Summary assessment of the status of floating powerplants

CE Delft

Committed to the Environment

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Content

Summary

Floating powerplants are ships or barges intended to generate electricity in coastal areas where the on-land generation capacity is insufficient to meet demand. The number of floating powerplants has been increasing in the past decades. Most floating powerplants run on fossil fuel and generate emissions into the air, create noise, and discharge emissions into the water which affects the local environment, air and water quality, and the climate. This report takes an in-depth look at floating powerplants and analyses the circumstances under which they are likely to present a cause for environmental concern.

There are two main types of floating powerplants: self-propelled power*ships*, which are often converted bulk carriers on which a powerplant has been installed, and non-propelled power*barges*, which are generally purpose-built floating structures hosting a powerplant. This report has identified 24 powerships, 69 powerbarges and 2 nuclear floating powerplants (mostly barges). The capacity of floating powerplants generally ranges from around 30 MWe to around 500 MWe, with some smaller and some larger exceptions. Powerships have a median capacity of 125 MWe, which is somewhat larger than the capacity of powerbarges (median 70 MWe). Most floating powerplants run on fossil fuels. Fuel oil used to be the main fuel, but an increasing number of floating powerplants have dual fuel generators or run exclusively on LNG. The fuel is sometimes stored on board but more often stored ashore or in a floating storage unit. The total power generation capacity of all fossil fueled floating power stations amounts to a little less than 10 GW, which is roughly 0.1% of global electricity capacity.

Floating powerplants are deployed in different types of markets:
- As a long-term power generation installation (for several years and sometimes even decades), often in developing countries where:
  - there is no powerplant on land to supply the required electricity; or
  - it is difficult to build a powerplant on land, such as on islands and in remote areas; or
  - ownership and payment structures make it financially attractive to deploy a floating powerplant rather than invest in on-land capacity.
- As a temporary replacement for a powerplant on land that is under construction or temporarily out of order.
- In emergency situations when electricity is temporarily not available on land due to a (natural) disaster.
- To supply electricity to ships at berth so that they can switch off their generators. This can result in a reduction of emissions in the ports if the powerbarge is fueled by LNG and the ship’s generators run on fuel oil while at berth.

Most powerships are deployed in Africa, Asia and the Caribbean. The market is growing, with one of the major suppliers having an orderbook which would increase the global power generation capacity of floating powerplants by 50% in the next few years.

Powerships have the following impact on the environment during normal operations:
- greenhouse gas (GHG) emissions;
- emissions of other pollutants to air (e.g. nitrous oxides, sulfur oxides, volatile organic compounds, and particulate matter);
- ambient and underwater noise; and
- discharge, mainly of cooling water.

The GHG emissions per unit of electricity from floating powerplants are generally no higher than the GHG emissions of a comparable on-land power station because most floating powerplants have modern generation equipment. Many also run on LNG, which releases fewer criteria pollutants than conventional fuels, and can have lower greenhouse gas emissions if methane leakage rates are low across the fuel supply chain. However, the majority of floating powerplants run on fossil fuel and this carries the risk of displacing renewable electricity or creating a lock-in to a fossil fuel-based power system.

The emissions of air pollutants depend on the type of fuel and the aftertreatment of exhaust gases. Aftertreatment is typically only used when required by the regulator. Compared with powerstations onshore, and provided that both installations are kept to the same standards, emissions of floating powerplants would be similar to emissions of on-land fossil fueled powerplants, but higher than renewable electricity.

The noise generated by a floating powerplant is not necessarily higher in volume than noise generated by other power generation sources, but it could have a higher impact on human health if the powership is moored near residential areas. The noise impact on the marine environment will almost always be higher.

The discharge of cooling water may cause thermal pollution, which could be harmful to sensitive species. In general, cooling water should not contain pollutants. Oily water is usually treated in an oil water separator.

In addition to the impact of floating powerplants during normal operations, incidents and accidents have a different risk profile than on-shore powerplants because of the potential impact on the marine environment. Fuel spills, for example, could pollute the water and the sediment.

An assessment of whether the deployment of a floating powerplant will have a larger or smaller impact on the environment than an alternative land-based powerplant will depend on the relevant local source of alternative power generation. This report has developed a checklist to help with the assessment, and to qualitatively assess the environmental and human health risk of a floating powerplant - see Table 1.

Table 1 - Criteria checklist to qualitatively assess the environmental and human health risks of a floating powerplant project

#	Checklist item	Description
Greenhouse gas emissions (CO_2-eq.) and local emissions (SO_x, NO_x, PM) to the air		
1	World Bank Standard	The World Bank Standard is used as the minimum requirement for floating powerplants, whereby the Standard applicable to onshore projects (in this case powerplants on land) also apply to offshore projects (in this case floating powerplants). The World Bank Environmental and Social Standard (ESS) #3 'Resource Efficiency and Pollution Prevention and Management' ***stipulates*** requirements to address resource efficiency, and pollution prevention and management throughout the project life-cycle. The World Bank Group Environmental, Health, and Safety Guidelines contain the performance levels and measures that are normally acceptable to the World Bank Group. These performance levels and measures are considered to be achievable in new facilities at reasonable costs by existing technology.

#	Checklist item	Description
2	MARPOL	The International Maritime Organization (IMO) is a specialized agency of the United Nations that is responsible for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships. Self-propelled floating powerplants from a certain gross tonnage (depending on the regulations but often from 400 GT) need to comply with the IMO conventions. MARPOL is the international Convention of the IMO for the prevention of pollution of the marine environment by ships from operational or accidental causes. MARPOL Annex VI covers the prevention of air pollution from ships and set limits on the NO_x, SO_x and PM emissions. Although MARPOL does not officially apply to non-self-propelled powerbarges, we propose that the same requirements are set as for self-propelled powerships. This means that we recommend that all floating powerplants comply with MARPOL.
3	Laws and regulations in the relevant country	If a country has its own emissions laws and regulations, floating powerplants which are deployed in this specific country must comply with the regulations.
4	Comparison of emissions with powerplants ashore	Unfortunately, there are currently no unambiguous regulations for global greenhouse gas emissions. Both the global and local emission intensity to the air of a floating powerplant need to be no greater than those of the powerplant on land that is displaced or not built because of the deployment of the powership. The selected fuel type and the efficiency of the power generating equipment, both on board the floating powerplant and at the powerplant on land, are the main drivers of emission intensity.
Warning sign: the specific emissions of the powership or powerbarge are higher than the other existing or planned types of electricity generation connected to the same grid; laws and regulations in the relevant country; MARPOL; or the world bank standard.		
Emissions to the water		
5	Oily water discharge	Self-propelled ships, including self-propelled powerships, must adhere to MARPOL. Although MARPOL does not officially apply to non-self-propelled powerbarges, we propose that they should adhere to the same MARPOL requirements as self-propelled powerships. Oil, which is necessary to operate the floating powerplant, could end up in the water due to several causes. MARPOL Annex I provides regulations for the prevention of pollution by oil. One of the regulations in this Annex sets the requirement to use an oily water separator on board ships above 400 GT. An oily water separator (OWS) is a piece of equipment which is used to separate oil and water mixtures into separate components. The OWS is used to separate oil from oily wastewater, such as bilge water, before the wastewater is discharged at sea. The wastewater which will be discharged at sea can have a maximum oil content of 15 ppm according MARPOL Annex I. It is therefore recommended that floating powerplants use an OWS.
6	Cooling water	The engines for the power generation of on board floating powerplants must be cooled to dissipate excess heat and prevent damage to the engines. However, there are no international regulations as yet regarding maximum allowable temperature differences between seawater and cooling water. There are two types of cooling water systems, namely: – A sea water cooling system, whereby seawater is directly used in the machinery system as a cooling media for heat exchangers. The seawater is discharged back into the sea at an increased temperature after use. – A fresh water or central cooling system, whereby the freshwater is used in a closed circuit to cool down the engine room and power generation machinery. The freshwater which returns from the heat exchanger after cooling the machinery

#	Checklist item	Description
		is further cooled by an air cooling component to conduct some heat to the air, possibly in combination with cooling by seawater. In this way, less heat is conducted into the sea compared to a seawater cooling system, but more heat is conducted into the air. Both systems have their own advantages and disadvantages. The main disadvantage of sea water cooling systems is that they increase the temperature of the seawater that is discharged back into the sea. A fresh water, or central cooling system, may make more noise because of the air-cooling component. Depending on the location where the floating powerplant is deployed, the potential impact of cooling water systems should be evaluated and an assessment should be made about the best system for the location of the floating powerplant. Acceptable values of temperature increases of cooling water discharges may not be well-defined and will be location dependent.
Noise		
7	Noise	Continuous noise from floating powerplants can have an adverse impact on human health, not only for the crew (if applicable), but also for residents in the area (if applicable). – Self-propelled floating powerplants need to comply with a regulation of the International Convention for Safety of Life at Sea (SOLAS) of the IMO, which requires ships to be constructed to reduce on-board noise and to protect personnel, in accordance with the maximum noise level limits sets out in the Code on noise levels on board ships. – The International Maritime Labour Convention of the IMO also has requirements with respect to preventing the risks of exposure to hazardous levels of noise on board of ships. It is recommended that all floating powerplants regardless of their size, both self-propelled and unmotorized, comply with these noise regulations of the IMO.
8	Underwater noise	Floating powerplants produce underwater noise when they are in operation. Depending on the location where the floating powerplants are deployed and on the amount of underwater noise, this noise can produce loss of hearing in marine species, inhibit communication between animals, increase stress levels, and cause behavioral changes. The influence that sound has on marine life depends on the sound level (in decibel) and on the frequency (in hertz). Sounds between 120-170 dB can disturb animal behavior, while sounds above 170 dB can even injure marine animals. The machinery (power generation, pumps, air conditioning) on board a floating powerplant will transmit vibrations to its foundation structure as well as cause airborne noise. This noise will travel to the hull through the ships structure and the air, and will cause underwater noise. Although there are no international regulations on underwater noise as yet, it is recommended that floating powerplants comply with the Guidelines for the reduction of underwater noise from commercial shipping to address adverse impacts on marine life. These guidelines focus on the primary sources of underwater noise, such as propellers, hull form, and on-board machinery, and contain various operational and maintenance recommendations, such as hull cleaning. Since floating powerplants are moored at one location for a long period, the focus must be on the on-board machinery. Depending on the location where the floating powerplant is deployed, there may also be local regulations which have to be complied with. The U.S.A., for example, has the following regulations to minimize the effect of underwater noise:

#	Checklist item	Description
		— the National Environmental Policy Act (NEPA); — the Marine Mammal Protection Act (MMPA); — the Endangered Species Act (ESA). Extra attention should be paid to underwater noise if it is known that mammals, such as whales and dolphins, live in the area where the floating powerplant is deployed.
Risks		
9	Fuel bunkering	Fuel bunkering should be carried out in a safe and environmentally responsible manner. Fuel must also meet engine specifications to avoid engine problems. Regardless of the location of the floating powerplant, the fuel supplier must be reliable. Since a worldwide bunker licensing system (for example of the IMO) does not yet exist, it is recommended that a well-known fuel supplier is selected, which has a good worldwide reputation for fuel bunkering to avoid and mitigate the risk of illegal and unsafe activities (i.e. venting during bunker operations and leaking bunker systems).
10	Classification of the floating powerplant	All marine and safety-related aspects need to be classified by classification societies. Although regulations are currently under development for floating powerplants, power generation equipment currently falls outside the mandatory verification scope of the classification societies. At the specific request of the owner of the floating powerplant, power generation equipment can be included in the verification scope, and it is recommended that the classification society is requested to include power generation equipment in the verification scope.
11	Bad weather accidents	Accidents may occur due to bad weather. For example, the floating powerplant could break loose from its anchorage and run aground, it could capsize and sink, or the electricity cable to shore could break loose. To prevent the risk of accidents, a HAZOP should be performed. HAZOP stands for 'Hazard and Operability study' and is a systematic assessment tool used to identify and address potential hazards before an incident occurs.
Environmental Impact Assessment (EIA)		
12	Environmental Impact Assessment	An environmental impact assessment (EIA) is an assessment of the potential positive or negative impact that a proposed project may have, and contains a comparison of the environmental consequences of the project and any alternatives. Aspects, such as greenhouse gas emissions, local air emissions, noise, emissions to water, underwater noise, safety, potential risks and impact on human health and environment must be included in the environmental impact assessment.

A second checklist has been developed to help to assess whether an operational powership is being operated in an environmentally sound way. It contains warning signs and causes for concern – Table 2. If a powership is assessed as having one of several of these warning signs, mitigating action should be considered.

Table 2 - List of warning signs of cause for concern

#	Warning signs of cause for concern
1	There is limited publicly available information about the floating powerplant project.
2	The floating powerplant is large, as the emissions are correlated with the total fuel burn.
3	The floating powerplant is old, for example more than 20 years old, and therefore likely to have an inefficient generator and outdated (or no) pollution abatement technology.
4	The generators on board are old and have a lower efficiency and higher emissions than the reference land-based power generation asset.

#	Warning signs of cause for concern
5	The use of heavy fuel oil or coal as fuel for the floating powerplant, especially without the use of exhaust gas treatment systems.
6	Fuel bunkering does not take place with an automatic pumping system, but manually. Or the fuel is stored on deck in separate fuel drums instead of in fixed fuel tanks.
7	No oily water separator system is used on board to prevent oil from being discharged into the water.
8	No measurements of the volume and temperature of cooling water discharge are available.
9	The proximity of sensitive natural areas or densely populated areas.
10	Black, grey, or yellow smoke is visible from the exhaust funnels of the floating powerplant when it is in operation.
11	Odor nuisance when the floating powerplant is in operation.
12	The floating powerplant makes strange noises or causes noise nuisance when it is in operation.
13	There are oil slicks floating on the water in the vicinity of the floating powerplant.
14	There are dead fish found near the floating powerplant.
15	The water temperature in the area in which the floating powerplant operates is higher than usual.
16	Human beings and animals in the surrounded areas have health problems which cannot be explained.
17	Whales, sea turtles, or other endangered or threatened species are located in the area where the floating powerplant operates.
18	There are misgivings with regards to the contracting or funding of the floating powerplant project.
19	Long-term contracts for the deployment of floating powerplants, which can lock-in fossil fuel generation.

List of Abbreviations

Abbreviation	Description
ASEAN	Association of Southeast Asian Nations
A-USC	Advanced Ultra Super Critical
BV	Bureau Veritas
CAPEX	Capital Expenses
CCS	Carbon Capture and Storage
CFBC	Circulating Fluidized Bed Combustion
CGN	China General Nuclear Power Group
CH_4	Methane
CO_2	Carbon dioxide
CO_2-eq.	Carbon dioxide equivalent.
CPP	Coal-fired power plant
dB	Decibel
DF	Dual-fuel
DFFE	Department of Forestry, Fisheries, and the Environment
EAP	Environmental Assessment Practitioner
ECA	Emission Control Area
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
ESA	Endangered Species Act
ESS	Environmental and Social Standard
FGD	Flue Gas Desulphurizer
FNPP	Floating nuclear powerplants
FPP	Floating powerplant
FSRU	Floating Storage Regasification Unit
GenSets	Generator sets
GT	Gross Tonnage
HAZOP	Hazard and Operability study
HELE	High Efficiencies Low Emissions
HFO	Heavy Fuel Oil
H_2	Hydrogen
IAEA	International Atomic Energy Agency
ICE	Internal Combustion Engine
ICSID	World Bank's International Centre for Settlement of Investment Disputes
IEA	International Energy Agency
IGCC	Integrated coal Gasification Combined Cycle
IGFC	Integrated Gasification Fuel Cell
IMO	International Maritime Organization
IPP	Independent Power Producer
kV	Kilovolt
kWh	Kilowatt hour
LFO	Low Fuel Oil
LNG	Liquefied Natural Gas
LO	Lube Oil
MARPOL	International Convention for the Prevention of Pollution from Ships
MDO	Marine Diesel Oil
MGO	Marine Gas Oil

Abbreviation	Description
mg/m^3	Milligram per cubic metre
Mg/Nm^3	Milligram per normal cubic metre (at 0 °C, ambient pressure)
MMPA	Marine Mammal Protection Act
MOX	Mixed Oxide fuel, nuclear fuel made from reprocessed plutonium and uranium
MW	Megawatt
MWh	Megawatt hour
MWe	Megawatt electrical
m/m	Mass per mass
NEPA	National Environmental Policy Act
NGO	Non-Governmental Organization
NO_x	Nitrogen Oxides
NO_2	Nitrogen dioxide
OFPU	Optimized Floating Power Unit
OWS	Oily water separator
PBC	Power Barge Corporation
PC	Pulverized Coal
PM	Particulate Matter
PPA	Power Purchase Agreement
ppm	Parts per million
PV	Photovoltaic
RMIPPP	Risk Mitigation Independent Power Producer Procurement Program
SCR	Selective Catalytic Reduction
SDG	Sustainable Development Goals
SG	Spark-ignition
SMR	Small Modular nuclear Reactors
SOLAS	International Convention for Safety of Life at Sea
SO_x	Sulphur oxides
SO_2	Sulphur dioxide
TRL	Technology Readiness Level
USC	Ultra Super Critical
U.S.A	United States of America
WHO	World Health Organization

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1 Introduction

1.1 Aim of the study

Electricity is critical for all aspects of modern life, such as local and national development, health care, safety and education. Worldwide there is an increasing demand for electricity and stable sources are needed to ensure sufficient and reliable electricity supply. Floating powerplants can contribute to meeting this need. A floating powerplant can be defined as a special purpose ship on which a powerplant is installed to serve as a power generation source. The generated electricity is then transported to land where it is used for various purposes.

Although there is an increasing demand for electricity, not everyone has a positive opinion about the deployment of floating powerplants. There are, for example, some countries such as South Africa where certain organizations and communities are opposed to the deployment of floating powerplants because of a potential risk to the environment and human health.

However, there is limited literature available on the deployment of floating powerplants. Marais et al., (2022) has been the first to publish a paper in which the lifecycle emissions of GHGs and air pollutants in South Africa are estimated and extended to the global fleet. According to this paper, powerships could have an important regional impact, although emission estimates are uncertain. In this context, CE Delft has been asked by environmental non-profit and funder communities to conduct independent research into the use of floating powerplants. The aim of this study is to:
- assess the status of the floating powerplant market;
- assess the impact and risks of floating powerplants to the environment and human health;
- identify characteristics of floating powerplant projects that may present unnecessary environmental or human health risks.

The information required to conduct this study has been collected by means of desk research in combination with interviews with stakeholders in the floating powerplant market.

1.2 Outline of the report

Chapter 1 briefly summarizes the aim of this study. Chapter 2 provides baseline information on the floating powerplant market, including history, deployment purposes, stakeholders, technical aspects, disputes in the market, and the use of nuclear energy for floating powerplants. A statement is also made at the end of this chapter about anticipated developments in the market. Chapter 3 focuses on the environmental and social impact of floating powerplants. The global impact, local impact, social impact, and lock-in considerations are discussed. The risk of accidents when using floating powerplants is also covered here. Chapter 4 provides the conclusions of this study and recommendations for environmental non-profits and funders on how they should view the deployment of floating powerplants. The recommendations include a list of criteria to determine whether a floating powerplant project presents a relatively low risk or high risk to the environment or human health. Finally, there are also several appendices that provide information about the interviews, the questionnaires used during the interviews, the customers in the floating powerplant market, and factsheets with more information about existing floating powerplants.

2 Baseline understanding of floating powerplants

There is limited literature available on floating powerplants. Moreover, there is no publicly available database with a comprehensive overview of installations. This chapter provides the first synthesis of the global floating powerplant market of which we are aware.

Section 2.1 describes the definition and history of floating powerplants, including a differentiation between self-propelled powerships and unmotorized powerbarges. Section 2.2 describes the purpose and deployment of floating powerplants. A distinction is made between deployment in developing and developed countries and between long, medium and short-term installations. Section 2.3 provides an overview of the market, including a discussion of stakeholders and their mutual relationship in Section 2.3.1, and an overview of the existing fleet in Section 2.3.2. All technical aspects of floating powerplants, such as the hull, the power generating equipment including the necessary auxiliary systems and the fuel required for power generation are provided in Section 0. The regulations which must be complied with are discussed in Section 2.5. Section 2.6 presents projects in the Dominican Republic, South Africa and Pakistan where the deployment of floating powerplants has led to discussions, disagreements, and political sensitivity between different stakeholders. A few floating powerplants use nuclear energy for power generation and the developments in this submarket are described in Section 2.7. Section 2.8 presents likely developments for the floating powerplant market.

Sections 2.2 through 2.6 only focus on conventional floating powerplants. Nuclear floating powerplants are discussed separately in Section 2.7.

2.1 Definition and history of floating powerplants

2.1.1 Definitions of floating powerplants

A floating powerplant can be defined as a special purpose ship on which a powerplant is installed to serve as a power generation source. A distinction can be made between self-propelled floating powerplants and unmotorized floating powerplants. Self-propelled floating powerplants are also called powerships, while unmotorized powerships are also called powerbarges or barge mounted powerplants (ABS, 2022).

In practice, powerships have always been converted from existing ships, such as from bulk carriers, while powerbarges are often purpose built.

Powerships have an IMO number, which is an internationally recognized 7-digit identification number, inextricably linked to the vessel regardless of ship owner change or retrofit. Because of this, we can assume that we have compiled a complete overview of existing powerships. Powerbarges do not have an IMO number, which makes it more challenging to provide a comprehensive overview, but we have compiled a list of projects and an overview of the market through bottom-up research

Powerships are self-propelled and can be flexibly deployed at locations that have a sudden need for electricity (i.e. Lebanon after the explosion in the port of Beirut in 2020).

Powerbarges appear to be deployed more often when the construction of a land-based powerplant is difficult.

Figure 1 presents an example of a self-propelled powership and Figure 2 presents an example of an unmotorized powerbarge.

Figure 1 - An example of a self-propelled powership

Source: Karpowership, (2021a).

Figure 2 - An example of an unmotorized powerbarge

Source: BWSC, (2016).

2.1.2 History of floating powerplants

The *SS Jacona* was one of the first powerships in the world. The ship was formerly a cargo ship and was converted in 1931 by the Newport News and Shipbuilding and Drydock Company of Virginia for the New England Public Service Company of Augusta, Maine.
The idea arose when one winter a severe storm took out a lot of the New England major power transmission lines. The purpose of the *SS Jacona* was to dock as near as possible to the affected area and to hook into the local power grid, restoring power. During the summer periods, she was used for vacation area power grids where power needs are extremely low during the off season and extremely high during the summer holiday season. In this way, the peak load could be absorbed. The *SS Jacona* was equipped with steam boilers which drove two generators which could produce 10 MW each (Windsor, 1931).

At one time the US Navy used its submarines as power sources when a disaster hit a local community that brought down the commercial power grid. This led to the idea to develop US Navy powerships. The *USS Saranac* was one of the first US Navy powerships. It was built in 1942 and used to be a fleet oiler which was converted after the Second World War to serve as a floating powerplant (The Maritime Executive, 2019).
The *Sturgis* was built in the 1940's and served as a World War II Liberty ship. After the war, she was converted into the world's first floating nuclear powerplant in the 1960's, housing the MH-1A nuclear reactor. The ship was used in the Panama Canal zone from 1968 to 1976 to generate electricity for military and civilian use and was decommissioned and scrapped between 2015 and 2019 (The Maritime Executive, 2019).

There are currently two main players in the floating powerplant market, Power Barge Corporation and Karpowership, a subsidiary of the Karadeniz Energy Group. Power Barge Corporation was established in 2000 and owns and purchases unmotorized powerbarges (Power Barge Corporation, ongoing). Karpowership owns floating powerplants converted from other ship types and began the production of its fleet in 2007 (Karadeniz Holding, ongoing). The fleets of both companies have expanded over the years. Since the construction years of the unmotorized powerbarges are unknown and the dates when ships were converted to floating powerplants are not always provided, it is not possible to show the number of existing floating powerplants over time.

2.2 Purpose and deployment of floating powerplants

Floating powerplants are used for different purposes in both developed and developing countries and for the short, medium, and long-term. These purposes are further explained in this section and have been informed by expert interviews and desktop research.

1. **Deployment as a permanent power station**
   Floating powerplants are often deployed as a permanent power station in developing countries. They can provide energy to both mainland and island locations. Floating powerplants are deployed for the long-term in developing countries for several reasons, including:
   - Insufficient generation capacity on land in the area concerned, but a need for energy.
   - Sometimes it is difficult to install a reliable powerplant on land, for example on remote islands. In cases like this, it can be easier to deploy floating powerplants.
   - The feedstock used for the powerplants ashore vary by area. It is a possible that the fuel required for the generation of electricity by the floating powerplant is more environmentally friendly or cheaper than the feedstock required for existing

powerplants on land, and that governmental agencies and electricity companies therefore make the choice to deploy floating powerplants.

- Government agencies and electricity companies decide to deploy floating powerplants from a financial point of view. Floating powerplants can be leased (under several type of contracts) which means that there are no high investment costs, as is the case for powerplants on land.

Floating powerplants are rarely used as permanent power stations in developed countries. Interview (NGO's, 2022, Equipment suppliers, 2022).

2. **Deployment for medium term purposes**
   In addition to the deployment as permanent power station, floating powerplants can also be used for medium term purposes. This is often the case in developing countries when a powerplant on land is under construction or when the supporting infrastructure is not yet ready for use. Floating powerplants are temporary deployed in these cases until the powerplant on land is ready for use. Interview (NGO's, 2022, Equipment suppliers, 2022).

3. **Short-term deployment in emergency situations**
   (Natural) disasters, such as for example a hurricane or a war, can destroy power generation plants and transmission lines resulting in blackouts. Floating powerplants can be temporarily deployed in these areas as emergency use to provide electricity until the onshore power generation plants are repaired or replaced. Besides the supply of electricity, in the case of an emergency it is sometimes also difficult to obtain clean drinking water. Some powerbarges therefore not only have power generation equipment installed on board, but also seawater desalination equipment to supply clean drinking water (Mitsubishi Heavy Industries, 2018).

4. **Support renewable energy integration**
   Growing deployments of variable renewable energy sources, such as wind and solar, are increasing the need for grid balancing services to match electricity supply to demand. Floating powerplants can offer a solution to this challenge, in both developed and developing countries. Although all existing installations use fossil energy, floating powerplants could also use biofuels (Equipment suppliers, 2022, POWERmag, 2019).

5. **Deployment as power source for ships at berth**
   Powerbarges are currently used on a small scale in developed countries to supply energy to cruise ships when they are berthed, so the cruise ships can switch off their on-board generators. Cruise ships normally use their own generators to power the hotel facilities on board. The ship’s generators create unwanted noise and emissions in ports and cities. By using electric shore power, ships can shut down their generators. However, not every port is currently able to facilitate shore power. As an alternative, powerbarges can be deployed to supply the required energy to the cruise ships so that they can switch off their generators. The port of Hamburg in Germany currently makes use of powerbarges for the energy supply to cruise ships. The powerbarges in Hamburg generate electricity from LNG and produce significantly lower emissions than the diesel engines which are often used to generate power onboard cruise ships. In contrast to the use of shore power, whereby noise is reduced, noise will probably not be reduced significantly when using powerbarges for the electricity supply (Becker Marine Systems, ongoing).

2.3 Overview of the market of floating powerplants

The market of floating powerplants is small compared to the entire energy supply market.

It is also not very transparent, with few publications or sources of data about the industry. This section provides an overview of the floating powerplant market, whereby the stakeholders involved and their mutual relationship are discussed in Section 2.3.1 and an overview of the existing fleet is shown in Section 2.3.2.

2.3.1 Involved stakeholders and their mutual relationship

1. **Suppliers of floating powerplants**
   There are two main players in the floating powerplant market, namely Karpowership, a subsidiary of the Karadeniz Energy Group, and Power Barge Corporation.

   Karpowership, a subsidiary of the Karadeniz Energy Group
   Karadeniz Holding was founded in 1948 and is located in Istanbul in Turkey.
   The company entered the energy market in 1996. It is the first electricity exporter in Turkey and operates both in domestic and international markets. In 2007, Karadeniz Holding began the production of a floating powerplant fleet. The floating powerplants are owned and operated by Karpowership, a subsidiary of the Karadeniz Energy Group. Karpowership currently owns and operates a fleet of 24 floating powerplants with an installed capacity exceeding 4,100 MW. *As comparison: As of 2020, Cuba's installed generating capacity was 6,661 MW* (OLADE, 2021).

   Karpowership supplies electricity to Cuba, Gambia, Ghana, Guinea-Bissau, Guinea, Senegal, Indonesia, Iraq (former project), Lebanon, Mozambique, Sierra Leone, Sudan and Zambia (former project). These projects are realized via several commercial structures such as short-term IPPs (Independent Power Producer), long-term IPPs, PPAs (power purchase agreements) and rental contracts (Karadeniz Holding, ongoing, Karpowership, ongoing-b).

   Power Barge Corporation
   Power Barge Corporation (PBC) is a privately held company which provides turnkey engineering, procurement and construction contracting, as well as aftermarket and consulting service to developers, owners, and operators of barge-mounted powerplants with gas turbines, medium speed engines, and energy storage system. The company also purchases and owns powerbarges. Power Barge Corporation was established in 2000 and is located in Houston, U.S.A. The company owns 58 powerbarges with an installed capacity exceeding 4,400 MW (Power Barge Corporation, ongoing).

   Other suppliers of floating powerplants
   There may be other floating powerplant suppliers besides Karpowership and Power Barge Corporation, but this has not been confirmed. Based on information from our interviews with industry experts, we assume that a number of its stakeholders involved, such as, customers, designers, and equipment suppliers, also own floating powerplants, but we do not know how many.

2. **Customers**
   Customers using floating powerplants are mainly energy suppliers and governmental agencies. They are located all over the world, but most are in Africa, Asia, South America and Central America. An overview of the customers of both Karpowership and Power Barge Corporation is provided in Appendix B.

The agreements between the owner of the floating powerplant and the customer regarding the amount of power required and the duration of the energy delivery are laid down in a Power Purchase Agreement (PPA). A PPA is an arrangement whereby a third-party, called an independent power producer (IPP), installs, owns, and operates an energy system on a customer's property. The customer purchases the system's electricity output for a predetermined period from the independent power producer (IPP). These contracts can be both short and long-term (The World Bank, 2021). Finally, it is also possible for customers to lease floating powerplants through a rental contract with the supplier.

3. **Designers and engineers**
   Engineering involves both the design of the ship or barge and the selection of all the necessary equipment on board, including the integration of the various systems.

   The engineering of the floating powerplants can be performed by an independent engineering bureau, an in-house engineering department of the floating powerplant supplier, the supplier of the power generating equipment installed on board, or even at the yard which builds floating powerplants. Waller marine Inc., Burmeister & Wain Scandinavian Contractor and Ecap Marine are examples of independent engineering companies. MAN, Wärtsilä and Siemens Energy are suppliers of power generating equipment that are also able to engineer floating powerplants. Both Power Barge Corporation and Karpowership, the main suppliers of floating powerplants, have their own in-house naval architecture and marine electrical engineers. These companies were all regularly mentioned during the expert interviews we conducted and the statements we received (see Appendix A.1), but it is not a comprehensive list (Waller Marine Inc., 2019, BWSC & TGE, 2018, Karpowership, 2019)

4. **Equipment suppliers**
   Equipment must be installed on board floating powerplants to generate electricity.

