

Article

eCooking Delivery Models: Approach to Designing Delivery Models for Electric Pressure Cookers with Case Study for Tanzania

Jensen C. Shuma¹, Estomih Sawe¹, Anna Clements^{2,*}, Shukuru B. Meena¹, Katarina Aloyce¹
and Anande E. Ngaya¹

¹ Tanzania Traditional Energy Development Organization (TaTEDO), Dar es Salaam P.O. Box 32794, Tanzania; jcshuma@yahoo.com (J.C.S.); sawe_en@yahoo.com (E.S.); shukurumeena@gmail.com (S.B.M.); catherine_aloyce@yahoo.com (K.A.); anandenilla@gmail.com (A.E.N.)

² Gamos Ltd., Reading RG1 4LS, UK

* Correspondence: anna@gamos.org

Abstract: This paper defines eCooking Delivery Models (eCDMs) as the activities, resources and actors needed to deliver modern electric cooking (eCooking) appliances to end-users in need of innovative clean cooking solutions in the Global South. We define the eCooking Market System (socio-economic and cultural context, the enabling environment, market chains, support services) which conceptualizes the real-world market factors and surrounding context related to enabling the uptake and sustained use of eCooking appliances by end-users. We also describe an approach to design eCDMs and identify the support services required to start and sustain the market delivery infrastructure. The eCDM concept and approach are demonstrated through designing eCDMs and support services for electric pressure cookers (EPCs) for two end-user segments in Tanzania: rural and peri-urban/urban customer segments. Research methods included: focus groups and workshops (12), household surveys (51), cooking demonstrations (11), offering end-users the chance to purchase EPCs through various financing mechanisms, and interviews (eight with market actors, 18 with enabling environment stakeholders). This led to stakeholder mapping, understanding end-users, market chains, and enabling environment, and identification of eCDMs and support services to reach the focus customer segments. The case study outcome was a plan to implement support services, which is being carried out by a Tanzanian NGO, and we reflect on progress thus far in supporting the eCooking market in Tanzania. The concept and approach can support similar action research in other contexts to accelerate the transition to modern energy cooking services.

Keywords: clean cooking; modern energy cooking services; electric cooking; delivery models; market system; enabling environment; socio-economic and cultural context; Tanzania



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1. Introduction

1.1. Research Context

The latest data tracking Sustainable Development Goal 7, achieving universal access to affordable, reliable, sustainable and modern energy by 2030, shows that in 2019 2.6 billion people were still without access to clean fuels and technology for cooking [1]. The adverse health impacts of household air pollution caused by cooking on solid fuels and kerosene are estimated to culminate in 4 million deaths a year, and there are other adverse effects on the environment, global climate and poverty, with time and drudgery burdens concentrated on women [2,3]. Projections show that current business-as-usual scenarios will not significantly improve the situation by 2030, leaving 2.4 billion still without access [4]. In 2019, Batchelor et al. argued that it was time to consider the electricity access and clean cooking challenges together, taking advantage of increased electricity access (and electricity access opportunity) in the Global South to target electric cooking solutions [3].

Various electric appliances have been investigated as candidates to suit existing cooking practices, menus, and fulfil affordability and access requirements [5–9]. In [9], electric appliances are compared and classified according to their heat transfer mechanism, power requirements, speed and versatility, with the five most efficient classified as ‘most efficient modern appliances’ (rice cooker, microwave, insulated electric frying pan, thermo-pot, and electric pressure cooker (EPC)). From this study and others, it is clear that the EPC in particular has high potential to transform cooking practices. It is a highly energy efficient device, reducing the energy demand to cook ‘heavy’ foods by 80% compared to electric hot plates [9]. It has been proven suitable for the cuisine of select target countries; studies in Tanzania, Kenya and Zambia show that it is possible to cook over 90% of typical households’ menu on an EPC [10]. The Global LEAP awards have recently released a Buyers’ Guide for EPCs [11] and user-experience investigations suggest users find EPCs easy, fast, and clean to cook with.

Currently, the market for EPCs and other ‘most efficient modern appliances’ (hereafter collectively referred to as eCooking appliances) is underdeveloped in countries most in need of transformative clean energy cooking solutions. Africa, combined with the Middle East, accounted for just 5.3% of multi cooker sales in 2018 (compared to 19.9% for Asia-Pacific and 25.6% for Europe) [12]. Multi cooker here refers to appliances for automated cooking which can be labelled and marketed as ‘multi cookers’ but can also include rice cookers, EPCs and slow cookers. There is a need to enable and strengthen the market system for delivering eCooking appliances to end-users and support their sustained use of the appliances.

However, the markets themselves, the contexts they operate in, and drivers for end-user cooking behavior are far from simple. Cooking is highly cultural, affected by social context, norms and traditions [13]. End-user drivers for appliance acquisition include socio-economic circumstance and perceived desirability, which can be affected by marketing and advertising. On the supply side, appliance acquisition is affected by availability and accessibility (physical and economic). Market systems are affected by policies and legal frameworks which set the conditions in which and by which markets operate, influencing the existence and functionality of supply chains and thus appliance availability. Sustained use of any product depends on product quality and longevity, and product reparability, which depends on product complexity and local capacity to do repair and maintenance. Perceptions of quality and reparability also effect initial uptake. This complex system of market chains, market actors (including end-users) and their norms and practices, and surrounding contextual influencing factors, needs to be systematically understood and analyzed in order to design successful interventions to increase the dissemination of eCooking appliances.

This paper responds to this need by putting forward a concept and approach to aid the design of interventions to enable thriving markets for clean cooking energy innovations for low and middle-income countries, focusing on eCooking appliances. The aim is to conceptualize the eCooking appliances market system and conceive a structured approach to design interventions to improve uptake and sustained use of eCooking appliances. As a case study and demonstration of the concept and approach, the paper focuses on the market system for EPCs in Tanzania. In 2020 Tanzania had a population of 59.7 million [14] and, according to the 2017 Household Budget Survey, the majority use solid biomass as their main cooking energy source: 60.9% use firewood and 28.8% use charcoal [15]. Just 2.1% use electricity as their main cooking energy source, but with 73.2% of the urban population with access to electricity, eCooking could be a transformative clean and sustainable cooking solution.

The authors are staff and associates of a Tanzanian NGO called TaTEDO, who work on business and delivery models for sustainable energy services, employment and income generating activities. TaTEDO is a partner in the UK Aid funded Modern Energy Cooking Services (MECS) program, and this paper draws heavily on TaTEDO’s recent experience of exploring markets for the MECS project as well as their broader experience of delivery

models. Being outside of the main market chain actors, TaTEDO is in a strategic position to implement supporting interventions in Tanzania.

1.2. Literature Review

Three existing models and frameworks are reviewed here because they provide useful references and insights to coping with complex systems such as these; the concept and approach put forward in this paper are inspired by them.

1.2.1. Energy Delivery Models

The Energy Delivery Model (EDM) approach can be used to conceptualize the delivery of energy systems to increase energy access [16]. An EDM is the ‘core set of activities, inputs, and actors needed to deliver the energy service, which includes supporting services for the delivery infrastructure’ [17]. The activities, inputs and actors that constitute the energy service sit within an ‘energy delivery system’, which breaks down the complexity of the surrounding context and influencing factors into building blocks (from [17]):

- The enabling environment: the legal frameworks and policies that influence the delivery of energy services.
- The socio-cultural context: the cultural and social values of the end-users and other actors in the energy service supply chain.
- Support services: additional inputs required to overcome barriers or weaknesses in the enabling environment or socio-cultural context, these are extensions of the EDM itself.

The EDM concept has previously been used to analyze existing interventions or businesses to assess their performance and, in some cases, suggest where improvements could be made. Wilson et al. use it to do a comparative analysis of four energy related interventions in the Global South (one of which is an improved cook stove (ICS) distribution initiative in Sri Lanka), finding that taking account of socio-cultural factors and the enabling environment were crucial for intervention success, and that remaining flexible in response to changes in these was also important [16]. In [18] a structured analytic approach was found conducive to producing recommendations to improving operations in making biomass briquettes in Haiti, and in [19] for identifying routes to scale for solar lantern distribution in Nigeria.

A key premise of the EDM concept is that the private sector and market forces alone are unlikely to be able to deliver energy services to poorer sectors of society, which is frequently where energy access progress needs to be targeted [16]. This is where the support services come in to make the delivery model ‘work’; that is, reach target end-users. These services are frequently provided by actors other than the implementer of the EDM approach, for example, by NGOs, or (in the longer term) government agencies. This issue is also pertinent for eCooking appliances and the need to reach sectors of society who are the most trapped into harmful ‘dirty’ cooking practices. Support services will be crucial to stimulate a thriving market which enables all end-users to access safer cooking solutions.

The EDM concept was further developed in order to be useful for designing interventions, with a focus on energy services for people who live in poverty, culminating in ‘The Energy Delivery Model Toolkit’ for planning pro-poor energy services [20,21]. The toolkit consists of a six-step participatory design process and two assistive analysis tools. It starts with understanding the wider development needs of end-users (with their participation) and then advocates bringing in other stakeholders to the conversation to systematically analyze the factors that influence the delivery of an energy service and to develop solutions (EDMs). In [17], the toolkit was used during a 6-month process with a rural community in Indonesia to come up with an EDM that met community needs and to plan its implementation. More recently, it has been applied to local government energy planning in Kenya to develop energy service solutions for Kitui County Energy Plan [22]. It has also been used to analyze previous interventions, such as in [23], where the toolkit provided a structured way to assess impact of a CAFOD-led project involving greenhouses and solar-irrigation systems in rural Kenya, identifying gaps in the original project design.

One of the EDM toolkit tools is an adaptation of Osterwalder's Business Model Canvas (BMC), a popular tool in business strategy and analysis [24]. The original canvas has been used in Global South contexts (see [25,26]); however, a common criticism against the BMC is that it is focused only on economic value rather than taking account of other kinds of values (or costs), which is inappropriate for entities which have more of a social mission, rather than being purely profit driven [27]. The BMC has been adapted by in various ways to expand it beyond just the economic realm: by adding an environmental layer and a social layer to take account of environmental and social value created by an organization [28–30], and by adding or editing the building blocks of the canvas to reflect the mission and impact aims of social enterprises [31,32]. The EDM toolkit adapts the original BMC's four categories (customers, offer, infrastructure, finances) to better reflect the delivery model concept and be inclusive of nonfinancial costs and benefits: value proposition, end-users, delivery infrastructure, accounting [22]. The value proposition category contains social and environmental value created, and accounting contains a building block called 'other costs/benefits' to account for social and environmental costs and benefits. It is also adapted to work as a tool within the EDM design approach, with questions prompting consideration about socio-cultural factors, enabling environment and potential support services required across the canvas.

