DE1 – Material and Manufacturing

REVENG Report

iGadgitz Xtra 5m Waterproof Eco Rechargeable Solar

& Hand Crank LED Torch



for

Lisa's Eco Innovation

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Technical Summary

This report focuses on the reverse engineering process of a iGadgitz Xtra 5m Waterproof Eco Rechargeable Solar & Hand Crank LED Torch. Our team disassembled the product, conducted a systematic study on its various components, material composition, and corresponding manufacturing processes, and created a Bill of Materials. I used the Eco Audit tool from CES EduPack to assess the environmental impact of the product throughout its entire lifecycle. Based on the customers' requirements for sustainability, durability, and user experience, we carried out a series of redesigns.

The results of the Eco Audit show that the original design is expected to consume 58.3 MJ of embodied energy and generate a CO_2 footprint of 3.93 kg. Although this product has certain off-grid emergency lighting capabilities and basic waterproofing performance, its end-of-life potential is relatively low, with only about 0.168 MJ of energy recovery potential and 0.0104 kg of CO_2 reduction potential. This indicates that although the original plan has the advantages of low cost, complete basic functions, and suitability for general outdoor or household emergency use, it still has significant deficiencies in maintainability, brightness performance, and structural detachability.

Based on comprehensive considerations of structural reliability, functional performance, environmental impact and user experience, this report, on the basis of reverse engineering analysis, proposed several improvement plans. The improved product is expected to reduce embodied energy to 39.1 MJ and CO_2 footprint to 2.42 kg. While maintaining the core functions, it will further enhance product lifespan, repairability and overall design quality, and is more suitable to be launched on the market as a sustainable emergency lighting product targeted at mid-to-high-end users.

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1.Introduction

This report reverse engineers the iGadgitz Xtra 5 m Waterproof Eco Rechargeable Solar & Hand Crank LED Torch, a compact multifunction torch designed for all-weather use. The product integrates multiple energy pathways (manual dynamo charging and a small solar panel) with multi-mode LED lighting.

This product will be redesigned for our customer, Lisa's Eco-Innovation, which adheres to sustainable and environmentally friendly design principles. We need to consider the impact of the design on the environment throughout the product's entire lifecycle, as well as practical factors such as durability, ease of use, and maintainability.

The report examines sustainability-relevant design trade-offs, with particular focus on the tension between waterproofing and repairability, the use of adhesives at sealed interfaces, and opportunities for material simplification, modularity, and design-for-disassembly without compromising core functional requirements. A structured teardown was first conducted to understand the torch's architecture and operating principles. The components were then analysed to identify likely material choices and manufacturing processes. Additionally, the CES EduPack tool was used to generate Eco Audit Report for quantifying the environmental impact and identifying the key areas for design improvement. The final outcome is an adjustment based on the original product architecture and sustainability assessment, providing a customized design solution for the customer.

2.Background

2.1 Product category and use context

Portable LED torches are widely used for outdoor activities and emergency situations. Compared to filament lamps, LEDs enable compact form factors, low power consumption and long operating life, making them the dominant light source in modern handheld devices. For emergency use, the product value is often defined not only by brightness, but also by availability of power, robustness in harsh environments, and ease of use under stress.

2.2 Existing solution archetypes and sustainability trade-offs

Within the emergency-torch market, the main archetypes are disposable-battery lights, rechargeable models, solar-assisted products and hand-crank designs. Low-cost torches are commonly built around injection-moulded polymer housings, whereas more rugged or premium products often use aluminium bodies for improved durability.[1][2] Primary-cell torches are simple and inexpensive, but their batteries have finite life and must be replaced; rechargeable designs reduce repeated battery consumption, although integrated battery systems and electronics can complicate end-of-life recovery, particularly in Li-ion products.[3][4] Solar-assisted products add a photovoltaic panel and charge-management hardware, while hand-crank lights rely on a small generator and extra transmission parts, increasing component count and

assembly complexity.[5][6] Waterproof torches typically depend on O-rings and sealed interfaces, which improve wet-use durability but can reduce serviceability and make disassembly more difficult.[7][8]

2.3 Redesign Opportunities for Lisa's Eco-Innovation

For a client that is committed to ecological innovation, "environmental protection" not only means reducing power consumption during the operation process; it also requires ensuring the sustainability of the product throughout its entire usage period. We have transformed this concept into three design priorities to guide the subsequent analysis and redesign work: 1. Extension of service life (durability of wear surfaces, protection of vulnerable seals and control devices); 2. Design for easy disassembly/maintenance (ability to achieve non-destructive access to batteries/electronic components and the ability to replace worn or high-risk components); 3. End-of-life recycling (simplification of material types, clear material identification, and avoidance of unnecessary permanent connections).

These background factors help us better meet the client's sustainability requirements when formulating the redeign plan, and differentiate it from existing solutions on the market.

3.Method

Our team carried out the teardown process in a logical approach to disassemble the machine into its smallest possible parts. All the major teardown steps was documented with labels and photographs, and the **Teardown Overview Board** is provided in the Appendix E.

3.1 Device Teardown

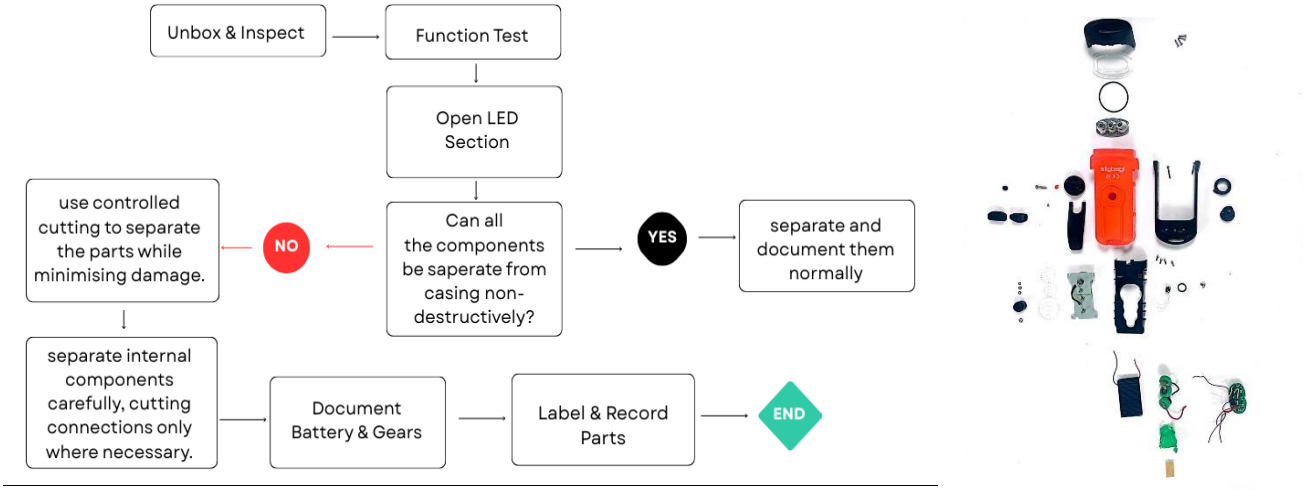


Figure 1:Simplified Teardown Flowchart and Components Photograph （Full flowchart is provided in Appendix C）

The teardown followed a **non-destructive-first** approach. After unboxing, the torch was checked by testing both the light output and the hand crank to confirm basic functionality. Disassembly then started from the **LED head**, as this was the most accessible entry point and allowed the optical and sealing components to be

inspected first.

