FINAL PROJECT REPORT

EMS622U - Sustainability Assessments for Design

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Introduction

Background and Product Description

The consumption of nicotine industry is evolving rapidly. Although conventional tobacco products like cigarettes have ruled for almost a century, the arrival of electronic nicotine delivery systems, especially disposable vapes has brought a new wave of consumer behavior, especially among a younger demographic. This development has triggered public health, addiction, and increasingly sustainability a critical discussion.

This paper compares the sustainability of two widely used nicotine delivery systems.

Malboro Gold: Made by Philip Morris International, a normal pack of twenty Marlboro Gold Cigarettes consists with Renowned for its enormous market reach and premium positioning, Marlboro is still among the most smoked cigarettes brand worldwide.

Elf Bar 600: Designed as a single-use, pre-filled electronic vape offering around 600 puffs, Elf Bar 600 Disposable Vape is particularly among 18–24-year-olds, Elf Bar is among the most often used disposable vape brands available in the UK right now.

Though both products contain nicotine, their material compositions, energy intensity, waste generation, regulatory profile, and end-of-life effects differ greatly.

Justification for Product Selection

The selection of Marlboro Gold cigarettes and Elf Bar 600 disposable vapes for this sustainability assessment was based on their significant social impact and contrasting environmental profiles. With Marlboro still among the top-selling cigarette brands, the tobacco market in the UK was predicted to be £22.28 billion in 2023 [1]. Simultaneously, the vape market is expected to reach USD 1.47 billion by 2029, expanding at a compound annual growth rate of 13.6%, where disposable vapes like Elf Bars account for a significant portion of this expansion [2].

National health statistics show this shift in consumption behaviors. The rate of smoking among UK adults fell to an all-time low of 11.6% in 2023, owing primarily to public health initiatives and legal pressure [3]. Environmentally, the two items differ significantly. Cigarette butts remain the most commonly wasted item in the world, with an estimated 9 trillion thrown out each year [4]. Many of them are made of non-biodegradable cellulose acetate. Although they are marketed as a greener alternative, disposable vapes contribute significantly to e-waste due to their integrated lithium-ion batteries, heavy metals, and often improperly recycled plastic casings.

The comparison interests to me personally since I have close family who have been smoking for a long time, and I have seen firsthand how some of them have shifted to disposable vaping in recent years. Watching their actions has made me more aware of the environmental impact of the products they consume on a daily basis, as well as the poor health implications of a nicotine addiction. The clear distinction between traditional cigarettes and disposable vapes provides an excellent opportunity to apply life cycle assessment approaches, as I am very interested in sustainability and the practical impact of common items. Examining two regularly used things allows me to better understand how individual consumer decisions relate to larger environmental challenges and how well-informed design or policy reforms might lead to better, more sustainable future.

Aim and objectives

This paper aims to evaluate, using environmental, financial, and social factors, a pack of Marlboro Gold cigarettes and an Elf Bar 600 disposable vape.

Objectives

Envirmental	Using LCA approach, quantify the life cycle effects of both items with a focus on waste generation, carbon emissions, and resource extraction.
Economic	Calculate the whole life cycle cost for each pruduct, including distribution, manufacture, and disposal, identifying trade-offs and cost hotspots.
Social	Using Social Life Cycle Assessment (S-LCA) indicators, examine social implications including health hazards, work practices, and society views.
Recommendation	Identify sustainability hotspots across every life cycle, compare performance, and suggest design or policy-level solutions to minimize social or environmental damage.

Whats to come

Environmental assesment (LCA)

Goal and Scope definition

This Life Cycle Assessment (LCA) aims to assess compare the environmental effects of two nicotine delivery products: an Elf Bar 600 disposable vape device and a standard pack of Marlboro Gold cigarette, both lasting a day for a regular smoker. The main goals are to find environmental hotspots all through their life cycles and suggest ways to lower their total environmental effects.

The providing of a like nicotine experience to the user defines the functional unit for this investigation. For simplicity and alignment with real-world purchase behavior, the assessment contrasts 1 Elf Bar 600 against 1 pack of Marlboro Gold cigarettes even though 20 cigarettes give approx 160–240 puffs.