   During the interviews we were told by various stakeholders that, in principle, any power generating equipment suppliers could be selected for the supply and installation of the equipment required for the power generation on board of the floating powerplants since it is no different (except possibly the dimensions and the manner of installation) than equipment used on land or other floating structures. However, both Karpowership and Power Barge Corporation mainly select the major players in the power (generation) market. A number of well-known engine and/or gas turbine suppliers which they regularly select are MAN, Wärtsilä, Caterpillar, Siemens Energy and General Electricity (GE). ABB is a well-known and regularly selected supplier of generators, machines which convert the mechanical energy from the engines entering through a rotating shaft into electrical energy (ABB, 2022). GE is also a supplier of transformers, which transport the electricity which is generated on board of the floating powerplants via cables to local transmission grids ashore from where it will go to the end user.

5. **Yards**
   Shipyards are responsible for the construction of the floating powerplant or the conversion from an old ship and for the installation work on board. The floating powerplants of Karpowership are converted from old ships at the Sedef shipyard in Istanbul in Turkey, near the Karpowership office (Clarksons PLC, ongoing). The floating powerplants of Power Barge Corporation (and possibly also floating powerplants of other unknown owners) are mainly new builds. The construction of floating powerplants can take place anywhere in the world, but is mainly carried out by leading shipyards to ensure high quality standards.

Suppliers deliver their equipment to the yard for installation. While the yard is responsible for the construction and the delivery of the complete floating powerplant, the commissioning and the adjustments to the power generating equipment will take place in collaboration with the suppliers.

6. **The mutual relationship between the stakeholders involved**
The mutual relationship between the stakeholders involved varies by project - sometimes they are each other's competitors, while other times they work together in a consortium. The party responsible for project management can also vary from project to project.

Wärtsilä, MAN and Siemens Energy are three examples of power generating equipment suppliers that have also taken on the role of project manager for certain projects for the construction of complete floating powerplants. Other aspects of a project can also vary, such as who owns the floating powerplant and who has the service contract.

2.3.2 Overview of the existing fleet

This section will provide an overview of the existing floating powerplants that we were able to gather information on (Table 3). We know from the interviews conducted that there are an unknown number of other powerbarges operating in the world, about which we have no data.

Table 3 - Overview of the existing fleet about which any form of information is known

Company	Number of floating powerplants
Karpowership/Karadeniz Holding	24
Power Barge Corporation	68 (58 owned, 4 for sale and 6 recently sold)
E-cap Marine	1
Seaboard Corporations	1
Total	**94**

The floating powerplants of Karpowership have been converted from existing ships and are registered in the World Fleet Register of Clarkson (an online shipping database). Since these floating powerplants are registered in a publicly accessible paid system, a lot of information is known. Detailed information per floating powerplant can be found in the factsheets in Appendix C.1. A brief summary is provided below in Table 4.

Table 4 - Summary of the floating powerplants owned by Karpowership

#	Name of the floating powerplant	IMO number	Propulsion type	Status	Last received position
1	Karadeniz Powership Osman Khan	9189158	Diesel 2-stroke	In Service	Gulf of Guinea, off the coast of Ghana, Africa
2	Karadeniz Powership Onur Sultan	9047441	Diesel 2-stroke	In Service	Belawan, Indonesia, Asia
3	Karadeniz Powership Orka Sultan	9198252	Diesel 2-stroke	In Service	Yalova, Turkey in Europe/Asia
4	Karadeniz Powership Orhan Ali Khan	9248514	Diesel 2-stroke	In Service	Yalova, Turkey in Europe/Asia
5	Karadeniz Powership Kaya Bey	7925546	Diesel 2-stroke	In Service	Marsa Bashayer, Sudan, Africa
6	Karadeniz Powership Rauf Bey	7925522	Diesel 2-stroke	In Service	Marsa Bashayer, Sudan, Africa

#	Name of the floating powerplant	IMO number	Propulsion type	Status	Last received position
7	Karadeniz Powership Fatmagul Sultan	Not available	Non propelled	In Service	Unknown
8	Karadeniz Powership Dogan Bey	8117031	Diesel 2-stroke	In Service	Freetown, Sierra Leone, Africa
9	Karadeniz Powership Mehmet Bey	9232785	Diesel 4-stroke	In Service	Nacala, Mozambique, Africa
10	Karadeniz Powership Ibrahim Bey	9216638	Diesel 4-stroke	In Service	Conakry, Guinea, Africa
11	Karadeniz Powership Zeynep Sultan	8116051	Diesel 4-stroke	In Service	Java Sea, Indonesia, Asia
12	Karadeniz Powership Irem Sultan	8222252	Diesel 4-stroke	In Service	Yalova, Turkey, Asia
13	Karadeniz Powership AliCan Bey	Not available	Non propelled	In Service	Unknown
14	Karadeniz Powership Yasin Bey	9214551	Diesel 4-stroke	In Service	Ambon, Indonesia, Asia
15	Karadeniz Powership Gokhan Bey	9214563	Diesel 4-stroke	In Service	Kupang, Indonesia, Asia
16	Karadeniz Powership Orhan Bey	Not available	Non propelled	In Service	Unknown
17	Karadeniz Powership Aysegul Sultan	Not available	Non propelled	In Service	Unknown
18	Karadeniz Powership Baris Bey	9166546	Diesel 4-stroke	In Service	Colonia del Sacramento, Uruguay, South-America
19	Karadeniz Powership Metin Bey	9034779	Diesel 4-stroke	In Service	Bissau, Guinea-Bissau, Africa
20	Karadeniz Powership Nezih Bey	9034781	Diesel 4-stroke	In Service	Amurang, Indonesia, Asia
21	Karadeniz Powership Esra Sultan	Not available	Non propelled	Laid Up	Unknown
22	Karadeniz Powership Ela Sultan	Not available	Non propelled	Laid Up	Unknown
23	Karadeniz Powership Filiz Sultan	Not available	Non propelled	Laid Up	Unknown
24	Karadeniz Powership Koray Bey	9086203	Diesel 4-stroke	In Service	Dakar, Senegal, Africa

In addition to the installed capacity of 4,100 MW, Karpowership has 25 more powerships under construction and in the pipeline with a capacity of 4,400 MW (Karpowership, ongoing-a). However, no further information is available about this expansion of the fleet.

The floating powerplants of Power Barge Corporation are not registered in Clarkson's World Fleet Register, do not have an IMO number and are not self-propelled. It is even unknown whether they have a name. Therefore, it is difficult to identify and trace the location of all these floating powerplants. All the information we were able to gather on powerbarges is provided in Appendix C.2. A summary is also provided below in Table 5. A distinction is made between powerbarges owned by PBC, for sale by PBC, and recently sold by PBC. Unfortunately, we were unable to obtain information about the buyers of the six recently sold powerbarges.

Table 5 - Summary of the floating powerplants of Power Barge Corporation

Power generating equipment installed on board the floating powerplant (manufacturer and type)	Number of floating powerplants	Status
MAN medium speed diesel engines	4	Not for sale
MAN slow speed diesel engines	2	Not for sale
Wärtsilä medium speed diesel engines	16	Not for sale
General Electric gas turbines	25	Not for sale
Siemens Westinghouse gas turbines	6	Not for sale
Miscellaneous powerbarges	5	Not for sale
Total number of floating powerplants owned	**58**	**Not for sale**
Wärtsilä dual fuel medium speed diesel engines	1	For sale
Wärtsilä medium speed diesel engines	2	For sale
Westinghouse gas turbine	1	For sale
Total number of floating powerplants for sale	**4**	
Wärtsilä diesel engines	2	Recently sold
Siemens gas turbines	3	Recently sold
MAN medium speed diesel engine	1	Recently sold
Total number of floating powerplants recently sold	**6**	
Total	**68**	**Not for sale, for sale & recently sold**

E-cap Marine is a relative new company located in Hamburg in Germany which offers environmental and flexible clean power solutions. One of their products is an LNG fed powerbarge. The powerbarge of E-cap Marine has a different function compared to above mentioned floating powerplants. This LNG fed powerbarge supplies power to cruise ships during the summer season and operates as a floating power and heat plant in the winter. She operates in Hamburg and produces significantly lower emissions than the diesel engines used to generate power on board cruise ships. A brief summary of this powerbarge is provided in Table 6 (eCap Marine, ongoing).

Table 6 - E-cap Marine powerbarge

Description	Data
Length (m)	76.0
Width (m)	11.4
Draught (m)	2.5
Power generating equipment	5 x 1.5 MW LNG GenSets
Fuel storage	2 x 17 ton LNG containers

Seaboard Corporation owns the Estrella del Mar II powerbarge which is moored at the mouth of the Ozama river in the middle of the city center of Santo Domingo in the Dominican Republic. The powerbarge has six engines and a combines cycle (heat recovery system) with a rated capacity of 108 MW and was put into service in April 2012. More about the powerbarge situation in the Dominican Republic can be found in Section 2.6.

2.4 Technical aspects of floating powerplants

This section focuses on the technical aspects of floating powerplants. The hull is discussed in Section 2.4.1, the power generating equipment including the necessary auxiliary systems is discussed in Section 2.4.2, the required fuel for power generation is discussed in Section 2.4.3 and the regulations which must be complied with are discussed in Section 2.5.

2.4.1 Hull

Powerships are mainly converted from old bulk carriers. The ship's dimensions balance the available cargo space for electricity generating equipment, transformers and fuel storage. Powerbarges are typically new builds and are not constrained by the dimensions of an existing ship.

Both powerships and powerbarges can operate in shallow water because of their limited draft. This allows them, depending on their dimensions, to be moored close to the coast, in ports, in cities and on rivers.

The hull of floating powerplants need to comply with certain regulations. These regulations are discussed in Section 2.5.

2.4.2 Power generating equipment and the necessary auxiliary systems

Power generating equipment

Different types of electricity generating equipment can be installed on board floating powerplants, each with different environmental impacts (Chapter 3). Examples of commonly used systems are:
- reciprocating Internal Combustion Engines (ICEs);
- dual-fuel (DF) engines;
- gas engines which are only able to run on gas;
- gas turbines.

Combustion engines are a well-known technology used for many purposes, such as marine propulsion, trucks, automobiles, and construction equipment. Modern combustion engines that are used for electric power generation are internal combustion engines (ICEs) in which an air-fuel mix is compressed by a piston and a cylinder. Reciprocating internal combustion engines are characterized by the type of combustion, namely spark-ignited (SG) or compression-ignited. The conventional reciprocating ICEs are able to run on fuel oil, diesel oil, gas oil and biofuel (Wärtsila, 2022a)

Dual-fuel (DF) engines are internal combustion engines which are designed with the ability to burn both liquid and gaseous fuels. When the engine is operating in gas mode, the gaseous fuel is premixed with air, injected just after the compression stroke, and ignited by a pilot fuel flame. The pilot fuel flame acts as a 'spark plug' to ignite the gas-air mixture. Dual fuel engines can also act as conventional internal combustion engines (Wärtsila, 2022a).
A gas engine is an ICE that can use several types of gasses, for example natural gas. The engine utilizes an ignition source such as a small amount of pilot fuel to start the gas fuel burn (Wärtsila, ongoing).

A generator is a machine which converts the mechanical energy from a combustion engine entering through a rotating shaft into electrical energy. Every engine is connected to a shaft which is connected to an electric generator. These groups of a shaft, an engine, and a generator are also called gensets (Wärtsila, 2022a).

A gas turbine is an ICE that burns an air-fuel mix which produces hot gases that spin a turbine to produce power. A gas turbine consists of three sections which are mounted on the same shaft, namely a compressor, a combustion chamber, and a turbine. It can use a variety of fuels such as natural gas, fuel oils, and synthetic fuels. Unlike reciprocating ICEs in which combustion occurs intermittently, combustion occurs continuously in gas turbines (Wärtsila, 2022b).

A summary of the different types of power generating equipment can be found below in Table 7.

Table 7 - Different types of power generating equipment

Commonly used electricity generating equipment	Working principle	Fuel type
Reciprocating Internal Combustion Engines (ICEs)	Air-fuel mixture is compressed by the piston and ignited by a spark from a plug. Combustion occurs intermittently.	Fuel oil, diesel oil, gas oil and biofuel.
Dual-fuel (DF) engines	ICE which is designed with the ability to burn both liquid and gaseous fuels. Combustion occurs intermittently.	Dual-fuel mode: gas in combination with a pilot fuel as ignition source. As conventional ICE: Dual-fuel mode: gas in combination with a pilot fuel for the ignition flame.
Gas engines	ICE which is only able to burn gaseous fuels. Combustion occurs intermittently.	Gas in combination with a pilot fuel as ignition source.
Gas turbines	A gas turbine consists of three sections mounted on the same shaft: a compressor, a combustion chamber and a turbine. The burning of an air-fuel mixture produces hot gases that spin a turbine to produce power during a continuous process.	Natural gas, fuel oils and synthetic fuels

Depending on the required power capacity and the available space on board the floating powerplant, multiple engines or gas turbines can be placed on board for power generation. This can vary from a few up to 21 generator sets on the large floating powerplants owned by Karpowership.

Auxiliary systems required for power generation

In addition to the power generating equipment, various ‘auxiliary’ systems are also necessary on board floating powerplants to operate safely. Examples of important ‘auxiliary’ systems which are required are: the mooring system, the fuel storage system including the fuel bunkering system, the cooling water system, the firefighting equipment and the transformer and transmission lines to transport the electricity to shore.

Floating powerplants only generate electricity when they are moored, at a quay, or at anchor. The mooring system must be robust to prevent loosening in bad weather conditions. Floating powerplants must therefore comply with certain safety regulations, which are further explained in Section 2.5.

The power generation equipment converts fuel into electricity. Sufficient fuel storage is therefore necessary. When fuel storage capacity on board the floating powerplant is insufficient, fuel needs to be stored on shore or at a fuel storage vessel nearby. More information about the fuel supply and fuel storage can be found in Section 2.4.3.

The power generation equipment is designed to work at maximum efficiency and to run for long hours. To improve efficiency and prevent malfunctions, the generation systems are equipped with cooling systems. There are two types of cooling water systems:

- A sea water cooling system, whereby seawater is directly used as a cooling media for heat exchangers. The seawater is discharged back into the sea at an increased temperature after use.
- A fresh water or central cooling system, whereby the freshwater is used in a closed circuit to cool down the engine room and power generation machinery. The freshwater which returns from the heat exchanger after cooling the machinery is further cooled by an air cooling component, possibly in combination with seawater from a sea-water cooler.

Both systems have their own advantages and disadvantages. The choice for the type of cooling water system depends on the dimensions of the floating powerplant and local circumstances. However, acceptable temperature increases of seawater used for cooling differences and noise levels are not well defined (Marine Insight, 2019).

One of the main causes of accidents on board of ships and other floating structures is fire because of the presence of high temperatures, the quantity of flammable oil and other combustible materials. Examples of firefighting equipment and measures which must be present on board are: fire retardant bulkheads, fire doors, fire dampers, fire pumps, fire hose and nozzles, portable fire extinguishers, fixed fire extinguishing system, inert gas system, fire detectors and alarms, remote shut and stop system, emergency escape breathing device, fire fighter’s outfits, escape routes, etcetera. More information about the regulations that floating powerplants must comply with can be found in Section 2.5 (Marine Insight, 2021)

Once the power generation equipment has converted the fuel into electricity, this electricity still must be transmitted to the user. Transformers send the power which is generated over cables to local transmission grids. From there the electricity will go to the end user. Exposure to large temperature differences, corrosion due to salt water and impact to the local ecosystem must be considered in the design (Stakeholders, 2022).

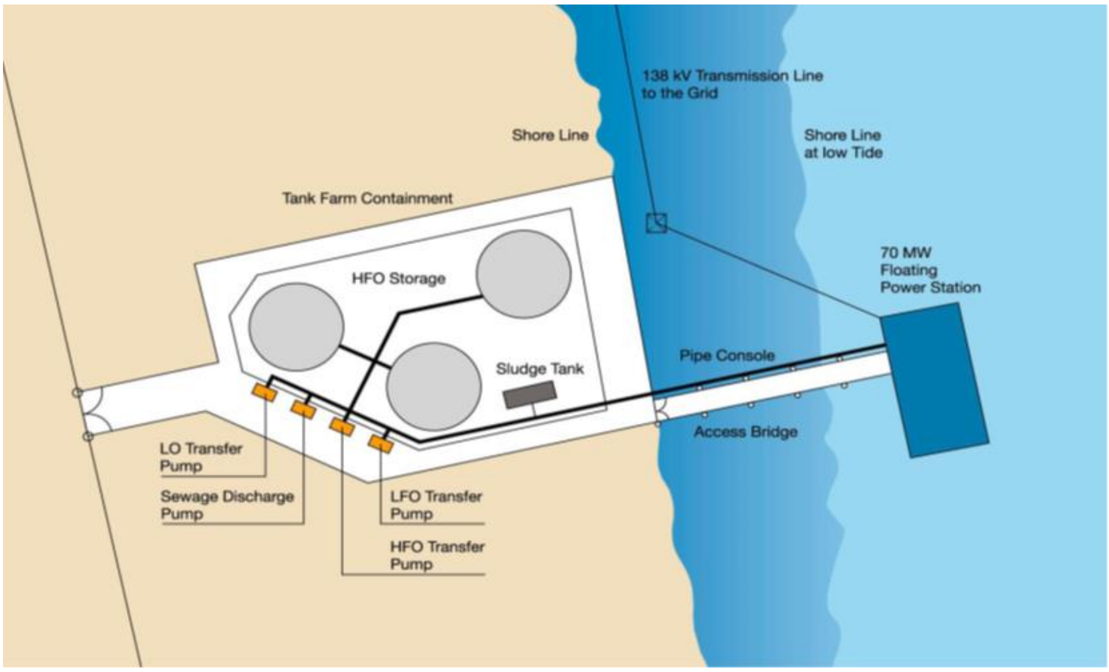
2.4.3 Fuel required for power generation

Fuel supply and storage

Fuel is required for electricity generation on board floating powerplants. Depending on the size of the ship and the fuel type, a certain amount of fuel storage capacity is available but limited to a few days or weeks of supply.

Fuel can be supplied to floating powerplants in two ways, namely by land or by sea by means of a ship. If the floating powerplant is located close to shore, near a fuel production or storage location, the fuel necessary for the powership can be supplied directly from shore. Figure 3 provides an example of a configuration whereby a floating powerplant is fueled from a fuel storage location ashore.

Figure 3 – Example of a floating powerplant which is fuelled from a fuel storage location ashore

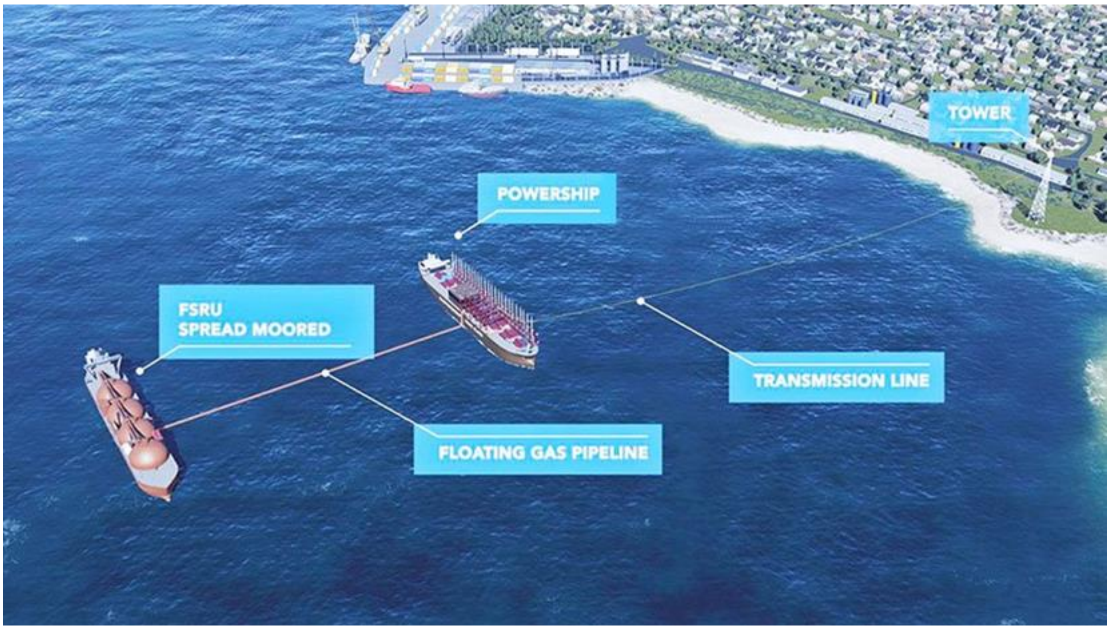


Source: With Permission MAN Energy Solutions, (2019).

Where the required fuel is not available in the vicinity, a fuel storage vessel can be positioned close to the floating powerplant. The fuel is supplied to this fuel storage vessel by another vessel (fuel carrier). The combination of a floating powerplant and a storage vessel is also called a 'power island'.

Natural gas is cooled to –162˚C at the source of production to reduce its volume for better transportation and storage efficiency. Powerships and powerbarges which are running on LNG make use of a floating storage regasification unit (FSRU) which is positioned close to them. In addition to the fact that a FSRU has extra LNG storage capacity on board for the concerned floating powerplant, a FSRU also has a regasification unit. The regasification unit can convert LNG back into a gas to power the electricity generating equipment on board the floating powerplant. An example of this is a 'power island' configuration as shown in Figure 4.

Figure 4 – Example of a 'power island', a combination of a floating powerplant and an FSRU



Source: MOL, (2019).

Fuel outlook

Several types of fuel can be used for power generation by floating powerplants. This section will present a short overview of the fuel currently used and an outlook on the types of fuel that will likely be used in the medium to long-term.

Typical conventional fuel types used for the power generation by floating powerplants are HFO, MDO and MGO. However, the share of natural gas is quickly increasing, especially projects using LNG:
- In 2020, Karpowership started its first floating LNG-to-power project in Indonesia , whereby the LNG is converted from liquid into gas via a floating storage regasification unit (Offshore Energy, 2020) (FSRU). Karpowership has the aim to 'at least' double the company's LNG assets over the next couple of years and wants to raise its natural gas and LNG powered global electricity generation capacity from 50 to 80% by 2025 (Gasworld, 2021).
- Most of the new powerbarges of Power Barge Corporation are designed for gas turbine applications (Power Barge Corporation, 2020).
- Siemens Energy's LNG powerbarge named the Estrella del Mar III reached her destination in Santo Domingo in the Dominican Republic in April 2021 (Onward, 2021)
- Other power generation manufacturers, such as MAN and Wärtsilä, provide equipment which can run on gas.
- The powerbarge of E-cap Marine which provides electricity to cruise ships in Hamburg is equipped with gensets running on LNG.

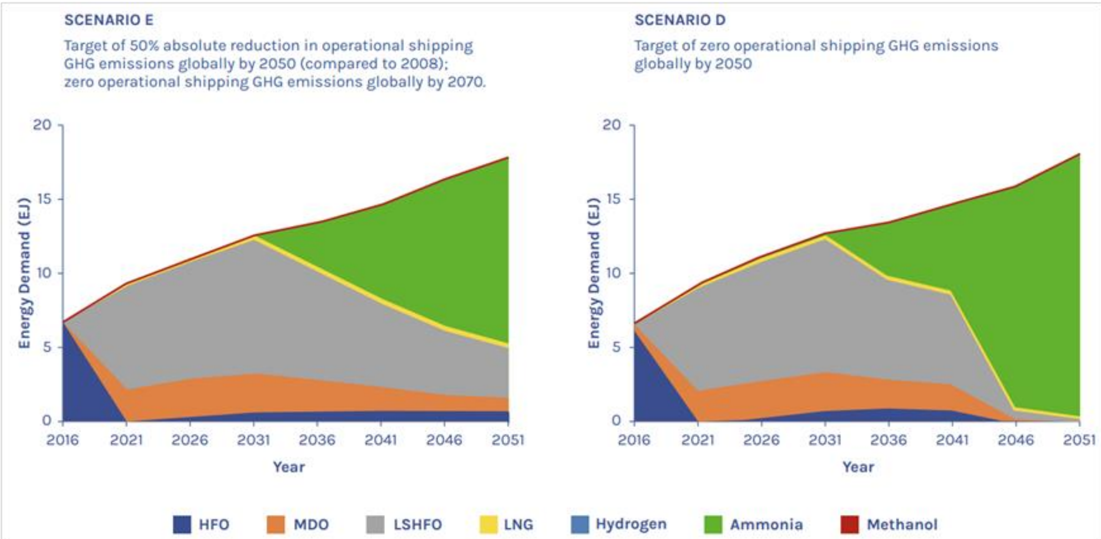
Combustion of natural gas releases fewer criteria pollutants than conventional fuels, and can have lower greenhouse gas emissions if methane leakage rates are low across the fuel supply chain. LNG is also seen as a transitional fuel.

The interviewed stakeholders believe that floating powerplants can switch easily to renewable fuels, such as methanol, ammonia, or hydrogen, in the future:

- Power generation manufacturers are conducting research to explore the use of hydrogen/gas mixtures and customers seem to be interested in the application of hydrogen as a fuel. It is thereby relevant for the customer to know that different options exist to produce hydrogen. When one talks about hydrogen as a renewable fuel, what is meant is 'green' hydrogen which is produced by a process called hydrolysis of water. Hydrogen can also be produced from fossil fuels.
- In the medium to long-term e-ammonia looks set to be the backbone for decarbonizing international shipping. The validation of ammonia engine designs by 2023 will be a key milestone in unlocking the use of renewable ammonia. Recent projections by UMAS show that the first commercial use of e-ammonia would likely start around 2030, while e-ammonia will become the most abundant marine fuel around 2040. This is shown in Figure 5. It is important to emphasize that this expectation concerns marine fuels used by propulsion and auxiliary engines on board ships. It does not automatically mean that floating powerplants use the same trajectory for the fuel required for their power generation as the marine fuels used on board ships.
- Bio methanol and e-methanol are likely to play a smaller but still significant role in the transition of marine fuels. These renewable fuels require little to no engine modifications and can provide significant carbon emission reductions in comparison to conventional fuels. Especially e-methanol is of interest to the shipping industry (IRENA, 2021).

Since floating powerplants currently use similar fuels to the shipping industry for their power generation, it is likely that they will follow the same trend towards the use of e-ammonia and e-methanol in the medium to long-term.

Figure 5 - Projected future marine fuel demand in two UMAS scenarios



Source: Raucci et al., (2020).

2.5 Regulations applying to powerships

Floating powerplants

Depending on the type of floating powerplant and the location where the floating powerplant is deployed, the vessel must comply with certain guidelines and regulations. These various guidelines and regulations concern environmental, technical and safety related aspects as discussed below.

Environmental aspects

There are no global regulations specific to the environmental performance of floating powerplants, such as greenhouse gas emissions, local air emissions, pollution and noise to both the air and the water. Powerships with IMO numbers may be subject to regulations for both ships and electricity generation facilities, while powerbarges will usually not be covered by any ship regulations. This section explores the regulatory context for floating powerplants.

Minimum environmental requirements for power generation

Most floating powerplants are installed in developing countries, many of which do not have their own environmental regulations for these facilities. Several stakeholders interviewed for this project stated that, in the absence of any local regulations, the World Bank Standards and Guidelines are often used as the minimum requirement, whereby the Standard applicable to onshore projects (in this case powerplants on land) also apply to offshore projects (in this case floating powerplants). All relevant information about these standards can be found on the website of the World Bank:

- The World Bank Environmental and Social Standard (ESS) #3 'Resource Efficiency and Pollution Prevention and Management' recognizes that economic activity can consume finite resources and generate pollution to air, water, and land that may threaten human beings, ecosystems, and the environment at local, regional, and global levels. ESS #3 sets out requirements to address resource efficiency and pollution prevention and management throughout the project life-cycle.
- The World Bank Group Environmental, Health, and Safety Guidelines contain the performance levels and measures that are normally acceptable to the World Bank Group. These performance levels and measures are considered to be achievable in new facilities at reasonable costs by existing technology.

Local environmental requirements for power generation

In the event that local (environmental) regulations are in force, these must be complied with. The general picture provided by our interviews is that powerships are generally held to **the same regulations as on-land power generation assets**. But regulations for emissions from land-based powerplants vary worldwide by country and by fuel type from land-based alternatives. Also the location of the powerplant plays a role, i.e. the proximity to human population centers. A full overview would require an extensive study: therefore we made a selection. T**he approach is that powership emissions should be benchmarked with the local land-based alternative, in line with the stakeholder positions in our interviews.** Note that this could mean that emissions of local land-based coal fired powerplants are benchmarked with emissions of LNG fed powerships or land-based natural gas turbines with powerships using HFO as a fuel.

The worst-case CO_2 emission benchmark for land-based power generation is a coal fired powerplant. A report of Economic Research Institute for ASEAN and East Asia states the following emission table for coal fired powerplants in different countries, comparing western countries with ASEAN countries, where powerships and powerbarges are used on a regular basis:

Figure 6 - Emission standards for new CPPs in selected countries

Country	SOx	NOx	PM
Australia	SO_3: 200 mg/m^3	NO_2: 800 mg/m^3	80 mg/m^3
Germany	SOx: 150 mg/m^3	NOx: 150 mg/m^3	10 mg/m^3
Japan	SOx: 50 ppm* (SO$_2$: 133 mg/m^3)	NOx: 200 ppm (NO$_2$: 383 mg/m^3)	100 mg/m^3
Republic of Korea	SOx: 50 ppm (SO$_2$: 133 mg/m^3)	NOx: 50 ppm (NO$_2$: 96 mg/m^3)	10 mg/m^3
United States**	SO_2: 130 ng/J	NOx: 88 ng/J	11 ng/J
Cambodia	SO_2: 500 mg/m^3	NO_2: 1000 mg/m^3	400 mg/m^3
China	SO_2: 200 mg/m^3	NO_2: 200 mg/m^3	30 mg/m^3
India	SO_2: 80 mg/m^3	NO_2: 80 mg/m^3	100 mg/m^3
Indonesia	SO_2: 750 mg/m^3	NO_2: 750 mg/m^3	100 mg/m^3
Lao PDR	SO_2: 320 ppm (SO$_2$: 853 mg/m^3)	NOx: 350 ppm (NO$_2$: 670 mg/m^3)	120 mg/m^3
Malaysia	SOx: 500 mg/m^3	NOx: 500 mg/m^3	50 mg/m^3
Myanmar	SOx: 200 mg/m^3	NOx: 400 mg/m^3	50 mg/m^3
Philippines	SO_2: 700 mg/m^3	NO_2: 1000 mg/m^3	150 mg/m^3
Singapore	SO_2: 500 mg/m^3	NO_2: 700 mg/m^3	100 mg/m^3
Thailand	SO_2: 180 ppm (SO$_2$: 480 mg/m^3)	NOx: 200 ppm (NO$_2$: 383 mg/m^3)	80 mg/m^3
Viet Nam	SO_2: 500 mg/m^3	NO_2: 650 mg/m^3***	200 mg/m^3

CPP = coal-fired power plant, mg/m^3 = milligram per cubic metre, PM = particulate matter, ppm = parts per million, NO_2 = nitrogen dioxide, NOx = nitrogen oxides, SO_2 = sulphur dioxide, SOx = sulphur oxides.
Notes: * Based on the CPP's location, sulphur content of fuel, stack height, etc. the emission standard varies by CPP. The value is an example of specific CPP based on agreement between CPP and local government.

