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Case study of the ecological impact of a typical mechanical Swiss watch

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Abstract

Sustainability is an increasingly important concern for consumers and manufacturers. Acting for a sustainable future becomes urgent for everyone. Watch manufacturers are often criticized for their lack of transparency in manufacturing practices, and the production of technical pieces is generally considered to be a highly energy-consuming process.

In this work, an audit of the environmental footprint caused by the production of a mechanical watch equipped with a sapphire glass is presented. It is a case study of a hypothetical watch piece, aiming to represent a typical Swiss watch. The analysis was performed with the help of the Granta EduPack software[1], courteously provided by Ansys and in collaboration with a class of engineering students in Industrial Design Engineering led by David Weber, scientific assistant in the watchmaking research department of HE-Arc.

Our analysis shows that most of the energy required (86%) is "material embodied energy", meaning that it goes into making the rough parts, billets or ingots that are then transformed at the manufacturing stage. 14% goes into manufacturing, among which 61% of the energy is used for the sapphire watch cover, despite the fact that it only accounts for 7% of the weight of the entire watch.

Why does it matter?

The world is striving for reducing CO_2 emissions and energy consumption. Understanding how and where the watch industry uses energy is essential to identify areas that contribute most to the emission and find innovative solutions to reduce their footprints. Such concerns are particularly relevant to Switzerland, the country renowned for its large watch manufacturing industry and one of the greenest countries in the world[2].

Energy consumption also has direct financial consequences for manufacturers. Increasing demand could lead to higher prices, as well as higher taxes as states apply pressure to reduce energy spending.

Environmental organizations are often criticizing watch manufacturers. According to an environmental rating and industry report from the Swiss WWF in 2018[3], *"[...]Most of the surveyed companies have taken no or very limited steps to actively counter climate change. The problem of climate change itself and the global challenges associated with it have not been appropriately addressed, no ambitious targets have been set and no notable measures have been taken by the industry".*

Moreover, it revealed, *"There is a lack or even non-existence of reporting and transparency among the evaluated brands, and an apparent absence of commitment to determined action, [...]. This is highly undesirable for the environment, but also for consumers, investors, communities, political bodies and other stakeholders. Furthermore, it is a major economic and reputational risk for the industry itself".*

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On consumer sentiment, the Swiss WWF reported: "*Sustainability has become a key factor for consumers. There is an evident trend for a transition towards more sustainable patterns of production and consumption. [...] Customers are now demanding leadership from brands to succeed in dealing with planetary challenges: they expect more responsible stewardship of natural resources and the environment and more transparency.*"

With the help of Eco-Audit tools, the materials and processing methods that bear the largest footprints of a specific watch are here showcased.

The watch studied

The goal of the study was to evaluate the fabrication footprint of a common watch, independently of any feature that could significantly influence the results. Therefore, the presence of a bracelet was not considered, as choosing a metallic over a plastic or leather one would have had a major impact.

We designed this watch in the context of courses during the *Haute Ecole Spécialisée de Suisse Occidentale* (HES-SO) master's degree in horology.

It features a circular dial, a domed sapphire watch cover, and a second dial that is offset. The movement is mechanical with manual rewinding and oscillates at 3 Hz. It counts 147 parts in total. Its case has a diameter of 40 mm and its thickness is 15 mm.


(a)

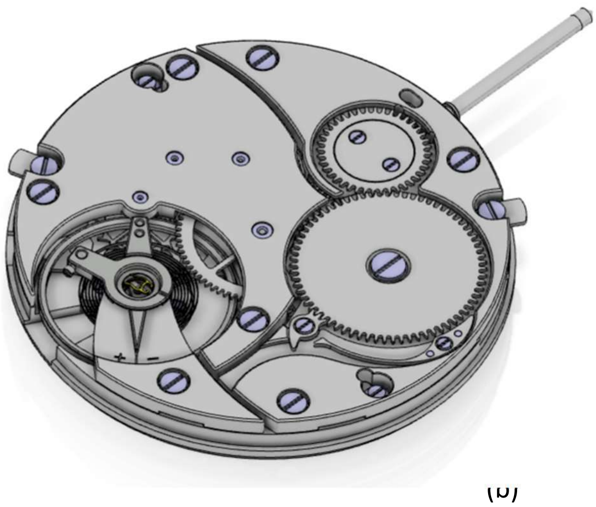
(b)