Initial front-end disassembly exposed the lens and reflector but did not release the LED module. Further inspection revealed a concealed fixing screw behind the rubber insert in the crank hub. Removing this screw allowed partial extraction of the internal assembly. However, full non-destructive separation was still not possible because the solar module was adhered to the orange casing and remained electrically connected to the internal circuit. As a result, complete removal of the internal module would have required damage to either the adhesive interface or the wire connections. The battery construction and gear interfaces were then recorded in more detail.

3.2 Massing and Measurements

Massing and measurement followed a **measure-where-possible, state-uncertainty-clearly** approach. The total product mass and all components of **1 g or above** were measured using a digital scale with **1 g resolution**. Smaller items, such as screws, pins, and seals, were either weighed in groups and averaged or recorded as **"<1 g"** where reliable individual measurement was not possible.Key external dimensions and representative feature sizes were measured using **digital vernier calipers**, typically recorded as maximum overall dimensions where appropriate.

4.Product Analysis

4.1 Bill of Materials

Part code	Name	Quantity /unit	Material	Mass per unit/kg	Primary Process	Material Embodied Energy / MJ	Material CO2 Footprint / kg
6	Main orange casing	1	Polyurethane (tpPUR)	0.05600	Polymer molding	4.56	0.180
8	Black grip casing	1	Polyurethane (tpPUR)	0.01500	Polymer	1.22	0.048
1	Front bezel / lamp	1	Polyurethane (tpPUR)	0.01000	Polymer	0.81	0.032
19	Internal electronics	1	Polyurethane (tpPUR)	0.01100	Polymer	0.90	0.035
3	Transparent lens	1	Polystyrene (PS)	0.00500	Polymer	0.43	0.017
4	Light seal ring	1	Silicone elastomers (SI, Q)	0.00100	Polymer	0.11	0.004
29	Button seal	1	Silicone elastomers (SI, Q)	0.00100	Polymer	0.11	0.004
32	Battery cells	3	NiMH battery proxy	0.00333	Component	27.97	2.098
33	Solar panel	1	Single crystalline silicon,	0.00600	Component	10.00	0.760
31	PCB with wires	1	Printed circuit board	0.00300	Component	1.50	0.120
31b	LEDs	3	Semiconductor diodes, LEDs	0.00033	Component	2.97	0.218
21-23	Gear set	3	Polyoxymethylene (Acetal,	0.00100	Polymer	0.30	0.011
20	Gear & alternator	1	Low carbon steel	0.03600	Metal	0.90	0.065
2.1-2.4, 7.1-7.2, 13, 16, 24, 26-28	Steel fasteners & pins	1	Low carbon steel	0.01000	Wire drawing / thread rolling	0.25	0.018
Total				0.15866		**52.03**	**3.610**

Table 1 : Key Bill of Materials (The full detailed version is in Appendix D)

The Key BoM also indicates that the torch is mainly composed of polymers, and the orange main body, front frame, and grip frame themselves occupy a considerable proportion of the total weight. In contrast, some low-quality components, such as sealing elements and electronic components, although accounting for a very small proportion in the total weight, are still crucial in terms of functionality. However， the Eco-Audit report (baseline version) further shows that the greatest environmental burden is not simply caused by the heaviest components, but is caused by the combination of quality and material strength, such as batteries and solar modules. This means that the next stage of analysis needs to go beyond the scope of the component list and explore the reasons for the selection of these materials, the reliability of their identification, and their alignment with the product's functions and sustainability requirements.

4.2 Material Analysis

In this section, we used the material identification process provided in the *Plastics and Elastomers Identification Chart* (Appendix G) to determine the materials of each component of the torch. However, there were still some components whose materials could not be accurately identified.

1) Polymers: Polymers are the main components of this product. The orange casing, the black handle part, the front frame around the lamp, and the internal electronic carrier are all identified as polyurethane, with a relatively high degree of confidence. From a manufacturing perspective, these components are found to have injection molding features such as core-pulling marks and smooth molded surfaces, which are consistent with the common application of thermoplastic polyurethane in industry.[9] From a functional perspective, this polymer is suitable for a lightweight and impact-resistant casing; moisture resistance in use is then supported by the sealed enclosure design, while thermoplastic processing also keeps manufacturing relatively straightforward.[10]

2) Metal: This type of material is applied to the fastening framework. Through magnetic tests and the markings on the parts, it can be reasonably inferred that screws, pins, handle fasteners and bracket-type support parts are low-carbon steel, which is consistent with the widespread use of low-carbon steel in fasteners and general hardware.[11] In cases where local strength, thread retention force, stiffness, or wear resistance are required, steel is a reasonable choice.

3) Polyoxymethylene: The white gears were confirmed to be polyoxymethylene materials, and the identification result has a high degree of reliability. This is consistent with the requirement for a material with good dimensional stability and low friction in a compact transmission system.[12]

4) Elastomeric materials: The seals around the lenses and buttons are made of elastomeric materials. However, we cannot determine whether it is an EPDM type of rubber or a silicone material.

4.3 Manufacturing and Assembly Analysis

In this torch, the main processing category is **Injection Molding**. The main orange shell, the front frame, the black handle section, and the handle components are all confidently identified as components manufactured through Injection Molding. The ejector pin marks, the smoothness of the forming surface, the visible parting features, and the complex closed geometries on these components also prove this fact. In this torch, the factory uses Injection Molding to produce the torch shell instead of the traditional two-piece flip cover

structure. This process removes the main dividing lines, thereby preventing water from entering. Although this process has obvious advantages in manufacturing and waterproof performance, it also makes it more difficult to access the battery and internal modules without damage.

Metal forming processes were concentrated in the fasteners and the hand-crank generation. For screws, nuts, bolts, and several small hardware components, we consider cold heading followed by thread rolling to be the most reasonable manufacturing process, which is consistent with the standard low-cost production method for small steel fasteners. However, gears and generator brackets are different: their geometries and bill of materials descriptions indicate that they should be steel support components cut by stamping or CNC cutting, rather than machined or forged components. These steel molding processes are functionally appropriate because the crank sub-system requires local stiffness, threaded fixation, and wear resistance.

Apart from the manufacturing of individual components, the assembly strategy itself is also an important manufacturing outcome. This torch adopts a mixed assembly logic. The front optical components and the side grip part can be disassembled using screws, and the hand-winding shaft can also be disassembled using the detachable fastening parts. However, internally, the complex circuits, battery packaging, and solar panel part are further increased in difficulty for direct disassembly due to the adhesive fixation method. From the perspective of sustainability and redesign, although it is sufficiently waterproof and sturdy, the maintainability and service life are greatly compromised. It is almost impossible to reassemble it without damage after disassembly.

4.4 Embodied Energy and CO_2 Analysis

As shown in Table. 2, one flashlight is estimated to have a first-life embodied energy of 35.1 MJ and a CO_2 footprint of 1.93 kg. The dominant contribution comes from the material stage, which accounts for 28.2 MJ (80.4%) and 1.68 kg CO_2 (87.0%). By comparison, manufacturing contributes 3.19 MJ (9.1%) and 0.221 kg CO_2 (11.4%), while transport and disposal are negligible. The use phase adds 3.24 MJ (9.2%) in the Eco Audit model, but no CO_2 was assigned because this product is powered by solar charging and hand cranking rather than direct electricity.

