Course: Product Sustainability

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ELECTRIC MIXER ECO-DESIGN

A Comparative Life Cycle Assessment

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1.0 Abstract

In this report, the eco-design of a household electronic product (BOSCH Clevermixx electric mixer) is analyzed in order to explore a more sustainable version. Key alterations that suggested the most promising results were found in applying material substitution, improved energy optimization and manufacturing optimization. To approach this analysis, software tools for material life cycle assessment (LCA) were utilized, notably OpenLCA and

Granta Edupack. The LCA reported the mixer's major environmental impacts; conclusively, greenhouse gas emissions. Granta Edupack supported the proposal of specific material substitution (PA6 and ABS) that consisted of appropriate physical properties with lowered carbon emissions. Additionally, energy calculations were performed to decrease electric consumption impacts. Finally, proposed changes to manufacturing processes are listed to encompass a well-rounded eco-design.

2.0 Introduction

Currently, the EU consumes about 18.2 kg of electronic goods per person; including small appliances, such as electric kitchen appliances. Although these appliances are designed to be durable, it is common for the appliances to break down after 2.3 years, or become obsolete [2]. Consequently, the European Environment Agency (EEA) reported 10.4 million tons of waste electrical and electronic equipment (WEEE) generated in 2017, alone [1]. Climate action has reached a pivotal point, and WEEE heavily impacts the environment. Thus, the need for sustainable electronic goods production is urgent. It is clear that the substitution of ecologically irresponsible materials must be implemented throughout household consumerism. By employing material life cycle assessment (LCA) software tools, such as OpenLCA and GRANTA Edupack, material optimization can be achieved. Additionally, optimizing energy use and production processes further satisfies an eco-design that can be a suitable competitor for the market.

2.1 Functional Unit Definition

A functional unit defines a measured function of a specific system; it is a reference unit that may be used in relation to inventory data. In this study, the functional unit is defined as a BOSCH CleverMixx 350W electric mixer, presumed to perform for a period of 10 minutes, once per week (e.g to bake pancakes on Sundays) for a period of 5 years.

2.2 Goal & Scope Definition

This study was carried out to assess the electric mixer's environmental impacts and potential improvements. The eco-design targets greenhouse gas emissions by proposing material substitution, energy optimization, and process optimization:

Material Substitution: Substitution of PA6 and ABS plastic with biopolymer PLA, and incorporating recycled materials (PA6 and steel) to reduce CO_2 emissions.

Energy Optimization: Providing guidance for responsible energy usage of the device without compromising the product's life span and function.

Process Optimization: Employing a manufacturing facility that utilizes renewable electric sources vs. non-renewable energy; incorporating bulk transport saves on carbon emissions

A collection of intermediate units which make up the electric mixer was used for analysis. Subunits were weighed and their relative compositions identified (Table 1). Note that PCB was not fully assessed to keep the LCA feasible. The reason for exclusion is because glass fiber is a composite material that requires specific binders and resins which result in steep expenses and in-depth R&D analysis.

3.0 Inventory Analysis

The Bosch electric mixer composition includes: plastic (PP/ABS) from the powerswitch and outer casing, Nylon (polyamide) from the fan and gearing, and metals (copper and iron) from the power cord and electric motor; epoxy from the PCB was also observed (Table 1).

Table 1. Bosch electric mixer subunits & material identification (*gray marks units not assessed in LCA*)

Part #	Part Name	Material	Weight	Manufactured via	Function
1	Power Switch	Polypropylene	8.0g	Injection Moulding	Aids to control and switch the product on and off.
2	Outer Casing	ABS Plastic	84.7g	Injection Moulding	Protecting the electronics & holding the product together
3	Power Cord	Copper & Plastic	31.0g	Overmolding	To deliver electricity to the electronics to turn the whisks
4	PCB	Glass fiber, epoxy, copper	50g	Laser cutting, edge etching & more	Controls the product function
5	Electric Motor	Copper & Iron	520g	Multiple Methods	Turn the whisks and fan.
6	Fan & Gearing	Nylon (Polyamide)	37.5g	Injection molding	Transfers the rotation motion of the motor & cools the PCB.
7	Whisk	Stainless steel, PP	27.9g	Overmolding	Mixing substances

