NATIONAL TECHNICAL UNIVERSITY OF ATHENS

SCHOOL OF NAVAL ARCHITECTURE & MARINE ENGINEERING

«COMPARATIVE ASSESSMENT OF BALLAST WATER TREATMENT SYSTEMS»

THESIS

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1. Introduction

The inadvertent transfer of harmful aquatic organisms and pathogens in the ballast water of ships has been determined to have caused a significant adverse impact to many of the world's coastal regions. The international maritime community, under the auspices of the International Maritime Organization (IMO) has developed several documents, including the "International Conventions for the Control and Management of Ship's Ballast Water and Sediments, 2004", (Ballast Water Management Convention), which are aimed at preventing the introduction of unwanted aquatic organisms and pathogens through the discharge of ballast water and sediments.

Upon entry intro force, the Ballast Water Management Convention will apply to vessels registered in a country which is party to the Convention and to those vessels registered in other countries when operating in waters of a country which is party to the Convention.

As a means to prevent, minimize and ultimately eliminate the risk to the environment, human health, property and resources arising from the transfer of harmful aquatic organisms and pathogens through the control and management of vessel's ballast water and sediment, as well as to avoid unwanted side-effects from that control, the Convention requires vessels to conduct a ballast water exchange or be fitted with an approved water ballast management system. It is noted that several studies have shown that the effectiveness of ballast water exchange varies and is dependent on the vessel type (design), exchange method (sequential, flow-through and dilution methods), ballasting system configuration, exchange location, weather conditions and vessel's trading pattern. For these reasons (and others), it has been determined that ballast water exchange does not provide adequate protective measures to prevent damage from organisms and pathogens carried in a vessel's ballast, even though exchange was considered to be acceptable as an interim solution.

The installation of ballast water management/treatment systems, designed reviewed, approved, installed and operated to satisfy an agreed-upon ballast water discharge performance standard has been determined by the international marine industry to provide a more effective means to prevent, minimize and ultimately eliminate the transfer of organisms and pathogens via vessel ballast discharge, when compared to ballast water exchange.[1]

2. Main Technologies of Ballast Water Treatment Systems

Currently, Ballast Water Treatment technologies fall into two large groups: (a) Separation technologies (remove organisms); or (b) Disinfection technologies (kill or render organisms incapable of reproducing).

Each category though has its flaws. For example, in Separation technologies, maximum pressure loss across the BWMS could prevent the ability of the ballast system to supply an acceptable flow rate. Regarding Disinfection technologies, a thorough assessment is needed to verify that any possible hazard has been mitigated to acceptable levels (i.e. hydrogen release, ozone etc.).

Below diagram, shows a more detailed categorization of available Ballast Water Management technologies.

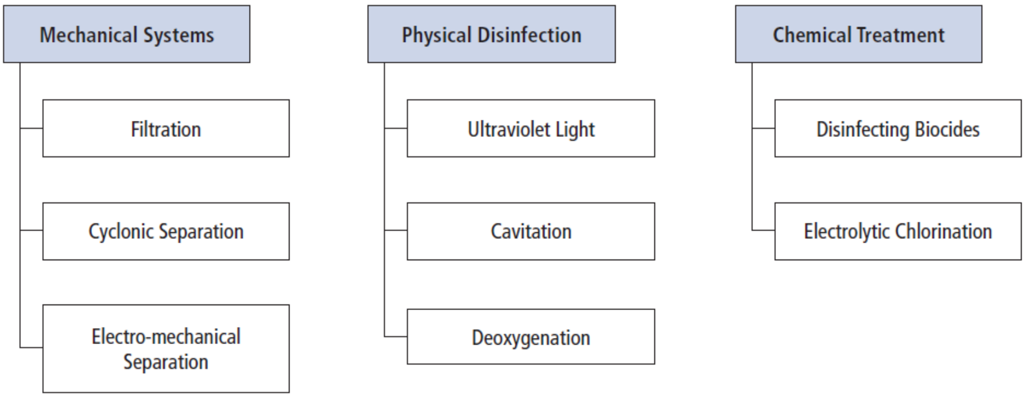

Figure 1: Ballast Water Management Technologies

2.1 Filtration in BWTS

Most Ballast Water Treatment Systems available in the market use filtration as an additional measure to treat the ballast water. Although it has been proven to be quite effective, there are some pros and cons, depending also on the technology used each time. First of all, on the positive side, there is a possible reduction in power consumption given the fact that the system only has to kill smaller organisms. In addition, minimized shading and shadowing of organisms improve the UV and the active substance effectiveness. At last, reduction of sediment loading is observed.

On the other hand, filters are only effective for larger particle and organisms. They also effect the ballast pump flow reduction with added differential pressure. This problem is encountered more often in vessels with submerged ballast pumps into the ballast tanks. Attention should be paid in the additional maintenance that is needed for filter elements and how it affects the total Operational Expenses. Another issue may be the reliability of the mechanical components. Also, added cost of freshwater supply and if filters are installed in a pump room or deck house are subjects that should be taken into consideration. Finally, clogging of filter beyond its self-cleaning ability may potentially cause cargo operation interruptions and back-flushing of filter could have an impact on ballasting by extending its duration.

All in all, filters seem to improve the effectiveness of Ballast Water Treatment Systems to a great extent besides their negative aspects and have become nowadays a prerequisite in the selection of a competitive BWTS.

2.2 Different Technologies in Ballast Water Treatment Systems

Although the differences between the filters available in market for BWTS might be minor, the different technologies applied to BWTS by many makers do not have so much in common. The main technologies that are available today are Ultraviolet Radiation (UV), Electro-chlorination divided in Full Flow Electro-chlorination and Side-Stream Electro-chlorination and Treatment with Chemical Injection.

2.2.1 Ultraviolet Technology

Description

Systems based on UV technology kill or inactive the organisms by disrupting the DNA through UV light, leaving them unable to perform vital cellular functions. During ballasting, the seawater is filtered and UV-treated, only to then be UV-treated a second time during de-ballasting. These systems do not produce any harmful by-products and they are mostly independent of temperature and salinity. Different UV transmittance in the seawater will imply higher energy demand.

Advantages and disadvantages

This type of water treatment has many advantages and that is why there are so many UV systems available in the market. First of all, there are no active substances used in the water treatment meaning that there is not additional corrosion. The fact that there is no chemical handling enhances the system's life cycle with reduced hazardous conditions. In addition, no filtration takes place on discharging the treated ballast water meaning that the flow rate restrictions are only associated to the UV chamber limitations. Finally, some UV BWTS makers provide modules that can adjust and reduce the power consumption of the system based on the condition and the quality of the water in each ballasting or deballasting operation.

However, UV systems have weaknesses too. For example, UV treatment has to also take place during discharging leading to additional power requirements and pressure losses across UV chambers during ballasting/deballasting operation should cause considerations for reduced ballast flow in the future. On top of that, there is the possibility of damage to UV sleeves by water hammer thus posing operational restrictions and limits on the water ballast system. Regarding safety issues, attention should be paid for the mercury inside medium pressure lamps. It is desirable that the maker provides a spill kit in case of an accident. Also, the vessel's crew that will be responsible for the maintenance of UV lamps, should avoid exposure to UV light. Life cycle and replacement cost of the UV lamps may be an issue that will affect the overall operational cost and should be calculated with precision in advance of any BWTS purchase. At last, the efficacy of a UV-based BWTS is still uncertain in water with high suspended and dissolved solids and colorants.

In order to prevent the crew from exposing to excessive amounts of UV light, BWTS makers have developed various safeguards. For example, high temperature alarm, high-high temperature alarm with an automatic shutdown, UV intensity meter, means to prevent the accumulation of air in the top of the lamp enclosure or treatment chamber, interlock to prevent the operation of UV lamps without water in the treatment chamber thus avoiding over-heating of the UV unit, protection of electrical equipment with respect to the degree of enclosure (IP), insulation materials and maximum ambient temperatures (45 ^{o}C).

2.2.2 Full Flow Electro-chlorination Technology

Description

Systems based on Electro-chlorination technology produce a disinfectant that breaks down the cell membranes of the organisms through the process of electrolysis. The active substances are produced through oxidation of seawater in the electrolysis chamber. Electrolysis also produces hydrogen gas which shall be correctly handled for safety of the ship. During ballasting, the seawater is filtered and active substances are injected. During de-ballasting, the active substance is neutralized prior to discharge overboard.[2]

Advantages and disadvantages

In general, electro-chlorination systems are based on a process that produces hydrogen (which is flammable) and chlorine (which is toxic). Creating an oxidizing solution at the moment of ballasting eliminates the additional chemical storage and handling. It should be mentioned that the treatment chamber is bypassed on discharge and the only flow rate restrictions are set by the discharge piping. On the plus side, the residual disinfectant in ballast tanks provides additional protection against organism regrowth.

Nonetheless, the active substances used for the treatment of the ballast water may increase the potential for corrosion in the future. Also, ballasting operations in freshwater might require alternative salinity sources in order for the process of electrolysis to take place. Regarding the operational expenses, life cycle and maintenance of electrodes should be estimated adequately before purchasing a BWTS. Additionally, the necessity for a centralized DC power supply will require interconnection to freshwater cooling increasing the installation cost. Last but not least, a significant aspect of electro-chlorination based BWTS is that neutralization is required during discharging. In case there is a failure in that section of the water treatment, operation should be stopped and cannot be continued unless all failures are rectified.

2.2.3 Side-stream Electro-chlorination Technology

Description

Similar to full flow electro-chlorination, the disinfectant produced breaks down the cell membranes of the organisms. However, in side-stream electrolysis, the active substances are produced in an external line where approximately only 1% of the total ballasting seawater passes through.

Advantages and disadvantages

In this type of ballast water treatment, there are no additional flow restrictions since side-stream injection does not affect the overall ballast piping flow. As mentioned above, the oxidizing solution that is created upon ballasting cancels any further need for additional chemicals. Also, a great advantage is that the fact that the system's equipment can be modularized in order to fit the spaces available, benefitting any retrofitting projects.

On the other side, side-stream systems have all the disadvantages mentioned βεφορε for the Full flow electro-chlorination systems as they are both based on the same principles.

2.2.4 Prepared Chemical Treatment Systems

Description

Systems based on chemical injection are often used in combination with filtration, same as all other systems previously mentioned. A chemical solution is injected into the ballast water to ensure disinfection. The disinfectant may be liquid or granular and will require neutralization prior to discharge overboard. Chemicals used are trademarked, and supply might be limited to specific ports. The chemicals must be stored on board in closed containers and may be hazardous. The use of chemicals requires implementation of strict safety provisions and crew training. These BWMS have a higher operational cost than other ballast water technologies.

Advantages and disadvantages

BWTS with chemical injection offer a reduced CAPEX in comparison with other systems due to the fact they often have a simpler system design. They also do not require filtration upon discharge of the treated ballast water meaning there are no flow rate restrictions beside discharge piping.

However, additional safety safeguards for the crew should be taken since they will be handling stored chemicals. Use of active substances may also increase the potential for corrosion in the piping system and the ballast tanks. Shelf-life of treatment chemicals is always an issue and may pose limits on on-board storage capacity. Makers have also to make sure that the chemicals used are not on prohibited lists (i.e. FIFRA) in major ports. At last, storage space for chemicals should be constantly ventilated and its temperature should be always under control.[3]

3 Parameters for the Selection of a Ballast Water Treatment System

As described above, all systems have some major advantages compared to each other but also have some flaws. Each BWTS, regardless of the technology on which it is based, tries to meet all IMO and USCG standards and wants to cover in the best possible way the needs of the ship-owner that will purchase the system for his vessels. This means that the operation field of a BWTS should not be restricted by environmental conditions such as salinity, temperature or UV intensity nor by any other operational parameters such as maximum pressure in piping, maximum TRO or holding time.
Every maker wants to build the simplest BWTS at the lowest cost covering as many needs as possible. But such a system cannot be applied to all vessels. In other words, some BWTS are more likely to be installed in smaller size vessels (like MRs) and

some are more likely to be installed in larger size vessels (like suezmax). The factor that will influence the most the final decision on which system to choose, will be the total cost of the system. This means that the ship-owner should take in consideration not only the initial cost of the system but also the operational expenses that will occur over the lifetime of the vessel.
Although the cost factor is the most important for the ship-owner, other parameters may influence the final choice. For example, the existing electrical capacity of a vessel could restrict the choices of the available Ballast Water Treatment Systems in the market and lead the way to systems that have not been considered in the first place. In the end, deciding which BWTS should be installed on-board a vessel is a complicated procedure, with a wide variety of parameters, and should be studied for each case separately.[4]

4 Presentation of Ballast Water Treatment Systems

Below, they are going to be presented some Ballast Water Treatment Systems that already have an IMO Type Approval, an AMS Letter from the USCG and are most likely to get the final USCG Approval.

The equipment presented for each system will be quoted for a small Product/Chemical tanker (8.000 DWT), an MR tanker (40.000 DWT) and a suezmax tanker (160.000 DWT).

Vessel	DWT
M/T Minitank Five	8.084 MT
M/T Jenny I	40.128 MT
M/T Mabrouk	160.000 MT

1) Environmental Protection Engineering S.A. Greece (E.P.E.)

- System: ERMA FIRST FIT

- Technology: Filtration & Full Stream Electrolysis

- Major Components of the system:

i) Main high end backwash filter (40 μm mesh from Filtersafe)
ii) Electrolytic Cells
iii) Transformer rectifier with 5 modules from AC to DC
iv) Control cabinet with flow sensor which controls and switches off the system
v) 3 TRO sensors
vi) Flow meters, flow switches and salinity measurement device
vii) Suction pump
viii) Neutralizing tank and pump/valve

- Approvals:

i) USCG AMS Acceptance
ii) IMO Type Approval
iii) LR Class Type Approval
iv) Approval by Greek administration

Tests were carried out by USCG approved independent Lab NSF USA in brakish water, fresh water, open sea and shipboard (inside water ballast tanks)

- System's parts lifetime and maintenance cost

i) Electrode	Lifetime: 10 years or 5.000 hrs	Cost: 15.000-19.000 usd
ii) Main filter element	Lifetime: 5 years	Cost: 6.715-10.535 usd

- Operational Information[5],[6]

1) Neutralization of water during deballasting is carried out by using chemical reagent, sodium disulphide.
2) Electrodes are coated with Mixed Metal Oxides coating and not with Pt coating because it has a lower consumption rate.
3) No cleaning of electrodes is required under normal operating conditions, given that their lifetime is 5.000 hrs.
4) No fixed hydrogen sensor is required.
5) No calibration of TRO sensor is required.
6) Indicator reagent will have to be changed every 90 days. Buffer reagent, pump tubes and rest tubing will have to be changed to be changed annually.
7) Water hardness does not affect TRO sensor's performance and there is no risk for corrosion.
8) Design pressure of the system is about 10 bar. Pressure loss at the filter is about 0,5 bar. Case study will have to be carried out in order to find out whether modification will have to be done in the existing piping system or booster pump will have to be installed.
9) Minimum operational temperature is 3 ^{o}C and minimum operational salinity is 0,9 PSU. In case salinity level drops below 0,9 PSU, salt water will have to be stored in APT tank for mixing.
10) Creation of the oxidizing solution is controlled by a DPD sensor. Its response time is 60 seconds and its sampling range is 1-10 minutes.
11) Maximum TRO concentration is 6 ppm. In general, 3-4 minutes are required for initial dosage to be stabilized.
12) There is no ORP sensor and there is no electrical connection between the rectifier and the TRO sensor. In case of emergency operation, the BWTS can be bypassed.
13) Power consumption is increased in lower temperatures and lower salinity levels.
14) Stripping eductors do not affect the de-ballasting procedure.

- System's cost

Vessel	**System**	**Equipment Cost** (USD)	**Maintenance Cost** for 10 years (USD)	**Operational Cost** for 10 years (Chemicals/ Additives/ Fuel) (USD)	**Power Demand** (KW)
M/T Minitank Five	Option 1 : 2 x ErmaFirst 300 Ex & 1 x ErmaFirst 100 Ex	368.000	41.264	32.760	48 KW
Ballast Pumping System 1) For WBTs: Framo SB200-2 x 2 Units x 300 m^3/h 2) For FPT: Taiko Fire General Service Pumps x 2 Units x 115/150 m^3/h	Option 2: 1 x ErmaFirst 600 Ex & 1 x ErmaFirst 100 Ex	303.000	32.294	28.618	41,75 KW
M/T Jenny I	Option 1: 2 x ErmaFirst 600 Ex & 1 x ErmaFirst 100 Ex	473.000	55.724	60.764	93,5 KW
Ballast Pumping System 1) For WBTs & FPT: Framo SB300-2 x 2 Units x 650 m^3/h 2) For APT: Taiko Fire General Service Pumps x 2 Units x 100/110 m^3/h	Option 2: 1 x ErmaFirst 1500 Ex & 1 x ErmaFirst 100 Ex	423.000	44.934	61.132	109 KW
M/T Mabrouk Ballast Pumping System 1) For WBTs: 1 Steam driven & 1 Electrical driven CV400-2 x 2000 m^3/h 2) For APT: Shinko Fire General Service Pumps X 2 Units X 240/220 m^3/h	2 x ErmaFirst 2000 Ex & 1 x ErmaFirst 100 Ex	858.000	65.344	45.127	265 KW

2) Alfa Laval

- System: PureBallast 3.1

- Technology: UV Treatment with advanced oxidation technology

- Major components of the system:

i) AOT reactor (including valves, sensors and UV lamps)
ii) Lamp Drive Cabinet
iii) Control Cabinet
iv) CIP module (including tank, pump and valves)
v) Automatic back flushing filter
vi) Valves
vii) Control Flow valve
viii) Flow transmitter
ix) Pressure monitoring device

- Approvals: USCG AMS Acceptance, IMO Type Approval

- System's parts lifetime and cost

i) UV lamps to be replaced every 3.000 hours or 3 years

ii) Filter's basket mesh to be replaced every 10.000 hours or 10 years

iii) CIP liquid to be replaced every 3 months

- Operational Information

i) Maximum pressure of the system is about 6 bar. Pressure loss at the filter is about 0,5 bar. Case study will have to be carried out in order to find out whether modification will have to be done in the existing piping system or booster pump will have to be installed.

ii) CIP liquid is used for the cleaning of the UV lamps. No mechanical cleaning takes place that could possibly harm the UV system.

iii) No restrictions regarding salinity levels and temperature. Low UV transmittance in some ports could be an issue though.

iv) A UV sensor is available that adjusts power consumption. A total reduction of 50% can be achieved.

- System's cost

Vessel	System	**Equipment Cost** (USD)	**Maintenance Cost** for 10 years (USD)	**Operational Cost** for 10 years (Chemicals/ Additives/ Fuel) (USD)	**Power Demand** (KW)
M/T Minitank Five	Option 1 : 2 x PB300 & 1 x PB170	510.510	24.502	14.230	86 KW
Ballast Pumping System 1) For WBTs: Framo SB200-2 x 2 Units x 300 m^3/h 2) For FPT: Taiko Fire General Service Pumps x 2 Units x 115/150 m^3/h	Option 2: 1 x PB600 & 1 x PB170	339.966	17.220	14.210	83 KW
M/T Jenny I	Option 1: 2 x PB750 & 1 x PB170	645.150	60.876	95.860	220 KW
Ballast Pumping System 1) For WBTs & FPT: Framo SB300-2 x 2 Units x 650 m^3/h 2) For APT: Taiko Fire General Service Pumps x 2 Units x 100/110 m^3/h	Option 2: 1 x PB1500 & 1 x PB170	After 3D-Scanning took place onboard the vessel, it was concluded that pipe interferences could not allow a large diameter pipe to be placed across the main deck. Thus, this is option is considered unfeasible.			- KW
M/T Mabrouk Ballast Pumping System 1) For WBTs: 1 Steam driven & 1 Electrical driven CV400-2 x 2000 m^3/h 2) For APT: Shinko Fire General Service Pumps X 2 Units X 240/220 m^3/h	2 x PB2000 & 1 x PB250	1.100.000	96.324	98.310	533 KW

3) Panmarine

- System: Trojan Marinex

- Technology: UV Treatment

- Major components of the system:

i) Ballast Inlet valves with pneumatic actuators
ii) De-ballast inlet valves with pneumatic actuators
iii) Outlet valve with pneumatic actuators
iv) Filter-Backwash valve with pneumatic actuators
v) Drain connection
vi) Technical Water Connection
vii) Drain pump
viii) Flow meter
ix) LCD cables for the lamps
x) Hydraulic hose kit

- Approvals: USCG AMS Acceptance, IMO Type Approval

- System's parts lifetime and cost

i) UV lamps to be replaced every 12.000 hours or 10 years

ii) Filter elements not required to be changed in the first 10 years. Exchange of filter is done only in demand.

- Operational Information

i) Pressure loss at the filter requires modification in the existing piping system or installation of a booster pump.

ii) Recalibration of any sensors of the system is not required unless there is a malfunction on the monitoring system.

iii) The system can operate at all salinities and between -5 ^{o}C to 40 ^{o}C.

iv) Ballast pump should not exceed 6 bar of operating pressure for safety reasons of the system. In any case, a mechanical pressure relief could be installed.

v) Medium pressure UV lamps contain toxic liquid mercury. Special safety measures are recommended to be taken for the crew when cleaning the UV lamps. A mercury spill kit is included in case a UV lamps breaks.

vi) Power consumption cannot be reduced.

- System's cost

Vessel	**System**	**Equipment Cost** (USD)	**Maintenance Cost** for 10 years (USD)	**Operational Cost** for 10 years (Chemicals/ Additives/ Fuel) (USD)	**Power Demand** (KW)
M/T Minitank Five	Option 1 : 2 x TM500 Ex & 1 x TM150 Non Ex	544.600	99.880	16.031	60,9 KW
Ballast Pumping System 1) For WBTs: Framo SB200-2 x 2 Units x 300 m^3/h 2) For FPT: Taiko Fire General Service Pumps x 2 Units x 115/150 m^3/h	Option 2: 1 x TM750 Ex & 1 x TM150 Non Ex	362.000	69.008	10.864	43,4 KW
M/T Jenny I	Option 1: 2 x TM750 Ex & 1 x TM150 Non Ex	624.500	125.304	47.866	77,7 KW
Ballast Pumping System 1) For WBTs & FPT: Framo SB300-2 x 2 Units x 650 m^3/h 2) For APT: Taiko Fire General Service Pumps x 2 Units x 100/110 m^3/h	Option 2: 1 x TM1500 Ex & 1 x TM150 Non Ex	527.000	125.304	46.137	75 KW
M/T Mabrouk Ballast Pumping System 1) For WBTs: 1 Steam driven & 1 Electrical driven CV400-2 x 2000 m^3/h 2) For APT: Shinko Fire General Service Pumps X 2 Units X 240/220 m^3/h	4 x TM1000 Ex & 1 x TM250 Non Ex	1.526.500	326.880	46.265	179,2 KW

4) Desmi

- System: RayClean

- Technology: UV Treatment

- Major components of the system:

i) Filters (1 per UV unit)
ii) UV units
iii) Main Control Panel
iv) UV Control Panel
v) Sensors
vi) Hydraulic actuated valves

- Approvals: USCG AMS Acceptance, IMO Type Approval, DNV-GL Type Approval

- System's parts lifetime and cost

i) UV lamps to be replaced every 12.000 hours or 12 years

ii) Filter candles to be replaced every 5.000 hours or 5 years

iii) UV intensity sensors to be replaced every 2 years

- Operational Information

i) Pressure loss at the filter requires modification in the existing piping system or installation of a booster pump.

ii) Salinity should be between 0-40 PSU and temperature between 0-45 ^{o}C for normal operation of the system.

iii) Approximate power consumption per UV unit is about 20 kW. Minimum power consumption per UV unit is 12 kW. UV sensors are able to adjust power consumption according to the requirements. Power consumption can be reduced up to 50%.

- System's cost

Vessel	**System**	**Equipment Cost** (USD)	**Maintenance Cost** for 10 years (USD)	**Operational Cost** for 10 years (Chemicals/ Additives/ Fuel) (USD)	**Power Demand** (KW)
M/T Minitank Five	Option 1 : 2 x RC300 Ex & 1 x RC200	427.405	41.896	14.753	66 KW
Ballast Pumping System 1) For WBTs: Framo SB200-2 x 2 Units x 300 m^3/h 2) For FPT: Taiko Fire General Service Pumps x 2 Units x 115/150 m^3/h	Option 2: 1 x RC600 Ex & 1 x RC200	382.294	39.171	14.753	66 KW
M/T Jenny I	Option 1: 2 x RC800 Ex & 1 x RC200	650.353	228.559	68.234	110 KW
Ballast Pumping System 1) For WBTs & FPT: Framo SB300-2 x 2 Units x 650 m^3/h 2) For APT: Taiko Fire General Service Pumps x 2 Units x 100/110 m^3/h	Option 2 is not available.	-	-	-	- KW
M/T Mabrouk Ballast Pumping System 1) For WBTs: 1 Steam driven & 1 Electrical driven CV400-2 x 2000 m^3/h 2) For APT: Shinko Fire General Service Pumps X 2 Units X 240/220 m^3/h	2 x RC2000 Ex & 1 x RC200	1.154.923	533.409	82.782	330 KW

5) Optimarin

- System: Optimarin

- Technology: UV Treatment

- Major components of the system:

i) UV chamber
ii) UV manifolds
iii) Inlet/outlet valves for UV-chambers
iv) Temperature transmitter
v) UV sensor
vi) Pressure sensor
vii) Boll&Kirh filter
viii) Filter valves
ix) Optimarin bypass valve
x) Flow pressure valve
xi) Flow meter
xii) UV power panel
xiii) Control and filter control panel
xiv) Sensor box and terminal box
xv) Back-flushing pump
xvi) Air valve
xvii) Valve for manifold- ventilation/drain

- Approvals: USCG AMS Acceptance, IMO Type Approval, DNV-GL Type Approval

- System's parts lifetime and cost

i) UV lamps to be replaced every 3 years or 4.000-6.000 running hours

ii) Candle elements to be replaced every 5-7 years

iii) Anode inside of the filter to be replaced every 5 years

- Operational Information

i) Booster pump will be required due to pressure loss at the filter.

ii) Calibration of the system to be performed by authorized service engineer every 2,5 years

iii) The system can operate at all salinities and between -2^{o}C to 37^{o}C. Relevant humidity for the electronics can reach up to 90%.

iv) The OBS system operates with medium pressure lamps, meaning that there is always the danger of spill of liquid mercury which is inside of the lamps in case one of them breaks.

v) Total system pressure loss is around 0,56 bar while the design pressure of the system is 10 bar.

vi) Power consumption of the system can be reduced down to 40% of the maximum power in case the vessel's ballasting water has high UV transmittance .

