/16dzd-behydro
3	Fuel cell	Fuel cells - PEM	Domestic vessels	Hydrogen	100	NedStack	MT-FCPI-100	Commercial	-	Zero-emission shipping enabler	https://nedstack.com/en/pemgen-solutions/maritime-power-installations/pemgen-mt-fcpi-100
4	Fuel cell	Fuel cells - PEM	Domestic vessels	Hydrogen	500	NedStack	MT-FCPI-500	Commercial	-	Compact and robust LT-PEM power supply option for inland waterways or in short-sea domain	https://nedstack.com/en/pemgen-solutions/maritime-power-installations/pemgen-mt-fcpi-500
5	Fuel cell	Fuel cells - PEM	Domestic vessels	Hydrogen	200	PowerCell	Marine System 200	Commercial	-	Designed to accomplish compact integration together with high power output	https://powercellgroup.com/product/marine-system-200/
6	Fuel cell	Fuel cells - PEM	Domestic vessels	Hydrogen	400	TECO 2030	FCM 400	Pilot	-	Compact system size (less than 2/3 of a comparable diesel genset), which simplifies retrofitting	https://teco2030.no/solutions/teco-marine-fuel-cell/
7	Fuel cell	Fuel cells - SOFC	Domestic vessels	Flex (Ammonia, Methanol, etc.)	2000	Alma Clean Power	-	Pilot	-	Clean power systems for ocean industries and other remotely located power needs	https://almacleanpower.com/what-we-do



#	Type of solution	Subclass	Application	Fuel	Power range (kW)	Manufacturer	Model	Availability	Price range	Comments	Source
8	Fuel cell	Fuel cells - PEM	Domestic vessels	Hydrogen	5 - 1.2 MW	Argo-Anleg GmbH	-	Commercial	-	-	https://www.argo-anleg.de/
9	Fuel cell	Fuel cells - PEM	Trucks	Hydrogen	400 kW - 1.2 MW	Argo-Anleg GmbH	-	Commercial	-	-	https://www.argo-anleg.de/
10	Fuel cell	Fuel cells - PEM	Locomotives	Hydrogen	400 kW - 1.2 MW	Reuschling Lokomotiven Fabrik	-	Pilot	-	-	https://www.argo-anleg.de/
11	Fuel cell	Fuel cells - PEM	Cargo Handling Equipment	Hydrogen	35 kW - 1.2 MW	Argo-Anleg GmbH	-	Pilot	-	-	https://www.argo-anleg.de/
12	Fuel cell	Fuel cells - PEM	Domestic vessels	hydrogen	20 kW - 100 kW	Proton Motor	HyShip	Commercial	-	Combined fuel cell technology with a battery system plus metal hydride H2 storage	https://www.proton-motor.de/en/products/fuel-cell-systems/
13	Fuel cell	Fuel cells - PEM	Trucks	Hydrogen	40 - 150 kW	Ballard	Fcmove	Commercial	-	Designed to address different commercial fuel cell vehicle types and duty cycles	https://www.ballard.com/fuel-cell-solutions/fuel-cell-power-products/motive-modules
14	Fuel cell	Fuel cells - PEM	Domestic vessels	Hydrogen	70	EODEV	REXH2	Commercial	-	Marinized hydrogen power generator built around a Toyota PEM fuel cell	https://eo-dev.imgix.net/documents/REXH2_fiche_produit_EN_web.pdf
15	Internal combustion engine (ICE)	Engine - 4 strokes	Domestic vessels	Methanol	-	MAN	ME-LGIM series	Commercial	-	Methanol achieved by blending increasing amounts of green or blue methanol with grey methanol	https://www.man-es.com/docs/default-source/document-sync/the-methanol-fuelled-man-b-w-lgim-engine-eng.pdf?sfvrsn=36b925d2_2