Figure 1 - Sketches of the watch considered for this study: (a) habillage of the watch, (b) movement

Methodology

As the main goal of this study is to evaluate the impact of each component of the watch in the global energy consumption, the estimation that we have made is a partial Eco-audit. Contrary to a global study, only embodied material energy and manufacturing processes were considered. Transportation between each step, use, maintenance and recycling were not considered because we estimate that their analysis would have relied upon too many hypotheses.

The total required energy and emitted CO_2 were calculated by adding values contributed by a) initial material production, defined as "Embodied energy & CO_2 footprint of primary production" in Granta EduPack, and b) manufacturing of each component or "Material processing energy & CO_2" in the Granta EduPack database.

The embodied energy and CO_2 footprint of primary production cover the energy and CO_2 emitted from ore extraction to casting rough products such as ingots, billets or other simple parts. Here, it is considered that none of the components contained recycled elements, although some values are available for partly recycled material.

The material processing energy and CO_2 contribution are calculated for each item depending on its material and processing stages. Between 1 and 3 processing stages are considered. The given values account for operating the processing equipment, the energy associated with running the facility (A/C, lighting, etc.) and the "tacit" energy, associated with the generation and supply of energy to the processing.

The CO2 associated with running the processing equipment is derived from:

- The energy required to heat up the base material to its processing temperature (based on melting point, heat capacity, etc.)
- The energy required to heat up and maintain the equipment at its operating temperature
- The energy required to deform the material at the processing temperature (based on tensile strength, yield strength, density, etc.)

Machining processes are usually done in two stages, a coarse stage and a fine stage, the latter of which demands more energy per unit of weight. As a convention, we defined that 70% of the material was taken off with coarse machining parameters, and 30% was taken off with fine machining ones.

Surface treatments such as annealing, hardening heat treatment and alike are taken into account in terms of energy and CO_2 at the material selection stage. Painting and electroplating are calculated separately and take into account the exact coated surface of each object.

The assembly stages were not considered because many assembly operations would be done by hand.

The materials selected in the Granta EduPack database were chosen to resemble as closely as possible the materials that would be used in a real watch. However, in a few cases, we have not found an exact match in the database. For example, Nivaflex, a material used for springs, was replaced by Phynox, also used for springs and very resistant to corrosion. Rubies used for their low friction are replaced in the database by sapphire.

The processes were also chosen to be as close as possible to reality within the limits of the Granta EduPack Database, which encompasses; casting/injecting, roll forming, forging, extrusion, machining, grinding and non-conventional machining. The surface treatments considered are electroplating and, for the dials, painting.

All values are based on estimates and represent high volume production.

Results

While examining the results, note that the proportion between parts footprints is more pertinent than the absolute amount of energy and CO2 calculated in this study, because all parts were treated in the same way. However, the evaluation of micro-machining and special processes as used in the watchmaking industry may differ from the mean values used in the Granta EduPack database for standard mechanical machining.

The evaluation shows that the total energy required for one watch is 22.20± 1.03 MJ. This is equivalent to heating 66 liters of water from 20°C to 100 °C.

The total CO_2 emitted is 1.52±0.08 kg, that corresponds to a distance of 12.9 km driven by a modern car emitting 118 grams of CO_2 per kilometer or the filling of 310 balloons.

These values are lower than what could be intuitively expected. But, as mentioned previously, it is much more interesting to compare proportions rather than absolute values.

The CO_2 emission is usually proportional to the consumed energy. The database does not account for the fact that manufacturing may take place in different areas of the world, where the electricity mix is different. A typical coal-fired power plant would emit 0.8-1.2 kg of CO_2 per kWh[4]. A hydropower reservoir such as a dam would only emit 23 grams of CO_2 equivalent per kWh[5]. Therefore, the results for CO_2 would be very different depending on the country where the watch is manufactured. In Switzerland, the CO_2 equivalent is around 40 grams of CO_2 per kWh[6].