System's cost

Vessel	**System**	**Equipment Cost** (USD)	**Maintenance Cost** for 10 years (USD)	**Operational Cost** for 10 years (Chemicals/ Additives/ Fuel) (USD)	**Power Demand** (KW)
M/T Minitank Five	Option 1 : 2 x OBS-334 Ex & 1 x OBS-167	530.200	78.179	51.710	200 KW
Ballast Pumping System 1) For WBTs: Framo SB200-2 x 2 Units x 300 m^3/h 2) For FPT: Taiko Fire General Service Pumps x 2 Units x 115/150 m^3/h	Option 2: 1 x OBS-667 Ex & 1 x OBS-167	437.800	71.657	51.710	200 KW
M/T Jenny I	Option 1: 2 x OBS-667 Ex & 1 x OBS-167	722.700	121.710	222.793	380 KW
Ballast Pumping System 1) For WBTs & FPT: Framo SB300-2 x 2 Units x 650 m^3/h 2) For APT: Taiko Fire General Service Pumps x 2 Units x 100/110 m^3/h	Option 2: 1 x OBS-1334 Ex & 1 x OBS-167	673.200	94.677	222.793	380 KW
M/T Mabrouk Ballast Pumping System 1) For WBTs: 1 Steam driven & 1 Electrical driven CV400-2 x 2000 m^3/h 2) For APT: Shinko Fire General Service Pumps X 2 Units X 240/220 m^3/h	No system available	-	-	-	- KW

6) Panasia

- System: GloEn-Patrol

- Technology: UV Treatment

- Major components of the system:

i) Filter Unit
ii) UV Unit
iii) Control Panel
iv) Power Supply Panel

- Approvals: USCG AMS Acceptance, IMO Type Approval

- System's parts lifetime and cost

i) UV lamps to be replaced every 4.000 hours or 4 years.

ii) Filter is semi-permanent with cleaning after treatment using freshwater. It will have to be replaced every 10 years.

iii) Sensors to be replaced every 5 years.

- Operational Information

i) According to studies already carried out by Panasia, no pump modification or installation of an additional booster pump will be needed.

ii) According to USCG AMS Certificate, GloEn-Patrol can operate only for salt and brackish water. However, USCG Final Type Approval may include operation also in fresh water.

iii) The system can operate between 0^{o}C and 55^{o}C.

iv) Total system pressure loss is around 0,45 bar while the maximum system pressure is 4,9 bar.

v) Power consumption of the system is automatically adjusted to three levels depending on water quality.

Level 1: 75%
Level 2: 90%
Level 3: 100%

- System's cost

Vessel	**System**	**Equipment Cost** (USD)	**Maintenance Cost** for 10 years (USD)	**Operational Cost** for 10 years (Chemicals/ Additives/ Fuel) (USD)	**Power Demand** (KW)
M/T Minitank Five	Option 1 : 2 x GloEn-P350 Ex & 1 x GloEn-P150	430.000	19.287	29.353	100 KW
Ballast Pumping System 1) For WBTs: Framo SB200-2 x 2 Units x 300 m^3/h 2) For FPT: Taiko Fire General Service Pumps x 2 Units x 115/150 m^3/h	Option 2: 1 x GloEn-P700 Ex & 1 x GloEn-P150	326.000	19.287	25.424	100 KW
M/T Jenny I	Option 1: 2 x GloEn-P700 Ex & 1 x GloEn-P150	520.000	34.534	49.915	180 KW
Ballast Pumping System 1) For WBTs & FPT: Framo SB300-2 x 2 Units x 650 m^3/h 2) For APT: Taiko Fire General Service Pumps x 2 Units x 100/110 m^3/h	Option 2: 1 x GloEn-P1500 Ex & 1 x GloEn-P150	420.000	30.714	36.876	130 KW
M/T Mabrouk Ballast Pumping System 1) For WBTs: 1 Steam driven & 1 Electrical driven CV400-2 x 2000 m^3/h 2) For APT: Shinko Fire General Service Pumps X 2 Units X 240/220 m^3/h	2 x GloEn-P2000 & 1 x GloEn-P250	860.000	23.713	39.184	337 KW

7) Hyde Marine

- System: Hyde Marine Guardian

- Technology: UV Treatment

- Major components of the system:

i) Automatic Backwash Filter
ii) Medium Pressure UV Treatment
iii) Power Panel
iv) Control Panel
v) Valves
vi) Flow meter

- Approvals: USCG AMS Acceptance, IMO Type Approval, ABS Type Approval

- System's parts lifetime and cost

i) UV lamps and quartz tubes to be replaced every 5.000 working hours or 5 years.

ii) Filter's sacrificial anode must be inspected every 6 months and be replaced if needed..

- Operational Information

i) Pressure loss at the filter may some modifications in the existing ballast pumps or the installation of a new booster pump.

ii) Salinity should be higher than 1 PSU for normal operation and temperature should between 0-55 ^{o}C.

iii) An annual calibration of the UV intensity sensor, the flowmeter and the pressure sensor is required.

iv) Maximum system pressure is 10 bar and maximum filter pressure is 6 bar.

v) Power consumption of the system is adjusted to nominal mode in normal water conditions meaning 70% of the total maximum power consumption.

- System's cost

Vessel	**System**	**Equipment Cost** (USD)	**Maintenance Cost** for 10 years (USD)	**Operational Cost** for 10 years (Chemicals/ Additives/ Fuel) (USD)	**Power Demand** (KW)
M/T Minitank Five	Option 1 : 2 x HG300GX & 1 x HG150G (FPT)	463.000	70.394	25.382	101,5 KW
Ballast Pumping System 1) For WBTs: Framo SB200-2 x 2 Units x 300 m^3/h 2) For FPT: Taiko Fire General Service Pumps x 2 Units x 115/150 m^3/h	Option 2: 1 x HG600GX & 1 x HG150G (FPT)	350.000	62.994	16.525	71,5 KW
M/T Jenny I	Option 1: 2 x HG700GX & 1 x HG100G (APT)	616.500	112.503	104.744	170 KW
Ballast Pumping System 1) For WBTs & FPT: Framo SB300-2 x 2 Units x 650 m^3/h 2) For APT: Taiko Fire General Service Pumps x 2 Units x 100/110 m^3/h	Option 2: 1 x HG1500GX & 1 x HG100G (APT)	526.500	79.203	80.793	134 KW
M/T Mabrouk Ballast Pumping System 1) For WBTs: 1 Steam driven & 1 Electrical driven CV400-2 x 2000 m^3/h 2) For APT: Shinko Fire General Service Pumps X 2 Units X 240/220 m^3/h	2 x HG2000GX & 1 x HG250G (APT)	1.195.000	195.708	78.184	331,5 KW

8) EcoChlor

- System: EcoChlor

- Technology: Chlorate-based Chlorine Dioxide Generation & Chlorination of the Ballast Water

- Major components of the system:

i) ClO_2 Generator
ii) ClO_2 Control Panel CP-1
iii) BWTS Remote Monitoring Panel CP-3
iv) Chemical Storage Tanks
v) Motive Water Booster Pump Assembly
vi) Chemical Fill/Vent Station with required valves
vii) Filter Unit
viii) Filter Control Panel CP-2
ix) Filter Control Valves and Instrumentation
x) Filter Cleaning Pumps
xi) Set of ClO_2 Injection Flow Control Components
xii) Ballast Flow meters
xiii) Motive Water Automatic Isolation Valves

- Approvals: USCG AMS Acceptance, IMO Type Approval

- System's parts lifetime and cost

i) Expected lifetime of screen filters is about 5-10 years.

ii) Cost is about 5.000-12.500$ per filter element.

- Operational Information

i) According to USCG AMS Certificate, Ecochlor System is not suitable for freshwater and can operate only in salt and brakish water.

ii) Salinity should higher than 1 PSU for normal operation and temperature between 0-50 ^{o}C.

iii) HVAC system might have to be installed within the deckhouse to control the temperature inside since the limitations for the ambient temperature are 5 and 38 ^{o}C.

- System's cost

Vessel	**System**	**Equipment Cost** (USD)	**Maintenance Cost** for 10 years (USD)	**Operational Cost** for 10 years (Chemicals/ Additives/ Fuel) (USD)	**Power Demand** (KW)
M/T Minitank Five	Option 1 : 2 x HV410 & 1 x HV180	649.000	50.545	93.073	18,2 KW
Ballast Pumping System 1) For WBTs: Framo SB200-2 x 2 Units x 300 m^3/h 2) For FPT: Taiko Fire General Service Pumps x 2 Units x 115/150 m^3/h	Option 2: 1 x HV850 & 1 x HV180	595.400	37.385	92.217	12,4 KW
M/T Jenny I	Option 1: 2 x HV850 & 1 x HV125	729.100	50.545	399.335	19,5 KW
Ballast Pumping System 1) For WBTs & FPT: Framo SB300-2 x 2 Units x 650 m^3/h 2) For APT: Taiko Fire General Service Pumps x 2 Units x 100/110 m^3/h	Option 2: 1 x HV1500 & 1 x HV180	After 3D-Scanning took place onboard the vessel, it was concluded that pipe interferences could not allow a large diameter pipe to be placed across the main deck. Thus, this is option is considered unfeasible.			- KW
M/T Mabrouk Ballast Pumping System 1) For WBTs: 1 Steam driven & 1 Electrical driven CV400-2 x 2000 m^3/h 2) For APT: Shinko Fire General Service Pumps X 2 Units X 240/220 m^3/h	2 x HV2250 & 1 x HV275	865.300	113.373	484.492	38,2 KW

9) JFE Engineering

- System: BallastAce

- Technology: Filtration and Formulated Chemical Injection with Sodium Hypochlorite

- Major components of the system:

i) Ballast Filter with Normal and High Flow Backwash Valve
ii) Disinfectant Injector & Pump
iii) Neutralizer Injector & Pump
iv) TRO Unit
v) Disinfectant tank with level sensor and flowmeter
vi) Neutralizer tank with level sensor and flowmeter
vii) Control Panel

- Approvals: USCG AMS Acceptance, IMO Type Approval, NKK Type Approval

- System's parts lifetime and cost

i) Parts of disinfectant agent pumps should be renewed every 5 years.

ii) Parts of neutralizer agent pumps should be renewed every 5 years.

iii) Parts of filters should be renewed every 2,5 years.

- Operational Information

i) BallastAce System can operate in all salinities, even in fresh water condition.

ii) Temperature levels should be between 0 and 45 ^{o}C for normal operation.

iii) TRO sensors should be cleaned with the proposed reagent every 3 months.

iv) It is desirable that following limitations might not be exceeded:

- Maximum static transverse inclination (heel): 15^{o}
- Maximum static longitudinal inclination (trim): 5^{o}
- Maximum dynamic transverse inclination (roll): 22.5^{o}
- Maximum dynamic longitudinal inclination (pitching): 7.5^{o}
- Vibration Displacement: ±1mm at 2Hz-13.2Hz
- Acceleration: 0.7G at 13.2Hz-80Hz4

- System's cost

Vessel	**System**	**Equipment Cost** (USD)	**Maintenance Cost** for 10 years (USD)	**Operational Cost** for 10 years (Chemicals/ Additives/ Fuel) (USD)	**Power Demand** (KW)
M/T Minitank Five	Option 1 (Liquid Type Disinfectant): 2 x 300 m^3/h for BPs & 1 x 300 m^3/h for FPT	512.397	25.000	98.250	11,6 KW
Ballast Pumping System 1) For WBTs: Framo SB200-2 x 2 Units x 300 m^3/h 2) For FPT: Taiko Fire General Service Pumps x 2 Units x 115/150 m^3/h	Option 2 (Granular Type Disinfectant) : 2 x 300 m^3/h for BPs & 1 x 300 m^3/h for FPT	545.455	25.500	138.540	24,4 KW
M/T Jenny I	Option 1 (Liquid Type Disinfectant): 2 x 750 m^3/h for BPs & 1 x 300 m^3/h for APT	570.248	26.700	464.940	11,6 KW
Ballast Pumping System 1) For WBTs & FPT: Framo SB300-2 x 2 Units x 650 m^3/h 2) For APT: Taiko Fire General Service Pumps x 2 Units x 100/110 m^3/h	Option 2 (Granular Type Disinfectant): 2 x 750 m^3/h for BPs & 1 x 300 m^3/h for APT	570.248	27.200	687.360	24,4 KW
M/T Mabrouk Ballast Pumping System 1) For WBTs: 1 Steam driven & 1 Electrical driven CV400-2 x 2000 m^3/h 2) For APT: Shinko Fire General Service Pumps X 2 Units X 240/220 m^3/h	Option 1 (Liquid Type Disinfectant): 2 x 2000 m^3/h for BPs & 1 x 300 m^3/h for APT	702.479	78.000	583.420	17,3 KW
	Option 2 (Granular Type Disinfectant): 2 x 2000 m^3/h for BPs & 1 x 300 m^3/h for APT	702.479	81.850	869.920	35,4 KW

10) Evoqua

- System: Seacure

- Technology: Filtrarion & Side-stream Electrolysis

- Major components of the system:

i) Filter
ii) Generator
iii) Transformer Rectifier
iv) Tank
v) Fans
vi) System Controls
vii) Dosing system & Monitoring

- Approvals: USCG AMS Acceptance, IMO Type Approval

- System's parts lifetime and cost

i) Expected lifetime of cells is 60.000 hours.

- Operational Information

i) Minimum salinity is 25 PSU and maximum ambient temperature is 50 ^{o}C. There are no limitations in seawater temperatures.

ii) According to Evoqua, each filter has maximum pressure drop 1.6 bar but operation of ballast pumps will not be affected since normal pressure drop is between 0,35 and 0,5 bar.

iii) Seacure system can work also in freshwater. Only requirement is an additional tank filled with normal seawater so that it will be possible for the electrolysis to take place.

- System's cost

Vessel	**System**	**Equipment Cost** (USD)	**Maintenance Cost** for 10 years (USD)	**Operational Cost** for 10 years (Chemicals/ Additives/ Fuel) (USD)	**Power Demand** (KW)
M/T Minitank Five	Option 1 : 1 x SeaCure BWTS 800 with 2 x 300 cbm BW pump filters & 1 x 150 cbm GS pump filter	668.000	82.496	10.119	83,2 KW
Ballast Pumping System 1) For WBTs: Framo SB200-2 x 2 Units x 300 m^3/h 2) For FPT: Taiko Fire General Service Pumps x 2 Units x 115/150 m^3/h	Option 2: 1 x SeaCure BWTS 800 cbm with 1 x 750 cbm BW pump filter & 1 x 150 cbm GS pump filter for FPT treatment	585.000	68.496	7.181	50 KW
M/T Jenny I	Option 1: 2 x SeaCure BWTS 800 with 2 x 750 cbm filters & 1 x 150 cbm filter	736.000	86.496	28.474	114,3 KW
Ballast Pumping System 1) For WBTs & FPT: Framo SB300-2 x 2 Units x 650 m^3/h 2) For APT: Taiko Fire General Service Pumps x 2 Units x 100/110 m^3/h	Option 2: 1 x SeaCure BWTS 1500 cbm with 1 x 1500 cbm BW pump filters & 1 x 150 cbm GS pump filter for APT treatment	645.000	74.496	24.034	95 KW
M/T Mabrouk Ballast Pumping System 1) For WBTs: 1 Steam driven & 1 Electrical driven CV400-2 x 2000 m^3/h 2) For APT: Shinko Fire General Service Pumps X 2 Units X 240/220 m^3/h	Option 1: 1 x SeaCure BWTS 4000 cbm with 2 x 2000 cbm filters & 1 x 300 cbm GS pump filter	1.200.000	121.451	27.721	264 KW
	Option 2: 1 x SeaCure BWTS 4000 cbm with 1 x 4000 cbm filters & 1 x 300 cbm GS pump filter	995.000	93.496	26.711	255 KW

11) Wartsila

- System: Aquarius UV & Aquarius EC

- Technology: UV Treatment & Electro-chlorination

- Major components of the system:

Aquarius EC
i) Filter
ii) Side Stream Pump Module
iii) Hypochlorite Generation Module
iv) Hypochlorite Dosing Module
v) Neutralization Module
vi) Mixer Module
vii) Power Distribution Cabinet
viii) Control Cabinet
ix) Isokenetic Sample Point

Aquarius UV
i) Filter
ii) UV Chamber
iii) Power Distribution Cabinet
iv) Control Cabinet
v) Isokenetic Sample Point

- Approvals: USCG AMS Acceptance, IMO Type Approval,
ATEX Certificate for UV by DEKRA

- System's parts lifetime and cost

i) UV lamps to be replaced every 5 years

ii) Filter Elements to be replaced every 5 to 7 years.

- Operational Information

i) Pressure drop on normal operation is 0,3 bar. However, the Backwash setpoint is 0,8 bar. Consequently, a feasibility study will have to be carried out in order to find out whether a booster pump will be required due to pressure loss.

ii) UV lamps of the Aquarius UV system are medium pressure. Thus, a Mercury Spill Kit is included in case a UV lamp breaks and liquid mercury is spilled.

iii) As far as the Aquarius UV system is concerned, there are no restrictions regarding salinity levels and temperature. Although, it is affected by turbidity and dissolved metals in the water that can absorb UV light.

iv) Regarding the Aquarius EC system, salinity levels should be greater than 10 PSU.

Also, minimum temperature for normal operation is set at 10^{o}C. In case the vessel is in freshwater environment, seawater storage will be required.

v) Power consumption of the system cannot be reduced since there are modules that are able to adjust the intensity of the UV lamps.

vi) An accuracy check of the duty UV sensor should be undertaken annually or every 1.000 hours using a calibrated UV intensity sensor.

- System's cost

Vessel	**System**	**Equipment Cost** (USD)	**Maintenance Cost** for 10 years (USD)	**Operational Cost** for 10 years (Chemicals/ Additives/ Fuel) (USD)	**Power Demand** (KW)
M/T Minitank Five	Option 1 : 2 x Ex AQ-375-UV & 1 x Non Ex AQ-180-UV	528.342	105.970	13.831	86 KW
Ballast Pumping System 1) For WBTs: Framo SB200-2 x 2 Units x 300 m^3/h 2) For FPT: Taiko Fire General Service Pumps x 2 Units x 115/150 m^3/h	Option 2: 1 x Ex AQ-750-UV & 1 x Non Ex AQ-180-UV	410.597	94.470	24.422	130,8 KW
M/T Jenny I	Option 1: 2 x Ex AQ-750-UV & 1 x Non Ex AQ-125-UV	681.866	126.975	74.020	121,2 KW
Ballast Pumping System 1) For WBTs & FPT: Framo SB300-2 x 2 Units x 650 m^3/h 2) For APT: Taiko Fire General Service Pumps x 2 Units x 100/110 m^3/h	Option 2: 1 x Ex AQ-1500-EC & 1 x Non Ex AQ-125-UV	620.038	60.324	200.754	126,2 KW
M/T Mabrouk Ballast Pumping System 1) For WBTs: 1 Steam driven & 1 Electrical driven CV400-2 x 2000 m^3/h 2) For APT: Shinko Fire General Service Pumps X 2 Units X 240/220 m^3/h	2 x Ex AQ-2000-EC & 1 x Non Ex AQ-250-UV	1.251.461	118.056	181.161	198 KW

5 Calculation of Operational Expenses for Ballast Water Treatment Systems

1) Environmental Protection Engineering S.A. Greece (E.P.E.)

- System: ERMA FIRST FIT

- Technology: Filtration & Full Stream Electrolysis

- Operational Expenses Calculation

A. Minitank Five – Option 1: 2 x Erma First 300 Ex

ERMA FIRST SYSTEM FOR M/T MINITANK FIVE			UNITS
Ballast capacity:		300	m3/hr
a.	No	2	used for total BW treatment
b.	Total	600	m3/hr
Total BW per operation		3.138	m3
Hours to fill tanks		5	Hrs
Period of calculations		10	Years
Ballast Voyages		360	Voyages
Total Ballasting Time		1.883	Hrs
Total De-ballasting Time		1.883	Hrs
Total Ballast Pump Operating Time		3.776	Hrs
Total BWTS Operating Time		1.883	Hrs
Operating Costs			
Neutralizing Agent consumption (NaSO3 powder)		0,0015	[1] Kgr/m^3 treated BW
Ballast Voyages per year with a duration of more than 5 days		260	
Ballast Voyages per year with a duration of less than 5 days		100	
Total Discharged Treated BW		1.129.680	m^3
Total Discharged BW which requires neutralization		313.800	m^3
Total Neutralizing agent required		471	Kgr
Cost of Neutralizing Agent		0,5	[2] $/kgr
Total Cost of Neutralizing Agent		235	$
Cost of TRO reagents		10.000	$
Consumables Cost		10.235	$
Power Consumption			
Power consumption per hour		10,80	kW
Total BWTS operating hours		1.883	
Total Power Consumption		20.334	kWhr
Fuel Consumption Rate		0,00015	Ton/kW
Fuel Cost Rate		400	USD/ton
Fuel Consumption		3,1	Ton

Fuel Cost	1220,054	$
Electrodes Consumption[3]		
Price per electrode	13.000	$
Number of Electrodes	2	pcs
a. Lifetime	5.000	Operating hours
b. Cost	9790,56	$
Total Operating Cost	21.246	$
Filter		
No Filters	2	pcs
Filter Repair Kit Cost per filter	800	$
Filter Repair Kit Cost for 10 years	16.000	$
Filter Basket		
a. Lifetime	5	Years
b. Cost	16.400	$
Total Maintenance Cost	32.400	$
Total Maintenance & Operating Cost	**53.646**	**$**

[1] for neutralizing appx 1-3 mg/L residual chlorine in tank
[1] average duration of 2-5 days for each ballast voyage
[2] cost may vary from port to port
These are accumulative costs
[3] Electrodes Warranted life time is 5000 hrs at operation in low salinity and low temperature. Electrodes consumption is based on this figure. The complete electrode will be replaced when its will be consumed.

B. Minitank Five – Option 2: 1 x Erma First 600 Ex

ERMA FIRST SYSTEM FOR M/T MINITANK FIVE		UNITS
Ballast capacity:	600	m3/hr
a. No	1	used for total BW treatment
b. Total	600	m3/hr
Total BW per operation	3.138	m3
Hours to fill tanks	5	Hrs
Period of calculations	10	Years
Ballast Voyages	360	Voyages
Total Ballasting Time	1.883	Hrs
Total De-ballasting Time	1.883	Hrs
Total Ballast Pump Operating Time	3.776	Hrs
Total BWTS Operating Time	1.883	Hrs
Operating Costs		
Neutralizing Agent consumption (NaSO3 powder)	0,0015	[1] Kgr/m^3 treated BW
Ballast Voyages per year with a duration of more than 5 days	260	

Ballast Voyages per year with a duration of less than 5 days	100	
Total Discharged Treated BW	1.129.680	m^3
Total Discharged BW which requires neutralization	313.800	m^3
Total Neutralizing agent required	471	Kgr
Cost of Neutralizing Agent	0,5	[2] $/kgr
Total Cost of Neutralizing Agent	235	$
Cost of TRO reagents	10.000	$
Consumables Cost	10.235	$
<u>Power Consumption</u>		
Power consumption per hour	10,80	kW
Total BWTS operating hours	1.883	
Total Power Consumption	20.334	kWhr
Fuel Consumption Rate	0,00015	Ton/kW
Fuel Cost Rate	400	USD/ton
Fuel Consumption	3,1	Ton
Fuel Cost	1220,054	$
Electrodes Consumption[3]		
Price per electrode	15.000	$
Number of Electrodes	1	pcs
a. Lifetime	5.000	Operating hours
b. Cost	5648,4	$
Total Operating Cost	17.104	$
<u>Filter</u>		
No Filters	1	pcs
Filter Repair Kit Cost per filter	1000	$
Filter Repair Kit Cost for 10 years	10.000	$
Filter Basket		
a. Lifetime	5	Years
b. Cost	13.430	$
Total Maintenance Cost	23.430	$
<u>Total Maintenance & Operating Cost</u>	**40.534**	**$**

[1] for neutralizing appx 1-3 mg/L residual chlorine in tank
[1] average duration of 2-5 days for each ballast voyage
[2] cost may vary from port to port
These are accumulative costs
[3] Electrodes Warranted life time is 5000 hrs at operation in low salinity and low temperature. Electrodes consumption is based on this figure. The complete electrode will be replaced when its will be consumed.

C. Minitank Five – Option 1 & 2: 1 x Erma First 100 Ex

ERMA FIRST SYSTEM FOR M/T MINITANK FIVE			UNITS
Ballast capacity:		100	m3/hr
a.	No	1	used for total BW treatment
b.	Total	100	m3/hr
Total BW per operation		218	m3
Hours to fill tanks		2	Hrs
Period of calculations		10	Years
Ballast Voyages		360	Voyages
Total Ballasting Time		785	Hrs
Total De-ballasting Time		785	Hrs
Total Ballast Pump Operating Time		1.570	Hrs
Total BWTS Operating Time		785	Hrs
Operating Costs			
Neutralizing Agent consumption (NaSO3 powder)		0,0015	[1] Kgr/m^3 treated BW
Ballast Voyages per year with a duration of more than 5 days		260	
Ballast Voyages per year with a duration of less than 5 days		100	
Total Discharged Treated BW		78.480	m^3
Total Discharged BW which requires neutralization		21.800	m^3
Total Neutralizing agent required		33	Kgr
Cost of Neutralizing Agent		0,5	[2] $/kgr
Total Cost of Neutralizing Agent		16	$
Cost of TRO reagents		10.000	$
Consumables Cost		10.016	$
Power Consumption			
Power consumption per hour		1,80	kW
Total BWTS operating hours		785	hrs
Total Power Consumption		1.413	kWhr
Fuel Consumption Rate		0,00015	Ton/kW
Fuel Cost Rate		400	USD/ton
Fuel Consumption		0,2	Ton
Fuel Cost		84,7584	$
Electrodes Consumption[3]			
Price per electrode		9.000	$
Number of Electrodes		1	pcs
a.	Lifetime	5.000	Operating hours
b.	Cost	1412,64	$
Total Operating Cost		11.514	$
Filter			
No Filters		1	pcs

Filter Repair Kit Cost per filter		500	$
Filter Repair Kit Cost for 10 years		5.000	$
Filter Basket			
a.	Lifetime	5	Years
b.	Cost	3.864	$
Total Maintenance Cost		8.864	$
Total Maintenance & Operating Cost		**20.378**	**$**

[1] for neutralizing appx 1-3 mg/L residual chlorine in tank
[1] average duration of 2-5 DAYS for each ballast voyage
[2] cost may vary from port to port
These are accumulative costs
[3] Electrodes Warranted life time is 5000 hrs at operation in low salinity and low temperature. Electrodes consumption is based on this figure. The complete electrode will be replaced when its will be consumed.

