Appendix A: Fast-track LCA calculation:

The case of water recreation PSS in Friesland

Fast-track LCA methodology for EVR

Life Cycle Assessment, according to e.g. ISO 14044 and the handbook of LCA (ILCD, 2010), is a lengthy and laborious process, which makes it unpractical for use before, during and even after industrial design engineering processes. Thereby a "full" LCA is only possible after the design has been made, not allowing much room for adaptation of the design towards environmental impact reduction, especially in the early phases of the design process, where the potential for environmental impact reduction is higher. Therefore in EVR application, the use of so-called fast-track LCA is recommended. Fast-track refers to a LCA methodology which uses look-up tables where e.g. weighting and allocation already has been performed when determining the Life Cycle Inventories (LCI's). These look-up tables can be found on www.ecocostsvalue.com. The basic idea is that it is easier to multiply the inputs and outputs of the Life Cycle Inventory directly with the factors for single indicators, by building look-up tables (e.g. using Simapro software and e.g. the EcoInvent and Idemat Database) for common materials and processes. In such a process it is not required to go through rigorous LCA process steps such as classification, characterization, normalization etc., which allows for a "quick and dirty" analysis. Thereby the design engineer immediately sees which materials and/or processes cause the bulk of eco-burden for their design decisions. It must be noted that the accuracy of the fast track method is similar to the rigorous LCA, and not to be confused with streamlined LCA. The main difference between LCA and fast-track LCA is that FTLCA uses look-up tables for LCI's and that the latter method allows discarding insignificant material and process ecocosts, e.g. less than 2%, greatly reducing complexity and increasing applicability by design engineers.

According to (Vogtländer, 2012),the formal steps in Fast-track LCA are:

Step 1: Establish the aim and goal of the analysis *(in case of New Product Development, steps 1 and 2 are interchanged)*

- Is it a comparison of two or more products?
- Is it an attempt to improve the environmental characteristics of a typical design?
    - Less, or less harmful, materials
    - Less, or less harmful energy in the use phase?
    - Less transport
    - Better recycling or better incineration of waste for electricity?
    - Cradle-2-cradle solution?
    - Better durability?

Step 2: Establish the system, functional unit and boundary limits

- Describe the function of the product or service: functional unit
- Make a drawing of the product system
- Determine the life time of system components
- Establish one or more transport scenarios
- Establish the boundary limits

Step 3: Quantify materials, use of energy, etc. in the system

- Collect data (e.g. weight, material, energy consumption)
- Determine accuracy and relevance; establish allocation rules (or scenarios) and cut-off criteria

Step 4: Enter data in calculation sheet or computer program

- If an indicator value for a material or process is missing from the look-up table, this can be resolved in a number of ways:
    - Check whether the missing material or process could make a significant contribution to the total of environmental impact, if not, neglect it (if it is expected under the cut-off criterion
    - Substitute a known material or process for the unknown one which has the same characteristics (take a surrogate material or process)
    - Request an environmental expert to calculate a new indicator value. Software packages are available for such purposes
    - Take the required energy for the process, calculate its eco-burden, and multiply with a factor of 1.4

Step 5: Interpret the results and draw your conclusions

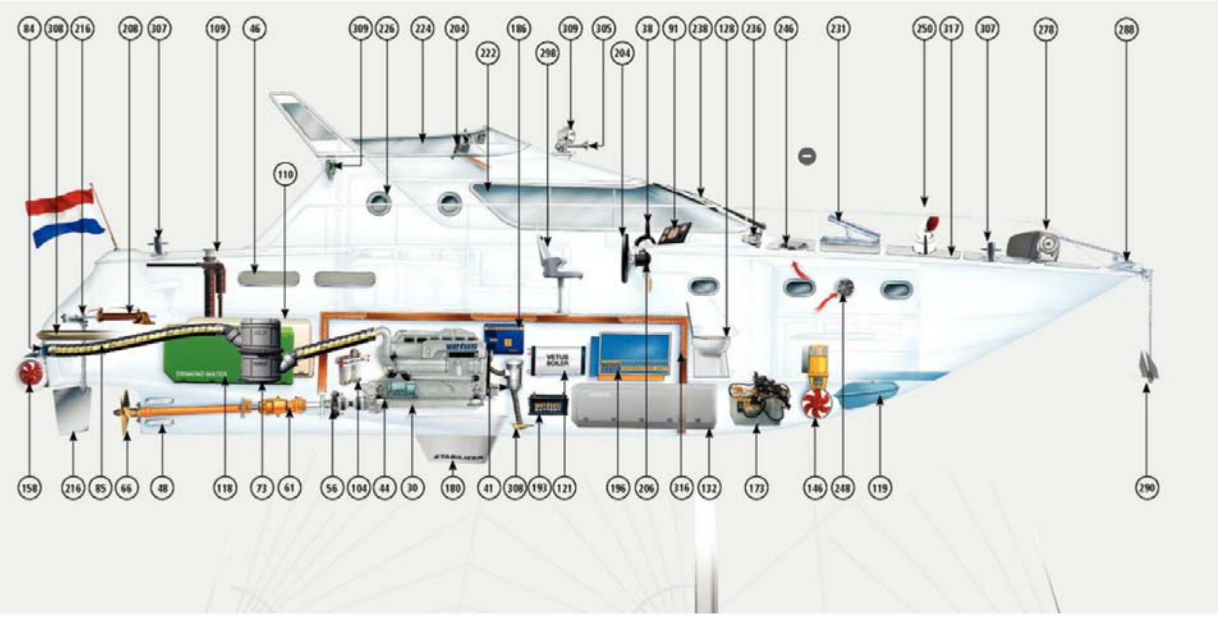
- The addition of the total ecocosts is not the aim of LCA, it is always the aim of LCA to generate a comparison with other designs and/or processes. Therefore the final step includes an analysis of the total output, including relevant details.
- Note that it might be the case that the calculation has to be (partly) redone, if elements and/or accuracy are missing.

