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# Understanding the current market enablers for Nepal's biomass cookstove industry

Benjamin L. Robinson , Sarah Jewitt , Mike J. Clifford , and Joseph Hewitt 

## ABSTRACT

This paper applies the market map tool to the Nepalese biomass improved cookstove (ICS) sector highlighting existing weaknesses in government policy and biomass cookstove market chains to provide recommendations to better address the social, economic, and cultural needs of users. This addresses the problem of low adoption rates of biomass ICS in Nepal. Our research objectives set out to explore the effectiveness of market maps designed for East Africa's ICS sector (Stevens et al. [2019]. "Market Mapping for Improved Cookstoves: Barriers and Opportunities in East Africa." *Development in Practice*) in Nepal, co-develop a revised market map for Nepal's biomass ICS sector, conduct a parallel process for institutional-scale biomass ICS and draw on the co-produced market map to inform policy and regulatory frameworks relating to biomass-fuelled ICS. The methodological approach involved reviewing cookstove-related policy documents and regulatory frameworks, undertaking 31 semi-structured interviews, analysing findings from an Institutional Top-Loading Down-Draft (TLUD) Natural Draft Gasifier Pilot study and co-developing the final market map in collaboration with key ICS stakeholders. The results indicate that although government policy actively promotes biomass ICS, this often results in cookstove "stacking" rather than the sustained and exclusive use of clean cooking solutions necessary to promote health benefits. Attention is also focused on the underdeveloped nature of the institutional cookstove market. Our conclusions highlight the usefulness of market maps with a monitoring and evaluation element for identifying barriers to clean cooking uptake and facilitating product improvement by integrating end-user feedback.

## ARTICLE HISTORY

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## 1. Introduction and background

Energy access is prioritised in Sustainable Development Goal 7 (The World Bank 2018b) which seeks to "Ensure access to affordable, reliable, sustainable and modern energy for all" with target 7.1.2 promoting "universal access to clean fuels and technologies for cooking". The history of cookstove interventions has evolved in response to shifts from a desire to increase combustion efficiency whilst reducing deforestation and drudgery associated with wood collection (Mehetre et al. 2017), towards a focus on reducing the health and environment-related concerns associated with reducing household air pollution (HAP) and black carbon emissions (Tielsch et al. 2014; Lindgren 2020; WHO 2020).

Reflecting the twin emphases on addressing health and environmental concerns, cookstove performance is evaluated using an internationally standardised testing methodology devised by the

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International Workshop Agreement (IWA) which categorises them into five tiers with Tier 0 representing a traditional open fire and Tier 4 an electric hob (International Organization for Standardization 2012). The categorisation process reflects a range of factors including their production of high and low power carbon monoxide, high and low power particle matter, combustion efficiency, specific combustion efficiency, time taken to boil and simmer a predetermined volume of water, and safety considerations (International Organization for Standardization 2012).

Despite recent efforts to promote clean cooking solutions, the uptake of higher tier systems in many low- and middle-income countries has been slow (Mobaraka et al. 2012; Hewitt et al. 2018). Nepal's current level of primary access to clean cooking facilities is just 28% – well below the global average of 59% – and has been linked to approximately 56,700 people every year dying from household and ambient air pollution (The World Bank 2018a). Whilst it is problematic to directly relate this to traditional “three stove fire” cooking methods (traditionally with wood or other available biomass), the fact that over 50% of Nepalese households cook with firewood (National Planning Commission 2018) suggests that it is a large contributing factor to both micro and macro pollution. Efforts to promote transitions to cleaner energy sources include a longstanding policy of providing subsidies to promote the adoption of improved cookstoves (ICS) of tier 2 and above among rural households (Ministry of Population and Environment 2016). ICS designs that meet or exceed IWA tier 2 criteria and comply with government regulations are made eligible for dissemination under the government's Renewable Energy Subsidy Policy. The Renewable Energy Subsidy also gives varied support to a range of technologies including hydropower, solar power, solar thermal, biogas, wind energy, hybrid systems, and biomass energy by reducing costs at the user end. Significantly, however, the Renewable Energy Subsidy does not apply to LPG (Ministry of Population and Environment 2016) and Nepal's long-term aim is to promote a shift to the electrification of cooking facilities. Nevertheless, the country's Biomass Energy Strategy (Ministry of Population and Environment 2017) highlights biomass as a key contributor to the country's energy needs in the short and medium term as reflected by the installation of 1.3 million ICS of Tier 2 and above in households compared to 365,000 biogas units and 600 solar cookers.

### **1.1. Market mapping to promote ICS**

To help promote the adoption of clean cooking solutions, market assessments have been promoted in East Africa by the Clean Cooking Alliance to better understand barriers to the uptake of clean fuels and stoves and how to create markets for them (Accenture Development Partnerships 2012). Stevens et al. (2019) applied market mapping techniques to the ICS sector in East Africa to enable market-based comparisons to be made between countries. Building on their approach, this paper applies market mapping techniques to the Nepali biomass ICS market. Whilst this approach shares some similarities with other models (Clean Cooking Alliance 2011), the market map has two core differences. First, the demand and supply elements are separated with the understanding that demand drives the value chain through various contextual factors (social, financial, economic, etc.). Second, the market map focuses on a particular market segment. In this example, we focus on the Biomass ICS sector, not the entire energy sector.

The mapping process is divided into two stages comprising market system mapping followed by the identification and analysis of potential supporting interventions. During market system mapping, energy sector markets are divided into three levels to facilitate systematic analysis of market gaps, key actors, stakeholders, and beneficiaries. The first level is the market or value chain which contains all the functions and actors associated with a product going to market including development, manufacture, distribution, retail, and consumption. Additional weakly defined or poorly linked steps in this process can negatively influence the effective and efficient dissemination of technologies and the overall success of cookstove intervention initiatives. The second level contains the inputs, services, and finance that connect and support the market chain. Inputs typically include materials or products as well as labour or the manufacturing capability needed to deliver

the products. Services include processes that are required for products to be sold and distributed by a number of different actors, public or private. Contained within finance is access to financial institutions such as traditional or community banks which provide loans to enable users to purchase the product. Some elements or actors are responsible for more than one function and together these inputs are of critical importance in the effective working of the market chain. The third level is the enabling environment which is sub-divided into political and regulatory factors, social and cultural factors, and financial and economic factors that influence this market chain and which must be accounted for in the development of business proposals. In the case of ICS, these help to capture how country-specific regulations, standards, and policies (including subsidies, quality testing requirements, regulations on the use of particular fuels) along with socio-economic and cultural factors (e.g. affordability relative to existing stoves/fuels or locally-specific cooking practices and preferences) influence demand and affect ICS markets.