D. Jenny I – Option 1: 2 x Erma First 600 Ex

ERMA FIRST SYSTEM FOR M/T JENNY I			UNITS
Ballast capacity:		600	m3/hr
a.	No	2	used for total BW treatment
b.	Total	1200	m3/hr
Total BW per operation		20.429	m3
Hours to fill tanks		17	Hrs
Period of calculations		10	Years
Ballast Voyages		270	Voyages
Total Ballasting Time		4.597	Hrs
Total De-ballasting Time		4.597	Hrs
Total Ballast Pump Operating Time		9.193	Hrs
Total BWTS Operating Time		4.597	Hrs
Operating Costs			
Neutralizing Agent consumption (NaSO3 powder)		0,0015	[1] Kgr/m^3 treated BW
Ballast Voyages per year with a duration of more than 5 days		220	
Ballast Voyages per year with a duration of less than 5 days		50	
Total Discharged Treated BW		5.515.830	m^3
Total Discharged BW which requires neutralization		1.021.450	m^3
Total Neutralizing agent required		1.532	Kgr
Cost of Neutralizing Agent		0,5	[2] $/kgr
Total Cost of Neutralizing Agent		766	$

Cost of TRO reagents	10.000	$
Consumables Cost	10.766	$
Power Consumption		
Power consumption per hour	21,60	kW
Total BWTS operating hours	4.597	hrs
Total Power Consumption	99.285	kWhr
Fuel Consumption Rate	0,00015	Ton/kW
Fuel Cost Rate	400	USD/ton
Fuel Consumption	14,9	Ton
Fuel Cost	5957,096	$
Electrodes Consumption[3]		
Price per electrode	15.000	$
Number of Electrodes	2	pcs
a. Lifetime	5.000	Operating hours
b. Cost	27579,15	$
Total Operating Cost	44.302	$
Filter		
No Filters	2	pcs
Filter Repair Kit Cost per filter	1000	$
Filter Repair Kit Cost for 10 years	20.000	$
Filter Basket		
a. Lifetime	5	Years
b. Cost	26.860	$
Total Maintenance Cost	46.860	$
Total Maintenance & Operating Cost	**91.162**	**$**

[1] for neutralizing appx 1-3 mg/L residual chlorine in tank
[1] average duration of 2-5 days for each ballast voyage
[2] cost may vary from port to port
These are accumulative costs
[3] Electrodes Warranted life time is 5000 hrs at operation in low salinity and low temperature. Electrodes consumption is based on this figure. The complete electrode will be replaced when its will be consumed.

E. Jenny I – Option 2: 1 x Erma First 1500 Ex

ERMA FIRST SYSTEM FOR M/T JENNY I		UNITS
Ballast capacity:	1.500	m3/hr
a. No	1	used for total BW treatment
b. Total	1500	m3/hr
Total BW per operation	20.429	m3
Hours to fill tanks	14	Hrs
Period of calculations	10	Years
Ballast Voyages	270	Voyages
Total Ballasting Time	3.677	Hrs

Total De-ballasting Time		3.677	Hrs
Total Ballast Pump Operating Time		7.354	Hrs
Total BWTS Operating Time		3.677	Hrs
Operating Costs			
Neutralizing Agent consumption (NaSO3 powder)		0,0015	[1] Kgr/m^3 treated BW
Ballast Voyages per year with a duration of more than 5 days		220	
Ballast Voyages per year with a duration of less than 5 days		50	
Total Discharged Treated BW		5.515.830	m^3
Total Discharged BW which requires neutralization		1.021.450	m^3
Total Neutralizing agent required		1.532	Kgr
Cost of Neutralizing Agent		0,5	[2] $/kgr
Total Cost of Neutralizing Agent		766	$
Cost of TRO reagents		10.000	$
Consumables Cost		10.766	$
Power Consumption			
Power consumption per hour		27,00	kW
Total BWTS operating hours		3.677	hrs
Total Power Consumption		99.285	kWhr
Fuel Consumption Rate		0,00015	Ton/kW
Fuel Cost Rate		400	USD/ton
Fuel Consumption		14,9	Ton
Fuel Cost		5957,096	$
Electrodes Consumption[3]			
Price per electrode		19.000	$
Number of Electrodes		2	pcs
a.	Lifetime	5.000	Operating hours
b.	Cost	27946,87	$
Total Operating Cost		44.670	$
Filter			
No Filters		1	pcs
Filter Repair Kit Cost per filter		1500	$
Filter Repair Kit Cost for 10 years		20.000	$
Filter Basket			
a.	Lifetime	5	Years
b.	Cost	21.070	$
Total Maintenance Cost		36.070	$
Total Maintenance & Operating Cost		**80.740**	**$**

[1] for neutralizing appx 1-3 mg/L residual chlorine in tank
[1] average duration of 2-5 days for each ballast voyage
[2] cost may vary from port to port
These are accumulative costs

[3] Electrodes Warranted life time is 5000 hrs at operation in low salinity and low temperature. Electrodes consumption is based on this figure. The complete electrode will be replaced when its will be consumed.

F. Jenny I – Option 1 & 2: 1 x Erma First 100 Ex

ERMA FIRST SYSTEM FOR M/T JENNY I			UNITS
Ballast capacity:		100	m3/hr
a.	No	1	used for total BW treatment
b.	Total	100	m3/hr
Total BW per operation		643	m3
Hours to fill tanks		6	Hrs
Period of calculations		10	Years
Ballast Voyages		270	Voyages
Total Ballasting Time		1.736	Hrs
Total De-ballasting Time		1.736	Hrs
Total Ballast Pump Operating Time		3.472	Hrs
Total BWTS Operating Time		1.736	Hrs
Operating Costs			
Neutralizing Agent consumption (NaSO3 powder)		0,0015	[1] Kgr/m^3 treated BW
Ballast Voyages per year with a duration of more than 5 days		220	
Ballast Voyages per year with a duration of less than 5 days		50	
Total Discharged Treated BW		173.610	m^3
Total Discharged BW which requires neutralization		32.150	m^3
Total Neutralizing agent required		48	Kgr
Cost of Neutralizing Agent		0,5	[2] $/kgr
Total Cost of Neutralizing Agent		24	$
Cost of TRO reagents		10.000	$
Consumables Cost		10.024	$
Power Consumption			
Power consumption per hour		1,80	kW
Total BWTS operating hours		1.736	hrs
Total Power Consumption		3.125	kWhr
Fuel Consumption Rate		0,00015	Ton/kW
Fuel Cost Rate		400	USD/ton
Fuel Consumption		0,5	Ton
Fuel Cost		187,4988	$
Electrodes Consumption[3]			
Price per electrode		9.000	$
Number of Electrodes		2	pcs
a.	Lifetime	5.000	Operating hours
b.	Cost	6.249,96	$

Total Operating Cost	16.462	$
Filter		
No Filters	1	pcs
Filter Repair Kit Cost per filter	500	$
Filter Repair Kit Cost for 10 years	5.000	$
Filter Basket		
a. Lifetime	5	Years
b. Cost	3.864	$
Total Maintenance Cost	8.864	$
Total Maintenance & Operating Cost	**25.326**	**$**

[1] for neutralizing appx 1-3 mg/L residual chlorine in tank
[1] average duration of 2-5 days for each ballast voyage
[2] cost may vary from port to port
These are accumulative costs
[3] Electrodes Warranted life time is 5000 hrs at operation in low salinity and low temperature. Electrodes consumption is based on this figure. The complete electrode will be replaced when its will be consumed.

G. Mabrouk: 2 x Erma First 2000 Ex

ERMA FIRST SYSTEM FOR M/T MABROUK		UNITS
Ballast capacity:	2.000	m3/hr
a. No	2	used for total BW treatment
b. Total	4000	m3/hr
Total BW per operation	50.000	m3
Hours to fill tanks	13	Hrs
Period of calculations	10	Years
Ballast Voyages	120	Voyages
Total Ballasting Time	1.500	Hrs
Total De-ballasting Time	1.500	Hrs
Total Ballast Pump Operating Time	3.000	Hrs
Total BWTS Operating Time	1.500	Hrs
Operating Costs		
Neutralizing Agent consumption (NaSO3 powder)	0,0015	[1] Kgr/m^3 treated BW
Ballast Voyages per year with a duration of more than 5 days	100	
Ballast Voyages per year with a duration of less than 5 days	20	
Total Discharged Treated BW	6.000.000	m^3
Total Discharged BW which requires neutralization	1.000.000	m^3
Total Neutralizing agent required	1.500	Kgr

Cost of Neutralizing Agent	0,5	[2] $/kgr
Total Cost of Neutralizing Agent	750	$
Cost of TRO reagents	10.000	$
Consumables Cost	10.750	$
Power Consumption		
Power consumption per hour	72,00	kW
Total BWTS operating hours	1.500	hrs
Total Power Consumption	108.000	kWhr
Fuel Consumption Rate	0,00015	Ton/kW
Fuel Cost Rate	400	USD/ton
Fuel Consumption	16,2	Ton
Fuel Cost	6.480	$
Electrodes Consumption[3]		
Price per electrode	22.000	$
Number of Electrodes	2	pcs
a. Lifetime	5.000	Operating hours
b. Cost	13.200	$
Total Operating Cost	30.430	$
Filter		
No Filters	2	pcs
Filter Repair Kit Cost per filter	1200	$
Filter Repair Kit Cost for 10 years	24.000	$
Filter Basket		
a. Lifetime	5	Years
b. Cost	32.480	$
Total Maintenance Cost	56.480	$
Total Maintenance & Operating Cost	**86.910**	**$**

[1] for neutralizing appx 1-3 mg/L residual chlorine in tank
[1] average duration of 2-5 days for each ballast voyage
[2] cost may vary from port to port
These are accumulative costs
[3] Electrodes Warranted life time is 5000 hrs at operation in low salinity and low temperature. Electrodes consumption is based on this figure. The complete electrode will be replaced when its will be consumed.

H. Mabrouk: 1 x Erma First 100 Ex

ERMA FIRST SYSTEM FOR M/T MABROUK		UNITS
Ballast capacity:	100	m3/hr
a. No	1	used for total BW treatment
b. Total	100	m3/hr
Total BW per operation	1.052	m3
Hours to fill tanks	11	Hrs
Period of calculations	10	Years

Ballast Voyages		120	Voyages
Total Ballasting Time		1.262	Hrs
Total De-ballasting Time		1.262	Hrs
Total Ballast Pump Operating Time		2.525	Hrs
Total BWTS Operating Time		1.262	Hrs
Operating Costs			
Neutralizing Agent consumption (NaSO3 powder)		0,0015	[1] Kgr/m^3 treated BW
Ballast Voyages per year with a duration of more than 5 days		100	
Ballast Voyages per year with a duration of less than 5 days		20	
Total Discharged Treated BW		126.240	m^3
Total Discharged BW which requires neutralization		21.040	m^3
Total Neutralizing agent required		32	Kgr
Cost of Neutralizing Agent		0,5	[2] $/kgr
Total Cost of Neutralizing Agent		16	$
Cost of TRO reagents		10.000	$
Consumables Cost		10.16	$
Power Consumption			
Power consumption per hour		1,80	kW
Total BWTS operating hours		1.262	hrs
Total Power Consumption		2.272	kWhr
Fuel Consumption Rate		0,00015	Ton/kW
Fuel Cost Rate		400	USD/ton
Fuel Consumption		0,3	Ton
Fuel Cost		136,3392	$
Electrodes Consumption[3]			
Price per electrode		9.000	$
Number of Electrodes		2	pcs
a.	Lifetime	5.000	Operating hours
b.	Cost	4.544,64	$
Total Operating Cost		14.697	$
Filter			
No Filters		1	pcs
Filter Repair Kit Cost per filter		500	$
Filter Repair Kit Cost for 10 years		5.000	$
Filter Basket			
a.	Lifetime	5	Years
b.	Cost	3.864	$
Total Maintenance Cost		8.864	$
Total Maintenance & Operating Cost		**23.561**	**$**

[1] for neutralizing appx 1-3 mg/L residual chlorine in tank
[1] average duration of 2-5 days for each ballast voyage

[2] cost may vary from port to port
These are accumulative costs
[3] Electrodes Warranted life time is 5000 hrs at operation in low salinity and low temperature. Electrodes consumption is based on this figure. The complete electrode will be replaced when its will be consumed.

2) Alfa Laval

- System: PureBallast 3.1

- Technology: UV Treatment with advanced oxidation technology

- Operational Expenses Calculation

Vessel	Minitank Five	System Installed	2 x PB300 & 1 x PB170
Information about the System and the Vessel			
Ballast Tank Capacity	3.138 m^3	No/ Ballast Systems:	(Main + Afterpeak)
Ballast Pump Rating @ 25m total head	300 m^3/h	Ballast pump location:	Engine Room
Number of Ballast per year	36	Voltage on board:	440/220 V
Number of De-ballast per year	36	Frequency:	60 Hz
Maximum Ballast Volume to be treated per year:	225.965 m^3	Compressed air:	30/7 bar
Quantity of PB systems	2		
Capacity of each system	375 m^3/h		
Total installed PB Capacity:	750 m^3/h	Ballast operation per year @ 100% Pump Efficiency	301,29 hours
No. Filters per system	1	No. AOT per system	1
Capacity per Filter	650	No. Lamps per AOT	10

Power Consumption per Year					
Consumer	Qty	kW	Total kW	Ballast hrs/year	kW hours
A. AOT	2	30	80 (2x30+20)	301,29	24.103
Average AOT power as a result of automatic power reduction due to high UV intensity of treated ballast water in operation (automatically controlled according to UV intensity measurement)				73% (Appendix A)	17.534
B. Filter (Only in operation during ballasting)	3	0,37	1,11	150,64	167
C. Controls including CIP	3	0,5	1,5	301,29	452

TOTAL			82,61 kW		18.153 kWh

Fuel Oil Consumption per Year				
kW hours	Specific Fuel Oil Consumption (SFOC) g/kWh	Tonne/yr	Fuel Price $/Tonne	Fuel cost to operate per year
18.153	224,00	4,07	350,00	1.423 $

Spare Parts for 10 Years Operation (in Euro)					
Item	Assumed Failure rate in 10 years	Unit PPL	Discount	Unit	Ext
Lamps	10%	427,68 €	40%	256,61 €	6.700,42 €
Filter Sealing kit	Changes/year: 0,08	1.224,07 €	40%	746,44 €	1.686,70 €
Filter Basker	Changes/year: 0,02	12.284,75 €	40%	7.370,85 €	3.331,11 €
CIP Pump spares	Changes/year: 0,12	1.826,00 €	40%	1.095,60 €	3.961,07 €
CIP Fluid	Changes/year: 4	137,40 €	40%	82,44 €	6.595,20 €
UV Sensor	Changes/year: 0,04	750,00 €	40%	450,00 €	540,00 €

Spare Parts for 10 years operation (in USD)					
Description	Ballast treated/year	Ballast treated/5 years	1-Year	10-Years	$/m^3
System Maintenance	225.965 m^3	1.129.824 m^3	5.390 $	24.502 $	0,0217 $/m^3

Opex per Year		Exchange Rate Eur/Usd: 1,1
Description	Euro €	USD $
Fuel Oil Consumption	1.294 €	1.423 $
Spare Parts	2.227,45 €	2.450 $
TOTAL		3.873 $

Vessel	Minitank Five	System Installed	1 x PB600 & 1 x PB170
Information about the System and the Vessel			
Ballast Tank Capacity	3.138 m^3	No/ Ballast Systems:	(Main + Afterpeak)
Ballast Pump Rating @ 25m total head	300 m^3/h	Ballast pump location:	Engine Room
Number of Ballast per year	36	Voltage on board:	440/220 V
Number of De-ballast per year	36	Frequency:	60 Hz
Maximum Ballast	225.965 m^3	Compressed air:	30/7 bar

Volume to be treated per year:					
Quantity of PB systems	1				
Capacity of each system	770 m^3/h				
Total installed PB Capacity:	770 m^3/h	Ballast operation per year @ 100% Pump Efficiency		293,46 hours	
No. Filters per system	1	No. AOT per system		1	
Capacity per Filter	770	No. Lamps per AOT		20	
Power Consumption per Year					
Consumer	Qty	kW	Total kW	Ballast hrs/year	kW hours
A. AOT	1	63	83 (1x63+20)	293,46	24.357
Average AOT power as a result of automatic power reduction due to high UV intensity of treated ballast water in operation (automatically controlled according to UV intensity measurement)				73% (Appendix A)	17.719
B. Filter (Only in operation during ballasting)	2	0,37	0,74	146,73	109
C. Controls including CIP	2	0,5	1,5	293,46	293
TOTAL			84,74 kW		18.121 kWh

Fuel Oil Consumption per Year				
kW hours	Specific Fuel Oil Consumption (SFOC) g/kWh	Tonne/yr	Fuel Price $/Tonne	Fuel cost to operate per year
18.121	224,00	4,06	350,00	1.421 $

Spare Parts for 10 Years Operation (in Euro)					
Item	Assumed Failure rate in 10 years	Unit PPL	Discount	Unit	Ext
Lamps	10%	427,68 €	40%	256,61 €	6.526,38 €
Filter Sealing kit	Changes/year: 0,08	1.224,07 €	40%	746,44 €	1.095,26 €
Filter Basker	Changes/year: 0,02	12.284,75 €	40%	7.370,85 €	2.163,06 €
CIP Pump spares	Changes/year: 0,12	1.826,00 €	40%	1.095,60 €	2.572,13 €
CIP Fluid	Changes/year: 4	137,40 €	40%	82,44 €	3.297,60 €
UV Sensor	Changes/year: 0,04	750,00 €	40%	450,00 €	360,00 €

Spare Parts for 10 years operation (in USD)					
Description	Ballast treated/year	Ballast treated/5 years	1-Year	10-Years	$\$/m^3$
System Maintenance	225.965 m^3	1.129.824 m^3	3.788 $	17.220 $	0,0152 $\$/m^3$

Opex per Year			Exchange Rate Eur/Usd: 1,1
Description	Euro €		USD $
Fuel Oil Consumption	1.292 €		1.421 $
Spare Parts	1.565,44 €		1.722 $
TOTAL			3.143 $

Vessel	Jenny I	System Installed		2 x PB750 & 1 x PB170	
Information about the System and the Vessel					
Ballast Tank Capacity	20.429 m^3	No/ Ballast Systems:		(Main + Afterpeak)	
Ballast Pump Rating @ 25m total head	650 m^3/h	Ballast pump location:		Engine Room	
Number of Ballast per year	27	Voltage on board:		440/220 V	
Number of De-ballast per year	27	Frequency:		60 Hz	
Maximum Ballast Volume to be treated per year:	1.103.166 m^3	Compressed air:		30/7 bar	
Quantity of PB systems	2				
Capacity of each system	750 m^3/h				
Total installed PB Capacity:	1.410 m^3/h	Ballast operation per year @ 100% Pump Efficiency		782,39 hours	
No. Filters per system	1	No. AOT per system		1	
Capacity per Filter	770	No. Lamps per AOT		16	
Power Consumption per Year					
Consumer	Qty	kW	Total kW	Ballast hrs/year	kW hours
A. AOT	2	96	212 (2x96+20)	782,39	165.866
Average AOT power as a result of automatic power reduction due to high UV intensity of treated ballast water in operation (automatically controlled according to UV intensity measurement)				73% (Appendix A)	120.663
B. Filter (Only in operation during ballasting)	3	0,37	1,11	391,19	434
C. Controls including CIP	3	0,5	1,5	782,39	1.174
TOTAL			214,61		122.271

			kW		kWh

Fuel Oil Consumption per Year				
kW hours	Specific Fuel Oil Consumption (SFOC) g/kWh	Tonne/yr	Fuel Price $/Tonne	Fuel cost to operate per year
122.271	224,00	27,39	350,00	9.586 $

Spare Parts for 10 Years Operation (in Euro)					
Item	Assumed Failure rate in 10 years	Unit PPL	Discount	Unit	Ext
Lamps	26%	427,68 €	40%	256,61 €	25.430,46 €
Filter Sealing kit	Changes/year: 0,20	1.224,07 €	40%	746,44 €	4.380,05 €
Filter Basker	Changes/year: 0,04	12.284,75 €	40%	7.370,85 €	8.650,29 €
CIP Pump spares	Changes/year: 0,31	1.826,00 €	40%	1.095,60 €	10.286,20 €
CIP Fluid	Changes/year: 4	137,40 €	40%	82,44 €	6.595,20 €
UV Sensor	Changes/year: 0,04	750,00 €	40%	450,00 €	540,00 €

Spare Parts for 10 years operation (in USD)					
Description	Ballast treated/year	Ballast treated/5 years	1-Year	10-Years	$/m^3
System Maintenance	1.103.166 m^3	5.515.830 m^3	13.393 $	60.876 $	0,0110 $/m^3
Opex per Year			Exchange Rate Eur/Usd: 1,1		

Description	Euro €	USD $
Fuel Oil Consumption	8.715 €	9.586 $
Spare Parts	5.534,22 €	6.088 $
TOTAL		15.674 $

Vessel	Mabrouk	System Installed	2 x PB2000 & 1 x PB250
Information about the System and the Vessel			
Ballast Tank Capacity	53.635 m^3	No/ Ballast Systems:	(Main + Afterpeak)
Ballast Pump Rating @ 25m total head	2.000 m^3/h	Ballast pump location:	Engine Room
Number of Ballast per year	12	Voltage on board:	440/220 V
Number of De-ballast per year	12	Frequency:	60 Hz
Maximum Ballast	1.287.240 m^3	Compressed air:	30/7 bar

Volume to be treated per year:			
Quantity of PB systems	2		
Capacity of each system	2.125 m^3/h		
Total installed PB Capacity:	4.250 m^3/h	Ballast operation per year @ 100% Pump Efficiency	321,81 hours
No. Filters per system	5	No. AOT per system	2
Capacity per Filter	886	No. Lamps per AOT	16

Power Consumption per Year					
Consumer	Qty	kW	Total kW	Ballast hrs/year	kW hours
A. AOT	4	125	533 (4x125+33)	321,81	171.525
Average AOT power as a result of automatic power reduction due to high UV intensity of treated ballast water in operation (automatically controlled according to UV intensity measurement)				73% (Appendix A)	124.780
B. Filter (Only in operation during ballasting)	5	0,37	1,85	160,91	298
C. Controls including CIP	2	0,5	1	321,81	322
TOTAL			535,85 kW		125.399 kWh

Fuel Oil Consumption per Year				
kW hours	Specific Fuel Oil Consumption (SFOC) g/kWh	Tonne/yr	Fuel Price $/Tonne	Fuel cost to operate per year
125.399	224,00	28,09	350,00	9.831 $

Spare Parts for 10 Years Operation (in Euro)					
Item	Assumed Failure rate in 10 years	Unit PPL	Discount	Unit	Ext
Lamps	20%	427,68 €	40%	256,61 €	39.378,86 €
Filter Sealing kit	Changes/year: 0,15	1.224,07 €	40%	746,44 €	11.304,12 €
Filter Basker	Changes/year: 0,03	12.284,75 €	40%	7.370,85 €	22.324,83 €
CIP Pump spares	Changes/year: 0,24	1.826,00 €	40%	1.095,60 €	7.964,05 €
CIP Fluid	Changes/year: 4	137,40 €	40%	82,44 €	6.595,20 €
UV Sensor	Changes/year: 0,04	750,00 €	40%	450,00 €	720,00 €

Spare Parts for 10 years operation (in USD)					
Description	Ballast treated/year	Ballast treated/5 years	1-Year	10-Years	$\$/m^3$
System Maintenance	1.287.240 m^3	6.436.200 m^3	21.191 $	96.324 $	0,0150 $\$/m^3$
Opex per Year			Exchange Rate Eur/Usd: 1,1		
<u>Description</u>		Euro €			USD $
Fuel Oil Consumption		8.937 €			9.831 $
Spare Parts		8.756,71 €			9.632 $
TOTAL					19.463 $

3) Panmarine

<u>- System</u>: Trojan Marinex

<u>- Technology</u>: UV Treatment

<u>- Operational Expenses Calculation</u>

A. M/T Minitank Five – Option 1: 2 x TM500 Ex & 1 x TM 150 Non Ex (FPT)

i) <u>Power/Fuel Cost for 10 Years</u>

System: 2 x TM500 Ex	
Ballast Tanks Total Capacity	3.138 m^3
Number of Ballast Operations per Year	36
Number of De-ballast Operations per Year	36
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	225.936 m^3
Total Ballast Capacity of Ballast Pump	600 m^3/h
Total Ballast Capacity of UV BWTS	1.000 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	377 hrs
Total Power Demand	51,8 kW
Total kWhrs per Year	19.506 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	1529 USD
Fuel Cost/10 Years	**15.293 USD**

System: 1 x TM150 Non Ex	
Ballast Tanks Total Capacity	218 m^3
Number of Ballast Operations per Year	36
Number of De-ballast Operations per Year	36
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	15.696 m^3
Total Ballast Capacity of Ballast Pump	150 m^3/h
Total Ballast Capacity of UV BWTS	150 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	105 hrs
Total Power Demand	9 kW
Total kWhrs per Year	942 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	74 USD
Fuel Cost/10 Years	**738 USD**

TOTAL FUEL COST IN 10 YEARS: 16.031 USD

ii) Spares Cost for 10 Years

System: TM500 Ex			
Item	Qty	Unit Price	Total
Solo UV Lamp	48	700	33.600 USD
Wiper Seals	48	8	384 USD
Sleeve	48	200	9.600 USD
Total			**43.584 USD**
System: TM150 Non Ex			
Item	**Qty**	**Unit Price**	**Total**
Solo UV Lamp	14	700	9.800 USD
Wiper Seals	14	8	112 USD
Sleeve	14	200	2.800 USD
Total			**12.712 USD**

2 x TM500 Ex	87.168 USD
1 x TM150 Non Ex	12.712 USD
TOTAL SPARE COST IN 10 YEARS	**99.880 USD**

B. M/T Minitank Five – Option 2: 1 x TM750 Ex & 1 x TM150 Non Ex (FPT)

i) Power/Fuel Cost for 10 Years

System: 1 x TM750 Ex	
Ballast Tanks Total Capacity	3.138 m^3
Number of Ballast Operations per Year	36
Number of De-ballast Operations per Year	36
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	225.936 m^3
Total Ballast Capacity of Ballast Pump	600 m^3/h
Total Ballast Capacity of UV BWTS	750 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	377 hrs
Total Power Demand	34,3 kW
Total kWhrs per Year	12.916 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	1.013 USD
Fuel Cost/10 Years	**10.126 USD**

System: 1 x TM150 Non Ex	
Ballast Tanks Total Capacity	218 m^3
Number of Ballast Operations per Year	36
Number of De-ballast Operations per Year	36
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	15.696 m^3
Total Ballast Capacity of Ballast Pump	150 m^3/h
Total Ballast Capacity of UV BWTS	150 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	105 hrs
Total Power Demand	9 kW
Total kWhrs per Year	942 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	74 USD

Fuel Cost/10 Years	**738 USD**

TOTAL FUEL COST IN 10 YEARS: 10.864 USD

ii) Spares Cost for 10 Years

System: TM750 Ex			
Item	**Qty**	**Unit Price**	**Total**
Solo UV Lamp	62	700	43.400 USD
Wiper Seals	62	8	496 USD
Sleeve	62	200	12.400 USD
Total			**56.296 USD**