#	Type of solution	Subclass	Application	Fuel	Power range (kW)	Manufacturer	Model	Availability	Price range	Comments	Source
16	Battery	Fuel cells - Other	Cargo Handling Equipment	Electric		Kalmar	ChargePod	Commercial	-	Suitable for charging batteries used in Kalmar light and medium electric forklift trucks	https://www.kalmar.es/equipment-and-services/carretillas-elevadoras/kalmar-chargepod/
17	Other	Fuel cells - Other	Cargo Handling Equipment	Electric	-	Taylor Machine Works, Inc., Rocsys	-	Pilot	-	The Rocsys charging system works with any high-power DC charging station that uses a CCS-1 charging connector, thus allowing autonomous charging with existing charging equipment.	https://www.worldcargonews.com/news/autonomous-charging-for-taylor-electric-top-picks-71056
19	Battery	Fuel cells - Other	Cargo Handling Equipment	Electric	-	CalBatt	Smart charging	Commercial	1400-2000€/each	Replacing of existing electric forklift chargers with dynamic models	https://www.calbatt.com/shared-files/5686/?CalBatt-Smart-Charging-Technology-EN.pdf
18	Other	Fuel cells - Other	Other	-	-	Generic	-	Commercial	-	-	-



Table 13: CHE technologies

#	Type of terminal	Type of equipment	Technology	Fuel	Model	Availability	Price range	Comments	Source
1	Container	RTG	Pure electric	Electric	Kalmar Zero-Emission RTGs	Commercial	-	Safe working load SWL 41 t	https://www.kalmarglobal.com/equipment-services/rtg-cranes/zero-emission/
2	Container	Straddle carrier	Hybrid	Diesel/Electric	Kalmar FastCharge™ Straddle Carrier	Commercial	-	Lifting capacity 40/50/60 t	https://www.kalmarglobal.com/equipment-services/straddle-carriers/fastcharge-straddle/#
3	Container	Other	Pure electric	Electric	Kalmar Electric RMG	Commercial	-	Safe working load SWL 41 t	https://www.kalmarglobal.com/equipment-services/rail-mounted-gantry-cranes/
4	Other	Other	Fuel cell	Hydrogen	Fuel Cell H2	Commercial	-	Energy generator	https://www.gaussin.com/h2-powered-generator
5	Container	RTG	Hybrid	Diesel/Electric	ARTG System Version 2.0	Commercial	-	Total load 50,8t	https://www.konecranes.com/sites/default/files/2021-01/Hybrid%20Retrofit_2020%20%2802%29.pdf
6	Container	RTG	Pure electric	Electric	B-RTG	Commercial	-	Battery packs available: liquid-cooled with 4 or 8 hours	https://www.konecranes.com/sites/default/files/2022-08/Battery%20RTG_Tech%20Spec_EN.pdf
7	Container	Straddle carrier	Hybrid	Diesel/Electric	Battery Konecranes Noell Straddle Carrier	Commercial	-	6 battery modules, for total 4-hr capacity	https://www.konecranes.com/sites/default/files/2022-06/Battery_Konecranes_Noell_Straddle_Carrier_EN.pdf
8	Container	Other	Hybrid	Diesel/Electric	Generation 6 Mobile Harbor Cranes	Commercial	-	Maximum lifting capacity of 200 t	https://www.konecranes.com/sites/default/files/2022-04/KC_GEN6_brochure_web_EN_FINAL_220222.pdf
9	Container	Straddle carrier	Hybrid	Diesel/Electric	SPRINTER CARRIERS	Commercial	-	Maximum lifting capacity 60 t	https://www.konecranes.com/sites/default/files/download/kc-spc-en-01.pdf
10	Container	Terminal tractors	Pure electric	Electric	Kalmar ERG420-450	Commercial	-	Lifting capacities up to 45 tonnes	https://www.kalmarglobal.com/equipment-services/reachstackers/electric-reachstacker/
11	Container	Terminal tractors	Pure electric	Electric	YT203-EV terminal tractor	Commercial	-	Vehicles can use any charger with a	https://www.terbergspecialvehicles.com/en/development/electric/



