Life Cycle Study of ROKBOX ™ Crates Versus Traditional Crate Shells

Comparison Assessment Relative to the 2021 STiCH Report[1]

Author: Carolyn Liu
Collaborators: Anthony Fraser, Sarah Sanchez, Matthew Eckelman, Jackie Isaacs

Background

Conservators, art collectors, and cultural heritage professionals transport artwork in packaging crates with features to protect their art pieces from impact, strain, compressive forces, and weather. The insides of the crates are typically lined with plastic foam to provide cushioning and absorb vibration, while the crate shells are traditionally manufactured from wood for limited use or composite fiberglass for increased reuse[2].

The environmental impact of traditional wooden crates and reusable fiberglass crates have been extensively examined in a 2021 study conducted by Northeastern students and published by the Sustainability Tools in Cultural Heritage (STiCH) team, "Crates for 3D Objects and Flatwork: Comparing Single Trip, Round Trip, and Reusable Assemblies". These results showed that alternatives to wood and fiberglass crate shells should be considered to drive down environmental burdens that result from the materials, manufacturing, usage, and disposal processes of the four types of crates that were studied.

An alternative design like this already exists – ROKBOX is a Great Britain-based company with an award-winning crate "specifically designed to reduce the environmental impact, risk and cost of shipping and storing high value art"[3]. They produce two types of flat artwork crates at this time: ROKBOX Original, which is a 100x trip polyethylene and fiberglass composite crate, and ROKBOX Lite, which is a smaller and more affordable 10x trip polypropylene crate. This study examines the environmental impacts of the plastic ROKBOX crates compared to low-use wooden and reusable fiberglass crates using the same LCA techniques employed by the STiCH team.

1 Sustainability Tools in Cultural Heritage. (2021). (rep.). *Crates for 3D Objects and Flatwork: Comparing Single Trip, Round Trip, and Reusable Assemblies*. https://stich.culturalheritage.org/crates/

2 Canadian Conservation Institute. 2021. "Five Steps to Safe Shipment – Canadian Conservation Institute (CCI) Notes 20/3." https://www.canada.ca/en/conservation-institute/services/conservation-preservation-publications/canadian-conservation-institute-notes/five-steps-safe-shipment.html

3 ROKBOX. 2022. "Products & pricing" https://rok-box.com/products-pricing/

LCA Modeling Tools

Both the STiCH report and the present study were modeled using a free, open-source software OpenLCA[4] with material-specific data from the EcoInvent Database (v3.7)[5]. Global Warming, or carbon footprint in units of mass of carbon-dioxide equivalents, and nine other environmental and human impact categories were calculated using the Tool for the Reduction and Assessment of Chemical and other environmental Impacts (TRACI, v2.1)[6] assessment method developed by the US Environmental Protection Agency. When possible, the providers for all the materials and manufacturers were Global or RER markets.

In addition to modeling the environmental impacts of the ROKBOX crates in OpenLCA, LCA software Ansys Granta EduPack (2021)[7] was also used to cross-compare and validate relative results, as well as to determine the benefits and drawbacks of each software. Assessment methods in EduPack were conducted using the Level 3 Sustainability Database and Eco Audit Tool for engineering design with the results examining the energy utilization and carbon footprint throughout the product life cycle.

4 GreenDelta. 2020. “openLCA.” https://www.openlca.org/

5 ecoinvent. 2020. “Systems Models in ecoinvent 3: Allocation at the Point of Substitution.” https://www.ecoinvent.org/database/system-models-in-ecoinvent-3/apos-system-model/allocation-at-the-point-of-substitution.html

6 U.S Environmental Protection Agency. 2012. “Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts (TRACI).” https://www.epa.gov/chemical-research/tool-reduction-and-assessment-chemicals-and-other-environmental-impacts-traci

7 Ansys. 2022. “Ansys (CES) Granta Edupack | Software for Materials Education.” https://www.ansys.com/products/materials/granta-edupack