While designing a pro-poor community energy service has marked differences from starting or influencing a market system to disseminate eCooking appliances, the conceptualization and description of the many interacting factors that influence the delivery of an energy service provides useful inspiration for how to handle the complexity of factors around the market system for eCooking appliances. The EDM concept or toolkit has not yet been applied to design innovative delivery models and solutions for the cooking sector, and neither has its use been investigated to support market development or more market-based initiatives.

1.2.2. Energy Market System Framework

The second framework of interest is the Energy Market System Framework (EMSF) by Practical Action Consulting and EUEI PDF [33,34]. Unlike the EDM concept, the EMSF has more of a market-based perspective on the delivery of energy services to end-users. The framework conceptualizes an energy market system, such as the market for solar mini-grids or biomass stoves, as comprising three levels:

- The market chain: the actors and actions that comprise the delivery of the product or service to the end-users.
- Inputs, services, finance: secondary inputs that support the actors and their activities in the main market chain, some of which will have their own value chains (e.g., physical materials, transport services, loans).
- The enabling environment: the conditions in which the other two levels operate (political, regulatory, financial, and, in contrast to the EDM concept, inclusive of socio-cultural factors which affect energy service uptake and use).

The EMSF provides a systematic approach to map and assess energy market systems and determine effective interventions to support market development. The first step is to map the particular energy market system of interest according to the three levels, and the second step is to use the maps to identify the barriers which prevent the market system operating effectively, and to design interventions to overcome these. In [33], generic energy market system maps are set out for mini-grids, solar lanterns, solar-home-systems, biomass ICS and fuel, and liquified petroleum gas (LPG) stoves and fuel. Ten case studies of actual energy access initiatives are then used to illustrate the process of mapping and identification of the barriers and supporting interventions, including four biomass ICS enterprises and one LPG stove and fuel project. Stevens et al. provide the other documented use of the EMSF in [35], using the framework purely for the analysis step to guide market mapping for ICS in East Africa to identify barriers, drawing short of designing supporting interventions. We have not been able to find accounts of the EMSF being used to design

market interventions in real time, including reports on the outcomes and successes of the interventions.

1.2.3. Clean Cooking Scale-Up Models

While the two previous subsections have presented frameworks related more generally to energy, there is prior work focused specifically on the clean cooking sector and the scale-up of clean cooking fuels. Puzzolo et al. conducted a systematic review of barriers and enablers of adoption and sustained use of clean cooking fuels across 44 studies in low- and middle-income countries (though none of the studies were about eCooking) [36]. Influential factors were grouped into seven domains which span factors related to end-user perceptions and setting and the wider market, policy, and societal aspects. Building on this, Rosenthal et al. set out a fuel-specific logic model for LPG to map the dimensions and factors that influence scale-up and sustained use [37], and this was generalized to be a conceptual model relevant for four clean fuels (LPG, biogas, solar (thermal), alcohol fuels), by Quinn et al. [38]. The five dimensions of the model are key areas of influence that are linked but operate independently:

- The enabling environment: policy and regulations, fiscal context, the political context.
- ‘Industry’ structure and services: physical infrastructure related to the fuel; practices, rules and regulations related to the industry actors; sustainability of supply.
- Energy pricing and costing: capital and running costs of clean fuels and the alternatives, possible cobenefits.
- User and community needs and perceptions: perceptions of affordability, safety, convenience, and aspirational nature of the fuel; awareness of the options.
- Factors influencing consumer demand: other factors not yet covered including consumer knowledge of fuel performance; consumer setting; reliability and quantity of supply; affordability; accessibility; presence of training and finance; and other socio-economic factors.

The aim of the model is to support policy and program actors in planning new initiatives. It was used in [39] to analyze the supply side considerations of scaling up clean cooking fuels, focusing on the factors related to the first three dimensions. The outcome of the review is a framework of considerations in planning clean fuel access expansion to initiate comparison between fuels, and to aid medium to long-term planning.

1.2.4. Reflection on Literature

These three frameworks are different ways to conceptualize the complex real-world factors related to clean cooking uptake and sustained use. All three frameworks highlight the enabling environment as a separate aspect, though in the EMSF this includes socio-cultural factors, whereas both the energy delivery system and clean fuels logic model draw out this area as separate blocks. For the EDM concept, the actors involved in the delivery of the service and their activities comprise the EDM itself, but the wider market context (actors engaged in other aspects of the industry or market, other industry/market practices and norms) is not represented. A wider market viewpoint is taken by the EMSF and the clean fuels logic model through the market chains and inputs, services and finance blocks, and industry structure and services and pricing and costs blocks. However, while the energy delivery system lacks this wider market viewpoint, it has more thematic components than the clean fuels logic model because the components are broader in scope. In the clean fuels logic model, the ‘factors influencing consumer demand’ component comprises a mix of factors related to the supply side, consumers, and finance which don’t fit into the other components as they are narrower in scope (user and community needs and perceptions compared to socio-cultural context), whereas some aspects such as the availability of loans for financing might be better placed in enabling environment. Nonetheless, the clean fuels logic model provides useful input of influential factors through a focused cooking lens (as opposed to general energy) in comparison to the EDM concept and EMSF which are generalized to an ‘energy’ focus.

The concept outlined in this research paper, that of eCooking Delivery Models (eCDMs), and the conceptualization of the eCooking Market System in which they operate, draw on both the EDM approach and the EMSF, and cover the factors highlighted by the clean fuels logic model. Both the EDM and EMSF include designing interventions to improve how a system is operating: in the EMSF, interventions are designed in response to the analysis of market barriers; in the EDM approach, the support services are a key aspect of the delivery model, comprising interventions which are required for the delivery model to function. The intervention design focus is critical for this research due to the positionality of the authors and their aims for this work. The clean fuels logic model has less of a design of market interventions focus but aids with the adaptation of the first two frameworks to the eCooking research focus.

1.2.5. Paper Scope and Layout

This paper sets out the concept of eCDMs that are situated within the eCooking Market System. The output is a framework to describe the many factors involved or influencing the delivery of eCooking appliances through the market. This enables systematic and thorough investigation, building of a shared understanding among the design team, and leads to structured assessment to identify where interventions could be made to instigate or strengthen an eCDM that delivers eCooking appliances to end-users; also described is a 7-step approach to design eCDMs. This approach guides the design team through research and design activities to develop a thorough understanding of the eCooking Market System, and then identify the best eCDM and design required support services for specific end-user segments.

In Section 2, the concept of eCooking Delivery Models within the eCooking Market System is described alongside the approach to design eCDMs, together with the research activities conducted in Tanzania in order to design eCDMs for EPCs. Section 3 presents new insight into the eCooking Market System for Tanzania. It describes eCDMs and support service interventions designed to reach two groups of end-users with EPCs, including a review of their implementation. Section 4 reflects on the eCDM concept and design approach. This research shows how the eCDM concept and approach can be used to identify the implementation activities that will be most effective at enabling a thriving market of eCooking appliances in countries in need of clean cooking solutions.

2. Materials and Methods

2.1. eCooking Delivery Models and the eCooking Market System

Drawing on the EDM approach, we take the concept of delivery models and support services as the underlying structure for reaching end-users with eCooking appliances. We define eCDMs and associated support services as the activities, actors, and resources required to reach end-users with eCooking appliances and the interventions required to support these activities. The more market-based perspective of the EMSF is important given the market-based approach in this research, and so we adapt the Energy Market System concept to introduce the eCooking Market System, in which eCDMs and associated support services are situated. The eCDM is, therefore, the market-based delivery or business model through which eCooking appliances are disseminated to end-users, and which supports their ongoing use of the appliances.

The EDM, EMSF, and clean fuels logic model have logical and systematic ways to identify and map the context and influencing factors that impact delivery of energy services to end-users. We adapt the levels of the EMSF (which describe the energy market system), and the building blocks of the EDM (which describe the energy delivery system), to best conceptualize the context and influencing factors for the eCooking Market System and eCDMs concept. Figure 1 shows the eCooking Market System building blocks, and the layout of the map illustrates the relationships between the blocks. We include a new building block, 'market chains', adapting the market chain level in the EMSF to be market characteristics pertinent to eCooking appliances. This is coherent with the industry

structure and services, and energy pricing and costing blocks, of the clean fuels logic model. This emphasizes how market-based aspects of the delivery models envisaged in this research are judged to be the best way to reach end-users. The enabling environment and socio-cultural factors building blocks from the EDM bring in the legal and regulatory context and factors that influence human behavior, practices, and norms to the eCooking Market System. The label of the ‘socio-economic and cultural context’ block has been adjusted from the EDM to highlight the importance of the economic circumstances of the end-users given the market focused approach. The fusion of these factors maintains the market-based emphasis of the EMSF, the wider market lens of the EMSF and the clean fuels logic model, and the differentiation of the enabling environment and socio-cultural factors in the EDM.

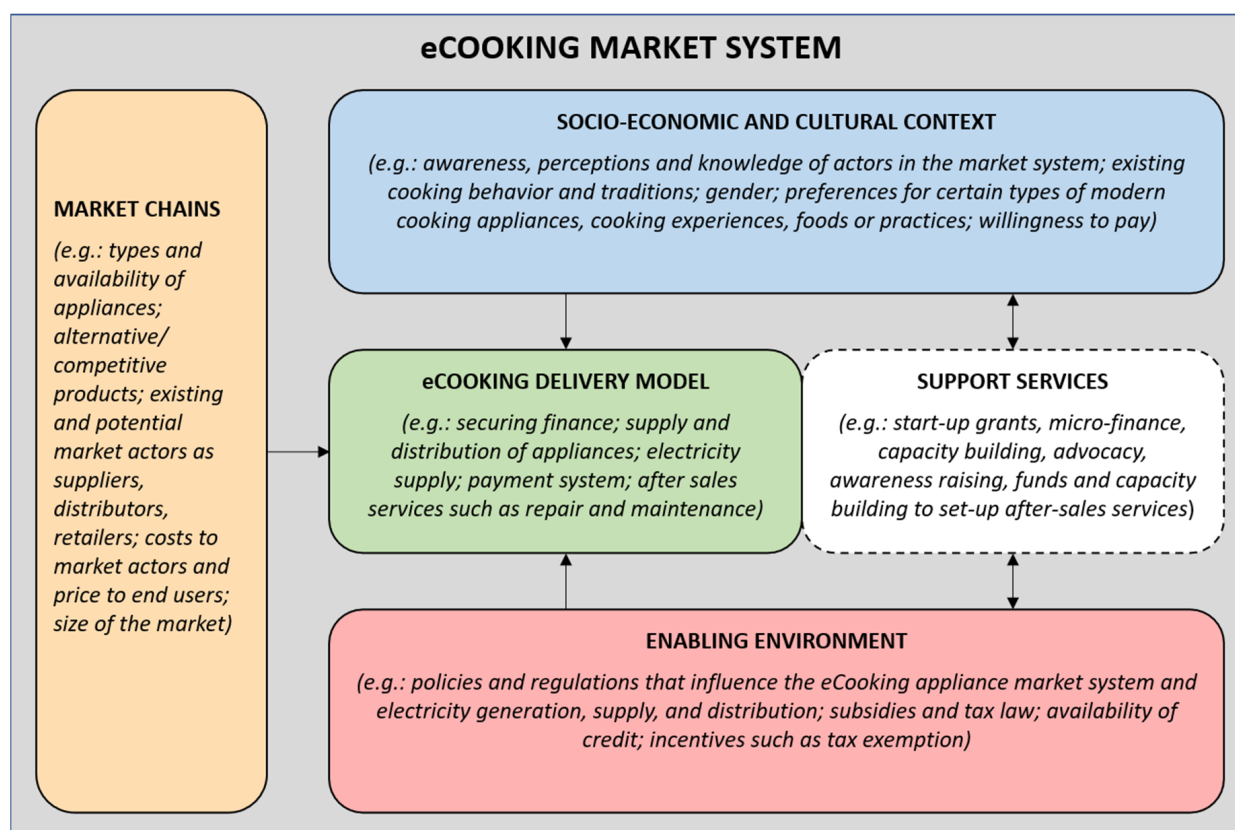


Figure 1. The eCooking Market System with component building blocks.