Phase	Energy (MJ)	Energy (%)	CO2 footprint (kg)	CO2 footprint (%)
Material	54.5	93.4	3.64	92.7
Manufacture	3.02	5.2	0.226	5.8
Transport	0.769	1.3	0.0554	1.4
Use	0	0.0	0	0.0
Disposal	0.0467	0.1	0.00327	0.1
Total (for first life)	**58.3**	**100**	**3.93**	**100**
End of life potential	-0.168		-0.0104	

Table 2 : Overall embodied energy and CO_2 footprint in various life phases of the torch

A closer reading of Table. 2 and the component bill shows that the main hotspot is the energy-storage and electronics system, rather than the screws or outer housing. The NiMH battery is the single largest contributor, at about 10 MJ and 0.69 kg CO_2. The LED module adds a further 5.4 MJ and 0.40 kg CO_2, while the solar panel contributes around 1.3 MJ and 0.11 kg CO_2. Together, these three parts account for roughly 48% of total embodied energy and over 60% of total CO_2 footprint. In contrast, the casing and grip are

visually dominant and relatively heavy, but individually contribute much less. This means that redesigning only the casing material would give limited benefit unless the charging architecture or product lifetime is also improved.

Although the hand crank is not the biggest eco-audit hotspot, it is one of the most failure-prone parts. If a relatively low-impact crank failure causes the entire torch to be discarded, the real life-cycle burden becomes much higher than the per-part data suggests. Therefore, improving repairability and service life may be more effective than only reducing material impact. However, since several material grades and manufacturing routes were simplified in CES EduPack, the value shown should be treated as estimate value, especially for electronics, elastomers and metalworking processes.

5.Redesign Solution

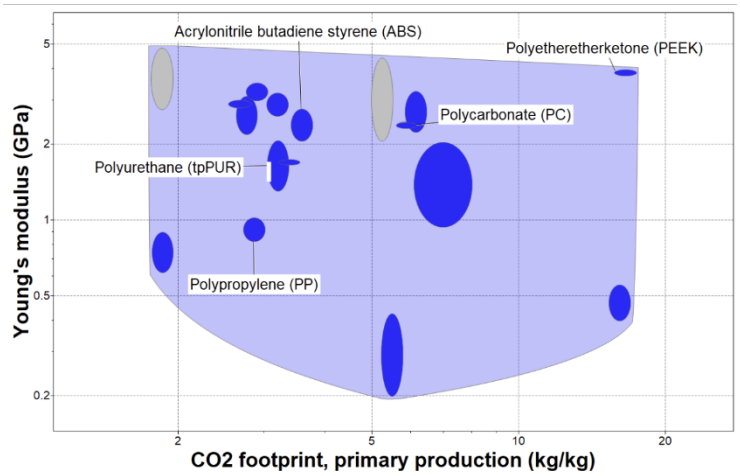
5.1 Casing redesigning

Previous disassembly indicated that the repair path of this flashlight was not intuitive for ordinary users, and it was prone to damaging the key seals during the operation. More importantly, even if the internal LED/circuit module was released, the solar panel was still adhered to the shell and connected to the circuit through wires, preventing the entire internal assembly from being truly removed without damage or loss. This means that once users attempt to repair it, there is a high possibility of damaging the waterproof property or the electrical connection integrity during the disassembly process, making the repair an irreversible operation. In my redesign plan, I enhanced the environmental performance of the product by making two directional changes to the shell part, making it more easy to disassemble and repair, and more user-friendly, thereby increasing the actual service life of the product; then I changed the material of the shell to improve its performance and overall reduce its CO2 footprint.

In terms of the **shell structure**, 1) The main body remains closed overall, maintaining the waterproof advantage. However, a clearly identifiable maintenance cover is added on the back or side. This maintenance cover is made of rubber and further ensures its waterproof performance. During the design process, by adding pull rings/handles on the surface of the rubber plug, it can be ensured that the rubber plug is easy to remove. 2) The solar panel is no longer permanently attached to the shell but is fixed by the framework positioning and screws as a latch. 3) LED + PCB + battery becomes an internal module that can be withdrawn. 4) Instead of permanent hard wiring between the solar panel and the circuit, small connectors are used, making it convenient for users to disassemble.

When **choosing the material** for the casing, I compared the candidate thermoplastic plastics using an Ashby plot with CO_2 footprint and Young's modulus as the axes. This plot can simultaneously reflect the environmental burden and structural stiffness of the materials. Materials located in the upper left area have an advantage, meaning they maintain a high stiffness while having a lower CO_2 footprint.

Table 3 : Ashby Plot of Young's modulus against CO_2 footprint



The comparison results show that although PP has a lower CO_2 footprint, its modulus is low. If directly used for the main body of the casing, it may need to compensate for the insufficient rigidity by increasing the wall thickness; PC and PEEK have higher moduli, but have a higher environmental burden. Among them, PEEK is clearly an over-design for this product. In contrast, ABS shows a more balanced overall characteristic between rigidity and CO_2 footprint, and is also in line with the common material selection logic for consumer-grade casing materials. Therefore, this plan selects ABS as the main candidate material for the redesigned casing. In addition to the indicators shown in the figure, the final judgment also takes into account its impact resistance, surface quality, and the user's expectations for a "solid and reliable" appearance and touch.

From a **manufacturing perspective**, ABS is suitable for injection molding processing, which can effectively achieve the complex geometric features required for the flashlight housing, such as screw columns, positioning structures, assembly boundaries, and local reinforcing ribs. At the same time, its surface quality is high, making it easy to meet the requirements of consumer products for appearance integrity and hand-held feel.

5.2 Upgrade in LED and Battery

The current torch uses three LEDs with up to 8 lm output and up to 4 h battery life; Amazon's review summary also shows brightness as a mixed issue, with 38 mentions and 11 negative, which aligns with the low-brightness complaints identified in the earlier Amazon review scan.[13][14] The redesigned head therefore replaces the three-LED array with one high-efficiency white power LED, for example an XP-G3-class emitter, operated at a modest level to deliver about 20–30 lm.[15] This is technically realistic because a single modern white LED can exceed 180 lm at 350 mA.[15] The battery is upgraded from the original 80 mAh NiMH unit to a higher-capacity low-self-discharge NiMH button pack in the 150–300 mAh range, such as the Varta V150H/CP300H family.[16] This raises rated capacity by about 1.9–3.8×, so runtime should increase substantially while reducing the need for frequent hand-cranking and lowering wear on the crank mechanism.[16]

5.3 Overall Comparison with the Original Design

Compared with the original design (Table 2), the redesigned torch reduces the estimated first-life embodied energy from **58.3 MJ to 39.1 MJ,** a decrease of **19.2 MJ (32.9%)**. The estimated CO_2 footprint is reduced from **3.93 kg to 2.42 kg**, a decrease of **1.51 kg CO_2 (38.4%).** In both cases, the dominant improvement

comes from the material stage, where embodied energy decreases from **54.5 MJ to 35.4 MJ** and CO_2 footprint decreases from **3.64 kg to 2.15 kg.** By contrast, manufacturing and transport change only slightly, while disposal remains almost unchanged.

Phase	Energy (MJ)	Energy (%)	CO2 footprint (kg)	CO2 footprint (%)
Material	35.4	90.6	2.15	88.8
Manufacture	2.88	7.4	0.216	8.9
Transport	0.729	1.9	0.0525	2.2
Use	0	0.0	0	0.0
Disposal	0.0467	0.1	0.00327	0.1
Total (for first life)	**39.1**	**100**	**2.42**	**100**
End of life potential	-0.168		-0.0104	

Table 4 : Overall embodied energy and CO_2 footprint in various life phases of the redesigned torch

6.Conclusion

This report conducted a disassembly analysis, material identification, environmental impact assessment, and improvement design for a solar-powered and hand-crank dual-energy waterproof flashlight. The disassembly results showed that although the original product met the waterproof design requirements through an integrated casing, it also exposed obvious irreversible disassembly issues. Additionally, by using the CES edu pack to disassemble the product life cycle, we found that the material stage was the main source of embodied energy and CO_2 footprint. Based on the above issues, the redesign proposed in this report mainly focuses on the optimization of the enclosure system, the lighting and battery system, and the assembly logic. Among them, for the enclosure part, through material selection analysis and manufacturing feasibility discussion, a material solution that is more suitable for injection molding and more balanced in terms of stiffness and environmental burden is proposed. Moreover, a more distinct disassembly structure is adopted to enhance the maintainability of the product. For the lighting and energy storage part, by using more efficient single LED and higher capacity rechargeable batteries, the brightness and endurance performance are improved. The quantitative results show that, compared with the original design, the first-life embodied energy and CO_2 footprint of the improved scheme have significantly decreased. Material stage got the greatest improvement, indicating that the environmental benefits of this redesign mainly come from the rational selection of materials and the simplification of product composition.