Source: ERIA, (2017).

Equipment suppliers stated in interviews with the authors of this report that where emission regulations exist for onshore powerplants, these regulations should also be applied to new powerships and powerbarges. It is therefore important that new projects adhere to this. When land-based emission regulations are not present in a country, World Bank Standards should be applied. For specific projects in sensitive areas, one can agree on stricter regulations for emissions, noise and thermal discharge. One could demand that strict land-based regulations of a particular western country (i.e. Japan) are used in order to provide support from Ocean Kind for a specific project. In many cases this can readily be achieved by using LNG as the fuel.

Although this does not relate to large powerplants, the World Bank addresses emission standards of Particulate Matter, Sulphur Dioxide, and Nitrogen Oxides for small combustion facilities from 3-50 MW_{th}, see Figure 7. Please note that powerships typically have higher power values and these values are merely a worst-case scenario in relation to smaller power cases.

Figure 7 - Small Combustion Facilities Emission Guidelines (3-50 MWth) - (in mg/Nm^3 or as indicated)

Combustion Technology / Fuel	Particulate Matter (PM)	Sulfur Dioxide (SO_2)	Nitrogen Oxides (NOx)	Dry Gas, Excess O_2 Content (%)
Engine				
Gas	N/A	N/A	200 (Spark Ignition) 400 (Dual Fuel) 1,600 (Compression Ignition)	15
Liquid	50 or up to 100 if justified by project specific considerations (e.g. Economic feasibility of using lower ash content fuel, or adding secondary treatment to meet 50, and available environmental capacity of the site)	1.5 percent Sulfur or up to 3.0 percent Sulfur if justified by project specific considerations (e.g. Economic feasibility of using lower S content fuel, or adding secondary treatment to meet levels of using 1.5 percent Sulfur, and available environmental capacity of the site)	If bore size diameter [mm] < 400: 1460 (or up to 1,600 if justified to maintain high energy efficiency.) If bore size diameter [mm] > or = 400: 1,850	15
Turbine				
Natural Gas =3MWth to < 15MWth	N/A	N/A	42 ppm (Electric generation) 100 ppm (Mechanical drive)	15
Natural Gas =15MWth to < 50MWth	N/A	N/A	25 ppm	15
Fuels other than Natural Gas =3MWth to < 15MWth	N/A	0.5 percent Sulfur or lower percent Sulfur (e.g. 0.2 percent Sulfur) if commercially available without significant excess fuel cost	96 ppm (Electric generation) 150 ppm (Mechanical drive)	15
Fuels other than Natural Gas =15MWth to < 50MWth	N/A	0.5% S or lower % S (0.2%S) if commercially available without significant excess fuel cost	74 ppm	15
Boiler				
Gas	N/A	N/A	320	3
Liquid	50 or up to 150 if justified by environmental assessment	2000	460	3
Solid	50 or up to 150 if justified by environmental assessment	2000	650	6

Notes: -N/A/ - no emissions guideline; Higher performance levels than these in the Table should be applicable to facilities located in urban / industrial areas with degraded airsheds or close to ecologically sensitive areas where more stringent emissions controls may be needed.; MWth is heat input on HHV basis; Solid fuels include biomass; Nm^3 is at one atmosphere pressure, 0°C.; MWth category is to apply to the entire facility consisting of multiple units that are reasonably considered to be emitted from a common stack except for NOx and PM limits for turbines and boilers. Guidelines values apply to facilities operating more than 500 hours per year with an annual capacity utilization factor of more than 30 percent.

Source: IFC, (2007).

Noise guidelines for power generation

Floating powerplants create noise, just like land-based powerplants, and have therefore an impact on the people who live in the neighborhood and on the wildlife. The World Health Organization (WHO) has addressed the problem of community noise since 1980 and released the Guidelines for Community Noise in 1999 (Berglund et al., 1999). These guidelines were prepared as a practical response to the need for action on community noise at the local level, as well as the need for improved legislation, management, and guidance at the national and regional levels.

Environmental requirements for ships

The International Maritime Organization (IMO) is a specialized agency of the United Nations responsible for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships. Self-propelled floating powerplants above a certain gross tonnage (depending on the regulations but often 400 GT) need to comply with the IMO conventions:

- The complete list of IMO conventions can be found on the website of the IMO (ongoing-b). Not all conventions apply to self-propelled floating powerplants. Conventions such the Convention for safe containers, the Convention for safety of fishing vessels and the Special trade passenger ship agreement are of course not intended for self-propelled floating powerplants.
- One of the most important IMO conventions with regard to the environment is MARPOL, the International Convention for the Prevention of Pollution from Ships (IMO, 1973 -). It

includes regulations aimed at preventing and minimizing pollution from ships, both from operational or accidental causes, and currently includes six technical annexes. Most annexes include ‘special areas’ with stricter controls on operational discharges. MARPOL sets limits for pollution of the air (for example, SO_x, NO_x and PM emissions), but also for pollution of the water (for example, oil, sewage and garbage). The current Emission Control Areas (ECAs) for NO_x, SO_x and PM emissions are shown in Table 8. The SO_x limits in and outside these ECAs are shown in Table 9.

- Continuous noise from floating powerplants can have an adverse impact on human health, not only for crew (if applicable), but also for residents in the area (if applicable). Self-propelled floating powerplants need to comply with a regulation (MSC, 2012a) in the International Convention for Safety of Life at Sea (SOLAS) that requires ships to be constructed to reduce on-board noise and to protect personnel from noise, in accordance with the maximum noise level limits sets out in the Code on noise (MSC, 2012b)levels on board ships.
- The International Maritime Labour Convention (ILO, 2006) also has requirements with respect to preventing the risks of exposure to hazardous levels of noise on board of ships.

Table 8 - Current Emission Control Areas (ECAs) established by the IMO

Emission Control Areas (ECAs)	SO_x and PM limits in effect from	NO_x limits in effect from
Baltic Sea	May 19th, 2006	January 1st,2021**
North Sea	November 22nd, 2007	January 1st,2021**
North America ECA	August 1st, 2012	January 1st,2016*
United States Caribbean Sea	January 1st, 2014	January 1st,2016*

* A ship built on or after January 1st 2016 and operating in this ECA must comply with NO_x Tier III standards as set out in Article 13.5 of MARPOL Annex VI.

** A ship built on or after January 1st 2021 and operating in this ECA must comply with NO_x Tier III standards as set out in Article 13.5 of MARPOL Annex VI.

Source: IMO, (2021).

Table 9 - SO_x limits inside and outside ECAs

Global	Inside SO_x ECA
4.50% m/m before January 1st, 2012	1.50% m/m before July 1st, 2010
3.50% m/m on or after January 1st, 2012	1.00% m/m on or after July 1st, 2010
0.50% m/m on or after January 1st, 2020	0.10% m/m on or after January 1st, 2015

Source: IMO, (2019).

Table 8 - NO_x limits inside and outside ECAs

Tier	Date	NO_x limit, g/kWh		
		n < 130	130 ≤ n < 2,000	n ≥ 2,000
Tier I	2000	17.0	45 n-0.2	9.8
Tier II	2011	14.4	44 n-0.23	7.7
Tier III	2016†	3.4	9 n-0.2	1.96

† In NO_x Emission Control Areas (Tier II standards apply outside ECAs).

MARPOL Annex VI NO_x emission limits (DieselNet, ongoing).

Underwater noise guidelines for ships

There are no international regulations as yet regarding underwater noise and water temperature heating (for example due to the use of cooling water systems on board).

However, it has been proven that the behavior of underwater life is influenced by underwater noise. The impact of sound on marine life depends on its level (in decibel) and frequency (in hertz). Sounds between 120-170 dB can disturb animal behavior, while sounds above 170 dB can even injure marine animals. For reference, a cargo ship creates sounds of about 192 dB. Some frequencies may be of particular concern, for example those that overlap the frequencies of whale calls.

- The impact of noise on endangered species, such as whales and sea turtles should be carefully considered.
- Although compliance is not mandatory, the IMO has made Guidelines for the reduction of underwater noise from commercial shipping to address adverse impacts on marine life. These guidelines focus on the primary sources of underwater noise, such as propellers, hull form, on-board machinery, and various operational and maintenance recommendations such as hull cleaning. Since floating powerplants are moored at one location for a long period, the focus must be on the on-board machinery.
- Depending on the location where the floating powerplant is deployed, there may also be local regulations which have to be complied with. The U.S., for example, has the following regulations to minimize the effect of underwater noise:
  - the National Environmental Policy Act (NEPA);
  - the Marine Mammal Protection Act (MMPA);
  - the Endangered Species Act (ESA).

  (Stakeholders, 2022)

Safety related aspects

One of the most important IMO conventions with regard to safety is SOLAS, the International Convention for the Safety of Life at Sea (IMO, ongoing-a) (which applies to ships (and thus also to self-propelled floating powerplants) above 300 GT. The main objective of this Convention is to specify minimum standards for the construction, equipment, and operation of ships, compatible with their safety. Flag States are responsible to ensure their flagged ships comply with these requirements. Safety is also part of the verification scope of classification societies. Classification societies therefore check during their surveys whether the floating powerplants meet these safety requirements.

Seaworthiness

Floating powerplants must comply with technical standards for construction and operation. A ship classification society is a non-governmental organization that establishes and maintains these technical standards for the construction and operation of ships and offshore structures. Bureau Veritas (BV) and the American Bureau of Shipping are examples of classification societies that have developed guidelines and requirements for reviews of design, construction, and survey for class designation, as well as approval for ‘power service’ vessels. These guidelines apply to both new constructions and conversions of existing ships, and to manned and unmanned barges.

The guidelines set requirements for various aspects of the floating powerplant, such as:

- hull construction and equipment;
- machinery, piping and electrical systems;
- safety systems;
- power generation, battery and distribution systems and equipment.

The guidelines of classification societies for floating powerplants (or power service vessels) are still under development and the power generation equipment currently falls outside the mandatory verification scope of the classification societies. Only at the specific request of the owner is the power generation equipment included in the verification scope. However, since classification societies do verify the safety of the entire floating powerplant, the adjacent systems of the power generation equipment and all safety related aspects on board of the floating powerplant are included in the surveys (Stakeholders, 2022)

The guidelines also provide requirements for the surveys that need to be carried out, both during construction, commissioning, and after construction (during operation) (ABS, 2022)

Classification societies focus mainly on technical and safety requirements.

2.6 Case studies of action against the deployment of powerships

From a government and utility perspective, it can be useful to deploy floating powerplants to generate the necessary electricity in certain remote regions or on islands. It is a proven technology that can satisfy energy needs quickly. They can also be financially attractive, as governments or energy supply utilities only need to pay operational costs if the deployed floating powerplants are owned by another entity. In the absence of a (sustainable) infrastructure on land for power generation, the deployment of floating powerplants can offer a (temporary) solution for these parties. The deployment of floating powerplants, however, can also be controversial. Three recently proposed floating powerplant projects in the Dominican Republic, South Africa, and Pakistan were controversial and highlight some of the concerns about these projects.

Dominican Republic

In the Dominican Republic floating powerplants are moored at the mouth of the Ozama river in the middle of the city center of Santo Domingo. Floating powerplants have been in operation at this location since 1989. The Ozama river is one of the most important rivers that flows into the Caribbean Sea and Santo Domingo is a busy touristic town. Some residents of the neighborhoods complain about disease caused by air pollution and vibration and noise from the powerbarges. There are also concerns about heating of the river water from cycling through the powerplants' cooling systems and potential impacts on oxygen levels and the associated impacts on aquatic life. Some organizations in the Dominican Republic have filed an appeal against the deployment of these floating powerplants at the mouth of the Ozama river, claiming that it affects human health and is therefore illegal under Dominican law.

Another ~280 MW powerbarge is installed in the tourist area of Boca Chica, on the east side of Santo Domingo. There is opposition to this powerbarge due to the potential damage to the ecosystem. The same applies to powerbarges located in San Pedro de Macoris in the Eastern part of the Dominican Republic, due to concerns about the impact on human health and the environment.

Despite some organizations and communities expressing serious concern about the impact on human health and environment, these floating powerplants have not yet been found to be operating outside of regulatory or legal requirements(Stakeholders, 2022).

South Africa

In March 2021, the Minister of Mineral Resources and Energy in South Africa announced that eight preferred bidders had been selected for the Risk Mitigation Independent Power Producer Procurement Program (RMIPPP) to reduce the country's reliance on expensive peaking plants and to fill the short-term electricity supply gap. These proposals included three gas-fueled powership projects of Karpowership to be located in Richard's Bay KwaZulu-Natal, Ngqura Eastern Cape, and Saldanha Bay Western Cape in South Africa.

The Department of Forestry, Fisheries, and the Environment (DFFE) in South Africa refused to provide the environmental authorizations required for the floating powerplants. Small-scale fishers from the West Coast and some other stakeholders sent responses to the Environment Minister, commending the DFFE and urging her department to also refuse the decision. In their view, there were several serious flaws in the Environmental Impact Assessment (EIA). Green Connection, a not-for-profit organization established in South Africa and focused on a sustainable environment, supported this opinion. No underwater noise study was conducted and, in their view, it is impossible to comprehend the impact that the powerships, which could operate for 20 years, would have on the marine environment and fish that small-scale fishers depend on. In addition, there were also other concerns and issues, including the impact on public safety, the impact on air quality, and the impact on ambient noise levels in residential areas. Green Connection made submissions to the DFFE and welcomed the refusal from the Minister to grant Karpowership an EIA authorization.

Karpowership and the Environmental Assessment Practitioner (EAP) appealed against the refusal of the DFFE. As result of the refusal, they subsequently provided noise levels for their powerships operating in Ghana. Based on this information, they tried to prove that Karpowership's operations will not have a negative impact on marine life in South African ports. Green Connection had an expert take a critical look at the analysis of the noise studies and found that it was not credible or independent and did not form a sound basis for decision-making. The noise levels were not based on modelling of the sound that would be produced by powerships of Karpowership in the South African ports where they are intended to be located.

The current situation is unknown: it is unclear whether this case has now been settled or whether Karpowership is still appealing against the refusal to grant authorization for the deployment of its powerships in South Africa (The Green Connection, 2021).

Pakistan

Karadeniz Powership Kaya Bey and Karadeniz Powership Ali Can Bey of Karpowership were deployed in Karachi in Pakistan in 2010 and 2011, for both power generation and to deliver humanitarian aid for the victims of the 2010 Pakistan floods. They were contracted to bridge the electricity shortage for the 12 million people of Karachi for a five-year term. Both powerships burn heavy fuel oil (HFO), the only available energy resource in Pakistan (bigpara, 2010).

However, Karadeniz Powership Kaya Bey and Karadeniz Powership Ali Can Bey generated electricity for Pakistan only for two years (until the end of 2012), because they were set to return to Turkey after the Pakistani High Federal Court cancelled all energy rental agreements in the country on the grounds that the energy deals were undertaken in an irregular manner. Authorities decided the ships had to leave after repaying the unused amount of the $ 17.2 million deposit issued by the Pakistani government.

However, a Pakistani member of parliament lodged an objection with the court, claiming that Turkish ship-owners Karkey – a subsidiary of Karadeniz Holding – should pay a certain amount of money including interest for the ships release. The court blocked the ships from leaving the country, and Kaya Bey and Ali Can Bey, with a value of $ 400 million, were detained in the territorial waters of Karachi, one of the main cities of Pakistan (Daily News, 2012).

Almost two years later, in 2014, Karadeniz Powership Kaya Bey left Pakistan after a decision of the International Centre for Settlement of Investment Disputes (ICSID). Karadeniz Powership Ali Can Bey was still retained at that time.

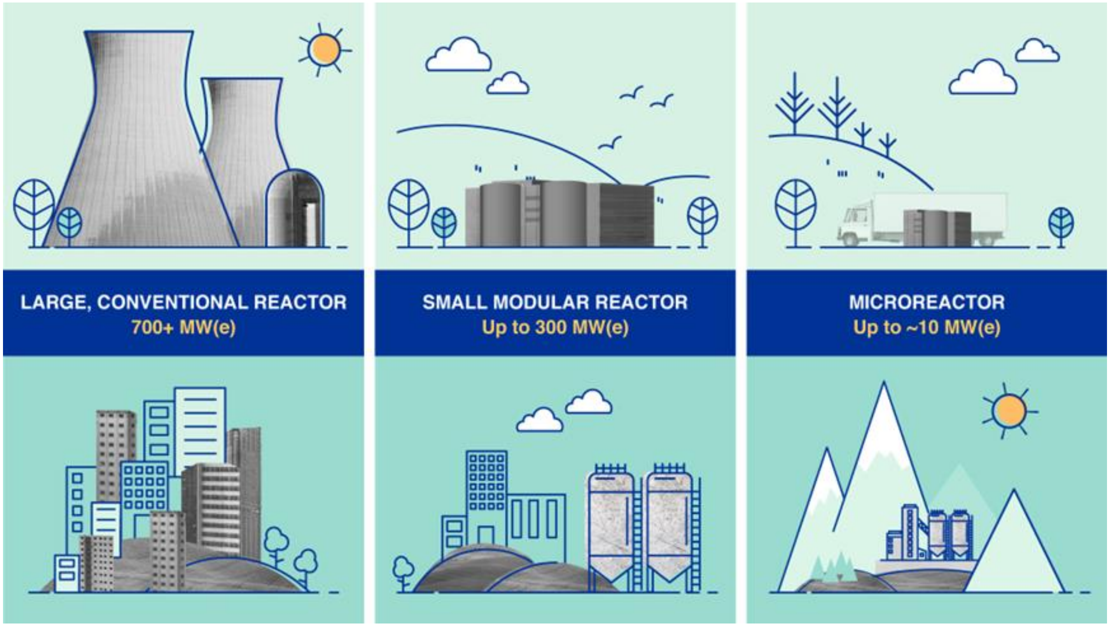
A tribunal constituted under the World Bank's arbitral center, ICSID, issued the award in August 2017 in favor of Karpowership in the case filed by Karpower against Pakistan. Pakistan was ordered to pay the company one of the highest compensation amounts under ICSID. The dispute was finally resolved at the end of 2019, although the final terms were not publicized (Dawn, 2019).

2.7 Overview of floating nuclear powerplants

In addition to using common fuels such as fuel oil, diesel oil, gas oil and LNG, there is also the option for floating powerplants to convert nuclear energy into power. This section provides an overview of nuclear floating powerplant developments and the market.

There are a considerable number of developers of small modular nuclear reactors, SMR's, many of which are conceptual. These are classified as delivering power in the range of 10-300 MWe (see Figure 8) and are the types of reactors used for floating powerplants.

Figure 8 - Classification of SMRs



Source: IAEA, (2021).

Smaller nuclear units have operated for decades and have proven their applicability in remote areas and in marine vessels like ice breakers. Their main advantages are their small footprint and the very long period between 'refueling' (change of elements) - typically 2-10 years. These characteristics have spurred interest in the development of floating nuclear powerplants (FNPP) or Optimized Floating Power Units (OFPUs). These are power facilities, usually in the form of a compact non-self-propelled vessel or barge, which can have a small modular reactor plant on board. This similar to existing small nuclear reactors in ships and submarines. The FNPP reactors are typically Small Modular Reactors of less than 300 MWe, but can also be as large as a few MWe's. There are safety issues related to the use of nuclear power (though manageable as it has been used in subs and icebreakers for years) as well as the environmental issue of the ultimate disposal of spent rods. Additionally, these aspects could add cost to the price per kWh.

Figure 9 shows an artists impression of an OFPU powerbarge with Russian reactors.

Figure 9 - Optimized Floating Power Unit with two RITM-200M rector plants

Source: IAEA, (2020).

2.7.1 What is the status of FNPP's?

Although Russia has been at the forefront of developing nuclear floating powerplants, many other countries have development projects in different Technology Readiness Levels (TRL) as well, see Table 9.

Both public and private institutions are actively participating in efforts to bring SMR technology to fruition within this decade. Russia's *Akademik Lomonosov*, the world's first floating nuclear powerplant that began commercial operation in May 2020, is producing energy from two 35 MW(e) SMRs. Other SMRs are under construction or in the licensing stage in Argentina, Canada, China, Russia, South Korea and the United States of America.
More than 70 commercial SMR (IAEA, 2020) designs being developed around the world target varied outputs and different applications, such as electricity, hybrid energy systems, heating, water desalinization, and steam for industrial applications. Though SMRs have lower upfront capital costs per unit, their economic competitiveness is still to be proven in practice once they are deployed (IAEA, 2021).

Figure 10 – Small modular reactor in a floating nuclear powerplant

Source: IAEA, (2020).

Table 9 provides a list of various supplier SMR activities focused on floating nuclear powerplants.

Table 9 – A list of various supplier SMR activities focused on floating nuclear powerplants

No.	Country	Power (MWe)	Refueling interval (year)	Tag	Application	Status	Remarks
1	USA	10	10	MH-1A	Military	Realized, historical.	First, mounted on Liberty ship in Panama from 1968-77.
2	Russia	38.5*	3-4	KLT-40S	Remote	Connected to the grid in Pevek in December 2019. Entered full commercial operation in May 2020.	PWRs derived from icebreakers, OKBM Afrikantov. Two units are mounted on a 21,500 tonne barge.
3	Russia	20	10	KLT-20	Barge	In development.	Specifically designed for floating nuclear plants.
4	Russia	50	10-12	RITM-200M/N	Ice breaker /barge	In development for FNPP. 6 Prototype reactors were manufactured and installed on icebreakers (two are in the process of testing).	Specifically designed also for floating nuclear plants, OFPU, planned.
5	Russia	110/200	2 or 5	VBER-150/300	Civil/ship	In development.	Originally envisaged in pairs as a floating nuclear powerplant, displacing 49,000 tonnes.
6	Russia	4-18	10-12	ABV-3/6M	Barges (1,600/3,500 tonne)	In development.	Factory-produced and designed as a universal power source for floating nuclear plants.
7	USA	77	?	NuScale	Land/barge	In development.	$5.078/kWe net, levelized cost of electricity (LCOE) expected to be $ 90-100/MWh. MOX fuel compatible. With Fluor, Samsung C&T. NRC design approval of 50 MWe version in Sept. 2020.
8	South Korea	60	4-5	BANDI-60S	Barge	In development.	Designed particularly for floating nuclear powerplants.
9	France	100->300	?	Nuward NP-300	Navy/civil	In development.	TechnicAtome/CEA/EdF.

No.	Country	Power (MWe)	Refueling interval (year)	Tag	Application	Status	Remarks
				(K15 naval)			Flexblue submerged nuclear powerplant version was cancelled. EdF plans basic design pre-licensing phase with ASN in 2022. Some € 1 billion state funding promised.
10	China	125	2	ACP100S Linglong One	Land/barge	In development.	IAEA report Generic Reactor. Safety Review process. UK-Lloyd's Register support.
11	China	40/220	2	CAP50/200 OceanstarV	Land/barge	In development.	CAP50 is SNERDI project.
12	China	60	2.5	ACPR50S	Barge	In development, planned construction.	Construction start announced at Bohai Shipyard in November 2016.
13	China	25	?	HHP25	Off-shore	In development.	Offshore nuclear power platform with 29,800 t. displacement. Derived from a submarine reactor.
14	Denmark	~125	?	Seaborg Technologies	Land/barge	In development, planned construction.	Compact Molten Salt Reactor (CMSR). American Bureau of Shipping (ABS) feasibility statement for use on 200-500 MWe barges. Runs on spent LWR fuel and thorium. Very fast power ramp time claimed. High temperature output will allow application to hydrogen production, synthetic fuels, etc. Full scale planned 2025.

* Power only, no heat production.

The Chinese nuclear powerbarge development of **C**hina **G**eneral **N**uclear Power Group, CGN presents a floating reactor concept (see Figure 11).

Figure 11 – CGN’s floating reactor concept

2.8 Expected developments in the floating powerplant market

Even though the first floating powerplant was designed and built almost one hundred years ago, the market has only started developing in the recent decades. Large player Power Barge Corporation was founded in 2000 and the other large player Karpowership started producing its floating powerplant fleet in 2007.

Based on the interviews conducted it seems that the market will continue to grow. Karpowership, for example, still has floating powerplants under construction, which will double its power generation capacity. In addition to the large players (Karpowership and Power Barge Corporation), smaller players are also entering the market. These small players are mainly well-known equipment suppliers who are expanding the services they are offering. Moreover, floating powerplants are currently not only deployed in developing countries where there is a temporary shortage of electricity, but they are also deployed in developed countries. An example is the supply of power to cruise ships in ports so that they can shut down their own generators, which improves the local air quality. We therefore concluded that there is an increase in the number of stakeholders, both on the supply and on the demand side of the market. However, we expect that the developing world will continue to dominate the market for floating powerplants and that a much smaller volume will fulfil niche applications in the developed world.

We also see collaborations being established to gain more control and influence over the entire energy chain. An example is the joint venture between Karpowership and Mitsui OSK Lines, also called KARMOL. Their FSRU, called KARMOL LNGT AFRICA, will enable KARMOL to offer LNG powered electricity to Senegal (a country in West Africa) using the Karadeniz Powership Ayşegül Sultan of Karpowership. The combination of an FSRU and a powership will bring power, converted from LNG, to countries with no domestic gas supply (Karpowership, 2021b).

The players in the market are aware of the energy transition and are increasing the use of fuel with a lower impact on local air quality compared to a couple of years ago, such as LNG. Moreover, manufacturers of power generating equipment are already developing equipment which can run on renewable fuels, such as e-ammonia, methanol, or hydrogen. At the same time, classification societies are developing guidelines for the classification of power service vessels, which indicates that they see a growing floating powerplant market as well.

However, based on the interviews conducted and on our desk research, we conclude that the floating powerplant market is still a niche part of the global electricity generation market and will remain so, even with the expected growth in the number of floating powerplants. Nuclear floating powerplants can be described as a niche within the niche market of floating powerplants.

3 Environmental and social impact

Floating powerplants can replace conventional modes of power generation on land or be deployed instead of expanding generation capacity on land. When assessing the environmental impacts of floating powerplants, conventional land-based power generators provide a relevant benchmark. However, the conventional option to power generation is largely dependent of the specifics of the local situation.

Industrial areas located near the shore have the conditions necessary for the construction and operation of large efficient powerplants, i.e. space, grid capacity, and ample cooling water. In such cases, the capital and operating costs and the availability of coal, gas, or renewables will determine the generation asset of choice and the emission profiles.

Smaller isolated communities, such as islands, have different conditions. Because of the smaller demand for power, they often rely on generator sets which are less energy efficient. They also usually do not choose to clean the exhaust gas although more modern engines may have $DeNO_x$ and SCR installed.
This chapter therefore provides information regarding the environmental and social impact of floating powerplants. Section 3.1 compares the global and local impact of floating powerplants and powerplants on land. Section 3.3 explains the societal impact and lock-in considerations. And finally, several potential risks and a number of accidents that actually occurred are further discussed on Section 3.4.

3.1 Global impact and local impact

This section analyses the comparative environmental impact of emissions of powerships and powerbarges. It compares the emissions of conventional land-based generation assets (Section 3.1.1) with the emissions of powerships and powerbarges (Section 3.1.2) and draws conclusions in Section 3.1.3. Please note that the local land-based power generation emission benchmark may apply a fuel other than the fuel used by the powership or powerbarge of the project, such as the use of LNG instead of HFO by powerships or powerbarges will be important for the outcome in this comparison.

Emissions affect the environment depending on their nature. Greenhouse emissions such as carbon dioxide (CO_2) and methane (CH_4) affect the climate on a global scale, while SO_x, NO_x and particulate matter of 2.5 micrometers or less ($PM_{2.5}$) affect local environment and the health of people living and working nearby. The level of emissions depend on fuel type, conversion type and added emission control measures.

3.1.1 Reference impact of typical conventional power generation

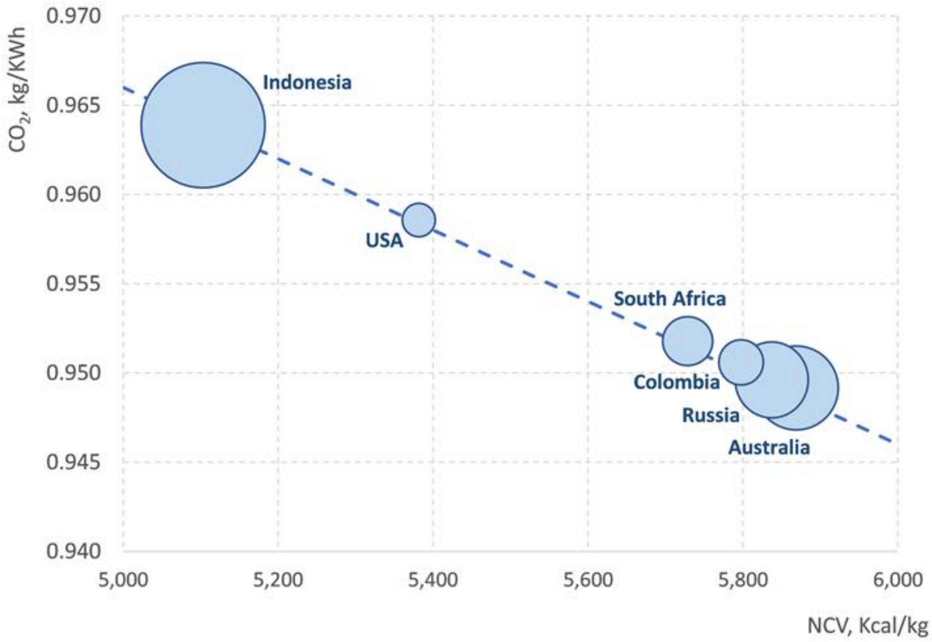
This section summarizes the emissions of conventional power generation. Because the emissions depend to a large extent on the type of fuel used, this section is organized by fuel type. It starts with emissions of coal-fired powerplants, followed by powerplants running on natural gas and finally summarizes the emissions of diesel generator sets.