The blocks in Figure 1 are defined as follows:

- **eCooking Delivery Model.** The specific route to end-users, comprising the activities, resources, and actors in the market chain needed to deliver eCooking appliances to them. These include:
 - The appliance itself.
 - The market chain to be used or optimized for appliance distribution to end-users: Manufacturers, importers, retailers, distributors.
 - The electricity infrastructure to supply the electricity.
 - Securing finance to enable market actors in their activities.
 - Maintenance and repair of the appliances.
- **Support services.** These are an extension of the delivery model itself, being additional support services needed to deliver eCooking appliances to end-users and support their sustained use. The support services are required to strengthen the market system,

addressing weaknesses or gaps in the enabling environment, socio-economic and cultural context, or market chains.

- **Socio-economic and cultural context.** While this encompasses socio-economic and cultural context of end-users (their values, customs, and practices that might influence their behaviors towards adopting or not adopting an eCooking appliance), it is also applied to other actors in the market chain, given these factors could be drivers or barriers for their participation in an eCDM or support service.
- **Enabling environment.** The policies and legal frameworks that influence the delivery of eCooking appliances and the electricity infrastructure. Although many of the enabling environment factors are beyond the direct control of the market actors and end-users, assessment of these attributes is important for designing measures for developing sustainable eCDMs.
- **Market chains.** Market chain actors and established and potential market chains, and data on how the market chains are functioning, i.e., the size of the market and its existing operation.

The support services are adjacent to the eCDM as they are extensions of it and required to address current gaps or barriers in the other blocks. Socio-economic and cultural context, the enabling environment and the market chain influence the eCDM and the required support services that enable it, so have arrows feeding in to the combined eCDM and support services blocks. The support services are ideally temporary, implemented to support eCDMs to start and/or flourish, and may then cease to be required as the system adapts, or they impact components of the enabling environment, market chain, or socio-economic and cultural context such that their effect becomes long term. For example, start-up grants for importers to import large numbers of eCooking appliances into a country may be required as initial cash flow, but once turnover increases, the importer becomes self-sufficient. Advocacy may produce changes in import tax laws, which become permanent features of the enabling environment. Training for technicians on repair of eCooking appliances, perhaps initially provided as a support service by an NGO or other external organization, will eventually become a standard part of technician training. To indicate this, the support services building block has a dashed line to show that they are time-limited, and arrows feedback from it to the enabling environment, market chain, and socio-economic and cultural context blocks to illustrate the impact the support services aim to have on these blocks.

It is helpful, also, to consider the position of the eCooking Market System in relation to existing market systems. While the eCooking Market System is often nascent in many Global South contexts, electricity access and clean cooking market systems are more often well established. It is, therefore, forming at the intersection of these two pre-existing market systems, and over-lapping components of the electricity access and clean cooking market systems will be important to understand while using the eCDM and eCooking Market System concepts.

2.2. eCooking Delivery Model Design Approach

Figure 2 describes the seven-step approach to identify and design the eCDM and support services for target end-user segments. The first step is an in-depth study of eCooking compatibility and potential in the target context, and further steps are only pursued if eCooking potential is identified. An example of a suitable approach can be found in [6]. Having mapped the stakeholders, a deep dive investigation is conducted into each of the eCooking Market System building blocks (steps 3–5).

1. Assessment of eCooking compatibility and potential	Assessment of existing cooking practices and how eCooking devices would integrate into them. Determine the appliance to focus on. This should fit with cultural cooking practices, and have high potential for alleviating health, time, environmental, and gender impacts of current cooking methods.
2. Map stakeholders	Map stakeholders in the eCooking Market System
3. Understand the end user	Identify potential customers of the device, customer segments, and the level of potential demand. Assess customer drivers and barriers for adoption and sustained use and articulate the value proposition for end users. Assess the socio-economic and cultural context of end users.
4. Understand the market chains	Assess the existing or potential market chains for the appliance for the various customer segments. Investigate drivers and barriers for market chain actors, focusing particularly on gaps in their capacity, and articulate the value proposition for each actor.
5. Understand the enabling environment	Assess the enabling environment in which an eCooking Delivery Model (eCDM) will operate, including the relevant policies and legal frameworks which exist and affect the market system and actors in it. Identify the state of electricity access and understand possible future trends or planned developments.
6. Identify & design eCDM and support services	Identify the market chain and involved actors who make up the route the appliance will take to get to the customers. The identified market chain should aim to both reach a high number of customers but also provide a reasonable profit margin for other market actors. Responding to the barriers, needs, and gaps identified in the eCooking Market System, identify and design the required support services to support the eCDM.
7. Plan and implement	An implementation work-plan should be created to guide activities required to establish the eCDM implementation of support services. Implementation should start at the level of pilots and be scaled up as learning increases and success is proved. Particular attention should be given to risk assessment and mitigation, which will influence the design of support services and plan for their implementation.

Figure 2. Seven-step design approach for eCDMs and support services.

End-users can be segmented according to various data such as socio-economic, demographic, geographical, and income and livelihood data, with the aim to find coherent groupings of end-users with similar drivers and barriers to taking up and using eCooking appliances. These data can be gathered through suitable methods such as surveys or focus groups of a sample of end-users. If care is taken to choose variables carefully, data can be compared with national data to estimate the percentage of end-users across the country that align with each of the end-user segments found in the sample data.

Other methods suitable to gather data on the end-users, market chains, and the enabling environment include reviewing literature and policy documents, interviews, focus groups and surveys with relevant actors, and market surveys. In step 6 the eCDM pursued to reach the target end-user segment is identified, alongside the support services required to enable this eCDM, which are designed in response to gaps and barriers discovered in the previous steps. The final step involves planning and implementation of these support services in order to create or grow the identified eCDM.

To support the approach, this research has adapted the two tools in the EDM toolkit to be relevant for eCDMs, which can be used as references for organizing information, planning research, and as a framework for discussion throughout the process. The eCooking Delivery Model Canvas in Appendix A is based on Osterwalder's original canvas and the adaptation of it by Garside et al. [24]. The questions in italics are to prompt consideration of the building blocks in the eCooking Market System not explicitly set out in the canvas; that of socio-cultural and economic context, enabling environment, and support services. An additional 'Market Chains' block has been added under the delivery infrastructure topic to prompt direct consideration of it. The eCooking Delivery Model Map, also in Appendix A, expands Figure 1 to give a more detailed understanding of the eCooking Market System and populates the map with factors from the canvas to show how they interrelate. The

intention for both tools is to assist with planning and implementing a systematic approach to data-gathering, particularly for the deep dive investigation steps 3–5. Then they can be used to organize the data gathered and examine the interactions between the different building blocks during Step 6, where, following the data-gathering and analysis stages, the eCDM and support services are identified. Other steps, such as stakeholder mapping and risk assessments, can be conducted using standard tools available for such tasks.

Implementation of the support services that emerge from the design can be an iterative process, where learning through implementation is used to refine the design of the support service, but also feedback new system data into the framework. The design approach should be returned to periodically after the initial analysis and design sequence once implementation has begun to provide a structured way to assess the changing system and how the support services need to evolve. This is advisable as the eCooking Market System starts to shift in response to the new support services, and as a deeper understanding of actors and the other system components is gained. The aim is to assess whether new support services are needed to address new emerging gaps and barriers in the system, to learn lessons from current implementation, and to retire those support services which have become part of, or effected change in, other component blocks of the eCooking Market System.

2.3. Conducting the eCooking Delivery Model Design Approach in Tanzania

Research activities were undertaken over 6 months in 2019 using the steps in the eCDM design approach. Previous work carried out in 2018 constituted step 1, ‘Assessment of eCooking compatibility and potential’, through several field work exercises with end-users aimed at understanding existing cooking practices and preferences around shifting to electric cooking [6]. Targeting urban households in Dar es Salaam, 22 households kept detailed cooking diaries of existing cooking practices and their experiences shifting to electric cooking appliances [40], and four focus groups were carried out to discuss practices, aspirations, and perceptions of existing and future cooking methods (including demonstrations with electric cooking appliances) [41]. Discrete choice modelling was conducted with 214 respondents (25% rural, 75% urban) to assess the importance of different eCook design features [42]. These studies demonstrated that eCooking had high potential in Tanzania in terms of being compatible with Tanzanian cuisine, started to illuminate the end-user barriers to adoption, and showed that the EPC in particular had high potential to save end-users money, time, and be a cleaner way to cook. It was therefore determined that the EPC would be the focus of the research going forward.

The work reported in this paper focuses on two categories of end-users differentiated by their location, electricity infrastructure and socio-economic circumstances:

1. Rural end-users: End-users in rural areas who have access to electricity through mini-grids run by PowerGen Renewable Energy. They were mostly low-income smallholder farmers who depend on income from agricultural products at Kitaita and Songambele, Gairo District, Morogoro Region.
2. Peri-urban/urban end-users: End-users in peri-urban and urban areas who have access to electricity through the national grid. They were from high, medium and low-income households of Kinondoni and Ubungu Districts in Dar es Salaam Region.

Table 1 summarizes the research activities undertaken to understand the socio-economic and cultural context, market chains, and potential required support services of the eCooking Market System. Participants were selected through convenience sampling guided by village leaders (rural) and local government staff at the ward level (urban). Household surveys were questionnaires conducted at each house and filled out on paper by enumerators and then transferred to Excel for analysis. For the focus groups, workshop and interviews, enumerators took notes of answers, discussion points, and additional observations throughout the sessions. Data were triangulated between the different methods to validate them, and the eCooking Delivery Model Canvas and Map used to organize them.

Table 1. Research activities undertaken for each end-user group.

