Induction stoves: An option for clean and efficient cooking in Indonesia

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Abstract. Energy sustainability and carbon emission reduction programs are widespread issues in various countries. One sector of concern in the program is the household sector with cooking activities as its focus. Therefore the cooking fuel conversion program is often carried out in various countries and even in Indonesia, such as the program of conversion of kerosene to LPG. In this article, we review the options for using induction stoves for Indonesian society. The method for our review is based on the comparison of articles in previous studies. In various experiments, it has been stated that induction stoves have better energy efficiency than electric filament stoves and LPG stoves. As a result, the operational costs of induction stoves are lower than those of the two stoves. Also, the carbon emissions of induction stoves are lower than LPG stoves. However, several challenges must be resolved if the policy about the conversion of LPG stoves to induction stoves will be implemented in Indonesia.

Keywords: cooking, energy sustainability, induction stove

1. Introduction

In recent years, issues related to energy sustainability and clean energy are big issues that are widely raised in various countries. Besides, producing and utilizing clean and renewable energy, efforts to develop efficient and low-carbon equipment are an attractive focus \([1,2]\).

To support energy sustainability, the Republic of Indonesia’s Government has issued policies related to the supply of renewable energy. On the National Energy Policy in Presidential Regulation No. 79/2014 has been mandated that the utilization of new renewable energy must continue to increase. In 2025, it is targeted that renewable energy will supply 23% of primary energy and will continue to increase to 31% in 2050. To integrate with the response of climate change, several recommendations made by the Republic of Indonesia’s Government. Some low-carbon recommendations proposed to be implemented during the period 2020-2045 in the energy
sector include: encouraging the transition of energy use to renewable energy sources, increasing efficiency, and increasing the amount of biofuel use [3].

One of the sectors with the most significant amount of energy needs in Indonesia is the household sector. In 2019, the household sector filled 14% of national energy use with an average growth rate of 4% per year. The household sector's position is below the transportation sector (43%) and the industrial sector (35%). Energy demand in the household sector is currently dominated by electrical energy and is predicted to increase by 50% in 2050. The increasing need for electrical energy in the household sector cannot be separated from the increasing human needs for various electronic equipment such as air conditioners, refrigerators, water pumping machines, induction stoves, lighting, and various devices. Moreover, in several scenarios to improve energy efficiency and reduce carbon emissions, it is stated that the government will make efforts to convert LPG stoves to induction stoves. In 2050 it is projected that the use of LPG has decreased by 31% [3, 4].

The effort to convert LPG stoves to induction stoves in the household sector is an effort that has been carried out by many countries such as Ecuador [5, 6] and India [7]. Induction stoves are considered to reduce carbon emissions and have a higher efficiency than conventional electric stoves [8, 9].

In this paper, the authors evaluated and studied of the potential use of induction stoves in Indonesia. Several aspects of opportunities and challenges that might be faced in making policies related to the conversion of LPG stoves to induction stoves will be the focus of this article.

2. Basic principles of induction stoves
Induction stoves use electricity to produce heat; however, unlike conventional electric stoves that use heating elements that generate heat due to the resistance when the current passes through elements, which are usually in the form of coil metal. The induction stove generates heat through a magnetic field oscillation effect that induces cooking equipment made from a ferromagnetic material. The oscillation of a magnetic field is caused by the alternating current flowing in the coil. The mechanism of heat on ferromagnetic-based cooking equipment can occur due to the emergence of eddy currents at the base of the cooking equipment. In summary, the working principle of an induction stove can be seen in Figure 1 [10].

![Figure 1. Schematic of the principle of induction stove](image)

Because it uses the electromagnetic induction effect between the magnetic field of the coil and the ferromagnetic surface, the surface of the induction stove, which is usually made of ceramic will
remain cold. This is one of the advantages of induction stoves because it is relatively safer than electric filament stoves or LPG stoves, causing accidents or even fire. Most electric filament stoves store heat on the surface of the stove for a long time, and it is hazardous if it comes in contact with human organs. Another advantage is that because it is made of ceramic, the induction stove’s surface can be cleaned easily [11,12]. Also, the induction stove can be integrated with photovoltaics to support energy sustainability programs [13].

