Østfold University College

Life cycle assessment of environmental impact for FL 40K series projector's light source module, Barco As

Master's thesis

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Abstract

This study conducts a life cycle assessment (LCA) of FL-40K projectors light source, which is commonly used in the entertainment and education industries. The goal of the assessment is to evaluate the environmental impact of the product across its entire life cycle, including raw material extraction, manufacturing, distribution, use, and disposal. The study uses a cradle-to-grave approach and follows the ISO 14040/44 standards for LCA. The results indicate that the use phase contributes the most to the product's overall impact, particularly in terms of energy consumption and greenhouse gas emissions.

The study demonstrates that by recycling the modules, we can preserve important raw elements such as zinc, copper, and silver rich minerals that may be used to produce efficient and low-cost goods. Recycling electronic waste is vital for environmental preservation, resource conservation, landfill waste reduction, and economic advantages. Electronics contain hazardous compounds that, if not handled appropriately, can poison the environment. Recycling electronics protects precious resources while reducing the need for new mining and extraction. It also provides jobs and helps people and companies save money. In general, recycling electronics helps to create a more sustainable future.

The study also identifies potential areas for improvement, such as increasing the product's energy efficiency and promoting responsible end-of-life disposal. Overall, this LCA provides valuable insights for manufacturers and consumers to make informed decisions about the environmental impact of FL-40k projectors light source.

List of Aabbreviation

- Waste Electrical and Electronic Equipment Directive (WEEE Directive)
- European Union (EU)
- Life cycle assessments (LCAs)
- High intensity discharged (HID)
- Ultra-high performance (UHP) lamps
- Light emitting diodes (LED)
- Compound annual growth rate (CAGR)
- Digital light processing (DLP)
- Sustainable Development Goals (SDGs)
- Life Cycle Inventory (LCI)
- Consumer electronics (CE)
- End of life (EOL)
- Life cycle impact assessment approach. (LCIA)

Table of Contents

List of Figures

List of Tables

Thesis Structure

Chapter 1. Introduction

Chapter 2. Background

Chapter 3. Objectives

Chapter 4. Methodology

Chapter 5. Analysis and results based on the LCA.

Chapter 6. Conclusion

Chapter 1. Introduction

1. Introduction

The European Union (EU) has developed a policy for a comprehensive approach to energy efficiency and climate change. The strategy's goals include ensuring stable energy supplies, creating a competitive environment for energy operators that provides affordable homes, companies, and industries, and promoting sustainable energy usage by reducing greenhouse gas emissions, pollution, and reliance on fossil fuels. To achieve these goals, the EU has set energy and climate targets for 2020 and 2030[1]. Energy-using or energy-related items have an environmental effect throughout their life cycle, from raw material selection to production, packaging, transportation, consumption, disposal, and/or recycling. Many domestic items in the European Union, such as washing machines, refrigerators, and kitchen appliances, bear energy labels and are meant to fulfill minimal energy efficiency criteria. The Energy Labeling Directive 2010/30/EU broadens the original 1992 Directive's scope to include energy-related items that have a substantial direct or indirect influence on energy consumption while in use. Labeling provides accurate, concise, and comparable product energy consumption information, allowing consumers to pick items that use less energy and resources[2].

Environmental issues concerns, such as climate change, have called into question the industrial society's existing energy supply system. Improvements in energy efficiency are viewed as significantly contributing to the accomplishment of greenhouse gas emission objectives in contemporary environmental and energy policy. As a result, because energy consumption is a dominant element of the life cycle impact, the environmental priority in eco-design standards for energy-related goods is clearly defined in energy efficiency increase [3].

However, the manufacture of electrical items has significant environmental consequences. Consumer electronics and information technology equipment have a complicated material composition due to the nature of their products, containing several different metals deemed crucial in terms of resource availability. The actual time of usage reduces as a result of fast innovation and release cycles, as well as dropping prices for end user equipment, but newer products consume more energy and other resources [4].

The Waste Electrical and Electronic Equipment Directive (WEEE Directive) is the European Community Directive 2012/19/EU regulating waste electrical and electronic equipment[5].

The WEEE guideline requires makers or distributors of such equipment to assume responsibility for waste electrical and electronic equipment disposal. However, only recovery and recycling objectives have been adopted, allowing raw materials and energy to be recaptured for new goods while retaining the original design and function of old items. Furthermore, present WEEE collecting practices impede reuse since potentially functioning gadgets are destroyed during shipment due to filling processes [6].

Life Cycle Assessment (LCA) is a process for examining the environmental elements and possible implications of a product's life cycle, beginning with raw materials and energy extraction, and ending with ultimate end-of-life treatment such as disposal, recycling, and energy recovery (i.e., cradle-to-grave). Climate change, stratospheric ozone depletion, toxicological stress on human health and ecosystems, resource depletion, water consumption, and other environmental and resource consequences are only a few examples[7].

This case study will concentrate on projectors because it is a collaborative effort with the well-known and reputable projectors manufacturing business BARCO As Frederiksted, Norway. Because video projector product systems are seldom evaluated, this research offers a detailed product life cycle analysis of a light source module for FL 40 series projectors. LED-based light sources were employed in the FL 40 series. The Light Emitting Diode (LED) is a light source that may be used instead of high intensity discharged (HID) and ultra-high performance (UHP) lamps. LED light source harnesses the capabilities of semiconductor to emit light when current runs through it. It does not create as much heat as bulbs, thus it requires less room for cooling. As a result, the projector may be significantly smaller, quieter, and more compact. Also, it consumes less electricity. It does not contain mercury, making it more ecologically friendly. Furthermore, by comparing reconditioning for reuse of a secondary projector to manufacture and usage of a main device with reduced energy consumption, the study evaluates the environmental consequences of lifetime extension in contrast to energy efficiency enhancement.

Chapter 2. Background

2. Background

2.1. Environmental impact of electronics

Electronics items have changed dramatically in recent decades due to fast technological advancement. Life cycle assessments (LCAs) have been performed to investigate the environmental consequences of this advancement for consumer electronics devices. The consistency of several LCA studies for desktop computers, laptop computers, mobile phones, and television sets has also been evaluated[8]. Electronic items receive less attention in terms of life-cycle assessment (LCA), most likely because they are small and hence have a low environmental effect per unit. In this regard, it is uncertain how to carry out eco-design for electrical items in practice throughout all phases of their life cycle[9]. However, when their entire (year) consumption is taken into account, the overall influence cannot be underestimated.

Many dangerous chemicals, such as benzene, lead, and arsenic, are employed in the production of electronics. When devices are discarded, these materials leak into the earth, air, and water over time. This not only has a negative impact on the ecosystem and wildlife, but it may also be harmful to human health. Electronics disposed away in landfills also make it hard to re-use finite raw resources. Every year, around 7500 tons of silver are utilized, yet only 15% of precious metals are recovered for reuse[10]. E-waste is dangerous, non-biodegradable, and accumulates in the environment, including soil, air, and water, as well as living beings. Toxic elements seep into the environment when open-air burning and acid baths are used to recover precious materials from electronic components[11].

The incorrect disposal of e-waste results in a huge loss of scarce and expensive raw materials, including precious metals such as neodymium (essential for motor magnets), indium (used in flat panel TVs), and cobalt (for batteries). Almost no rare earth minerals are taken via informal recycling; mining them is polluting[12]. However, metals in e-waste are difficult to remove; for example, overall cobalt recovery rates are just 30% (despite the fact that there is technology available to recycle up to 95%). The metal is, nevertheless, in great demand for laptop, smartphone, and electric car batteries. Metals derived from recycled ore use two to ten times less energy than metals derived from virgin ore.[13].

Electronics are unquestionably here to stay, and they are also unquestionably an environmental hazard, thus in order to rescue our inhabitants, we must take severe action immediately by obtaining WEEE approval for all of our electronic product, i.e., taking responsibility for the product from cradle to grave.

2.2. Global use of Projectors

As of 2021, the Projector Market had an estimated value of USD 1506 million. It is estimated to reach a worth of USD 2131 million by 2030, exhibiting a compound annual growth rate (CAGR) of 3.94% between the years 2022 and 2030 [14]. The growing government funding on education and the rising need for complete, comprehensive listed views in the business and educational sectors are driving the expansion of the Projector Market. The usage of projectors for corporate events, like presentations and conferences, has experienced a significant surge in recent years. This growth has been further fuelled by the investment of some startups in these displays, which has contributed to the revenue expansion of the Projector Market [15]. Furthermore, the market's growth has been influenced by the adoption of projector screens in cinemas, which remains a significant factor. Technological improvements in the Projector Market are expected to drive market growth in terms of screen quality, display, and mobility. Portable projectors are no longer large, complicated, and difficult-to-use gadgets with low quality and strange effects, thanks to technological advancements. They are light and easy to use for commercial, educational, and recreational purposes. Modern portable projectors may connect to the internet and include memory devices for storing important data. Furthermore, portable projectors have USB, HDMI, and MHL connectors, which are essential for data access and may be readily connected to mobile devices. Portable projectors also have high resolutions, such as HD and Full HD, for improved image quality, as well as built-in speakers and batteries. These gadgets are small enough to fit in a pocket and are easy to travel[14].

2.3. LED based projectors

LED is the solution in a consumer environment where sustainability is at the forefront of innovation. An LED light source is more energy efficient and has a longer lifespan than a regular bulb. LED projection is significantly less expensive for users, whether in the commercial or public sector, who will profit from not having to replace projectors as regularly[15].

