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Energy Sustain Dev. Author manuscript; available in PMC 2019 October 01.

Published in final edited form as:

Energy Sustain Dev. 2018 October ; 46: 71–81. doi:10.1016/j.esd.2018.05.011.

The Mega Conversion Program from Kerosene to LPG in Indonesia: lessons learned and recommendations for future clean cooking energy expansion

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Abstract

Background: In 2007, the Indonesian Government instigated a national program to convert domestic kerosene users to liquefied petroleum gas (LPG) for cooking. This was primarily motivated by the rising cost of kerosene subsidies.

Objective: To review the national conversion program and LPG scale up by evaluating its impacts, including assessing sustained changes in cooking behaviour and consequent reductions in exposure to household air pollution (HAP).

Methods and data sources: Searches of peer-review and grey literature in both English and Bahasa Indonesian were conducted and supplemented by interviews with key informants, data from the National Statistics Agency and results from household surveys. The data were extracted and analyzed using an Implementation Science approach.

Results: The main kerosene to LPG conversion phase took place in highly populated kerosene dependent areas between 2007-2012 reaching over 50 million households, approximately two thirds of all households in Indonesia. Since then the drive to expand LPG use has continued at a slower pace, especially in more remote provinces where solid fuel is more widely used. Over 57 million LPG start up kits were distributed as of 2015. Beginning in 2018, the open subsidy for LPG is expected to be replaced by one targeted at lower income households. While the main conversion phase has been highlighted as an example of effective and impressively fast fuel switching at scale, the impact on domestic biomass use remains limited.

Conclusions: Addressing HAP and the health impacts associated with kerosene and biomass use was never an objective of the program. Consequently, there is limited evidence of impact in

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this area, and in hindsight, missed opportunities in terms of influencing cooking behavior change among biomass users, who are more at risk.

Keywords

LPG; kerosene; clean fuels; clean cooking; fuel subsidies

1. Introduction

Indonesia is the world's largest archipelago and the fourth largest country, with over 260 million inhabitants in 2016. It is classified as a lower-middle income country with GDP per capita of US$3,570 and an urban population of 55% (World Bank, 2017). Household air pollution (HAP) from daily use of solid fuels is an important contributor to mortality and morbidity in Indonesia. In 2016, an estimated 60,835 deaths (4% of all deaths) and 33.7 million lost disability-adjusted life years (DALYs) (2.5% of all DALYs) due to ischemic heart disease, stroke, chronic obstructive pulmonary disease, lung cancer, and acute lower respiratory infections were attributed to HAP (IHME, 2017). These numbers have dropped from 1990, when HAP accounted for 8% of all deaths and 6% of all DALYS reported.

In 2007, the Indonesian Government embarked on the largest household fuel conversion program for cooking that had been attempted at that time, to phase out the domestic use of kerosene completely in five years and replace it with Liquefied Petroleum Gas (LPG). LPG is an abundant byproduct of oil refining and natural gas extraction, and is a clean-burning and portable fuel used as the primary or secondary cooking fuel by almost 3 billion people across developing and developed countries (Bruce, Aunan, & Rehfuess, 2017; WLPGA & Argus, 2018).

In terms of the Government's stated objectives, the program was successful in reducing domestic kerosene use by 92% in less than 10 years. While subsidy reductions were achieved, the cost effectiveness of these reductions need to be considered in light of a high initial subsidy and the sustainability of the changes in terms of rising energy prices and growing energy needs. The impact on household cooking behavior, sustained usage of LPG for daily cooking and associated health gains has also been less clear.

The objectives of this investigation were to review the conversion program in terms of sustained changes in cooking behaviour and consequent reductions in exposure to HAP. It also sought to characterize the factors that contributed to successful program implementation and determine what lessons might be transferrable to other countries seeking to rapidly move towards clean cooking, particularly at scale.

2. Sources, methods and approach

Multiple sources of quantitative secondary data, combined with primary qualitative data, have been used for this case study investigation. Searches of peer-reviewed and grey literature concerning the conversion program and current household fuel use were conducted in both English and Bahasa Indonesian. Searches were conducted in Scopus and Google Scholar using the keywords 'LPG' and 'Indonesia' in order to be as inclusive as possible.

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Primary fuel usage data were extracted from the National Statistics Agency (Badan Pusat Statistik Indonesia) and from household surveys published in peer-reviewed and grey literature identified through the search, which also provided information on cooking fuel use practices and expenditure. Data were also accessed from the Ministry of Health and the National Consumer Protection Agency with online local newspaper searches being carried out in Bahasa Indonesian using the terminology of LPG consumer use and safety. It is rare that exchange rates accompany figures, so these are not always included when presenting costs that are only given in US dollars rather than in Indonesian rupiah (IDR). Where calculations have been made by the authors, unless otherwise specified, the exchange rate used is the exchange rate as of January 1st in the quoted year; consequently some costs given in US dollars might be different than those published in previous literature.

We contacted all stakeholders involved in program implementation in order to review data that existed. Six semi-structured face-to-face interviews plus a telephonic interview were conducted with the main program implementers and other key stakeholders with continued follow-up. Those interviewed included representatives of the Ministry of Energy and Mineral Resources (MEMR) (Analyst, Price and Subsidy Directorate), the Industry and Energy Agency of Jakarta Provincial Government (Head of Energy and Electricity, and colleagues), the National Oil Company Pertamina (Assistant Manager - Planning and Evaluation, Senior officer and colleagues), as well as the World Bank in relation to the Indonesia Clean Stove Initiative (Senior Energy Specialist) and the International Institute for Sustainable Development (IISD), Indonesia office (Indonesian Program Co-ordinator, Global Subsidies Initiative, (GSI)[1]). Due to the length of time that had passed since the program's initial implementation in 2007 we were unable to follow-up with some stakeholders, primarily the Ministry of Women's Empowerment and Ministry of Social Affairs where no program records appeared to have been retained. Informal enquiries were also made with the World Health Organization Regional Office for South East Asia, international and local NGOs focusing on clean cookstoves such as GERES and Kopernik, the Air Pollution Division of the Ministry of Environment and Forestry, and the Economics Faculty of the University of Indonesia in Jakarta.

Two of the six interviews were conducted in Bahasa Indonesian and the rest in English. Interviews were digitally recorded, transcribed verbatim and translated into English when necessary. The interview data were extracted and analyzed in Microsoft Word using an implementation science approach (Glasgow, Vogt, & Boles, 1999). Data were synthesised according to the following categories: (i) program goals and geographical reach, (ii) program roll-out and sustained use of technology and fuel over time; (iii) environmental and health impacts; and (iv) where the program stands now.

[1]The IISD Global Subsidy Initiative supports international processes, national governments and civil society organizations to align subsidies with sustainable development. See http://www.iisd.org/gsi/.

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3. Kerosene to LPG conversion program

Background

Indonesia was, until the 1990s, a net exporter of oil and gas. The country has traditionally provided energy subsidies to its citizens, which peaked at 18% of total state expenditure in 2005 (Pertamina & WLPGA, 2012). These subsidies, including diesel, gasoline and kerosene, were justified as a form of social assistance. In 2007, kerosene was the primary cooking fuel for 37% of households (MEMR, 2016a) − 20.9 million households out of a total of 56.4 million (BPS, 2017) (see Figure 1). However, a decline in domestic supply and increase in oil prices meant the amount of subsidy the Government was providing for household kerosene was becoming onerous, climbing from USD $1.96 billion in 2005 to USD $5.24 billion in 2008 (Budya & Arofat, 2011). Reducing the subsidy by increasing the price of kerosene had resulted in serious rioting (Beaton & Lontoh, 2010). The overriding motivation for the conversion program was therefore to reduce the total subsidy while protecting households from economic shocks. Kerosene subsidies had already been phased out in the industrial sector in 2005 and fuel leakage from the subsidized domestic sector to the industrial sector (and even abroad where kerosene was more expensive) was further increasing the strain on the state budget (Pertamina & WLPGA, 2012).

