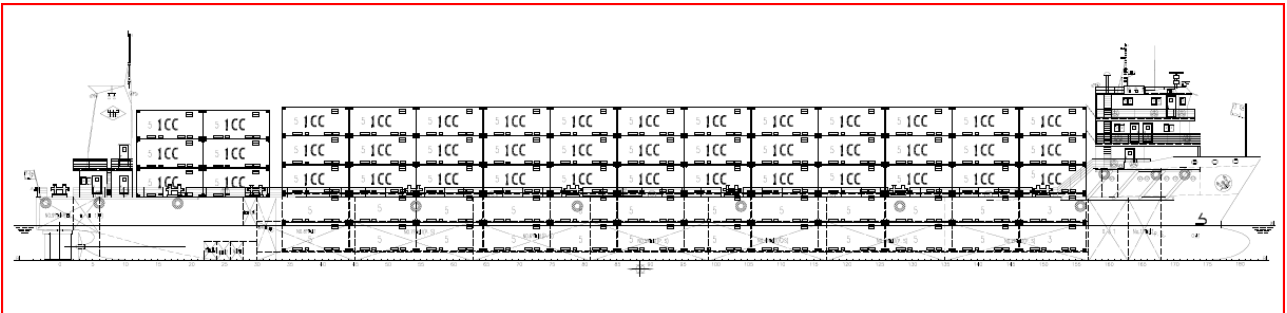


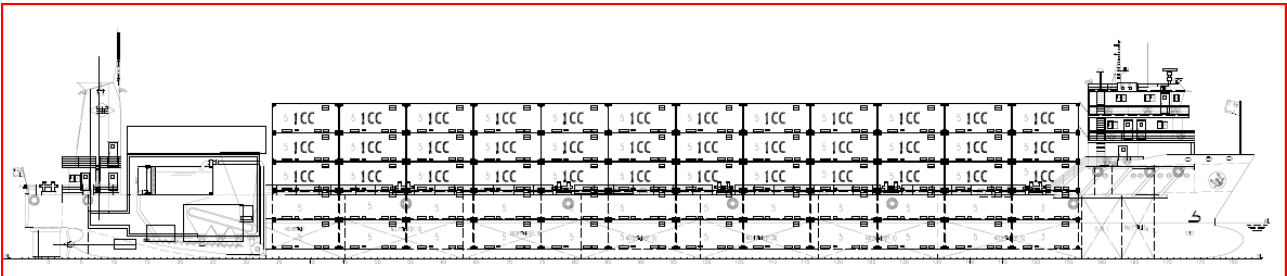
GREENRIVER BI-FUEL 3,5K

Patented technology

3,500 DWT CONTAINERSHIP



Fuel Arrangement (Dwg ID 414-100-001 existing vessel)



Dual Fuel Arrangement (engine room modified vessel)

Prepared By:



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1. Executive Summary

WEST Logistics S.r.l. (“WEST”) controls a patented naval propulsion system that allows ships to be fuelled by treated municipal or industrial wastes, biomass or any other type of refuse derived fuel (“RDF”), in lieu of petroleum based fuels. The energy produced from burning RDF is used for both the propulsion of the ship, as well as, all of its electrical and thermal requirements, while reducing air emissions by up to 98% when compared to a traditional maritime propulsion system. The WEST system offers significant environmental benefits, an exceptional return on investment and provides a hedge against the constant fluctuation in bunker fuel prices.

This report summaries the technical aspects of the confirmed feasibility in converting an existing 3,500 DWT containership from a traditional diesel propulsion system to a bi-fuel WEST technology system utilizing RDF as the primary fuel. In short, with a net shipping capacity loss of 30 standard shipping containers (equal to 10% of the overall ship capacity), there is the potential to reduce fuel costs to zero while reducing the air emission to levels well within MARPOL Annex VI levels and beyond. As the fuel cost represent upwards of 50% of the overall operating costs of a merchant ship, the costs of retrofitting the ship are quickly recovered and thereafter significant economic saving are realized by the ship owner-operator.