Fast-track LCA water recreation products

Step 1. Aim and Goal of analysis

This analysis is aimed at assessment (and improvement) of the environmental characteristics of a typical water recreation product design as used in water recreation Product-Service Systems (PSS) in the province of Friesland (NL). After determining the eco-burden of one of the most polluting products within such PSS (Diesel Motor Yacht), a comparison is made with the products that are being stimulated by the local government that are supposedly more environmentally sustainable.

The selected product in this analysis is a motor yacht of approx. 10 meters/33 feet, with cabin. Since these products are designed and manufactured to last at least 25 years, it is expected that the use of motor yachts, with the highest impacts in the use-phase, contribute most to the environmental impacts on regional level. The average sized motor yacht in this region is approx. 10 meters, which is determined by a questionnaire performed in Sneek, Friesland in the summer of 2010.



Figuur 1: The main components of a yacht. (taken from www.vetus.com (accessed 15-03-2013))

In order to maximize potential environmental impact reduction, all six directions should be achieved:

- Less, or less harmful, materials
- Less, or less harmful energy in the use phase
- Less transport
- Better recycling or better incineration of waste for electricity
- Cradle-2-cradle solution
- Better durability

However, first the fast-track LCA of the existing product needs to be completed, in order for the designer to "get a feel" for the relative magnitude of the different environmental impacts associated with water recreation PSS products.

Step 2. Establish system, functional unit and boundary limits

Functional unit

The primary function of the motor yacht rental PSS is to provide mobility and shelter for water recreants that do not own such products. On a more holistic level, the function of the PSS is to facilitate optimal enjoyment of everything the region has to offer water recreants. This is fulfilled by providing (a mix of) products and services which enable water recreants to travel through the region whilst providing luxury and comfort to optimally enjoy the holiday or trip, or, in other words, a PSS.

Hence the functional unit is determined at:

“the use of a rental Linssen Grand Sturdy 34,9 ft. for one week, 3 hrs. a day, at nominal speed and power.“

From interviews conducted at the Boot Dusseldorf trade fair we know that it is highly dependent on the user’s behaviour when estimating duration of use of the propulsion systems. Since rental companies generally not allow the use of their yachts after dark, it is safe to conclude that the boats are not used for approx. 12 hrs. a day. For the remaining 12 hrs. it is difficult to determine how much these boats are used during the day. Based on the industry estimates, we have estimated the use of the boat at nominal power at 25% of the time: The yacht is used as overnight stay, and as luxury transport to visit and explore the province of Friesland. Though it has been mentioned that some tourists use their yachts for more than 8 hrs a day, this is expected to be a fair estimate. Many tourists may also stay in the same marina for multiple nights, not using the boat for transport at all.

Figuur 2: Linssen Grand Sturdy 34,9

The Linssen Grand Sturdy is selected for this analysis, since Linssen also offers hybrid electric Grand Sturdy products, allowing for a value comparison as well.

(This is thereafter linked to sales information derived from an interview with Linssen on the “HISWA te water” Marine fair in Amsterdam, September 2012: Linssen: “of the approx. 140 products that were sold in the previous 2 years, none were sold with hybrid technology”. Hence it is safe to conclude that the perceived value of these offerings is too low to trigger a Willingness to Pay for the 36% higher price: Diesel Linssen Grand Sturdy SCF 25,9 (€156.500,-) vs. Hybrid Linssen Grand Sturdy SCF 25,9 Hybrid (€212.500,-).)