Methods

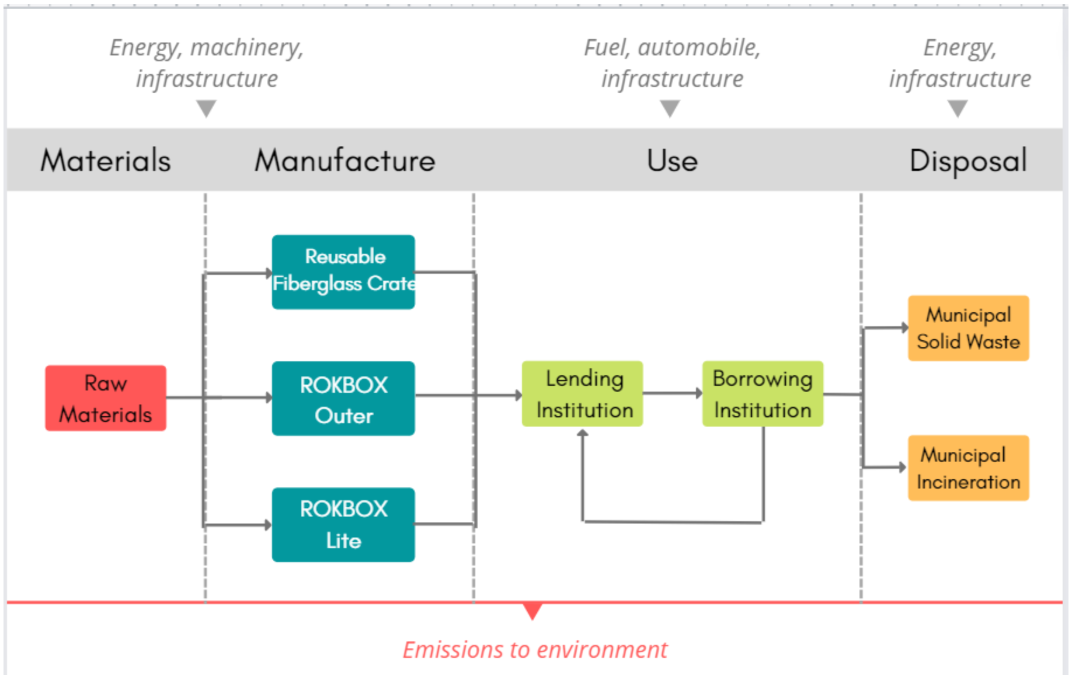


Figure 1. Study scope showing the life cycle stages of the reusable crates, based on the tool developed by the STiCH team (Figure 1, page 11) and utilized for this report. The single-use wooden crates are excluded from this image

Both studies solely examined the impacts resulting from the crate shells, and not the associated accessories such as the art pieces or equipment and tools for handling the crates. In addition, the impacts related to the assembly and delivery of the crates to the first cultural heritage location are also excluded, as differences among these options and actions are expected to be minor. The sizes that were selected for ROKBOX Original was the 1.6x1.6m crate and for ROKBOX Lite was the 1.24x1.24m crate.

The four stages that were examined through LCA are: materials production, manufacturing (if not accounted for during production), transportation/usage of the crates, and disposal.

ROKBOX Original			
Materials	*Mass (kg)*	*Manufacture Process*	*End-of-Life*
MDPE	22.795	Blow molding	
RPET Foam	3.894	Foaming	
PS Foam	0.499	Foaming	Incineration
Glass fiber	9.21	Winding	
Epoxy resin	9.21		
Casted aluminum	2.7		Scrap metal waste

Extruded aluminum	2.2		
Stainless steel	0.891		
Synthetic rubber	5.25		Incineration
PE Foam	0.688	Foaming	
PP Velour	1.126	Weaving	
Art piece	2.5		
Total weight	61.2		

