Green shipping requires broad horizon

Green?

The challenge set for the shipping industry is to design new green ships. First approach is usually to focus on the reduction of CO_2 emissions in the use phase by reducing energy consumption for propulsion and hotel load and/or replacing the fuel by a cleaner source of energy. This avoids the emission of CO_2, and avoids pressure on fossil fuels as a scarce resource. However, 'green' or 'eco friendly' encompasses more than CO_2 and fossil fuels only. Throughout the life cycle of a vessel, other environmental issues than climate change are relevant as well, like toxicity (think of antifouling), or scarcity of resources.

Horizon

A green design starts with having insight in the (predicted) impact of the ship on the environment during its life. If this information is available in a well-organized, uniform structure, it is easier to choose the direction towards an optimized design. This fundamental analysis is done by TNO based on an environmental life cycle assessment. During the design process, the ecological footprint of several design options is determined over the full life cycle of the ship:

- Influence of **production** on raw materials, production processes, including upstream processes (the production processes up to mining of raw materials)
- Influence of the **use phase**: energy consumption (marine diesel, heavy fuel oil, cold ironing) and maintenance (antifouling, coatings, etc.)
- Influence of **end-of-life**: dismantling and reuse, recycling and incineration of materials, or submersion

The ecological footprint of the life cycle of a ship is calculated in two steps.
Data is collected on resource consumption, emissions to air, water and soil, and waste (including processing of waste) for the ship production, use and disposal. The necessary data are obtained from commercially and publicly available databases, as well as scientific journals and reports.
The pressure on the environment is calculated in the second step, using the Eco-indicator 99 impact assessment method[1]. This method includes information about the environmental damage that would be caused for each kg of resource consumption, each kg of emission and each kg of waste. For resources, this is information about how quickly the reserves of metals, fossil fuels and biological sources like wood are depleted. For emissions the information includes the way or ways these emissions distribute in atmosphere, water and soil, and their damage to human beings and ecosystems.

Environment is defined by three types of damages in Eco-indicator 99:

- Damage to human health expressed as the number of life years lost and the number of years lived disabled due to environmental conditions. The effects included here are climate change, ozone layer depletion, carcinogenic effects, respiratory effects and ionising (nuclear) radiation.

[1] The Eco-indicator 99. A damage-oriented method for Life Cycle Impact Assessment. Manual for Designers. Ministry of Housing, Spatial Planning and the Environment, October 2000.

- Ecosystem quality: effects on the diversity of species, especially on vascular plants and lower organisms. The effects included are ecotoxicity, land-use, acidification and eutrophication.
- Resources: the surplus energy needed in the future to extract lower quality mineral and fossil resources.

The three damage types are in fact aggregations of several environmental issues. This is illustrated in figure 1.