Through this project, I learned to use reverse engineering to help understand the structure, materials and manufacturing logic of my product, and was able to identify opportunities for redesign. This project also made me realize that improvement solutions do not merely aim for the optimal performance of a single metric, but rather achieve a more reasonable engineering balance among material selection, manufacturing processes, user experience and sustainability.

References

1. Made How. “How torch is made - history, used, parts, components, structure, design.” Made How. Accessed 19 March 2026.
2. Fenix Lighting. “Tactical Torchs - Powerful, Bright Tactical Lights.” Fenix Lighting. Accessed 19 March 2026.
3. Energizer. “Compare Batteries.” Energizer UK. Accessed 19 March 2026.
4. Rezaei, M. et al. “A review of lithium-ion battery recycling for enabling a circular economy.” Journal of Power Sources, 2025. Accessed 19 March 2026.
5. Eton. “FRX2 Multifunctional Outdoor Radio.” Eton Corporation. Accessed 19 March 2026.
6. HowStuffWorks. “How Motion-powered Electronics Work.” HowStuffWorks. Accessed 19 March 2026.
7. Fenix Lighting. “PD35 V3.0 Custom Engraved Torch.” Fenix Lighting. Accessed 19 March 2026.
8. INON. LED Light LE Series User Manual. Accessed 19 March 2026.
9. Covestro. Thermoplastic Polyurethane. Accessed 19 March 2026.
10. BASF. Elastollan® – Thermoplastic Polyurethane Elastomers (TPU), brochure. Accessed 19 March 2026.
11. Xometry. Iron Carbon Phase Diagram: Definition and How It Works. Accessed 19 March 2026.
12. Delrin. Delrin®: Engineered for Industrial Strength. Accessed 19 March 2026.
13. *iGadgitz Xtra 5m Waterproof Eco Rechargeable Solar & Hand Crank LED Torch Flashlight with 5 Year Warranty*. Amazon.in, product listing, accessed 19 March 2026.
14. *iGadgitz Xtra 5m Waterproof Eco Rechargeable Solar & Hand Crank LED Torch Flashlight with 5 Year Warranty*. Amazon.co.uk, customer review summary, accessed 19 March 2026.
15. Cree LED. *XLamp XP-G3 LED Data Sheet*. 2025.
16. RS Components. *Varta 6 V Nickel Metal Hydride Button Rechargeable Battery, 300 mAh (CP300H) product page*. Accessed 19 March 2026.
17. Product Information References:

    -*iGadgitz Xtra 5m Waterproof Eco Rechargeable Solar & Hand Crank LED To — INNOV8 GB Ltd*

    -*Amazon.com: igadgitz Xtra 5m Waterproof Eco Rechargeable Solar & Hand Crank LED Torch Torch with 5 Year Warranty : Tools & Home Improvement*

    - Global torch production: MarketResearch.com (Global Torch Supply, Demand and Key Producers, 2026-2032)

    - Niche torch production capacity: Made-in-China.com (Portable LED Camping Lantern)

    - iGadgitz brand profile: Ubuy Burkina Faso (iGadgitz Brand Overview)

    - Product inventory/status: Algopix (iGadgitz Xtra U4456)

Appendixes

A．Typical Materials and Manufacturing Methods Summary

To enable the torch with multiple functions, here is a typical structure and materials that manufacturer may used during the production.

Subsystem / Part	Typical materials (examples)	Key technical data (typical)	Typical manufacturing / joining	Why it matters for sustainability (what it affects)
Outer housing & internal structure (shell, ribs, bosses)	ABS (common), sometimes PC/ABS blend	ABS: density ~**1.04 g/cm³**; tensile yield strength ~**40–45 MPa**; modulus ~**2.0–2.4 GPa** (grade-dependent)	Injection moulding; assembly by screws/snaps; sometimes adhesives/heat-stakes	Often a **mass-dominant** part → can be a major driver of **embodied impact**; joining choice determines **disassembly/repair/recycling**
Transparent lens / window (front cover)	Polycarbonate (PC)	PC: density ~**1.19 g/cm³**; tensile yield ~**~62 MPa**; high impact resistance (grade-dependent)	Injection moulding; retained by bezel/screws; sealed by gasket/O-ring	PC often has **higher embodied carbon** than commodity plastics; interface is critical for **waterproofing vs serviceability**
Optics / reflector	ABS/PC substrate with **vacuum metallised Al**; or thin metal reflector	Reflective layer is thin but creates a **composite surface**	Injection moulding + vacuum metallisation + assembly	Metallised plastics can reduce **recyclate quality**; optics often drive **part complexity**
Sealing elements (O-rings, gaskets, button boot)	Silicone, EPDM, NBR, TPE (depending on sealing/feel)	Typical elastomer temperature ranges (approx.): Silicone **−70 to +230°C**, EPDM **−50 to +150°C**, NBR **−40 to +120°C**; typical O-ring hardness **~70–80 Shore A**	Compression seal (preferred for service); sometimes adhesive-bonded boots/films	Core driver of **IP performance**, but can strongly limit **repairability** if adhesive-bonded; also affects **end-of-life separation**
Fasteners (screws)	Carbon steel or stainless steel	Steel generally lower embodied impact than stainless (per kg); stainless improves corrosion resistance	Cold heading + thread rolling; screw assembly	Screws improve **design-for-disassembly**, but too many/too many types increase **assembly burden** and service friction
Solar panel module (small PV)	Crystalline silicon PV + encapsulation layers (EVA/backsheet)	PV modules (screening, per area): mono-Si embodied energy ~**~4750 MJ/m²** and embodied carbon ~**~242 kgCO_2/m²** (ranges exist)	Lamination/encapsulation; electrical interconnect; bonded or retained in housing	PV adds meaningful **embodied impact**; sustainability depends on **service life** and whether the panel/module is **replaceable/separable**
Hand-crank transmission (gears, shafts)	POM (acetal) gears; steel pins/shafts; sometimes PA (nylon)	POM: density ~**1.39–1.43 g/cm³**; tensile strength ~**~55–80 MPa** (grade-dependent); good wear/friction behavior	Injection moulded gears + pinned assembly; lubrication/fit influences wear	Added mechanics increase embodied burden and create **wear hotspots** → lifetime sustainability hinges on **durability + replaceability**
Micro-generator (dynamo)	Copper windings + steel/iron core + magnets	Metals can be high impact drivers per mass; copper often significant	Winding + assembly; soldered/connected to PCB	Additional subsystem for functionality → must be justified by **long life** and **serviceability**
PCB + electronics	FR-4 laminate + copper traces + components	FR-4: density ~**~1.85 g/cm³** (typical); electronics can have high impact per kg relative to bulk plastics	PCB manufacture + SMT assembly + soldering	Even at low mass, electronics can dominate impacts; also critical for **WEEE/end-of-life pathways**
Rechargeable battery (NiMH in your case)	NiMH cell(s) + tabs + wrap	NiMH: nominal **1.2 V/cell**; specific energy typically **~60–120 Wh/kg**; cycle life varies widely (use/application dependent)	Cell manufacture + welded tabs + pack integration	Battery ageing often sets **end-of-life**; if not replaceable, it can drive **premature whole-product disposal**
Adhesives at sealed interfaces (e.g., bonded switch boot)	Epoxy, acrylics, pressure-sensitive adhesives (varies)	Adhesives add material + can create permanent joints; embodied values depend on resin	Bonding/curing; often used to guarantee sealing quickly	Adhesives typically reduce **non-destructive disassembly**, harming repairability and recycling—even if sealing improves