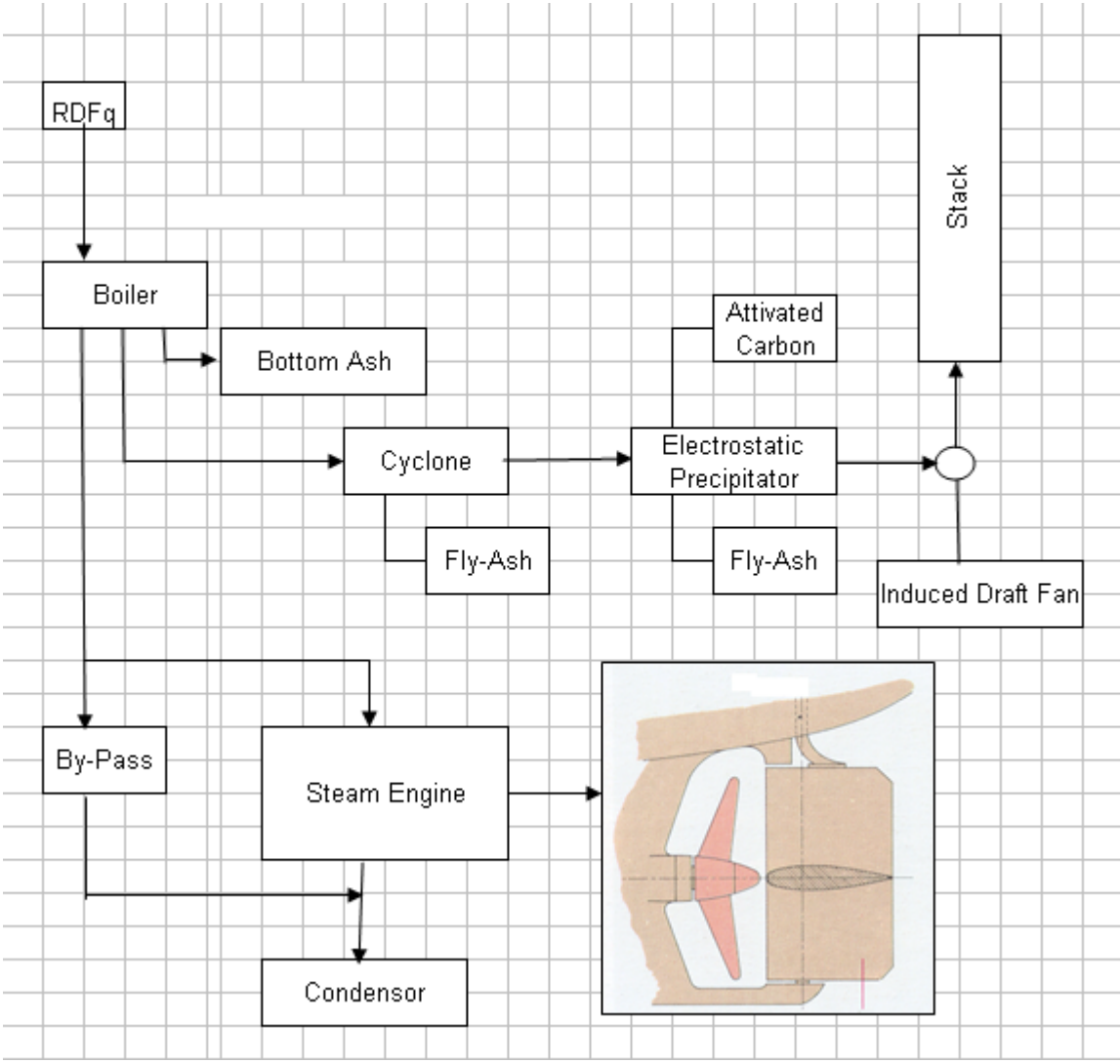
The system is fully compliant with all the latest European directives regarding the use of renewable energy sources and in particular: Directive 2003/30/Ce – ‘Promoting the use of bio-fuels and other renewable fuels for transport’.

Environmental concerns of the maritime nations have been transformed into a series of regulatory constraints which are addressing the way in which owners and operators build and manage their fleets. The effect of the MARPOL VI regulations is already seen in the cost of bunker fuels where low sulphur fuels are being increasingly required along with exhaust scrubbing equipment. New multi-lateral regulatory bodies and rules of governance and operations are having more influence in the way ships are designed, built and operated. MARPOL VI regulations dealing with sulphur and NOx emissions are only the first series in a wave of measures designed to reduce both land and maritime pollution.

WEST is seeking a strategic partner or financial investor to bring the patent to the next step; the first merchant ship fuelled by RDF.

2. Technical Highlights

The WEST system employs the use of treated municipal or industrial wastes, biomass or any other type of RDF meeting UNI 9903. The combustion system will be equipped with all the necessary measures for compliance with the most stringent environmental parameters in force. The ship's propulsion system is made up of the following main groups:



3. Ship for the river trade

An existing ship operating on the Yangtze River, with the following technical characteristics, was utilized to perform the technical feasibility study:

Length Overall LO	112,00	m
Length Between Perpendiculars LPP	106,30	m
Breadth Moulded	17,20	m
Depth Moulded	5,80	m
Design Draft	3,20	m
Scantling Draft	3,80	m
Light Weight	1346	t
Dead Weight at Design Draft	3500	t
Dead Weight at Scantling Draft	4492	t
Design Cruising Speed	11,34	knots
Primary Engine Power (two engines)	1167	kW
Onboard Services	1058	kW
Endurance	3000	miles
Capacity	300	TEU
Ref Dwg ID 414-100-001		

The conversion of a traditional diesel powered 3500 DWT containership to the WEST propulsion technology utilizing refuse derived fuel (RDF) in lieu of petroleum based fuels based upon the following constraints:

- 1) The entire existing engine room could be utilized for the new propulsion system, from frame 6 to frame 33, eliminating the existing diesel fuel tanks and modifying as necessary the ballast tank n.8.
- 2) The lose in shipping capacity must be kept to the bare minimum and in any case no more than 10% or the overall shipping capacity of the existing ship;
- 3) The WEST propulsion system shall utilize a specialized boiler for RDF combustion and implement a conservative steam cycle with the following parameters, 28 bar e 360 °C.