Trends in primary cooking fuel usage from 2007 to 2015 are illustrated in Figure 1.

LPG was chosen as the conversion fuel for various reasons. Although the economic price per kilogram of LPG was 24% more expensive than kerosene at the time of the program launch in 2007 (IDR 7,966/US$ 0.89/kg for LPG compared to IDR 5,570/US$ 0.61/l for kerosene) it was calculated that LPG’s higher calorific value would make it cheaper to subsidize, allowing the Government to maintain low and constant energy costs to the consumer at lower budgetary cost (MEMR, 2007). The University of Trisakti in Jakarta estimated that 1 litre of kerosene was equivalent in end use to 0.39 kg of LPG and this was used as the basis for calculating subsidy savings (Budya & Arofat, 2011). Secondly, LPG was chosen as elements of the supply chain were already in place (e.g. storage tanks and filling plants) and it was the easiest fuel to distribute to rural and remote populations across a vast territory. Indonesia is made up of many islands with seismically active volcanoes impeding grid infrastructure. It is not clear if cost benefit analyses were done on alternative fuels for cooking, but these were not seen as commercially developed enough to consider at the time (Budya & Arofat, 2011).

In 2008, Pertamina commissioned a private company, GreenWorks Asia, to calculate projected greenhouse gas emission reductions as a result of the program but health indicators were not considered (Budya & Arofat, 2011). Table 1 indicates that in comparison to LPG, kerosene contributes three times as much carbon monoxide (CO) emissions and 30% more particulate matter (PM) per unit of energy delivered to the cooking pot. Kerosene is now also categorized as a polluting fuel based on assessments of the relative risks and exposures associated with its use. The World Health Organization (WHO) Indoor Air Quality Guidelines recommend against the use of kerosene as household fuel for both cooking and lighting (WHO, 2014). Overall, LPG is a clean fuel in comparison to other major fuels for cooking, meeting guidelines for the highest tier level (Tier 4) under the International

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Organization for Standardization, International Workshop Agreement 11 (ISO/IWA-11) (Shen et al., 2018).

Program goals and implementation process

The kerosene to LPG conversion program, also known as the *Zero Kero Program*, was initiated in 2007 based on the Presidential Decree No. 104/2007. The initial program goal was to convert 6 million households in 2007 and approximately 42 million households and micro-businesses nationally by 2012 (MEMR, 2007). This was approximately two-thirds of the number of households estimated to be in the country in 2012 and included households that used kerosene not as their primary fuel. (MEMR, 2016a).

A taskforce chaired by MEMR was set up for the implementation of the scheme, comprised of the Ministries reported in Table 2 (MEMR, 2007).

Pertamina, as the only wholesale LPG marketer in the country, was given the sole license to supply domestic LPG under the program. Pertamina was initially concerned that lower subsidies would result in lower revenues to invest in infrastructure and wanted a longer time-frame for implementation in order to expand the LPG supply and ensure adequate storage facilities and filling stations to meet the ambitious program target.

The leadership of the Vice President Jusuf Kalla in driving the program through was mentioned by interviewed stakeholders as a key factor influencing the success of the program. Parliamentary approval was key to create the legal and regulatory framework, as well as the enforcement capacity needed for widespread LPG dissemination (Budya & Arofat, 2011; MEMR, 2007; Pertamina & WLPGA, 2012).

Provincial Governments also had a key role in implementation with responsibility for: (i) licensing LPG distributors to ensure regular supply; (ii) regulating the LPG retail price to accommodate additional costs for transportation; and (iii) targeting households for conversion. The provincial Government of Jakarta, for example, specifically targeted households with expenditure of less than IDR 1,500,000 (about US$ 167) a month and without an LPG stove (Jakarta Provincial Government, 2011).

Phases of Conversion

Implementation focused on areas with LPG infrastructure readiness, ease of distribution and high consumption of kerosene. Consequently, the initial focus was on the capital region in Western Indonesia, which is highly populated. About half of the country’s population live on the island of Java.

In total, there are 34 Provinces in Indonesia (see Figure 2). The program was divided into several stages. Eight provinces a year were targeted in the first three years of the program (yellow, green and orange in Figure 2) with a primary focus on bigger cities and urban areas; a further 5 between 2012 and 2015 (blue), and since 2016 targetted areas have been those previously considered out of scope in the Eastern part of the country - Nusa Tenggara, Maluku and Papua, plus further consolidation on islands off Sumatra (red circles). This

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involves the construction of 5 new LPG primary storage facilities for a total storage capacity of 6,000 tons at a cumulative cost of IDR 871.45 billion (US$ 62 million) (MEMR, 2016b).

As part of the conversion program, free LPG starter packages were distributed to households and micro-businesses consisting of a 3kg filled cylinder (chosen for easy handling), a one-burner stove, a rubber hose and a regulator. The cost to Pertamina of one conversion package is estimated at around IDR 300,000 (US$ 33 in 2007 or US$ 21 in 2017, due to the drop in value of the Indonesian Rupiah) (Interview with Pertamina). By 2010 the original target of distributing 42 million starter packages by 2012 was reached (see Figure 1) and the target was increased to 54-58 million units (Pertamina & WLPGA, 2012). By 2015, over 57 million starter packages were distributed (MEMR, 2016b). While the number of microbusinesses (e.g. food street vendors) converted to LPG has not been clearly tracked, the Industry and Energy Department of the Jakarta Province indicated that 6% of their support was targeted to micro-businesses in Jakarta (Interview with Industry and Energy Agency of Jakarta Provincial Government).

The Ministry of Industry supported the early phase of the conversion in terms of ensuring the LPG starter packages were ready for distribution and developing an Indonesian National Standard for the LPG stoves, hoses and regulators (Pertamina & WLPGA, 2012). The number of cylinders initially injected in the early phase of the conversion program was insufficient to meet demand, so local manufacturing of cylinders quickly became a job growth area. The number of cylinder manufacturing centres grew from 13 to 67 by 2012. However, manufacturing capacity quickly overshot actual cylinder demand, reaching a national production surplus of 7 million cylinders per month in 2012 (Pertamina & WLPGA, 2012). This created opportunities for illegal cylinder filling, as further explained in the ‘cost and subsidy savings’ section later in the document.

Consumption of LPG and Kerosene

Provincial authorities were responsible for withdrawing kerosene sale licenses and distributing LPG sale licenses, and needed to pass regulations to do this. They faced challenges in streamlining supply and segmenting distribution channels (Interview with Industry and Energy Agency of Jakarta Provincial Government).

Overall, domestic kerosene consumption in Indonesia shrank dramatically, from 10 million kiloliters (kl) in 2006 to 0.8 million kl in 2015 – a 92% reduction in use. In the same period, LPG household consumption rose from 1.1 million tons (Mt) to 6.3 Mt in 2015 (Pertamina, 2017b) contributing to 8% of Indonesia’s total energy mix (MEMR, 2016a). As shown in Figure 4, this corresponds to an increase in LPG consumption from 4.7 kg/capita in 2007 to 24.4 kg/capita in 2015 and a concomitant decrease of kerosene from 57.3 kg/capita to 3.1 kg/capita in the same period. Compared to the global LPG market, Indonesia started with a low LPG penetration (less than 5 kg/capita per year), which is comparable to current LPG penetration levels in many Sub-Saharan African countries (Argus & WLPGA, 2016). It then doubled its penetration in just a few years and by 2015 it reached penetration rates similar to those of mature LPG markets such as Brazil (25.5 kg/capita in 2014). The data presented in Figure 4 take into account population growth, which has increased from 214 million in 2001 to 258 million in 2015.