LED projectors run at lower temperatures, resulting in quieter rooms (since fans do not need to spin as fast) and safer settings. LED projectors are also more compact, which reduces the carbon impact of moving them around the world. And, of course, LED projectors are ideal for carrying to interesting and instructive trade exhibitions[16].

Figure 2.3. 1 FL 40-4K, LED based projector

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2.4. Light sources

A light-emitting diode, or LED, is a tiny light source that illuminates when electricity flows through it. LEDs have long been used in electrical equipment, often as alert or indication lights. The original LEDs were only available in red. However, they quickly evolved in terms of power and versatility to generate new hues and even higher light intensities[17, 18].

Conventional light sources, such as incandescent lamps and high-pressure mercury lamps, are prohibited in the European Union. The market for light sources is rising, particularly for LED lamps and luminaires. These significant changes in the lighting sector necessitate assessing the environmental performance of light sources, especially as the changes are supported by environmental factors such as energy usage[18].

LED light engines replace consumable lamps with inorganic LED light sources as shown in fig 2.4.1. LED light engines are very dependable and may provide up to 20,000 hours of operation with no maintenance required, resulting in lower-cost operations, if service planned followed strictly LED light source can provide up to 50,000 hours of operation. When opposed to laser light engines, LED light sources are mercury-free and can be turned on and off rapidly[19].

LED lighting is becoming increasingly popular, thanks to its compact size, minimal heat output, and inexpensive cost. Although LEDs have typically produced significantly less light than lamp and laser-based projectors, this is changing. OSRAM, Samsung, and other manufacturers of high-output LED lights have made significant advances in raising the Lumens of the LED light engines.

Figure 2.4. 1 LED light source working mechanism.[20]

Beginning in 2019, high Lumen, separate RGB LED light engines will be found in projectors. Red, green, and blue light are produced by discrete RGB LEDs. High-speed LED switching replaces the color and phosphor-wheels often used in DLP projectors to show each color at a frequency that is mechanically difficult to accomplish. Because a wheel is not required, noise is decreased, and dependability is enhanced. RGB LED delivers deeper, richer colors than similar technologies for pure white reproduction, and it creates less "rainbowing" than DLP (color breakup)[21].

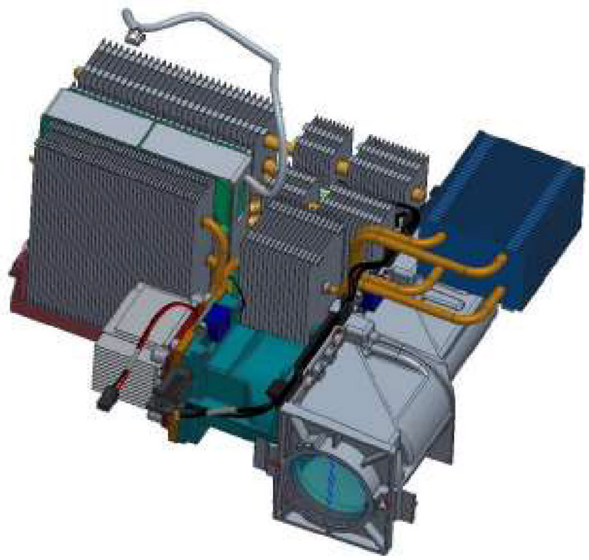

Figure 2.4. 2 LED based light source for FL-40K projectors. Source Barco As

2.5. Barco As

2.5.1. Company's overview

Barco is a global technology company that specializes in developing networked visualization solutions for various industries, including entertainment, corporate, and healthcare. Their products are designed to enhance consumer entertainment experiences, facilitate effective information exchange and decision-making in businesses, and support hospitals in providing optimal patient care.

Barco Fredrikstad AS is a subsidiary of the Barco Group based in Belgium that specializes in developing innovative, small high-performance projectors for demanding applications in various specialized areas, including training and simulation, virtual and augmented reality, visitor attractions, events, and high-end residential settings. It is considered a Centre of Excellence within the Barco group and is well-known for its cutting-edge single-chip DLP projection technology. The Barco Fredrikstad campus comprises different sections that allow staff to explore all facets of hi-tech practical research, from scientific research to product design and testing. Barco provides a wide range of projection technology products suitable for various markets, including ultra-quiet DLP installation projectors for conference rooms and boardrooms, tough big venue projectors for auditoriums and projection mapping projects, laser-illuminated and lamp-based movie projectors for the digital cinema sector, simulation projectors for specific training needs, and 3D stereoscopic projectors for virtual reality applications.

2.5.2. Company's sustainability strategy

Company strategy, 'enabling bright results,' includes a sustainability plan. They choose to incorporate 'go for sustainable impact' into our corporate strategy because we believe that sustainable business is good business. Barco creates and acts to achieve sustainable results for our planet, people, and communities, in accordance with our objective to completely incorporate sustainability into our corporate DNA.

Barco's Sustainable Impact approach is built on three pillars: the earth, the people, and the communities. They created an overall ambition statement for each pillar.

- ✓ They will reduce both their own and their customers' environmental footprints.
- ✓ They will invest in long-term employability by encouraging our employees to learn and grow, as well as by establishing the conditions for a physically and psychologically healthy working environment. They try to create an inclusive environment that values our employees' differences.
- ✓ They shall take an active role in the communities by upholding the highest ethical and quality standards and expect our business partners to do the same. Through solutions, services, and capabilities, they continually strive to provide added value to our clients. Furthermore, they work to guarantee that more individuals can participate in and benefit from the innovation society.

The company wish to reduce not just our own footprint, but also that of our customers. That is why they incorporated eco-design into our product development process. The eco-design programs take into account not just energy performance, but also material utilization, packaging and transportation, and end-of-life optimization. They developed the Barco Eco scoring technique to provide an objective means of assessing the environmental performance of our products. The Barco ECO label is given to products that have an eco-score of A or better. By 2023, we hope to have 70% of our hardware revenues originating from Barco ECO branded goods.

In this study the company proposed to perform a detailed LCA of their latest light source module that has been widely used in FL-40 series projector. Light sources are one of the most frequently swapped components of projectors as shown in fig 2.5. As the number of swap products increased it give rise to electronics and optical waste, which is not favorable at all specially when companies ambitions for sustainability are very high. That is the reason light sources are considered as the main subjects of this LCA out of all the components of projector.

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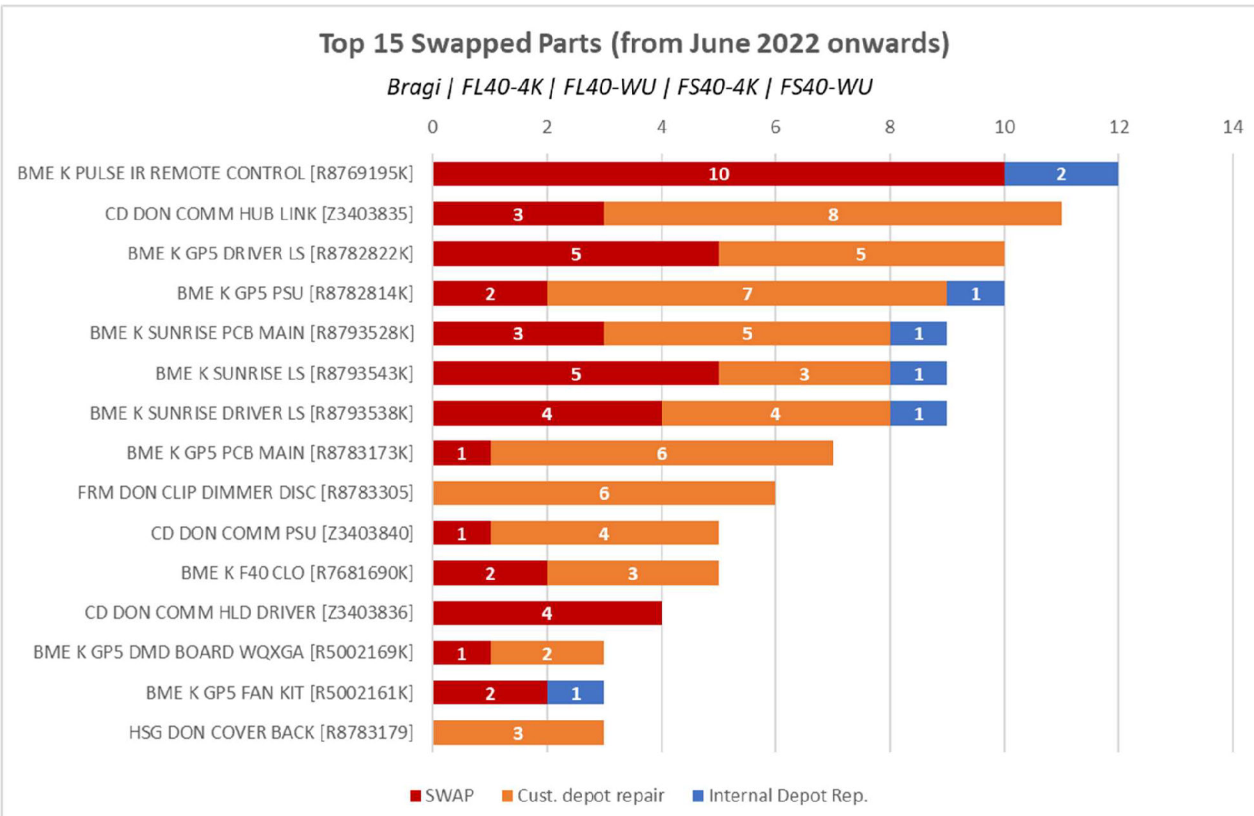

Figure 2.5. 1 Product components failure report

Barco right reserved.

