

A Study on Sustainability of a Multipurpose Cooker Using SolidWorks Sustainability Analysis

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Abstract

This study focuses on designing and assessing the sustainability of a multipurpose cooker to meet the growing demand for eco-friendly, energy-efficient kitchen appliances. Using SolidWorks Sustainability tools, the research evaluates material selection, thermal efficiency, and environmental impact through lifecycle analysis. Key metrics such as carbon footprint, energy consumption, air acidification, and water eutrophication are analyzed. The study balances environmental benefits with production costs, comparing design alternatives to identify the optimal solution for performance and sustainability. The findings aim to reduce waste, enhance recyclability, and promote durable, safe, and cost-effective cooker designs, contributing to sustainable engineering practices.

1. Introduction

This part highlights the growing importance of sustainable design in addressing environmental challenges such as resource depletion and climate change. The focus is on the kitchen appliance sector, particularly the multipurpose cooker, as a way to reduce energy consumption and material waste. The study aims to design, analyze, and optimize a sustainable multipurpose cooker using SolidWorks Sustainability tools. It identifies key objectives: selecting sustainable parameters, designing based on these parameters, and analyzing the environmental impact [1]. The study emphasizes balancing cost, performance, and environmental benefits.

2. Materials and methods

This part will give insight into the preparation of materials and sustainability parameters such as material selection, social responsibility and cost efficiency

2.1 Model preparation

The multipurpose cooker is chosen for its functionality and relevance as a widely used appliance that supports various cooking methods like boiling, frying, and steaming. Its frequent use in households highlights its significant impact on energy consumption and resource usage. Furthermore, its construction, typically involving materials like plastics, metals, and electronic components, presents opportunities for optimization in terms of energy efficiency, waste reduction, and recyclability. The study begins by identifying the key components of the multipurpose cooker, such as the body, handles, heating element, lid, and inner coating. Each component is analyzed for its material, function, and contribution to the overall design. A detailed 3D model of the multipurpose

cooker is then created in SolidWorks, beginning with the collection of dimensions, either from manufacturer specifications or measurements of an existing product then assembled using SolidWorks' mate features to ensure proper alignment and fit. To enhance the accuracy of the subsequent sustainability analysis, materials are assigned to each component using SolidWorks' material library

2.2 Design consideration

A survey was carried out to 100 people with random status which is student, employed and unemployed. 97% of users prefer a wok for its versatility in frying, boiling, and stir-frying, compared to 59% for frying pans and 14% for pots. This suggests a high demand for a multipurpose cooker that mimics the wok's functionality, especially for those with limited space. Additionally, 75% of respondents prepare two or more dishes, while 47% cook for one person and 45% for two to three, indicating that a moderate-capacity appliance is ideal. With frying being the most common cooking method, the cooker must support high-heat applications with heat-resistant, non-stick materials and precise temperature control. Lastly, since 64% are only willing to spend below RM50 and only 36% up to RM100, affordability is crucial, necessitating a focus on essential functions and cost-effective materials.

Multipurpose cooker designs are changing quickly to satisfy the demands nowadays customers who place a high value on efficiency, convenience, and environmental responsibility [2]. The increasing importance of visual attractiveness and user-centric design is one major market trend. Consumers now seek kitchen appliances that complement modern kitchen interiors, leading to the popularity of sleek, minimalist designs

From a functionality standpoint, modern cookers emphasize versatility. Most models combine multiple cooking modes such as frying, steaming, sautéing, boiling, pressure cooking, and slow cooking in one appliance. User-friendly interfaces, and non-stick, easy-to-clean components further increase functionality and ease of use [3].

In terms of sustainability, there is a growing shift toward using eco-friendly materials and energy-efficient technologies [4]. Additionally, sustainable design now includes considering the full product lifecycle ensuring ease of disassembly, repairability, and recyclability at the end of life.

2.3 Sustainability parameters

In this project, three key sustainability parameters were emphasized which are material selection, social responsibility, and cost efficiency [5].