System: TM150 Non Ex			
Item	**Qty**	**Unit Price**	**Total**
Solo UV Lamp	14	700	9.800 USD
Wiper Seals	14	8	112 USD
Sleeve	14	200	2.800 USD
Total			**12.712 USD**

1 x TM750 Ex	56.296 USD
1 x TM150 Non EX	12.712 USD
TOTAL SPARE COST IN 10 YEARS	**69.008 USD**

C. M/T Jenny I – Option 1: 2 x TM750 Ex & 1 x TM150 Non Ex (APT)

i) Power/Fuel Cost for 10 Years

System: 2 x TM750 Ex	
Ballast Tanks Total Capacity	20.429 m^3
Number of Ballast Operations per Year	27
Number of De-ballast Operations per Year	27
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	1.103.166 m^3
Total Ballast Capacity of Ballast Pump	1300 m^3/h
Total Ballast Capacity of UV BWTS	1500 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	849 hrs
Total Power Demand	68,6 kW
Total kWhrs per Year	58.213 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224

HFO Price (USD/tn)	350 USD
Fuel Cost/Year	4.564 USD
Fuel Cost/10 Years	**45.639 USD**

System: 1 x TM150 Non Ex	
Ballast Tanks Total Capacity	643 m^3
Number of Ballast Operations per Year	27
Number of De-ballast Operations per Year	27
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	34.722 m^3
Total Ballast Capacity of Ballast Pump	110 m^3/h
Total Ballast Capacity of UV BWTS	150 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	316 hrs
Total Power Demand	9 kW
Total kWhrs per Year	2.841 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	223 USD
Fuel Cost/10 Years	**2227 USD**

TOTAL FUEL COST IN 10 YEARS: 47.866 USD

ii) Spares Cost for 10 Years

System: TM750 Ex			
Item	**Qty**	**Unit Price**	**Total**
Solo UV Lamp	62	700	43.400 USD
Wiper Seals	62	8	496 USD
Sleeve	62	200	12.400 USD
Total			**56.296 USD**

System: TM150 Non Ex			
Item	**Qty**	**Unit Price**	**Total**
Solo UV Lamp	14	700	9.800 USD
Wiper Seals	14	8	112 USD
Sleeve	14	200	2.800 USD
Total			**12.712 USD**

2 x TM750 Ex	112.592 USD
1 x TM150 Non EX	12.712 USD
TOTAL SPARE COST IN 10 YEARS	**125.304 USD**

D. M/T Jenny I – Option 2: 1 x TM1500 Ex & 1 x TM150 Non Ex (APT)

i) <u>Power/Fuel Cost for 10 Years</u>

System: 1 x TM1500 Ex	
Ballast Tanks Total Capacity	20.429 m^3
Number of Ballast Operations per Year	27
Number of De-ballast Operations per Year	27
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	1.103.166 m^3
Total Ballast Capacity of Ballast Pump	1300 m^3/h
Total Ballast Capacity of UV BWTS	1500 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	849 hrs
Total Power Demand	66 kW
Total kWhrs per Year	56.007 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	4.391 USD
Fuel Cost/10 Years	**43.909 USD**

System: 1 x TM150 Non Ex	
Ballast Tanks Total Capacity	643 m^3
Number of Ballast Operations per Year	27
Number of De-ballast Operations per Year	27
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	34.722 m^3
Total Ballast Capacity of Ballast Pump	110 m^3/h
Total Ballast Capacity of UV BWTS	150 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	316 hrs
Total Power Demand	9 kW

Total kWhrs per Year	2.841 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	223 USD
Fuel Cost/10 Years	**2227 USD**

TOTAL FUEL COST IN 10 YEARS: 46.137 USD

ii) <u>Spares Cost for 10 Years</u>

System: TM1500 Ex			
Item	**Qty**	**Unit Price**	**Total**
Solo UV Lamp	124	700	86.800 USD
Wiper Seals	124	8	992 USD
Sleeve	124	200	24.800 USD
Total			**112.592 USD**

System: TM150 Non Ex			
Item	**Qty**	**Unit Price**	**Total**
Solo UV Lamp	14	700	9.800 USD
Wiper Seals	14	8	112 USD
Sleeve	14	200	2.800 USD
Total			**12.712 USD**

1 x TM1500 Ex	112.592 USD
1 x TM150 Non EX	12.712 USD
TOTAL SPARE COST IN 10 YEARS	**125.304 USD**

E. M/T Mabrouk: 4 x TM1000 Ex & 1 x TM250 Non Ex (APT)

i) <u>Power/Fuel Cost for 10 Years</u>

System: 4 x TM1000 Ex	
Ballast Tanks Total Capacity	53.635 m^3
Number of Ballast Operations per Year	12
Number of De-ballast Operations per Year	12
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	1.287.240 m^3
Total Ballast Capacity of Ballast Pump	4000 m^3/h
Total Ballast Capacity of UV BWTS	4000 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	322 hrs

Total Power Demand	179,2 kW
Total kWhrs per Year	57.668 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	4.521 USD
Fuel Cost/10 Years	**45.212 USD**

System: 1 x TM250 Non Ex	
Ballast Tanks Total Capacity	1052 m^3
Number of Ballast Operations per Year	12
Number of De-ballast Operations per Year	12
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	25.248 m^3
Total Ballast Capacity of Ballast Pump	250 m^3/h
Total Ballast Capacity of UV BWTS	250 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	101 hrs
Total Power Demand	13,3 kW
Total kWhrs per Year	1.343 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	105 USD
Fuel Cost/10 Years	**1053 USD**

TOTAL FUEL COST IN 10 YEARS: 46.265 USD

ii) Spares Cost for 10 Years

System: TM1000 Ex			
Item	**Qty**	**Unit Price**	**Total**
Solo UV Lamp	84	700	58.800 USD
Wiper Seals	84	8	672 USD
Sleeve	84	200	16.800 USD
Total			**76.272 USD**

System: TM250 Non Ex			
Item	**Qty**	**Unit Price**	**Total**
Solo UV Lamp	24	700	16.800 USD
Wiper Seals	24	8	192 USD
Sleeve	24	200	4.800 USD
Total			**21.792 USD**

4 x TM1000 Ex	305.088 USD
1 x TM250 Non EX	21.792 USD
TOTAL SPARE COST IN 10 YEARS	**326.880 USD**

4) Desmi

- System: RayClean

- Technology: UV Treatment

- Operational Expenses Calculation

A. M/T Minitank Five – Option 1: 2 x RC-300 Ex

i) Power/Fuel Cost for 10 Years

System: 2 x RC-300 Ex	
Ballast/de-ballast operations per year	36
Hours per ballast operation	5 hours
Hours per deballast operation	5 hours
FO Price	315 EUR/ton
Specific fuel consumption per kWh	0,224 kg/kWh
Total operating hours in 10 years	3.600 hours
Power consumption	44 kW
Total kWh	158.400 kWh
Total FO consumption	35.482 kg
Total fuel cost in 10 years [EUR]	11.176 EUR
Fuel cost per treated ton of ballast water	0,010 EUR/ton
Total fuel cost in 10 years [USD]	**12.294 USD**

ii) Spares Cost for 10 Years

For 1 x RC-300 Ex unit	
UV lamps	175 EUR/pc
60 UV lamps with replacement every 12.000 hours of operation	10.500 EUR
Filter Candles	775 EUR/pc
16 filter candles with replacement every 5.000 hours of operation	12.400 EUR
1 UV intensity sensor	300 EUR

Required replacements in 10 years	
UV lamps	18
Filter candles	12
UV intensity sensor	10
Spare cost for 1 unit in 10 years	15.078 EUR
Spare cost for 2 units in 10 years	**33.172 USD**

B. M/T Minitank Five – Option 2: 1 x RC-600 Ex

i) Power/Fuel Cost for 10 Years

System: 1 x RC-600 Ex	
Ballast/de-ballast operations per year	36
Hours per ballast operation	5 hours
Hours per deballast operation	5 hours
FO Price	315 EUR/ton
Specific fuel consumption per kWh	0,224 kg/kWh
Total operating hours in 10 years	3.600 hours
Power consumption	44 kW
Total kWh	158.400 kWh
Total FO consumption	35.482 kg
Total fuel cost in 10 years [EUR]	11.176 EUR
Fuel cost per treated ton of ballast water	0,010 EUR/ton
Total fuel cost in 10 years [USD]	**12.294 USD**

ii) Spares Cost for 10 Years

System: 1 x RC-600 Ex	
UV lamps	175 EUR/pc
120 UV lamps with replacement every 12.000 hours of operation	21.000 EUR
Filter Candles	890 EUR/pc
24 filter candles with replacement every 5.000 hours of operation	21.360 EUR
2 UV intensity sensors	600 EUR
Required replacements in 10 years	
UV lamps	36
Filter candles	17
UV intensity sensor	10
Spare cost for 1 unit in 10 years	27.679 EUR
Total spare cost in 10 years	**30.447 USD**

C. M/T Minitank Five – Option 1 & 2: 1 x RC-200

i) Power/Fuel Cost for 10 Years

System: 1 x RC-200	
Ballast/de-ballast operations per year	36
Hours per ballast operation	2 hours
Hours per deballast operation	2 hours
FO Price	315 EUR/ton
Specific fuel consumption per kWh	0,224 kg/kWh
Total operating hours in 10 years	1.440 hours
Power consumption	22 kW
Total kWh	31.680 kWh
Total FO consumption	7.096 kg
Total fuel cost in 10 years [EUR]	2.235 EUR
Fuel cost per treated ton of ballast water	0,010 EUR/ton
Total fuel cost in 10 years [USD]	**2.459 USD**

ii) Spares Cost for 10 Years

System: 1 x RC-200	
UV lamps	175 EUR/pc
60 UV lamps with replacement every 12.000 hours of operation	10.500 EUR
Filter Candles	775 EUR/pc
16 filter candles with replacement every 5.000 hours of operation	12.400 EUR
1 UV intensity sensor	300 EUR
Required replacements in 10 years	
UV lamps	7
Filter candles	5
UV intensity sensor	10
Spare cost for 1 unit in 10 years	7.931 EUR
Total spare cost in 10 years	**8.724 USD**

D. M/T Jenny I – Option 1: 2 x RC-600 Ex

i) Power/Fuel Cost for 10 Years

System: 2 x RC-600 Ex	
Ballast/de-ballast operations per year	27
Hours per ballast operation	17 hours
Hours per deballast operation	17 hours
FO Price	315 EUR/ton

Specific fuel consumption per kWh	0,224 kg/kWh
Total operating hours in 10 years	9.180 hours
Power consumption	88 kW
Total kWh	807.840 kWh
Total FO consumption	180.956 kg
Total fuel cost in 10 years [EUR]	57.002 EUR
Fuel cost per treated ton of ballast water	0,010 EUR/ton
Total fuel cost in 10 years [USD]	**62.702 USD**

ii) Spares Cost for 10 Years

For 1 x RC-600 Ex unit	
UV lamps	175 EUR/pc
120 UV lamps with replacement every 12.000 hours of operation	21.000 EUR
Filter Candles	890 EUR/pc
24 filter candles with replacement every 5.000 hours of operation	21.360 EUR
2 UV intensity sensors	600 EUR
Required replacements in 10 years	
UV lamps	92
Filter candles	44
UV intensity sensor	10
Spare cost for 1 unit in 10 years	96.955 EUR
Spare cost for 2 units in 10 years	**213.301 USD**

E. M/T Jenny I – Option 1: 1 x RC-200

i) Power/Fuel Cost for 10 Years

System: 1 x RC-200	
Ballast/de-ballast operations per year	27
Hours per ballast operation	6 hours
Hours per deballast operation	6 hours
FO Price	315 EUR/ton
Specific fuel consumption per kWh	0,224 kg/kWh
Total operating hours in 10 years	3.240 hours
Power consumption	22 kW
Total kWh	71.280 kWh
Total FO consumption	15.967 kg
Total fuel cost in 10 years [EUR]	5.030 EUR
Fuel cost per treated ton of ballast water	0,010 EUR/ton
Total fuel cost in 10 years [USD]	**5.533 USD**

ii) Spares Cost for 10 Years

System: 1 x RC-200	
UV lamps	175 EUR/pc
60 UV lamps with replacement every 12.000 hours of operation	10.500 EUR
Filter Candles	775 EUR/pc
16 filter candles with replacement every 5.000 hours of operation	12.400 EUR
1 UV intensity sensor	300 EUR
Required replacements in 10 years	
UV lamps	16
Filter candles	10
UV intensity sensor	10
Spare cost for 1 unit in 10 years	13.870 EUR
Total spare cost in 10 years	**15.257 USD**

F. M/T Mabrouk – Option 1: 2 x RC-2000 Ex

i) Power/Fuel Cost for 10 Years

System: 2 x RC-2000 Ex	
Ballast/de-ballast operations per year	12
Hours per ballast operation	14 hours
Hours per deballast operation	14 hours
FO Price	315 EUR/ton
Specific fuel consumption per kWh	0,224 kg/kWh
Total operating hours in 10 years	3.360 hours
Power consumption	308 kW
Total kWh	1.034.880 kWh
Total FO consumption	231.814 kg
Total fuel cost in 10 years [EUR]	73.022 EUR
Fuel cost per treated ton of ballast water	0,010 EUR/ton
Total fuel cost in 10 years [USD]	**80.324 USD**

ii) Spares Cost for 10 Years

For 1 x RC-2000 Ex unit	
UV lamps	175 EUR/pc
420 UV lamps with replacement every 12.000 hours of operation	73.500 EUR
Filter Candles	1350 EUR/pc
36 filter candles with replacement every 5.000 hours of operation	48.600 EUR

7 UV intensity sensors	2.100 EUR
Required replacements in 10 years	
UV lamps	118
Filter candles	24
UV intensity sensor	10
Spare cost for 1 unit in 10 years	238.543 EUR
Spare cost for 2 units in 10 years	**524.795 USD**

G. M/T Mabrouk – Option 1: 1 x RC-200

i) Power/Fuel Cost for 10 Years

System: 1 x RC-200	
Ballast/de-ballast operations per year	12
Hours per ballast operation	6 hours
Hours per deballast operation	6 hours
FO Price	315 EUR/ton
Specific fuel consumption per kWh	0,224 kg/kWh
Total operating hours in 10 years	1.440 hours
Power consumption	22 kW
Total kWh	31.680 kWh
Total FO consumption	7.096 kg
Total fuel cost in 10 years [EUR]	2.235 EUR
Fuel cost per treated ton of ballast water	0,010 EUR/ton
Total fuel cost in 10 years [USD]	**2.459 USD**

ii) Spares Cost for 10 Years

System: 1 x RC-200	
UV lamps	175 EUR/pc
60 UV lamps with replacement every 12.000 hours of operation	10.500 EUR
Filter Candles	775 EUR/pc
16 filter candles with replacement every 5.000 hours of operation	12.400 EUR
1 UV intensity sensor	300 EUR
Required replacements in 10 years	
UV lamps	7
Filter candles	5
UV intensity sensor	10
Spare cost for 1 unit in 10 years	7.831 EUR
Total spare cost in 10 years	**8.614 USD**

5) Optimarin

- System: Optimarin

- Technology: UV Treatment

- Operational Expenses Calculation

A. M/T Minitank Five – Option 1: 2 x OBS 334-370BK & 1 OBS 167-180 FS (FPT)

i) Power/Fuel Cost for 10 Years

System: 2 x OBS 334-370BK	
Ballast Tanks Total Capacity	3.138 m^3
Number of Ballast Operations per Year	36
Number of De-ballast Operations per Year	36
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	225.936 m^3
Total Ballast Capacity of Ballast Pump	600 m^3/h
Total Ballast Capacity of UV BWTS	668 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	377 hrs
Total Power Demand	160 kW
Total kWhrs per Year	60.250 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	4.724 USD
Fuel Cost/10 Years	**47.236 USD**

System: 1 x OBS 167-180 FS	
Ballast Tanks Total Capacity	218 m^3
Number of Ballast Operations per Year	36
Number of De-ballast Operations per Year	36
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	15.696 m^3
Total Ballast Capacity of Ballast Pump	110 m^3/h
Total Ballast Capacity of UV BWTS	167 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	143 hrs

Total Power Demand	40 kW
Total kWhrs per Year	5.708 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	447 USD
Fuel Cost/10 Years	**4.475 USD**

TOTAL FUEL COST IN 10 YEARS: 51.710 USD

ii) <u>Spares Cost for 10 Years</u>

2 x OBS 334-370BK	56.576 USD
1 x OBS 167-180 FS	21.603 USD
TOTAL SPARE COST	**78.179 USD**

B. M/T Minitank Five – Option 2: 1 x OBS 667-750BK & 1 OBS 167-180 FS (FPT)

i) <u>Power/Fuel Cost for 10 Years</u>

System: 1 x OBS 667-750BK	
Ballast Tanks Total Capacity	3.138 m^3
Number of Ballast Operations per Year	36
Number of De-ballast Operations per Year	36
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	225.936 m^3
Total Ballast Capacity of Ballast Pump	600 m^3/h
Total Ballast Capacity of UV BWTS	668 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	377 hrs
Total Power Demand	160 kW
Total kWhrs per Year	60.250 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	4.724 USD
Fuel Cost/10 Years	**47.236 USD**

System: 1 x OBS 167-180 FS	
Ballast Tanks Total Capacity	218 m^3

Number of Ballast Operations per Year	36
Number of De-ballast Operations per Year	36
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	15.696 m^3
Total Ballast Capacity of Ballast Pump	110 m^3/h
Total Ballast Capacity of UV BWTS	167 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	143 hrs
Total Power Demand	40 kW
Total kWhrs per Year	5.708 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	447 USD
Fuel Cost/10 Years	**4.475 USD**

TOTAL FUEL COST IN 10 YEARS: 51.710 USD

ii) Spares Cost for 10 Years

1 x OBS 667-750BK	50.053 USD
1 x OBS 167-180 FS	21.603 USD
TOTAL SPARE COST	**71.657 USD**

C. M/T Jenny I – Option 1: 2 x OBS 667-750BK & 1 x OBS 167-180 FS (APT)

i) Power/Fuel Cost for 10 Years

System: 2 x OBS 667-750BK	
Ballast Tanks Total Capacity	20.429 m^3
Number of Ballast Operations per Year	27
Number of De-ballast Operations per Year	27
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	1.103.166 m^3
Total Ballast Capacity of Ballast Pump	1300 m^3/h
Total Ballast Capacity of UV BWTS	1334 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	849 hrs
Total Power Demand	320 kW

Total kWhrs per Year	271.549 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	21.289 USD
Fuel Cost/10 Years	**212.894 USD**

System: 1 x OBS 167-180 FS	
Ballast Tanks Total Capacity	643 m^3
Number of Ballast Operations per Year	27
Number of De-ballast Operations per Year	27
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	34.722 m^3
Total Ballast Capacity of Ballast Pump	110 m^3/h
Total Ballast Capacity of UV BWTS	167 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	316 hrs
Total Power Demand	40 kW
Total kWhrs per Year	12.626 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	421 USD
Fuel Cost/10 Years	**9.899 USD**

TOTAL FUEL COST IN 10 YEARS: 222.793 USD

ii) Spares Cost for 10 Years

2 x OBS 667-750BK	100.107 USD
1 x OBS 167-180 FS	21.603 USD
TOTAL SPARE COST	**121.710 USD**

D. M/T Jenny I – Option 1: 1 x OBS 1334-1400BK & 1 x OBS 167-180 FS (APT)

i) Power/Fuel Cost for 10 Years

System: 1 x OBS 1334-1400BK	
Ballast Tanks Total Capacity	20.429 m^3
Number of Ballast Operations per Year	27
Number of De-ballast Operations per Year	27

Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	1.103.166 m^3
Total Ballast Capacity of Ballast Pump	1300 m^3/h
Total Ballast Capacity of UV BWTS	1334 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	849 hrs
Total Power Demand	320 kW
Total kWhrs per Year	271.549 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	21.289 USD
Fuel Cost/10 Years	**212.894 USD**

System: 1 x OBS 167-180 FS	
Ballast Tanks Total Capacity	643 m^3
Number of Ballast Operations per Year	27
Number of De-ballast Operations per Year	27
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	34.722 m^3
Total Ballast Capacity of Ballast Pump	110 m^3/h
Total Ballast Capacity of UV BWTS	167 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	316 hrs
Total Power Demand	40 kW
Total kWhrs per Year	12.626 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	421 USD
Fuel Cost/10 Years	**9.899 USD**

TOTAL FUEL COST IN 10 YEARS: 222.793 USD

ii) Spares Cost for 10 Years

2 x OBS 667-750BK	73.074 USD

1 x OBS 167-180 FS	21.603 USD
TOTAL SPARE COST	**94.677 USD**

6) Panasia

- System: GloEn-Patrol

- Technology: UV Treatment

- Operational Expenses Calculation

A. Minitank Five – Option 1: 2 x GloEn-P350 Ex

1. Running Cost Per Cubic Meter (F.O.)	
Model	GloEn-P350 x 2 set
Power Consumption (kW)	40 x 2 set
Weight (kg)	Abt. 1.918 x 2 set
Capacity (m^3/hr)	600
Total Power (kW/h)	80
Power Consumption / CBM	0,133
Generator Efficiency (kg/kW)	0,224
FO Price / Kg (USD)	0,35
F.O. consumption / CBM (USD/CBM)	0,0105 $

2. Operating Cost per Cubic Meter (Parts)					
Model	GloEn-P350 x 2 set				
Parts	Life Time (hr)	Nos. (EA)	Unit Price (USD)	Total (USD)	Consumer parts (USD/hr)
1. Lamp	4000	24	600	14400	3,60
2. Wiper	5000	24	50	1200	0,24
3. Sleeve	43800	24	160	3840	0,09
4. Reed Switch	43800	4	50	200	0,00
5. Scanner Tip	87800	8	50	400	0,00
6. Filter Element	87800	1	15000	15000	0,17
Capacity (CBM/hr)	600				
Consumer parts / CBM (USD/CBM)	0,0068 $				

3. Running Cost per Year (F.O.)	
Model	GloEn-P350 x 2 set
F.O. / CBM (USD)	0,0105 $
Capacity (CBM/hr)	600
Spending time for Ballast & De-ballast (hr)	12
Times for Ballast/De-ballast	36
F.O. Consumption (USD/Year)	2.709,50 $
Treatment Hours	432 hours/year

4. Operating Cost per Year (Parts)	
Model	GloEn-P350 x 2 set
Consumer parts / CBM (USD)	0,0068 $
Capacity (CBM/hr)	600
Spending time for Ballast & De-ballast (hr)	12
Times for Ballast/De-ballast	36
Total Consumer (USD/Year)	1.774 $
Treatment Hours	432 hours/year

B. Minitank Five – Option 2: 1 x GloEn-P700 Ex

1. Running Cost Per Cubic Meter (F.O.)	
Model	GloEn-P700 x 1 set
Power Consumption (kW)	80 x 1 set
Weight (kg)	Abt. 3.100 x 1 set
Capacity (m^3/hr)	600
Total Power (kW/h)	80
Power Consumption / CBM	0,114
Generator Efficiency (kg/kW)	0,224
FO Price / Kg (USD)	0,35
F.O. consumption / CBM (USD/CBM)	0,0089 $

2. Operating Cost per Cubic Meter (Parts)					
Model	GloEn-P700 x 1 set				
Parts	Life Time (hr)	Nos. (EA)	Unit Price (USD)	Total (USD)	Consumer parts (USD/hr)
1. Lamp	4000	24	600	14400	3,60
2. Wiper	5000	24	50	1200	0,24
3. Sleeve	43800	24	160	3840	0,09
4. Reed Switch	43800	4	50	200	0,00
5. Scanner Tip	87800	8	50	400	0,00
6. Filter Element	87800	1	15000	15000	0,17
Capacity (CBM/hr)	600				
Consumer parts / CBM (USD/CBM)	0,0068 $				

3. Running Cost per Year (F.O.)	
Model	GloEn-P700 x 1 set
F.O. / CBM (USD)	0,0089 $
Capacity (CBM/hr)	600
Spending time for Ballast & De-ballast (hr)	12
Times for Ballast/De-ballast	36
F.O. Consumption (USD/Year)	2.316,63 $
Treatment Hours	432 hours/year

4. Operating Cost per Year (Parts)	
Model	GloEn-P700 x 1 set
Consumer parts / CBM (USD)	0,0068 $
Capacity (CBM/hr)	600
Spending time for Ballast & De-ballast (hr)	12
Times for Ballast/De-ballast	36
Total Consumer (USD/Year)	1.774 $
Treatment Hours	432 hours/year

C. Minitank Five – Option 1 & 2: 1 x GloEn-P150

1. Running Cost Per Cubic Meter (F.O.)	
Model	GloEn-P150 x 1 set
Power Consumption (kW)	20 x 1 set
Weight (kg)	Abt. 1.918 x 1 set
Capacity (m^3/hr)	150
Total Power (kW/h)	20
Power Consumption / CBM	0,133
Generator Efficiency (kg/kW)	0,224
FO Price / Kg (USD)	0,35
F.O. consumption / CBM (USD/CBM)	0,0105 $

2. Operating Cost per Cubic Meter (Parts)					
Model	GloEn-P150 x 1 set				
Parts	Life Time (hr)	Nos. (EA)	Unit Price (USD)	Total (USD)	Consumer parts (USD/hr)
1. Lamp	4000	6	600	3600	0,90
2. Wiper	5000	6	50	300	0,06
3. Sleeve	43800	6	160	960	0,02
4. Reed Switch	43800	4	50	200	0,00
5. Scanner Tip	87800	4	50	200	0,00
6. Filter Element	87800	1	15000	7500	0,09
Capacity (CBM/hr)	150				
Consumer parts / CBM (USD/CBM)	0,0072 $				

3. Running Cost per Year (F.O.)	
Model	GloEn-P150 x 1 set
F.O. / CBM (USD)	0,0105 $
Capacity (CBM/hr)	150
Spending time for Ballast & De-ballast (hr)	14
Times for Ballast/De-ballast	36
F.O. Consumption (USD/Year)	225,79 $
Treatment Hours	144 hours/year

4. Operating Cost per Year (Parts)	
Model	GloEn-P150 x 1 set
Consumer parts / CBM (USD)	0,0072 $
Capacity (CBM/hr)	150
Spending time for Ballast & De-ballast (hr)	4
Times for Ballast/De-ballast	36
Total Consumer (USD/Year)	154,68 $
Treatment Hours	144 hours/year

D. Jenny I – Option 1: 2 x GloEn-P700 Ex

1. Running Cost Per Cubic Meter (F.O.)	
Model	GloEn-P700 x 2 set
Power Consumption (kW)	80 x 2 set
Weight (kg)	Abt. 3.200 x 2 set
Capacity (m^3/hr)	1300
Total Power (kW/h)	154
Power Consumption / CBM	0,118
Generator Efficiency (kg/kW)	0,224
FO Price / Kg (USD)	0,35
F.O. consumption / CBM (USD/CBM)	0,00929 $

