HSLU Lucerne University of Applied Sciences and Arts

Engineering and Architecture
B.Sc.. Energy and Environmental Systems Engineering
Bachelor-Thesis

Environmental Impact Analysis of a Water Meter

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1. Introduction, Goals and Research Questions

The manufacturing industry faces increasing regulatory pressure to quantify and reduce the environmental footprint of its products. Life Cycle Assessment (LCA) provides a standardised, quantitative framework for this purpose, in accordance with ISO 14040 and ISO 14044. Despite growing interest in sustainable product design, no component-level LCA of compact ultrasonic water meters had been conducted prior to this study. This study aims to quantify the environmental impacts of a compact ultrasonic water meter across four size variants and three hydraulic body material configurations, identify environmental hotspots, and assess the improvement potential of alternative materials as a basis for future sustainability communication.

2. Method Overview and Materials

A cradle-to-gate LCA was conducted, covering raw material extraction, component manufacturing, transport, and final assembly. The use phase is excluded as the water meter requires no external energy input during operation, meaning its inclusion would only have negligible effect on the assessed impact categories. End-of-life treatment is likewise excluded, as the fate of the meter after replacement varies by customer and region and cannot be controlled or generalised. The functional unit is defined as the production of one water meter, providing a consistent reference for all comparisons. Environmental impacts were assessed using the ReCiPe Midpoint (H) method across two categories selected for their relevance to material-intensive products: climate change, expressed in kg CO_2-eq, and resource depletion, expressed in kg Cu-eq. The Hierarchist perspective was applied, reflecting scientific consensus on relevant time frames and impact mechanisms. The process flow of the assessment are illustrated in the following figure 1.

Figure 1: Process Flow

Three material configurations were assessed across four size variants, spanning the smallest and largest available pipe diameters. The baseline configuration uses a primary brass hydraulic body. Two alternative configurations were assessed in parallel: a fibre reinforced polymer body, modelled using a glass-fibre reinforced polyamide dataset, and a recycled brass body, derived from an adapted primary brass production process with adjusted material and energy inputs. Primary data on material composition and assembly energy were collected directly from the manufacturer. All upstream background data were sourced from the ecoinvent 3.11 database. A sensitivity analysis examined the influence of recycled brass content, upstream electricity mix, and transport distance on the results, confirming that transport is negligible and that the electricity mix is the dominant variable for climate change.

3. Results and Discussion

The baseline assessment confirms that environmental impact is dominated by material production rather than transport or assembly. This is directly attributable to the growing share of the brass body, which increases substantially from the smallest to the largest variant. As shown in Figure 2, climate change impact for the primary brass configuration reaches 237% of the small-variant baseline at the largest size. Both FRP and recycled brass remain below 105% across all sizes, demonstrating that their climate change impact is largely independent of component size. The resource depletion results, presented in Figure 3, reveal an even more pronounced divergence: primary brass reaches 378% of the small-variant baseline at the largest size, while FRP and recycled brass remain stable at approximately 56 to 59% regardless of size. This confirms that the resource depletion impact of both alternatives is entirely decoupled from component size, as neither material contains the high-characterisation-factor metals that drive copper equivalents in the brass configuration. Both alternative materials therefore become substantially more advantageous as component size increases, with the environmental benefit most pronounced for resource depletion.

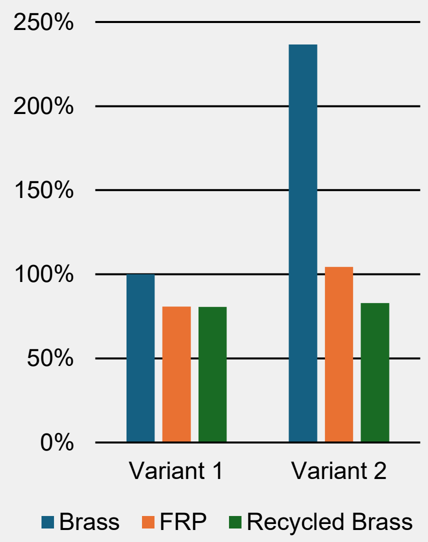

Figure 2: Climate Change Impact

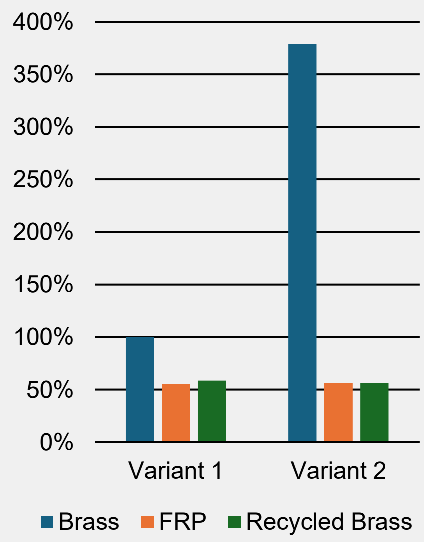

Figure 3: Resource Depletion Impact

4. Conclusion and Recommendations

Material substitution and supply chain decarbonisation are the two primary levers for environmental improvement. Recycled brass achieves near-equivalent performance to FRP whilst retaining a recyclability advantage, making it the preferred choice. Results provide the quantitative basis for an Environmental Product Declaration.

References

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