2.3.1 Material selection

Choosing the right materials can significantly reduce environmental impacts throughout a product's life cycle, from production to disposal. Sustainable materials are typically renewable, recyclable, or biodegradable, and they are sourced in ways that minimize harm to ecosystems and communities

2.3.1.1 Material selection for body part

Polyether Ether Ketone (PEEK), Polytetrafluoroethylene (PTFE), Polyethylene Terephthalate (PET), High-Density Polyethylene (HDPE), Low-Density Polyethylene (LDPE), Polypropylene Homopolymer (PPH) and Silicon are well known materials in food and beverage industry (Table 1). This is because all these materials were approved by Food and Drug Administration (FDA) which means they are all safe food contacts material.

Table 1 Material properties

Material	Thermal Conductivity (W/m.K)	Mass Density (kg/m ³)	Financial Impact (USD/kg)
PEEK	0.24	1310	99.225
PTFE	0.30	2320	15.829
PET	0.261	1420	2.205
HDPE	0.461	952	2.205
LDPE	0.322	917	2.536
PPH	0.117	933	2.646
Silicon	124	2330	2.072

Figure 1 shows that there are few material with low thermal conductivity and lightweight that suitable to be chosen as the body material. It is obvious that PPH is more suitable for multipurpose cooker body due to its low thermal conductivity, even though its value is higher, but it is still economical.

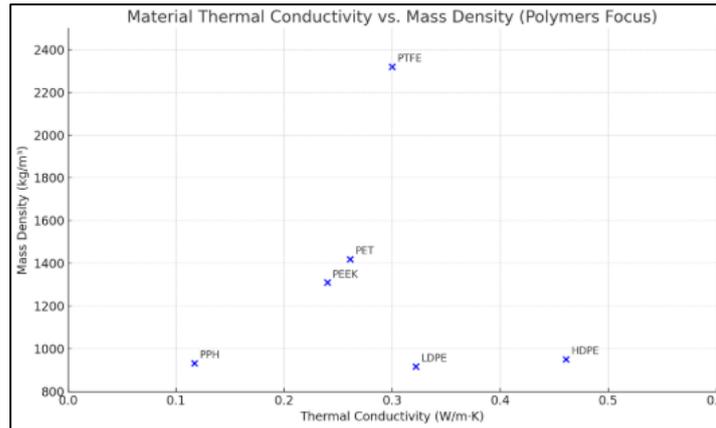


Fig 1 Thermal conductivity versus mass density

2.3.1.1 Material selection for inner pot

In contrast, Stainless Steel 304 offers strong corrosion resistance, high mechanical durability, and is certified food-safe, making it ideal for long-term usage (Table 2). It is also widely recyclable, contributing to the environmental sustainability of the product. While it is heavier and slightly more expensive than alternatives like PPH or aluminium, these trade-offs are justified by its superior strength, safety, and resistance to scratching and denting.

Table 2 Material properties

Material	Thermal Conductivity (W/m.K)	Max. use Temperature (°C)	Food- safe	Durability
Stainless Steel (304)	~16	>500	yes	Excellent
Aluminium (6061)	~167	250	Coating needed	Good
Polypropylene Homopolymer (PPH)	~0.12	140	yes	Moderate
Polytetrafluoroethylene (PTFE)	~0.25	260	Yes	Coating wears

2.3.1.1 Material selection for steamer tray

The steamer component of a multipurpose cooker must be designed to handle high heat and constant exposure to steam without deforming or corroding. It should be made from food-safe, non-reactive materials to ensure the safety and purity of the food. PPH was ultimately chosen for its balance of performance and cost. It can withstand temperatures up to 140 °C and is chemically resistant, lightweight, and easy to mold into complex shapes with perforations for steam flow (Table 3).