Raw material extraction, manufacture, packing, transportation, use, and end-of-life disposal make up this LCA's system boundary called cradle to-grave as shown in figure 1 for a cigrette and figure 2 for a disposale vape.

Figure 1. Life cycle of a cigarette

Figure 2. Life cycle of a disposable vape

Inventory Analysis (LCI)

The life cycle inventory (LCI) is the obtaining of material inputs, energy use, emissions, and generated waste related with the manufacture, distribution, use, and disposal of Marlboro Gold cigarettes and Elf Bar 600 disposable vapes.

Tobacco leaf is the main raw ingredient used in Marlboro Gold cigarettes, which calls for large agricultural inputs including huge volumes of water, fertilizers, and pesticides while growing [5]. Comprising cellulose acetate, a non-biodegradable plastic that stays in the environment for up to ten years [5], the cigarette filters are made. During manufactuing, cigarettes involves tobacco curing, often flue-curing with fossil fuels, blending, and filter assembly, all of which require significant energy and water use. Cigarette packs are packaged both inside and outside using low-density polyethylene (LDPE), aluminium foil, and wrapping sheets. Each cigarette pack includes a cardboard box (6 g), aluminium foil (0.5 g), and plastic wrap (0.3 g). [reference]. Distribution is typically via diesel trucks across national supply chains. An average distance of approx 950 km from the regional Phillip Morris manufacturing plant in Switzerland. Disposal is problematic, with 4.5 trillion cigarette butts discarded globally each year, most of which contain non-biodegradable filters and persistent toxins [5].

Elf Bar 600 Disposable Vapes incorporate increasingly sophisticated materials including an aluminium case, plastic body, a circuit board, a lithium-ion battery, and e-liquid comprising propylene glycol, vegetable glycerin, nicotine, and flavourings []. Additionally with battery assembly and electronic components, the manufacturing process is energy-intensive. Usually, packaging consists in inside plastic trays and a printed cardboard box. Since most disposable vapes are made in China and shipped to the UK by sea freight, a distance of approximately 20000 km, transportation logistics increase the environmental load more. Disposable vapes end-of-life phase also raises environmental issues of growing importance. More than 90% of used Elf Bars, end up in landfills or burn without material recovery, which causes notable e-waste buildup and leaking of heavy metals including lithium, cobalt, and nickel into ecosystems.

Table 1 : Philip Morris Malboro Gold

	Component	Material	Estimated Mass (g)	Primary Process Energy (MJ/kg)	Climate Change Impact (CO2e kg/kg)
Pruduct	Tobacco	Cured Tobacco Leaves	14	6	0.6
	Cigarette Paper	Bleached Flax/Wood Pulp	5.5	12	1.2
	Filter	Cellulose Acetate	4.5	80	5
Packaging	Inner Foil Liner	Aluminum Foil	1	30	1.5
	Outer Pack	Paperboard	6	12	1.2

Table 2 : Elf Bar 600

	Component	Material	Estimated Mass (g)	Primary Process Energy (MJ/kg)	Climate Change Impact (CO2e kg/kg)
Pruduct	Casing	ABS/PC Plastic	12	90	4.5
	Battery	Lithium-ion Cell	11	180	12
	Coil	Stainless Steel	1	50	3
	Wick	Cotton Fiber	0.2	10	0.8
	E-liquid	Propylene Glycol	2	8	0.6
	Mouthpiece	Silicone Rubber	1.5	90	4.5
Packaging	Outer Box	Cardboard	3.5	25	1.8
	Inner Wrapping	PET Plastic Film	1.5	80	4

The values presented in Tables 1 and 2 were derived from a combination of sources, including studies such as “Analysis of carbon footprint of cigarette based on life cycle assessment [7], and a recent article from turner et al called “Deconstructing contemporary disposable vapes: A material and elemental analysis” [8], inaddition to edupack [9].

Envirmental Indicatior 1 - Global Warming Potential (CO_2e)

Global Warming Potential (GWP) quantifies the total emissions of greenhouse gases associated with a product over its life cycle, expressed as kilograms of carbon dioxide equivalent (kg CO_2e). Converted to a CO_2 baseline across a 100-year time horizon, it reflects the climate influence of all significant greenhouse gases including CO_2, CH_4, and N_2O.