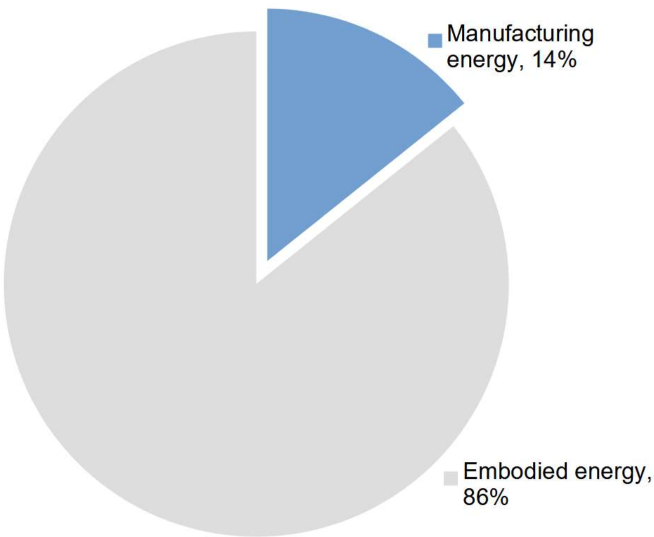

Figure 2 - Processing and embodied energy proportions

Considering the partition of manufacturing and embodied energy (Figure 2), a majority of the required energy stems from the material itself. The embodied energy depends on the material and the component's geometry before processing.

Considering the two main parts of the watch, - on the one hand the "habillage"(Figure 1 (a)) and, on the other the movement (Figure 1 (b)) - the "habillage" accounts for 89% of the energy required in total, and 87% of the total mass of the watch, which is 65 grams. Therefore, these two main parts use a similar proportion of energy for their manufacturing. However, the proportion of matter removed for parts of the "habillage" is more important than for the movement (64% to 54%). Their total energy requirements are however still proportional because several of the movement's parts are electroplated, a process which requires a lot of energy.

The manufacturing energy partition per processing for the two main parts is presented in Figures 3 and 4, respectively.