#	Type of terminal	Type of equipment	Technology	Fuel	Model	Availability	Price range	Comments	Source
								CCS2.0 connection	
12	Container	Terminal tractors	Fuel cell	Hydrogen	Concept hydrogen-powered terminal tractor	Pilot	-	Successful test period in Antwerp	https://www.terbergspecialvehicles.com/en/development/hydrogen/
13	Container	Terminal tractors	Pure electric	Electric	APM 75T FULL ELEC (BEV)	Commercial	-	Traction motor 189kW	https://www.gaussin.com/apm
14	Container	Terminal tractors	Fuel cell	Hydrogen	APM 75T FUEL CELL/HYDROGEN (FCEV)	Commercial	-	Batteries 35kwh	https://www.gaussin.com/apm
15	Container	Terminal tractors	Pure electric	Electric	APM 75T Autonomous FULL ELEC	Commercial	-	Traction motor 189kW	https://www.gaussin.com/apm-autonomous
16	Container	Terminal tractors	Pure electric	Hydrogen	APM 75T Autonomous Fuel cell/electric	Commercial	-	Traction motor 189kW	https://www.gaussin.com/apm-autonomous
17	Container	Terminal tractors	Pure electric	Electric	AIV REVOLUTION	Commercial	-	Traction motor 4*76kW permanent magnet	https://www.gaussin.com/aiv
18	Container	Terminal tractors	Fuel cell	Hydrogen	AIV REVOLUTION	Commercial	-	Traction motor 4*76kW permanent magnet	https://www.gaussin.com/aiv
19	Container	Terminal tractors	Pure electric	Electric	TT	Commercial	-	Payload 70t	https://www.gaussin.com/tt
20	Container	Terminal tractors	Pure electric	Electric	T 230e	Commercial	-	Lifting capacity up to 32 t	https://www.mafi.de/en/products/tractors/electric-terminal-tractor-t-230e/
21	Container	Empty container handlers	Fuel cell	Hydrogen	Nuvera fuel cell	Pilot	-	First-ever empty container	https://www.hyster.com/en-us/north-america/why-hyster/press-releases/2022/hyster-to-provide-hamburger-hafen-und-logistik-ag-with-hydrogen-fuel/



#	Type of terminal	Type of equipment	Technology	Fuel	Model	Availability	Price range	Comments	Source
								handler powered by fuel cell technology	
22	Container	Other	Pure electric	Electric	ZLC 906 EV	Pilot	-	Top Handler	https://www.taylorforklifts.com/press-release/Electric-ZLC-Loaded-Container-Handler-press-release.pdf
23	Container	Terminal tractors	Pure electric	Electric	8Y	Commercial	-	Clean and quiet, with fewer moving parts than carbon-burning trucks	https://en.byd.com/truck/terminal-tractor/
24	Container	Reach Stacker	Fuel cell	Hydrogen		Pilot	-	H2Ports project - Nuver Fuel Cell	https://h2ports.eu/pilots/
25	Ro-ro	Terminal tractors	Fuel cell	Hydrogen		Pilot	-	H2Ports project - Ballard Fuel Cell	https://h2ports.eu/pilots/
26	Container	RTG	Hybrid	Diesel/Electric	EcoCrane Battery Hybrid System	Commercial	-	60-70% reduction in fuel consumption as compared with traditional RTGs	https://mi-jack.com/ecocrane-battery-hybrid-system/
27	Other	Other	Pure electric	Electric	Electric Lazer Series	Commercial	-	Forklift	https://www.hoistlift.com/lazer-series-15-000-40-000-lbs-/
28	Container	Other	Pure electric	Electric	Generic forklift	Commercial	23000-42000€	-	https://www.sip.net/2022-new-forklift-price-how-much-you-can-expect-to-pay/
29	Container	RTG	Pure electric	Electric	Generic	Commercial	2,3M €	-	https://www.porttechnology.org/wp-content/uploads/2020/01/AECOM-3.pdf



#	Type of terminal	Type of equipment	Technology	Fuel	Model	Availability	Price range	Comments	Source
30	Container	RTG	Hybrid	Diesel/Electric	Generic	Commercial	2,15M€	-	https://www.porttechnology.org/wp-content/uploads/2020/01/AECOM-3.pdf
31	Container	Terminal tractors	Pure electric	Electric	Generic	Commercial	143.000,00 €	-	https://soymotor.com/coches/noticias/tesla-semi-932747
32	Container	Terminal tractors	Fuel cell	Hydrogen	Generic	Commercial	200000-600000 €	-	https://theicct.org/publication/purchase-cost-ze-trucks-feb22/