Rural	Urban/Peri-Urban
11 household surveys	40 household surveys
Two focus groups (1 incl. eCooking demo) (Participants: village leaders, leaders of women's groups, leaders and members of VICOBA, minigrid staff)	Nine focus groups (incl. eCooking demos) (Participants: One with VICOBA representatives; Three with local government staff; Five with mixed stakeholders: women's group representatives, local government staff, local appliance vendors, VICOBA/SACCO representatives)
One participatory rural appraisal workshop (incl. eCooking demo) (Participants: village leaders and a demographic range of village members)	
Total participants: 47 smallholder and medium scale farmers, 86 households, and 24 businesses	Total participants: 117 households, 92 households engaging in the informal business sector, and 29 enterprises

Following the cooking demonstrations, demand was investigated by offering EPCs to attendees to gauge how many would be interested and what payment strategies would be appropriate. This exercise tested willingness to pay for and uptake appliances, and enabled the collection of further user experience data from those who opted in.

To understand the enabling environment, a review of existing policies and regulations was undertaken to identify those that support or impede the transition to modern energy cooking services. This was supplemented by interviews with five financial institutions, seven development partners, six sectoral ministries and government institutions in Dodoma and eight market chain actors (importers, distributors, retailers) (see Appendix B for complete list). Financial institutions were engaged to understand present and future possibilities for funding and subsidies, and development partners were consulted to understand their future plans and any other existing initiatives around modern energy cooking services. Interviews with market chain actors and their presence in select focus groups sought to understand their roles in the market chain, their gaps in capacity, and their drivers and barriers to participate in the chain.

3. Results

The results presented here for the Tanzanian EPC market system and end-user sample seek to present overviews of research or implementation detail for each step of the design approach (where possible, more detailed resources are referenced) or, where more detail is given, have been judiciously chosen to be most relevant for interested stakeholders.

3.1. Step 2: Stakeholder Mapping

The stakeholder mapping approach in [43] was used to identify and map stakeholders according to their participation and influence on the eCDM and eCooking Market System, adapted to show reducing participation/influence via expanding concentric circles. Figure 3 shows the resulting stakeholder map. It was broadly possible to label each ring: actors who are part of the core market chain for the eCooking appliance are in the center; those who provide or are instigating support services required to realize eCDMs are one ring out; and the final two rings contain actors who set the enabling environment (such as government institutions and regulatory bodies), who are involved in advocacy to effect the enabling environment, or who are involved in research and innovation. The two outer rings differentiate between those situated in Tanzania and those who are external to the country. This mapping exercise ensured that all stakeholders, and their barriers and drivers to participation or supporting eCDMs, were assessed and considered in the research activities and eCDM development that followed. Readers may be interested in a more detailed stakeholder mapping analysis from the perspective of socio-technical innovations systems in [44].

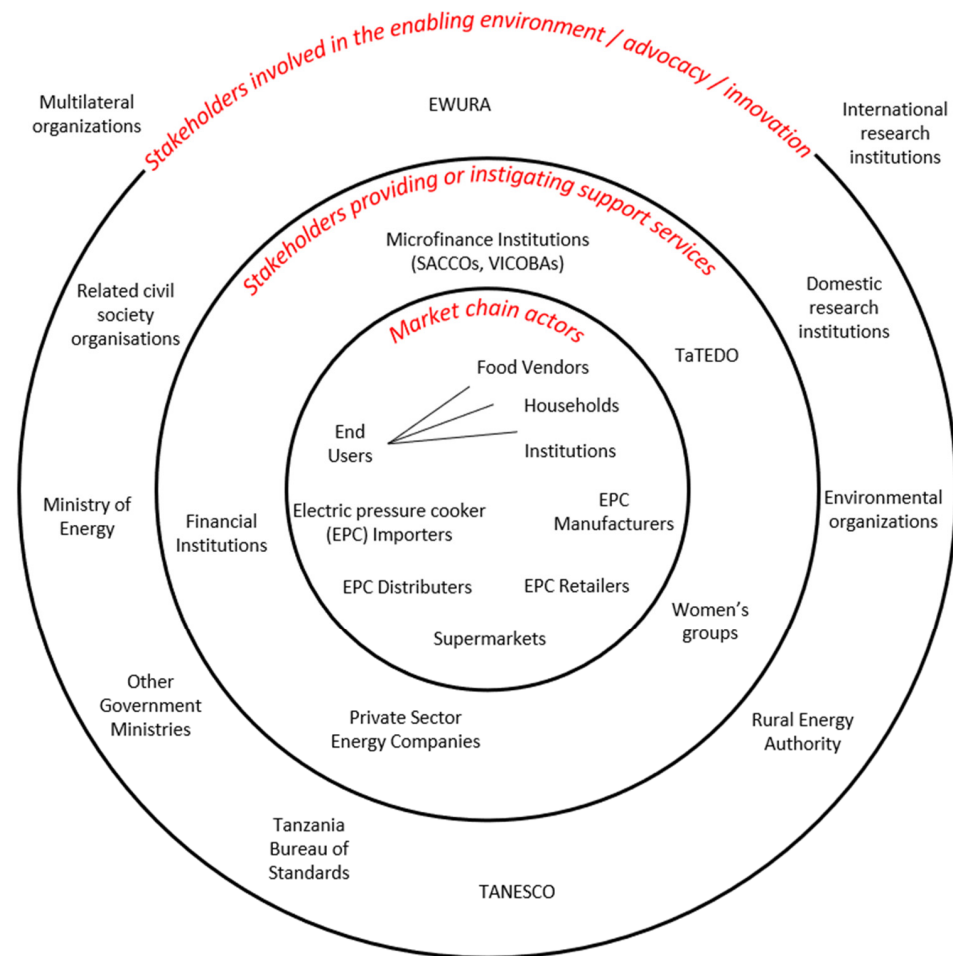


Figure 3. Map of stakeholders in the eCooking Market System. Acronyms: EWURA—Energy and Water Utilities Regulatory Authority; SACCO—Savings and Credits Cooperative Society; VICOBA—Village Community Bank; TANESCO—Tanzania Electric Supply Company Ltd.

3.2. Step 3: Understanding the End-User

3.2.1. End-User Segments

Two end-user segmentations were used in the analysis. The simplest was geographical, splitting end-users into rural and urban/peri-urban. A more detailed segmentation was made according to whether end-users lived in rural or peri-urban/urban areas, their income, and their livelihood activities. This segmentation is shown in Table 2. Surveys on income revealed the range in daily income of respondents was from £1.50–£15.00. The respondents were split into two groups: those who earned up to £7.50/day and those who earned £7.50–£15.00. During an income ranking activity in focus groups, participants identified a group in their perception of society who were not represented in the sample and who earned over £15.00 per day. This gave an additional end-user segment that it is important to be aware of, despite their lack of representation in the sample of participants. Using the National Bureau of Statistics Household Budget Survey of 2017 [15], we estimate the percentage of the Tanzanian population that falls into each end-user segment.

Table 2. Segmentation of end-users.

	Low Income Segment	Medium Income Segment	High Income Segment
Daily income (GBP)	<7.50	$7.50 \leq x < 15.00$	≥ 15.00
Livelihood activities and location	Smallholder farmers (rural) Informal business sector (rural and urban) Other rural and urban households	Medium-scale farmers (rural) Rural enterprises Faith-based organization employees (rural and urban)	Large farmers (rural) Salaried employees (urban) Business owners (urban)
% National population	53 (31.6 million)	32 (19.1 million)	15 (9 million)

Throughout the rest of the paper, we refer to end-users using both ‘rural’ and ‘urban/peri-urban’ groups, and ‘low income’, ‘medium income’, and ‘high income’ as described in Table 1, depending on the level of detail we report.

3.2.2. Demand for EPCs

EPC demand was assessed through offering end-users the chance to purchase EPCs during and at the end of the project (Table 3). The EPC was a rotary dial 6 L model and the price presented to end-users was TZS 180,000 (£58.62 using midmarket rates on 24 November 2021). A total of 22 end-users purchased EPCs through direct payments and local credit mechanisms at the start of the project. The six rural end-users purchased the EPCs through credits from Village Leaders who acted as guarantors. They made upfront payments of 20% of the EPC price (TZS 36,000 or £11.72) and signed a contract to pay the rest by mobile money in six installments over 6 months (TZS 24,000 or £7.82/month. Three made the payments on time, with three defaulting and completing payments over a year instead, which shows the affordability barrier that is particularly prevalent for low-income end-users. Sixteen peri-urban/urban end-users purchased EPCs through a variety of mechanisms as shown in Table 3. At the end of the study, end-users had another opportunity to purchase EPCs, and demand in the peri-urban/urban group had grown nearly fivefold, whereas a more muted increase of just under twofold was found for the rural group.

Table 3. EPCs purchased during the study for each end-user group, and demand at the end of the study.

End-User Group	EPCs Purchased in Study	EPCs Purchased at End of Study
Rural (all deposit and installments)	6	10
Peri-urban/urban (Cash)	16 (9)	72
(VICOBAAs)	(5)	
(SACCOs)	(2)	

Focus groups and household surveys revealed a number of factors that were observed to influence the demand of EPCs:

Price of the Appliance. The retail price to end-users of the EPCs ranges from TZS 180,000 (£65) to TZS 250,000 (£90) depending on the length of the market chain. The EPCs have a high price elasticity of supply; an increase in price due to associated market costs will influence customer demand, particularly in low-income segments.

Awareness. The EPC is a new product in the market. End-users in households, government departments, local governments, financial institutions and donors are not aware of the benefits of EPCs on energy and budget savings in their households and can instead think that using an EPC will cost them more.

Ability to Pay by Customers. High-income end-users can pay for EPCs easily. The medium-income end-users showed they could buy the appliance through credit facilities. The low-income end-users are expected to buy the EPC if it is subsidized through market schemes or affordable credit mechanisms.

Seasonality of Income. For some rural end-users, there are times in the year when they have relatively high income, and times when they have low income and less cash flow. This is due to seasonality of income from agriculture.

Prices of Substitutes and Complements. The substitutes of EPCs are LPG stoves, normal pressure cookers, charcoal stoves, and firewood stoves. The complementary service of EPCs is electricity. If the tariffs of electricity are higher than prices of alternative energy sources, end-users may weigh the cost of the EPC and electricity against costs of alternative fuels and stoves and switch to substitutes if there is no perceived cost advantage.

Quality of the Appliance. The quality of the appliance varies according to brand. Low quality EPCs are starting to appear in the Tanzanian market, which are not well thermally insulated, get hot when a user is cooking and use more electricity than a well-insulated device would. While this is a safety factor to consider, it is not different to hot surfaces caused by other cooking appliances such as a pan on a hotplate, or the inside of an oven. The bigger concern is that these EPCs are more expensive to cook with and can lead end-users to develop the perception that all EPCs are too expensive to cook with.

3.2.3. Barriers for End-User Adoption of EPCs

The barriers identified that hinder end-users adopting EPCs are grouped thematically in this section.

