Egidija Rainosalo,
Centria University of Applied Sciences
R&D Coordinator

Centria offers the ideal environment for transferring theoretical knowledge to practical applications. It provides opportunities to engage in regional development, collaborate closely with industrial applications, and connect with professionals from various sectors of the composite industry.

With 15 years of experience in the development, testing and manufacturing of fiber-reinforced composite materials, I have acquired broad expertise across various aspects of the field. I am currently driving new projects, which develop 3D printing as a composite manufacturing solution.

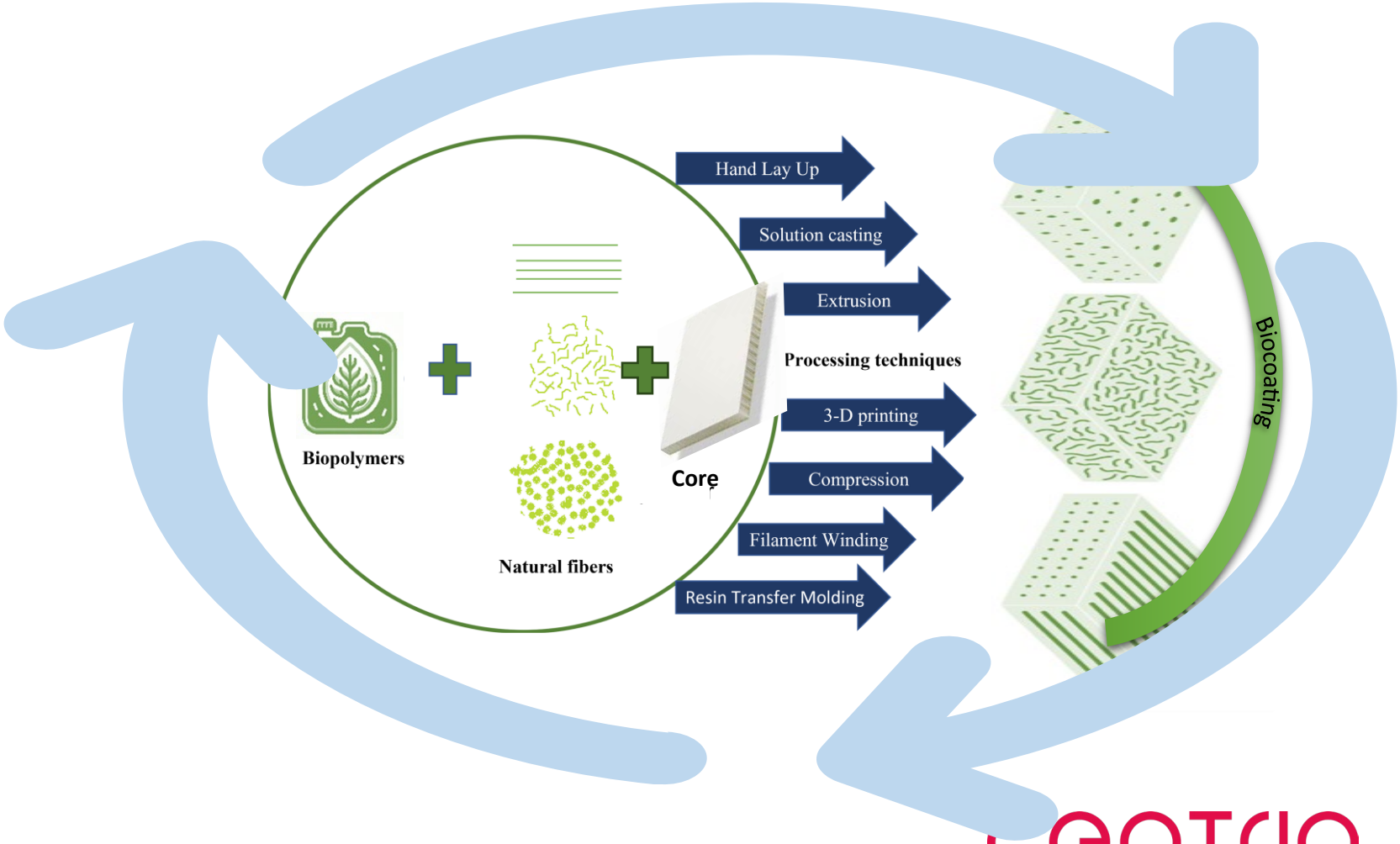
Environmental Impact of Biobased Materials in Composites