Table 14: Truck technologies

#	Technology	Type	Fuel	Power range (hp)	Fuel Storage	Manufacturer	Model	Availability	Price range	Comments	Source
1	Hybrid	Tractor	Diesel	220 - 360	-	SCANIA	HEV/PHEV	Commercial	-	Up to 42 tonnes	https://www.scania.com/group/en/home/products-and-services/trucks/plug-in-hybrid-truck.html
2	Pure Electric	Tractor	Electric	645	773 kWh	Nikola/IVECO	TRE	Commercial	-	Up to 42 tonnes	https://nikolamotor.com/tre-bev
3	Fuel Cell	Tractor	Hydrogen	-	-	Volvo Truck		Pilot	-	Up to 65	https://www.volvotrucks.es/es-es/news/press-releases/2022/jun/volvo-trucks-showcases-new-zero-emissions-truck.html
4	Pure Electric	Tractor	Electric	-	-	Volvo Trucks		Commercial	-	Finding the right flows and transport patterns, close to easily accessible charging infrastructure	https://www.worldcargonews.com/news/electric-dravage-trucks-start-calling-at-gothenburg-70812
5	Pure Electric	Tractor	Electric	560	12 kWh	Toyota/Kenworth	T680 FCEV	Commercial	-	Range of about 300+ miles when fully loaded to 82,000 lbs. with no downtime between shifts for charging	https://www.kenworth.com/about-us/news/toyota-kenworth-prove-fuel-cell-electric-truck-capabilities-with-successful-completion-of-truck-operations-for-zanzeff-project/
6	Pure Electric	Tractor	Electric	-	-	TransPower	ElecTruck	Commercial	-	Technological innovations in energy storage, power conversion, and vehicle control	https://transpowerusa.com/
7	Pure Electric	Tractor	Electric	-	-	Orange EV	e-TRIEVER	Commercial	-	Batteries can charge fully in as little as 2 hours	https://orangeev.com/electric-trucks/



#	Technology	Type	Fuel	Power range (hp)	Fuel Storage	Manufacturer	Model	Availability	Price range	Comments	Source
8	Pure Electric	Tractor	Electric	-	-	Effenco	Electric Powertrain	Pilot	-	Electrification of heavy-duty vocational trucks	https://www.effenco.com/100-electric/
9	Pure Electric	Tractor	Electric	666	540 kWh	Volvo	Volvo FH Electric	Commercial	-	Range of 300 km	https://puertosymas.com/un-camion-100-electrico-de-grupo-torres-opera-ya-en-el-puerto-de-valencia/
10	Fuel Cell	Tractor	Hydrogen	-	-	Hyzon	-	Commercial	-	Deployment of the first hydrogen-powered 40-ton vehicle in cross-border traffic between Germany and Belgium	https://www.dbschenker.com/de-en/about/press/corporate-news/hylane-837236
11	Pure Electric	Tractor	Electric	-	-	Generic	Generic	Commercial	143.000,00 €	-	https://soymotor.com/coches/noticias/tesla-semi-932747
12	Fuel Cell	Tractor	Hydrogen	-	-	Generic	Generic	Commercial	200.000-600.000 €	-	https://theicct.org/publication/purchase-cost-ze-trucks-feb22/



Table 15: Other mobile vehicles technologies

#	Technology providers	Type	Fuel	Availability	Price range	Comments	Source
1	Reuschling Lokomotivenfabrik	Locomotive	Hydrogen	Pilot	-	Shunting locomotive transformation of diesel to electrical hydrogen solution	-
2	Norled	Vessel	Electric	Pilot	-	World's first electric-powered car ferry, generates zero emissions and minimum sound	https://corvusenergy.com/projects/mf-ampere/
3	TU Berlin	Vessel	Hydrogen	Pilot	-	Hydrogen inland barge	https://www.est-floattech.com/elektra-first-hydrogen-canal-tug/
4	Generic	Other	Other	Commercial	-	-	-



