What choices for an ecoresponsible design of carbon fiber bicycle frames

Simplified Carbon Cycle Analysis Report

Directed by
Magog Green

For
BeelivinU

May 8, 2023

Disclaimer of liability

The BeelivinU client is not responsible for the information retained in this analysis.

Magog Vert (Brigitte Blais) claims to have conducted the analysis to the best of its knowledge, based on data found in the scientific literature.

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Version	Name	Date
V1	Brigitte Blais	2023-05-08
V2	Brigitte Blais	2023-05-09

Standard followed

This report on the simplified carbon cycle analysis of carbon fiber bicycle frames is partly based on the ISO-14040 standard without guaranteeing its completeness. Some concepts from ISO-14064-1 were also used in the report.

Regulatory body

This report will not be submitted to any regulatory body unless the client decides to submit it.

Table of contents

Acronyms

ACC	Carbon cycle analysis
LCA	Life cycle analysis
CFRP	Carbon fiber reinforced polymer or *Carbon fiber reinforced polymer*
CO_2	Carbon dioxide
g	Grams
GHG	Greenhouse gases
GJ	Gigajoules (1 000 000 000 joules)
UHM fiber	Ultra high modulus fiber
kg	Kilograms
kWh	Kilowatt hours
m^2	Square meters
MJ	Megajoules (1,000,000 joules)
PAN	Polyacrylonitrile
R&D	Research and development
t	Tons
t CO_2 eq	Tons of CO_2 equivalent
t.km	Portion of tonnes per kilometer travelled attributable to the object transported (by weight) in a delivery vehicle
10^6	1 000 000

This report explores, for BeelivinU, the carbon footprint of a carbon fiber bicycle frame production project in Montreal versus Asia. A simplified carbon cycle analysis was conducted, from manufacturing to end of life, based on data obtained from the scientific literature. The carbon footprint of different options, at different stages of production, is also presented.

GHG Project

Title and location of the project

Carbon fiber bicycle manufacturing project in Montreal (Qc, Canada).

Description of the project

The project consists of manufacturing lightweight (1.9 kg), high-end, high-performance carbon fiber bikes. The frame and many parts could be machined in Montreal, while other parts could be imported mainly from Canada and the Eastern United States, and elsewhere, aiming at the least possible.

As BeelivinU has environmental concerns, the project owner wants to design a product with the smallest possible carbon footprint, right from the start. He also wants to be able to compare his product with an equivalent production in Asia.

The origin of the materials and the energy required for their transformation, delivery and recycling are thus part of the evaluation.

The target audience for the bikes is within a 500 km radius of Montreal, limiting transportation for delivery and maintenance of the product.

Type of project

Industrial project.

Duration of the project

The company is in the pre-start-up phase. The objective is to start a small production plant, there is no end of project planned.

The p project manager

The promoter of the project is Benjamin du Haÿs, founder of the future company BeelinviU.

Project scope

This analysis is limited to the production of carbon fiber bicycle ***frames***. The stages analyzed (the scope of the project) are: the purchase of a roll of already manufactured carbon fiber (or spools of weaving yarn), its transformation, its delivery and its end-of-life management. However, a short passage in the science watch reports the carbon footprint of the *manufacturing* stage under the responsibility of the supplier.

Respect for the fundamental principles

1. Relevance:

The data used in the spreadsheet comes primarily from published life cycle analyses. Other data comes from similar companies that produce carbon fiber bicycles. The latter data could not be verified, however, probably due to industry secrecy. This report is not intended to be verified, as the project proponent is not currently seeking to generate carbon credits.

2. Completeness:

The present study concerns bicycle frames only. The manufacture of the carbon fiber rolls, epoxy and hardener was overviewed using data obtained from scientific studies. Then, for each of the subsequent steps, over which the project proponent has decision-making authority, calculations were made so that the project proponent could make an informed decision about its input choices.

3. Consistency:

The emissions factors chosen are those recognized by Canada or the international community. Data other than energy used and transportation modes and distances are comparable.

4. Transparency (auditability):

All calculations are available and displayed in the Excel spreadsheet attached to this report, as well as the sources from which the quantities presented were obtained. This will allow any auditor to verify the relevance of the data and calculations.

5. Additionality:

The normal course of business is to manufacture bicycle frames in Asia or Africa, where labor is less expensive, since the manufacturing process is labor intensive. Thus, the choice to manufacture the frames in Montreal demonstrates a voluntary additionality to the project.

6. Realism:

The project seeks to avoid carbon emissions by choosing carbon fiber manufactured in Canada or the United States, using Canadian flax fiber, using hydroelectricity as an energy source, and ensuring the repair and recycling of carbon fiber frames at the end of their life. The emissions avoided will be measurable.

7. Managing uncertainty:

a. Clarification:

Only one data item showed significant variability, since two scientific studies conducted in two different countries showed very different LCA results. This is the energy required for pyrolysis to recycle the carbon fiber.

b. Be careful:

The data used comes from scientific studies. The emission factors for Quebec are those for hydroelectricity, those for China for coal and those for England for natural gas. When no data corresponding to the client's objectives was available, a conservative data was used, for example, for the weight of a fiber.

c. Permanence:

As long as the project proponent chooses materials, energy and end-of-life management close to the processing site, the permanence of the reductions will be assured. If, on the other hand, he does not manage the end-of-life of the bicycles he markets, a leakage of reduction will be observed.

d. Leaks:

The following leaks are possible:

1) if the carbon fiber rolls are produced in a country where the electricity is generated with coal or natural gas or any other fossil fuel;
2) if the distance between the place of production of the fiber and the place of transformation is high;
3) if the project developer abandons the idea of managing its customers' bikes at the end of their life.

Scientific watch

A search of the scientific literature was conducted to obtain data useful for the calculations in the attached spreadsheet. The following are summaries of the results for each of the steps studied.

Manufacturing

Although this report excludes the manufacturing stage of the carbon fiber rolls, it is important for BeelinviU to realize that this stage has the largest carbon footprint. Here are some of the findings we have encountered during our research.

According to a life cycle analysis of carbon fiber and biofiber composites prepared using vacuum bagging technology, "*The manufacture of carbon fiber is an **energy-intensive** process and is produced from polyacrylonitrile (PAN), which is a synthetic thermoplastic that undergoes polymerization resulting in a **high carbon footprint***. The manufacture of the composite material would consume 1100 MJ of energy for 1 kg of carbon fiber, while it would consume 203 MJ for 1 kg of flax fiber (Ramachandran, Gnanasagaran, & Vekariya, 2023).

In addition, this same life cycle assessment (LCA) identifies a series of other impacts, as illustrated in the following Table 1:

Table 1
Different toxicity emissions from carbon-fiber composites.

Processing technique	Acidification (SO_2 Eq.)	Human toxicity cancer (CTUh)	Human toxicity non-cancer (CTUh)	Respiratory inorganics (diseases incidence)	Ecotoxicity (CTUe)
Autoclave	0.00612	0.183	0.12	0.419	0.693
Finishing/winding	0.00654	0.196	0.128	0.448	0.074
Prepreg	0.011	0.338	0.215	0.753	0.124
Pyrolysis	0.0113	0.338	0.221	0.772	0.128
Sheet moulding	0	0	0.0189	0.0659	0.0109
Stabilisation	0.0203	0.609	0.398	1.39	0.23
Surface treatment	0.00115	0	0.0225	0.0786	0.013
Vacuum bagging	0	0	0	0.003	0
Carbonisation	0.0539	1.62	1.06	3.69	0.61
Nitrogen	0	0	0.0135	0.0672	0.0163
PAN fiber	0.0206	5.2	0.602	1.35	1.22

Source : Ramachandran et al.
https://www.sciencedirect.com/science/article/pii/S1526612523000944, page 28