2.5.3. Life cycle assessment background

2.5.3.1. Sustainable Development Goals (SDGs)

Through a collective plan known as the Sustainable Development Goals (SDGs), a worldwide agenda was agreed upon in 2015 in an attempt to drive society toward greater welfare and surroundings. The SDGs were hailed as a significant step toward achieving sustainable development that involved a wide range of stakeholders from across the globe. In comparison to their predecessor, the Millennium Development Goals, additional areas of focus were introduced, addressing challenges like as climate change, economic inequality, innovation, sustainable consumption, peace, and justice, among others [22]. The United Nations Sustainable Development Goals (SDGs) are a comprehensive set of goals and targets agreed upon by all 193 UN member countries. The 17 SDGs and their related 169 objectives constitute a worldwide agreement that has taken years to develop. They are a vital step toward a more sustainable future since they allow for much-needed additional labor. To accomplish the SDGs, policymakers, scientists, and practitioners will need to define how the goals and objectives interact, including trade-offs and synergies, as well as establish three new elements: (1) an amalgamation of human and ecological well-being measures, (2) dynamic models of the integrated human-natural world system, and (3) novel approaches to achieving wide public consensus on the future we desire [23].

2.5.3.2.Life cycle assessment (LCA)

Based on physical energy and material flows, LCA attempts to estimate the possible environmental implications of a product system [24]. The Midwest Research Institute in the United States is thought to have undertaken the first LCA analysis for the Coca-Cola Company in 1969, for decision making on bottle packaging [25]. The Society of Environmental Toxicology and Chemistry (SETAC) began holding an annual conference on LCA in 1990 to develop the technique. The first guideline was released three years later, in 1993 [26]. Since then, LCA has progressed in terms of standards, methodology, and applications. From the original International Organization for Standardization (ISO) version 14040-43 (1997-2000) through the updated version ISO 14040/44 (2006) [27], LCA has been internationally standardized over time. The Life Cycle Initiative of the United Nations Environment Program and the Society of Environmental Toxicology and Chemistry (UNEP/SETAC) strives to harmonize LCA via four stages: objective and scope definition, inventory analysis, impact assessment, and interpretation[28].

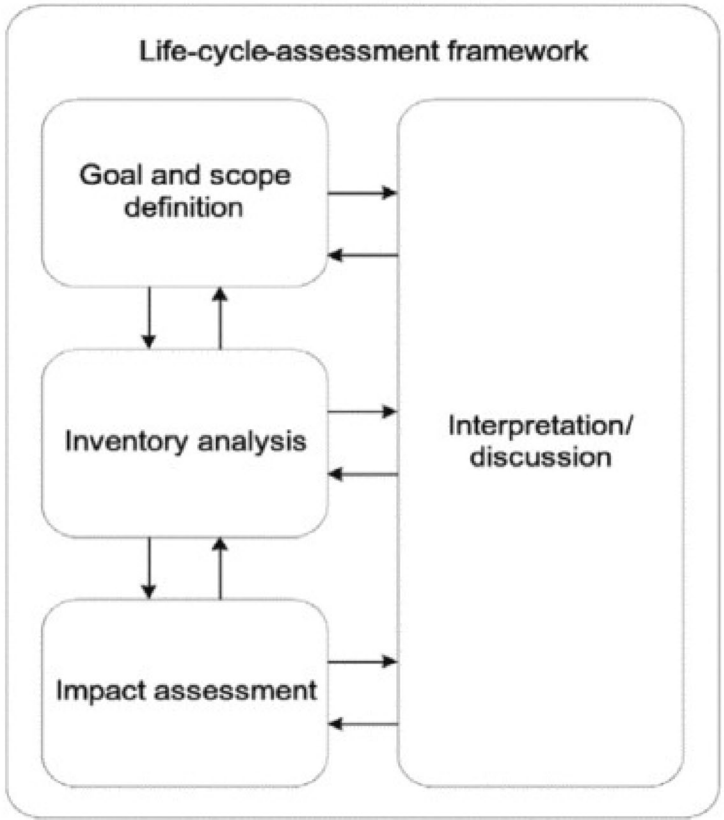

Figure 2.5. 2 The ISO 14040 series provides a methodological foundation for life cycle evaluation [29].

During the objective and scope definition phase, the scope is adequately defined to guarantee that the assessment's breadth, depth, and detail are compatible and sufficient to address the purpose. This necessitates the definition of a so-called functional unit in respect to which the environmental impacts are described. "One year of usage" or "thousand units" are typical functional units for electronics equipment. The functional unit is not always only an amount of stuff. Alternative types of electronics components can be compared, for example, in terms of kg CO_2-equivalents (CO_2e) per m3 of packed and delivered goods, or per service provided by the product.

The inventory analysis is the creation of a Life Cycle Inventory (LCI) for the defined system under consideration. This entails gathering data and quantifying the system's material and energy inputs and outputs (e.g., emissions). Because of the difficulties of acquiring this sort of data for all subsystems, databases with lifetime inventories are commonly used for this purpose.

The goal of impact assessment is to determine the importance of the defined inventory's affects. This is accomplished by categorizing the inventory data based on the numerous environmental effect categories.

The interpretation / discussion phase is tied to the previous three phases. It is the identification of key concerns based on the outcomes of the preceding phases' work. To establish the dependability of the results, an examination of the outcomes is performed. As a result, findings, limits, and suggestions are reached [30].

Chapter 3: objectives

Chapter 3: Objectives

3.1. Thesis objective and research problem

This master's thesis will evaluate the environmental effect of the light source module of the most recent Barco As FL-40K projectors across their whole life cycle, including production, usage, and end of life (EOL) treatment. The carbon footprints of light sources might be calculated using the LCA technique. The light engine used in the FL-40k series is LED-based, and it combines optical and electrical components in a single block. Depending on the service package, light sources can last up to 50,000 hours. In order to obtain the most accurate findings, we shall not consider the service plan in this study.

According to the June 2022 parts failure report, the light source is one of those components that has been failing more frequently and is being replaced with a new one. However, replacing the material will result in not only electronics waste but also resources and energy wastage, which must be addressed in this study. The detailed carbon footprint, energy consumption and cost analysis will be discussed later in the study in accordance with use phase of the product as well as the end of life of the product.

Chapter 4: Methodology

Chapter 4: Methodology

In recent decades, electrical and electronic equipment (EEE) has become a commodity, raising concerns about the destiny of waste electrical and electronic equipment (WEEE). WEEE has the potential to be either a contaminant or a resource, making its management and recycling a critical issue. Because of growing environmental concerns, our society has begun to look for innovative ways to protect and repair our planet's common living area. Manufacturers aim to learn how to reduce the potential environmental implications of each product as much as feasible[31]. Life-cycle assessment (LCA) in all of its forms and modifications is the main technique and instrument for meeting this demand today. The International Organization for Standardization has standardized LCA for all sorts of goods, while the European Telecommunications Standards Institute has standardized it for electronics. Despite standardization, the heterogeneity and inconsistency of similar consumer electronics (CE) LCA investigations remains an issue[32].

The initial phase in LCA is to identify the purpose and scope, followed by collecting emission and resource consumption data for the product or service. The third stage is to measure the impact using midpoint categories and midpoint category indicators. The fourth phase involves researchers attempting to assign an economic cost (end-point modeling) to the final consequences of the assessed eco-environmental effects. In the fourth phase, researchers attempt to assign an economic value to the ultimate consequences of the assessed Eco environmental effects (end-point modeling)[33].

4.1. Goal and Scope

The study's major purpose was to compare the environmental effects of regular usage of a video projector's light source module. The makers' (Barco As) advertised light source life duration is 50,000 hours. After 50,000 hours of use, the device may become faulty, and the consumer has two alternatives. The first alternative is to repair the primary module and utilize it as a secondary device; however, due to the manufacturing geometry of the light source, this procedure is rather difficult. The second alternative is to replace the old module with a new one. According to the company's records (attached above in section 2.5.2), most of their consumers choose to exchange the product rather than refurbish for a better experience. It is also easier for producers, but changing products results in hazardous electronics trash, which is not acceptable in the context of the circular economy and European integrated waste management policy. In this study, we will also look at the impact of replacing the module product.

4.2 Functional unit and product system

The device under consideration is a FL-40k series projector light source. On its own, the product is cutting-edge. It offers 4K (3840 x 2400) resolution, real solid state and ruggedized Bright LEDs with superb color integrity, and 100-0% LED dimming for training at any moment.

The feasibility of functional units for consumer electronics products is determined on their application. The functional unit was defined as two years of projected audiovisual content for an LCD-based projector in [34]. The functional unit for a desktop PC system, which consists of four main subunits: the desktop computer itself, the screen (CRT and LCD technologies), the keyboard, and the mouse, is used for six years before the entire system is turned over for EOL treatment[35]. The functional unit, on the other hand, was described as "the whole life cycle of a 61 kg direct-cooling double-door refrigerator built in China, utilized for 10 years (24 h/day) in[36]. Similarly, in the current study, a functional unit is defined as the usage of a FL-40k series projector's light source module for 50,000 hours in Canada. Because, according to the 2022 sales report, Barco As sold the majority of their products in Canada, accounting for 501 units and 23.47% of their total sales.

