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Powering Jobs: The Employment Footprint of Clean Cooking Solutions in Kenya

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Article

Powering Jobs: The Employment Footprint of Clean Cooking Solutions in Kenya

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Abstract

Background: Delivering clean cooking access to 1.2 billion people who cook with charcoal, kerosene and firewood may have a strong localized employment impact. With the challenge of a rapidly expanding youth population and growing job scarcity in sub-Saharan Africa, understanding the impact of clean cooking on employment as well as the skills gap is timely. However, there is little definitive data on clean cooking jobs. Recognizing this data gap, we sought to conduct a study focused specifically on employment from the clean cooking sectors in Kenya, covering liquefied petroleum gas (LPG), bioethanol, biogas and electric cooking solutions. This study provides an initial baseline and early estimate of clean cooking sectors' direct formal and informal employment based on one year of company survey data, expert interviews, available literature, and local focus group discussion.

Results: In Kenya, the clean cooking sector provided about 19,000 direct, formal jobs and potentially 15,000 to 35,000 direct, informal jobs in 2019. While the clean cooking sector provided many jobs, the level of compensation and retention is low. In the LPG and electric cooking sector, sales and distribution are the biggest part of the workforce, while for bioethanol and biogas, manufacturing and assembling is important. The majority of the direct, formal workforce is reported to be skilled. Management, finance and legal, and product development and research are the most difficult skills to recruit for. Women's participation is lower than 30% in the clean cooking sectors. Managerial positions have higher women's participation than non-managerial ones.

Conclusion: This research exercise establishes a baseline for understanding the employment impact of the clean cooking sectors. However, a massive data gap persists. Our study shows that while the clean cooking sectors, especially LPG, are already providing tens of thousands of jobs, further studies are critically needed to map the employment impact of delivering universal clean cooking access.

Keywords: clean cooking; employment; LPG; bioethanol; biogas; electric cooking

1. Background

1.1. Background of the Study

Globally, 2.8 billion people do not have access to clean cooking and use fuel sources that produce health hazards [1]. Among the population without access, 30% are in sub-Saharan Africa [1]. In Kenya, 36 million people still cook with charcoal, kerosene and firewood, a large majority of whom live in rural areas [1, 2]. Failing to deliver clean cooking solutions for all not only compromises the health and economic benefits that could otherwise be captured, but also forgoes the opportunity to create jobs for women, youth and rural populations.

Indeed, past studies have shown the expansion of clean cooking solutions has a strong influence on rural employment. As compared to off-grid solar jobs, jobs in the improved cookstove sector have a higher potential of reaching the poor, as the sector requires a local and less-skilled workforce [3]. For instance, many clean cooking programs are focused on training local masons and metalsmiths for the manufacturing of improved biomass cookstoves [4]. In Kenya, where the rural population is 73% of the total population as of 2018, delivering clean cooking access may also have a strong localized employment impact [5].

Not only do clean cooking jobs benefit the local population, there is also a strong gender dimension. On average, women spend 58 hours a week collecting fuel and cooking in Kenya [6]. Dirty fuels cause indoor air pollution and the resulting health hazards primarily affect women and children. Access to clean cooking options save time for women. Moreover, when women are engaged in the clean cooking workforce, studies show they deliver higher performance, for instance, often reporting better sales results than men [7]. With women being the main end-users, beneficiary, and agents of change of clean cooking access, exploring clean cooking jobs and gender warrants greater attention.

With the challenge of a rapidly expanding youth population and growing job scarcity across the continent, understanding the impact of clean cooking on employment as well as the barriers and solutions for unlocking employment opportunities (such as closing any outstanding skills gaps) is timely. However, there is little definitive data on clean cooking jobs for many countries in sub-Saharan Africa.

Recognizing this data gap, Power for All sought to conduct this study focused specifically on employment from the clean cooking energy sector in Kenya. This study is part of the Powering Jobs campaign, which aims to promote awareness of the energy access workforce potential and needs and which previously involved a study of employment from decentralized electricity sources in India, Kenya and Nigeria [8]. It provides an initial baseline and early estimate of clean cooking sectors' direct, formal and informal employment based on one year of company survey data, expert interviews, available literature and local focus group discussion.

1.2. Literature Review

Past clean cooking employment studies have mostly focused on biomass-based improved cookstoves and consisted mainly of monitoring and evaluation (M&E) exercises from donor-funded programs [9]. Such studies are useful but may not represent the sector as a whole. These individual M&E case studies, while illustrative, do not provide enough data to approximate an entire market impact. Furthermore, they do not provide much insight into employment trends or characteristics, which limits their ability to inform policy.

In terms of LPG for cooking, very little information exists on employment estimates in sub-Saharan Africa. In 2018, the Global LPG Partnership (GLPGP) estimated that by implementing the National LPG Master Plan, an estimated 18,000 jobs would be created over the course of 15 years serving 18 million Cameroonians [10]. The World Bank also estimated that about 10 to 20 man-days of work are created per TJ of LPG consumption [11]. Moreover, Nigeria Liquefied Petroleum Gas Association estimated in 2017 that a 50% shift from kerosene to LPG can create one million jobs [12].

Dalberg estimated that a full transition towards bioethanol, serving 500,000 customers in Kenya, can create between 40,000 to 70,000 new jobs. A majority of these jobs are in sugarcane farming, with just over 1,000 jobs in bioethanol production, storage, bulk transportation and retail sales, and distribution [13].

The International Renewable Energy Agency estimated that globally, the biogas sector provided some 333,000 jobs in 2015, with more than two thirds of the jobs in China and India, and less than 17,000 in sub-Saharan Africa [14]. The Africa Biogas Partnership Program reported 350 jobs in three countries between 2016–2017 (Kenya 115, Tanzania 126, Uganda 109), although not all jobs may provide full-time employment, plus part-time unskilled labor [15].

While the employment impact of clean cooking is widely reported anecdotally in the literature and monitoring and evaluation process of funded programs, there are few coherent efforts that track

the employment impact systematically, and sector-wide study remains limited. The study is intended to reduce this information gap through a direct, comprehensive, bottom-up survey of companies working in the clean cooking sector. To our knowledge, this is the first that such a study has been conducted for Kenya.

2. Methods

2.1. Research Questions

The key questions that are answered in this study include:

- What is the scale of employment impact, in terms of the number of direct formal and informal persons employed, in Kenya in 2019 from the use of modern and clean energy for clean cooking (see definition in Section 1.4.4)?
- What are the characteristics of these jobs, in terms of the occupational breakdown, gender, youth's engagement, skill level, permanency, and level of compensation?
- What are the skills demands and recruitment challenges of the clean cooking workforce?
- What are the implications for the clean cooking sector practitioners to deliver universal access (SDG 7) while stimulating the growth of decent jobs (SDG 8)?

2.2. Research Scope

2.2.1 Geographic Scope

The study focuses on employment within the clean cooking sector in Kenya, as one of the most developed clean cooking markets in sub-Saharan Africa. It captures jobs from the in-country activities that are located in Kenya, and held by Kenyan nationals and foreign workers. It does not consider the upstream employment impact from segments of the value chain that take place outside of Kenya, such as raw material extraction or manufacturing, nor does it take into account labor resource sharing of multinational companies.

2.2.2 Employment Type Scope

The study aims to assess the direct jobs that are within the clean cooking sector in Kenya, including *formal* employment (which involves work with/for registered companies) and *informal* employment (which refers to middle-persons, technology dealers, or those who are self-employed or working in unregistered home businesses). Literature review indicates small, marginal impacts through productive use of clean cooking technologies through income-generating purposes, and as such we do not focus the survey on productive use jobs. Neither do we estimate indirect or induced jobs, defined as those that are created through forward linkages as workers in the clean cooking sector spend salaries on goods and services throughout the larger economy, as such analysis requires macro-economic data not readily available for Kenya and is beyond our study scope. See the Appendix A for a complete list of definitions.

2.2.3 Technology Scope

Clean cooking is defined as those cooking solutions with low particulate and carbon monoxide emissions levels (IWA ISO Tier 3–4 for the indoor emissions indicator) [11]. The IWA tiers for indoor emissions are consistent with the World Health Organization indoor air quality guidelines. For the purpose of the study, only the cooking solutions that are based on modern fuel and renewable energy are considered. This covers the LPG, biogas, bioethanol, and electric cooking sectors, including fuel supply and accompanying cooking equipment (e.g. cylinders, cookstoves etc). Improved biomass-based cookstoves and kerosene-based cooking solutions are not in the scope of our research.

2.2.4 Value Chain Scope

The value chain of the clean cooking sector comprises two major segments: (1) the value chain of fuel supply and distribution, and (2) the value chain of cooking equipment manufacturing and distribution in relation to a particular fuel or energy source. The study covers both components for each cooking technology in scope. Each clean cooking technology value chain is unique and oftentimes the stakeholders involved do not overlap between technology types. As such, our survey tool comprised different sections, each with particular questions for an individual cooking solution. Below we describe the value chain for each cooking solution and explain the rationale for inclusion in scope.

2.2.5 Description of the Clean Cooking Technology Value Chains and Scope Inclusion

Among all the clean cooking sectors in scope, the LPG sector has the largest market in Kenya. In 2018, there were an estimated 3.7 million households in Kenya that use LPG for cooking (primary or secondary use), about 29.7% of the population, and 18.9% of the households used LPG as the primary cooking fuel, as compared to 13.3% in 2015–16 [2]. Household consumption of LPG makes up around 88% of all end-use LPG consumption in Kenya [16]. In 2018, annual import was 269.9 kilotonnes, with 87.5% arriving by sea and 12.5% arriving by road from Tanzania [16].