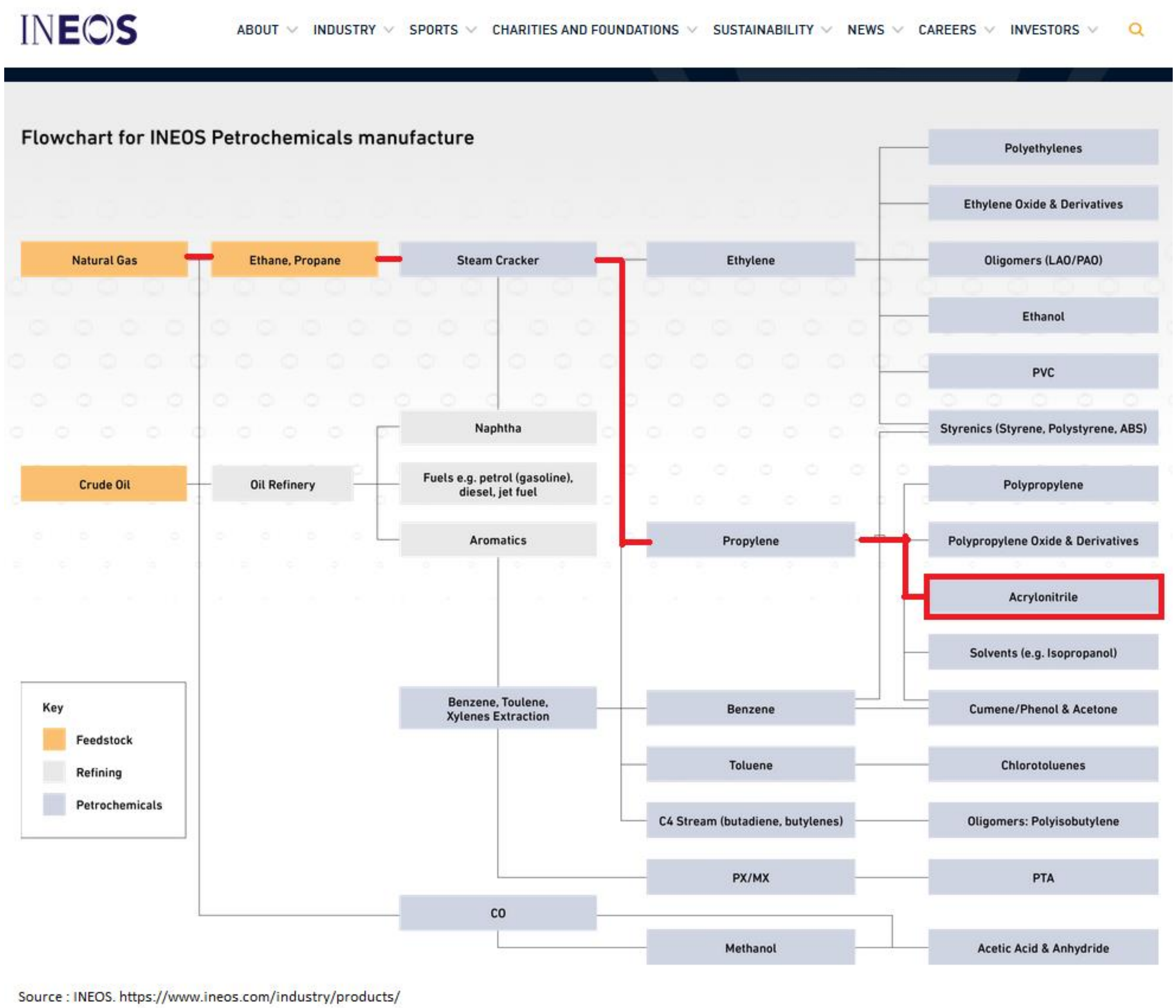


Figure 1: Fossil origins of carbon fiber

Another study analyzed the carbon footprint of using virgin fiber versus using fiber from recycled carbon fiber reinforced polymer (CFRP), i.e. carbon fiber-epoxy-hardener composite. It turns out that using a **recycled fiber as a raw material** would significantly reduce the carbon footprint of the product (1.52 kg CO_2 eq / kg fiber), compared to using a virgin fiber (24 kg CO_2 eq / kg fiber). Thus, voluntarily using recycled fiber would be worth a reduction in emissions on the carbon market, since there is no legal requirement for the manufacturer to use it. This credit would reduce the product's carbon footprint to 0.57 kg CO_2 eq / kg, according to the authors. (Kawajiri & Kobayashi, 2022)

Finally, a research center in St-Hyacinthe (Groupe CTT) is conducting research on recycling CFRP by microwave pyrolysis. The end product is a fiber that can be woven, like virgin fiber. The use of this recycled fiber for the design of certain products, emits 5 times less GHG than producing with synthetic virgin fiber (Dega C. , 2021).

Purchases of materials to

A life cycle assessment conducted in Bangladesh on the production of **aluminum** bicycles for sale in Bangladesh concluded that aluminum is a material with significant impacts, including human toxicity. Moreover, **local production** shows a smaller footprint than bicycles imported from Europe for impacts on climate change, human toxicity, particulate matter emissions, and depletion of metal and fossil fuel resources. (Papon, Danesh, & Tasneem, 2019)

As for **carbon fiber,** it is a material that is both lightweight and strong, and is increasingly in demand for a wide variety of applications, including bicycle manufacturing. According to a study conducted on the carbon fiber supply chain, in 2012 supply exceeded demand, while in 2020 demand exceeded supply, a sign of a craze for this material produced in limited quantities. The lower supply than demand also explains its high cost. (Das, Warren, West, & Schexnayder, 2016)

Distances between Montreal and suppliers of raw materials or materials

Since distance is an important factor in the carbon footprint of a product, here are the possible import locations of fiber rolls, epoxy and hardener in kilometers. BeelivinU will thus have the advantage of obtaining its carbon fiber from suppliers closest to Montreal to reduce the carbon footprint of transportation.

Rayplex Ltd seems to be the closest, in Ontario: 341 Durham Crt. Oshawa,Ont Canada L1J 1W8. It sells both meters of carbon fiber fabric, tubes (socks), epoxy and color pigments. Also, the fabric weight is only 6 oz/m^2 .

BeelivinU also wishes to purchase carbon fiber spools and flax fiber spools in order to weave itself in Montreal. Research and development (R&D) will have to be carried out in order to discover in which proportions of carbon versus linen the company will achieve the desired properties. Indeed, the more flax in the composition of the bicycle frame, the smaller its carbon footprint will be, since flax sequesters carbon during its growth and requires less energy to be transformed and recycled.

The following Table 2 is also found in the "Purchase of Supplies" tab of the Excel spreadsheet in Appendix 1, with the references hyperlinked. It shows **distances from 0 to 10,407 km** depending on the material and the supplier chosen. These transportation kilometers are a significant source of greenhouse gases. This is why the choice of a supplier in North America, even in Canada, would be preferable. **Flax fiber, in** addition to sequestering carbon during its growth, would have very interesting and competitive properties with synthetic composite fibers. For example, it is lighter than carbon fiber and requires less water to manufacture[1] . In addition, if flax is grown with fewer pesticides, and the spinning of the fiber is controlled, it can further reduce its carbon footprint. (Ramachandran, Gnanasagaran, & Vekariya, 2023)

Figure 2 shows, for illustrative purposes, other impacts identified in a full life cycle assessment of carbon fiber composites and biocomposites. It shows that composites have higher impacts, but biocomposites also have their impacts, to a lesser extent.

Table 2 presents potential material suppliers, according to their distance from Montreal. The hyperlinks to the suppliers' websites are in Appendix 1, Tab 2. Purchases of supplies, boxes G77 to G92.

[1] https://ici.radio-canada.ca/nouvelle/1718903/lin-agriculture-transformation-fibre-innolin

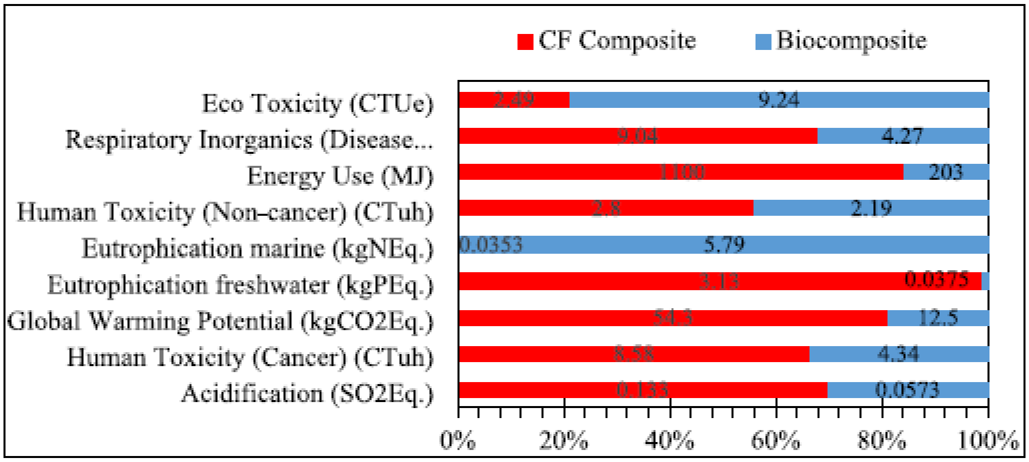


Fig. 3. Environmental analysis of carbon fibers composites and biocomposites.