Linssen Grand Sturdy 34.9

Length: 10.70 meter

Engine: 75 hp Volvo Penta Diesel
(http://vppneuapps.volvo.com/ww/PIE/ViewFileFrame.aspx?n=195639&r=2008-08-13-10-16-05&t=PDF1P&a=7749292&p=T416&d=Product%20Bulletins&s=787196&model=D2-75&transClassId=9&segmentId=13&lang=en-GB)
Weight: 8500-9000 kg.
Tank: 240 litre

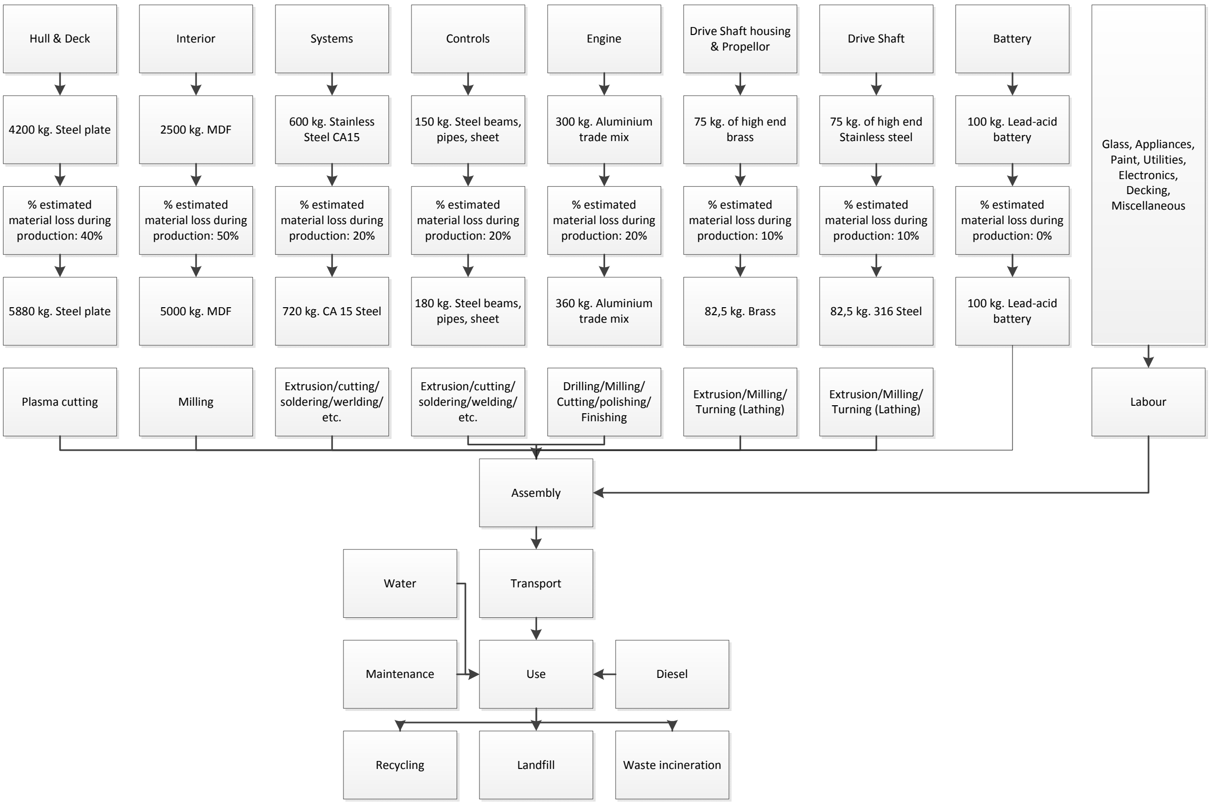
(note that Linssen only offers a hybrid Grand Sturdy 25,9, therefore in this analysis a 20% percentage of the cost of the hybrid system is taken over the price of the Diesel Grand Sturdy 34,9)

Figuur 3: Linssen Grand Sturdy 25.9 SCF

Figuur 4: Linssen Grand Sturdy 25.9 Hybrid

Product System

The product system taken into account in this assessment is depicted in the tree diagram in the figure below:



Component life time

In this LCA, the focus is on the components of the energy system and the physical product itself.