Egidija Rainosalo and Rathish Rajan

Centria UAS

Content

- LCA impact cathegories
- Biobased fibres
- Sustainable matrix resin
- Composites
- Conclusions



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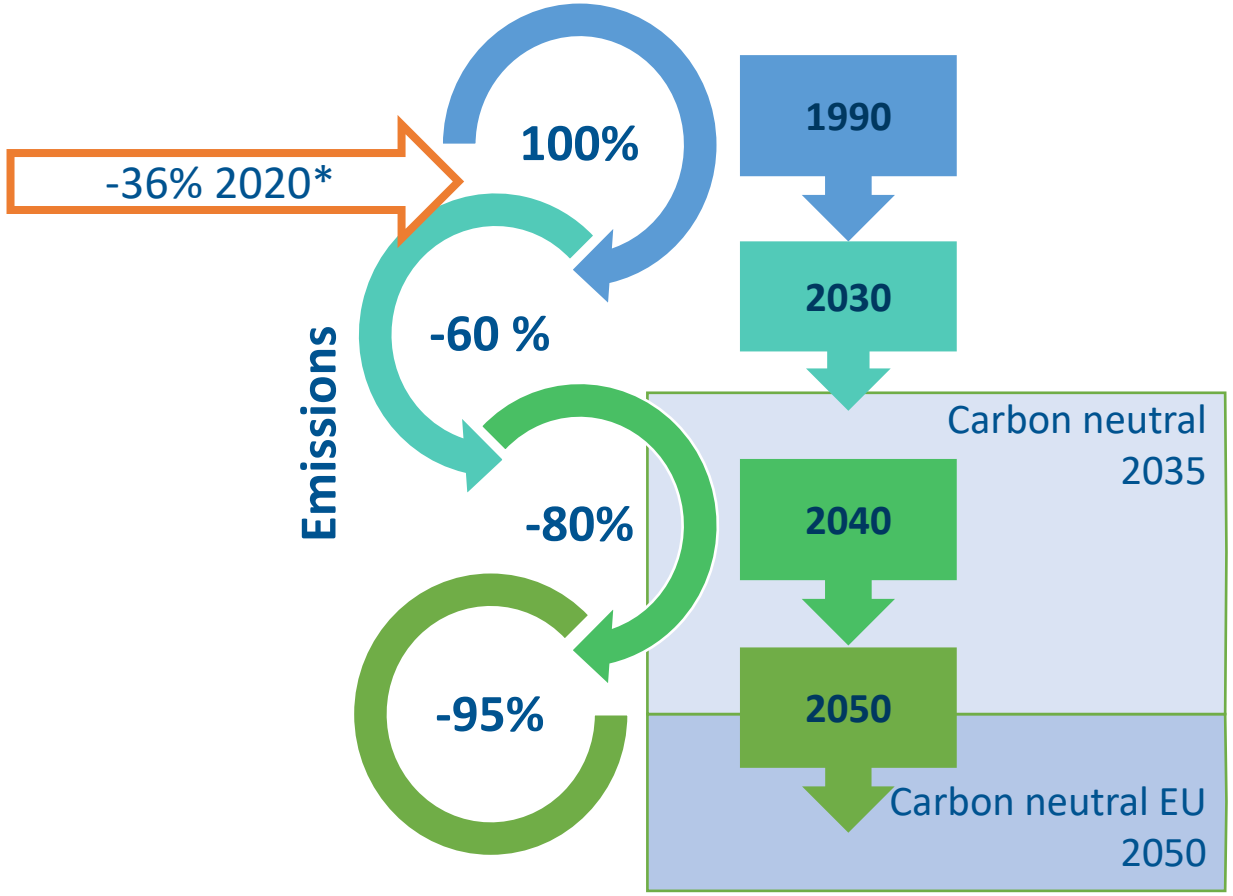
Finnish net zero carbon timeline

according to Finland's Climate Act (423/2022)