Figure 2 Environmental analysis of carbon fiber composites and biocomposites

Table 2: Raw material suppliers and distance from Montreal

See Appendix 1, "Purchasing Supplies" tab for more clarity and click on the links.

Calcul des distances entre Montréal et le lieu d'importation de la fibre de carbone (et de résine)

Produit	Entreprise	Ville	État	Distance de Montréal Selon GoogleMap et www.distancede.com	Note
Époxy, résines	**EcoPoxy (Fabricant)** et **Langevin Forest** (détaillant à Mtl)	**1-Fabricant** : EcoPoxy, Box 220, Morris MB, R0G 1K0 **2-Détaillant** au Qc : Langevin Forest, 9995 Boul. Pie-IX (Boul. Industriel), Montréal (QC) H1Z 3X1	Manitoba et Québec, Canada	2246	EcoPoxy GelCoat and BioPoxy 36® : résine écologique. Distributeur à Mtl : Langevin Forest
Fibre de lin et fibre de carbone recyclé	**Groupe CTT**	3000, avenue Boullé Saint-Hyacinthe (Québec) J2S 1H9 Canada	Québec, Canada	60	https://gcttg.com/en/research-and-development/ecotextiles-and-processes/
Fibre de carbone en tube (chaussettes), en feuilles, etc., résine, époxy, kits de fabrication tout inclus. Très léger.	**Rayplex Ltd.**	341 Durham Crt., Oshawa	Ontario, Canada, L1J 1W8	486	Rayplex Ltd. Vend tout le kit, ainsi que la résine et des chaussettes et des rouleaux
Fibre de lin (R&D)	**Innolin**, installé au Centre de formation professionnelle Mont-Joli-Mitis	Saint-Joseph-de-Lepage	Québec, Canada	580	Centre de formation professionnelle Mont-Joli-Mitis (CFPMM) 1414, rue des Érables Mont-Joli, Québec G5H 4A8 Téléphone : 418 775-7577 poste 1500 Télécopieur : 418 775-8262 courriel: cfpmm@cssphares.gouv.qc.ca
Fibre de Carbone		Rock Hill, SC	Caroline du Sud (SC)	1614	Das, Warren & West.
Fibre de Carbone		Greenville, SC	Caroline du Sud (SC)	1725	Das, Warren & West.
Fibre de Carbone		Rockwood, TN	Tennessee (TN)	1748	Das, Warren & West.
Fibre de Carbone		St. Charles, MO	Missouri (MO)	1772	Das, Warren & West., dans la zone des tornades
Fibre de Carbone		Decatur, Al	Alabama (Al)	1946	Das, Warren & West., dans la zone des tornades
Fibre de Carbone		Evanston, WY	Wyoming (WY)	3442	Das, Warren & West.
Fibre de Carbone		Salt Lake City, UT	Utah (UT)	3586	Das, Warren & West.
Fibre de Carbone		Moses Lake, WA	Washington (WA)	4054	Das, Warren & West.
Fibre de Carbone		Sacramento, CA	Californie (CA)	4610	Das, Warren & West.
Fibre de lin	**Bcomp**	Fribourg	Suisse	5933	https://www.bcomp.ch/solutions/rearts/
Fibre de carbone et de polyéthylène à très haut poids moléculaire (UHMwPE)	**Carbon with Dyneema®**	SEM Office: Specialty Engineered Materials, GLS Thermoplastic Elastomers, Manufacturing Plant 77 Shenggang Street, SIP, Suzhou, China, 215021	China	7000	https://www.dyneema.com/our-products/dyneema-fabric
		5750 Greenville Blvd NE Greenville, NC, United States, 27834	North Carolina, États-Unis	1385	

Transformation

Methods of manufacturing carbon fiber frames

Bladder molding, compression molding, vacuum infusion and autoclave processing are all energy-intensive steps in the manufacture of carbon fiber tubing.

Energy consumption in vacuum processing

In terms of **energy consumption,** the study by Ramachandran et al. analyzed the difference in energy required to process flax versus carbon fibers from PAN (polyamide-cyanides), both by vacuum bagging. The results show that 202 MJ/kg of flax fiber is required, compared to 1100 MJ/kg of carbon fiber. This energy intensity thus presents a significant footprint of carbon fiber. (Ramachandran, Gnanasagaran, & Vekariya, 2023)

Compression molding

"Statistics show that IMMs consume 6.68 × 108 GJ of energy each year worldwide (Thiriez and Gutowski, 2006, Iwko et al., 2018), which is equivalent to 1.86 × 1011 kWh of electricity. Typically, 1 ton of coal can generate 3,000 kWh of electricity and emit 2.7 tons of CO_2 . Therefore, IMMs consume 6.18 × 107 tons of coal and emit 1.67 × 108 tons of CO_2 every year worldwide." (He Liu, Xiaogang Zhang, Long Quan, & Hongjuan Zhang, 2021). **The point of** this quote is that any production in a country where electricity is generated through coal burning has great consequences on greenhouse gas emissions. They are therefore to be avoided by BeelivinU to meet its minimum footprint objectives.

"The specific energy consumption (SEC) values for the hydraulic, hybrid, and all-electric machines analyzed are 19.0, 13.2, and 12.6 MJ/kg, respectively (including auxiliaries, compounding, and power system inefficiency)." (Thiriez & Gutowski, 2006) **What we can learn from** this quote is that all-electric machines consume the least energy per kilogram of product.

Delivery

No scientific review has been conducted on delivery. It is known that the distance traveled between the factory and the ultimate customer, as well as the type of vehicle chosen for the delivery (plane, boat, train, heavy truck versus electric van) are the parameters that will influence the carbon footprint of the delivery.

End of life management

Furthermore, at the end of its life, carbon fiber presents recyclability issues. As of 2013, there were four methods of recycling fiber-reinforced resin composites: mechanical recycling, pyrolysis, a fluidized bed process, and chemical recycling, each with their shortcomings and energy demands. (Pinglai, Juan, & Jiangping, 2013)

A study from Kinsgton University in the UK investigated which material, between carbon fiber (synthetic) and biocomposite fibers (bio-based materials), had the lowest carbon footprint and the best recyclability. With similar properties (and even lighter for flax fiber), it turns out that bio composites are easier to recycle while holding a global warming potential of 12 kg CO_2 equivalent, compared to 54 kg CO_2 equivalent for carbon fiber, which represents a footprint 4 times smaller for flax. (Ramachandran, Gnanasagaran, & Vekariya, 2023)

Another study attempted to evaluate whether **recycling by vapo-thermolysis** had more benefits, over its entire life cycle, than **landfilling (non-recycling)** the carbon fiber composite. "Steam-thermolysis is the process that combines pyrolysis and superheated steam at ambient pressure to break down the organic matrix of the composite." Two composites were evaluated, polyamide 6 and polyphenylene sulfide matrices. The recovered fibers are clean, regular and similar to new fibers, although their tensile *strength is* only 80% of that of new fiber. According to this study, "the valorisation of composites by recovery of carbon fibers, brings clear advantages from an environmental point of view". (Oliveira Nunes & al., 2015) Among these advantages are the absence of extraction of raw material from the ground and the absence of energy-consuming and polluting petrochemical transformation, among other benefits.

Other research and development is underway, notably at the CTT Group in St-Hyacinthe, to separate carbon fibers from their resins and hardeners (CFRP), **using microwave pyrolysis**. The process takes 7 minutes at 650 watts to separate 99% of the resin from the fiber and consumes much less energy. In terms of GHG emissions, producing recycled fiber emits 5 times less GHG than producing virgin fiber (Dega C. , 2021).