Awareness Barriers. The main barrier observed for end-users at all levels was low awareness of using EPCs. Very few Tanzanians think that they will ever have the opportunity to cook using electricity and are unaware of the benefits of reduced household cooking expenditure, and the safe and clean cooking that is possible. This low awareness, if it is not resolved, will become a barrier for demand, support services and commercialization of electric cooking appliances and services.

Financial Barriers. Low ability to pay is a problem for medium and low-income segments of end-users in both peri-urban/urban and rural communities, the latter due to seasonality of income. For peri-urban/urban end-users, the affordability barrier was present because of a lack of priority put on cooking appliances, lack of adequate income and gender income allocation in the households. There was also a perception of a financial barrier to using an EPC, which overlaps with the 'Awareness' theme. Many peri-urban/urban households had tried to use electricity for cooking by using uninsulated and therefore less energy efficient appliances such as electric hotplates, which can use five times the energy to cook heavy foods such as beans as an EPC [9]. The high electricity bills experienced through using inefficient electric cooking appliances gave them a false perception of the affordability of cooking with EPCs.

Technical Barriers. Peri-urban/urban end-users came up with multiple technical barriers to adopting EPCs. First, the size of many appliances promoted and sold through different stores and supermarkets is six liters, which is inadequate for a large family of more than eight people. Additionally, power black outs and instabilities on the national grid were cited as a barrier to cooking with EPCs. High-income households also had concerns about the quality of the appliances they were being encouraged to invest in.

Both end-user groups flagged the issue that EPCs only come with one pot, which makes cooking more than one dish at a time a challenge. The EPC also requires certain technical knowledge to use it successfully. The longevity and repairability of the appliance were also concerns: anyone who buys an EPC will also require assurance of after sale services such as repairs and spare parts.

Barriers due to Existing Practices and Norms. For low income (rural) end-users, these include a need for space heating to warm a living space and to dry crops. The traditional cookstoves are used for cooking and cater for the space heating requirement, whereas the

EPC is only used for cooking. Therefore, families in cooler areas must find other means to access these co-benefits of biomass stoves. There is also considerable suspicion surrounding the introduction of EPCs as new products. Some end-users would prefer for someone else they know to try the EPC first before they buy it for themselves.

For peri-urban/urban end-users, there is the challenge that cooking in the wealthier households is done by a housekeeper, who will be required to change their normal practices when it comes to preparing meals, but who is not a decision-maker in the household.

Appliance Availability Barriers. High quality EPCs are not easily available in the market, and as demand grows it is likely to be challenging for end-users to source high quality appliances. There is a need to import EPCs in bulk into the country, while exploring the possibility of establishing an in-country manufacturing in Tanzania.

3.2.4. End-User Drivers for Adoption and Value Proposition

Table 4 sets out the factors which create value for each end-user group as gathered through focus groups and household surveys. These are the drivers that are expected to be involved in influencing end-users to shift to EPCs.

Table 4. Drivers and value proposition factors for rural and peri-urban/urban end-user groups to adopt EPCs.

Rural	Peri-Urban/Urban
Reduce time and labor for collecting cooking fuels	Reduce household expenditure on cooking fuels
Reduce time spent cooking	Reduce time and effort spent cooking
	Reduce indoor air pollution
	Increased safety when cooking
	Potential to use in a food vending business
	Cleaner kitchen environment

For the peri-urban/urban end-users, the biggest driver for change is the current high cost of cooking. Several households in the city are practicing energy stacking in their household to reduce household energy budgets. For the 51 households surveyed in the study, the cost of purchasing charcoal and LPG each month ranged from TZS 80,000–100,000 (£26.07–£32.59). Introducing EPCs clearly reduces the consumption of baseline fuels, and evidence from a typical household using a mix of LPG and biomass fuels indicated that the monthly energy budget could be reduced to as little as TZS 20,000–25,000 (£6.70–£8.30). For rural end-users, the main driver for adoption of EPCs is a scarcity of cooking fuel and the potential to reduce time and labor collecting this fuel. The main fuels used for cooking at the villages are firewood and charcoal which are used in traditional stoves. During the workshop with rural participants, it was reported that due to deforestation in the area, women and girls take 7–8 h on a round trip to Manyara Region where natural woodland forests are still available for firewood collection. A bundle of firewood is used for three days before they go back to the forest to recollect firewood. This account was validated through further conversations during household surveys and is typical for the rural areas around the borders of Dodoma, Manyara and Morogoro regions.

3.3. Step 4: Understanding the Market Chains

3.3.1. Identification of Market Chains

Surveys and interviews with market chain actors revealed eight possible chains to reach the two end-user groups, as shown by Figure 4.

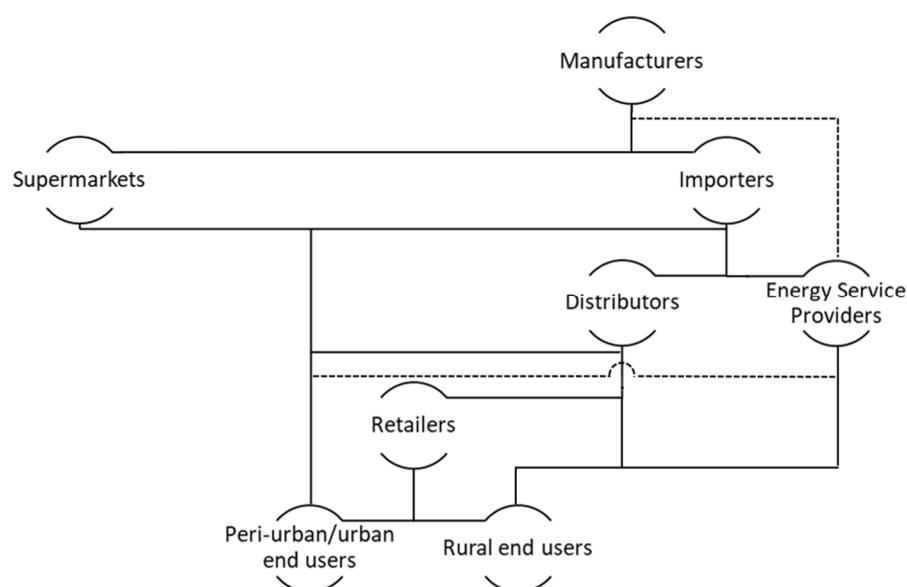


Figure 4. A map of the market chains that could be used to reach end-user groups. Solid lines represent those that already exist (though are nascent) and dashed lines indicate connections that could exist, but which are not currently known to be operational in Tanzania for EPCs.

The EPCs are manufactured in different countries (China, Japan, South Africa, Europe, etc.) and are imported by local importers or owners of supermarkets to Tanzania. These supermarkets are in urban areas. The EPCs vended through supermarkets are bought directly by peri-urban/urban end-users. The local importers may either supply EPCs to peri-urban/urban end-users directly if they have shops from which to vend them or supply them to distributors. These distributors may sell directly to end-users themselves or there may be an additional actor between them and the end-users; local retailers who have direct access to more remote market segments. The map also shows how energy service providers (the national utility (TANESCO), or off-grid energy providers) could be part of the system by vending EPCs to their customers, which might be an attractive proposition for them to increase electricity demand and, therefore, revenue. While we are aware of activity by off-grid energy companies acquiring EPCs through importers and selling to their customers, this research did not reveal that energy service providers are importing EPCs directly or that they are being vended to urban end-users, and so these connections are shown with a dotted line. These are viable market chains for the future, though may require additional effort and resource to start given they are not pre-existing.

The longer the market chain, the lower the share of revenue which is generated by EPCs as the work, reward and costs are spread out among many business enterprises. This also contributes to a high retail price for end-users.

3.3.2. EPC Gross Margin and Tax Analysis

A gross margin analysis was undertaken to understand the profit of the market chain actors and to illuminate how taxes affect the price of the EPC for end-users. We present an example pricing structure, assuming that the supply chain comprises established and VAT-registered importer, distributor, and retailer. We have divided a typical retail margin for distributor and retailer of 15% between nominal profit and operating costs, the latter of which comprises costs for transport, storage, training and promotion. Importer costs are drawn from experience. Table 5 shows that the tax burden would be of the order of 26%, and Figure 5 presents the data in a waterfall plot. However, we recognize that the supply chain in Tanzania will comprise actors who are small and informal businesses, and who may not be registered for VAT, and analysis shows this changes the resulting tax burden. For example, we note that if the distributor is not VAT registered, but is supplying a VAT-registered retailer, this has the effect of substantially increasing the tax burden because

the retailer is not able to reclaim the distributor's output tax. Therefore, depending on the nature of the businesses involved in the supply chain, the tax burden ranges from 25–35%. This indicates the potential order of magnitude of savings if products were duty exempt and zero rated for VAT.

Table 5. Gross margin and pricing structure analysis for EPCs.

Item	TZS	GBP
Retail price	211,192	69.69
VAT (18%)	32,216	10.63
Net value	178,976	59.06
Gross profit margin	7782	2.57
Retail costs	15,563	5.14
Input VAT	−28,014	−9.24
Distributor price	183,645	60.60
VAT (18%)	28,014	9.24
Net value	155,632	51.36
Gross profit margin	6767	2.23
Distributor costs	13,533	4.47
Input VAT	−24,360	−8.04
Importer price	159,692	52.70
VAT (18%)	24,360	8.04
Net value	135,332	44.66
Gross profit margin	6444	2.13
Importer costs	6138	2.03
Import duty	24,550	8.10
Assessable value	98,200	32.41
Importing costs	5200	1.72
Insurance & freight	15,500	5.12
Producer price	77,500	25.58

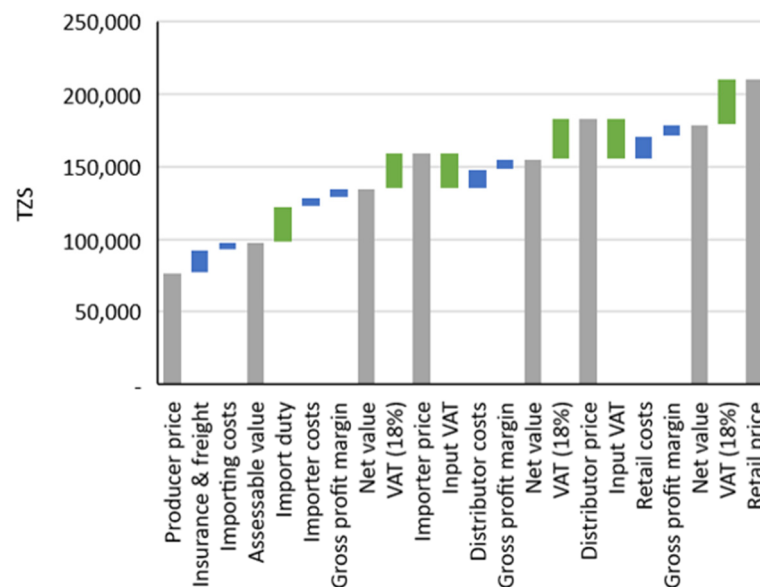


Figure 5. Waterfall plot of example EPC pricing structure.