The steam will feed two reciprocating motor-generator sets with the following characteristics:

	26	bar
Inlet Engine Steam	355	°C
Outlet Engine Steam	0,5	bar
RPM	900	
Cylinders	4	
Length	5,5	m
Width	3,2	m
Power (electrical) 450 V, 60 Hz (each)	640	kW

The power will be fed to the Main Switchboard and from there directed to the two electric motors fitted with inverters to provide variable speed for powering the propellers.

4. Boiler Positioning and Layout

The specialized boiler required to provide the necessary steam utilizing RDF as its primary fuel takes up approximately 290 m³. The following dimensions were utilized for the boiler:

Length (frame 12 - 32)	12,0	M
Width	3,6	M
Height	6,7	M

The breadth of the ship at frame 18 is 16.58m, leaving 2m on each side of the boiler for manoeuvring and maintenance; there remains 12.58m available to position the boiler.

The longitudinal distance from frame 33 to frame 6 is 16.20m.

Therefore the new boiler room has the following dimensions 12,58m wide by 16,20m long.

$$12,58:2 = 6,29\text{m}$$

$$3,60:2 = 1,80\text{m}$$

Therefore, from the longitudinal axis we have the following distances:

Boiler area	1,80	M
Available area	1,29	M
Motor-generator zone	3,20	M
Total	6,29	M

In order to avoid losing an additional 2-3m longitudinally for the ram feed system, two fuel feed hoppers and two ram feeds are positioned laterally between frames 29-31.

5. Flue Gas Control & Balance of Engine Room Equipment

The flue gas extraction system shall be located in the existing stack and consists of the following components:

- Economizer for pre-heating the primary combustion air
- A cyclone as first stage particulate removal
- Soda injection system to neutralize the flue gases
- Electrostatic precipitator for secondary particulate removal
- Induced draft fans
- Fly-ash and particulate collection system

The balance of the primary engine room equipment will be situated as indicated below, see drawing for details.

1 boiler l=3,6 L=12,0 H=6,7	m	frame 12-32
2 motor generator set l=3,2 L=5,5 H=3,3	m	frame 21-29 Portside and Starboard side
2 electric motor		frame 10-13 Portside and Starboard side
3 electrical generators		frame 13-18 Starboard side

6. RDF Storage

Considering a consumption of 1.9 T/h during navigation and the need for 1700 miles of autonomy, a coefficient of filling of 0.75 and density of 1 T/ m³; it is determined that approximately 400 m³ of RDF storage, equal to approximately 300 T, is sufficient.

The fuel storage area shall be located between frames 12-32 with an overall dimension of:

Length = 20 x 0,6 = 12m
Width = 16,5m
Area = 16,5 x 12 = 198m² (circa 200m²)
Height = 2,25 m

Considering a bit of margin on the height, we will assume the RDF storage vessel to have a height of 2,40m the situation is as follows:

Height of main deck:	5,80m
Boiler Height:	6,70m
Distance from the bottom of the boiler to the keel	2,40/2,70m min./max
Distance from top of boiler to bottom of RDF storage:	0,30m

Therefore:

$2,40 + 6,70 + 0,30 = 9,40/9,70$ min./max, height at the bottom of the RDF storage + 2,40m (height of top of RDF storage).

Distance from the keel to the top of the RDF storage (overall height) = 11,80/12,10m min/max.

The RDF storage area is comprised of two separate RDF storage vessels each with a gross capacity of 260 m³. Each vessel is complete with a movable floor and screw conveyer to transport the RDF to the fuel feed hopper that supplies the specialized boiler.

7. Ash Recovery System

The bottom ash are collected and quenched with water in a closed basin situated under the grate of the specialized boiler. The quenched bottom ash has the consistency of sludge and is mixed utilizing a screw pump, then transported by means of a piston pump to two dedicated standard shipping containers located on the main deck.

Within each container there is a filter set that allows the excess water to drain and be re-circulated to the ash collection basin under the boiler grate.

The amount of bottom ash generated from the combustion of the RDFq is approximately 10% by weight or 250 kg/h, plus a water content of 80%, therefore 450 kg/h of ash sludge is deposited in the containers. Considering a density of 2500 kg/m³, the containers receive 0,18 m³/h of this ash sludge. The net useful volume of each container is 22m³, as such, the two containers provide storage space for 240 hours of navigation.