The use of LPG is much more common in urban areas than rural. 54 % and 18% of households use LPG for cooking in urban and rural areas respectively [2]. Consumption level also differs: an average urban household consumes about 1.3 kg of LPG per week (or 5.2 kg/month), while a rural household uses about 0.9 kg (3.6 kg/month) [2]. As a result, 77% of the residential LPG cooking gas is consumed by urban households, despite that the majority of the Kenya population is in rural areas.

The LPG market in Kenya is competitive. According to industry experts, about 45% of the market share is taken by large LPG marketing companies ('LPG marketers'), including well-known brands such as Total Gas by Total Kenya, Supa Gas by National Oil, and K Gas by Kenol Kobil., among others. Another 55% of the market share goes to a large group of smaller but impactful companies. The number of licenced and registered marketers has increased over time. In 2019, the Energy and Petroleum Regulatory Agency (EPRA) introduced new regulations, LN100/2019, that requires all LPG distributors to be licensed with authorized brands [17]. Previously, illegal refilling activity was dominant in Kenya and many distributors were refilling the cylinders that they did not own. The introduction of LN100/2019 has reduced these activities and improved the safety standards of the workers [17]. The Energy Dealers Association (EDA), a consortium of 32 local gas suppliers, works closely with their distributors to comply with the new regulation [18].

The study scope includes bulk import and export of LPG, bulk transportation, bulk storage and cylinder filling, cylinder manufacturing, wholesale of cylinders, distribution of cylinders, and retail sale of cylinders by exclusive retailers. In Kenya, EPRA provides the licensing framework for the entire LPG sector except for the retail dealers, which are often informal, and relatively small businesses. The study captures all formal segments of the value chain. Figure 1 shows the part of the value chain activities that are included in the scope. However, some parts of the value chain, especially in LPG importing, are dominated by a few large companies. We were not able to capture some of the largest players in the sample, such as African Gas & Oil Limited (AGOL), which imports 77.2% of the LPG from Mombasa. Sampling is discussed in Section 2.4 [16].

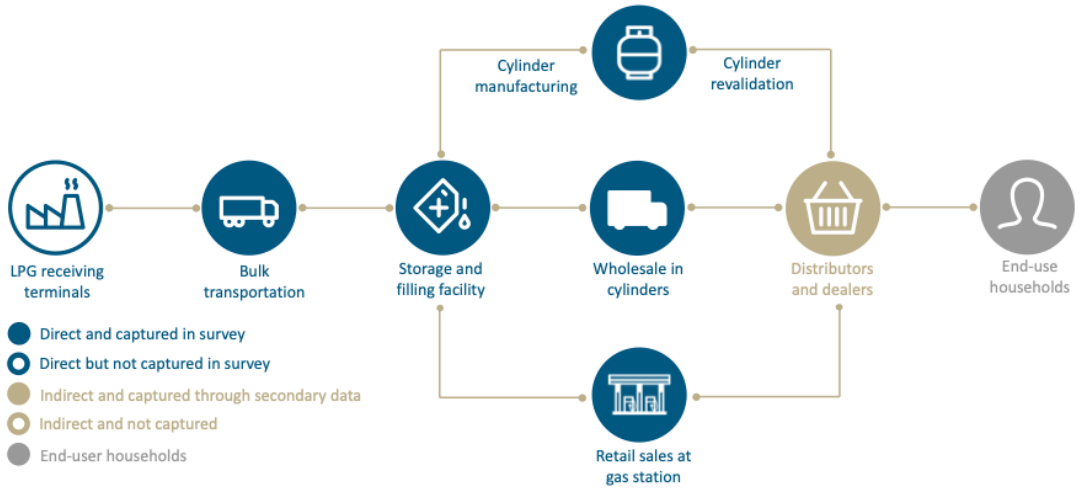

Figure 1. Illustration of the LPG value chain

Bioethanol is a much less established sector compared to LPG. Less than 0.1% of households in Kenya use bioethanol for cooking [2]. According to experts, there are more than 10,000 bioethanol residential users served mainly by three bioethanol producers and a few sales and distribution companies. There are fewer than 20 formal players along its fuel value chain in Kenya, including: sugar companies that produce bioethanol as a by-product, wholesalers that buy and transport bioethanol in bulk, retail sales and marketing companies, and last-mile distributors. According to our literature review and expert interviews, most bioethanol fuel for cooking is produced domestically, with imports from Tanzania and Uganda. However, because the current domestic production capacity is not keeping up with consumption growth, the sector expects to start importing fuel soon.

The survey included all formal segments of the bioethanol value chain, from cooking fuel production, which does not include bioethanol for non-cooking purposes, wholesale, to retail sales and distribution. In the case of the bioethanol sector, last-mile distributors are often self-employed local sales agents not directly employed by bioethanol companies, but rather, earning additional commission-based revenues. As such, we do not survey this informal segment of distributors directly, and it is intended as future work. Figure 2 illustrates the bioethanol value chain and identifies the part of the value chain activities that are captured in the study scope.

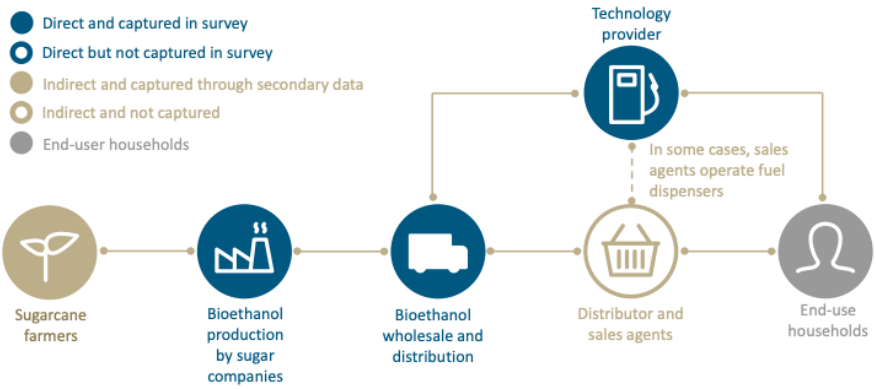

Figure 2. Illustration of the bioethanol value chain

Biogas is an emerging clean cooking solution in Kenya, representing roughly 0.1% of the residential cooking solutions [2]. At the time of writing, there are about 21,000 biogas digesters in operation, serving not only household cooking needs but also productive use activities on the farms, according to Kenya Biogas Program. The primary end-users of cooking biogas are primarily located in rural areas where access to other energy sources is scarce and access to crop residue or animal

waste is abundant. The biogas digester companies included in this study use floating drum, tubular biogas digesters and fixed dome biogas digesters for homes or businesses who themselves become the primary operators.

Biogas companies operate along a very different supply chain, where the fuel and cooking technology are integrated. There are less than 10 companies that import or manufacture prefabricated systems, and 147 Biogas Construction Entrepreneurs (BCE) who not only construct fix-dome biogas digesters but also work with a wide range of biogas technologies, according to BioNet, an association of the BCEs. These biogas companies import, fabricate, assemble and install the biogas digesters, and they often provide training for operations and maintenance (O&M) and/or extension services to end consumers. Once the biogas digesters reach the operator, they are often used with mixed purposes: cooking, heating, lighting, and power generation [14].

Figure 3 shows the scope of the biogas value chain that the study covers, including domestic manufacturing and assembling, installation, construction, sales and after-sale services. The survey includes biogas companies from the formal sector and through expert focus group discussions we have gained an understanding of the scale of employment impact stimulated through rural entrepreneurs owning and operating biogas digesters.

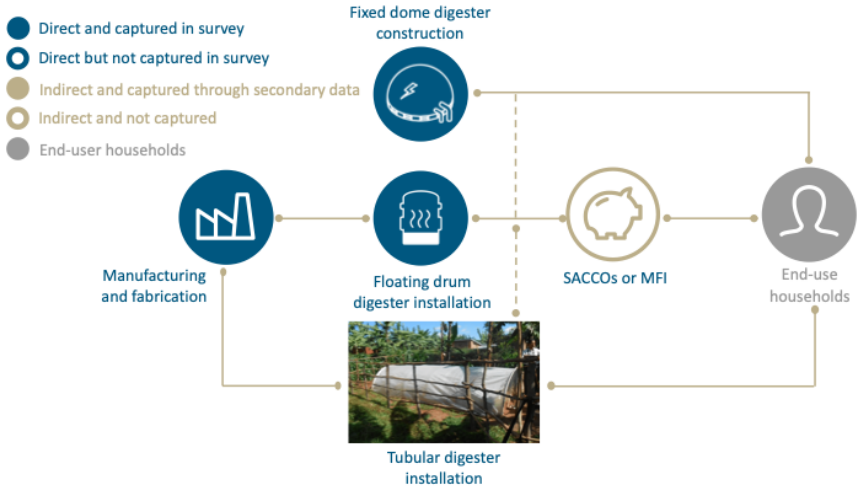

Figure 3. Illustration of the biogas value chain

Electric cooking is a newly emerging cooking solution in Kenya. About 3% of the households own an electric cooking appliance such as a mixed LPG-electricity stove, electric oven, electric coil stove or microwave [2]. These appliances, however, are most commonly used by high-end consumers in urban areas. For rural consumers, adopting clean cooking technologies for the first time, electric cooking is mostly used for fuel stacking alongside other fuel types.