2. Operating Cost per Cubic Meter (Parts)					
Model	GloEn-P700 x 2 set				
Parts	Life Time (hr)	Nos. (EA)	Unit Price (USD)	Total (USD)	Consumer parts (USD/hr)
1. Lamp	4000	48	600	28800	7.20
2. Wiper	5000	48	50	2400	0,48
3. Sleeve	43800	48	160	7680	0,18
4. Reed Switch	43800	8	50	400	0,01
5. Scanner Tip	87800	16	50	800	0,01
6. Filter Element	87800	2	15000	30000	0,34
Capacity (CBM/hr)	1300				
Consumer parts / CBM (USD/CBM)	0,00632 $				

3. Running Cost per Year (F.O.)	
Model	GloEn-P700 x 2 set
F.O. / CBM (USD)	0,00929 $
Capacity (CBM/hr)	1300
Spending time for Ballast & De-ballast (hr)	14
Times for Ballast/De-ballast	27
F.O. Consumption (USD/Year)	4.563,82 $
Treatment Hours	378 hours/year

4. Operating Cost per Year (Parts)	
Model	GloEn-P700 x 2 set
Consumer parts / CBM (USD)	0,00632 $
Capacity (CBM/hr)	1300
Spending time for Ballast & De-ballast (hr)	14
Times for Ballast/De-ballast	27
Total Consumer (USD/Year)	3.105,37 $
Treatment Hours	378 hours/year

E. Jenny I – Option 2: 1 x GloEn-P1500 Ex

1. Running Cost Per Cubic Meter (F.O.)	
Model	GloEn-P1500 x 1 set
Power Consumption (kW)	110 x 1 set
Weight (kg)	Abt. 5.978 x 1 set
Capacity (m^3/hr)	1300
Total Power (kW/h)	110
Power Consumption / CBM	0,085
Generator Efficiency (kg/kW)	0,224
FO Price / Kg (USD)	0,35
F.O. consumption / CBM (USD/CBM)	0,0066 $

2. Operating Cost per Cubic Meter (Parts)					
Model	GloEn-P1500 x 1 set				
Parts	Life Time (hr)	Nos. (EA)	Unit Price (USD)	Total (USD)	Consumer parts (USD/hr)
1. Lamp	4000	32	800	25600	6,40
2. Wiper	5000	32	50	1600	0,32
3. Sleeve	43800	32	160	5120	0,12
4. Reed Switch	43800	8	50	400	0,01
5. Scanner Tip	87800	30	50	1500	0,01
6. Filter Element	87800	5	6000	30000	0,34
Capacity (CBM/hr)	1300				
Consumer parts / CBM (USD/CBM)	0,00554 $				

3. Running Cost per Year (F.O.)	
Model	GloEn-P1500 x 1 set
F.O. / CBM (USD)	0,00663 $
Capacity (CBM/hr)	1300
Spending time for Ballast & De-ballast (hr)	14
Times for Ballast/De-ballast	27
F.O. Consumption (USD/Year)	3.259,87 $
Treatment Hours	378 hours/year

4. Operating Cost per Year (Parts)	
Model	GloEn-P1500 x 1 set
Consumer parts / CBM (USD)	0,00554 $
Capacity (CBM/hr)	1300
Spending time for Ballast & De-ballast (hr)	14
Times for Ballast/De-ballast	27
Total Consumer (USD/Year)	2.723,41 $
Treatment Hours	378 hours/year

F. Jenny I – Option 1 & 2: 1 x GloEn-P150

1. Running Cost Per Cubic Meter (F.O.)	
Model	GloEn-P150 x 1 set
Power Consumption (kW)	20 x 1 set
Weight (kg)	Abt. 1.918 x 1 set
Capacity (m^3/hr)	110
Total Power (kW/h)	20
Power Consumption / CBM	0,182
Generator Efficiency (kg/kW)	0,224
FO Price / Kg (USD)	0,35
F.O. consumption / CBM (USD/CBM)	0,0143 $

2. Operating Cost per Cubic Meter (Parts)					
Model	GloEn-P150 x 1 set				
Parts	Life Time (hr)	Nos. (EA)	Unit Price (USD)	Total (USD)	Consumer parts (USD/hr)
1. Lamp	4000	6	600	3600	0,90
2. Wiper	5000	6	50	300	0,06
3. Sleeve	43800	6	160	960	0,02
4. Reed Switch	43800	4	50	200	0,00
5. Scanner Tip	87800	4	50	200	0,00
6. Filter Element	87800	1	7500	7500	0,09
Capacity (CBM/hr)	110				
Consumer parts / CBM (USD/CBM)	0,0098 $				

3. Running Cost per Year (F.O.)	
Model	GloEn-P150 x 1 set
F.O. / CBM (USD)	0,0120 $
Capacity (CBM/hr)	110
Spending time for Ballast & De-ballast (hr)	12
Times for Ballast/De-ballast	27
F.O. Consumption (USD/Year)	427,68 $
Treatment Hours	324 hours/year

4. Operating Cost per Year (Parts)	
Model	GloEn-P150 x 1 set
Consumer parts / CBM (USD)	0,0098 $
Capacity (CBM/hr)	110
Spending time for Ballast & De-ballast (hr)	12
Times for Ballast/De-ballast	27
Total Consumer (USD/Year)	348 $
Treatment Hours	324 hours/year

G. Mabrouk: 2 x GloEn-P2000

1. Running Cost Per Cubic Meter (F.O.)	
Model	GloEn-P2000 x 2 set
Power Consumption (kW)	155 x 2 set
Weight (kg)	-
Capacity (m^3/hr)	4000
Total Power (kW/h)	310
Power Consumption / CBM	0,078
Generator Efficiency (kg/kW)	0,224
FO Price / Kg (USD)	0,35
F.O. consumption / CBM (USD/CBM)	0,0061 $

2. Operating Cost per Cubic Meter (Parts)					
Model	GloEn-P2000 x 2 set				
Parts	Life Time (hr)	Nos. (EA)	Unit Price (USD)	Total (USD)	Consumer parts (USD/hr)
1. Lamp	4000	64	800	51200	12,80
2. Wiper	5000	64	50	3200	0,64
3. Sleeve	43800	64	160	10240	0,23
4. Reed Switch	43800	16	50	800	0,02
5. Scanner Tip	87800	60	50	3000	0,03
6. Filter Element	87800	10	6000	60000	0,68
Capacity (CBM/hr)	4000				
Consumer parts / CBM (USD/CBM)	0,00360 $				

3. Running Cost per Year (F.O.)	
Model	GloEn-P2000 x 2 set
F.O. / CBM (USD)	0,00608 $
Capacity (CBM/hr)	4000
Spending time for Ballast & De-ballast (hr)	13
Times for Ballast/De-ballast	12
F.O. Consumption (USD/Year)	3.791,42 $
Treatment Hours	312 hours/year

4. Operating Cost per Year (Parts)	
Model	GloEn-P2000 x 2 set
Consumer parts / CBM (USD)	0,00360 $
Capacity (CBM/hr)	4000
Spending time for Ballast & De-ballast (hr)	13
Times for Ballast/De-ballast	12
Total Consumer (USD/Year)	2.247,90 $
Treatment Hours	312 hours/year

H. Mabrouk: 1 x GloEn-P250

1. Running Cost Per Cubic Meter (F.O.)	
Model	GloEn-P250 x 2 set
Power Consumption (kW)	27 x 1 set
Weight (kg)	Abt 1.918 x 1 set
Capacity (m^3/hr)	250
Total Power (kW/h)	27
Power Consumption / CBM	0,108
Generator Efficiency (kg/kW)	0,224
FO Price / Kg (USD)	0,35
F.O. consumption / CBM (USD/CBM)	0,0085 $

2. Operating Cost per Cubic Meter (Parts)					
Model	GloEn-P250 x 1 set				
Parts	Life Time (hr)	Nos. (EA)	Unit Price (USD)	Total (USD)	Consumer parts (USD/hr)
1. Lamp	4000	12	600	7200	1,80
2. Wiper	5000	12	50	600	0,12
3. Sleeve	43800	12	160	1920	0,04
4. Reed Switch	43800	4	50	200	0,00
5. Scanner Tip	87800	4	50	200	0,00
6. Filter Element	87800	1	7500	7500	0,09
Capacity (CBM/hr)	250				
Consumer parts / CBM (USD/CBM)	0,0082 $				

3. Running Cost per Year (F.O.)	
Model	GloEn-P250 x 1 set
F.O. / CBM (USD)	0,0085 $
Capacity (CBM/hr)	250
Spending time for Ballast & De-ballast (hr)	5
Times for Ballast/De-ballast	12
F.O. Consumption (USD/Year)	127,01 $
Treatment Hours	60 hours/year

4. Operating Cost per Year (Parts)	
Model	GloEn-P250 x 1 set
Consumer parts / CBM (USD)	0,0082 $
Capacity (CBM/hr)	250
Spending time for Ballast & De-ballast (hr)	5
Times for Ballast/De-ballast	12
Total Consumer (USD/Year)	123,37 $
Treatment Hours	60 hours/year

7) Hyde Marine

- System: Hyde Marine Guardian

- Technology: UV Treatment

- Operational Expenses Calculation

A. M/T Minitank Five – Option 1: 2 x HG300GX & 1 HG150G (FPT)

i) Power/Fuel Cost for 10 Years

System: 2 x HG300GX	
Ballast Tanks Total Capacity	3.138 m^3
Number of Ballast Operations per Year	36
Number of De-ballast Operations per Year	36
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	225.936 m^3
Total Ballast Capacity of Ballast Pump	600 m^3/h
Total Ballast Capacity of UV BWTS	600 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	377 hrs
Total Power Demand	80 kW
Total kWhrs per Year	30.125 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	2.362 USD
Fuel Cost/10 Years	**23.618 USD**

System: 1 x HG150G	
Ballast Tanks Total Capacity	218 m^3

Number of Ballast Operations per Year	36
Number of De-ballast Operations per Year	36
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	15.696 m^3
Total Ballast Capacity of Ballast Pump	150 m^3/h
Total Ballast Capacity of UV BWTS	150 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	105 hrs
Total Power Demand	21,5 kW
Total kWhrs per Year	2.250 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	176 USD
Fuel Cost/10 Years	**1.764 USD**

TOTAL FUEL COST IN 10 YEARS: 25.382 USD

ii) Spares Cost for 10 Years

2 x HG300GX	59.284 USD
1 x HG150G	11.110 USD
TOTAL SPARE COST	**70.394 USD**

System: 2 x HG300GX & 1 HG150G	
Total number of UV lamps:	2x8 + 6 = 22
Cost for UV lamps[1]	35.200 USD
Cost for quartz sleeves[2]	5.500 USD
Cost for filters	29.694 USD
Total Maintenance Cost	**70.394 USD**

[1]UV lamps have to be replaced every 5 years and the cost for each is UV lamp is 800 USD.
[2]Quartz sleeves have to be replaced every 10 years and the cost for each quartz sleeve & wiper is 250 USD.

B. M/T Minitank Five – Option 2: 1 x HG600GX & 1 HG150G (FPT)

i) Power/Fuel Cost for 10 Years

System: 1 x HG600GX	
Ballast Tanks Total Capacity	3.138 m^3
Number of Ballast Operations per Year	36

Number of De-ballast Operations per Year	36
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	225.936 m^3
Total Ballast Capacity of Ballast Pump	600 m^3/h
Total Ballast Capacity of UV BWTS	600 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	377 hrs
Total Power Demand	50 kW
Total kWhrs per Year	18.828 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	1.476 USD
Fuel Cost/10 Years	**14.761 USD**

System: 1 x HG150G	
Ballast Tanks Total Capacity	218 m^3
Number of Ballast Operations per Year	36
Number of De-ballast Operations per Year	36
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	15.696 m^3
Total Ballast Capacity of Ballast Pump	150 m^3/h
Total Ballast Capacity of UV BWTS	150 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	105 hrs
Total Power Demand	21,5 kW
Total kWhrs per Year	2.250 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	176 USD
Fuel Cost/10 Years	**1.764 USD**

TOTAL FUEL COST IN 10 YEARS: 16.525 USD

ii) Spares Cost for 10 Years

1 x HG600GX	51.884 USD
1 x HG150G	11.110 USD
TOTAL SPARE COST	**62.994 USD**

System: 1 x HG600GX & 1 HG150G	
Total number of UV lamps:	12 + 6 = 18
Cost for UV lamps[1]	28.800 USD
Cost for quartz sleeves[2]	4.500 USD
Cost for filters	29.694 USD
Total Maintenance Cost	**62.994 USD**

[1]UV lamps have to be replaced every 5 years and the cost for each is UV lamp is 800 USD.
[2]Quartz sleeves have to be replaced every 10 years and the cost for each quartz sleeve & wiper is 250 USD.

C. M/T Jenny I – Option 1: 2 x HG700GX & 1 HG100G (APT)

i) Power/Fuel Cost for 10 Years

System: 2 x HG700GX	
Ballast Tanks Total Capacity	20.429 m^3
Number of Ballast Operations per Year	27
Number of De-ballast Operations per Year	27
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	1.103.166 m^3
Total Ballast Capacity of Ballast Pump	1300 m^3/h
Total Ballast Capacity of UV BWTS	1400 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	849 hrs
Total Power Demand	150 kW
Total kWhrs per Year	127.288 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	9.979 USD
Fuel Cost/10 Years	**99.794 USD**

System: 1 x HG100G	
Ballast Tanks Total Capacity	643 m^3
Number of Ballast Operations per Year	27

Number of De-ballast Operations per Year	27
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	34.722 m^3
Total Ballast Capacity of Ballast Pump	110 m^3/h
Total Ballast Capacity of UV BWTS	100 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	316 hrs
Total Power Demand	20 kW
Total kWhrs per Year	6.313 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	495 USD
Fuel Cost/10 Years	**4.949 USD**

TOTAL FUEL COST IN 10 YEARS: 104.744 USD

ii) Spares Cost for 10 Years

2 x HG700GX	101.393 USD
1 x HG100G	11.110 USD
TOTAL SPARE COST	**112.503 USD**

System: 2 x HG700GX & 1 HG100G	
Total number of UV lamps:	2x18 + 6 = 42
Cost for UV lamps[1]	67.200 USD
Cost for quartz sleeves[2]	10.500 USD
Cost for filters	34.803 USD
Total Maintenance Cost	**112.503 USD**

[1]UV lamps have to be replaced every 5 years and the cost for each is UV lamp is 800 USD.
[2]Quartz sleeves have to be replaced every 10 years and the cost for each quartz sleeve & wiper is 250 USD.

D. M/T Jenny I – Option 2: 1 x HG1500GX & 1 HG100G (APT)

i) Power/Fuel Cost for 10 Years

System: 1 x HG1500GX	
Ballast Tanks Total Capacity	20.429 m^3
Number of Ballast Operations per Year	27

Number of De-ballast Operations per Year	27
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	1.103.166 m^3
Total Ballast Capacity of Ballast Pump	1300 m^3/h
Total Ballast Capacity of UV BWTS	1500 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	849 hrs
Total Power Demand	114 kW
Total kWhrs per Year	96.739 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	7.584 USD
Fuel Cost/10 Years	**75.844 USD**

System: 1 x HG100G	
Ballast Tanks Total Capacity	643 m^3
Number of Ballast Operations per Year	27
Number of De-ballast Operations per Year	27
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	34.722 m^3
Total Ballast Capacity of Ballast Pump	110 m^3/h
Total Ballast Capacity of UV BWTS	100 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	316 hrs
Total Power Demand	20 kW
Total kWhrs per Year	6.313 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	495 USD
Fuel Cost/10 Years	**4.949 USD**

TOTAL FUEL COST IN 10 YEARS: 80.793 USD

ii) Spares Cost for 10 Years

1 x HG1500GX	68.093 USD
1 x HG100G	11.110 USD
TOTAL SPARE COST	**79.203 USD**

System: 1 x HG1500GX & 1 HG100G	
Total number of UV lamps:	18 + 6 = 24
Cost for UV lamps[1]	38.400 USD
Cost for quartz sleeves[2]	6.000 USD
Cost for filters	34.803 USD
Total Maintenance Cost	**79.203 USD**

[1]UV lamps have to be replaced every 5 years and the cost for each is UV lamp is 800 USD.
[2]Quartz sleeves have to be replaced every 10 years and the cost for each quartz sleeve & wiper is 250 USD.

E. M/T Mabrouk – Option 1: 2 x HG2000GX & 1 HG250G (APT)

i) Power/Fuel Cost for 10 Years

System: 2 x HG2000GX	
Ballast Tanks Total Capacity	53.635 m^3
Number of Ballast Operations per Year	12
Number of De-ballast Operations per Year	12
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	1.287.240 m^3
Total Ballast Capacity of Ballast Pump	4000 m^3/h
Total Ballast Capacity of UV BWTS	4000 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	322 hrs
Total Power Demand	300 kW
Total kWhrs per Year	96.543 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	7.569 USD
Fuel Cost/10 Years	**75.690 USD**

System: 1 x HG250G	
Ballast Tanks Total Capacity	1.052 m^3
Number of Ballast Operations per Year	12

Number of De-ballast Operations per Year	12
Max. Ballast Volume to be treated per year (*Ballast volume refers to ballasting & de-ballasting)	25.248 m^3
Total Ballast Capacity of Ballast Pump	250 m^3/h
Total Ballast Capacity of UV BWTS	250 m^3/h
Ballast operation hours per year @ 100% Bpps Efficiency	101 hrs
Total Power Demand	31,5 kW
Total kWhrs per Year	3.181 kWh
Specific Fuel Consumption (tons/kWhr)	0,000224
HFO Price (USD/tn)	350 USD
Fuel Cost/Year	249 USD
Fuel Cost/10 Years	**2.494 USD**

TOTAL FUEL COST IN 10 YEARS: 78.184 USD

ii) <u>Spares Cost for 10 Years</u>

2 x HG2000GX	184.598 USD
1 x HG250G	11.110 USD
TOTAL SPARE COST	**195.708 USD**

System: 2 x HG2000GX & 1 HG250G	
Total number of UV lamps:	4x18 + 6 = 78
Cost for UV lamps[1]	124.800 USD
Cost for quartz sleeves[2]	19.500 USD
Cost for filters	51.408 USD
Total Maintenance Cost	**195.708 USD**

[1]UV lamps have to be replaced every 5 years and the cost for each is UV lamp is 800 USD.
[2]Quartz sleeves have to be replaced every 10 years and the cost for each quartz sleeve & wiper is 250 USD.

8) EcoChlor

- System: EcoChlor

- Technology: Chlorate-based Chlorine Dioxide Generation & Chlorination of the Ballast Water

- Operational Expenses Calculation

A. Minitank Five – Option 1: 2 x HV-410 & 1 x HV-180 (for FPT)

1. Fuel Cost	
Maximum Power Consumption	18,2 kW
Ballast Water Treated	112.982 cbm/year
Power Consumption per cbm	0,0303
FO Price	350 USD/ton
Fuel Consumption Rate	224 gr/kW
FO Price per cbm	0,00238 USD/cbm
FO Cost per year	269 $
FO Cost per 10 years	**2.687 $**

2. Chemical Cost	
Chemical Cost per m^3	0,08 $
Ballast Water Treated	112.982 cbm/year
Annual Chemical Cost	9.039 $
Chemical Cost per 10 Years	**90.386 $**

3. Spares Cost for 10 Years	
Main Filter Screen Replacement	26.320 $
FPT Filter Screen Replacement	4.225 $
Other Expenses	20.000 $
Total Maintenance Cost	**50.545 $**

B. Minitank Five – Option 2: 1 x HV-850 & 1 x HV-180 (for FPT)

1. Fuel Cost	
Maximum Power Consumption	12,3 kW
Ballast Water Treated	112.982 cbm/year
Power Consumption per cbm	0,02067
FO Price	350 USD/ton
Fuel Consumption Rate	224 gr/kW
FO Price per cbm	0,00162 USD/cbm
FO Cost per year	183 $
FO Cost per 10 years	**1.831 $**

2. Chemical Cost	
Chemical Cost per m^3	0,08 $
Ballast Water Treated	112.982 cbm/year
Annual Chemical Cost	9.039 $

Chemical Cost per 10 Years	**90.386 $**

3. Spares Cost for 10 Years	
Main Filter Screen Replacement	13.160 $
FPT Filter Screen Replacement	4.225 $
Other Expenses	20.000 $
Total Maintenance Cost	**37.385 $**

C. Jenny I – Option 1: 2 x HV-850 & 1 x HV-125 (for APT)

1. Fuel Cost	
Maximum Power Consumption	19,5 kW
Ballast Water Treated	491.940 cbm/year
Power Consumption per cbm	0,015
FO Price	350 USD/ton
Fuel Consumption Rate	224 gr/kW
FO Price per cbm	0,00118 USD/cbm
FO Cost per year	579 $
FO Cost per 10 years	**5.785 $**

2. Chemical Cost	
Chemical Cost per m^3	0,08 $
Ballast Water Treated	491.940 cbm/year
Annual Chemical Cost	39.355 $
Chemical Cost per 10 Years	**393.550 $**

3. Spares Cost for 10 Years	
Main Filter Screen Replacement	26.320 $
FPT Filter Screen Replacement	4.225 $
Other Expenses	20.000 $
Total Maintenance Cost	**50.545 $**

D. Mabrouk – Option 1: 2 x HV-2250 & 1 x HV-275 (for APT)

1. Fuel Cost	
Maximum Power Consumption	38,2 kW
Ballast Water Treated	600.000 cbm/year
Power Consumption per cbm	0,00955
FO Price	350 USD/ton
Fuel Consumption Rate	224 gr/kW
FO Price per cbm	0,00075 USD/cbm
FO Cost per year	449 $
FO Cost per 10 years	**4.492 $**

2. Chemical Cost	
Chemical Cost per m^3	0,08 $
Ballast Water Treated	600.000 cbm/year
Annual Chemical Cost	48.000 $

Chemical Cost per 10 Years	**480.000 $**

3. Spares Cost for 10 Years	
Main Filter Screen Replacement	86.240 $
FPT Filter Screen Replacement	7.133 $
Other Expenses	20.000 $
Total Maintenance Cost	**113.373 $**

9) JFE Engineering

- System: BallastAce

- Technology: Filtration and Formulated Chemical Injection with Sodium Hypochlorite

- Operational Expenses Calculation

A. Minitank Five – Option 1 (Liquid Type Disinfectant): 2 x 300 m^3/h for BPs & 1 x 300 m^3/h for FPT

1. Chemical Cost	
Dinfectant[1]	TG Ballastcleaner
Neutralizer[2]	TG Environmentalguard
Annual Chemical Cost	8.408 $
Chemical Cost per 10 Years	**84.080 $**

[1]Chemical is injected at 3.5ppm concentration and controlled at 2.5ppm chlorine concentration.

[2]Chlorine concentration in ballast tank is 0.5ppm assuming enough time has elapsed and it has already decomposed from 2.5ppm.

2. Power Consumption	
Per Ballasting	9 kW
Per De-ballasting	4,75 kW
Chiller for cooling Disinfectant[3]	2,6 kW
Fuel Cost per year	1.417 $
Fuel Cost per 10 Years	**14.170 $**

[3]In case the temperature of the disinfectant tank is higher than 13°C, a chiller runs to cool the disinfectant.

3. Maintenance Cost[4]	
Pump for Disinfecting Agent	1.500 $
Pump for Neutralizing Agent	1.500 $
Filter	2.000 $
TRO Meter	20.000 $
Total Maintenance Cost for 10 Years	**25.000 $**

[4]Maintenance cost is estimated as a sum of assumable essential items which are regularly required to be replaced. Replacement of other items may be required depending on specification, environment of usage or any other cause.

B. Minitank Five – Option 2 (Granular Type Disinfectant): 2 x 300 m^3/h for BPs & 1 x 300 m^3/h for FPT

1. Chemical Cost	
Dinfectant[1]	Neo-Chlor Marine
Neutralizer[2]	TG Environmentalguard
Annual Chemical Cost	12.613 $
Chemical Cost per 10 Years	**126.130 $**

[1]Chemical is injected at 3.5ppm concentration and controlled at 2.5ppm chlorine concentration.

[2]Chlorine concentration in ballast tank is 0.5ppm assuming enough time has elapsed and it has already decomposed from 2.5ppm.

2. Power Consumption	
Per Ballasting	12,5 kW
Per De-ballasting	4,75 kW
Heater for Freshwater[3]	11,9 kW
Fuel Cost per year	1.241 $
Fuel Cost per 10 Years	**12.410 $**

[3]In case the temperature of the freshwater used to dissolve granule disinfectant is lower than 20°C, a heater runs to heat the freshwater.

3. Maintenance Cost[4]	
Pump for Disinfecting Agent	1.500 $
Pump for Neutralizing Agent	1.500 $
Filter	2.000 $
TRO Meter	20.000 $
Dissolution Unit for Disinfecting Agent	500 $
Total Maintenance Cost for 10 Years	**25.500 $**

[4]Maintenance cost is estimated as a sum of assumable essential items which are regularly required to be replaced. Replacement of other items may be required depending on specification, environment of usage or any other cause.

C. Jenny I – Option 1 (Liquid Type Disinfectant): 2 x 750 m^3/h for BPs & 1 x 300 m^3/h for FPT

1. Chemical Cost	
Dinfectant[1]	TG Ballastcleaner
Neutralizer[2]	TG Environmentalguard
Annual Chemical Cost	45.302 $
Chemical Cost per 10 Years	**453.020 $**

[1]Chemical is injected at 3.5ppm concentration and controlled at 2.5ppm chlorine concentration.

[2]Chlorine concentration in ballast tank is 0.5ppm assuming enough time has elapsed and it has already decomposed from 2.5ppm.

2. Power Consumption	
Per Ballasting	9 kW
Per De-ballasting	4,75 kW
Chiller for cooling Disinfectant[3]	2,6 kW
Fuel Cost per year	1.192 $
Fuel Cost per 10 Years	**11.920 $**

[3]In case the temperature of the disinfectant tank is higher than 13°C, a chiller runs to cool the disinfectant.

3. Maintenance Cost[4]	
Pump for Disinfecting Agent	2.350 $
Pump for Neutralizing Agent	2.350 $
Filter	2.000 $
TRO Meter	20.000 $
Total Maintenance Cost for 10 Years	**26.700 $**

[4]Maintenance cost is estimated as a sum of assumable essential items which are regularly required to be replaced. Replacement of other items may be required depending on specification, environment of usage or any other cause.

D. Jenny I – Option 2 (Granular Type Disinfectant): 2 x 750 m^3/h for BPs & 1 x 300 m^3/h for FPT

1. Chemical Cost	
Dinfectant[1]	Neo-Chlor Marine
Neutralizer[2]	TG Environmentalguard
Annual Chemical Cost	67.594 $
Chemical Cost per 10 Years	**675.940 $**

[1]Chemical is injected at 3.5ppm concentration and controlled at 2.5ppm chlorine concentration.

[2]Chlorine concentration in ballast tank is 0.5ppm assuming enough time has elapsed and it has already decomposed from 2.5ppm.