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Pertamina secured LPG supply (increasingly imported over time) based on five and ten-year contracts, and between 2007-2015 added new LPG storage facilities in Java and other parts of the country to match demand. Oil and gas are split into upstream and downstream businesses and it is unclear to what extent Pertamina was able to invest in LPG production plants as domestic supply was shrinking. In terms of LPG refilling stations (also called bottling plants), 395 new stations were created during the main conversion phase (2007-2012), in addition to the 66 already operating in 2006 (Pertamina, 2016). As of 2017, there were 600 refilling stations across Indonesia with an estimated 3kg cylinder capacity of 6.5 million cylinders/day (Pertamina, 2016). In Jakarta itself, there were 15 refilling stations, 2,071 LPG wholesalers and 2,753 LPG retailers in 2017 to service a population of at least 10 million. However, it is not clear how this compares with those previously working in the kerosene supply chain (Interview with Industry and Energy Agency of Jakarta Provincial Government).

In 2007, only 11% of LPG was imported; by 2015, imports reached 64% to meet the increasing demand (MEMR, 2016a). The Government is now seeking to produce dimethyl ether (DME) from coal to reduce exclusive reliance on LPG (as dimethyl ether can be blended with LPG and be used as a domestic cooking fuel without modifications to equipment or distribution networks) (Sundaryani, 2017). China, for example, has been using LPG-DME blends (20% DME in LPG) for domestic cooking applications, but DME is more corrosive and there is some concern in the industry about the long term effects of DME-LPG blending on LPG equipment and components (leading to more leaks and thus more fires and explosions) (Larson & Huiyan, 2004). Thermal efficiency of LPG stoves is also reduced the more DME is in the blend (Arya, Tupkari, Satish, Thakre, & Shukla, 2016).

Cost and subsidy savings

According to MEMR figures, the conversion cost of the 57.2 million starter packages and their distribution between 2007 and 2016 is estimated at IDR 13.63 trillion or US$ 1.02 billion[2] (MEMR, 2016c).

The Government set the retail price in 2007 at the subsidized price of 4,250 IDR/kg (0.47 US$/kg) so a 3kg cylinder would cost IDR 12,750 (US$ 1.42) (Budya & Arofat, 2011). In comparison, the average cost of subsidized LPG in India for below poverty line households in 2017 was around 0.53 US$/kg (Indane, 2017) and around 0.97 US$/kg in Cameroon, where the LPG is universally subsidized (AllAfrica, 2016). Regional governments were also authorised to regulate the retail price to accommodate additional costs for transportation. In Jakarta, the highest retail price for a 3kg cylinder reported in 2016 was IDR 16,000 (US $ 1.20) (Pertamina, 2017a).

The total subsidy saving for the government between 2006 to 2016, compared to subsidizing kerosene at the historical rate and taking into account the starter package cost, is reported at IDR 216.4 trillion (US$ 15.6 billion) (MEMR, 2016c). However, while there have been savings in terms of subsidizing LPG instead of kerosene, with declining oil production and growing energy demands the cost of Government energy subsidies has continued to rise

[2]Exchange rate IDR 13,350 = US$ 1 used in MEMR conversions.

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relative to actual fuel cost (Asmarini, 2017). These are the very same factors that informed the decision to shift from kerosene. The cost of the LPG subsidy also remains highly unpredictable, fluctuating with the crude oil price. For example, the LPG subsidy cost to the government was almost twice as much in 2014 as in 2015, costing IDR 48.9 trillion (US$ 4 billion) in 2014 compared to IDR 25.8 trillion (US$ 2.1 billion) a year later (GSI, 2017). In 2016, Parliament agreed that further reform was needed with subsidies retained for LPG but only if targeted at poorer users (GSI, 2017).

Pertamina reported US$1.7 billion of direct investment as of 2009 to expand infrastructure (Budya & Arofat, 2011) and US$1.9 billion of investment was reported in a presentation given in 2016 (Pertamina, 2016). However, between 2008 and 2013 they also reported losses totaling IDR 22 trillion (quoted in source as US$1.5 billion) because of 12kg LPG refills being sold below market price (Toft, Beaton, & Lontoh, 2016). To address this, Pertamina tried to increase the price of 12kg cylinder refills in September 2014 (GSI, 2015). However, the difference between the subsidized price of LPG in 3kg cylinders and the unsubsidized price of LPG in 12kg cylinders created an arbitrage opportunity exploited by gray-market refillers and consumers willing to buy from them. While many consumers who used to purchase 12kg refills prior to the conversion program migrated to the cheaper 3kg refills, some bought 12kg refills from gray market refillers at the subsidised price, with concomitant safety issues.

Another attempt to increase revenue for unsubsidized fuel was the introduction in 2015 of a new 5.5kg cylinder. This was also to prepare for an anticipated end to uniform subsidies for 3kg cylinders (see section 6). The new 5.5kg cylinders are branded in pink, lighter in weight and promoted as safer than 3kg cylinders to encourage transition for so-called ‘capable communities’ who can afford the unsubsidized price. The 5.5kg LPG refill costs around IDR 64,000 (US$ 4.70), corresponding to 11,600 IDR/kg (0.90 US$/kg) - almost three times the price of 3kg cylinder refills. To date marketing has been targetted in East Java, Bali and Nusa Tenggara with uptake reported at a monthly average of 107 tonnes as of September 2017 (Hariyanto & Putra, 2017).

4. Initial program roll-out, adoption and usage of LPG

Before the launch of the program, Pertamina conducted two market tests (with 500 and 25,000 households, respectively) to check acceptance and test the distribution model, which offered encouraging results (Budya & Arofat, 2011). The Ministry of Woman’s Empowerment was initially tasked with building the consumer education component for the program, but Pertamina, as the direct implementer took on a key role in terms of addressing consumer concerns relating to supply, cost and safety.

Pertamina reported significant opposition from kerosene retailers worried about the lower margin and initial investment costs in switching to selling LPG in the first six months of implementation in Jakarta. Attempts to address this included establishing incentives and loans, and offsetting the cylinder warranty by the margin (Pertamina, 2008). Some protests arose also from the population as a result of inflation in both kerosene and LPG prices during the initial kerosene withdrawal period, and reports of kerosene scarcity outside

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conversion areas (which may have been a result of kerosene being sold from unconverted areas to converted areas). Pertamina addressed this concern by ensuring additional LPG buffer stock in areas undergoing conversion (Budya & Arofat, 2011) and general opposition diminished over time as the benefits of the program were demonstrated (Pertamina & WLPGA, 2012).

LPG affordability, access and safety

The distribution of the free starter packages and the fact that subsidized LPG was going to be cheaper than kerosene meant that the program taskforce expected little opposition to switching by kerosene consumers (while biomass users were never a target of the program). Reliability of supply was anticipated to be a greater issue, especially during the early stages of the conversion. In 2009, a household study in Central Java and Yogyakarta carried out by GERES found that unsurprisingly, affordability and accessibility were the key determinants in fuel choice (World Bank, 2013). Based on a 2007 market survey with 550 respondents in Central Java, the weekly usage of cooking with subsidized kerosene was estimated at 4.4l compared to approximately 2kg of subsidized LPG, costing US$1.10 and US$0.85 respectively (Budya & Arofat, 2011).

In the initial program roll-out, Provincial Governments collected information on accidents which were then investigated to ensure they were not a result of faulty products. However, no consolidated record of accidents seems to have been kept and identified records are sparse. The data available is summarized in Table 3. According to the Industrial and Energy Agency of Jakarta, the number of accidents was so small as to not impact consumer uptake (Interview with Industry and Energy Agency of Jakarta Provincial Government).