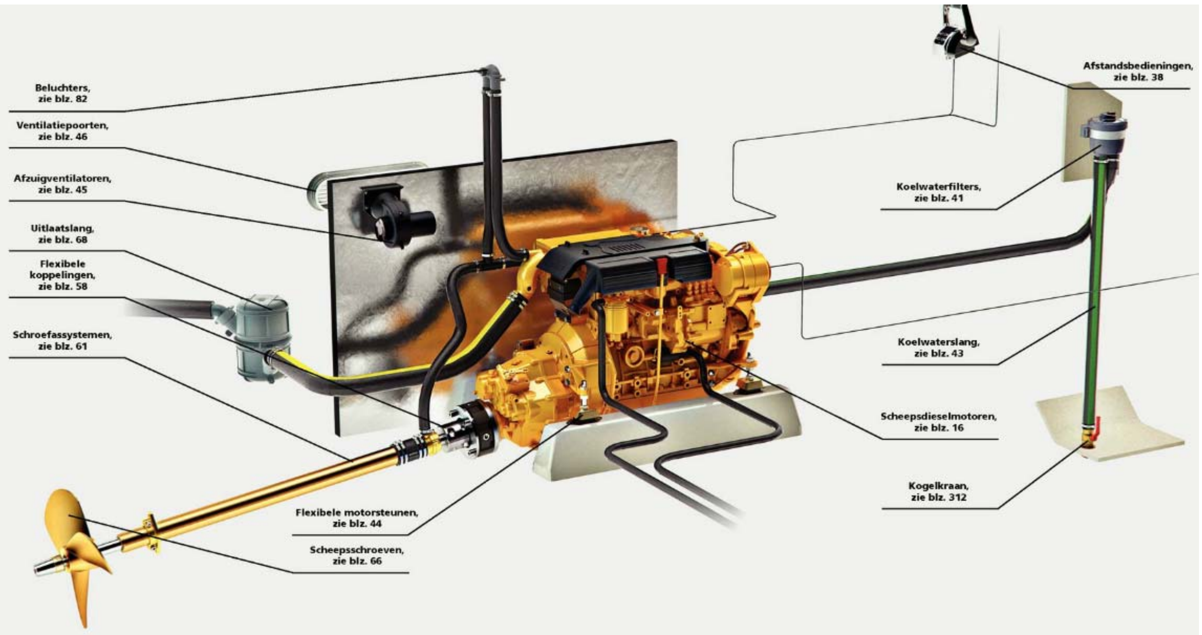


Figure 1: The main components of a drive system in a yacht. (taken from www.vetus.com (accessed 15-03-2013))

From interviews with yacht rental agencies we know that the estimated rental life-cycle of these products is five years, before being resold. The average fee for 1 week rental is approx. 1% of the consumer price of the product (rule of thumb of the rental industry). This is confirmed by the fact that a Linssen 34.9 Grand Sturdy costs approx. € 250.000,-, and rental fees are 2450,- per week at a yacht rental company in The Netherlands. (http://www.jachtcharter.com)

(http://www.linssenyachts.com/site_pub/index.php/en/linssen-price-list)

The use phase of these products is usually very long, given that a certain amount of maintenance and repair is executed at regular intervals. In this analysis, the estimated product-lifetime has been set to 25 years. Though this is quite short in relation to the use phase these products were designed for (according to interviews these products are designed to last at least 50 years or more), the intensity of the use phase for rental vessels would shorten the total life-time of the products. However in this analysis the maintenance is estimated to be insignificant relative to the energy use in the use phase.

As mentioned, interviews have indicated that new vessels acquired for use in boat rental, are sold after approx. 5 years. In order to allocate the environmental burden of the cradle-gate phase, economic allocation is applied. Where a new vessel costs 250.000[1],-, the estimated resale price is set to 125.000,-, resulting in an economic allocation of the cradle-gate ecocosts of 50% during the first five years of use in a rental context:

9028,- / 2 = 4514,- for the first five years

5 * 19,35 = 96,75 weeks of rental in the first five years

4514,-/96,75 = 46,66 per week.

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[1] Rental agencies probably are not required to pay the full market price, since the boat production companies also use the rental context to promote their products, as well as allow potential buyers to test the products in their intended contexts. However in this analysis, the fair price is taken, since it is difficult to determine the price agreed upon in this B2B scenario.

Transport scenario

To justify the system boundaries outside of the transport and end-of-life phases, a quick calculation of the transport eco-costs is presented below.

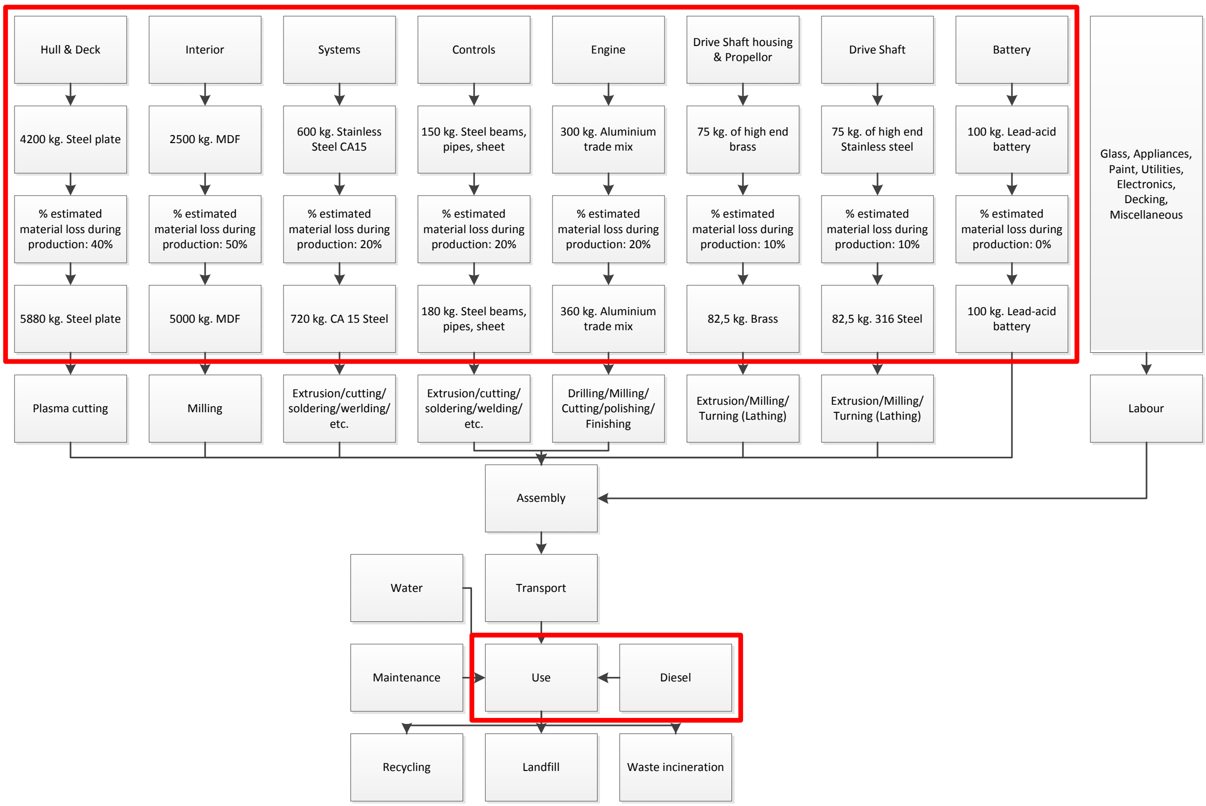
Since the Netherlands has a mature shipyard industry, it is assumed that the average rental motor yacht is made in NL. Many shipyards simultaneously are rental agencies as well. A typical motor yacht, which we know is also rented out (Linssen Grand Sturdy 34.9), is produced in Maasbracht, NL.