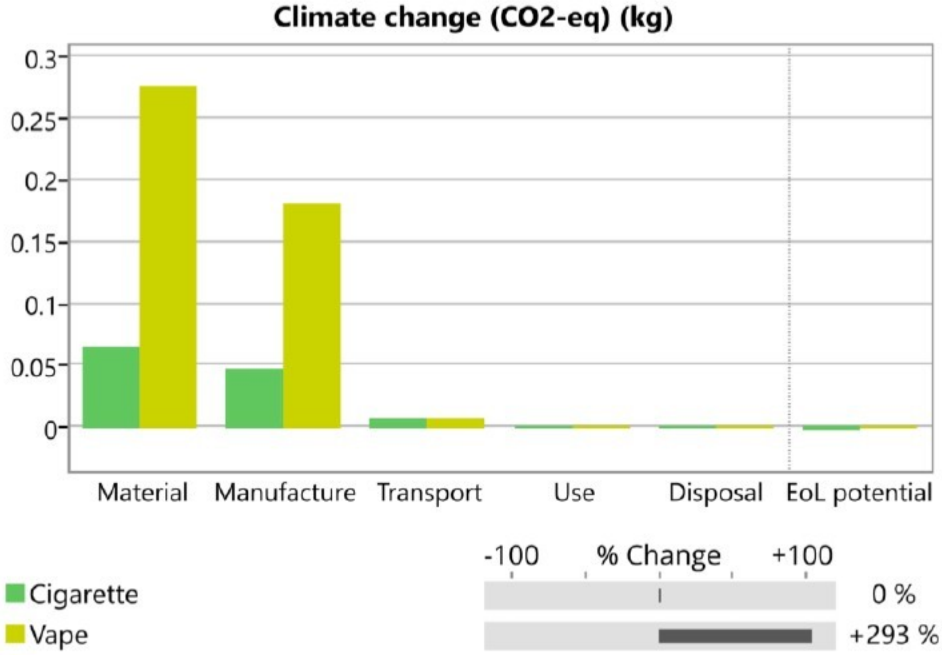

Figure 3. climate change analysis of vape and cigrette

The Granta EduPack EcoAudit results indicate that the Marlboro Gold cigarette pack has a total GWP of 0.118 kg CO_2e per pack. In contrast, the Elf Bar 600 disposable vape emits 0.464 kg CO_2e per unit over its life cycle. Despite comparable use, this shows a practically quadruple rise in emissions for the disposable vape as compared to the cigarette pack.

Together providing over 90% of each product's overall carbon footprint, material extraction and manufacture account for most of the emissions for both items. However due to the Elf Bar's material complexity, especially the lithium-ion battery, printed circuit board, alloyed steel coil, and mixed plastics, we see far higher emissions per unit. By comparison, the cigarette pack mostly comprises of paper-based materials, cellulose acetate for the filters, and cured tobacco leaves, all of which have less embodied emissions per kilogram. The embedded emissions of the Elf Bar's electronic components still exceed the extra combustion emissions produced by cigarettes.

Furthermore, although the Elf Bar's lengthy shipping distance from China meant predicted increased transportation emissions, the utilization of maritime freight reduces this effect. While Marlboro Gold, transported regionally by road and ferry from Switzerland, exhibits 5.6% transport emissions, despite the shorter distance, a reflection of the lower emissions efficiency of truck transport vs shipping, the transport emissions of the Elf Bar are just 1.4% of total CO_2e.

For both goods, disposal emissions are minimal, yet for cigarettes, the absence of recoverable value in most components causes somewhat greater emissions. The partly recyclable outer box and inner plastic wrap of the vape help to offset some CO_2e.

Envirmental Indicatior 2 – Energy (MJ)

The second key indicator analyzed is total energy consumption in megajoules (MJ). This includes the total energy input required for material extraction, component processing, manufacturing, transportation, and disposal from cradle to grave.