ROKBOX Lite			
Materials	*Mass (kg)*	*Manufacture Process*	*End-of-life*
Expanded PP	2.58	Injection molding	Municipal solid waste
Lid PP	4.507	Extruding	
Base PP	3.46		
PP Velour	0.65	Weaving	
PP Molding	0.44	Injection molding	
Stainless Steel	0.03		Scrap metal waste
Silicone adhesive/seal	0.75		Municipal solid waste
Art piece	2.1		
Total weight	14.8		

Table 1. Crate component inputs in OpenLCA for ROKBOX assemblies
Excluded from calculations: Nylon, PVC rubber

Materials

Previous models of the single or round-trip wooden crates are shown as references for comparison, with more emphasis on Set 2 crates (which contain less dense polystyrene foam).

The reusable fiberglass crate served as the base case scenario and its assembly is composed of birch plywood, glass fiber, epoxy resin, steel fasteners, neoprene gasket, rigid polyvinyl chloride (PVC), urethane foam, high density polyethylene (HDPE) film, nylon, wool, Tyvek, and tissue paper.

The alternative cases are ROKBOX Original and ROKBOX Lite, with their material properties detailed in Table 1 above. The Outer case assembly is primarily composed of medium/high density PE (MDPE/HDPE) and composite panels, which are made from a mixture of fiberglass sheets, polyurethane foam, and polystyrene foam. The Lite case assembly is almost completely made from polypropylene (PP) material, except for adhesives and rubber gaskets.