Fuel stacking as common practice

According to the Indonesian National Statistics Agency, the number of households indicating that LPG was their main cooking fuel in 2015 was 68.8% (BPS, 2017) (see Figure 1). Of the remaining households, 4.4% reported kerosene as their main cooking fuel, 24.4% firewood (with 14.1% in rural areas and 10.3% in urban areas), 0.6% electricity, and less than 0.2% charcoal (BPS, 2017). Figure 6 shows the information for LPG, firewood and kerosene primary usage per province, in the order in which provinces were converted. With the exception of the Bangka Belitung Islands, the eight provinces targeted since 2012 show little or no change in LPG primary usage to date. Kerosene still accounts for between 16%-52% of household primary fuel use in these eight provinces, which are those with more dispersed populations and where LPG distribution channels remain undeveloped. Of the provinces converted between 2007-2012, there is quite a varied picture. Jakarta shows both the smallest percentage increase in LPG primary users at 61% (having 34% primary users already in 2007) and the greatest percentage decrease in firewood primary users at 81% (although, in actual terms, it has the smallest number of firewood users). Two provinces in North Sulawesi show the greatest percentage increase in LPG primary use at 98%, while West Sumatra shows the smallest decrease in firewood primary users at 28% (BPS, 2017).

However, while primary fuel usage statistics are encouraging and show a significant switch to LPG, field studies with questions on secondary fuel usage show a high degree of fuel

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stacking (i.e. the side by side use of different stoves and cooking fuels). Total energy consumption figures provided by MEMR also indicate a continued high use of biomass that if correct, challenge the primary fuel usage figures (MEMR, 2016a).

A 2010 survey of 550 households across urban, peri-urban and rural sub-districts in Central Java found that while the conversion program had been successful in shifting use from kerosene to LPG, LPG was being used alongside traditional solid fuels rather than as a substitute (see Table 4). The survey showed that fuel stacking increased in 17% of the surveyed households after the conversion program (Andadari, Mulder, & Rietveld, 2014). One change documented was an increase in electricity use for cooking, which was attributed to households having increased income after switching to LPG from kerosene, as well as to the higher cost of unsubsidized kerosene for lighting compared to electricity.

A similar study conducted in 2013 under the World Bank Clean Stove Initiative (CSI) involving a survey of 1,434 households in peri-urban Yogyakarta, Central Java, showed that only 27% of the surveyed households used a single fuel (ASTAE, 2015; Durix et al., 2016). The rest used a mix of LPG, firewood and/or electricity (e.g. use of rice cooker or rice warmer) for cooking, warming food and boiling water (see Figure 6). Biomass tended to be preferred for boiling water.

The degree of LPG adoption and usage was also shown to be strongly correlated with household income and age of the main cook. Findings from the CSI study showed that the average monthly income of those that used LPG was significantly higher than that of households that did not use LPG (see Figure 7), while main cooks under age 35 were more likely to use LPG than those over 55 (ASTAE, 2015). Andadari and colleagues also reported that LPG adoption was positively correlated with the respondent’s level of education (Andadari et al., 2014).

Between 2007 and 2015, LPG conversion packages were distributed to two-thirds of Indonesian households. One third of these households were not previously using kerosene; yet it is not clear how much solid fuel users have reduced their reliance on solid fuel. While the Indonesian National Statistics Agency report a decrease in primary fuelwood usage from 50% to 24.4% between 2007 and 2015 (BPS, 2017), field studies discussed above show that most households continue to use it in combination with LPG. There is no evidence that the program implementers considered that for most biomass fuel users, LPG did not compare favorably in terms of affordability.

The continued use of solid fuel outside urban centers is primarily because LPG cannot compete with firewood and crop residues on affordability, as the latter can be collected for free. In the CSI pilot study, 77% of solid fuel users surveyed collected free biomass, about 13% partially collected and purchased it, and the remaining 10% paid for it. Biomass-only households were estimated to use approximately 153 kg of biomass per month, with households that used both biomass and LPG using only 9 kg less biomass (ASTAE, 2015). Although users reported about 2 hours a week spent to collect biomass and an increased cooking time of 13 to 14 minutes per day plus the time to light the fire and prepare the fuel, they did not see this as an issue that would influence fuel-switching. Those using biomass

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also tended to have larger families and were cooking larger volumes. In addition, the reduced cooking times of LPG users were affected by a higher proportion using electric rice cookers (ASTAE, 2015).

In terms of fuel expenditure, the 2010 Central Java survey reported an average expenditure of IDR 40,000 (US$ 4.20) on LPG per month (i.e. about 9 kg/per household or 3 small cylinders per month), which on average was equivalent to 3% of total household monthly expenditure (Andadari et al., 2014). Data on average monthly fuel costs from the 2013 CSI survey show an increase in spending on fuel in relation to income (see Figure 8), with users from the highest quintile spending around IDR 55,600 (US$ 5.75) on LPG per month (i.e. about 11 kg/per household or almost 4 small cylinders per month) (ASTAE, 2015).

Promotion of improved biomass cookstoves and biogas digesters

Recognizing that lower income and biomass using households were challenged to adopt and convert to LPG, especially in rural and remote areas, the MEMR Directorate of Bioenergy and the World Bank launched the Indonesia Clean Stove Initiative (CSI) in 2012. The initiative, which was part of a number of other similar World Bank/AusAID initiatives in East Asia and the Pacific, had the objective of focusing on the 25 million households that had not converted to LPG as their primary/secondary cooking fuel. The announced goal was to deliver 10 million improved biomass cookstoves by 2020 with the goal of reducing exposure to HAP (Zhang, Tuntivate, Aristanti, & Wu, 2013).

The initiative took a phased approach. Based on the initial findings from Phase I (2012-2013) the second Phase (2014-2016) focused on four areas: (i) establishing stove standards and testing facilities (ii) strengthening institutions and building stakeholder capacity (iii) designing and implementing a results-based financing pilot; and (iv) designing and preparing the master plan for a national program (World Bank, 2014). As of 2016, the results-based financing pilot incentivized ten private companies to sell about 10,000 improved biomass stoves in two pilot areas, Yogyakarta and Central Java. The draft master plan is currently under consideration by the government and information on stove types being promoted and tier levels is not yet in the public domain (interview with World Bank).

Kopernik, an Indonesian NGO promoting biomass stoves, claimed that the distribution of free LPG packages as part of the conversion program created challenges in getting solid fuel users to purchase improved biomass stoves. They resorted to loaning the improved biomass stoves so that users were able to experience the benefits before purchasing (Kopernik, 2014).

Another smaller program targetted at rural farmers and supported by the Dutch Government – the household Biogas Program or BIRU program – started in 2009. As of 2017, 21,316 biogas systems have been installed in ten provinces of Indonesia (an average of nearly 2700 digesters a year) (BIRU, 2017).

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5. Emission and health impacts of the Zero Kero conversion program

$CO_2$and black-carbon emissions

Based on the reductions in kerosene and increase in LPG use, Permadi et al. estimated that the net reduction of combined Global Warming Potential (GWP) weighted emissions[3] in the first three years of the conversion program (2007-2010) was 8.1 Mt of CO_2 equivalent, or an approximately 31% reduction from the 2007 level. With complete elimination of domestic kerosene for cooking this was projected to rise to 1.1 Mt of CO_2 equivalent from the 2007 level or a 42% reduction (Permadi, Sofyan, & Kim Oanh, 2017). However, while successful in programmatic terms, this is only a 5% reduction of emissions from residential cooking overall due to the significant continued use of solid fuel.

In terms of short-lived climate pollutants ($PM_{2.5}$, sulphur dioxide, carbon monoxide, nitrogen oxide, black carbon, organic carbon and non-methane volatile organic compound) the same study estimated total polluting emissions would have decreased by 40% in 2010 and by 55% at program completion in 2012. Sulphur dioxide was estimated to have decreased the most at 90% and nitrogen oxide the least at 13% (Permadi et al., 2017). However, a reported significant increase in biomass open burning, as described in the same study, may mean that exposure is not reduced overall.