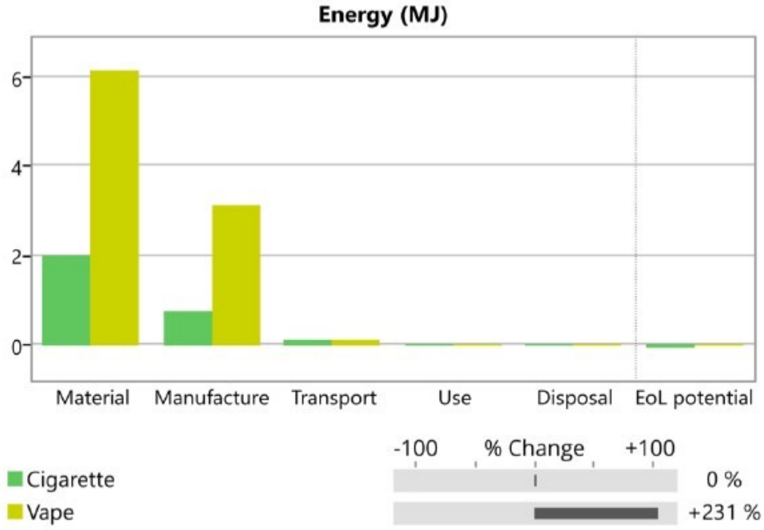

Figure 4. Energy analysis of vape and cigarette

The Marlboro Gold pack has embodied energy of 2.82 MJ, while the Elf Bar 600 consumes 9.33 MJ . For the disposable vape, this amounts to a 3.3× higher overall energy requirement. Both goods have an almost entirely material and manufacturing phase energy load. For Marlboro Gold, paper-based packaging, cellulose acetate filters, and agricultural and industrial tobacco processing account for seventy percent of the energy consumed. The manufacture of its lithium-ion battery (4.6 MJ), ABS+PC plastic enclosure (1.4 MJ), and precision assembly of electronics and steel coils drives the energy intensity for the Elf Bar 600.

Furthermore increasing the energy comsumtion of the Elf Bar is due to the high energy needed for mining and processing elements like cobalt, nickel, and lithium, which is necessary for battery manufacture. Among the most energy-intensive activities in the worldwide materials supply chain, these ones greatly affect the total environmental burden.

Surprisingly small in both circumstances is transportation energy. While Marlboro Gold's shorter truck and ferry travel from Switzerland provides 0.099 MJ (3.5%), while the long-distance maritime goods of the Elf Bar from Shenzhen to London contribute just 0.85 MJ (0.9%), therefore demonstrating the better energy efficiency of marine transport per tonne-kilometer.

In both examples, disposal energy is negligible with slight energy recovery potential in recyclable components like the outer box and PET wrap in the Elf Bar. But the implementation of these possible environmental advantages is limited by a lack of effective recycling systems for single-use vapes.

Interpretation

The hotspot analysis indicates that both products have similar life cycle stages, namely material extraction and manufacture. These processes require roughly 90% of a product's total energy and Global Warming Potential footprint. The lithium-ion battery is the Elf Bar's most important component, followed by the plastic case and electronic circuit assembly. Particularly stages in the Marlboro Gold manufacturing process are filter production and tobacco processing are identified as energy and emission intensive.

While the Elf Bar reduces direct combustion emissions during usage, it to long term environmental problems. Its energy and carbon intensive manufacturing processes, combined with low recyclability and an increasing globally e-waste, raise questions about its feasibility as a smoking replacement. Marlboro Gold, while simpler and quicker to dispose of, emits hazardous emissions during use and contributes to global litter via non-biodegradable filters.

To improve the sustainability of the Elf Bar 600:

- Create a modular design that allows for separate assembly and retrieval of the battery, shell, and electronics.
- A battery rreplacement or rechargeability will allow to switch to reusable vape devices with rechargeable batteries to distribute energy and carbon footprints over a longer usage period.
- The use of recycled materials allowing recycled plastics and aluminum to be used when safety allows to reduce emissions.
- A end of life infrastructure allows users to use deposit-return systems or required take-back programs to assure responsible disposal and component recovery.