Its components are probably not produced locally. However, their weight is considered insignificant relative to the weight of the product, therefore component transport is not taken into account in this analysis. Transport of approx. 9 ton by road, at less than 320 kg./ m^3 generates an ecocost of: 75 m^3 (since it is deemed unlikely such products will share their transport with other products) x (Truck+trailer, net 24 tons, m3.km, 0,0093 Idemat 2012, empty return (50% payload). The net volume of this trailer is approx 75 m3. for average load weight less than 320 kg/m3) x distance from Maasbracht to Sneek:

75 x 0,0093 x 275 = 191,81 ecocosts which is deemed insignificant relative to the ecocosts of the physical product, and therefore left out of this analysis.

Boundary limits

The boundary limits of this analysis is primarily defined by the significance of the environmental impacts associated with water recreation PSS offerings in the province of Friesland. Of the PSS offerings, it is assumed that the rental motor yachts generate the highest relative environmental burden, due to the intensive use-phase of these PSS. This assessment is limited to the materials used in such products, which are estimated by interviewing a renowned naval architect, and the ecocosts associated with estimated nominal use of these products. (See figure below).



Step 3. Quantify materials, use of energy, etc. in the system

Data

Cradle-Gate: Materials

For the fast-track cradle-to-gate LCA, the estimated amounts of materials used for the production of one average Diesel yacht are determined based on an interview with an established recreational marine products designer or naval architect. This is the only viable option for approaching such unknown inputs, since it is hardly possible to take apart such products and weigh each component.

The following list of estimated materials use for the production of one 10 meter yacht is used in this part of the analysis.

Parts (main components as indicated by naval architect)	**Main Material (www.ecocostsvalue.com)**	**Weight (kg.) as indicated by naval architect**	**Estimated material loss during production (%)**	**Amount of raw material needed (kg.)**
Hull	Idemat2014 Steel beams, pipes, sheet (from market mix 44% recycled)	2800	40%	3920
Deck	Idemat2014 Steel beams, pipes, sheet (from market mix 44% recycled)	1400	40%	1960
Interior	Idemat2014 MDF (750 kg/m3)	2500	50%	3750
Systems	Idemat2014 GX12Cr14 (CA15)	600	20%	720
Controls	Idemat2014 Steel beams, pipes, sheet (from market mix 44% recycled)	150	20%	180
Engine	Idemat2014 Aluminium trade mix (66% prim 33% sec)	300	20%	360
Propulsion shaft	Idemat2014 X5CrNiMo18 (316)	75	10%	82,5
Propellor	Idemat2014 CuNi44Mn	75	10%	82,5
Battery	Idemat2014 Lead battery cars (39 Wh per kg)	100	0%	100

The LCI's are taken from the LCI database file on ecocostsvalue.com, tab data. The estimated weights of the different materials are increased with an estimated factor for material loss during production. E.g. 40% loss of material for the cutting of plate material into the desired components of the hull is based on an interview with SnijTechniek Brabant, who frequently cut aluminium and steel plate material for the production of marine products.

Elements of marine products that are unlikely to be the subject of innovation in this research cycle are left out, such as paint, appliances and accessories.

The results of this assessment indicate a total of approx. 9000 euro ecocosts per average rental motor yacht (10m.)for the cradle-gate phase (material ecocosts). Note that it is not the goal of this fast-track LCA to precisely calculate the eco-burden of all materials in these products, but to get a rough idea of the relative magnitude of the eco-costs for (elements of) such products (cradle-gate), compared to the ecocosts for using the PSS.