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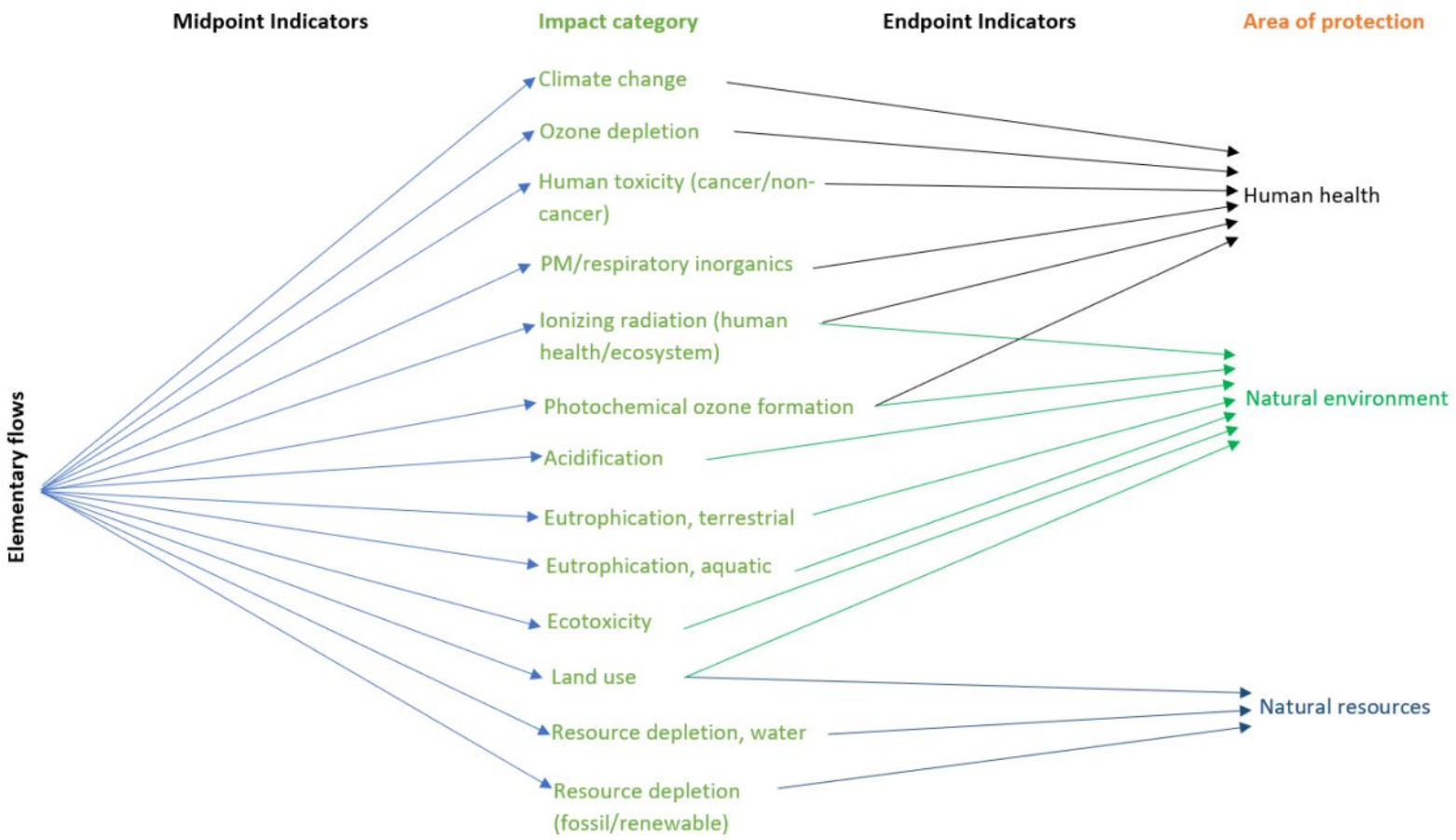
* https://www.ymparisto.fi/fi/ymparistontila/ilmastonmuutos/kasvihuonekaasujen-paastot

LCA - environmental sustainability quantification



LCA supports legislation

- Sustainable Ecodesign Directive and Digital Product Passport
- Green Claims Directive
- EU Taxonomy for Sustainable Activities
- The Product Environmental Footprint (PEF) and Organisation Environmental Footprint (OEF)
- Environmental product declaration (EPD)
- Corporate Sustainability Reporting Directive (CSRD)

Framework of the ILCD midpoint+ method, linking elementary flows to midpoint and endpoint indicators

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Biobased fibres for composites

Fiber type	Density g/cm^3	Tensile strength, MPa	Elongation at break, %	E-Modulus, GPa	Moisture absorption, %
E-Glass	2.54-2.6	900-3500	1.8-3.2	70-85	-
Carbon	1.75-1.95	2600-7000	1.3	100-700	-
Hemp	1.4-1.6	300-900	1.6	30-70	8
Flax	1.4-1.5	500-1500	1.2-2.4	50-80	7
Rayon (Cordenka)	1.5	700-800	13-15	14,5-18	13
Carbon recycled/solvolysis *	1-5% reduction				
Processing temperature of natural fibers ~200^{o}C for short time					