4.3 Life cycle inventory

LCI analysis is described by ISO as the 'phase of life cycle assessment comprising the compilation and quantification of inputs and outputs for a product throughout its life cycle. The inventory is a compilation of numerous environmental inputs and outputs involved in a product's life cycle. In practice, inventory analysis translates to data gathering and analysis. Data collecting entails documenting the important inputs and outputs of a product's or process's life cycle. ISO defines the unit process as the smallest element evaluated in the LCI analysis. To the best of my knowledge, the data collected for the present LCA of light source is validated. All material invoices were gathered from official sources supplied by Barco As. According to the accessible bill of materials, the total weight of the light source module is 6.7 kg, which is precisely what the manufacturer reported.

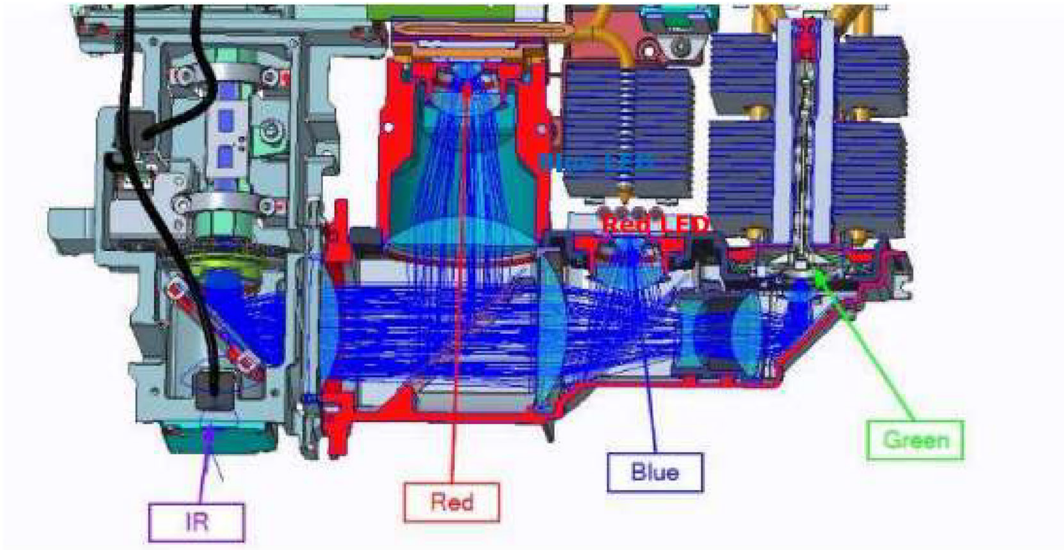

Figure 4.3. 1 Insight modules of Light source

(Copyrights Barco As)

4.3.1. Bom of light source of FL-40k projector.

Table 4.3. 1 BOM for R8782787 FRMC DON LS HOUSING

Part number/Component	Description	Qty	Material (kg)	Element
R8782789	FRM DON LS RGB INTERFACE MILL	1.000	~0,219	Mg - AZ91D
R8782792	FRM DON LENS RELAY 2	1.000	~0,053	N-BK7 or equivalent
R8783166	FRM DON CLIP RELAY LENS RGB	1.000	~0,002	(SS) EN10151-X10CrNi18-8/1.431O C1300
R8782799	FRM DON FILTER GREEN	1.000	~0,003	N-BK7
R8782949	FRM DON CLIP FILTER G	1.000	~0,001	(SS) EN10151-X10CrNi18-8/1.431O C1300
R8782786	FRM DON LS BARREL LNS GR	1.000	~0,024	(Al) EN AW-6060[AlMgSi]/T6
R8782797	FRM DON LENS GREEN 3	1.000	~0,012	N-BK7 or equivalent

R8789536	FRM DON LOCK RING Ø31,5	1.000	~0,001	(SS) EN10270-X10CrNi18-8/1.431O HS (AISI301/302)
R8782796	FRM DON LENS GREEN 2	1.000	~0,019	N-BK7 or equivalent
R8783186	FRM DON LS LENS LOCK WIRE	1.000	~0,001	(SS) EN10270-X10CrNi18-8/1.431O HS (AISI301/302)
R8783167	FRM DON CLIP GREEN BARREL	1.000	~0,002	(SS) EN10151-X10CrNi18-8/1.431O C1300
R8782800	FRM DON FILTER BLUE	1.000	~0,008	N-BK7
R8782950	FRM DON CLIP FILTER B	1.000	~0,001	(SS) EN10151-X10CrNi18-8/1.431O C1300
R8782801	FRM DON FILTER RED	1.000	~0,011	N-BK7
R8782948	FRM DON CLIP FILTER R	1.000	~0,002	(SS) EN10151-X10CrNi18-8/1.431O C1300
R8782806	FRM DON LENS HLDR B MILL	1.000	~0,010	Mg - AZ91D
R8782791	FRM DON LENS RELAY 1	1.000	0,053	N-BK7 or equivalent
R8783198	FRM DON RELAY LENS LOCK WIRE	1.000	~0,002	(SS) EN10270-X10CrNi18-8/1.431O HS (AISI301/302)
B3608621	SCRC D6900-3TX M 3 X 8 STZN	2.000	0,0005	steel zinc plated 3mm/8 mm
R8782925	FRM DON LS INTERPOSER RGB	1.000	~0,075	PEI

Table 4.3. 2 BOM for R8793544 FRMC SUNRISE LS BLUE

Part number/Component	Description	Qty	Material (kg)	Element
R8793548	FRMC SUNRISE LS HEATSINK B	1.000	~0,296	nickel plated aluminium
B1970911	TIM PCM LOCTITE TCP 4000 D	1.000	~0,002	Paraffins
R7682105	G UN SUNRISE LEDCNN B	1.000	0,021	Aluminium, magnesium, and silicon
R8793550	FRM SUNRISE LS LED INTERFACE MILL	1.000	~0,015	Mg - AZ91D
R8782793	FRM DON LENS LED 1	1.000	~0,001	N-BK7 or equivalent

R8783200	FRM DON CLIP LED LENS 1	1.000	~0,001	(SS) EN10151-X10CrNi18-8/1.431O C1300
R8782794	FRM DON LENS LED 2	1.000	~0,012	N-BK7 or equivalent
R8783201	FRM DON CLIP LED LENS 2	1.000	~0,001	(SS) EN10151-X10CrNi18-8/1.431O C1300
R8782924	FRM DON LS SEALING LED	1.000	~0,000	SILICONE RUBBER

Table 4.3. 3 BOM for R8793545 FRMC SUNRISE LS GREEN

Part number/Component	Description	Qty	Material (kg)	Element
R8782940	FRM DON HLD INTERFACE MILL	1.000	~0,024	Mg - AZ91D
R8795599	FRM SUNRISE HLD SHIM	1.000	~0,003	(SS) EN 10088-X5CrNi18-10/1.4301 (AISI304)
B132901	D LED HLD G303Plus	1.000	~0.07	aluminium gallium arsenide
R8782795	FRM DON LENS GREEN 1	1.000	~0,001	N-BK7 or equivalent
R8782945	FRM DON CLIP GREEN LENS 1	1.000	~0,000	(SS) EN10151-X10CrNi18-8/1.431O C1300
Z3403845	CD DON HLD DOCK EXTERNAL	1.000	~0.009	Copper
R8782942	FRM DON HLD FRAME MILL	1.000	~0,045	Mg - AZ91D
R8782944	FRM DON HLD SILICONE GASKET	1.000	~0,004	SILICONE RUBBER
R8782933	FRMC DON LS HEATSINK G	1.000	~0,484	nickel plated aluminium
508-0023	325 SpringPush1,1x8,75x11x4,6V	4.000	~0,001	Steel
R8782944	FRM DON HLD SILICONE GASKET	1.000	~0,004	SILICONE RUBBER
R8782933	FRMC DON LS HEATSINK G	1.000	~0,484	nickel plated aluminium
508-0023	325 SpringPush1,1x8,75x11x4,6V	4.000	~0,001	Steel

Table 4.3. 4 **BOM for R8793546 FRMC SUNRISE LS RED**

Part number/Component	Description	Qty	Material (kg)	Element
R8793552	FRM SUNRISE LS COLDPLATE R	1.000	~0,197	(Cu) EN13601 CW004A H065/R230
B1970911	TIM PCM LOCTITE TCP 4000 D	1.000	~0,002	Paraffins
R7682104	G UN SUNRISE LEDCNN R	1.000	0,021	Aluminium, magnesium and silicon
534-0035	390 Dew Point Sensor	1.000	~0.009	Copper
R8793550	FRM SUNRISE LS LED INTERFACE MILL	1.000	~0,015	Mg - AZ91D
R8782793	FRM DON LENS LED 1	1.000	~0,001	N-BK7 or equivalent
R8783200	FRM DON CLIP LED LENS 1	1.000	~0,001	SS) EN10151-X10CrNi18-8/1.431O C1300
R8782794	FRM DON LENS LED 2	1.000	~0,012	N-BK7 or equivalent
R8783201	FRM DON CLIP LED LENS 2	1.000	~0,001	(SS) EN10151-X10CrNi18-8/1.431O C1300
R8782924	FRM DON LS SEALING LED	1.000	~0,000	SILICONE RUBBER
R8782923	FRM DON LS LED INTERFACE R MIL	1.000	~0,108	Mg - AZ91D
R8782791	FRM DON LENS RELAY 1	1.000	~0,053	N-BK7 or equivalent
R8783198	FRM DON RELAY LENS LOCK WIRE	1.000	~0,002	(SS) EN10270-X10CrNi18-8/1.431O HS (AISI301/302)