3.3.3. Capacity Gaps for Market Chain Actors

Through interviews and surveys with market actors, their capacity gaps were identified and are summarized in Table 6 for importers, distributors, and retailers. We discuss supermarkets and energy service providers here separately as their capacity gaps are particular to the context and their prior experience. Although potentially unfamiliar with the EPC, supermarkets may have less challenges with capital for import and navigating

the import process as they have processes and methods already set up for other products. For energy service providers who are newly starting to import EPCs, it is likely they will face the issues by other generic importers, although they may be able to capitalize on their experience of importing energy access infrastructure. However, if they are acting as distributors only, they have the advantage of having strong relationships and transport links with a customer base already. They will, however, face the capacity gaps of requiring expertise in repair and after sales services, and they will have to learn how to market EPCs effectively.

Table 6. Capacity gaps of market chain actors.

Importers	Distributors	Retailers
Lack of capital for import duties Lack of knowledge on quality, and no standards to regulate quality Requires business training (enterprise development training)	Lack of established market networks Undeveloped marketing techniques/experience for EPCs	Weak transport links Lack of established customer network
Lack of awareness of the EPC Does not have EPC repair skills or links to after sales services		
—————Lack of capital for bulk appliance purchase—————		

These capacity gaps are important to uncover in the process of designing eCDMs, so that the eCDM and associated support services can address them.

3.4. Step 5: Understanding the Enabling Environment

3.4.1. Electricity Access

Electricity in Tanzania is generated from different sources including hydro (large and small-scale), natural gas, solar, small hydro and thermal diesel and biomass generation. In 2019, 37.7% of Tanzanians had access to electricity (73.2% in urban environments) [45,46]. Since 2017, the cost of electricity including tax and other levies has been 350 TSh/kWh (£0.13), and there is a lifeline tariff for customers using less than 75 kWh/month of 100TSh/kWh (£0.03) [47]. With six hydropower projects and four gas-fired plant projects in progress, the aim is to increase generation capacity from 1.6 GW 2019/20 to nearly 5 GW by 2025/26 [48].

The rural end-users in this study come from villages with access to solar mini-grid electricity operated by PowerGen Renewable Energy. The technology is based on a centralized solar PV-battery system with an electricity distribution grid connecting households in two villages. Customers can pre-pay on a Pay as You Go (PAYG) basis through their mobile phones. Mini-grids are an important part of the electricity infrastructure for off-grid Tanzania; in 2020 there were 209 mini-grids [49]. Their tariffs tended to be higher than national grid tariffs (for example, 2000 TSh/kWh [50] and 2300 TSh/kWh (£1.01) [9]) until mid-2020, when a Ministry of Energy directive instructed that mini-grid companies must charge no more than the regulated national grid tariffs.

Currently, 2.1% of Tanzanians are cooking mainly with electricity [15]. Frequent power cuts frustrate households cooking with electricity, who often require a back-up supply of charcoal and LPG. Dar es Salaam, where the peri-urban/urban end-users were drawn from, has the highest percentage (58.9) of households using mainly charcoal for cooking [15]. Although the whole urban area of Dar es Salaam region is electrified, only 7.8% of households are using mainly electricity for cooking. The high charcoal consumption contributes to the degradation of Tanzania's natural forests—Dar es Salaam consumes more than 50% of all the charcoal produced in the country.

3.4.2. Policies and the Policy Environment

Here, we give a very brief overview of policies and the policy environment that relate to eCooking. For more comprehensive reviews we point readers to Leary et al. (2019) and Byrne et al. (2020) [44,51]. Key relevant policies, regulations and legal documents are identified in Table 7.

Table 7. Policies, strategies/programs and legal documents in the enabling environment.

Policies	Strategies/Programs	Legal Documents
Tanzania Monetary Policy (2018)	Power System Master Plan (2016)	
Tanzania Fiscal Policy (2017)	SE4ALL Action Agenda (2015)	
Tanzania Trade Policy (2017)	Tanzania Investment Prospectus (SE4ALL) (2015)	Tanzania Trade Development Authority Act (2009)
National Micro-Finance Policy (2017)	Electricity Supply Industry Reform	Electricity Act of 2008
National Energy Policy (2015)	Strategy and Roadmap 2014–2025 (2014)	Business Activities Registration Act 2007
Energy Subsidy Policy (2013)	Biomass Energy Strategy for Tanzania (BEST) (2014)	Energy and Water Utility Regulatory Authority Act (2006)
National Public Private Partnership Policy (2009)	Standardized Power Purchase Agreement & Tariffs (2008)	Rural Energy Agency Act of 2005
Feed-in Tariff Policy (2004)		Environmental Management Act 2004
National SMEs Policy (2003)	National Five-Year Development Plan 2021/22–2025/26	

Since 2003 National Energy Policies have had a focus on promoting renewable energy, and the 2015 update actually features eCooking as an alternative modern energy source to wood fuel (Section 3.1.6 in [52]). Other important Acts set up influential national actors: the Energy and Water Utilities Regulatory Authority (EWURA) that regulates electricity tariffs and other sector aspects, and the Rural Electrification Authority (REA) that supports the extension of electricity access to rural areas. However, the Ministry of Energy is also recently active in these areas, as a once strong mini-grid enabling policy environment was derailed in 2020 through a directive which restricts mini-grid tariffs to the national grid level. Before this, minigrid tariffs were frequently at least 20 times the lifeline utility tariff due to the high capital cost and operational costs of providing off-grid energy access. This has created uncertainty around the future of mini-grids in Tanzania and thus the role they might play in the eCooking arena.

Tanzania is heavily dependent on charcoal for cooking energy, and interest in the reduction of charcoal demand is apparent through the 2014 Biomass Energy Strategy (BEST) and the most recent Five Year Development Plan [48,53]. The BEST had no legal weight but was intended to give an action plan that could be translated into policy. Although it includes electric cooking as a way to reduce biomass cooking, it emphasized increased use of ICS as one of the quickest and cheapest ways to reduce charcoal energy demand [53]. The Five Year Development plan sets out targets for increased ‘alternative charcoal’ use in urban areas and a reduction in deforestation, but also states the key intervention to ‘develop renewable energy sources for cooking’, which paves the way for genuinely clean cooking fuels such as renewable electricity and bioLPG/biogas [48].

Alongside TANESCO, the Ministry of Energy, REA and EWURA, the Tanzania Bureau of Standards (TBS) is also a notable policy and regulation actor, though when it comes to clean cooking regulation it is weak. ICS testing is voluntary, and standards do not yet exist for eCooking devices.

Byrne et al. note that ‘the policy environment as it currently exists is only partially conducive to strong action in favor of eCooking practices’ [44]. They describe the strong electrification drive to be conducive to eCooking but the lack of direct policy interventions on clean cooking, and the lack of quality assurance, to indicate a weak policy environment that requires sustained action to make it more conducive to eCooking. Their recommendations include constructing narratives which link eCooking to other challenge areas, such as local environmental degradation, climate change, and air pollution, so that linkages to

eCooking are articulated across government ministries, and to widen the scope of clean cooking activity beyond promoting ICS.

3.5. Step 6: Identify and Design eCDM and Support Services

The above research and analysis enabled the identification of the eCDMs for rural and urban/peri-urban end-users respectively, and the design of the support services required to enable them. The support services required to support delivery of EPCs to customers can be summarized as follows:

- Awareness-raising campaigns and promotion of EPCs to end-users and other market actors.
- Capacity building training on how to use the EPC for end-users.
- Financial support for market chain actors and end-users.
- After sale services for EPCs.
- Advocacy for import tax exemptions and quality standards.

The subsequent sections go into more detail on these, identifying the eCDM and clarifying the support services' roles for each end-user group where relevant. Support services which relate to the general eCooking Market System or both end-user groups are described in more detail in the third subsection.

3.5.1. eCDM for Rural End-users

For rural areas such as Kitaita and Songambele, where there is a scarcity of firewood, there is a strong driver for EPC adoption due to the high time and effort burden currently borne by women and girls to fetch wood. The two important market chains for end-users are from manufacturers to importers, distributors, and retailers, or, if there is an off-grid energy company present, manufacturers to energy service providers. If there is no energy service provider company present, a longer market chain is required as importers and distributors in Dar es Salaam do not have the reach to the rural end-users. There is a possibility of selecting market actors at the local district level, who, if the relationships were to be established, could distribute EPCs received from the importers directly to end-users. This would shorten the market chain by one actor, which could be advantageous to end-users or the other market actors, depending on where the gross margin of the missing actor is allocated.

However, a key factor for rural end-users who are farmers is that their income is seasonal because it is based on seasonal crop sales. This calls for flexible payment strategies to be employed. During harvesting time, it is highly likely that end-users will be willing to pay and can afford EPCs. Otherwise, any EPCs which will be delivered to end-users will require credit services. The availability of these credit services is a crucial support service for rural end-users.

The eCDM for EPCs is likely to be financially successful in rural areas if it starts with high and middle-income households. It will be easier to reach poor segments once the delivery model is already established and when trust in EPCs is high in the community. The low-income segment of rural end-users not only faces the issue of affordability, but also the issue that by using an EPC they lose the co-benefit of warmth and creating smoke, which they use to deter insects and preserve crops. Awareness raising campaigns should target medium-to high-income end-users in the first instance.

3.5.2. eCDM for Peri-Urban/Urban End-Users

There is high potential for adoption of EPCs in peri-urban/urban settings due to high household cooking budgets and the potential to save meal preparation time. Currently, the supply of EPCs is low, but it is slowly growing as demand increases and signals to market actors that EPCs are being increasingly adopted.

There are many permutations of markets chains possible to reach peri-urban/urban end-users. The most common existing market chain that could be developed further is that from manufacturers to importers, to distributors to end-users. However, the focus

should be on developing shorter market chains to increase the gross margin available for market actors and keep the price low for end-users. There is potential, if the right support is in place, for distributors (perhaps supermarkets or others) who are dealing directly with end-users to import directly from manufacturers outside the country. Capital for bulk ordering and covering import duty, improved transport links, and support for marketing and awareness raising among customers are required for distributors to take on this importing role.

Another possibility to increase the delivery of EPCs into peri-urban and urban areas is to support existing importers, distributors and retailers, already dealing with electric cooking appliances, to incorporate appliances such as the EPC into their product line. This would require awareness raising, marketing training, and capacity building within these actors so that they understand the EPC, realize its attraction for end-users, and are incentivized to start dealing in it.

3.5.3. Other Support Services

Awareness raising is a crucial support service required for all market chain actors and end-users. This will stimulate demand, and encourage importers, distributors and retailers to stock and trade in EPCs as demand begins to grow. For rural end-users, awareness raising activities should comprise informative brochures, leaflets, and posters, advertisements over radio, and live cooking demonstrations. For peri-urban/urban end-users, TV and social media are also important for awareness raising, as well as printed materials and radios. Trade fairs have also been identified as important platforms for awareness raising for end-users and other market chain actors.