Cradle-Gate: Production

Steel

For some data on the ecocosts of materials taken into account in this analysis, the data is calculated for semi-finished products, such as Idemat 2012 Steel Beams, pipes, sheet (from market mix). However, these sheets need to be cut (in this case of steel plates a common technology is plasma cutting), shaped and welded (e.g. Idemat2012 welding steel, gas, € 0,159 per meter). Interviewing Snijtechniek Brabant, we know that the material loss from plate-cutting for production of 10 meter yachts can be estimated at 40%, and the average length of cutting per plate can be estimated at approx. 100 meters for a 6 x 2 (x 0,005) meter steel plate. Even though plasma cutting generates toxic fumes, it is seen as similar in ecocosts as gas welding, since a high current converts a gas into plasma hot enough to cut steel. The same applies to e.g. CO2 welding, therefore the ecocosts for gas welding are taken to approach the ecocosts for plasma-cutting steel plate.

The volume of such a steel plate is 6 x 2 x 0,005 = 0,06 m^3

Multiplying with the specific weight of carbon steel generates: 0,06 x 7800 = 468 kg. Steel plate

100 meters of cutting per plate (100 x 0,159 = 15,9) x weight % of total product (4200/468 = 8,97) = € 142,7 ecocosts for cutting steel plate into parts for marine products.

For the welding, this number is similar, assuming that every cut in the plate material yields a weld, except divided by two since two plates are joined at most welds: 142,7/2 = € 71,35 ecocosts

Therefore the total of ecocosts for production of the steel hull & deck, including cutting and welding comes down to: (2759,95 + 1379,98 =) + (142,7 + 71,35) = € 4353,98 ecocosts. However, since these process ecocosts are deemed insignificant relative to the ecocosts of the material itself, production ecocosts are not taken into account in this analysis.

MDF

The basis for the interior nowadays is made from Medium Density Fibreboard, or MDF (see figure below).

Thereafter the MDF is finished with a thin layer of wood veneer in order to achieve a high quality and aesthetically appealing finish. Most yacht interiors have a wooden finish. However, this layer of veneer (approx. 0.6 – 2 mm.) is hardly significant relative to the amount of MDF, therefore is discarded in this analysis. The amount of MDF is therefore taken as the single material for building the interior, weighing approx. 2500 kg.. Since there is no data available on CNC cutting of MDF, we would use the LCI of CNC cutting aluminium without the ecocosts of the waste produced. (or bandsaw cutting?)

The standard size of MDF boards is 2,44 x 1,22 x 0,02. At a density of 500 kg./m^3, 1 “standard” board weighs (2,44 x 1,22 x 0,02 = 0,059536) x 500 = 29,768 kg. Estimating a cutting length of 10 meter per MDF board, the total estimated cutting length for MDF for 10 meter motor yachts is 2500/29,768 x 10 = 840 meter of MDF cutting. Since no data is available on the exact ecocosts of MDF cutting (bandsaw) two alternatives were identified from the database that closely resemble such a process.

However, since these ecocosts are deemed insignificant, as shown with steel material vs. processes, these are not taken into account in this analysis.

Assembly ecocosts are left out of this analysis since these are expected to consist mostly of human labour, and a small amount of screw and or glue joinery.

It is therefore concluded that the most valuable yet efficient analysis is the assessment of material ecocosts and use phase ecocosts. It needs to be noted though that for a more complete assessment the material processing and assembly ecocosts need to be taken into account, since these are also subject to change if the materials are replaced with more environmentally sustainable materials. Further research conducted as a follow-up to this study will reveal in more detail how these ecocosts compare to the calculation in this paper.

Gate-Gate

The calculation of the gate-gate phase of the selected water recreation products is slightly more complex. For the analysis of the gate-gate phase of the water recreation PSS product, a scenario for the use phase is needed. The scenario is similar to the functional unit: use of the PSS product at nominal speed for 3 hrs. day, 7 days a week for 19,35 weeks per season (Toerdata Noord).

Technology

The benchmark technology is Diesel internal combustion engine technology, which is the dominant technology for such products in today's market. As seen in the cradle-gate assessment, 300 kg. of aluminium, 75 kg. of brass and 75 kg. of high grade stainless steel represent the material ecocosts of the drive system in this analysis.

The assumption is made that the gate to gate phase eco-costs are primarily caused by the use of energy (since it is a mobility product), in this case Diesel. First we need an estimation of the diesel use per unit of time, in order to estimate the total amount of diesel used during one week of average water recreation (see functional unit). The ecocosts of maintenance and repair etc. are for now discarded since these are expected to be unavoidable for a high quality product such as a yacht.

The first information we need is what kind of engine is typically installed in these products (approx. 10 m.). A web-query showed that the mean power, installed in these products, is around 75 hp engines:

	Power	Tank capacity	Price per week	Fuel consumption
www.friesland-boating.nl:	62 hp.	250 l.	€1250,-	4-5 l/h
www.friesland-boating.nl:	88 hp.	500 l.	€1550,-	5-8l/h
www.holidayboatin.nl:	75 hp.	400l.	€1250,-	4-5l/h

(http://www.linssenyachts.com/en/grand-sturdy-34-9-ac-sedan.html)

Although the above indicated use of fuel are provided by some rental companies, the actual fuel use is derived from the engine specifications of a marine engine manufacturer. The above information only concerns older boats than a new Linssen yacht, explaining the lower prices per week of rental than used in this scenario.