4.0 Impact Assessment

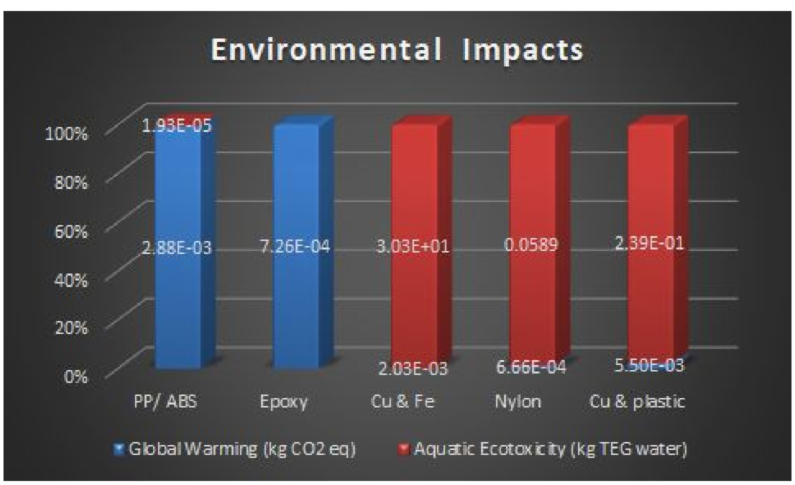
System Boundaries

In this study, a Cradle to Grave analysis approach was employed (Appendix A). Parameters were defined by subunit weights, transport flows (500-1000 km via 16' lorry train or van), and a single functional unit per energy production consumption.

4.1 Life Cycle Assessment (LCA)

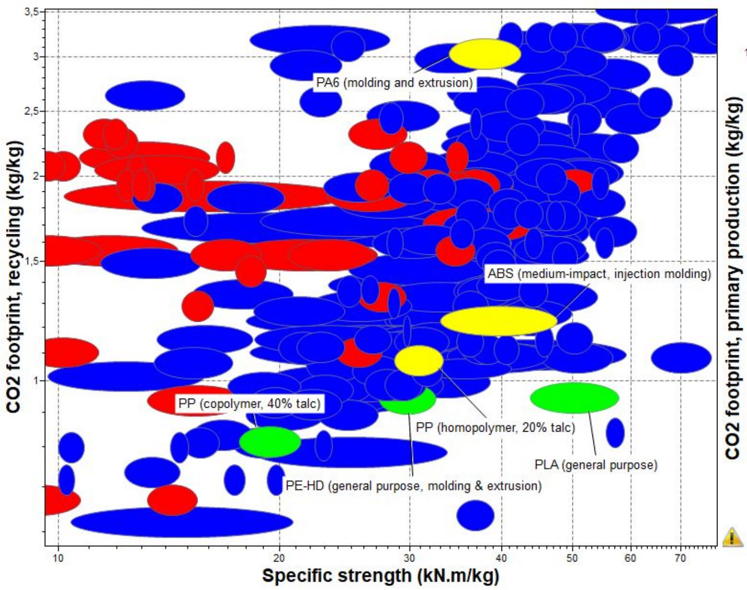
The LCA results suggested that the main environmental impacts were related to Greenhouse gas emissions (CO_2, NO_x, SO_x), such as, terrestrial ecotoxicity, aquatic acidification, and more generally, global warming (Appendix B, Table 2). The component of the electric mixer that seemed to have the largest impact came from the 520g electric motor made of copper and iron (3.03E+1 kg TEG water per unit).

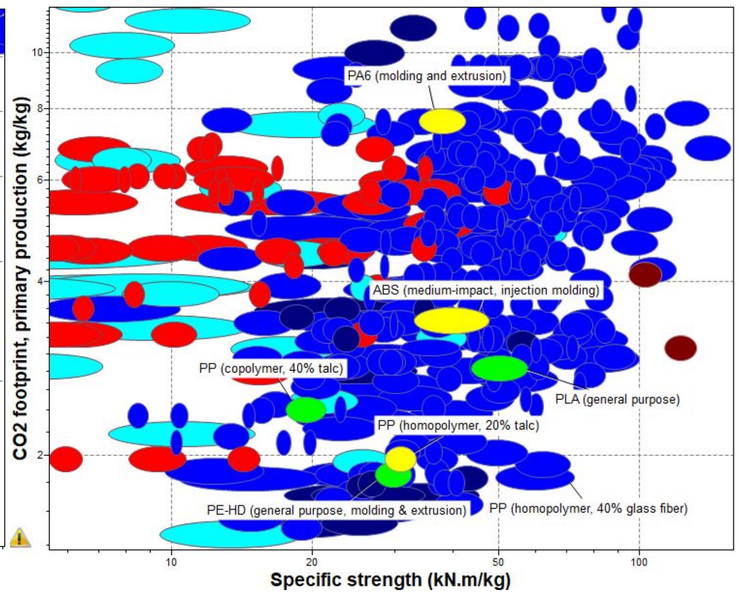
Aquatic acidification is caused by the unbalanced levels of Greenhouse gas emissions, which change the pH of the ocean water [3]. Knowing that global warming is directly caused by Greenhouse gas emissions, especially carbon dioxide [4], this study will focus on reducing these emissions by optimizing supply chain, transport and finding better raw materials.