In Kenya, the electric pressure cooker (EPC) is the most commonly promoted electric cooking technology and is perceived to be viable for rural weak-grid and off-grid areas. Currently, EPCs are largely imported, with little local assembly or manufacture. As such, this study focuses on jobs from EPC import, sale and distribution, as shown in Figure 4. It does not include the indirect jobs associated with electricity service provision in the utility sector.

Figure 4. Illustration of the electric cooking value chain

2.3 Data Collection and Analysis

Data collection was conducted through an online survey directed at companies in the clean cooking sector, complemented by data evidence collected through literature review and interviews with industry associations and experts. The survey tool not only solicited direct, formal and informal employment estimates from companies, but also asked questions related to the demographic trends of the clean cooking workforce. Data insights from this survey were validated through focus group discussion with recognized industry experts.

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The data collection exercises proceeded as follows:

1. A contact list of clean cooking companies was developed with the support of the Powering Jobs campaign partners. The contact list covers the defined clean cooking value chain.
2. Survey was designed with input from these stakeholders and tested with a small number of commercial companies in Kenya to ensure appropriateness.
3. Survey was disseminated over the first quarter 2020. Targeted communications were sent to companies with large market share during data collection, particularly for the LPG sector, which is dominated by large market players.
4. After the survey was completed, the researchers visited and interviewed key organizations that represent more than 10% market share of their respective sectors.
5. To help contextualize survey findings, the team also conducted interviews with industry associations, NGOs, and regulatory authorities who provided insights on employment from their respective sectors. In-person meetings were held with Kenya Biogas Program (KBP), GLPGP, BioNet and Energy Dealers Association, and the Energy and Petroleum Regulatory Authority.
6. A focus group discussion was held with industry experts to validate findings and provide qualitative context for insights.

Calculation of full-time equivalence (FTE) of jobs reported in the survey and the interviews was computed using the following formulae to equate part-time and contract work with the workload of a full-time job:

$$FTE\ for\ a\ part-time\ job = \frac{part-time\ working\ hours}{full-time\ working\ hours}\ , \quad (1)$$

$$FTE\ for\ a\ contract\ job = \frac{average\ length\ of\ contract}{full-time\ retention}\ . \quad (2)$$

All direct, formal jobs presented in this report are in FTE terms. Therefore, while a company might employ many casual workers by giving out short contracts, its FTE direct, formal employment impact might be discounted due to the short duration of contracts. Informal jobs are not translated into FTE. While it is widely recognized that informal jobs are less secure and less compensated, the study has limited understanding of the quality of these jobs.

Having translated reported direct formal jobs into FTE, we developed employment factors of the direct formal and informal jobs in 2019 by applying the following formulae:

$$direct\ formal\ employment\ factor = \frac{total\ number\ of\ direct\ formal\ jobs}{total\ reported\ volume\ of\ sales\ or\ processing\ capacity}\ , \quad (3)$$

$$direct\ informal\ employment\ factor = \frac{total\ number\ of\ direct\ informal\ jobs}{total\ reported\ volume\ of\ sales\ or\ processing\ capacity}\ . \quad (4)$$

Each part of the value chain has an employment factor that is then applied to a market estimate to map the employment impact to a sectoral scale. The formulae used in this method is as follows:

$$total\ direct\ formal\ jobs = \text{direct formal employment factor} \times \text{2019 market estimate}, \quad (5)$$

$$total\ direct\ informal\ \text{jobs} = \text{direct informal}\ employment\ factor \times \text{2019}\ market\ estimate. \quad (6)$$

This methodology of mapping employment impact with an employment factor (sometimes referred to as job multiplier) is commonly used in past studies on energy and jobs. Starting with the employment impacts of green investment, a number of estimates have been made. Kammen et al. and Wei et al. have respectively estimated the employment impact of renewable energy, low-carbon energy, and energy efficiency with a bottom-up of jobs created per MW over the lifetime of an energy facility [19, 20]. Others have used a top-down method of input-output (I-O) analysis that can estimate the employment impact on both direct and indirect jobs [21]. A major issue with the bottom-up employment factor approach is that there are a limited number of studies that report employment factors of different energy sources and they are applicable to limited geographical contexts. In 2015, Cameron and Zwaan analyzed renewable energy employment factors from 70 publications, and found that only 31 yielded original results [22]. Moreover, not only are the employment factors in the literature outdated and limited, their applicability to the energy access context is also questionable. For example, an employment factor for a large-scale biogas plant is not applicable to the small-scale plant of less than 15 m^3 in this scope of work. Thus, the study relies on a set of primary data on employment impacts based on the survey results and expert interviews.

2.4 Sample Representation

In total, there were 31 survey responses and 13 organizations interviewed. The survey respondents and interview participants of the study represent a significant share of the market for most parts of the value chain segments. Table 1 summarizes the population, sample of the study, market representation of the employment factors, and margins of error for each part of the value chain activities in each sector.

The study reports margins of error at a 90% confidence level. In the findings, the study provides high employment estimates and conservative estimates, as a range of potential employment impacts from the deployment of clean cooking solutions. The high employment estimates were based on all the employment factors collected, regardless of the market representation and margins of error. The conservative employment estimates were based on only the part of the value chain where the employment factors' margins of error are lower than 15%. As shown in Table 1, the employment factors of LPG bulk import, LPG stove sales and distribution, biogas stove manufacturing, and biogas stove sales and distribution have their margins of error lower than 15%, and therefore, the employment impacts of these parts of the value chain are not considered in the conservative estimates.

Table 1. Number of survey respondents and interview participants in each clean cooking sectors

Clean cooking technology type	Value chain activity	Estimated number of companies in the Kenyan market	Number of companies or facilities included in study sample	Estimated market representation (by production volume or sales)	Survey Margin of Error, 90% Confidence Level
Electric cooking	EPC sales and distribution	Less than 10 companies provide off-grid and weak-grid appropriate electric cooking solutions.	The sample includes 5 companies, among which one also imports.	50%	8%
Bioethanol	Fuel production	3 companies that produce bioethanol in Kenya for beverages and fuel.	The sample captures one of the fuel producers.	33%	12%
	Wholesale and distribution	Less than 5 companies are working in bioethanol wholesale.	The sample relied on the wholesale employment factor provided by 3 companies, including a bioethanol fuel producer and a wholesaler.	50%	8%
	Retail sales and distribution	Less than 5 companies on the market are actively selling bioethanol to end-users. Most of them are selling in urban and peri-urban areas.	The sample captured 2 of the largest companies that are currently selling bioethanol directly to end-users.	70%	5%
	Bioethanol equipment manufacturing	As far as authors are aware, there are less than 3 companies that manufacture bioethanol stoves and other equipment.	One company reported its employment factor for this category.	30%	13%
	Bioethanol stove sales and distribution	As far as authors are aware, there are less than 10 companies that are selling bioethanol stoves and other equipment.	3 companies contributed to the employment factor in the sample.	30%	13%
Biogas	Importing and assembly	6 companies importing biogas digesters.	Our sample captures 3 companies that are importing biogas digesters.	50%	8%
	Manufacturing and fabrication	Less than 5 companies manufacture biogas digesters in Kenya.	Our sample captures 2 companies that reported manufacturing and fabrication activities.	40%	10%

	Installation and construction	There are in total 153 companies that are installing and constructing small-scale biogas digesters, and 147 of them are the BCEs.	The sample represents 150 companies.	95%	2%
	After-sale service	See above, all 153 companies are trained to provide after-sale service.	The sample represents 150 companies.	95%	2%
	Biogas stoves manufacturing and fabrication	N/A. Not known number of companies manufacturing biogas stoves as of 2019.	The sample includes one company that manufactures biogas stove.	N/A	N/A
	Biogas stoves sales and distribution	NA. Not known number of companies selling biogas stoves as of 2019.	The sample includes 2 companies that sell and distribute biogas stove.	N/A	N/A
LPG	Bulk import and wholesale	65 licensed, as of June 2018, 16 reported actively importing LPG. [16, 23]	The sample captures only importing activities through the Kenyan-Tanzanian border, reported by 1 company and EDA.	3%	N/A
	Bulk transportation	98 licensees that operate 402 fleets for LPG bulk transportation. [23]	NA. Not known exact total number of fleets the sample represents. However, detailed information was provided by 5 respondents that together capture a large market share.	60%	7%
	Filling and storage	63 storage and filling facilities operated by 61 companies. [23]	The sample captures 35 companies who together operates 37 storage and filling facilities	60%	7%
	Wholesale in cylinder	150 companies licensed as wholesaler for LPG in cylinders. However, GLPGP reported that as of June 2018, only 48 of them are actively selling, who together operates more than 1,000 fleets to distribute LPG cylinders to selling points. [23]	The sample covers 6 licensees, including 2 of the biggest LPG marketers in Kenya and a few smaller companies. Our employment factor also includes numbers reported by the EDA, which alone sells about 55% of the LPG in cylinders.	70%	5%
	Retail sales in cylinder	It is estimated that there are more than 10,000 retail businesses, while only	The study only attempts to capture the retail activities through secondary	70%	5%

	5,762 of them are licensed by EPRA, many of them operated by the 48 LPG marketers. [23]	insights from the LPG marketers and EDA. There are 5 responses that provide insights on LPG retail activities, either via their own fuel stations, or through local distributors.		
Cylinder manufacturing and revalidation	7 companies manufacture LPG cylinders. [16]	The sample captures 3 of cylinder manufacturing and revalidation companies, including the largest cylinder manufacturer in Kenya.	80%	13%
LPG stove sales and distribution	N/A. Not known number of companies selling LPG stoves as of 2019.	The sample includes 3 companies that sell LPG stoves.	N/A	N/A

The focus group discussion was held in February 2020, with 18 selected participants representing the governments, financiers, recruitment agencies, research organizations, NGOs, and industry associations. The focus group discussion was divided into three discussion sessions: (1) employment impact along the value chain, (2) trends, skill needs and recruitment challenges, (3) women and youth participation in the workforce. The research team presented the data findings from the survey, and invited focus group participants to comment on the findings.