Accessories around the frame

According to the study *Cycling mobility - a life cycle assessment based approach,* the use of **carbon fiber wheels (rims)**, rather than aluminum, presents a significant gain in terms of reducing the environmental footprint of the bicycle, over its entire life cycle. Conversely, the use of **a carbon fiber fork** rather than a *low alloy steel* fork slightly reduces its environmental footprint on different impacts. Thus, **aluminum** parts have the largest footprint, while **low-alloy steel** parts with a small footprint compete with carbon fiber. In short, choosing carbon fiber over aluminum reduces the environmental footprint of the bicycle, at least for this study that compares bicycles from the Netherlands versus Portugal. Note that **this study did not evaluate the life cycle of a carbon frame**, but of carbon rims and a carbon fork. (Margarida & Diogo , 2015)

The impacts assessed by this study are: lung health damage (through organic and inorganic particles), contribution to climate change (through greenhouse gas emissions), radiation emission, ozone layer damage, ecotoxic impacts, water acidification and eutrophication, land use, mineral use, and fossil fuel use. (Margarida & Diogo , 2015)

Simplified Carbon Cycle Analysis (SCA)

The current analysis was limited to the carbon footprint of each stage of the production of a carbon fiber bicycle frame. Other life cycle assessments also evaluate water requirements, impacts on human health, biodiversity, air quality, etc... which is not the case here.

Vision of the company

1. Use recycled / organic products
2. Remove dependency on any remote supplier
3. Produce the highest quality product we can at all times

Objectives

Among the objectives of the project, here are those related to the environmental footprint of the product:

1. Determine what the best material choices are;
2. Determine acceptable and unacceptable sources of materials and parts;
3. Influence the design of the bikes that BeelivinU will produce.
4. Create a design that will have the smallest possible footprint on the environment
5. Work with local suppliers (80%) from Canada or the Eastern United States
6. Design, manufacture and assemble the bikes locally
7. Avoiding programmed obsolescence
8. Have a deep understanding of our impact on the environment
9. Serve customers within a 500 km radius

Emission sources

The main sources of greenhouse gas emissions identified in this analysis are

1. Emissions related to the transportation of raw materials, finished product and end-of-life product;
2. Emissions related to energy sources needed to produce electricity;

Steps

The *manufacture of* the fiber itself has been analyzed only modestly, based on data found in a scientific study.

The following steps have been further researched and calculated with data from the scientific studies cited above:

1. Purchase of materials and supplies
2. Transformation
3. Delivery
4. End of life management

Raw material purchasing / Supply chain

Among BeelivinU's challenges is the search for lightness and quality of materials, coupled with a desire for local sourcing. In the best of worlds, the frame would weigh 1 kg, the fork 300 g and the two rims 600 g in total, for a total of 1.9 kg. Minus 40% resin (0.76 g), that's 1.14 kg for the frame, fork and rims.

The source of the raw materials and/or parts, their composition and their own life cycle, even before they arrive at the BeelivinU factory, will have an impact on the carbon footprint of the finished product. The choices made by the company throughout the supply chain will impact the carbon footprint of the finished product.

When procuring, BeelivinU will have to choose from the following options:

Purchase of fiber

1. Virgin fiber from petrochemicals
    a. From Canada / Ontario
    b. From the Eastern United States
    c. From Europe / Switzerland
2. Fiber recycled by conventional pyrolysis
    a. From Canada
    b. From the Eastern United States
    c. From Europe
3. Fiber recycled by microwave pyrolysis
    a. From Canada / Quebec
4. Flax fiber
    a. From Canada / Quebec
    b. From Switzerland
5. Ultra high molecular weight polyethylene carbon fiber (UHMwPE)
    a. North Carolina / United States
    b. China

Transformation

1. Resin transfer vacuum molding
    a. By vacuum bagging (Vaccum bagging)
    b. By electric press
    c. By hydraulic press

2. Other technique

Delivery

a. Delivery by 40' heavy truck
b. Delivery by light gasoline truck

End of life management of the product

1. Transport of the product to the recycling site
    a. Heavy truck (with container) to St-Hyacinthe
    b. Heavy truck (with container) to Lake City, South Carolina
    c. Heavy truck (with container) to Tazewell, TN
2. Recycling method
    a. Recycling by pyrolysis of carbon fiber
    b. Recycling of flax fibre by pyrolysis
    c. Recycling by microwave pyrolysis
    d. Grinding
3. Recycling location

a. Canada
b. United States

Carbon footprints according to project proponent's choices

Before presenting the different choices available to BeelivinU, let's recall what a ton of CO equivalent is₂ . It is a gas that weighs one ton. The attached balloon illustrates what a ton is.

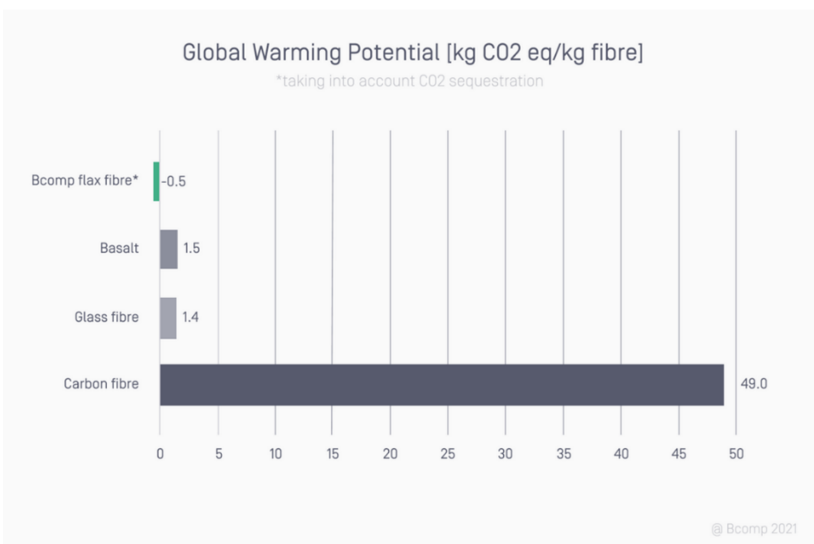
Une sphère de 10,1 m de diamètre (TPS)

Figure 4: Representation of a ton of CO_2 equivalent

Choice of materials

The project developer will therefore have to make choices that could influence the carbon footprint of its products. Here is a brief reminder of the possible choices, from the most sober to the most impacting in carbon:

1. **Flax fiber**: This fiber **absorbs** carbon as it grows (rather than emitting it, which is the case with carbon fiber) and requires less energy to process and recycle.
2. **Recycled carbon fiber:** Depending on the method used for its upstream recycling, if it is energy intensive, it can have a carbon footprint nonetheless, except for microwave pyrolysis which is very low in energy ;
3. **Virgin carbon fiber from petrochemicals:** The transformation process is energy intensive and its recyclability is currently energy demanding (with possibilities of innovation with microwave pyrolysis);



Source : Bcomp. https://www.bcomp.ch/solutions/sports/

Figure 5: Global warming potential of different materials, according to Bcomp.

Recommendations

Buying virgin or recycled fiber?

For example, in an effort to reduce the carbon footprint of carbon fiber *manufacturing*, BeelivinU could explore the possibility and feasibility of sourcing recycled fiber to build its bikes. To do this, you could work with the

[CTT Group](), which "supports the growth of companies in the **textile** and **geosynthetic industry** through [technical services](), [research and development](), and [expertise]() in product innovation and improvement, promoting sustainable development." This research center will be able to help you test different composite material mixes with their equipment, including the tube spinner. They will also be able to test product recyclability through microwave pyrolysis.

For your information, see a hybrid bike model, half linen / half carbon. BeelivinU could be inspired by it to create its model: [MF1-MF5: 50% to 80% linen.]()

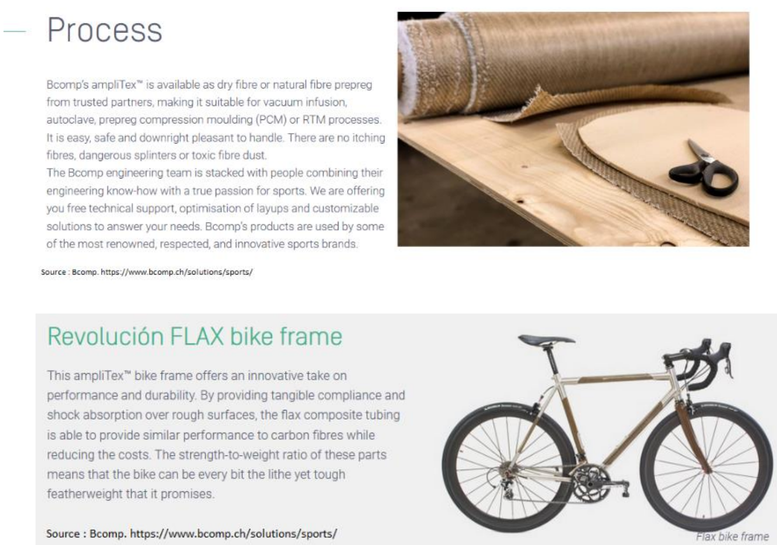


Figure 6: Above, a roll of Bcomp pre-impregnated flax fibre and below, a Bcomp flax fibre bicycle

Figure 7: Museeuw MF-1, half-lin / half-carbon 1

Figure 8: Tubular carbon braiding at CTT Group

Figure 9: Bike frame made with Dyneema with Carbon fiber

Dyneema also made its first bike with the Dyneema with Carbon fiber. The idea of BeelivinU is therefore plausible with this fiber. The company invites entrepreneurs like you to contact them. See the bottom of this page. In an ideal scenario, the carbon fiber spools would be manufactured in the United States rather than in Japan to reduce the carbon footprint of the final product.

