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Life Cycle Assessment and Circularity Indicators to Design Future Circular and Sustainable Electric Outboards: Results from Workshops with Industrial Experts

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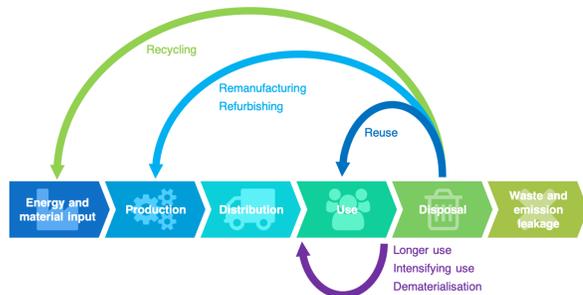
MOTIVATIONS

Energy transition:

- A pathway toward transformation of the global energy sector from fossil-based to zero-carbon by the second half of this century. At its heart is the need to reduce energy-related CO₂ emissions to limit climate change.
- The benefits of switching diesel-powered machines for fossil-free, electric counterparts are numerous: green house gases (GHG) emissions reduction, lower noise level, energy efficiency, ease of maintenance.

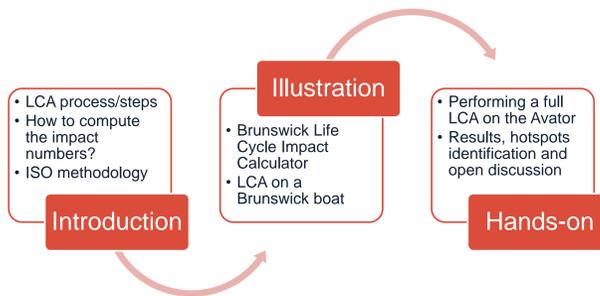
Circular economy (CE):

- Momentum to rethink, create and optimize a circular supply chain in the recreational boat industry.
- Need to identify and quantify opportunities to design for Re-X (reuse, remanufacturing, recycling).

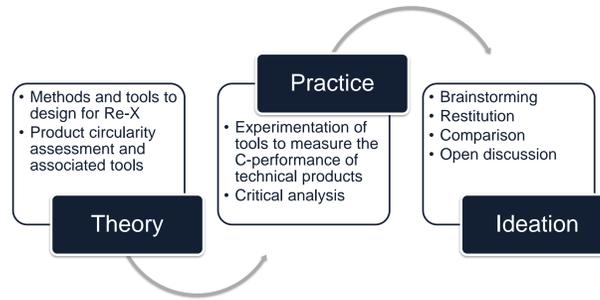


TWO HALF-A-DAY WORKSHOPS

Session #1 on life cycle analysis (LCA)



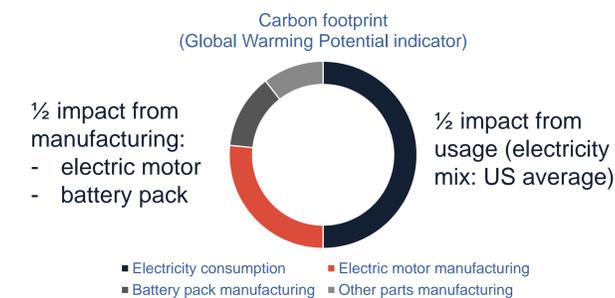
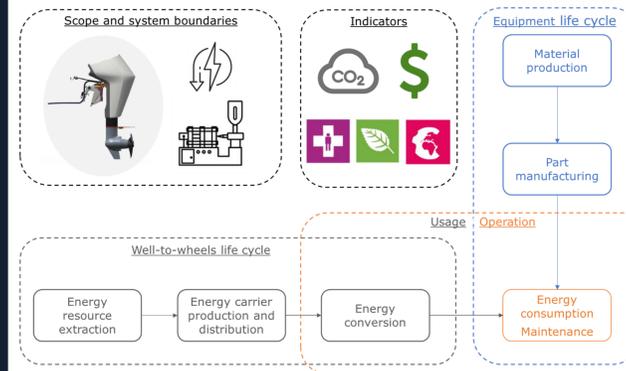
Session #2 on circularity indicators



RESULTS & INTERPRETATIONS

Life cycle impact assessment (LCIA):

Database: ecoinvent 3.7 ; Method: ReCiPe (H) 2016
Functional unit: Manufacture and operate one electric outboard of 1 hp (the Avator 15-inch) during one lifetime, i.e., 35 hours a year during 15 years.