As a result, the most feasible impact to target is carbon dioxide. This is because we can approach lowering the emissions of CO_2 from multiple angles, such as accounting for weight in material choices (Appendix B, Chart 1) to optimize transport emission, or optimizing manufacturing processes by using renewable electricity (Appendix B, Chart 3).

4.2 Granta Edupack





Alternative materials were evaluated using GRANTA EduPack. For the injection molded parts, alternatives were limited to materials with at least acceptable injection molding properties. Plastics used in the original product are highlighted with yellow and selected alternatives are highlighted with green. Elastomers are shown in red and polymers in blue.

Since weight is a concern for transport, the CO2 footprints were assessed against specific strength rather than plain yield strength. Polypropylene shows a relatively low footprint depending on the exact composition. ABS is somewhat stronger than most compositions of polypropylene at a significant cost in footprint. PLA, familiar to many from 3D printing, could be a reasonable alternative if dimensional stability is not a problem in production or customer usage. Furthermore, PA6 (Nylon) used in the gearing and fans has the highest footprint, but in these applications, creep or wear might be crucial factors not factored in these comparisons.

Similarly plotting electrical conductivity against CO2 footprint, copper could be replaced with aluminum to reduce the ecotoxicity. Aluminum has been verified as a suitable material for motor windings [5], but it does have a larger CO2 footprint by up to 50% depending on the aluminum grade.

4.3 Energy Usage

Based on the usage defined in the functional unit definition calculations for energy usage were done. The mixer has a power rating of 350W and the calculations are done based on the fact that the device is consistently using this amount of power. The equation used for the energy calculation is the following:

$$E = P \, x \, t$$

Where E is the total energy used, t the time and P the power. If the device is used for 10 min/week (0,166667h) in 5 years it will be used for (5 x 52 x 0.1667) 43.342 hours. With this usage the energy consumption will be 43.342 x 350W = 15169.7Wh. To see the impact on global warming the CO2 emissions were calculated by using an online tool provided by the United States Environmental Protection Agency [6] . The results showed that the emissions were 1.1 Kg of CO2 per lifecycle. This can be considered significant. To get a comparative analysis a calculation for a 100W [7] mixer was performed. The calculation showed that the (see Appendix D) that emissions would be reduced significantly. (1.1kg vs 0.306kg of CO2 emissions)

Nevertheless, reducing the power rating can have an effect on the product life cycle and performance. This is due to the relation of power and torque [8].

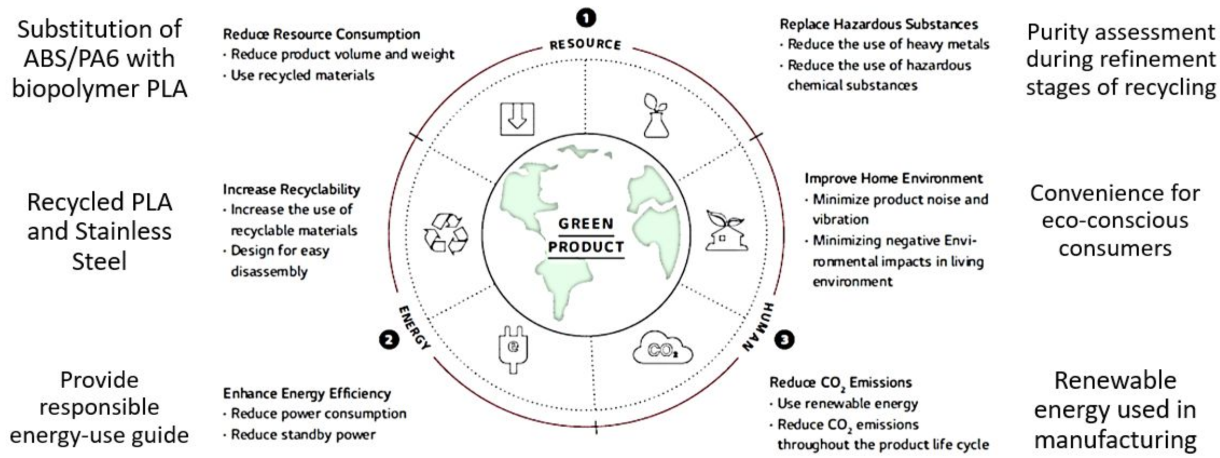
5.0 Improvement & Interpretation

The illustration below depicts the electric mixer’s eco-design improvements.