8. Structure & Estimate of its Weight

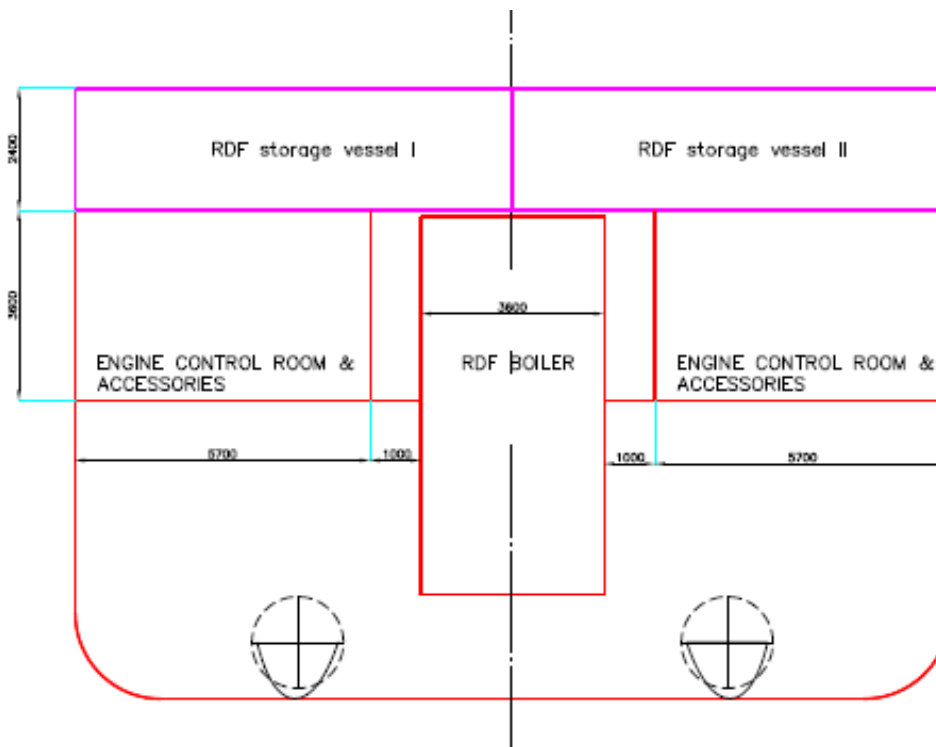
The height of the RDF storage vessel from the main deck is 3,6m. The structure enclosing the boiler above the main deck has a width of:

$$3,6\text{m (boiler width)} + 1,0 + 1,0 \text{ (free space portside and starboard side)} = \text{Total } 5,6 \text{ m.}$$

Therefore the available space, portside and starboard side for the engine control room and accessories $17 \text{ (breadth)}/2 - 5,6 \text{ (boiler enclosure)}/2 = 5,7\text{m}$

Note: if necessary the free space between the boiler and enclosure can be reduced

Hereafter we calculate the added weight associated with the new structure required by the retrofitting of the WEST propulsion system. First we calculate the added surface area, then assuming a specific weight of carbon steel 64 kg/m^2 , plus 33% to account for the underlying structure and an addition 7% margin for accessories (stairs, railings, etc.) we arrive at a total of approximately 90 kg/ m^2 .



Ship Cross-Section at Frame 22

- **1 bulkhead at frame 33, thickness 8mm**

length: 16,50m, height 6,00m \approx area 100 m^2

- **2 longitudinal bulkheads between frames 33 & 12**

length 12,60m, height 6,00m x 2 \approx area 150 m²

- **1 longitudinal bulkhead between frames 33 & 12**

length 12,60m, height 2,40m \approx area 32 m²

- **2 boiler enclosure bulkheads between frames 33 & 12**

length 12,60m, height 3,90m x 2 \approx area 100 m²

- **Area of the base and covering surfaces of the RDF storage area**

width 16,50m, length 12,60m x 2 \approx area 420 m²

- **Vertical aft surface of the RDF storage**

width 16,50m, height 2,40m \approx area 40 m²

Total added surface area

$$100 + 150 + 32 + 100 + 420 + 40 \approx 850\text{m}^2$$

Therefore, the total additional weight required for the conversion is:

$$850\text{m}^2 \times 90 \text{ kg/m}^2 \approx 80.000 \text{ kg} = 80 \text{ T.}$$

9. Consideration of Stability

Having calculated the additional weight required by the structure for the conversion in the previous section, we now need to confirm that the stability of the ship will not be compromised.

The ship as originally designed had 30 TEU positioned on the main deck, above the engine room. If we consider each container having a weight of 5 Tons and the centre of gravity of those containers to be 3,6 meters above the main deck we will have a moment equal to:

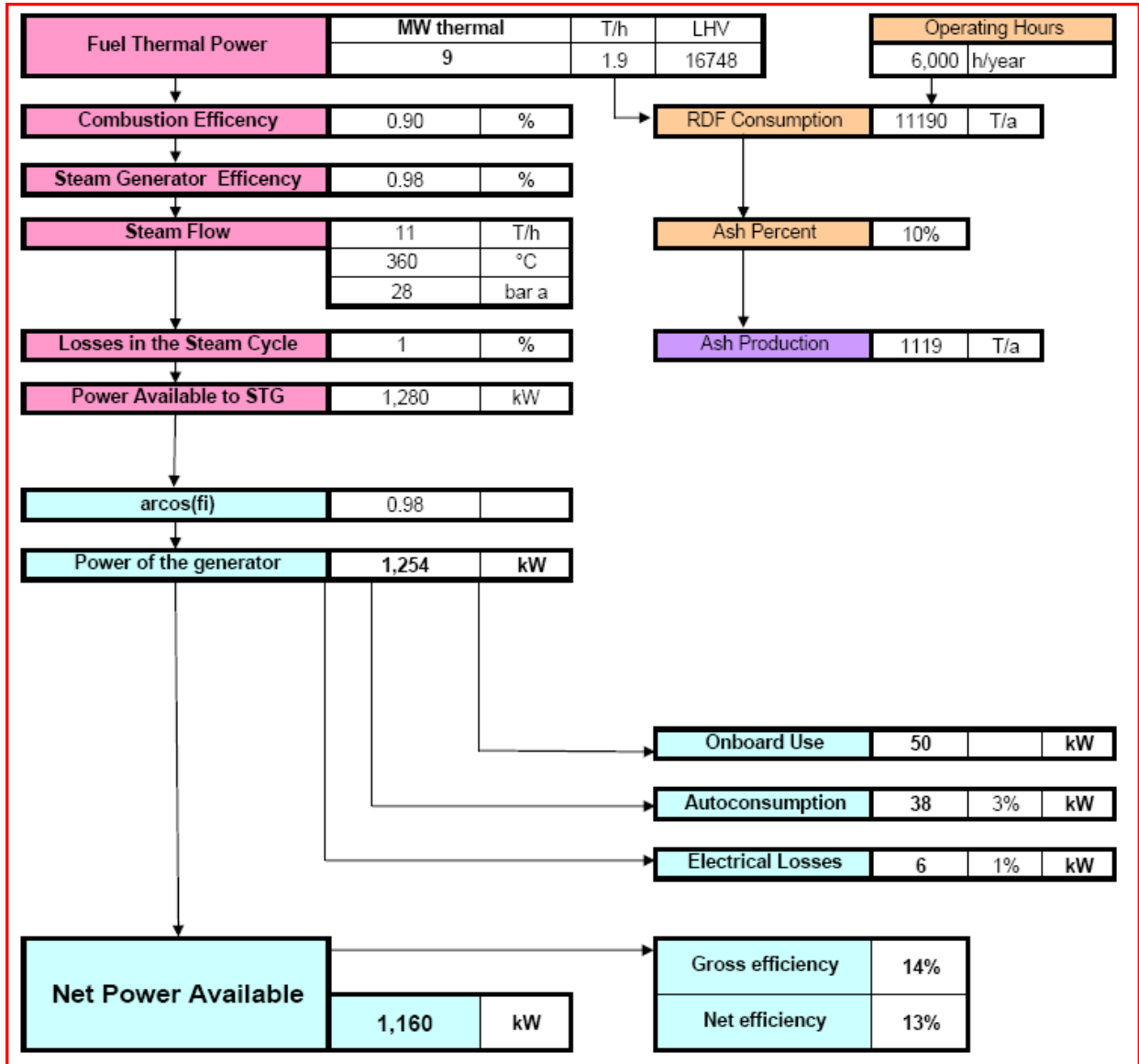
$$30 \times 5 \text{ T} \times 3,6 \text{ m} = 540 \text{ Tm}$$

After retrofitting the WEST propulsion system, the 30 TEU above the engine room have been eliminated to make room for the new structure describe in the Section 8. The new moment will be calculated using the additional weight of the new structure (80T) with a centre of gravity 3,0 meters above the main deck, or;

$$80 \text{ T} \times 3,0 = 240 \text{ Tm};$$

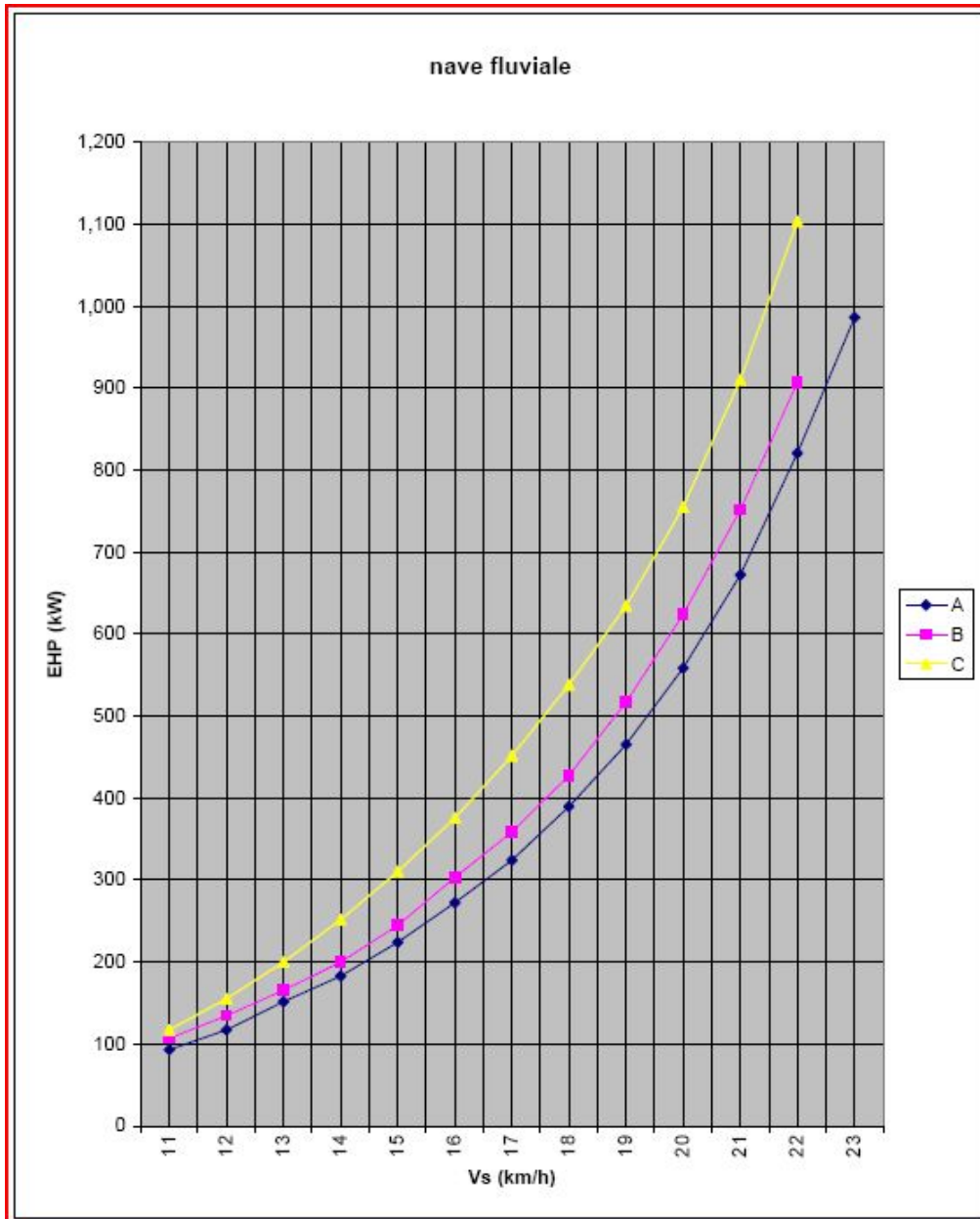
less than one-half of the original configuration. Clearly stability of the retrofitted ship will not be a concern.

