# Development of Eco-Friendly Fishing Vessel
# An ecological vehicle powered by renewable energy

**Dr. Iryna Korol**
Association- Vessel Renewable Energy Research &Technology A-VERT
5809 Nicholson Lane Suite 410, N Bethesda MD. 20852 USA
Email: **irinakorol@hotmail.com**
I
**Prof.  Robert Latorre**
School of Naval Architecture and Marine Engineering
University of New Orleans, USA
Email: prof.latorre@live.com

**Abstract***:    Throughout the world fishermen sail to coastal fishing grounds and their catch provides daily food for millions of people. Given the impact of fishing, it is an important activity to enhance and align fishing operations with environmentally friendly practices. The authors have been active in this pursuit for more than a decade*

*The authors' survey of fishing practices identified the fuel consumed per kilogram of catch.  In turn this was used to estimate amount of greenhouse gasses per kg of catch for different kinds of seafood. Seafood like shrimp which are harvested by trawl nets has the highest values.*

*On going work is now focused on the use of bio-gas from fish waste as a means to reduce carbon footprint as well as fuel costs.  The results show there is a possibility for achieving a target of 10-15% reduction by modifying the fishing vessel engines to burn diesel and bio-gas.*

**Keywords:** carbon footprint, commercial fishing, fishing boat engine emissions.

## 1.  Introduction

The EVER 10 theme of ecological vehicle and renewable energy applies to fishing boats. Sail craft with small carbon footprints were the world's first fishing boats. Today fishing boats can be powered by sails, low emission engines, or a combination of both sail and engine.  An engine's carbon footprint can be reduced by burning renewable bio-gas (methane).

## 2. Problem Statement

Today's challenge is to develop the next generation of fishing vessel.  The portfolio of fishing vessel has thousands of designs. The boat designer's challenge is creating an ecological fishing vessel powered by renewable energy.  This design evolution must reflect the tight economic situation that is present in today's commercial fishing operations'                          .

1.  Increased operational costs, fuel, labor, insurance etc.
2.  Reduced fishing season and catch share reflecting reduced fish stocks from over fishing and environmental change.
3.  Reduced financial resources for updating/rebuilding fishing boats and gear.

## 3.  Approach and Results

Table 1 2005-2011 SC-3 Panel Goals

| Goal | Description (year) |
|------|--------------------|
| A | Formulation of fishboat engine emissions (2005) |
| B | Estimate of carbon footprint and NOx/kg of catch (2009) |
| C | Identification of fishing vessel types generate large air pollution |
| D | Estimate of fishing vessel carbon footprint and greenhouse gas emissions |
| E | Sustainable Fishing |
| F | Incorporation of Bio-gas Fuel |
| G | Utilization of Sail Power Technology |

Over the past decade, a series of studies were organized by Dr.Latorre, chair, Society of Naval Architects and Marine Engineers (SNAME) Technical and Research Panel, SC-3 Fishing Systems. [1,2]. The initial SC-3 study was on reducing fishing vessel fuel consumption at the design stage [1]. This was followed by an on-going SC-3 study pursuing the seven goals summarized in Table 1 This paper summaries these SC-3 activities and research results.

### A .Formulation of fishboat engine Emissions

To provide the framework for estimating fishing boat exhaust emissions, the authors developed equation (1) for the fuel Q burned by the engines. The fuel burn Q can be estimated using the engine specific fuel rate, SFR g fuel/kW-hr, the engine power kW and the hours of at-sea operation T and conversion factor $\gamma$

$$Q = SFR x kW x T x \gamma \quad [t] \quad (1)$$

For combined sail and engine powered fishing boats, it is useful to introduce $\alpha j$ the percent of voyage running at power levels $kWj$ corresponding to specific fuel rate $SFRj$:

$$Q = \sum_{j=1}^{n} Qj = \sum_{j=1}^{n} SFRj x kWj x \alpha j T \quad (2)$$

Equation (2) requires details of the fishing vessel operation to define $\alpha j$. This is difficult to generalize. It depends on boat design, as well as fishing location.
For emissions Ei kg/day, equation (3) is introduced. It is useful to identify the higher emissions fishing vessels.

$$Ei = ki x SFR x kW x T x \gamma \quad [kg/day] \quad (3)$$

Table 2 Carbon footprint from fishing adopted from [2]

| Fishing System | kg catch / liter fuel | gram $CO_2$ /kg catch |
|----------------|----------------------|----------------------|
| Dredging | 18 | 180.75 |
| Purse Seining | 5.4-7.8 | 417-656 |
| Long Liner | 2.15 | 1340.3 |
| Bottom Trawling | 1.55-3.0 | 1084.5-2085.5 |