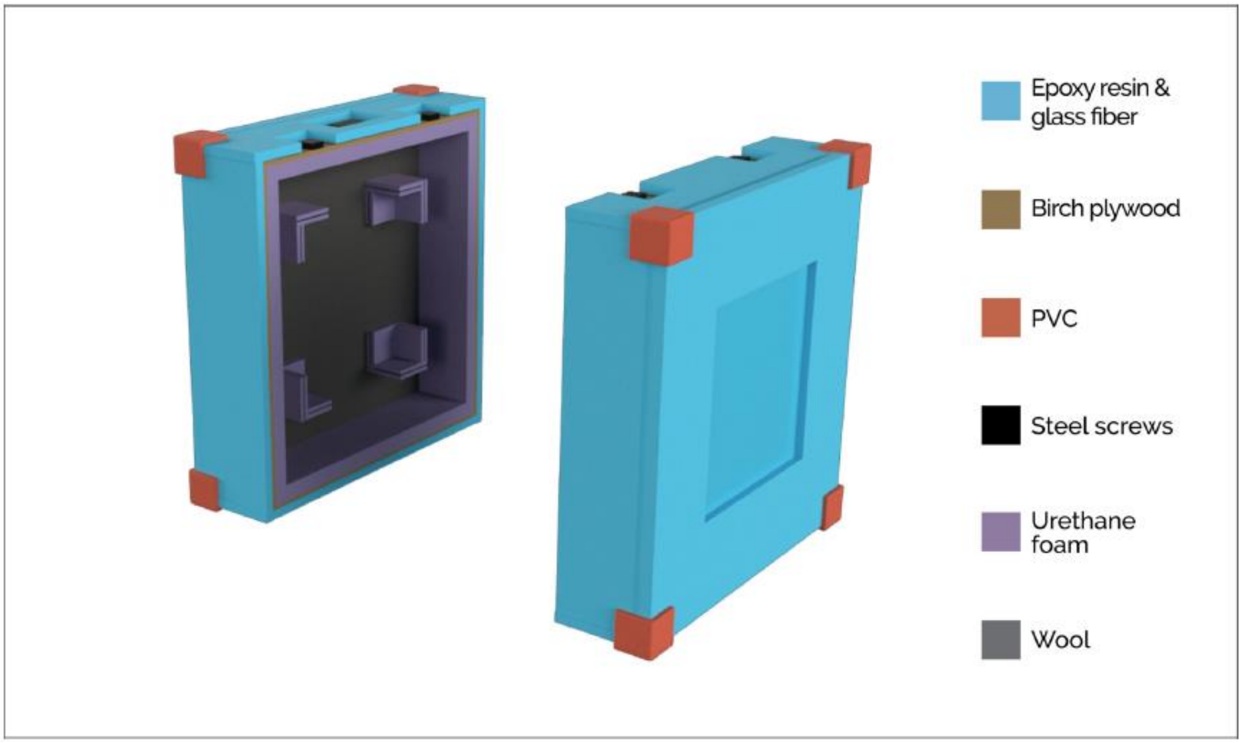


Illustration 1. Simplified model of the reusable fiberglass crate that was studied in the STiCH report

Illustration 2. ROKBOX Original simplified model

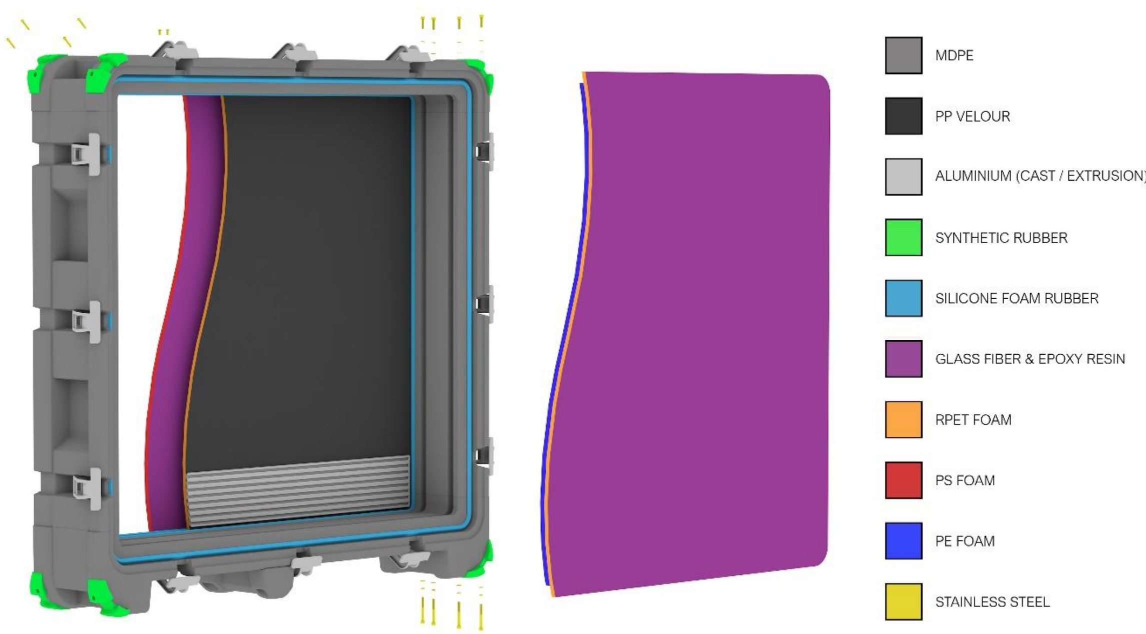
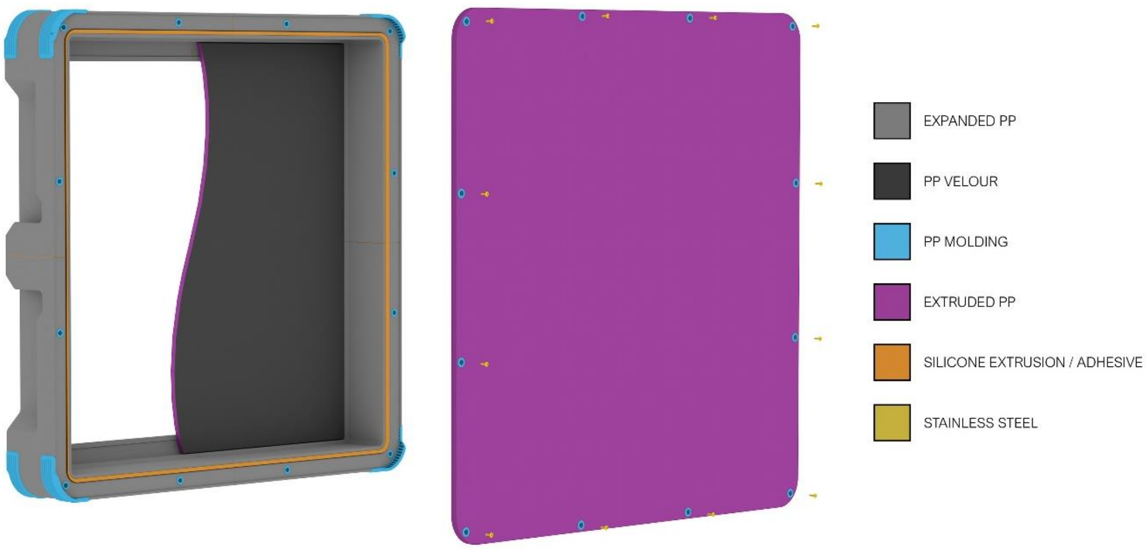