R8794645	FRMC SUNRISE HEATSINK LED R	1.000	~0,539	nickel plated aluminium
508-0076	390 spring Scheimpflug	4.000	~0,001	(SS) EN10151-X10CrNi18-8/1.431O C1300
R8783165	FRM DON HEATSINK SCREW R	4.000	~0,004	(Fe) EN 10025-S235JR
R8783182	FRM DON SUPPORT HS RED	1.000	~0,045	PC
535-0010	Fan Axial 119x25	1.000	~0.20	Aluminium or mild steel
511-0061	343 Rubber Fan 119x25	1.000	~0.001	shinetsu silicon rubber
R8783206	FRM DON BRACKET FAN LS	1.000	~0,033	(Al) EN AW-5754[AlMg3]H12/H22

Table 4.3. 5 BOM for labels and packaging

Part number/Component	Description	Qty	Material (kg)	Element
R379000	CLEAN_ACCESSORY	1.000	¨~0.60	100% polyester
R8114781	LBL WARN THIS WAY UP 70X85.	1.000	~0,002	PVC
R5911950	LBL WARN FRAGILE GLASS INSIDE 125X85.	1.000	~0,004	PVC
R811478	LBL WARN FRAG+KEEP DRY	1.000	~0,004	PVC
Z3403845	BOXF SPEC F40 LS TOP PEF	1.000	~0,315	PE FOAM
B591639	BOXF SPEC F40 LS KIT CDB	1.000	~0,05	CARDBOARD
B591630	BOXF SPEC F40 LS BTM PEF	1.000	~0,705	PE FOAM
B591638	BOXF SPEC F40 LS BOX PUF	1.000	~0,409	PU Foam
B591513	BOX201 525X 450X350 5RB	1.000	~1,392	CARDBOARD

4.3.2. Weight distribution with respect to each module.

Module	weight contribution kg	Percentage
FRMC DON LS HOUSING	0.5	7%
FRMC SUNRISE LS BLUE	0.35	5%
FRMC SUNRISE LS GREEN	1.13	17%
FRMC SUNRISE LS RED	1.246	19%
Labelling and Packaging	3.481	52%
Total	6.707	

Table 4.3. 6 Weight Contribution

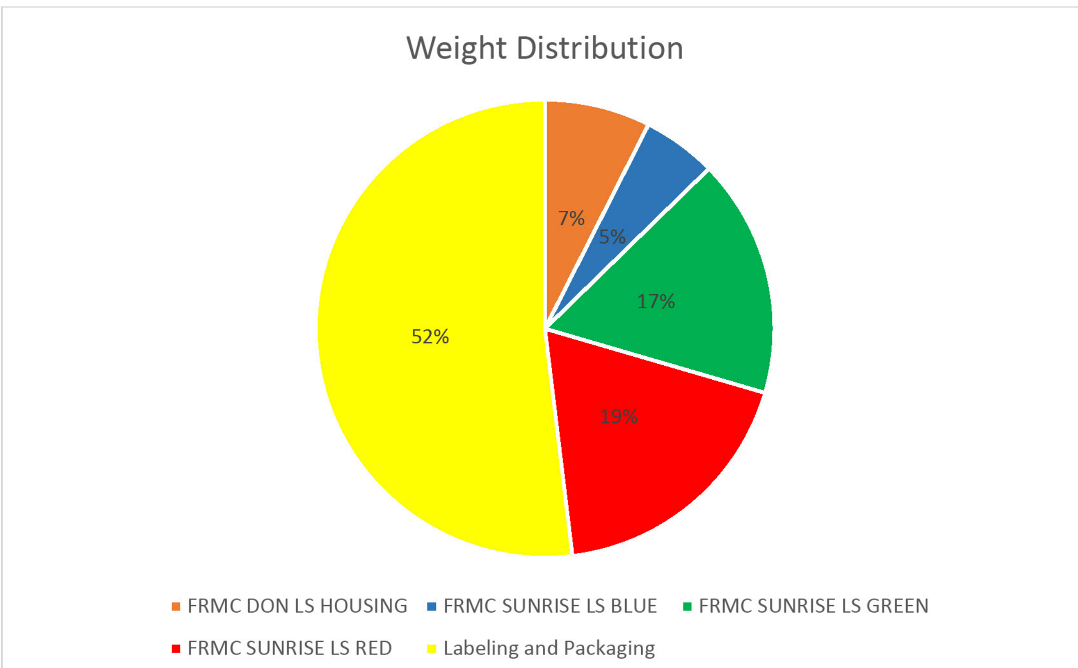

Figure 4.3. 2 Weight Distribution

4.4 Life cycle impact assessment

Following the definition of the aim and scope, the functional unit and life cycle inventory analysis software went on to the life cycle impact assessment. To meet the LCA standards, we must choose a technique in the software. I utilized the LCA technique Recipe 2016, ReCiPe is a life cycle impact assessment approach. (LCIA). It was created for the first time in 2008[37].

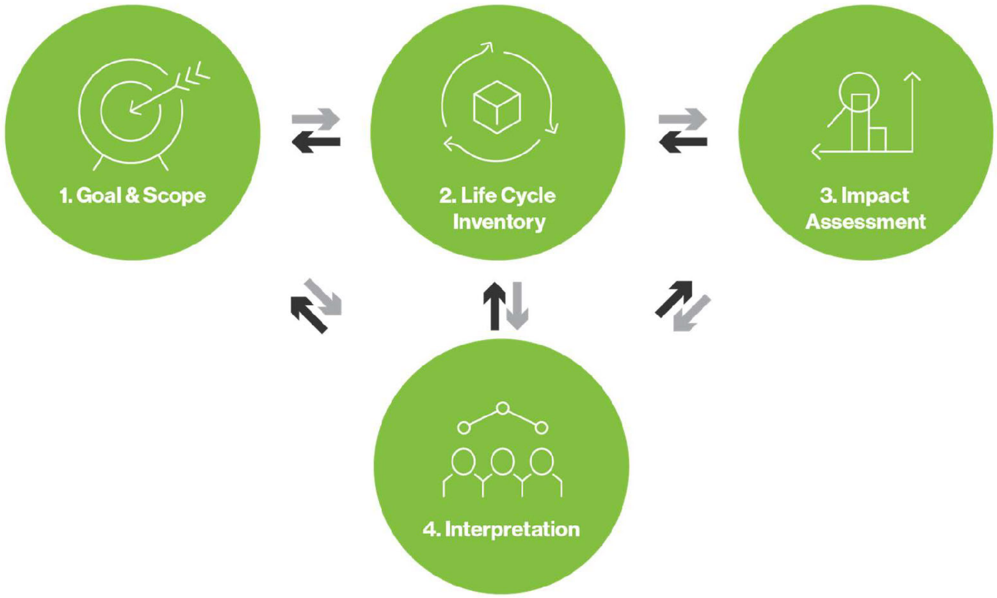

Figure 4.4. 1 Life Cycle Assessment stages

The major goal of the ReCiPe approach is to reduce a large number of life cycle inventory data to a small number of indicator scores. The relative severity of an environmental effect category is expressed by these indicator ratings. Environmental and climatic consequences for humans' life are included in these indicators. The LCA findings will be provided based on specified factors, with the % weightage impact of each stage shown.

The power consumption of a light source over a 50,000-hour period is also necessary for LCA. Since the power rating of any light source varies greatly depending on how it is utilized in the projector, there is no such thing as a nominal power rating. Because a light source cannot be linked to a conventional voltage source, it must be powered by specialist light source driver electronics, the voltage rating is irrelevant. Based on the available data, the nominal power of the light source is considered to be 179W. The indicators used to display and compare the findings are shown in the table below, along with their associated units.

Impact category	Unit
Global warming	kg CO_2 eq
Stratospheric ozone depletion	kg CFC11 eq
Ionizing radiation	kBq Co-60 eq
Ozone formation, Human health	kg NOx eq
Fine particulate matter formation	kg PM2.5 eq
Ozone formation, Terrestrial ecosystems	kg NOx eq
Terrestrial acidification	kg SO2 eq
Freshwater eutrophication	kg P eq
Marine eutrophication	kg N eq
Terrestrial ecotoxicity	kg 1,4-DCB
Freshwater ecotoxicity	kg 1,4-DCB
Marine ecotoxicity	kg 1,4-DCB
Human carcinogenic toxicity	kg 1,4-DCB
Human non-carcinogenic toxicity	kg 1,4-DCB
Land use	m2a crop eq
Mineral resource scarcity	kg Cu eq
Fossil resource scarcity	kg oil eq
Water consumption	m3

Table 4.4. 1 Indicators for LCA

Chapter 5. Results and discussions based on LCA.

Chapter 5. Results and discussions based on LCA.

This section will go through and explain the results of the LCA.A life cycle assessment (LCA) typically requires a wide range of information, such as details about the product or service being evaluated, as well as information about the materials, energy, and other resources used in its manufacture, emissions, wastewater, and wastes generated, transportation and logistics, use, and end-of-life. I attempted to use authentic information to meet the standards of excellent LCA. I must make some assumptions that I already outlined in my previous part.