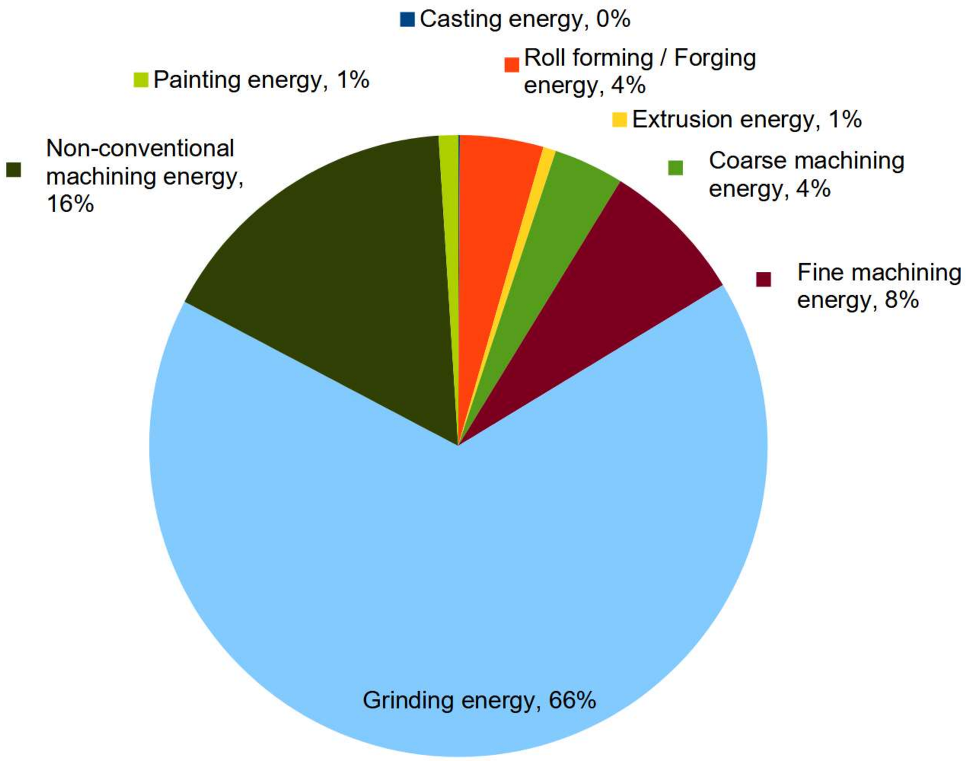

Figure 3 – Manufacturing energy repartition - Habillage

Figure 3 evidences that a large part of the manufacturing energy for the "habillage" is used for grinding. The main reason is that the sapphire cover, or "glace", requires significant grinding.

Figure 4 shows that coating processes are an important part of the energy required for the movement (around 26% in total). However, taking all of them into account, these small pieces are not significant to the entire watch, as coating accounts for 3% of manufacturing, as shown in Figure 5.