Exposure and Health

The 2016 Global Burden of Disease estimates indicate reductions in mortality and morbidity rates associated with exposure to HAP from solid fuel use in Indonesia since the program was implemented. Mortality is estimated to have halved from 109,846 in 1990 to 60,835 in 2016, representing 8% and 4% of total deaths respectively, while morbidity is estimated to have decreased from over 39.6 million to 33.7 million DALYs, corresponding to 6% and 2.5% of total DALYS in the same years (IHME, 2017). The Indonesian population has notably increased from 181 million to 258 million over the same time period (World Bank, 2017).

However, these mortality and morbidity figures are only based on primary fuel use estimates collected at the national level. Actual fuel consumption figures, fuel-stacking and continued use of kerosene for lighting are likely to mean that the real levels of HAP and exposure to toxic pollutants have not decreased as much as these estimates suggest. To the best of our knowledge, no longitudinal studies have been conducted to compare exposure to HAP before and after the conversion program. A cross-sectional study carried out in 2011 by Huboyo et al. reviewed 24-hour exposure at the cooking site of 40 dual LPG and firewood users in two locations in West and Central Java (high-altitude and low-altitude rural areas). This showed that the average $PM_{2.5}$ emission rate at the cooking site was approximately 0.57 mg/min (Huboyo, Tohno, Lestari, Misohata, & Okumura, 2014), twice the level recommended by WHO IAQG (i.e. 0.23 mg/min for unvented stoves) (WHO, 2014). The study also reported that $PM_{2.5}$ concentrations in the living area were almost twice as high in

[3]GHGs (CO_2, CH_4 and N_2O) and SLCPs e.g. BC particles and ozone precursor gases (NOx, NMVOC and CO), and cooling agents, e.g. OC particles and SO_2 weighted against CO_2 over a 20 year horizon.

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high-altitudes areas due to longer cooking times with firewood and smaller kitchens and ventilation areas.

At the national level, although no evidence is available to directly attribute national health improvements to the *Zero Kero Conversion Program*, health statistics data indicate a decline in the prevalence rate per 1,000 individuals of four diseases that can be linked to HAP, based on available data for 2007 and 2013. Prevalence rates for pneumonia decreased from 2.1% to 1.8% between 2007 and 2013; Chronic Obstructive Pulmonary Disease (COPD) from 11.2% to 5.1%; Acute Respiratory Infection (ARI) for children below 5 years from 11.2% to 5.1%; and tuberculosis from 0.99% to 0.4% (Riset Kesehatan Dasar, 2017).

Health statistics data for the same diseases were also available at the provincial level. For provinces completely converted in 2013, it was observed that a majority exhibited a decrease in the prevalence rate of the four diseases above between 2007 and 2013 (Riset Kesehatan Dasar, 2017). However, it should be noted that this reduction, most evident for ARI and tuberculosis, was also observed in provinces which were not converted in 2013. Both national and provincial-level health data for stroke and hypertension, however, generally showed an increase in rates from 2007 to 2013.

It is important to frame the above statistics in the context of national and international trends of increased wealth, increased access to medical care, and complex changes in nutrition, making the impact of fuel conversion on health outcomes difficult to assess. The Indonesian public health agenda has been focussing on addressing the health impacts of smoking and changes in smoking will also impact results.

6. Where Indonesia stands now: announced subsidy reform

While universal energy subsidies (that is, subsidies to the price of energy itself) are easier to administer than targeted subsidies, they are often not very efficient and disproportionately benefit wealthier households (Pandey & Morris, 2006). International experience shows that only about 8% of all energy subsidies reach the lowest income quintile and that LPG subsidies can be even more regressive than average, with only 4% reaching the lowest income quintile and over 50% reaching the highest income quintile (Granado, Coady, & Gillingham, 2012). The 2016 Government proposals for subsidy reform are primarily being driven by relieving budgetary pressure with the added objective of improving social welfare.

Overall, Indonesia’s energy subsidies have continued to rise and there has been strong pressure, particularly from the international community, to reduce them and direct funds to infrastructure and social security instead. An LPG subsidy of IDR 46.87 trillion (US$ 3.5 billion) has been reportedly allocated in 2018 (Rambu Energy, 2017), but the Government has agreed to target it to 26 million households considered the poorest 40%, and address distribution in harder to reach areas (GSI, 2017). 2.3 million micro-businesses and an undisclosed number of farmers and fishermen are also expected to be targeted (GSI, 2017).

Proposals suggest that households will be targeted through registration in the Unified Database (UDB) for social protection programs and the subsidy for 3kg cylinders transferred using e-cash through smart-card technology, integrated with Indonesia’s banking system, the

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Sejahtera Family Card (Kompas, 2017a). The subsidy budget is based on each household using three 3kg LPG cylinders per month. This is in line with LPG actual use of 8-11 kg/per household per month as described by survey data reported in Section 4. However, challenges to this plan remain. Up to 2017, only 800,000 households have Sejahtera Family Cards, few anticipated end-users are registered and the number and locations of LPG distribution points do not yet match location of targeted populations (GSI, 2017; Kompas, 2017a). Furthermore, at least some Provincial Governments have expressed reluctance to take on the responsibility of deciding who is and isn't eligible to receive the subsidy (Interview with IISD official).

We also know that it is the poorest who tend to rely on biomass, and that fuel subsidies alone may not be effective without a targeted campaign that also takes into account the existing Clean Stove Initiative for improved biomass stoves and other opportunities.

7. Discussion

This case study offers a comprehensive summary of the existing literature and public information, supplemented by stakeholder interviews, in relation to the Indonesia LPG to kerosene conversion program from inception to date (2007-2017). Our findings confirm that the program was broadly successful in terms of shifting Indonesian households from kerosene to LPG for cooking and expanding the LPG market; this was primarily due to the fact that, in most cases, the shift to LPG was designed to be less expensive than not shifting for end-users and kerosene was taken out of circulation in conversion areas. Taking this and the speed of the conversion into account, the ability to ensure accessibility to the new fuel was particularly impressive, and was in part due to the national scale of the conversion, which realized substantial economies of scale in LPG infrastructure investments (bulk storage, filling plants, transportation and cylinder inventory).

Strong government leadership provided for an effective enabling environment and regulation of an affordable and accessible fuel supply. The national oil company, Pertamina was an effective implementer, in part due to its extensive operational capabilities controlling both kerosene and LPG supply systems nationally, while converting existing agents and retailers from kerosene to LPG meant supply chains did not have to be established from scratch. In addition, Indonesia, was already operating under the LPG 'cylinder recirculation model' (where empty cylinders are exchanged for filled ones), which is considered the safest and most sustainable LPG market model, as it gives the LPG company or marketer ownership and responsibility for its own distribution network and cylinder brands, discouraging illegal and unsafe practices such as micro-filling (WLPGA, 2012).

There was effective co-ordination between Ministries in implementing the program, although Provincial Governments initially faced challenges issuing retail permits and identifying beneficiaries perhaps indicating a need for greater central co-ordination and oversight of these functions, to avoid them becoming politicized. More detailed research into options for vertical integration between central and local implementation may be of interest going forward, particularly as local Governments may need to play a greater role in the areas still undergoing conversion and once the targeted subsidy is introduced in Indonesia.