The aim of this paper is to understand current market enablers for, and barriers to, the adoption of both household (tier 2+) and institutional biomass-fuelled (tier 2+ if less than 20 kW, with no testing required for subsidised 20kW+ units) ICS in Nepal to better understand how to create markets for them. Our objectives were to:

- (1) Explore the effectiveness of market maps designed for East Africa's ICS sector (Stevens et al. 2019) for identifying currently underdeveloped household-scale biomass-fuelled ICS market sections in Nepal that would benefit from market-based interventions.
- (2) Draw on semi-structured interviews and participatory research with a range of key stakeholders to co-develop a revised market map for Nepal's biomass ICS sector.
- (3) Conduct a parallel process for institutional-scale biomass ICS and integrate this into our co-developed market map.
- (4) Draw on the co-produced market map to inform policy and regulatory frameworks relating to biomass-fuelled ICS.

Our methodology was primarily qualitative and involved 31 semi-structured interviews and participatory exercises with 24 stakeholders in Nepal's ICS sector to explore biomass ICS markets at both household and institutional scales. The stakeholders included government policy representatives, national cookstove testers, national cookstove design centres, manufacturers, distributors, non-governmental organisations, and users, and all are key actors in the shared value chain associated with the household and institutional biomass cookstove sectors. Our focus covered all biomass cookstoves in use in Nepal, including, but not limited to, traditional three stone fires (TSF) and both locally produced and imported metallic and mud-based ICS with a range of efficiencies and emissions ratings, in both the institutional and household cookstove markets. In order to understand barriers to the adoption of improved biomass cookstoves, we also explored the use of other fuel and stove combinations such as LPG, kerosene, and electric which were often used (or "stacked"; Masera, Taylor, and Kammen 2000) alongside both unimproved and higher tier biomass stoves to meet users' cooking preferences and requirements.

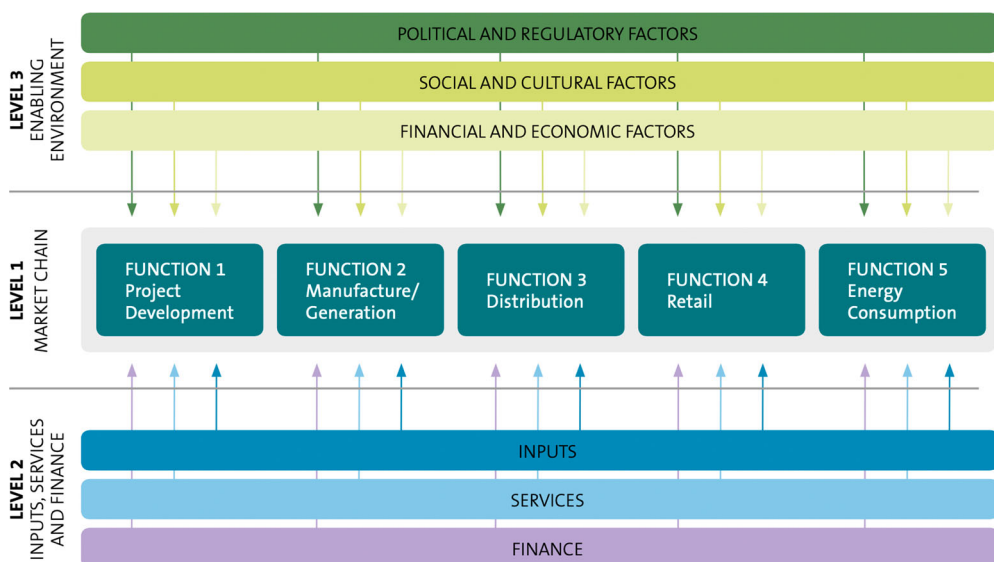
The novelty of this paper lies in the application of the market mapping framework to Nepal's institutional as well as household biomass ICS sectors. Our use of participatory approaches to co-develop an ICS market map with key stakeholders resulted in the addition of a monitoring and evaluation function to the market map framework which has not been used in previous market map applications (Stevens et al. 2019). This function forms part of the project cycle but has significant potential to enhance future product development by building on user feedback whilst integrating elements of co-production seen in other models such as the Responsible Innovation Framework (Engineering and Physical Sciences Research Council 2013).

The rest of the paper is structured as follows: Section two provides an explanation of the methodology used while Section three sets out phase one of the market map; satisfying research

objectives two and three. Sections four and five satisfy research objectives one and four by providing a discussion of phase two of the market map and bringing these results together in the conclusion.

## 2. Methodology

We obtained primary data for this study in three main segments to populate the three levels and multiple sub-levels of the market map seen in [Figure 1](#). The first segment focused on exploring the policy and regulatory frameworks influencing Nepal's household and institutional biomass ICS sectors. In addition to reviewing Nepalese Government policy documents and ICS regulatory frameworks, the lead author conducted seven semi-structured interviews with seven key stakeholders (government policy representative, national cookstove tester, national cookstove design centres, manufactures, distributors, and a non-governmental organisation) in the ICS sector and biomass stove value chain to provide a framework for constructing the Market Model. This process represented both institutional and household actors as they share the value chain. Our second segment focused on the institutional ICS sector and was informed by a pilot study looking at the design, implementation, and evaluation of an Institutional Top-Loading Down-Draft (TLUD) Natural Draft Gasifier; the key results of which will be presented elsewhere. We conducted the pilot study between October 2017 and April 2020. This involved a participatory approach in which the lead author co-designed, manufactured and tested a Natural Draft Institutional TLUD Gasifier with the Centre for Rural Development Nepal, according to Nepal's Interim Benchmark for solid biomass cook stoves Ministry of Population & Environment and AEPC, 2016. Following the testing process, the lead author placed ten TLUDs at a series of institutions comprising dairy farmers, high altitude Buddhist retreat centres, schools, and small businesses and collected feedback on longer term performance and sustained use at around three months, one year, and two years after first use. This included 24 semi-structured interviews with 11 TLUD users and six community members from the area surrounding the pilot sites plus progress updates from the Nepali project partner NGO and research assistants. Whilst the TLUD pilot focused on the institutional ICS sector, all of the pilot sites have access to household-scale biomass ICS enabling user perspectives from the household sector to be noted and integrated into the results. This paper draws on the lead author's direct