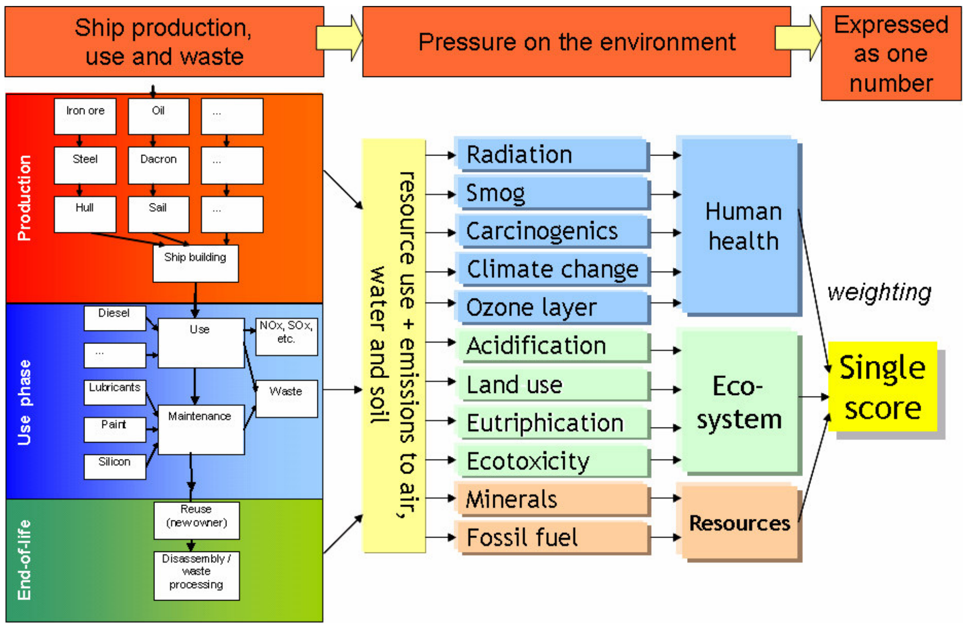

Figure 1 Schematic overview of calculation of Eco-indicator points

The transparent way of analysis described here, makes it possible to have information about the environmental performance of a ship at several levels.

1. Single score. For easy comparison of design permutations, a single score is calculated (yellow box in figure 1).
2. Damage type level. How do your design alternatives measure up for human health, ecosystem damage and resource depletion?
3. Environmental issue-level. Should you be interested only in CO_2 reduction or the land use ‘footprint’ of your design options, this is possible.

<u>Background</u>
The single score was calculated. Each of the three damage types factor into this single score. The damage types are compiled in their turn from several environmental issues (e.g. climate change, smog formation). Ecoindicator 99 provides three fixed sets of weighting factors, one being the de facto default. This weighting procedure is obviously subjective, because there is no global ‘truth’ about whether damage to humans counts heavier than damage to ecosystems or resource depletion. Although the weighting sets in Ecoindicator are well thought-out, everybody is free to rate the damage types according to their own criteria or perceptions. Alternatively, you could interpret the results separately or pick one or two issues to base your considerations on.

Comparing alternatives

During the design process, options can be compared to see if they lead to the desired improvement. For example:

- What are the advantages of a more compact ship with the same functionality compared to a larger sized ship?
- What is the environmental efficiency of new propulsion techniques?
- What is the net effect of several end-of-pipe emission reduction techniques, taking the fuel penalty into account?
- What type of anti-fouling has preference from an environmental point of view, looking at differences like maintenance strategies

A case study

Recently a comparison was made for several hull materials for a fictive yacht with an overall length of 25-40 m. Hull materials were: steel, aluminium, glassfibre reinforced epoxy (GRE), and several wood types. From an environmental point of view this is quite an interesting comparison, as these materials differ for several aspects:

Category	Production	Use	Disposal
Resources	Fossil fuels, metals, wood	Fossil fuels	Recycling saves resources
Ecosystem	Land use	Emissions	Emissions, land use
Human health	Climate change	Climate change + air pollution	Air pollution if burned, climate change

Table 1 Examples of relevant issues for yachts

- Aluminium production is energy intensive compared to the production of wood or steel
- Steel and aluminium can (and will be) recycled once the ship is no longer used, as these materials still have a significant economic value. Recycling avoids the production of new metals, and therefore has an environmental benefit. Wooden ships can be recycled, but incineration is more likely, with or without making use of the heat.
- Wooden, GRE and aluminium hulls have a lower weight compared to steel hulls. A low weight results in lower fuel consumption when the ship is motoring.
- Steel and aluminium rely on metal resources and fossil resources for their production. Wood needs land to be produced;
- There are many types of wood, and these differ in their ecological footprint als a result of differences in the way the forest is maintained (or not) , transport distances and means of transport.

Wood as a building material can not be addressed as one single choice. Wood harvested for ships occupied a lot of space. Land is scarce, and its current function is in competition with other possible functions. Moreover its use can put more or less pressure on the environment. Both are of interest in yacht design: while hardwood is the material of choice for yachts (if wood), the use of hardwood from tropical forests adds to deforestation. From an environmental perspective, a valuable form of land use is turned into a less valuable use like arable farming or roads. This leads, in the end, to the loss of biodiversity because habitats are diminished.

An alternative would be hardwood from plantations. According to the FAO, hardwood plantations have been, and are, emerging quickly. A ship's hull out of wood from such a renewable source does decrease the occupation of land, but more importantly it does not (directly) contribute to deforestation.

Softwood from forestry would be the best option, because of the higher speed of growth means that the land is occupied for a shorter period of time. However, for a comparable life span to be reached, a form of preservation is necessary.