3. Results

3.1 Clean Cooking Job Estimates

According to our survey findings, the total number of direct formal jobs provided by the clean cooking sectors in Kenya in 2019 was about 11,000–19,000, of which, 9,100–17,000 are in the LPG sector, 700 in the bioethanol sector, 800 in the biogas sector, and 200 in the electric cooking sector.

In 2019, the total number of direct informal jobs provided by the clean cooking sectors in Kenya was between 15,000 to 35,000. The large majority are in the LPG sector, 800 in the biogas sector, and 900 in the bioethanol sector. There is potentially a much wider informal job impact from the LPG sector, especially in its end-use sales and distribution activities.

The latest available estimate shows that the charcoal sector employed nearly 900,000 for production and trade, and contributed US$ 1.6 billion per year to Kenyan economy in 2013 [4]. Assuming that the size of the charcoal workforce remained the same, by 2018, the sector was serving about 4.9 million households who used charcoal for cooking [2]. This means that roughly 180 people are employed to serve 1,000 households. This is significantly higher than the employment factor of the LPG sector from this study, which is 7 jobs per 1,000 households. The finding shows that the employment potential of charcoal is more than 20 times that of the LPG sector and as a result, the job displacement effect of fuel switch from charcoal to LPG may be strong. On the other hand, the employment factor of the biogas sector is about 263 jobs per 1,000 households, much higher than the charcoal sector.

This survey also asked companies to report the likelihood of their respective clean cooking solutions used for biomass displacement or fuel stacking. Figure 5 shows that bioethanol and biogas are far more likely to displace biomass than LPG and electric cooking, moreover, electric cooking is almost always used for fuel stacking. As illustrated from the data, it is difficult to distinguish new clean cooking access and attribute jobs thereto.

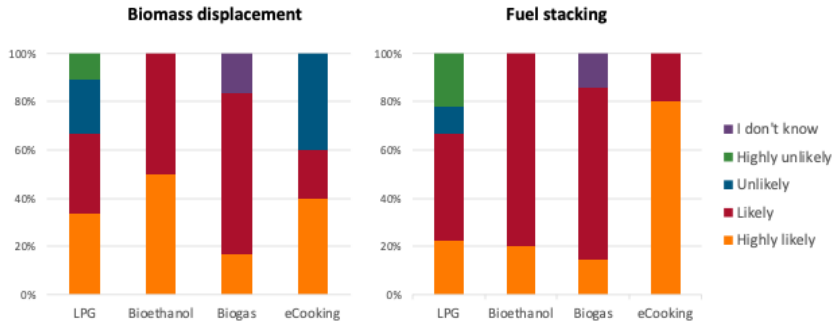

Figure 5. Application of clean cooking technologies for biomass displacement or fuel stacking

Finally, we note that comparison between the clean cooking employment data and data on the charcoal workforce cannot be conflated, as further considerations would include displacement effect, the formal and informal nature of the employment, differences in retention, and level of compensation, etc.

3.1.1 Jobs in the LPG Sector

In the LPG sector, job estimates were as follows: import and bulk wholesale accounted for 3,400 direct formal jobs, transportation in bulk about 400 jobs, storage and filling about 1,000 jobs, wholesale in cylinder 3,100 jobs, and retail sales in cylinder 3,800 jobs. The sector also provided job estimates along its cylinder value chain: cylinder manufacturing plants provided 300 jobs and revalidation provided 200 jobs. In addition, there were 4,500 jobs in the LPG stove value chain. Figure 6 shows that in 2019, the LPG sector provided about 17,000 direct formal jobs and 9,100 direct formal jobs if LPG bulk import and stove sales and distribution jobs are not considered.

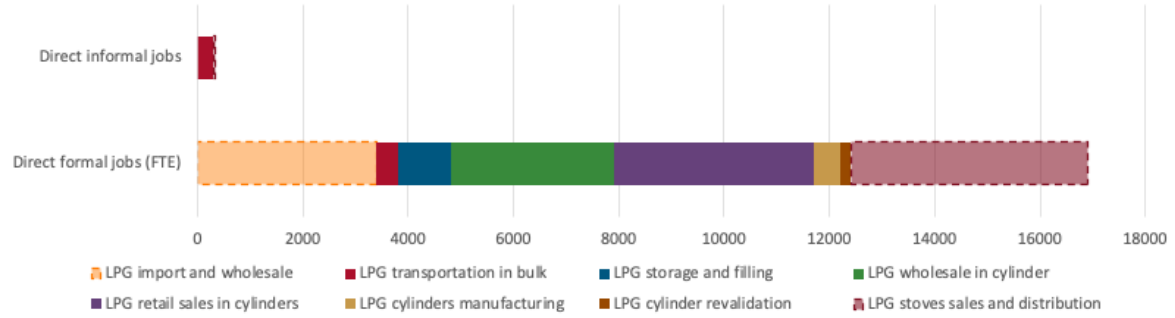

Figure 6. Estimated direct formal and informal jobs along the LPG value chain showing high estimates and conservative estimates (in transparent colors)

Direct informal job estimates in the formal sector was 300, marginal compared to direct formal jobs. These informal jobs are often casual laborers who work as loaders in depots and filling plants. While they are characterized by some companies as informal labor, these workers more often get short contracts of a few months but renew their contracts regularly.

The LPG sector not only creates a large number of jobs along its formal value chain, it potentially has a wider impact in its downstream linkages among retailers, distributors and selling points of LPG in cylinders. In addition to the 3,800 direct formal jobs provided by some of the LPG marketers who also engage in direct retail sales to end-users, early estimates of the downstream retail job impact falls between 10,000 to 35,000, provided by 10,000 to 18,000 retailers according to the analysis and EDA feedback. Each retailer would employ roughly one marketing person and one delivery person, distributing to one to five selling points that further serve about 50 to 100 households in urban areas and 20 to 30 in rural areas. The influence of employment impact of these selling points, is however less obvious, as most selling points are already existing businesses such as supermarkets and small kiosks. According to experts, selling LPG in cylinders often does not create new jobs in these selling points, but instead brings in new revenue for the business.

About 40% of the 10,000 to 35,000 retailer jobs at the moment are formal. The other 60% of the jobs have unknown status. The latest regulation LN100/2019 dictates that all LPG retailers should be licensed by EPRA and it is regulated that LPG retailers can only sell the brands that they are licensed for [17]. From September 2019 until the time of writing, 5,672 LPG retailers have registered their businesses and obtained licenses from EPRA [23]. Employment of these retailers are therefore more formalized. The remaining LPG retail businesses are given until the end of the first quarter of 2020 to register and obtain license for their businesses. However, according to experts this may have a negative short-term impact on employment, due to the costs associated with licensing (estimated to be at least US$50) [17]. Some retailers may choose to give up on the LPG business, and therefore, leading to short-term job loss. On the other hand, long-term positive impact of the Act expects continuous job growth and improved health and safety of LPG jobs due to better work environment, higher quality standards, and reduced conflict between legitimate brand owners and illegal refillers.

3.1.2 Jobs in the Bioethanol Sector

In the bioethanol sector, production of bioethanol cooking fuel provided about 80 direct, formal jobs, wholesale and distribution provided 340 jobs, and retail sales and distribution provided 270 jobs, and bioethanol equipment manufacturing, sales and distribution provided 40 jobs. Figure 7 shows the estimated direct formal and informal employment impact along the bioethanol value chain in 2019.

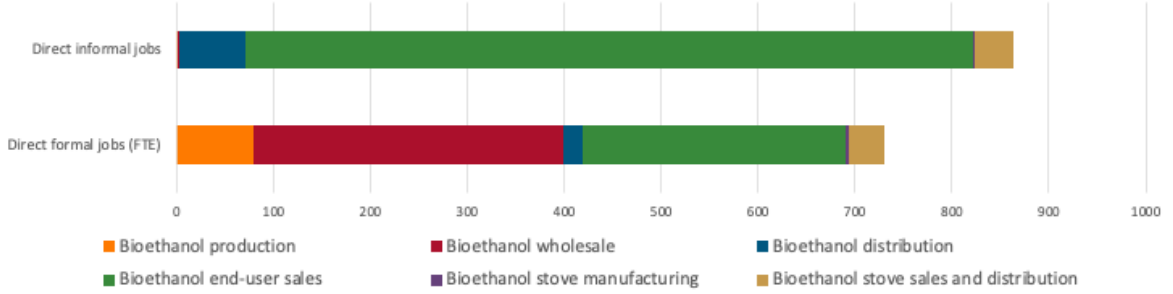

Figure 7. Estimated direct formal and informal jobs along the bioethanol value chain

Bioethanol fuel is produced in Kenya as a by-product of sugar production. About 85% of the bioethanol produced in Kenya is sold to the beverage companies, while the remaining 15% is used as fuel, according to experts. After discounting for the percentage used as fuel, we estimate the sugar companies themselves provided 80 direct formal jobs for bioethanol cooking fuel production, while wholesale activities account for 320 direct formal jobs.