**Figure 1.** Market map developed by Practical Action Consulting and EUEI PDF (2015).

experience of the manufacturing and testing process coupled with data collected through a combination of direct observation, semi-structured interviews, and informal discussions with TLUD users and ICS stakeholders (details of which were recorded in a field diary and supported with photographs) to obtain different perspectives on ICS use. These stakeholders included staff at the Centre for Rural Technology, Nepal (CRT/N), Child Reach Nepal (CRN), Kathmandu University, Alternative Energy Promotion Centre (AEPIC), and Dhulikhel Hospital Community Department (DHCD). Our third segment involved working with a number of key stakeholders to co-develop an early draft of the market map and identify key barriers to biomass-based ICS development and uptake in Nepal with the aim of reducing bias and grounding the research with stakeholder voices. This involved the lead author in presenting initial findings from the pilot study and seeking feedback from government officials, staff from international and national non-governmental organisations, private sector representatives, and academics from around the globe at the ICIMOD Indoor Air Pollution Conference in Kathmandu. This feedback was in accordance with the ethical clearance granted in advance of the study and we obtained informed consent from all participants and anonymised the information they gave.

We analysed data obtained from the first two segments qualitatively employing an inductive theming and coding approach and using Nvivo12 (QSR International 2019) to help identify site- and method-specific themes as well as those present across the different sites and methods. We designed this approach to explore and interpret key barriers to adoption for different technologies in different contexts and enhance understandings of how these were underpinned by prevailing social practice and cultural norms, as well as economic and pragmatic factors (Malakara, Greiga, and Fliert 2018; JagadisH and Dwivedi 2018; Jewitt, Atagher, and Clifford 2020). While we chose a combination of approaches to reduce the chance of systematic bias, it is important to acknowledge researcher positionality. The lead author facilitated the production and distribution of the institutional TLUDs as well as the monitoring, evaluation and data collection from the pilot study as TLUDs were a novel technology in the Nepalese cookstove market. The lead author's relationship with the technology was made clear to users at the start of the study when visits were made to the pilot sites prior to the dissemination of the TLUDs. He made efforts during these visits to build trust, encourage transparency and foster an environment in which the users could give honest, open feedback to the lead author, co-author or the Nepali project partners. However, we acknowledge a risk of "social desirability" bias (Sovacool, Aksen, and Sorrella 2018) in the TLUD pilot interviews linked to the lead author's "outsider" status and involvement in the design of the TLUD. In an effort to reduce this, semi-structured interviews by the lead author were undertaken in collaboration with either a research assistant (as an interpreter and translator) or a co-author who had no previous involvement in the TLUD. To further reduce the potential for bias, we triangulated interview data with direct observation coupled with feedback and photographs from the Nepali project partner and end users. The direct observation was structured to note evidence of the nature and frequency of TLUD use such as general condition, heat from recent use, soot deposits, ash build up, and firewood stacks or appropriately sized pots located nearby.

### 3. Phase one: market system mapping – biomass market map development

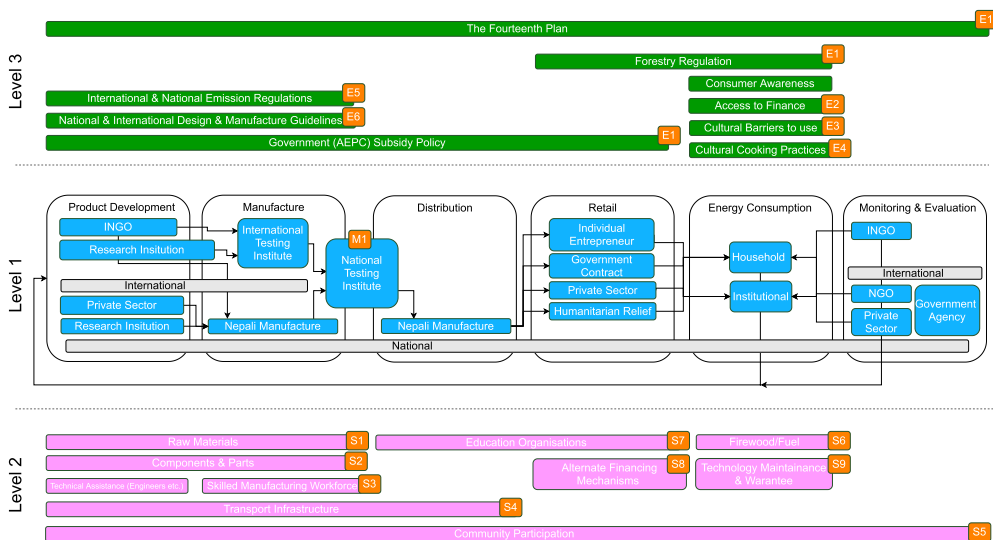
In order to develop a biomass ICS market map for Nepal that captures the entire biomass energy chain and includes monitoring and evaluation aspects, some adjustments needed to be made to the original market map structure (Practical Action Consulting and EUEI PDF 2015). These adjustments drew from discussions and interviews with key stakeholders which clarified the nature of Nepal's ICS market chain, the testing process, allocation of ICS subsidies, broader regulatory frameworks governing ICS, key bottlenecks and user priorities. These discussions also highlighted monitoring and evaluation as a key market segment as national organisations routinely bid on tenders for the monitoring and evaluation aspects of government projects. Although the household and

institutional aspects of the improved biomass cookstove industry are considered separately by Nepal's Alternative Energy Promotion Centre (AEPCC), we consider them both in one market map in order to simplify a complex system.