Table 1 Typical architecture, materials, processes and sustainability-relavent data for a waterproff solar + hand-crank LED torch

B . Product Introduction[17]



Figure 2 : Product Images

Product name :

iGadgitz Xtra 5m Waterproof Eco Rechargeable Solar & Hand Crank LED Torch Torch with 5 Year Warranty

Target customer :

- Outdoor enthusiasts (campers, hikers, travelers)

- People preparing for emergencies and power outages

- Eco-friendly consumers preferring solar/hand-crank power

- Daily users needing a durable, waterproof, rechargeable torch

Retail cost : £15.99

Estimated production volume : 50,000-150,000 units (annual)

Location of manufacture:

INNOV8 GB Ltd, Unit 12 Oakhurst Business Park, West Sussex, RH13 9RT, UK. Made in China

C . Teardown Process

1. Photographs



Figure 3: Before and after the Teardown

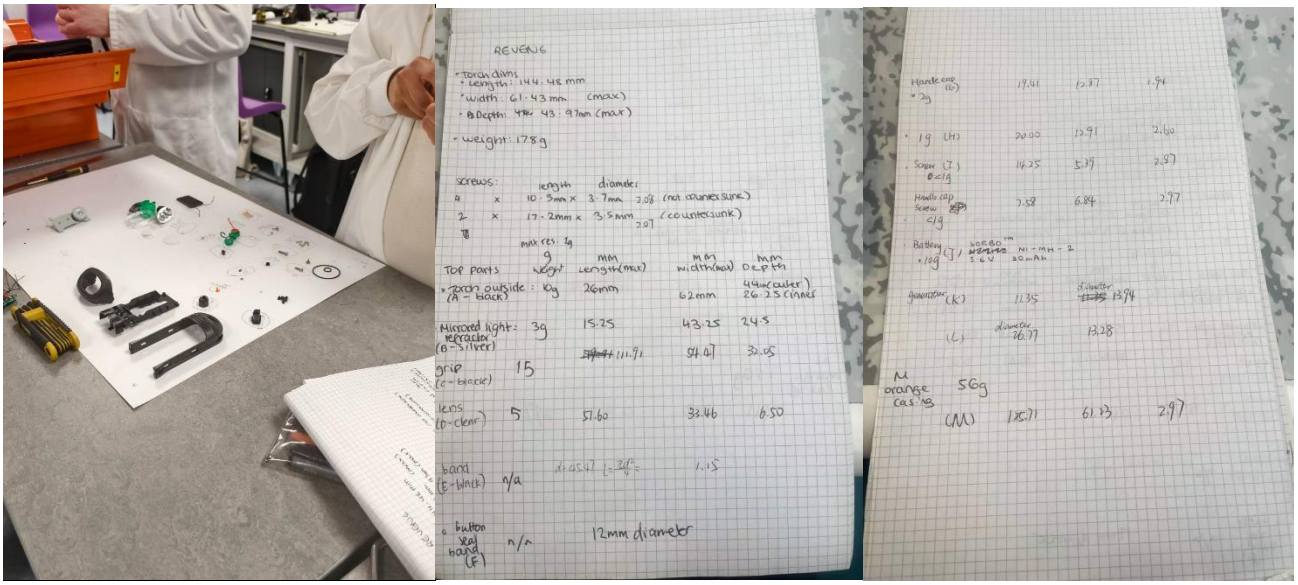


Figure 4: Documenting and labeling the components



Figure 5: Plastic Identification, Massing, Measurements



Figure 6: Trying to separate the internal electronic components from the casing

2. Detailed Workflow Chart

D . Bill of Materials (full-version)

E . Teardown Overview Board

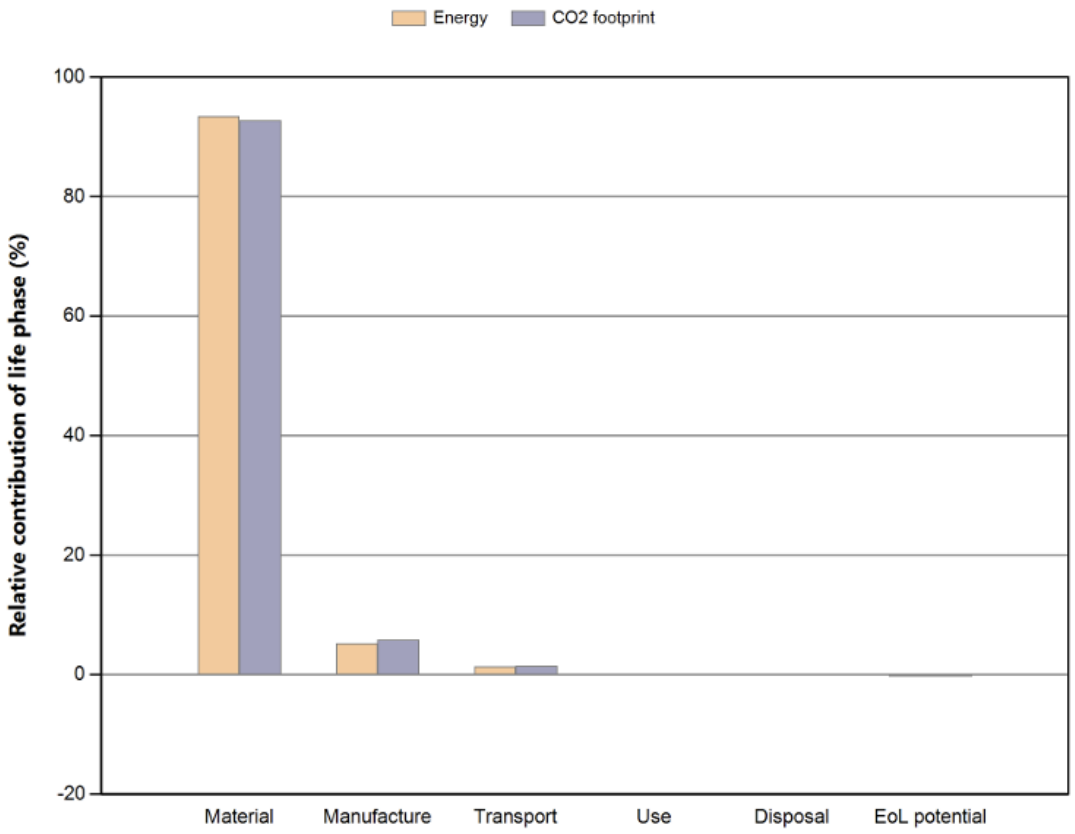
F . Eco Audit Report

1. Model A (baseline model)

Eco Audit Report

Product name	Torch_Model_A
Country of use	World
Product life (years)	5

Summary:



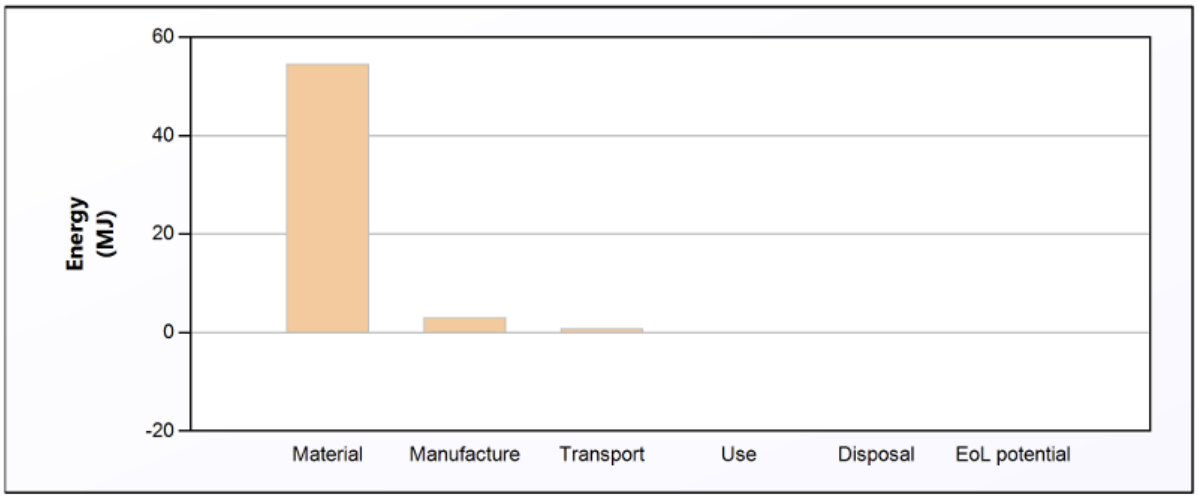
Energy details CO2 footprint details

Phase	Energy (MJ)	Energy (%)	CO2 footprint (kg)	CO2 footprint (%)
Material	54.5	93.4	3.64	92.7
Manufacture	3.02	5.2	0.226	5.8
Transport	0.769	1.3	0.0554	1.4
Use	0	0.0	0	0.0
Disposal	0.0467	0.1	0.00327	0.1
Total (for first life)	**58.3**	**100**	**3.93**	**100**
End of life potential	-0.168		-0.0104	

Eco Audit Report

Energy Analysis

Summary



	Energy (MJ/year)
Equivalent annual environmental burden (averaged over 5 year product life):	11.7

Detailed breakdown of individual life phases

Material:

Summary

Component	Material	Recycled content* (%)	Part mass (kg)	Qty.	Total mass (kg)	Energy (MJ)	%
Outer casing	Polyurethane (tpPUR)	Virgin (0%)	0.081	1	0.081	6.6	12.2
Lens	Polystyrene (PS)	Virgin (0%)	0.005	1	0.005	0.41	0.7
Battery	Small (hand held) electronic devices	Virgin (0%)	0.01	1	0.01	28	51.9
Solar panel	Single crystalline silicon, photovoltaics	Virgin (0%)	0.006	1	0.006	10	18.5
Electronics (PCB)	Printed circuit board assembly	Virgin (0%)	0.003	1	0.003	0.39	0.7
Metal parts (screws)	Low carbon steel	Virgin (0%)	0.01	1	0.01	0.31	0.6
Residual components	Polyurethane (tpPUR)	Virgin (0%)	0.063	1	0.063	5.2	9.5
Electronics (LED)	Semiconductor diodes, LEDs	Virgin (0%)	0.001	1	0.001	3	5.5
Rubber	Silicone elastomers (SI, Q)	Virgin (0%)	0.002	1	0.002	0.25	0.5
Total				**9**	**0.18**	**55**	**100**

*Typical: Includes 'recycle fraction in current supply'

***User-defined material

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Manufacture:

Summary

Component	Process	Amount processed	Energy (MJ)	%
Outer casing	Polymer molding	0.081 kg	1.5	50.4
Lens	Polymer molding	0.005 kg	0.087	2.9
Metal parts (screws)	Wire drawing	0.01 kg	0.2	6.5
Residual components	Polymer molding	0.063 kg	1.2	39.2
Rubber	Polymer molding	0.002 kg	0.03	1.0
Total			**3**	**100**

Transport:

Summary

Breakdown by transport stage

Stage name	Transport type	Distance (km)	Energy (MJ)	%
China inland haulage	14 tonne (2 axle) truck	2e+02	0.054	7.1
Global shipping	Ocean freight	2e+04	0.64	82.6
UK local delivery	Light goods vehicle	2e+02	0.08	10.4
Total		**2e+04**	**0.77**	**100**

Breakdown by components

Component	Mass (kg)	Energy (MJ)	%
Outer casing	0.081	0.34	44.8
Lens	0.005	0.021	2.8
Battery	0.01	0.043	5.5
Solar panel	0.006	0.026	3.3
Electronics (PCB)	0.003	0.013	1.7
Metal parts (screws)	0.01	0.043	5.5
Residual components	0.063	0.27	34.8
Electronics (LED)	0.001	0.0043	0.6
Rubber	0.002	0.0085	1.1
Total	**0.18**	**0.77**	**100**

Use:

Summary

Relative contribution of static and mobile modes

Mode	Energy (MJ)	%
Static	0	
Mobile	0	
Total	**0**	**100**

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Disposal:

Summary

Component	End of life option	Energy (MJ)	%
Outer casing	Landfill	0.016	34.7
Lens	Downcycle	0.0025	5.4
Battery	Downcycle	0.005	10.7
Solar panel	Downcycle	0.003	6.4
Electronics (PCB)	Downcycle	0.0015	3.2
Metal parts (screws)	Downcycle	0.005	10.7
Residual components	Landfill	0.013	27.0
Electronics (LED)	Downcycle	0.0005	1.1
Rubber	Landfill	0.0004	0.9
Total		**0.047**	**100**

EoL potential:

Component	End of life option	Energy (MJ)	%
Outer casing	Landfill	0	0.0
Lens	Downcycle	-0.054	32.0
Battery	Downcycle	0	0.0
Solar panel	Downcycle	-0.0006	0.4
Electronics (PCB)	Downcycle	0	0.0
Metal parts (screws)	Downcycle	-0.11	67.6
Residual components	Landfill	0	0.0
Electronics (LED)	Downcycle	0	0.0
Rubber	Landfill	0	0.0
Total		**-0.17**	**100**

Notes:

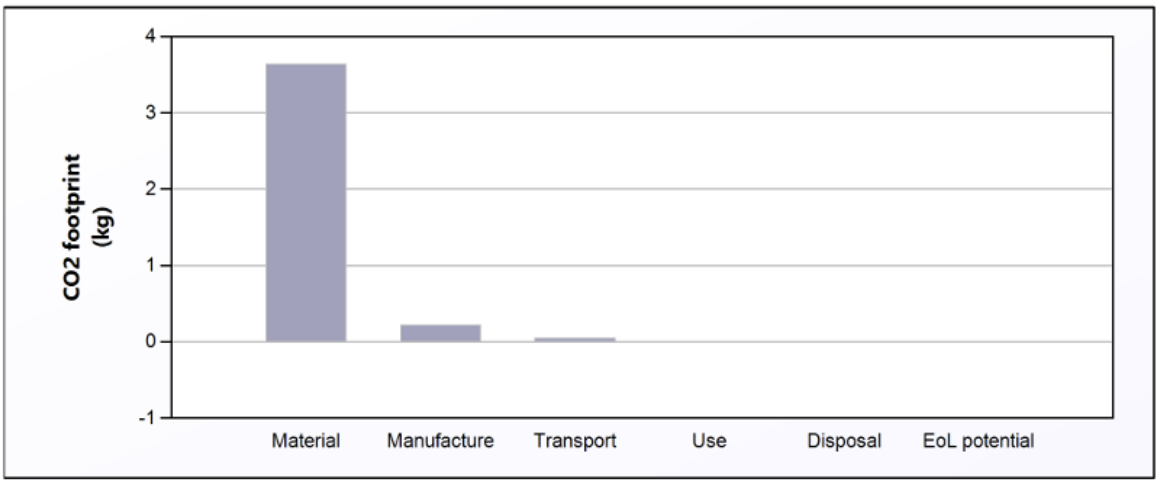
Summary

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Eco Audit Report

CO2 Footprint Analysis

Summary



	CO2 (kg/year)
Equivalent annual environmental burden (averaged over 5 year product life):	0.786