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Assumptions of cost-effectiveness were backward looking based on a counter-factual comparison with earlier policy. The legacy of being a net oil and gas producer has meant that Indonesian Governments have tended to see oil and gas revenue as Government income, with subsidies as a component to be managed affordably within this. This has meant that successive Indonesian Governments have focused subsidy reform on fiscal concerns rather than articulated clear social concerns and, consequently, opportunities for greater developmental impact have been missed (Beaton & Lontoh, 2010). In comparison to other countries, Indonesia has also invested little in establishing a demographic database or financial inclusion policies, making targeted fuel support to poorer households more challenging. For example, in 2016, only 34% of adult Indonesians were reported as having access to a financial account compared to 63% of the Indian adult population (FII, 2017). Although in 2005 Indonesia did introduce a Direct Cash Assistance program (Banuan Langsung Tunai – BLT) intended to mitigate the impact of kerosene fuel-price rises on the poor, this relied heavily on provincial Governments identifying beneficiaries and appeared more suited to emergency relief than a sustainable long-term approach (Beaton & Lontoh, 2010).

The narrow objective of the Zero-Kero program meant that few program monitoring indicators were collected and there is very limited HAP exposure data available in the country as a whole. While health is stated as a driver for the Clean Stove Initiative launched in 2012 there is no Government program raising awareness of the health impacts of burning biomass in inefficient stoves to drive demand for change. Interview findings suggest a continuing division within the MEMR in terms of responsibility for different categories of users of domestic fuel and no involvement of health professionals. It is suggested that publicly highlighting existing health data that may be attributed to household air pollution could be a simple way of raising the issue, increasing support for behavior change without the need for additional resources.

8. Conclusions

The Indonesian Zero-Kero program achieved a five-fold national increase in LPG domestic consumption from 4.7 kg/capita in 2007 to 24.4 kg/capita in 2015. The strong government role and regulatory environment were essential to creating safe, reliable and nationwide distribution of the new fuel. Pertamina’s position as the nation’s sole national oil company allowed it to direct the conversion of existing fuel distributors to LPG and undertake infrastructure expansion at a rapid pace. The free initial LPG start-up package overcame the conversion cost to the consumer. However, while primary use of firewood is recorded as having halved over the same period, replacing a free fuel with a costed fuel such as LPG is challenging, particularly in rural areas, and the practice of fuel-stacking underestimated. LPG subsidies have replaced kerosene subsidies as a budgetary burden to the Government, which was the main driver of the conversion program. Plans for limiting subsidies to those who need them most are being considered but face a new set of challenges and it will be interesting for Indonesia to both learn from and compare progress with other countries who are further ahead in taking such an approach. It is suggested that without greater awareness raising on the health and social benefits of transitioning to clean fuel, health impacts will necessarily be harder to achieve.

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Acknowledgements

This work was supported in part through the Clean Cooking Implementation Science Network (ISN) with funds from the United States National Institutes of Health Common Fund program for Global Health. We are grateful for the assistance with data collection provided by Dr. Joni Jupesta and Rana Rafidah Giani.

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Highlights

- The Indonesian kerosene to LPG program is one of the largest household energy transition initiatives to have been carried out, with over 50 million households gaining access to LPG for cooking in 5 years.
- The transition is unlikely to have been carried out in the absence of Indonesia's fuel subsidy policies, which affect comparative analysis of the program's cost effectiveness.
- The degree of LPG adoption and usage is strongly influenced by household income, LPG infrastructure readiness and access to sales points.
- Biomass use as a secondary fuel is still high and there were missed opportunities to address its usage and health impacts both during the main program phase and in future plans.

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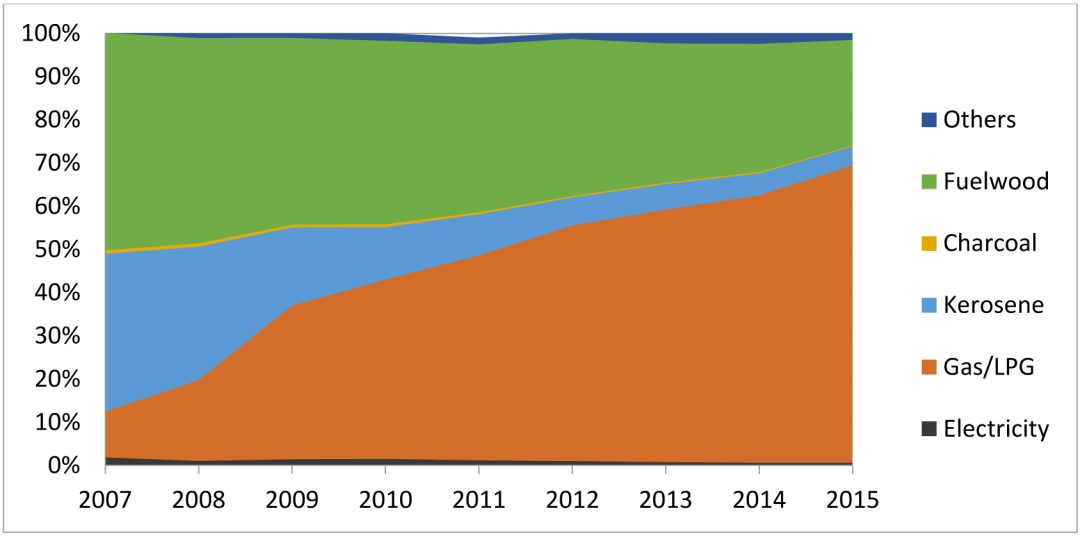

Figure 1. Percentage of households and their primary cooking fuel in Indonesia, 2007-2015
Source: Badan Pusat Statistik, 2017

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Figure 2. Phases of kerosene to LPG conversion by Province (2007-2016)
Source: Adapted from (Wiratmaja, 2016)

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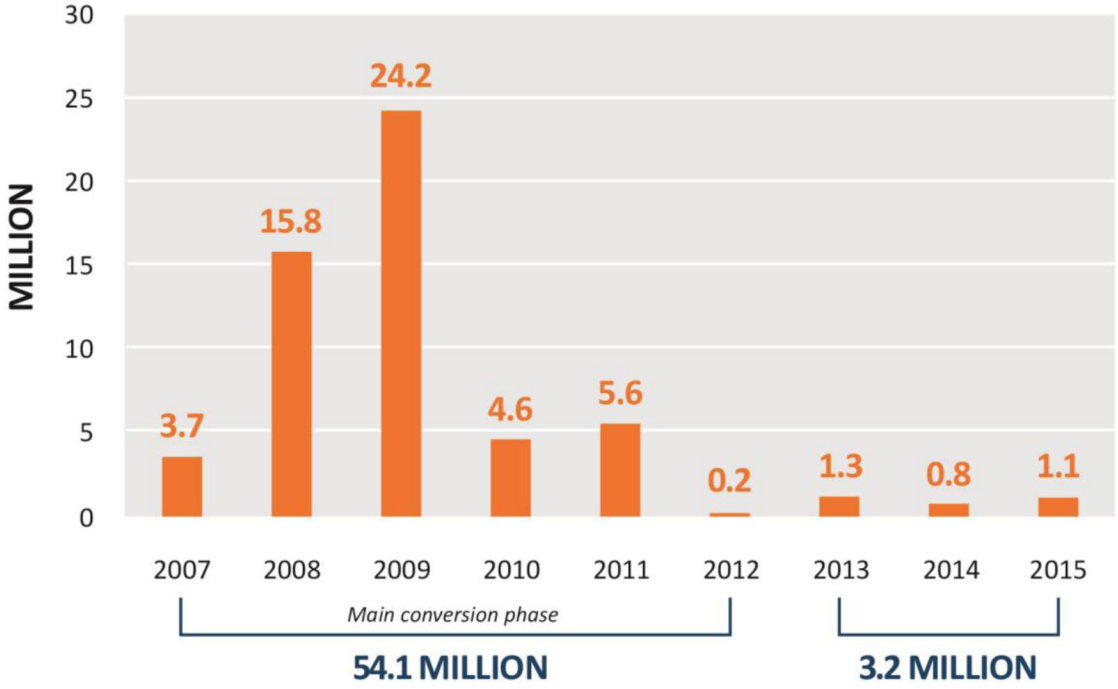