Further upstream linkages in sugarcane farming may also experience indirect employment impact. Approximately 50,000 sugarcane farmers may benefit from the additional value-add to their production activities due to the use of bioethanol as cooking fuel [24]. However, the data input from the literature has not been recently updated and the assumption of the number of sugarcane farmers in Kenya was published in 2011. Therefore, the study has low confidence in the potential impact of bioethanol production on upstream sugarcane farmers' income. Furthermore, there is no evidence of additional job creation in sugarcane farming from bioethanol.

Our findings roughly fall in the range of Dalberg's early projection in 2018, when the bioethanol sector was just emerging. It was estimated that to serve 500,000 customers, the bioethanol sector would create 40,000 to 70,000 new jobs, mostly in sugarcane farming, with slightly over thousand jobs in the other parts of the value chain [13].

About 800 informal jobs were in the sales and distribution activities of bioethanol fuel value chain and 40 in stoves sales and distribution. These informal jobs are mainly sales agents, kiosk business owners who sell bioethanol alongside their regular businesses. As a result, the influence of these informal jobs is unknown.

3.1.3 Jobs in the Biogas Sector

The biogas sector provided about 5 direct formal jobs in importing, 450 jobs in manufacturing and fabrication, 220 jobs in installation and construction, 320 jobs in after-sales services, and 30 jobs in its stoves value chain.

In addition to direct formal jobs, the sector also provided about 750 informal jobs in installation and construction, and another 50 in after-sales services. Figure 8 shows that the LPG sector provided about 1,000 direct formal jobs in 2019, and 970 direct formal jobs if those from stove sales and distribution are not considered.

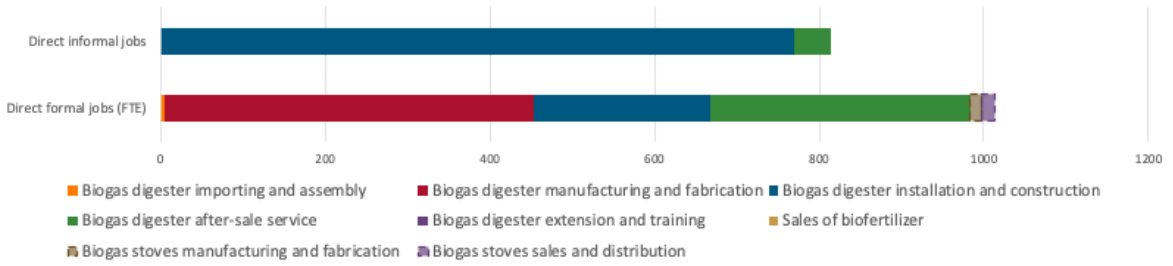

Figure 8. Estimated direct formal and informal jobs along the biogas value chain

There are a few biogas technology providers that import, assemble and fabricate the biogas digesters. Most of these companies are small, and their employees work across different functions. Therefore, it is not expected that only 5 FTE jobs are provided to import biogas digesters. These moveable systems generally take less than a day to assemble. Usually, a salesperson and a technician are called on site to carry out the installation after a customer has placed an order. The technician may go back to service the system after three months.

Alongside the biogas technology providers, about 60% of the market share is taken up by the BCEs who construct fixed-dome biogas digesters locally. A BCE generally has at least one full-time entrepreneur who is equipped with the technical knowledge and business training. The entrepreneur would rely on the support of about 5 to 6 local masons. When a customer places an order, the BCE can construct a fixed-dome, domestic system within two weeks, with the support of one mason and three unskilled casual workers.

In Kenya, there are 147 BCEs, all of which are formally registered as businesses. These BCEs play a crucial role in the success of the biogas sector because they are in close and direct contact with the end users. In addition to their usual fix-dome system construction work, the BCEs sometimes source from the biogas technology providers. The high potential of employment impact of the biogas sector can also be observed in the growth of BCEs. Every one or two years, the masons who used to work for a BCE would branch out and start businesses of their own as soon as they learn the trade.

Although productive use jobs are out of the study scope, the biogas sector, in particular, has very high potential to be creating income-generating opportunities, according to the experts in the focus group discussion. In addition to generating biogas for cooking, the bio-slurry output of a biogas digester can also be a great source of biofertilizer. In some cases, about 10% to 20% of the biogas digesters are used for power generation, brooding or egg incubation. However, the extent to which these activities can create jobs is difficult to estimate.

3.1.4 Jobs in the Electric Cooking Sector

Electric cooking is an emerging clean cooking solution in Kenya. General perception of the technology is that it currently caters to higher income consumers. There are a number of solutions that are now designed to be compatible with mini-grid or weak-grid rural contexts so this is likely to change in the future. EPC, for one, have been proven to be a more efficient and cost-effective way to cook certain types of food.

In 2019, the importing, wholesale, retail sales and distribution activities of EPC provide about 200 direct formal jobs. Currently, there is no manufacturing activity of EPC in Kenya. While the electric cooking market is still nascent in Kenya, Kenya Power (KPLC) has formed key partnerships to raise awareness and pilot electric cooking initiatives in rural areas. There are already players on the market that are exploring the possibility of manufacturing of EPC as domestic demand picks up.

Figure 9. Estimated direct, formal and informal jobs along the eCooking value chain in 2019

3.2 Clean Cooking Employment Trends

In this chapter, the study discusses the employment trends within the clean cooking sectors, including skill level, compensation level, retention, and women and youth participation. All findings describe the direct formal workforce unless specified otherwise.

3.2.1 Skill Level and Retention

The direct formal jobs in the clean cooking sector are highly skilled. In the LPG and electric cooking sectors, more than 80% are skilled jobs. The biogas sector, on the other hand, reported a lower percentage of skilled labour. This, however, does not imply that most jobs in the biogas sectors are unskilled. In the biogas sector, the most in-demand skills are more often semi-skilled masons, who are equipped with the technical knowledge but do not necessarily possess higher education.

In terms of the informal jobs, the LPG sector's informal workers are rarely skilled. These workers are mostly the loaders who are working at depots or filling plants. The work undertaken by the loaders is labor-intensive and requires little skill and training.

While LPG and electric cooking sectors are the most skilled sectors, both sectors report short employee retention. On average, employees stay 18 months in the LPG sector, 24 months in the bioethanol sector, 36 months in the biogas sector and 20 months in the electric cooking sector. This is lower than the decentralized renewable energy sector in Kenya, where employees generally stay for more than 30 months [25]. See Figure 10 for comparison of skill level across different sectors.

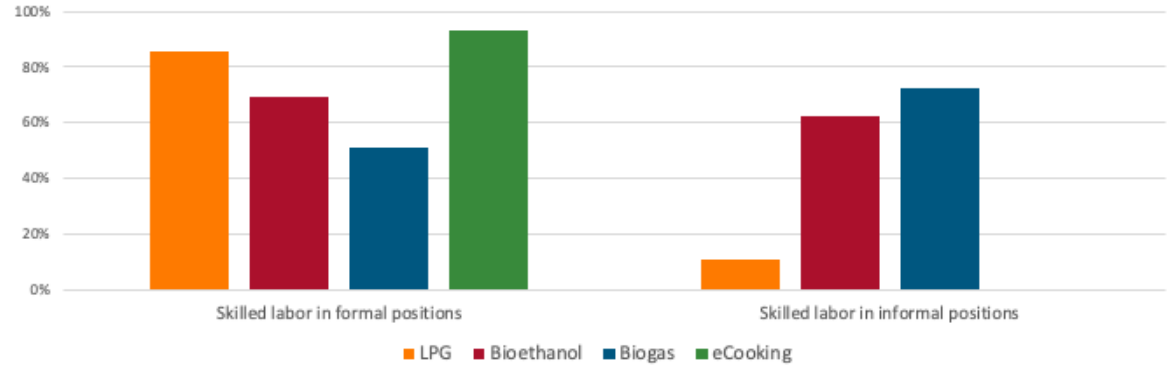

Figure 10. Skill level of formal and informal workers across clean cooking technologies

3.2.2 Level of Compensation

According to the survey findings, shown in in Figure 11, the level of compensation is the highest in the LPG and electric cooking sectors. Both sectors pay more than 80% of their managerial employees more than US$ 500 per month, as compared to just over 40% in the bioethanol sector and barely 20% in the biogas sector. For non-managerial employees, more than 80% of the workers earn more than US$ 200 per month in the LPG and electric cooking sectors, while it is only 50% in bioethanol and 20% in the biogas sector. For informal workers, all informal workers in the bioethanol and biogas sectors are estimated to earn less than US$ 200 per month.