2. Power Consumption	
Per Ballasting	12,5 kW
Per De-ballasting	4,75 kW
Heater for Freshwater[3]	11,9 kW
Fuel Cost per year	1.142 $
Fuel Cost per 10 Years	**11.420 $**

[3]In case the temperature of the freshwater used to dissolve granule disinfectant is lower than 20°C, a heater runs to heat the freshwater.

3. Maintenance Cost[4]	
Pump for Disinfecting Agent	2.350 $
Pump for Neutralizing Agent	2.350 $
Filter	2.000 $
TRO Meter	20.000 $
Dissolution Unit for Disinfecting Agent	500 $
Total Maintenance Cost for 10 Years	**27.200 $**

[4]Maintenance cost is estimated as a sum of assumable essential items which are regularly required to be replaced. Replacement of other items may be required depending on specification, environment of usage or any other cause.

E. Mabrouk – Option 1 (Liquid Type Disinfectant): 2 x 2000 m^3/h for BPs & 1 x 300 m^3/h for FPT

1. Chemical Cost	
Dinfectant[1]	TG Ballastcleaner
Neutralizer[2]	TG Environmentalguard
Annual Chemical Cost	57.200 $
Chemical Cost per 10 Years	**572.000 $**

[1]Chemical is injected at 3.5ppm concentration and controlled at 2.5ppm chlorine concentration.

[2]Chlorine concentration in ballast tank is 0.5ppm assuming enough time has elapsed and it has already decomposed from 2.5ppm.

2. Power Consumption	
Per Ballasting	12 kW
Per De-ballasting	9,25 kW
Chiller for cooling Disinfectant[3]	5,25 kW
Fuel Cost per year	1.142 $
Fuel Cost per 10 Years	**11.420 $**

[3]In case the temperature of the disinfectant tank is higher than 13°C, a chiller runs to cool the disinfectant.

3. Maintenance Cost[4]	
Pump for Disinfecting Agent	8.000 $
Pump for Neutralizing Agent	8.000 $
Filter	2.000 $
TRO Meter	60.000 $
Total Maintenance Cost for 10 Years	**78.000 $**

[4]Maintenance cost is estimated as a sum of assumable essential items which are regularly required to be replaced. Replacement of other items may be required depending on specification, environment of usage or any other cause.

F. Mabrouk – Option 2 (Granular Type Disinfectant): 2 x 2000 m^3/h for BPs & 1 x 300 m^3/h for FPT

1. Chemical Cost	
Dinfectant[1]	Neo-Chlor Marine
Neutralizer[2]	TG Environmentalguard
Annual Chemical Cost	85.800 $
Chemical Cost per 10 Years	**858.000 $**

[1]Chemical is injected at 3.5ppm concentration and controlled at 2.5ppm chlorine concentration.

[2]Chlorine concentration in ballast tank is 0.5ppm assuming enough time has elapsed and it has already decomposed from 2.5ppm.

2. Power Consumption	
Per Ballasting	15,5 kW
Per De-ballasting	4,75 kW
Heater for Freshwater[3]	19,9 kW
Fuel Cost per year	1.192 $
Fuel Cost per 10 Years	**11.920 $**

[3]In case the temperature of the freshwater used to dissolve granule disinfectant is lower than 20°C, a heater runs to heat the freshwater.

3. Maintenance Cost[4]	
Pump for Disinfecting Agent	8.000 $
Pump for Neutralizing Agent	11.350 $
Filter	2.000 $
TRO Meter	60.000 $
Dissolution Unit for Disinfecting Agent	500 $
Total Maintenance Cost for 10 Years	**81.850 $**

[4]Maintenance cost is estimated as a sum of assumable essential items which are regularly required to be replaced. Replacement of other items may be required depending on specification, environment of usage or any other cause.

10) Evoqua

- System: Seacure

- Technology: Filtrarion & Side-stream Electrolysis

- Operational Expenses Calculation

A. Minitank Five – Option 1: 1 x SeaCure BWTS 800 cbm with 2 x 300 cbm ballast water pump filters & 1 x 150 cbm general service pump filter for FPT treatment

i) Vessel Operational Data

No of ballasting operations per year	36
No of de-ballasting operations in less than 5 days	10
Total ballast pump capacity	600 m^3/h
Total ballast water capacity	3.138 m^3
Ballasting time	5,23 hours
De-ballasting time[1]	6,80 hours
Specific fuel consumption	0,224 kgr/kWh

[1]De-ballasting operation is considered to be 30% slower.

ii) External Factors

Sodium sulfite cost	0,9 $/kg
Fuel cost	350 $/ton

iii) System Data: Power Consumption & Consumables

Power consumption during ballasting[2]	58,2 kW
Average sodium sulfite consumption	5 kg/1.000 m^3
Power consumption during de-ballasting	2,8 kW
Consumption of sodium sulfite per year	156,9 kg

[2]Normal conditions are considered in this case, meaning 30-35 PSU at 15^oC water temperature and 50% backwashing time for the filter.

iv) Maintenance Cost for period of 10 years

Spare Parts	76.000 $
Electrolyte, Verification & Calibration Solution	6.496 $
Total	**82.496 $**

v) Operational Cost for period of 10 years

Energy cost per uptake	24 $
Energy cost per discharge	1$

Cost of sulfite per discharge	14 $
Energy cost per year	870,64 $
Energy and dechlorination chemical cost per year	1.011,85 $
Total operational cost for 10 years	**10.119 $**

Grand Total Cost for 10 Years	**92.615 $**

B. Minitank Five – Option 2: 1 x SeaCure BWTS 800 cbm with 1 x 750 cbm ballast water pump filters & 1 x 150 cbm general service pump filter for FPT treatment

i) Vessel Operational Data

No of ballasting operations per year	36
No of de-ballasting operations in less than 5 days	10
Total ballast pump capacity	600 m^3/h
Total ballast water capacity	3.138 m^3
Ballasting time	5,23 hours
De-ballasting time[1]	6,80 hours
Specific fuel consumption	0,224 kgr/kWh

[1]De-ballasting operation is considered to be 30% slower.

ii) External Factors

Sodium sulfite cost	0,9 $/kg
Fuel cost	350 $/ton

iii) System Data: Power Consumption & Consumables

Power consumption during ballasting[2]	38,3 kW
Average sodium sulfite consumption	5 kg/1.000 m^3
Power consumption during de-ballasting	2,8 kW
Consumption of sodium sulfite per year	156,9 kg

[2]Normal conditions are considered in this case, meaning 30-35 PSU at 15^{o}C water temperature and 50% backwashing time for the filter.

iv) Maintenance Cost for period of 10 years

Spare Parts	62.000 $
Electrolyte, Verification & Calibration Solution	6.496 $
Total	**68.496 $**

v) Operational Cost for period of 10 years

Energy cost per uptake	16 $
Energy cost per discharge	1$
Cost of sulfite per discharge	14 $

Energy cost per year	576,87 $
Energy and dechlorination chemical cost per year	718,08 $
Total operational cost for 10 years	**7.181 $**

Grand Total Cost for 10 Years	**75.677 $**

C. Jenny I – Option 1: 2 x SeaCure BWTS 800 cbm with 2 x 750 cbm ballast water pump filters & 1 x 150 cbm general service pump filter for APT treatment

i) Vessel Operational Data

No of ballasting operations per year	27
No of de-ballasting operations in less than 5 days	5
Total ballast pump capacity	1500 m^3/h
Total ballast water capacity	20.429 m^3
Ballasting time	13,62 hours
De-ballasting time[1]	17,71 hours
Specific fuel consumption	0,224 kgr/kWh

[1]De-ballasting operation is considered to be 30% slower.

ii) External Factors

Sodium sulfite cost	0,9 $/kg
Fuel cost	350 $/ton

iii) System Data: Power Consumption & Consumables

Power consumption during ballasting[2]	82,3 kW
Average sodium sulfite consumption	5 kg/1.000 m^3
Power consumption during de-ballasting	2,8 kW
Consumption of sodium sulfite per year	510,725 kg

[2]Normal conditions are considered in this case, meaning 30-35 PSU at 15^{o}C water temperature and 50% backwashing time for the filter.

iv) Maintenance Cost for period of 10 years

Spare Parts	80.000 $
Electrolyte, Verification & Calibration Solution	6.496 $
Total	**86.496 $**

v) Operational Cost for period of 10 years

Energy cost per uptake	88 $
Energy cost per discharge	3 $

Cost of sulfite per discharge	92 $
Energy cost per year	2.387,76 $
Energy and dechlorination chemical cost per year	2.847,41 $
Total operational cost for 10 years	**28.474 $**

Grand Total Cost for 10 Years	**114.970 $**

D. Jenny I – Option 2: 1 x SeaCure BWTS 1500 cbm with 1 x 1500 cbm ballast water pump filter & 1 x 150 cbm general service pump filter for APT treatment

i) Vessel Operational Data

No of ballasting operations per year	27
No of de-ballasting operations in less than 5 days	5
Total ballast pump capacity	1500 m^3/h
Total ballast water capacity	20.429 m^3
Ballasting time	13,62 hours
De-ballasting time[1]	17,71 hours
Specific fuel consumption	0,224 kgr/kWh

[1]De-ballasting operation is considered to be 30% slower.

ii) External Factors

Sodium sulfite cost	0,9 $/kg
Fuel cost	350 $/ton

iii) System Data: Power Consumption & Consumables

Power consumption during ballasting[2]	66,9 kW
Average sodium sulfite consumption	5 kg/1.000 m^3
Power consumption during de-ballasting	2,8 kW
Consumption of sodium sulfite per year	510,725 kg

[2]Normal conditions are considered in this case, meaning 30-35 PSU at 15°C water temperature and 50% backwashing time for the filter.

iv) Maintenance Cost for period of 10 years

Spare Parts	68.000 $
Electrolyte, Verification & Calibration Solution	6.496 $
Total	**74.496 $**

v) Operational Cost for period of 10 years

Energy cost per uptake	71 $
Energy cost per discharge	3 $

Cost of sulfite per discharge	92 $
Energy cost per year	1.943,76 $
Energy and dechlorination chemical cost per year	2.403,41 $
Total operational cost for 10 years	**24.034 $**

Grand Total Cost for 10 Years	**98.530 $**

E. Mabrouk – Option 1: 1 x SeaCure BWTS 4000 cbm with 2 x 2000 cbm ballast water pump filters & 1 x 300 cbm general service pump filter for APT treatment

i) Vessel Operational Data

No of ballasting operations per year	12
No of de-ballasting operations in less than 5 days	2
Total ballast pump capacity	4000 m^3/h
Total ballast water capacity	53.635 m^3
Ballasting time	13,41 hours
De-ballasting time[1]	17,43 hours
Specific fuel consumption	0,224 kgr/kWh

[1]De-ballasting operation is considered to be 30% slower.

ii) External Factors

Sodium sulfite cost	0,9 $/kg
Fuel cost	350 $/ton

iii) System Data: Power Consumption & Consumables

Power consumption during ballasting[2]	181 kW
Average sodium sulfite consumption	5 kg/1.000 m^3
Power consumption during de-ballasting	2,8 kW
Consumption of sodium sulfite per year	536,35 kg

[2]Normal conditions are considered in this case, meaning 30-35 PSU at 15^{o}C water temperature and 50% backwashing time for the filter.

iv) Maintenance Cost for period of 10 years

Spare Parts	112.000 $
Electrolyte, Verification & Calibration Solution	9.451 $
Total	**121.451 $**

v) Operational Cost for period of 10 years

Energy cost per uptake	190 $
Energy cost per discharge	3 $

Cost of sulfite per discharge	241 $
Energy cost per year	2.289,34 $
Energy and dechlorination chemical cost per year	2.772,05 $
Total operational cost for 10 years	**27.721 $**

Grand Total Cost for 10 Years	**149.172 $**

F. Mabrouk – Option 2: 1 x SeaCure BWTS 4000 cbm with 1 x 4000 cbm ballast water pump filters & 1 x 300 cbm general service pump filter for APT treatment

i) Vessel Operational Data

No of ballasting operations per year	12
No of de-ballasting operations in less than 5 days	2
Total ballast pump capacity	4000 m^3/h
Total ballast water capacity	53.635 m^3
Ballasting time	13,41 hours
De-ballasting time[1]	17,43 hours
Specific fuel consumption	0,224 kgr/kWh

[1]De-ballasting operation is considered to be 30% slower.

ii) External Factors

Sodium sulfite cost	0,9 $/kg
Fuel cost	350 $/ton

iii) System Data: Power Consumption & Consumables

Power consumption during ballasting[2]	173 kW
Average sodium sulfite consumption	5 kg/1.000 m^3
Power consumption during de-ballasting	2,8 kW
Consumption of sodium sulfite per year	536,35 kg

[2]Normal conditions are considered in this case, meaning 30-35 PSU at 15°C water temperature and 50% backwashing time for the filter.

iv) Maintenance Cost for period of 10 years

Spare Parts	87.000 $
Electrolyte, Verification & Calibration Solution	6.496 $
Total	**93.496 $**

v) Operational Cost for period of 10 years

Energy cost per uptake	182 $
Energy cost per discharge	3 $

Cost of sulfite per discharge	241 $
Energy cost per year	2.188,41 $
Energy and dechlorination chemical cost per year	2.671,13 $
Total operational cost for 10 years	**26.711 $**

Grand Total Cost for 10 Years	**120.207 $**

11) Wartsila

<u>- System</u>: Aquarius UV & Aquarius EC

<u>- Technology</u>: UV Treatment & Electro-chlorination

<u>- Operational Expenses Calculation</u>

A. Minitank Five – Option 1: 2 x AQ-375-UV & 1 x AQ-180-UV (FPT)

i) Maintenance Cost for 10 years

System: 2 x AQ-375-UV	
Complete Filter Screen Assembly	14.639 USD
UV Treatment Spares (UV Lamps, etc.)	43.877 USD
UV Intensity Sensor Annual Calibration	44.000 USD
Total	**58.516 USD**
System: 1 x AQ-180-UV	
Complete Filter Screen Assembly	4.963 USD
UV Treatment Spares (UV Lamps, etc.)	20.491 USD
UV Intensity Sensor Annual Calibration	22.000 USD
Total	**47.454 USD**
Grand Total of Spares for 10 Years	**105.970 USD**

ii) Power Consumption Cost

System: 2 x AQ-375-UV	
Number of Ballast Operations per Year	36
Number of Deballast Operations per Year	36
Total Ballast Volume to be treated per Year	225.936 m^3
Total Available Capacity of the BWTS	750 m^3/h
Total Running Hours of the BTWS per Year	301 hr
Total Power Demand	47,33 kW
Total kWh per Year	14.258 kWh
Specific Fuel Consumption	0,224 kgr/kWh
FO Cost	350 USD/ton
Power Consumption Cost per Year	1.118 $
Power Consumption Cost per 10 Years	**11.178 $**

System: 1 x AQ-180-UV	
Number of Ballast Operations per Year	36
Number of Deballast Operations per Year	36
Total Ballast Volume to be treated per Year	15.768 m^3
Total Available Capacity of the BWTS	180 m^3/h
Total Running Hours of the BTWS per Year	88 hr
Total Power Demand	38,63 kW
Total kWh per Year	3.384 kWh

Specific Fuel Consumption	0,224 kgr/kWh
FO Cost	350 USD/ton
Power Consumption Cost per Year	265 $
Power Consumption Cost per 10 Years	**2.653 $**

Grand Total of Power Consumption for 10 Years	**13.831 $**

B. Minitank Five – Option 2: 1 x AQ-750-UV & 1 x AQ-180-UV (FPT)

i) Maintenance Cost for 10 years

System: 1 x AQ-750-UV	
Complete Filter Screen Assembly	9.816 USD
UV Treatment Spares (UV Lamps, etc.)	37.200 USD
UV Intensity Sensor Annual Calibration	22.000 USD
Total	**47.016 USD**
System: 1 x AQ-180-UV	
Complete Filter Screen Assembly	4.963 USD
UV Treatment Spares (UV Lamps, etc.)	20.491 USD
UV Intensity Sensor Annual Calibration	22.000 USD
Total	**47.454 USD**
Grand Total of Spares for 10 Years	**94.470 USD**

ii) Power Consumption Cost

System: 1 x AQ-750-UV	
Number of Ballast Operations per Year	36
Number of Deballast Operations per Year	36
Total Ballast Volume to be treated per Year	225.936 m^3
Total Available Capacity of the BWTS	750 m^3/h
Total Running Hours of the BTWS per Year	301 hr
Total Power Demand	92,17 kW
Total kWh per Year	27.766 kWh
Specific Fuel Consumption	0,224 kgr/kWh
FO Cost	350 USD/ton
Power Consumption Cost per Year	2.177 $
Power Consumption Cost per 10 Years	**21.769 $**

System: 1 x AQ-180-UV	
Number of Ballast Operations per Year	36
Number of Deballast Operations per Year	36
Total Ballast Volume to be treated per Year	15.768 m^3
Total Available Capacity of the BWTS	180 m^3/h
Total Running Hours of the BTWS per Year	88 hr
Total Power Demand	38,63 kW
Total kWh per Year	3.384 kWh

Specific Fuel Consumption	0,224 kgr/kWh
FO Cost	350 USD/ton
Power Consumption Cost per Year	265 $
Power Consumption Cost per 10 Years	**2.653 $**

Grand Total of Power Consumption for 10 Years	**24.422 $**

C. Jenny I – Option 1: 2 x AQ-750-UV & 1 x AQ-125-UV (APT)

i) Maintenance Cost for 10 years

System: 2 x AQ-750-UV	
Complete Filter Screen Assembly	19.633 USD
UV Treatment Spares (UV Lamps, etc.)	74.400 USD
UV Intensity Sensor Annual Calibration	44.000 USD
Total	**94.032 USD**
System: 1 x AQ-125-UV	
Complete Filter Screen Assembly	3.194 USD
UV Treatment Spares (UV Lamps, etc.)	7.748 USD
UV Intensity Sensor Annual Calibration	22.000 USD
Total	**32.943 USD**
Grand Total of Spares for 10 Years	**126.975 USD**

ii) Power Consumption Cost

System: 2 x AQ-750-UV	
Number of Ballast Operations per Year	27
Number of Deballast Operations per Year	27
Total Ballast Volume to be treated per Year	1.103.166 m^3
Total Available Capacity of the BWTS	1500 m^3/h
Total Running Hours of the BTWS per Year	735 hr
Total Power Demand	121,2 kW
Total kWh per Year	89.136 kWh
Specific Fuel Consumption	0,224 kgr/kWh
FO Cost	350 USD/ton
Power Consumption Cost per Year	6.988 $
Power Consumption Cost per 10 Years	**69.882 $**

System: 1 x AQ-125-UV	
Number of Ballast Operations per Year	27
Number of Deballast Operations per Year	27
Total Ballast Volume to be treated per Year	34.722 m^3
Total Available Capacity of the BWTS	125 m^3/h
Total Running Hours of the BTWS per Year	278 hr
Total Power Demand	19 kW
Total kWh per Year	5.278 kWh

Specific Fuel Consumption	0,224 kgr/kWh
FO Cost	350 USD/ton
Power Consumption Cost per Year	414 $
Power Consumption Cost per 10 Years	**4.138 $**

Grand Total of Power Consumption for 10 Years	**74.020 $**

D. Jenny I – Option 2: 1 x AQ-1500-EC & 1 x AQ-125-UV (APT)

i) Maintenance Cost for 10 years

System: 1 x AQ-1500-EC	
Complete Filter Screen Assembly	23.760 USD
EC Treatment Pump Maintenance Kit	3.621 USD
Total	**27.381 USD**
System: 1 x AQ-125-UV	
Complete Filter Screen Assembly	3.194 USD
UV Treatment Spares (UV Lamps, etc.)	7.748 USD
UV Intensity Sensor Annual Calibration	22.000 USD
Total	**32.943 USD**
Grand Total of Spares for 10 Years	**60.324 USD**

ii) Power Consumption Cost

System: 1 x AQ-1500-EC	
Number of Ballast Operations per Year	27
Number of Deballast Operations per Year	27
Total Ballast Volume to be treated per Year	1.103.166 m^3
Total Available Capacity of the BWTS	1500 m^3/h
Total Running Hours of the BTWS per Year	735 hr
Total Power Demand	126,2 kW
Total kWh per Year	92.813 kWh
Specific Fuel Consumption	0,224 kgr/kWh
FO Cost	350 USD/ton
Power Consumption Cost per Year	7.277 $
Power Consumption Cost per 10 Years	**72.765 $**

System: 1 x AQ-125-UV	
Number of Ballast Operations per Year	27
Number of Deballast Operations per Year	27
Total Ballast Volume to be treated per Year	34.722 m^3
Total Available Capacity of the BWTS	125 m^3/h
Total Running Hours of the BTWS per Year	278 hr
Total Power Demand	19 kW
Total kWh per Year	5.278 kWh
Specific Fuel Consumption	0,224 kgr/kWh

FO Cost	350 USD/ton
Power Consumption Cost per Year	414 $
Power Consumption Cost per 10 Years	**4.138 $**

Grand Total of Power Consumption for 10 Years	**76.903 $**

iii) Chemical Cost

TRO Sensor Reagent Renewal Annual Cost	3.879 USD
TRO Sensor Reagent Renewal Cost for 10 Years	**38.786 USD**
Sodium Bisulphite Cost per 1000 m^3 of discharged ballast water	7,01 EUR
Total Ballast Volume to be treated per Year	1.103.166 m^3
Total Ballast Volume to be treated per 10 Years	11.031.660 m^3
Sodium Bisulphite Cost for 10 Years	77.332 EUR
Sodium Bisulphite Cost for 10 Years	**85.065 USD**

Grand Total of Operational Cost for 10 Years	**200.754 $**

E. Mabrouk – Option 2: 2 x AQ-2000-EC & 1 x AQ-250-UV (APT)

i) Maintenance Cost for 10 years

System: 2 x AQ-2000-EC	
Complete Filter Screen Assembly	63.360 USD
EC Treatment Pump Maintenance Kit	7.242 USD
Total	**70.602 USD**
System: 1 x AQ-250-UV	
Complete Filter Screen Assembly	4.963 USD
UV Treatment Spares (UV Lamps, etc.)	20.491 USD
UV Intensity Sensor Annual Calibration	22.000 USD
Total	**47.454 USD**
Grand Total of Spares for 10 Years	**118.056 USD**

ii) Power Consumption Cost

System: 2 x AQ-2000-EC	
Number of Ballast Operations per Year	12
Number of Deballast Operations per Year	12
Total Ballast Volume to be treated per Year	1.287.240 m^3
Total Available Capacity of the BWTS	4000 m^3/h
Total Running Hours of the BTWS per Year	322 hr
Total Power Demand	158,3 kW
Total kWh per Year	50.943 kWh
Specific Fuel Consumption	0,224 kgr/kWh
FO Cost	350 USD/ton
Power Consumption Cost per Year	3.994 $

Power Consumption Cost per 10 Years	**39.939 $**

System: 1 x AQ-250-UV	
Number of Ballast Operations per Year	12
Number of Deballast Operations per Year	12
Total Ballast Volume to be treated per Year	25.248 m^3
Total Available Capacity of the BWTS	250 m^3/h
Total Running Hours of the BTWS per Year	101 hr
Total Power Demand	40,13 kW
Total kWh per Year	4.053 kWh
Specific Fuel Consumption	0,224 kgr/kWh
FO Cost	350 USD/ton
Power Consumption Cost per Year	318 $
Power Consumption Cost per 10 Years	**3.177 $**

Grand Total of Power Consumption for 10 Years	**43.116 $**

iii) Chemical Cost

TRO Sensor Reagent Renewal Annual Cost	3.879 USD
TRO Sensor Reagent Renewal Cost for 10 Years	**38.786 USD**
Sodium Bisulphite Cost per 1000 m^3 of discharged ballast water	7,01 EUR
Total Ballast Volume to be treated per Year	1.287.240 m^3
Total Ballast Volume to be treated per 10 Years	12.872.400 m^3
Sodium Bisulphite Cost for 10 Years	90.236 EUR
Sodium Bisulphite Cost for 10 Years	**99.259 USD**

Grand Total of Operational Cost for 10 Years	**181.161 $**

6 Economical Analysis of Ballast Water Treatment Systems

Below, a CAPEX for all above ballast water treatment systems is going to be presented after taking into account the initial equipment cost and the maintenance/operational cost for a period of 10 years.

For each vessel, two options are presented. Option 1 refers to one system that fulfills the needs of both ballast pumps. On the other hand, option 2 refers to two systems, one for each ballast pump.

For vessels "Minitank Five" and "Jenny I", there are different graphs representing Option 1 and Option 2. For vessel "Mabrouk", Option 1 & 2 are presented in the same graph.