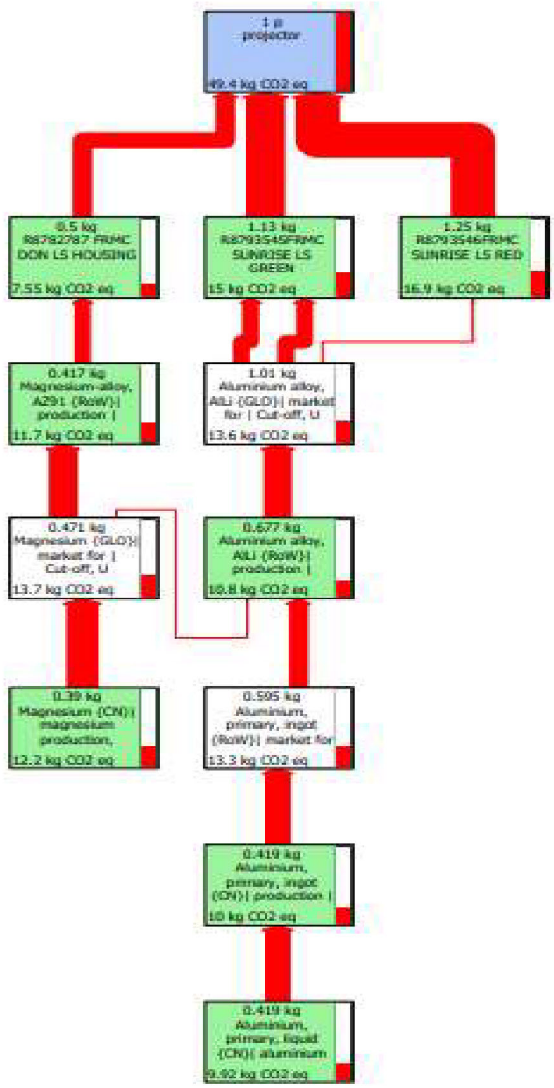

Figure 5. 1 Tree Format LCA results for Light Source

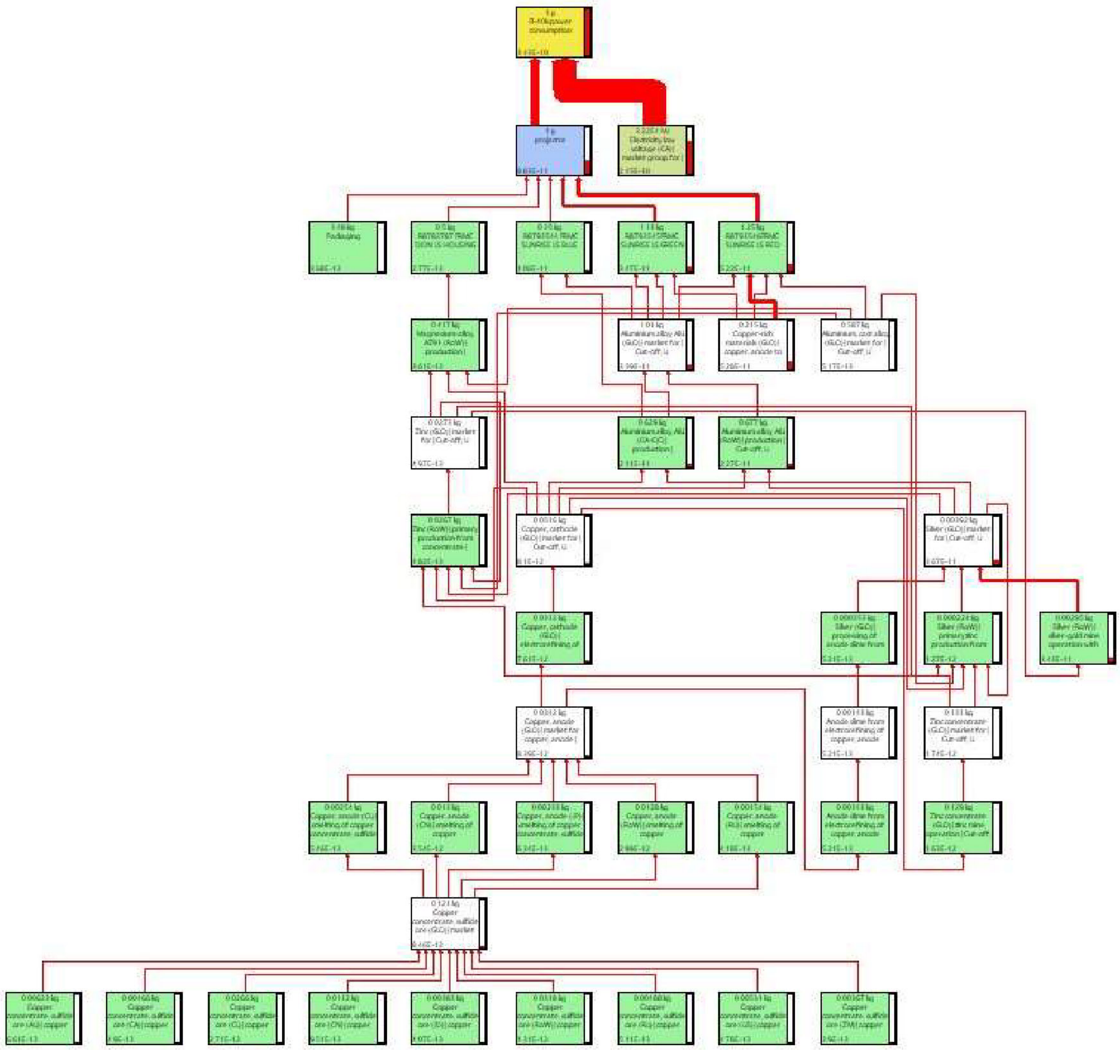

Figure 5. 2 Expanded network Tree of LCA.

A bold red line can be seen in the above expanded tree flow, indicating that the FRMC SUNRISE LS RED module contributes the most to carbon footprints when compared to the others. It can also be seen from the red thermometer indicator that using phase contributes so much to carbon emissions, which is 3.22E4 MJ.

The findings of a Life Cycle Assessment (LCA) reveal that the figures presented represent the carbon footprint associated with the production or consumption of a specific product or service. In this scenario, the total carbon footprint is 49.357044 kg CO_2eq, which is the total quantity of greenhouse gas emissions (measured in CO_2 equivalent) created over the product or service's complete life cycle, including manufacture, use, and disposal. The breakdown of emissions by modules indicates the contribution of different phases of the product or service's life cycle where greenhouse gas emissions were created.

The table below depicts the environmental impact assessment of several categories for a certain activity or product. Global warming, stratospheric ozone depletion, ionizing radiation, ozone formation (human health and terrestrial ecosystems), fine particulate matter formation, terrestrial acidification, freshwater eutrophication, marine eutrophication, terrestrial ecotoxicity, freshwater ecotoxicity, marine ecotoxicity, human carcinogenic toxicity, human non-carcinogenic toxicity, land use, mineral resource scarcity, fossil resource scarcity, and water contamination are among the impact categories.

The table provides the total impact in the specified unit, as well as the individual effects from five distinct viewpoints, for each impact category: Packaging. R8782787 FRMC DON LS HOUSING, R8793544 FRMC SUNRISE LS BLUE, FRMC SUNRISE LS GREEN, FRMC SUNRISE LS RED.

Each category has a different unit of measurement, such as kilograms of CO_2equivalent for global warming, kilograms of Cu equivalent for mineral resource shortage, and cubic meters of water for water use. The table's values can be used to compare the environmental effect of various activities or items, with higher numbers indicating a stronger environmental impact.

Impact category	Unit	Total	Packaging	LS HOUSING	LS BLUE	LS GREEN	LS RED
Global warming	kg CO_2 eq	49.35704	6.6799703	7.5472326	3.1495825	15.04491	16.935349
Stratospheric ozone depletion	kg CFC11 eq	1.63E-05	3.70E-06	1.48E-06	1.27E-06	5.00E-06	4.85E-06
Ionizing radiation	kBq Co-60 eq	1.624413	0.27538364	0.22651678	0.1347965	0.570227	0.41748947
Ozone formation, Human health	kg NOx eq	0.139104	0.016304231	0.018370412	0.011141112	0.0480431	0.04524463
Fine particulate matter formation	kg PM2.5 eq	1.68E-01	1.26E-02	2.89E-02	1.01E-02	4.24E-02	7.44E-02
Ozone formation, Terrestrial ecosystems	kg NOx eq	0.143281	0.016595985	0.019744408	0.011343902	0.0488527	0.04674442
Terrestrial acidification	kg SO_2 eq	0.314884	0.025767927	0.019502616	0.02190319	0.0856213	0.16208855
Freshwater eutrophication	kg P eq	0.036675	0.005198582	0.003278963	0.003200282	0.0116325	0.01336461
Marine eutrophication	kg N eq	0.002022	0.000823656	0.00019088	0.000107108	0.0004456	0.00045441
Terrestrial ecotoxicity	kg 1,4-DCB	1351.176	17.942439	9.0865266	43.698136	183.964	1096.4846
Freshwater ecotoxicity	kg 1,4-DCB	14.669	0.2032002	0.28270804	1.3061457	4.326502	8.5504442
Marine ecotoxicity	kg 1,4-DCB	19.99046	0.27144536	0.3676526	1.94E+00	6.3589987	11.056796
Human carcinogenic toxicity	kg 1,4-DCB	7.247137	0.27712448	0.49889844	0.87687615	2.8316853	2.7625523
Human non-carcinogenic toxicity	kg 1,4-DCB	247.3835	5.0573879	5.4052249	22.572177	76.788205	137.56048
Land use	m2a crop eq	2.565219	1.4828933	0.1208013	0.097841833	0.3648459	0.49883699
Mineral resource scarcity	kg Cu eq	1.173215	0.017678981	0.017342875	0.14339384	0.4560517	0.53874797
Fossil resource scarcity	kg oil eq	11.8648	2.4225856	1.9074037	0.72629008	3.4433191	3.3652023
Water consumption	m3	0.530423	0.17038735	0.025565663	0.068526842	0.1392535	0.12668958

Table 5. 1 Environmental score indicators.