Source of materials

As desired by BeelivinU, the materials and parts chosen will have the advantage of coming from a supplier in Quebec first, then in Canada or in the Eastern United States, in order to limit the transportation mileage as much as possible. Imported products will take into account both the distance and the weight of the goods. A product from Europe, depending on its weight, may have a higher carbon footprint than an import from Asia of a lighter material. Here are the places of origin to consider, in ascending order, from the least to the most impactful, for fibers as well as for epoxy and hardeners:

1. Flax fiber from Innolin, Quebec;
2. Carbon fiber recycled in Quebec by microwave pyrolysis;
3. Flax fiber from Bcomp in Switzerland;
4. Virgin carbon fiber from Rayplex in Ontario;
5. Epoxy and hardener from Rayplex in Ontario ;
6. Virgin carbon fiber Dyneema from the United States ;
7. Manitoba EcoPoxy;
8. Virgin carbon fiber Dyneema from China;
9. Virgin carbon fiber Bcomp from Switzerland;

We discovered an EcoPoxy made in Manitoba (7.) and distributed by Langevin Forest in Montreal. Some of the ingredients come from plants. By using this epoxy, BeelivinU would be consistent with its environmental objective. Note that we did not find out where the epoxy for Rayplex (5.) comes from. If it comes from far away, it could have a higher footprint than EcoPoxy.

Choice of energy source

Manufacturing in Montreal, Quebec allows for the use of clean, renewable hydroelectricity, which greatly reduces the carbon footprint of manufacturing compared to fossil fuel power generation.

Repair offer

Offering bike repair is a great way to extend the life of bikes and reduce waste generation and, incidentally, the production of greenhouse gases.

Without having researched the subject in depth, we can assume that any transportation of a bike to the Montreal factory for maintenance or repair will have a carbon footprint due to transportation. Thus, BeelivinU could imagine offering its more distant customers alternatives to sending their bikes to Montreal. For example, the company could have an agreement with a local repairer (in Toronto for example), or it could offer a mini-repair kit with the bike, from the start, with a tutorial on the repair method. Or they could do an annual tour of customers within 500 km to offer an upgrade. The tour could be done by electric vehicle. Such a personalized service would meet a social objective mentioned by BeelivinU, namely the creation of a community.

End of life product management

BeelivinU will have to choose which company to send its bike frames and factory residues to for recycling. As previously noted, microwave pyrolysis recycling, still in the research and development stage at CTT Group, is the most promising route with a carbon footprint 5 times lower than other pyrolysis techniques. Moreover, its fiber recovery rate is 99%, which exceeds all other techniques. Here are the end-of-life bike management options in ascending order, from best to worst:

1. Recycling by microwave pyrolysis, in Quebec ;
2. Recycling by conventional pyrolysis of flax fiber, as close as possible ;
3. Recycling by conventional pyrolysis of carbon fiber, as close as possible ;
4. All of the above, but in a remote location (avoid sending to another continent);
5. The crushed material, not analyzed, would be used as material in concrete, for example, and not to become carbon fiber again.

Results

As detailed in *Appendix 1 - Excel Spreadsheet of Calculations*, some choices are better than others, and some choices would be reasonable. In the "Results" tab of the spreadsheet, you will find the amount of tonnes of greenhouse gases (GHGs) generated by each production step. This table shows several choices. The green boxes indicate the best choices in terms of GHG emissions. The yellow boxes indicate less efficient, but reasonable choices. The red boxes indicate the worst choices, to be avoided.

*The choices must be added together to obtain the total in tons of CO_2 equivalent per 500 m^2 of carbon fiber fabric

Then divide by 3 to get the tons *per bike* (assuming 3 m^2 of fabric per bike)

In summary, anything from Asia should be avoided for two reasons: first, because their electricity is produced with coal, the worst fossil fuel, and second, because the products must be transported by GHG-emitting vehicles over very long distances. The weight of the package is also part of the equation. For example, a heavier roll of fabric from Switzerland has more GHG emissions than a lighter roll from China.

Sommaire des résultats pour 500 m² de fibre de carbone

Légende :
- Meilleurs choix (vert)
- Choix alternatifs imparfaits (orange)
- Pires choix (rouge)

Étapes	Selon le choix	Résultats Amérique ou Eur. (tonne CO_2 éq. pour 500 m²)	Résultats pour l'Asie (tonnes CO_2 éq. pour 500 m²)
1. Fabrication	Fibre **vierge** issue de la pétrochimie	16,80	
	Fibre **recyclée** par pyrolyse	1,06	
	Fibre **recyclée** par pyrolyse à **micro-ondes**	0,01	
	Fibre UHM (Ultra Haut Module) **Carbon with Dyneema**		?
2. Achat de fourniture	**Livraison de la fibre de carbone**		
	Fibre de carbone recyclée du Québec (En cours de développement)	0,001	
	Camion de livraison, aller (Rayplex de l'Ontario)	0,004	
	Camion de livraison, aller (Dyneema des États-Unis)	0,03	
	Avion (Bcomp de la Suisse)	2,23	
	Avion (Dyneema de la Chine)		0,63
	Camion de livraison, du port (Dyneema)	0,0002	
	Livraison de la résine et autre sous-produits de colle		
	Camion de livraison, aller (Rayplex, Ont.)	0,01	
	mion de livraison, aller (EcoPoxy, Manitoba)	0,06	
	Livraison de la fibre de lin		
	Camion de livraison, aller (Innolin, Qc)	0,04	
	Avion aller (Bcomp, Suisse)	2,07	
	Camion de livraison, du port	0,001	

4. Livraison au client	**Vélo entier** en fibre de carbone composite livré par camion lourd	0,016	1,77
	Cadre de vélo en fibre de carbone livré par camion lourd	0,009	0,93
	Vélo entier en fibre de carbone livré par camion léger	0,189	1,77
	Cadre de vélo en fibre de carbone livré par camion léger	0,100	0,93
5. Fin de vie	**Transport vers le centre de recylage**		
	Camion lourd (avec conteneur) vers St-Hyacinthe	0,00	
	Camion lourd (avec conteneur) vers Lake City, South Carolina	0,11	
	Camion lourd (avec conteneur) vers Tazewell, TN	0,13	
	Recyclage		
	*de la fibre de **carbone** (en Angleterre)*	37,8	
	*de la fibre de **lin** (en Angleterre)*	8,4	
	*de la fibre de **carbone par pyrolyse** (au Québec)*	16,7	7372
	*de la fibre de **lin par pyrolyse** (au Québec)*	9,3	4110
	*de la fibre de carbone par **pyrolyse à micro-ondes** (au Québec)*	0,01	
	Recyclage par pyrolyse de la fibre de carbone (en Angleterre)	16,8	
	TOTAL :	*	*

***On doit additionner les choix pour obtenir le total en tonne de CO_2 équivalent par 500 m^2 de tissus de fibre de carbone**

Puis diviser par 3 pour obtenir les tonnes par vélo (avec l'hypothèse qu'il faut 3 m2 de tissus par vélo)

Best choices

In short, here are the best choices for BeelivinU, based on these results, regardless of the quality of the products, which will require research and development (R&D) and testing:

Manufacturing

The use of microwave pyrolysis recycled fiber from Quebec, woven by BeelivinU in Montreal using hydro-electricity, would be the most GHG efficient solution.

Purchase of supplies

If the company purchases virgin carbon fibre rolls or spools of yarn from a third party company, purchasing this fibre in Ontario (Rayplex) would be the lowest in terms of GHG emissions.