To improve the sustainability of Marlboro Gold:

- Design biodegradable filters to reduce litter, replacing cellulose acetate filters allowing for lower emissions.
- Reducing packaging by removing unneeded plastic wrap from cigarette packs to reduce packaging emissions.

While neither product shows significant environmental awareness, redesigning disposable vape devices for sustainability and enhancing material recycling might result in significant sustainability benefits. Likewise, small but widespread modifications to cigarette packaging and filter design might reduce global environmental effects.

Economic assesment

Economic Indicatior - Pruduction Cost

This section compares the economic performance of the two nicotine delivery products, a pack of Marlboro Gold cigarettes and an Elf Bar 600 disposable vape, using a Life Cycle Cost (LCC) approach. The goal is to calculate and assess the unit costs of producing, distributing, and disposing of each item from cradle-to-grave.

This research looks at costs during the product's life cycle, ignoring all other costs like marketing, taxation, and retail markups. The product's life cycle consisting of five main parts:

- The raw material costs which are determined by the type and quantity of materials utilized
- The packaging expenses
- Manufacturing costs which are evaluated based on energy consumption during processing and assembly.
- Transportation costs are determined depending on the distance, method, and weight of each unit.

The Elf Bar 600 is manufactured in Shenzhen, China, and shipped to the UK via sea freight, while the Marlboro Gold is made in the regional production site in Switzerland and transported by road freight.

Raw Material Costs

Raw material costs were determined by combining each component's mass (as stated in Tables 1 and 2 of the Environmental Assessment) with material-specific cost data obtained from EduPack [9]. Prices were calculated per kilogram for each key material type, allowing for an economic comparison of the Marlboro Gold cigarette pack and the Elf Bar 600 disposable vape.

Table 3 : Philip Morris Malboro Gold materials Cost analysis

	Component	Material	Estimated Mass (g)	Cost per kg	Estimated cost
Pruduct	Tobacco	Flax fiber	14	0.604-2.16	£ 0.01935
	Cigarette Paper	Paper (cellulose based)	5.5	0.777-0.949	£ 0.004747
	Filter	Cellulose Acetate	4.5	3.58-5.19	£ 0.01973
					£ 0.0438

Table 4 : Elf Bar 600 materials cost analiysis

	Component	Material	Estimated Mass (g)	Cost per kg	Estimated cost
Pruduct	Casing	ABS/PC Plastic	12	2.61-3.00	£ 0.03366
	Battery	Lithium-ion Cell	11		£ 0.87
	Coil	Stainless Steel	1	1.15-1.67	£ 0.00141
	Wick	Cotton Fiber	0.2	1.41-4.08	£ 0.000549
	E-liquid	Propylene Glycol	2	0.604-2.16	£ 0.002764
	Mouthpiece	Silicone Rubber	1.5	3.08-3.48	£ 0.00492
					£ 0.9133

Packaging Costs
Packaging costs were determined by multiplying the mass of each packaging component by the corresponding cost per kilogram, which was obtained from EduPack material price data.

Table 5 : Philip Morris Malboro Gold packaging costs

	Component	Material	Estimated Mass (g)	Cost per kg	Actual cost
Packaging	Inner Foil Liner	Aluminum Foil	1	17.0-33.3	£ 0.02515
	Outer Pack	Paperboard	6	0.558-1.18	£ 0.005214
					£ 0.03036

Table 6: Elf Bar 600 packaging costs

	Component	Material	Estimated Mass (g)	Cost per kg	Actual cost
Packaging	Outer Box	Cardboard	3.5	0.588-1.18	£ 0.0030415
	Inner Wrapping	PET Plastic Film	1.5	0.988-1.24	£ 0.001671
					£ 0.0047125

Marlboro Gold's principal packaging consists of an outside paperboard pack and an inner aluminium foil liner, with a total cost of roughly £0.03036 per pack.

The Elf Bar 600's packaging comprises of an outside cardboard box and an interior PET plastic film, with a total estimated cost of £0.0047125 per unit. The Elf Bar's packaging materials are lighter and made of lower priced materials, resulting in a cheaper overall package cost.