Table 16: Fuel producers technologies

#	Manufacturer	Fuel	Availability	Price range	Comments	Source
1	Neste Oil	HVO	Commercial	-	Cooked Oil	https://www.neste.com/products/all-products/renewable-road-transport/neste-my-renewable-diesel
2	Repsol	Synthetic	Pilot	-	CCS and green H2 from electrolysis	https://www.repsol.com/en/energy-and-innovation/technology-lab/new-mobility/net-zero-emissions-fuels/index.cshhtml?gclid=EAlaIQobChMI1vmO8dO8_AIVCtXRCh3lvARFEAYASAAEgLvD_BwE
3	Fertiberia	Green Ammonia	Commercial	-	Initially for fertilisers production	https://www.iberdrola.com/press-room/news/detail/iberdrola-fertiberia-launch-largest-plant-producing-green-hydrogen-industrial-europe
4	Generic	Other	Commercial	-	-	-



Table 17: Fuel production technologies

#	Type of solution	Fuel	Capacity (t/day or kWh/day)	Manufacturer	Model	Availability	Price range	Comments	Source
1	Electrolysers	Hydrogen	0.53 - 1.05	Nel	M SERIES CONTAINERIZED	Commercial	-	Easy outdoor installations	https://nelhydrogen.com/product/m-series-containerized/
2	Electrolysers	Hydrogen	4.34	ThyssenKrupp	10 MW module	Commercial	-	Modular, skid mounted design	https://ucpcdn.thyssenkrupp.com/legacy/UCPthyssenkruppBAISUhdChlorineEngineers/assets/files/products/water_electrolysis/tk_19_0820_hydrogen_broschure_2019_03.pdf
3	Electrolysers	Hydrogen	0 - 9.5	Argo Anleg		Commercial	-		www.argo-anleg.de
4	Electrolysers	Hydrogen	0.5 - 10	Siemens	Silyzer	Commercial	-	Easy to operate and requires low maintenance	https://www.siemens-energy.com/global/en/offerings/renewable-energy/hydrogen-solutions.html
5	Electrolysers	Hydrogen	0.5 - 10	John Cockeril	DQ500 & DQ1000	Commercial	-	Designed for friendly operation maintenance, fast & easier installation / commissioning operations	https://h2.johncockerill.com/en/products/electrolysers/
6	Electrolysers	Hydrogen	0.1 - 2	ITM Power	PEM	Commercial	-	The hydrogen produced can be stored as a gas or liquid and can be released into the gas grid, be used as clean vehicle fuel, or in a host of industrial processes	https://itm-power.com/how-it-works/pem
7	Electrolysers	Hydrogen	0.5 - 4	Sunfire	HyLink SOEC	Commercial	-	The electrolyzer provides renewable hydrogen as an essential feedstock for decarbonizing industries	https://www.sunfire.de/files/sunfire/images/content/Sunfire.de%20(neu)/Sunfire-Factsheet-HyLink-SOEC-20210303.pdf
8	Other	Other	-	Generic	-	Commercial	-	-	-



Table 18: Carbon capture technologies

#	Developer	Description	Availability	Price range	Source
1	Air Liquide, BASF, Borealis, ExxonMobil, INEOS, TotalEnergies, Fluxys, and Port of Antwerp	CCUS, which involves offshore storage and the future re-use of CO ₂ as a raw material for the chemicals industry	Pilot	-	https://www.porttechnology.org/news/port-of-antwerps-carbon-capture-project-reaches-new-milestone/
2	Göteborg Energi, Nordion Energi, Preem, St1, Renova, and Gothenburg Port Authority	Joint infrastructure for the transport of liquefied carbon dioxide extracted using CCS technology	Pilot	-	https://www.portofgothenburg.com/the-project-of-the-port/cinfracap/
3	Generic	-	Pilot	-	-