The charts below show the results of the case study.

<u>Some assumptions:</u>
Sailing yacht, length over all ~ 25-40 m
Use profile: 10% sailing, 15% motoring, 65% in harbour, 10% maintenance
Life span 30 years (theoretical approach)
Built and demolished in Europe
Material need for the hull is estimated, and among wood types based on weight rather than volume

Figure 2 shows the impact of the hull only: production and recycling of the hull out of steel and aluminium. Steel is considered the baseline in the graph. Since aluminium saves weight in comparison to steel, fuel is saved. Expressed as an environmental benefit, this is shown in the column 'Energy saving'.

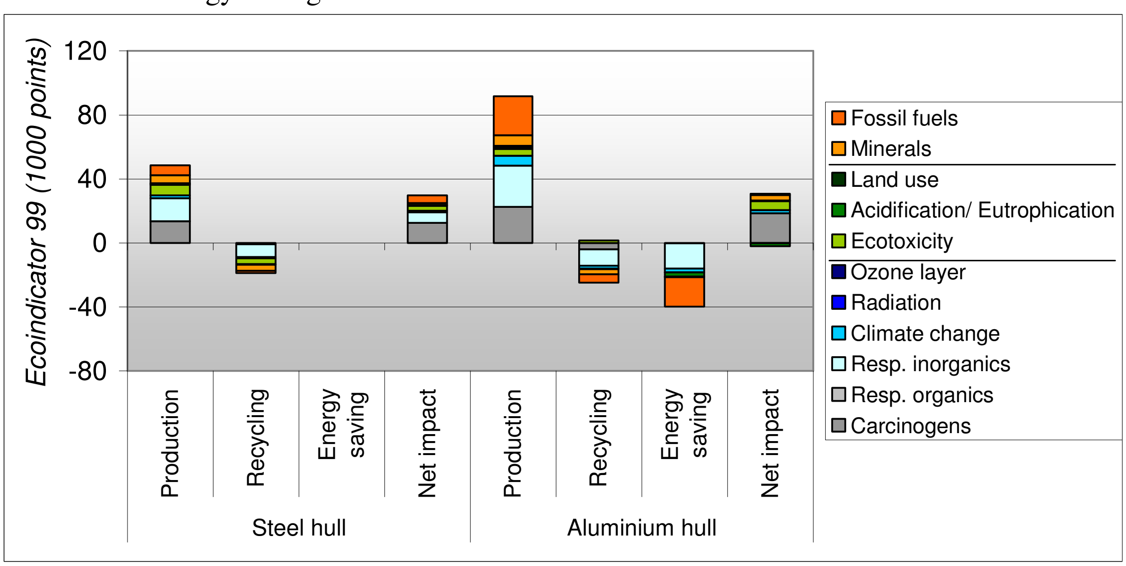

Figure 2 Relative environmental performance of steel hull and aluminium hull

The net impact of the aluminium hull is slightly higher than that of the steel hull. Further down we will see how this difference measures up with the impact of the ship during use.

Two more alternatives are included in figure 3:

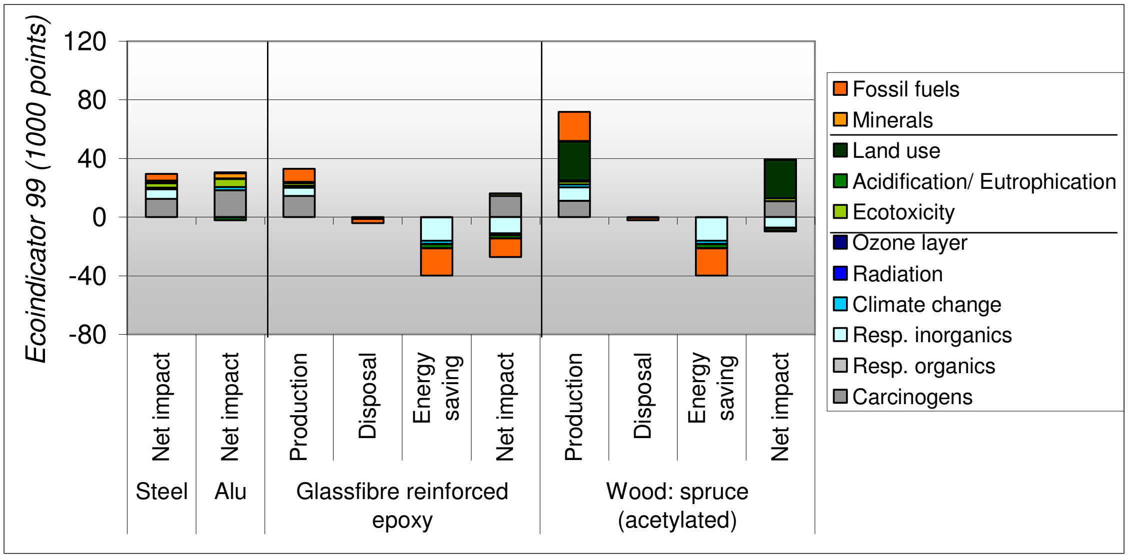

Figure 3 Environmental performance of four hull materials

The glass fibre reinforced epoxy hull seems the best option, even though disposal gives little benefit. For wood, this chart shows a best-case option: Scandinavian softwood, replanted, having underwent a preservation technique without hazardous substances. Clearly visible is the contribution of land use, land occupation in this case.

Interesting to know at this point, is how relevant are the differences among these four hulls if we consider the whole life cycle of the ship, and not just the influences of the hull? Figure 4 shows the impact of a yacht, during 30 years, constructed with each of these hulls.

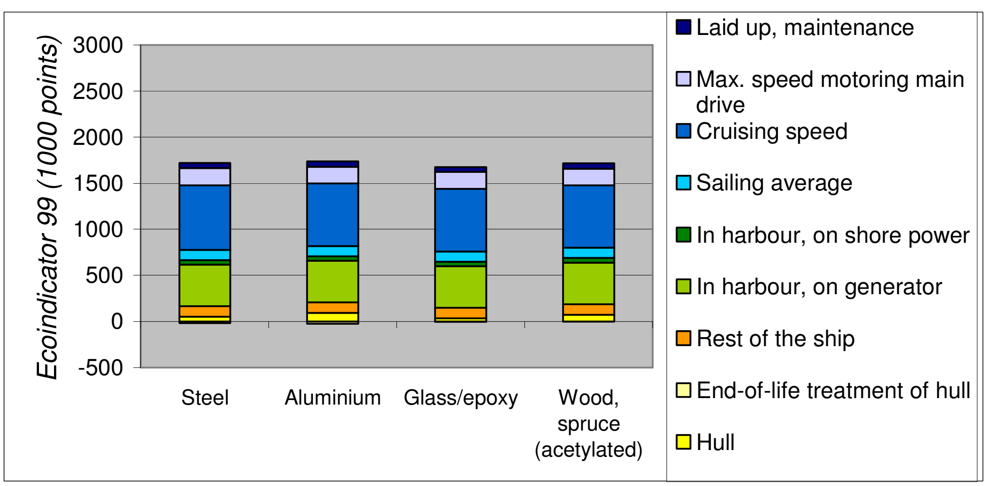

Figure 4 Influence of hull materials on life cycle ecological footprint of yacht

The results don't look very spectacular, the differences among the hull materials are minimal when expressed as a percentage of the total.

For wood this is approximately the best case situation. For the hardwood hull one would expect worse results. Figure 5 additionally shows two hardwood options.

