# GREEN TUGS - BEING ENVIRONMENTALLY-FRIENDLY THROUGH DESIGN, CONSTRUCTION AND OPERATION

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## SUMMARY

As concerns about global warming and the impact of modern society on the environment continue to be debated, the marine industry has an opportunity to demonstrate its commitment to responsible stewardship of the waters and coastlines that we travel.

This paper focuses on one aspect of the industry: ship assist tugs that are in every port city. These vessels have a unique operating profile that lends itself to different propulsion technologies and hence opportunities for reducing engine emissions. Beyond improving the propulsion plant, there is also opportunity for use of recycled materials, selection of low-energy equipment, use of environmentally-friendly operating practices, and design for ultimate vessel disposal. The author hopes that the environmentally-friendly design principles laid out in this paper might apply to a wide range of vessel types. The author will also discuss the possibility that the shipping industry adopt an environmental certification program for vessels similar to those certification programs for buildings that have been developed in the U.S. and Europe.

## 1. ENVIRONMENTAL AWARENESS

It seems that every maritime magazine and newspaper is carrying articles about the marine industry and the environment. Starting with the ***Exxon Valdez*** and continuing with other high profile marine pollution incidents such as the ***Erica***, the initial focus was on oil pollution. In recent times with the Kyoto Treaty, debate on global warming, and various studies, the emphasis has expanded to all aspects of the environment. Marine operators need to carefully consider their role in air pollution, water quality, hazardous materials disposal and handling of various waste streams.

As the awareness of environmental issues grows, so does the pressure for increasing regulation. We have seen localized efforts, such as the Port of Los Angeles mandating speed zones, as well as regional efforts, such as the designation of Sulfur Emissions Control Area (SECA) in the Baltic. On the global front, the International Maritime Organization (IMO) has recently enacted standards for engine emissions. This standard, MARPOL Annex VI, became effective worldwide on May 2005. It is enforceable on vessels of 400 gross tons and larger. Among other things, Annex VI sets limits on sulphur oxide ($SO_x$) and nitrogen oxide ($NO_x$) emissions for diesel engines of >175 horsepower. As of September 2006, 36 countries have ratified this annex, representing 70.6% of world tonnage [1].

In the United States, we have seen national, state and local government efforts to regulate the marine industry. These efforts have ranged from the U.S. Environmental Protection Agency (EPA) setting standards for exhaust emissions from marine diesels to Alaska State Department of Environmental Conservation setting requirements for gray and black water discharge. As of 2007, the EPA is requiring all marine engines to comply with its so-called Tier 2 requirements, which limit the amount of $NO_x$, total hydrocarbons, carbon monoxide and particulate matter that an engine can produce. These requirements apply to all diesel engines of 50 horsepower or more.

One area that has been a focus of attention is harbour service craft (HSC). Various studies of air pollution in port areas have pointed to tugs, pilot boats and lighters as a significant source of air pollution. A study in California [2] has shown that HSC contribute up to 21% of the air pollution in 2001 and, as land-based transportation continues to reduce its contribution to air pollution, the contribution by HSC will increase to 26% by 2020 [Figure 1].

| $NO_x$ tons per day) | 2001 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|
| Ships | 94.4 | 116.9 | 123.6 | 89.9 | 77.8 |
| Harbour craft | 85.8 | 86.1 | 61.5 | 55.7 | 47.5 |
| Cargo handling equipment | 20.9 | 18.7 | 12.2 | 5.9 | 3.5 |
| Trucks | 128.9 | 113.7 | 61.3 | 48.5 | 44.2 |
| Locomotives | 76.5 | 59.2 | 43.1 | 22.0 | 8.7 |
| Total | 406.5 | 394.6 | 301.7 | 222.0 | 181.7 |

*Figure 1 – $NO_x$ Emissions: State of California Environmental Action Plan*

Being a good environmental citizen has been taken by some businesses as meaning just greater costs. In some cases this may be true but there is a more holistic way of regarding corporate social responsibility. The Fractal Triangle [Figure 2] is a concept introduced by McDonough-Braunhart in 1998. Companies can make a profit while balancing the needs of the environment and the needs of different peoples. For example, Starbucks can sell premium coffee that has been raised in a way that least impacts the environment and provides a viable living for the farmers.

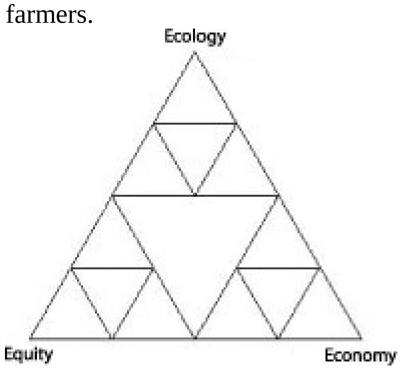


*Figure 2 – The Fractal Triangle*

The marine industry has a clear choice. It can be reactive to a variety of different environmental regulations or it can become a strong voice for clear, measurable environmental standards. It can become actively involved in the debate in the EU and the United States on how various sources of pollution should be regulated. It can also promote the development of new vessel technologies to offer a variety of ways to meet the environmental challenges. One way to establish leadership in environmental issues is to promote the construction and operation of "green" harbour tugs.