Illustration 3. ROKBOX Lite simplified model



Manufacture

When the specific manufacturing processes of materials are not directly included in the materials stage input, custom addition of manufacturing processes were added and specified in Table 1 above. To avoid double-counting, materials that were accounted for in both the materials production phase and the manufacturing phase were deleted from the production phase by customizing the material database.

Usage

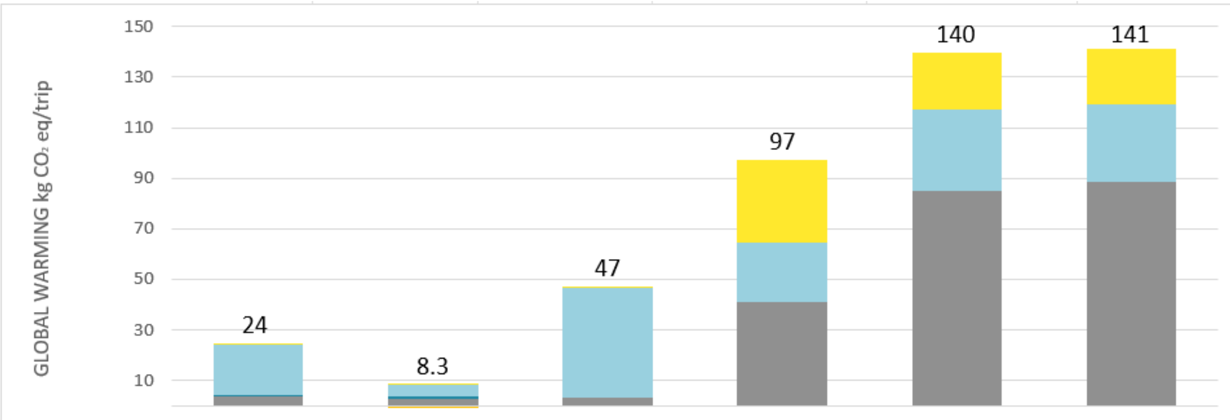
Both the STiCH case study and present report specifically examined the transportation phase between two cultural heritage institutions, and not for other uses such as initial delivery from the manufacturer to the heritage site, short, or long-term storage. Transportation by truck was modeled from New York, New York to Miami, Florida for a total distance of 2,060 kilometers. This corresponds to 1/200 of the fiberglass crate, 1/100 of Original, and 1/10 of Lite, with crates weighing approximately 130 kilograms (kg) for the fiberglass crate, 60 kg for Original, and 12 kg for Lite. The truck selected for usage is the 16-32 metric ton lorry freight.