5.1. The LCIA results of Light Source:

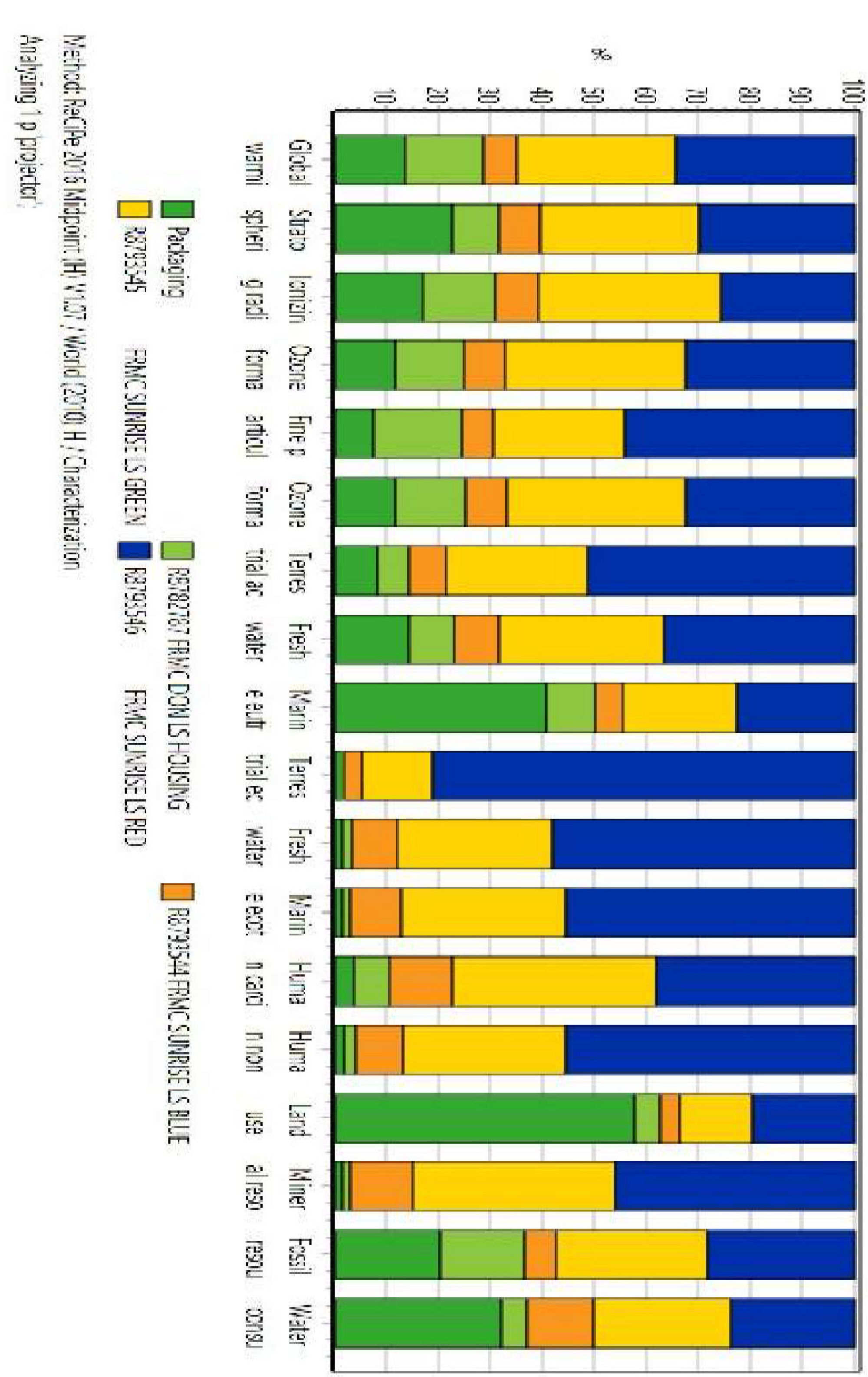

Figure 5. 3 The LCIA results of Light Source

As seen in the bar graph of the FL-40k light source, blue has a greater influence on all environmental parameters except land usage. The packing materials of the product have the greatest influence on land use. Here are the outcomes of the most important and minor environmental impacts:

1) The packaging module has the greatest influence on land usage (57.8%) and the least impact on Terrestrial ecotoxicity (1.36%). The study of how environmental toxins influence land-dependent species and their habitat is known as terrestrial ecotoxicology[38].

2). FRMC Don Housing has a 17.6% importance on fine particulate matter and a 0% relevance on mineral resource scarcity.

3). Sunrise LS Blue has an estimated 12% influence on human carcinogenicity, mineral resource scarcity, and water use. The lowest effect terrestrial ecotoxicity is 3.23%.

4). Sunrise LS Green has the greatest influence on mineral resource scarring (38.9%) and the least impact on terrestrial ecotoxicity (13.6%).

5). Sunrise LS Red has an 81.2% major influence on terrestrial ecotoxicity and a 19.4% little impact on land usage.

More precise numbers are shown in table 5.1.

5.2. Energy Consumption

SimaPro has a number of impact assessment methods for calculating impact assessment findings. SimaPro has utilized the IPC 2021 GCP 100 approach to calculate the environmental effect in terms of energy usage. Energy consumption analysis is important because the energy consumed during the life cycle of a product is often a significant contributor to its environmental impact. For example, the production of electricity from non-renewable sources such as coal and natural gas is a major source of greenhouse gas emissions, contributing to climate change. Therefore, analysing the energy consumed during the production, use, and disposal of a product is essential to identify opportunities to reduce its environmental impact Energy consumption analysis can also help to evaluate the sustainability of different energy sources[39]. It can help us understand the environmental impact associated with the production and transportation of energy, including the extraction of fossil fuels and the production of renewable energy technologies. This analysis can inform decisions about how we produce and use energy, such as choosing to use renewable energy sources and increasing energy efficiency. In summary, energy consumption analysis is a crucial component of LCA because it helps to identify the environmental impact associated with energy use during the entire life cycle of a product. It can inform decisions about reducing the environmental impact of a product, as well as inform decisions about the production and use of energy.

The figures show the environmental impact of a projector in kilograms of CO_2-equivalent (kg CO_2-eq) units, divided into three impact categories: global warming potential (GWP100) - fossil, GWP100 - biogenic, and GWP100 - land transformation.

1). The GWP100 - fossil category measures the projector's influence on climate change as a result of greenhouse gas emissions from fossil fuel sources such as coal, oil, and gas. The overall effect in this category is 1789.354368 kg CO_2-eq, with the majority of this impact (1741.540922 kg CO_2-eq) ascribed to the projector's power usage derived from the region's low voltage electricity market group. The remaining effect (47.813446 kg CO_2-eq) is caused by the projector itself, most likely as a result of its production process, transit, and disposal.

2). The influence of the projector on climate change is quantified in the GWP100 - biogenic category owing to the production of biogenic greenhouse gases, such as methane and nitrous oxide, which are created by biological activities. The overall effect in this category is 12.27265221 kg CO_2-eq, with the majority of this impact attributable to the projector (0.167073501 kg CO_2-eq), most likely owing to biogenic gas emissions from materials used in its manufacture.

3). The influence of the projector on climate change is quantified in the GWP100 - land transformation category owing to the transfer of land from its natural condition to various uses, such as agriculture or urbanization. The overall effect in this category is 91.70601278 kg CO_2-eq, with the majority of this ascribed to the projector (0.13964396 kg CO_2-eq). This impact might be attributed to the extraction and processing of raw materials used in the projector, as well as the land use implications related with the projector's manufacture and disposal.

Overall, this chart gives insight into a projector's environmental effect, emphasizing the significance of examining a product's whole life cycle, from raw material extraction through end-of-life disposal, as well as the influence of its energy usage.