Detailed breakdown of individual life phases

Material:

Summary

Component	Material	Recycled content* (%)	Part mass (kg)	Qty.	Total mass (kg)	CO2 footprint (kg)	%
Outer casing	Polyurethane (tpPUR)	Virgin (0%)	0.081	1	0.081	0.26	7.1
Lens	Polystyrene (PS)	Virgin (0%)	0.005	1	0.005	0.015	0.4
Battery	Small (hand held) electronic devices	Virgin (0%)	0.01	1	0.01	2.1	58.2
Solar panel	Single crystalline silicon, photovoltaics	Virgin (0%)	0.006	1	0.006	0.76	20.7
Electronics (PCB)	Printed circuit board assembly	Virgin (0%)	0.003	1	0.003	0.029	0.8
Metal parts (screws)	Low carbon steel	Virgin (0%)	0.01	1	0.01	0.023	0.6
Residual components	Polyurethane (tpPUR)	Virgin (0%)	0.063	1	0.063	0.2	5.5
Electronics (LED)	Semiconductor diodes, LEDs	Virgin (0%)	0.001	1	0.001	0.22	6.2
Rubber	Silicone elastomers (SI, Q)	Virgin (0%)	0.002	1	0.002	0.013	0.4
Total				**9**	**0.18**	**3.6**	**100**

*Typical: Includes 'recycle fraction in current supply'

***User-defined material

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Manufacture:

Summary

Component	Process	Amount processed	CO2 footprint (kg)	%
Outer casing	Polymer molding	0.081 kg	0.11	50.4
Lens	Polymer molding	0.005 kg	0.0065	2.9
Metal parts (screws)	Wire drawing	0.01 kg	0.015	6.5
Residual components	Polymer molding	0.063 kg	0.089	39.2
Rubber	Polymer molding	0.002 kg	0.0024	1.0
Total			**0.23**	**100**

Transport:

Summary

Breakdown by transport stage

Stage name	Transport type	Distance (km)	CO2 footprint (kg)	%
China inland haulage	14 tonne (2 axle) truck	2e+02	0.0039	7.1
Global shipping	Ocean freight	2e+04	0.046	82.6
UK local delivery	Light goods vehicle	2e+02	0.0057	10.4
Total		**2e+04**	**0.055**	**100**

Breakdown by components

Component	Mass (kg)	CO2 footprint (kg)	%
Outer casing	0.081	0.025	44.8
Lens	0.005	0.0015	2.8
Battery	0.01	0.0031	5.5
Solar panel	0.006	0.0018	3.3
Electronics (PCB)	0.003	0.00092	1.7
Metal parts (screws)	0.01	0.0031	5.5
Residual components	0.063	0.019	34.8
Electronics (LED)	0.001	0.00031	0.6
Rubber	0.002	0.00061	1.1
Total	**0.18**	**0.055**	**100**

Use:

Summary

Relative contribution of static and mobile modes

Mode	CO2 footprint (kg)	%
Static	0	
Mobile	0	
Total	**0**	**100**

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Disposal:

Summary

Component	End of life option	CO2 footprint (kg)	%
Outer casing	Landfill	0.0011	34.7
Lens	Downcycle	0.00018	5.4
Battery	Downcycle	0.00035	10.7
Solar panel	Downcycle	0.00021	6.4
Electronics (PCB)	Downcycle	0.00011	3.2
Metal parts (screws)	Downcycle	0.00035	10.7
Residual components	Landfill	0.00088	27.0
Electronics (LED)	Downcycle	3.5e-05	1.1
Rubber	Landfill	2.8e-05	0.9
Total		**0.0033**	**100**

EoL potential:

Component	End of life option	CO2 footprint (kg)	%
Outer casing	Landfill	0	0.0
Lens	Downcycle	-0.0019	18.5
Battery	Downcycle	0	0.0
Solar panel	Downcycle	-4.2e-05	0.4
Electronics (PCB)	Downcycle	0	0.0
Metal parts (screws)	Downcycle	-0.0084	81.1
Residual components	Landfill	0	0.0
Electronics (LED)	Downcycle	0	0.0
Rubber	Landfill	0	0.0
Total		**-0.01**	**100**

Notes:

Summary

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2. Sensitivity Models Exploration

Model B : Solar-use sensitivity model ------ Will the result significantly change if solar energy charging is explicitly incorporated into the 'use phase'?

Model C : LED output sensitivity model ------ What would happen if the lighting output itself were regarded as the main function of the use-phase?

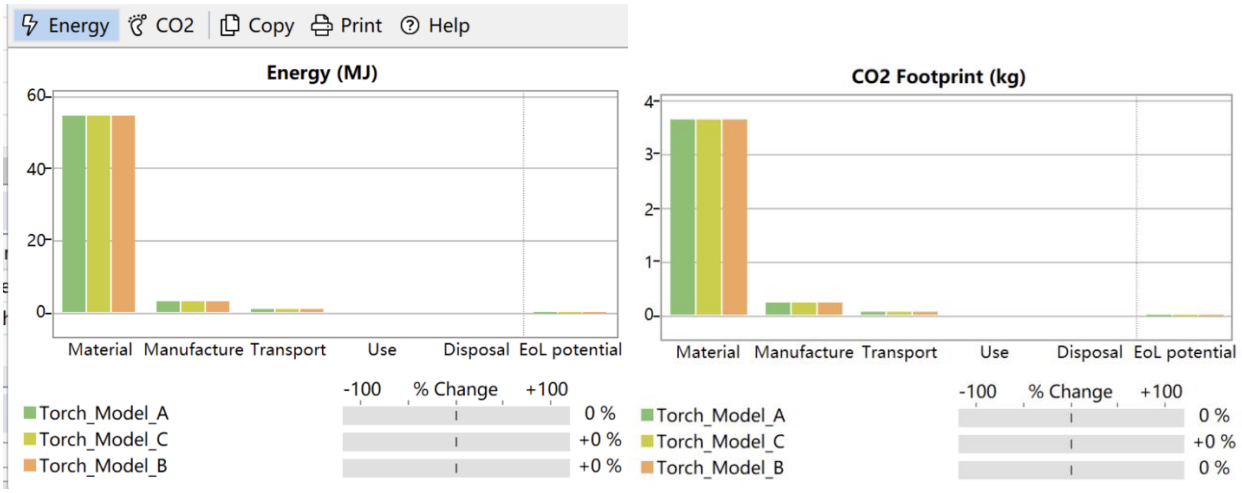


Table 5 : Change in Model B and C

Calculation for changes:

The usage phase of Eco Audit is calculated based on power × duty cycle (usage time) × product lifespan. The official white paper also clearly states that after selecting a certain energy-conversion mode, the tool will call the efficiency and multiply it by power and duty cycle.