Manufacturing Costs
Manufacturing costs were estimated using the total energy required per component multiplied by the national average power cost per MJ.

The price of electricity in swizerland per MWh is 117.11 euros which is £99.91. Every MWh is 3600 MJ meaning everry MJ of energy costs £0.0278 [10]

Table 7 : Philip Morris Malboro Gold Manfufacturring costs

	Component	Material	Energy	Cost
Pruduct	Tobacco	Cured Tobacco Leaves	0.75	£ 0.02085
	Cigarette Paper	Bleached Flax/Wood Pulp	0.51	£ 0.01418
	Filter	Cellulose Acetate	0.44	£ 0.01223
Packaging	Inner Foil Liner	Aluminum Foil	0.16	£ 0.00445
	Outer Pack	Paperboard	0.12	£ 0.00334
				£ 0.05505

For the Marlboro Gold, tobacco curing, filter fabrication, and paper packaging were identified as energy-intensive procedures, with a total manufacturing cost of £0.05505 per pack.

The price of electricity in mainland china per MWh is 0.088 USD which is £0.066. Every MWh is 3600 MJ meaning everry MJ of energy costs £0.0000184 [11].

Table 8 : Elf Bar 600 manufacturing costs

	Component	Material	Energy	Cost
Pruduct	Casing	ABS/PC Plastic	1.1	£ 0.00002017
	Battery	Lithium-ion Cell	1.9	£ 0.00003483
	Coil	Stainless Steel	0.03	£ 0.00000055
	Wick	Cotton Fiber	0.002	£ 0.00000004
	E-liquid	Propylene Glycol	0.016	£ 0.00000029
	Mouthpiece	Silicone Rubber	0.014	£ 0.00000026
Packaging	Outer Box	Cardboard	0.0088	£ 0.00000016
	Inner Wrapping	PET Plastic Film	0.012	£ 0.00000022
				£ 0.00005652

The lithium-ion battery, plastic casing, and steel coil soldering are the most energy and cost-intensive components of the Elf Bar 600, with a manufacturing cost of £0.04802 per unit. While vape manufacture requires more energy, China's lower electricity prices completely make up for the cost difference.

Transport Cost

Transportation costs were calculated using the weight of one unit of each product, the entire distance from the manufacturing site to London, and typical transport cost rates per tonne-kilometer for each form of freight.

Table 9: Transport cost

	Marlboro Gold	**Elf Bar 600**
Total distance	1,020 km	20,160 km
Route	Switzerland -> Calais (Truck, 850 km) Calais -> Dover (Ferry, 40 km) Dover -> London (Truck, 130 km)	Shenzhen -> Yantian Port (Truck, 30 km) Yantian Port -> Dover (Ship, 20,000 km) Dover -> London (Truck, 130 km)
Freight mode	Truck + ferry	Truck + sea + truck
Cost rate	£0.12 per tonne-km	£0.05 per tonne-km
Weight	0.0218 kg	0.027 kg

$$Malboro\ gold\ transport\ cost = 1020 * £0.12 * \frac{0.0218\ kg}{1000} = £0.0027$$

$$Elf\ bar\ 600\ transport\ cost = 20160 * £0.05 * \frac{0.027\ kg}{1000} = £0.0272$$

Total cost Interpretation

The life cycle economic performance of each product were combined to figure out the total production cost per unit, as seen in Table 10.

Table 10: Total costs

	Marlboro Gold	Elf bar 600
Raw materials	£ 0.0438	£ 0.9133
Packaging	£ 0.03036	£ 0.0047125
Manufacturing	£ 0.05505	£ 0.00005652
Transportation	£ 0.0027	£ 0.0272
Total	£ 0.1319	£ 0.9452

The Elf Bar 600's unit production cost is more than seven times that of Marlboro Gold. This substantial difference is mostly due to the high material cost of the Elf Bar's lithium-ion battery, which alone accounts for roughly £0.87 of the £0.91 raw material total. Although the vape product requires more energy to create, the much cheaper electricity prices in China, where the Elf Bar is made, result in lower manufacturing costs than the cigarette.