* Solvolysis tests performed at Centria, RE-COMP project

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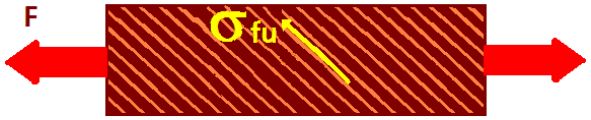
Examples of continuous fibres

- Non twist fibre bundels consolidated into various structures
- Low CTE allows hybrids with carbon fibre

- Highly twisted fiber bundles can be difficult to impregnate
- Fibre properties not fully utilized in load direction when fibers are twisted,



Highly twisted flaxfibre in yarn

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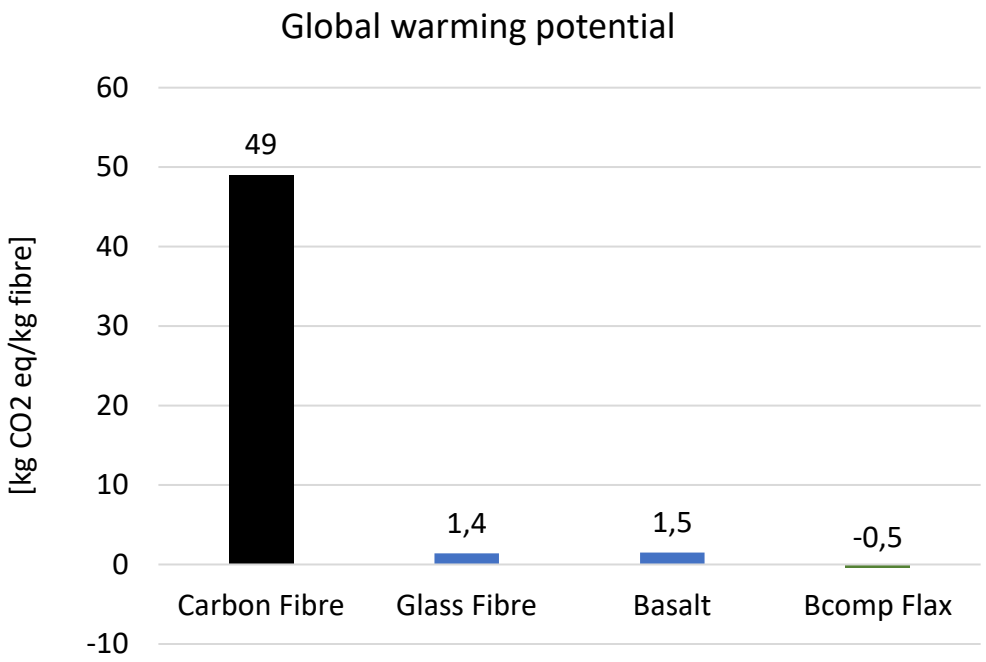
Advantages of biobased fibres



Adapted from
https://www.bcomp.com/applications/marine/

ENVIRONMENTAL BENEFITS Less energy for production, biodegradable, less human toxicity

INCREASED RECYCLABILITY of composite

VIBRATION DAMPING* Up to twice as absorbent as glass and three times as absorbent as carbon.

SOUNDPROOFING* Up to 15% better absorption compared to glass, based on flax epoxy composite

RADIOWAVE TRANSPARENCY* 15% less permittivity for 17% signal attenuation and 10% more velocity than glass composites.

THERMAL INSULATION* 15 to 30% better insulation compared to glass.