Disposal

At the crates' end-of-life (EOL), all crate materials for the wooden and fiberglass cells were assumed to be incinerated, Outer plastic components were mostly incinerated but metal parts were assumed to become metal scraps, and most Lite components were landfilled as municipal solid waste (MSW). An additional EOL potential is considered for Outer and Lite with the assumption that *all* polypropylene plastic could be recovered and specifically recycled or remanufactured. The EOL potential would suggest favorable actions for extended producer responsibility (EPR)[8] due to the reduced impacts from recycling used materials over extracting virgin petrochemical material.

8 OECD. 2022. "Extended Producer Responsibility" https://www.oecd.org/env/tools-evaluation/extendedproducerresponsibility.htm#:~:text=Extended%20Producer%20Responsibility%20(EPR)%20is,disposal%20of%20post%2Dconsumer%20products.

Results



	RB Outer	RB Lite	Fiberglass crate	Single Trip Wooden	Round Trip Wooden Type 1	Round Trip Wooden Type 2
EOL potential	-0.01188	-0.869				
Disposal	0.00137	0.182	0.4426	32.52	22.83	21.95
Use	19.83	4.5	43.16	23.49	31.93	30.78
Manufacture	0.264	0.799				
Materials	3.887	2.779	3.2813	41.14	85.09	88.56

Figure 2. Global warming impacts of ROKBOX Original 1.6x1.6m, RB Lite 1.24x1.24m, reusable fiberglass crate 1.32x1.32m, single trip wooden crate 1.32x1.32m, and round trip crates (with two polystyrene types) 1.32x1.32m for flatwork pieces

The EcoInvent results showed that both the ROKBOX Original and ROKBOX Lite have total CO2 impacts that are significantly lower than the wooden crates and reusable fiberglass crate. Even though the fiberglass shell is used for 200 trips, the Original is used for 100 trips, and the Lite for 10 trips, the fiberglass crate is approximately two times heavier than ROKBOX Original and ten times heavier than ROKBOX Lite. As a direct reflection of that, the transportation impacts between cultural heritage sites are scaled almost directly based on mass. Although the total of materials production, manufacturing, and disposal phase impacts of ROKBOX Original and ROKBOX Lite are slightly higher than that of the fiberglass crate (between 12% and 32% higher), the total over all global warming impact has been significantly reduced based on the materials chosen and the reduced mass of the alternative crates.

ROKBOX Lite has the lowest relative impact despite having the shortest reusable lifespan. In addition, it has the highest end-of-life potential if all the propylene material is properly recycled versus being directly disposed of as municipal solid waste. A responsible and efficient recycling facility would be considered for proper reuse of the polypropylene material, perhaps directly in the ROKBOX itself.

DISCLAIMER: It is important to note that these results reflect environmental impacts assuming production of the crates in global and US markets, in order to directly compare with the STiCH report methods and results. In reality, most of the ROKBOX materials are produced, assembled, and used locally in Europe.