Emissions of coal-fired powerplants

CO_2 emissions

Emissions of coal powerplants depend on the energy content of the coal used, the plant age, heat to power conversion efficiency, and the level of integration of the powerplant. These aspects vary per country and therefore so does the level of CO_2 emissions per kWh, although the difference is limited to a few percent. Some typical CO_2 emissions per country or region using different coal types are shown in the following figure:

Figure 12 – Typical CO_2 emissions of coal fired powerplants for the above mentioned countries



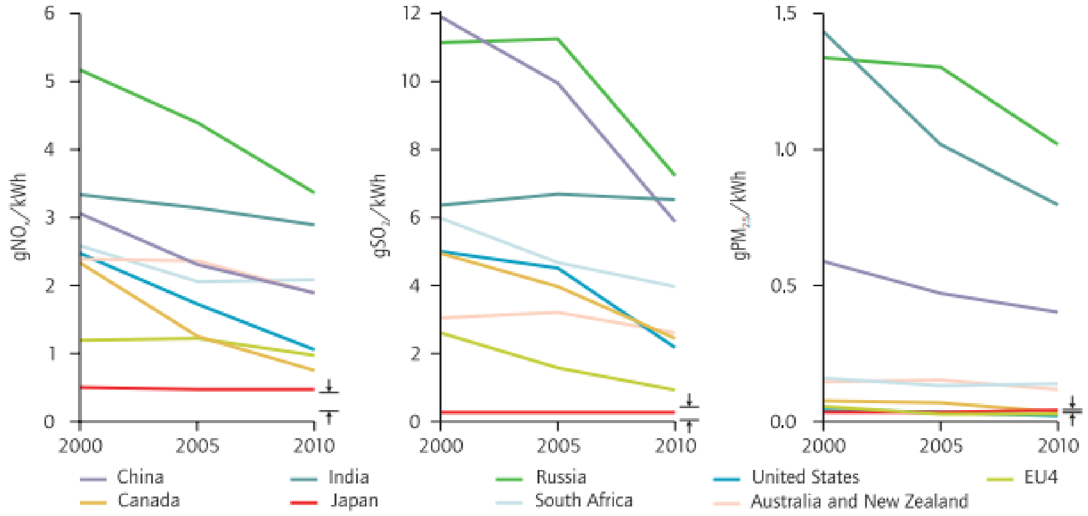
Source: Coaltrans, (2021).

CO_2 emissions therefore range from 947 to 965 g/kWh for the above mentioned countries. When relating powership emissions to land-based values these regional difference can be taken into account.

Local emissions

Emissions with local impact include NO_x, SO_2, and Particulate Matter (PM). Emissions of these pollutants are highly dependent on the use of end-of-pipe pollution abatement technology, the adoption of which is generally driven by regulations. Over time, countries tend to adopt more state of the art pollution abatement technologies and achieve lower emission rates (Figure 13).

Figure 13 - NO_x, SO_2 and PM emissions from coal-fired powerplants



Note: EU4 includes France, Germany, Italy and the United Kingdom. Ranges sandwiched between the arrows indicate currently achievable performances from flue gas treatment systems.

Source: Includes data from Cofala *et al*, 2010.

Source: IEA, (2012).

A new powerplant that is conducive to the local context should be used as a reference power generation facility with which to compare a floating powerplant. Powerplants in developed countries like Japan are more likely to be equipped with state-of-the-art technologies for efficient power generation and exhaust gas treatment than powerplants in developing countries like India. The end points in time of the emission trends per country in the preceding graphs can be taken as a starting point for the future where new High Efficiency Low Emission (HELE) technologies are being applied.

The outlook for future High Efficiency Low Emission (HELE) technologies for coal, including the energy penalty when applying CCS, is indicated in the following figure:

Figure 14 - Performance of HELE coal-fired powerplant with CCS

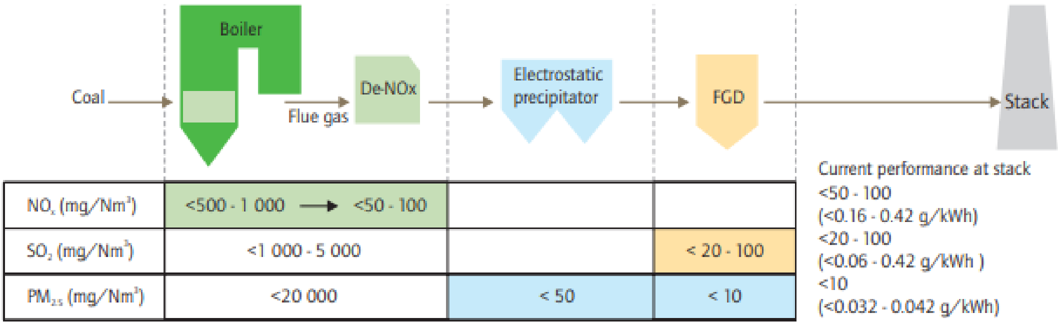
Fuel type	Plant type	Emissions CO_2 (g/kWh)	NO_x (mg/Nm³)	SO_2	PM	Max. unit capacity (MWe)	Capacity factor (%)	CCS energy penalty (%-points)
Coal	PC (USC)	740	<50 to 100 (by SCR)	<20 to 100 (by FGD)	<10	1 100[3]	80	7 to 10 (post-combustion and oxy-fuel)
	CFBC	880 to 900	<200	<50 to 100 (in situ)	<50	460	80	
	PC (A-USC)[1]	670 (700°C)	<50 to 100 (by SCR)	<20 to 100 (by FGD)	<10	<1 000 (possible)	-	
	IGCC[1,2]	670 to 740	<30	<20	<1	335	70	7
	IGFC[1]	500 to 550	<30	<20	<1	<500	-	

[1] Under development.
[2] Only six IGCC plants currently in operation.
[3] In operation (sliding pressure-type).
Note: For the successful realisation of IGFC, the development of reliable fuel-cell technology is essential.
Source: Includes data from IEA, 2011a; Henderson and Mills, 2009; and VGB, 2011.Source: VBG, 2011.

Source: IEA, (2012).

Reduction of emissions other than CO_2 are obtained by the serial connection of flue gas treatment systems as shown in Figure 15.

Figure 15 - Reduction of different emissions (left) by various gas treatment systems (top)



Note: To convert mg/Nm³ into g/kWh, it is necessary to assume values for the plant efficiency and the flue-gas volume per unit of energy. In Figure 18, plant efficiency is assumed to range from 30% to 40% (LHV, net) based on regional average efficiencies. The flue gas volume is assumed to be 353 m³/GJ (LHV); this will vary with coal composition, but the fluctuation from this value is commonly less than 5%.

Source: IEA, (2012).

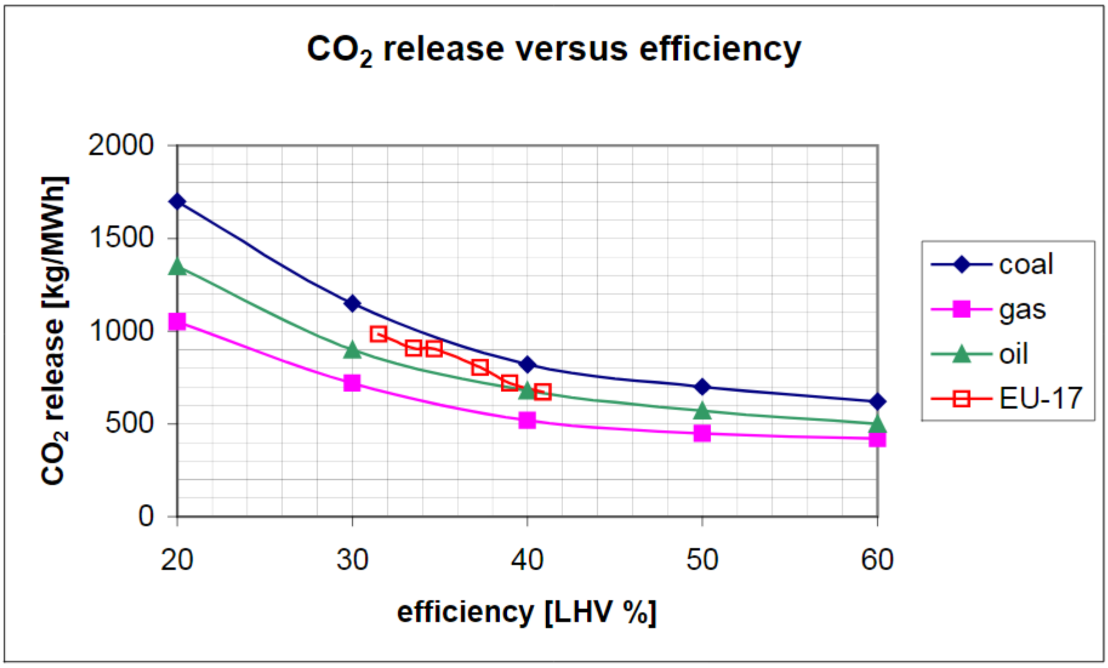
Flue gases are cleaned in three steps. First, the concentration of NO_x is reduced by the $DeNO_x$ process connected to the boiler. This process is based on the addition of ammonia reacting with nitrogen gas and a catalyst may be used. This is then followed by the electrostatic precipitator which removes particulate matter PM. Then SO_x is removed in a Flue Gas Desulphurizer FGD. If carbon capture is applied, the desulphurization of the treated flue gas should be complete in order to protect the capture solvent.

Natural gas powerplants

CO_2 emissions from combustion

Modern land-based natural gas powerplants operate in a combined cycle for optimal power generation efficiency. This results in lower CO_2 emissions per kWh of electrical energy produced compared to other types of power generation, as shown in the figure:

Figure 16 - CO_2 emission per kWh versus efficiency for natural gas and other fuels



Source: Steen, (2001).

Typically, the lowest CO_2 emission value for land-based combined cycle power generation with natural gas amounts to about 400 gCO_2/kWh.
Note: the origin of the natural gas and its logistics may add greenhouse gas emissions due to leakages. For example, natural gas from West-Siberia faces more methane leakage from the gas pipelines than natural gas from other regions.

Small generator plants

For particular locations, i.e. small islands, the land-based benchmark is comprised of diesel generators. Many diesel generator sets originate from the USA. In 1994 the EPA along with major diesel engine manufacturers (Caterpillar, Cummins, Detroit, and others), and the California Air Research Board (ARB) collaborated to release a structured plan aimed at reducing diesel engine emissions. A tiered approached was introduced for the reduction of emissions for different kW/hp power classes:

Figure 17 - Tiered approach for diesel generator emissions of different power categories

Source: General Source, (ongoing).

The above tiers are based on the EPA Title 40, Part 1039 regulations for land-based diesel:

Table 10 - Emission limits for different power categories in gram/kWh

Maximum Engine Power (kW)	Application	PM (g/kWh)	NO_x (g/kWh)	NMHC (g/kWh)	NO_x + NMHC (g/kWh)	CO (g/kWh)
kW < 19	All	0.40	-	-	7.5	6.6
19 < kW < 56	All	0.03	-	-	4.7	5.0
56 < kW < 136	All	0.02	0.40	0.19	-	5.0
136 < kW < 560	All	0.02	0.40	0.19	-	3.5
kW > 560	Generator sets	0.03	0.67	0.19	-	3.5
kW > 560	All except generator sets	0.04	3.5	0.19	-	3.5

Source: EPA, non road compliance (EPA, 2022), eCFR, (2022), Paul et al., (2017).

The > 560 kW maximum engine power category for land-based generator sets (yellow) is the most relevant for the benchmarking of floating powerplants, which have generation power numbers in the > 560 kW range.

The CO_2 emissions per kWh of diesel generators can be derived from the fuel consumption, which amounts to 0.263~0.345 L/kWh depending on load and generator size. This results in 0.710~0.932 gCO_2/kWh Paul et al., (2017).

A dataset was found for CO_2 emissions with regard to diesel gensets on an island with an isolated grid with a power demand of 80-90 GWh per year. In a comparative case, existing diesel gensets will be replaced by either new diesel gensets, the benchmark, or by alternative emission free solar-pv. In a study of JCM, (s.d.) it was calculated that a future expected emission factor for new diesel gensets for the Micronesian islands of Palau in order to determine the impact on CO_2 emission reduction when choosing the emission free option of solar-pv. This emission number is related to larger diesel genset powered grids with engines in the range of 2-8 MW power. The following figure depicts power generation efficiency and CO_2 emission of the old existing gensets:

Figure 18 - Power generation efficiency and CO_2 emission factor

		IRENA (in 2011)		SPC (in2009)
		Malakal Power Station	EPSECO Power Station	Palau total
Electricity	kWh	43,375,400	45,375,400	83,000,000
Diesel fuel	US gal	2,650,504	3,640,389	-
Efficiency	kWh/gal	14.2	12.5	-
Diesel fuel	Litre	10,033,249	13,780,371	23,808,000
Efficiency	kWh/litre	4.20	3.30	3.49
Power generation efficiency of existing power station	%	41%	33%	34%
CO2 emission factor	ton-CO2/MWh	0.631	0.804	0.761

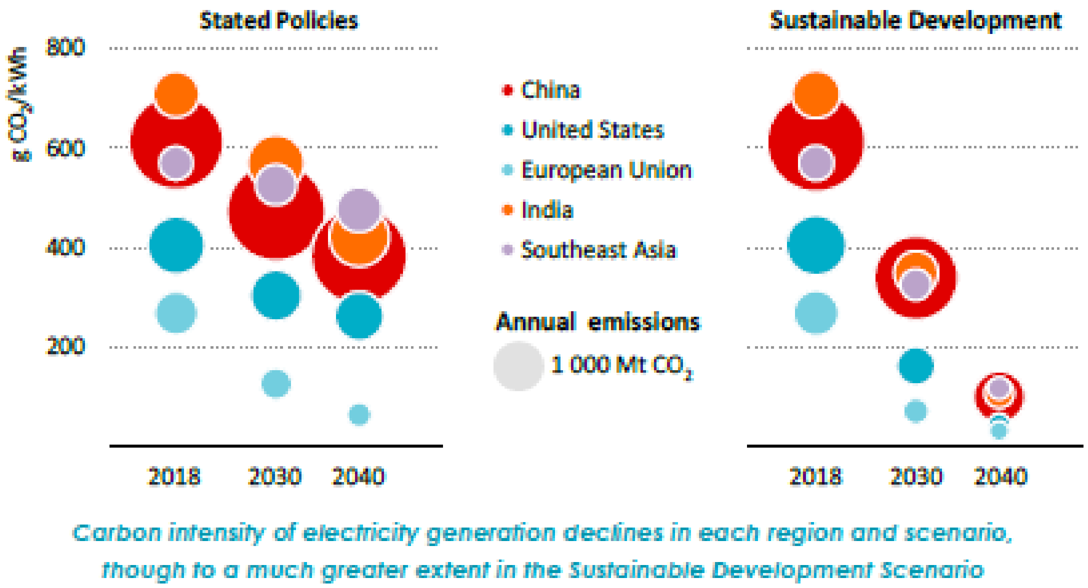
Source: JCM, Displacement of Grid and Captive Genset Electricity by a Small-scale Solar PV System, Additional Information (JCM, s.d.), Paul et al., (2017).

For the benchmarking of the new power gensets, conservatively 49% fuel efficiency was assumed. This results in an emission factor of 0.533 t-CO_2/MWh or **533 grams CO_2/kWh.**

Overall power generation (grid mix)

For the overall power generation (including renewables) typical per continent, please refer to the following graph:

Figure 19 - CO_2 intensity of overall electricity generation by region and scenario



Source: IEA, (2019).

This means that for existing powerplants in 2018, the benchmark for China, India and Southeast Asia or similar regions is approximately **600 g CO_2/kWh**, which is a reasonable benchmark. For the US and Europe, much lower values of **400 and 250 g CO_2/kWh** respectively are foreseen for the overall power production. This value is much lower, while it includes the effect on renewable power generation on emissions of CO_2.
For 2020, for the US this is:

Figure 20 - U.S. electric utility and independent power electricity generation and resulting CO_2 emissions by fuel in 2020

	Electricity generation	CO_2 emissions		
	million kWh	million metric tons	million short tons	pounds per kWh
Coal	757,763	767	845	2.23
Natural gas	1,402,438	576	635	0.91
Petroleum	13,665	13	15	2.13

Electricity generation is net electricity generation.
Includes electricity-only power plants. Combined heat and power plants are excluded because some of their CO_2 emissions are from fuel consumption for heating purposes.

Source: IEA, (2020).Source: EIA, (2021).

This shows that the fuel type of local land-based power generation in the US largely affects the CO_2 emissions per kWh and thus the local US land-based reference. This means that the requirements of a floating powerplant should be stricter near a natural gas plant.

3.1.2 Typical emissions of floating powerplants

Similar to the emissions of powerplants, the emissions of floating powerplants depend on the type of fuel, which is either petroleum-based or natural gas. Because of the limited size available on board, powerships and powerbarges are usually equipped with generators (see Section 3.1.1). Information on the types of generators is scarce. This section summarizes the publicly available information.

CO_2 emissions

In general, typical emission numbers are usually not indicated in engine product datasheets. The interviews conducted indicated that these emission numbers are adapted to the local requirements and typical values for CO_2 could not be provided. However, power generation efficiency is given. Combined with the lower heating value of a specific fuel type, this provides an indicator for CO_2 emissions per kWh as well. CO_2 emission can be calculated per type of fuel using the following data:

Table 11 - CO_2 emission per type of fuel

Fuel type	E (GJ LHV/ton)	CO_2 emission (kgCO_2 /kg fuel)
HFO	39.0	3,762
MGO/MDO	42.8	3,436
LNG	48.6	3,651

Sources: Engineering toolbox (ongoing).
CO_2 emissiefactoren (in Dutch), CO2emissiefactoren.nl, (ongoing).

E-Cap mentioned in the interview they use new engines with a power generation efficiency of **45%** using MGO, (bio) LNG, or green hydrogen with a fuel cell in the future.
This efficiency is similar to power efficiencies of land-based powerplants ((PBL, 2021), Dutch government energy outlook).

MAN applies 4-stroke engines combined with steam turbines, which they indicate have about 60% power generation efficiency, depending on the project. They claim this is higher than most land-based gas turbines.

Siemens describes its SeaFloat powerbarge with its SGT-800 gas turbines for 150- > 650 MW. They claim 4%pt. higher net efficiency than reciprocating engines using diesel/fuel oil. This in a combined cycle of 54.18 (150-300 MW) or 61% (600 MW). With LNG, a 50% reduction of CO_2 emissions is claimed compared to reciprocating engines, but no specific value is indicated.

The efficiency values from the generator engine suppliers we interviewed are stated in the following table:

Table 12 - Supplier generation efficiency per type of fuel

Fuel type	Wärtsilä 4-recip (est.)*	E-cap	MAN	Siemens 150-300 MW	Siemens 600 MW
HFO	50%		60%	54,18%	60%
MGO/MDO	50%	45%	60%	54%	60%
LNG		45%			

Sources: Supplier interviews and -presentations.
* Estimate from: Wärtsila, (2022c).

From these data the CO_2 emissions can be estimated per type of fuel and per supplier, as in the following table:

Table 13 - Typical CO_2 emission per kWh for different types of fuel and suppliers

Fuel type	Wärtsilä 4-recip (est.)	E-cap	MAN	Siemens 150-300 MW	Siemens 600 MW
HFO	695		579	641	579
MGO/MDO	578	642	482	533	482
LNG		601			

The above values can be benchmarked with the existing IEA values for fossil land-based powerplants of 600 g/kWh for Asia (2030) and 400 and 250 g/kWh for the US and Europe respectively (Section 3.1.1). For coal fired powerplants, these figures amount to 500-964 natural gas combined cycle 400 g/kWh and diesel generators on small islands of approx. 533 g/kWh (See Figure 18).

Conclusion CO_2 emissions

The high efficiency of power generators on floating powerplants ensure that their CO_2 emission per kWh is more or less similar to land-based power generation. For land-based combined cycle generation with natural gas this is lower and for diesel generators and coal land-based emissions this is higher. The application of LNG in floating powerplants results in lower CO_2 emissions than HFO or MGO.

Other emissions

Also no full listing of typical other emissions was provided per generator product type and fuel by the suppliers. Wärtsilä provided a more general Environment Product Guide with MARPOL Annex VI-Air Pollution limits for NO_x and SO_x, which they use as a guideline for power generation. Based on local ship regulation emissions, reduction measures are taken.

Emissions per kWh:
- SO_x: 0.5% in fuel (0.1% in fuel for ECA's) or scrubber eq. 0.1 % in fuel;
- NO_x: 7.7-14.4 g (2-3.4 g for ECA's), depending on rpm. SCR ECA/optional 75 (BAT)-400 (dual fuel) g/Nm^3;
- Sea Float: < 25 ppm.

3.1.3 Typical emissions compared

Table 14 - Comparison of emissions of land-based and floating powerplants

Mode of generation	Net efficiency (%)	CO_2 (kg/MWh)	NO_x (g/MWh)	SO_x (% based on fuel)	$PM_{2.5}$ (g/MWh)
Land-based					
Powerplants					
– Natural gas	Up to 60				
– Coal		500-965	< 30-< 200 g/Nm^3	< 20-100 g/Nm^3	< 1-< 50 g/Nm^3
Overall average 2018, incl. renewables		600 (Asia) 400 (US) 250 (EU)			
Diesel GenSets > 560 kW small islands		533-930	670		30
Floating powerplants					
Wärtsilä		578-695	35-97 ppm SCR: 5-35 ppm	0.5% 0.1%*	
E-Cap, various	45	601-642			
MAN	60	482-579			
Siemens 150-300 MW	54.18	482-641			
Siemens 600 MW	61				

* For ECA's.

Conclusions on emissions

The typical power generation efficiencies of new floating powerplants are not significantly lower than larger land-based powerplants, quite the contrary. Therefore similar or better CO_2 emission values are expected compared to fossil land-based power generation. Displacement of renewable projects should be avoided, but powerships may also be used for solving imbalances caused by renewables. Suppliers should prove CO_2 emissions are the same or better when compared to local land-based standards.

For local emissions, interviews indicate that at a minimum powerships and powerbarges comply with local land-based regulations. This means that in some countries and regions $DeNo_x$/SCR systems will be added for emission reduction. Application of LNG as a fuel also reduces both CO_2 and local emissions, but methane leakage should be corrected. Suppliers should prove that they meet local land-based standards or better.

3.2 Emissions to water

In the interviews, we identified several types of possible emissions into water.
These emission types comprise:
1. Emissions from cooling water.
2. This is focused on thermal emissions to surface water. In sensitive areas, such as near coral reefs and fishing grounds, this can be mitigated with (noiseless) top air coolers.
3. Emissions from lubrication systems.
4. Limited risks were seen here due to the common practice of placing a sump under the engines, which collects all lube oil losses. For other oil containing streams, an Oily Water Separator (OWS) should be used.
5. Emissions from leaks from fuel storage tanks, such as during a fire.
6. This type of incident is regarded as identical for land-based power generation plants where fuel storage tanks are placed near the shore to enable easy logistics. This risk is also mitigated by placement of a concrete sump under the fuel storage tanks and preventive measures such as the pre-emptive use of floating booms, having oil skimmers in place and a ready supply of sorbents, dispersants and chemical stabilizers.

3.3 Societal impact and lock-in considerations

The decision for choosing a powership or powerbarge can be made under different conditions:
1. Emergencies/short-term temporary power after a disaster.
2. Mid-term bridging of grid issues and new powerplant construction delays.
3. Long-term solution.

And these decisions can be made for use in:
- developing countries;
- developed countries.

and:
- remote areas/small islands;
- populated or industrial areas.

In both developing as well as developed countries, powerships and powerbarges can fill eventual gaps in the availability of power. In critical ‘life-or-death’ situations there will be less discussion about cost per kWh, CO_2, SO_x, NO_x and PM emissions and noise. If areas are remote, the lack of power infrastructure plays a significant role in the choice of power production. Therefore, a floating powerplant’s emission and cost profile should be benchmarked based on the local context, e.g. against diesel gensets that are the norm for local land-based generation. In developing countries, lack of access to stable and secure power affects economic opportunities, the provision of health care and education, and safety. Floating power may be the only option and the difference between life without electricity and life with electricity, and is a balancing act between cost, noise, impact on fishing, and lastly air quality.

In populated areas, large scale powerplants are the norm. Here, cost per kWh, emissions of CO_2, SO_x, NO_x and PM of floating powerplants should be benchmarked against these large-scale powerplants and the presence of renewables in the grid mix. This means that where large coal fired powerplants are a viable alternative, floating powerplants with modern engines can readily result in less emissions. But in locations where natural gas fired combined cycle powerplants are the norm, floating powerplants are likely to have higher emissions, even if powered by LNG. Also, a location near densely populated areas may affect the impact of emissions.

If floating powerplants are used in the medium term to long-term and are situated near shore, in densely populated areas an assessment should be made between the pros and cons of the solution. The following table compares various emission types for small- and large-scale land-based powerplants to typical floating powerplants. A scale ranging from – to ++ represents from very problematic to very advantageous:

Table 15 - Pros and cons of powerships and powerbarges compared to land-based power generation

Issues	Land-based powerplants	Floating powerplants
1. Local emissions air/water	Remote: - genset Populated: ++/- gas/coal	++/-- ++/-
2. Greenhouse emissions	Remote: - genset Populated: +/-- gas/coal	++/- ++/-
3. Noise	Remote: -- genset Populated: +/- gas/coal	- -
4. Cost per kWh	Remote: -- genset Populated: ++/+ gas/coal	+/-- +/-

This shows that for remote sites using diesel gensets, the reference situation is quite different than in populated areas with a grid infrastructure and the opportunity to realize large scale powerplants. Additionally, if at a particular location coal is used as the fuel in powerplants, LNG and in the future hydrogen-fed floating powerplants will outperform them on both CO_2 and local SO_x, NO_x and PM emissions.

Due to economies of scale, large powerplants tend to offer low kWh prices. But if there is no grid infrastructure available, the CAPEX cost of grid extensions may be significant and local alternatives such as floating powerplants may become more cost effective. Alternatively, floating powerplants can be attractive in the short-term, but expensive long-term contracts can result in a costly lock-in with alternatives present or becoming available in the near future e.g., solar-pv and wind energy. The overall cost per kWh should be assessed against all alternatives and short-term contracts for powerships are preferred.

Powerships and powerbarges show a large variety in terms of impact on the issues stated above. This is largely related to the fuel of choice and emission mitigation options chosen. This relates to HFO/MGO versus LNG/H_2 and SCR/DeNO_x measures installed. On a larger scale, combined cycle gas turbines offer high electrical efficiencies comparable to land-based power production, also resulting in low greenhouse emissions per kWh compared to fuel oil and coal.

Local renewable alternatives may also include solar-PhotoVoltaïc and wind power. Realization of fossil-fed powerships and powerbarges may compete with the realization of renewable projects, resulting in a highly unwanted lock-in. Budget for investing in renewables on land may have to compete with powerships and powerbarges. But after renewables have been realized, renewable power generation under sunny and/or windy conditions may outperform power from powerships and powerbarges, because they offer near zero marginal cost. This has already occurred in developed Western-European countries with ample renewables, where coal fired powerplants became largely cost unattractive.

Per situation it should be determined whether powerships or powerbarges perform better than their land-based alternatives such as coal, diesel generators, gas turbines, combined cycle gas plants and renewables with storage facility to mitigate imbalances. Also the presence of a grid plays a role if these alternatives are viable. A lock-in with a worse, land-based alternative such as coal should be avoided.

In order to reach the global sustainable development goals (UN SDGs), a transition phase is underway from largely fossil fuels towards a significant amount of renewables. In some cases, floating powerplants could support solar-PhotoVoltaïc and wind energy projects by filling grid load imbalances during periods of lack of supply, particularly at locations where grid extensions will not be realized in time. Powerships or powerbarges may cost-effectively fill in this gap and save on fossil powerplant investments and expensive grid infrastructure extension. Some parties envisaged this concept, i.e. Wärtsilä, during the interviews.

Because there are a large variety of powerships and powerbarges, and they are used in different contexts, the relative environmental and human health impact of these projects compared to alternative solutions will vary from project to project. The choice of fuel for a floating powerplant relative to the alternative shore-based solution will largely be determined by the relative greenhouse gas and localized pollution impact. Application of green (bio-)gas and hydrogen instead of LNG or even on-board carbon capture, are potential solutions that could reduce emissions from floating powerplants.
Dedicated measures for emission control to air, such as SCR and $DeNO_x$, and to water by treatment can reduce the environmental impact of floating powerplants.
Before a specific project it is uncertain which emission control measures will be taken, which is in line with the study by Elouise A. Marais (2022) of a powership project in South Africa. Therefore, it is important to assess this upfront on a case-by-case basis in order to formulate an ideal.

3.4 Risks and accidents when using floating powerplants

The use of floating powerplants to generate electricity exposes the environment to certain risks. Possible risks may include:
- increase of air pollution due to global and local air emissions;
- water pollution, including oil pollution;
- negative impact on human health and wildlife due to noise;
- negative impact on marine life due to underwater noise;
- negative impact on marine life and ecosystems due to the increase of water temperature from seawater cooling systems;
- bad weather, which could cause grounding, capsizing, or sinking;
- fire on board of the floating powerplant;
- Economic impact, for example on local fishing and local tourism.

Most of these risks are mitigated and minimized because floating powerplants must comply with certain regulations. The regulations floating powerplants and powerplants on land must comply with are described in Section 2.5. Some of these regulations apply to both floating powerplants and powerplants on land, but there are also regulations that apply specifically to ships and/or floating structures.

The risks associated with floating powerplants should be viewed relative to the risks of an alternative powerplant on land. Some risks may be similar between on-land generators and floating powerplants. For example:

- fire can, for example, also break out on powerplants on land;
- powerplants installed on land near the coast may also use seawater cooling systems which affect the temperature of the water, although cooling towers are not possible to install on floating powerplants.

On the other hand, floating powerplants have their own unique set of risks, such as underwater noise, oil leakages or other water pollution.

Not much is known about actual accidents of floating powerplants. Accidents that have occurred and that we know about are:

- An explosion occurred on a powerbarge off Iloilo City in the Philippines in July 2020, whereby an estimated 12,000 gallons of bunker fuel was spilled into the waters of Iloilo Strait. According to CNN Philippines, the Philippine Coast Guard has the suspicion that hot work with an acetylene torch was the proximate cause of the blast. The powerbarge was operated by AC Energy Corporation, which is a division of Aylala Group, one of the large business conglomerates in the Philippines (The Maritime Executive, 2019).
- On 8th November 2013, a powerbarge broke loose from its mooring and grounded on the shores of Estancia (Iloilo Province, Panay Island, the Philippines) after typhoon Haiyan struck with extraordinary force, with wind speeds up to 275 kilometers per hour. The powerbarge was operated by National Power Corporation (NAPOCOR), had a capacity of 32 MW and carried 1,400 m^3 of heavy fuel oil. The fuel tanks had been damaged when the powerbarge ran aground, causing a spill of fuel oil into the water. The fuel spill polluted Barangay Botongon, near Estancia's port area. Because of a change in wind direction the following day, the oil spill drove up to 10 km southwards. Sand, rocks and mangroves were affected (Cedre, 2018).

4 Conclusions and recommendations

4.1 Conclusions

General

A floating powerplant can be defined as a special purpose ship on which a powerplant is installed to serve as power generation source. A distinction can be made between self-propelled and unmotorized floating powerplants. Self-propelled floating powerplants are called powerships. Unmotorized floating powerplants are called powerbarges or barge mounted powerplants.