*COMPOSITES & TECHNOLOGY - Safilin

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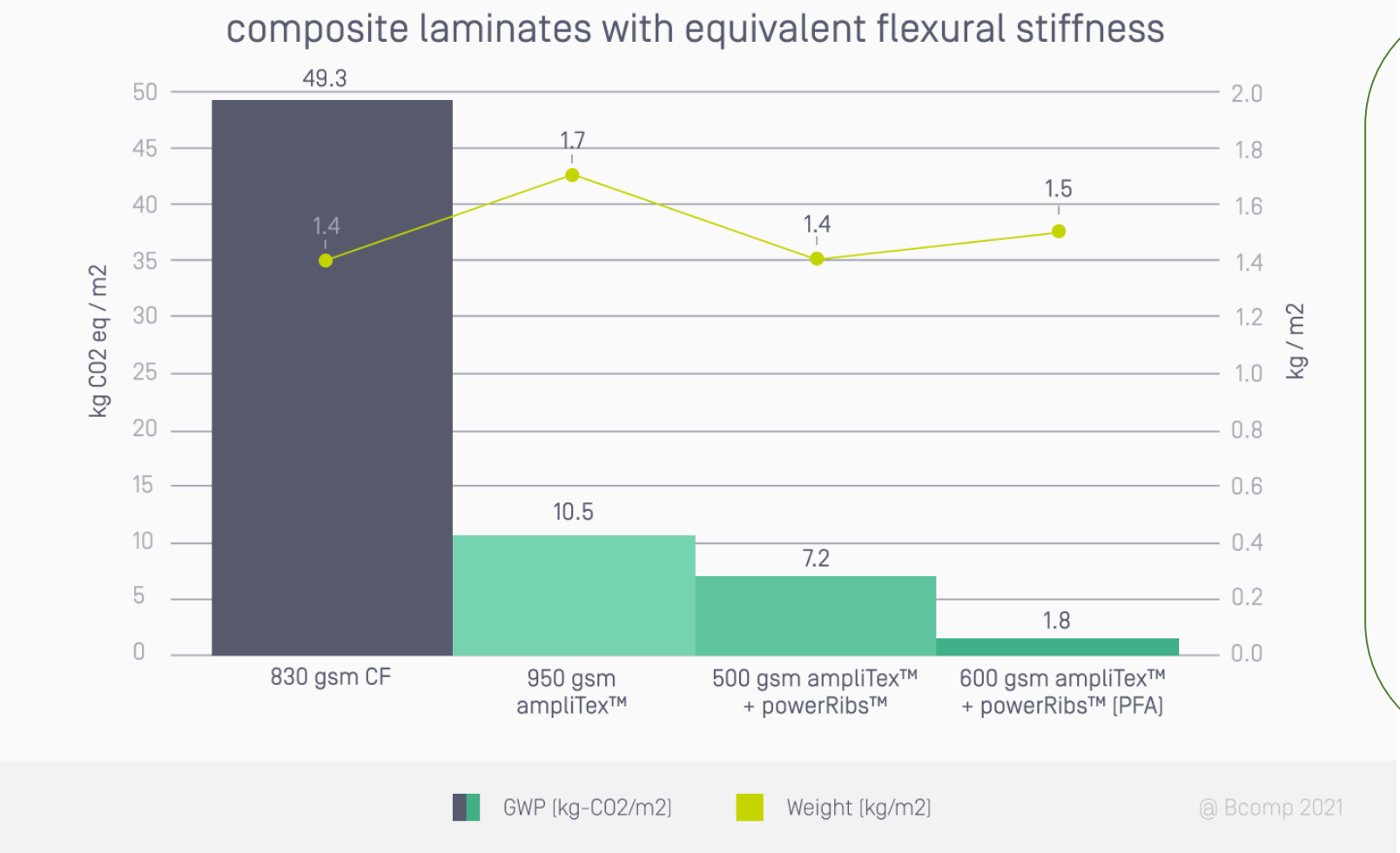
Comparisson of fibre and resin influence on composite global warming potential



- Replacing carbon fibres with ampliTex™ reduces CO_2 emissions by nearly 80%, though it slightly increases part weight.
- Combining ampliTex™ with powerRibs™ reinforcement grid matches the weight and stiffness of a thin-walled monolithic carbon fibre part, while lowering cradle-to-gate CO_2 emissions by up to 85%.
- Using a bio-based resin, such as one made from sugar cane waste (PFA), can cut CO_2 emissions by up to 96%.

https://www.bcomp.com/sustainability/#CO2-Reduction

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Sustainable matrix

Thermoplastic vs Thermoset		
Raw material form	Granules, powder	Liquids, gels (chemically reactive)
Processing	Melting, forming, cooling	Mixing reactants, hardening by heat, UV light or other method
Behaviour at higher temperatures	Melts	Softens, but doesn't melt
Tooling	Expensive	Cheaper
Recycling	**Recyclable**	**Not possible to recycle without breaking chemical structure to monomers**
Mechanical properties	Very good impact resistance	Hard and rigid, good strength, poor impact resistance
Dimensional stability	Poor, high thermal expansion	Excellent, low thermal expansion

