



## Utilization of refuse derived fuel (RDF) as fuel for Naval Propulsion

### 1. Objective of the proposed technology

**to utilize in an ecologically sound and innovative way RDF, generated from treated municipal and industrial wastes, to fuel a steam-powered naval propulsion system**

**The technology can be summarized as follows:**

- Innovative,* use for marine propulsion of a fuel born from very different needs and circumstances.
- Reliability,* utilizes the time tested principals of steam-powered naval propulsion systems, however the boiler is fueled with RDF an innovative and renewable fuel in lieu of bunker oil or coal.
- Improvements,* dramatically reduces operating costs and the associated impacts of petroleum price fluctuation.
- Environment,* allows the recovery through energy production wastes that would otherwise be unutilized and disposed of in landfills, reduces petroleum dependency, reduces air emissions and protects the seas

### 1.a The Principal aspects of it Feasibility:

#### *Aspects developed*

- The technology for the exploitation of RDF as a primary fuel in steam cycles is time tested and reliable, derives from the coal-fired boilers.;
- The RDF fueled steam-powered propulsion system requires 8-10% more space then its equivalent diesel counterpart (including fuel storage requirements).
- The use of RDF represents a significant reduction in operating costs (between 30-60%) and frees the owner operator from the petroleum fluctuations.
- The use of RDF allows an enormous reduction in air emissions, as the land based limits are orders of magnitude lower than the current MARPOL Annex VI limits.

#### *Issues to be developed*

- Shipboard storage of the RDF
- A logistics network to ensure availability of RDF and collection of ashes at the ports
- Integration of this new fuel into the existing maritime regulations
- Issuance of by one of the Classification Societies, certification of the fuel storage and handling systems
- For new builds, integration of the boiler and fuel storage systems into the hull structure to reduce weight and space loss. This should include the following.
  - Fuel loading and handling systems
  - Automation of the fuel handling system



- Fire protection systems for the storage areas
- Water-proofing the RDF or separation in watertight compartments
- storage of the ashes for port disposal/recovery

## 2. Brief Description of the Plant

The propulsion system is essentially comprised of the following components:

### - A grate type boiler for the generation of super-heated steam

- compact, ample turn-down ratio low ash production, high combustion efficiency and very reliable.

### - Steam Cycle

- condensing steam engine or turbine, condenser, boiler feedwater pumps

### - Flue Gas Treatment System

- exact make-up to be determined by the emission limits one wishes to achieve. Typically a scrubber and electrostatic precipitator should be sufficient. The system would be integrated with a automated control system.

### - Supervision and Control

- the plant should be fitted with a centralized 0distributed control system to allow remote control and archiving of all pertinent data.

### - Propulsion

- The steam produced feeds the condensing steam engine or turbine which in turn driver the propeller through a reduction gear or a electrical generator which powers electrical motors for propulsion and manoeuvring.

## 3. The Fuel

The fuel procurement, handling and storage requires particular attention.

The following characteristics are fundamental:

- **structure,**  
The RDF is prepared from manual or semi-automated selection of municipal and industrial solid wastes, in which the majority of recoverable material is removed, what remains represents ~50% by weight and has a relatively high heating value. The project envisions utilizing this material to fuel merchant ships.  
The RDF shall be compressed, bailed and stored in standard shipping containers; thus providing a mobile fuel warehouse that can be stored at port without environmental concerns.

- **Heat Value,**

The choice of a grate-type boiler was driven by its flexibility in accepting fuels of variable heating values, always respecting the air emissions required. The average heating value anticipated for the RDF is ~3600BTU/lb.

#### 4. Environmental Aspects

The following shows a comparison between the air emission of a 50MW diesel fueled propulsion system and a comparable RDF fueled system.

Fuel Type	Annual Usage in	Tons x year						
		HCl	CO	NO <sub>x</sub>	SO <sub>2</sub>	Total Organic Compounds	Particulates	HF
<b>Bunker Oil</b>	<b>46.200</b>	<b>0</b>	<b>30</b>	<b>391</b>	<b>2840</b>	<b>6</b>	<b>201</b>	<b>0</b>
<b>RDF</b>	<b>175.175</b>	<b>6</b>	<b>3</b>	<b>133</b>	<b>35</b>	<b>2</b>	<b>2</b>	<b>0.002</b>
<b>Increased emissions RDF vs.bunker Oil</b>		<b>6</b>						<b>0.002</b>
<b>Reduced emissions RDF vs Bunker Oil</b>			<b>27</b>	<b>258</b>	<b>2805</b>	<b>4</b>	<b>199</b>	
<b>% Change</b>		<b>100</b>	<b>-90</b>	<b>-66</b>	<b>-98.8</b>	<b>-67</b>	<b>-99</b>	<b>100</b>

#### 5. Cost Benefit Analysis

Without a specific project (ship) to evaluate it is not possible to provide detailed analysis, however from our studies the payback of the investment is achieved after 4-5 years and the IRR ranges between 25-100% depending upon the sizing of the propulsion unit and the leverage used in financing the investment.