Marlboro Gold is manufactured in Switzerland with Swiss energy prices substantially exceed those in China, the entire life cycle cost of Marlboro Gold is significantly cheaper than that of the Elf Bar due to its reduced material costs and shorter transportation distances.

Marlboro Gold economic improvements:

- Simplifying packaging by eliminating unnecessary aluminum and plastic wrap.
- Optimising tobacco supply chains to improve labour conditions and reduce dependence on chemicals, which may result in lower processing costs.

Elf bar 600 economic improvements:

- Shifting to modular, reusable formats that increase product life and lower per-use costs.
- Standardising battery modules and connectors to encourage reuse and make production easier.
- Using recyclable or low-impact materials, including recycled ABS plastics or aluminum casings.

To summarize, while the Elf Bar 600 may provide a perceived health or lifestyle advantage, its economic footprint, particularly in material sourcing and transportation, raises severe concerns about its long-term viability as a sustainable consumer product.

Social assessment

Social Indicatior - Health Impact
This Social Life Cycle Assessment (S-LCA) employs health impact as the primary social indicator, investigating how the Marlboro Gold cigarette pack and Elf Bar 600 disposable vape impacts human health over their life cycles. The analysis uses a reference scale approach, as per the UNEP (2020) S-LCA principles. The three main stakeholder groups are considered being the users, workers, and larger communities. The study is qualitative, but it is supported by peer reviewed research and regulatory data.

Ciggrette
Cigarette users have the largest impact as cigarette usage is commonly acknowledged as one of the leading preventable causes of death worldwide. Tobacco smoking kills more than 8 million people each year, including more than 1.2 million from secondhand exposure [12]. Cigarette smoke includes more than 7,000 chemical components, including 70 recognized carcinogens like benzene, formaldehyde, and polonium-210. Direct inhalation exposes the user to these compounds, which increases the risk of lung cancer, cardiovascular disease, stroke, chronic obstructive pulmonary disease (COPD), and reproductive health difficulties.

Another health impact is on the workers in the tobacco supply chain, particularly in low and middle-income countries, are exposed to pesticides, chemical fertilizers, and green tobacco sickness, a type of acute nicotine poisoning caused by the skin's absorption of wet tobacco leaves [12]. Curing and processing tobacco emit hazardous particles, which contribute to respiratory problems among industrial workers.

The community is also impacted by second hand smoking as it is a big issue in public places, and cigarette litter, particularly non-biodegradable filters. Cigarette butts are the most frequent type of plastic litter found worldwide, and they leak poisons into soil and water. Air pollution, fire dangers, and waste disposal difficulties are among the externalities of tobacco manufacturing and usage that communities face.

Vape
For users Disposable vapes are frequently marketed as a safer alternative to smoking, however, their health benefits remain unknown. E-cigarette aerosols contain nicotine, propylene glycol, vegetable glycerin, flavoring compounds, and trace metals. Users are exposed to formaldehyde, acetaldehyde, and ultrafine particles, all of which can have an impact on their respiratory and cardiovascular systems. While tobacco combustion disappears, nicotine dependence persists, and the negative consequences on teenage brain development are well documented. Disposable vapes are the most popular type of vaping among 18-24 year olds, raising public health concerns about addiction , social normalization of smoking behaviors, and the long-term hazards of persistent exposure to heated e-liquids [14].

The majority of disposable vapes are assembled in Chinese factories, which impacts workers exposing them to solvents, soldering fumes, and battery components. While automation may reduce direct exposure, the lack of transparency in labor methods and the possibility of occupational inhalation or skin contact with chemical agents remain a concern [15].

The included lithium-ion batteries in vapes pose chemical and fire concerns the community when disposed of. Leaks from abandoned batteries and unmanaged landfill disposal increase the risk of groundwater pollution and harmful chemical leaching. Nicotine residues are harmful to aquatic life, and poor e-liquid discharge can degrade water quality. In the United Kingdom, e-waste from disposable vapes has skyrocketed, putting a strain on local garbage infrastructure.