### 3.1. Level 1: the ICS market chain

Both function one (project development) and two (manufacture) can be subdivided into international and national value chain segments with testing and approval processes taking place in both. Participant observation at Renewable Energy Test Service (RETS) indicated that international organisations develop and test their biomass ICS outside of Nepal and tend not to modify the design to account for local social, cultural, and financial factors. Many of these designs are replicated by local manufacturers, the most common of which is a continuous loading single pot rocket type cookstove which makes up 72.3% of Nepal's Government Approved Cookstoves (Renewable Energy Test Station 2019). This system of replication further exacerbates the lack of contextual design and has a significant impact on sustained use, resulting in complex, expensive, and less well adapted ICS (Stanistreet et al. 2014; Malakara, Greiga, and Fliert 2018; JagadisH and Dwivedi 2018). For example, in the household sector, the Mimi Moto imported cookstove uses wood pellets which are not widely available in Nepal and costs up to 10,000 Npr (100USD). In the institutional sector, the InStove 60 & 100L cookstove has a very high thermal efficiency of 50% but retails at 850USD (InStove 2016). Although these are both technologically advanced Tier 4 biomass ICS, their appropriateness in Nepal is questionable.

At the national level, a range of organisations including the Centre for Rural Technology Nepal, Regional Knowledge and Testing Centre, Kathmandu University, and other small private engineering firms have developed household and institutional scale biomass ICS, although the number of stoves that they produce is relatively small due to the high cost of developing new cooking technologies (Renewable Energy Test Station 2019). There are also some hybrid models which involve product design and testing by international research institutes outside Nepal followed by refinements to adapt the product to local needs during manufacture within Nepal; often undertaken by trained technicians from villages in which the initiatives are conducted. These processes are represented by S1, S2, and S3 in Figure 2.



**Figure 2.** Nepal biomass ICS modified market map and policy framework.



The methods of manufacture for the household and institutional biomass ICS sector include Nepalese Manufacture with Approved Design (NM), International Manufacturer and Imported Product (IM) and Centrally Manufactured and Locally Assembled (CMLA) (Renewable Energy Test Station 2019). An example of the latter which qualifies under the stove subsidy policy is the Hybrid Mud/Steel type ICS (for both household and institutional use) for which the steel components are manufactured in Kathmandu and the mud elements are built on site by builders pre-approved by AEPC. Regarding international ICS imports, India is the second biggest contributor to the market (44.7%), after Nepal (40.4%), whereas China has an unusually small market share (8.5%) (Renewable Energy Test Station 2019). This could be due to the lack of road links between China and Nepal which increases the cost of importing alternative energy products from the Chinese market.

The process of government approval for all biomass ICS within Nepal is influenced by the Ministry of Energy, Water Resource, and Irrigation (MoEWI – formally known as the Ministry of Population and Environment – MoPE) which sets government policy for strategy periods (E1). This policy is implemented through the AEPC which puts out tenders for new designs to fulfil MoEWI Policy. These include 100% cookstove subsidies for marginalised groups or government tenders for contractors to fulfil the policy requirement (Ministry of Population and Environment 2016). New biomass ICS designs are either tested directly through the Renewable Energy Test Service<sup>1</sup> (RETS) or at the Regional Testing and Knowledge Centre (RTKC) for AEPC. However, stoves tested at RTKC must still be signed off by RETS (M1) if the model is being promoted under government programmes. All submitted ICS designs must comply with Nepalese Government regulations for emissions, materials, and safety as set out by MoEWI (E5 & E6), which include being Tier 2 or above in the IWA Standards (Ministry of Population and Environment and AEPC 2016). The National Standards contain information about material used, material thickness, etc. which can restrict cost whilst helping to ensure quality (Ministry of Population & Environment and AEPC 2016). Significantly, however, for Institutional Cookstoves “larger than 20 kW firepower, the emission testing requirements are optional”. There are 47 (at last update of the list) government approved biomass ICS which comply with the National Standards for manufacture and emissions, 45 of which are for household use and only two for institutional use. In addition, there are four biomass household-scale ICS that could be used in institutional settings as they are constructed with mud/stone and can be sized accordingly. The Renewable Energy Subsidy Policy is a key element in the market chain but due to its longevity, it has started to distort users’ perceptions of the value of individual ICS. If an ICS design complies with the policy and is subsequently certified, it is placed on the approved ICS list and made eligible for a subsidy subject to being manufactured using one of the pre-approved companies.

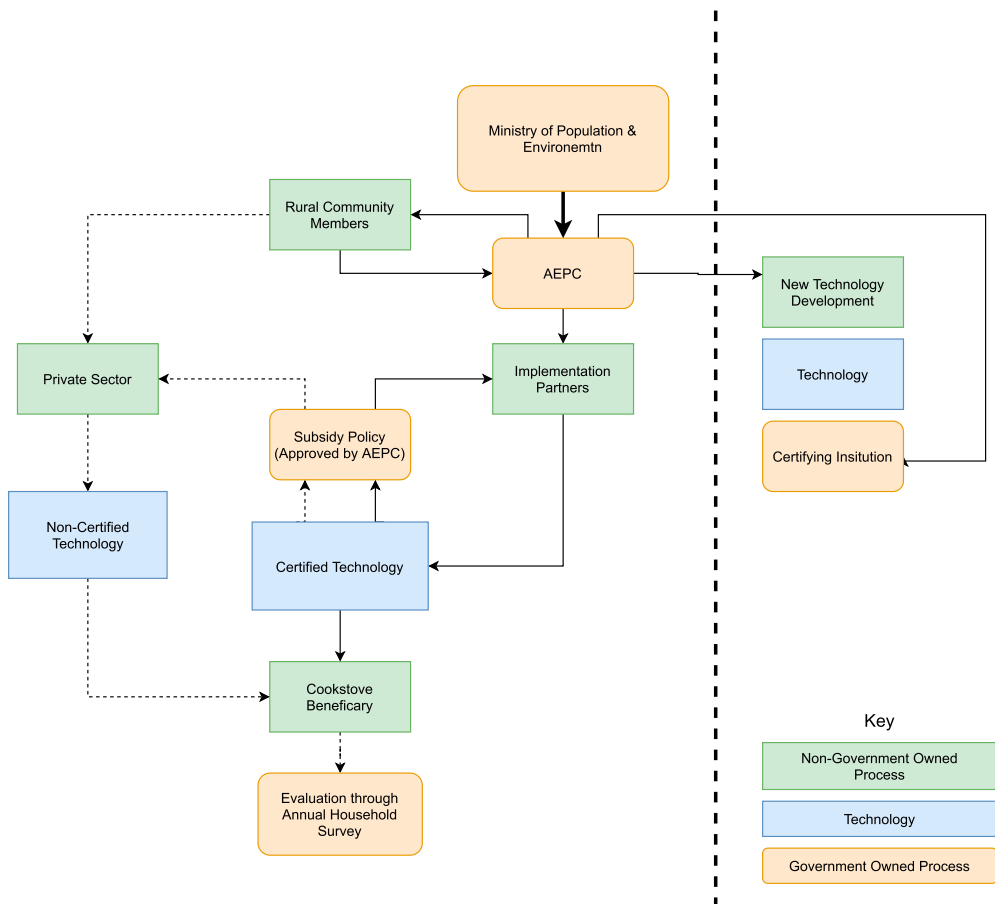
There are a limited number of institutional solutions for specific markets that lie outside of regular policy. The paper making and the milk-based sweet industries (see Figure 3) fall into this category and have been developed by AEPC to promote rural entrepreneurship and increase efficiency. One key informant spoke of an improved biomass cooking solution designed for the paper making industry that enabled it to increase productivity by 350%.