Table 3 *Material properties*

Material	Thermal Resistance (°C)	Food-safe	Durability
Polypropylene Homopolymer (PPH)	~140	Yes	Moderate
Stainless Steel (304)	>500	Yes	Excellent
High-Density Polyethylene (HDPE)	~120	Yes	Low
Polyethylene Terephthalate (PET)	~115	Yes	Moderate

2.3.1.1 Material selection for lid

It should be lightweight for ease of handling but strong enough to withstand repeated use, high temperatures, and possible pressure build up. Transparency can be a valuable feature, allowing users to monitor food without lifting the lid, which helps maintain consistent cooking temperatures. The material must also be food-safe, non-reactive, and easy to clean, especially since it comes into direct contact with steam and food splatter (Table 4).

Table 4 *Material properties*

Material	Thermal Resistance (°C)	Transparency	Seal Effectiveness	Durability
Tempered Glass	~250	Excellent	Excellent with silicone ring	Excellent
Polycarbonate	~130	Good	Degrades with time	Moderate

2.3.2 Social responsibility

The design emphasizes user safety and inclusivity, with features that are easy to use for people of different ages and abilities. By combining multiple cooking functions into one appliance, it reduces clutter, energy use, and overall consumption, making it an ideal solution for modern, responsible living.

2.3.3 Cost efficiency

In order to obtain accurate and up-to-date material cost data, Alibaba.com was used as a reference platform to source current prices from industry suppliers, ensuring the cost analysis reflects real market value (Table 5). The same international website, Alibaba.com also do customize manufacturing of every material (Table 6).

Table 5 *Material rate from supplier*

No.	Material	Cost
1.	Polypropylene Homopolymer (PPH)	5.12 RM/kg
2.	Stainless Steel AISI 304	6.39 RM/kg
3.	Glass	12.78 RM/m ²

Table 6 Pricing list of manufacturing and labor cost

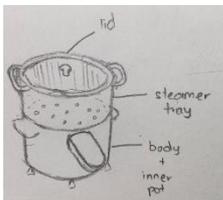
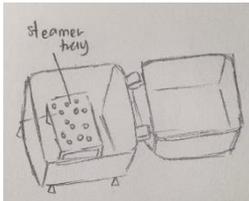
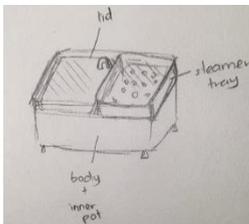
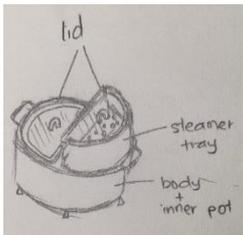
No.	Process	Cost (RM/part)
1.	Plastic injection molding	0.85 - 21.3
2.	Deep drawing and stamping	22.58
3.	Glass forming and tempering	2.13

3. Result and discussion

3.1 New concepts

Table 7 shows the new concepts and descriptions of each proposed design concept. The sketches also were provided to illustrate the combination of alternative component concepts.

Table 7 New concepts and descriptions

Concept Sketching	Description
	<p>The first concept is almost the same as the original product of the multipurpose cooker. Which is single cooking compartment with detachable inner pot, suction rubber at the bottom and more handles for easy handling while cooking.</p>
	<p>Concept 2 of multipurpose cooker incorporates an innovative foldable design. This folding concept not only saves space but also aligns with modern minimalist design trends. This concept has two cooking compartments with detachable inner pot and suction rubber. In order to steam, the steamer tray will be put inside the bottom inner pot and the top inner pot will act as the lid.</p>
	<p>This concept is almost the same as Concept 2 which has two cooking compartments. What differs is that it has lid that covers both of cooking compartments. So, people are able to steam and cook other things at the same time compared to Concept 2. This concept also comes with detachable inner pots and suction rubber at the bottom for safety.</p>
	<p>This concept is an innovative concept of Concept 3. This concept has two cooking compartments with split lids. The split lids are important because not all cooking methods can be covered during the process. Some dishes need moisture during the process, and some do not. This concept has the same safety features as the previous concepts, which are detachable inner pot, suction rubber at the bottom and more handles.</p>

3.2 Concept evaluation on SolidWorks

Figure 2 shows the environmental impact on original design, Figure 2 to 4 show the environmental impact on the first, second, third and fourth new design of the multipurpose cooker.