As for the purchase of the resin and hardener, the EcoPoxy brand (BioPoxy 36 product) is available from a Montreal distributor (Langevin Forest), but it comes from Manitoba, 2246 km from Montreal, which increases its carbon footprint if it is assumed by BeelivinU. However, since it is partly made from plants, it certainly has a lower carbon footprint than conventional petrochemical epoxies. At the same time, we don't know where Rayplex's epoxy comes from, but this Ontario company is less remote than the one in Manitoba. Rayplex's product looks conventional, with no green credentials.

Moreover, buying flax fiber from Quebec rather than from Switzerland would greatly reduce its carbon footprint. In addition, BeelivinU would contribute to the development of this new flax fiber production sector in the Lower St. Lawrence region of Quebec.

Transformation

Vacuum bagging in Quebec and the electric press in Quebec are both the processing methods with the smallest carbon footprint. Any processing in Asia is to be avoided because processing is energy intensive. Hydroelectricity should be prioritized over coal-electricity.

Delivery

Counter-intuitively, heavy truck delivery reduces the carbon footprint of delivery compared to light truck transport, since the heavy truck moves more freight at a time, which divides the amount of GHGs by the weight of the freight per km driven. This means that the heavy truck emits less GHG per ton of freight transported than the light truck (if the heavy truck is filled with freight). Thus, for long distances, the heavy truck is preferred, followed by the light truck for the last few kilometers of the delivery.

End of life of the product

The mode of transportation of used bicycles to the recycling site with the lowest GHG emissions is by heavy truck.

The most efficient recycling method in terms of GHGs is microwave pyrolysis. The research center is in St-Hyacinthe, but no plant exists yet for this form of recycling.

Methodology for stepwise CCA calculations

In order to be able to make calculations, we have taken as a basic quantity a 500 m^2 roll of woven but not impregnated fiber.

Here are the results in brief, available in the "Results" tab in Appendix 1. This table will be followed by the methodology.

Manufacturing

This is the initial manufacturing of carbon fiber rolls or spools of yarn at specialized manufacturers.

Methodology

Having already in hand the CO_2 eq emissions, we multiplied the kg CO_2 eq/kg of fabric by the weight of 500 m^2 of fabric. To reduce the kg to tons, we divided the total by 1000.

Since the scientific study we relied on did not specify the energy source, we could not assess the difference between manufacturing in North America and Asia.

Calculations

$T\ CO_2\ eq = (C \times (P \times Nbm^2)) * FéH$

Where

C = kg CO_2 eq/kg tissue

P = Weight in kg of fiber/m^2

Nbm^2 = Number of m^2 of fabrics

$T\ CO_2$ eq = tons of CO_2 eq per m^2

Missing data: The kg CO_2 eq per kg of Carbon with Dyneema UHM (Ultra High Modulus) fiber is unknown, so we could not calculate its carbon footprint. However, we reproduce here an image that illustrates that it has a much smaller carbon footprint than other fibers. Please note that the source of this image is the company itself, which does not guarantee its veracity.

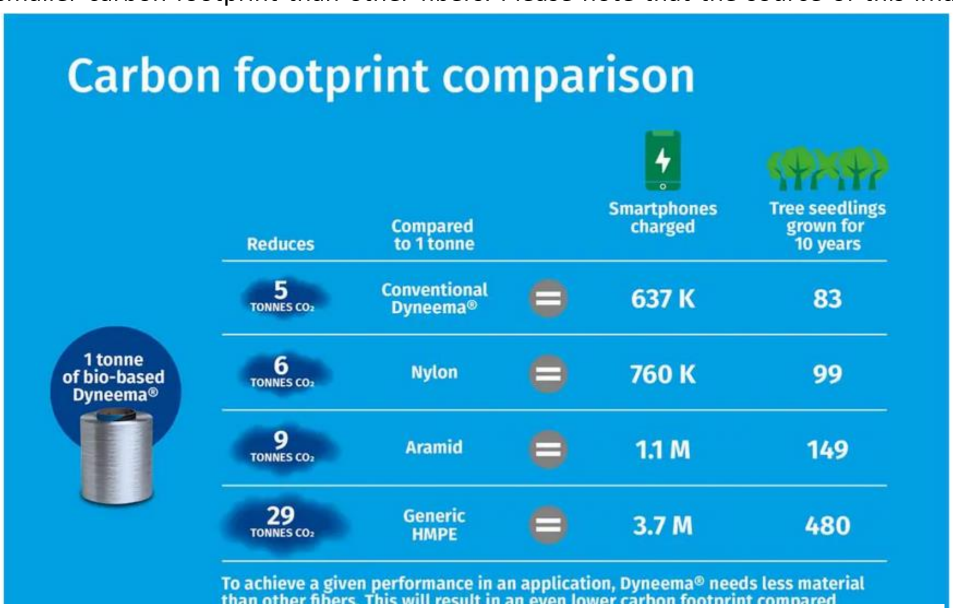


Figure 10: Emission reduction with the use of bio-based Dyneema fiber compared to other fiber types.

Purchase of supplies

This refers to the purchase and delivery of materials to the Montreal plant from various potential locations. The calculation excludes the carbon footprint of the machinery required for the operations.

Methodology

We reduced the weight in kg of one m^2 of fabric to a ton, multiplied by 500 to get the weight of 500 m^2 of fabric in a ton.

We then determined the distance between certain suppliers and Montreal.

We found an emission factor for freight transport in t.km, which determines the amount of kg CO_2 eq attributable to one of several goods in a delivery truck.

Thus, by multiplying the weight in tons per kilometer, multiplied by the emission factor in t.km, we obtained the quantity of kg CO_2 eq / t.km.

We have reduced this amount to tons of CO_2 eq.

Calculations

T CO_2 eq = ((((500 x P) / 1000) x NbKm) x FéT) / 1000

Where:

T CO_2 eq = tons of CO_2 equivalent for 500 m^2

P = weight in kg of fiber per m^2

NbKm = Number of kilometers to go

FéT = Emission factor for the chosen transport (heavy truck or plane) in kg CO_2 eq / t.km

Missing data

The kg CO_2 eq / m^2 of Rayplex and Dyneema products were not found. Therefore, we used a calculation method based on the weight of the product and its mileage for delivery (in tonne-kilometres).

Not surprisingly, carbon fibers from Switzerland or China have a very high carbon weight compared to products from Ontario or the eastern United States.

We also did not have the weight of recycled carbon fiber from Quebec (in the event that microwave pyrolysis would allow the purchase of recycled carbon fiber in Quebec). We conservatively used the weight of virgin Bcomp fiber in our calculations.

As for the resin, we have calculated that it has a weight of 40% of that of the fiber. The source is an assumption that comes from Benjamin du Haÿs, owner of BeelivinU.

Transformation

It is a question here of transforming the fabric rolls into bicycle frames, following several stages. This transformation is done with electrically powered equipment. Since the plant will be located in Montreal, we assume that the electricity will come from hydroelectricity. As a comparison, we have evaluated the GHG emissions of consuming the same amount of electricity, but from burning coal, as would be the case in China.

Methodology

We found the energy consumption of various devices required for molding, unmolding, and baking of parts. The units of measurement were in MJ or kW/hr. We converted these units to GJ/kg of composite material. Then we converted to kWh per kg of composite material. We multiplied this by the weight of 500 m^2 of fabric, then multiplied by the emission factor of hydro or coal. Finally, to get the grams into tons, we divided by 10^6.

Calculations

T CO_2 eq = (((E/1000) x FcGJ) x P) x FéH) /10^6

Or for China

T CO_2 eq = (((E/1000) x FcGJ) x P) x FéC) /10^6

Where:

T CO_2 eq = tons of CO_2

E = energy in MJ

FcGJ = Conversion factor of gigagoules to kilowatt-hours (GJ to kWh)

P = Weight in g of CO_2 eq for 500 m^2 of fabric

FéH = Emission factor for hydroelectricity

FéC = Emission factor for coal

Missing data

Data considered to have no or negligible impact were excluded from the calculations.

Delivery

This refers to the delivery of frames or entire bikes, either by heavy truck or light truck, since the goal is to sell them within a 500 km radius of Montreal. For comparison purposes, we have also calculated the carbon footprint of the same bike that would be delivered from China to Montreal (if it were made in China).