Closely associated with awareness raising is the requirement for end-user capacity building in the use of EPCs, to support integrating them into cooking practices. A new and unknown device can be intimidating, but this knowledge barrier can easily be overcome through live or recorded cooking demonstrations and dissemination of training materials.

Another support service important for both end-user groups is to have trained technicians available who can provide after sales services to EPCs in the event of malfunction or breakdown. This requires training technicians, setting up the supply chain for spare parts, and ensuring end-users are aware that such a service exists, which will contribute to their increased confidence in purchasing and using the appliance. An open question is who should bear the costs of training technicians and setting up the after-sales service ecosystem. Given the EPC is a complex product in the commercial market and requires specialized technical support, large global brands interested in the East African market may be willing to invest in this to increase consumer confidence in their products. Before large brands become interested, however, donor and development organizations could helpfully step in to start this process. Once the market grows, the informal repair sector is likely to make efforts to 'catch-up', as it will be within the interest of electrical technicians to invest in learning to repair and maintain the devices as it becomes more common for people to approach them requesting repair services.

To address the end-user affordability barrier and the issue of required capital for import duty, advocacy should be pursued to exempt the EPC from import tax and VAT. The analysis in this research has shown that if that the saving is passed to the end-user, the price of the EPC could reduce by 25–35%. This is the situation for solar PV modules and some associated equipment, which is zero-rated and VAT-exempt in Tanzania [54]; other countries have various exemptions [55]. This is a significant saving, which will increase the number of end-users who are able to buy the appliance outright and decrease the payment burden on those who require credit services (rural end-users outside of harvest time). Further advocacy work should focus on encouraging TBS to set standards for eCooking devices to ensure only quality appliances are available in Tanzania, thus reducing the risk of appliances with poor energy efficiency putting end-users off.

Also, addressing the affordability barrier, it has been discussed how credit services are particularly important for rural end-users due to their seasonal income. Credit services for

EPCs would be advantageous for the low-income customers in peri-urban/urban settings, which are expected to see a growth in demand for the EPC once it is a fixture in middle to high-income kitchens.

To address the issue of availability, working capital for market chain actors would enable the bulk importation, distribution, and retail of EPCs, which will be necessary as awareness raising activities and increased experience lead to demand growth.

3.6. Step 7: Plan and Implement

Following the analysis, TaTEDO planned to implement the following support services over a two-year period starting February 2020:

- Dissemination of the Tanzania eCookbook [56], and training and workshop events, to raise awareness and provide training in how to use an EPC.
- Investigation of EPC repair and maintenance and compilation of a technical manual to be used by technicians providing after sales services.
- Training of technicians in Dar es Salaam, Dodoma, and Kilimanjaro to provide these after sales services.
- Recruitment and training of distribution agents—individuals with strong links into target communities, to disseminate EPCs from an importer of quality EPCs (to reduce the length of the market chain).
- Advocacy targeted at relevant ministries to remove import tax on EPCs to reduce the cost to the end-user.
- Advocacy for financial support for market chain actors to bulk trade in EPCs to address the upcoming availability barrier.
- Advocacy directed at TBS to set eCooking appliance standards and a process to enforce them.
- Conception of an alliance of market chain actors in the eCooking Market System in Tanzania to work together to address enabling environment gaps or market system deficits.
- Trialing credit services for low-income end-users and investigating which microfinance institutions can offer these successfully.

Implementation Thus Far

In this section we describe the progress to date on implementation of the above activities to support the eCooking Market System (as of February 2021). This has been the piloting phase of these interventions, and while some are proving successful and ready to shift to a scaling phase, others are still in earlier trailing and development. Some support services have been easier to implement and more successful in outcome than others, and for these the focus is shifting to scale and replication. Others are still in the piloting stage, as TaTEDO iterates using the eCDM framework and approach, modifying the services using the learning gained from previous attempts, as they work to address the gap or weakness in the eCooking Market System.

One of the areas that is still undergoing testing and development is regarding credit and microfinancing services. Through various attempts, it has been found that VICOBA (Village Community Banks), which are the most basic of microfinance institutions and serve lower income, often rural segments, commonly lack rigorous accounting practices and members with the sufficient reliable capital required to successfully microfinance high-cost consumer goods such as EPCs. However, some particularly strong community microfinancing groups based around reliable income-generation activities have been found to work well. Women's groups who are connected to dairy processing in Kilimanjaro are successfully financing EPCs for their members. Currently, trials are ongoing with financing institutions which are situated within other entities which are more formal, larger, and secure. One is a microfinance institution made up of the staff of an established NGO, and another is a formal association of teachers. The outcomes of these trials will influence whether or not further pilots are required, or a 'winning formula' has been found which

can start to be replicated. However, clearly these more formal institutions are serving a higher-income customer segment containing those in formal employment.

The other support services TaTEDO have implemented have been established as useful and enabling to the market, and best practices for replication are now being sought. One of these is to train agents in the EPC so they can start to distribute them. As part of this, three Sustainable Energy Services Support Centers have been set up in Tanzania in Dar es Salaam, Dodoma, and Kilimanjaro. From these Centers, 28 agents have been trained to use and market the EPC and are active in distribution of EPCs in small batches (<20), imported by the social enterprise Sustainable Energy Services Company (SESCOM) (a sister company to TaTEDO). This keeps the market chain short (three actors), and the agents use their own networks to encourage end-user interest and then fulfill orders in small batches. Further along the life cycle of the EPC, to support the sustained use of EPCs such that they last, and end-users can have confidence in their purchase, six technicians have been trained to repair and maintain EPCs, situated at the Support Centers. A manual for these technicians has been developed and will shortly be made freely available, and in the latest shipment of SESCOM EPCs, spare parts have been delivered to create repair inventory at the Centers. Regarding user preferences and practices, this shipment also contained spare EPC pots, in response to end-user requests that additional pots would make cooking multiple dishes on an EPC for one meal quicker.

Advocacy work is ongoing with three key focuses: to remove the import tax on EPCs; to support the Tanzanian Bureau of Standards to make a standard to control EPC quality, to reduce the influx of low quality EPCs which threaten positive public attitudes towards the appliance being fostered by the awareness campaigns undertaken by TaTEDO, and to make financing available to support market actors bringing quality EPCs into the country. With regard to the issue of import tax, another potential future avenue has emerged from the work over the first year of implementation, in that it would be prudent to think ahead to enable the manufacture of EPCs in-country, as the import of raw materials face much lower import duties than finished products. However, the readiness of supply chains for raw materials requires investigating, and if quality standards are not in place this may result in appliances being manufactured which can be marketed in Tanzania, but which cannot be exported to countries with quality standards in place.

To further support market actors and to enable them to present a united and aligned front in advocacy work, a Clean Cooking Alliance of Tanzania (CCAT) is in the process of being set up. The CCAT is open to market actors, and other clean cooking stakeholders, and will lobby on behalf of its members for policy and regulation changes to improve the enabling environment, as well as aiding members in matters of intellectual property and legal action, monitoring market trends and providing market data.

Awareness raising efforts are also gathering pace. As well as disseminating the Tanzanian eCookbook and holding in-person trainings and EPC events, TaTEDO has been featured on National news channels and radio to increase awareness about the potential of EPCs. In-person demonstrations remain fruitful. In March 2021, the Regional Administrative Secretary of Mkuranga District in the Coast Region purchased 35 EPCs to gift to district leaders, having been very impressed with the device after witnessing an EPC demonstration and awareness raising session.

4. Discussion

As discussed in the introduction above, the eCDM and eCooking Market System concept was introduced to map out the real-world complexity of the markets and surrounding context of clean energy innovations in low and middle-income countries. It has been used to understand the delivery models best-placed to enable end-users in Tanzania to access EPCs and to identify the support services to enable these delivery models to grow and thrive and the support the sustained use of the appliances by end-users. In this section we discuss the key emerging theme of access to credit in light of other literature on the subject and reflect on the use of the method and approach.

4.1. Finance and Credit Mechanisms

It is well established that the affordability barrier and a lack of access to credit is a major barrier to uptake of clean cooking appliances, and a recent review sets out numerous methods that use credit to increase affordability to end-users [57]. The review includes automated pay-as-you-go (PAYGO) strategies which remove the barrier of high upfront cost and allow end-users to pay affordable installments over time. Asset financing involves businesses providing loans for appliances, while the razor and blades strategy sells the appliance at little or no margin to encourage sales of a complementary product such as a fuel. Finally, they consider utility-led financing where the electricity company recoups the upfront cost of electric appliances through bills to the customer. In the review, the authors reflect that the extent to which an appliance is viewed as aspirational, and the value of the product, determine to what extent and which credit mechanism are best suited. For example, scaling uptake of high value aspirational appliances such as EPCs will depend more on credit mechanisms than more moderately valued appliances (LPG stoves, bioethanol stoves), and the less aspirational a product the more credit is also required as customers are less likely to save up themselves. This is further motivation for carefully crafted marketing campaigns to ensure end-users understand the benefits of EPCs and they are viewed as an aspirational product. While reports of PAYGO for LPG are increasing ([58,59]), activity on PAYGO EPCs is at much earlier stages of innovation [60], although one company has integrated PAYGO into induction stoves [61]. Asset financing company Bidhaa Sasa in Kenya has started to include financing for EPCs alongside LPG connections [57]. A systematic review of barriers and enablers for the adoption of clean fuels showed that many end-users struggle with upfront costs of LPG and bioethanol stoves [36], so it is clear that EPCs, which are more expensive, will require credit financing, even more so when the target is lower income segments as in this research.

As a result of this research, the authors are exploring credit mechanisms that do not appear in the above review of financing methods for clean cooking appliances; that of community-based small-scale lending groups such as VICOBA's which serve low-income end-user segments. Elements of the model do appear in Bidhaa Sasa's activities, who work with community groups, but there is still an external lender to the group in that case. These community lending groups could be understood as variations on the asset financing mechanism, consisting of groups of community members pooling money and lending to each other, paying back in small installments over time. TaTEDO is well placed to explore this kind of community-based credit mechanism due to its strong links across Tanzania to community organizations. The evidence suggests that unless a lending group is built around a strong and reliable income-generation activity, EPCs are simply too expensive for these VICOBA's to finance because members either don't have sufficient capital even when pooling it together or lack rigorous accounting practices. A modified approach will be required to reach the lower-income segments of society with microfinancing, and PAYGO may offer such an approach if seasonality of income is accounted for those who rely on agribusiness.