1) Vessel: Minitank Five   DWT: 8.084 MT

MINITANK FIVE			1)FOR WBTs: FRAMO SB200-2 X 2 UNITS X 300 M3/HR 2)FOR FPT: TAIKO FIRE GS PUMPS X2 X 115/150 M3/H		
MAKER	EQUIPMENT COST (USD)		MAINTENANCE & OPERATIONAL COST (USD)		REMARKS
UV	1 System	2 Systems	1 System	2 Systems	
Alfa Laval	339.966	510.510	31.430	38.732	
Panmarine	362.000	544.600	79.872	115.911	
Desmi	382.294	427.405	53.924	56.649	
Optimarin	437.800	530.200	123.367	129.889	
Panasia	326.000	430.000	44.711	48.640	
Hyde Marine	225.000	338.000	79.519	95.776	
Wartsila	410.597	528.342	118.892	119.801	
ELECTROLYSIS					
E.P.E.	303.000	368.000	60.912	74.024	
Evoqua	585.000	668.000	75.677	92.615	
CHEMICAL INJECTION					
JFE	512.397	545.455	123.250	164.040	1st System = Liquid 2nd System = Granular
Ecochlor	595.400	649.000	129.602	143.618	

CAPEX for Installation of 1 Ballast Water Treatment System

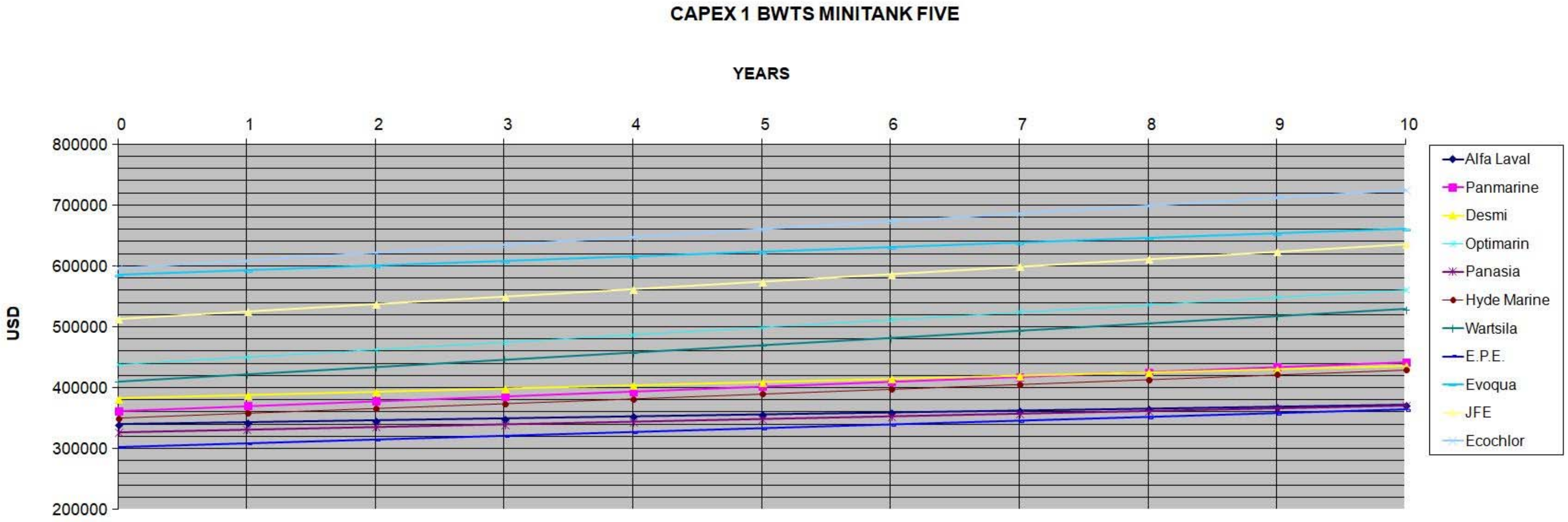

Figure 2: CAPEX for 1 BWTS installed on Minitank Five

<u>**CAPEX for Installation of 2 Ballast Water Treatment Systems**</u>

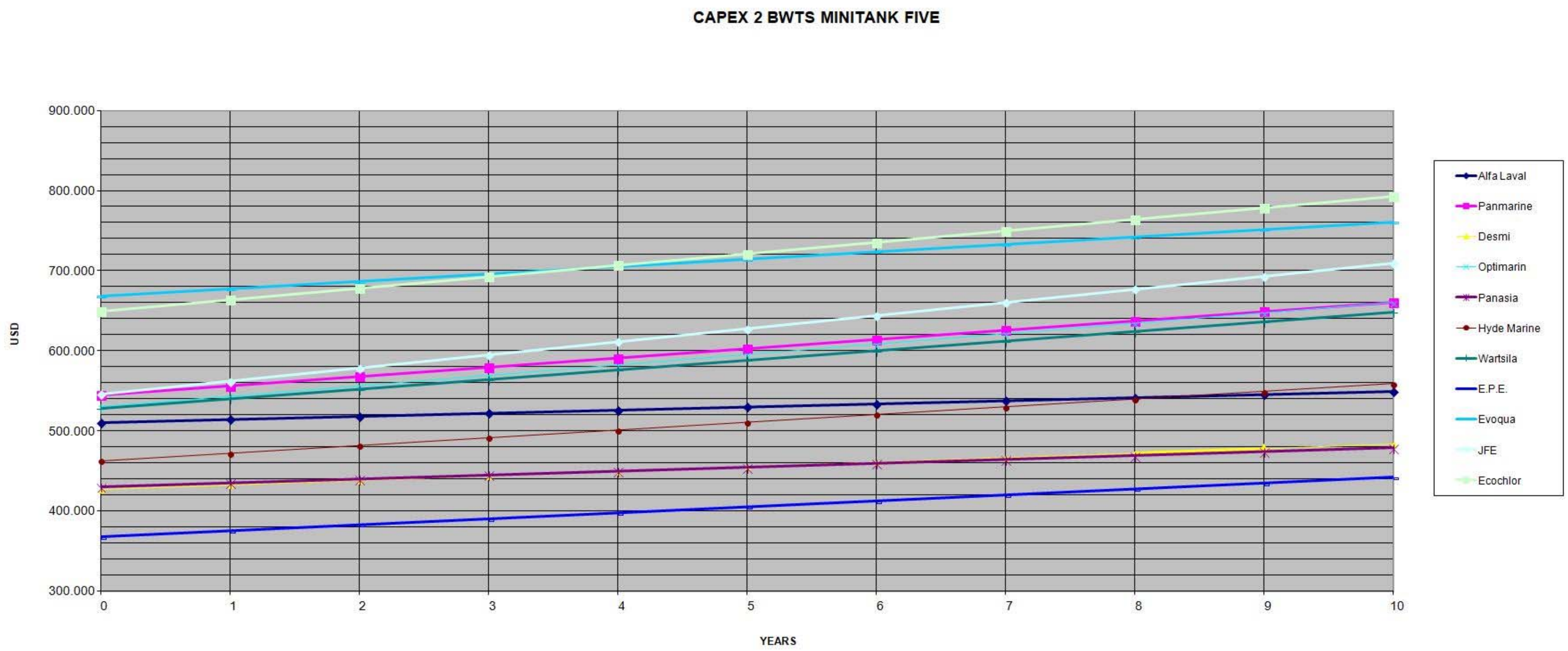

Figure 3: CAPEX for 2 BWTS installed on Minitank Five

2) Vessel: Jenny I DWT: 40.128 MT

JENNY I		1)FOR WBTs,FPT: FRAMO SB300-2 X 2 UNITS X 650 M3/HR SUBM IN NR 5&S WBTs , 2)FOR APT: TAIKO FIRE GS PUMPS X2 X 100/110 M3/H		
MAKER	**EQUIPMENT COST (USD)**		**MAINTENANCE & OPERATIONAL COST (USD)**		**REMARKS**
UV	**1 System**	**2 Systems**	**1 System**	**2 Systems**	
Alfa Laval	-	645.150	-	156.736	Spatial constraints exclude installation of 1 System.
Panmarine	527.000	624.500	171.441	173.170	
Desmi	-	650.353	-	296.793	Spatial constraints exclude installation of 1 System.
Optimarin	673.200	722.700	317.470	344.503	
Panasia	420.000	520.000	67.590	84.449	
Hyde Marine	526.500	616.500	159.996	217.247	
Wartsila	620.038	681.866	261.078	200.995	
ELECTROLYSIS					
E.P.E.	423.000	473.000	106.066	116.488	
Evoqua	645.000	736.000	98.530	114.970	
CHEMICAL INJECTION					
JFE	570.248	570.248	491.640	714.560	1st System = Liquid 2nd System = Granular
Ecochlor	-	729.100	-	449.880	Spatial constraints exclude installation of 1 System.

CAPEX for Installation of 1 Ballast Water Treatment System

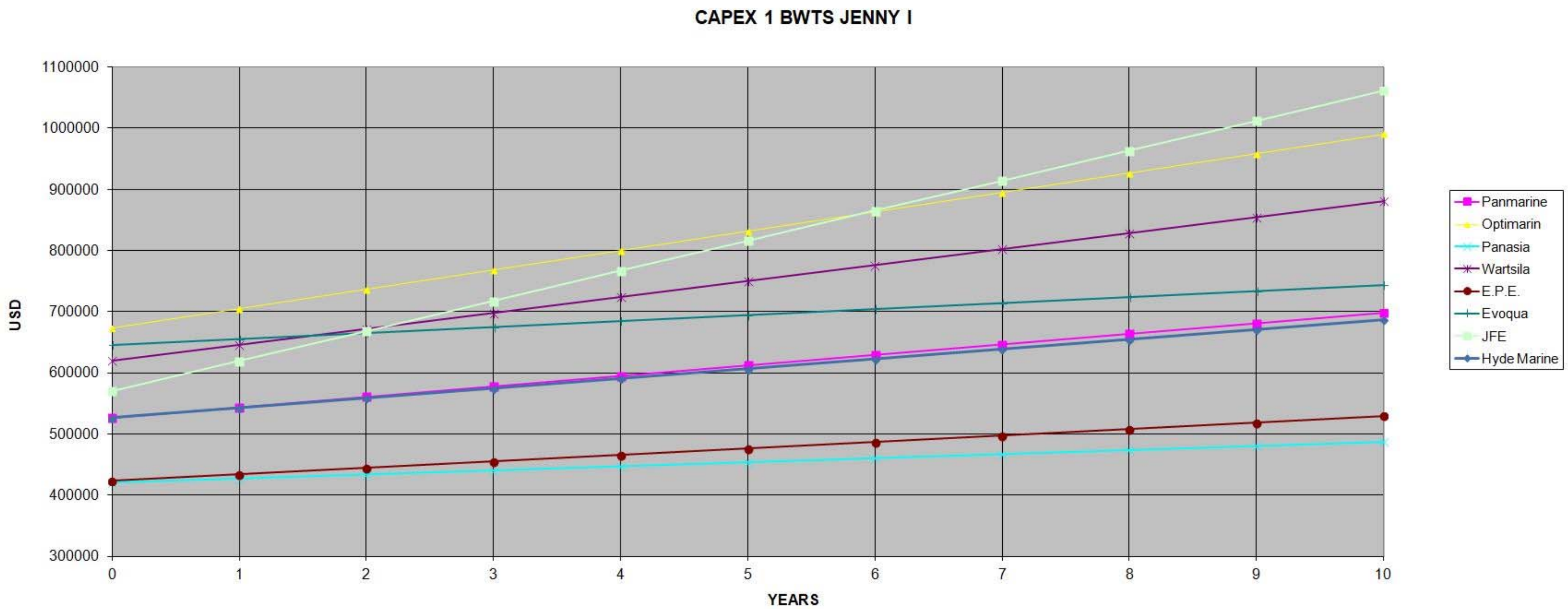

Figure 4: CAPEX for 1 BWTS installed on Jenny I

CAPEX for Installation of 2 Ballast Water Treatment Systems

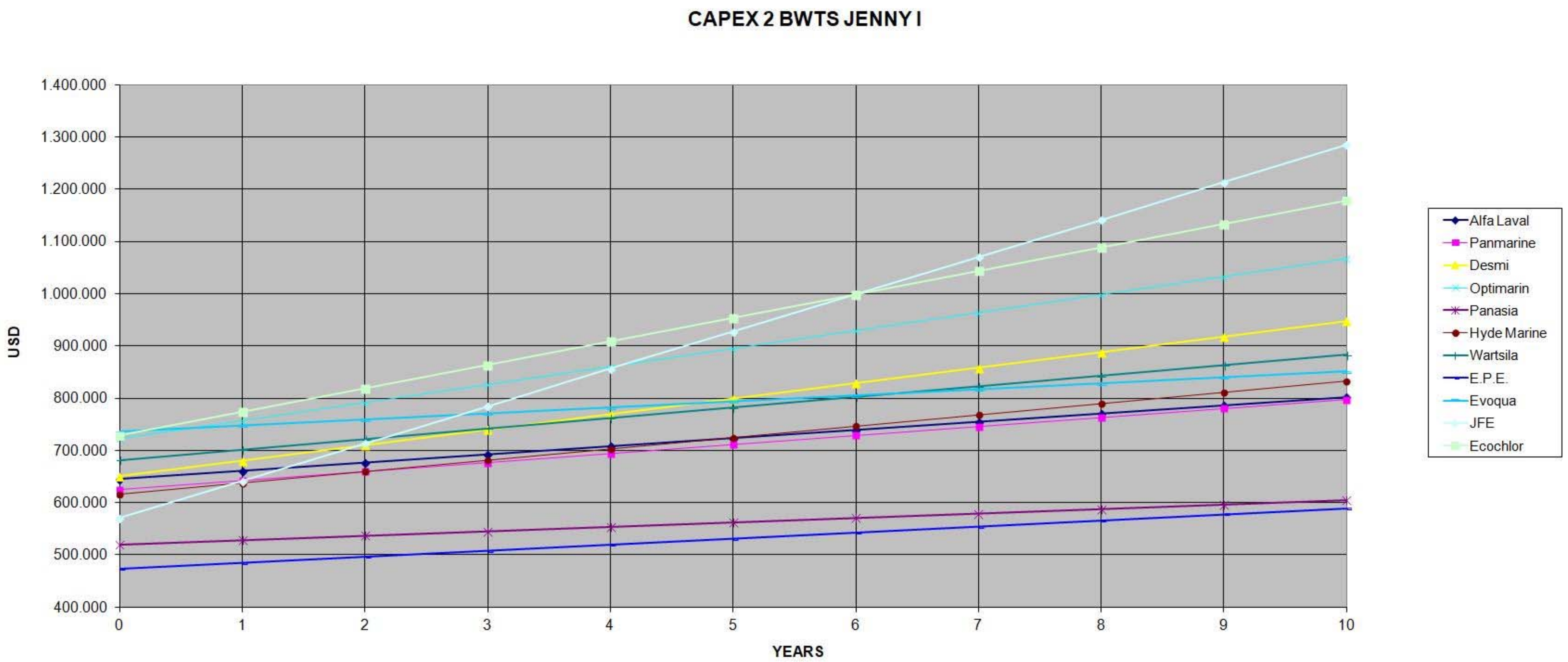

Figure 5: CAPEX for 2 BWTS installed on Jenny I

3) Vessel: Mabrouk DWT: 160.000 MT

MABROUK			1)FOR WBTs: 1 STEAM DRIVEN & 1 EL.DRIVEN CV400-2 X 2000 M3/H INSIDE PUMP ROOM 2)FOR APT: SHINKO FIRE GS PUMPS X2 X 240/200 M3/H		
MAKER	EQUIPMENT COST (USD)		MAINTENANCE & OPERATIONAL COST (USD)		REMARKS
UV	1 System	2 Systems	1 System	2 Systems	
Alfa Laval	-	1.100.000	-	194.634	
Panmarine	-	1.526.500	-	373.145	4 Systems
Desmi	-	1.154.923	-	616.191	
Panasia	-	860.000	-	62.897	
Hyde Marine	-	1.195.000	-	273.892	
Wartsila	-	1.251.461	-	299.217	
ELECTROLYSIS					
E.P.E.	-	858.000	-	110.471	
Evoqua	995.000	1.200.000	120.207	149.172	
CHEMICAL INJECTION					
JFE	702.479	702.479	661.420	951.770	1st System = Liquid | 2nd System = Granular
Ecochlor		865.300		597.865	

CAPEX for Installation of Ballast Water Treatment System

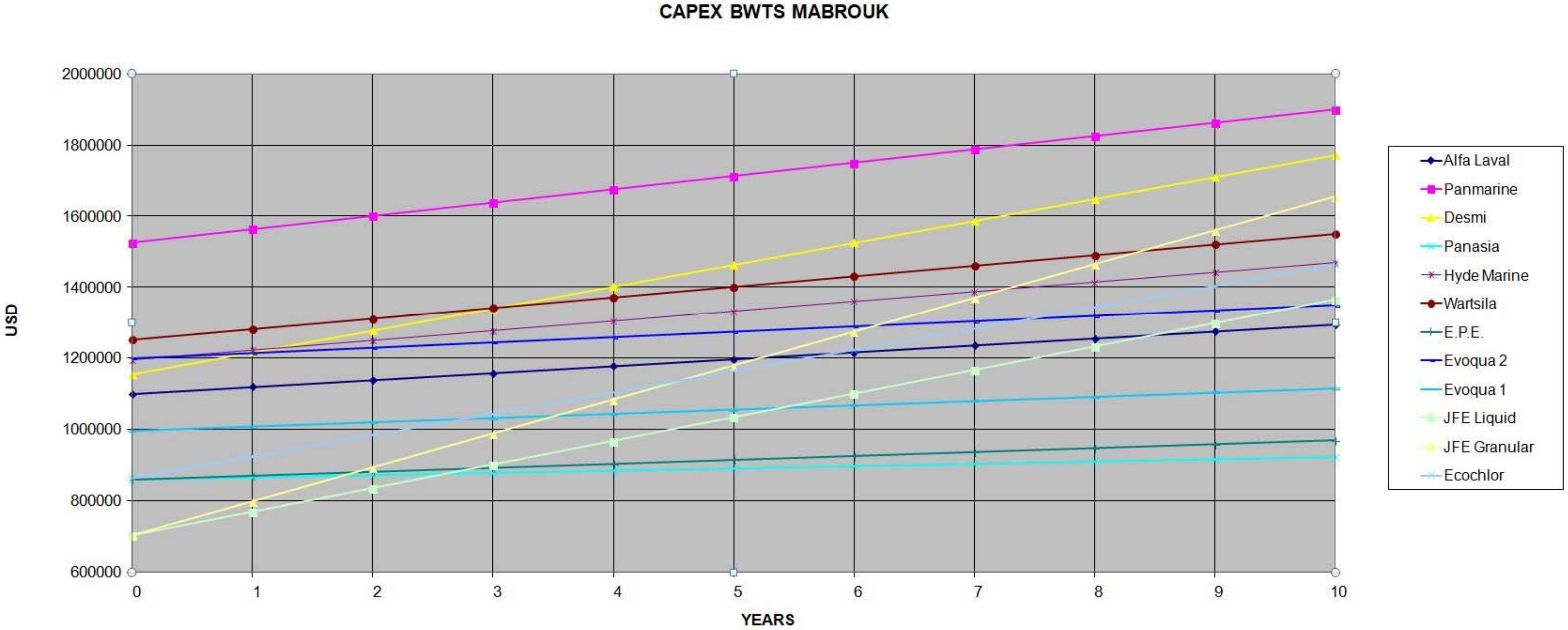

Figure 6: CAPEX for BWTS installed on Mabrouk

7 Investigation for Electrical Power Availability on Loading/Unloading Condition

Below, it is going to be presented the Electrical Power Availability for each vessel based on their Electrical Load Analysis. In this way, it will be possible to assess the energy efficiency of the BWTS.

VESSEL	M/T MINITANK FIVE
DWT	8.084 MT
D/G	
CAPACITY	480 KW (+900 KW)
NO. OF SET	3 (+1 SHAFT GEN.)
VOLTAGE	AC 445 V
PHASE	3PH
FREQUENCY	60 HZ

CONDITION	CARGO HANDLING
NITROGEN GENERATOR AT 100%	
NO. OF D/G IN OPERATION	2
LOAD FACTOR	60.9%
SHAFT GENERATOR	1
LOAD FACTOR OF SHAFT GEN.	68.1%
NITROGEN GENERATOR AT 50%	
NO. OF D/G IN OPERATION	3
LOAD FACTOR	60.5%

Power Reserves with Nitrogen Generator running at 100%	
Condition	Cargo Handling
Total Power	2 x 480 = 960 kW
Maximum Power of each generator is **95%** of Total Load	960 x 0.95 = 912 kW
As Built Power Consumption (Cargo Unloading)	876.5 kW
Available Power for WBTS	**35.5 kW (with a stand-by D/G)**

The nitrogen generator is on the shaft generator (load factor 68.1%)

Power Reserves with Nitrogen Generator running at 50%	
Condition	Cargo Handling
Total Power	3 x 480 = 1440 kW
Maximum Power of each generator is **92%** of Total Load	1440 x 0.92 = 1324.8 kW
As Built Power Consumption (Cargo Unloading)	870.5 kW
Available Power for WBTS	**453.3 kW (without stand-by D/G)**

Power Reserves without Nitrogen Generator running at 50%	
Condition	Cargo Handling
Total Power	3 x 480 = 1440 kW
Maximum Power of each generator is **85%** of Total Load	1440 x 0.85 = 1224 kW
As built Power Consumption (Cargo Unloading)	870.5 kW
Available Power for WBTS	**353.3 kW (without stand-by D/G)**

VESSEL	M/T JENNY I
DWT	40.128 MT
D/G	
CAPACITY	740 KW / 990 KW
NO. OF SET	2 / 1
VOLTAGE	440 V
PHASE	3 PH
FREQUENCY	60 HZ

CONDITION	LOAD/UNLOADING
NO. OF D/G IN OPERATION	3
LOAD FACTOR	80.4%

Power Reserve at Load Unloading (without a stand-by generator)	
Condition	Cargo Handling
Total Power	2 x 740 + 1 x 990 = 2470 kW
Maximum Power of each generator is **85%** of Total Load	2470 x 0.85 = 2099.5 kW
As Built Power Consumption (at load/unloading)	1986.2 kW
Available Power for WBTS	**113.3 kW**

VESSEL	M/T MABROUK
DWT	160.000 MT
D/G	
CAPACITY	850 KW
NO. OF SET	3
VOLTAGE	440 V
PHASE	3 PH
FREQUENCY	60 HZ

CONDITION	CARGO HANDLING
NO. OF D/G IN OPERATION	2 / 3
LOAD FACTOR	76% / 54,3%

Power Reserve at Cargo Handling Condition (with 1 stand-by generator)	
Condition	Cargo Handling
Total Power	2 x 850 = 1700 kW
Maximum Power of each generator is **85%** of Total Load	1700 x 0.85 = 1445 kW
As Built Power Consumption (at load/unloading)	1291.4 kW
Available Power for WBTS	**153.6 kW**

Power Reserve at Cargo Handling Condition (without a stand-by generator)	
Condition	Cargo Handling
Total Power	3 x 850 = 2550 kW
Maximum Power of each generator is **85%** of Total Load	2550 x 0.85 = 2167.5 kW
As Built Power Consumption (at load/unloading)	1291.4 kW
Available Power for WBTS	**876.1 kW**

Now, a comparison will be made to see which systems are possible to be installed in each vessel based on their power availability.

1) M/T MINITANK FIVE

TOTAL LOAD AT LOADING-UNLOADING CONDITION	876,5	KW		TOTAL LOAD AT LOADING-UNLOADING CONDITION	876,5	KW	TOTAL LOAD AT LOADING-UNLOADING CONDITION	870,5	KW	TOTAL LOAD AT LOADING-UNLOADING CONDITION	870,5	KW
TOTAL LOAD OF GENERATOR	1440	KW		**0,95% LOAD**	912	KW	**0,92% LOAD**	1324,8	KW	**0,85% LOAD**	870,5	KW
	3	SET			2	SET		3	SET		3	SET
AVAILABLE POWER FOR BWTS (100%)	**563,5**	KW			**35,5**	KW		**454,3**	KW		**353,3**	KW

Alfa Laval	Option 1	2 x 300 + 170 m3/h	86 KW	Power consumption can be reduced down to 50%
	Option 2	1 x 600 + 170 m3/h	83 KW	Power consumption can be reduced down to 50%
Trojan Marinex	Option 1	2 x 500 + 150 m3/h	60,9 KW	
	Option 2	1 x 750 + 150 m3/h	43,4 KW	
Desmi	Option 1	2 x 300 + 200 m3/h	66 KW	Power consumption can be reduced down to 50%
	Option 2	1 x 600 + 200 m3/h	66 KW	Power consumption can be reduced down to 50%
Optimarin	Option 1	2 x 334 + 167 m3/h	200 KW	Power consumption can be reduced down to 40%
	Option 2	1 x 667 + 167 m3/h	200 KW	Power consumption can be reduced down to 40%
Panasia	Option 1	2 x 350 + 150 m3/h	100 KW	Power consumption can be reduced down to 75%
	Option 2	1 x 700 + 150 m3/h	100 KW	Power consumption can be reduced down to 75%
Hyde Marine	Option 1	2 x 300 + 150 m3/h	101,5 KW	Power consumption can be reduced down to 70%
	Option 2	1 x 600 + 150 m3/h	71,5 KW	Power consumption can be reduced down to 70%
Wartsila	Option 1	2 x 375 + 180 m3/h	86 KW	
	Option 2	1 x 750 + 180 m3/h	130,8 KW	
E.P.E.	Option 1	2 x 300 + 100 m3/h	48 KW	
	Option 2	1 x 600 + 100 m3/h	41,75 KW	
Evoqua	Option 1	2 x 300 + 150 m3/h	83,2 KW	
	Option 2	1 x 750 + 150 m3/h	50 KW	
Ecochlor	Option 1	2 x 410 + 180 m3/h	18,2 KW	
	Option 2	1 x 850 + 180 m3/h	12,4 KW	
JFE	Option 1	2 x 300 + 300 m3/h	11,6 KW	
	Option 2	2 x 300 + 300 m3/h	24,4 KW	