Here:
ki      Emissions per tone of fuel burned [kg/ton fuel]
kW      Fishing Vessel propulsion power [Kw]
Q      Fuel consumed [kg]

SFR      Engine specific fuel rate [g/kW-hr]
.      Here SFR = 212 g/kW-hr is used.
T      Operating time [hrs]
$\alpha$      At sea operating ratio for engine power level $kWj$
$\gamma$      Conversion factor [tons/kg]

### B Estimate of Carbon Footprint and NOx/kg catch

The motivation for the initial SC-3 study was to reduce the fishing boat fuel consumption [1]. This study included collecting data on fuel consumed per kg of catch. Table 2 shows the bottom trawlers have the largest values. For this paper we have used the 1995 onboard engine measurements [4] to estimate the carbon footprint g $CO_2$ /kg catch in Table 2.

### C Identification of fishing vessel types generate large air pollution

The values of 1-2 kg of $CO_2$ /kg catch for long liners and bottom trawling are nearly twice the values of purse seining.
Table 3 Marine Diesel Engine Emissions circa 1995, [3]
Key: *slow speed diesel measurements,
     **medium speed diesel measurements

| Emission | ki =kg/ton fuel | g/kW hr |
|----------|-----------------|---------|
| NOx | 87* 57** | 17* 12** |
| CO | 7.4 | 1.6 |
| HC | 2.4 | 0.5 |
| $CO_2$ | 3170 | 660 |

Fig 1  Trawler Power versus Vessel Length L[2]
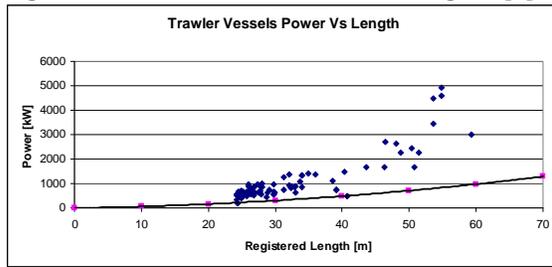

Trawler Vessels Power Vs Length

Table 2 provides a clear indication that these fishing operations are not very environmentally friendly. Part of the problem is the large propulsion engines in these fishing boats. The other greenhouse emissions [GHE] measured for the IMO rules are summarized in Table 3. To further understand the reason for the high level in seiner and trawler emissions, a separate study of US fishing vessels was made. [2]. Figure 1 shows a comparison of 98 trawlers' engine power kW versus the design line kWo for similar ships.

$$kWo = 3.9217 L + 0.2054 L2 \quad [kW] \qquad (4)$$
where 10<L<70 m

Both seiner and trawler propulsion power is compared to this baseline kWo value by a ratio:

$$PIR = kW/ kWo \text{ at length L} \qquad (5)$$

The ratio PIR is that of the actual fishing vessel power kW to reference power kWo at 12 kts for a given fishing vessel length L

To examine this powering trend, the seiners and trawlers are separated into two groups in Table 4:
Group I   PIR  < 2.5
Group II PIR > 2.5
Table 4 shows that for the seiners Group II contain 32% of the seiners and 50% of the total seiner power. Trawlers have a different trend with Group II containing 66% of the trawlers and 80% of the total trawler power.
 From the viewpoint of carbon footprint, and

Table 4 US Fishing Vessel PIR Values [2]

| Vessel Type (No) | Total kW total | Group I 1.0 <PIR< 2.5 | | Group II 2.5< PIR | |
|---|---|---|---|---|---|
| | | No (%) | kW (%) | No (%) | kW (%) |
| Seiner (120) | 209, 714 | 82 68% | 50% | 38 32% | 50% |
| Trawler (98) | 98, 716 | 33 34% | 20% | 65 66% | 80% |

Table 5  Calculated US fishing vessel engine emissions for vessels L> 23m[2]

| Emission | Ei Value | Units |
|---|---|---|
| NOx | 306 | [ton/day] |
| CO | 40 | [ton/day] |
| HC | 13 | [ton/day] |
| $CO_2$ | 16995 | [ton/day] |

greenhouse emissions, a detailed analysis of the Group II fishing vessels is needed. This design problem is an ongoing subject in the current  SC-3 panel activities.  The target is to define what is the appropriate seiner and trawler power for a given vessel length L.