Floating powerplants have been built and operated since the 1930s. There are currently at least about 100 powerships and powerbarges in operation and the market is increasing. Karpowership, one of the two main players in the market, has currently an installed power generating capacity of 4,100 MW and an additional capacity of 4,400 MW in the pipeline. The other main player, Power Barge Corporation, has an installed capacity exceeding 4,400 MW. As comparison: As of 2020, Cuba's installed generating capacity was 6,661 MW.

Technical

Floating powerplants can be both newly built and converted from existing cargo ships. Self-propelled powerships are mainly converted from existing bulk carriers. Since there is a limited amount of space on board a ship, the ship's dimensions balance the available cargo space against the space for electricity generating equipment, transformers and fuel storage. This means that the power generation capacity is fixed for a given floating powerplant. In the case of new construction, the designers determine the size of the floating powerplant dependent on the desired power capacity.

Different types of electricity generating equipment can be installed on board floating powerplants. Examples of commonly used systems are reciprocating internal combustion engines, dual-fuel engines, gas engines and gas turbines. Depending on the type of equipment and on the requirements that apply at the location where the floating powerplant is deployed, fuels such as heavy fuel oil, diesel oil, gas oil and liquefied natural gas are typically used to generate the needed electricity. Several companies are also exploring the possibility of floating powerplants using nuclear energy.

Depending on the type of floating powerplant and its location, it must comply with certain guidelines and regulations. These various guidelines and regulations cover environmental, technical and safety related aspects. A distinction can be made between regulations covering power generation assets and those covering ships. The former cover both powerbarges and powerships, while the latter are only applicable to self-propelled powerships with an IMO number.

The market for floating powerplants

Floating powerplants are used for different purposes in both developed and developing countries and for the short-term, medium term and long-term:

- Growing deployments of variable renewable energy sources, such as wind and solar, are increasing the need for grid balancing services to match electricity supply to demand. Floating powerplants can offer a solution to this challenge in both developed and developing countries.
- Floating powerplants can be deployed for the long-term to supply electricity to the cruise ships so that they can switch off their generators when they are berthed. In the event that the floating powerplant generates electricity from LNG (as is the case in Hamburg, Germany), this results in a reduction in local air emissions in the ports since the generators on board a cruise ship often use diesel as fuel and are less efficient.
- Floating powerplants can be deployed as a long-term power generation installation (for several years and sometimes even decades) in areas, often in developing countries:
  - where there is insufficient generation capacity on land in the area concerned, but a need for energy;
  - where it is difficult to build a powerplant on land, such as on islands and in remote areas;
  - where the feedstock necessary to generate electricity is more environmental friendly for the floating powerplant than for the powerplant which is installed on land;
  - when governmental agencies and electricity companies decide to deploy floating powerplants from a financial point of view.
- Floating powerplants can be deployed temporarily in the event that a powerplant on land is under construction or out of order.
- (Natural) disasters, such as a hurricane or a war, can destroy power generation plants and transmission lines resulting in blackouts. Floating powerplants can be temporarily deployed in these areas as emergency use to provide electricity until the onshore power generation plants are repaired or replaced. An emergency situation can happen in either a developed or a developing country. However, at the moment, emergency situations mainly take place in developing countries.

There are two main suppliers in the floating powerplant market, namely Karpowership (a subsidiary of the Karadeniz Energy Group) and Power Barge Corporation. Karpowership is located in Turkey and owns and operates 25 converted floating powerplants, both self-propelled and unmotorized. Power Barge Corporation is located in the U.S.A. and provides turnkey engineering, procurement, and construction contracting, as well as aftermarket and consulting services to developers, owners, and operators of barge mounted powerplants with both gas turbines, medium speed engines, and engine storage system. The company currently owns 58 powerbarges and also purchases powerbarges. Both companies work together with designers, yards and equipment suppliers via several commercial structures. Customers who would like to use the floating powerplants are mainly electricity companies and governments in developing countries.

Controversies around floating powerplants

Not all stakeholders support the deployment of floating powerplants for electricity supply. They have their concerns about the environmental, social, and financial impact. These concerns have underpinned controversies and debates about the use of floating powerplants in a number of countries. Examples of controversies which we are aware of are:

- In the Dominican Republic, powerbarges have been operating since 1989 on the river in the middle of the city of Santo Domingo. Residents of the neighborhoods complain about

disease caused by air pollution, vibration and noise, and the thermal impact of cooling water discharges into the river.
- In South Africa, a not-for-profit organization, Green Connection, and small-scale fishers are litigating against the use of floating powerplants by the government. They are concerned about the impact of floating powerplants on marine life and believe that the environmental impact assessment was inadequate.
- In Pakistan, two floating powerplants from Karpowership have provided electricity to alleviate shortage and provide humanitarian aid for the victims of the 2010 Pakistan floods in the city of Karachi. A contract was signed for five years, but the floating powerplants of Karpowership were sent back to Turkey after two years after the Pakistani High Federal Court cancelled all energy rental agreement in the country on the grounds that the energy deals were undertaken in an irregular manner.

Environmental and social impact

To evaluate the relative impact of floating powerplants, their emissions should be compared with the most likely alternative land-based powerplant project in the same location, including renewable electricity. From a climate perspective and an air quality perspective, renewables such as wind and solar PV are the preferred options over any type of fossil fueled power generation.

- Emissions to air: due to similar or higher power efficiencies of modern engines, no additional CO_2 emission per kWh is expected when the same fuels are used. Renewables have lower GHG emissions and care should be taken not to replace renewables with fossil-fueled power generation. When local land-based regulations for other emissions are implemented by the engine suppliers and enforced, this will also not result in extra emissions. This is met by additional emission reduction systems. Additionally, the use of LNG as a fuel will further help reduce emissions of NO_x, SO_x and PM, although emissions of methane may increase, depending on the engine type.
- Emissions to water: cooling water can produce thermal emissions. This can be mitigated by cooling the air in closed loop systems. Noise: noise generated by a powership need not have a higher volume than noise generated by other power sources, but it could have a higher impact on human health when the powership is moored near residential areas. The impact on the marine environment will almost always be higher.
- Accidents, incidents, and risks: No additional risks are expected compared to land-based power generation, where fuel tanks are also situated near the shore.
- Social impact: For long-term contracts, the total cost per kWh should not exceed that of land-based power generation if reasonably possible at that location. When the local situation makes land-based power generation difficult or impossible, floating powerplants can pose an advantage over more expensive and less efficient small generators.

Expected developments in the market

Even though the first floating powerplant was designed and built almost one hundred years ago, the market has only started developing in recent decades. Besides the two main players, Karpowership and Power Barge Corporation, other small players are also entering the market. Moreover, floating powerplants are currently not only deployed in developing countries where there is a (temporary) shortage of electricity, but are also deployed in developed countries. We therefore expect that growth of the floating powerplant market in general will continue. We also expect that the developing world will continue to dominate the market for floating powerplants and that a much smaller volume will fulfil niche applications in the developed world.

Most players in the market are aware of the energy transition and are increasing the use of fuel that has a lower impact on local air quality compared to a couple of years ago, for example LNG. Moreover, manufacturers of power generating equipment are already developing equipment which can run on renewable fuels, such as e-ammonia, methanol or hydrogen, once commercially available. At the same, classification societies are developing guidelines for the classification of power service vessels, which indicates that they see a market growth and the development of this market as well.

However, the floating powerplant market is a niche market in the global energy market and will remain so, despite the current and expected growth in the market. The nuclear floating powerplant market can be seen as a niche market in the niche market of floating powerplants, with the advantage of very long time between refueling for very remote areas.

Supporting, investigating or litigating against the deployment of floating powerplants?

Worldwide there is an increasing demand for electricity. Floating powerplants can contribute to meeting this need. Whether the use of floating powerplants makes a positive or negative contribution to human health, environment and ocean life depends entirely on the situation. It does not only depend on the fuel type used and the equipment on board the floating powerplant to generate the electricity, but it also depends on the frame of reference. Why is there a need for electricity in a specific country or region? Is it a long-term situation or an emergency situation? Which regulations apply in the country concerned? What are the options for the generation of electricity on land? And how does the powerplant on land (if present) compare to the floating powerplant in terms of exhaust gas emissions? These are all questions to take into account when determining whether or not it is wise to deploy a floating powerplant. In summary, every situation is unique. Because of this, no unambiguous conclusion can be drawn on the question of whether NGOs should campaign against the use of floating powerplants, support these powerplants or remain neutral. Section 4.2 therefore provides recommendations on how to draw a conclusion regarding the deployment of floating powerplant for each specific situation.

4.2 Recommendations

This section provides guidance on how to evaluate the risk of specific floating powerplant projects.

The general question that must be answered is whether a floating powerplant has a larger environmental impact compared to a powerplant on land. To answer this question, we considered emissions to the air, emissions to the water and noise. If there are no indications that the environmental impact of a floating powerplant project is larger compared to the frame of reference, it should receive similar levels of scrutiny to the alternative land-based generation project. However, if warning signs have been detected indicating that the floating powerplant could have outsized impacts, it should be the subject of additional scrutiny and, perhaps, a campaign to oppose the project.

4.2.1 A ‘normal’ situation

By a ‘normal’ situation, we mean a planned deployment of a floating powerplant, not in an emergency situation (e.g., a natural disaster). In these cases, the frame of reference for the deployment of floating powerplants should be a powerplant which is technically and economically feasible to install on land in this area. The frame of reference differs per location, because of local regulations. Developed countries, for example, have stricter emission requirements compared to developing countries.

The criteria checklist in Table 16 and the list of warning signs in Table 17 can help to qualitatively assess the risk of a floating powerplant project. If there are elements of concern from this assessment, environmental NGOs should consider opposing the project.

Table 16 - Criteria checklist to qualitatively assess the environmental and human health risks of a floating powerplant project

#	Checklist item	Description
Greenhouse gas emissions (CO_2-eq.) and local emissions (SO_x, NO_x, PM) to the air		
1	World Bank Standard	The World Bank Standard is used as the minimum requirements for floating powerplants, whereby the Standard applicable for onshore projects (in this case powerplants on land) also apply to offshore projects (in this case floating powerplants). The World Bank Environmental and Social Standard (ESS) #3 'Resource Efficiency and Pollution Prevention and Management' sets requirements to address resource efficiency and pollution prevention and management throughout the project life-cycle. The World Bank Group Environmental, Health, and Safety Guidelines (IFC, 2007) contain the performance levels and measures that are normally acceptable to the World Bank Group. These performance levels and measures are considered to be achievable in new facilities at reasonable costs by existing technology.
2	MARPOL	The International Maritime Organization (IMO) is a specialized agency from the United Nations with responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships. Self-propelled floating powerplants from a certain gross tonnage (depending on the regulations but often from 400 GT) need to comply with the IMO conventions. MARPOL is the international Convention from the IMO for the prevention of pollution from ships and is the main international convention covering prevention of the marine environment by ships from operational or accidental causes. MARPOL Annex VI covers the prevention of air pollution from ships and set limits on the NO_x, SO_x and PM emissions. Although MARPOL does not officially apply to non-self-propelled powerbarges, we propose that the same requirements are set as for self-propelled powerships. This means that we recommend that all floating powerplants comply with MARPOL.
3	Law and regulations in the relevant country	If a country has its own emissions laws and regulations, floating powerplants which are deployed in this specific country must comply with the regulations.
4	Comparison of emissions with powerplant ashore	Unfortunately, there are currently no unambiguous regulations for global greenhouse gas emissions. If there is already a powerplant on land in use, both the global and local emissions to the air of a floating powerplant therefore need to be lower or at least equal to the powerplant on land that is displaced or not built because of the deployment of the powership. In this way a situation will be prevented whereby the emissions to the air increase. The selected fuel type and the efficiency of the power generating equipment both on board the floating powerplant and at the powerplant on land are the main drivers of differences.

#	Checklist item	Description
Warning sign: the specific emissions of the powership or powerbarge are higher than the minimum of other existing or planned types of electricity generation connected to the same grid; laws and regulations in the relevant country; MARPOL; or the world bank standard.		
Emissions to the water		
5	Oily water discharge	Self-propelled ships, including self-propelled powerships, must adhere to MARPOL. Although MARPOL does not officially apply to non-self-propelled powerbarges, we propose that they should adhere to the same MARPOL requirements as self-propelled powerships. Oil, which is necessary to operate the floating powerplant, could end up in the water due to several causes. MARPOL Annex I provides regulations for the prevention of pollution by oil. One of the regulations in this Annex sets the requirement to use an oily water separator on board of ships above 400 GT. An oily water separator (OWS) is a piece of equipment which is used to separate oil and water mixtures into separate components. The OWS is used to separate oil from oily wastewater, such as bilge water, before the wastewater is discharged at sea. The wastewater which will be discharged at sea can have a maximum oil content of 15 ppm according MARPOL Annex I. It is therefore recommended that floating powerplants use an OWS.
6	Cooling water	The engines for the power generation of on board floating powerplants must be cooled to dissipate excess heat and prevent damage to the engines. However, there are no international regulations as yet regarding maximum allowable temperature differences between seawater and cooling water. There are two types of cooling water systems, namely: — A sea water cooling system, whereby seawater is directly used in the machinery system as a cooling media for heat exchangers. The seawater is discharged back into the sea at an increased temperature after use. — A fresh water or central cooling system, whereby the freshwater is used in a closed circuit to cool down the engine room and power generation machinery. The freshwater which returns from the heat exchanger after cooling the machinery is further cooled by an air cooling component to conduct some heat to the air, possibly in combination with cooling by seawater. In this way less heat is conducted to the sea compared to a seawater cooling system, but more heat is conducted to the air. Both systems have their own advantages and disadvantages. The main disadvantage of sea water cooling systems is that they increase the temperature of seawater that is discharged back into the sea. A fresh water, or central cooling system, may make more noise because of the air cooling component. Depending on the location where the floating powerplant is deployed, the potential impact of cooling water systems should be evaluated and an assessment should be made about the best system for the location of the floating powerplant. Unfortunately, acceptable values of temperature increases of cooling water discharges may not be well-defined and are location dependent.
Noise		
7	Noise	Continuous noise from floating powerplants can have an adverse impact on human health, not only for crew (if applicable), but also for residents in the area (if applicable). — Self-propelled floating powerplants need to comply with a regulation (MSC, 2012a) in the International Convention for Safety of Life at Sea (SOLAS) from the IMO to require ships to be constructed to reduce on-board noise and to protect personnel, in accordance with the maximum noise level limits set out in the Code on noise (MSC, 2012b) levels on board ships.

#	Checklist item	Description
		— The International Maritime Labour Convention (ILO, 2006) also has requirements with respect to preventing the risks of exposure to hazardous levels of noise on board of ships. It is recommended that all floating powerplants regardless of their size, both self-propelled and unmotorized, comply with these noise regulations of the IMO.
8	Underwater noise	Floating powerplants produce underwater noise when they are in operation. Depending on the location where the floating powerplants are deployed and on the amount of underwater noise, this noise can produce loss of hearing in marine species, inhibit communication between animals, increase stress levels, and cause behavioral changes. The influence that sound has on marine life depends on the sound level (in decibel) and on the frequency (in hertz). Sounds between 120-170 dB can disturb animal behavior, while sounds above 170 dB can even injure marine animals. The machinery (power generation, pumps, air conditioning) on board a floating powerplant will transmit vibrations to the foundation structure as well as cause airborne noise. This noise will travel through the ships structure and the air to the hull, where it will be radiated into the water as underwater radiated noise. Although there are no international regulations as yet on underwater noise, compliance with the (not mandatory) Guidelines for the reduction of underwater noise from commercial shipping to address adverse impacts on marine life is recommended. These guidelines focus on the primary sources of underwater noise such as propellers, hull form, and on-board machinery, and contain various operational and maintenance recommendations such as hull cleaning. Since floating powerplants are moored at one location for a long period, the focus must be on the on-board machinery. Depending on the location where the floating powerplant is deployed, there may also be local regulations which have to be complied with. The U.S.A., for example, has the following regulations to minimize the effect of underwater noise: — the National Environmental Policy Act (NEPA); — the Marine Mammal Protection Act (MMPA); — the Endangered Species Act (ASE). Extra attention should be paid to underwater noise if it is known that mammals, such as whales and dolphins, live in the area where the floating powerplant is deployed.
Risks		
9	Fuel bunkering	Fuel bunkering should carried out in a safe and environmentally responsible manner. Fuel must also meet engine specifications to avoid engine problems. Regardless of the location of the floating powerplant, the fuel supplier must therefore be reliable. Since a worldwide bunker licensing system (for example of the IMO) does not yet exist, it is recommended that a well-known fuel supplier is selected, which has a good worldwide name for fuel bunkering to avoid and mitigate the risk of illegal and unsafe activities (i.e. air blowing during bunker operations and leaking bunker systems).
10	Classification of the floating powerplant	All marine and safety related aspects need to be classified by classification societies. Although regulations are currently under development for floating powerplants, the power generation equipment currently falls outside the mandatory verification scope of the classification societies. At the specific request of the owner of the floating powerplant, the power generation equipment can be included in the verification scope, and it is recommended that a request is made to the classification society to include the power generation equipment in the verification scope.

#	Checklist item	Description
11	Bad weather accidents	Due to bad weather, various accidents may occur. The floating powerplant could, for example, break loose from its mooring and run aground, it could capsize and sink, or the electricity cable to shore could break loose. To prevent the risk of accidents, a HAZOP should be performed. HAZOP stands for 'Hazard and Operability study' and is a systematic assessment tool used to identify and address potential hazards before an incident actually occurs.
Environmental Impact Assessment (EIA)		
12	Environmental Impact Assessment	An environmental impact assessment (EIA) is an assessment of the potential positive or negative impact that a proposed project may have and in which the environmental consequences of the project will be compared to possible alternatives. Aspects, such as greenhouse gas emissions, local air emissions, noise, emissions to water, underwater noise, safety, potential risks and impact on human health and environment, must be included in the environmental impact assessment.

If a certain floating powerplant meets all the criteria of the above table, it is likely that the environmental impact of the floating powerplant will not exceed those of an alternative on-land power generation source. In such a case, there could still be a reason to object to the deployment of a floating powerplant, for example because the floating powerplant has an impact on the marine environment that a land-based powerplant does not. Another reason to object is the possibility of lock-in effects, and the crowding out of investments in cleaner generation technologies.

There are also several warning signs that should trigger deeper scrutiny of the deployment of a floating powerplant. Table 17 lists several warning signs that should be cause for concern. Just one warning signal is sufficient to proceed with additional research. Only after additional research can it be determined whether there is good reason to oppose or litigate against a specific floating powerplant.

Table 17 – List of warning signs of cause for concern

#	Warning signs of cause for concern
1	There is limited publicly available information about the floating powerplant project.
2	The floating powerplant is large, as the emissions are correlated with the total fuel burn.
3	The floating powerplant is old, for example more than 20 years, and therefore likely to have an inefficient generator and outdated (or no) pollution abatement technology.
4	The generators on board are old and have a lower efficiency and higher emissions than the reference land-based power generation asset.
5	The use of heavy fuel oil or coal as fuel for the floating powerplant, especially without the use of exhaust gas treatment systems.
6	Fuel bunkering does not take place with an automatic pumping system, but manually. Or where the fuel is stored on deck in separate fuel drums instead of fixed fuel tanks.
7	No oily water separator system is used on board to prevent oil from being discharged into the water.
8	No measurements of the volume and temperature of cooling water discharge are available.
9	The proximity of sensitive natural areas or densely populated areas.
10	Black, grey or yellow smoke is visible from the exhaust funnels of the floating powerplant when it is in operation.
11	Odor nuisance when the floating powerplant is in operation.
12	The floating powerplant makes strange noises or causes noise nuisance when it is in operation.
13	There are oil slicks floating on the water in the vicinity of the floating powerplant.
14	There are dead fish found near the floating powerplant.

#	Warning signs of cause for concern
15	The water temperature in the area in which the floating powerplant operates is higher than usual.
16	Human beings and animals in the surrounded areas have health problems which cannot be explained.
17	Whales, sea turtles, or other endangered or threatened species are in the area where the floating powerplant operates.
18	There are misgivings with regard to the contracting or funding of the floating powerplant project.
19	Long-term contracts for the deployment of floating powerplants, since these can have lock-in effects as a consequence.

The above criteria checklist and warnings signs are mainly focused on the environment and on the equipment installed on board of the floating powerplant to minimize the impact on the environment. However, it is also important to be aware of the social societal impact. In the event that governments or local electricity companies, for example, pay high prices for the deployment of floating powerplants over a longer time period, they will not use this money for the investment in a structural and sustainable solution on land. A social cost benefit analysis is therefore also recommended.
Finally, it is important for environmental non-profit and funder communities to consciously consider what their opinion is about certain types of fuel in the future. Despite the fact that the majority of the maritime sector still operates on conventional carbon containing fuels, the transition to cleaner fuels has been started. At the moment that cleaner fuels are commercially and worldwide available, it is an option not to encourage the use of heavy fuel oil anymore, even when the floating powerplants make use of exhaust gas cleaning systems.

4.2.2 An emergency situation

The criteria checklist to support the deployment of floating powerplants and the warning signs of cause for concern which are provided in Section 4.2.1 apply to normal situations whereby a floating powerplant will be used for electricity generation and supply over a longer period (in terms of years).

In the event of an emergency, where electricity is urgently needed, stakeholders will need to balance these criteria and warning signs against the urgent need to provide people with electricity. In these situations, the emergency deployment of a floating powerplant with high environmental and human health risks, must not turn into a long-term solution.

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A Involved stakeholders and questionnaires

This Appendix provide two lists with stakeholders which are involved in this study in Appendix A.1 and the questionnaires which are shared with the stakeholders in Appendix A.2.

A.1 Stakeholders involved in this study

We have reached out 25 experts involved in the floating powerplant market, such as owners, classification societies, equipment suppliers, shipyards, clients and organizations who litigates against the deployment of floating powerplants. Eight interviews were conducted for this study. Five other organizations have provided us with written information and statements. The list of interviewed stakeholders is shown in Table 18. The list with stakeholders from who written information and statements were received is shown in Table 19.

Table 18 - List of interviewed stakeholders

#	Organization	Type of organization
1	Bureau Veritas (BV)	Classification Society
2	MAN	Engine manufacturer
3	Wärtsilä	Engine manufacturer
4	Siemens Energy	Engine manufacturer
5	E-cap Marine	Supplier of power generation equipment and solutions
6	ELAW	Lawyer
7	Oceans5	Advocacy
8	Bureau of Ocean Energy Management	An agency within the United States department of the interior

Table 19 - List with stakeholders of which written information/statements are received

#	Organization	Type of organization
1	Power Barge Corporation	Owner
2	American Bureau of Shipping (ABS)	Classification Society
3	World Bank Arbitration	International bank
4	INSAPROMA	Not-for-profit organization in the Dominican Republic
5	Green Connection	Not-for-profit organization in South Africa

A.2 Questionnaires

This appendix provides the questions which have been asked during the conducted interviews and by e-mail. Depending on the type of stakeholder, the questions vary slightly.

A.2.1 Questionnaires for owners of floating powerplants

- Can you start with an introduction about your organization, yourself and your role in the organization?
- There are very few powerships/powerbarges in the world. Can you explain how the idea came up to build and operate these type of ships?
- What are the advantages and disadvantages of the use of powerships?
- Do you have competition in this market from other organizations? What makes you special/good in this market?
- Are there situations/locations where the use of powerships is inconvenient or very useful?
- Are there higher risks involved when using powerships compared to the use of power stations ashore? If so, what kind of risks must be taken into account? And is there any mitigation plan for these risks?
- Have there ever been accidents when using powerships? If so, can you explain a bit more about this?
- To what extent do you think about the environmental impact of powerships and is action taken on this?
- And is the type of fuel which will be used during operation a choice of the shipowner or does it depend on the requirements of the customer or what fuels are available in the relevant environment?
- What is your long-term vision regarding the use of powerships?
- Is there anything else you would like to inform us about?

A.2.2 Questionnaires for classification societies

- Can you start with an introduction about your organization, yourself and your role in the organization?
- How many powerships/powerbarges are classified by your organization?
- There are a very few powerships/powerbarges in the world. Can you explain why your organization started/chose to classify these type of ships?
- Are powership/powerbarges classified in the same way as other ships such as containerships, tankers and bulk carriers? Or is there extra attention on certain aspects, for example the power station on deck? If so, can you please explain a bit more about this? (Think about stability and vibrations.)
- What advantages and disadvantages do you see in the use of powerships/powerbarges?
- Are there situations/locations where the use of powerships is inconvenient or very useful?
- Do you know if there are higher risks involved when using powerships compared to the use of power stations ashore? If so, what kind of risks must be taken into account?
- Do you know if there have ever been accidents when using powerships? If so, are you allowed to explain a bit more about this?
- Is the environmental impact of powerships/powerbarges considered during the classification? If yes, can you explain more about this?
- What is your long-term vision regarding the use of powerships?
- Is there anything else you would like to inform us about?

A.2.3 Questionnaires for equipment manufacturers

- Can you start with an introduction about your organization, yourself and your role in the organization?
- Can you explain more about the equipment you supply to powerships/powerbarges?

- Is the equipment you supply to powerships also used at power stations ashore? If yes, are there any modifications necessary to use the equipment on board compared to the use of the same equipment ashore?
- Do you also install this equipment on board of the powerships/powerbarges? Or do you only supply the equipment?
- Can you shortly explain what you know about powerships?
- What advantages and disadvantages do you see in the use of powerships/powerbarges?
- Are there situations or locations where the use of powerships is inconvenient or very useful?
- Do you know if there are higher risks involved when using powerships compared to the use of power stations ashore? If so, what kind of risks must be taken into account? (When answering this question, the focus may also be on the equipment you supply.)
- Do you know if there have ever been accidents when using powerships? If so, are you allowed to explain a bit more about this?
- Is there anything else you would like to inform us about?

A.2.4 Questionnaires for shipyards/powerbarge suppliers

- Can you start with an introduction about your organization, yourself and your role in the organization?
- There are a very few powerships/powerbarges in the world. How many of these powerships/powerbarges have you built/converted from other ship types?
- What is your connection your shipyard and the shipping companies who owns powerships/powerbarges? Why have they selected you as (conversion) shipyard?
- Do you have competition from other shipyards? And what makes you good in this job?
- Can you explain about the building/conversion process? Which organizations (i.e. shipowner, shipyard, constructor, equipment manufacturers) are involved? How much time does the conversion/building take? What is the most critical element in the process?
- What advantages and disadvantages do you see in the use of powerships/powerbarges?
- Are there situations or locations where the use of powerships is inconvenient of very useful?
- Do you know if there are higher risks involved when using powerships compared to the use of power stations ashore? If so, what kind of risks must be taken into account? (When answering this question, the focus may also be on the building/conversion process.)
- Do you know if there have ever been accidents when using powerships? If so, are you allowed to explain a bit more about this?
- To what extent do you think about the environmental impact of powerships and is action taken on this during the building/conversion process? If yes, can you provide some examples?
- What is your long-term vision regarding the use of powerships?
- Is there anything else you would like to inform us about?

A.2.5 Questionnaires for powership clients

- Can you start with an introduction about your organization, yourself and your role in the organization?
- Why did your organization choose to use powership(s)? And how did you become familiar with these type of ships and this type of energy supply?
- Can you explain more about the project(s)? How many powerships are involved? What kind of contract do you have with the shipowners? What is your experience so far?
- What advantages and disadvantages do you see in the use of powerships/powerbarges?

- Are there situations or locations where the use of powerships is inconvenient or very useful?
- Do you know if there are higher risks involved when using powerships compared to the use of power stations ashore? If so, what kind of risks must be taken into account?
- Do you know if there have ever been accidents when using powerships? If so, are you allowed to explain a bit more about this?
- Is the environmental impact of powerships/powerbarges considered during the term of the contract? If yes, can you explain more about this?
- And is the type of fuel which will be used during operation a choice of the shipowner or does it depends on the requirements of the customer or what fuels are available in the relevant environment?
- What is your long-term vision regarding the use of powerships? Is it only a temporary solution to supply electricity to a specific area until a power station is built? Or will it replace future power stations on land?
- Is there anything else you would like to inform us about?

A.2.6 Questionnaires for lawyers/advocacy

- Can you start with an introduction about your organization, yourself and your role in the organization?
- Can you explain more about the reason why you have litigated against Karpowership (and others) in South Africa and the Dominican Republic? And on behalf of which party did you litigate?
- Based on your experiences with the powerships/powerbarges can you explain more about the advantages, disadvantages and risks when using powerships/powerbarges for electricity supply?
- Do you know if there have ever been accidents when using powerships? If so, are you allowed to explain a bit more about this?
- Do you have any knowledge about the environmental impact of powerships/ powerbarges? If so, can you explain this?
- What is your long-term vision regarding the use of powerships?
- Is there anything else you would like to inform us about?

B Customers in the floating powerplant market

Table 20 provides a list of customers from Karpowership, including the countries where they are located. Table 21 provides a list of customers from Power Barge Corporation, including the countries where they are located.

Table 20 - Customers from Karpowership

Customers from Karpowership	Country
Unión Eléctrica de Cuba (UNE)	Cuba
National Water and Electricity Supply Company Ltd. of Gambia	Gambia
Electricity Company of Ghana	Ghana
Electricidade e Aguas da Guiné-Bissau (EAGB)	Guinea-Bissau
Electricité Nationale de Guinée	Guinea
Senegal's Electricity Authority (SENELEC)	Senegal
PT PLN (Persero)	Indonesia
Ministry of Electricity of Iraq (MoE)	Iraq
Lebanese Electricity Utility (EDL)	Lebanon
Electricidade de Mozambique (EdM)	Mozambique
Sierra Leone national utility company, Electricity Distribution and Supply Authority (EDSA), ministry of Energy and ministry of Finance	Sierra Leone
Sudanese Thermal Power Generating Company (STPGC)	Sudan
ZESCO	Zambia

Source: (Karpowership, 2022).

Table 21 - Customers from Power Barge Corporation

Customers from Power Barge Corporation	Country
AES Corporation	Nigeria/Panama
AngloGold Ashanti	Ghana
APIX/Senelect	Senegal
Barrick Gold	Dominica
Burmiester & Wain	Scandinavian Contractors (global)
BW Maritime LNG	Singapore
BlueCrest Capital	Kenya/Philippines/Ecuador
Cielemca/PDVSA	Venezuela
Deloitte	Kenya
Elliot Management/Prime NRI	Ecuador/Panama
El Paso International	Brazil/Bangladesh
Enron International	Nigeria
ExxonMobil	Nigeria
Golar LNG/Energy	Norway
Gold Fields	Ghana
GMR Energy	India
Hyundai Engineering and Construction	India
IC Power	Guatemala/Panama

Customers from Power Barge Corporation	Country
Isolux Corsan	Angola
Karadeniz/Karkey Energy	Global
KarPower	Turkey
Keppel Energy	Ecuador
Mercuria Energy	South Africa
ProEnergy Services	-
Smith International	Pakistan/India/Bangladesh/China
Stark Capital	USA
STX Heavy Industries	Yemen
Turbine Technology Services	-
Wood Group/Ethos Energy	-
World Bank Arbitration	Pakistan/Turkey

Source: Power Barge Corporation, (ongoing).