From the cradle: material substitution, incorporating recycled material, and employing renewable energy sources for manufacturing, provides reduced greenhouse gas emissions.

During usage: providing guidance for responsible energy use, and providing convenience for eco-conscious consumers, promotes energy efficiency and can improve home environments.

To the grave: executing purity assessments during refining processes of recycled material reduces hazardous substances, and assures the quality of the product, resulting in a circular economic flow.



5.1 Energy Usage

After researching the power rating of the product, it is clear that the reduction of the power rating will have an effect on the mixers performance and lifetime [9]. The solutions for gearing would undoubtedly over-complicate the eco-design, so for the sake of practicalities, we decided to look more into awareness and usage of the mixer.

Our proposal is to: Educate the user to use the device with as little power as possible to concern energy. This can be achieved by measuring the power usage with the 4 different settings the mixer has and encouraging the user to use the right setting for the right product. To achieve this, testing with different food products will have to be performed. The resulting information can be presented in the manual or in the packaging of the product. See Appendix C for an exemplifying illustration.

5.2 Material Selection

The material software indicated that the substitution of PA6 and ABS with PLA can reduce the carbon footprint, without compromising the physical properties needed. Production of

PA6 emits 7.8 kg CO_2 eq, and ABS emits 3.5 kg CO_2 eq; whereas, biopolymer PLA emits 3 kg CO_2 eq, roughly speaking. Moreover, recycled PLA only emits 0.8 kg CO_2 eq. PP had very little impact, thus its material substitution is not necessary; however, the choice of using PLA over PP, is granted by PLA's higher specific strength. Additionally, one study by Broadbent, suggests that recycled stainless steel (scrap metals) saves 1.5 kg CO_2 eq per 1 kg of steel production [10].

5.3 Process Optimization

The LCA results indicated that utilization of renewable energy sources for production stages decreased the energy impact by 2-3 magnitudes, compared to non-renewably sourced energy (Appendix B, Table 2). Similarly, a significant difference in organizing transportation of goods also provided decreased CO_2 impacts. By incorporating bulk transport methods, this process saves on carbon emissions, e.g. bulk loads delivered by train compared to van transport; additionally, the reduction of motor mass (520g to 400g) resulted in lowered global warming impacts (Appendix B, Chart 2).