3. The potential use of induction stoves in Indonesia
In this section, we discuss the potential use of induction stoves in Indonesia based on the distribution data of the type of fuel used by the Indonesian people and the data of electricity and gas energy usage in Indonesia. In Figure 2a, a comparison of cooking fuel types by households in Indonesia is presented [14]. According to Figure 2, it is clear that the use of wood and kerosene continues to decline, and on the other hand, LPG continues to increase as a consequence. On the other hand, the fuel users in the form of coal, electricity, etc. tend to hold below 5%. It indicates the fuel for cooking based on coal, electricity, and so on has not yet become a priority for the Indonesian people. As an example, Figure 2b presents a comparison between the number of electric stove users and LPG stoves in the three most populous provinces in Indonesia, namely West Java, East Java, and Central Java. In all three provinces, it is clear that LPG fuel users increased significantly around 2009, while electric stove users tend to be around 1-2% of total users. The increasing number of LPG stove users in Indonesia is one proof of the success of the kerosene to LPG conversion program in Indonesia. This program is one of the Indonesian government's steps in reducing carbon emissions and particulate matter because LPG has lower emissions than kerosene [15,16].

![Figure 2](image-url). (a) Distribution of cooking fuel types in Indonesia; (b) Comparison of the number of LPG and electricity users for cooking in the three most populous provinces in Indonesia. Comparisons were made from 2002 to 2016 [14].

The small number of electric stove users in Indonesia can be understood because there is still a lack of information about the use of electric stoves for the people of Indonesia. Most of the electric stoves known to the public are resistant filament electric stoves, and its efficiency is reduced. On the other hand, most induction stoves require much power, and it will cause problems for the people of Indonesia because the majority of which still use the low power group (R-1) [4,17].
However, to increase the use of energy efficiency and reduce carbon emissions, the government in several regions in Indonesia began implementing policies related to the use of induction stoves. One area that has declared this is West Java [18]. Besides, to increase induction stove users, PLN - Greater Jakarta Distribution Unit offers a discount on the cost of adding power for customers who use induction stoves or electric motors [19]. The conversion of the use of LPG stoves to induction stoves is actually in line with the realization of the 35,000 MW megaproject, which was intensively realized by PT. PLN (Persero). On the other hand, the amount of distributed electricity and electricity consumers always increase, as shown in Figure 3. In 2018, the number of household electric customers even reached more than 65 million customers, while the R-1 group was 64,720,077 customers [4,20].

![Figure 3](image1.png)

**Figure 3.** Comparison between the number of electric customers and the distribution of electricity in Indonesia from 2011 - 2018 [4,20].

![Figure 4](image2.png)

**Figure 4.** Comparison between distributed electricity and electricity production in Indonesia from 2006 - 2018 [20,21]

To prove that Indonesia's electricity production is higher than demand, Figure 4 presents a comparison between electricity production and the amount of its distribution from 2006 to 2018. This fact becomes an opportunity to disseminate induction stoves among Indonesian society. Figure 5 presents a comparison between electricity and gas distribution in Indonesia from 2006 to 2018. It appears that gas distribution has stagnated since 2012. On the other hand, thedistributed
electricity continues to increase until it reaches around 240,000 GWh. This fact can be an opportunity for the conversion program of LPG stoves to induction stoves.

4. Review of efficiency and carbon emissions of induction stoves

This section will conduct a review of the efficiency of the induction stove, which includes aspects of energy used, cooking time, costs incurred, and carbon emissions compared to conventional electric stoves and LPG stoves. In Table 1, it appears that the cooking time using an induction stove is relatively shorter than conventional electric stoves or approaching LPG stoves. Thus, according to cooking time aspects, the induction stove is superior to conventional stoves and is equivalent (even in some cases shorter) with LPG stoves. Based on the aspect of energy consumed during the cooking process, it also appears that the induction stove is more efficient than other fuels.

![Figure 5](image_url)