*D US FISHING FLEET ENGINE EMISSIONS ESTIMATES*

The SC-3fishing boat analysis also estimated the total US fishing vessel engine emissions [kg/day].  Table 5 summarizes the US fishing vessel engine emissions/day obtained from eq (3)
The breakdown of NOx emissions by decade is shown in Fig. 2.This  is for fishing vessels with length L greater than 23  m.  It is clear from this figure the largest contributors are the fishing vessels built in the 1970's and 1980's. This trend is also evident when the average NOx emissions/vessel values are compared by decade in Figure. 3   Figure 3 shows that relatively newer US fishing vessels built in 1970 -1980 decades have a significantly higher NOx emission (300 kg/day) averages compared to (NOx 100-200 kg/day) average values for vessels built in 1920-1950.
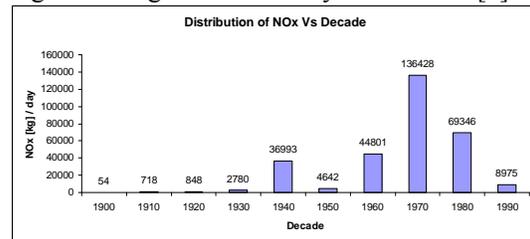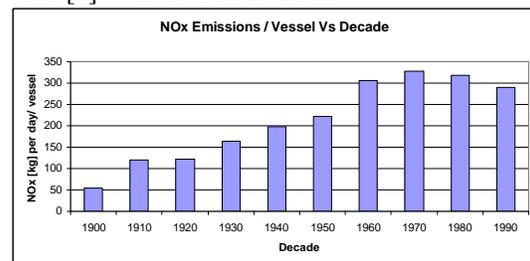.

Fig 2  Fishing Vessel NOx by decade built[2]


Distribution of NOx Vs Decade

Fig 3  Average Fishing Vessel NOx by decade built [2]  Vessel with L>23 m.


NOx Emissions / Vessel Vs Decade

The main recommendations from this analysis of the US fishing vessels are:
1The power/length ratio is a better index than vessel age for deciding the fishing vessel's environmental impact.
2. Fitting the fishing vessel engines with emission reducing systems will need to be implemented

## 4. Current Research Direction

The current SC-3 direction is based on adopting a fisherman's perspective. The consequence is the design and operation of fishing vessels are currently being examined for three fishing operation periods T:
(I)      a morning (T< 6 hrs),
(II)     day   (T<12 hrs)
(III)    day out (T< 24 hrs).
TheSC-3 panel is looking at ecological fishing boats powered by renewable energy for each scenario. This approach allows the inclusion of a number of interesting fishing vessel design concepts including:

- Sail powered
- Combined sail-powered boats
-  Propulsion engine burning a range of fuels such as bio-gas (methane) to conventional heavy oil.

*A Sustainable Fishing*

The market forces of energy costs and restricted fish harvesting is downsizing the current vessel size to a smaller  more economical fishing boat. A smaller boat fits well in achieving sustainable fishing.   There is also an important linkage of processing the waste  part of the catch into bio-gas (methane).

*B Incorporation of Bio-gas Fuel*

On going work is now focused on the use of bio-gas from fish waste as a means to reduce carbon footprint as well as fuel costs.  The results show there is a possibility for achieving a target of 10-15% reduction by modifying the fishing vessel engines to burn diesel and bio-gas.

It is clear that bio-gas production requires a proportionally large amount of waste.  This implies the need to use duel fuel engines for the near term.  Current duel fuel engines have shown the effectiveness of injecting a small amount of diesel fuel to ignite the bio-gas. This injection scheme allows the engine to run on both fuels.

Working with the system design approach it becomes clearer that the fish processor will become an energy center generating the bio-gas from its process waste.
A current study is examining this concept and the amount of bio-gas generation.

*C  Utilization of Sail Power Technology*

 Finally the development of fishing vessels powered by affordable renewable energy will mark a return to sail power.  The hope of the authors is to join the authors of this EVER'10 session to develop state of art wind propulsion.

## 5. Conclusions
The following are the main conclusions:
1. The current US fishing fleet experienced a growth in numbers and installed power in the 1970-1980's.
2. An estimate of 306 ton/day NOx was obtained in the fleet emission analysis.
 3. A significant number of trawlers and seiners are overpowered.
4.  Using the Powering index ratio PIV = kW/kWo, the overpowered value of PIV > 2.5 represents 32% of the Seiners, 66% of the trawlers

## 6. References

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