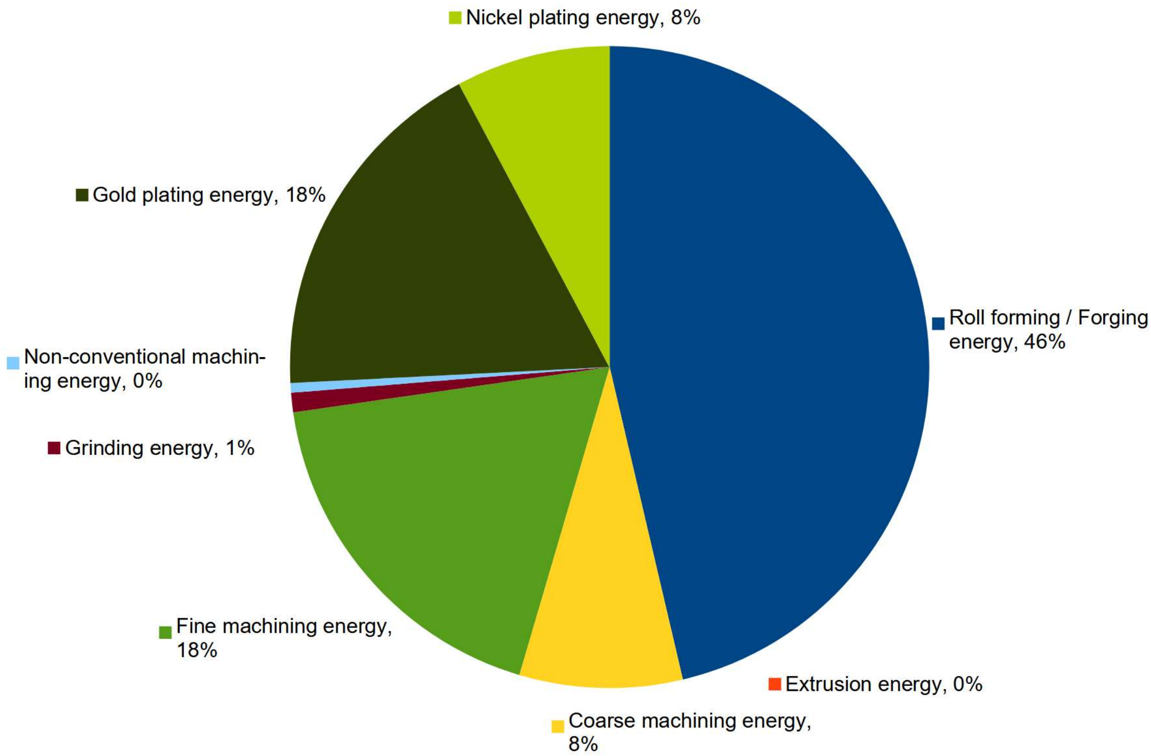

Figure 4 – Manufacturing energy repartition – Movement

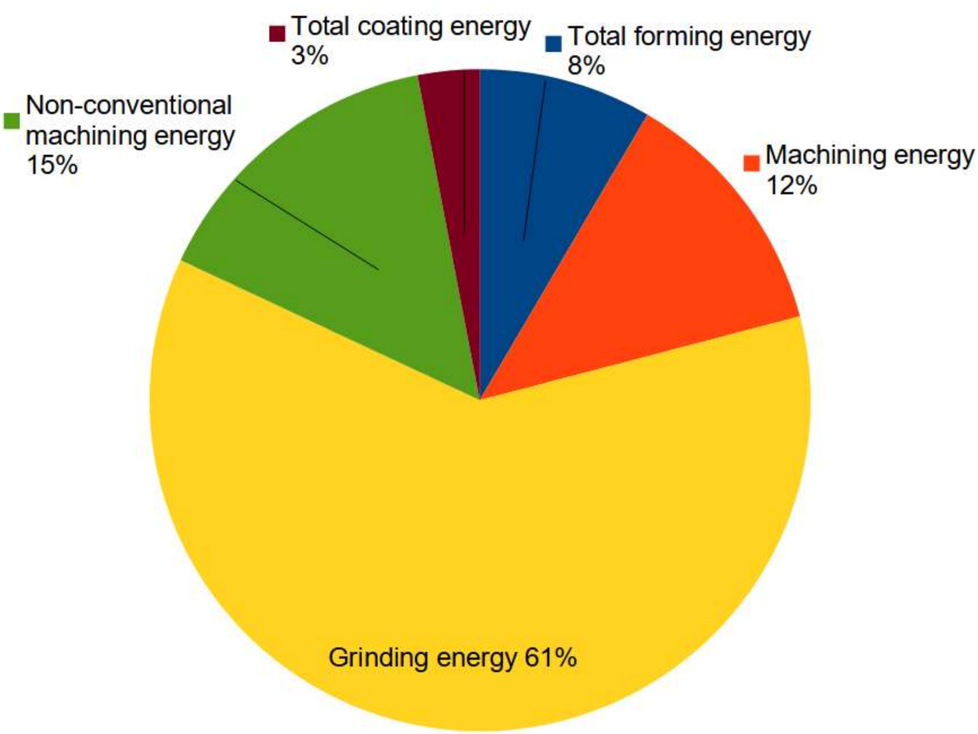

Figure 5 – Processing energy proportions – Entire watch

A typical mechanical watch will generally use several steel parts, some copper alloys, ruby, some special alloys for springs, and some polymers for the hermetic seal. Figure 6 presents the importance of these materials in the total energy requirements. Figure 7 is a more detailed pie chart for each material.