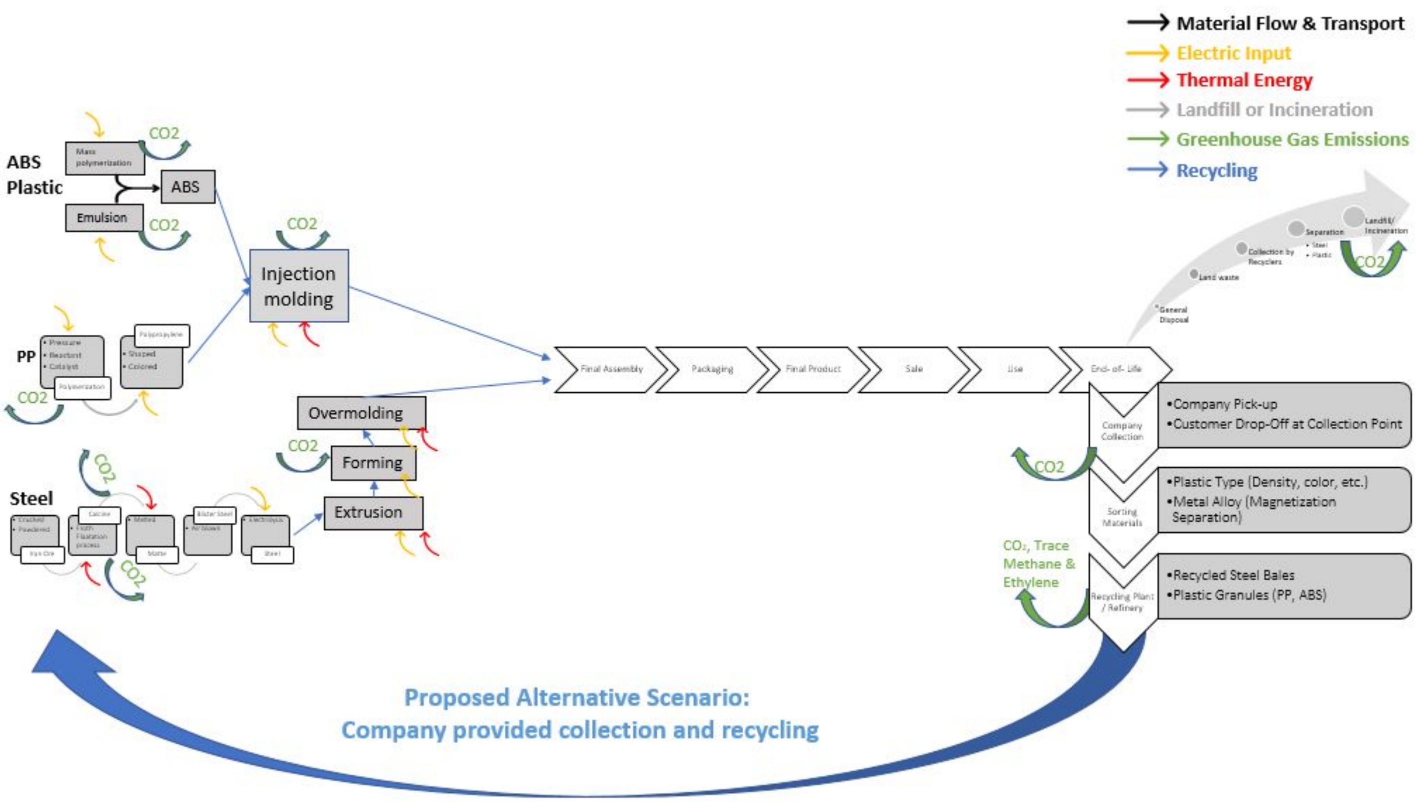
6.0 Conclusion

The eco-design study of the BOSCH Clevermixx electric mixer provided insight in exploring a sustainable design opportunity. By critically examining the life cycle stages of the electric mixer, the most environmentally impactful components were assessed. Although there were complexities throughout the evaluation of this sustainable product, we were able to propose a clear and justified eco-design alternative. Our main areas of improvements for the design targeted its carbon footprint. The sustainable version of the electric mixer was realized by utilizing material software to find suitable substitutes, determining energy efficiency in usage, and proposing effective production and transport processes to minimize the current product's ecological shortcomings.

7.0 Appendices

Appendix A: Visualization of the product life cycle

The flow chart below outlines the raw material production stage, manufacturing stage, use stage, and end-of-life stage of the Bosch CleverMixx electric mixer. It exhibits input/output variables, such as material flow and transport (black), electric (yellow), thermal energy (red), and Greenhouse Gas emissions (green).



Appendix B:

Table 2: *Main environmental impact: carbon footprint, energy, and aquatic ecotoxicity*

Production Scenarios		**Carbon Footprint**	**Type of Energy Impact**		**Largest Impact**
Subunit	Material	CO_2 Emissions	Non-renewable Fossil Fuel (MJ)	Renewable wind, solar, geothermal (MJ)	Aquatic Ecotoxicity (kg TEG water)
Powerswitch/ Casing	PP/ ABS	2.88E-3	4.52E-2	3.48E-5	1.93E-5
PCB	Epoxy	7.26E-04	1.09E-02	1.92E-05	
Electric Motor	Cu & Fe	2.0362E-03	6.2295	2.900E-01	3.0293E+01
Fan & Gearing	Nylon	6.66311e-4	1.05E-02	8.06E-06	0.0589
Power Cord	Cu & plastic	5.50366E-3	1.54E-01	3.126E-2	2.39E-01

Table 3. The main environmental impacts of Bosch CleverMixx electric mixer subunits (note that some parts were left out of the analysis, see the numbering for reference).

Part #	**Part Name**	**Material**	**Weight**	**Main environmental impact**
1	Power Switch	Polypropylene	8.0g	Aquatic Acidification 1.27 kg TEG water
2	Outer Casing	ABS Plastic	84.7g	See Polypropylene
3	Power Cord	Copper & Plastic	31.0g	Ionization Radiation 0.676 Bq C-14 eq
5	Electric Motor	Copper & Iron	520g	Global Warming 0.4 kg CO2 eq
6	Fan & Gearing	Nylon (Polyamide)	37.5g	Aquatic ecotoxicity 0.0589 kg TEG water

Chart 1. Process contributions to different motor mass (520/400g)