**Figure 5.** Comparison between distributed electricity and distributed gas in Indonesia from 2006 to 2018 [21,22].

**Table 1.** Comparison of the performance of LPG stove, conventional electric stove and induction stove

| Dish                | LPG Stove | Conventional Electric Stove | Induction Stove |
|---------------------|-----------|------------------------------|-----------------|
|                     | $T_i$ ($^\circ$C) | $T_f$ ($^\circ$C) | Time (s) | Energy (kWh) | $T_i$ ($^\circ$C) | $T_f$ ($^\circ$C) | Time (s) | Energy (kWh) | $T_i$ ($^\circ$C) | $T_f$ ($^\circ$C) | Time (s) | Energy (kWh) | Ref. |
| Hard-Boiled Eggs   | 15        | 94                           | 1125            | 0.456   | 15            | 94                           | 3000            | 0.298   | 15            | 94                           | 542            | 0.169   | [5]  |
| Grilled Chicken    | 15        | 72                           | 510             | 0.427   | 15            | 72                           | 1575            | 0.281   | 15            | 72                           | 425            | 0.233   | [5]  |
| Steamed Fish       | 15        | 75                           | 620             | 0.439   | 15            | 92                           | 1525            | 0.250   | 15            | 92                           | 365            | 0.214   | [5]  |
| Water (350 cc)     | -         | -                            | -               | -       | 25            | 50                           | 304             | 0.034   | 25            | 30                           | 152            | 0.012   | [24] |
| Water (1 liter)    | 30        | 90                           | 251             | 0.208   | 30            | 90                           | 932             | 0.142   | 30            | 90                           | 332            | 0.108   | [23] |

In Figure 6, we present the amount of energy consumed by the stove when boiling 1 liter of water and its thermal energy to determine the energy efficiency of various stoves [23]. Through this curve, it can be calculated that the highest efficiency is successively achieved by induction stoves (74.03%), conventional electric stoves (56.29%), and LPG stoves (38.55%) [23]. The operational costs of a stove to cook 1 liter of water can be calculated through these data. For induction stoves, it is Rp. 158.4 (non-subsidized electricity costs Rp. 1,467/kWh), conventional
electric stoves are Rp. 208.3, and non-subsidized LPG stoves, which is Rp. 173.7 (LPG price of Rp. 11,583/kg) and if subsidized is Rp. 80 (LPG price of Rp. 16,000/3 kg). It appears that the operational costs of induction stoves are lower than all non-subsidized stoves.

In Figure 7, the carbon emission curves of the three stoves are presented. It appears that LPG stoves when working emit CO₂ and CO with a much higher amount compared to other stoves. When used to cook, LPG stoves can emit CO₂ up to over 2000 ppm and CO to around 13 ppm. The value is much higher than the induction stove, which has CO₂ gas emissions around 500 ppm and CO around one ppm with shorter cooking time. The source of carbon emissions from the induction stove may arise from heating the food itself. Therefore, if the Government of the Republic of Indonesia or related parties want to try to reduce carbon emissions in the household sector, the conversion of LPG stoves to induction stoves can be the right choice.

![Figure 6. Comparison of efficiency between LPG stoves, conventional electric stoves, and induction stoves in the process of boiling water [23].](image)

![Figure 7. Comparison of carbon emissions in the cooking process using LPG stoves, conventional electric stoves, and induction stoves: (a) CO₂ and (b) CO [5].](image)

5. The challenges of implementing induction stoves
In the previous section, we explained that induction stoves could be a clean and efficient cooking option. Carbon emissions and energy consumption and costs of induction stoves can be lower compared to conventional electric stoves and LPG stoves. However, some notes regarding the
challenges if the Government of the Republic of Indonesia adopts policies related to the conversion of LPG stoves to induction stoves as follows:

- The majority of electricity consumers in the household sector are low power customers. Although there is a program to increase electricity production in the 35,000 MW megaproject, a policy related to ease of power transfer is needed. This is because induction stoves that are marketed mostly require high power, which is around 1000 W. Policies related to the transition of power types are needed, and the use of induction stoves does not interfere with community activities.
- Induction stoves can reduce carbon emissions significantly in the cooking process. However, what should be noted is that as long as the source of electricity supplied to the community is still dominated by fossil fuels, of course, the reduction in carbon emissions in the household sector will shift to increasing carbon emissions in power plants. Therefore, efforts to apply low-carbon renewable energy in electricity sources need to be continuously improved.
- The operational costs of induction stoves are indeed lower compared to electric filament stoves and LPG stoves. However, the price of an induction stove is currently higher compared to others. Therefore, government intervention is needed, such as the price of induction stove subsidies. Besides, sustainable research related to the production of an induction stove is needed to reduce its price.

6. Conclusions
Induction stoves have better energy efficiency and lower operational cost compared to conventional electric stoves and LPG stoves. Even based on aspects of carbon emissions, the induction stove is still superior to others. Therefore, to achieve energy sustainability and reduce carbon emissions, the conversion of LPG stoves to induction stoves can be one of the policy options that can be undertaken by the Government of the Republic of Indonesia. However, the conversion program will face challenges such as the majority of electricity consumers in the household sector are low power customers, efforts to continue producing electricity from renewable energy, and it requires efforts to reduce the price of induction stoves on the market.

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