## 2. GREEN HARBOUR TUGS

One could legitimately ask, "Why harbour tugs?" For the author, they are the symbol of the harbour, always present, always assisting. If we can use the harbour tug to sell the message of environmental stewardship, then we are also communicating with the local authorities that the marine industry is serious about the environment. Another advantage of reducing the pollution from harbour tugs is that the expense may be offset by selling pollution credits. This approach is being used in the Los Angeles area with some success.

The energy demand of a vessel is characteristic of the type of vessel. Ocean-going ships require steady output for many operating hours annually. Yachts may need high bursts of power, but they are at dockside or anchor most of the time. A harbour tug, however, needs high power output for approximately 20% of the time underway. For most of their time they move around the port at relatively low power and also spend a moderate amount of time dockside.

## 2.1 DESIGN & CONSTRUCTION

The opportunities for a green tug begin with the design. As naval architects, our brief should be to look at all aspects of the vessel and consider ways to address environmental issues. This can range from protective location of the fuel tanks, to minimize the chance of a tank being breached due to a collision or an allision, to the use of light emitting diodes instead of incandescent light bulbs. Two specific examples are given below.

<u>Propulsion</u>

The propulsion system needs to produce minimum emissions for the required power. This begins with careful hull design to minimize drag when the vessel is underway. It also goes to using the most efficient means of translating power into the water. For a typical diesel engine driving a fixed pitch propeller, approximately 55% of the chemical energy from the fuel gets wasted as heat. Therefore, for every 1% improvement in propulsive efficiency, the chemical energy demand is reduced by 2.2%.

Azimuthing propulsion has found favor in the majority of harbour tug applications because of its combination of high maneuverability and good propulsive efficiency. Let's assume that remains the system of choice. How then to drive it? We need a system that will produce fewer emissions than a conventional diesel. Some options, in order of decreasing emissions, are given below:

- Diesel with SCR or exhaust scrubbers
- Diesel-electric with battery storage
- LNG spark-ignited engine with battery storage
- Fuel cell

This energy profile is similar to switching engines that move rail cars around a train yard. Many of these engines are powered by diesel engines driving electric motors to produce the high torque necessary to shove a train of cars into motion. This is proven technology and very robust, making it suitable for consideration in a tug application. Therefore, we can imagine fitting a twin screw tug with each propulsion system consisting of a battery bank, an electric motor driving the propeller, and a diesel generator of modest size to recharge the battery bank. My company is currently working on such a project for an East Coast client.

<u>Materials</u>

Another opportunity in the design of vessels is to look at the materials selected. There is a carbon footprint associated with every material. By being aware of the energy effect, the designer can look for choices that balance cost with environmental benefit. Some areas to consider include the use of recycled material, such as recycled tires for fendering or steel (owners need to demand that shipyards and steel suppliers post the recycled content). A graph of materials and their energy content is given below [Figure 3].

## 2.2 OPERATION

The quest for reducing the environmental impact continues into the operation. Every aspect of the vessel, from the type of light bulbs to the choice of paint, can be examined for opportunities. Some ideas are given below:

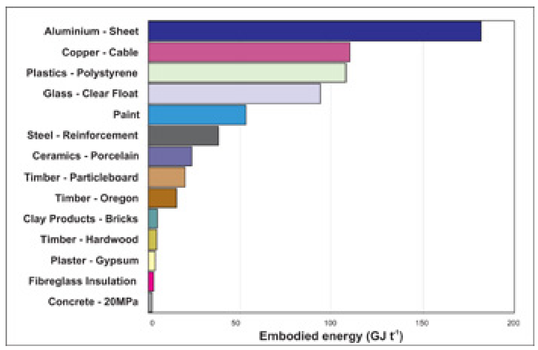


*Figure 3 – Embodied Energy for Various Materials*

<u>Propulsion</u>

- Paint the hulls with an antifouling that reduces resistance, either one of the ablative types or one of the silicone types.
- Polish the propellers periodically to optimize performance.
- Monitor the operational styles of the various captains. Offer incentives for those who drive the boats in a "low energy" style with smooth accelerations and de-accelerations.
- Calculate the optimal underway trim for greatest efficiency at different speeds and drafts.

<u>Electrical</u>

- Periodically conduct thermographic surveys of the vessels to identify areas where poor electrical connections may be resulting in heat loads and loss of efficiency. Areas to examine include the main and emergency switchboard, electrical distribution panels and transformers.

- Replace incandescent light bulbs wherever possible with low wattage LED bulbs.
- Select modern programmable HVAC system controls that might include cut-outs for when the people are not in staterooms.
- Install thermally efficient double-pane windows to minimize heating and cooling loads. Additionally, reflective films can be used to reduce solar loading.
- Paint the vessel with light colors to reflect the solar load to the greatest extent possible.
- Select galley/food service equipment and laundry equipment with high energy efficiency ratings.