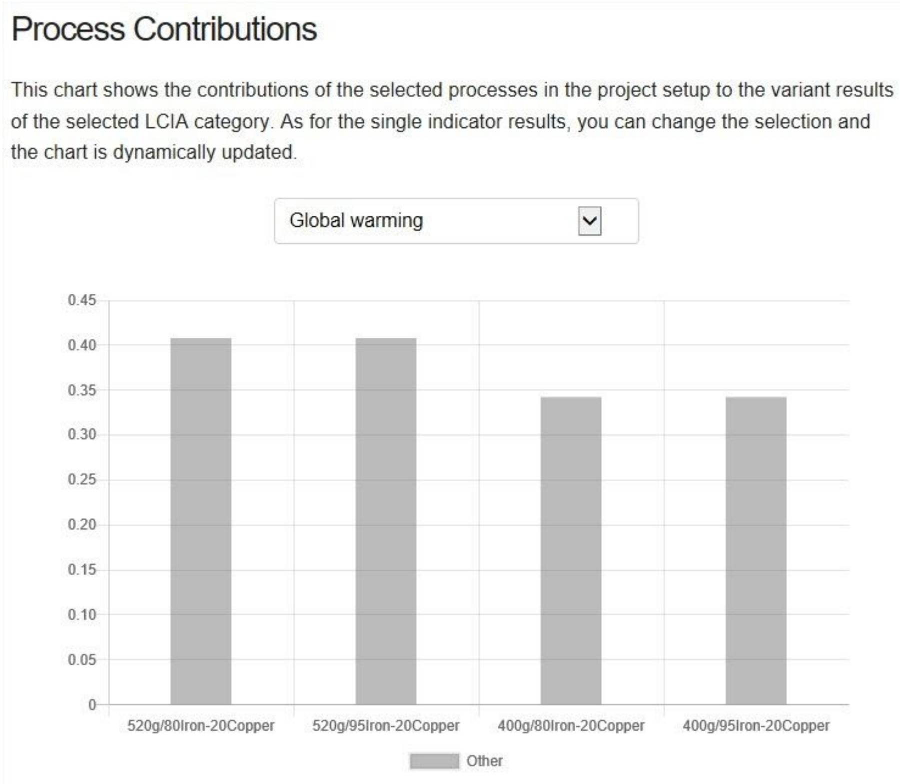


Chart 2. An analysis of the CO_2 emissions was taken for each transport scenario. Table 4 exhibits the impact of CO_2 equivalent emission from biogenic, land transformation, uptake, and fossil CO_2; fossil CO_2 having the highest impact when using van transportation.

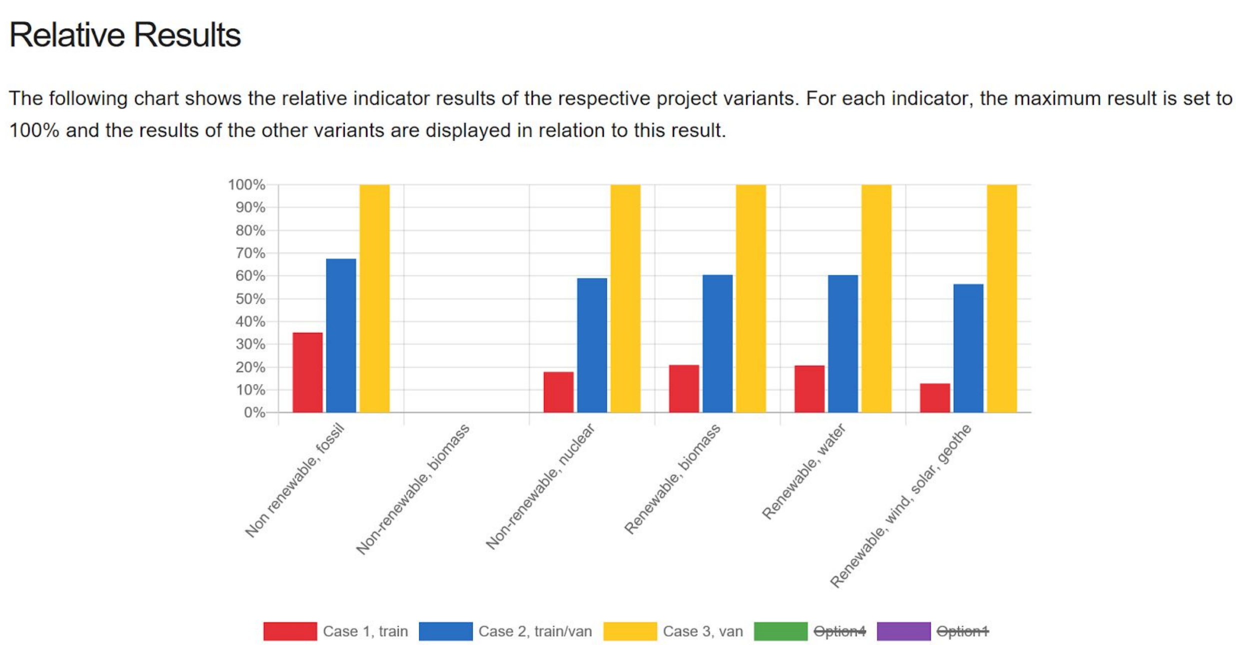
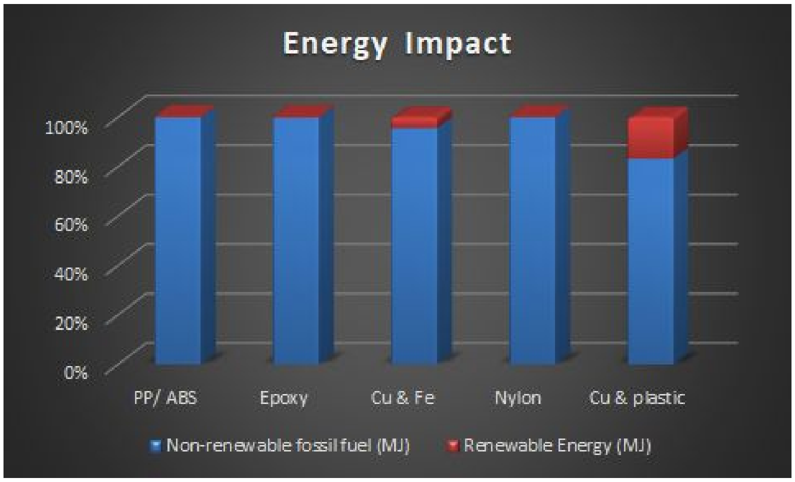
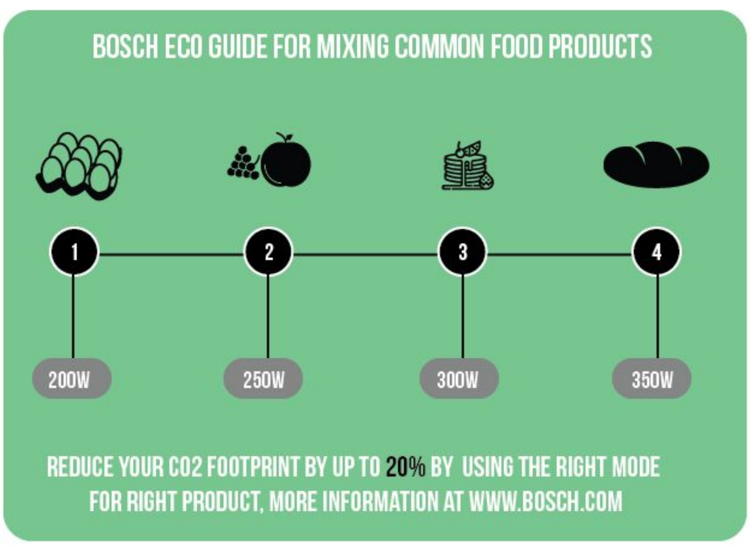