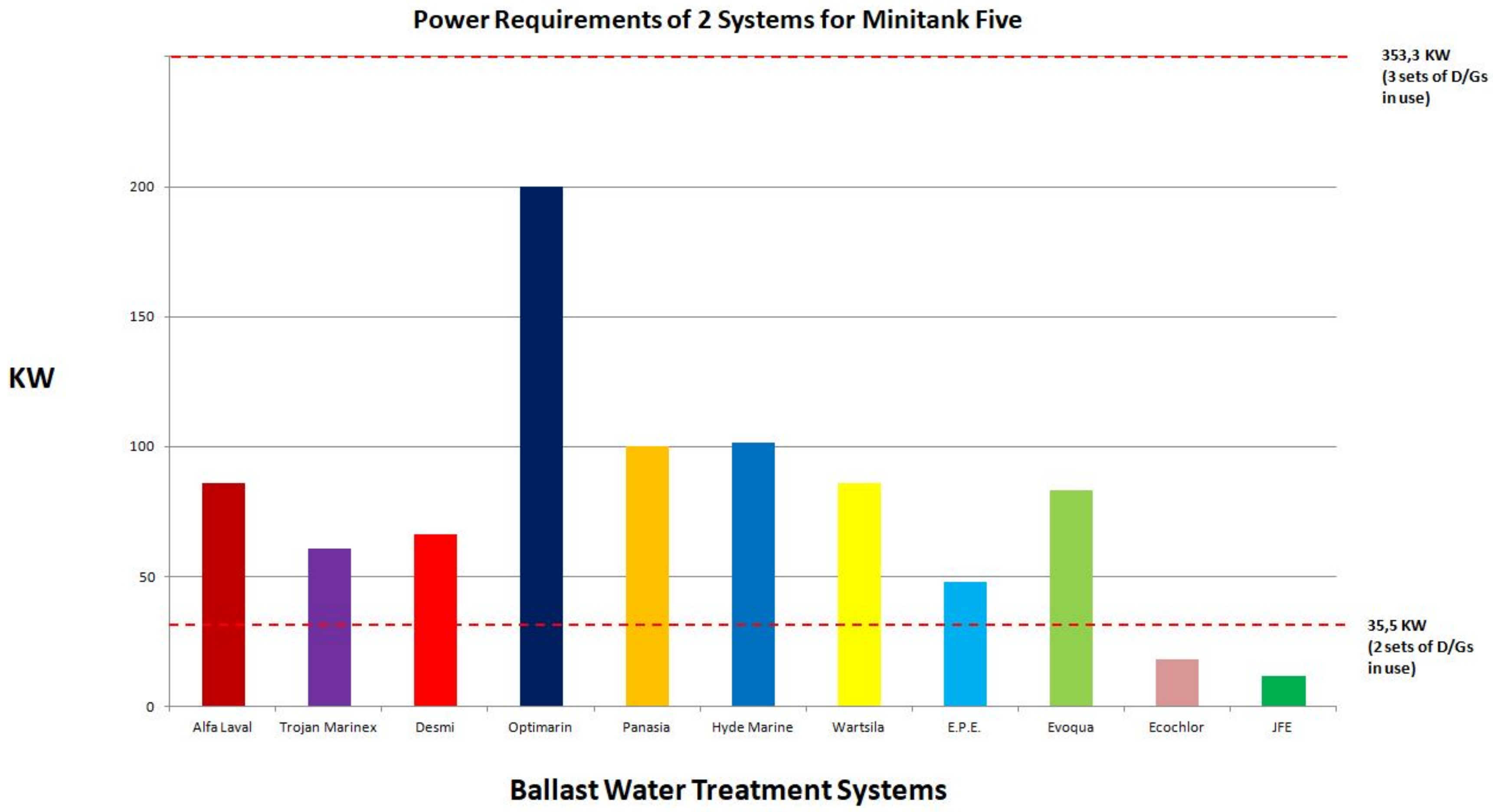

Figure 7: Power Requirements for 2 BWTS on Minitank Five

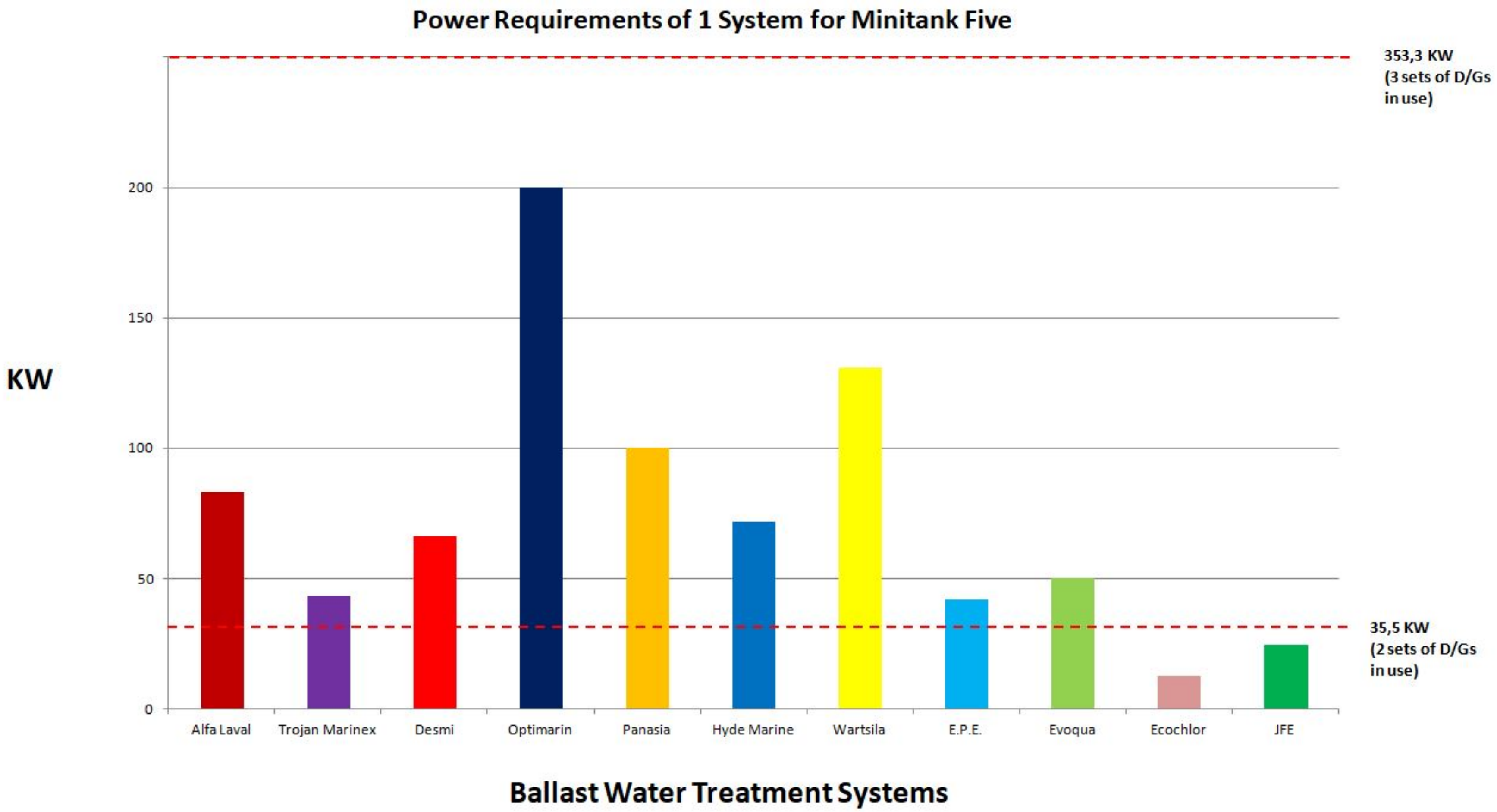

Figure 8: Power Requirements for 1 BWTS on Minitank Five

2) M/T JENNY I

TOTAL LOAD AT LOADING-UNLOADING CONDITION	1986,2	KW				
TOTAL LOAD OF GENERATOR	2470	KW		**0,85% LOAD**	2100	KW
	3	SET			3	SET
AVAILABLE POWER FOR BWTS (100%)	**483,8**	KW			**113**	KW

Alfa Laval	Option 1	2 x 750 + 170 m3/h	220 KW	Power consumption can be reduced down to 50%
	Option 2	1 x 1500 + 170 m3/h	-	Option is not feasible.
Trojan Marinex	Option 1	2 x 750 + 150 m3/h	77,7 KW	
	Option 2	1 x 1500 + 150 m3/h	75 KW	
Desmi	Option 1	2 x 800 + 200 m3/h	110 KW	Power consumption can be reduced down to 50%
	Option 2	-	-	Option is not available.
Optimarin	Option 1	2 x 667 + 167 m3/h	380 KW	Power consumption can be reduced down to 40%
	Option 2	1 x 1334 + 167 m3/h	380 KW	Power consumption can be reduced down to 40%
Panasia	Option 1	2 x 700 + 150 m3/h	180 KW	Power consumption can be reduced down to 75%
	Option 2	1 x 1500 + 150 m3/h	130 KW	Power consumption can be reduced down to 75%
Hyde Marine	Option 1	2 x 700 + 100 m3/h	170 KW	Power consumption can be reduced down to 70%
	Option 2	1 x 1500 + 100 m3/h	134 KW	Power consumption can be reduced down to 70%
Wartsila	Option 1	2 x 750 + 125 m3/h	121,2 KW	
	Option 2	1 x 1500 + 125 m3/h	126,2 KW	
E.P.E.	Option 1	2 x 600 + 100 m3/h	93,5 KW	
	Option 2	1 x 1500 + 100 m3/h	109 KW	
Evoqua	Option 1	2 x 750 + 150 m3/h	114,3 KW	
	Option 2	1 x 1500 + 150 m3/h	95 KW	
Ecochlor	Option 1	2 x 850 + 125 m3/h	19,5 KW	
	Option 2	1 x 1500 + 180 m3/h	-	Option is not feasible.
JFE	Option 1	2 x 750 + 300 m3/h	11,6 KW	
	Option 2	2 x 750 + 300 m3/h	24,4 KW	

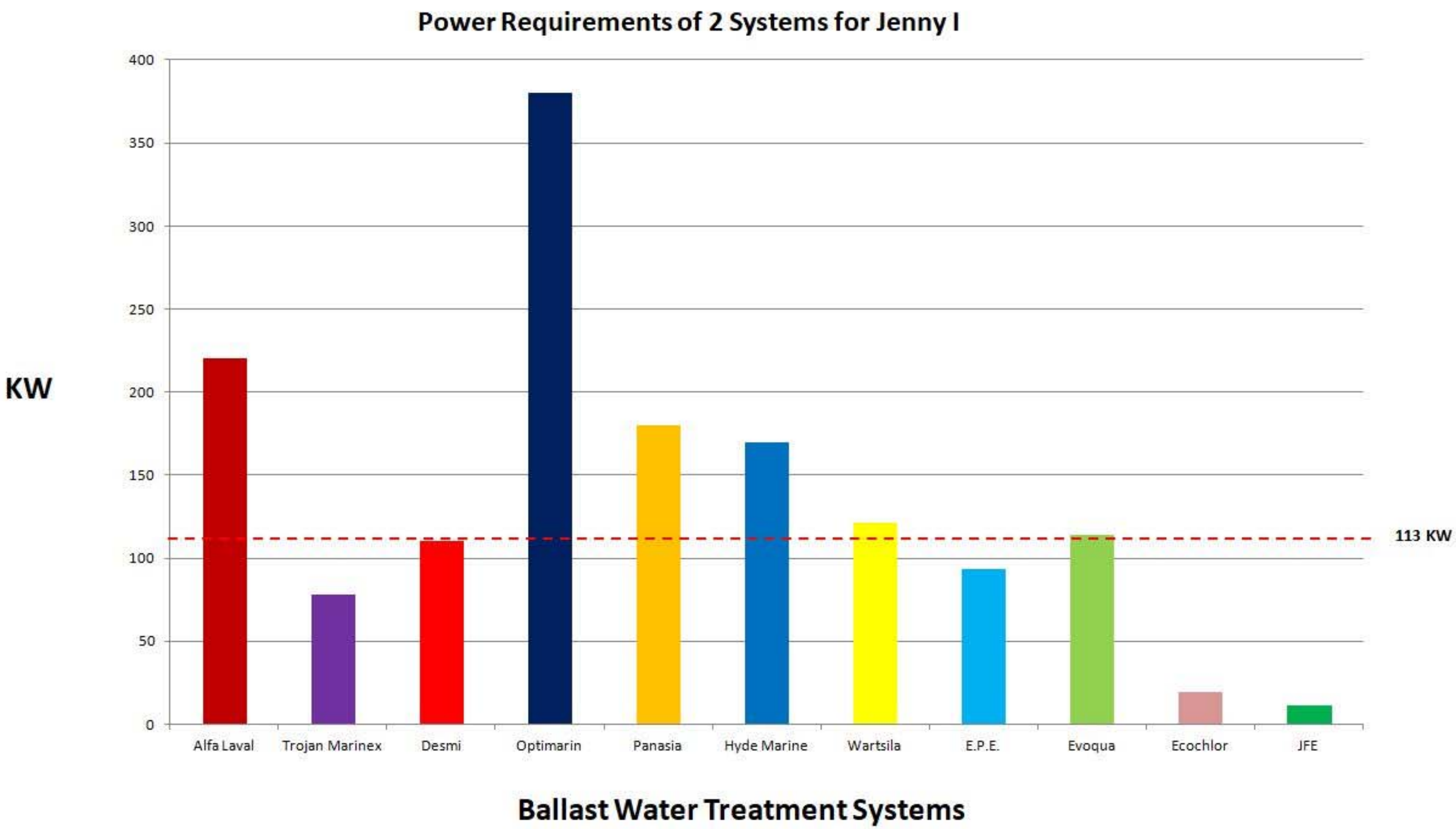

Figure 9: Power Requirements for 2 BWTS on Jenny I

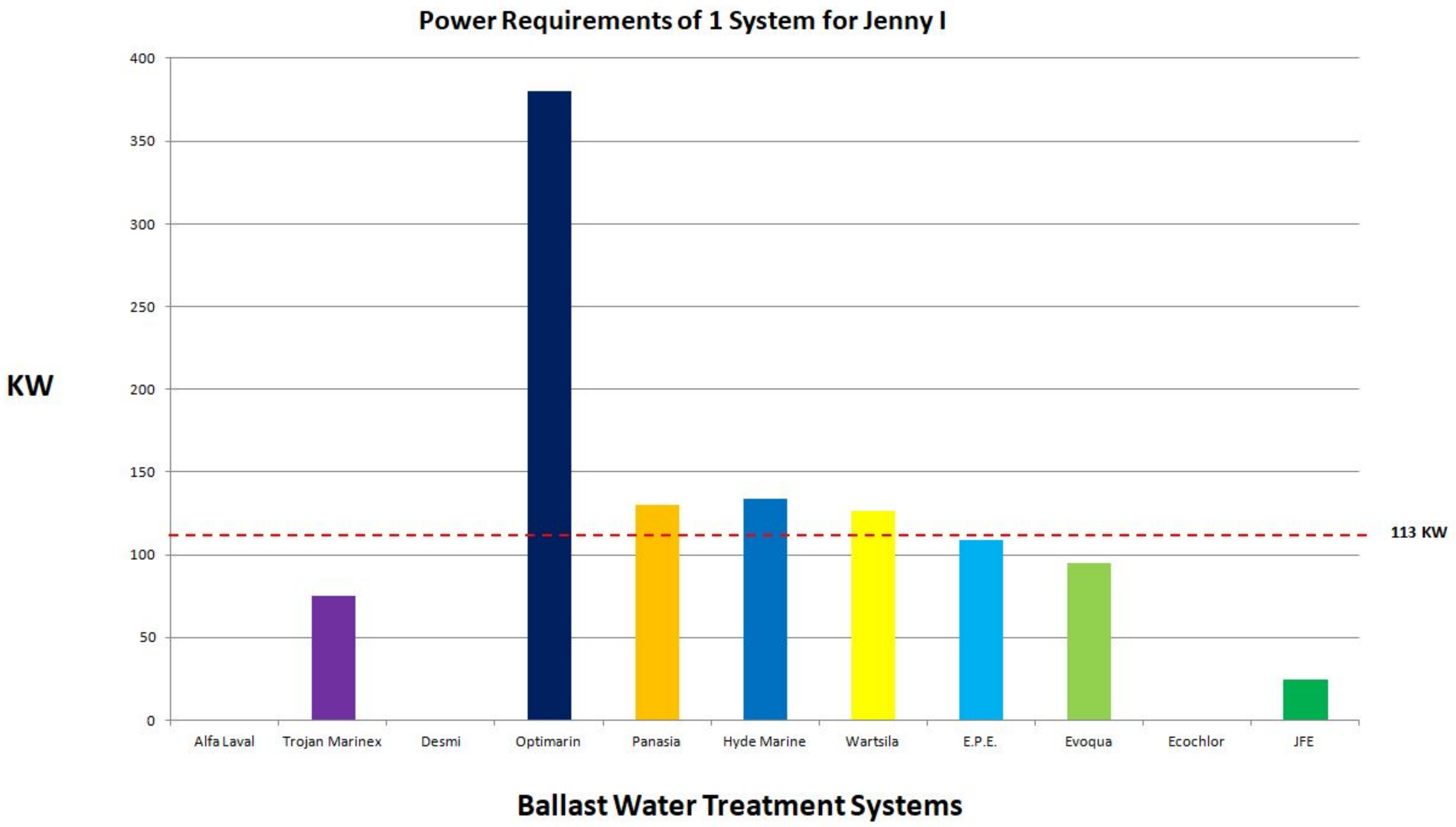

Figure 10: Power Requirements for 1 BWTS on Jenny I

3) M/T MABROUK

TOTAL LOAD	1291,4	KW								
TOTAL LOAD OF GENERATOR	2550	KW		**0,85% LOAD**	1445	KW		**0,85% LOAD**	2167,5	KW
	3	SET			2	SET			3	SET
AVAILABLE POWER FOR BWTS	**1258,6**	KW			**153,6**	KW			**876,1**	KW

Alfa Laval		2 x 2000 + 250 m3/h	533 KW	Power consumption can be reduced down to 50%
Trojan Marinex		4 x 1000 + 250 m3/h	179,2 KW	
Desmi		2 x 2000 + 200 m3/h	330 KW	Power consumption can be reduced down to 50%
Panasia		2 x 2000 + 250 m3/h	337 KW	Power consumption can be reduced down to 75%
Hyde Marine		2 x 2000 + 250 m3/h	331,5 KW	Power consumption can be reduced down to 70%
Wartsila		2 x 2000 + 250 m3/h	198 KW	
E.P.E.		2 x 2000 + 100 m3/h	265 KW	
Evoqua	Option 1	2 x 2000 + 300 m3/h	264 KW	
	Option 2	1 x 4000 + 300 m3/h	255 KW	
Ecochlor		2 x 2250 + 275 m3/h	38,2 KW	
JFE	Option 1	2 x 2000 + 300 m3/h	17,3 KW	
	Option 2	2 x 2000 + 300 m3/h	35,4 KW	

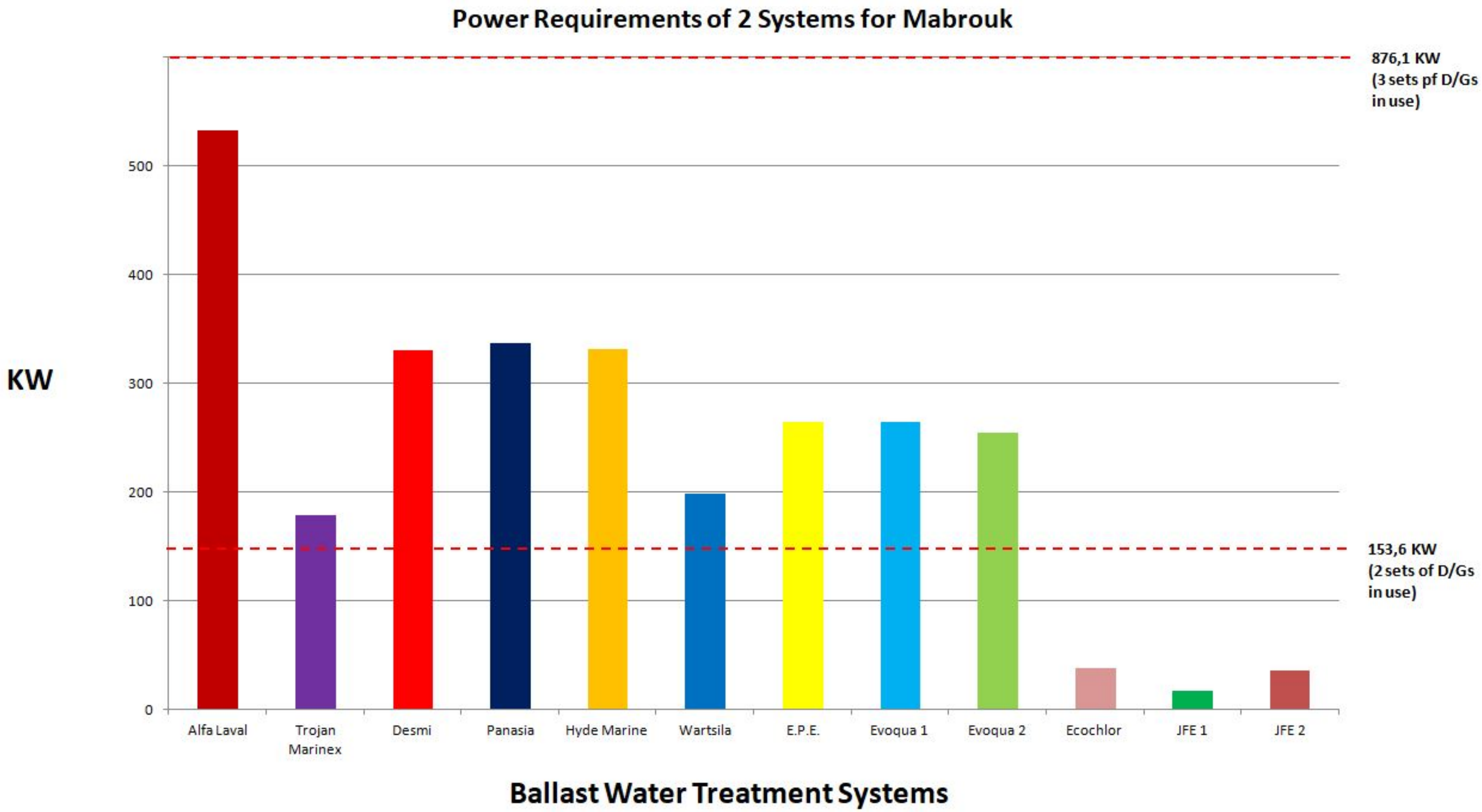

Figure 11: Power Requirements for BWTS on Mabrouk

8 Conclusions after Comparison of Ballast Water Treatment Systems based on their Power Demand

As mentioned above, the selection of a BWTS for a vessel is a complicated procedure due to the wide variety of parameters influencing each case. Although, the cost factor and the power demand factor remain the two most important parameters that determine the final decision. Given this fact, an explanatory analysis is presented for each vessel separately.

On M/T Minitank Five, it is clear that only the two systems with chemical injection (EcoChlor, JFE) are able to meet the power requirements with only two sets of diesel generators in use. That is applied in both cases, meaning it does not matter whether one or two systems are installed. On the other side, all other BWTS require three diesel generators to be in use in order to operate normally and have enough power at any time. In case the systems with chemical injection are rejected due to their high initial price and their increased maintenance and operational cost compared to the other systems, operational limitations may occur in the future. More specifically, the installation of BWTS will automatically mean that the vessel will require all three diesel generators to be available at every port in order to carry out loading and unloading operation successfully. If one diesel generator is stopped or a failure occurs, the vessel will not be able to carry out any cargo handling operation unless the problem is solved. This situation should be taken into consideration before deciding which BWTS should be installed. Nevertheless, it is obvious that with three diesel generators in use, all systems' power demands are fulfilled. Thus, BWTS with UV treatment should be well examined since their power consumption can be reduced at considerable levels, leading to reduced operational and maintenance cost. All in all, in the case of small size vessels like Minitank Five, it seems that the cost factor is the most decisive one as the power requirements are not too restrictive.

As far as the case of M/T Jenny I is concerned, a slightly different approach to the selection of BWTS is applied. First of all, spatial limitations restrict the options of BWTS when the installation of one system is preferred because pipe interferences do not allow for a large diameter pipe to be placed across the main deck. However, the factor that mostly determines the outcome of BWTS selection is the power demand. Based on the electrical load analysis, in loading and unloading condition, all three diesel generators are required. This means that there is only limited power available for the operation of the BWTS. As shown in the diagram of power requirements, most UV systems' power demands exceed the available power meaning they are automatically excluded from the selection process. On the other hand, BWTS with chemical injection, full-stream electrolysis and side-stream electrolysis meet the power requirements of the vessel and can operate normally within the set limits. A solution that could be proposed in order to improve the current situation would be the installation of another diesel generator. Given the fact, that the BWTS will be installed when the drydock repairs take place, it will be easier for the shipyard to complete the installation of another D/G. Although, even if a fourth diesel generator may widen the options of the available BWTS and ameliorate the power capacity in cargo handling operations, it is a difficult decision to be made due to the high cost of the new D/G and the changes that will take place in crucial areas of the engine room of the vessel. At the end, we should keep in mind that there are still available UV-based systems that comply with power limitations and that the total CAPEX cost should be involved in the final decision.

In the case of the suezmax vessel M/T Mabrouk, a similar pattern is observed as in Minitank Five. Chemical injection systems have low power demands and allow the vessel to complete cargo operations with only two diesel generators in use. However, if other BWTS technologies are to be chosen, it will be required for all three diesel generators to be in use while loading or unloading. The main difference between a suezmax and a smaller size vessel is that the chemical injection based systems have a lower initial cost meaning that they would be profitable in the foreseeable future. In the end although, the final decision will be made after taken in consideration all the aspects that might affect the vessel's operations and obviously the CAPEX cost for the following years.

A fact also noteworthy that cannot be projected in the diagrams is the quality of each system and their percentages of problems occurred during operation of the BWTS. In the CAPEX diagrams, it is noted that similar systems of the same technology have different equipment and maintenance costs. These variations are justified through the reliability of each system. Unfortunately, this factor cannot be measured accurately and will only noticed when the "flow of the market" is analyzed. In particular, some companies may choose a system that is slightly more expensive than other ones, believing that there will be less complications in the future influencing the vessel's operations. Below, there is a diagram showing the percentage of complications occurred for each type of BWTS technology.[7]

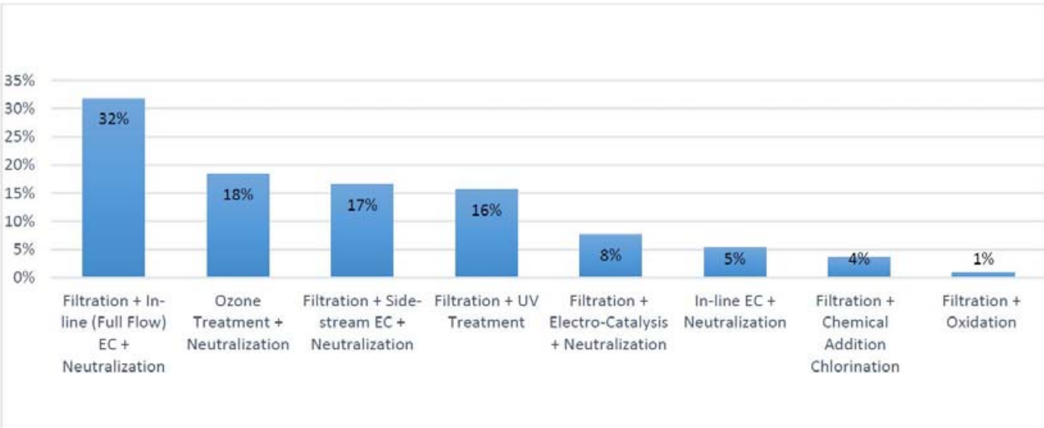

Figure 12: Percentages of incidents for different BWTS technologies

In conclusion, the selection of the most suitable ballast water treatment system for a vessel is a long process that requires from the ship-owner to take in consideration many factors that are usually different from one vessel to another. That means each case should be studied separately and having always in mind that there is no perfect system. Only the time will prove which decision was better since the operation of a vessel is a dynamic process with many parameters constantly changing. The only sure thing is that the shipping world is taking a step forward to a greener future.

9 Proposals for further research

The installation of BWTS was only applied on tanker vessels. It would be helpful if a study is carried out focusing on BWTS for bulk carries, containerships and LNG carriers. Also, it has to mentioned that the ballast water treatment systems are constantly updating and trying to improve their efficiency. This means that their power demands will be lower in some years and their reliability will increase. Nevertheless, the ship owners will always seek for the best solution for their vessels that will comply with the regulations and have the minimum economical impact on their shipping company. At last, from now and on, each Convention of the IMO is expected to provide many changes to the rally for the best BWTS and always affect the new technologies that are trying to comply with his requirements.

Appendix A

Following table projects the Ultra Violet Transmission (UVT) Data based on the condition and the quality of water in each port.

Port	Recorded UVT
Gothenburg, Sweden	87%
Bremerhaven, Germany	40%
Zeebrugee, Belgium	83%
Southampton, UK	68%
Port of Singapore	92%
Halifax, Canada	94%
Baltimore, USA	84%
Brunswick, USA	53%
Charleston, USA	85%
Shanghai, China	52%
Vera Cruz, Mexico	94%
Houston, USA	74%
New Orleans, USA	54%
Hong Kong, China	80%
Antwerp, Belgium	66%
Rotterdam, Netherlands	93%
Average	**74%**

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