Methodology

We converted the weight into tons for a bike weighing 1.9 kg (or 1 kg for the frame only). We then evaluated the distance between Montreal and the delivery location. In order to be conservative, we chose the distance of 546 km, which is Toronto. We also estimated the distance from Beijing to Montreal by plane to be 10,468 km. We then multiplied this by the delivery emission factor per tonne-kilometre to account for the fact that the bicycle is one of many products in the delivery truck or on the plane. Two types of delivery trucks were evaluated, a 40' heavy duty truck fueled by "highway diesel" and a light duty vehicle fueled by gasoline. The resulting grams were divided by 1,000,000 to obtain tons of CO_2 equivalent and then multiplied by 166, the number of bicycles made from 500 m^2 of carbon fiber (3 m^2 per bicycle).

Calculations

T CO_2 eq = (((((Pv or Pc)/1000) x NbKm) x FeT) /1 000 000) x 166

Where:

T CO_2 eq = tons of CO_2

Pv = Weight of the *bike* in kg

Pc = *Frame* weight in kg

NbKm = Number of kilometers to go

FéT = Emission factor for the chosen transport (heavy or light truck) in kg CO_2 eq / t.km

Missing data

None.

End of life

For the BeelivinU producer, it is a matter of assuming the end of life of the product by ensuring that it will be recycled or recovered rather than buried in a landfill. More and more solutions are being developed to separate the fiber from the resin, allowing the fiber to be put back into the mouth with sufficient quality for many applications. The resin can also be recycled into hundreds of chemical compounds.

One thing is certain, this stage of the product life cycle can be a large emitter of GHGs, except for microwave pyrolysis.

Methodology

We identified three possible recycling locations, in Quebec, South Carolina (USA) and Tennessee (USA). The kilometers to send the carcasses to these locations were evaluated with GoogleMap.

We then identified different recycling techniques, including pyrolysis and shredding. Shredding was not explored further here. For pyrolysis, we found some data for **carbon** fiber recycling and some for **flax fiber**. However, the data varied greatly from one study to another. Thus, we obtained very variable evaluations.

For transportation to the recycling site, we multiplied the weight of 500 m2 of composite by the number of kilometers, multiplied by the emission factor of three different modes of transportation, taking into account the tons per kilometer.

For recycling, two types of data were available. The kg CO2 eq data were simply multiplied by the weight of the 500 m^2 of fabric. For the energy data, we converted the energy consumption data of the pyrolysis appliances identified in watts, kW, or MJ to kWh. Next, we converted the energy units to kWh. Then we multiplied these kWh by the weight in kg of 500 m^2 of fabric. This was multiplied by an emission factor (either hydro, natural gas or coal) to get the amount of emissions in g CO_2 eq / kWh. Finally, the result in grams was divided by 1,000,000 to convert it to tons of CO_2 equivalent.

Calculation of the **transport of** the bicycle carcasses to the recycling site

T CO_2 eq = (((((Pv or Pc)/1000) x NbKm) x FéT) /10^6)

Where:

$T\ CO_2\ eq$ = tons of CO_2

Pv = Weight of the *bike* in kg

Pc = *Frame* weight in kg

NbKm = Number of kilometers to go

FéT = Emission factor for the chosen transport (heavy or light truck) in kg CO_2 eq / t.km

<u>Calculations of the **recycling** method</u>

$T\ CO_2\ eq = (((Fc\ kWh/GJ)*P) \times Fé)/10^6$

Where:

$T\ CO_2\ eq$ = tons of CO_2

Fc kWh/GJ = Conversion factor in kWh per GJ of energy

P = Weight in kg of 500 m^2 of fabric

Fé = Emission factor in g CO_2 eq / kWh or per m^3

<u>Missing data</u>

None.

Alternative materials

Linen

As mentioned above, flax is a natural fiber that sequesters carbon as it grows. Its properties make it rival carbon fiber. Finding out in what proportion it can be used, with or without carbon fiber, would lead BeelivinU to distinguish itself from its competitors, since this proportion will have a direct impact on the carbon footprint of the product.

For transportation reasons, Quebec flax is to be preferred over Swiss flax. We recommend that you contact Innolin in the Lower St. Lawrence. Their contact information is in Appendix 1, Tab 2. Purchase of supplies, box G80.

Bamboo

In the course of our research, we saw that bamboo bikes could fulfill several criteria sought by performance bike pros. The weight is probably slightly heavier than high performance carbon fiber bikes, but its carbon footprint is infinitely lower than the carbon fiber bike.

Figure 11: Microscopic view of a flax fiber

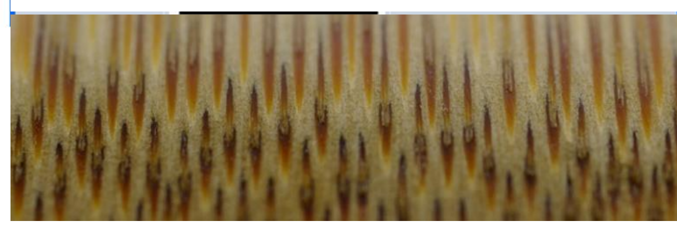


Figure 12: Bamboo fiber

Why? Because nature takes care of weaving the carbon fibers into the bamboo. No factories or energy sources are needed, since the sun and photosynthesis are responsible for making the material. In addition, bamboo sequesters carbon rather than emitting it. The plant grows quickly, without the need for pesticides. In addition, bamboo absorbs vibrations well and is lighter than metal. It can be repaired with resin and is compostable at the end of its life. Finally, it costs much less to produce. Its only carbon footprint is related to transportation, but since it is a light material and hundreds of bicycles could be built with the contents of a single container delivered (transportation), its footprint would remain smaller.

We therefore recommend that BeelivinU conduct research and development on bamboo bikes when the company is ready to offer a "mainstream" bike. Several hundred species of bamboo exist, some more relevant than others for bikes.

Here are some websites to inspire you:

- Are Bamboo Bikes Actually Any Good? - YouTube
- Build Your Own Bamboo Bike - Custom Bamboo Bicycle - Bamboobee
- Environmental and social life cycle assessment of bamboo bicycle frames made in Ghana - ScienceDirect
- Sustainability - Bamboo Bicycle Club
- The Urban One Bamboo Flax Bike
- American Bamboo Society
- 12 best bamboo and wood bikes 2023

Reflection on the tools necessary for the transformation

Our research has shown that manufacturing **carbon fiber** bikes requires a lot of machinery, which has its own carbon footprint and consumes a lot of energy. In addition, there are several steps involved in designing the frames, and specialized labor is required.

On the other hand, using **bamboo** rods, for example, requires only a simple woodworking shop with few tools to assemble bicycles. This is not the same if the bamboo fiber is processed. Thus, from a global point of view, taking into account the means necessary for the transformation, bamboo stems would win hands down from a "carbon footprint" point of view.

On the other hand, the use of **flax fibers**, in roll or bobbin form, probably requires the same equipment as for carbon fiber processing.

Laws and regulations

Our research in the Quebec legislation shows us that the carbon fiber bicycle manufacturing plant will have to pay particular attention to the **management of its residual materials (GMR),** i.e. carbon fiber and linen fabric scraps, carbon and linen thread spools remains, frames returned by its customers, etc.

Some **hazardous materials** may need to be managed in accordance with the *Hazardous Materials Regulations*, but the advice of a chemist will be required once the company has decided which products will be used in the manufacturing process (epoxy, hardener, lacquer, etc.).

It is also possible that there is **dust management**, depending on the choices and processes chosen by the company. This dust management is more related to *health and safety at work*, but can also concern the environment if a fan rejects air outside.

Water does not seem to be used in large quantities, which alleviates the company's environmental obligations, unless we have missed this element.

The energy will be hydroelectricity, a clean energy that does not generate any gases harmful to humans and the environment. There are no special rules that BeelivinU has to follow in this respect.

See **Appendix 2 for** the sections of the law and regulations that we believe should be brought to the attention of the project proponent.

Recommendations for the future of the project

With this analysis, BeelivinU will be able to choose which materials it will use for research and development. We recommend that the company work with the CCT Group in St-Hyacinthe to test different amalgams (e.g. proportion of flax and carbon fiber) and different resins.

At the same time, the company will carry out a market study to ensure the economic and social viability of such a project and its short, medium and long term objectives.