Figure 3. Number of free LPG starter kits distributed from 2007 to 2015 as part of the Zero Kero program

Source: Adapted from (MEMR, 2016b)

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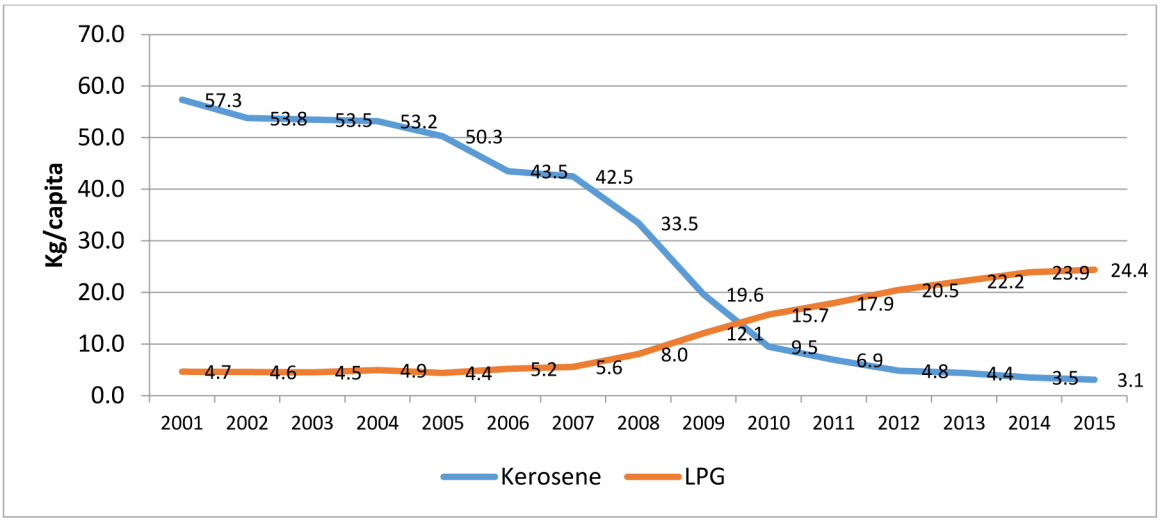

Figure 4. Kerosene and LPG Consumption (kg/capita), 2001-2015
Source: Authors' calculations based on released data (Pertamina, 2017b)

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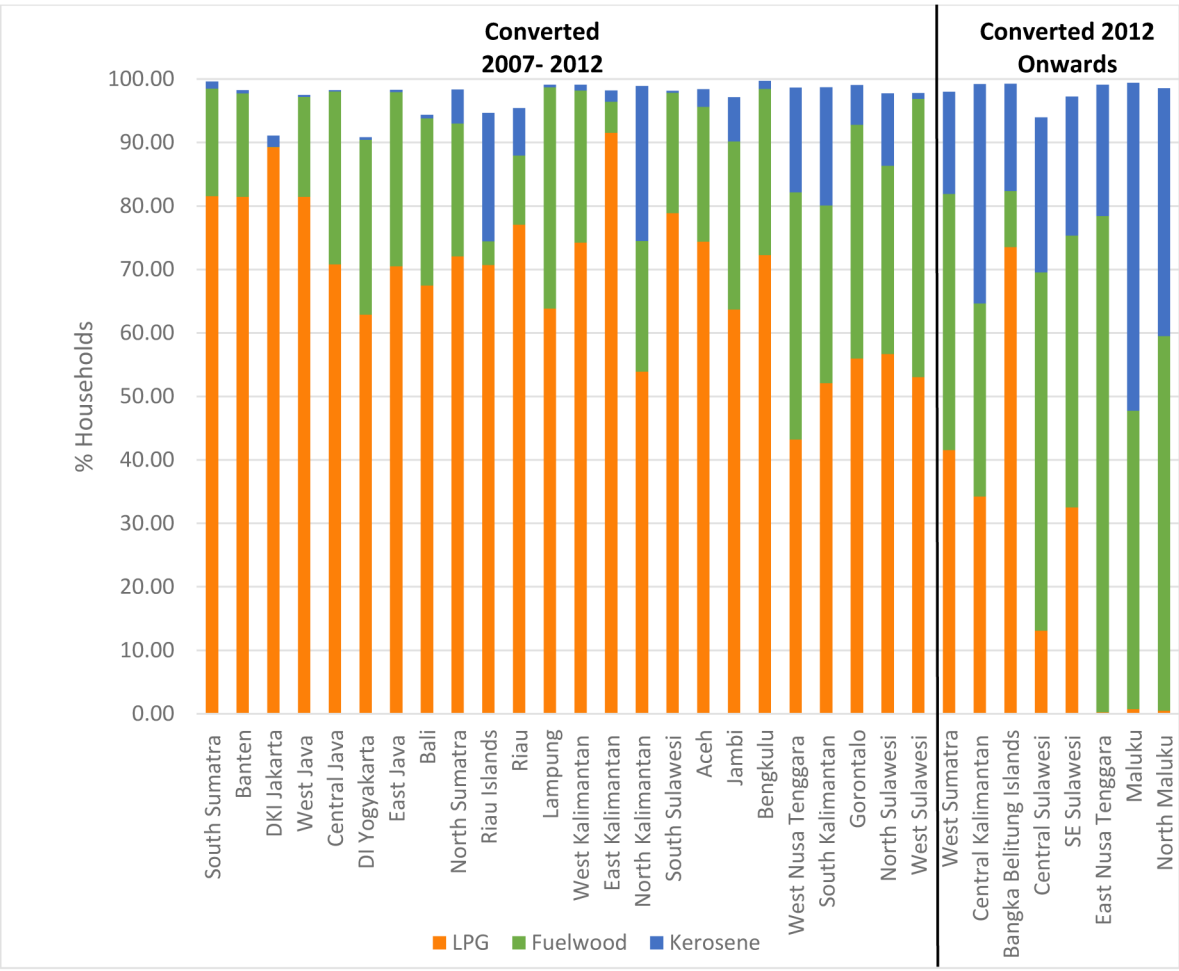

Figure 5. Percentage of households per province in 2015 indicating LPG, firewood or kerosene as their main cooking fuel

Source: Adapted from (BPS, 2017) Note: The two Papua Provinces are omitted.

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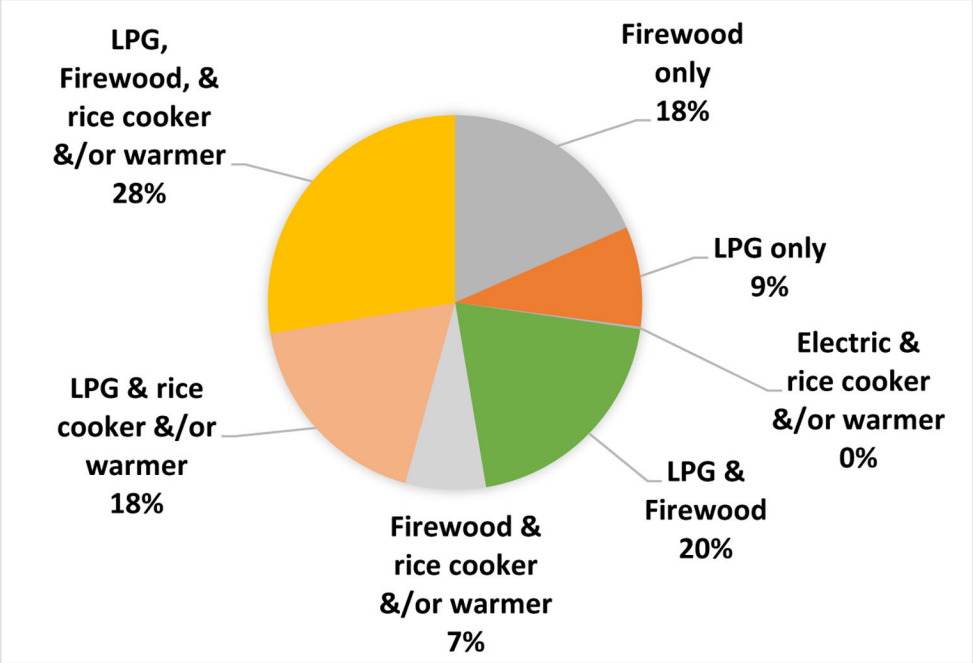