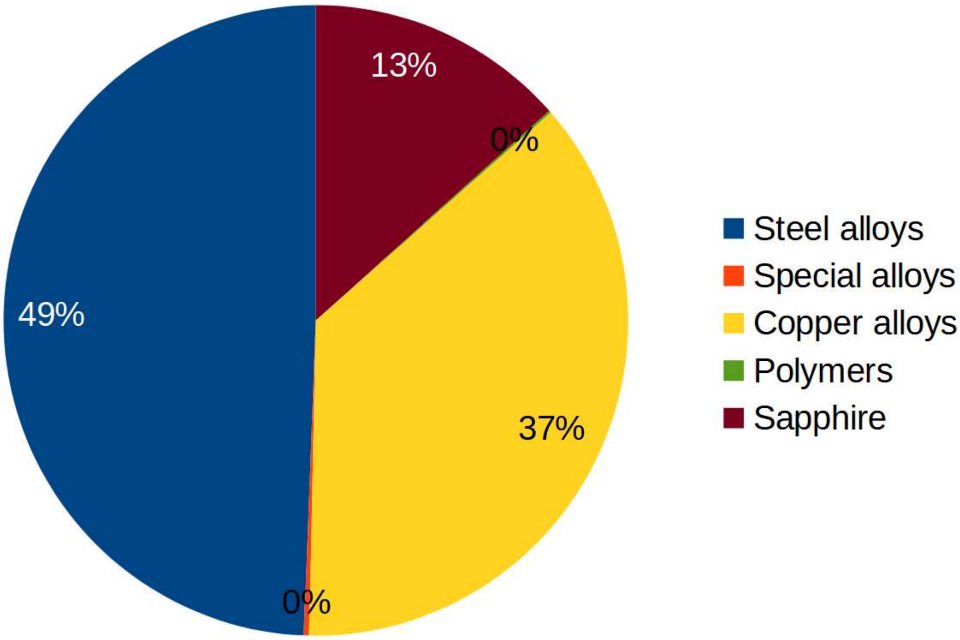

Figure 6 – Material group proportions for energy

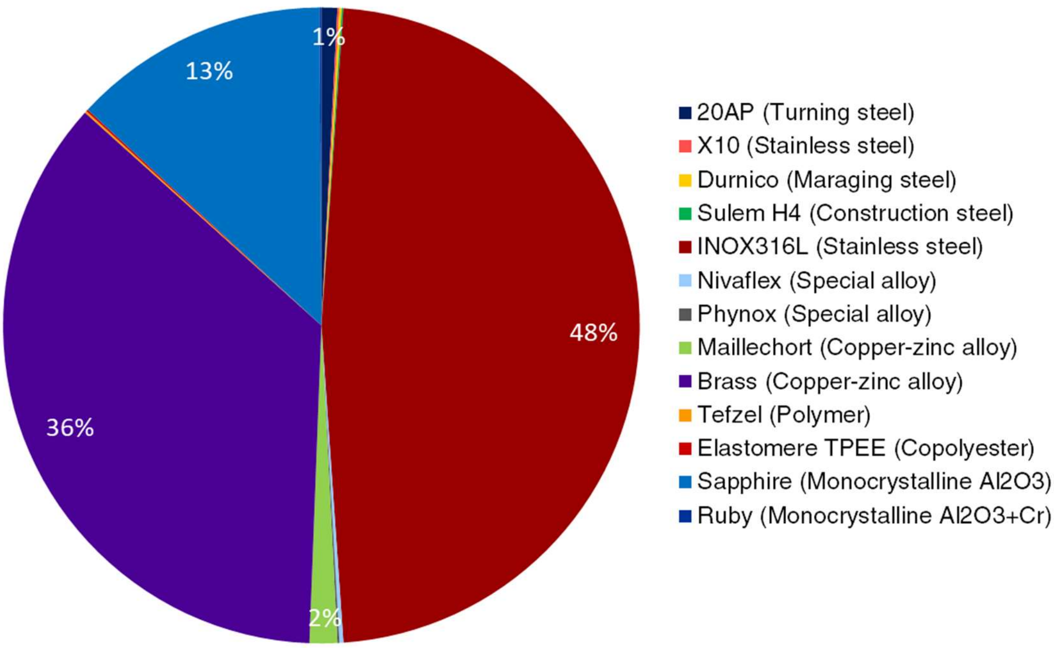

Figure 7 – Individual material proportions for energy

Steel, in particular Stainless Steel requires the biggest energy portion. It isn't a surprise, as steel constitutes roughly 38% of the weight of the final watch. Copper alloys are also well represented, as they are used for the gears and a lot of material gets removed during processing. Sapphire contributes to the third largest part, with 13% of the energy cost, while it represents only 7% of the total weight.