Gate-Grave

In this analysis, the gate-grave phase is not taken into account, since the estimated product life-time is very long: 25 years. Therefore it is estimated that the use-phase ecocosts will render the end-of-life phase eco-costs insignificant, and thus are not taken into account in this analysis. Thereby in this PSS scenario, the products are not decommissioned, but sold second-hand after 5 years. This means that there are no end-of-life impacts and/or credits for the PSS scenario, except for certain replaced parts, which are deemed insignificant.

Accuracy and relevance

As mentioned earlier, this fast-track LCA is not intended to provide superior accuracy in terms of environmental impact assessment. It serves as a "quick and dirty" tool for design engineers to get a grasp on the magnitude and relevance of environmental impacts associated with, in this case, a water recreation PSS product. It is important to note that the accuracy of the data is similar to LCA, and not to be confused with Streamlined LCA.

In this assessment only a small number of eco-cost variables have been taken into account, however it is argued that these ecocosts variables (materials and Diesel use) represent the bulk of eco-burden generated through such offerings.

Step 4. Enter data in calculation sheet or computer program

Calculation

Cradle-Gate phase calculation: materials

Parts	Main Material	Weight (kg.)	Estimated material loss during production	Amount of raw material needed	Ecocosts	ecocosts per part
Hull	Idemat2014 Steel beams, pipes, sheet (from market mix 44% recycled)	2800	40%	3920	0,64	2522,09
Deck	Idemat2014 Steel beams, pipes, sheet (from market mix 44% recycled)	1400	40%	1960	0,64	1261,04
Interior	Idemat2014 MDF (750 kg/m3)	2500	50%	3750	0,20	755,76
Systems	Idemat2014 GX12Cr14 (CA15)	600	20%	720	2,12	1526,79
Controls	Idemat2014 Steel beams, pipes, sheet (from market mix 44% recycled)	150	20%	180	0,64	115,81
Engine	Idemat2014 Aluminium trade mix (66% prim 33% sec)	300	20%	360	4,35	1567,22
Propulsion shaft	Idemat2014 X5CrNiMo18 (316)	75	10%	82,5	4,80	395,71
Propellor	Idemat2014 CuNi44Mn	75	10%	82,5	9,92	818,75
Battery	Idemat2014 Lead battery cars (39 Wh per kg)	100	0%	100	0,65	65,41

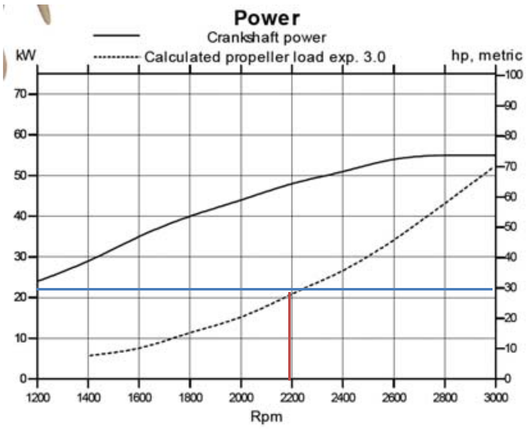
Total: 9028,58

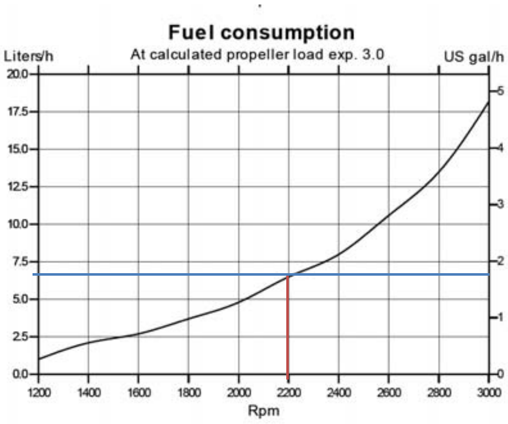
The results of the fast-track LCA indicate a total of approx. 9029 euro per average rental motor yacht (10m.). Note that it is not the goal of this fast-track LCA to precisely calculate the eco-burden of all materials in these products, but to get a rough idea of the relative magnitude of the eco-costs for (elements of) such products (cradle-gate).

Gate-Gate Phase calculation

Diesel:

The first assumption concerns the nominal power output, revs/minute and fuel consumption during normal cruising. The estimation is now set at a fuel consumption for 22 kW/30 hp , at 2200 revs/minute and approx. 7 l./hr. for the use of the Volvo Penta engine on board of rental Linssen yachts:





7 litres/hr. results in a fuel consumption of 5,81 kg. Diesel/hr.
Multiplying this with the functional unit yields a use of 122 kg. Diesel per week.
The ecocosts of 125 kg. of Diesel equal 125 * 1,26 (*Idemat2014 Diesel low-sulphur including combustion*) = € 158,- ecocosts per week.