Thermoplastic resin – Elium from ARKEMA

- ✓ Reactive Liquid Thermoplastic Resin with accelerator and low exotherm
- ✓ Formulations for most of composite manufacturing techniques
- ✓ Low viscosity for easy wettability with any type of fibers
- ✓ Curing at room temperature and moderate temperature
- ✓ High mechanical properties, superior impact and fatigue resistance
- ✓ **Advantage for being recyclable,** thermoforming and more

On **multi 50 *Arkema 4*** with cockpit, deckhouse, front outtrigger arm fairing are made with Elium® resin. 30% of the parts were made from recycled Elium® resin.

Carbon reinforced, filament winded hydrogen tank, tested for 1500 bar presuure

25 m blade

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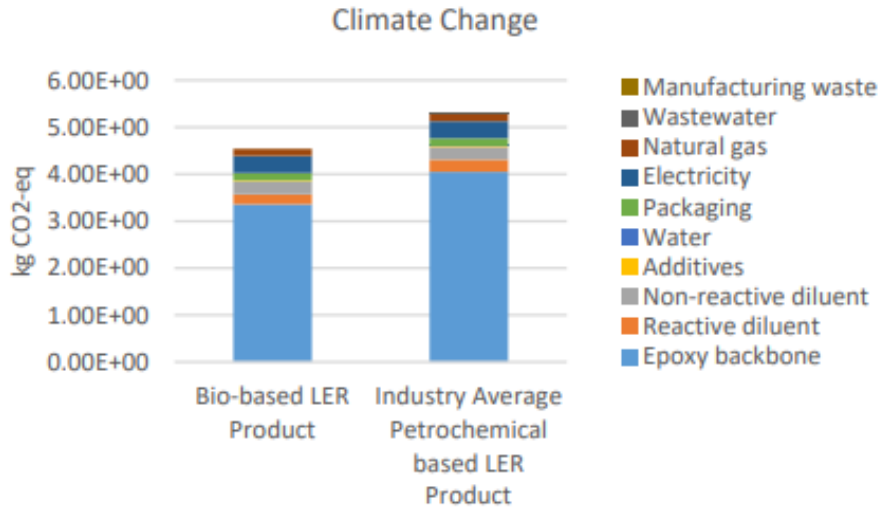
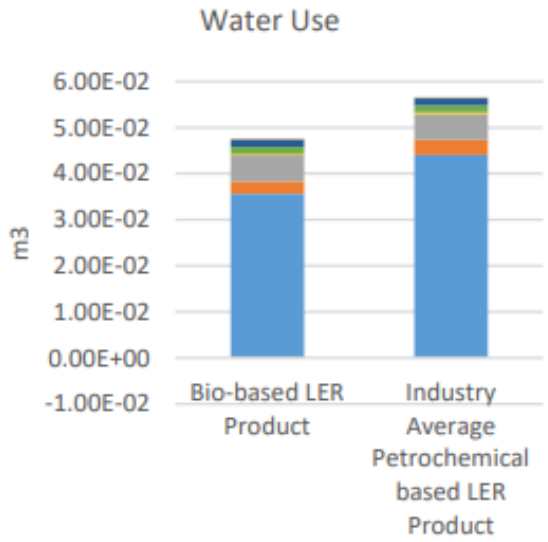
Comparisson example of LCA results for biobased vs petrol based epoxy resin

	Human Health (DALY)	Ecosystems (Species * yr)	Resources ($/kg)	Cumulative Energy Demand (MJ)	Climate Change (kg CO_2 eq.)	Water Use (m3)
Bio-based LER Product	1.09E-05	2.10E-08	6.04E-01	9.10E+01	4.54E+00	4.74E-02
Industry Average Petrochemical based LER Product	1.25E-05	2.42E-08	6.81E-01	1.03E+02	5.28E+00	5.64E-02
Percent Difference	-13%	-13%	-11%	-12%	-14%	-16%



IPCC 2013 GWP 100a v1.03



ReCiPe 2016 Midpoint (H) v1.03

- The majority of the impacts are from the epoxy backbone.
- The biobased LER product has 11% - 16% fewer environmental impacts than the industry average petrochemical based