C Factsheets floating powerplants

This Appendix provides factsheets for existing floating powerplants. Desktop research was carried out, including review of the Clarkson database to collect information. These factsheets likely cover most of the existing deployments, but is not comprehensive.

Unfortunately, it is not possible to find the same amount of information for all existing floating powerplants. A lot of information can be found about the floating powerplants which are registered at the Clarkson database. Only a little information can be found about the floating powerplants which are not registered at the Clarkson database. Of these floating powerplants it is not even known whether they have a name.

For that reason separate factsheets are made for all the floating powerplants which are registered at the Clarkson database. In order to keep overview, the information in these factsheets is divided into four different aspects: ship identity, ship data, power generation data and deployment data. The factsheets for these floating powerplants are shown in Table 22 until Table 46. These floating powerplants are almost all from Karpowership and are converted from other ship types.

The floating powerplants which are not registered at the Clarkson database are all non-self-propelled floating powerplants. For these floating powerplants only the power generation engine manufacturer, the engine type and the power are provided. This is shown in Table 47 until Table 49. These floating powerplants are all from Power Barge Corporation.

Due to lack of information on the internet we do not guarantee that this list of floating powerplants is complete.

C.1 Factsheets for floating powerplants registered at the Clarkson database

Table 22 - Floating powerplant #1 'Karadeniz Powership Osman Khan'

Description	Data	Source
Ship identity		
Name	Karadeniz Powership Osman Khan	Clarksons
IMO number	9189158	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	2000	Clarksons
Conversion year	2016	MV Karadeniz Powership Osman Khan
Conversion yard and location	Sedef Gemi End., Gebze in Turkey	Clarksons
Status	In Service	Clarksons
Ex ship type and ex name	Bulk carrier 'Pacific Triangle'	Clarksons
Flag state	Liberia	Clarksons
Classification society	Bureau Veritas	Clarksons
Owner	Karmarine Karadeniz	Clarksons
Group owner	Karadeniz Holding	Clarksons
Registered owner company	KARADENIZ POWERSHIP OSMAN KHAN COMPANY LIMITED	Clarksons
Operator	Karmarine Karadeniz	Clarksons

Description	Data	Source
Ship data		
Gross tonnage (GT)	107,326	Clarksons
Deadweight (dwt)	184,744	Clarksons
Length over all (m)	299.76	Clarksons
Draught (m)	17.02	Clarksons
Beam (m)	50.00	Clarksons
Speed (knots)	14.50	Clarksons
Self-propelled	Yes, diesel 2-stroke	Clarksons
Horsepower	21,080	Clarksons
Main engine	1 x Diesel - MAN B. & W. 6S70MC6	Clarksons
Main engine fuel type	VLS IFO	Clarksons
Auxiliary engine	3 x Aux. Diesel Gen. - MAN Energy Solutions	Clarksons
Auxiliary engine fuel type	VLS IFO	Clarksons
Emergency engine	Not available	Clarksons
Emergency engine fuel type	Not available	Clarksons
Boiler	2 x Boiler, Exhaust Heated - Kangrim, 1 x Boiler, Oil/Gas fired	Clarksons
Alternative fuel type	Not available	Clarksons
Shaft generator	Not available	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	80	Karpowership : Powership Classes
Power generation data		
Power generation equipment	24 x 18.32 MW Wärtsila engines and 30 MW of steam turbines	Powermag: The 470-MW Floating Powership That Buoyed Ghana
Engine technology	Dual fuel HFO-NG	Karpowership : Powership Classes
On-board fuel storage	± 8 weeks	Karpowership : Powership Classes
Capacity (MW)	470	Powermag: The 470-MW Floating Powership That Buoyed Ghana
Substation voltage (kV)	100-420	Karpowership : Powership Classes
Frequency (Hz)	42	Karpowership : Powership Classes
Deployment data		
Last location	Gulf of Guinea, off the coast of Ghana, Africa (last received position is from 15/08/2019).	KPS OSMAN KHAN (Bulk Carrier) Registered in Liberia - Vessel details, Current position and Voyage information - IMO 9189158, MMSI 636011235, Call Sign ELXS8 | AIS Marine Traffic
Deployment history	The Karadeniz Powership Osman Khan, which has a capacity of 470 MW, supplied 450 MW (or about 26% of Ghana's generated power) to Tema, Ghana, burning heavy fuel oil between 2017 and 2019.	Powermag: The 470-MW Floating Powership That Buoyed Ghana
	In the end of 2019, the ship was relocated to Sekondi Naval Base, about 300 kilometres away on Ghana's southern coast. At that location the ship continues producing power using indigenously produced natural gas.	Powermag: The 470-MW Floating Powership That Buoyed Ghana

Description	Data	Source
Clients	In June 2014 a 10-year 450-MW power purchase agreement (PPA) is signed between Karpowership and the Electricity Co. of Ghana (ECG). The electricity company of Ghana is a limited liability company wholly owned by the Government of Ghana.	Powermag: The 470-MW Floating Powership That Buoyed Ghana
Incidents, issues or problems	No information found.	

Table 23 - Floating powerplant #2 'Karadeniz Powership Onur Sultan'

Description	Data	Source
Ship identity		
Name	Karadeniz Powership Onur Sultan	Clarksons
IMO number	9047441	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	1999	Clarksons
Conversion year	2016	Clarksons
Conversion yard and location	Sedef Gemi End., Gebze in Turkey	Clarksons
Status	In Service	Clarksons
Ex ship type and ex name	Powership 'Karadeniz Powership Orhan Ali Khan' (2015), bulk carrier 'Abyo Four' (2014), bulk carrier 'Mineral Sakura' (1999), bulk carrier 'Giuseppe Lembo' (1999)	Clarksons & Vesselfinder: KPS ONUR SULTAN Power Station Vessel, IMO 9047441
Flag state	Liberia	Clarksons
Classification society	Bureau Veritas	Clarksons
Owner	Karmarine Karadeniz	Clarksons
Group owner	Karadeniz Holding	Clarksons
Registered owner company	KARPOWERSHIP INDONESIA 14 DMCC	Clarksons
Operator	Karmarine Karadeniz	Clarksons
Ship data		
Gross tonnage (GT)	90,884	Clarksons
Deadweight (dwt)	172,632	Clarksons
Length over all (m)	295.83	Clarksons
Draught (m)	18.03	Clarksons
Beam (m)	46.00	Clarksons
Speed (knots)	14.00	Clarksons
Self-propelled	Yes, diesel 2-stroke	Clarksons
Horsepower	22,920	Clarksons
Main engine	1 x Diesel - MAN B. & W. 6S70MC6	Clarksons
Main engine fuel type	VLS IFO	Clarksons
Auxiliary engine	3 x Aux. Diesel Gen. - MaK	Clarksons
Auxiliary engine fuel type	VLS IFO	Clarksons
Emergency engine	1 x Emergency Diesel Gen. - Detroit Diesel Corp	Clarksons
Emergency engine fuel type	VLS MDO	Clarksons
Boiler	1 x Boiler, Oil/Gas fired - Aalborg, 1 x Boiler, Exhaust Heated - Aalborg	Clarksons

Description	Data	Source
Alternative fuel type	Not available	Clarksons
Shaft generator	Not available	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	80	Karpowership : Powership Classes
Power generation data		
Power generation equipment	24 generators‡	Clarksons
Engine technology	Dual fuel HFO-NG	Karpowership : Powership Classes
On-board fuel storage	± 8 weeks	Karpowership : Powership Classes
Capacity (MW)	470	Karpowership : Powership Classes
Substation voltage (kV)	100-420	Karpowership : Powership Classes
Frequency (Hz)	42	Karpowership : Powership Classes
Deployment data		
Last location	Belawan, Indonesia, Asia (last received position is from 20/05/2021).	Ship KPS ONUR SULTAN (Special Vessel) Registered in Liberia - Vessel details, Current position and Voyage information - IMO 9047441, MMSI 636016953, Call Sign D5IO8 | AIS Marine Traffic
Deployment history	Since May 2017 Karadeniz Powership Onur Sultan supplies 240 MW steady and reliable power to Medan, Indonesia.	https://www.shell.com/inside-energy/karadeniz-onur-sultan-powership-indonesia.html
Clients	Karpowership signed five contracts with PT PLN (Persero) to deploy five Powerships of 1,000 MW in total for a period of five years. PT PLN (Persero) is a state-owned electric utility in Indonesia.	https://karpowership.com/en/project-indonesia-asia
Incidents, issues or problems	No information found.	

Table 24 - Floating powerplant #3 ‘Karadeniz Powership Orka Sultan’

Description	Data	Source
Ship identity		
Name	Karadeniz Powership Orka Sultan	Clarksons
IMO number	9198252	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	2001	Clarksons
Conversion year	2016	Clarksons
Conversion yard and location	Besiktas Shipyard, Altinova Yalova in Turkey	Clarksons
Status	In Service	Clarksons
Ex ship type and ex name	Bulk carrier ‘Kohyohsan’	Clarksons
Flag state	Liberia	Clarksons
Classification society	Bureau Veritas	Clarksons

‡ Not 100% certain. The number of generators for the power generation on board of the floating powerplant are based on the number of exhaust gas systems which are visible at images of the powership. Although we do not know for 100% sure the number of generators on board, we know that the number of generators exactly match with the number of exhaust gas systems.

Description	Data	Source
Owner	Karmarine Karadeniz	Clarksons
Group owner	Karadeniz Holding	Clarksons
Registered owner company	KARADENIZ POWERSHIP ORKA SULTAN COMPANY LIMITED	Clarksons
Operator	Karmarine Karadeniz	Clarksons
Ship data		
Gross tonnage (GT)	87,493	Clarksons
Deadweight (dwt)	172,564	Clarksons
Length over all (m)	289.00	Clarksons
Draught (m)	17.81	Clarksons
Beam (m)	45.00	Clarksons
Speed (knots)	14.70	Clarksons
Self-propelled	Yes, diesel 2-stroke	Clarksons
Horsepower	20,000	Clarksons
Main engine	1 x Diesel - MAN B. & W. 6S70MC6.1	Clarksons
Main engine fuel type	VLS IFO	Clarksons
Auxiliary engine	2 x Aux. Steam Turb. Gen.	Clarksons
Auxiliary engine fuel type	Not available	Clarksons
Emergency engine	Not available	Clarksons
Emergency engine fuel type	Not available	Clarksons
Boiler	21 x Boiler, Oil/Gas fired - Aalborg, 2 x Boiler, Oil/Gas fired	Clarksons
Alternative fuel type	Not available	Clarksons
Shaft generator	Not available	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	80	Karpowership: khan-class
Power generation data		
Power generation equipment	21 x Generator, Power Production - Wartsila 4-stroke & 2 x 16 MW steam turbine generators	Clarksons & Gemak
Engine technology	Dual fuel HFO-NG	Karpowership: khan-class
On-board fuel storage	± 8 weeks	Karpowership: khan-class
Capacity (MW)	470	Karpowership: khan-class
Substation voltage (kV)	100-420	Karpowership: khan-class
Frequency (Hz)	42	Karpowership: khan-class
Deployment data		
Last location	Yalova, Turkey in Europe/Asia (last received position is from 31/01/2020).	Ship KPS ORKA SULTAN (Bulk Carrier) Registered in Liberia - Vessel details, Current position and Voyage information - IMO 9198252, MMSI 636017429, Call Sign D5KX4 | AIS Marine Traffic
Deployment history	No information found.	
Clients	No information found.	
Incidents, issues or problems	No information found.	

Table 25 - Floating powerplant #4 'Karadeniz Powership Orhan Ali Khan'

Description	Data	Source
Ship identity		
Name	Karadeniz Powership Orhan Ali Khan	Clarksons
IMO number	9248514	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	2001	Clarksons
Conversion year	2016	Clarksons
Conversion yard and location	Besiktas Shipyard, Altinova Yalova in Turkey	Clarksons
Status	In service	Clarksons
Ex ship type and ex name	Powership 'Karadeniz Powership Onur Sultan' (2016), bulk carrier 'Nisshin Trader' (2005), bulk carrier 'Lowlands Trader' (2001)	Clarksons & KPS ORHAN ALI KHAN, Bulk Carrier - Details and current position - IMO 9248514 MMSI 636017311 - VesselFinder
Flag state	Liberia	Clarksons
Classification society	Bureau Veritas	KPS Orhan Ali Khan - IMO 9248514 - Callsign DYFV - ShipSpotting.com - Ship Photos and Ship Tracker
Owner	Karmarine Karadeniz	Clarksons
Group owner	Karadeniz Holding	Clarksons
Registered owner company	Karadeniz Powership Ela Sultan Co. Ltd.	Clarksons
Operator	Karmarine Karadeniz	Clarksons
Ship data		
Gross tonnage (GT)	87,390	Clarksons
Deadweight (dwt)	172,517	Clarksons
Length over all (m)	289.00	Clarksons
Draught (m)	17.83	Clarksons
Beam (m)	45.00	Clarksons
Speed (knots)	14.30	Clarksons
Self-propelled	Yes, diesel 2-stroke	Clarksons
Horsepower	19,980	Clarksons
Main engine	1 x Diesel - MAN B. & W. 6S70MC6.1	Clarksons
Main engine fuel type	VLS IFO	Clarksons
Auxiliary engine	2 x Aux. Steam Turb. Gen.	Clarksons
Auxiliary engine fuel type	Not available	Clarksons
Emergency engine	Not available	Clarksons
Emergency engine fuel type	Not available	Clarksons
Boiler	21 x Boiler, Oil/Gas fired - Aalborg, 2 x Boiler, Oil/Gas fired	Clarksons
Alternative fuel type	Not available	Clarksons
Shaft generator	Not available	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	80	Karpowership: khan-class
Power generation data		
Power generation equipment	21 x Generator, Power Production - Wartsila 4-stroke & Turbine Generator	Clarksons
Engine technology	Dual fuel HFO-NG	Karpowership: khan-class
On-board fuel storage	± 8 weeks	Karpowership: khan-class
Capacity (MW)	470	Karpowership: khan-class
Substation voltage (kV)	100-420	Karpowership: khan-class

Description	Data	Source
Frequency (Hz)	42	Karpowership: khan-class
Deployment data		
Last location	Yalova, Turkey in Europe/Asia (last received position is from 01/10/2019).	Ship KPS ORHAN ALI KHAN (Bulk Carrier) Registered in Liberia - Vessel details, Current position and Voyage information - IMO 9248514, MMSI 636017311, Call Sign D5KH5 | AIS Marine Traffic
Deployment history	No information found.	
Clients	No information found.	
Incidents, issues or problems	No information found.	

Table 26 - Floating powerplant #5 'Karadeniz Powership Kaya Bey'

Description	Data	Source
Ship identity		
Name	Karadeniz Powership Kaya Bey	Clarksons
IMO number	7925546	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	1983	Clarksons
Conversion year	2010	Clarksons
Conversion yard and location	No information found.	
Status	In Service	Clarksons
Ex ship type and ex name	Bulk carrier 'Kamari' (2000), bulk carrier 'St-Cergue', bulk carrier 'El Amaan' (1983)	Clarksons & Vesselfinder: KPS KAYA BEY Power Station Vessel, IMO 7925546, currently sailing under the flag of Liberia
Flag state	Liberia	Clarksons
Classification society	Bureau Veritas	Clarksons
Owner	Karmarine Karadeniz	Clarksons
Group owner	Karadeniz Holding	Clarksons
Registered owner company	Karpowership Mena Co. Ltd.	Clarksons
Operator	Karpowership	Clarksons
Ship data		
Gross tonnage (GT)	41,449	Clarksons
Deadweight (dwt)	75,485	Clarksons
Length over all (m)	241.88	Clarksons
Draught (m)	13.60	Clarksons
Beam (m)	32.20	Clarksons
Speed (knots)	14.00	Clarksons
Self-propelled	Yes, diesel 2-stroke	Clarksons
Horsepower	17,960	Clarksons
Main engine	1 x Diesel - MAN Energy Solutions K8SZ70/150C	Clarksons
Main engine fuel type	VLS IFO	Clarksons
Auxiliary engine	Not available	Clarksons
Auxiliary engine fuel type	Not available	Clarksons
Emergency engine	Not available	Clarksons
Emergency engine fuel type	Not available	Clarksons

Description	Data	Source
Boiler	1 x Boiler, Oil/Gas fired, 1 x Boiler, Exhaust Heated	Clarksons
Alternative fuel type	Not available	Clarksons
Shaft generator	Not available	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	50[§]	Shark Class (karpowership.com)
Power generation data		
Power generation equipment	19 generators[*]	Clarksons
Engine technology	Dual fuel engine technology (HFO-NG)[†]	Shark Class (karpowership.com)
On-board fuel storage	2 weeks[†]	Shark Class (karpowership.com)
Capacity (MW)	216 MW	Karpowership: Powership Fleet
Substation voltage (kV)	70-170[†]	Shark Class (karpowership.com)
Frequency (Hz)	50/60[†]	Shark Class (karpowership.com)
Deployment data		
Last location	Marsa Bashayer, Sudan, Africa (last received position if from 10/10/2019).	Ship KARADENIZ POWERSHIP KAYA BEY (Power Station Vessel) Registered in Liberia - Vessel details, Current position and Voyage information - IMO 7925546, MMSI 636016802, Call Sign D5HW7 | AIS Marine Traffic
Deployment history	Karpowership had a contract with the Sudanese Thermal Power Generating Company (STPGC) to deploy a Powership of 150 MW to Sudan for a period of three years. Given its current location, it is possible that Kaya Bey is deployed under this contract or a follow-up contract.	Karpowership: Sudan Africa
	In December 2008, Karpowership signed a contract with ministry of Electricity of Iraq (MoE) to deploy three Powerships of 520 MW in total. Karadeniz Powership Doğan Bey, Rauf Bey and Kaya Bey gradually started their operations in Basrah in the second half of 2010. Project is completed.	Karpowership: IRAQ (Past Project) Middle East
	In November 2010 the ship set sail to Karachi, Pakistan also carrying humanitarian aid for the victims of the 2010 Pakistan floods. She bridged electricity shortage supplying around 20% of the power demand of the 12-million population city of Karachi for a five-year term. The Powership burns heavy fuel oil (HFO), the only available energy resource in Pakistan. This	Wikipedia: MV Karadeniz Powership Kaya Bey

§ Ship class not given on Karpowership website. Based on ship characteristics should be part of the Shark Class.

* Based on number of exhaust systems from images of the powership.

Description	Data	Source
	activity in Pakistan overlaps the contract in Iraq. It is therefore 100% clear and certain what exactly happened.	
Clients	Ministry of Electricity of Iraq (MoE).	Karpowership: IRAQ (Past Project) Middle East
	Pakistan National Accountability Bureau (NAB).	Wikipedia: MV Karadeniz Powership Kaya Bey
Incidents, issues or problems	Karadeniz Powership Kaya Bey and Karadeniz Powership Ali Can Bey generated electricity for Pakistan for 2 years (until end 2012), but were set to return to Turkey after the Pakistani High Federal Court cancelled all energy rental agreements in the country on the grounds that the energy deals were undertaken in an irregular manner. Authorities decided the ships had to leave after repaying the unused amount of the $ 17.2 million deposit issued by the Pakistani government. However, a Pakistani member of the country's parliament lodged an objection with the court, claiming that Turkish ship-owners Karkey - a subsidiary of Karadeniz Holding - should pay $ 229[**] including interests for the ships release. The court blocked the ships from leaving the country, and 'Kaya Bey' and 'Ali Can Bey' with a value of $ 400 million, are being held in the territorial waters of Karachi, one of the main cities of Pakistan.	Turkish power ships retained in Karachi

Table 27 - Floating powerplant #6 'Karadeniz Powership Rauf Bey'

Description	Data	Source
Ship identity		
Name	Karadeniz Powership Rauf Bey	Clarksons
IMO number	7925522	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	1982	Clarksons
Conversion year	2010	Clarksons
Conversion yard and location	Tuzla Sedef Shipyard, Istanbul, Turkey	What is Karadeniz Powership? (marineinsight.com)
Status	In Service	Clarksons

[**] $ 229 sounds as a very low amount and may be an error in the article.

Description	Data	Source
Ex ship type and ex name	Agios Raphael (2001), bulk carrier; El Pampero (1991), bulk carrier; Gulf Grain (1982), bulk carrier	KPS RAUFBEY, Power Station Vessel - Scheepsdetails en huidige positie - IMO 7925522 MMSI 271045639 - VesselFinder
Flag state	Turkey	Clarksons
Classification society	Turk Loydu	Clarksons
Owner	Karmarine Karadeniz	Clarksons
Group owner	Karadeniz Holding	Clarksons
Registered owner company	Karpowership Mena Co. Ltd.	Clarksons
Operator	Karmarine Karadeniz	Clarksons
Ship data		
Gross tonnage (GT)	41,010	Clarksons
Deadweight (dwt)	75,485	Clarksons
Length over all (m)	241,88	Clarksons
Draught (m)	13,59	Clarksons
Beam (m)	32,20	Clarksons
Speed (knots)	14,00	Clarksons
Self-propelled	Yes, diesel 2-stroke	Clarksons
Horsepower	17,960	Clarksons
Main engine	1 x Diesel - MAN Energy Solutions K8Z70/150CL	Clarksons
Main engine fuel type	VLS IFO	Clarksons
Auxiliary engine	2 x Aux. Diesel Gen. - MAN Energy Solutions	Clarksons
Auxiliary engine fuel type	Not available	Clarksons
Emergency engine	Not available	Clarksons
Emergency engine fuel type	Not available	Clarksons
Boiler	1 x Boiler, Oil/Gas fired, 1 x Boiler, Exhaust Heated	Clarksons
Alternative fuel type	Not available	Clarksons
Shaft generator	Not available	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	50[†]	Shark Class (karpowership.com)
Power generation data		
Power generation equipment	15 generators[*]	Sudan (karpowership.com)
Engine technology	Duel-fuel engine technology HFO-NG[†]	Shark Class (karpowership.com)
On-board fuel storage	2 weeks[†]	Shark Class (karpowership.com)
Capacity (MW)	179	https://karpowership.com/en/sudan
Substation voltage (kV)	70-170[†]	Shark Class (karpowership.com)
Frequency (Hz)	50/60[†]	Shark Class (karpowership.com)
Deployment data		
Last location	Marsa Bashayer, Sudan, Africa (last received position is from 16/12/2021).	Ship KARADENIZ POWERSHIP RAUF BEY (Special Vessel) Registered in Turkey - Vessel details, Current position and Voyage information - IMO 7925522, MMSI 271045639, Call Sign TCA4799 | AIS Marine Traffic

[†] Ship class not given on Karpowership website. Based on ship characteristics should be part of the Shark Class.
[*] Based on number of exhaust systems from images of the powership.

Description	Data	Source
Deployment history	From 2010 to 2018 supplying Iraq 150 MW.	https://karpowership.com/en/iraq
	Since 2018 supplying Sudan 150 MW.	https://karpowership.com/en/sudan
Clients	In December 2008, Karpowership signed a contract with ministry of Electricity of Iraq (MoE) to deploy three Powerships of 520 MW in total. Karadeniz Powership Doğan Bey, Rauf Bey and Kaya Bey gradually started their operations in Basrah in the second half of 2010. Iraq holds a unique position for the Power of Friendship Project. Iraq is the first country where Karpowership deployed a Powership, the first country to order additional Powerships and the first country to extend its contract terms after initial term was successfully completed. Karpowership supplied 15% of Iraq's total electricity needs.	https://karpowership.com/en/iraq
	In April 2018, Karpowership signed a contract with Sudanese Thermal Power Generating Company (STPGC) to deploy a Powership of 150 MW to Sudan for a period of three years. Karadeniz Powership Rauf Bey has been in operation since May 2018. Karpowership has been supplying 10% of Sudan's total electricity needs.	https://karpowership.com/en/sudan
Incidents, issues or problems	No information found.	

Table 28 - Floating powerplant #7 'Karadeniz Powership Fatmagul Sultan'

Description	Data	Source
Ship identity		
Name	Karadeniz Powership Fatmagul Sultan	Clarksons
IMO number	Not applicable since this floating powerplant is not self-propelled	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	2009	Clarksons
Conversion year	2013	Clarksons
Conversion yard and location	Tuzla Sedef Shipyard, Istanbul, Turkey	Karadeniz Powership Fatmagul Sultan departs from Tuzla Sedef shipyard in Istanbul - gCaptain
Status	In Service	Clarksons
Ex ship type and ex name	Sainty No., barge carrier	Clarksons
Flag state	Liberia	Clarksons
Classification society	Bureau Veritas	Clarksons
Owner	Karmarine Karadeniz	Clarksons
Group owner	Karadeniz Holding	Clarksons

Description	Data	Source
Registered owner company	KARPOWERSHIP LEBANON COMPANY LIMITED	Clarksons
Operator	Karmarine Karadeniz	Clarksons
Ship data		
Gross tonnage (GT)	30,294	Clarksons
Deadweight (dwt)	10,468	Clarksons
Length over all (m)	141,96	Clarksons
Draught (m)	5,40	Clarksons
Beam (m)	42,00	Clarksons
Speed (knots)	Not applicable	Clarksons
Self-propelled	No, non-propelled	Clarksons
Horsepower	Not applicable	Clarksons
Main engine	Not applicable	Clarksons
Main engine fuel type	Not applicable	Clarksons
Auxiliary engine	Not applicable	Clarksons
Auxiliary engine fuel type	Not applicable	Clarksons
Emergency engine	Not applicable	Clarksons
Emergency engine fuel type	Not applicable	Clarksons
Boiler	Not applicable	Clarksons
Alternative fuel type	Not applicable	Clarksons
Shaft generator	Not applicable	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	60	https://karpowership.com/orca-class
Power generation data		
Power generation equipment	11 x generator, power production	Clarksons
Engine technology	Dual-fuel engine technology HFO-NG	https://karpowership.com/orca-class
On-board fuel storage	2 weeks	https://karpowership.com/orca-class
Capacity (MW)	202	https://karpowership.com/lebanon
Substation voltage (kV)	100-240	https://karpowership.com/orca-class
Frequency (Hz)	50/60	https://karpowership.com/orca-class
Deployment data		
Last location	No information found.	
Deployment history	202 MW to Lebanon for nine years.	https://karpowership.com/lebanon
Clients	In June 2012, Karpowership signed a contract with the Lebanese Electricity Utility (EDL) to deploy two Powerships of 404 MW in total. Karadeniz Powership Fatmagül Sultan and Orhan Bey have been in operation in Zouk and Jieh since 2013. In 2018, the contract period was extended for an additional three years, making the contract duration nine years in total. Karpowership has been supplying 25% of Lebanon's total electricity needs.	https://karpowership.com/lebanon
Incidents, issues or problems	The contract expired in September 2021, while Électricité du Liban owed Karpowership overdue payments in excess of $ 100 million. Powership has stopped its supplies on 1 October 2021.	Turkish company cuts off electricity supply to Lebanon | Daily Sabah

Table 29 - Floating powerplant #8 'Karadeniz Powership Dogan Bey'Z

Description	Data	Source
Ship identity		
Name	Karadeniz Powership Dogan Bey	Clarksons
IMO number	8117031	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	1984	Clarksons
Conversion year	2010	Clarksons
Conversion yard and location	Tuzla Sedef Shipyard, Istanbul, Turkey	Clarksons
Status	In Service	Clarksons
Ex ship type and ex name	Melpomeni (2007), bulk carrier; Seapace (2003), bulk carrier; Saqqara (1984), bulk carrier; Sono (1983), bulk carrier	KPS DOGAN BEY, Power Station Vessel - Ship details and current position - IMO 8117031 MMSI 636014323 - VesselFinder
Flag state	Liberia	Clarksons
Classification society	Bureau Veritas	Clarksons
Owner	Karmarine Karadeniz	Clarksons
Group owner	Karadeniz Holding	Clarksons
Registered owner company	KARADENIZ POWERSHIP KAYA BEY COMPANY LIMITED	Clarksons
Operator	Karpowership	Clarksons
Ship data		
Gross tonnage (GT)	24,729	Clarksons
Deadweight (dwt)	41,534	Clarksons
Length over all (m)	188,14	Clarksons
Draught (m)	10,71	Clarksons
Beam (m)	31,04	Clarksons
Speed (knots)	14,75	Clarksons
Self-propelled	Yes, diesel 2-stroke	Clarksons
Horsepower	11,200	Clarksons
Main engine	1 x Diesel - MAN B. & W. 6L67GFCA	Clarksons
Main engine fuel type	VLS IFO	Clarksons
Auxiliary engine	3 x Aux. Diesel Gen. - Yanmar	Clarksons
Auxiliary engine fuel type	Not available	Clarksons
Emergency engine	Not available	Clarksons
Emergency engine fuel type	Not available	Clarksons
Boiler	1 x Boiler, Oil/Gas fired, 1 x Boiler, Exhaust Heated	Clarksons
Alternative fuel type	Not available	Clarksons
Shaft generator	Not available	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	(50)[†]	Shark Class (karpowership.com)
Power generation data		
Power generation equipment	12 generators of 11 MW	Wayback Machine (archive.org)
Engine technology	Not found Duel-fuel engine technology HFO-NG[†]	Shark Class (karpowership.com)
On-board fuel storage	2 weeks[†]	Shark Class (karpowership.com)

† Ship class not given on Karpowership website. Based on ship characteristics should be part of the Shark Class.

Description	Data	Source
Capacity (MW)	144 MW	Wayback Machine (archive.org)
Substation voltage (kV)	70-170†	Shark Class (karpowership.com)
Frequency (Hz)	50/60†	Shark Class (karpowership.com)
Deployment data		
Last location	Freetown, Sierra Leone, Africa (last received position is from 24-11-2021).	Ship KARADENIZ POWERSHIP DOGAN BEY (Power Station Vessel) Registered in Liberia - Vessel details, Current position and Voyage information - IMO 8117031, MMSI 636014323, Call Sign A8TB7 | AIS Marine Traffic
Deployment history	Since 2010 delivering 125 MW to Iraq as a powership.	Iraq (karpowership.com)
Clients	In December 2008, Karpowership signed a contract with ministry of Electricity of Iraq (MoE) to deploy three Powerships of 520 MW in total. Karadeniz Powership Doğan Bey, Rauf Bey and Kaya Bey gradually started their operations in Basrah in the second half of 2010. Iraq holds a unique position for the Power of Friendship Project. Iraq is the first country where Karpowership deployed a Powership, the first country to order additional Powerships and the first country to extend its contract terms after initial term was successfully completed. Karpowership supplied 15% of Iraq's total electricity needs.	Iraq (karpowership.com)
Incidents, issues or problems	No information found.	