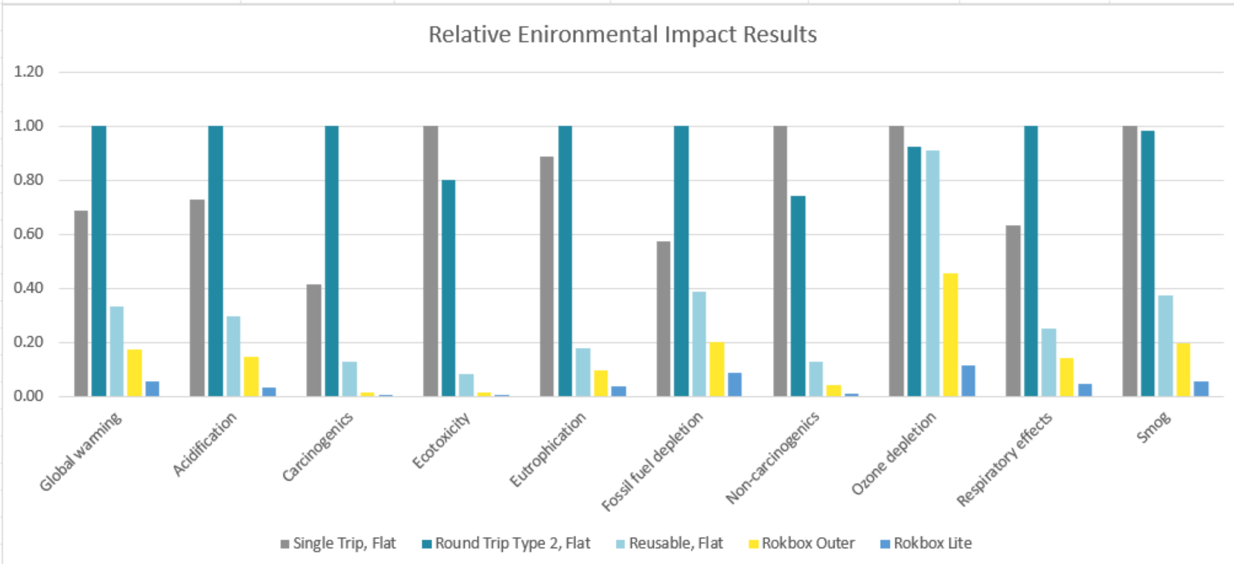


Figure 3. Relative results for single trip, round trip type 2, reusable fiberglass flatworks crates, ROKBOX Original, and ROKBOX Lite over 10 environmental impact categories

When considering wholistic environmental impacts of these crates, it is important to also examine factors besides global warming potential. The ten environmental impact categories for the single and round-trip wooden crates and the reusable fiberglass crates were directly extracted from the STiCH report, while the ROKBOX Original and ROKBOX Lite impacts are superimposed onto the graph. These results reflect the reduced masses of the plastic crates contributing less to climate change, with carcinogenics and ecotoxity impacts being particularly small. Of the major contributors to these results, polyethylene production in the ROKBOX Original, polypropylene production in the ROKBOX Lite, and freight vehicle production and use during transportation and usage have the largest footprints across these categories.

Conclusions

While the protection of cultural heritage artifacts is of utmost importance to the preservation and education of art and history, modern times have brought forth the increasingly important subject regarding sustainability in technology and innovation. Both the STiCH report and this LCA serve to educate producers and manufacturers on the environmental impacts of their crates such that future developments will include such parameters for design improvement and materials reduction. When considering structural integrity and quality, crate production companies should keep in mind that the greater ability to reuse, remanufacture, and reduce would be beneficial to both artistic institutions as well as the environment. Responsible product development and materials selection should be taken into account during all stages of the crates' life cycle.

The 2021 STiCH report has already demonstrated that reusable fiberglass shells are substantially better for the environment than the low-usage, fully wooden shells based on reusability and weighted material production. This follow-up report shows that ROKBOX crates have even further reduced impacts due to substantial mass reduction, despite heavier reliance on petrochemical materials. In particular, the added examination of end-of-life potentials suggest that successful implementation of extended producer responsibility could positively reduce overall life cycle impacts, particularly in the case of polyethylene in Original and polypropylene in Lite. Both crates are considered as environmentally preferable over traditional wooden and fiberglass shells when used for cultural artifact exchange. The results of this report could be referenced during decision-making around purchasing and loans.

Lastly, LCA results are one of many considerations to take when planning around sustainability aspects of cultural artifact preservation. Cost concerns, ease of assembly, ease and safety of use, and quality of the materials are all important throughout the process. This report aims to provide further details on a field that has been traditionally overlooked with the recommendation that multiple factors, in addition to the relatively new area of life cycle assessments, should be accounted for to better protect and preserve relics of our culture and history.

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