Value Diesel for EVR (market price)
125 kg. Diesel/ 147 litres of Diesel per week = 147 * 1,45 (current price of Diesel) = € 213,-

Step 5. Interpret the results and draw your conclusions

Comparison to “green” technologies as promoted by the local government

For a fair comparison, the Diesel engine itself should be considered separately and compared with an electric motor and enough lead-acid batteries to drive the boat for 8 hrs. at 22 kW output (even if the normal scenario would be 3 hrs.). This is very important, because it is needed to preserve the surplus value of the offering: Since recharging is intended to happen at night in the harbour, people should be able to drive the boat at least a full day without recharging.

For the hybrid system, enough batteries for 3 hrs. at 22 kW output should be taken into account, and a smaller version of the diesel engine.

(http://www.restyle.biz/site/zoekresultaat/linssen-grand-sturdy-25-9-hybrid.20070170.html)

http://www.boot.de/cipp/md_boot/custom/pub/content,lang,2/oid,26101/ticket,g_u_e_s_t/~/Mastervolt_and_Linssen_Yachts_equip_Linssen_yacht_with_hybrid_drive_system.html

Two alternatives to the standard Diesel engine are taken into account in this analysis: A hybrid (Diesel electric) and full electric system.

Hybrid:

Batteries for 1 day = 3 hours: 22.000*3 /39 * 1.2 = 2030 kg * 0.654 = 1334 euro eco-costs, 13,79 per week for 5 years lifespan (8120 euro real price (4 euro per kg)). (83,93 euro real costs per week). (Note that a lead-acid battery is 39 Wh/kg in Idemat)

For the hybrid electric variant, the ecocosts of the batteries per boat week are 1334/96,75 = € 13,79 ecocosts

This engine has a weight of approx. 300 kg. thus the ecocosts of the Diesel engine in a hybrid boat are estimated at the same as the Diesel boat: = € 1567,22 ecocosts (which in this calculation is assumed to last the total life-time of the boat: 25 years): Economic allocation yields 50% depreciation over the first 5 years: 783,61/96,75 = € 8,1 ecocosts per week

Equipped with regular diesel engine: € 46,66 ecocosts/week

Equipped with hybrid engine (serial): 46,66(production) + 13,79 (battery production) + 3,22 (electric motor production)+ 4,05 (generator production) = € 59,28 ecocosts/week

Batteries for 1 day = 3 hours: 22.000*3 /39 * 1.2 (battery efficiency) = 2030 kg * 0.654 = 1327,62 euro eco-costs, 13,72 per week for 5 years lifespan (8120 euro real price (4 euro per kg)). (83,93 euro real costs per week). (Note that a lead-acid battery is 39 Wh/kg in Idemat)

Costs of the engine are around 10.000,-[2] for a 35 kW engine. This translates in a real cost of approx. 10.000,-/2/96,75 = € 51,68 per week

Full electric:

If we are to compare Diesel with electric drive systems, that have the same perceived value as the incumbent Diesel systems, the same power output must be available.

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[2] http://www.bellmarine.nl/?nr=3&Prijs%20Info

Therefore, we have to calculate the ecocosts and costs of 22 kW of power for 21 hrs./week, with enough batteries to at least be able to use cruising speed for 8 hrs per day:

Power for 1 day = 8 hours: 22.000 * 8 / 39 *1.2 = 5415 kg * 0.654 = 3558 euro eco-costs, 36,78 per week for 5 years economic lifespan (21.660 euro real price (4 euro per kg)) (223,86 euro real costs per week). (the batteries are worthless after 5 years, but are likely to last 10 years, mostly because of the high price). The environmental lifespan is therefore estimated at 10 years.

Equipped with electric engine: 38,22 (production) + 36,78 (battery production) + 3,22 (electric motor production)= € 78,22 ecocosts/week

22 * 21 * 1.105 (*1,2) = 510 kWh of electricity = € 127,5 (at a price of 0,25 euro/kWh)

(note: 1.105 is for the motor efficiency, see also http://www.engineeringtoolbox.com/electrical-motor-efficiency-d_655.html, 1,2 is for battery efficiency)

Costs of the engine are estimated around 15.000,- euro for a 60 kW electric marine engine. This translates to an additional cost per week of 15.000,-/2/96,75= 77,52 per week.

References

a. Vogtländer JG., 2010b. A practical guide to LCA for students, designers and business managers, cradle-to-grave and cradle-to-cradle. 2nd edition, VSSD: Delft, the Netherlands

b. ILCD, (European Commission, Joint Research Centre, Institute for Environment and Sustainability); International Reference Life Cycle Data System (ILCD) Handbook: General guide for Life Cycle Assessment (LCA) – Detailed Guidance, First Edition, 2010. Freely available on www.lct.jrc.ec.europa.eu/publications