Function 3 (distribution) and 4 (retail) are often undertaken by manufacturers with distribution costs being included in the initial product cost and varying according to the distance from the manufacturer and the accessibility of the destination community. In addition, APEC, after the certification of all stoves, sets the price for specific districts, reflecting distance from the manufacturer, to control uneven prices, keep competition amongst the suppliers and ensure the user gets value for money (Ministry of Population and Environment 2016). Drawing on the semi-structured interviews, Figure 4 outlines the methods of distributing ICS to beneficiaries and provides more detail on the connectivity between distribution and retail than it is possible to show on the market map. The first product pathway illustrated in this figure starts from a policy change at the MoPE or through identification of a technology sector which needs development. This involves evaluation/testing of a new technology by RETS and approval by the AEPC followed by the implementation partners collecting the subsidy for the project. Under this product pathway, end-user beneficiaries receive a certified technology which is later evaluated via a household survey conducted yearly by the National Planning Commission (National Planning





**Figure 3.** Milk sweet industry (left) and paper making industry (right).



**Figure 4.** Biomass cookstove distribution network.

Commission 2018). For the manufacturer, the process of claiming the subsidy from AEPC requires the installer to take photographs of the beneficiary, installer, the installed cookstove and the beneficiary's citizenship ID card. This is to ensure there is only one cookstove present as the subsidy only covers one cookstove per household. After all the documentation has been submitted to AEPC and approved, the manufacturer receives the subsidy which effectively requires them to work in negative equity whilst waiting for the subsidy payment to be processed. As a means of quality control, the AEPC retains 5% of the subsidy amount for one year after installation, releasing it following a satisfactory independent evaluation or retaining it in the event of an unsatisfactory evaluation. Whilst this is a subsidy requirement, in reality, retention of the 5% subsidy may not occur.

A second pathway starts with a rural community whose members draw a particular need to the attention of AEPC, through a local government official, who reacts by either creating a new policy or tender to be bid on. From this point, the product follows the same pathway as above. A third pathway involves the identification of a community need by a private sector company (or individual entrepreneurs), which develops a technology, seeks approval by AEPC and provides a certified technology (which may or may not receive a subsidy) to beneficiaries. As the subsidy process requires a significant amount of bureaucracy for the manufacturer, in some cases private funding organisations, or more commonly international organisations, prefer to disseminate the technology without applying for a subsidy. The third pathway can therefore involve operating outside of government policy with beneficiaries receiving non-certified technologies direct from the developer/manufacturer. The advantage of this method is speed and simplicity and it is sometimes used by organisations developing a new technology and building a case for approval through the AEPC.

The role of the AEPC is likely to change in the context of the new government's stance on the de-centralisation and federalism of power. AEPC will act as a facilitator, developing standards and policies, and the local arms (such as RIMREC) will provide the financial aid of the subsidy policy.

In order for manufacturers to take advantage of the government's Renewable Energy Subsidy policy for biomass ICS, cookstoves have to be produced by certified or formally registered manufacturers using approved designs and installed by an approved installer. The subsidy amount is a pre-determined percentage of the total cookstove cost (Ministry of Population and Environment 2016); hence, if the cost of the ICS increases so does the monetary value of the subsidy up to a maximum of 50% of the total cost. This is done to ensure the final stove cost covers transport. Retailers can also set their own prices and the subsidy will cover a percentage, so if one retailer sets a higher price, the subsidy will rise up to a limit depending on where the user is situated. This means there is an opportunity to make money in the private sector as there are insufficient numbers of retailers to drive costs down through free markets and user choice, although this is slowly being negated by AEPC price limits.

The energy consumption function (5) is sub-divided in accordance with AEPC subsidy policy, where each policy group – hydropower, solar power, solar thermal, biogas, wind energy, hybrid systems, or biomass energy – is split into household and institutional sectors. This is to enable tailored subsidy policies, as the cost of these interventions varies greatly. In this study, a household is defined as a non-commercial premises containing less than ten people as the average Nepalese Household size is 4.5 with poorer households tending to have more (average 5.9) family members compared to 3.5 for the wealthiest group (National Planning Commission 2018). The institutional category is categorised as anything that is not household and includes SMEs, schools, monasteries, military barracks, farms, etc. Although energy and biomass consumption statistics are not widely available for institutions, observations carried out in ten rural institutions during the second segment of this study indicated the majority of rural institutions cook with firewood. According to data from the national household survey (National Planning Commission 2018) most urban institutions use LPG, presumably due the lack of available fire wood for urban institutions and households. There are exceptions, however, as urban schools on average do not cook at all whilst, as one TLUD pilot showed, some rural schools use a combination of methods which are cost driven. Figure 5 shows the results of the 2016/17 Annual Household Survey, and the breakdown of consumption by urban/rural location and by economic status. One interesting observation is the lack