<u>Materials</u>

- Paint the hulls with low VOC paints or use vinyl films that don't require frequent repainting.
- Select low maintenance materials wherever possible, including fiberglass, stainless steel and aluminum.
- Use environmentally-friendly cleaners to maintain interior and exterior spaces.
- Use bio-degradable oil in all hydraulic systems.
- Examine the vessel's waste stream to minimize packaging, maximize recycling, and responsibly dispose of what remains.

### 2.3 DISPOSAL

The economic life of all vessels ultimately must end. At that time, the ship owner should ensure that the disposal is handled in a proper manner. There has been some significant discussion of this at IMO and the voluntary use of a "Green Passport" has been promoted as a way to deal with disposal issues. Lloyd's Register issued the first such passport in 2004. The author sees the greatest challenge is making it financially rewarding for shipyards to get the necessary training and certification to properly dispose of vessels.

## 3.0 CERTIFICATION PROGRAM

The maritime industry needs to promote firms that go the extra distance in environmental awareness. We should create a program similar to those in the building industry, such as the Leadership in Energy and Environmental Design (LEED) that has been developed by the U.S. Green Building Council. We are increasingly seeing the marketplace and the municipalities recognize the benefits of LEED construction. I believe the marine industry would benefit from a similar program.

What is LEED certification? It is a "voluntary, consensus-based, market-driven" system that is "based on accepted energy and environmental principals and strikes a balance between established practices and emerging concepts." [3] A building project is reviewed by an independent panel. Points are assigned in five core and one bonus credit areas as shown below [Figure 4]. Depending upon how well the building complies with various credits, it is recognized as Certified, Silver, Gold or Platinum [4].

In the building arena, a project that meets various levels of certification may be granted favorable tax status or may just simply be a means for the community or developer to say "We care". Of course, there are operating benefits from the lower energy demand though initial construction costs are typically higher.

I propose a marine version that I will call Significant Environmental Awareness and Stewardship (SEAS). This certification program could be developed by a technical organization, such as the Society of Naval Architects and Marine Engineers. Core areas similar to the building focus would be:

| *LEED Core Credit Areas* | *Proposed SEAS Core Credit Areas* |
|---|---|
| Sustainable sites | Construction Site |
| Water efficiency | Propulsive Efficiency |
| Energy and Atmosphere | Emissions |
| Materials and Resources | Materials and Resources |
| Indoor Environmental Quality | Human Factors Engineering |
| Process and Design Innovation | Process and Design Innovation |

*Figure 4 – Comparison of Core Credit Areas*

By volunteering to have a vessel certified under SEAS, an owner shows a commitment to good environmental policies. We should encourage companies contracting for services, such as oil majors, to state a preference for SEAS certified vessels. Potentially, the lower emissions from SEAS certified vessels could form part of the carbon dioxide commodities trading through exchanges such as the Chicago Commodities Exchange. Ideally, the market should offer incentives to operators for SEAS compliance. These vessels will undoubtedly have a higher capital cost but would offer life-cycle cost benefits.

It should be noted that such a certification scheme could also be applied to refurbished vessels, just as LEED certification can apply to existing buildings. The core areas identified above would equally apply. The assigned points might be adjusted to reflect disposal of removed material and proper remediation of hazardous materials. While there have been successful programs to re-power existing vessels, such as California's Carl Moyer fund, the total environmental benefits of such programs would be enhanced if the total vessel refurbishment were addressed.

## 4. CONCLUSIONS

Green harbour tugs are the right direction for designers and operators to pursue. By reducing the emissions of such harbour service craft, we can improve the air quality in port areas and make a contribution to the global environment. Some of the steps to make vessels green can be applied to existing vessels and some are inherently part of new construction. Tug operators need to promote environmentally beneficial approaches to their clients and to their suppliers. They should be conducting energy audits of their vessels to ensure that energy isn't being wasted. They also need to examine their procedures for purchasing of materials and disposal of wastes. Hopefully, more will also commit to corporate social responsibility programs that will lead them to clean seas and clean air. By adopting an environmental certification program, such as the SEAS program introduced in this paper, a marine operating company would show its employees, its customers and the general public that taking care of the environment is the responsible course to steer.

## 5. REFERENCES

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## 6. AUTHOR'S BIOGRAPHY

**John Waterhouse** holds the position of President of Elliott Bay Design Group, Ltd. Mr. Waterhouse is a registered professional engineer in Naval Architecture and Marine Engineering. He received a Bachelors degree in Mechanical Engineering from U.C. Berkeley in 1979 and a Masters of Science degree in Naval Architecture and Marine Engineering from MIT in 1984. He is a Fellow of the Society for Naval Architects and Marine Engineers and sits on the Board of the Mystic Seaport Museum.