Table 30 - Floating powerplant #9 'Karadeniz Powership Mehmet Bey'

Description	Data	Source
Ship identity		
Name	Karadeniz Powership Mehmet Bey	Clarksons
IMO number	9232785	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	2002	Clarksons
Conversion year	2016††	KPS MEHMET BEY, Power Station Vessel - Ship details and current position - IMO 9232785 MMSI 636017383 - VesselFinder
Conversion yard and location	Sedef Gemi End., in Gebze in Turkey	Clarksons
Status	In Service	Clarksons
Ex ship type and ex name	Bulk carrier Transwood (2008); bulk carrier Finnwood (2002)	KPS MEHMET BEY, Power Station Vessel - Ship details and current position - IMO 9232785 MMSI 636017383 - VesselFinder

†† Year of registration of powership name. Should be approximately the year of conversion.

Description	Data	Source
Flag state	Liberia	Clarksons
Classification society	Bureau Veritas	Clarksons
Owner	Karmarine Karadeniz	Clarksons
Group owner	Karadeniz Holding	Clarksons
Registered owner company	Karadeniz Powership 25 DMCC	Clarksons
Operator	Karmarine Karadeniz	Clarksons
Ship data		
Gross tonnage (GT)	23,223	Clarksons
Deadweight (dwt)	18,855	Clarksons
Length over all (m)	178.84	Clarksons
Draught (m)	9.00	Clarksons
Beam (m)	25.60	Clarksons
Speed (knots)	17.50	Clarksons
Self-propelled	Yes, diesel 4-stroke	Clarksons
Horsepower	17,123	Clarksons
Main engine	2 x Diesel - Wartsila 4-stroke 6L46C	Clarksons
Main engine fuel type	VLS IFO	Clarksons
Auxiliary engine	3 x Aux. Diesel Gen. - Wartsila 4-stroke	Clarksons
Auxiliary engine fuel type	VLS IFO	Clarksons
Emergency engine	1 x Emergency Diesel Gen.	Clarksons
Emergency engine fuel type	VLS MDO	Clarksons
Boiler	1 x Boiler, Oil/Gas fired - Gesab, 1 x Boiler, Exhaust Heated	Clarksons
Alternative fuel type	Not available	Clarksons
Shaft generator	Shaft generator (PTO), 400V, 50Hz	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	50	Shark Class (karpowership.com)
Power generation data		
Power generation equipment	6 generators*	Clarksons
Engine technology	Dual-fuel engine technology HFO-NG	Shark Class (karpowership.com)
On-board fuel storage	2 weeks	Shark Class (karpowership.com)
Capacity (MW)	125	Mozambique (karpowership.com)
Substation voltage (kV)	70-170	Shark Class (karpowership.com)
Frequency (Hz)	50/60	Shark Class (karpowership.com)
Deployment data		
Last location	Nacala, Mozambique, Africa (last received position on 3-11-2021).	Ship KARADENIZ POWERSHIP MEHMET BEY (Special Vessel) Registered in Liberia - Vessel details, Current position and Voyage information - IMO 9232785, MMSI 636017383, Call Sign D5KQ4 | AIS Marine Traffic
Deployment history	Delivering 125 MW to Mozambique.	Mozambique (karpowership.com)
Clients	In March 2018, upon the completion of The Zambian contract, Karpowership signed a new contract with Mozambique's electricity utility company, Electricidade de Mozambique	Mozambique (karpowership.com)

* Based on number of exhaust systems from images of the powership.

Description	Data	Source
	(EdM), to deploy a Powership of 125 MW for a period of ten years. Upon the LNG conversion notice of EdM, Karpowership has been taking necessary actions to enhance the first LNG - to - Power Project in Sub-Saharan Africa via its own LNG assets (FSRU) to be ready for operation in 2021. Karpowership has been supplying 10% of Mozambique's total electricity needs via 125 MW Karadeniz Powership Mehmet Bey.	
Incidents, issues or problems	No information found.	

Table 31 - Floating powerplant #10 'Karadeniz Powership Ibrahim Bey'

Description	Data	Source
Ship identity		
Name	Karadeniz Powership Ibrahim Bey	Clarksons
IMO number	9216638	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	2002	Clarksons
Conversion year	2016‡	KPS IBRAHIM BEY, Power Station Vessel - Ship details and current position - IMO 9216638 MMSI 636017324 - VesselFinder
Conversion yard and location	Besiktas Shipyard, in Altinova Yalova in Turkey	Clarksons
Status	In Service	Clarksons
Ex ship type and ex name	Bulk carrier Transpine (2008); bulk carrier Finnpine (2001)	KPS IBRAHIM BEY, Power Station Vessel - Ship details and current position - IMO 9216638 MMSI 636017324 - VesselFinder
Flag state	Liberia	Clarksons
Classification society	Bureau Veritas	Clarksons
Owner	Karmarine Karadeniz	Clarksons
Group owner	Karadeniz Holding	Clarksons
Registered owner company	KARADENIZ POWERSHIP IBRAHIM BEY COMPANY LIMITED	Clarksons
Operator	Karmarine Karadeniz	Clarksons
Ship data		
Gross tonnage (GT)	20,851	Clarksons
Deadweight (dwt)	18,855	Clarksons
Length over all (m)	178,60	Clarksons
Draught (m)	9.00	Clarksons
Beam (m)	25.60	Clarksons
Speed (knots)	17.50	Clarksons
Self-propelled	Yes, diesel 4-stroke	Clarksons
Horsepower	16,884	Clarksons
Main engine	2 x Diesel - Wartsila 4-stroke 6L46C	Clarksons
Main engine fuel type	VLS IFO	Clarksons

‡ Year of registration for powership name. Should be approximately the year of conversion.

Description	Data	Source
Auxiliary engine	3 x Aux. Diesel Gen. - Wartsila 4-stroke	Clarksons
Auxiliary engine fuel type	VLS IFO	Clarksons
Emergency engine	1 x Emergency Diesel Gen.	Clarksons
Emergency engine fuel type	VLS MDO	Clarksons
Boiler	1 x Boiler, Oil/Gas fired - Gesab, 1 x Boiler, Exhaust Heated	Clarksons
Alternative fuel type	Not available	Clarksons
Shaft generator	Shaft generator (PTO), 400V, 50Hz	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	50	Shark Class (karpowership.com)
Power generation data		
Power generation equipment	6 generators*	Clarksons
Engine technology	Dual-fuel engine technology HFO-N	Shark Class (karpowership.com)
On-board fuel storage	2 weeks	Shark Class (karpowership.com)
Capacity (MW)	120	"Black Sea Powership Ibrahim Bey Passed Through the Bosphorus (denizhaber.com)
Substation voltage (kV)	70-170	Shark Class (karpowership.com)
Frequency (Hz)	50/60	Shark Class (karpowership.com)
Deployment data		
Last location	Conakry, Guinea, Africa (latest position reported on 15-12-2021).	Ship KPS IBRAHIM BEY (Power Station Vessel) Registered in Liberia - Vessel details, Current position and Voyage information - IMO 9216638, MMSI 636017324, Call Sign D5KJ2 | AIS Marine Traffic
Deployment history	Since 2020 supplying 105 MW to Guinea.	PROJECT GUINEA (karpowership.com)
Clients	In December 2019, Karpowership signed a contract with Guinea's national electricity company, Electricité Nationale de Guinée to deploy a Powership to supply 105 MW for a period of one year. Karadeniz Powership İbrahim Bey started operation in February 2020, in Conakry and is supplying 10% of Guinea's total electricity needs.	PROJECT GUINEA (karpowership.com)
Incidents, issues or problems	No information found.	

Table 32 - Floating powerplant #11 'Karadeniz Powership Zeynep Sultan'

Description	Data	Source
Ship identity		
Name	Karadeniz Powership Zeynep Sultan	Clarksons
IMO number	8116051	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	1984	Clarksons

* Based on number of exhaust systems from images of the powership.

Description	Data	Source
Conversion year	2012	Clarksons
Conversion yard and location	Tuzla Sedef Shipyard, Instanbul, Turkey[‡]	Wikipedia
Status	In Service	Clarksons
Ex ship type and ex name	Explorer (2003), barge carrier; Smit Explorer (1999), barge carrier; Pavel Antokolskiy (1984), barge carrier	KPS ZEYNEP SULTAN, Power Station Vessel -Ship details and current position- IMO 8116051 MMSI 636015325 - VesselFinder
Flag state	Liberia	Clarksons
Classification society	Bureau Veritas	Clarksons
Owner	Karmarine Karadeniz	Clarksons
Group owner	Karadeniz Holding	Clarksons
Registered owner company	KARPOWERSHIP INDONESIA 11 DMCC	Clarksons
Operator	Karpowership	Clarksons
Ship data		
Gross tonnage (GT)	19,453	Clarksons
Deadweight (dwt)	8,638	Clarksons
Length over all (m)	158.90	Clarksons
Draught (m)	4.40	Clarksons
Beam (m)	31.00	Clarksons
Speed (knots)	13.50	Clarksons
Self-propelled	Yes, diesel 4-stroke	Clarksons
Horsepower	7,660	Clarksons
Main engine	2 x Diesel - Wartsila 4-stroke 9R32	Clarksons
Main engine fuel type	VLS IFO	Clarksons
Auxiliary engine	2 x Aux. Diesel Gen.	Clarksons
Auxiliary engine fuel type	Not available	Clarksons
Emergency engine	Not available	Clarksons
Emergency engine fuel type	Not available	Clarksons
Boiler	Not available	Clarksons
Alternative fuel type	Not available	Clarksons
Shaft generator	Not available	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	50	Shark Class (karpowership.com)
Power generation data		
Power generation equipment	6 generators[*]	Shark Class (karpowership.com)
Engine technology	Dual-fuel engine technology with HFO-NG	Shark Class (karpowership.com)
On-board fuel storage	2 weeks	Shark Class (karpowership.com)
Capacity (MW)	125	PROJECT INDONESIA ASIA (karpowership.com)
Substation voltage (kV)	70-170	Shark Class (karpowership.com)
Frequency (Hz)	50/60	Shark Class (karpowership.com)

‡ Wikipedia source is no longer available. Conversion yard seems likely, since many of the other powerships are also converted here.

* Based on number of exhaust systems from images of the powership.

Description	Data	Source
Deployment data		
Last location	Java Sea, Indonesia, Asia (latest position reported on 15-12-2021).	Ship KPS ZEYNEP SULTAN (Special Vessel) Registered in Liberia - Vessel details, Current position and Voyage information - IMO 8116051, MMSI 636015325, Call Sign A8ZZ9 | AIS Marine Traffic
Deployment history	Since 2016 supplying Indonesia with 125 MW.	PROJECT INDONESIA ASIA (karpowership.com)
Clients	Indonesia is Karpowership's first project in South East Asia. In 2015 and 2016, Karpowership signed five contracts with the state utility PT PLN (Persero) to deploy five Powerships of 1,000 MW in total for a period of five years. Karadeniz Powership Zeynep Sultan and Nezih Bey, Onur Sultan, Gökhan Bey and Yasin Bey has been in operation in Amurang, Medan, Kupang and Ambon islands respectively since 2016. Since 2018, Karadeniz Powership Onur Sultan in Medan has been operating with indigenous gas. Karpowership has been supplying 30% of North Sulawesi's, 55% of East Nusa Tenggara's, 80% of Ambon's, 10% of Medan's total electricity needs. As of Q4 2020, Amurang project has started transitioning to becoming the company's first LNG to Power project. Karadeniz Powership Zeynep Sultan is expected fully operate with natural gas by the end of the year.	PROJECT INDONESIA ASIA (karpowership.com)
Incidents, issues or problems	No information found.	

Table 33 - Floating powerplant #12 'Karadeniz Powership Irem Sultan'

Description	Data	Source
Ship identity		
Name	Karadeniz Powership Irem Sultan	Clarksons
IMO number	8222252	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	1984	Clarksons
Conversion year	2010	Clarksons
Conversion yard and location	Tuzla Sedef Shipyard, Istanbul, Turkey	Black Sea Powership Irem Sultan to Give Iraq "Energy" (haberler.com)
Status	In Service	Clarksons
Ex ship type and ex name	Enterprise (2003), barge carrier; Smit Enterprise (1998), barge carrier;	KPS IREM SULTAN, Power Station Vessel - Ship details and current position- IMO 8222252 MMSI 636014808 - VesselFinder

Description	Data	Source
	Danube Express (1992), barge carrier; Nikolay Markin (1984), barge carrier	
Flag state	Liberia	Clarksons
Classification society	Bureau Veritas	KARADENIZ POWERSHIP IREM SULTAN - IMO 8222252 - ShipSpotting.com - Ship Photos and Ship Tracker
Owner	Karmarine Karadeniz	Clarksons
Group owner	Karadeniz Holding	Clarksons
Registered owner company	Powership Operation DMCC	Clarksons
Operator	Karpowership	Clarksons
Ship data		
Gross tonnage (GT)	17,395	Clarksons
Deadweight (dwt)	8,727	Clarksons
Length over all (m)	157.75	Clarksons
Draught (m)	4.43	Clarksons
Beam (m)	29.00	Clarksons
Speed (knots)	10.00	Clarksons
Self-propelled	Yes, diesel 4-stroke	Clarksons
Horsepower	18,120	Clarksons
Main engine	2 x Diesel - Fiat BL230.8V, 2 x Diesel - Fiat BL230.12V	Clarksons
Main engine fuel type	VLS IFO	Clarksons
Auxiliary engine	Not available	Clarksons
Auxiliary engine fuel type	Not available	Clarksons
Emergency engine	Not available	Clarksons
Emergency engine fuel type	Not available	Clarksons
Boiler	1 x Boiler, Oil/Gas fired	Clarksons
Alternative fuel type	Not available	Clarksons
Shaft generator	Shaft generator (PTO), voltage (V) and frequency (Hz) unknown	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	50	Shark Class (karpowership.com)
Power generation data		
Power generation equipment	6 generators	Karadeniz Power Ship KPS-6 Irem Sultan - 110 MW On Dual Fuel (HFO and Gas Fired) (berksan.com)
Engine technology	Dual-fuel engine technology HFO-NG	Shark Class (karpowership.com)
On-board fuel storage	2 weeks	Shark Class (karpowership.com)
Capacity (MW)	115	Zambia (karpowership.com)
Substation voltage (kV)	70-170	Shark Class (karpowership.com)
Frequency (Hz)	50/60	Shark Class (karpowership.com)
Deployment data		
Last location	Yalova, Turkey, Asia (last position reported on 17-12-2021).	Ship KPS IREM SULTAN (Power Station Vessel) Registered in Liberia - Vessel details, Current position and Voyage information - IMO 8222252, MMSI 636014808, Call Sign A8WQ6 | AIS Marine Traffic
Deployment history	From 2016-2018 supplying 115 MW to Zambia.	Zambia (karpowership.com)

Description	Data	Source
Clients	In November 2015, Karpowership signed a contract with Mozambique's and Zambia's national utilities, Electricidade de Mozambique (EdM) and ZESCO to deploy a Powership of 115 MW to supply power to land-locked Zambia via Mozambique for a period of two years. Karadeniz Powership İrem Sultan supplied electricity to Nacala between 2016-2018. This delivery of economically critical electricity was the world's first cross-border power delivery by a single Powership. Karpowership supplied 16% of Zambia's total electricity needs.	Zambia (karpowership.com)
Incidents, issues or problems	No information found.	

Table 34 - Floating powerplant #13 'Karadeniz Powership AliCan Bey'

Description	Data	Source
Ship identity		
Name	Karadeniz Powership AliCan Bey	Clarksons
IMO number	None	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	2009	Clarksons
Conversion year	No information found	
Conversion yard and location	Turkey	Wikipedia: MV Karadeniz Powership Alican BeyWi
Status	In Service	Clarksons
Ex ship type and ex name	Kim Heng Barge No.	Clarksons
Flag state	Turkey	Clarksons
Classification society	No information found	
Owner	Karmarine Karadeniz	Clarksons
Group owner	Karadeniz Holding	Clarksons
Registered owner company	No information found	
Operator	Karmarine Karadeniz	Clarksons
Ship data		
Gross tonnage (GT)	14,797	Clarksons
Deadweight (dwt)	10,393	Clarksons
Length over all (m)	91.44	Clarksons
Draught (m)	No information found	
Beam (m)	30.48	Clarksons
Speed (knots)	Not applicable	Clarksons
Self-propelled	No, non-propelled	Clarksons
Horsepower	Not applicable	Clarksons
Main engine	Not applicable	Clarksons
Main engine fuel type	Not applicable	Clarksons
Auxiliary engine	Not applicable	Clarksons
Auxiliary engine fuel type	Not applicable	Clarksons
Emergency engine	Not applicable	Clarksons

Description	Data	Source
Emergency engine fuel type	Not applicable	Clarksons
Boiler	Not applicable	Clarksons
Alternative fuel type	Not applicable	Clarksons
Shaft generator	Not applicable	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	No information found	
Power generation data		
Power generation equipment	No information found	
Engine technology	No information found	
On-board fuel storage	No information found	
Capacity (MW)	104[‡]	Rental Power: Turkish ship conducts test (tribune.com.pk) Iraq (karpowership.com)
Substation voltage (kV)	No information found	
Frequency (Hz)	No information found	
Deployment data		
Last location	No information found.	
Deployment history	From 2011 until 2012 supplying 104 MW to Pakistan.	Turkse energieschepen verlaten Pakistan - Breaking News (sabah.com.tr)
Clients	End January 2011, she arrived at Port of Karachi, Pakistan joining MV Karadeniz Powership Kaya Bey, the first Powership of the fleet, which came to Korangi on November 17, 2010. The Powerships were with 232MW able to meet almost 50% of the electricity power needs of the 18 million people in Karachi.	Turkish energy ships leave Pakistan - Breaking News (sabah.com.tr)
Incidents, issues or problems	The Supreme Court of Pakistan declared on March 30, 2011 that all rental powerplants (RPP) are illegal and the operating RPPs have to be closed. In March 2012, the Karadeniz Energy Group (Karkey) annulled the energy purchase agreement - a RPP contract- with the Pakistan National Accountability Bureau (NAB), which covered the service of the Powerships MV KPS Kaya Bey and the later stationed MV KPS Alican Bey. The reason was that the Pakistani side failed to perform their obligations in payments and oil supply. By the end of October 2012, the Pakistani government ordered the repayment of the unused deposit in amount of US$ 17.2 million from the Turkish partner before the ships can leave.	Turkish energy ships leave Pakistan- Breaking News (sabah.com.tr) The sad saga of rental powerplants | Pakistan Today Case Details | ICSID (worldbank.org)

‡ Capacity calculated based on total capacity at location and the capacity of the other powership located there.

Description	Data	Source
	Upon a complaint filed by a politician in the Parliament of Pakistan, the Supreme Court of Pakistan ordered the seizure of the retained Powerships due to a fine of US$ 120 million demanded by the NAB. The case went to international arbitration on March 11, 2013. On May 16, 2014 after two years of retainment, LPS Kaya Bey left Karachi heading Dubai for repairs and maintenance in compliance with an intermediate decision of the International Centre for Settlement of Investment Disputes (ICSID). On August 1 of the same year, a second decision of the ICSID enabled the definitive and lasting release of the Powership. The dispute was also subject of talks at highest-level of politicians between the two countries' prime ministers and state presidents. It was reported that KPS Alican Bey and two other vessels of the Turkish company were still in retainment by August 2014. Tribunal constituted under the World Bank's arbitral center, ICSID, issued the award in August 2017 in favor of Karkey in the case filed by Karkey against Pakistan. Pakistan has been sentenced to pay the company one of the highest compensation amounts under ICSID.	

Table 35 - Floating powerplant #14 'Karadeniz Powership Yasin Bey'

Description	Data	Source
Ship identity		
Name	Karadeniz Powership Yasin Bey	Clarksons
IMO number	9214551	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	2000	Clarksons
Conversion year	2016	Clarksons
Conversion yard and location	Sedef Gemi End., in Gebze in Turkey	Clarksons
Status	In Service	Clarksons
Ex ship type and ex name	HR Intonation (2011); Nirint Atlas (2008); Beluga Intonation (2004); Nirint Atlas (2003); Atlas (2002); TMC Atlas (2002); Industrial Atlas (2001); CEC Atlas (2000), cargo carrier	KPS YASIN BEY, Power Station Vessel - Ship details and current position - IMO 9214551 MMSI 636016955 - VesselFinder
Flag state	Liberia	Clarksons
Classification society	Bureau Veritas	Clarksons

Description	Data	Source
Owner	Karpowership	Clarksons
Group owner	Karadeniz Holding	Clarksons
Registered owner company	KARPOWERSHIP INDONESIA 23 DMCC	Clarksons
Operator	Karpowership	Clarksons
Ship data		
Gross tonnage (GT)	14,621	Clarksons
Deadweight (dwt)	5,675	Clarksons
Length over all (m)	162.15	Clarksons
Draught (m)	7.88	Clarksons
Beam (m)	20.40	Clarksons
Speed (knots)	15.20	Clarksons
Self-propelled	Yes, diesel 4-stroke	Clarksons
Horsepower	10,605	Clarksons
Main engine	1 x Diesel - Wartsila 4-stroke 8L46B	Clarksons
Main engine fuel type	VLS IFO	Clarksons
Auxiliary engine	3 x Aux. Diesel Gen. - Cummins Inc	Clarksons
Auxiliary engine fuel type	VLS MGO	Clarksons
Emergency engine	1 x Emergency Diesel Gen. - Cummins Inc	Clarksons
Emergency engine fuel type	VLS MGO	Clarksons
Boiler	1 x Boiler, Oil/Gas fired, 1 x Boiler, Exhaust Heated	Clarksons
Alternative fuel type	Not available	Clarksons
Shaft generator	Shaft generator (PTO), voltage (V) and frequency (Hz) unknown	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	50	Shark Class (karpowership.com)
Power generation data		
Power generation equipment	6 generators*	PROJECT INDONESIA ASIA (karpowership.com)
Engine technology	Duel-fuel engine technology HFO-NG	Shark Class (karpowership.com)
On-board fuel storage	2 weeks	Shark Class (karpowership.com)
Capacity (MW)	125	PROJECT INDONESIA ASIA (karpowership.com)
Substation voltage (kV)	70-170	Shark Class (karpowership.com)
Frequency (Hz)	50/60	Shark Class (karpowership.com)
Deployment data		
Last location	Ambon, Indonesia, Asia (latest position reported on 17-12-2021).	Ship KARADENIZ POWERSHIP YASIN BEY (Power Station Vessel) Registered in Liberia - Vessel details, Current position and Voyage information - IMO 9214551, MMSI 636016955, Call Sign D5BY8 | AIS Marine Traffic
Deployment history	Since 2016 supplying 125 MW to Indonesia.	PROJECT INDONESIA ASIA (karpowership.com)
Clients	Indonesia is Karpowership's first project in South East Asia. In 2015 and 2016, Karpowership signed five contracts with the state utility PT PLN	PROJECT INDONESIA ASIA (karpowership.com)

* Based on number of exhaust systems from images of the powership.

Description	Data	Source
	(Persero) to deploy five Powerships of 1,000 MW in total for a period of five years. Karadeniz Powership Zeynep Sultan and Nezih Bey, Onur Sultan, Gökhan Bey and Yasin Bey has been in operation in Amurang, Medan, Kupang and Ambon islands respectively since 2016. Since 2018, Karadeniz Powership Onur Sultan in Medan has been operating with indigenous gas. Karpowership has been supplying 30% of North Sulawesi's, 55% of East Nusa Tenggara's, 80% of Ambon's, 10% of Medan's total electricity needs. As of Q4 2020, Amurang project has started transitioning to becoming the company's first LNG to Power project.	
Incidents, issues or problems	No information found.	

Table 36 - Floating powerplant #15 'Karadeniz Powership Gokhan Bey'

Description	Data	Source
Ship identity		
Name	Karadeniz Powership Gokhan Bey	Clarksons
IMO number	9214563	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	2000	Clarksons
Conversion year	2016	Clarksons
Conversion yard and location	Sedef Gemi End., in Gebze in Turkey	Clarksons
Status	In Service	Clarksons
Ex ship type and ex name	HR Indication (2011); Beluga Indication (2007); Nirint Iberia (2006); Beluga Indication (2004); CEC Apollon (2000), cargo carrier	KPS GOKHAN BEY, Power Station Vessel - Ship details and current position - IMO 9214563 MMSI 636016857 - VesselFinder
Flag state	Liberia	Clarksons
Classification society	Bureau Veritas	Clarksons
Owner	Karmarine Karadeniz	Clarksons
Group owner	Karadeniz Holding	Clarksons
Registered owner company	Karpowership Indonesia 22 DMCC	Clarksons
Operator	Karmarine Karadeniz	Clarksons
Ship data		
Gross tonnage (GT)	14,190	Clarksons
Deadweight (dwt)	5,675	Clarksons
Length over all (m)	162.15	Clarksons
Draught (m)	7.88	Clarksons
Beam (m)	20.40	Clarksons
Speed (knots)	15.20	Clarksons
Self-propelled	Yes, diesel 4-stroke	Clarksons
Horsepower	10,605	Clarksons

Description	Data	Source
Main engine	1 x Diesel - Wartsila 4-stroke 8L46B	Clarksons
Main engine fuel type	VLS IFO	Clarksons
Auxiliary engine	3 x Aux. Diesel Gen. - Cummins Inc	Clarksons
Auxiliary engine fuel type	VLS MGO	Clarksons
Emergency engine	1 x Emergency Diesel Gen. - Cummins Inc	Clarksons
Emergency engine fuel type	VLS MGO	Clarksons
Boiler	1 x Boiler, Oil/Gas fired, 1 x Boiler, Exhaust Heated	Clarksons
Alternative fuel type	Not available	Clarksons
Shaft generator	Shaft generator (PTO), 60 Hz, voltage (V) unknown	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	50	Shark Class (karpowership.com)
Power generation data		
Power generation equipment	6 generators*	PROJECT INDONESIA ASIA (karpowership.com)
Engine technology	Duel-fuel engine technology HFO-N	Shark Class (karpowership.com)
On-board fuel storage	2 weeks	Shark Class (karpowership.com)
Capacity (MW)	125	PROJECT INDONESIA ASIA (karpowership.com)
Substation voltage (kV)	70-170	Shark Class (karpowership.com)
Frequency (Hz)	50/60	Shark Class (karpowership.com)
Deployment data		
Last location	Kupang, Indonesia, Asia (last position reported on 2-12-2021).	Ship KARADENIZ POWERSHIP GOKHAN BEY (Power Station Vessel) Registered in Liberia - Vessel details, Current position and Voyage information - IMO 9214563, MMSI 636016857, Call Sign D5BY7 | AIS Marine Traffic
Deployment history	Since 2016 supplying Indonesia with 125 MW.	PROJECT INDONESIA ASIA (karpowership.com)
Clients	Indonesia is Karpowership's first project in South East Asia. In 2015 and 2016, Karpowership signed five contracts with the state utility PT PLN (Persero) to deploy five Powerships of 1,000 MW in total for a period of five years. Karadeniz Powership Zeynep Sultan and Nezih Bey, Onur Sultan, Gökhan Bey and Yasin Bey has been in operation in Amurang, Medan, Kupang and Ambon islands respectively since 2016. Since 2018, Karadeniz Powership Onur Sultan in Medan has been operating with indigenous gas. Karpowership has been supplying 30% of North Sulawesi's, 55% of East Nusa Tenggara's, 80% of Ambon's, 10% of	PROJECT INDONESIA ASIA (karpowership.com)

* Based on number of exhaust systems from images of the powership.

Description	Data	Source
	Medan's total electricity needs. As of Q4 2020, Amurang project has started transitioning to becoming the company's first LNG to Power project.	
Incidents, issues or problems	No information found.	

Table 37 - Floating powerplant #16 'Karadeniz Powership Orhan Bey'

Description	Data	Source
Ship identity		
Name	Karadeniz Powership Orhan Bey	Clarksons
IMO number	Not applicable, since this floating powerplant is not self-propelled.	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	2009	Clarksons
Conversion year	2013	Clarksons
Conversion yard and location	No information found.	
Status	In Service	Clarksons
Ex ship type and ex name	Sainty No.	Clarksons
Flag state	Liberia	Clarksons
Classification society	Bureau Veritas	Clarksons
Owner	Karmarine Karadeniz	Clarksons
Group owner	Karadeniz Holding	Clarksons
Registered owner company	KARPOWERSHIP LEBANON COMPANY LIMITED	Clarksons
Operator	Karmarine Karadeniz	Clarksons
Ship data		
Gross tonnage (GT)	12,575	Clarksons
Deadweight (dwt)	20,000	Clarksons
Length over all (m)	135.80	Clarksons
Draught (m)	5.50	Clarksons
Beam (m)	42.00	Clarksons
Speed (knots)	Not applicable	Clarksons
Self-propelled	No, non-propelled	Clarksons
Horsepower	Not applicable	Clarksons
Main engine	Not applicable	Clarksons
Main engine fuel type	Not applicable	Clarksons
Auxiliary engine	Not applicable	Clarksons
Auxiliary engine fuel type	Not applicable	Clarksons
Emergency engine	Not applicable	Clarksons
Emergency engine fuel type	Not applicable	Clarksons
Boiler	Not applicable	Clarksons
Alternative fuel type	Not applicable	Clarksons
Shaft generator	Not applicable	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	60	Orca Class (karpowership.com)

Description	Data	Source
Power generation data		
Power generation equipment	11 generators	Orhan Bey will meet with Fatmagül Sultan and enlighten Lebanon- Son Haberler - Milliyet
Engine technology	Fuel-fuel engine technology HFO-NG	Orca Class (karpowership.com)
On-board fuel storage	2 weeks	Orca Class (karpowership.com)
Capacity (MW)	202	Lebanon (karpowership.com)
Substation voltage (kV)	100-240	Orca Class (karpowership.com)
Frequency (Hz)	50/60	Orca Class (karpowership.com)
Deployment data		
Last location	No information found.	
Deployment history	From 2013 until 2021 supplying Lebanon 202 MW.	Lebanon (karpowership.com)
Clients	In June 2012, Karpowership signed a contract with the Lebanese Electricity Utility (EDL) to deploy two Powerships of 404 MW in total. Karadeniz Powership Fatmagül Sultan and Orhan Bey have been in operation in Zouk and Jieh since 2013. In 2018, the contract period was extended for an additional three years, making the contract duration nine years in total. Karpowership has been supplying 25% of Lebanon's total electricity needs.	Lebanon (karpowership.com)
Incidents, issues or problems	The contract expired in September 2021, while Électricité du Liban owed Karpowership overdue payments in excess of $ 100 million. Powership has stopped its supplies on 1 October 2021.	Turkish company cuts off electricity supply to Lebanon | Daily Sabah

Table 38 - Floating powerplant #17 'Karadeniz Powership Aysegul Sultan'

Description	Data	Source
Ship identity		
Name	Karadeniz Powership Aysegul Sultan	Clarksons
IMO number	Not applicable, since this floating powerplant is not self-propelled	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	2009	Clarksons
Conversion year	No information found	
Conversion yard and location	No information found	
Status	In Service	Clarksons
Ex ship type and ex name	Karadeniz Powership Esra Sultan	Clarksons
Flag state	Liberia	Clarksons
Classification society	Bureau Veritas	Clarksons
Owner	Karmarine Karadeniz	Clarksons
Group owner	Karadeniz Holding	Clarksons
Registered owner company	KARPOWERSHIP 15 DMCC	Clarksons
Operator	Karmarine Karadeniz	Clarksons

Description	Data	Source
Ship data		
Gross tonnage (GT)	12,513	Clarksons
Deadweight (dwt)	23,664	Clarksons
Length over all (m)	135.80	Clarksons
Draught (m)	5.40	Clarksons
Beam (m)	42.00	Clarksons
Speed (knots)	Not applicable	Clarksons
Self-propelled	No, non-propelled	Clarksons
Horsepower	Not applicable	Clarksons
Main engine	Not applicable	Clarksons
Main engine fuel type	Not applicable	Clarksons
Auxiliary engine	Not applicable	Clarksons
Auxiliary engine fuel type	Not applicable	Clarksons
Emergency engine	Not applicable	Clarksons
Emergency engine fuel type	Not applicable	Clarksons
Boiler	Not applicable	Clarksons
Alternative fuel type	Not applicable	Clarksons
Shaft generator	Not applicable	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	60	Orca Class (karpowership.com)
Power generation data		
Power generation equipment	12 generators*	PROJECT SENEGAL (karpowership.com)
Engine technology	Duel-fuel engine technology HFO-NG	Orca Class (karpowership.com)
On-board fuel storage	2 weeks	Orca Class (karpowership.com)
Capacity (MW)	235	PROJECT SENEGAL (karpowership.com)
Substation voltage (kV)	100-240	Orca Class (karpowership.com)
Frequency (Hz)	50/60	Orca Class (karpowership.com)
Deployment data		
Last location	No information found.	
Deployment history	From 2015 until 2019 supplying Ghana 235 MW. Since 2019 supplying Senegal 235 MW.	Press Release (karpowership.com) PROJECT SENEGAL (karpowership.com)
Clients	In August 2019, Karpowership signed an LNG to Power contract with Senegal's Electricity Authority (SENELEC) to deploy a Powership of 235 MW for a period of 5.5 years. Karadeniz Powership Ayşegül Sultan started operation in October 2019, in Dakar. Karpowership is supplying 15% of Senegal's electricity.	PROJECT SENEGAL (karpowership.com)
Incidents, issues or problems	No information found.	