Figure 6: Percentage of fuel stacking in peri-urban Yogyakarta City (2013)
Source: Durix et al., 2016

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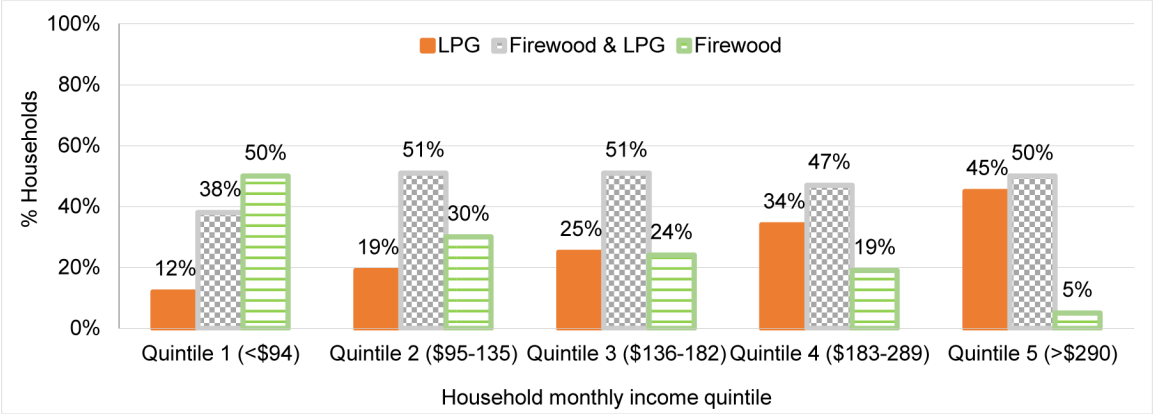

Figure 7. Household fuel use by income quintile in peri-urban Yogyakarta City, Central Java (2013)

Source: Adapted from ASTAE, 2015. Note: Exchange rate to US$ are as of October 2013, the time when the survey was completed.

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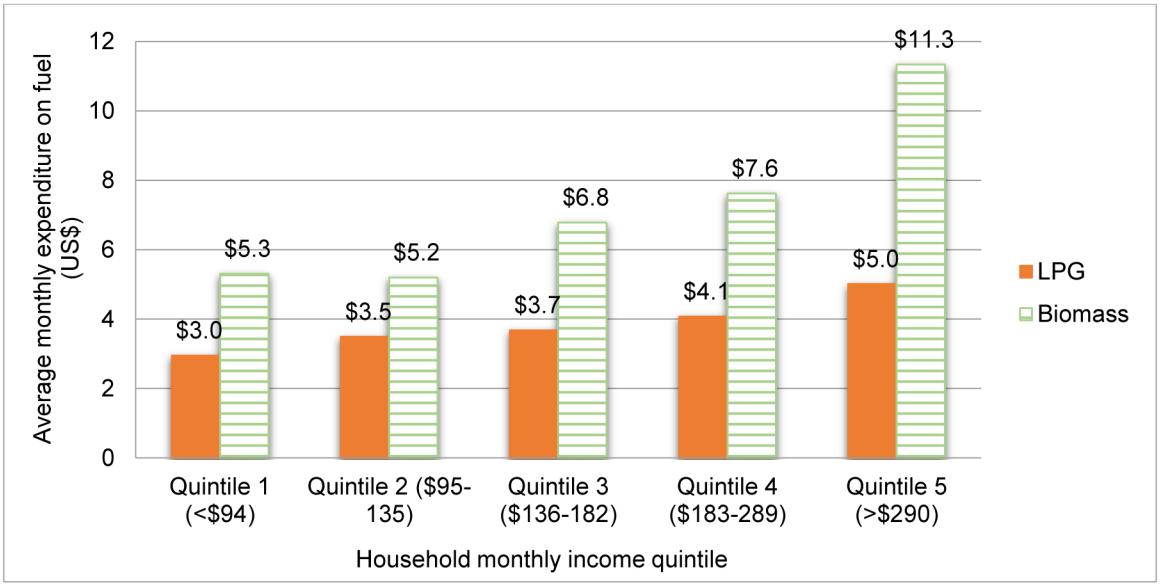

Figure 8. Household monthly spending on purchased fuel (US$) by income in peri-urban Yogyakarta City, Central Java (2013)

Source: Adapted from ASTAE, 2015. Note: Only approximately 10% of surveyed households purchased biomass. Exchange rate to US$ are as of October 2013, the time when the survey was completed.

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Table 1.

Relative health-damaging pollutant emissions of various fuels relative to LPG (g/MJ_d)

Emissions	Biogas	LPG	Kerosene	Wood Residues	Crop
CO	0.1	1	3	19	60
Particulate Matter (PM)	2.5	1	1.3	26	124

Source: (Smith, Rogers, & Cowlin, 2005; Smith et al., 2000). Note: The values are shown as grams per megajoule of energy delivered to the cooking pot

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Table 2.

Governmental Steering Team for the LPG Conversion Program

Ministries	**Role**
National team for Poverty Alleviation (TNP2K) under the Vice President's office	Political instigator
Ministry of Energy and Mineral Resources (MEMR)	Co-ordinator
Ministry of Finance	Budget
Ministry of Industry	Procurement of cylinders
Ministry of Small and Medium Enterprise	Procurement of stoves
Oil and Gas Regulatory Agency	Withdrawal of kerosene
Ministry of Social Affairs	Transfer of professions in kerosene trading business
Ministry of Women Empowerment	Socialisation/communication

Source: (MEMR, 2007)

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Table 3.

Number of recorded LPG accidents from 2007 to 2012, based on numerous sources

	2007	2008	2009	2010	2011	2012
Reported accidents	9[a]	64[a]	90[a]	352 [b]	59 [b]	8 [c]
Deaths among reported accidents	0	2	12	Not specified	Not specified	2
Distributed packages (millions)	3.7	15.8	24.2	4.6	5.6	0.2

[a]Sources: (BPKN (National Consumer Protection Agency), 2011);

[b](Pertamina & WLPGA, 2012);

[c](Budhiana, 2012; Jaya, 2012; Kompas, 2017b; Liputan6.com, 2012; Munawar, 2012; Rahardjo, 2012, July 13; Traffic, 2012)

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Table 4.

Percentage of fuel stacking in selected districts in Central Java and Yogyakarta City before and after the conversion program

	Central Java sub-districts (Andadari et al., 2014)			**Yogyakarta City, Central Java (Durix, Rex, & Mendizabal, 2016)**
	2010 survey with n=550 rural / periurban / urban HHs			*2013 survey with n=1434 peri-urban HHs*
	Before (%)	After (%)	Change (%)	After (%)
LPG only	2.2	19.5	17	9
LPG + other *	4.2	71.6	67	66 (28 LPG + wood + electricity, 18 LPG + electricity, 20 LPG + wood)
Kerosene only	32.0	0.4	−32	0
Kerosene + other *	55.5	7.8	−48	0
Wood only	6.5	6.5	0	18
Wood + other *	37.1	35.6	−1	7 (wood + electricity)

* No disaggregated fuel data available for Central Java