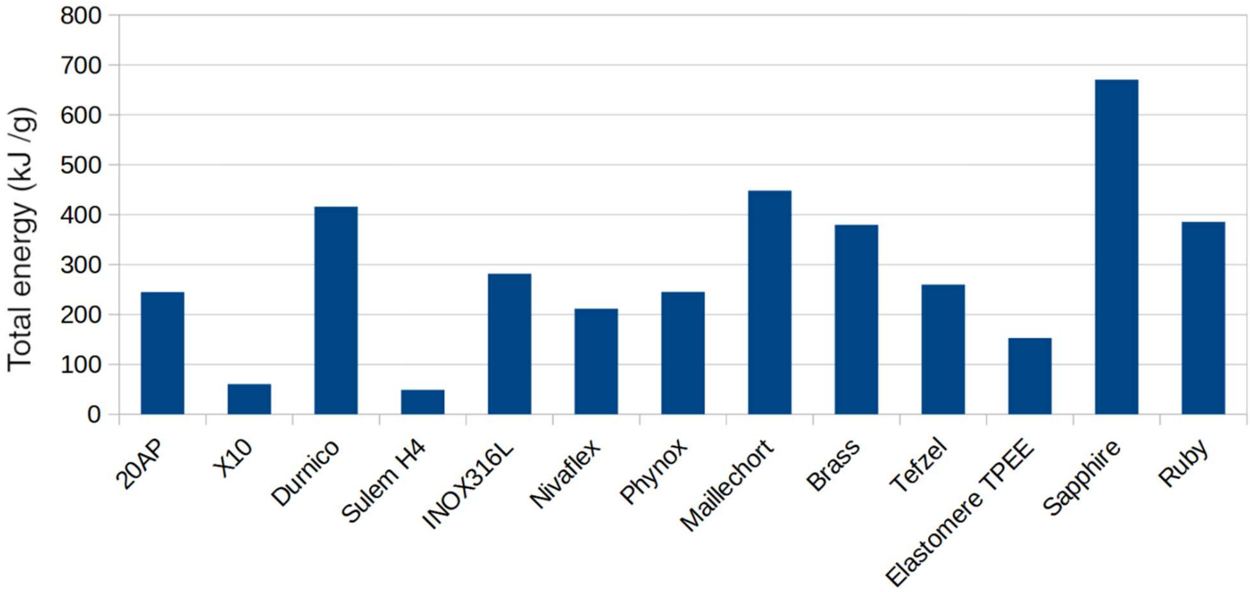

Figure 8 – Total energy in KJ per gram of material in assembled watch

Figure 8 shows, for each material in the watch, the energy requirements of each material per unit of weight. This is for the total of all embodied energy and processing.