Chart 3: Energy impact of non-renewable fossil fuel and renewable energy (MJ)



Appendix C:

Proposal for label (illustration purposes only)



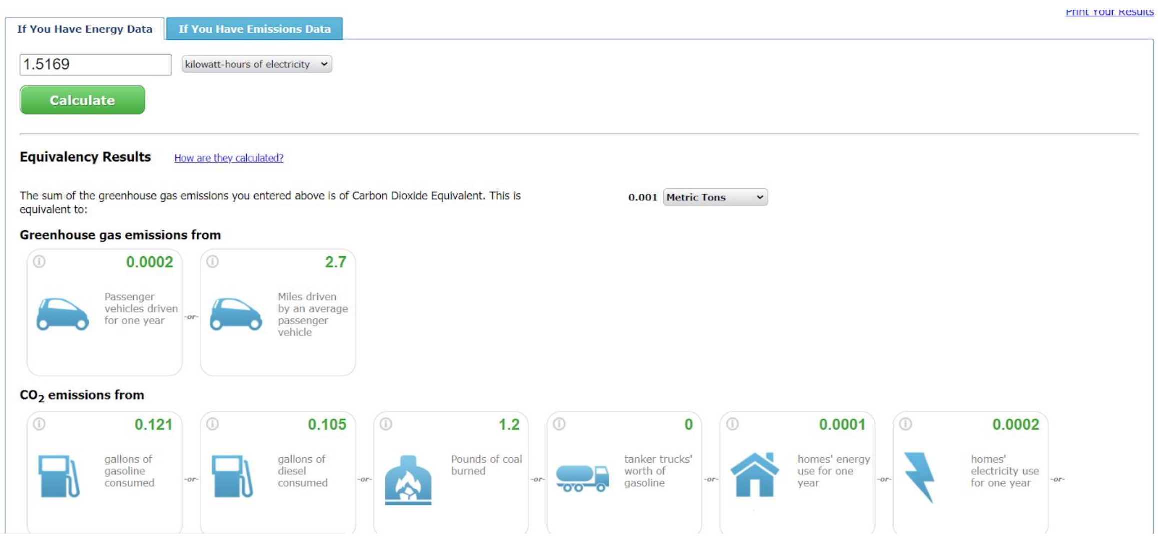
Appendix D:

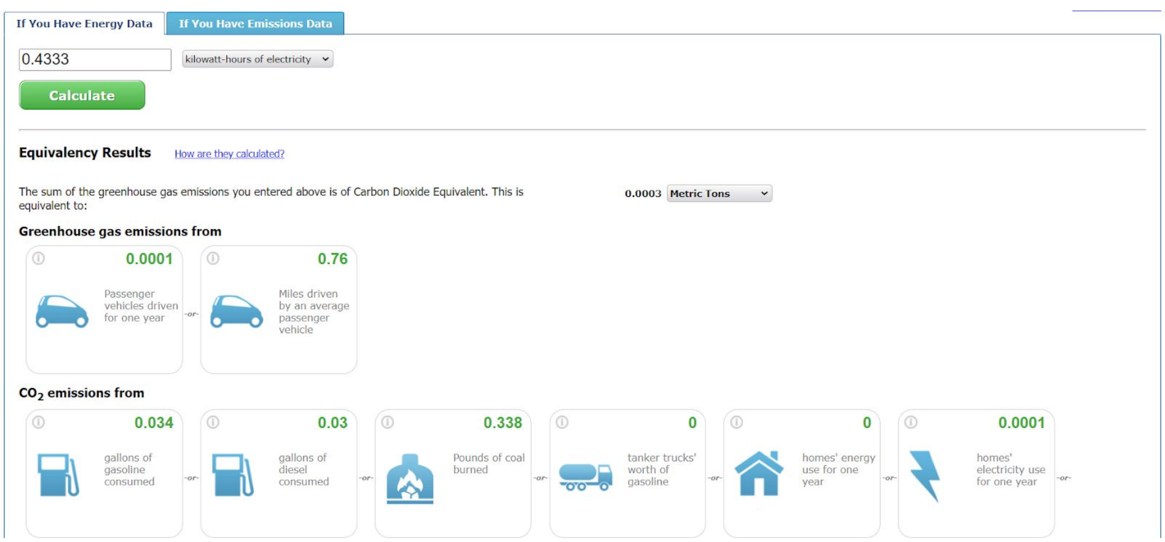
Mixer Comparison

An alternative mixer with the same function is chosen as a comparative one. The power rating of the mixer is 100W.

The device uses 16.6667Wh of energy per 10 min usage (350W * 0.166667h). Therefore during its whole life cycle of 10 years it will use 520 * 16.667 =8666.84 Wh during its life.

	100W Mixer	**350W Mixer**
Energy used for 10min	(E*t) 100W * 0.16667h = 16.67Wh	(E*t) 350W * 0.1667 = 58.33Wh
Energy used for 10 years	260 * 16.667 = 4333.42 Wh	260 * 58.33345 = 15169.7Wh
CO2 emissions caused by the energy use	0.306 kg	1.1 kg


Print Your Results
If You Have Energy Data
If You Have Emissions Data
1.5169
kilowatt-hours of electricity
Calculate
Equivalency Results
How are they calculated?
The sum of the greenhouse gas emissions you entered above is of Carbon Dioxide Equivalent. This is equivalent to:
0.001 Metric Tons
Greenhouse gas emissions from
0.0002
Passenger vehicles driven for one year
-or-
2.7
Miles driven by an average passenger vehicle
CO2 emissions from
0.121
gallons of gasoline consumed
-or-
0.105
gallons of diesel consumed
-or-
1.2
Pounds of coal burned
-or-
0
tanker trucks' worth of gasoline
-or-
0.0001
homes' energy use for one year
-or-
0.0002
homes' electricity use for one year
-or-


If You Have Energy Data
If You Have Emissions Data
0.4333
kilowatt-hours of electricity
Calculate
Equivalency Results
How are they calculated?
The sum of the greenhouse gas emissions you entered above is of Carbon Dioxide Equivalent. This is equivalent to:
0.0003 Metric Tons
Greenhouse gas emissions from
0.0001
Passenger vehicles driven for one year
-or-
0.76
Miles driven by an average passenger vehicle
CO2 emissions from
0.034
gallons of gasoline consumed
-or-
0.03
gallons of diesel consumed
-or-
0.338
Pounds of coal burned
-or-
0
tanker trucks' worth of gasoline
-or-
0
homes' energy use for one year
-or-
0.0001
homes' electricity use for one year
-or-

8.0 References

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