Once the prototype that is most satisfactory to the project proponent is designed, an environmental expert can initiate a project document based on the ISO-14064-2 standard. This analysis will compare two bicycles: the one manufactured in the normal course of business, and the one that BeelivinU will manufacture. This will allow the company to demonstrate how much more environmentally friendly its product is than those of its competitors. Today, this study cannot be done, because the company has not yet decided if it will choose recycled carbon fiber or not as a base material, if it will include flax fiber or not, if it will choose EcoPoxy or conventional epoxy, which repair service will be offered to its customers and which recycler it will choose.

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Appendix 1 - Excel spreadsheet of calculations

An Excel spreadsheet named "BeelivinU-ACC" presents the calculations made from information found in scientific studies.

Supplier addresses and other relevant information are also included.

Appendix 2 - Laws and Regulations to be followed

	Laws and regulations to be respected		
Chapter Q-2	**Environmental Quality Act**		
Articles	**Bonds**	**Bonds**	**Notes**
20	No person shall discharge or permit the discharge of any contaminant into the environment in excess of the quantity or concentration determined in accordance with this Act. The same prohibition applies to the release of any contaminant whose presence in the environment is prohibited by regulation or is likely to endanger human life, health, safety, welfare or comfort or to cause damage or otherwise adversely affect the quality of the environment, ecosystems, living species or property.	General principle that applies to all.	
21	Every person who is responsible for an accidental release into the environment of a contaminant referred to in section 20 or of a hazardous substance shall, without delay, notify the Minister. The person responsible **must** also, without **delay**: (1) stop the release; (2) in the case of a release of a contaminant, recover, clean or treat on site the materials contaminated by the release or, if this cannot be done, remove the contaminated materials from the area affected by the release and send them to an authorized site; (3) in the case of a release of hazardous materials, manage the materials contaminated by the release in accordance with sections 70.5.1 to 70.5.5.	In case of an accident, very important	

22	Subject to subdivisions 2 and 3, **no** person **may** carry out a project involving one or more of the following activities **without first obtaining an authorization** from the Minister (1) the **operation of an industrial establishment** referred to in Division III, to the extent provided for therein; ... (5) the management of hazardous materials, to the extent provided in subdivision 4 of Division VII.1; .. . The following activities, among others, are also subject to prior authorization by the Minister: (1) the construction of an industrial establishment; (2) the operation of an industrial establishment other than those referred to in subparagraph 1 of the first paragraph; (3) the use of an industrial process; and (4) the increase in the production of a good or service.	Obtaining a ministerial authorization from the MDDELCCFP. Information to be provided in sections 23 to 24	The authorization is renewable every 5 years.
53.3	The purpose of the provisions of this division is: (1) to **prevent or reduce the generation of residual materials**, in particular by acting on the manufacture, marketing and other types of distribution of products; (2) to **promote the recovery and reclamation** of residual materials; (3) to **reduce the quantity of residual materials to be disposed of** and to ensure the safe management of disposal facilities; and (4) to **require manufacturers and importers of products to take into account** the effects such products have on the environment and the costs of recovering, reclaiming and disposing of the residual materials generated by such products.		The choice of materials (eco-design), repair and treatment at the end of the product's life must be taken into account by the manufacturer in order to reduce landfill

53.4.1	The policy referred to in section 53.4 and any plan or program developed by the Société québécoise de récupération et de recyclage in the area of residual materials management must give priority to reduction at source and respect the following order of priority in the treatment of such materials: (1) **reuse;** **(2) recycling, including by biological treatment or land application;** **(3) any other recovery operation by which residual materials are treated to be used as a substitute for raw materials;** **(4) energy recovery; and** **(5) disposal**. ...		Order of priority, in case of breakage or at the end of the product's life
53.29	**No person may**, in the course of a commercial transaction, offer for sale, sell, distribute or otherwise make available to users: (1) **containers, packaging, packaging materials, printed matter or other products that do not meet the regulatory standards prescribed pursuant to section 53.28**; (2) **products that are in containers or packaging that do not comply with** the aforementioned regulatory standards.		To be taken into account for the packaging if the bike is delivered by mail.

53.30	The Government may, by regulation, govern the recovery and reclamation of residual materials in all or part of the territory of Québec. Such regulations may, in particular: ... **(6)** require any person, in particular a person operating an establishment of an industrial or commercial nature, who manufactures, markets or otherwise distributes containers, packaging, packaging materials, printed matter or other products, **who markets products in containers or packaging obtained by him for that purpose** or, more generally, who generates residual materials by his activities: ... **(c) to keep records** and provide the Minister or the Société, on the terms and conditions determined, with information on the **quantity and composition** of such containers, **packaging**, packaging materials, printed matter or **other products**, **on the residual materials generated by their activities** and on the **results obtained in terms of reduction, recovery or reclamation**;	Yes. Record keeping.	To be taken into account for the packaging if the bike is delivered by mail.

53.31	Every person must, on the conditions determined by the Minister, provide the Minister or the Société québécoise de récupération et de recyclage, as the case may be, for the purposes of the responsibilities entrusted to it under this Act, with the information the Minister requests concerning the origin, nature, characteristics, quantities and destination (1) the products, among those referred to in subparagraph 6 of the first paragraph of section 53.30, that it manufactures, markets or otherwise distributes; (2) the residual materials generated by the products referred to in subparagraph 1; and (3) the residual materials that it generates through its activities, remits to a third party or takes in charge. In addition to the information that may be requested under the first paragraph, the information concerning the recovery or reclamation of the residual materials referred to in subparagraphs 2 and 3 of that paragraph and the costs generated by their recovery or reclamation must be provided.	Yes. Record keeping.	
53.31.1	The persons referred to in subparagraph 6 of the first paragraph of section 53.30 are required, within the framework and under the conditions provided for in this subdivision, to **pay compensation to the municipalities** for the services they provide to ensure the recovery and reclamation of materials designated by the Government under section 53.31.2.	Pay compensation to municipalities for the recovery and reclamation of RM	
70.5	Every person who is in possession of a hazardous material shall provide the Minister, within such time as the Minister may specify, with any information or document requested by the Minister concerning the hazardous material.		Epoxy resins and hardeners are hazardous materials of categories B09, B11, B13 and M06, according to schedule 4 of r. 32 below.
70.5.1 à 70.7	In case of handling of hazardous materials, in case of an incident or contamination of a property, read these sections of the CEQA Q-2	Yes. Record keeping.	

70.8	**The possession of a residual hazardous material for a period of more than 24 months** is subject to obtaining an authorization from the Minister in accordance with subparagraph 5 of the first paragraph of section 22. In addition to the information and documents required under section 23, the application for authorization must be accompanied by a hazardous materials management plan prepared in accordance with the Government regulation. The management plan must contain an attestation of the accuracy of the information given and the signature of the person who has possession of the hazardous materials or, in the case of a person other than a natural person, of a person authorized for that purpose	Authorization from the Minister of the Environment if in possession of material. Hazardous Residuals for more than 24 months.	
chapter Q-2, r. 32	**Hazardous Materials Regulation**		
Articles	**Bonds**	**Bonds**	**Notes**
2	**The following are not** hazardous materials: (19) residues from the shredding of motor vehicle carcasses;		Probably applicable to carbon fiber bicycle frames

References	Categories		Notes
Appendix 3 Business Sectors	Major Groups 32 (transportation equipment industry) and 45 (transportation, except limousine services at airports and railway stations, cabs and other transportation)		
Schedule 4, Section 1, CATEGORIES OF HAZARDOUS MATERIALS	B09 Sludges and residues from the formulation and use of ink, paint, dyes, **lacquers and varnishes**		
	B11 Sludges and residues from the formulation and use of residues, latex plasticizers, **glues**, adhesives and **polymers**		
	E13 Solids, **dust** or sludge generated by air cleaning systems		
	M06 Discontinued ion exchange **resins**		Is epoxy one of these resins?
	O02 Non-hazardous materials		
Schedule 8 (s. 109), SECTORS OF ACTIVITY REFERRED TO IN THE REQUIREMENT TO PRODUCE AN ANNUAL MANAGEMENT REPORT	**Economic activity**	**Activity code**	**Min. number of employees**
	Machine shops	3081	20
	Transportation equipment industry	Large group 32	50
Schedule 9 (ss. 110, 131, 135 and 136) HAZARDOUS MATERIALS MANAGEMENT	Regarding Processing for Recycling or Reuse:		
	R05: Recovery of inorganic materials, other than metals or metal compounds		
	R14: Other recovery or reclamation of a substance or other use or reuse of hazardous materials		