10. Thermal Cycle Summary



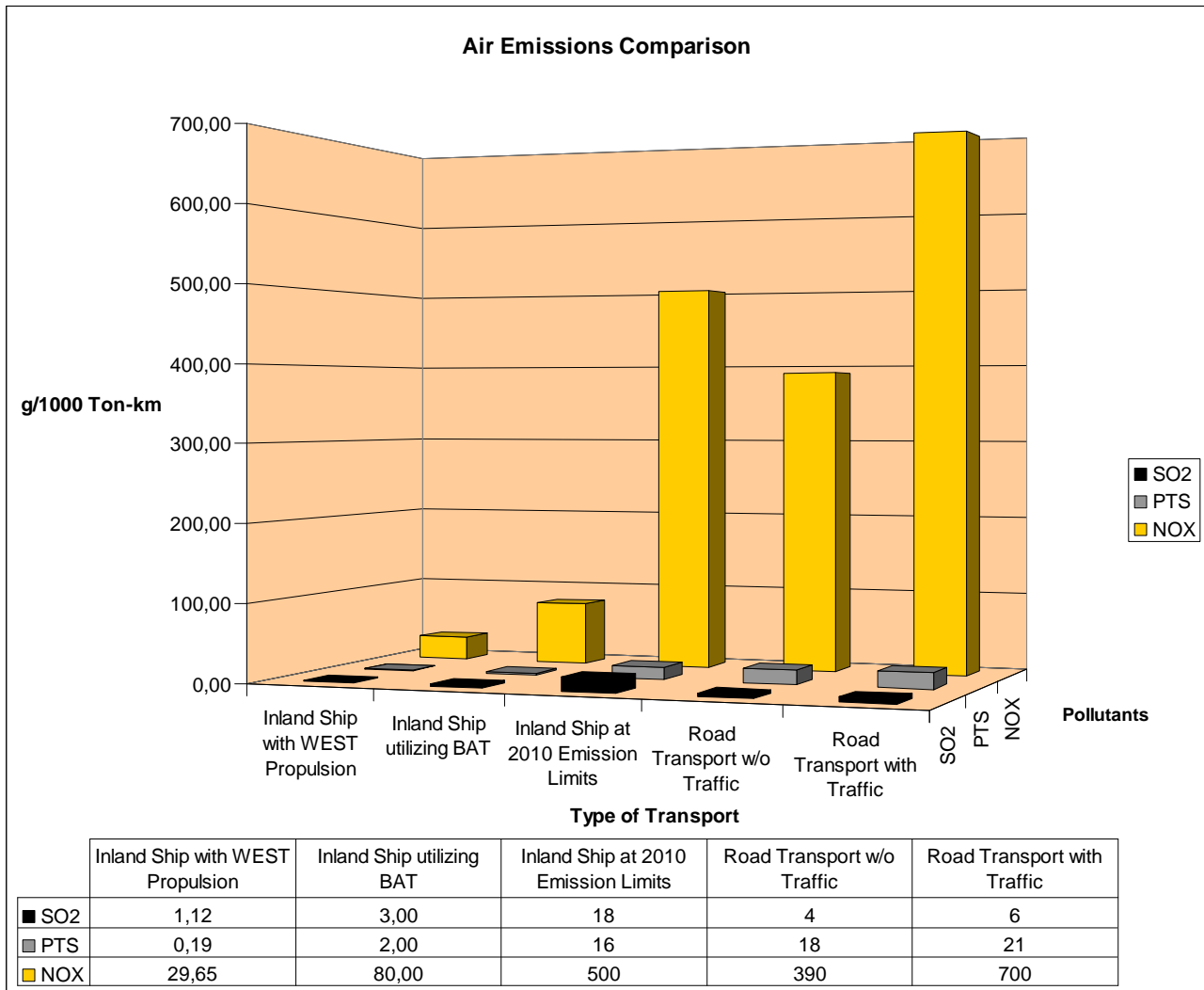
11. Power-Speed Curve

With the WEST RDF propulsion system 1160 kW net is available to the propellers, therefore a cruising speed of 11.9 knots is achievable at maximum load as the ship was originally designed.



12. Emissions Comparison

The below Chart represents the principal air emissions generated utilizing various transport modes and propulsion systems. The WEST propulsion system offers environmental benefits even when compared to the currently Best Available Technology (BAT); air emissions are between 60-90% lower than the current BAT. It is also extremely important to note that few if any fleet owners are implementing the current BAT due to its extremely high capital and operations costs. On the other hand, the WEST solution provides better environmental results with a return on investment and significantly lower operating costs.



13. Economic Considerations

Based upon the above technical modifications required to implement the WEST propulsion system, we prepared a financial projection of such retrofitting and subsequent operations. We used the following assumptions.

Ship Requirements