Table 11: Health impact risk assesment

Stakeholder	Product	Exposure Type	Severity	Reversibility	Timeframe	Overall Risk Level
Users	Marlboro Gold	Inhalation of carcinogens and toxins	Very High	Irreversible	Long-term	Very High
	Elf Bar 600	Inhalation of aerosols, nicotine addiction	Moderate–High	Partially Reversible	Medium-term	Moderate–High
Workers	Marlboro Gold	Dermal pesticide exposure, inhalation of curing fumes	High	Partially Reversible	Medium to Long-term	High
	Elf Bar 600	Inhalation of solvents, contact with lithium compounds	Moderate	Reversible (with PPE)	Short to Medium-term	Moderate
Communities	Marlboro Gold	Second-hand smoke, litter toxicity	Moderate	Irreversible	Long-term	Moderate–High
	Elf Bar 600	Battery disposal hazards, e-liquid leaks	Moderate	Partially Reversible	Medium-term	Moderate

To improve the social impact of the Elf Bar 600:

- A Youth Protection Policy would Implement rigorous laws prohibiting flavours aimed at minors and limiting sales through verified ID systems.
- A Workforce Protection program would require chemical hazard training and personal protective equipment (PPE) use in vape manufacturers, particularly for soldering and battery handling.
- Safe Collection Schemes would Establish nationwide recycling points for used vape goods, particularly in urban areas and university campuses.
- Health Warning Labelling on all packaging should clearly identify the hazards of long-term addiction and the strength of the nicotine similar to one on cigarettes.

To improve the social impact of the Marloro Gold

- Investing in entirely biodegradable filters made of cellulose or bamboo to help reduce persistent litter.
- Safer Tobacco Processing by using enclosed tobacco curing systems to limit emissions and safeguard workers from smoke inhalation.
- Farm Labor Ethics Encourages equitable wages and allows pesticide safety programs in tobacco-producing regions.
- An anti-littering Infrastructure with municipalities, installing cigarette butt disposal containers in public areas and monitor waste reduction metrics.

Sensivity Analysis and Assumtions

The analysis relied on several assumptions, which may influence the results. A sensitivity study identifies critical parameters that may substantially affect conclusions:

The cost of electricity in Switzerland (£0.0278/MJ) makes cigarette manufacture more costly, while China's industrial electricity is significantly less expensive (£0.0000184/MJ). Should the Elf Bar be produced in Europe, its manufacturing expenses would increase significantly.

The emissions and costs associated with the Elf Bar's transport are predicated on global distribution through maritime routes. If the goods be transported by air freight, which could occur during times of urgent demand, the transport CO_2e could escalate by up to 10 times. The use of road and ferry by Marlboro Gold is efficient and regionally limited.

The analysis considers one Elf Bar 600 to be functionally comparable to one pack of cigarettes. This is predicated on a rough equivalent of puffs but fails to consider behavioral considerations such as puff frequency or user reliance.

Expenses were calculated based on bulk industrial production assumptions. Current consumer prices would be influenced by taxes, branding, and retail logistics, which were ignored in this study.

Conclusion

This paper analyzed the life cycle sustainability performance of Marlboro Gold and the Elf Bar 600 based on environmental, economic, and social indicators.

The Marlboro Gold pack is an economical, logistically efficient product, however, it results in significant health harm on consumers and workers, and contributes to plastic pollution. Although the Elf Bar 600 prevents combustion, it faces significantly higher production costs, demands substantial energy and materials, and introduces additional issues about young addiction and electrical waste.

The main findings were:

- The Elf Bar exhibits four times the CO_2e emissions and three times the energy consumption compared to Marlboro Gold.
- The production cost of Elf Bar exceeds seven times greater due to the addition of high-value components and international shipping expenses.
- Marlboro Gold has better economic performance but, it continues to pose social and environmental harm.

To improve this some recommendations include:

- Redesign disposable vapes to be modular, rechargeable, and recyclable.
- Implement sustainable design and labeling regulations for nicotine products.
- Substitute cigarette filters with biodegradable options and reduce unnecessary packaging.

A future study could include retail cost vs production cost comparisons. and consumer behaviour impacts on sustainability performance.

This study shows how comprehensive, data-informed sustainability evaluations can improve product design, regulatory frameworks, and public health initiatives.

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