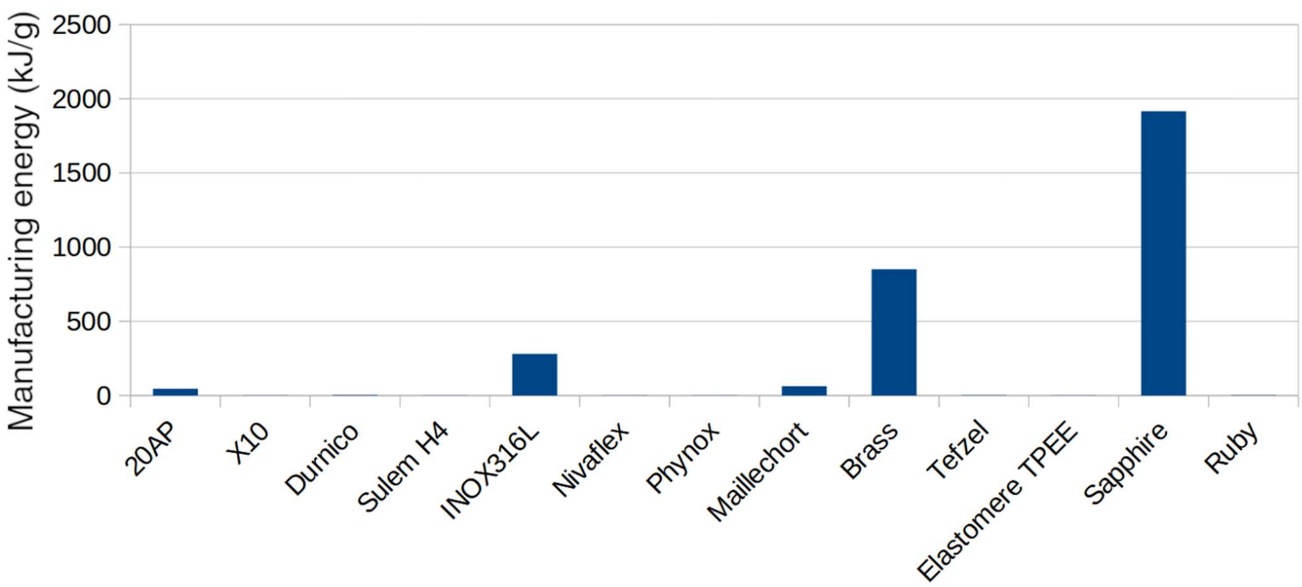

Figure 9 – Manufacturing energy in KJ per gram of material in assembled watch

Figure 9 focuses on manufacturing. Interpreting this graph is difficult, as some of the materials are mostly constituted of embodied energy, for example because they are directly cast into shape. However, the materials that are transformed significantly through machining, such as steel, brass and sapphire parts, are quite different.

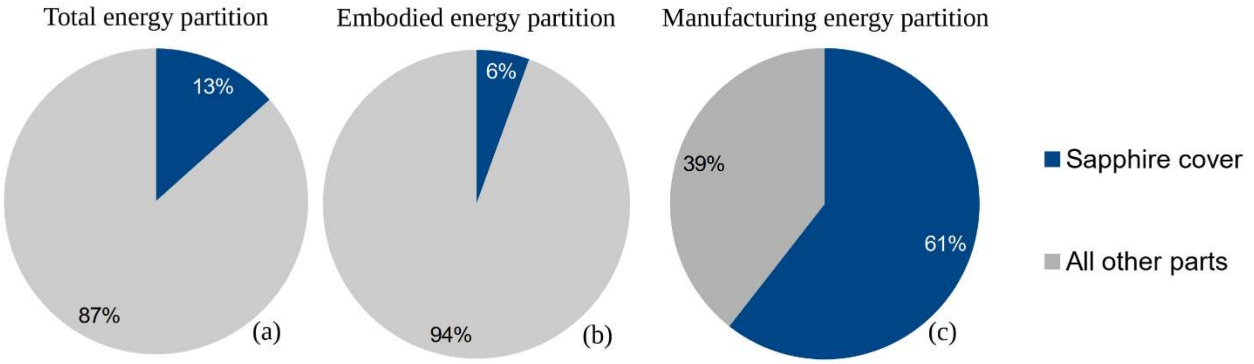

Figure 10 - Pie charts of the partition per material of (a) total, (b), embodied, and (c) manufacturing energy required for the fabrication of a sapphire cover

Figure 10 displays the proportions of energy required for the sapphire cover and it emphasizes how sapphire is important for the total manufacturing energy. The sapphire cover amounts for approximately 13% of the total energy requirements. However, while its embodied energy accounts for around 6% of the embodied energy of all the other items, manufacturing of the sapphire cover has a staggering importance, at 61% of the total manufacturing energy consumption.

Conclusions

The proportions of energy consumption and CO2 emission necessary to the production of a watch with a sapphire cover were analyzed, taking into account not only the energy and CO2 footprint embodied by the materials but also by the manufacturing processes. The study revealed that:

1. For the entire watch, except the sapphire cover, the embodied energy is much more important than the manufacturing one. The choice of material and its origin therefore is the most critical parameter. As an example, AISI 316L annealed Stainless steel has an embodied energy of 73-80.5 MJ/kg without any recycling. A version with the current recycling rate at 49.4-54.6% has an embodied energy of 41.7-49.4 MJ/kg, a difference of around 40%.

2. The manufacturing energy for the sapphire stands out as one the most energy consuming for its weight, accounting for 61% of total manufacturing energy requirements.

This last conclusion indicates the priority that eco-friendly watch brands should address.

Given that database values are opaque and might not reflect the specificity of particular manufacturers, a specialized study in the context of the Swiss watch industry would be beneficial to bring further details.

Acknowledgments

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