Output of Traditional Propulsion System	1.250	kW _e
Output of RDF Prop. System	1.250	kW _e

Capital Cost of Retrofit

Fuel Handling	€ 100.000
Boiler	€ 1.400.000
Ash handling system	€ 60.000
Steam Piping	€ 150.000
Steam Engines	€ 1.050.000
Sea-water Heat exchanger	€ 300.000
Condenser	€ 100.000
Flue gas Treatment	€ 250.000
BOP	€ 400.000
Electric Motors propulsion	€ 40.000
MCC/DCS	€ 250.000
Steel Works	€ 165.000
	<u>€ 4.265.000</u>

Fuel

Cost of MDO	404	€/ton
MDO Consumption	0,2516	T/hr
Tipping Fee RDF	15	€/ton
RDF Consumption	1,9	T/hr

Operating Costs

Fly Ash Disposal Fee	130	€/ton
Bottom Ash Disposal Fee	70	€/ton
Fly Ash Production	8,00%	
Bottom Ash Production	12,00%	
Operating Cost Traditional System	0,025	€/kW-Hr
Operating Cost RDF System	0,03	€/kW-Hr

Shipping Limitations

Days of navigation Annually	250	Days
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Escalation Factors

MDO	10,00%
RDF	1,00%
Fly Ash Disposal	5,00%
Bottom Ash Disposal	3,00%
Operations	3,00%

FINANCING

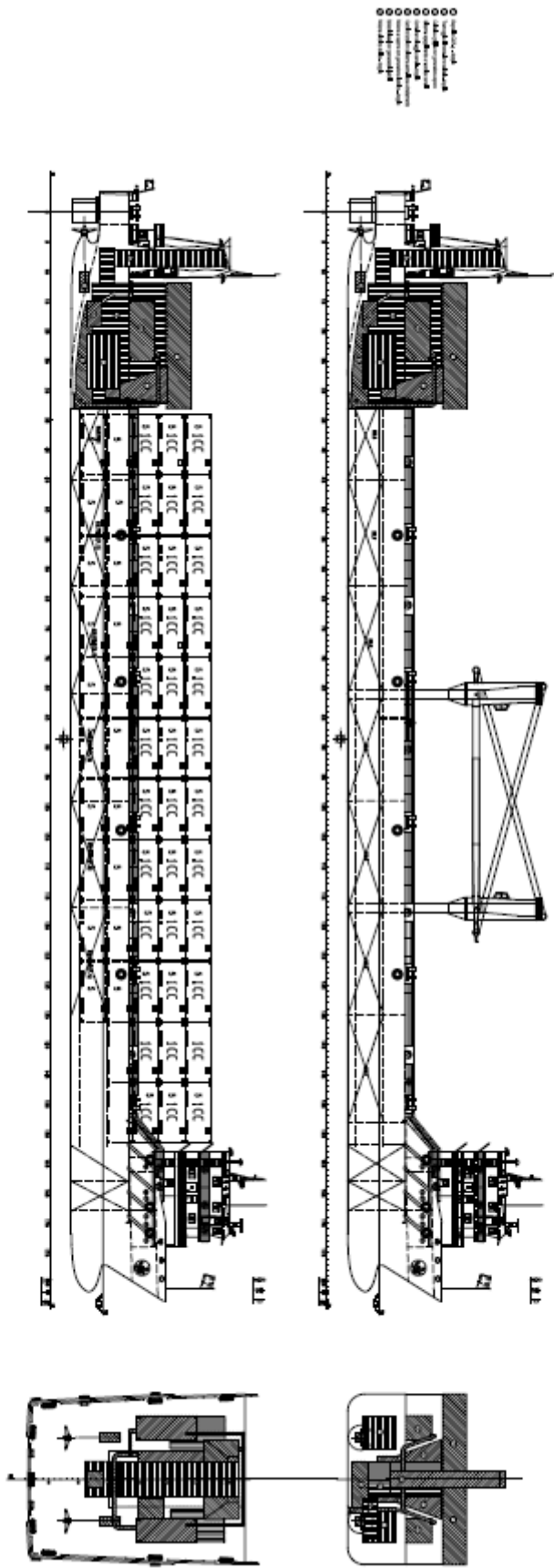
Bank Debt Interest Rate	5,41%	Percent
Project Contingency	5,00%	Percent
Equity	50,00%	Percent
Bank Debt	50,00%	Percent
Long Term EURIBOR	4,25%	Percent/Year
Senior Debt Margin	1,16%	Percent/Year