* Based on number of exhaust systems from images of the powership.

Table 39 - Floating powerplant #18 'Karadeniz Powership Baris Bey'

Description	Data	Source
Ship identity		
Name	Karadeniz Powership Baris Bey	Clarksons
IMO number	9166546	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	1998	Clarksons
Conversion year	Information not found.	
Conversion yard and location	Karmarine Shipyard	Clarksons
Status	In Service	Clarksons
Ex ship type and ex name	Normand Vester (1998), offshore tug/supply ship	KPS BARIS BEY, Offshore Tug/Supply Ship - Details and current position - IMO 9166546 MMSI 636017988 - VesselFinder
Flag state	Liberia	Clarksons
Classification society	Bureau Veritas	Clarksons
Owner	Karpowership	Clarksons
Group owner	Karadeniz Holding	Clarksons
Registered owner company	Karadeniz Powership Latam 1 Co. Ltd.	Clarksons
Operator	No information found.	
Ship data		
Gross tonnage (GT)	6,701	Clarksons
Deadweight (dwt)	3,061	Clarksons
Length over all (m)	84.38	Clarksons
Draught (m)	6.32	Clarksons
Beam (m)	18.80	Clarksons
Speed (knots)	16.00	Clarksons
Self-propelled	Yes, diesel 4-stroke	Clarksons
Horsepower	9,095	Clarksons
Main engine	2 x Diesel - Wichmann 10V28B	Clarksons
Main engine fuel type	VLS MDO	Clarksons
Auxiliary engine	No information found	
Auxiliary engine fuel type	No information found	
Emergency engine	No information found	
Emergency engine fuel type	No information found	
Boiler	No information found	
Alternative fuel type	No information found	
Shaft generator	2 x shaft generator (PTO), voltage (V) and frequency (Hz) unknown	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	20	Seal Class (karpowership.com)
Power generation data		
Power generation equipment	2 generators*	Cuba (karpowership.com)
Engine technology	Duel-fuel engine technology HFO-NG	Seal Class (karpowership.com)
On-board fuel storage	2 weeks	Seal Class (karpowership.com)
Capacity (MW)	40	Cuba (karpowership.com)
Substation voltage (kV)	36-170	Seal Class (karpowership.com)
Frequency (Hz)	50/60	Seal Class (karpowership.com)

* Based on number of exhaust systems from images of the powership.

Description	Data	Source
Deployment data		
Last location	Colonia del Sacramento, Uruguay, South-America (last position reported on 24-11-2021).	Ship KPS BARIS BEY (Offshore Supply Ship) Registered in Liberia - Vessel details, Current position and Voyage information - IMO 9166546, MMSI 636017988, Call Sign D5NR5 | AIS Marine Traffic
Deployment history	Since 2019 supplying Cuba 40 MW.	Cuba (karpowership.com)
Clients	In October 2018, Karpowership signed a contract with Unión Eléctrica de Cuba (UNE), the state electricity company of Cuba, to deploy three Powerships of 110 MW in total for a period of 51 months. Karadeniz Powership Barış Bey and Karadeniz Powership Esra Sultan started operation in Port de Mariel in July 2019 and Karadeniz Powership Ela Sultan started operations in November 2019. In November 2019, the contract capacity was increased to 184 MW. Cuba is Karpowership's first project in Western Hemisphere. Karpowership will supply 10% of Cuba's total electricity needs.	Cuba (karpowership.com)
Incidents, issues or problems	Unknown why currently positioned in Uruguay.	

Table 40 - Floating powerplant #19 'Karadeniz Powership Metin Bey'

Description	Data	Source
Ship identity		
Name	Karadeniz Powership Metin Bey	Clarksons
IMO number	9034779	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	1992	Clarksons
Conversion year	2016‡	KPS METIN BEY, Offshore Tug/Supply Ship - Details and current position - IMO 9034779 MMSI 636017601 - VesselFinder
Conversion yard and location	Turkey	Clarksons
Status	In Service	Clarksons
Ex ship type and ex name	Maersk Fighter (1992), Offshore Tug/Supply ship	KPS METIN BEY, Offshore Tug/Supply Ship - Details and current position - IMO 9034779 MMSI 636017601 - VesselFinder
Flag state	Liberia	Clarksons
Classification society	Bureau Veritas	Clarksons
Owner	Karpowership	Clarksons
Group owner	Karadeniz Holding	Clarksons

‡ Year of registration of powership name. Approximately equal to the year of conversion.

Description	Data	Source
Registered owner company	KARADENIZ POWERSHIP METIN BEY COMPANY	Clarksons
Operator	Eni Angola Exp.	Clarksons
Ship data		
Gross tonnage (GT)	6,380	Clarksons
Deadweight (dwt)	2,588	Clarksons
Length over all (m)	82.50	Clarksons
Draught (m)	6.25	Clarksons
Beam (m)	18.80	Clarksons
Speed (knots)	15.60	Clarksons
Self-propelled	Yes, diesel 4-stroke	Clarksons
Horsepower	7,200	Clarksons
Main engine	2 x Diesel - Ulstein Bergen BRM-6	Clarksons
Main engine fuel type	VLS MGO	Clarksons
Auxiliary engine	2 x Aux. Diesel Gen. - Cummins Inc	Clarksons
Auxiliary engine fuel type	VLS MDO	Clarksons
Emergency engine	No information found.	
Emergency engine fuel type	No information found.	
Boiler	No information found.	
Alternative fuel type	No information found.	
Shaft generator	2x shaft Generator (PTO), 440V, 60Hz	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	20	Seal Class (karpowership.com)
Power generation data		
Power generation equipment	2 generators*	Project Guinea-Bissau (karpowership.com)
Engine technology	Duel-fuel engine technology HFO-NG	Seal Class (karpowership.com)
On-board fuel storage	2 weeks	Seal Class (karpowership.com)
Capacity (MW)	35	Project Guinea-Bissau (karpowership.com)
Substation voltage (kV)	36-170	Seal Class (karpowership.com)
Frequency (Hz)	50/60	Seal Class (karpowership.com)
Deployment data		
Last location	Bissau, Guinea-Bissau, Africa (last position reported on 14-10-2021).	Ship KARADENIZ POWERSHIP METIN BEY (Offshore Supply Ship) Registered in Liberia - Vessel details, Current position and Voyage information - IMO 9034779, MMSI 636017601, Call Sign D5LU5 | AIS Marine Traffic
Deployment history	Since 2019 supplying Guinea Bissau 35 MW.	Project Guinea-Bissau (karpowership.com)
Clients	In January 2019, Karpowership signed a contract with Electricidade e Aguas da Guiné-Bissau (EAGB) to deploy a Powership of 35 MW for a period of 5 years. Karadeniz Powership Metin Bey has been in operation in Bissau since February 2019. Karpowership has been	Project Guinea-Bissau (karpowership.com)

* Based on number of exhaust systems from images of the powership.

Description	Data	Source
	supplying 100% of Guinea Bissau's total electricity needs.	
Incidents, issues or problems	No information found.	

Table 41 - Floating powerplant #20 'Karadeniz Powership Nezih Bey'

Description	Data	Source
Ship identity		
Name	Karadeniz Powership Nezih Bey	Clarksons
IMO number	9034781	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	1992	Clarksons
Conversion year	2016[†]	KPS NEZIH BEY, Power Station Vessel - Details and current position - IMO 9034781 MMSI 636017602 - VesselFinder
Conversion yard and location	Turkey	Clarksons
Status	In Service	Clarksons
Ex ship type and ex name	Offshore supply ship 'Maersk Forwarder' (1992)	KPS NEZIH BEY, Power Station Vessel - Details and current position - IMO 9034781 MMSI 636017602 - VesselFinder
Flag state	Liberia	Clarksons
Classification society	Bureau Veritas	Clarksons
Owner	Karpowership	Clarksons
Group owner	Karadeniz Holding	Clarksons
Registered owner company	KARPOWERSHIP INDONESIA 3 DMCC	Clarksons
Operator	No information found	
Ship data		
Gross tonnage (GT)	6,380	Clarksons
Deadweight (dwt)	2,588	Clarksons
Length over all (m)	82.50	Clarksons
Draught (m)	6.25	Clarksons
Beam (m)	18.80	Clarksons
Speed (knots)	14.00	Clarksons
Self-propelled	Yes, diesel 4-stroke	Clarksons
Horsepower	7,200	Clarksons
Main engine	2 x Diesel - Ulstein Bergen BRM-6	Clarksons
Main engine fuel type	VLS MGO	Clarksons
Auxiliary engine	2 x Aux. Diesel Gen. – Caterpillar	Clarksons
Auxiliary engine fuel type	VLS MGO	Clarksons
Emergency engine	No information found	
Emergency engine fuel type	No information found	
Boiler	No information found	
Alternative fuel type	No information found	
Shaft generator	2x shaft Generator (PTO), 440V, 60Hz	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	20	Seal Class (karpowership.com)
Power generation data		

† Year of registration of powership name. Approximately equal to the year of conversion.

Description	Data	Source
Power generation equipment	2 generators[*]	PROJECT INDONESIA ASIA (karpowership.com)
Engine technology	Duel-fuel engine technology HFO-NG	Seal Class (karpowership.com)
On-board fuel storage	2 weeks	Seal Class (karpowership.com)
Capacity (MW)	37	PROJECT INDONESIA ASIA (karpowership.com)
Substation voltage (kV)	36-170	Seal Class (karpowership.com)
Frequency (Hz)	50/60	Seal Class (karpowership.com)
Deployment data		
Last location	Amurang, Indonesia, Asia (last position reported on 24-5-2018).	Ship KARADENIZ POWERSHIP NEZIH BEY (Special Vessel) Registered in Liberia - Vessel details, Current position and Voyage information - IMO 9034781, MMSI 636017602, Call Sign D5LU6 | AIS Marine Traffic
Deployment history	Since 2016 supplying Indonesia 37 MW.	PROJECT INDONESIA ASIA (karpowership.com)
Clients	Indonesia is Karpowership's first project in South East Asia. In 2015 and 2016, Karpowership signed five contracts with the state utility PT PLN (Persero) to deploy five Powerships of 1,000 MW in total for a period of five years. Karadeniz Powership Zeynep Sultan and Nezih Bey, Onur Sultan, Gökhan Bey and Yasin Bey has been in operation in Amurang, Medan, Kupang and Ambon islands respectively since 2016. Since 2018, Karadeniz Powership Onur Sultan in Medan has been operating with indigenous gas. Karpowership has been supplying 30% of North Sulawesi's, 55% of East Nusa Tenggara's, 80% of Ambon's, 10% of Medan's total electricity needs. As of Q4 2020, Amurang project has started transitioning to becoming the company's first LNG to Power project. Karadeniz Powership Zeynep Sultan is expected fully operate with natural gas by the end of the year.	PROJECT INDONESIA ASIA (karpowership.com)
Incidents, issues or problems	No information found.	

[*] Based on number of exhaust systems from images of the powership.

Table 42 - Floating powerplant #21 'Karadeniz Powership Esra Sultan'

Description	Data	Source
Ship identity		
Name	Karadeniz Powership Esra Sultan	Clarksons
IMO number	Not applicable, since this floating powerplant is not self-propelled.	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	2011	Clarksons
Conversion year	No information found	
Conversion yard and location	No information found	
Status	Laid up, since 26/04/2016	Clarksons
Ex ship type and ex name	Karadeniz Powership Ebru Sultan	Clarksons
Flag state	Liberia	Clarksons
Classification society	Bureau Veritas	Clarksons
Owner	Karmarine Karadeniz	Clarksons
Group owner	Karadeniz Holding	Clarksons
Registered owner company	Karadeniz Powership Latam2 Co. Ltd.	Clarksons
Operator	No information found	
Ship data		
Gross tonnage (GT)	3,105	Clarksons
Deadweight (dwt)	7,445	Clarksons
Length over all (m)	91.50	Clarksons
Draught (m)	4.30	Clarksons
Beam (m)	24.40	Clarksons
Speed (knots)	Not applicable	Clarksons
Self-propelled	No, non-propelled	Clarksons
Horsepower	Not applicable	Clarksons
Main engine	Not applicable	Clarksons
Main engine fuel type	Not applicable	Clarksons
Auxiliary engine	Not applicable	Clarksons
Auxiliary engine fuel type	Not applicable	Clarksons
Emergency engine	Not applicable	Clarksons
Emergency engine fuel type	Not applicable	Clarksons
Boiler	Not applicable	Clarksons
Alternative fuel type	Not applicable	Clarksons
Shaft generator	Not applicable	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	20	Mermaid Class (karpowership.com)
Power generation data		
Power generation equipment	4 generators[*]	Cuba (karpowership.com)
Engine technology	Duel-fuel engine technology HFO-NG	Mermaid Class (karpowership.com)
On-board fuel storage	2 weeks	Mermaid Class (karpowership.com)
Capacity (MW)	35[†]	Cuba (karpowership.com)
Substation voltage (kV)	36-170	Mermaid Class (karpowership.com)
Frequency (Hz)	50/60	Mermaid Class (karpowership.com)

[*] Based on number of exhaust systems from images of the powership.

[†] Approximate capacity. Based on calculation of contracted total power and known capacity of other powerships at location.

Description	Data	Source
Deployment data		
Last location	Not available.	
Deployment history	Since 2019 supplying Cuba with 35 MW.	Cuba (karpowership.com)
Clients	In October 2018, Karpowership signed a contract with Unión Eléctrica de Cuba (UNE), the state electricity company of Cuba, to deploy three Powerships of 110 MW in total for a period of 51 months. Karadeniz Powership Barış Bey and Karadeniz Powership Esra Sultan started operation in Port de Mariel in July 2019 and Karadeniz Powership Ela Sultan started operations in November 2019. In November 2019, the contract capacity was increased to 184 MW. Cuba is Karpowership's first project in Western Hemisphere. Karpowership will supply 10% of Cuba's total electricity needs.	Cuba (karpowership.com)
Incidents, issues or problems	No information found.	

Table 43 - Floating powerplant #22 'Karadeniz Powership Ela Sultan'

Description	Data	Source
Ship identity		
Name	Karadeniz Powership Ela Sultan	Clarksons
IMO number	Not applicable, since this floating powerplant is not self-propelled.	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	2011	Clarksons
Conversion year	No information found	
Conversion yard and location	No information found	
Status	Laid up, since 26/04/2016	Clarksons
Ex ship type and ex name	Karadeniz Powership Selma Sultan	Clarksons
Flag state	Liberia	Clarksons
Classification society	Bureau Veritas	Clarksons
Owner	Karmarine Karadeniz	Clarksons
Group owner	Karadeniz Holding	Clarksons
Registered owner company	Karadeniz Powership Latam3 Co. Ltd.	Clarksons
Operator	No information found	
Ship data		
Gross tonnage (GT)	3,105	Clarksons
Deadweight (dwt)	7,445	Clarksons
Length over all (m)	91,50	Clarksons
Draught (m)	4.30	Clarksons
Beam (m)	24.24	Clarksons
Speed (knots)	Not applicable	Clarksons
Self-propelled	No, non-propelled	Clarksons
Horsepower	Not applicable	Clarksons

Description	Data	Source
Main engine	Not applicable	Clarksons
Main engine fuel type	Not applicable	Clarksons
Auxiliary engine	Not applicable	Clarksons
Auxiliary engine fuel type	Not applicable	Clarksons
Emergency engine	Not applicable	Clarksons
Emergency engine fuel type	Not applicable	Clarksons
Boiler	Not applicable	Clarksons
Alternative fuel type	Not applicable	Clarksons
Shaft generator	Not applicable	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	20	Mermaid Class (karpowership.com)
Power generation data		
Power generation equipment	4 generators*	Mermaid Class (karpowership.com)
Engine technology	Duel-fuel engine technology HFO-NG	Mermaid Class (karpowership.com)
On-board fuel storage	2 weeks	Mermaid Class (karpowership.com)
Capacity (MW)	35	Cuba (karpowership.com)
Substation voltage (kV)	36-170	Mermaid Class (karpowership.com)
Frequency (Hz)	50/60	Mermaid Class (karpowership.com)
Deployment data		
Last location	No information found.	
Deployment history	Since 2019 supplying Cuba 35 MW.	Cuba (karpowership.com)
Clients	In October 2018, Karpowership signed a contract with Unión Eléctrica de Cuba (UNE), the state electricity company of Cuba, to deploy three Powerships of 110 MW in total for a period of 51 months. Karadeniz Powership Barış Bey and Karadeniz Powership Esra Sultan started operation in Port de Mariel in July 2019 and Karadeniz Powership Ela Sultan started operations in November 2019. In November 2019, the contract capacity was increased to 184 MW. Cuba is Karpowership's first project in Western Hemisphere. Karpowership will supply 10% of Cuba's total electricity needs.	Cuba (karpowership.com)
Incidents, issues or problems	No information found.	

* Based on number of exhaust systems from images of the powership.

Table 44 - Floating powerplant #23 'Karadeniz Powership Filiz Sultan'

Description	Data	Source
Ship identity		
Name	Karadeniz Powership Filiz Sultan	Clarksons
IMO number	Not applicable, since this floating powerplant is not self-propelled	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	2010	Clarksons
Conversion year	No information found.	
Conversion yard and location	No information found.	
Status	Laid up, since 24/10/2015	Clarksons
Ex ship type and ex name	Lamnalco 2	Clarksons
Flag state	Liberia	Clarksons
Classification society	Bureau Veritas	Clarksons
Owner	Karmarine Karadeniz	Clarksons
Group owner	Karadeniz Holding	Clarksons
Registered owner company	KARPOWERSHIPYARD RAUF BEY COMPANY LIMITED	Clarksons
Operator	No information found	
Ship data		
Gross tonnage (GT)	3,105	Clarksons
Deadweight (dwt)	7,445	Clarksons
Length over all (m)	91.50	Clarksons
Draught (m)	4.30	Clarksons
Beam (m)	24.40	Clarksons
Speed (knots)	Not applicable	Clarksons
Self-propelled	No, non-propelled	Clarksons
Horsepower	Not applicable	Clarksons
Main engine	Not applicable	Clarksons
Main engine fuel type	Not applicable	Clarksons
Auxiliary engine	Not applicable	Clarksons
Auxiliary engine fuel type	Not applicable	Clarksons
Emergency engine	Not applicable	Clarksons
Emergency engine fuel type	Not applicable	Clarksons
Boiler	Not applicable	Clarksons
Alternative fuel type	Not applicable	Clarksons
Shaft generator	Not applicable	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	20	Mermaid Class (karpowership.com)
Power generation data		
Power generation equipment	4 generators*	Mermaid Class (karpowership.com)
Engine technology	Duel-fuel engine technology HFO-NG	Mermaid Class (karpowership.com)
On-board fuel storage	2 weeks	Mermaid Class (karpowership.com)
Capacity (MW)	80	Karpowership op Instagram: "Karadeniz Powership Filiz Sultan, fresh out of the shipyard with 80 MW, is ready to set sail

* Based on number of exhaust systems from images of the powership.

Description	Data	Source
		into new lands. Named after our Supply Chain..."
Substation voltage (kV)	36-170	Mermaid Class (karpowership.com)
Frequency (Hz)	50/60	Mermaid Class (karpowership.com)
Deployment data		
Last location	No information found.	
Deployment history	No information found.	
Clients	No information found.	
Incidents, issues or problems	No information found.	

Table 45 - Floating powerplant #24 'Karadeniz Powership Koray Bey'

Description	Data	Source
Ship identity		
Name	Karadeniz Powership Koray Bey	Clarksons
IMO number	9086203	Clarksons
Vessel type	Electricity Generating Vessel	Clarksons
Built	1994	Clarksons
Conversion year	2016†	Clarksons
Conversion yard and location	No information found	
Status	In Service	Clarksons
Ex ship type and ex name	Maersk Finder (1994), cargo ship	KPS KORAY BEY, Power Station Vessel - Details and current position - IMO 9086203 MMSI 636017600 - VesselFinder
Flag state	Liberia	Clarksons
Classification society	Bureau Veritas	Clarksons
Owner	Karpowership	Clarksons
Group owner	Karadeniz Holding	Clarksons
Registered owner company	Karpowership Orient Co. Ltd.	Clarksons
Operator	No information found	
Ship data		
Gross tonnage (GT)	2,961	Clarksons
Deadweight (dwt)	2,588	Clarksons
Length over all (m)	82.50	Clarksons
Draught (m)	6.24	Clarksons
Beam (m)	18.80	Clarksons
Speed (knots)	11.00	Clarksons
Self-propelled	Yes, diesel 4-stroke	Clarksons
Horsepower	7,200	Clarksons
Main engine	2 x Diesel - Ulstein Bergen BRM-6	Clarksons
Main engine fuel type	VLS MGO	Clarksons
Auxiliary engine	2 x Aux. Diesel Gen. - Caterpillar	Clarksons
Auxiliary engine fuel type	VLS MDO	Clarksons
Emergency engine	No information found	
Emergency engine fuel type	No information found	
Boiler	No information found	

† Year of registration of powership name. Approximately equal to year of conversion.

Description	Data	Source
Alternative fuel type	No information found	
Shaft generator	2x shaft generator (PTO), 440 V, 60 Hz	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	20	Seal Class (karpowership.com)
Power generation data		
Power generation equipment	2 generators*	Gambia (karpowership.com)
Engine technology	Duel-fuel engine technology HFO-NG	Seal Class (karpowership.com)
On-board fuel storage	2 weeks	Seal Class (karpowership.com)
Capacity (MW)	36	Gambia (karpowership.com)
Substation voltage (kV)	36-170	Seal Class (karpowership.com)
Frequency (Hz)	50/60	Seal Class (karpowership.com)
Deployment data		
Last location	Dakar, Senegal, Africa (last position reported on 9-12-2021).	Ship KARADENIZ POWERSHIP KORAY BEY (Power Station Vessel) Registered in Liberia - Vessel details, Current position and Voyage information - IMO 9086203, MMSI 636017600, Call Sign D5LU4 | AIS Marine Traffic
Deployment history	Since 2018 supplying Gambia with 36 MW.	Gambia (karpowership.com)
Clients	In February 2018, Karpowership signed a contract with National Water and Electricity Supply Company Ltd. of Gambia to deploy a Powership of 35 MW for a period of two years. Karadeniz Powership Koray Bey has been in operation in Banjul since May 2018. Karpowership has been supplying 60% of Gambia's total electricity needs. As of May 2020, the contract was extended for another two years.	Gambia (karpowership.com)
Incidents, issues or problems	Unknown why currently positioned in Senegal.	

Table 46 - Floating powerplant #25 'Luise'

Description	Data	Source
Ship identity		
Name	Luise	Clarksons
IMO number	Not applicable, since this floating powerplant is not self-propelled	
Vessel type	Electricity generating vessel	Clarksons
Built	2011	Clarksons
Conversion year	No information found	
Conversion yard and location	No information found	
Status	In Service	Clarksons
Ex ship type and ex name	No information found	

* Based on number of exhaust systems from images of the powership.

Description	Data	Source
Flag state	No information found	
Classification society	No information found	
Owner	Lihir Mngt Pty Ltd	Clarksons
Group owner	Lihir Mngt Pty Ltd	Clarksons
Registered owner company	LIHIR GOLD LIMITED	Clarksons
Operator	Lihir Mngt Pty Ltd	Clarksons
Ship data		
Gross tonnage (GT)	4,000	Clarksons
Deadweight (dwt)	No information found	
Length over all (m)	84.60	Clarksons
Draught (m)	No information found	
Beam (m)	25.40	Clarksons
Speed (knots)	Not applicable	Clarksons
Self-propelled	No, non-propelled	Clarksons
Horsepower	Not applicable	Clarksons
Main engine	Not applicable	Clarksons
Main engine fuel type	Not applicable	Clarksons
Auxiliary engine	Not applicable	Clarksons
Auxiliary engine fuel type	Not applicable	Clarksons
Emergency engine	Not applicable	Clarksons
Emergency engine fuel type	Not applicable	Clarksons
Boiler	Not applicable	Clarksons
Alternative fuel type	Not applicable	Clarksons
Shaft generator	Not applicable	Clarksons
Environmental equipment	No SO_x scrubber installed	Clarksons
Accommodation (Pax)	No information found	
Power generation data		
Power generation equipment	No information found	
Engine technology	No information found	
On-board fuel storage	No information found	
Capacity (MW)	No information found	
Substation voltage (kV)	No information found	
Frequency (Hz)	No information found	
Deployment data		
Last location	No information found.	
Deployment history	No information found.	
Clients	No information found.	
Incidents, issues or problems	No information found.	

C.2 Factsheets for floating powerplants not registered at the Clarkson database

The floating powerplants of Power Barge Corporation, E-Cap Marine and Seaboard Corporation do not have an IMO number, are not self-propelled and it is even unknown whether they have a name. For that reason little information is known about these floating powerplants. It is also not possible to trace the location of these floating powerplants. The information that is available is shown in Table 47 until Table 51.

Table 47 - Floating powerplants from Power Barge Corporation (not for sale)

	Power generation equipment	Capacity (MW)
1	MAN B&W medium speed engine	124
2	MAN B&W medium speed engine	70
3	MAN B&W medium speed engine	60
4	MAN B&W medium speed engine	40
5	MAN B&W slow speed engine	100
6	MAN B&W slow speed engine	100
7	Wärtsilä medium speed engine	149
8	Wärtsilä medium speed engine	120
9	Wärtsilä medium speed engine	72
10	Wärtsilä medium speed engine	72
11	Wärtsilä medium speed engine	66
12	Wärtsilä medium speed engine	57
13	Wärtsilä medium speed engine	55
14	Wärtsilä medium speed engine	55
15	Wärtsilä medium speed engine	55
16	Wärtsilä medium speed engine	55
17	Wärtsilä medium speed engine	52
18	Wärtsilä medium speed engine	40
19	Wärtsilä medium speed engine	36
20	Wärtsilä medium speed engine	36
21	Wärtsilä medium speed engine	30
22	Wärtsilä medium speed engine	9
23*	32 X 8 General Electric Frame 5 simple cycle gas turbines	800
24*	9 X 9 General Electric Frame 6B simple cycle gas turbines	290
25*	4 X 1 General Electric LM6000 combined cycle gas turbines	220
26*	1 X 2 General Electric Frame 7 combined cycle gas turbines	185
27*	2 X 2 General Electric Frame 6 simple cycle gas turbines	70
28*	2 X 1 General Electric LM5000 simple cycle gas turbines	56
29*	2 X 1 General Electric LM5000 simple cycle gas turbines	56
30*	2 X 1 General Electric LM2500 simple cycle gas turbines	40
31	2 X 1 Siemens Westinghouse V64A simple cycle gas turbines	123
32	1 X 1 Westinghouse 501D5A simple cycle gas turbine	115
33	1 X 1 Westinghouse 501D5 simple cycle gas turbine	105
34	2 X 1 Westinghouse 251 simple cycle gas turbines	98
35	2 X 1 Westinghouse 251B12 simple cycle gas turbines	98
36	1 X 1 Westinghouse 251 simple gas turbine	48
37	Caterpillar high speed diesel engines	52
38	Caterpillar high speed diesel engines	52
39	4 X 1 Pratt Whitney FT 4 simple cycle gas turbines	88
40	2 X 2 thermal power	150
41	Nuclear powerbarge	20

* Power Barge Corporation owns a total of 25 powerbarges which has General Electric gas turbines installed. It is unknown how much powerbarges they have per type of gas turbine from General electric.

Table 48 - Powerbarges of Power Barge Corporation (for sale in March 2022)

	Power generation equipment	Fuel type	Capacity (MW)	Additional information
1	60 Hz Wärtsilä 18V50DF combined cycle medium speed engine	Natural gas or low sulphur fuel oil	108	
2	60 Hz Wärtsilä 18V38 simple cycle medium speed engine	Low sulphur fuel oil	72	Operating with a 69 kV/138 kV substation and an associated fuel tank-barge and a 69 kV to 115 kV autotransformer
3	50 Hz Westinghouse 251B11 simple cycle gas turbine	Unknown	48	Operating with a 33 kV substation
4	50 Hz Wärtsilä 18V32 simple cycle medium speed engine	Unknown	54 & 60	132 kV substation

Table 49 - Powerbarges of Power Barge Corporation (recently sold)

	Power generation equipment	Capacity (MW)
1	60 Hz Wärtsilä diesel engine	72
2	Siemens gas turbine	96
3	Siemens gas turbine	105
4	Siemens gas turbine	115
5	MAN medium speed engine	44
6	Wärtsilä medium speed engine	40

Table 50 - E-cap Marine powerbarge

Description	Data
Length (m)	76.0
Width (m)	11.4
Draught (m)	2.5
Power generating equipment	5 x 1.5 MW LNG GenSets
Fuel storage	2 x 17 ton LNG containers

Table 51 - Seaboard Corporation powerbarge

Description	Data
Name	Estrella del Mar II
Power generating equipment	6 engines and a combined cycle (heat recovery system)
Fuel	Heavy fuel oil and natural gas
Capacity	108 MW