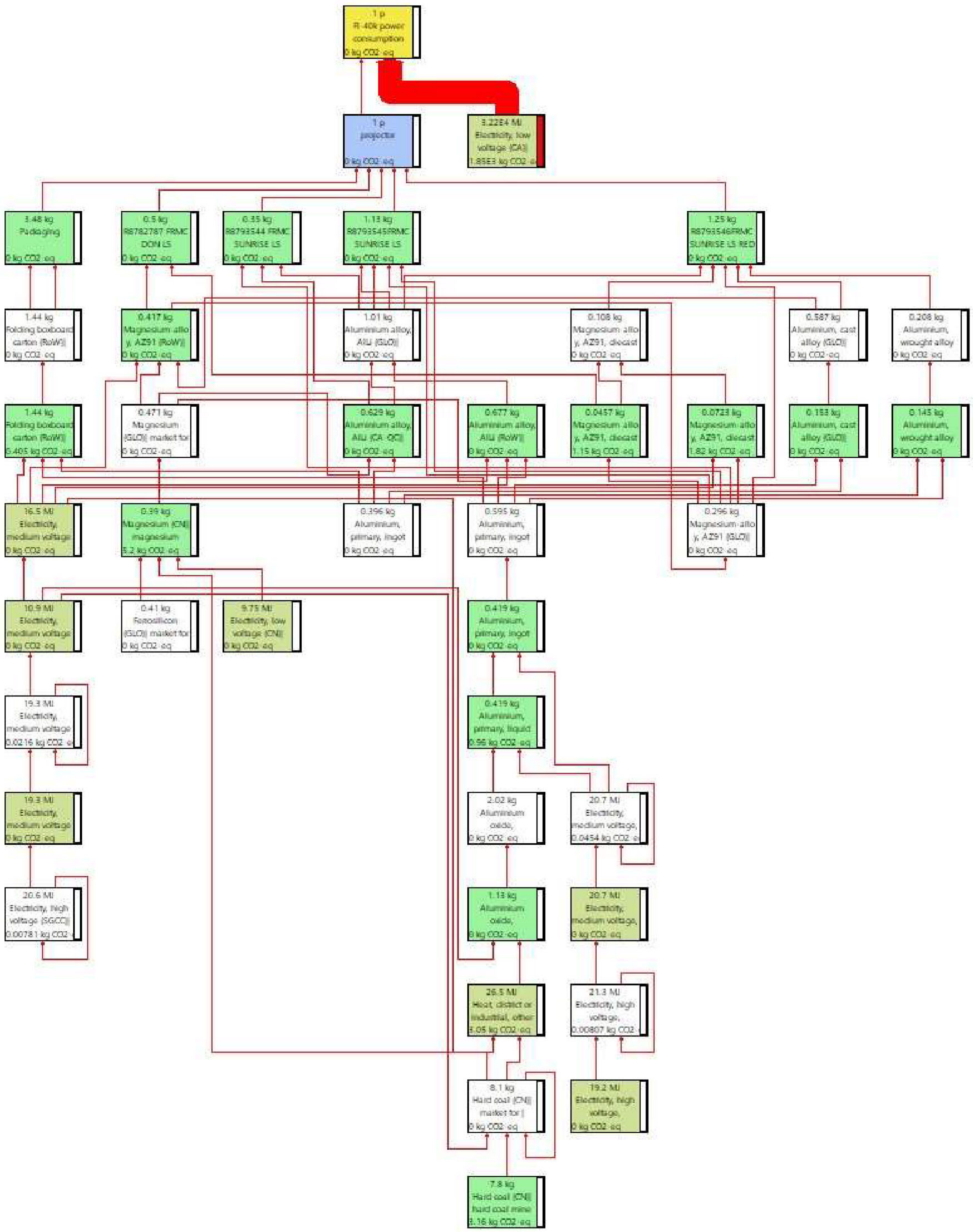

Figure 5. 4 Energy Consumption Assessment

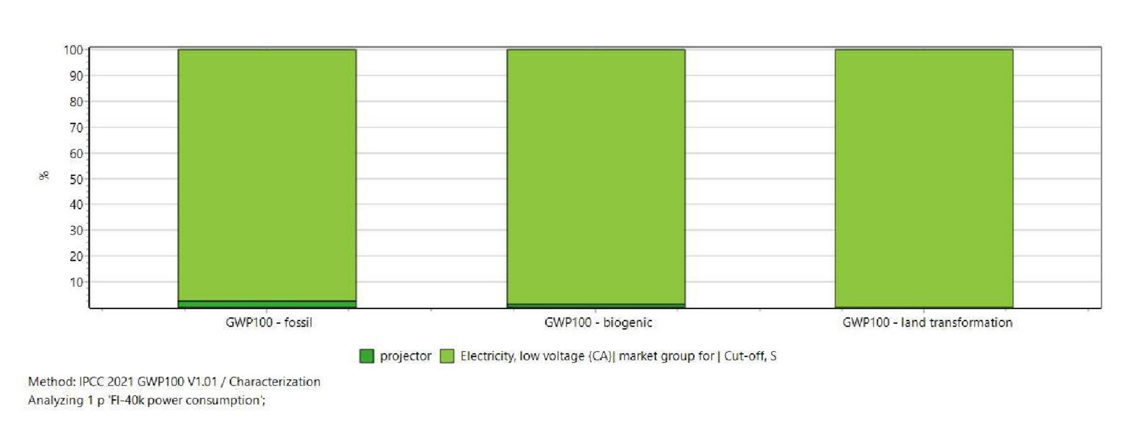

Figure 5. 5 Use phase analysis.

5.3. Reusability of modules

The European Union announced intentions to speed its transition to green technology and expand production of essential raw resources in order to reduce dependency on nations such as China. By the end of the decade, the 27-nation bloc wants at least 10% of its use of such materials to be generated domestically, and it will set recycling and processing objectives. Lithium, cobalt, silicon, and rare-earth metals are key minerals used in everything from cellphones to electric vehicles to solar panels to wind turbines to steel. Security of raw material supply has also climbed to the top of the agenda in Asia, particularly among high-tech firms such as Japan, South Korea, and Taiwan. While demand for vital raw resources is likely to climb rapidly, according to a European Commission statement, Europe relies largely on imports, frequently from quasi-monopolistic third-country providers. "In order to improve its economic resilience, the EU must mitigate the risks associated with supply chains that are linked to such strategic dependencies."[40]

In the face of rising geopolitical tensions and increased resource rivalry, the EU seeks to limit its reliance on other nations, notably China, which controls a major amount of the world supply of numerous important resources such as magnesium and rare-earth metals. “Raw materials are critical for the production of key technologies for our twin transition, such as wind power generation, hydrogen storage, and batteries," said European Commission President Ursula von der Leyen. "We are strengthening our cooperation with dependable trading partners around the world in order to reduce the EU's current reliance on just one or a few countries." When the COVID outbreak interrupted global supply networks, concerns mounted about the country's reliance on imports. For example, in 2021, China will reduce its supply of magnesium to the

EU by almost 95%. It is currently aiming to reduce its reliance on any foreign source to 65% or less of all strategic raw material imports[41].

In figure 5.2. It also explains the above EU policy in context of electronics waste the unhighlighted boxes indicates materials that are not being reused, if we do not consider recycling or reusing our modules, we will lose so many essential elements. Aluminum alloys, aluminum castings, and copper-rich materials are all available that remain unuse at the end of life of the product. Significant amounts of zinc and silver-rich material are wasted. However, these materials can be recycled to make cheaper parts and it can be helpful to reduce the dependence of EU in importing materials from China. In recent decades, electrical and electronic equipment (EEE) has become a commodity, raising concerns about the destiny of waste electrical and electronic equipment (WEEE)[42]. WEEE has the potential to be either a contaminant or a resource, making its management and recycling an essential area of study. WEEE is now pursuing corporations for dumping such crucial raw materials in landfills. We must see it as a critical problem for both the economy and the environment, and we must encourage component reusability and recycling.

Chapter 06. Conclusion

6.1. Conclusion

In conclusion, this study has conducted a life cycle assessment (LCA) of FL-40k projector light source, evaluating its environmental impact across its entire life cycle. The results show that the use phase has the greatest impact on the environment, mainly due to energy consumption and greenhouse gas emissions. This finding highlights the importance of improving the energy efficiency of projectors and promoting responsible use practices. Additionally, the manufacturing stage was identified as a significant contributor to the product's environmental impact, particularly due to the production of electronic components. The LCA also suggests potential areas for improvement, such as using renewable energy sources and promoting end-of-life recycling. Overall, this study provides valuable insights for manufacturers and consumers to make informed decisions about the environmental impact of FL-40k projectors light source and to promote more sustainable practices in the entertainment and education industries.

1) The packaging module has the greatest influence on land usage (57.8%) and the least impact on Terrestrial ecotoxicity (1.36%). The study of how environmental toxins influence land-dependent species and their habitat is known as terrestrial ecotoxicology[38].

2). FRMC Don Housing has a 17.6% importance on fine particulate matter and a 0% relevance on mineral resource scarcity.

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Significant amounts of zinc and silver-rich material are wasted without recycling light source. However, these materials can be recycled to make cheaper parts and it can be helpful to reduce the dependence of EU in importing materials from China. In recent decades, electrical and electronic equipment (EEE) has become a commodity, raising concerns about the destiny of waste electrical and electronic equipment (WEEE).

6.2. Future Work and Research Challenges

There are several possibilities for future research in the life cycle assessment (LCA) of projectors. One potential area of investigation could be to expand the scope of the study beyond just the environmental impact and incorporate a social and economic analysis to better understand the full life cycle of the product. Another area of research could be to explore alternative energy sources and technologies to power projectors, such as renewable energy sources or energy-efficient technologies, in order to reduce the environmental impact of projector use. Additionally, future studies could explore the impact of projector disposal and end-of-life management on the environment and identify strategies to improve the recycling and disposal process. Overall, there are numerous avenues for future research in the LCA of projectors, and continued investigation in this field is essential for promoting sustainable and environmentally responsible practices in the technology industry.

The lack of information regarding the actual energy usage of each unit made it challenging to accurately predict the energy consumption and complete the price reduction task in this study. However, the product has the potential to significantly reduce carbon emissions and improve efficiency. In order to further reduce costs, future research could explore alternative recycling technologies and substitute raw materials to create modules. Additionally, while the use hours in this study were fixed at 50,000 hours, it may be beneficial to consider observing customers' usage behavior to enhance the use phase findings. Furthermore, the modules can be tested in a workshop to gather more information and improve the overall product.

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