Table 19: Electricity production technologies

#	Type of solution	Manufacturer	Power	Availability	Price range	Comments	Source
1	Solar	Tesla	400 W	Commercial	-	Dimensions 74.4" x 41.2" x 1.57" (including frame)	https://www.tesla.com/solarpanels
2	Solar	Electromur	990 MWh/year	Pilot	-	The project is expected to make Gandia the first European port to be energy self-sufficient	https://www.offshore-energy.biz/spains-gandia-to-house-europes-1st-energy-self-sufficient-port/
3	Wind	Vestas	15 MW	Commercial	850000 €/MW	Swept area of 43,742 m ² and a capacity factor of over 60% from the 115.5m blades	https://www.vestas.com/en/products/offshore/V236-15MW
4	Solar	Victron Energy	20-360 W	Commercial	2000 €/kWp	Exceptional low-light performance and high sensitivity to light across the entire solar spectrum	https://www.victronenergy.com.es/upload/documents/Datasheet-BlueSolar-Monocrystalline-Panels-ES.pdf
5	Solar	Jinko	635 W	Commercial	1850 €/kWp	23,23% efficiency, 85% max. bifaciality	https://www.jinkosolar.com/en/site/tigerneo#s1
6	Storage	Siemens Energy	-	Commercial	250-500€/kWh	BlueVault™ Energy Storage Solutions aimed for vessel energy storage	https://www.siemens-energy.com/global/en/offerings/storage-solutions/battery-energy-storage/bluevault.html
7	Storage	IHE	-	Pilot	-	Hydropower pump storage from tidal energy in inland lagoons. Being developed at IHE, lab-scale.	https://www.un-ihe.org/
8	Other	EcoWave Power	-	Commercial	-	Floater draw energy from incoming waves by converting the rising and falling motion of the waves into a clean energy generation process	https://www.ecowavepower.com/
9	Solar	Generic	500W	Commercial	2000€/kWp	-	-
10	Wind	Generic	1000W	Commercial	1000€/kW	-	-
11	Storage	Generic	-	Commercial	325€/kWh	-	https://www.nrel.gov/docs/fy21osti/79236.pdf



Table 20: Energy efficiency technologies

#	Technology providers	Type	Availability	Price range	Comments	Source
1	Hysilabs	Other-please add	Pilot	-	Emission-free liquid carrier (HydroSil) which allows transport of hydrogen safely by ships and road transport	https://www.hysilabs.com/technology
2	Enappgy	Buildings	Commercial	-	Network of sensors that enable remote monitoring of machinery to optimise delivery routes and save energy by clustering spaces	https://www.enappgy.com/en/oplossing/smart-energy/
3	Navlandis	Other-please add	Pilot	-	Foldable shipping containers that occupy 75% less space than traditional containers, lowering transport costs for empty containers	https://navlandis.com/zbox/
4	Total Terminals International, Southern California Edison, ChargePoint, Kalmar/TransPower, International Brotherhood of Electrical Workers, Electric Vehicle Infrastructure Training Program, South Coast Air Quality Management District	Other-please add	Pilot	-	Design, install, and deploy electrical charging infrastructure, including electrical conduit, wires, switchboards, transformers, and switchgears, to support battery-electric yard tractors and forklifts	https://sustainableworldports.org/wp-content/uploads/CEC-PAVEprojectFactSheet_8_10_18.pdf
5	CE-CERT	Other-please add	Pilot	-	Application which uses traffic signal timing information to optimize acceleration and deceleration of trucks.	https://www.cert.ucr.edu/transportation-systems-vehicle-infrastructure-interaction/sustainable-freight
6	Effenco	Other-please add	Pilot	-	Effenco Active StopStart technology's aim is to reduce the engine runtime and, as a result, reduce fuel consumption	https://sustainableworldports.org/wp-content/uploads/Effenco-performance-review-Centerm-20181121.pdf
7	Ingelia	Other-please add	Commercial	-	Hydrothermal carbonisation of organic waste/sludge to produce solid fuel	https://ingelia.com/?lang=en
8	Energia Europa	Buildings	Commercial	-	The E-Power is based on an innovative and patented technology that	https://www.energia-europa.com/en/e-power/