DISCUSSION

- These workshops met the following key objectives:
 1. Learn how to calculate the environmental impact of a design, in alignment with ISO 14040-44
 2. Learn how to assess the circularity of a design
 3. Complete LCA and Re-X assessments and, leveraging the assessments, generate practical ideas
 4. Gather key experts/stakeholders to collaborate on sustainable and circular design, including the Director of Sustainability Engineering Programs, the Remanufacturing General Manager, the Product Technical Leads, Materials Engineers (x2), and Interns (x3)
- The participants found both frameworks (the Excel-based LCA Calculator and the two circularity indicators-based tools) simple of utilization and efficient: “very easy to use” ; “the workshop today was excellent, from my perspective” ; “the engagement was very high”.

OBJECTIVE

Three complementary research questions (RQ):

- 1. What is the ecological impact of Brunswick's new electric outboard and what are the critical components (environmental hotspots)?
- 2. How to assess the circularity performance of this electric outboard (Avator 1hp 15-inch)?
- 3. Which design for Re-X strategies and mechanisms to deploy to close-the-loop in a sustainable fashion?

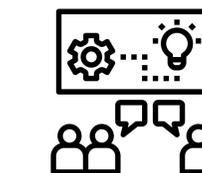
Circular Economy Indicator Prototype (CEIP) to assess the circularity potential of the electric outboard at a full product level

3 RESULTS					
Product Rating	Product Ranking	Points			
43%	Good	Scored	Available		
		65	152		
Lifecycle	# Questions	Scored	Available	Rating	Ranking
Design/Redesign	3	10	27	37%	Fair
Manufacturing	2	0	25	0%	Poor
Commercialisation	3	3	30	10%	Poor
In Use	4	17	35	49%	Good
End of Use	3	35	35	100%	Excellent
TOTAL	15	65	152	43%	Good

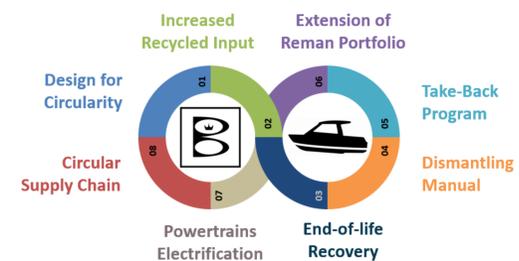
Circular Potential Indicator (CPI) to assess the circularity performance of the two key components: electric motor and li-ion battery

Circularity Performance Indicator	Circularity Score of the Motor = (out of 100)	Score
Unlock the Circularity Potential of your Product	47.23	
BB#1 - Circular Product Design		13.89
BB#2 - New Business Model		7.50
BB#3 - Reverse Cycles		8.75
BB#4 - Favourable System Conditions		17.09

Circularity Performance Indicator	Circularity Score of the Battery = (out of 100)	Score
Unlock the Circularity Potential of your Product	55.04	
BB#1 - Circular Product Design		11.43
BB#2 - New Business Model		5.00
BB#3 - Reverse Cycles		19.58
BB#4 - Favourable System Conditions		19.03



10+ CE-related ideas generated and associated projects to increase the circularity performance



PERSPECTIVES

Quantify the actual sustainable benefits from closing the loop:

1. At a material level: Assess the potential impact savings from recycled materials in manufacturing (by increasing the recycled content).
2. At a component/product level: Look further at the components and parts that can be reused and/or remanufactured.
3. At a system level: Analyze and experiment the opportunities discussed after the circularity assessment, such as circular business model, take-back scheme, etc.

REFERENCES

Cayzer, S., Griffiths, P., Beghetto, V., 2017. Design of indicators for measuring product performance in the circular economy. *Int. J. Sustain. Eng.* 10 (4e5).

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