The clean cooking sectors' level of compensation can be compared to the charcoal sector. With the exclusion of the biogas sector, charcoal producers in Kenya earn about US$ 60 per month [11], this is well below the reported monthly earnings range of direct formal jobs in the clean cooking sector. This insight validates the earlier assertion that the displacement effect of fuel switching is a complex topic. While the total number of jobs may decrease due to better labor efficiency in the clean cooking sectors, the level of compensation is likely to improve.

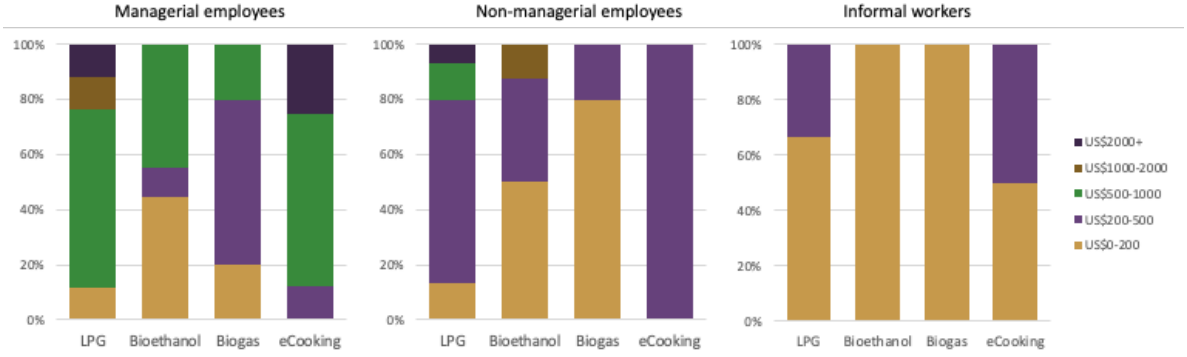

Figure 11. Level of compensation for managerial, non-managerial and informal workers

3.2.3 Women and Youth Participation

The survey response data (in Figure 12) showed that in the clean cooking sectors, women's participation is higher in managerial positions than non-managerial positions; it is also higher in the bioethanol and electric cooking sectors, as compared to the LPG and biogas sectors. This can be explained by the fact that many direct formal, non-managerial jobs in the sector are labor-intensive. Take the LPG sector for example: in a storage and filling plant, it is mostly men who are operating the machinery and loading the cylinders. For the biogas sector, most non-managerial jobs are the construction and installation work that more men than women are willing to perform. This also explains the low women's participation in informal jobs. Other barriers for women to work in the clean cooking sector include perceived limitations to travel, the perception of danger associated with and distribution of fuel, and the stigma associated with the sector. Particularly in the bioethanol sector, there is a negative connotation with "drinking alcohol" and therefore sometimes deters talents.

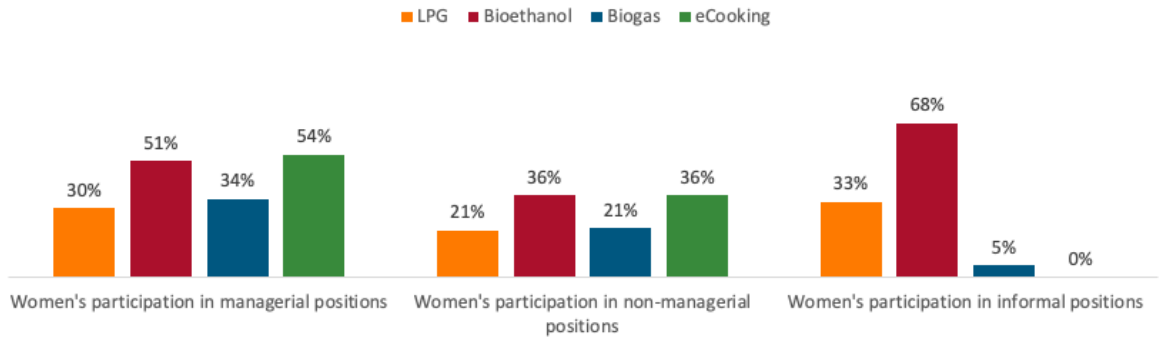

Figure 12. Women's participation in managerial, non-managerial and informal positions

On the other hand, women are highly valued in some key positions such as analytics, finances, marketing, sales, customer relations, and business administration. In Kenya, almost 100% of the end-use consumers of cooking fuel and technologies are women. Therefore, sales activities are often performed better by women than men [26].

Women's participation is also highly valued in product research and design. Companies expressed strong interest in engaging women in these activities, particularly because women are more aware of the needs of the end users, who are also mostly women.

The change of market dynamic in the clean cooking sectors may provide an opportunity for better women's engagement. In parts of the LPG value chain, such as cylinder manufacturing, revalidation, and filling, the process is highly automated. The automation trend may see a shift of workforce need from hard labor to machine operation and management, and therefore, provide more opportunity for women. In the biogas sector, the technology shift from fixed-dome digesters to the moveable systems may also provide an opportunity for women, since the deployment of these moveable systems require less construction labour, which is traditionally held by more men than women.

The survey data shows that youth participation in the clean cooking sectors is high (Figure 17). The LPG sector has lower youth participation in its formal workforce than informal. Higher youth participation in the informal workforce may be associated with lower skill requirements. Focus group experts also commented that LPG companies are interested in working with and often train youth groups to sell and distribute their products. Bioethanol companies express strong interest in hiring young people, and they often train young people into senior positions. In the biogas sector, while there is a high youth participation, young people may face capital constraints and find it difficult to start their own businesses after training as biogas constructors or installers.

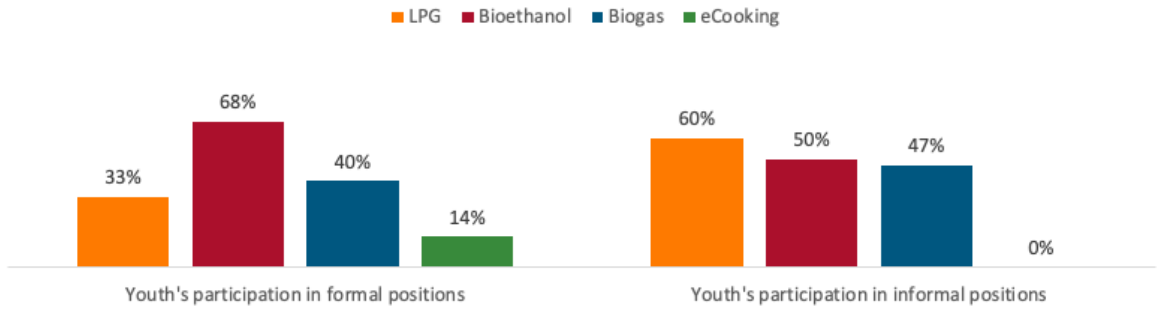

Figure 17. Youths' participation in formal and informal positions

3.3 Recruitment Challenges and Skill Development Needs

According to the survey outcome in Figure 18, the LPG sector has a wide and diverse occupational or job function breakdown. The skills are evenly spread across different job functions, with slightly more demand for sales and marketing, and after-sales service talents. The bioethanol and biogas sector, on the other hand, has a stronger need for manufacturing and assembly workforce. The electric cooking sector has a large share of its workforce in sales and distribution.

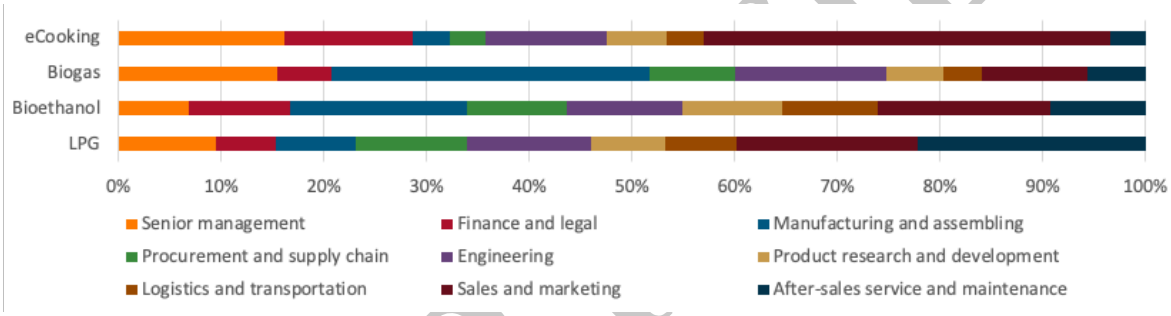

Figure 18. Occupational breakdown, as percentage of direct, formal jobs

The occupational breakdown of the clean cooking sectors provides an indication to where the skill demand and skill gaps exist. While most companies have a strong need for sales and after-sales service workforce, not many find these talents difficult to recruit. As shown in Figure 19.