	Firewood	Cow dung	Leaves/ straw/ thatch	Cylinder gas	Bio- gas	Other	Total
<b>Urban/Rural</b>							
Urban	35.4	4.6	1.7	54.1	3.8	0.4	100
Rural	65.8	11.7	3.4	16.5	2.5	0.2	100
<b>Consumption Quintile</b>						0.0	
Poorest	67.2	20.7	8.3	2.2	1.1	0.4	100
Second	71.7	12.6	5.2	7.7	2.8	0.0	100
Third	69.3	8.1	1.9	16.6	3.8	0.4	100
Fourth	49.3	4.8	0.4	41.4	3.7	0.3	100
Richest	19.8	2.0	0.0	74.5	3.3	0.4	100
<b>Nepal</b>	<b>52.4</b>	<b>8.5</b>	<b>2.7</b>	<b>33.1</b>	<b>3.1</b>	<b>0.3</b>	<b>100</b>

**Figure 5.** Percentage distribution of households by main fuel used for cooking (National Planning Commission 2018).

of electric stoves, despite Nepal's policy on electrification. Reflecting the views of all key stakeholders, the head of biomass projects in the AEPC suggested why this may be the case:

there was a huge problem with load-shedding and also we have an issue with energy security and energy sustainability. (Interviewee 15 (AEPC) – Mar 2019)

A TLUD pilot member added:

... in my homeland, Dolpa, there is no LPG gas, no electricity, they only have two types of things for cooking, the cow dung and wood. So yearly they are cutting lots of wood for making fire. (Interviewee 8 (TLUD Pilot Member) – Mar 2019)

Finally, each year, AEPC prequalifies competent companies to take part in the dissemination of ICS through the subsidy channels. In addition, the Rural Technology Producer Association Nepal (RuTPAN) – formed from private companies working in the sector – advocates for the sector and contributes toward the Alternative Energy Promotion Centre (AEPC) subsidy policy and delivery mechanism.

Function 6, Monitoring and Evaluation (M&E), is an aspect of the value chain that has not previously been included in market maps. We have included it here as it contributes a significant proportion of the project cost and for some energy sources such as micro-hydro, is required by the Nepalese Government to realise funds<sup>2</sup> (Ministry of Population and Environment 2016). For cookstoves, M&E is only required by the government if the initiative has been partially subsidised, so private sector projects outside of the policy are not required to partake in M&E.

In AEPC tendered projects there are multiple methods of M&E which include an internal review led by the AEPC M&E Team, a review led by an independent M&E Team, and a review that is contained in the Subsidy Policy through documentation collected in the Household Survey. Significantly, however, it is unusual for any of these methods to monitor use over time to ascertain whether subsidised ICS remain in use a year after dissemination. Another limitation is that the annual household government survey tracks national statistics on *primary* cooking methods, which means that the tendency of households to use multiple cookstoves and fuels simultaneously (Masera, Taylor, and Kammen 2000) is not captured (National Planning Commission 2018).

### 3.2. Level 2: inputs, services, and finance

Raw material costs fluctuate regularly as Nepal relies heavily on imports, especially after the 2015 earthquake. In 2017, iron and steel imports from China and India<sup>3</sup> totalled 950 million USD while

exports only accounted for 43 million USD (United Nations Comtrade Database 2019). The cost of labour is low in Nepal and most biomass ICS manufacturing processes are done by hand which – although less time efficient – does reduce costs. The cost of engineering professionals is also low at both the product design and quality assurance stages with an average Nepalese engineer earning “around 15,000 USD per year” (Interviewee 14 (cookstove engineer) – Feb 2019).

As the quality of transport infrastructure varies greatly throughout Nepal (S4), the location of the end user has an important influence on the price of a stove, the total cost of which will reflect transport costs. Transport costs and infrastructure coupled with high fuel and vehicle maintenance costs, therefore, have a dramatic impact on stove distribution networks and on stove markets more generally as additional transport-related costs can make stoves unaffordable for more remote communities.

### **3.3. Level 3: political and regulatory factors [enabling environment] (E1)**

There are two key policies that influence biomass ICS markets: one being the Nepalese Government Renewable Energy Subsidy Policy (Ministry of Population and Environment 2016) which enables the dissemination of subsidised biomass ICS as outlined in Section 3.1 and the other being the Biomass Energy Strategy 2017 (Ministry of Population and Environment 2017). The Biomass Energy Strategy dictates general strategy and outlines a commitment by the Nepalese Government to “focus on biomass energy to fulfil the energy needs on short and medium term”. Nevertheless, there is a realisation, due to the abundance of hydropower, that the “longer term needs [will be] met by electricity reducing the consumption of biomass energy” (Ministry of Population and Environment 2017). These goals are echoed in the Fourteenth Plan (2016/17) which “aspires to reach additional 9% of population with electricity from solar, hydro (mini and micro) and wind resources. The 14th plan also aims to promote 0.2 million units of biogas digester and 1.065 million units of improved cooking stoves” (National Planning Commission 2016).

Additional policies promoting alternative energy technologies alongside the overarching government strategy and the Fourteenth Plan (National Planning Commission 2016) are based around controlling deforestation; promoting forest enterprises, the environment, and biodiversity; diversifying energy use through an emphasis on alternative energy (Ministry of Environment 2006); and the reduction of GHGs through the Climate Change Policy 2011.

#### **3.3.1. Social, cultural, and economic factors [enabling environment]**

Echoing studies elsewhere, many users prefer to “stack” different stove technologies for household cooking purposes according to fuel price, season, type of food being cooked, convenience, and broader social practices regarding fuel and stove type (Jewitt, Atagher, and Clifford 2020; Masera, Taylor, and Kammen 2000; Jagadish and Dwivedi 2018; Malakara, Greiga, and Fliert 2018). TLUD pilot users often had LPG and a traditional three stone fire in their household as well as a larger cookstove for preparing animal feed:

*[they use] firewood, they also use gas, They use both. People mostly who have animals still use firewood. (Interviewee 2 (TLUD Pilot Member) – Nov 2017)*

This often makes it hard to assess the extent to which ICS displace “traditional” biomass-based cooking systems. Direct observation in rural communities and interviews with ICS stakeholders indicated that the choice of stoves from within different users’ cooking system stacks may vary over time or with the occasion for which cooking is taking place. A number of factors influence this decision, including social prestige, convenience, and time saving:

*There is some social prestige with LPG, like if very important people are coming and if we are using the woodstove then there is smoke in the kitchen and that won’t be comfortable for them. If their friends are there, their preference will be to cook fast on LPG ... They don’t want to discard this wood cookstove ... their preference will*

always [be] to use wood as wood is easily available. But, if they have a guest or want fast cooking they would use the LPG. (Interviewee 13 (National ICS design centre) – Feb 2019)

Seasonality also has an important influence on user choice, as a traditional three stone fire provides space heating in homes that lack alternative systems for generating warmth:

It also gets quite cold at night [in the winter] so after the fire goes out the kids stay around the warm coal to make themselves warm. (Interviewee 1 (TLUD Pilot Member) – Feb 2018)

However negative experiences of using ICS for heating can sometimes have extreme consequences (Stanistreet et al. 2014; Malakara, Greiga, and Fliert 2018), especially when recounted by influential community members, as noted by a biomass ICS manufacturer:

In one project, a woman was using the [biomass] metallic cookstove sitting on the floor. She went to stand up and put her hand on the cookstove and burnt it. She told the community it wasn't safe so the whole community discarded. (Interviewee 13 (National ICS design centre) – Feb 2019)

Some rural stakeholders made strong links between the Indian fuel blockade and “backsliding” (Jewitt, Atagher, and Clifford 2020) by former LPG users to traditional open fires as the increase in LPG cost resulted in fuelwood becoming more cost effective:

LPG is very expensive especially after the blockade it became very difficult as gas was going on the black market ... so we had to find an alternative. (Interviewee 1 (TLUD Pilot Member) – Nov 2017)

Not only did this experience influence user choice during the blockade, it continues to influence stacking tendencies by users keeping old technologies in case the blockade returns. At the same time, the potential to shift to improved household scale biomass-fuelled cooking systems seemed to be hindered by the lack of end-user engagement in the ICS value chain which was linked to the fact that changing an “approved” design on the basis of user feedback could result in it not qualifying for subsidies without being retested, the cost of which can be up to 400USD. One way around this would be to involve communities in the creation of design parameters. This process was outlined in a key informant interview with the case of the Kathmandu University three pot ICS (KU3): a metallic biomass cookstove designed for use at high altitude for both heating and cooking – ICS1124 on the NIBC Approved Cookstove List (Renewable Energy Test Station 2019). The community provided feedback on its design and performance following a pilot study which took place before the RETC testing commenced. Utilising this model more widely could help to address key socio-cultural and economic barriers within the enabling environment.

Finance has also traditionally been a barrier to ICS adoption (Hewitt et al. 2018; The World Bank 2017), although the emergence of microfinance-schemes coupled with government subsidy programmes has potential to overcome this barrier among potential users who want to purchase ICS but cannot afford the cost. This approach tends to be less effective where there are low levels of demand for ICS and/or where potential users are unable/unwilling to pay for them on account of competing financial priorities:

when you do the user survey or [determine] willingness to pay, even for the household cooking they don't value [ICS]. They can buy mobile phones of 10,000 rupees without feeling like, “okay my money is going” but if you want [the users] to pay 400 or 500 or 1000 rupees for the [biomass] stove then they don't want to. (Interviewee 16 (Microfinance Co-ordinator) – Jun 2019)

Uptake can also be limited by potential users lacking the confidence to take out loans, not only for biomass ICS but for other business activities:

when they [the community members] started participating in micro-finance, they are very shy in speaking their name [...] Now they are asking for more money which means they have another type of empowerment, confidence building and [able to] explain themselves .... (Interviewee 16 (Microfinance Co-ordinator) – Jun 2019)

Financial barriers are also affected by potential users' past experiences with other biomass ICS actors such as NGOs, local distributors, and local government representatives who have

often provided biomass ICS free of charge. Not only can this distort the perceived value of ICS (e.g. when potential users see the same models for different prices) but it can also create an expectation that these products will be free of cost and reduce their perceived value:

If you wanted to make a sustainable technology for a rural community there must be some investment of the people. (Interviewee 13 (National ICS design centre) – Feb 2019)

A final theme affecting biomass ICS adoption had intersecting social, cultural, and environmental dimensions and was linked to a desire to increase efficiency and time-saving benefits whilst reducing smoke and associated health impacts. This was apparent in the use of an institutional biomass stove for paper-making in a location close to the user's household:

It is primarily cost driven as well as health also. Since the smoke goes here and there and comes inside [the house], if you have the chimney outlet it will not do this. That is one reason and another reason is time saving, in a week they could only do 1 or 2 burns but with this system they can do it daily. Larger time is being saved with this intervention. (Interviewee 14 (National cookstove tester & manufacturer) – Feb 2019)

#### 4. Phase two: identification and analysis of potential supporting interventions

Stage 1 of the market map, the market system mapping (RO2&3), identified a series of market gaps and bottlenecks. Stage 2 of the market map which involves addressing these market gaps with new interventions offers potential to address the cycle of failed biomass cookstove projects in Nepal and beyond (RO1&4). This section draws on interviews and discussions with key stakeholders to outline a series of market gaps and identifies potential supporting interventions to address them.

One of the most significant lessons learned from discussions that fed into the creation of the market map is that in Nepal, institutional cookstoves do not have to comply with national emissions regulations to qualify for the government subsidy so long as the firepower is above 20 kW. This low hurdle of official approval reflects an attempt to increase the number of approved institutional solutions, as currently there are limited solutions and funding for institutional biomass ICS resulting in an underdeveloped institutional ICS market. This results in institutions using inefficient solutions that negatively impact community members in terms of HAP-related health issues and contribute to black carbon emissions (Soneja et al. 2015; Smith et al. 2009). As the only two institutional ICS approved by RETS are rocket stoves with pot skirts to increase heat transfer (Bryden et al. 1997), there are opportunities for supporting interventions around low cost alternatives that outperform existing ICS whilst better meeting the needs of local cooks outlined in the social, cultural, and economic factors section of 3.3.1.