Adapted from https://entropyresins.com

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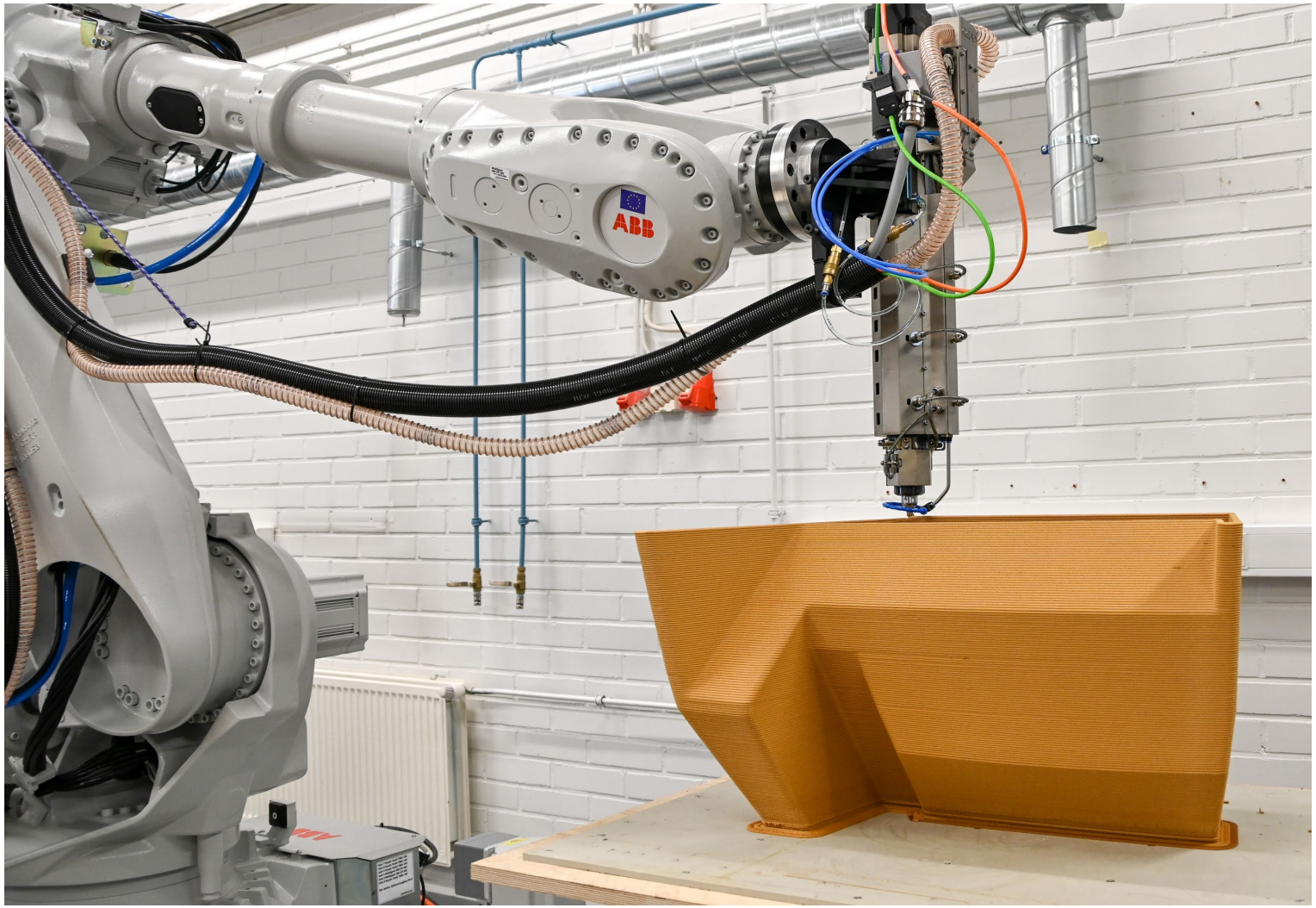
3D printed boat steering console



Material: 50% sawdust+
50% PP
Size: 56x45x65 cm
Nozzle: 6 mm
Layer height: 3 mm
Duration about: 4 hours