With these assumptions the operating cash flow, including debt repayment is represented below.

CASHFLOW	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
<i>Cashflow Euro</i>																
Gross Revenue	0	781.119	843.841	912.681	988.250	1.071.218	1.162.325	1.262.383	1.372.284	1.493.013	1.625.649	1.771.382	1.931.520	2.107.502	2.300.910	2.513.486
Operating Cost	0	-273.786	-284.489	-295.638	-307.252	-319.352	-331.959	-345.095	-358.785	-373.052	-387.922	-403.422	-419.580	-436.426	-453.990	-472.304
Operating Margin	0	507.333	559.352	617.043	680.997	751.866	830.366	917.287	1.013.500	1.119.961	1.237.727	1.367.960	1.511.940	1.671.076	1.846.920	2.041.182
Financed Capital	2.132.500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Equity Contribution	2.132.500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cashflow before Debt Service	4.265.000	507.333	559.352	617.043	680.997	751.866	830.366	917.287	1.013.500	1.119.961	1.237.727	1.367.960	1.511.940	1.671.076	1.846.920	2.041.182
Senior Debt Principle	2.132.500	1.855.275	1.492.750	1.066.250	533.125	0	0	0	0	0	0	0	0	0	0	0
Repayment Senior Debt Principle		-277.225	-362.525	-426.500	-533.125	-533.125	0	0	0	0	0	0	0	0	0	0
Senior Debt Interest Payment		-122.867	-110.177	-92.295	-72.105	-43.263	0	0	0	0	0	0	0	0	0	0
Total Debt Service		-400.092	-472.702	-518.795	-605.230	-576.388	0	0	0	0	0	0	0	0	0	0
VAT Settlement	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pre-Tax Cashflow	-4.265.000	107.241	86.650	98.248	75.767	175.478	830.366	917.287	1.013.500	1.119.961	1.237.727	1.367.960	1.511.940	1.671.076	1.846.920	2.041.182
Funds Available for Debt Service		507.333	559.352	617.043	680.997	751.866	830.366	917.287	1.013.500	1.119.961	1.237.727	1.367.960	1.511.940	1.671.076	1.846.920	2.041.182
Annual Percentage		13,00%	17,00%	20,00%	25,00%	25,00%										
Running Total - Percentage		13,00%	30,00%	50,00%	75,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%
Debt Service Coverage Ratio (DSCR)		1,27	1,18	1,19	1,13	1,30										
Average DSCR		1,21														
Net Pre-Tax Cashflow	-2.132.500	107.241	86.650	98.248	75.767	175.478	830.366	917.287	1.013.500	1.119.961	1.237.727	1.367.960	1.511.940	1.671.076	1.846.920	2.041.182
NPV@8%	3.803.383	-1.813.810	-1.741.595	-1.690.029	-1.579.448	-1.094.937	-599.355	-92.353	426.406	957.246	1.500.482	2.056.419	2.625.355	3.207.581	3.803.383	4.413.039
TIR	20,95%															

14. Conclusions

From our study it emerges that there is sufficient space available and the distribution of the weight make it feasible to convert an existing small containership from a traditional diesel propulsion system to the WEST bi-fuel propulsion system utilizing RDFq as the primary fuel. The result of this conversion is a much more environmentally responsible ship with significantly lower operating costs that more than justify the investment required. Actually after 5-7 years of operation, the retrofitting will have been repaid and thereafter important profits will fall to the bottom line of the owner-operator of the ship. The WEST bi-fuel propulsion system provides the owner-operator a cutting edge approach to naval propulsion, an interesting return on investment and the security that no matter what the fuel market brings this ship will be in condition to operate successfully.



- ① Перила ГИЭА - 0998
- ② Тимпал дийрэгжүүлэх модил - 0998
- ③ Цайга зүйлж наргасан зэрэг
- ④ Спирт хэргэмж зэрэг
- ⑤ Цайга дийрэгжүүлэх модил - 0998
- ⑥ Цайга зүйлж наргасан зэрэг
- ⑦ Мөрв наргасан зэрэг
- ⑧ Мөрв дийрэгжүүлэх модил - 0998
- ⑨ Мөрв дийрэгжүүлэх модил - 0998