4.2. Reflection on the eCDM Concept and Approach

Both the eCDM and the eCooking Market System are influenced by the Osterwalder BMC (and the various adaptations of it), and the approach to design eCDMs contains a version of a BMC as a guidance tool. The BMC used in this approach took the focus off a purely economic analysis and included the social and environmental aspects of the proposition, taking inspiration from the Triple Layered BMC and the modified BMC from Garside et al. [22,28]. We can see this is very important for eCooking market development in the low-and middle-income country context. First, eCooking appliances are not common, and the social and cultural context of cooking needs to be understood and incorporated into strategies to disseminate appliances. In addition, segments of the market containing low and middle-income users need more than just the product being available in a market to be able to access it. Market forces alone may not provide the type of services required

by poorer segments of society or make existing required services accessible. Strong focus on the support services is required to make clean cooking energy innovations such as eCooking appliances accessible through the market to end-user segments who require a modern energy cooking solution. To effectively design these support services, social, cultural and environmental contexts must be understood—for example to run effective awareness raising campaigns, to determine what market chain actors need to be activated to reach end-users, and to refocus microcredit facilities to enable them to see social and environmental value of the loan.

A strength of the eCDM and eCooking Market System concepts and the eCDM design approach is that by returning to the methodology periodically, they cope with dynamic systems. A static snapshot of any changing system in a complex world can be misleading. The nature of the eCDM design approach is that it creates an ongoing reflection as the market system changes, so that strategies and support services are updated for a changing world. This can be seen in insights emerging after a year of support service implementation, such as the increasing need for more capital to supply appliances to end-users as demand grows, and the emerging need to establish a local factory for appliances since import duties for raw materials are lower than that of finished products. Such a dynamic approach will also be important in the near future. The world has experienced the COVID pandemic, and this will likely continue to affect end-user behavior and supply chains. By employing the eCDM approach as a framework to undertake biannual or annual reviews of the strategy, such global changes will also be captured and addressed with clean energy innovations.

5. Conclusions

We have defined eCDMs within the eCooking Market System as a way to conceptualize the complexity of the market and surrounding context as it relates to the uptake and sustained use of innovative clean cooking solutions. The accompanying design approach provides a structured way to design strategies and support services required to strengthen nascent delivery models of clean cooking solutions or, where appropriate, encourage new ones. In this case we have been considering the clean energy innovation of eCooking and its associated appliances. The eCDM and eCooking Market System have drawn attention to the intersection of understanding the end-user, the market chains and the enabling environment. By reviewing the context of eCooking appliance markets and the factors that influence their uptake and use, the processes have enabled the team to gain a deep understanding of the market context and to identify which market chains and which support services are required to move towards a thriving market. This has led to targeted action to address market system challenges, which is yielding fruitful results, such as an expanding network of distribution agents and EPC end-users.

The concept and approach can be utilized in other low and middle-income countries to map out the real-world complexity of the market system, and to design strategies to enable market transformation for clean cooking energy innovations there.

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Conflicts of Interest: TaTEDO is an NGO working on business and delivery models for sustainable energy services, employment and income generating opportunities. It works on programs concerned with a range of sustainable energy sources, including a Modern Energy Cooking Services (MECS) project that focuses on cooking with electricity. The paper draws heavily on TaTEDO's recent experience of exploring markets for the MECS project as well as their broader experience of delivery models. TaTEDO declares a potential conflict of interest posed by SESCOM (a sister company to TaTEDO), which distributes a range of renewable energy and electrical products including EPC.

Appendix A

Delivery Infrastructure		End Users	
Key Activities	Key Stakeholders	End User Segments	End User Relationships and Means of Engagement
What activities do we need to carry out to deliver the value proposition, and create a thriving market for eCooking appliances? (These could be about designing or implementing the eCDM and support services.)	Who are the key stakeholders in the eCooking market system? Which key resources do we require from them, and which key activities do we need them to perform? What are the expectations between stakeholders?	What end user segments exist, and for who is the value created? (End users can be disaggregated socio-cultural and economic factors (gender, income, age, education) – all likely to play into the formation of cooking practices and norms). Who are the most important end users and why?	How do end users expect to be reached in terms of who they have relationships with? Both in terms of acquisition of the appliances and ongoing maintenance. What relationships exist already and how can these be strengthened or utilized in this delivery model?
How shall we prioritize these activities – what is essential and what is non-essential?	What value is created for the stakeholders? How does the value proposition fit with government policy and regulation?	What socio-cultural and economic factors influence end user perceptions around eCooking appliances and effect the value proposition?	What are the associated costs of these relationships? How do end users want to be reached in terms of awareness-raising and other support services?
How might the planned activities affect other stakeholders and the current system? Is there potential for conflicts?	What capacity gaps do key stakeholders have and what support services are required to fill these?	What capacity gaps exist for end users which might inhibit their uptake or sustained use of eCooking appliances? What support services could assist?	How can we ensure the interactions with end users fit their preferences and current practices?
Market Chain	Key Resources	Value Proposition	
What market chains do end users want to be reached by, and what makes the most sense for other market actors in order to create a sustainable, thriving market?	What key resources are required to deliver the value proposition? Are these resources easily available?	What value do eCDMs deliver to end users? What problems are we helping end users to solve? What end user needs are we helping to meet?	
What existing market chains operate and which ones work best?	Can support services supply missing resources which are required?	What collection of products and services will add value to the various end user segments? What social and environmental effects does this value proposition have? (see 'Other costs/benefits'). What value is created for wider society?	
Accounting			
Revenue streams	Other costs/benefits		Cost structure
How would end users prefer to pay for the appliance – upfront, in installments over time, pay for service? How is revenue shared across the market chain? Are there any stakeholders who can offer any subsidies or incentives? Are there stakeholders who can offer microfinance with terms which work for different types of end users, for example, those with seasonal income?	Environmental – Very applicable to cooking practices that make use of biomass fuels. Includes environmental degradation, effects on local and global ecosystems, contribution to greenhouse gas and climate forcing emissions (biomass burning and electricity generation). Social – health impacts of choice of fuels; impact on gender roles, in particular, time and effort burden on women of cooking and surrounding cooking practices such as fuel gathering; empowerment of women; job creation through strengthening of market or end use opportunities.		What are the costs associated with delivering the eCooking appliances (fixed and variable costs)? What are the most significant? Which activities and resources are the most expensive? Can economies of scale and scope help to reduce per unit costs?

Figure A1. eCooking Delivery Model Canvas (Author's own adapted from [22,24]).

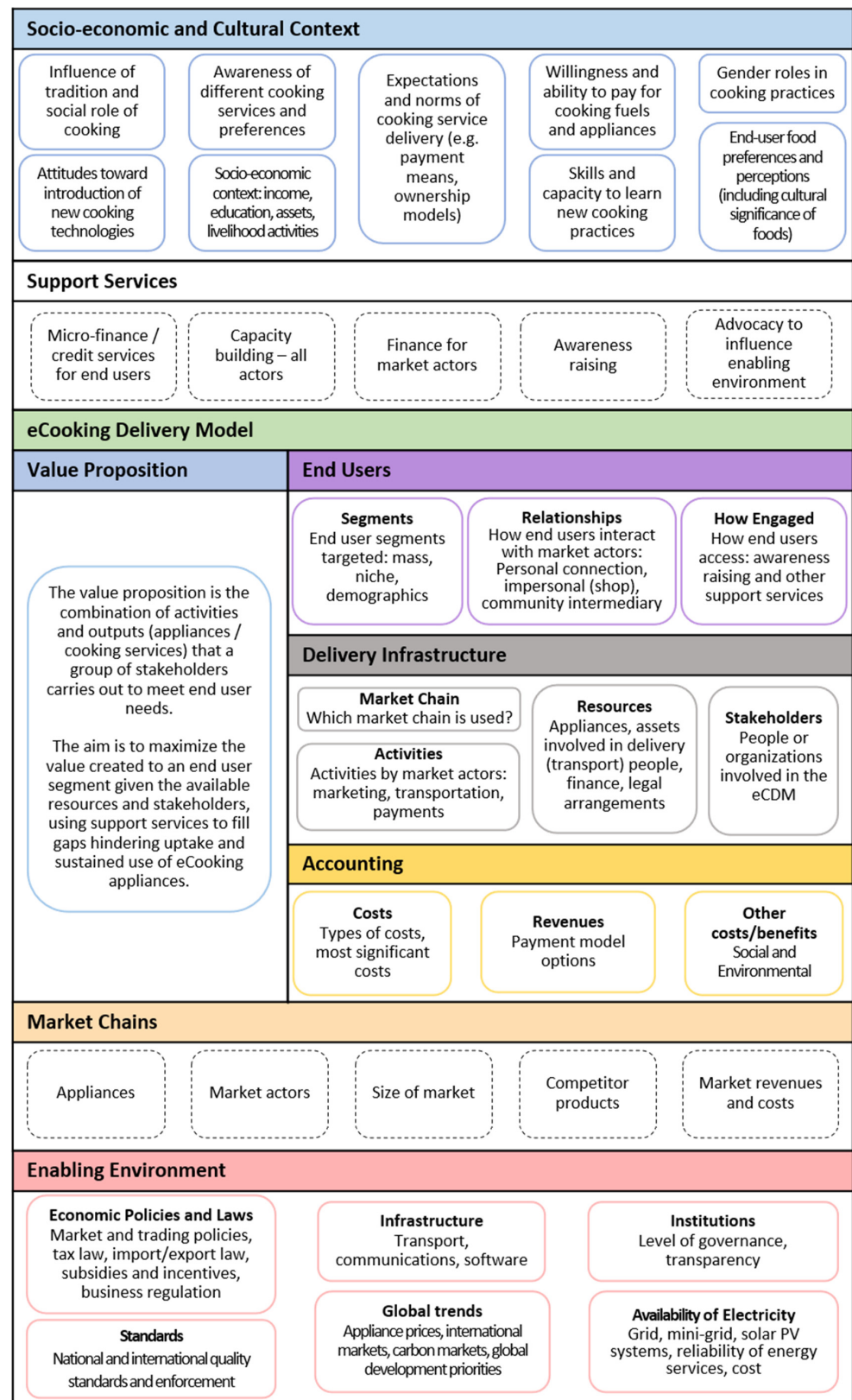


Figure A2. eCooking Market System map (Authors' own, adapted from [17]).

Appendix B

Table A1. List of institutions with which interviews were conducted to understand the eCooking enabling environment.

Financial Institutions	Development Partners	Sectoral Ministries and Government Institutions
Access Bank Akiba Commercial Bank National Microfinance Bank FINCA Microfinance Bank Ngome SACCOS	Embassy of People’s Republic of China Embassy of Japan DFID Tanzania Delegation of the European Union to Tanzania Swedish Embassy in Tanzania United Nations Development Programme (UNDP) United Nations Capital Development Fund (UNCDF)	Ministry of Energy Ministry of Trade and Industries President Office-Ministry of Regional Administration and Local Governments Energy and Water Utilities Regulatory Authority (EWURA) Rural Energy Agency (REA) Tanzania Electric Supply Company (TANESCO)

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