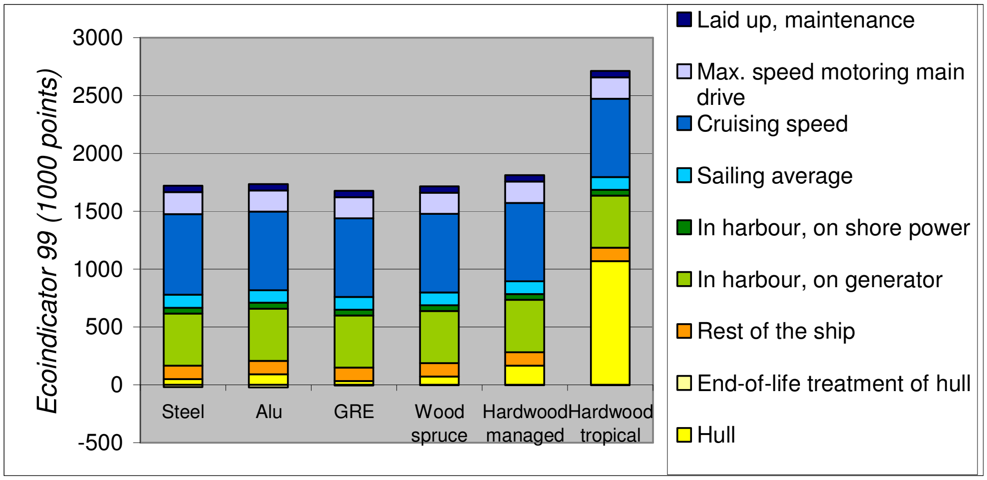

Figure 5 Hardwood influence on life cycle ecological footprint of yacht

The choice for non-renewable hardwood certainly increases the Ecoindicator 99 result. The choice among hull materials therefore makes a difference big enough to be considered during design, because the effect may well be in the same range as options for improving energy efficiency of the ship.

What can also be concluded from figure 5, is that hardwood forestry overcomes the larger part of the disadvantage ("hardwood managed").

A little more detail is shown in figure 6.

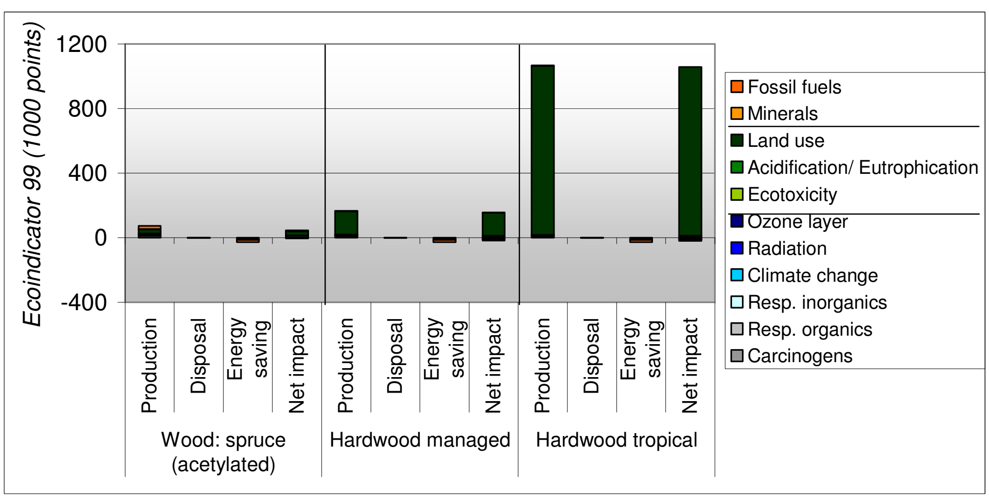

Figure 6 Breakdown wood options

Clearly land use is the main theme for non-sustainable wood.

For a ship of this size, approximately 0.5 km^2 of forest is needed in the case of tropical hardwood.

Conclusions for the case study:

- For sailing yachts, energy consumption is not the only relevant aspect for ecological footprint
- The best wood scenario (conserved softwood) is approximately equal to aluminium, GRE has a slight advantage, if the whole life cycle is considered.
- Large differences occur among wood types, driven mainly by three parameters: replanted or not, growth density and speed of wood growth

Conclusion

Green shipping starts with green design, and awareness of implications that various choices during the design and production process may have on the total ecological footprint of the ship. The sum of these implications is likely to turn out different with every new yacht.

Like the illustration for wooden hulls, other topics could be interesting in terms of the life cycle ecological footprint: controlled and uncontrolled dismantling (or submersion), emissions from e.g. antifouling, coatings, and the use of scarce materials.

For all TNO research in the maritime sector see http://www.tno.nl/maritiem or contact one of the authors, René van Gijlswijk (rene.vangijlswijk@tno.nl), Suzanne de Vos (suzanne.devos@tno.nl).