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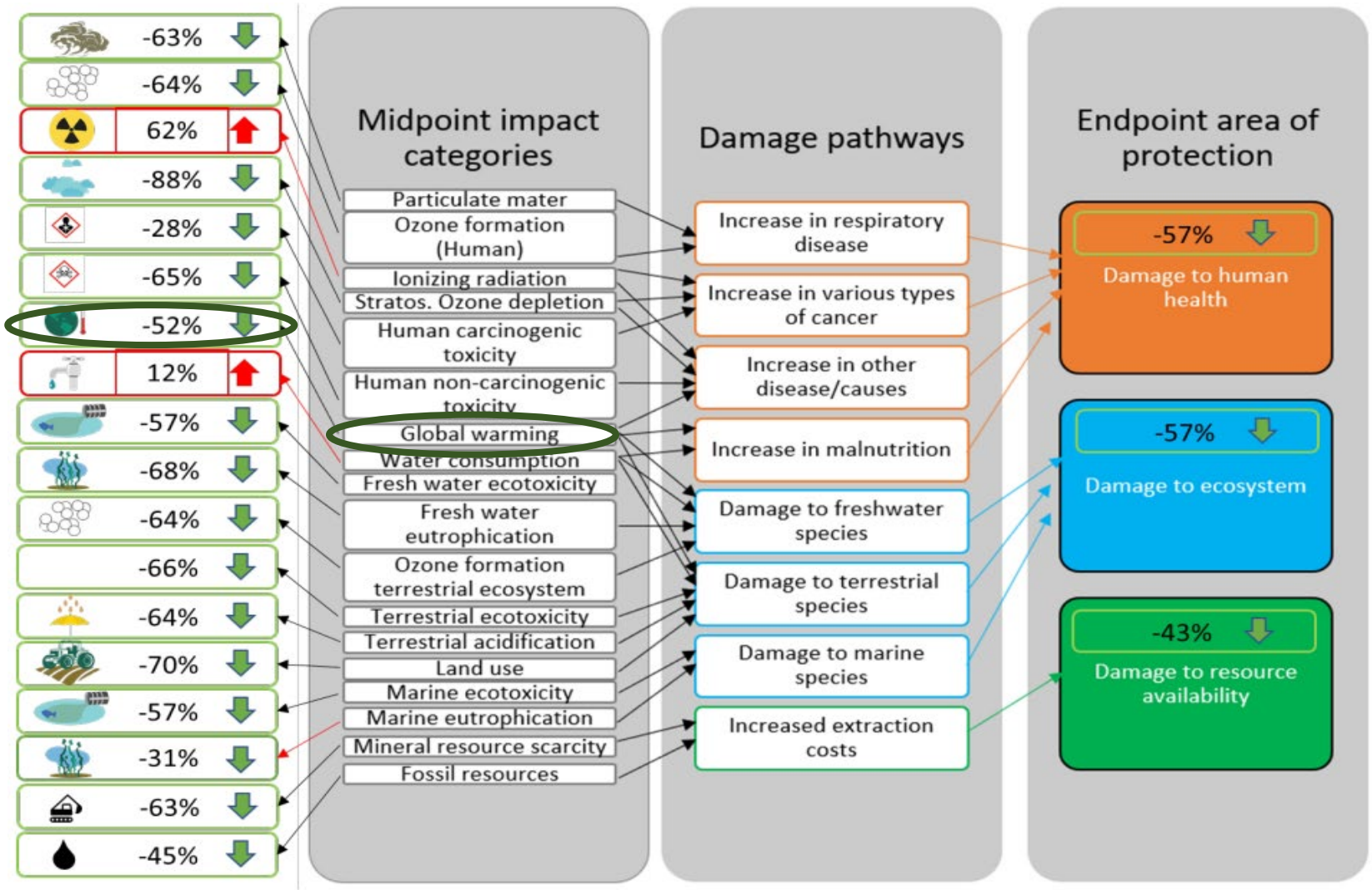
Comparison of GFRP vs 3D printed biobased thermoplastic composite



Method: ReCiPe,
Software: Simapro 9.3

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Summary: Advantages of Bio-based Composites

- ✓Environmental Friendliness: Reduced dependence on fossil raw materials, lower greenhouse gas emissions.
- ✓Recyclability: Easier to recycle and utilize in a circular economy.
- ✓Social Acceptability: Growing consumer demand for sustainable products.
- ✓Energy Efficiency: Lower energy needs reduce costs
- ✓Reduced waste: Lower costs for waste handling
- ✓Innovation: New material combinations and business models to support sustainable development.

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Challenges

- New products structural design
- Process adjustments
- Risk of Greenwashing, need for extended LCA
- Performance trade-offs
- Lack of industry standards
- Quality control
- Cost and availability

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The best time to plant a tree was 20 years ago.
The second best time is now.
Chinese Proverb

Thank you!

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