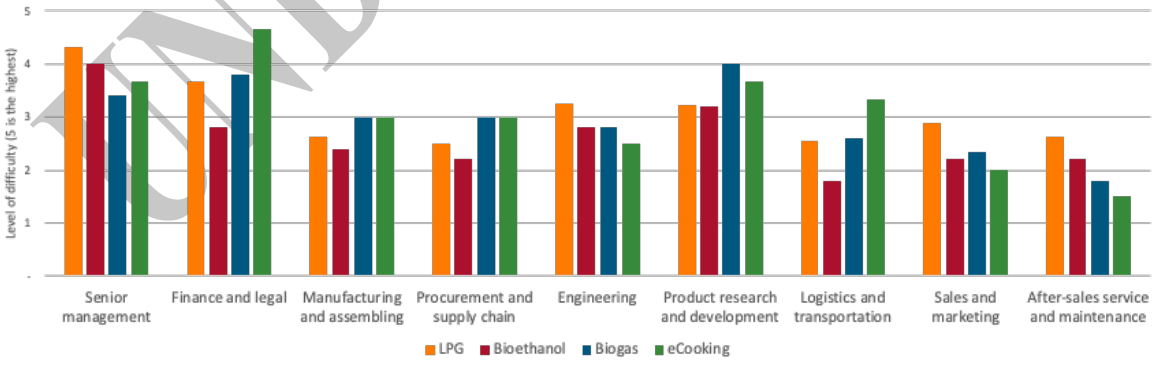

Figure 19. Recruitment difficulty of different job types for each clean cooking sector

On the other hand, senior management, finance and legal persons are said to be the most difficult to find. This is because the changing regulatory environment in the clean cooking sector makes it more difficult to find legal professionals. Companies also express more interest in recruiting entry-level talents and training them into managerial positions, rather than recruiting for managerial talents externally. This is particularly pronounced in the bioethanol sector. In the biogas sector, companies

have strong preference in recruiting technical talents for their "core functions" and outsourcing finance or business administration. Research and development (R&D) represent another skill gap in the biogas sector. R&D talents are costly and difficult to find.

While the clean cooking sector creates many jobs for young talents and is investing resources in training entry-level professionals into managerial positions, experts expressed concerns for the mismatch between formal education and the technical skills required in the sector day-to-day. Graduates often lack soft skills and workplace readiness.

4. Discussion

4.1 Practical Implications of the Data Findings

In 2019 the clean cooking sectors provided about 11,000–19,000 direct formal jobs and potentially more than 35,000 direct informal jobs in Kenya, mainly through downstream linkages with the retail businesses. While the LPG sector has a high informal employment impact, this is expected to change as the government continues to formalize the downstream value chain after the introduction of LN100/2019. While the new regulations have a positive impact on ensuring the health and safety of LPG workers, this process may have a short-term negative impact on some of the smaller retail businesses that do not have the capital or the ability to become licensed. The government can mitigate this by continuous policy communication and small business support.

While the clean cooking sectors provided many jobs, the level of compensation is low, especially compared to that of the decentralized renewable energy sectors; it is barely in the range of Kenya middle income [4]. Most clean cooking sectors' formal non-managerial employees earn a decent income of more than US$ 200 per month, compared to charcoal workers, who earn about US$ 60 per month (US$2 per day is barely above the Kenya poverty line of US$1.9 per day of 2011 PPP). In the case of managerial employees, most of them earn more than US$500 per month.

As of 2019, LPG is the single most important jobs engine in the clean cooking sector. Bioethanol and biogas are emerging as key drivers, particularly for rural employment. Bioethanol has a wide impact on sugarcane farmers, while biogas creates productive use opportunities through a diverse range of applications. To reap the employment benefits of productive uses of biogas systems, a stronger product development, research and innovation workforce is needed. The survey data showed that research and development is one of the top three talents that are the most difficult to recruit.

While product research and development skills represent one of the biggest gaps in the clean cooking workforce, it also provides a direct opportunity for strengthening women's participation in the formal workforce, which is currently lower than 30% on average. Companies express high interest in engaging women in product design and innovation, especially because most of their users are women.

Several sectoral trends shed light on opportunities for women. In the biogas sector, a shift towards moveable technologies is changing the perception of the biogas jobs; from what used to be perceived as labor intensive masonry to jobs that require sales and marketing skills. In addition, there is also a major opportunity in tapping into the referral network capabilities of women end-users.

The majority of the direct, formal workforce is reported to be skilled, with a wider potential for semi-skilled and unskilled workers in the informal and indirect jobs. Skill development pathways are most often internal, and therefore, there is a strong need for workforce ready entry-level talents. Formal institutions can help with preparing more workforce-ready young graduates.

Support for entrepreneurs is also said to be lacking. In Kenya, recent estimates suggest that 46% of micro, small and medium enterprises (MSME) close down in their first year of operation [27]. Entrepreneurs face fierce competition among themselves. As the clean cooking sectors are highly dependent on MSMEs as their selling points, it is key to ensure the sustainable operation of these small businesses.

For the biogas sector, almost 60% of the market share is served by entrepreneurs. Currently, the government's tax exemption benefits only large shipments of prefabricated systems and these

benefits are not captured by the small entrepreneurs [15]. For the sector to grow, clear guidelines for entrepreneurs to obtain tax exemption status is needed.

4.2 Study Limitations

Impact of new access. The data here provides employment estimates for the clean cooking sectors, but does not represent jobs from "new access" only. It is difficult for companies to specifically identify those customers who are first time users of clean cooking technologies, and whether there is fuel stacking with other technologies in the home. In the survey, companies were asked to estimate the likelihood of fuel stacking, but further analysis would be required to attribute jobs to new access.

Consideration of jobs displacement. The employment impact of the clean cooking sector has a strong element of job displacement caused by fuel-switch. The World Bank estimates that the sub-Saharan Africa charcoal sector alone employs 7 million Africans, with aggregate employment expected to reach 12 million by 2030 [11]. Recent individual country studies estimate the involvement of 700,000 people in the charcoal sector in Kenya [11].Given the lack of available data, the study does not explore past, current or future job displacement that may result from fuel switching, or automation etc. This is a major limitation towards understanding the scale of net employment. Broader macro-economic studies are required.

Sample period. The data represents only one year of employment history. Trends are likely to change in the future and thus further surveying would allow for a more nuanced understanding of employment scale, and future predictions.

Sample representation. Further, the sample size is limited and may not capture certain value chain segment areas. For instance, the survey only covers EPC as electric cooking technologies, while there are many other electrical appliances for cooking such as, water boilers and toasters that are available in Kenya. Furthermore, the sample may not capture the value chain of every hardware and/or equipment used in LPG production, including LPG valves, regulators, and other equipment manufacturing. It also does not take into consideration the deployment and maintenance of bioethanol fuel dispensing technologies. Thus, future studies should incorporate these elements for the job estimates to be more comprehensive.

High-quality market estimate data. The study applies employment factors to best-available market estimates for Kenya. However, there exists very little market data on bioethanol fuel consumption and EPC sales, which reduces confidence in the estimates produced. Most recent and best available estimates are used where possible but stronger market data is needed for the sector.

Comparability of direct formal and informal jobs. Direct informal jobs cannot be fully estimated. Due to lack of data about the nature and time involved in work, direct informal and productive use jobs are not translated into FTE terms and therefore cannot be readily compared in scale to direct formal jobs. Further study is required into the nature of informal employment in Kenya.

Furthermore, the study does not yet explore the status of the informal retail businesses that support the sales and distribution of LPG and bioethanol fuel. Therefore, it is difficult to understand: how many of the retail businesses are informal, how workers are compensated, how many hours they are engaged in clean cooking businesses, and how long the workers are retained. Consequently, the numbers reported in this study are not comparable with the direct formal jobs. EPRA is in the process of licensing all LPG retail businesses. Future studies should work closely with the government to encourage continuous and transparent reporting and tracking of jobs in the LPG retail businesses.

Productive use jobs. The study only briefly discussed the productive use jobs in the biogas sector. There is a wider cost-saving and income generation opportunity from the productive use of clean cooking fuel and technologies for heating, milling, drying, pasteurization, etc. These activities are not part of the scope of our survey tool, and requires end-user facing studies to quantify.

Data aggregation in skill trends. Skill trends data such as retention, women participation, youth participation, occupational breakdown, and recruitment challenges are aggregated by fuel type. Detailed insights are not available for some parts of the value chain due to a limited sample.

5. Conclusions

This study has provided a comprehensive overview of employment in Kenya's clean cooking sectors. We find that in 2019, the clean cooking sectors covering LPG, bioethanol, biogas, and electric cooking, provided about 11,000–19,000 direct formal jobs and potentially 35,000 direct informal jobs in Kenya. According to the latest estimate by the Ministry of Energy, Kenya, most of the jobs are now in the LPG sector, which currently supplies 29.7% of households [2]. The bioethanol sector may create additional value in its upstream raw material production activities for the sugarcane farmers [13]. Further, in the downstream linkages, the biogas sector has high potential to provide productive use jobs.

The skill level of the direct formal jobs in the clean cooking sectors is high across the board. The most in-demand skills are sales and distribution in the LPG and electric cooking sectors while in bioethanol and biogas sectors, manufacturing and assembly are the most common job functions. Product research and development skills are reported to be the most difficult to recruit.

Women's participation in the sector is low, especially in the LPG and biogas sector, where only about one-fifth of the non-managerial workforce are women due to the labor-intensive activities involved in these jobs. In managerial positions, the clean cooking sectors see higher women's participation. Women represent about one-third of the managers in the LPG and biogas sectors and half in the bioethanol and electric cooking sectors. Companies generally express strong interest in engaging women in managerial positions and product research and development. These are also the positions that are reported to be the most difficult to fill. The clean cooking sectors are presented with a unique opportunity to close the skill gap and gender gap.