Model B（solar)

What I assumed:

- 0.03 W
- 100 days/year
- 1 hour/day
- 5 years

Total Energy Output:

- 0.03 × 100 × 1 × 5 = 15 Wh
- 15 Wh ≈ 0.054 MJ

Model C（LED)

What I assumed:

- 0.07 W
- 100 days/year
- 1 hour/day
- 5 years

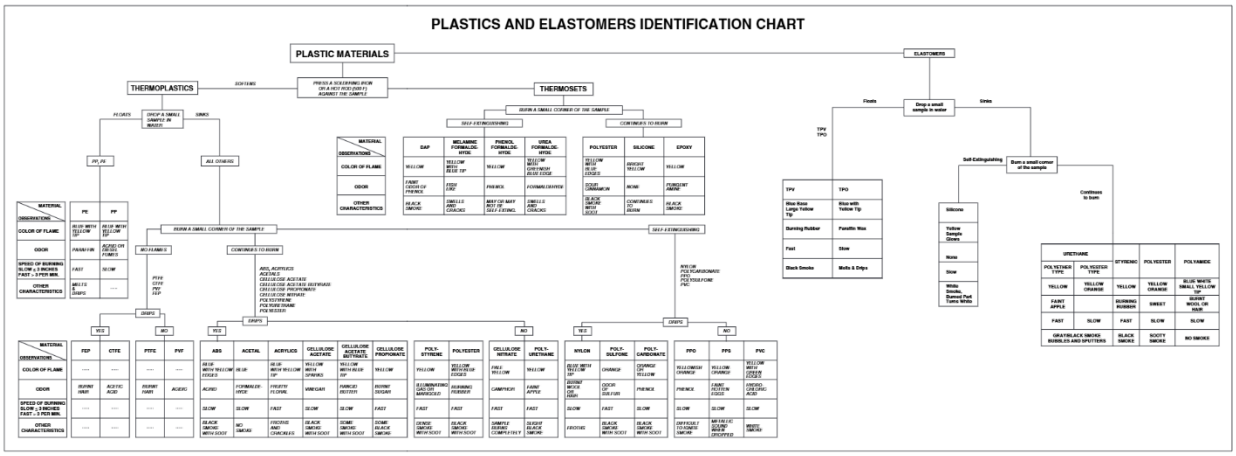
Total Energy Output:

- $0.07 \times 100 \times 1 \times 5 = 35$ Wh
- 35 Wh ≈ 0.126 MJ

Hence, they are too small to be seen compared to the 58MJ Material Burden

G . Plastic and Elastomers Identification Chart

1. Official Version



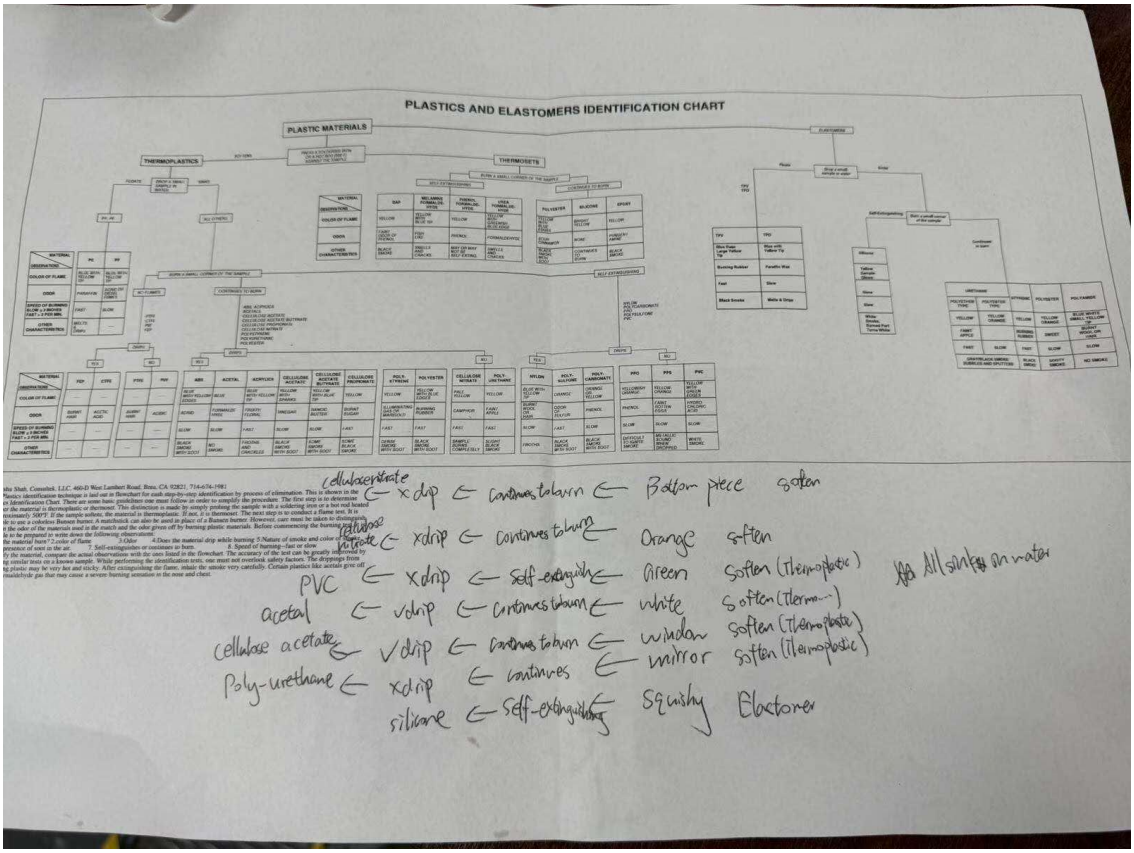
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The Plastics identification technique is laid out in flowchart for each step-by-step identification by process of elimination. This is shown in the plastics Identification Chart. There are some basic guidelines one must follow in order to simplify the procedure. The first step is to determine whether the material is thermoplastic or thermoset. This distinction is made by simply probing the sample with a soldering iron or a hot rod heated to approximately 500°F. If the sample softens, the material is thermoplastic. If not, it is thermoset. The next step is to conduct a flame test. It is desirable to use a colorless Bunsen burner. A matchstick can also be used in place of a Bunsen burner. However, care must be taken to distinguish between the odor of the materials used in the match and the odor given off by burning plastic materials. Before commencing the burning test, it is advisable to be prepared to write down the following observations:

1.Does the material burn? 2.color of flame: 3.Odor 4.Does the material drip while burning 5.Nature of smoke and color of smoke.
6. The presence of soot in the air. 7. Self-extinguishes or continues to burn. 8. Speed of burning--fast or slow

To identify the material, compare the actual observations with the ones listed in the flowchart. The accuracy of the test can be greatly improved by performing similar tests on a known sample. While performing the identification tests, one must not overlook safety factors. The drippings from the burning plastic may be very hot and sticky. After extinguishing the flame, inhale the smoke very carefully. Certain plastics like acetals give off a toxic formaldehyde gas that may cause a severe burning sensation in the nose and chest.

2. Our Record


PLASTICS AND ELASTOMERS IDENTIFICATION CHART
PLASTIC MATERIALS
THERMOPLASTICS
THERMOSETS
ELASTOMERS
cellulose acetate ← x drip ← continues to burn ← Bottom piece soften
cellulose nitrate ← x drip ← continues to burn ← Orange soften
PVC ← x drip ← self-extinguishing ← Green Soften (Thermoplastic)
acetal ← v drip ← continues to burn ← white Soften (Thermo...)
cellulose acetate ← V drip ← continues to burn ← window Soften (Thermoplastic)
Poly-urethane ← x drip ← continues ← mirror Soften (Thermoplastic)
silicone ← self-extinguishing ← Squishy Elastomer
All sinks on water