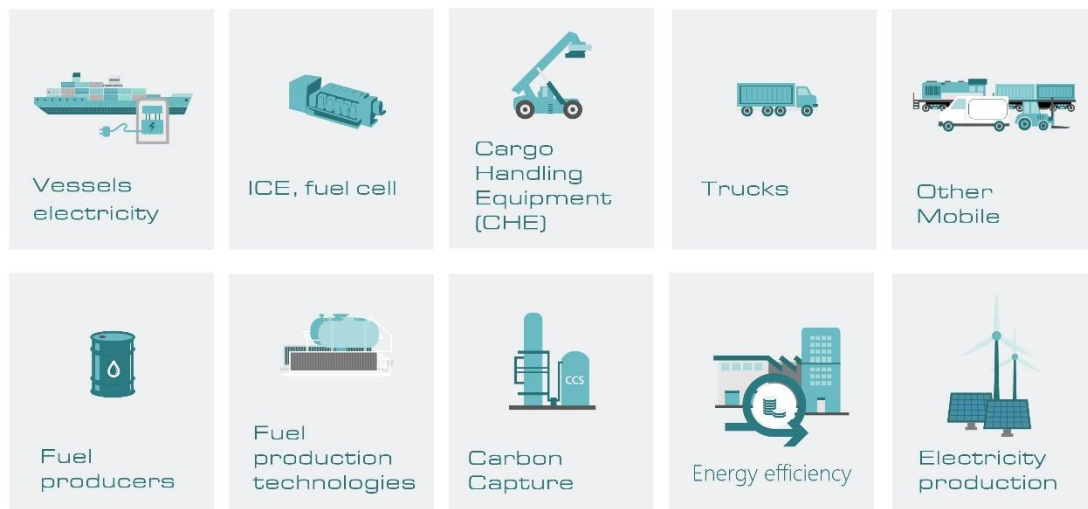
#	Technology providers	Type	Availability	Price range	Comments	Source
					generates energy efficiency improving the quality of energy	
9	Bable	Other-please add	Commercial	-	Automated data analytics supporting systematic planning for reducing shipping-related and port-related pollution emissions and port carbon footprints	https://www.bable-smartcities.eu/fr/home.html
10	Generic	Other-please add	Commercial	-	-	-



Annex II. Website

As previously mentioned, the catalogue of technologies will be included on the SEANERGY project's website. A specific section will be dedicated for the catalogue where users can find the ten solutions used to classify the different technologies, as shown in the image below:

Figure 1: SEANERGY website catalogue interface





Once a solution is selected, a new interface will show up with filters, allowing users to select different characteristics to obtain the technologies, as exemplified in the image below:

Figure 2: Sample of vessels' electricity section

Vessels electricity

Type of solutions ▼

Type of vessels ▼

<p>Manufacturer: Volterion</p> <p>Model: Mobile SPD</p> <p>Availability: Commercial</p> <p>Comments: Shore power connections used to be installed permanently in sockets set into the quay.</p>	 <p style="font-size: 8px; margin-top: 5px;">Source: https://www.igss.eu/info/industries-ockan-ool</p>	<p>Manufacturer: alterion</p> <p>Model: mertSTACK</p> <p>Availability: Commercial</p> <p>Comments: Flow-Battery-Stacks that consist of multiple electrochemical cells which are stacked together.</p>	 <p style="font-size: 8px; margin-top: 5px;">Source: https://www.volterion.com/en/stacks-ep-enc/</p>
<p>Manufacturer: WATTALPS</p> <p>Model: Battery model</p> <p>Availability: Commercial</p> <p>Comments: Patented immersion cooling.</p>	 <p style="font-size: 8px; margin-top: 5px;">Source: https://www.wattalps.com/wp-content/uploads/2021/11/TRA8003-UK.pdf</p>	<p>Manufacturer: Zparaq</p> <p>Model: OEM motor</p> <p>Availability: pilot</p> <p>Comments: High power, high efficiency submerged electric motor system for propeller-driven watercraft.</p>	 <p style="font-size: 8px; margin-top: 5px;">Source: https://zparaq.co.uk/products</p>