This research exercise establishes a baseline for understanding the employment impact of the clean cooking sectors. However, a massive data gap persists. Our study shows that while the clean cooking sectors, especially LPG, are already providing tens of thousands of jobs, further studies are critically needed to map the employment impact of delivering universal clean cooking access.

Kenya's Sustainable Energy for All Action Agenda commits to achieving universal clean cooking access by 2030. Many trends will determine the size and characteristics of clean cooking workforce, including the shift away from biomass-based solutions to modern energy, formalization of the fuel retail businesses, growing market share of prefabricated biogas digester providers, entrants of global conglomerates into the bioethanol sector, among others.

This study is the first attempt towards understanding the current clean cooking employment trends in a systematic and structured way. Future iteration will provide more insights on job growth predictions and future workforce trends.

List of Abbreviation:

African Gas & Oil Limited (AGOL)

Biogas Construction Entrepreneurs (BCE)

Electric pressure cooker (EPC)

Energy and Petroleum Regulatory Agency (EPRA)

Energy Dealers Association (EDA)

Full-time equivalence (FTE)

Global LPG Partnership (GLPGP)

International Labour Organization (ILO)

Kenya Biogas Program (KBP)

Liquefied petroleum gas (LPG)

Micro, small and medium enterprises (MSME)

Monitoring and evaluation (M&E)

Operations and maintenance (O&M)

Research and development (R&D)

Ethics approval and consent to participate: Not applicable. This manuscript does not report on or involve the use of any animal or human data or tissue.

Consent for publication: Not applicable. This manuscript does not contain any individual person's data in any form.

Availability of data and materials: All data generated or analysed during this study are included in this published article and the Appendices.

Competing interests: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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Author Contributions: CL and RS conceptualized the study and developed its methodology. CL, MO and HN curated the sample and collected the data. CL conducted the formal analysis and visualized the data findings. CL and RS prepared the original draft, reviewed and edited the manuscript. RS supervised and administered the study. All authors have read and agreed to the published version of the manuscript.

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Appendix A

Employment factor. An employment factor measures the number of jobs per unit of produced product or service. For instance, direct employment factors are calculated based on the number of total direct, formal jobs and number of products sold or systems built, in sales unit or capacity terms.

Full-time employment. A full-time employee is on the payroll with a registered company, enjoys benefits as an employee, and works full-time hours, which is generally more than 35 hours per week, but this may differ according to company policy.

Part-time employment. A part-time employee is on the payroll with a registered company but does not work full-time hours, which is defined according to company policy.

FTE job. An FTE job is the equivalent of one employee working full time over the course of a year where full-time work is defined in accordance with the country context. Part-time and contract work are converted to FTE based on the number of hours worked or length of contract. All estimates of direct formal jobs are presented in FTE job terms. All other references to jobs outside of direct formal employment do not assume full-time equivalency.

Direct formal jobs. In the scope of this study, direct formal jobs are those created through contractual engagement with an incorporated company in the clean cooking sector. For example, an IT professional or a project manager who is employed by a clean cooking company.

Indirect jobs. Indirect jobs are those created by backward-linked industries or companies that serve and supply the clean cooking sector. That is, those vendors and suppliers who serve the sector upstream or provide services for the sector's day-to-day operations either contractually or non-contractually. For example, indirect employment can be observed in sugarcane farming activities that supply the raw material for bioethanol.

744 **Informal sector.** According to the International Labour Organization (ILO), the informal sector
745 comprises all work for unincorporated enterprises and for which no complete accounts are
746 available that would permit a financial separation of the production activities of the enterprise from
747 other activities of its owner(s). Informal jobs can even be extended to include non-remunerative
748 work of contributing family members, and thus can be difficult to bound definitively [28].

749 **Direct informal jobs.** Those informal jobs that are created through contractual or non-contractual
750 engagement with an incorporated company in the clean cooking sector. Informal employment in
751 the sector takes on various forms—from long-term arrangements with companies (e.g. product
752 retail) to commission-based sales activities. For example, a home business that works as a selling
753 point for a bioethanol fuel.

754 **Induced jobs.** Induced jobs are those created through forward linkages as workers in the clean
755 cooking sector spend salaries on goods and services throughout the larger economy. For example,
756 during the construction of a biogas plant, induced jobs are created for masons at the construction
757 site. Induced jobs are estimated using "job multipliers". However, this study does not explore the
758 macroeconomic effects of spending on the economy and further job creation thereof. Induced jobs
759 are excluded from the analysis and this report.

760 **Productive use jobs.** Productive use jobs are those created by the end users themselves as a result
761 of newly-acquired or enhanced electricity access. For the purpose of this study, productive use is
762 defined as any income-generating application of a clean cooking product or service [29].

763 **Retention.** Retention is the total period of time that an employee continues to work with an
764 organization.

765 **Senior managers.** For the purpose of this study, senior managers include the top executive
766 management of a company, such as the CEO, CFO, and COO.

767 **Skilled workers.** Skilled workers are those who hold leadership, management, professional,
768 technical, or associate professional positions. Their responsibilities typically involve the
769 performance of complex technical and practical tasks that require an extensive body of factual,
770 technical, and procedural knowledge in a specialized field, as defined by the International Standard
771 Classification of Occupation (ISCO-08) Skill Level [30]. Workers in Skill Level 3 or above are
772 considered skilled workers. While there is a qualification and skills framework developed by the
773 East African Community, there is little substantial difference between these frameworks [31]. Our
774 study adopts the ILO framework to allow for consistency and comparability with results from other
775 SSA countries.

776 **Youth.** Youth are defined as persons between the ages of 15 to 24.

777 **Appendix B. Employment Factors and Jobs Estimates**

778 Table A1–A4 summarizes the employment factors used by the study to scale the job numbers.
779 All reported job numbers are rounded to two significant figures.

780 **Table B1.** Employment Factors and Jobs Estimates of the LPG Sector

LPG value chain activities	Direct formal employment factor	Direct informal employment factor	Direct formal jobs estimate	Direct informal jobs estimate
LPG import and wholesale	0.015 jobs per tonne	0.000 jobs per tonne	3,400	0

LPG transportation in bulk	0.002 jobs per tonne	0.001 jobs per tonne	400	300
LPG storage and filling	0.004 jobs per tonne	0.000 jobs per tonne	1,000	0
LPG wholesale in cylinder	0.013 jobs per tonne	0.000 jobs per tonne	3,100	0
LPG retail sales in cylinders	0.016 jobs per tonne	0.000 jobs per tonne	3,800	0
LPG cylinders manufacturing	0.260 jobs per 1,000 cylinders	0.000 jobs per 1,000 cylinders	520	0
LPG cylinder revalidation	0.571 jobs per 1,000 cylinders	0.000 jobs per 1,000 cylinders	170	0
LPG stove manufacturing	0.000 jobs per 1,000 stoves	0.000 jobs per 1,000 stoves	0	0
LPG stoves sales and distribution	45 jobs per 1,000 stoves	0.059 jobs per 1,000 stoves	4,500	10

781 **Table B2.** Employment Factors and Jobs Estimates of the Bioethanol Sector

Bioethanol value chain activities	Direct formal employment factor	Direct informal employment factor	Direct formal jobs estimate	Direct informal jobs estimate
Bioethanol production	0.014 jobs per 1,000 liters	0.000 jobs per 1,000 liters	80	2
Bioethanol wholesale	0.055 jobs per 1,000 liters	0.000 jobs per 1,000 liters	320	2
Bioethanol distribution	0.003 jobs per 1,000 liters	0.012 jobs per 1,000 liters	20	70
Bioethanol end-user sales	0.047 jobs per 1,000 liters	0.130 jobs per 1,000 liters	270	750
Bioethanol stove manufacturing	0.258 jobs per 1,000 stoves	0.117 jobs per 1,000 stoves	4	2
Bioethanol stove sales and distribution	2.396 jobs per 1,000 stoves	2.604 jobs per 1,000 stoves	40	40

782 **Table B3.** Employment Factors and Jobs Estimates of the Biogas Sector

Biogas value chain activities	Direct formal employment factor	Direct informal employment factor	Direct formal jobs estimate	Direct informal jobs estimate
Biogas digester importing and assembly	2 jobs per 1,000 biogas digesters	0 jobs per 1,000 biogas digesters	5	0
Biogas digester manufacturing and fabrication	210 jobs per 1,000 biogas digesters	0 jobs per 1,000 biogas digesters	450	0
Biogas digester installation and construction	30 jobs per 1,000 biogas digesters	9 jobs per 1,000 biogas digesters	220	770
Biogas digester after-sale service	15 jobs per 1,000 biogas digesters	2 jobs per thousand biogas digesters	320	50

Biogas stoves manufacturing and fabrication	6 jobs per 1,000 stoves	0 jobs per 1,000 stoves	10	0
Biogas stoves sales and distribution	7 jobs per 1,000 stoves	0 jobs per 1,000 stoves	20	0

Table B4. Employment Factors and Jobs Estimates of the eCooking Sector

Electric cooking value chain activities	Direct formal employment factor	Direct informal employment factor	Direct formal jobs estimate	Direct informal jobs estimate
EPC manufacturing and assembly	0 jobs per 1,000 stoves	0 jobs per 1,000 stoves	0	0
EPC import and wholesale	3 jobs per 1,000 stoves	0 jobs per 1,000 stoves	10	0
EPC retail sales and distribution	50 jobs per 1,000 stoves	9 jobs per 1,000 stoves	210	770

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