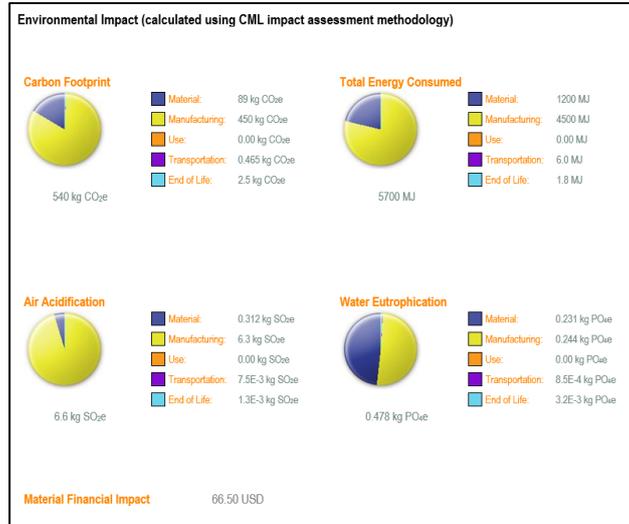


Fig 2 Environmental impact on original design

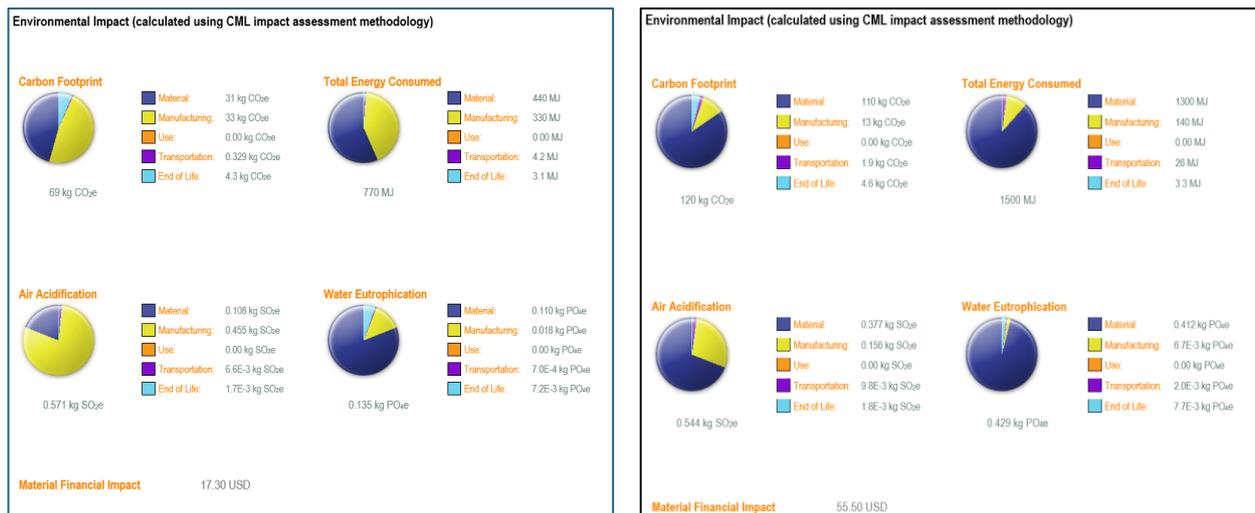


Fig 3 Environmental impact on first and second concept designs

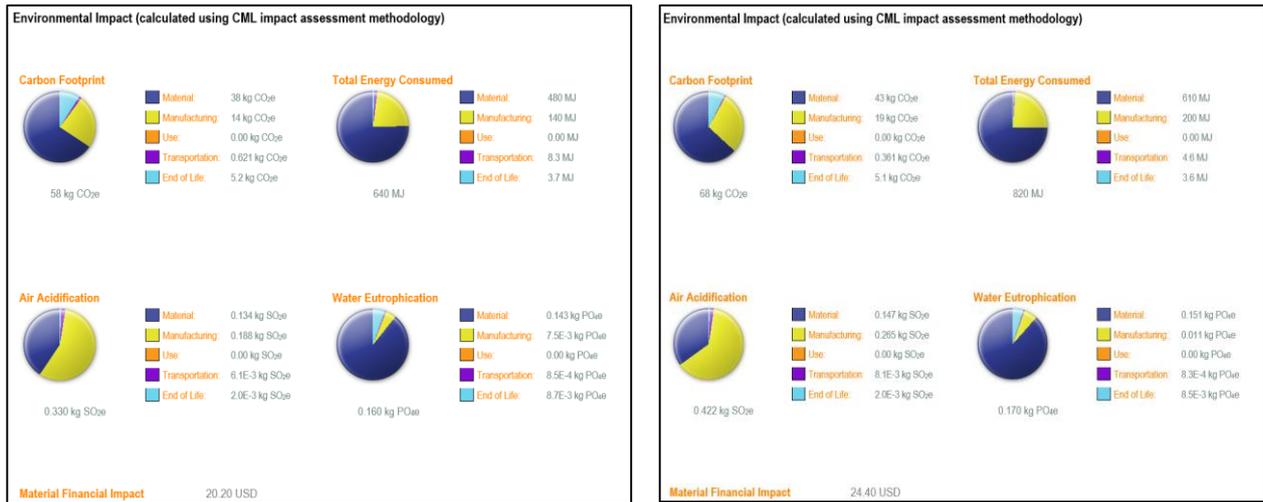


Fig 4 Environmental impact on third and fourth concept design

Table 7 is the detailed comparison of environmental effect and financial impact of the multipurpose cooker.

Table 7 New concepts and descriptions

Design	Carbon Footprint (kg)	Air Acidification (kg)	Water Eutrophication (kg)	Total Energy Consume (MJ)	Cost (RM)
Original	540	6.6	0.478	5700	283.29
Concept 1	69	0.571	0.135	770	73.70
Concept 2	120	0.544	0.429	1500	236.43
Concept 3	58	0.330	0.160	640	86.10
Concept 4	68	0.422	0.170	820	103.10

From Table 7, there are three concepts that can be considered as more sustainable in terms of environmental impact compared to the original which are Concept 1, Concept 3 and Concept 4. Among these three concepts, in terms of finance, Concept 1 and Concept 3 offer good prices. Back to these concepts, Concept 3 and Concept 4 come with two compartments. What differs them is that concept 4 comes with split lids. In terms of social sustainability and market need, Concept 4 satisfies them better because it is commonly known that not all cooking methods can be closed during the process.

4. Conclusion

This study successfully demonstrated that sustainable engineering practices can significantly enhance the environmental performance of a multipurpose cooker. By using SolidWorks Sustainability Analysis, the research evaluated the lifecycle impact of different design alternatives and material selections. The optimized design featuring polypropylene homopolymer for the body, stainless steel for the inner pot, PPH for the steamer, and tempered glass for the lid achieved improved energy efficiency, reduced carbon footprint, and greater recyclability compared to conventional products. Furthermore, the design balanced cost efficiency, user safety, and functional performance, meeting both environmental and customer requirements. The research highlights the importance of integrating sustainability into product development to promote responsible consumption and production. It is recommended that future designs further explore the use of biodegradable or bio-based plastics for non-heated parts to reduce reliance on petroleum-based materials. Additionally, integrating smart technologies, such as precise temperature control and energy usage monitoring, could further enhance the cooker’s sustainability. Collaboration with manufacturers to adopt cleaner production methods and support recycling programs will also contribute to minimizing the overall environmental footprint. Lastly, expanding user education on proper use and disposal can maximize the sustainable potential of the product and promote eco-friendly consumer behavior.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

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