The findings of this study also show that Nepal's subsidy programme does not discriminate between nationally and internationally manufactured biomass ICS, even though the carbon footprint of both models differs significantly. Likewise, most end-users make no distinction between local or imported biomass ICS, as for them affordability is central to acceptability. Unfortunately, international manufacturers often prioritise combustion efficiency over cost and also fail to take local usability fully into account. This echoes similar research in India as well as West and East Africa (Hewitt et al. 2018; Agbokey et al. 2019; Palit and Bhattacharyya 2014). A possible short-term solution would be subsidy incentives for local manufacturers to reduce their manufacturing costs and increase the production quality, resulting in a biomass ICS able to compete commercially with the imported products.

With the importance of usability reinforced by the interviewees, cost and convenience come next in the list of priorities which often results in Nepalese institutions and households<sup>4</sup> stacking multiple technologies to meet different cooking needs. For example, in one of the TLUD pilot sites, an open fire is used for rice and boiling water as these are energy intensive and unaffordable with LPG. LPG is preferred for preparing side dishes as it is faster, does not blacken cooking pots, and is considered safer. This type of fuel and stove stacking tends to go unrecognised by the government subsidy policy, in part due to the one subsidised ICS per kitchen rule but also because the National



Household Survey only captures data on “main fuel use”. The impact of this is significant not only on the subsidised biomass and electric ICS markets but also on LPG markets as this fuel is excluded from the Renewable Energy Subsidy (Ministry of Population and Environment 2016). This phenomenon of stacking is not exclusive to Nepal. Ruiz-Mercado and Masera (2015) and Namagembe et al. (2015) observed similar patterns in Mexico and Uganda.

Building on the cookstove stacking issue, the inclusion of monitoring and evaluation aspects of the project life cycle in the market map highlighted that the government closely monitors the distribution of biomass ICS but household surveys do not cover whether they are used exclusively or for an extended time. This causes major issues when biomass ICS become broken or discarded and, as the beneficiary does not qualify for another ICS, there is a tendency for them to “backslide” to unimproved stoves, as seen in Jewitt, Atagher, and Clifford (2020). This is a drawback of the complex and overdeveloped nature of government policy which results in a slow and inflexible system requiring extended periods of time to change. An increased focus on tracking multi-dimensional aspects of stove use including the extent of fuel/stove stacking and whether biomass ICS use is sustained over time would increase understanding of the problem and provide evidence for the development of more sustainable solutions.

Another result of this complexity is the underutilisation of local biomass ICS artisans, as they are not included in current value chains. Currently, the failure of government and AEPC’s subsidy and regulation processes to include the role of artisans significantly increases transport costs as technologies must be manufactured at centrally approved hubs. By integrating local artisans into the process, transport costs could be captured in the manufacturing cost of the product, thus reducing the price for the beneficiary. Local artisans may also have a better sense of locally specific end-user priorities. However, without sufficient training and engagement with end-users, the quality and acceptability of artisan-produced technologies may be low and, due to the higher number of artisans making fewer ICS, more difficult to monitor. Government policy must then encourage local artisans to manufacture high quality products either through financial incentives, by providing preferential access to high quality materials, or training on manufacturing methods. This method could be self-regulating by biomass ICS users’ choices regarding which ICS to purchase if there was more than one artisan in each community.

## 5. Conclusion

Unlike in many other countries where biomass cookstoves are largely ignored by governments (Stevens et al. 2019), Nepal has a government policy in place to promote biomass stove technologies and has produced significant numbers of cooking interventions for the household market. Its subsidy policies have been largely successful in both creating and sustaining a market which fosters alternative energy projects and the dissemination of household scale biomass ICS. Our interviews also indicated that the government is willing to modify the subsidy policy to support specific institutional-scale ICS projects such as the milk sweet or paper making stoves. This implies there is scope for new policy that promotes institutional-scale technologies whilst improving cooking efficiency in settings such as schools, monasteries, and small businesses. This policy could either be separate to the Renewable Energy Subsidy Policy or integrated as part of the biomass energy sub-section.

We argue that market maps can be a useful tool for highlighting key barriers to the uptake of biomass-fuelled and other ICS, especially in terms of identifying bottlenecks and complexities within the policy and regulatory framework. We also highlight the need for multi-scalar, multi-institutional approach to better understand the needs of biomass ICS end-users. In the case of Nepal, these include regulations in place for subsidy collection, multiple ministries working in similar industries, and over-regulation of a market that fulfils a core need. The addition of a monitoring and evaluation element to the market map framework is particularly valuable for capturing the biomass-fuelled ICS lifecycle and also has potential to facilitate product improvements through the



integration of end-user feedback. The monitoring and evaluation element also has scope to encourage more nuanced understandings of how success is measured in relation to promoting improved biomass stove adoption. Currently, Nepal's national cookstove statistics are measured by implementation (numbers installed) but the claim that "ICS have been installed in 1.3 million households" (Ministry of Population and Environment 2017) is somewhat misleading in that it provides no indication of whether these ICS are being used. Such statistics also fail to reveal if improved biomass ICS have replaced existing stoves as the primary cooking system (rather than acting as additional stoves) or whether their use occurs year-round as opposed to seasonally (e.g. for heating purposes).

To address such issues, the National Planning Commission's yearly household surveys should seek information on how various types of subsidised ICS are used as part of wider household fuel and stove stacks during different seasons as this would give a clearer indication of the success of different ICS initiatives in reducing HAP exposure and promoting transitions to clean cooking solutions. Additionally, institutional scale ICS warrant more attention by both cookstove manufactures and research institutions. Finally, with regards to applying market maps to future work on household and institutional biomass cookstoves, there has been limited work to date comparing the Asian and African ICS sectors despite the similarities in their base needs (but significantly different policy frameworks) as seen when comparing the results from Stevens et al. (2019). The market map outlined here provides a useful framework to build such comparisons on, as well as to identify broader barriers to biomass ICS uptake, promote inter-country learning, enhance monitoring approaches, and integrate end-user feedback into the future development of these stoves.

## Notes

1. The Government of Nepal official testing facility is independent from government but situated geographically very close to the Alternative Energy Promotion Centre (Government department of the Ministry of Energy, Water Resources, and Irrigation).
2. 10% of micro-hydro project fund are held by the AEPC until an independent evaluation (either privately funded or government) confirms the power unit has been built correctly.
3. India accounted for 95% of Nepal's iron and steel imports in 2017 (UN Comtrade Database 2019).
4. Institutional and household cooking practices are generally reflective in practice but different in volume.

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